Marketing Earth Observation Products & Services

part # 2

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SEVENTH FRAMEWORK PROGRAMME

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Table of contents

Summary

The second report on marketing of earth observation products and services is one of the outcomes of the GEONetCab project of 7th Framework Programme of the European Commission.

The main guiding motto of the report is:

"Earth observation helps you
... save lives
... save money
... save the environment"

The activities of the GEONetCab project are directed at three different target groups: professionals, decision makers and communities. The report builds on the findings of regional studies on bottlenecks and opportunities for earth observation in the four regions of the project (French-speaking Africa, Southern Africa, Poland and the Czech Republic) and a general framework study (marketing of earth observation products and services, part #1).

Earth observation applications are analysed in terms of different categories of products and services, the phase in the life cycle of the product or services, and regional differences, thus resulting in an optimal marketing mix. Clients want a product or service that is fit-for-purpose, practical, reliable, cost-effective, integrated in the business or organizational process and easy-to-manage in terms of client capacity.

The following portfolio of actions has been implemented:

- Intensive awareness raising
- Initiation of a dialogue with promising end-user communities
- Demonstration of successful applications
- Increasing knowledge on "weakest link aspects" for each particular country or region
- Stimulating demand through a mix of workshops, success stories and quick-win projects, supported by marketing toolkits and a web facility for capacity building

To target these actions more specifically, international trends, earth observation applications, socio-economic benefits and capacity building aspects are described for a number of areas. These areas are: disaster management, crop modelling, water management, environmental management, climate change, marine environment, forest management, health, energy, weather, and finally urban management, land administration and spatial data infrastructures.

The issue of cost-benefit proves to be particularly complicated. Quantified benefits and costs can sometimes be given at a general level, but capturing the cost-benefit picture for local applications poses a challenge. Often so-called externalities are involved, which make quantification in economic terms difficult.

To better relate to customer value propositions, the following questions should be asked:

- Does the new application cause a paradigm shift?
- Has the current business or organizational process improved?
- Does the application provide economic value that can be quantified?
- Does the earth observation application contribute to a clearly defined measurable goal?
- Does the earth observation application fit into a future payment scheme or other economic mechanism?

If earth observation provides added value, the answers to the questions yield a set of comparative advantages attuned to the state-of-the-art of the problem to be tackled and to the way the client perceives this problem.
For relatively new and unknown technologies such as earth observation, marketing consists of both

Summary

promotion and capacity building. Practical tips are given for more effective promotion and how to improve raising the awareness of potential clients as well as capacity building for EO professionals.

The report concludes with a mix of advice and trend watching:

- Exploit internet and the GEOSS common infrastructure.
- Local applications are of key importance for the integration and acceptance of earth observation solutions across the board.
- Governments will remain the most important clients for earth observation products and services.
- The cooperation between governments, scientists and the private sector needs to be continued to introduce earth observation applications successfully.
- The establishment of end-user communities of practice, regarding applications of earth observation for tackling concrete problems is a useful tool when introducing earth observation applications and helps improve earth observation products and services.

List of acronyms

AEGOS	African-European geo-resources observation system
AGRICAB	project for capacity building in earth observation for agriculture
AMS	American meteorological society
AQI	air quality index
AU	African Union
B2B	business to business
B2G	business to government
C2G	citizens to government
BalkanGEONet	Balkan GEO network
CAPRA	Central American probabilistic risk assessment
CBD	convention on biological diversity
CCSP	climate change science programme (US)
CEDRA	climate change and environmental degradation risk and adaptation assessment
CEOS	committee on earth observation satellites
CFSVA	comprehensive food security vulnerability analysis
ChloroGIN	chlorophyll global integrated network
CITES	convention on international trade in endangered species of wild fauna and flora
CNES	centre national d'etudes spatiales (France)
CoML	census of marine life
CRASTE-LF	African regional centre for space science and technology in the French language
CRECTEALC	regional centre for space science and technology education in Latin America and the Caribbean
CSIS	centre for strategic and international studies (US)
CSSTEAP	centre for space science and technology education in Asia and the Pacific
CUNI	Charles university
DEM	digital elevation model
DevCoCast	GEONETCast for developing countries
DNI	direct normal irradiation
DOPA	digital observatory for protected areas
DPSIR	driving force, pressure, state, impact, response
DSS	decision support system
EC	European Commission
ECP	energy community of practice
ECMWF	European centre for medium-range weather forecasts
EEA	European environment agency
EGIDA	coordinating earth and environmental cross-disciplinary projects to promote GEOSS
EnerGEO	Energy observation for monitoring and assessment of the environmental impact of energy use
EnviroGRIDS	building capacity for a Black Sea catchment observation and assessment system supporting sustainable development
ENVISOLAR	space-based environmental information for solar energy industries
EO	earth observation
EO2HEAVEN	earth observation and environmental modelling for the mitigation of health risks
EOPOWER	earth observation for economic empowerment

List of acronyms

EPA	environmental protection agency (US)
ESA	European space agency
ESPI	European space policy institute
ESRI	environmental systems research institute
EU	European Union
Eurisy	organization for acting collectively to bridge space and society
EuroGEOSS	a European approach to GEOSS
FAO	food and agriculture organization
FARO	fisheries applications in remotely-sensed ocean colour
FeliX	full of economic-environment linkage and integration dx/dt
FESA	food early solutions for Africa
FEWSNET	famine early warning system network
FOOD-SEC	food security
FP7	7th framework programme
FRA	forest resource assessment
FSC	forest stewardship council
G20	group of twenty finance ministers and central bank governors
G2C	government to citizens
G2G	government to government
GEWEX	global and regional energy and water exchanges
GCI	GEOSS common infrastructure
GEIS	global energy information system
GEO	group on earth observations
GEOBON	group on earth observations biodiversity observation network
GEONetCab	GEO network for capacity building
GEONETCast	global network of satellite based data dissemination systems
GEOSS	global earth observations system of systems
GFOI	global forest observation initiative
GHI	global horizontal irradiation
GIC	geo-magnetically induced currents
GIEWS	global information and early warning system
GIS	geographic information system
GLAM	global agricultural monitoring
GMES	global monitoring of environment and security
GMFS	global monitoring for food security
GOFC-GOLD	global observation for forest and land cover dynamics
GOOS	global ocean observation system
GPS	global positioning system
HOMER	hybrid optimization model for electric renewables
HRSI	high resolution satellite images
IEA	international energy agency
IFC	international finance cooperation
IFPRI	international food policy research institute
IGBP	international geosphere biosphere programme
ILWIS	integrated land and water information system

List of acronyms

IMF	international monetary fund
INCOIS	Indian national centre for ocean information systems
INPE	national institute for space research (Brazil)
INSPIRE	infrastructure for spatial information in the European Community
IOC	intergovernmental oceanographic commission
IPCC	international panel on climate change
IRD	institute for research and development (France)
IRP	international resource panel
ISRO	Indian space research organization
IT	information technology
ITC	faculty of geo-information science and earth observation, university of Twente (the Netherlands)
ITTA	international tropical timber agreement
ITTO	international tropical timber organization
JRC	joint research centre
LCOE	levelised cost of energy
LME	large marine ecosystems
MARS	monitoring agriculture with remote sensing
MESoR	management and exploitation of solar energy knowledge
MRV	measurement, reporting, verification
MSWS	malaria early warning system
NAMEA	national accounting matrix with environmental accounts
NASA	national aeronautics and space administration (US)
NDVI	normalized difference vegetation index
NGO	non-governmental organization
NLBI	non-legally binding instrument on all types of forests
NMO	national meteorological organization
NOAA	national oceanic and atmospheric administration (US)
NPP	net primary production
NRSC	national remote sensing centre (India)
NWP	numerical weather prediction
OBSERVE	strengthening and development of earth observation activities for the environment in the Balkan area
OECD	organization for economic cooperation and development
OGC	open geospatial consortium
PES	payment for ecosystem services
PGIS	participatory GIS
PI	Pacific islands
PIPEMON	pipeline monitoring
PROFOR	programme on forests
QGIS	quantum GIS
Ramsar	convention on wetlands of international importance
RAOCC	African network of experts on earth observation and climate change
RECTAS	regional centre for training in aerospace surveys
REDD	reduced deforestation and forest degradation

List of acronyms

RICS	royal institution of chartered surveyors
RS	remote sensing
RSS	rich site summary
SADC	Southern African development community
SAFARI	societal applications in fisheries and aquaculture using remote sensing
SAFER	services and applications for emergency response
SAHFOS	Sir Alister Hardy foundation for ocean science
SANSA	South African national space agency
SAR	synthetic aperture radar
SBA	societal benefit area
SDI	spatial data infrastructure
SEEAW	system of environmental economic accounting for water
SEIS	shared environmental information system
SEOCA	GEO capacity building initiative in Central Asia
SERVIR	regional visualization and monitoring system
SIGMED	spatial approach of the impact of agricultural activities in the Maghreb on sediment transport and water resources in major watersheds
SME	small and medium enterprise
SRC-PAS	space research centre – Polish academy of sciences
SSE	surface meteorology and solar energy dataset
START	global change system for analysis, research and training
TEEB	the economics of ecosystems and biodiversity
THORPEX	the observing system research and predictability experiment
TIGER	technology informatics guiding education reform
TIGGE	THORPEX interactive grand global ensemble
UCAR	university corporation for atmospheric research
UK	United Kingdom
UN	United Nations
UNCCD	United Nations convention on combating desertification
UNCTAD	United Nations convention on trade and development
UNDP	United Nations development programme
UNEP	United Nations environmental programme
UNESCO	United Nations educational, scientific and cultural organization
UNFCC	United Nations framework convention on climate change
UNSDI	United Nations spatial data infrastructure
US	United States
USDA	United States department of agriculture
USGS	United States geological survey
UV	ultraviolet
VCS	verified carbon standard
VGI	volunteered geographic information
VRC	village resource centre
WB	World Bank
WEC	World energy council
WFP	World food programme

List of acronyms

WHC	World heritage convention
WHO	World health organization
WISE	water information system for Europe
WMO	World meteorological organization
WPP	water partnership programme
WRI	World resources institute
WTA	willingness to adapt
WTP	willingness to pay
WWRP	World weather research programme

1. Introduction

The second report on marketing of earth observation products and services appears more than two years after the first report on marketing of earth observation products and services.
The experience and insight gained in these years of actual promotion and capacity building in earth observation can be captured in the new report that builds on, and is the logical continuation of, the first one.

Although the contributors to this report, and there are many, certainly have obtained more expertise in the field, they do not pretend that they are now experts in marketing earth observation. This report rather is a reflection of a journey that will ultimately lead to more effective and efficient applications of earth observation solutions. If the report helps to generate ideas and stimulate discussion on the subject, it has achieved its goal. The report does not pretend to be complete and if readers can formulate better solutions and strategies than offered in the report, they are invited to do so.

The main motto of this report is (as prelude to a so-called elevator pitch):

"Earth observation helps you
... save lives
... save money
... save the environment"

(without the sequence indicating any priority)

The statement is about "earth observation", because it is truly our conviction that earth observation can achieve this. It states "helps", because earth observation does not provide stand-alone solutions, but provides support integrated solutions that also include other disciplines. It puts "you" in a central place, because fulfilling the requirements of the client (i.e. the end-user) is what matters. It talks about "save", because, though generating income through earth observation is very well possible, the benefit of a lot of applications concerns so-called externalities that cannot be expressed in monetary terms, at least not in our current economic models. Finally, examples presented in this report and in many other places show that the motto is actually true.

The next section describes the general marketing approach for earth observation. Subsequently examples will be given for disaster management, crop modelling, water management, environmental management, climate change, marine environment, forest management, health, energy, weather, and, finally, urban management, land administration and spatial data infrastructures. In each of these sections attention will be given to international trends regarding the subjects: earth observation applications, socio-economic benefits, and promotion and capacity building. A separate section is dedicated to promotion and capacity building, as it merits extra attention.

The last section of the report contains some special considerations related to the marketing of earth observation, giving directions for future steps. This is also the place to state that it is impossible to cover all aspects related to these subjects and that therefore a selection is made that admittedly never does justice to the broad range of topics contained in the headings mentioned above.

This is not a scientific report, nor does it pretend to be original. Rather, it presents a compilation of available information and ideas. By rearranging and recombining this existing knowledge, new insights for action can be obtained.

The literature references that are given in the appendices provide a link to the information used as a basis for this report. The references are part of the GEONetCab capacity building web that can also be accessed through the GEO web portal.

1. Introduction

Paradoxically, although this report is about earth observation, it seems to contain less "earth observation" than the first report. Most probably this is caused by the fact that the full benefits of earth observation are only obtained when earth observation is integrated in more general services and that, to achieve this, one has to step outside the "earth observation box".

The introduction to this report is not complete without special thanks to all those who contributed directly or indirectly: the GEONetCab project partners, the GEONetCab advisory board, the GEO community and numerous earth observation specialists and experts in other fields.

The European Commission is especially acknowledged: the generous suport of the 7th Framework Programme made this report and many other promotion and capacity building activities possible.

2. General approach

The approach towards marketing of earth observation can be described as follows:

- Earth observation applications are on the verge of reaching new user communities;
- To be successful these new user communities need to be involved;
- Special attention needs to be given to the weakest link / last mile aspects; and
- A marketing mix that consists of promotion and capacity building can achieve this.

Later in the report concrete examples are given to illustrate the importance of involving the end-users and what the weakest link and last mile aspects exactly are. The GEONetCab project has engaged in a number of promotion and capacity building activities of which an overview is given in the following figure.

Marketing of Earth Observation Products & Services (framework study)	Regional Studies (Poland, Czech Republic, French-speaking Africa, Southern Africa) + Synthesis
Capacity Building Strategy	Success Stories, Toolkits, Roadshow, Quick Win Projects, Workshops, Capacity Building Web

Figure 1:
GEONetCab promotion and capacity building activities

The philosophy behind these activities will be explained below. The activities are directed at three different target groups: professionals, decision makers and communities (figure 2).

Professionals may be earth observation specialists, but also engineers or experts in other disciplines that are interested in using remote sensing. Earth observation specialists are very well aware of the technical possibilities of remote sensing, but less acquainted with the general context in which earth observation can play a role and less equipped with promotion and acquisition skills.

Other professionals tend to get lost in the myriad options that earth observation seems to offer and do not have a clear insight in how earth observation can help them solve their day-to-day problems.

Similarly, decision-makers (managers, politicians, etc.) have no idea what earth observation is all about. On the one hand raising awareness about the potential of earth observation is needed; on the other hand it is necessary to gain sufficient knowledge for proper demand articulation.

Communities (non-governmental organizations, civil society organizations, farmers' groups, indigenous communities, etc.) also need to be made aware, as earth observation can be a powerful tool for community participation and the advancement of community interests.

All these groups can apply simple earth observation tools, such as Google Earth applications, but they need to be told what the possibilities are and shown how the applications actually work.

The sections on societal benefit areas will give

Figure 2: GEONetCab target groups

2. General approach

a number of examples on how this works in practice. Of course the first step is to mobilize the different target groups in order to start up a dialogue and this is one of the main achievements of the GEONetCab project.

Before this first step could be taken a thorough analysis of the situation had to be made and this was done through a combination of regional studies on bottlenecks and opportunities for earth observation in the four regions of the project (French-speaking Africa, Southern Africa, Poland and the Czech Republic) and a general framework study (marketing of earth observation products and services, part #1).

The studies are all described in detail in separate reports and can be found at
www.geonetcab.eu

The main findings of the regional studies are summarized below:

- The levels of capacity in earth observation in Africa differ considerably; in some countries there is almost no capacity, and therefore very little application. Academics are usually the main agents for change.
- South Africa has a comprehensive framework for the development of a national space sector, accompanied by substantial investment in the sector; the difference with the other countries in the SADC region is therefore quite large.
- Poland and the Czech Republic have benefited considerably from European cooperation programmes involving space applications; this has enabled them to increase their individual, institutional and infrastructural capacity.
- In terms of market perspective, disaster management and climate change are most frequently mentioned (whether this translates to real opportunities for economic development will be discussed in the next sections).
- The private sector in earth observation is growing across the board; the main client is the public sector.
- There is sufficient capacity at academic level to absorb new developments (with the exception of some African countries, as mentioned above).
- Within the public sector itself, there is a need for stronger earth observation capacities, especially at the local level.
- Data access for all, in terms of accessibility, affordability and usefulness, is mentioned as the major constraint.
- Concrete applications at local level offer the best perspective for benefiting from earth observation applications, while most attention seems to be going to global and scientific initiatives.

The framework study (marketing of earth observation products and services, part #1) identified different categories of products and services, analysed the life cycle phase of these products and services and looked at regional differences.

The categories will appear again in the following sections on societal benefit areas. The life cycle of products and services consists of six phases (initialization, system analysis & design, rapid prototyping, system development, implementation and post-implementation). The distinction in phases is made to assess the possibilities of application and to determine the type of marketing that is needed: obviously this is different for selling a ready-to-use product than for product development. Regional aspects take the various levels of development into account: some solutions may be better suited to some regions than others, because of the differences in capacity and investment potential. All this resulted in a preliminary indication of the optimal marketing mix for earth observation, which is elaborated further in this report.

Two important factors deserve special mention. One is the concept of "customer value proposi-

2. General approach

tion", i.e. the value of the product or service as perceived by the client. This is not the same as, although there could be overlap with, a listing of excellent features of the product or service.

For example, if the most important priority of a client is mobilization of the extended family, a spacious (and safe) car will probably be the overriding consideration in the purchase of a vehicle and the promotion of other features (speed, design) will have little or no effect on decision-making.

Or, as geo-information example, take the case of the city of Turrialba in Costa Rica, where quite an effort was made (with the help of free open-scource software) to map buildings and gather data on and from the population with the aim of disaster reduction, and where the municipal authority discovered that the resulting GIS-system was also very effective for introducing a property tax.

In marketing earth observation the focus until now has been very much on the (technical) features of products and services, a revaluation in terms of customer value propositions is desperately needed and may yield surprising results.

The second important factor is the demonstration of socio-economic benefits. At the macro-level (global, continental) sufficient studies are available that show the economic benefit of earth observation applications and some examples will be highlighted in this report.

Surprisingly, at a more local level, demonstrations of economic benefit become very scarce and examples of quantification of cost-benefit are hard to come by. This is perhaps related to the fact that the focus has notoften been on the local client.

For instance, many politicians and managers firmly believe that the cost-benefit ratio for earth observation applications is still an important barrier preventing its wider usage. In the next sections an attempt will be made to redress this shortage of examples and hopefully there will be many more "out there" that can be added.

In summary, clients want a product or service that is fit-for-purpose, practical, reliable, cost-effective, integrated in the business or organizational process and easy-to-manage in terms of client capacity (i.e. the client is clearly in the driver's seat).

All these considerations led to the following portfolio of actions:

- Intensive awareness raising
- Initiation of a dialogue with promising end-user communities
- Demonstration of successful applications
- Gaining of more knowledge about "weakest link aspects" for each particular country or region
- Stimulating of demand through a mix of workshops, success stories and quick-win projects, supported by marketing toolkits and a web facility for capacity building

First of all the capacity building strategy and the concept of the capacity building web were developed. Section 4 will will elaborate on this.

In the project regions a number of quick-win or demonstration projects were implemented. Where relevant, they will be referred to in the sections of the respective societal benefit areas.
A series of promotion and training workshops was held in the project regions. In parallel quite a number of promotion visits to international organizations took place, such as the World Bank, the Inter-American Development Bank, OECD, IFPRI (on crop modelling), and, of course, the European Commission.

Promotion has different forms: meetings, presentations, but also contributions to publications, such as on geo-information applications for UNCTAD.

2. General approach

An important element of the promotion package is the compilation of success stories and marketing toolkits. Success stories are one- or two- page leaflets in a non-technical language that show the feasibility, replication capacity and sustainability of concrete earth observation applications. Success stories are not only developed by projects, such as GEONetCab, but also by partner organizations, such as Eurisy.

Getting the message across is more important than the format in which the message is delivered. Marketing toolkits give a short introduction into the potential of remote sensing applications for different subject matters in presentation-form. They can be shortened or extended using local examples, depending on the place and goal of the event. They also provide a short, low-barrier, tutorial for decision makers, who want to know more about earth observation in relation to a specific subject, or to earth observation professionals, who want to know more about promotion of earth observation.

The marketing toolkits extract information from the wealth of information of the GEONetCab capacity building web and the GEO web portal to accommodate decision makers and others with limited time available to absorb information. Each marketing toolkit comes with a reference list that guides the reader to (freely available) documents that contain more in-depth information (the links are already provided, minimising search time). The marketing toolkits also form the basis of this report.

In addition to the promotion events in the project regions a final workshop was held on April 23, 2013, in Brussels, in cooperation with Eurisy, with the title: "Environment and risk management - the added value of satellite applications".

The conclusions and findings of this workshop are also incorporated in this report.

Following this outline of the general approach and context will be concrete examples related to concrete earth observation applications. These are presented in the next sections and categorized roughly by societal benefit area, as used by GEO.

3. Earth observation products and services for societal benefit

The following sections cover the subjects of

- disaster management (3.1)
- crop modelling (3.2)
- water management (3.3)
- environmental management (3.4)
- climate change (3.5)
- marine environment (3.6)
- forest management (3.7)
- health (3.8)
- energy (3.9)
- weather (3.10)
- urban management, land administration and spatial data infrastructures (3.11)

International trends

Each section starts with a short description of salient international trends and developments in the field, providing a context for potential earth observation applications.

Earth observation applications

The options for the different earth observation applications themselves are assessed, based on the categories of the previous marketing report.

Socio-economic benefits

Where possible examples of successful practices are given and cost-benefit calculations are provided. If it is not possible to show quantitative cost-benefit figures, qualitative arguments are presented to show the added value of earth observation.

Promotion and capacity building

This results in indications for further promotion and capacity building.

As mentioned earlier, the report does not aspire to be a comprehensive compendium; the aim is to start a discussion in order to generate ideas that produce results.
It could even be that the outcome of such a discussion contradicts proposals in this report.

If the ensuing actions are successful, then the report has also accomplished its aim.

3.1 Disaster management

International trends

There are many different types of disasters. This section focuses mainly on so-called natural disasters, such as volcanic eruptions, earthquakes, landslides, floods, tsunamis, droughts or wild fires. Increasingly earth observation is used for other types of disasters as well, such as industrial calamities, explosions, terrorist attacks, etc. Climate change is a very important issue. The consequences of climate change are difficult to predict, especially at a local level. In most cases it is safe to predict that more extreme events will occur, the type depending on the location. Local governments should prepare for this and earth observation can play a supporting role to help authorities improve the resilience of the population.

Another trend is the increase in use of open-source software. This trend is across-the-board and not exclusive to disaster management, but disaster management is an area where the benefits of the use of open-source software can be seen most clearly.
Access to affordable software and data helps local governments to better prepare for disasters. This shift towards preparedness indicates another international trend.

After decades of focus on post-disaster relief, preparedness finally seems to get the attention it deserves. Historically, in most countries disaster management has been the responsibility of organizations that were more focused on emergency response than on the adoption of a culture of preparedness. It is a big step that the approach towards disaster management is now more inclusive.

The Netherlands are a case in point:
although they could now serve as an example for disaster preparedness, it took centuries of development and cooperation to reach a stage where adequate protection against flooding was achieved.

Empowerment of communities, in general and in combination with new technologies, is another important trend. Participatory approaches make community mapping possible and enable local decision making also with respect to early warning for disasters, flooding being the most obvious application. In combination with new technologies, such as sensor webs and satellite communication, local communities receive timely warnings and can implement coping strategies for each level of emergency.

Earth observation applications

In earth observation for disaster management the following categories of products and services can be distinguished: risk assessment and simulation models, forecasting and early warning, monitoring, damage assessment, and prevention and planning; each applicable to a specific type of disaster. All categories are interrelated and related to decision-making. For decision makers early warning is of cardinal importance, but they are very sensitive to false alarms: if half a country is mobilized and no extreme event occurs, this does not reflect well on local authorities. If an early warning is ignored and a disaster strikes, then the authorities are held responsible. This makes good communication between the specialists and decision makers very important.

Another consideration, and this does not only apply to the subject of disasters, concerns the persisting gap between technological capabilities and the availability of operational services for the end-users. This was one of the main findings of the workshop organized by Eurisy and the GEONetCab project in Brussels in April 2013: "decision-makers and professionals mentioned needing "tangible" services that are easy to access and that are compatible with their existing systems and work processes". The challenge is to provide these services, in cooperation with the end-users of course.

3.1 Disaster management

Below are some examples of steps in the right direction.

The International Charter on Space and Major Disasters is a famous example of monitoring, and tsunami and hurricane- / -cyclone early warning systems are equally well known. Early warning for earthquakes and volcanic eruptions is more complicated (recall what was mentioned above about false alarms). Subsidence may be a sign and detailed measurement by satellites is possible.

More generally, measuring and monitoring subsidence is important for assessing flood risk in low lying areas, especially in densely populated deltas. This is also related to increased risk due to climate change (sea level rise, more extreme events). Taiwan has an excellent and sophisticated land slide early warning system, which is part of an integrated disaster management process.

South Africa has a wild fire detection system, which is worth copying. The subjects of drought, forest fires, dust storms and extreme rainfall will appear in the sections on water management, forest management and weather, respectively.

At local level there are examples of combinations of earth observation and community participation for flood early warning and preparedness, for instance in Mozambique and the Philippines. Although in a pilot stage, they seem to be effective, especially if the communities at risk live in relative flat areas. The response time is then reasonable and the population can be relatively easily evacuated to safer areas (a school with a higher foundation serves this purpose in Southern Mozambique).

Although the warning is conveyed using satellite communication (systems such as GEONETCast can play a role here), very simple charts can be used locally to indicate the level of danger (see for example the chart in figure 3).

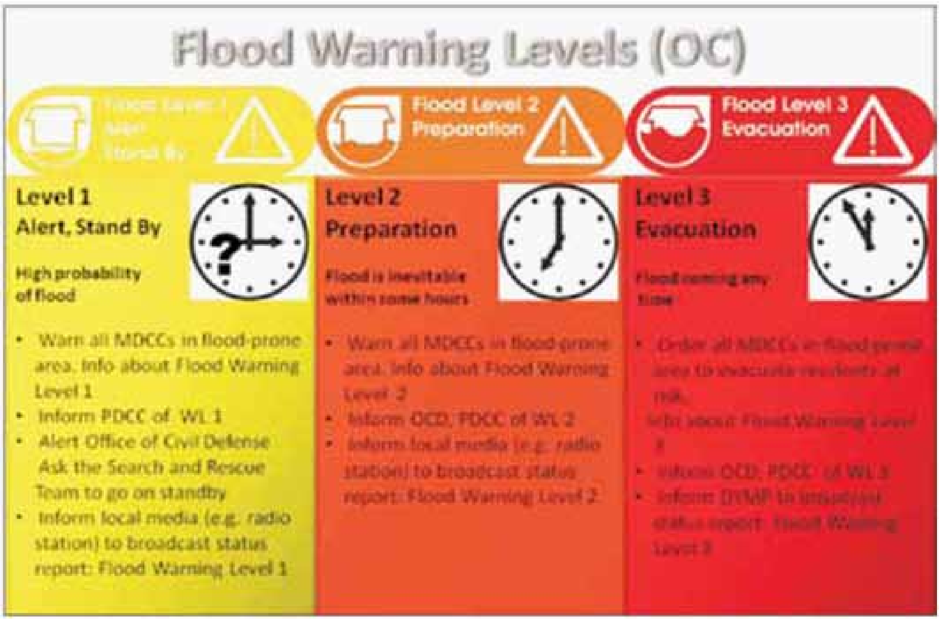


Figure 3: flood warning chart, as used in the Philippines

Although an intelligent approach is required, the process of determining the flood hazard level based on earth observation is technically not very complicated: with a digital elevation model and sufficient hydrological data the effect of potential floods can be shown. The level of sophistication depends of course on the requirements and available capacity, but in most developing countries a simple earth observation application already provides a substantial improvement, compared to the current situation.

Poland has gone through an interesting experience during and after the 2010 floods.

▶ 3.1 Disaster management

The Space Research Centre of the Polish Academy of Sciences (SRC-PAS) had a difficult time demonstrating the benefit of earth observation. Only after take-up by the media, the disaster management agencies realized that satellite monitoring could be useful. This resulted in a fruitful cooperation: in the Alice in Wonderland simulation game earth observation specialists, the police, fire squads and other disaster management agencies prepare together for future disasters.

A simple example is given in figure 5. SRC-PAS makes full use of the Copernicus SAFER programme.

Another indirect opportunity for the use of earth observation is the disaster preparedness initiative of the city of Nice in France. An app offering three types of services was developed for the city. One of them allows citizens to directly report a dysfunction or damage to infrastructure from a list of pre-defined possibilities, such as water leakage or traffic lights failure, with the Smartphone's inbuilt GPS divulging the location.
The user can also add a picture of the damage and send it directly to the urban risk prevention department. Furthermore, the application provides risk and hazard information transmitted by the application via RSS feeds and

Figure 4: initial situation (source SRC-PAS)

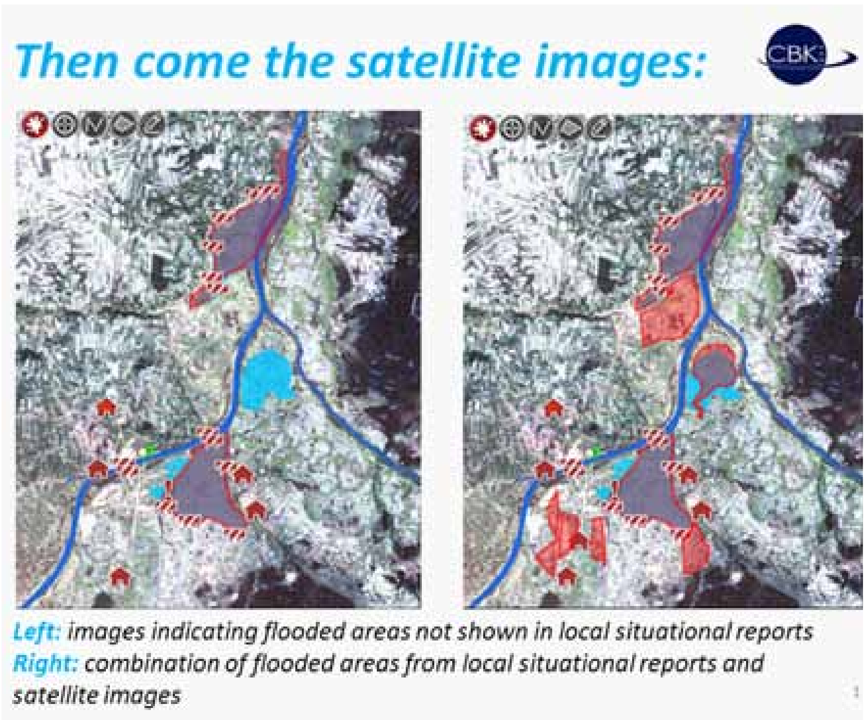
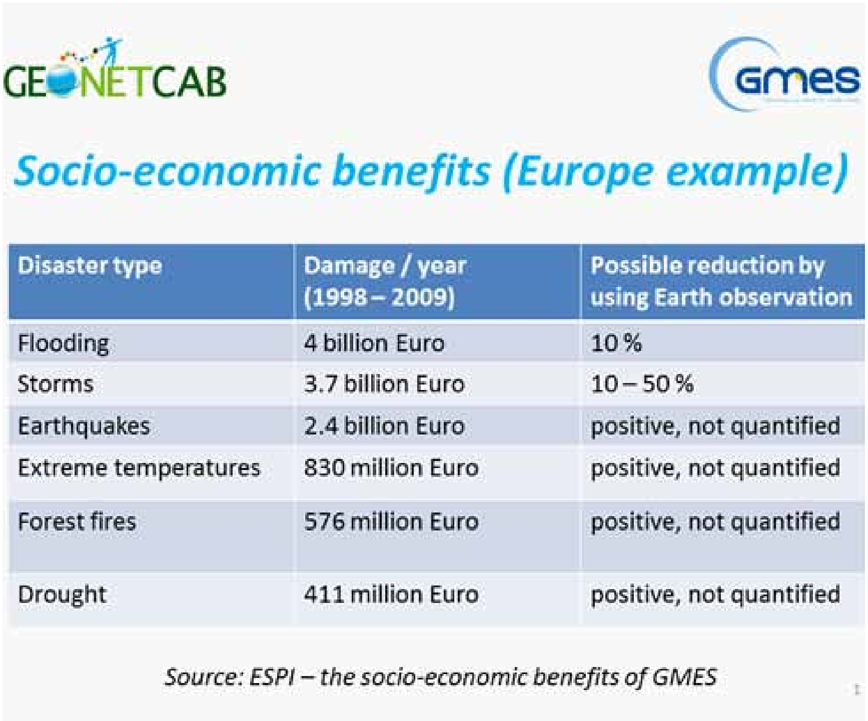


Figure 5: use of satellite images (source: SRC-PAS)

3.1 Disaster management

tweets. The citizens can also subscribe to a warning service with the choice to be alerted in cases of dangerous meteorological phenomena, floods, forest fires, accidents involving transport of hazardous goods, industrial incidents, pollution and exceptional alerts.
Earth observation obviously plays a background, but very necessary, role in risk assessment, early warning and disaster monitoring.

If more cities adopt such an approach this will create an interesting market for earth observation applications.
Decision makers are not only very interested in the location of infrastructure, but also of the people at the time of a disaster to help guide and set priorities for a rescue process. Again earth observation, in combination with GPS and GIS provides the needed background information. A number of companies, such as e-GEOS offer commercial disaster management services based on earth observation.



Disaster type	Damage / year (1998 – 2009)	Possible reduction by using Earth observation
Flooding	4 billion Euro	10 %
Storms	3.7 billion Euro	10 – 50 %
Earthquakes	2.4 billion Euro	positive, not quantified
Extreme temperatures	830 million Euro	positive, not quantified
Forest fires	576 million Euro	positive, not quantified
Drought	411 million Euro	positive, not quantified

Figure 6:
socio-economic benefits of earth observation for disaster reduction

The risk assessment studies and the related adaptation resilience plans with respect to climate change that were carried out for coastal cities in Northern Africa (Alexandria, Tunis, Casablanca, Bouregreg area) in the framework of a cooperation between the World Bank and ESA also show the supporting role of earth observation: in general it is used as a base layer for urban information, for subsidence measuring and for supporting early warning systems.

In principle, this type of study can be carried out anywhere at any level of sophistication and provide added value, as long as affordable access to remote sensing data and sufficient capacity are available.

Socio-economic benefits

Cost-benefit calculations that were made for Europe (several studies were carried out to this effect) show that investment in earth observation is not only beneficial with respect to disaster reduction, but the returns from disaster reduction alone justify the investment in the whole GMES (Copernicus) programme.

The figure above shows calculations derived from the ESPI report on the subject.

As stated earlier it is not always easy to translate the benefits of earth observation into

▶ 3.1 Disaster management

TOTAL ECONOMIC VALUE				
USE VALUES			NON-USE VALUES	
DIRECT USE VALUE	ECOLOGICAL FUNCTION VALUE	OPTION VALUE	EXISTENCE VALUE	BEQUEST VALUE
Outputs	Benefits	Benefits	Benefits	Benefits
• Petroleum and minerals • Transport • Communica-tions • Property and construction • Agriculture • Fishing • Forestry • Tourism • Public admi-nistration	• Flood control • Climate • Sustainable water resources • Sustainable natural resources management • Biosecurity • Biodiversity	• Protection from fires, floods, and natural disasters • Improved management of climate change • Insurance • Defence	• Satisfaction that resource is there • Preservation of environment and conserva-tion values • National security • Long baseline for historical analysis	• Altruistic • Preserving national assets for the next generation

Table 1: economic value of earth observation (source: based on ACIL Tasman, 2010)

monetary terms. An Australian report on the economic value of earth observation from space makes a useful distinction between different categories of benefit (see table 1).

The report estimates the annual benefit of EO for emergency management to be 200 million Australian dollars (while the total cost for all EO purposes is estimated at 100 million Australian dollars per year).

In this table economic value is perceived in terms of willingness to pay (WTP) for the existence of species and biodiversity (existence value), the ability to pass on a healthy environment to future generations (bequest value), options created or retained (option value), and indicators of status (prestige value).

This framework will also be used in other sections of this report.

Finally, the WB/ESA studies on coastal cities in Northern Africa provide calculations that show the cost-benefit of early warning systems, which can provide guidance when assessing cost-benefit at a local level.

Promotion and capacity building

There is quite a number of capacity building initiatives using earth observation for disaster management, such as the RISKcity package of ITC and the CAPRA and SERVIR programmes. Also several very instructive risk atlases have

3.1 Disaster management

been produced (Georgia, Andean region).

What is needed is a continuing dialogue with end-users (local authorities) and the local private sector to create a market for earth observation applications for disaster management.

As the cost-benefit picture for disaster reduction is relatively clear, as more extreme events will occur over time and as populations will continue to increase, it should be possible to formulate a convincing business case.

To deliver results, and this will apply to virtually all societal benefit areas, access to data has to be guaranteed and training needs to be continuously provided. Templates should be developed for simple earth observation disaster reduction operations at a local level, to stimulate uptake by local SMEs, especially in developing countries.

The best approach is to piggy-back these solutions to the development of interactive apps, either analogue or digital. That is the focus for contact with local decision makers. In addition, it is very useful to expose decision makers to examples of successful practices elsewhere, or even better, bring them into cotact with other decision makers, who already make use of operational services.

If the professionals can provide the tools and the decision makers are supportive, then it is easier to develop community initiatives for disaster management.

GEONETCast could serve as a low-cost dissemination tool for training and training material.

3.2 Crop modelling

International trends

For a variety of reasons food security is at the top of the agenda: in relation to climate change; due to the the surge in food prices a few years ago; the possible substitution of food crops by biofuel crops; and of course due to general humanitarian and development considerations. Crop modelling can play an important role, although it should not be equated with food security itself, as is a common mistake within the earth observation community. As documented extensively by FAO, World Bank, IMF, IFC, WFP and G20, food security is not only related to crop production, but also to food prices and markets. Access to markets, price risk management and handling of crises are therefore key issues; increasing production is only one element.

Another important development is the increased attention to empowerment of local communities (bridging the rural digital divide). Globally there are very good systems for agricultural monitoring, especially for early warning regarding reduced production, but the improved prediction capability of systems, such as FEWSNET, GIEWS (FAO), GMFS, FOOD-SEC (MARS), GLAM and HarvestChoice needs to be translated to the local level.

For any type of agricultural monitoring a historical analysis of weather and crop data is needed; the time dimension is very important input for decision-making. Proper analysis of time series of data will improve crop modelling capability, provide better monitoring of possible climate change effects, detect general trends (such as depletion of a natural resource) and help analyse the effects of different policies, practices, and customs, also across administrative borders.

Closely related to food security is agricultural insurance. Insurance is very much in focus as part of a general agricultural risk management strategy (see for example the World Bank report on managing agricultural production risk and agricultural insurance). The experiences in developed countries are mixed: most systems are more about income transfers than about risk management. In some cases analysis showed that indemnities paid are about equal to total premiums collected, but administration and operation are costs not taken into account. Especially the subject of index-based, weather-related agricultural insurance receives a lot of attention. The schemes are mostly based on rainfall or NDVI data. There are pilots for pasture and rangeland in Spain, Canada, Mongolia, Kenya and Mexico (for crops the correlation between NDVI and yields is apparently low). Another experiment in Africa is based on evapotranspiration (food early solutions for Africa (FESA)). Whatever the adopted methodology for an insurance scheme is, the indices should be observable and easily measurable, objective, transparent, independently verifiable, reportable in a timely manner and stable and sustainable over time. Of course the perception of the farmers is the main overriding factor here. The developed products are therefore best suited to homogeneous areas and systemic risk at an aggregated level (reinsurance).

Examples of management of other agricultural risks are the comprehensive food security and vulnerability analysis (CFSVA), food aid logistics of the world food programme (WFP) and locust habitat monitoring for GIEWS.

Earth observation applications

The global agricultural monitoring (GLAM) system of GEO is a good example of an earth observation application for crop modelling. When attached to the G20 agricultural market information system (AMIS), it will become a very powerful instrument.

The figure on the next page presents the different monitoring scales.

3.2 Crop modelling

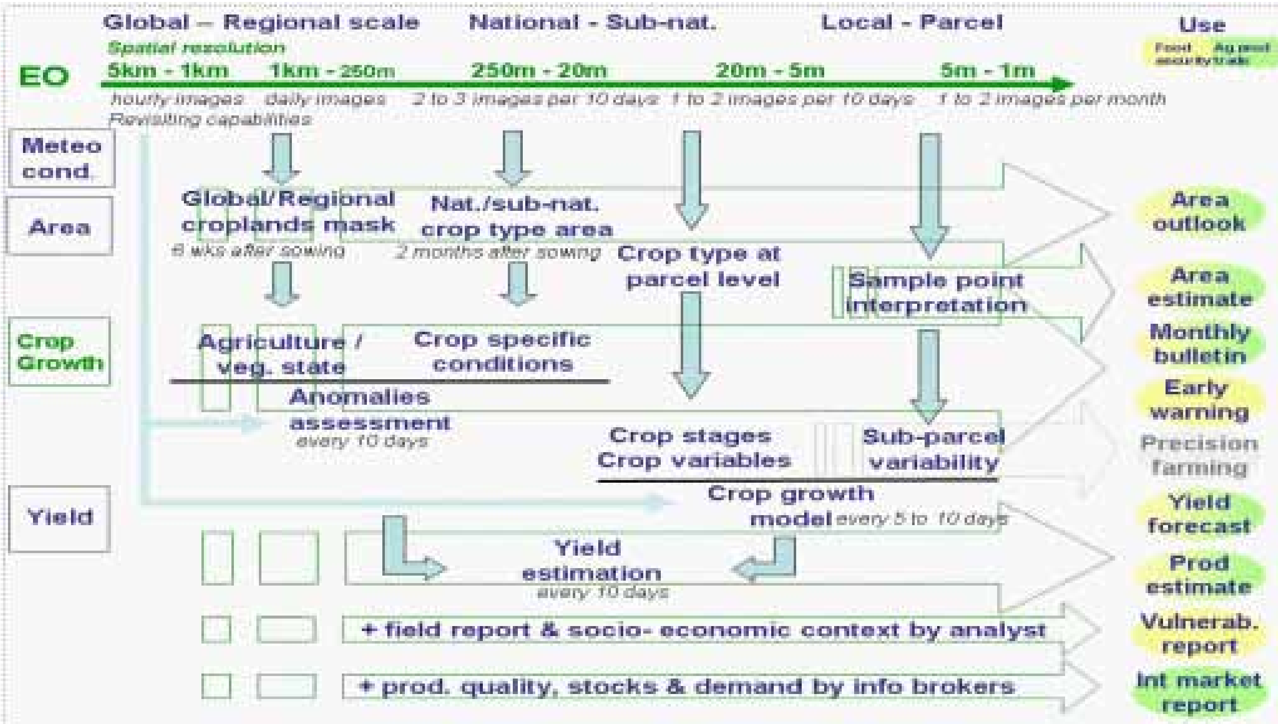


Figure 7: overview of global monitoring for food security (source: GLAM)

At local level operational sytems for crop modelling also exist, such as the Brazilian CanaSat initiative, but when a lot of small-holders with different crops are involved and land is intermittently cultivated using other vegetation, the picture becomes much more complicated.
According to the findings of the global monitoring for food security (GMFS) project EO professionals need to deliver the following:

- Accurate and reliable crop production information at specific reporting levels (national, district)
- Spatial distribution of cultivated area
- Crop growth models
- Timely and unbiased production information on main crops
- (Timely) availability of satellite data
- Good quality meteorological data
- Capacity building to enable correct use and integration of products and services

In summary, the maturity of EO services for crop modelling can be described as follows:

- Early warning: fully operational
- Cultivated area: further development needed (timely delivery of data, technical complexity)
- Extent of cultivation: accuracy needs to be improved for good local results (district, farm)
- Crop yield forecasting: fully operational
- Index-based insurance: better results for rangeland than for crops, especially for smallholders (NDVI-based, cloud cover is a problem)
- Precision agriculture: still in pilot phase (cloud cover in critical months of the growing season is a problem)

▶ 3.2 Crop modelling

Socio-economic benefits

The GMFS project provided tentative figures for the cost of crop-modelling with earth observation for Africa. (see table 2)

As development and training costs are included, it is safe to assume that a fully operational system will be cheaper. No benefits are given, but this is not strictly necessary when earth observation provides the most cost-effective alternative to achieve a clearly defined goal (see also figure 15 and the related discussion in section 3.5). Referring back to table 1 of the previous section the value of information for food security would mainly be a bequest (altruistic) value. However the value of information for markets will be determined by the market itself, as crop production will have direct consequences for market prices. What exactly this value amounts to, is not known. It may be that a process of 'forced rationalization' takes place, as with agricultural mechanization: at one point you will need the information, just to remain competitive.

An interesting experiment is that of the company e-LEAF in the Netherlands: farmers subscribe to an advisory service, for a small payment, per hectare and growing season. They receive advice on fertilizer use and irrigation requirements. The first years of the experiment were plagued by cloud cover at critical points in the growing season, but the model is innovative and could be a basis for delivering services to individual farmers or groups of farmers.

In a similar vein, the literature mentions a programme in South Africa where farmers received text messages regarding correct irrigation timing, which was estimated to have saved these farmers approximately $300 per hectare (2.47 acres). Another example is the precision agriculture service of GMV, a Spanish company: for different crops advice on fertilizer use and irrigation

Service	Definition of Unit Service	Cost (k€)
Early warning service	Annual coverage of Africa with suite of early warning indicators, at 10-day update frequency	230
Agricultural mapping	Validated map of cultivated area (10 – 20 m resolution) per 100 000 km2	175
Crop yield assessment	Yield forecast for 2-3 main crops, for 100 000 km2	85
Support to CFSVA	Support to one CFSVA mission	35

Table 2:
Costs of EO Services for crop modelling / food security support;
a very global estimate, including development for specific user needs and training (source: GMFS)

is given, based on parameters derived from earth observation. This service is fully operational, and apparently cloud cover during the growing season is less of a problem in the regions the service is on offer.

In the framework of bridging the rural digital divide the results of the village resource centres (VRC) programme of the Indian Space Research Organisation (ISRO) will be interesting. The programme provides satellite communication services to 600,000 villages throughout India, including interactive advice on agriculture. No cost-benefit calculation is available yet.

Governments or inter-government bodies use earth observation for insurance and monitoring, as well as for control of subsidies for agricultural

▶ 3.2 Crop modelling

production. USDA and the European Commission are examples. As this type of verification is mandatory, real cost-benefit is difficult to determine.

The general conclusion is that if cost can be lowered, for example by operating with reasonable rather than complete data, this will deliver sufficient added value to justify investment, also for smallholders in developing countries.

Promotion and capacity building

It is expected that the results of the GEO GLAM initiative will benefit all countries and organizations participating in GEO. If best practices are developed that trickle down and can be used locally, that would give a big boost to affordable agricultural monitoring at a scale that is relevant to the individual farmer. Reaching the local user is also one of the objectives of the AGRICAB project (the follow-up of the DevCo-Cast and GMFS projects). The project aims at capacity building in optical remote sensing, radar remote sensing, agro-meteorological modelling, food security information systems, and product validation for agricultural monitoring. Although reaching individual smallholders remains difficult, the project may generate valuable information and methodologies for agricultural extension services in developing countries.

Apart from capacity building practical products are needed that operate on data good-enough to provide added value locally. Focal points for the development of enhancement of such products are: cheaper processing of NDVI calculations, adequate assessment of ground truth, inclusion of a thorough historical analysis (making use of free and open data) and, perhaps most important of all, integration with other agricultural services. If the GEOSS common infrastructure (GCI) can provide affordable data for these operational purposes (and not only for research) then that is already a big step in the right direction.

3.3 Water management

International trends

For decision making in water management the theme is:
"we can only manage what we measure".

Trends concerning the water cycle (water resources availability and quality) are related to:

- Economic development
- The concept of the "green economy" (including climate change)
- Poverty reduction
- Community empowerment
- Risk management

An example related to these trends and the decision making is the Africa water atlas, an initiative supported by the African Union (AU), ESA-TIGER, the EC, the US state department and USGS. The atlas gives a very visual presentation of the modelling of Africa's surface water systems (water balance data), identifying:

- Hotspots:
  areas with a tenuous food security situation
- Hopespots:
  areas with potential for rainwater harvesting
- Water towers:
  areas with an upstream water surplus

The atlas includes a lot of earth observation images that help visualize problems and solutions. Action points (and these do not only apply to Africa) identified by the atlas are:

- Provide safe drinking water and ensure access to adequate sanitation
- Foster cooperation in transboundary water basins
- Provide water for food security
- Develop hydropower to enhance energy security
- Meet growing water demand
- Prevent land degradation and water pollution
- Manage water under global climate change
- Enhance capacity to address water challenges

Another regional example deals with water management in Europe (from: water resources across Europe – confronting water scarcity and drought (EEA)).

The European Environmental Agency (EEA) uses a framework used for water resources management, which is also used for environmental analysis, and is called DPSIR. DPSIR stands for driving force, pressure, state, impact, response (see figure 8).

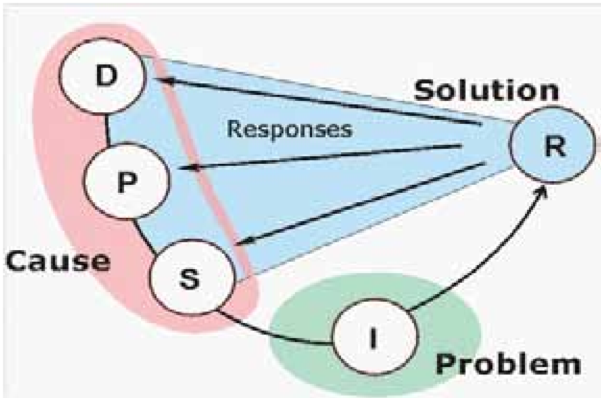


Figure 8:
DPSIR framework: driving force, pressure, state, impact, response (source: EEA)

A driving force (water use) causes pressure on the system, which alters the state of the system and causes a certain impact, which presents itself as a problem to society. In this case the water exploitation index (ratio of annual total water abstraction to available long-term freshwater resources) is used as an indicator for pressure on the system.

If the ratio is (too) high, this leads to an unsustainable situation, which needs to be addressed. Proposed actions are: water pricing, drought management plans, water efficiency and conservation measures, raising awareness, tackling ille-

3.3 Water management

gal water use, alternative supplies, and desalination. Europe has to comply with the information requirements of river basin scale water balances, based on the UN system of environmental economic accounting for water (SEEAW, 2007) and on WISE (water information system for Europe).

Drought management is another priority. An example from the US gives guidance on how to make information relevant to managers (from: managing drought: a roadmap for change in the United States).

Normally, the main messages given to managers are:

- It is definitely getting warmer
- Though we expect that the hydrological cycle will be enhanced due to more energy in the atmosphere, we really don't know how precipitation patterns will be affected

Managers are then liable to respond with:

"I need more information before I will invest in adaptive activities – I don't know how to respond to this much uncertainty".

Reframing the information in terms of combining the effect of temperature and demand identifies the following effects:

- Increased human demands for water for, among others, the human, agricultural and environment sectors
- Impacts on supply (increased evaporation from reservoirs, increased consumption by plants, decreased snowpack, etc.)
- If it does rain more in a warmer climate, it is likely to rain harder rather than more often

The message to managers then becomes:

"though we don't know much about whether total precipitation will increase or decrease, the implications of global warming for water management are likely a reduction in average supply availability and an increase in extreme events, including both droughts and floods".

This message is framed in terms of risk to managers' systems.

The above shows that it is necessary to incorporate institutional, political, and economic considerations, and translate physical science findings into relevant information for specific types of decisions within specific sectors.

In general, communication should be perceived by users as:

- Salient (answering the right questions)
- Credible (coming from a trusted source)
- Legitimate (accurate)

Earth observation applications

The categories of earth observation products and services for water management are: hydrologic information systems, soil moisture modelling, drought monitoring and early warning, monsoon monitoring and forecasting (see also section 3.10 Weather).

The added value of earth observation lies in:

- Increased insight in and visibility of available resources
- Analysis of historical and future use for planning and decision making
- Mapping of informal settlements, infrastructure and resources
- Analysis for more efficient use of water resources
- Hydropower: assessment of resources, planning and monitoring (see energy societal benefit area)

3.3 Water management

- Being an instrument for community empowerment

For practical earth observation supported water resource management the following information is needed (from: application of satellite remote sensing to support water resources management in Africa - results from the TIGER initiative (UNESCO, ESA)):

- Land use and land cover mapping and change monitoring
- Water abstraction estimates with respect to crop water demand estimates for irrigated areas
- Refined land use / land cover mapping
- Surface water bodies or water pools (location, extent, dynamics)
- Digital elevation models and derived products
- Estimates of basin-wide evapotranspiration and precipitation
- Water and vegetation monitoring (entire aquifer)
- Ground subsidence monitoring and its correlation with groundwater abstraction

As can be seen in the above list, earth observation for water management does not only deal with water, but consists of the integration of a lot of different data types, such as land cover and, digital elevation models. Data and methodological support can be obtained from GEWEX, GRDC and WMO (guide to hydrological practice).

Socio-economic benefits

The use value of sustainable water resources management is the ecological function value.

This value is more easily expressed in societal benefit terms then in monetary cost-benefit terms. Several attempts have been made (from: measuring water use in a green economy (UNEP, IRP)):

- Water registers (as key to fair distribution of access to water)
- Water and ecosystem capital (water is seen as natural capital, linked to the economy and general well-being (UN SEEAW 2007, NAMEA))
- Water scarcity and vulnerability indices (per capita, renewal versus withdrawal, etc.)
- Water footprint assessment (amount of water consumed per unit of product)
- Life cycle assessment (benchmarking for industries)
- Water stewardship (quantify corporate water monitoring)

From local to global, different levels play a role:

- User level:
  price and technology play a key role (creating awareness, charging prices based on full marginal costs, stimulating water saving technology)
- Catchment or river basin level:
  choice on how to allocate the available water resources to the different sectors of the economy (depends on the value of water in its alternative uses)
- International trade:
  water as a global resource (overall efficiency)

And then there are different attempts to calculate the monetary value of externalities, and ecosystem resources and services that are currently not priced, making use of so-called decoupling concepts:

- Resource decoupling:
  reducing resource use per unit of economic activity
- Relative decoupling:
  resource use still increases but at a lower rate of economic growth
- Impact decoupling:
  scale and character of resource use causes no negative environmental impact
- Absolute decoupling:
  resource use declines irrespective of the growth rate of the economic driver

3.3 Water management

These general value assessment methods are presented here, because it is also difficult to make direct cost-benefit calculations for earth observation products and services. But once these goals are clearly set, the added value of earth observation can be determined.

In some cases, for example in irrigation systems, the economic value of earth observation can be directly calculated, in terms of water resources saved (supposing that water is appropriately priced).

Figure 9: Bouregreg area in Morocco

Promotion and capacity building

The TIGER (targeted at Africa) and Dragon (targeted at China) programmes are examples of capacity building initiatives.

In the Bouregreg area of Morocco (see figure 9) a demonstration project (SIGMED) was implemented within the framework of the GEONetCab project on water resources management in relation to climate change. Although the project has a strong research and capacity building component, it brings all stakeholders together to achieve better water resources management.

Most items on the list of practical earth observation for water resource management can be derived from satellite images in a relatively straightforward way.
What complicates matters is that many different types of information are required and need to be integrated in an intelligent way. Still, as the example from Morocco shows, in most cases this additional benefit can be obtained by relatively simple means.

Another important feature of earth observation is the visualization aspect. Showing the effect of water resources management interventions over time is a powerful instrument for participation of stakeholders and raising awareness with the general public on what would otherwise remain very abstract and theoretical concepts, such as for example water footprints.

Not only in the Water Atlas of Africa, but also in quite a number of policy documents of international organizations, earth observation is mentioned as a promising option for the future. A special example is the water partnership programme (WPP) of the World Bank, which mentions earth observation specifically as an area for further exploration.

Focal points for promotion are: the general appraisal of water resources, support to hydrological models (such as improving on the "curve number" method through better land cover and DEM analysis), and the provision of a historical analysis (using free and open data). As shown in the list of practical applications earth observation for water resource management encompasses a broad range of operations. Here again, the added value in comparison with current practices is more important than an absolute performance standard.

3.4 Environmental management

International trends

Six major challenges are identified for environmental management:

- freshwater scarcity
- climate change
- habitat change
- invasive species
- overexploitation of oceans
- nutrient overloading

It is generally recommended that environmentally oriented policies and public investment in environmental management must be seen as life insurance, rather than luxury. This leads to the concept of payment for ecosystems (PES), which will be discussed in the socio-economic benefit section.

One of the initiatives that aim to provide a mechanism to achieve sound environmental management is TEEB (the economics of ecosystems and biodiversity). To answer the questions "what can be done?" and "what message should be given" a number of options are proposed.

Certification and labelling is one of the options. With respect to payment for ecosystem services the following market profiles could be further developed:

- Carbon, in the form of compliant and voluntary carbon forestry
- Water, including compliant water quality trading, voluntary watershed management payments, government-mediated watershed payment for ecosystem services
- Biodiversity, in the form of compliant and voluntary biodiversity offsets, government-mediated biodiversity payment for ecosystem services, individual fisheries quotas
- Bundled, in the form of certified agricultural products

The big challenge is to translate the interest of the general public in environmental issues, which is apparently not coupled with a willingness to bear the full burden of environmental accounting, in future policies that work.

The European environment agency proposes the following:

- Better implementation and further strengthening of current environmental priorities
- Dedicated management of natural capital and ecosystem services
- Coherent integration of environmental considerations across the many sectorial policy domains
- Transformation to a green economy

To achieve this, several elements are proposed for Europe by the EEA to support the environmental strategy:

- Eco-innovation in products and services
- Exploit the first-mover advantage in air pollution reduction, water and waste management, eco-efficient technologies, resource-efficient architecture, eco-tourism, green infrastructure and green financial instruments
- Combine climate change mitigation and air pollution abatement legislation. This could deliver benefits in the order of EUR 10 billion per year through reductions in damage to public health and ecosystems
- Build on key elements, such as European research programmes, European space and EO policy (including Copernicus (GMES) and Galileo), INSPIRE and SEIS
- Implement information systems in support of the EU 2020 strategy: cloud computing, smart grids and mobile GIS

The above serves as an example from one specific region (Europe) to give an idea what the discussion and policy formulation on environmental issues entail.

3.4 Environmental management

Earth observation applications

Categories of earth observation products and services for environmental management are:

- Analysis and monitoring of marine and coastal ecosystems (global, as well as regional)
- Analysis and monitoring of terrestrial and freshwater ecosystems (global, as well as regional)
- Biogeophysical variables (vegetation, soil, radiation, water cycle)
- Local applications, such as protected areas
- Biodiversity modelling & monitoring
- Invasive species monitoring
- Ecological forecasting

If strategies as proposed in the previous section are implemented, earth observation will play an important role in determining the status quo, monitoring and evaluation. The importance of spatial aspects of ecosystems and biodiversity management is underlined by the following considerations (from: geospatial tools address emerging issues in spatial ecology):

- Presence and abundance of organisms, their interactions with the environment, and the other ecological processes form spatial patterns over time
- Patterns of disturbance are heterogeneous and spatially structured
- Ecological models that account for spatial processes are more realistic and powerful than those that do not
- To prepare, monitor and achieve assessments and goals, quality data and information must be registered accurately to both place and time

Earth observation applications play a fundamental role in all these processes. Specific areas where earth observation has added value (for ecology) are listed in table 3.

Population ecology	GPS, satellite-telemetry. Landscape categories may become barriers or connecting corridors between population clusters. Models of landscape dynamics, using geospatial data, generate maps of suitable habitat over time for input into metapopulation models.
Landscape ecology	Interactions between species occur at spatial scales determined in part by the mobility of the organisms. Basic element of land inventory for resource management. Multi-temporal and hyper-temporal remote sensing and image analysis allow annual cycles, interannual variability, and state-changing anomalies caused by disturbance and succession in ecological communities to be tracked through biophysical measures of productivity, photosynthetic activity, foliar chlorophyll concentration, standing biomass, leaf area index, vegetation species type, and so on. Change detection to map changes in land cover that result from natural or anthropogenic disturbances.
Ecosystem ecology	Interactions between organisms and the environment with an emphasis on the exchange and flow of matter and energy between biota, water, soil, and atmosphere. Evaluating ecosystem services in support of sustainable ecosystem management requires the use of (spatial) models. Inclusion of individual species or functional types in ecosystem modelling and models linked to carbon.
Ecosystem goods and services	Assessing the status of ecosystem goods and services, provided by the regulation, habitat, production, and information functions of ecosystems. Predicting the impact of habitat loss and fragmentation on biodiversity elements and ecosystems processes.

Table 3: overview of EO added value for ecology (from: geospatial tools address emerging issues in spatial ecology)

3.4 Environmental management

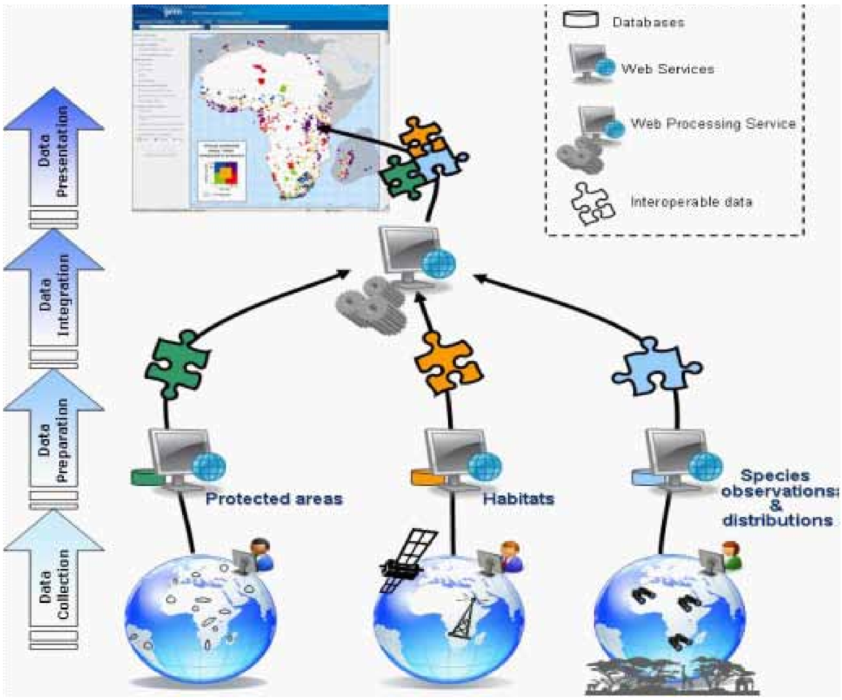


Figure 10:
set-up of digital observatory for protected areas in Africa (DOPA)

Factors that play an important role with respect to potential losses and benefits are:

- natural resource depletion
- increase in protected area coverage
- climate change
- change in consumer preferences
- increased scientific understanding
- spread of disease
- energy insecurity
- technological innovation
- increased environmental regulation
- etc.

To illustrate this, the different relationships are presented in figure 11 on the next page, which is an application of the DPSIR framework that was mentioned and shown in section 3.3 Water (figure 8).

An example is the operational framework for the digital observatory for protected areas in Africa (DOPA). Figure 10 shows how such a system could work.

The report on adequacy of biodiversity observation systems to support the CBD 2020 targets by GEOBON provides a very good overview, not only of existing and needed observation systems, but also of the added value earth observation provides.

Socio-economic benefits

Payment for ecosystem services (PES), such as the economics of ecosystems and biodiversity (TEEB) attempt to estimate economic benefits of management of the environment for business, policy makers as well as local and regional authorities.

The state and development have to be measured. There is quite a number of principles involved in valuation practices:

- The focus of valuation should be on marginal changes rather than on the "total" value of an ecosystem
- Valuation of ecosystem services must be context specific, ecosystem-specific, and relevant to the initial state of the ecosystem
- Good practices in "benefits transfer" need to be adapted to biodiversity valuation, while more work is needed on how to aggregate the values of marginal changes
- Values should be guided by the perception of the beneficiaries
- Participatory approaches and ways of em-

▶ 3.4 Environmental management

bedding the preferences of local communities may be used to increase the acceptance of valuation

- Issues of irreversibility and resilience must be kept in mind
- Substantiating bio-physical linkages helps the valuation exercise and contributes to its credibility
- As inevitable uncertainties arise in the valuation of ecosystem services, a sensitivity analysis should be provided for decision makers
- Valuation has the potential to shed light on conflicting goals and trade-offs but it should be presented in combination with other qualitative and quantitative information, and adaptation might still be necessary

situation where most people will only become active when the environment is in such a sorry state that any action is simply too late. This implies that people need coaxing to gain insight in the actual situation, without overcomplicating things.
Earth observation is an excellent instrument to do this, as it can serve as a tool to visualize the actual situation as well as changes over time. To add a thought experiment: a grid or raster system could be used as a basis for an environmental valuation of pixels or area by experts and by the public in an interactive mode, including future projections.

Although the underlying models might be complicated, the front end part would be easy for anyone to understand and a simple rating system of certain qualities would be sufficient.

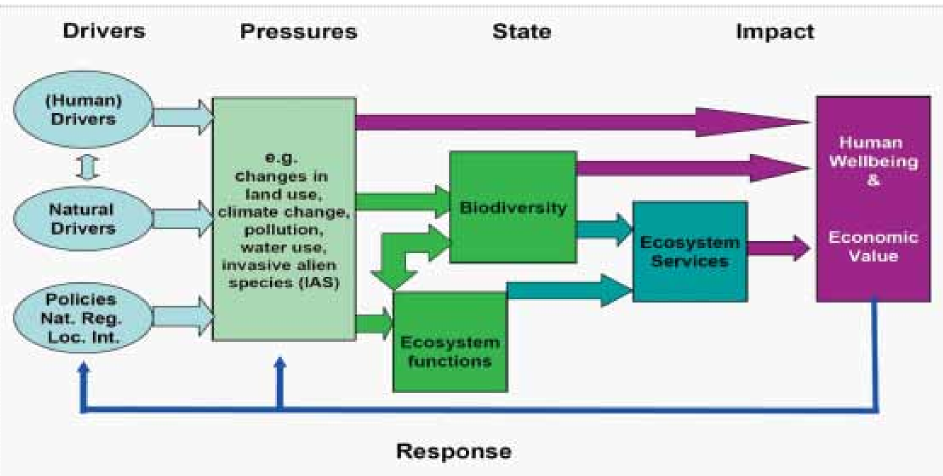


Figure 11:
DPSIR framework, leading to human well-being and economic value

Policies that are directed at anticipation and not at reaction would then receive more support, and hopefully more participation, from the population in general.

(Visualizations of) models, such as EUFASOM/GLOBIOM (see figure 12) or FeliX, could then not only perform scientific functions, but also provide the basis for societal policy discussions.

The advice "values should be guided by the perception of the beneficiaries" as well as the observation that "the general public has a genuine interest in environmental conservation, but is also guided by economic interest", both need some elaboration.
The apparently conflicting goals, combined with a lack of knowledge about effects of policies or non-intervention regarding the environment, lead to a

This idea is not new. It refers back to apps that are used by local governments to involve citizens in disaster reduction, but also INPE's initiative to involve citizens in monitoring conservation and deforestation in the Amazon region.

One example where the public already responds is formed by systems of certification, either according to international standards, such as the forest

▶ 3.4 Environmental management

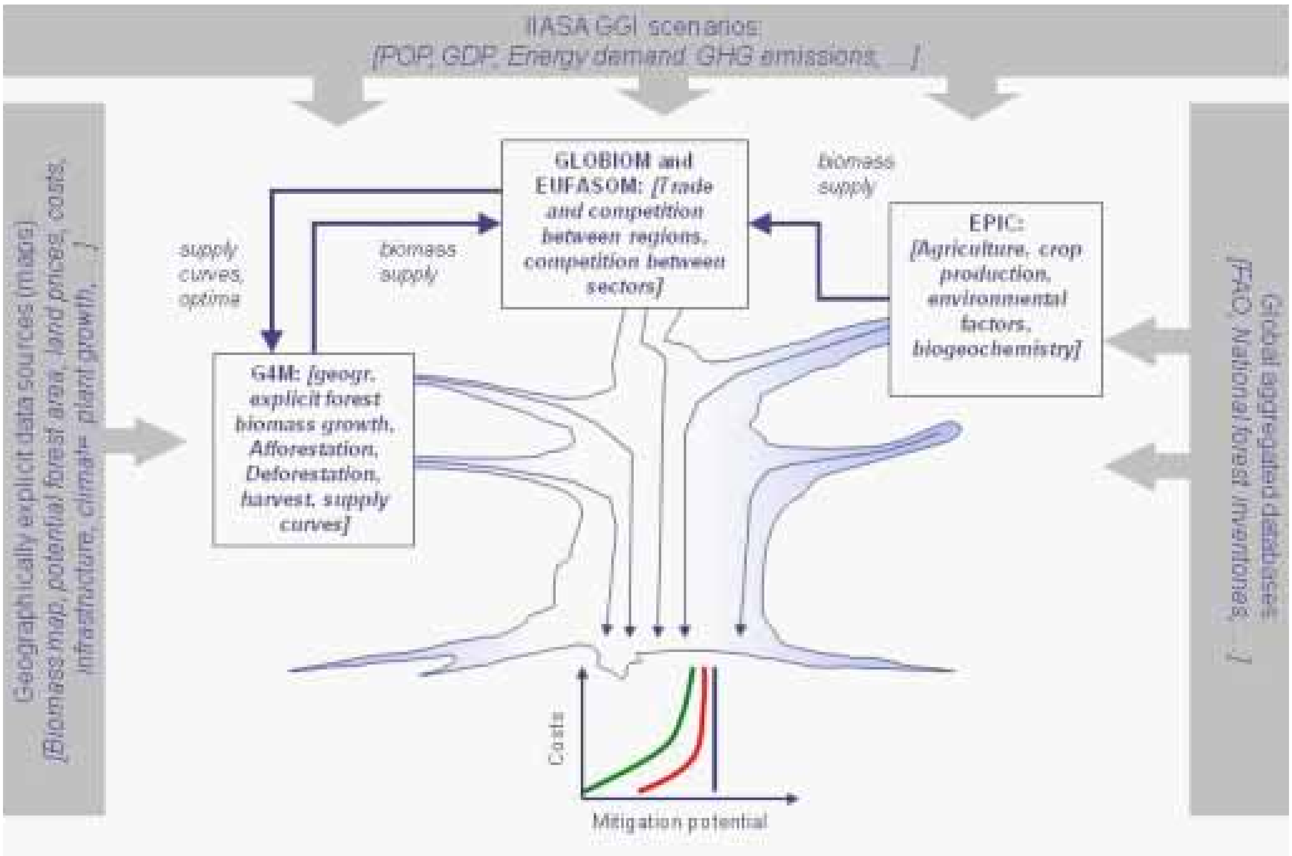


Figure 12: Biophysical/economic model cluster (source: EuroGEOSS)

stewardship council (FSC) certification, or according to individual standards, such as Starbucks' C.A.F.E. system.

In the GEOBON report for the CBD mentioned above, attempts are made to give cost estimates for observation systems, but it is very difficult to provide exact figures. Where approximate cost estimates can be calculated, it is difficult to quantify the benefits in monetary terms.

This problem of valuating ecological functions was discussed earlier. What can be done however, is calculate the difference in costs between using earth observation and not using earth observation to reach a predetermined goal. This has regularly been done for mapping in general and in most cases points to a clear benefit in using the alternative which includes earth observation (see also section 3.5 Climate change, figure 15).

Promotion and capacity building

The GEOBON project and the GBIF data portal provide a lot of tools for capacity building, as does the UNEP report "guidelines for biodiversity monitoring and for protected areas".

A good example of cooperation between scientists, managers and the general public is found in the Czech Republic, where Charles University works together with national park manage-

3.4 Environmental management

ment managers on earth observation for environmental conservation (including invasive species) and the results are used for educational packages for elementary and high school students.

The focus of earth observation for environmental management is already presented above: earth observation should be integrated in, and form a substantial element of, payment for ecosystem services systems, used for monitoring of sustainable development. It also should provide the basis for an interactive system, where the results of scientific research are made available to, and easy to understand for, the general public to increase active engagement in discussions on the environment and to generate support for environmental policies that are directed at anticipating future developments.

If environmental goals are clearly formulated along the lines of the example of the European Environment Agency in the section on international trends and the general framework of a payment for ecosystem services is in place, then it is comparatively easy to show the benefit of earth observation applications in economic terms, by demonstrating that a solution including earth observation is better than alternatives without earth observation.

Already various TEEB studies are available at national level. In the case of the Netherlands, for example, reducing tillage and leaving borders of cultivated fields fallow are the two measures proposed that would be of most benefit to environmental conservation. Although the contribution of earth observation to both solutions may be limited, the example shows a discussion that focuses on a few measures that will have most impact and it is quite imaginable that in a number of solutions earth observation could play a role (see also the discussion on no-regret, high-impact measures in the next section).

3.5 Climate change

International trends

Goals with respect to climate change fall into two main categories (from: mainstreaming adaptation to climate change in agriculture and natural resources projects (World Bank)):

- Increased resilience of communities with respect to climate variability
- Increased adaptive capacity of natural and managed systems under current and predicted climate variability

Table 4 presents an overview of data needed for monitoring (from: climate knowledge for action). It can already be seen that earth observation is indispensable for climate monitoring.

Atmospheric (over land, sea and ice)	Surface	• Air temperature • Precipitation* • Air pressure • Surface radiation budget • Wind speed and direction* • Water vapour
	Upper-air	• Earth radiation budget (including solar irradiance)* • Upper-air temperature* • Wind speed and direction* • Water vapour* • Cloud properties*
	Composition	• Carbon dioxide* • Methane* • Other long-lived greenhouse gases* • Ozone* and Aerosol properties*, supported by their precursors
Oceanic	Surface	• Sea-surface temperature* • Sea-surface salinity* • Sea level* • Sea state* • Sea ice* • Surface current • Ocean colour* • Carbon dioxide partial pressure • Ocean acidity
	Sub-surface	• Temperature • Salinity • Current • Nutrients • Carbon dioxide partial pressure • Ocean acidity • Oxygen • Tracers • Phytoplankton
Terrestrial		• River discharge • Water use • Ground water • Lakes* • Snow cover* • Glaciers and ice caps* • Ice sheets* • Permafrost • Albedo* • Land cover (including vegetation type)* • Fraction of absorbed photosynthetically active radiation* • Leaf area index* • Above-ground Biomass* • Fire disturbance* • Soil moisture* • Soil carbon

* Satellites make important monitoring contributions here

Table 4: Data needed for climate monitoring

3.5 Climate change

The role of science in climate change can be summarized as follows (from: an Earth-system prediction initiative for the twenty-first century (AMS)):

- Improved projections, predictions and monitoring of multidecadal, global to regional climate changes
- Stronger scientific foundation for adaptation and mitigation
- Improved predictions of high-impact weather and climate
- Science-based support to responses and planning
- Developing national and international climate services
- Education and capacity building

The scientific output needs to be suitable for use at local level to achieve the goals of increased resilience of communities and increased adaptive capacity of natural and managed systems.
The table below gives a very rough overview of expected trends for certain regions (with mainly developing countries).

Response strategies can be either reactive adaptation or anticipatory adaptation (from: climate change: impacts, vulnerabilities and adaptation in developing countries (UNFCCC)).
In either case, climate change needs to be treated as a major social and economic risk to national economies and not just as an environmental problem (from: managing climate risk (World Bank)). Addressing short-term vulnerabilities is the best strategy when preparing for long-term impacts. Communities and the private sector play an important role in climate risk management and should therefore be involved in the planning and implementation of adaptation. Of course, full buy in from regulatory agencies is needed. The final recommendation or lesson learned from the World Bank is that no-regrets strategies and "soft" solutions embedded in more sustainable natural resources management should be pursued where available.

Region	Temperature	Rainfall	Cyclones / Hurricanes	Floods	Droughts	Landslides	Heat waves	Glaciers
Africa	↑	↓		↑	↑			
Asia	↑	↓ except Central Asia	↑		↑		↑	
Latin America	↑	?	↑ Caribbean	↑		↑	↑	↓
Small island developing states (Pacific)	↑	↑/↓ depending on region	↑					

Table 5: Climate change trend in certain regions

▶ 3.5 Climate change

Carbon accounting programmes, such as REDD form an example of no-regrets strategies. Important elements that deserve attention for implementing REDD are (from: analysing REDD+, challenges and choices):

- A key role for measurement, reporting, verification (MRV)
- Control of emissions leakage (displaced emissions): reduction in one place may lead to higher emission in another area
- Any system of carbon accounting is closely related to tenure questions, which need to be taken into account (see also section 3.11)
- Payment for ecosystem services (PES) should play a role, where possible
- Communication with and involvement of villagers is indispensable
- Approved methodologies for verified carbon standards (VCS) should be used
- The establishment of a land use / land cover baseline, using GIS and remote sensing, is essential for implementation
- Due attention should be paid to the different phases, approaches, tiers and steps that constitute the framework for measuring and assessing REDD

Adaptation at farm level (from: mainstreaming adaptation to climate change in agriculture and natural resources projects (World Bank)) consists of the following possible measures:

- Crop calendar shifts and crop changes
- Soil and water management changes
- Fertilizer use and land use decisions
- Changes in water, labour, and capital use (intensive or not) efficiency

The example of the TEEB study for the Netherlands, mentioned in section 3.4 Environmental management, provides an illustration.

To facilitate adaptation to climate change, information is needed on: meteorological phenomena, seasonal climate forecasts, early warning, infrastructure, insurance, and technology development (crop varieties, irrigation technology).

Earth observation applications

In addition to what has been indicated above, the main advantages of using satellite data for climate change are (from: space technologies and climate change, implications for water management, marine resources and maritime transport (OECD)):

- Year-round data collection, also when field data collection is not possible (remote locations, bad weather conditions)
- Reduced costs when compared to traditional field data collection methods in remote environments (land cover classification, for example)
- Remote sensing systems can capture a synoptic view of the landscape and oceans, to more adequately characterise dynamics
- Remote sensing provides additional information that can supplement more intensive sampling efforts and help extrapolate findings

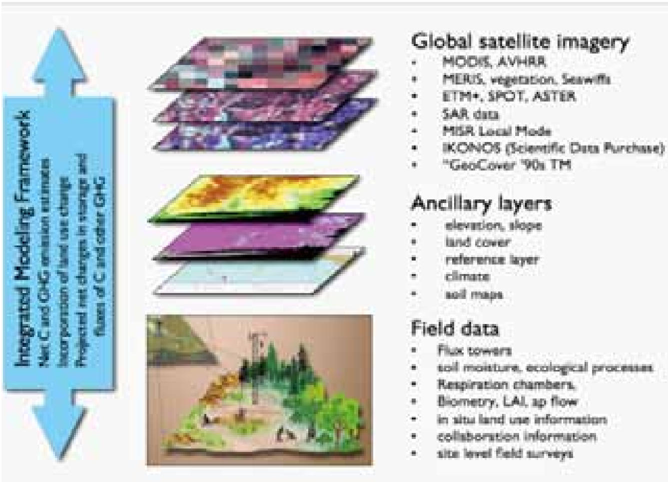


Figure 13:
decision support tools (GEO carbon strategy)

3.5 Climate change

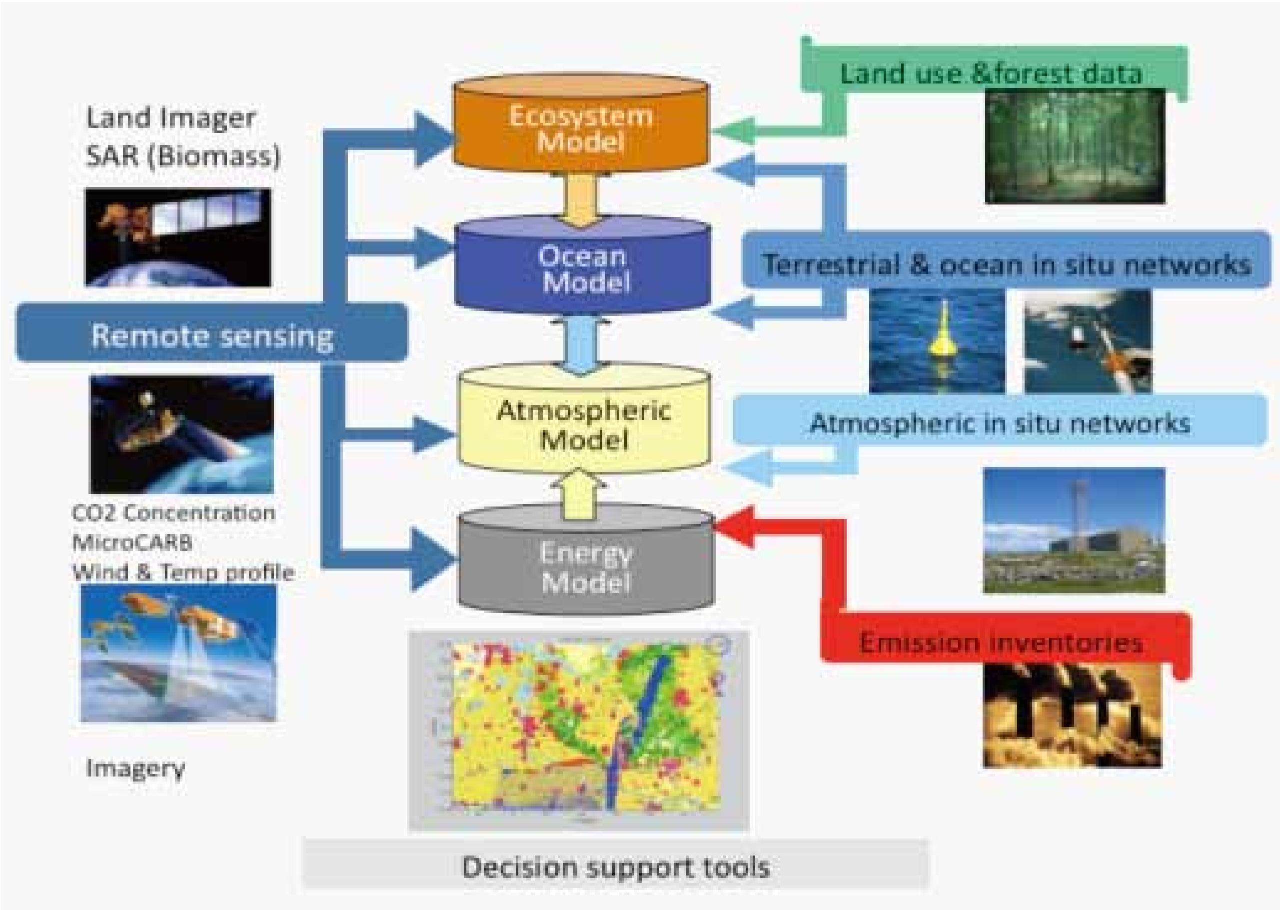


Figure 14: modelling framework (GEO carbon strategy)

The GEO carbon strategy aims at demonstrating these advantages. The decision support tools and the modelling framework are presented in figures 13 and 14.

Visualization with Google Earth is a very powerful tool for involving the general public. Pilot projects have been carried out, for example in Australia, on climate change, community forest monitoring and climate impact on the water cycle (visualization in four dimensions).

The role of earth observation for REDD is evident in the MRV process and the use of land cover / land use data as baseline.

Socio-economic benefits

The socio-economic benefits of earth observation for climate change related to disaster management, crop modelling, environmental management, marine environment, forest management, health, energy, etc., are discussed in the respective sections.

Carbon accounting is of course specifically aimed at climate change. Most benefits for local adaptation seem to be in the areas of food security and risk management, which are also mostly in the sphere of influence of local authorities.
A simple way of assessing adaptation is by

▶ 3.5 Climate change

ranking possible measures, according to different levels of possible regret (no, low, high) and levels of impact (no, low, high).

Figure 15 presents a practical and low threshold method for calculating or listing the socio-economic benefits of earth observation in different situations.

As the figure shows, to better relate to customer value propositions, the following questions are asked:

- Does the new application cause a paradigm shift?
- Is the current business or organization process improved?
- Does the application provide economic value that can be quantified?
- Is a clear measurable goal defined to which the earth observation application contributes?
- Is a future payment scheme or other economic mechanism foreseen in which the earth observation application fits?
- If earth observation provides added value, the answers to the questions yield a set of comparative advantages that is attuned to the state-of-the-art of the problem to be tackled and to the way the client perceives this problem.

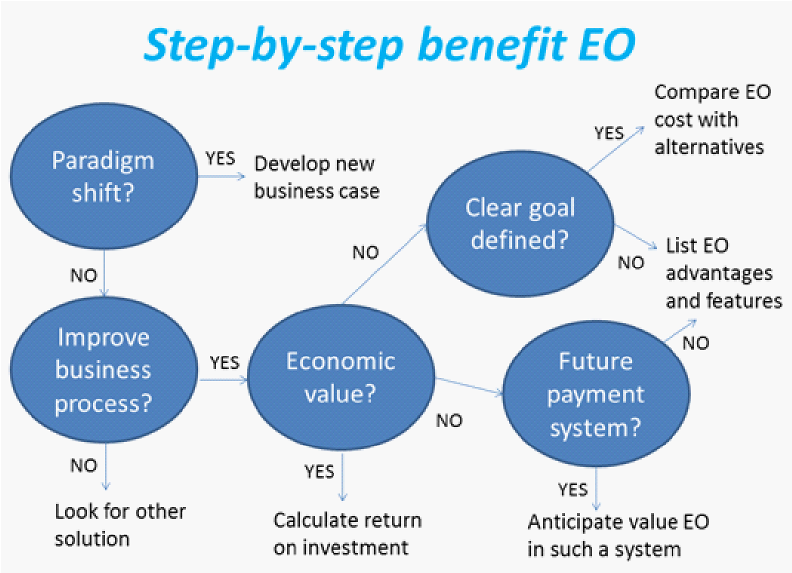


Figure 15: step-by-step benefit earth observation

Promotion and capacity building

Quite a number of data portals is available that include promotion and capacity building material.

The climate change knowledge portal of the World Bank, the climate change explorer, the climate wizard, the UNDP adaptation learning net, the IPCC data distribution centre and the earth system grid are a few to be mentioned.

Training is provided by initiatives such as the global change system for analysis, research and training (START) (guidelines and training opportunities related to climate change issues) and the Tearfund CEDRA toolkit (a step-by-step guide to define community climate adaptation activities in developing countries).

Climate change networks are also being created, such as the network of African experts on earth observation and climate change (RAOCC). ESRI has published guides on climate change with practical examples, such as "GIS for climate change" and "climate change is a geographic problem".
The GOFC-GOLD sourcebook provides an exhaustive overview regarding assessing carbon stocks and emissions, with a detailed description of the recommended methodology.

Related to the topic of tenure security and climate change, interesting literature is available as well, such as the article on remote sensing

3.5 Climate change

and participatory land tenure identification for payment for ecosystem services, with examples from Brazil, Mozambique and Indonesia (land administration options for projects involving payments for carbon sequestration).

Good advice for promotion of climate change adaptation (and thus, earth observation) comes from the World Bank (mainstreaming adaptation to climate change in agriculture and natural resources projects):

- Choose entry points such as food security or risk management
- Identify champions of change, they will be the most appropriate counterpart
- Show vulnerability patterns and socio-economic impact
- Indicate different levels of possible regret and impact (no, low, high) and aim at no regret, high impact intervention to optimise adaptation efforts

3.6 Marine environment

International trends

In managing the marine environment there is a trend towards paying extra attention to:

- (Sustainable) fisheries management
- Management of extreme events (flooding, safety, pollution)
- Management of marine ecosystems
- Effects of climate change
- More effective and efficient exploitation of resources (oil, wind, tidal, etc.)
- Community participation and public awareness

An ecosystems approach aims to reduce resource use and emission of greenhouse gases, minimize waste and improve governance (from: state of fisheries and aquaculture (FAO)).

This will ensure that:

- More food is produced sustainably
- Demand for the most resource-intense types of food is contained
- Waste in all areas of the food system is minimized
- The political and economic governance of the food system is improved

Sound management of marine resources is not only needed as goal in itself, but also to adapt to the following implications of climate change:

- Availability of aquatic foods will vary
- Stability of supply will be impacted
- Access to aquatic food will be affected
- Utilization of aquatic products will be impacted

Options for enabling change are:

- Developing the knowledge base
- Improving policy, legal and implementation frameworks
- Increasing capacity building efforts to build better technical and organizational structures
- Enabling financial mechanisms: embodying food security concerns in existing and new financial mechanisms

This can be achieved by taking action in the following areas (from: marine protected areas (FAO)):

- Biological/ecological: protection of fishery resources, restoration of degraded areas, as well as maintaining biological diversity, individual species, and habitat
- Social and economic: fostering food security, improving livelihoods, determining and emphasising non-monetary benefits, compatibility management and local cultures, enhancing awareness and knowledge
- Governance: effective management and legal structures, stakeholder participation and representation, management plan compliance by resource users, management and reduction of resource–use conflicts

Concrete examples of international initiatives for studying and managing the marine environment are: the census of marine life (CoML), the large marine ecosystem (LME) concept (NOAA), the Argo programme (what goes on below the ocean surface?), the SAHFOS ecological status studies and reports, and the IGBP marine ecosystems and climate change assessments.

Earth observation applications

Categories of earth observation products and services for the marine environment are:

- Ocean topography, temperature and currents
- Ocean colour
- Satellite-based fishing
- Marine and coastal ecosystems (see also section 3.4 Environmental management)

3.6 Marine environment

- Climate monitoring and modelling, mitigation of the effects of climate change (see also section 3.5 Climate change)
- Marine and coastal safety and disaster management (see also section 3.1 Disaster management)

Parameters that can be measured and assessed with earth observation are (from: discovering the ocean from space (Robinson)): sea surface height, sea surface temperature, ocean colour, wind vector, sea state (significant wave height, as well as directional wave spectra) and sea ice parameters.

This leads to applications in the following areas:

- Weather prediction, including extreme events and climate change studies modelling
- Ship route planning
- Maritime safety
- Satellite based fishery and sustainable fisheries management
- Ecosystem management
- Coastal zone management and solutions
- Energy
- Pollution tracking and mitigation

Characteristics and perspectives of earth observation products and services for the marine environment are:

- Multiple inter-related phenomena need to be considered
- In many cases expert knowledge is required (in addition to automated data processing)
- Application of complicated models is generally required
- Specialization provides a comparative advantage and is often a requirement (threshold for entering the market)
- Clients in the off-shore energy and shipping sectors are capable of defining specifications and appreciating technicalities (no difficulties with demand articulation)
- Ecosystem services are more directed at government clients and the general public
- The fisheries sector constitutes an intermediate case, depending on the development level of the country or region concerned

The above considerations sketch a market that is dominated by government organizations and specialized companies, with roles both as suppliers and clients.

Socio-economic benefits

Earth observation is very well suited for monitoring the marine environment, because the areas to be covered are large and not easily observable by other means. It is therefore comparatively simple to show the advantages of earth observation over conventional methods; a few examples have already been given above. Market entry is another matter, as generally the demand is for sophisticated products and services that require a high level of expertise and specialization.

Although international initiatives, government agencies and private companies all cover the whole range of the spectrum and all deal with sustainable management, international organizations can be found more at the "green" end and companies more at the "commercial" end. "Green economy in a blue world", a UNEP publication, gives an overview of options to combine economic development with sustainable management of the marine environment. Public services, such as My Ocean and the Copernicus/GMES Marine Core Services provide information and data on marine safety, marine resources, the coastal and marine environment, as well as weather and seasonal forecasting.

Private companies, such as BMT ARGOSS, Fugro and Astrium, specialize in subjects such as high resolution weather forecasting, global wind and weather forecast services, near-shore modelling,

▶ 3.6 Marine environment

persistence analysis (determining operational risks and workability), search and rescue information, and shipping applications (manoeuvring, performance). They also deliver climate design criteria and oil spill information services. Main clients are the off-shore industry and the shipping sector.

Initiatives, such as INCOIS, SAFARI and ChloroGIN (now FARO), cater to the needs of fisheries (indication of potential fishing zones, warning for harmful algal blooms), but also promote sustainable fisheries management.

For most applications, except those at the very green end of the spectrum, a clear business case can be made in terms of "classical" economics: return on investment or showing that earth observation is cheaper than other available alternatives.

Promotion and capacity building

All the initiatives mentioned above have websites that also aim at promotion and capacity building and most include earth observation applications as an important tool.
The IOC handbook of satellite remote sensing image interpretation provides case studies on air and water quality, phytoplankton and macro algae, fisheries and aquaculture, marine ecosystem characterization, and also contains exercises.
Another IOC publication (principles and strategy for capacity building) gives a general framework for capacity building that has a wider application than the marine environment.
A practical regional example is the website www.pi-goos.org which describes support to marine observing programmes, communication aspects and capacity building initiatives in the Pacific.

As mentioned above, entry into the marine market will only be possible for newcomers, if they are equipped with specialized technical skills. This means that it is more likely that water resources and civil engineers will add remote sensing to their portfolio, than vice versa, with perhaps the exception of the ecosystems and biodiversity aspects of marine resources.

3.7 Forest management

International trends

Forest governance is based on three pillars (from: framework for assessing and monitoring forest governance (PROFOR, FAO)):

- Policy, legal, institutional and regulatory frameworks
- Planning and decision-making processes
- Implementation enforcement and compliance

The usual cross-cutting aspects apply: accountability, effectiveness, efficiency, fairness and equity, participation and transparency.

Global monitoring of forests is one of the important trends. The FAO forest resource assessment of 2010 (FRA) summarizes the following outcomes:

- Knowledge on land cover and land use changes related to forests has improved, especially on deforestation, afforestation and natural expansion of forests
- The assessment gives clear information on the rate of change between 1990 and 2005 at global, biome and regional levels
- A global framework and method for monitoring forest change is established
- Easy access to satellite imagery through an internet-based data portal is achieved
- In many countries the capacity for monitoring, assessing and reporting on forest area and forest change is enhanced

There is quite a number of international agreements that deal with forests as an integral part of ecosystem management, such as:

- The non-legally binding instrument on all types of forests (NLBI)
- The convention on biological diversity (CBD)
- The United Nations framework convention on climate change (UNFCCC)
- The Kyoto Protocol
- The United Nations convention on combating desertification (UNCCD)
- The convention on international trade in endangered species of wild fauna and flora (CITES)
- The convention on wetlands of international importance (Ramsar)
- The World heritage convention (WHC)
- The international tropical timber agreement (ITTA)

Certification is another important issue. The international tropical timber organization (ITTO) and the forest stewardship council (FSC) have developed criteria and indicators for sustainable forest management and certification. Customers demand the FSC label, and producers therefore comply.

The increased use of social media and interactive instruments for forest cover monitoring and management constitutes another trend. Examples are the interactive forest cover atlas of Cameroon (published by the WRI), and websites and networks, such as Forestracker and Marketracker.

Earth observation applications

All the trends mentioned above potentially benefit from earth observation. Categories of products and services are:

- Fire monitoring and prevention (see section 3.1 Disaster management)
- Carbon accounting (see section 3.5 Climate change)
- Monitoring and management
- Pest and disease control and management

Forest applications are closely related to land cover products and services. There is a wide array of features that can be measured and assessed with earth observation.

3.7 Forest management

For example (from: remote sensing applications – forests and vegetation (NRSC)):

- Area coverage and stratification
- Change detection and forest land appraisal
- Timber harvest planning, monitoring, logging and reforestation
- Planning and assessing of plant vigour and health in forest nurseries
- Mapping fire potential and planning of fire suppression activities
- Assessing potential slope features and soil erosion
- Planning of forest roads
- Inventorying forest recreation resources
- Assessing wildlife habitat
- Monitoring vegetation regrowth in fire lanes and power lines rights-of-way
- Synoptic and periodic measurements
- Measuring and monitoring forest parameters: greenness, crown closure, vegetation type, species assemblage and gregarious formations

The report on critical earth observation priorities, agriculture societal benefit area – forests (GEO) suggests a number of improvements in modelling and observations:

- Improved correlation between remote sensing observations and ground-based observations
- Better algorithms to interpret and correct remote sensing data
- Validation and standardization of land cover maps
- Long time series of data and internally consistent products, and consistency of data availability
- Finer temporal and spatial resolution
- Model integration

Increasingly pilot projects are carried out to demonstrate the feasibility of earth observation applications. Under the auspices of FSC several case studies have been implemented on forest clearance and management in Sweden, Russia and South Africa. The studies dealt with land cover mapping, mapping of broadleaved trees, timber volume, mapping of retention trees, burnt area mapping, clearfell mapping, etc.

This resulted in the following products for forest management: digital surface model, mapping of forest area, forest type, burnt area, clear cut and re-growth, roads and settlements, monitoring of protected forest areas, and measurement of bio-physical parameters.

The case studies were then evaluated. The general conclusion was the earth observation for sustainable forest management works, but:

- Data calibration is the most complex and technical barrier
- Not many companies have the required skill set and technological expertise in EO, GIS and mensuration to successfully implement and use the data provided
- For optical data: the processing chain is known and understood. For SAR: processing support would be required
- It is easy to have misunderstandings on very technical issues. But provided the process is carefully managed data transferability is possible

Cost-benefit related aspects of these case studies will be discussed below.

There are plenty of other examples of operational forest management or monitoring applications or attempts to build these applications. The global forest land-use change 1990 – 2005 assessment of FAO has already been mentioned, in comparison with the FRA. The global forest observation initiative (GFOI) of GEO is another example, dedicated to forest carbon tracking. National examples can be found in the US (the use of satellite imagery for land cover), Canada (building a next

▶ 3.7 Forest management

generation forest management and monitoring system), Brazil (Amazon deforestation: detection of forest clearing and illegal logging) and the UK (the use of remote sensing techniques in operational forestry). Eurisy describes a number of applications in European regions (forest and biomass management using satellite information) and services. An interesting study on changes over the years is the one by SERVIR on Belize: forest cover and deforestation 1980 – 2010.

Socio-economic benefits

The forest sourcebook of the World Bank provides a comprehensive overview of forest management, including a discussion of remote sensing applications and a cost comparison between earth observation and conventional monitoring (see table 6).

Of course the situation with respect to images and prices has changed since the time this analysis was made. The cost comparison is limited to image acquisition and does not take processing and other operations into account, but still gives an idea of the comparative advantage of earth observation for global surveys. Market studies on forestry and earth observation that were commissioned by ESA and published in 2004, identify market drivers, but do not develop business cases. The GEOBENE project also provides an overview of costs that includes processing of images and also airborne LIDAR. Again, the conclusion is that application of remote sensing for forest management is cost-effective.

The case studies on sustainable forest management of FSC that were mentioned above are more detailed. A number of key observations are presented for each region. In South Africa costs

Region	Number of images needed				Imaging cost (US$ thousand)			Field plots only (US$ thousand)
	MODIS full coverage	Landsat 10% coverage	Ikonos 0,1% coverage	Ikonos 1% coverage	Landsat 10% coverage	Ikonos 0,1% coverage	Ikonos 1% coverage	
Africa	6	97	331	3,309	58	951	8,992	30,457
Asia	6	100	343	3,428	60	986	9,315	13,205
Europe	4	73	251	2,511	44	722	6,824	19,690
North and Central America	4	69	237	2,374	42	683	6,453	12,065
Oceania	2	28	94	943	17	271	2,564	4,795
South America	3	57	195	1,950	34	561	5,299	21,575
Total	**25**	**424**	**1,451**	**14,515**	**255**	**4,174**	**39,447**	**101,787**

Table 6:
Example of number of images needed plus the estimated costs for remote sensing surveys using differing resolution and sampling options, compared to field data only (from: forest sourcebook (World Bank)
Source: potential for a remote-sensing-aided forest resource survey for the whole globe (Tomppo and Czaplewski, 2002)

3.7 Forest management

are not seen as problematic, the price of image acquisition is considered very reasonable. Capacity building for required SAR processing and interpretation is identified as "quite daunting". In the Russian case costs for earth observation applications are seen as a problem, as the view is that EO will be used in addition to conventional methods: "it can improve quality of field checks, but cannot reduce cost, as amount of field work is usually increasing". Improvements and regular use (date stamping) might increase the confidence of auditors and operations and make the audits more efficient. As in the South African case, costs related to SAR are seen as a barrier. Capacity building costs for training of new products and new working practices are also considered a problem in the Swedish case.
If field efforts can be reduced, due to application of earth observation, then it may become more cost-effective to obtain certification.

This illustrates the fact that, similar to almost all categories of products and services in the societal benefit areas, it is also easier for forest management to list the societal benefits than to quantify the economic benefits.

Promotion and capacity building

Much literature mentioned (World Bank, FSC, FAO, etc.) is quite instructive on the use of earth observation for forest management. Especially the Canadian web book on building a next generation forest management and monitoring system presents what almost amounts to a tutorial on the application of remote sensing.

ESA and FSC have developed a forest management toolkit that assists forestry analysts in:

- Calculating and verifying areas harvested
- Protecting of conservation areas and buffer zones
- Validating maps of infrastructure
- Checking regeneration areas, forest types, forest inventory
- Estimating volumes, allowable cuts and rotations based on data from earth observation

The toolkit runs on the QGIS platform and is available at www.denisalder.net/fmt/.

Promotion will focus on two aspects: firstly, the interactive use that involves interested citizens (general features, such as deforestation that anyone can see) and, secondly, the development of valid business cases around the more technical applications (from pilot to operational).

3.8 Health

International trends

The trends of increasing population, economic growth, increasing urbanization, increasing (energy) consumption and increasing mobilization (motor vehicles) all lead to:

- increased pollution of water, air and soil.

There are also positive trends:

- New, cleaner technologies are available
- There is increased interest in environmental issues
- There is increased interest in sustainable economic development
- Living standards are improving and life expectancy is increasing
- Improved monitoring, forecasting and early warning is possible
- The understanding of processes affecting human health is increasing

Earth observation is especially relevant for the last two subjects.

Focal points for health are:

- Air quality (pollution, aeroallergens, dust storms)
- Fighting disease (malaria, meningitis, dengue fever, rift fever, west Nile virus, cholera, etc.)
- Climate change and health

To give an indication of issues, which play a role with respect to air quality, the following observations are cited from a study on air quality in Europe by the EEA:

- Particulate matter (PM) and ozone (O_3) are most harmful for human health
- Emissions of air pollutants declined in past decade: air quality improved across the region regarding some pollutants
- Emission reduction does not always cause a drop in atmospheric concentrations, especially for PM and O_3
- The main pollutants of interest are: PM, ground-level O_3, nitrogen oxides, sulphur dioxide, carbon monoxide, heavy metals, benzene and benzo(a)pyrene

In the US EPA has published a brochure on air quality for the general public (the Air Quality Index – a guide to air quality and your health) that explains how the air quality index works, causes of air quality variation (ozone, particle pollution, sulphur dioxide, carbon monoxide), health effects and possible action (mainly avoidance).

An example of an interactive approach is the EveryAware sensor box. This is a tool for community-based air quality monitoring, which users can apply to measure and monitor air traffic pollution.

Early warning systems for sand and dust storms (WMO, UNEP, Government of Japan and others) and malaria early warning systems (roll back malaria, WHO and others) are examples of fighting the spread of diseases.

In relation to climate change and health WHO and WMO identify the following areas of concern (atlas of health and climate):

- Infections:
  malaria, diarrhoea, meningitis, and dengue fever are the most important ones
- Emergencies:
  floods and cyclones, drought, and airborne dispersion of hazardous materials
- Emerging environmental challenges:
  heat stress, UV radiation, pollen, and air pollution

The human health climate change brochure from the US global change research program predicts the following effects: an increase in risk of illness and death related to extreme heat and heat waves, reduced extreme cold, a challenge to meet

3.8 Health

air quality standards, more extreme weather events (storms, floods, wild fires), an increase in certain diseases transmitted by food, water or insects (west Nile, lyme, salmonella, etc.), and an increased pollen health risk.

At global level advice from the IPCC on health and climate change covers the following topics (human health, climate change 2007: impacts, adaptation and vulnerability): heat and cold effects on health, wind, storms and floods, drought, nutrition and food security, food safety, water and disease, air quality and disease, aeroallergens and disease, vector-borne, rodent-borne and other infectious diseases, occupational health and UV radiation. Depending on the region different phenomena will occur with differing effects on health.

Earth observation applications

Earth observation applications for health cover the following categories of products and services:

- Air quality forecasting, early warning and monitoring
- Epidemics forecasting
- Relationships between diseases and environmental factors

All these categories, particularly the second and third, are of course linked, the time factor and response factor providing the main distinction.

An example from the United States (using earth observation data to improve health in the United States (CSIS)) presents practical earth observation applications. With respect to air quality, emissions from industrial processes and motor vehicles, as well as particulate matter in the air (sand, dust, volcanic and noxious gases, smoke and soot from fires) are measured and monitored. Temperature extremes are of interest, especially heat waves, as these lead to weather-related deaths and aggravation of chronic diseases. In relation to water health risks are caused by droughts (affecting supply of fresh water, causing famine, fires), floods (spreading diseases, fuel, pollutants) and contamination (through chemicals, toxins, sewage), meaning that all these need to be monitored. Special attention is paid to the "health" of the ocean, infectious diseases and disease vectors. Environmental factors (land and water surface temperatures, rainfall, water depth, marine organisms) contribute to disease outbreaks, changes in weather and climatic conditions (for example in the case of cholera).

The public health community requests remote sensing data on:

- Climate change parameters and health
- Heat island effects on urban areas
- Precipitation (water, drought)
- Data on at-risk populations
- Detection of algae blooms that are harmful to health
- Pesticides and crop prediction

Public health community users are interested in:

- Areas of intrinsic variability or high trend (rapid change)
- Integrated earth observation climate models for health impact (novel ways of using high spatial resolution)
- Indicators to monitor climate-change-related health outcomes within surveillance systems
- Development of early warning systems
- Improved decision support for vulnerability and adaptation assessment, operational predictions and understanding of the decision making process

Studies on air quality in Europe (from: monitoring the air we breathe from space (Copernicus/GMES)) highlight the following points:

- Healthcare costs associated with poor air

3.8 Health

quality amount to € 189 billion/year

- Satellite-based air quality assessments support the European Commission's goal of combating reduced life expectancy due to airborne particulate matter by providing compliance monitoring support to environmental agencies and through early warning when pollution exceeds allowed levels
- The WHO estimates that by reducing illness caused by airborne PM alone, the EU could save up to € 29 billion/year
- Regional and municipal governments already provide citizens with detailed air pollution alerts

The figures 16 and 17 from GEO show a framework with the role of earth observation for air quality and health and the schematic relation between disease and environmental factors.

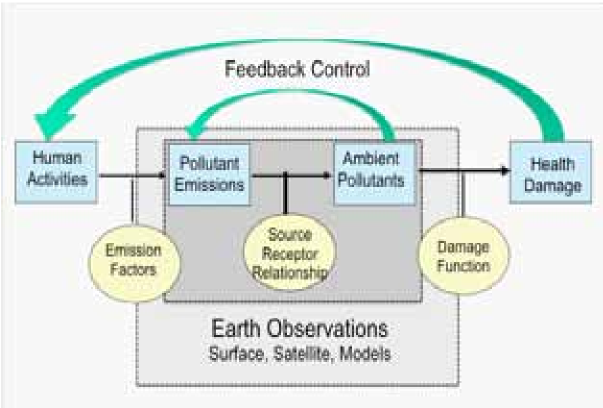


Figure 16:
Framework for categorizing earth observations for air quality and health (GEO)

Earth observation is extensively used for malaria early warning systems. It supports measuring the parameters and modelling of processes:

- Vulnerability assessment (pre-season, rainy season, malaria season)
- Seasonal climate forecast anomalies
- Rainfall monitoring

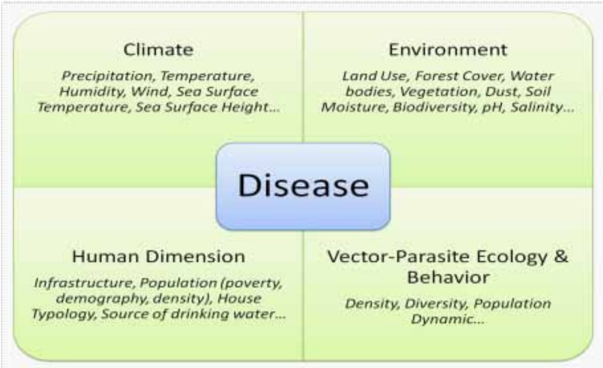


Figure 17:
Epidemiological system showing the four main categories of EO (EO priorities - GEO)

- Correlation rainfall – incidence and vegetation (NDVI) – incidence
- Malaria morbidity/mortality monitoring at sentinel sites
- Short-term as well as long-term forecasting

Tele-epidemiology is also a very popular subject (strategy, satellite data and modelling for public health (CNES)), as is the use of Google Earth for management of vector-borne diseases in resource-poor environments.
A case study from Mexico shows how Google Earth images can be used to extract urban infrastructure patterns. The advantage of Google Earth is that it is easy to use and easy to learn, the main disadvantage is that the capacity for spatial analysis and modelling is limited.

Of course ecosystems, biodiversity, and human health are interconnected. Earth observation can be of use to reduce and prevent infectious diseases. EPA shows how this can be achieved by establishing links between human health and environmental factors. Still, more integrated tools and approaches that link ecology to human health need to be developed. Equally projects such as EO2HEAVEN present state of the art environmental and health monitoring in air and water and show the feasibility of measuring and monitoring practices (including EO), and describe

▶ 3.8 Health

future developments. Child nutrition is a special subject, where earth observation can play a role. Early research shows that, in monsoon systems with high intensity rainfall, NDVI could be a better predictor of environmental risk associated with child nutritional status than rainfall.

Socio-economic benefits

Very general numbers are presented above: in Europe healthcare costs associated with poor air quality amount to € 189 billion/year and by reducing illness caused by airborne PM alone the EU could save up to € 29 billion/year. To what extent earth observation might contribute is not clear, but it certainly plays an important role.

The GEO-BENE project undertook some case studies on the geographical analysis of subjective happiness and well-being, in the form of combining secondary socio-economic data and environmental data. This is still in the research phase, but the approach is interesting.

Most earth observation applications for health can be categorized as fitting a clearly defined purpose, such as malaria eradication. In these cases it is comparatively easy to show that earth observation is more cost-effective than the next best alternative available.

In NASA's primer "measuring socio-economic impact of earth observations" a case study on MEWS is presented. Although the selected test case of Botswana did not produce enough reliable evidence to draw firm conclusions, a poll on experts opinions pointed to a reduction of 10% in malaria occurrences, thanks to NASA intervention.

That earth observation for health is already common practice is illustrated by the examples presented above for Europe and the US.

Promotion and capacity building

Promotion of business opportunities for health applications should take the following factors into account:

- Scientists, public health organizations, NGOs and the general public are the main players
- The market is mainly G2G or B2G market, government or international organizations are in virtually all cases the paying client
- Opportunities for business development in developing countries exist in the form of adaptation and refinement of existing models to suit local circumstances and processing of data flows
- The topic of air quality is particularly relevant in the large, densely populated cities

Capacity building material usually takes the form of brochures than tutorials; air quality is the most popular subject.
Examples for air quality are the EPA air quality index and the Every-Aware sensor box. The Planet Action programme offers some examples, for instance the development of a system to monitor particulate matter in the atmosphere in Dakar, Senegal.
This is a pilot measurement of aerosol optical depth, specifically aimed at Sahara desert dust. The approach described, concerns a combination of in-situ measuring and EO: satellite observations can detect gradient and therefore hotspots of emission. A similar practical example is a pilot on monitoring air pollution using remote sensing and GIS in Cyprus. Very instructive is the SERVIR air quality monitoring website for Central America. It provides a description of the use of EO for an air quality monitoring system, which also incorporates informing the public through a 'Smog-Blog', supplying information on agricultural fires, volcanic eruptions, Saharan dust, as well as capacity building information. The EO2HEAVEN project mentioned above also provides capacity building examples and opportunities.

3.9 Energy

International trends

The following trends in energy resources are of specific interest:

- Increased attention for renewable energy
- Search for new energy sources (including biofuel)
- Increased attention for energy saving
- Anticipation of the possible effects of climate change

Different renewable energy sources are:

- Solar energy
- Wind energy (onshore and land-based)
- Wind energy (offshore)
- Bioenergy
- Hydropower
- Geothermal energy

The international energy agency (IEA) and the world energy council (WEC) have published a lot of studies and handbooks on all the types of renewable energy mentioned above. They also deal with energy efficiency, particularly energy-efficient buildings (IEA). Other related issues of interest are: shale gas (studies by WEC) and the competition for rare materials used for renewable energy generation (report by CSIS).

In the report "climate impact on energy systems" the World Bank presents the following conclusions:

- Adaptation is essential: changing trends, increasing variability, greater extremes and large inter-annual variations in climate parameters are expected.
- Better risk management and more resilient infrastructure are required. Increasing the capacity to use this information is required, especially in developing countries (see also section 3.5 Climate change).
- Observation and monitoring of hydro-meteorological and climate parameters for select energy uses are important, virtually all involving earth observation (see also section 3.5 Climate change).
- Energy/water saving, demand-side management, energy storage, smart grids, decentralized energy structures and increased vehicle efficiency are important issues to be dealt with.
- Observation networks in developing countries need to be upgraded to minimum WMO standard.

The report presents interesting case studies from Albania and Mexico.

Earth observation applications

The categories of earth observation products and services for energy are:

- Resource assessment for (renewable) energy
- Energy resources exploration support
- Pipeline monitoring
- Optimization of biofuel production (see section 3.2 Crop modelling)

Apart from these categories the following niche markets can be distinguished:

- Sustainable building design (energy efficiency)
- Prediction of damaging geo-magnetically induced currents (GICs)
- Effect of climate change on energy requirements

In general earth observation offers the following comparative advantages:

- Increased accuracy
- Cost reduction / increase in revenue
- Better planning of energy operations
- General innovation in assessment of resources and monitoring

▶ 3.9 Energy

GEO has identified the critical priorities for earth observation in the energy societal benefit area:

- Tier 1 (high priority parameters):
  water run-off, wind speed, land cover, normalized difference vegetation index (NDVI), net primary productivity (NPP), global horizontal irradiation (GHI), direct normal irradiation (DNI)
- Tier 2 (medium priority parameters):
  elevation/topography, air temperature, surface temperature, relative humidity, and cloud cover

Some parameters, such as NDVI, are of course related to biofuel and not dealt with in this section. The full report is available through the GEO website and gives an overview of all priority observations for each type of renewable energy.

Even though more and more detailed observations are desirable, earth observation data currently available are adequate for use in decision support. The US climate change science programme (CCSP) gives an overview of uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions. A support tool for assessing hybrid renewable energy systems for decision support is HOMER (hybrid optimization model for electric renewables). HOMER makes use of earth observation data and a geospatial toolkit.
Another example is RETScreen of Natural Resources Canada. RETScreen includes clean energy decision-making software and uses a worldwide database of NASA satellite-derived meteorological data (NASA surface meteorology and solar energy dataset (SSE)) from a ten-year period (1983 – 1993).

European examples are the ENVISOLAR and MESoR projects. ENVISOLAR provides, as the name implies, space-based environmental information for solar energy industries. This includes services for investment decisions, plant management, utilities, time-series services for science and consulting, a description of the PV-calculator tool, and examples of practical applications. MESoR (management and exploitation of solar energy knowledge) also describes solar resource products, provides a summary of benchmarking results and examples of practical applications (20 use cases). The aim is to satisfy the need for new solar radiation services to develop the market for solar energy applications faster and optimize grid integration.

The renewable energy project UNEP/SWERA (solar and wind energy resource assessment) has carried out pilots in 13 countries, including substantial ones in Brazil, China and South Africa. The project focuses on data provision and an end-user assessment for SWERA products (policy-makers, developers, NGOs/universities, global modelling community) is presented. SWERA is used as first data source (to identify high-potential areas), but this is not enough for decision-making. More capacity building is needed.

A special subject is the relation between renewable energy and the environment, such as bird protection and wind energy development schemes.

Initiatives for energy resource exploration support that make ample use of earth observation are AEGOS (African-European geo-resources observation system) and OneGeology. Both provide platforms for geological information. AEGOS supplies spatial data infrastructure for geo-resources in Africa, and OneGeology geological maps for more than 70 countries. OneGeology further provides information on geothermal showcases in Australia and France, as well as the digital energy map of the UK.

Pipeline monitoring is another application, where earth observation has added value. A ground motion monitoring service and route planning for pipeline planning and management are out-

▶ 3.9 Energy

comes of the PIPEMON project. The detection of pipeline-related ground and structure motion is based on SAR and the planning system of routes for pipelines uses DEMs and interferometry. EPA in "oil and gas spill and pipeline condition assessment using remote sensing" gives an overview of methodologies for pipeline monitoring in the US.

Socio-economic benefits

As seen, EO is clearly indispensable for all types of renewable energy resource assessment. Business cases for the use of EO in renewable energy can be made.

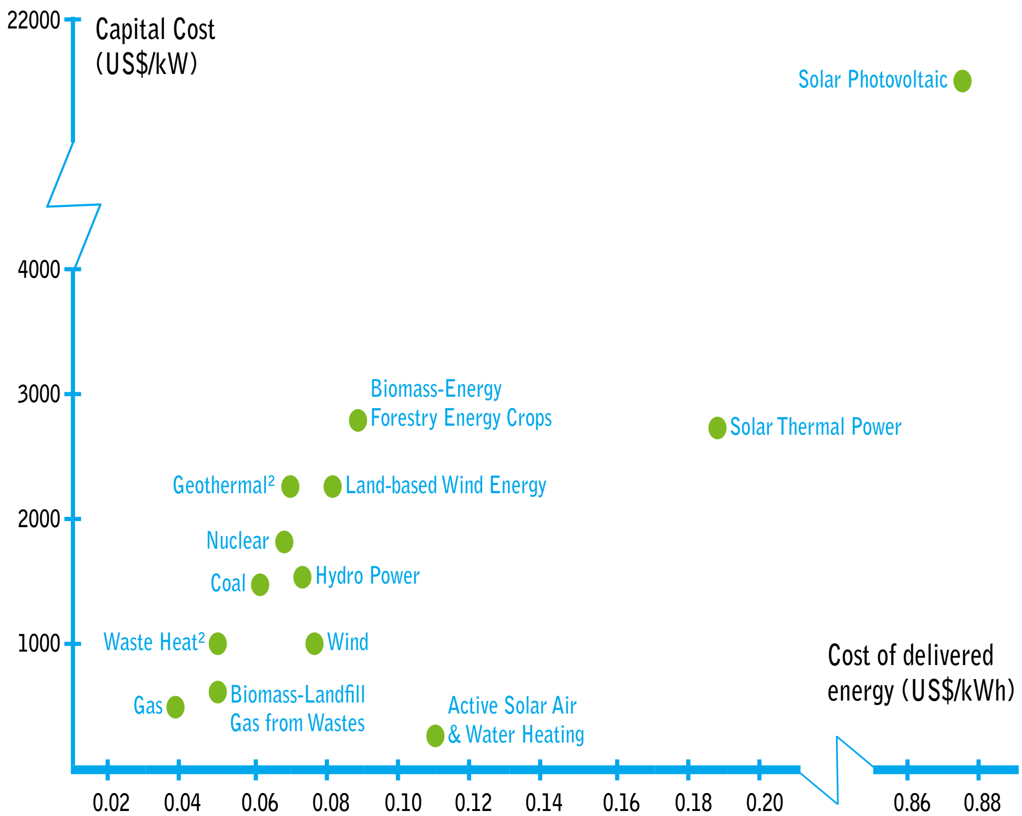
The cost-benefit of renewable energy itself is another matter; most programmes are subsidized on the basis of future expectations. One slogan used, for example, is that "90 minutes sunlight provides enough energy for the whole planet for one year".

This may be true, but technical potential and unit cost play a role, among other factors. It is not known what the consequences for the cost-benefit ratio will be if a system takes all environmental externalities into account (including carbon price increment).

Figure 18 shows where renewable and conventional energy resources stand.

In "the promise of renewables: recent success and the challenge of getting to scale (CSIS)" it is argued that the discussion of cost should be looked at from different angles.
Factors, such as the dynamics of the market, time-of-day value of energy, and volatility, all influence the equivalent cost per unit of energy, which is referred to as

AVERAGE CAPITAL AND DELIVERED COSTS
(Source: SHELL INTERNATIONAL RENEWABLES)



² Source: ORMAT

Figure 18:
Cost of renewable energy (from: renewable energy projects handbook (WEC), source: the case for renewable energy in emerging markets, W-J van Wijk, CDC, ORMAT)

3.9 Energy

LCOE (levelised cost of energy).
To really compare costs the cost of capital, fuel, operations, maintenance, financing, and environmental attributes need to be fully accounted for on an even basis. Furthermore, the existing energy options may have mostly or fully depreciated, which makes them significantly cheaper.
Still, the conclusion is that for now, based on the simple LCOE comparison many renewable energy sources are still more expensive than conventional energy sources. But this does not yet take the relative strong cost-reduction pathways that are expected for renewable energy into account or the depletion of non-renewable resources, or the effects of the exploitation of shale gas, etc. IEA and WEC have reported extensively on the subject.

For pipeline monitoring and energy efficiency cost-benefit calculations depend on a concrete application; they have to be calculated on a case-by-case basis.

The societal benefit derived from general information provision and tools, such as RETScreen or the geological information of AEGOS is beyond doubt.

Promotion and capacity building

Promotion activities should be tied to the following business opportunities:

- Further development and refinement of models and forecasts
- Application of existing models and software tools to improve knowledge base and forecasting ability (particularly in developing countries)
- Use earth observation to compensate for lack of in-situ data (particularly in developing countries)
- Market opportunities both B2G and B2B

For practical capacity building purposes the "renewable energy projects handbook" of WEC gives an overview of renewable energy options, potential and main features of each type of renewable energy, political and financial considerations, a project checklist and a description of the environmental credits acquisition process. The Global Energy Information System (GEIS, available at www.worldenergy.org) provides case studies on renewable energy from different countries. The "promise of renewables" of CSIS gives valuable commentary on trends, developments and problems: "renewable is more expensive than fossil, but investment is growing" (see also the discussion above).

The user manual for SWERA provides information on designing renewable resource assessment projects and using assessment products. It also gives guidance on where to find information for solar and wind energy. The MESoR training seminar on solar radiation services is also useful, presentations and use cases are available. The MESoR user handbook and RETScreen engineering textbook are good reference books, which can be used for capacity building.

One of the outcomes of the AEGOS project is an inventory of available curricula of training centres and practices. It gives an overview of IT, data management, GIS, RS and web application courses (in Europe, in Africa, as distance education). AEGOS also produced a concept note about the need for capacity building and training in Africa. EnerGEO is another project on research and capacity building for energy resources with a focus on Africa.

3.10 Weather

International trends

High impact weather prediction is used for disaster and water management, agriculture, energy, health, fisheries, aviation and transportation. Improvements in forecasting concern the time range (nowcasting and short-, medium- and long-range forecasting), accuracy, probability and risk (possible damage / lives lost).

Numerical weather prediction (NWP) deals with the application of model(s) using mathematical equations for weather prediction or simply put: divide the atmosphere into grid boxes, record data on processes for each grid box and then calculate the future state for that box. Nowcasting is the technique used for very short-range forecasting: map the current weather and use the speed and direction of movement to forecast the weather a short period ahead.

Another development is ensemble forecasting: estimate the risk of particular weather events and then use multiple forecasts, created by slightly altering either the starting conditions or the forecast model, or both, to assess the most probable outcome.

A key initiative is the world weather research programme (WWRP) and includes the improvement of weather forecasting in the form of the THORPEX and TIGGE programmes (as part of THORPEX). THORPEX (the observing system research and predictability experiment) is an international research programme to accelerate improvements in the accuracy and utility of high-impact weather forecasts up to two weeks ahead. TIGGE (THORPEX interactive grand global ensemble) provides a data base of ensemble predictions from the leading global NWP centres, for scientific research on predictability and development of probabilistic weather forecasting methods.

All this should result in better decision making. Factors that play a role are:

- High impact weather:
  accuracy and timing of forecasting should be balanced against the extent of avoidable loss.
- Communication of uncertainty:
  decision makers are very sensitive to false alarms (see also the discussion in section 3.1 Disaster management) and, at the same time, have a strong need for a high detection rate.
- Verification:
  verification results should be presented alongside the forecasts so that users can readily understand the quality of the forecast they are currently using.

As an example the following needs and recommendations for and from Africa are presented:

- Better dissemination of forecast information to reach end users
- Improved insight into how users do interpret and apply (or do not apply) forecast information
- Integrate all stakeholders through interaction to produce suitable information tailored to user needs
- Facilitate the quantification and evaluation of environmental, societal and economic benefits by the end user
- Find the most cost effective combination of observing system, data assimilation, forecast and application procedures (early warning system) to improve high impact weather forecasts from a user perspective

This user perspective is also very relevant to monsoon prediction and decision making:

- It is important when arranging the cropping strategy and taking preventive action in potential flooding zones
- Institutional mechanisms should be in place for communicating climate information to various user departments and agencies

3.10 Weather

- Forecasts should be released that match the lead-time requirements that are relevant to the end-users
- Seasonal forecast products should reflect local climatic zones (rather than administrative regions)
- Governments should rethink the value of climate prediction in societal and economic development

Related to this, the WMO has formulated the following requirements for an effective community response to warnings:

- Getting free warning and hazard information
- Receiving warning with sufficient lead time
- Understanding the warning content
- Believing the warning
- Believing that the threat is real
- Knowing when and what appropriate action to take
- Being in a state of preparedness

Earth observation applications

Categories of earth observation products and services for weather are:

- Global and local weather forecasting
- Precipitation monitoring and forecasting (see section 3.2 Crop modelling)
- Sand/dust storm forecasting (see section 3.8 Health)

Admittedly, this overview is incomplete: weather products and services are linked to all GEO Societal Benefit Areas and provide input to products and services related to these SBAs.

Because EO weather products and services support so many different purposes, it is good to list a few characteristics:

- It is considered to be mainly a public good, provided by NMOs and international specialized organizations
- Research topics on meteorological phenomena require specialization and are best studied in an international context
- Gains can be obtained by improving management of the whole communication chain, from specialized meteorological agencies to beneficiaries (think of timely warning for flooding or agricultural management)
- The envisaged role for business (SMEs) consists primarily of the delivery of meteorological products and services by specialized agencies to end users and/or using these as input for other products or services (think of agriculture, water management, health, energy, etc.)

Linking up with the end-users is therefore very important. A concrete example is the GEO initiative GEONETCast. GEONETCast is a satellite broadcasting and reception service that delivers meteorological products and services to end-users (among other services). Figure 19 shows the (almost) global coverage of the system.

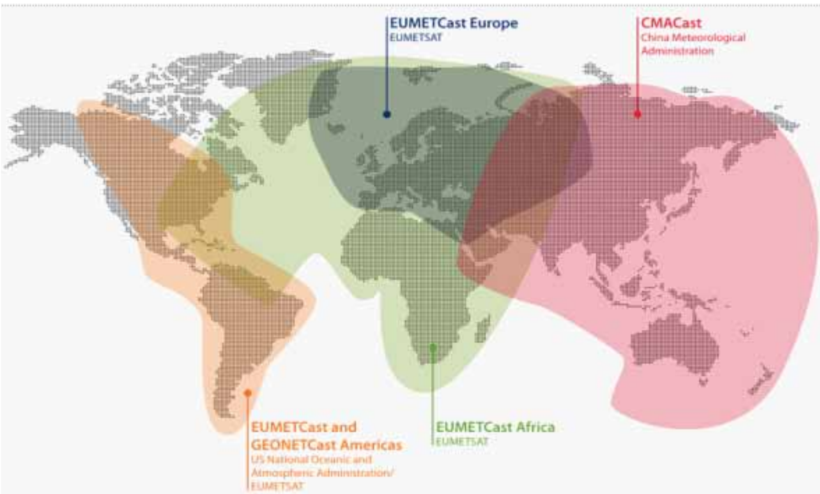


Figure 19: GEONETCast coverage

3.10 Weather

Socio-economic benefits

The above infers that the study of meteorological phenomena and the supply of products and services derived from this study are perceived to be a generally public service. On a global level the arguments in the discussion on cost-benefit are clear, just as applications in disaster management alone justify the use of earth observation as such, so does the reduction of damage and lives saved in extreme events justify investment in weather prediction. Several studies into the cost-benefits of NMOs are available (UK, France, the Netherlands). For specific weather applications, the analysis is provided in the sections on other SBAs.

To maximize societal benefits the link with decision making and the outreach to communities are important factors.

Promotion and capacity building

As indicated above, and as is so often the case, promotion should focus on communication with end-users, such as decision makers. Fortunately, international initiatives, such as GEO and activities of WMO, and national initiatives, such as in China and Indonesia, have resulted in, for example, a reduction of the warning time in the case of extreme events and improved communication with possibly affected communities.

For capacity building there is quite a number of user guides, tutorials, toolboxes and free software products available for self-study. One is the user guide for ECMWF forecast products. Colorado State University and UCAR provide web-based tutorials on weather and numerical weather production.

NavCanada offers a set of local area manuals with a general introduction on meteorology for aviation and description of weather phenomena for different regions in Canada, which is also instructive for other regions and purposes.

GEONETCast offers a toolbox that comes with a user guide and is based on ILWIS open software. The GEONETCast – DevCoCast application manual describes how to use the system and software with application examples on biomass quantification, crop monitoring, estimation of evaporation, assessing vegetation coverage and sugar cane production, crop growth and yield modelling, net primary production of grassland, rainfall estimates, ocean colour monitoring and coral bleaching risk (sea surface temperature).

3.11 Urban management, land administration and spatial data infrastructures

International trends

The subjects of urban management, land administration and spatial data infrastructures are joined in this section, because there is overlap between the subjects and because earth observation (potentially) plays a small, but important, supporting role.

Main trends in urban management are:

- Rapid urban growth: there is a clear need for management and planning
- Efforts to improve the urban living environment, such as infrastructure, services, health, and the urban environment
- Efforts to improve urban safety, such as risk management (natural and man-made disasters), crime reduction and anticipating and mitigating the effect of climate change
- Increased community participation through e-governance and web-based consultation of the general public

There is quite a difference in patterns across regions. The World Bank notes the following in a study on urban Africa:

- There is great diversity in urban sizes
- Large cities are growing at a faster rate than smaller cities
- Countries show a great heterogeneity in size distribution of their cities
- Faster urban growth means faster slum growth
- More and better infrastructure and service are needed

With respect to land administration, RICS notes the following benefits (crowd sourcing support of land administration systems):

- Improved security of tenure
- Improved land resources management
- Land disputes reduction
- Increased revenue generation
- Credit security, among many others

A standard work on land administration is "land policies for growth and poverty reduction" of the World Bank.
It lists a number of desirable characteristics of property rights to land, which should guide any land administration initiative:

- They should have a long enough horizon to provide investment incentives
- They should be defined in a way that makes them easy to observe, enforce and exchange
- They should be administered and enforced by institutions that have both legal backing and social legitimacy and are accessible by and accountable to the holders of property rights
- The rights and duties of individuals, within a group that holds communal rights, have to be clear
- Institutions administering property rights need to be flexible enough to evolve over time in response to changing requirements

Land administration systems could be construed as a type of, or part of a spatial data infrastructure.

The advantages of establishing a spatial data infrastructure are (from: advanced regional spatial data infrastructures in Europe (JRC)):

- A positive cultural change in the stakeholder organizations with greater willingness to cooperate and share resources
- More coordinated initiatives at local level regarding data collection, and reduction of duplication and costs
- Agreement on the common usage and maintenance of reference datasets
- More evidence-based applications, particularly in land use planning and infrastructure planning and maintenance
- Time and cost reduction in finding and accessing data held by other organizations

▶ 3.11 Urban management, land administration and spatial data infrastructures

- Improved shared understanding of the problems and issues affecting the region among public agencies

However, there are some important elements of SDIs that cannot be ignored:

- The "regional" dimension of SDIs is crucial, this is often neglected in professional and ademic debates that tend to focus more on the national dimension, subsuming the regional in a hierarchical view of SDIs
- SDIs facilitate building and supporting applications for citizens and local businesses related to land and property, planning, traffic, local services, as well as allowing new services from the private sector to be developed around addresses and locations

ConsultingWhere, a consulting firm, summarizes the do's and don'ts of SDIs (spatial data infrastructures: some lessons learned from UK and Europe):

- All stakeholders must feel ownership (public sector, private sector, third sector or social economy)
- Top-down leadership in the form of a clear government mandate is extremely valuable
- Bottom-up implementation (individual organizations will determine whether it is successful), the more participate the more useful the infrastructure becomes

The OGC, the UNSDI, GeoSUR, INSPIRE, the World Bank mapping for results initiative, and GEOSS (for a description see for example the EuroGEOSS literature) are all examples of SDIs where earth observation plays a role.

Earth observation applications

Earth observation provides an important base layer for urban management, land administration and spatial data infrastructure products and services. No special categories are therefore distinguished. Clearly, the different mapping scales (resolutions used) are related to various forms of planning.

Urban remote sensing provides the following benefits (from: remote sensing of urban and suburban areas):

- A multiplier effect that is partly attributable to earth observation: the growth of 'spatial data infrastructures', geo-portals and private sector initiatives (e.g. Google Earth, Microsoft Virtual Earth, etc.) produced an increase in geographical data availability at all scales and worldwide
- Remote sensing can provide a useful and direct indication of the physical form and morphology of urban land cover in cities
- Remote sensing represents a complementary data source to traditional socio-economic surveys
- Remote sensing supports "smart growth" (a range of urban strategies that focuses on sustainability of development under different economic scenarios)

Concrete urban remote sensing applications are urban population studies, health monitoring and early warning (including air quality), environmental management (urban ecosystems), interpreting urban land use from urban land cover (including impervious surfaces), desertification (especially relevant to rapidly growing cities in arid areas), urban heat islands (thermal mapping), crime mapping (a combination of remote sensing and GIS), characterization of the urban population (for example with night-time satellite data) and energy efficient buildings (see section 3.9 Energy).

A specific application is slum mapping, with upgrading and monitoring and evaluation of interventions as the ultimate aim. The following

▶ 3.11 Urban management, land administration and spatial data infrastructures

features can be more easily determined from space, than from the ground (from: an ontology of slums for image-based classification):

- Access network: slums have an irregular road layout with variable road types and widths.
- Density: the area is very densily built up, with generally very high roof coverage and very little open spaces and vegetation.
- Shape: the irregular shape of slums is easily distinguishable from planned areas and tends to follow the shape of features like roads, railways, etc., depending on easy availability of land.
- Connectivity: very poor connectivity with infrastructure in neighbouring areas.
- Location: slums tend to be located near to places that offer substantial economic opportunities and/or in hazard-prone areas.

Earth observation offers the following benefits to land administration (from: land administration: a key to sustainable economic development):

- In rural areas the main benefit is derived from surveying using images. HRSI (high resolution satellite imagery) as well as even lower resolution satellite imagery can provide high-speed cadastral surveying. The use has already been trialled in Ethiopia by the World Bank. This approach is particularly worthy for rural areas, as these contexts possess the wide-open spaces necessary for boundary identification.
- In urban areas, where highly precise boundaries are used (known to surveyors as fixed boundaries) current HRSI resolutions are not considered adequate. The situation will most likely change as image resolution increases and prices inevitably decrease.
- The benefits of using HRSI for cadastral applications, even in urban areas, should become increasingly apparent in some contexts.

However, the need for in field checks, surveys, and more importantly, agreement on where boundaries lie, will remain.

Socio-economic benefits

Table 8 shows a cost comparison for urban mapping in India, with a clear result in favour of remote sensing and GIS. This table is just an example. The general benefits of earth observation

Description project activity	RS & GIS methods (~ estimated values)		Traditional ground methods (~ estimated values)	
	~ costs per km2 (Indian rupees)	~ time required	~ costs per km2 (Indian rupees)	~ time required
Thematic/urban land use / land cover mapping and GIS database creation for Delhi NRC region (34,000 km2) on 1: 50,000 scale	1,000	1 year	10,000	more than 2 years
Cartographic quality large scale mapping on 1: 10,000 scale using high resolution satellite data; 5,000 km2 covering 40 towns	10,000	2 years	25,000	more than 3 years
Thematic quality urban land use / land cover mapping and GIS database created for Hyderabad, HUDA region on 1: 5,000 scale, using high resolution satellite data	5,000	6 months for 2,000 km2	20,000	more than 2 years

Table 8:
Cost and time requirements for preparation of urban thematic maps at various scales
Source: Remote sensing applications, chapter 5 – urban & regional planning (NRSC)

3.11 Urban management, land administration and spatial data infrastructures

for urban management and land administration have been listed earlier.
Earth observation is one of the basic layers of spatial data infrastructures and the benefits therefore coincide with the general benefits of SDIs that are listed in the first part of this section.

Promotion and capacity building

Promotion focuses on stressing the indicated benefits and demonstrating concrete successful applications. As earth observation is a support tool, promotion of a certain earth observation application will be part of the promotion of more general improvements in urban management or land administration practices or in the establishment or improvement of SDIs.

The book "remote sensing of urban and suburban areas" provides a collection of state-of-the-art chapters on urban remote sensing, also aimed at capacity building (with references and exercises). The focus is very strongly on science and technical aspects of the methodology.

With respect to slum mapping the already mentioned article "an ontology of slums for image-based classification" provides good guidance on approaches for slum identification and mapping, as well as suggestions on how remote sensing can help.

In the area of land administration the report "first experiences using high-resolution imagery-based adjudication approach in Ethiopia (World Bank) may be useful. It gives a description of a pilot for the use of Quickbird images by communities for land adjudication.

4. General aspects of marketing as promotion and capacity building

As indicated in section 2 marketing of a new technology not only entails promotion (and all the other usual marketing tools), but also capacity building. Potential clients need to be aware, up to a certain level, how the new technology can help them solve their problems and earth observation specialists need knowledge and skills on how to communicate with these potential clients.

Especially in developing countries, professionals returning to their home country after having received technical training abroad are confronted with a working environment, where they not only lack the possibility to implement their technical skills, but also where there is, for whatever reason, no apparent interest in their contribution.

In general, the following advice for promotion may be helpful:

- Look for opportunities, where can you have most success in a short time: quick-wins.
- Target the right audience to start with: who would be interested and listen to you?
- Identify the problem that they are trying to solve: is it the same as yours?
- Learn to speak the same language. Avoid abbreviations, such as PGIS or VGI, that politicians and managers do not understand and do not care about. If possible, use terms related to profits and losses.
- Look for examples from elsewhere (success stories): solutions that work and are affordable.
- Be patient: introduction of new technology and / or applications takes time.

A good approach is to share information on the subject you want to promote (your subject) and you think is interesting for your contact. Then look for the link, the connection. Could your solution solve a problem for your partner? Are adjustments necessary? Need other parties be involved? Take it from there. Even if this will not provide concrete results, it may generate so-called "leads": links to other persons or organizations that would potentially be interested in your solution. These should be followed up.

Promotion needs practice

Promotion also needs practice. For most people it is easier to assume a certain role, such as "I am a scientist", than to promote themselves or something they stand for. Either the subject is too close to their heart or they consider it so self-evident that they have lost the capability to explain it (in simple terms) to others.

There are certain tools, such as the Elevator Pitch, that help overcome this issue. In an Elevator Pitch you have about two minutes to convince somebody else about the importance or usefulness of something you want to promote. Examples and guidelines can be found on YouTube. Although the ultimate purpose is to establish long-term relationships, practising the Elevator Pitch is useful to help you focus your message.

Proposal writing

Lack of proposal writing knowledge and skills can also be an issue. In fact, the problem here is similar to the one described above, but this time concerns written communication: it is difficult for the proposal writer to connect with the purpose of, or behind, a call for proposals. This is partly caused by a lack of technical proposal writing skills, though these can be learned. Another part involves connecting to the issue itself, which is a skill that is much more difficult to acquire. Not surprisingly, there are professionals in this area offering their services to others. This means that those not familiar with project acquisition through calls for proposals are missing out on potential market opportunities. This is especially regrettable if they do have the technical skills and the comparative cost advantage to implement projects resulting from the call. The GEONetCab project has developed an outline for good proposal writing

4. General aspects of marketing as promotion and capacity building

and references to other manuals can be found in the appendices. The EOPOWER project will support business development by developing standard business procedures, template contracts, etc.

To summarise:

a shared problem, shared language and shared solution are keys to success

Promotion message

This leads us back to the content of the promotion message. The step-by-step overview presented in figure 15 in section 3.5 helps to construct a promotion message.
The questions can be answered for each earth observation application, resulting in a set of features that can be connected to the solution the client is looking for and an indication of the way the client should be approached.

As stated in section 2, clients want a product or service that is fit-for-purpose, practical, reliable, cost-effective, integrated in the business or organizational process and easy-to-manage in terms of client capacity. All these points should be addressed and the provider should take great care to look at the problem from the client's viewpoint. This does not mean that all demands of the client need to be met, only that the communication is based on common understanding and a joint approach of the problem.

Very little has been said in this report on quality and reliability of data and database management. Geostatistics is a very important field and it will become more important as the world is flooded with ever bigger quantities of data. GEOSS will be the system where all these issues come together. The GEOSS common infrastructure will provide data and metadata to users in a way that facilitates concrete applications, but that also indicates the limitations of and restrictions on the use of the data.

Promotion events

Promotion events also play an important role. The lessons learned from the GEONetCab project are that these events should preferably be short, targeted, at end-user events, local and, when possible, in the local language. The experiment with Eurisy in the final project workshop was very interesting as an exercise in communication: non-technical users teamed up with technical providers working on the same subject.

Succes stories

Success stories and demonstration projects are other important subjects. There is still a need for translation of scientific results and technical information into concrete business cases that work, or at least potentially work. The material is available, but not readily accessible. Accessibility refers to both "easy to find" and "easy to understand".
A concerted effort by scientists and marketing people is needed here. It is not enough to achieve a WTP (willingness to pay) with clients.
A WTA (willingness to adapt) from scientists and contributors to global initiatives to go beyond research publications and down to the "murky" practice of local reality is indispensable.

Capacity building

Capacity building complements promotion in marketing of earth observation, it is the instrument to increase self-sufficiency and make solutions work. Capacity building considerations are:

- Different instruments should be applied at different levels: e.g. workshops on raising

4. General aspects of marketing as promotion and capacity building

awareness for decision makers, and detailed technical training for professionals.

- Providing follow-up is essential, as obtaining funding for good capacity building is difficult: everybody agrees that it is important, but nobody has time, and priorities usually lie elsewhere.
- Training is usually included in the funding of big projects that are managed by big companies or government agencies; as a consequence capacity building is forgotten (or postponed to the very end of projects or programmes).
- The easiest way to obtain funding is to aim at small budgets that are available without having to tender.

Different players, such as the UN regional centres (CSSTE-AP, CRASTE-LF, RECTAS, CRECTEALC), European FP7 projects, space agencies, GEO, and CEOS, have put a lot of effort in capacity building for earth observation.

Often a multiplier effect has been achieved in fund raising, making it possible to reach a wide audience.
In capacity building it is also important to target young age groups: the South African programme Fundisa disk is an example (SANSA).
The Fundisa disk contains an assortment of EO data such as satellite imagery, a variety of vector data, open source software, and sample imagery, allowing students and instructors interested in pursuing studies in geospatial sciences, free access to a range of data and tools.
Other examples are Charles University's environmental conservation training packages in the Czech Republic (section 3.4) and the USGS tutorials on tracking change. Most space agencies have their own education and training programmes, catering to primary schools, high schools and tertiary education.

Similar to the situation concerning examples of (potentially) successful earth observation applications, capacity building material is available, but not easily accessible. The GEO capacity building web, designed by IRD in the framework of the GEONetCab project, aims to address this gap. Efforts will be continued during the EOPOWER project, which combines elements and partners of the GEONetCab, OBSERVE, BalkanGEONET, SEOCA, EnviroGRIDS and EGIDA projects.

Certification of capacity building?

With all the different capacity building activities that are carried out in the field of earth observation, a system of certification or at least synchronization would be a worthy endeavour. Such a system would make it possible for participants to put their learning achievements in a bigger framework and enable employers to better evaluate the acquired knowledge and skills. It is, however, a major task to set up such a system. ITC organized two workshops on cross-border recognition of education in earth observation (in 2007 and 2010). Although it brought different parties together, the main conclusion was that cross-border recognition of education is, in general, still a long way off and that cross-border recognition of education in earth observation should be part of a more general process. Scaling down the ambitions to mere certification, the search is on for a simple solution that allows maximum degrees of freedom, while providing structure.

Effect

The effect of capacity building activities is measured by the capacity building indicators developed in the GEO process.
The issue of measuring and evaluating capacity building is extensively dealt with in the GEONetCab capacity building strategy report.

5. Closing remarks

A few closing remarks are in order to highlight a few salient aspects of the marketing of earth observation. The remarks are a mix of practical guidance on the road ahead and anticipation of a future (better) situation:

- Exploit internet and the GEOSS common infrastructure

  Once the GCI is fully operational, this will provide a huge resource for earth observation applications and all kinds of background information. Moreover, if resources are available freely or at affordable cost, such as the internet itself, this will provide a big boost to business development in countries, where access to data is still a bottleneck.

- Local applications are of key importance

  Local applications are of key importance for the integration and acceptance of earth observation solutions across the board. Providing these solutions in the local language is equally important.

- Government will remain the most important client

  Government will remain the most important client for earth observation products and services, implying the market will be B2G or G2G, resulting probably in services from government to citizens (G2C), possibly making use of voluntary contribution by those citizens (C2G).

- Cooperation between governments, scientists and the private sector

  The cooperation between governments, scientists and the private sector needs to be continued to introduce earth observation applications successfully.

- Establishment of end-user communities

  The establishment of end-user communities of practice, around applications of earth observation for concrete problems is useful when introducing earth observation applications and helps improve earth observation products and services.

At the end of these approximately sixty pages on marketing of earth observation, which could easily have been six hundred pages, we return to the motto in the introductory section.
If the reader has been convinced that this statement is not just a declaration of faith, but one backed up by substantial evidence, then the aim of this report has been achieved.

"Earth observation helps you

... save lives
... save money
... save the environment"

Appendices (literature references and links)

N.B. The document can be found by clicking on the link. As links can change over time, copying the title into a search machine usually yields the desired result.

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