# GEO-BENE

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

**STREP**
**PRIORITY [1.1.6.3]**
**[Global Change and Ecosystems]**

**DELIVERABLE D3 (T12)**
**BENEFIT ASSESSMENT FRAMEWORK REPORT**

Due date of deliverable:     30 June 2007

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)

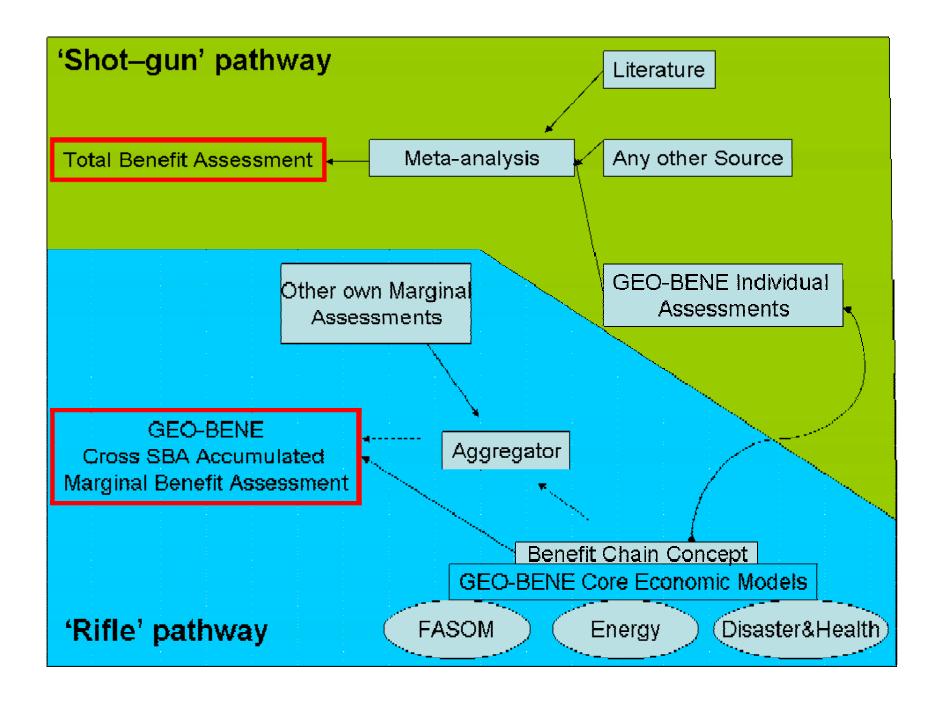| Dissemination Level | | |
|---|---|---|
| **PU** | Public | **X** |
| **PP** | Restricted to other programme participants (including the Commission Services) | |
| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | |
| **CO** | Confidential, only for members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

# Contents

# 1    Purpose of Deliverable

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.

# 2    Impact assessment framework

In the 2nd 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**.

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

## 2.1 Shot-gun 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.

For these ends we will employ meta-analysis which is mainly used in medical sciences and to a lesser and less rigorous extend in social sciences. The meta-analysis employed will most likely also be of fewer rigors since the current literature does not report statistical moments beyond at best the second statistical moment. This will limit improved statistically founded judgments of the total benefit assessment numbers. **Meta-analysis** in GEO-BENE combines the result of several studies that address a set of related benefit assessments. Analyzing the results from a group of studies, when addressing the same Sub-SBA, will allow more accurate and richer assessment. The main focus of the GEO-BENE meta-analysis is on the expected value and its ranges from individual studies and summary statistics. Results will be visualized by forrest plots or similar plot graphs and integration across SBAs will be done by application of the law of error propagation or simple Monte Carlo type of simulations using very simple model structures.

Due to the poor state of current literature on the topic of benefits of global earth observations on socio-economic systems, GEO-BENE partners have decided to also try to employ **systems dynamics modeling** as a methodology to arrive at total benefit assessment numbers under the shot-gun pathway (Figure 2). Systems dynamics is used as a method for understanding the dynamic behavior of complex earth systems and its dynamic interaction with global earth observations. The basis of the method in GEO-BENE is the recognition that the structure of the coupled earth-human-GEOSS system — the many circular, interlocking, sometimes time-delayed relationships among its components — is often just as important in determining its behavior as the individual components themselves. We claimed that, because there are often properties-of-the-whole which cannot be found among the properties-of-the-elements, in some cases the behavior of the whole cannot be explained in terms of the behavior of the parts. Thus, in order to avoid missing important total system effects we carry out system dynamics analysis as a complementary analysis to the meta-analysis. With system dynamics tools we aim at further explaining the integration of interconnected systems to SoS (Systems of Systems).
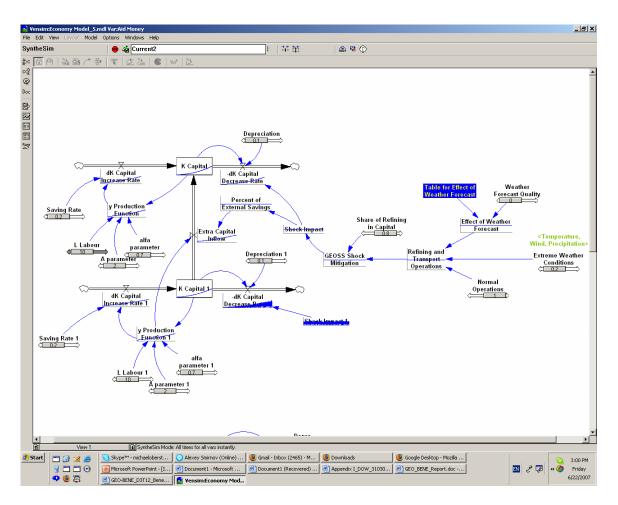
Figure 2: Illustrative Example of a systems dynamics model depicting a two region global economy model which is subject to an external capital shock and shocks to the transportation sector which can be mitigated by GEO information.

## 2.2   Rifle Pathway

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.

Cross SBA Marginal Benefit Assessment is a daunting task as it specifically addresses the integration effect of GEOSS. The methodology is not yet fully developed as a number
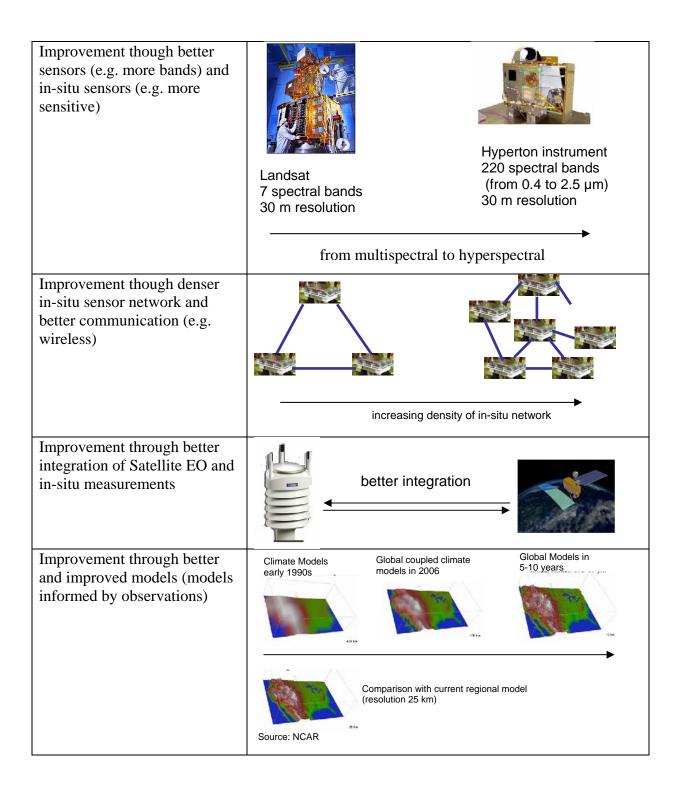
of issues such as how to bring results from a deterministic model in a comparable and consistent manner together with results from a stochastic model in a multi-sectoral setting. Brute force assumptions would make this possible today, however, to apply e.g. one discount rate across all SBAs would necessarily lead to substantial scrutiny of the results and might also lead to substantially biased policy recommendations resulting from GEO-BENE analysis. To overcome these problems GEO-BENE has implemented an 'Aggregator Task Force' with the aim to device a cross SBA global aggregation model framework that takes into account benefit accountability between SBAs and Sub-SBAs, across different spatial and income scales, and across substantially different time scales.

With respect to rifle pathway analysis there has been consolidation among the main models to be used. FASOM will be the economic framework model to analyze deterministic phenomena in the agriculture, ecosystem, biodiversity, water, climate and weather SBAs. GEO-BENE has developed a global geographic explicit Energy Systems Model mainly to be employed in the Energy and Climate Change SBAs. Finally, a global frame model to analyze stochastic events has been developed for the covering mainly the disaster and health SBAs. These models will be used to carry out individual or joint marginal benefit assessment studies employing the **Benefit Chain Concept** which is detailed below.
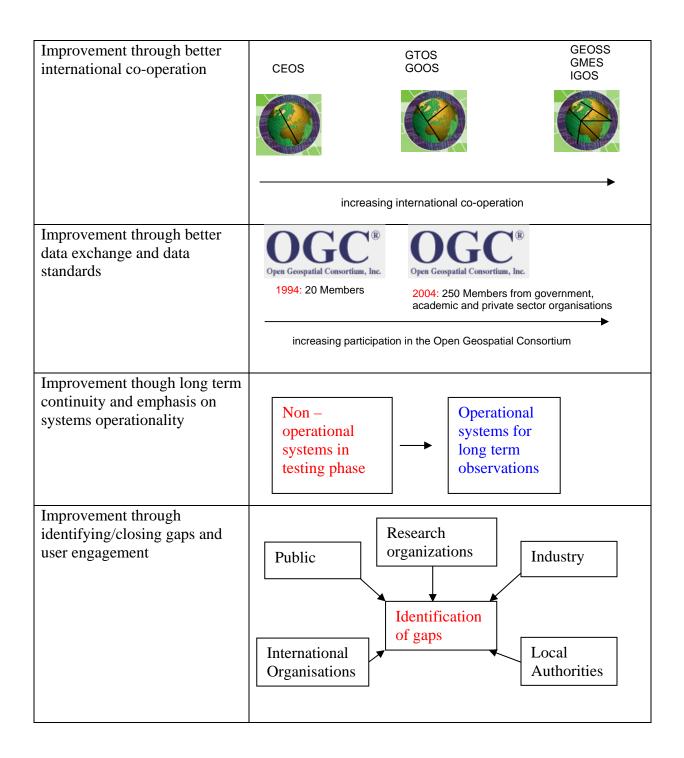
## *2.3   Benefit Chain Concept: Different improvements of EO to which GEOSS can contribute*
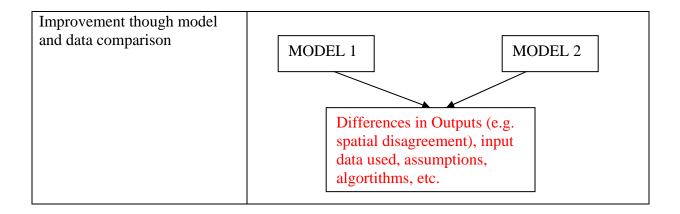
The GEOSS process is going to bring improvements in EO which will consequently affect different benefit areas. These improvements can occur in a number of different ways. The improvement can be achieved though technical improvements in the field of satellite observations as well as in-situ measurements. 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. Figure 3 identifies the improvements where GEOSS could play a role in an illustrative and non-comprehensive manner.

**Figure 3: Identified fields of improvements where GEOSS could play a role**
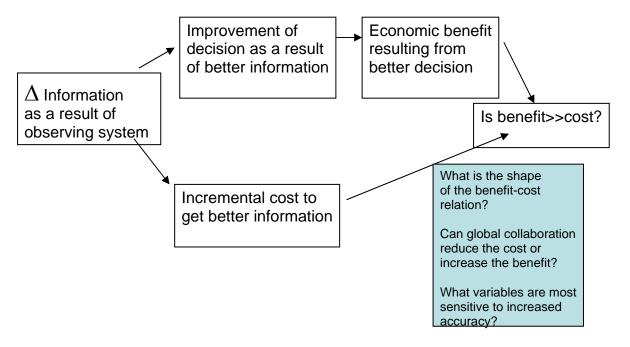
| Improvement realised though GEOSS | Illustration |
|---|---|
| Improvement though higher spatial resolution |  increasing spatial resolution |
| Improvement though higher temporal resolution |  increasing temporal resolution |

| | |
|---|---|
| Improvement though better sensors (e.g. more bands) and in-situ sensors (e.g. more sensitive) | <br><br>Landsat<br>7 spectral bands<br>30 m resolution<br><br>Hyperton instrument<br>220 spectral bands<br>(from 0.4 to 2.5 µm)<br>30 m resolution<br><br>from multispectral to hyperspectral |
| Improvement though denser in-situ sensor network and better communication (e.g. wireless) | <br><br>increasing density of in-situ network |
| Improvement through better integration of Satellite EO and in-situ measurements | <br>better integration |
| Improvement through better and improved models (models informed by observations) | Climate Models early 1990s   Global coupled climate models in 2006   Global Models in 5-10 years<br><br><br><br>Comparison with current regional model (resolution 25 km)<br><br>Source: NCAR |

| | |
|---|---|
| Improvement through better international co-operation | CEOS     GTOS GOOS     GEOSS GMES IGOS<br><br>increasing international co-operation |
| Improvement through better data exchange and data standards | **OGC®** Open Geospatial Consortium, Inc.     **OGC®** Open Geospatial Consortium, Inc.<br>1994: 20 Members     2004: 250 Members from government, academic and private sector organisations<br><br>increasing participation in the Open Geospatial Consortium |
| Improvement though long term continuity and emphasis on systems operationality | Non – operational systems in testing phase → Operational systems for long term observations |
| Improvement through identifying/closing gaps and user engagement | Public, Research organizations, Industry, International Organisations, Local Authorities → Identification of gaps |

| Improvement though model and data comparison | |
|---|---|
| | **MODEL 1**    **MODEL 2**<br><br>Differences in Outputs (e.g. spatial disagreement), input data used, assumptions, algortithms, etc. |

### 2.3.1 A conceptual model of the Benefit Chain Concept



The principle behind this concept is that through a better observing system more information (delta) will become available to the disposal of the decision maker. As a result the decision maker will make a more informed and better decision which will lead to a certain societal benefit. This benefit can be in some circumstances measured and directly compared to the incremental costs. In some circumstances it will however not be possible to directly measure the benefit. This will be the case for non-market benefits such as ecosystem services and biodiversity and for certain downstream or indirect

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benefits. Even though it will not always be possible to attribute a certain value in terms of Dollars or Euros to the economic benefit which results from a better decision it might be possible to know the shape of the benefit-cost relation. Can we say that the benefit will be much higher or at least higher than the incremental cost to get better information. In the case the benefit is larger than the cost a particular activity (incremental Delta) can be justified. We refer to this as the value chain of the observing system.

Due to the fact that a number of EO activities are taking place on a national level independently of GEOSS it is not easy to distinguish which activities can be attributed to GEOSS. However, it will be possible to use the different aspects from Figure X and to examine the additional benefit (and costs) an improved observing system / improved model will bring. However the particular role of GEOSS is the 'globalisation' of the observing system. The particular question which can be asked in this context is if global collaboration can either reduce the costs or increase the benefit. In that case the global observing system of systems can be justified.

Another question to ask is what variables are most sensitive to increased accuracy. For example which field of improvement (Figure x) will bring the most benefit. In which area will a incremental cost result in the largest benefit. Which fields of improvement will lead to the highest benefit?

### 2.3.2 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?

# 3 The Benefit Assessment Framework and the path to the final report

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 GEO-BENE report: GEO – Socio-economic benefit Analysis

**Executive Summary**

**Preface & Acknowledgements**

**Introduction to Review**

**Summary of Conclusions**

**Part I GEO-BENE approach**
Introduction
- Earth System Management in the 21st Century and beyond (PIK)
- The economics of GEO (IIASA) (incl. aggregation and integration)
- The science of Value of Information (UB)
- Economics, Ethics and Benefit Valuation (IVM)
Conclusion

**Part II The benefit of GEO**
Introduction
- How GEO lead to socio-economic benefits (CSIR)
- Implications of GEO for Earth System Management (PIK)
- {Expert judgments and Stakeholder based development scenarios of GEOSS (IVM)}
- The Potentials of increased GEO benefits (IIASA)
- GEOBENE Economic modelling framework (IIASA)
- Shot gun of total benefit assessment (IIASA)
- GEO-BENE Cross SBA Accumulated Marginal Benefit Assessment (IIASA)
- Synergies and ancillary benefits (IIASA)

**Part III The GEO benefits by SBA**
Introduction
- Disaster (IIASA)
- Health (KTL)
- Energy (FELIS)
- Water (EAWAG)
- Weather (BOKU)
- Climate (PIK)

- Ecosystems (UHH)
- Agriculture (BOKU)
- Biodiversity (CSIR)

**Part IV Policy responses for GEOSS** (Based on Outcome of Targeted Workshop)
Introduction
- Making GEO relevant for sustainable development
- Harnessing investment strategies
- Technological and Societal innovations
- Capacity building

**Part V GEOSS – Catalyzing the Emergence of a Global Public good**
(Theoretically Based on IIASA models)
Introduction
- Framework for understanding international collective action for GEO - Club good versus Public good
- Creating incentives to contribute to GEOSS
- Supporting the transition to GEO enabled Global Earth System Management
- Promoting effective international technology co-operation
- Nurturing GEO based businesses around the globe
- International support for down stream implementation
Conclusions

**GEO-BENE report Appendix**
 **Acronyms and Abbreviations**
 **Data Sources Used (SSCRI)**