Chapter 12
The Value of Global Earth Observations

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, Christian Schill, Christine Schleupner, Erwin Schmid, Uwe A. Schneider, Robert J. Scholes, Linda See, Rastislav Skalský, Alexey Smirnov, Jana Szolgayova, Zuzana Tarasovičová and Hong Yang

Humankind has never been so populous, technically equipped, and economically and culturally integrated as it is today. In the twenty-first century, societies are confronted with a multitude of challenges in their efforts to manage the Earth system. These global challenges range from multi-hazard disasters and new infectious diseases to basic food and energy security on a warming planet. Dealing with such a confluence of possible global-scale failures involves highly complex planning, coordination, and international cooperation (Walker et al. 2009); this will only progress effectively and efficiently if private and public policies are based on reliable information and sound science. Particularly distressing in this context are the continued deficiencies in basic global observations and information-processing infrastructure to monitor and document many of the important ongoing global changes with sufficient accuracy. Information paucity remains an obstacle to understanding major Earth system processes. In this decision-making context, collective efforts to manage the Earth system are in danger of being erratic and the result of competing interests rather than based on decisions informed by robust scientific analysis. While international conventions on the environment and security are today the main drivers of global Earth observations, the resulting space and in situ observing instruments are far from optimally structured, deployed, or used when considered in light of the value of the decisions that are at stake.

M. Obersteiner (✉) · J. Balkovič · H. Böttcher · J.A. Bouma · S. Fritz · S. Fuss · P. Havlik · C. Heumesser · S. Hochrainer · K. Jantke · N. Khabarov · B. Koch · F. Kraxner · O.J. Kuik · S. Leduc · J. Liu · W. Lucht · I. McCallum · R. Mechler · E. Moltchanova · B. Reyers · F. Rydzak · C. Schill · C. Schleupner · E. Schmid · U.A. Schneider · R.J. Scholes · L. See · R. Skalský · A. Smirnov · J. Szolgayova · Z. Tarasovičová · H. Yang
International Institute for Applied Systems Analysis, Schlossplatz 1, Laxenburg 2361, Austria
e-mail: oberstei@iiasa.ac.at

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Currently the most pertinent example of high-impact decision-making informed by science that would greatly benefit from an enhanced observing system is connected to the ongoing controversy around the interpretation of the mandate of the UN Framework Convention on Climate Change (UNFCCC) for *stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*. Although the Global Climate Observing System (GCOS) is already considered to be advanced in its implementation, the benefit of reducing uncertainty in climate predictions by even better informed models through an improved GCOS justifies further investment. The incremental annually recurring cost of implementing the GCOS is estimated to be in the range of 600–700 million USD, which can be compared to the average annual incremental climate mitigation cost for the next 20 years in the energy system, amounting to some 300 billion USD per annum (Rao 2009).

At the two UN Earth Summits, it was realized that complex Earth processes can be adequately measured to support environmental decision-making only by linking and coordinating current observing systems. Since then, a number of Earth observation summits have been held, resulting in the establishment of the intergovernmental GEO at the third occasion. GEO provides the platform for coordinating observation strategies and investment in support of decision-making in nine SBAs (see Sect. 4.1.2.1).

Prioritization of coordinating actions and investments to build a joint GEOSS necessitates an integrated assessment of the prospective economic, social, and environmental benefits. We have therefore developed methodologies and analytical tools—following a benefit chain concept (GEOBENE 2016)—and applied them to assess the societal benefits of investments in improving the GEOSS across the nine SBAs. The basic idea is that the costs incurred by an incremental improvement in the observing system—including data collection, interpretation, and information sharing—will result in benefits through information cost reduction or better informed decisions. The resulting incremental societal benefit is judged against the incremental cost of production. Since in many cases there are large uncertainties in the estimation of costs and particularly the benefits, it may not be possible to express them in comparable monetary terms. Therefore, order-of-magnitude approaches and a qualitative understanding of the shape of the cost–benefit relationships can help guide investment decisions.

There are generally two source categories for cost reductions in information delivery from building the 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, the costs of national forest carbon assessments aimed at policies of avoided deforestation typically amount to 100–500 USD per km^2, yielding carbon stock estimation uncertainties of between 10–20%. A similar precision achieved by one consistent global forest observatory could be realized at much lower costs of some 10–100 USD per km^2 (Böttcher et al. 2009).

The second source of cost reduction from GEOSS relates to economies of scope, which emerge when observing systems are combined. The Geo-Wiki Project

(Fritz et al. 2009) combines human sensors (a global network of volunteers) with satellite images to improve global land information. Substantially improved assessment of land resources are of particular importance, for example, for the currently hotly debated estimation of indirect land use effects of biofuel policies (Searchinger et al. 2009). We estimated that the opportunity cost of avoiding deforestation, thereby minimizing indirect land use effects, to differ on the order of 50% depending on which estimates of cropland availability are used, as taken from different state-of-the-art yet insufficiently accurate land cover maps (Fritz et al. 2009).

Economies of scale and scope are not only about leveraging cost reduction, but also accrue from increased benefit generation from integrating observing systems. Quantifying benefits, often of a "public good" nature, proves a significant challenge. In a local case study in the Little Karoo of South Africa, we investigated the benefits of improved land cover information, of the type to be expected from GEOSS, for local-scale ecosystem service monitoring for the parameters presented in Fig. 12.1. Using precolonial ecosystem service levels as a reference point, the assessment demonstrated substantial differences in current ecosystem service levels when measured using local-scale ground-truthed data associated with GEOSS systems versus national-scale non-ground-truthed data. The former finds substantial declines in ecosystem service levels of between 18–44% of precolonial levels, concurring with other local studies that highlight the extreme decline in ecosystem services in the Little Karoo region, while the latter paints a much rosier—but

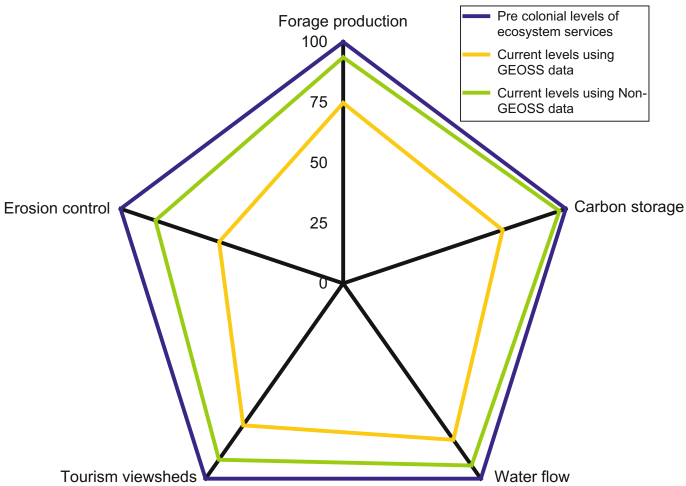

Fig. 12.1 Measuring changes in ecosystem services from precolonial times until the present day using GEOSS (local scale, ground-truthed) and non-GEOSS (national scale, non-ground-truthed) scenarios of data availability. The current levels are reflected as a percentage of the precolonial levels for each ecosystem service. Higher levels of ecosystem service degradation are identified in the GEOSS scenario revealing more degradation from precolonial levels (100%). Improved information on the actual degree of degradation (GEOSS levels) improves decisions and generates benefits such as avoided losses from floods. Data are extracted from Reyers et al. (2009)

incorrect—picture of almost intact systems providing ecosystem services at near precolonial levels (10–15% declines). Applying the benefit chain concept, we compare the costs of GEOSS-type data of some 12,000 USD to the incremental benefits of more accurate information on current ecosystem service condition. However, due to the limited development of procedures for quantifying the economic benefits of improved environmental information, the case study currently relies on proxies such as the costs of wrong decisions (including restoration costs of approximately 1100 USD per hectare) and flood costs (which in 2006 totaled 40 million USD damage in this region).

The GEOSS also improves the degree of accuracy with which information is provided. Although many studies assume more information is valuable, in reality this is not always the case. A study on prevention of potentially harmful algae blooms in the North Sea indicated that an early warning system with a considerable probability of a false warning (type-II error of some 20%) has no value (Bouma et al. 2009).

Managing the interlinked challenges of global change will require an increasing flow of information about developments in the global environment and the world's societies that interact with it. International agreements, as well as national management strategies, will be on weak footing unless relevant data streams are established with the foresight to support decision-making and the science that underpins it. With national contributions to GEOSS—a global public information good—now increasingly under pressure due to overall budget constraints and investments in observation infrastructure not keeping pace with the foreseeable demand for information, demonstrations of the potential benefits to global societies as well as of the impacts of failed international cooperation are a matter of increasing urgency. This is because implementation of global Earth observation assets and Earth system models require significant time from the development of technology and methods to their operational deployment.

Our assessment found that in the majority of case studies, the societal benefits of improved and globally coordinated Earth observation systems were orders of magnitude higher than the investment costs. A strong coordinating institution is required to ensure that an integrated architecture takes full advantage of the increased benefits and cost reductions achieved by international cooperation. Furthermore, boundary organizations interfacing between the science community and users such as businesses, and governmental and nongovernmental organizations have to be an integral part of an enhanced observation strategy in support of global change management.

Continuous and comprehensive monitoring of the Earth carries the potential for major advancements in global change science. Not only will science generate more robust knowledge through data assimilation into increasingly integrated Earth system models, new scientific fields will also arise. Pairing environmental monitoring with next-generation acquisition of socioeconomic parameters will yield new insights into possible societal pathways through the problematic bottleneck of twenty-first-century environmental exploitation on the road to increased sustainability. New GEOSS-informed Earth system science products and services will emerge and will need to be assisted to diffuse for wider societal use. The benefits from these emerging applications are among the least predictable today, but they must receive adequate support to guarantee a transition to more science- and evidence-based decision-making.

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Author Biography

Michael Obersteiner is program director of the Ecosystems Services and Management (ESM) Program at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. He joined IIASA's Forestry Program (FOR) in 1993 and has been leading the Group on Global Land-Use Modeling and Environmental Economics since 2001. His background includes the fields of global terrestrial ecosystems and economics, specializing in REDD and REDD+ modeling as well as policy assessments, with particular expertise on the tropical forest zones of South America, Africa, and Asia.

Dr. Obersteiner completed graduate studies both in Austria (BOKU University and the Institute for Advanced Studies Vienna) and abroad (Columbia University, New York, and the Siberian Branch of the Russian Academy of Sciences, Novosibirsk). Since 2004, he has made substantial contributions to the development, establishment, and management of the IIASA-ESM integrated modeling cluster, which includes widely recognized global biophysical and economic models in the area of agriculture, forestry, and land use (G4M, EPIC, GLOBIOM). In 2008–2009, Dr. Obersteiner served as a seconded staff expert for the Group on Earth Observations (GEO) in Geneva, Switzerland. Over the past decade, Dr. Obersteiner has been the principal investigator at IIASA for more than 30 international projects covering diverse fields of different scales and numerous funding organizations. Dr. Obersteiner has been a consultant to a number of national and international organizations, including inter alia the European Commission, WWF, OECD, and other national and international institutions. He has authored more than 250 scientific papers and consultancy reports in the aforementioned fields.