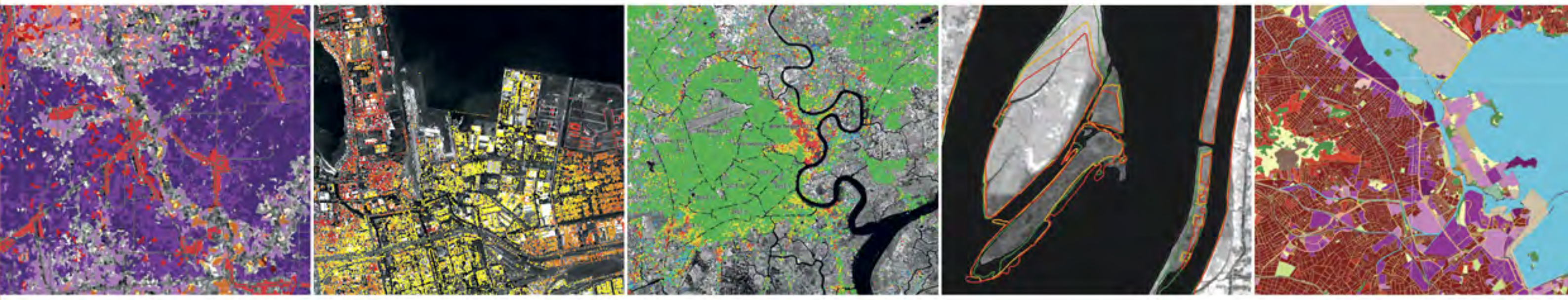
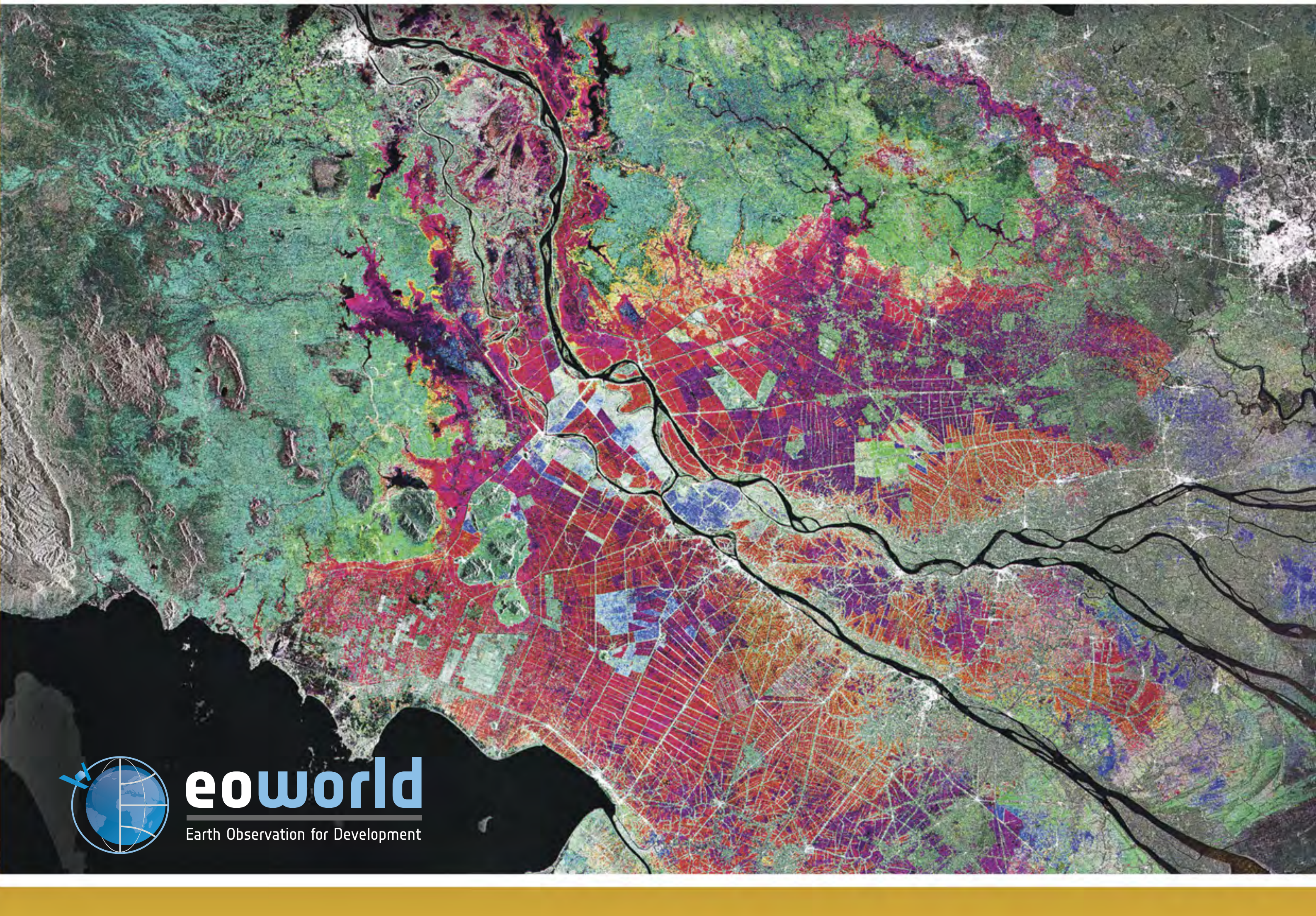
World Bank

European Space Agency

→ EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

Partnership Report | June 2013





eoworld

Earth Observation for Development

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FOREWORD

This is the second joint report published by the World Bank and the European Space Agency we have the pleasure of presenting. It sums up the results of the first five years of the increasing collaboration between our two international institutions, which is focused around the use of earth observation for sustainable development. In November 2011 we jointly published a first Progress Report, which provided updates on the early results of on-going joint projects. This Partnership Report now fully covers the outcomes and impacts of those projects, the feedback we have received from a variety of stakeholders, the lessons learned and the way forward.

During these five years of collaboration, the European Space Agency and the World Bank have explored and demonstrated the relevance of earth observation for development work that sets out to transform the physical environment - defined in its broadest possible terms. Earth observation has proven to be a valuable tool that provides cost effective, quick, and incontrovertible assessments. Through the sophisticated and comprehensive measurement systems provided by earth observation, we can better protect forests, manage urban growth, and harness water resources for agricultural use. Environmental transformations may occur as the positive results of voluntary development efforts or as the undesired consequences of uncontrolled economic activities. In either case, earth observation provides objective evidence of progress or baselines for remediation actions.

The report highlights how the introduction of earth observation services provided by the European Space Agency has impacted World Bank projects in a variety of sectors and geographic locations, helping the Bank achieve its development objectives and, in some cases, opening new and unexpected avenues for further engagement with country clients. In many cases, government counterparts have requested follow-up initiatives aimed at scaling-up of the use of earth observation; in others, the new initiatives are decided directly by World Bank teams.

The lessons learned provide us with a better understanding of the challenges before us: for the World Bank, further supporting internal and external users in order to mainstream the use of earth observation; for the European Space Agency, further adapting earth observation to the many facets of international development work. We are confident that the second phase of our partnership, starting now, will enable us to tackle these challenges successfully, for the benefit of sustainable development worldwide.

Zoubida Allaoua
Director
Urbanization and Disaster
Risk Management Department
The World Bank

Volker Liebig
Director
Earth Observation Programmes
European Space Agency

OVERVIEW

The European Space Agency (ESA) and the World Bank have been collaborating under the umbrella of the "Earth Observation for Development" initiative - branded *eoworld* - since 2008. The objective of this collaboration is to promote satellite Earth observation (EO) technology as a standard tool in planning, implementation, monitoring, and assessment of the World Bank projects for sustainable development. Within this framework, ESA provided the financial and technical capacity to demonstrate concrete examples of the use of EO information products and the value they bring to World Bank operations across its Sustainable Development Network.

Between 2008 and 2012 ESA and the World Bank jointly implemented fifteen dedicated technical assistance activities aimed at delivering high-impact EO-based data and knowledge products. The final results were delivered in the form of EO-based services: highly specialized mapping products and monitoring that leverage Earth Observation data.

The implementation of the *eoworld* portfolio took place in two stages. Between 2008 and 2010 three small-scale but highly focused demonstrations in the area of adaptation to climate change were carried out in the Latin America and Caribbean region (coral reef management in Belize), in the Middle-East and North Africa region (climate change adaptation in Alexandria and Tunis), and in the South Asia region (coastal zone management in Bangladesh). The success of the early pilots resulted in scaling up of the collaboration in 2010 to include twelve larger activities focused on demonstrating EO applications in seven additional sectors: disaster risk management, urban development, forestry, agriculture, water resources management, coastal zones and marine environment management. A set of demonstration projects were carried out in over 20 countries in Latin America (Bolivia, Peru, Brazil and Guyana) as well as a number of countries in West Africa (Ghana, Liberia, Senegal, Nigeria, Benin, Sao Tome and Principe), East and Southern Africa (Tanzania, Mozambique, Madagascar, Malawi, Zambia, South Africa, Comoros, Seychelles, La Reunion), along with India, Bangladesh, Indonesia, Vietnam, Cambodia and Papua New Guinea.

The EO activities addressed numerous areas of sustainable development, including climate change, sea-level rise, maritime surveillance and marine environmental monitoring, coastal erosion, flooding, urban land subsidence, water quality, forest resources assessment, agriculture monitoring and urban territorial development. Concrete examples of application areas include establishing baselines, results monitoring, impacts assessment and auditing, identifying hot-spot locations, and supporting dialogue with local partners by putting development issues in a spatial context. In many cases the results revealed ground-breaking information.

Satellite monitoring of Lake Titicaca – a UNESCO Heritage Site on the border of Bolivia and Peru demonstrated prominently that between 2003 and 2010 the size of the lake decreased by seven per cent, and documented for the first time, that the lands protected under the RAMSAR Convention as an important wetland and breeding ground for endemic species are facing unprecedented degradation.

A maritime surveillance system designed for the countries of the Mozambique Channel provided a near-real time oil spill warning system to assess and manage pollution in the region. It detected thirty eight oil spills in a five month period, and enabled backtracking and investigation of suspected polluters.

The project implemented within the framework of the World Bank's South Asia Megacities Improvement Program analysed the dynamics of urban expansion in Delhi, Mumbai, and Dhaka highlighting a rapidly growing need for quality data and information to better understand the distribution and evolution of urban land cover. In all three cities EO detected massive urban sprawl which in Dhaka was clearly dominated by residential built-up, while in Delhi and Mumbai these trends were accelerated by industrial development causing consumption of natural areas and agricultural land as well as gradual densification of rural settlements.

Urban risk assessment projects were also implemented in Jakarta, Rio de Janeiro, Ho Chi Minh City, Yogyakarta, Alexandria, Tunis, and Georgetown to assess the exposure of these cities to a full range of hydrological and geological hazards (such as floods, landslides and urban land subsidence). EO accurately and efficiently identified the subsidence problem in these metropolitan areas, revealing trends with milimetric precision and on the level of single infrastructure elements. In Jakarta the problem of urban subsidence is particularly disturbing. Pumping of water from deep wells (100 meters or deeper) causes the land to sink by as much as 10 cm a year. In the case of sea defence infrastructure this trend progresses at even faster pace which, if sustained at the current rate, may result in Jakarta's coastal areas sinking below sea-level. In other cities subsidence and flood hazard information was used to adjust planned interventions regarding flood risk management.

In Liberia, EO services provided independent verification of contradictory reports concerning available forest resources. EO provided new information for land use reform, which is critical to both the economic development and post-conflict reconstruction of the country. The study discovered that the deforestation rates in the investigated areas has been kept to a minimum, which in turn provides local communities better options for forest conservation and carbon credits generation. EO also provided important information concerning the location of different land use concession areas and potential overlaps between them.

In Zambia, EO tools enabled verification and consolidation of official databases of small water reservoirs, and creation of modern information systems that will enhance national data collection methods. A series of dedicated training sessions for local government officials were held to enhance the national and regional capacity to use EO in water resources management tasks. As a result, a series of six intensive two week trainings over a period of three years will become as a part of World Bank capacity building activities in the region.

In Papua New Guinea, EO-based agricultural monitoring was used to manage operational risks associated with palm oil production. New data supporting planting approval process will be included in bi-annual environmental audits and may potentially be used also for of other cash crops sectors such as coffee and cocoa production. Finally, in West Africa, where countries involved were lacking long-term, harmonized records of the evolution of coastal environment, historical satellite data analysis allowed assessment of long-term trends of coastal change and sea-level rise in a timely and cost effective manner. In Sao Tome and Principe, EO was used to monitor erosion hotspots and to engage target communities and district authorities in adaptation to climate change by providing options for better planning for the future locations of critical infrastructure and guidance in the expansion of settlements to less vulnerable sites.

Results of these projects revealed significant demand for EO information both at the World Bank and at the local level. Access to accurate and up-to-date analytical tools strengthens the strategic relevance and technical quality of proposed or on-going World Bank investments. Integration of Earth Observation in World Bank's operations lies at the core of its mission to collect data and analyze information to deliver high quality solutions for more informed, evidence-based and data-driven decision making. Moreover, EO technology is a source of high quality and reliable information which improves the efficiency of field work typically associated with the design and implementation of Bank projects. EO offsets some of the costs of traditional ground surveys (e.g. – to support mandatory environmental audits) used to define priority interventions.

The projects also provided comprehensive hands-on training and capacity-building to national counterparts – national level user organizations responsible for relevant policy areas (environmental protection, disaster risk management, urbanization, agriculture, regional development, fisheries, transport, maritime policy and many other). This specialized training and capacity building not only helped the local users understand the wider context of different satellite systems and how to use them on an operational basis, but it also underscored the fact that the World Bank has an important role to play as a catalyst of EO application among its stakeholders.

Finally, some of the most successful technical activities developed through the *eoworld* portfolio have been embedded in the World Bank regional operations. For example the real-time oil spill detection service became part of the Second Phase of Western Indian Ocean Marine Highway Development Projects tools used for water resources management were embedded in the Zambia Water Development Project forest monitoring became a part of the Forest Carbon Partnership Facility grant in Liberia, and coastal monitoring continues - Sao Tome and Principe Adaptation to Climate Change Project.

Part 2 of this Report describes in detail the outcomes of the individual *eoworld* projects. The success of the initial phase of the collaboration was also documented in the

ESA-World Bank Progress Report released in November 2011 and available on the program's dedicated website: *www.worldbank.org/earthobservation.*

The Earth Observation for Development initiative gave impulse to a range of activities aimed to raise awareness about Earth Observation and the value it brings to development. The World Bank has set up the Earth Observation Coordination unit to connect ESA teams with their counterparts at the Bank and to facilitate the organization of learning events at the World Bank headquarters and around the world with the objective to share best practices, experiences, and lessons learned. The World Bank has also created its first integrated and centralized spatial data portal called GeoWB which now serves as a repository of spatial data from across the institution, and enables teams to benefit from spatial data more widely.

In addition, both ESA and the World Bank took active part in a range of events dedicated to developing capacity concerning the use of EO in developing countries. The World Bank participated in ESA's TIGER Initiative to enhance the capacity of African countries to use EO for water resources management, and in the International Forum on Satellite Earth Observation and Geo-Hazard Risks in, respectively, 2011 and 2012. ESA, on the other hand, joined the 2012 Understanding Risk Forum organized by the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR), the 2012 Annual Meetings of the Global Partnership for Oceans (GPO), and the World Bank's bi-annual Urban Research Symposiums (URS) in 2012, as well as the 2013 Annual Meetings of the Wealth Accounting and the Valuation of Ecosystem Services (WAVES) Program.

Extending the partnership

In 2013 ESA and the World Bank are entering into the second phase of collaboration to broaden the initial scope of the partnership. Within this framework ESA will extend its support (financing and technical assistance) to produce and deliver EO information services to a set of sectors identified by the World Bank as having the biggest potential for transformative outcomes. These are: urban development, disaster risk management, forestry, and oceans. The reinforced partnership will also provide a platform to identify further opportunities and to include new areas of collaboration which have not yet been explored - such as operations in fragile and conflict affected states, ecosystem's services, extractive industries, renewable energy, and the insurance and reinsurance sector, as well as capacity building.

To date, ESA has financed the procurement of EO services for a total approximate value of €2.3 million (a figure which includes over €1 million in EO data from European and international public and private satellite missions). The Bank has allocated to this collaboration approximately US$1 million, in the form of staff involvement and follow up investments the majority of which will be financed through World Bank's regional projects. Following the success of the first phase of collaboration, the next steps are focused on the expansion of the partnership and its formalization via a Memorandum of Understanding in the near future.

The second phase of the ESA-World Bank partnership builds upon the existing collaboration. It will continue to provide a platform for services' expansion with the objective to take the partnership beyond the initial technology demonstration phase and toward a consolidation of EO technology use in the World Bank knowledge, information and services delivery systems. The objective is to build strategic relations that take the full advantage of the technological capabilities of ESA, European national satellite missions, the Global Monitoring for Environment and Security (GMES) Program, and the ground-breaking innovation opportunities they offer to the user communities around the world.

Stephen Coulson
Head of Industry Section
ESRIN
European Space Agency

Anthony G. Bigio
Senior Urban Specialist
Urbanization and Disaster Risk Management Department
World Bank

1. SCOPE OF THE PARTNERSHIP

The World Bank is one of the world's largest sources of development assistance. It provides financial resources to boost prosperity and inclusive growth, especially in low- and middle-income countries through loans and grants as well as policy advice, research, analysis, and specialized technical assistance. The World Bank is also the world's premier producer of knowledge and experience on development. Its research, data, and knowledge platforms inform not only Bank operations but also the activities of policy makers, researchers, and civil society throughout the world.

While the World Bank's mission is to reduce global poverty through economic development, the scope of the Bank's investments is expanding rapidly in the face of the magnitude and complexity of the challenges that the developing world has to meet: climate change, rapid urbanization, threats to food security, natural resource depletion, and the risk of natural disasters. The provision of robust data is key to addressing these issues, and the World Bank is looking for best available data and quality solutions to global challenges.

Over the last years the World Bank has gained significant experience in utilizing new technologies, including satellite Earth Observation tools and other geospatial technologies. The Bank has developed partnerships with external organizations, including national space agencies such as the European Space Agency (ESA), U.S. National Aeronautics and Space Administration (NASA), NOAA (National Oceanic and Atmospheric Administration) and JAXA (Japan's Space Exploration Agency) as well as private sector satellite operators to improve its access to available EO data, information services, and knowledge products.

The partnership with ESA is leading the way in the use of EO information for development investments. The existing ESA technological capabilities place it at the forefront of Earth Observation as a key partner to international financing institutions seeking innovative solutions to address sustainable development challenges. In the next decade ESA plans to launch more than twenty new EO satellites, providing an enormous wealth of new data to be exploited by scientific as well as operational communities. This includes the most ambitious existing operational Earth Observation program - the Global Monitoring for Environment and Security, or GMES - which will combine data from the world's biggest fleet of satellites and from thousands of in situ sensors worldwide to provide joined-up, timely, reliable and easily accessible information services covering land, marine environment, atmosphere and emergency response.

The collaboration between the World Bank and ESA initiated in 2008 has successfully implemented a range of technical assistance projects addressing climate change adaptation, disaster risk management, urban development, water resources management, coastal zone management, marine environment management, agriculture, and forestry. Through these projects the World Bank has begun to harness the potential of advanced EO tools and techniques to achieve greater development impact and to equip partner institutions in client countries with the knowledge and innovations they need for more informed, evidence-based and data-driven decision making.

Sustainable development challenge

Many areas of sustainable development are facing their defining moments. Today's urban population of about 3.6 billion people is projected to reach 5 billion by 2030 with over 90% of urban population growth expected to occur in the developing world. Increasing population and asset density will intensify exposure to natural disasters. In 2011, the world experienced the highest disaster losses ever recorded and this trend will continue, exacerbated by the effects of climate change on the poorest and most vulnerable communities. Moreover, with global population on the rise, the world will need to feed 9 billion people by 2050. That will require a 50% increase in food production. It is also estimated that by 2025, nearly two-thirds of countries will be water-stressed and 2.4 billion people will face absolute water scarcity - posing challenges to agriculture productivity and food security. Other major global issues related to natural resource depletion such as deforestation, soil degradation, desertification and loss of biodiversity also reveal alarming trends.

Deforestation and degradation of 2 billion hectares of forest landscapes affect not only the local environment and the balance of greenhouse (GHG) gases, but also the livelihoods of 350 million people who live within, or close to, dense forests and depend on them for their subsistence and income. Similarly, healthy, bio-diverse, and economically productive oceans are essential for food security, jobs, and the sustainable quality of life on earth. It is estimated that 61% of the world's total GNP comes from areas within 100 kilometers of the coastlines. The oceans as a whole provide 16% of the global population's animal protein intake. However over-exploitation is undermining the socio-economic performance of these resources. As much as 85% of the world's ocean fisheries are fully exploited, over-exploited or depleted. More than 60% of global coral reefs are under direct threat from land- and ocean-based activity. Taken together they are creating an annual global efficiency loss of some $US 50 billion, not taking into account the disruptive effects of sea-level rise and other effects of climate change.

Counteracting all these challenges will require targeted, focused, and result-driven development programs which must actively explore practical paths of action to ensure that natural resources are used sustainably, whilst meeting the demands of our growing global population, managing disruptive impacts of climate change, and preparing for increased frequency and intensity of natural disasters. Therefore, the World Bank is introducing new knowledge products and services, and testing innovative ideas, including the potential of the next generation Earth Observation tools and techniques that can help it achieve its development objectives while facing such challenges.

Satellite Earth Observation can address a number of areas of sustainable development. EO is a valuable source of information for management and protection of valued ecosystems, counteracting overexploitation of resources, desertification and land degradation, and to support sustainable agriculture and biodiversity conservation. In the same way, EO´s capabilities extend to support marine and coastal ecosystems management to mitigate the negative impact of both natural and anthropogenic effects in sensitive habitats. EO is also extensively used to support risk assessment as well as crisis mapping including post disaster recovery, rehabilitation, and reconstruction, as well as monitoring of urban development to understand how cities are evolving over time at the local, regional and, global level. Examples of operational services developed with the use of EO data include:

- integrated maritime surveillance to generate situational awareness of activities at sea impacting maritime safety and transport, pollution (i.e. oil-spills, off-shore contamination), and monitoring of fisheries and coastal resources,
- assessment and monitoring of water quality parameters, as well as the state and dynamics of the oceans and coastal zones to help protect and manage marine environment,
- assessment of land use practices and land use changes to monitor biodiversity, soil, water, forests and other natural resources to boost the efficiency of agriculture, food security, as well as sustainable land use,
- urban planning and monitoring of sustainable urban development,
- risk assessments of natural (as well as manmade) disasters such as floods, forest fires and earthquakes,
- rapid mapping to contribute to humanitarian aid and emergency response,
- monitoring of air quality, ultraviolet radiation and ash clouds from volcanic eruptions as well as greenhouse gases emissions, and
- information services cutting across all of the above, can be used to formulate appropriate strategies for adapting and mitigating the effects of climate change.

EO is inherently multipurpose in scope. As satellites routinely orbit the Earth they build up a time series of data that permits measurement of specific phenomena (i.e. sea-level, wave height, clouds, vegetation) or of particular domains (land, marine, or atmosphere) through time and space. Collected data inputs into modern information systems that are used to assess and monitor processes related to terrestrial landscapes, atmosphere and oceans, and for improved understanding of the Earth system as a whole – its weather, climate, oceans, land, geology, natural resources, ecosystems, and natural and human induced hazards. This information can be marshalled in a way which supports specific projects and activities, local communities or addresses concrete problems via innovative diagnostics and analytical tools.

Delivering information to support sustainable development goals is at the core of ESA's exploitation activities. The overall vision for ESA is to play a central role in developing the global capability via dedicated space-based observations and specialized Earth Observation services to understand Earth's environment and its changes and support disaster management. ESA currently undertakes a wide variety of projects in these areas and develops advanced satellite technologies, concepts and applications that will radically improve the management of the planet's resources and its growing population in a sustainable manner. In particular, to enhance the utilization of EO data for sustainable development ESA has partnered with the World Bank, the European Investment Bank (EIB), Asian Development Bank (ADB), and International Fund for Agricultural Development (IFAD) to build a comprehensive approach toward this user community.

The partnership with the World Bank is the Agency's leading effort in this area. In 2008 ESA and the World Bank launched the Earth Observation for Development initiative – branded *eoworld* – with the objective to develop EO-based applications for operational decision making that can be used to support World Bank operations. It currently focuses on promoting the utilization of satellite Earth Observation (EO) technology, while raising awareness of the capabilities of European Earth Observation missions. Also, *eoworld* identified specialized EO services providers that produce and deliver information which can be customized to the specific strategic information requirements of the World Bank. In this context ESA provides independent technical guidance as well as financing to develop a better understanding of Earth Observation technologies and to facilitate access to this highly specialized EO service sector.

ESA – World Bank partnership

The World Bank's partnership with ESA is anchored within the Bank's Sustainable Development Network (SDN) which is the largest Network at the World Bank. It comprises global practices in sustainable energy, water, ICT, transport, infrastructure, urban development and disaster risk management, environment, agricultural and rural development, social development, and climate change. SDN brings together projects and programs across the six World Bank regions: Latin America and Caribbean, Sub-Saharan Africa, North Africa and the Middle East, South Asia, East Asia and the Pacific, and Europe and Central Asia, with a total of US$110 billion in its lending portfolio. SDN also manages 39 Global Partnerships - including Global Facility for Disaster Risk Reduction and Recovery (GFDRR), Global Partnership for Oceans (GPO), Global Agriculture and Food Security Program, Program on Forests (PROFOR), Global Environment Facility (GEF), Climate Investment Funds (CIF), Wealth Accounting and the Valuation of Ecosystem Services (WAVES), and Water Partnership Program (WPP). These Global Programs and Partnerships (GPPs) play a key role in the Bank's sustainable development agenda, in creating and sharing of knowledge, and in mobilizing financial and technical resources of a larger community of donor organizations, as well as public and private stakeholders, particularly on environmental issues.

WORLD BANK SUSTAINABLE DEVELOPMENT NETWORK SECTORS

- Agriculture
- Climate Change
- Disaster Risk Management
- Energy
- Environment
- Information & Communication Technologies
- Infrastructure
- Oceans
- Oil, Gas & Mining
- Social Development
- Transport
- Urban Development
- Water

At ESA, the collaboration is led by the Science, Applications and Future Technologies Department of the Directorate of Earth Observation (D/EOP). It is built in as an element of the Earth Observation Envelope Programme (EOEP) which plays an essential role in advancing science and fostering research into new methods of using EO data. In addition to EOEP, ESA has developed its flagship GMES Services Element portfolio (2002-2012) in maritime

security, coastal water quality, land motion, agriculture monitoring, environmental monitoring, forestry and emergency response, which includes:

- Land cover and land use change information services (GSE Land)
- Flood and fire risk management services (Risk-EOS)
- Information services for Humanitarian Aid (Respond)
- Information services for atmospheric pollution monitoring (Promote)
- Marine and coastal environmental information services (MarCoast)
- Polar environnent information services (Polar View)
- Forest monitoring information service (GSE Forest Monitoring)
- Geotechnical risk management services (Terrafirma)
- Food security information services for Africa (Global Monitoring for Food Security)
- Maritime security information services (MARISS)

The EOEP program currently works toward demonstrating tested, validated and cost-effective EO-based information services (such as oil-spill monitoring, agricultural monitoring, geo-hazard risk management, land motion monitoring, environmental monitoring) that can be provided to new user communities around the world on an operational basis.

Other on-going international development activities at ESA are related to supporting African institutions in managing water resources as well as international disaster relief efforts through the International Charter for Space and Major Disasters, which provides the rapid mapping to the countries affected by natural disasters. The Charter evolved into a collaboration of fourteen space agencies providing a unified system to task and deliver satellite imagery to support disaster management. Since 2000 it has delivered EO services over 360 times in more than 110 national users. ESA is also a leading organization within the inter-governmental Group on Earth Observation (GEO) and the Committee for Earth Observation Satellites (CEOS), where, along with other key space agencies, it supports Forest Carbon Tracking system, Global Forest Observing Initiative, as well as global drought monitoring for food security, agriculture mapping and monitoring, global urban observation and information, and the global Earth Observation strategy for disasters and risk management.

Building upon this experience, ESA and the World Bank have jointly designed and implemented fifteen dedicated technical assistance activities – the *eoworld* projects – aimed at delivering high-impact EO-based data and knowledge products to support World Bank operational projects. They were carried out between 2008 and 2012 in Latin America, Africa, South and East Asia in the following areas:

- climate change adaptation
- disaster risk management,
- urban development,
- water resources management,
- coastal zone management,
- marine environment management,
- agriculture, and
- forestry.

The primary purpose was to showcase the added value of specialized EO applications to development work, and raise awareness within the World Bank of the potential of European and Canadian EO missions (both ESA and national), and the capabilities of the European and Canadian specialist EO service providers to provide information customised to the specific needs of individual projects. The long-term objective is to promote the use of EO as a component of 'best-practices' in the definition of future programs, projects and other development initiatives, and to promote the use of Earth Observation technology as a standard tool in planning, implementation, monitoring and assessment of World Bank investments.

Implementing *eoworld* projects

Implementation of the eoworld portfolio took place in two stages. Between 2008 and 2010 three small-scale but highly focused demonstrations in the area of adaptation to climate change were implemented in Belize, North Africa and Bangladesh. The success of these early pilots resulted in scaling up of the collaboration in 2010 to include twelve larger activities as a first step to linking EO technology to sustainable development in a comprehensive, all-encompassing manner. The geographic scope of the services expanded to all of the World Bank regions. Projects were carried out in over 20 countries: in Latin America (Brazil, Bolivia, Peru, Guyana), West Africa (Ghana, Liberia, Senegal, Nigeria, Benin, Sao Tome and Principe), East and Southern Africa (Tanzania, Mozambique, Madagascar, Malawi, Zambia, South Africa, Comoros, Seychelles, La Reunion), along with India, Bangladesh, Indonesia, Vietnam, Cambodia and

Papua New Guinea. Concrete examples of application areas include establishing baselines, results monitoring, impacts assessment, and auditing, identifying hot-spot locations, and supporting dialogue with local partners by putting development issues in a spatial context.

The selection of the technical activities carried out by ESA was based on the competitive Call for Proposals which was launched in May 2010. It attracted a large number of requests for technical assistance from the World Bank operational units. Following the Call, ESA issued an Invitation to Tender (ITT) to the European and Canadian EO services industry to deliver services as specified. The Total value of ITT was approximately €1.3 million covering twelve separate activities. In addition, ESA supported this work by providing access to EO data from fifteen different satellite missions, mainly ERS, ENVISAT, RapidEye, SPOT, Cosmo-Skymed, TerraSAR-X, Radarsat, GeoEye, WorldView and others, for a total value of €1 million. It also facilitated data acquisition via satellite tasking and programming of observations to respond to specific needs of the World Bank projects (in cases where no previous data was available or to support tailored real time mapping).

The primary recipients of the *eoworld* final results were World Bank teams implementing targeted Bank-financed interventions. The Bank has also catalysed the involvement of country-level end users - national and regional public agencies in the World Bank projects' countries which are receiving loans, grants, technical assistance and other analytical or advisory support available through World Bank instruments. These local stakeholders represented the community of users in environmental protection, disaster risk management, urbanization, agriculture, regional development, fisheries, transport, maritime policy and many other public policy areas. They played a critical part in implementation of the *eoworld* projects through collection of in-situ data, the interpretation of the satellite-based findings, the evaluation of causal processes, and the assessment of the utility of the services provided.


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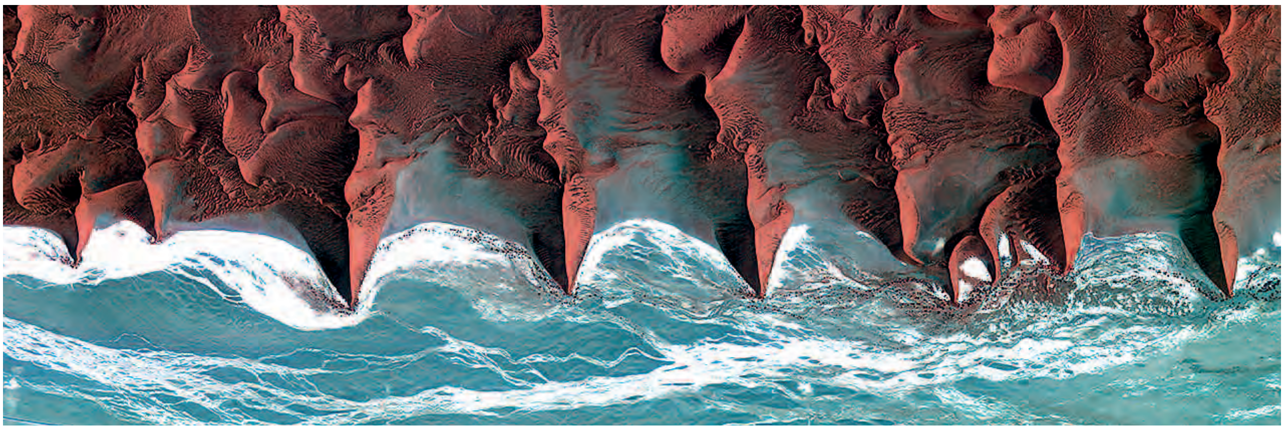
In addition to final mapping products, in an effort to assist local users in understanding the wider context of the different information systems and how to use them operationally, five dedicated hands-on training workshops were organized in collaboration with the World Bank Country Offices in Brazil, Papua New Guinea, Zambia, Indonesia and at the Headquarters of the Indian Ocean Commission.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1. Training in Sao Tome. One of the primary recipients of project results were country-level end users. Photo by Geoville.
2. Sand seas of the Namib Desert on 7 January 2012 captured by Korea's Kompsat-2 satellite. Copyright KARI/ESA.

Disaster Risk Management

The rising economic impact of disasters across the globe is attributed to the growing concentration of assets and population in areas at high risk for natural hazards. Developing countries are particularly exposed to a range of extreme weather events, as well as sea-level rise and other impacts of climate change. Moreover, cities of the developing world, which currently host more than 50% of the global population and hundreds of billions worth of assets, are growing fast attracting increasingly more residents and resources. The effects of natural disasters on urban areas can be devastating, and therefore the *eoworld* projects focused on demonstrating how EO data and information can support urban risk assessment and formulation of better urban resilience strategies. A set of applications was developed for Rio de Janeiro, Jakarta, Ho Chi Minh City, Yogyakarta, Alexandria, Tunis, and Georgetown (Guyana) to help assess the exposure of urbanized areas to a full range of hydrological and geological hazards (Fig. 1b).

As a foundation for disaster preparedness, EO-based urban mapping allows to assess the structure of the built-up areas and prepare for disaster risk management operations. In Rio de Janeiro where urban expansion is progressing at an unprecedented rate, and the territorial conditions are extremely constrained, EO data helped to create easily updatable baseline maps of urban assets while taking into account location of informal settlements and their high vulnerability to floods and landslides. For the local authorities, satellite-based mapping has become a useful and available tool to keep up with the dynamic expansion of Rio's agglomeration, also providing an affordable alternative to the traditional types of surveys.

"The information on subsidence at local level provides the knowledge to enable a better idea of infrastructure reconfiguration needs going forward in the long term flood mitigation efforts in Jakarta.
The high resolution analysis provides for a more compelling justification for projects and better impact when in project discussions and dialogue with the authorities and stakeholders".

Fook Chuan Eng,

Senior Water and Sanitation Specialist,
Jakarta Country Office, World Bank

Moreover, satellite radar data have the capability to deliver highly specialized EO applications to detect and monitor geological hazards. In particular, new pioneering techniques to identify land and urban infrastructure instability (such as landslides risk assessment and urban subsidence) have been breaking ground in the urban disaster risk management practice. In Jakarta and Ho Chi Minh City EO provided the first accurate assessment of the at-risk areas which were previously not provided by

1a

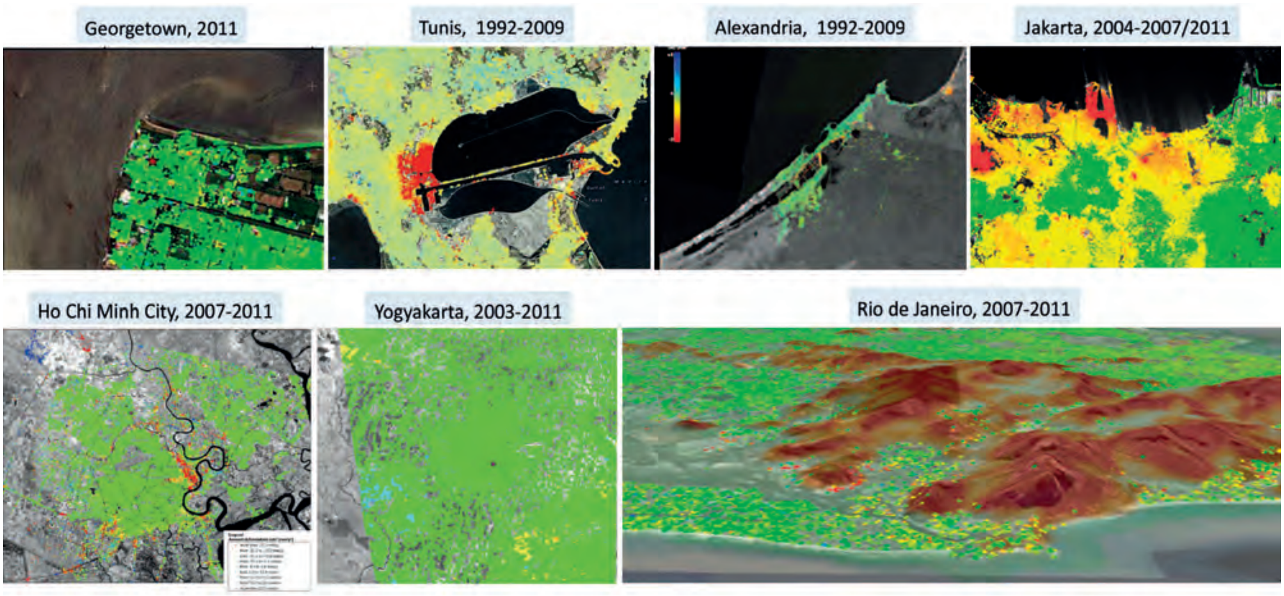
1a. Flooded village and houses south of Dhaka, Bangladesh. Credit: Yann Arthus Bertrand.

in-situ techniques. In Georgetown (Guyana), Alexandria and Tunis, it helped to assess the subsidence of low-lying coastland areas and their vulnerability to a range of risks including climate change-induced sea-level rise. These new methods offered unprecedented level of precision and accuracy and helped to adjust long term plans for urban infrastructure development in these cities. They are currently being put to operational use by World Bank teams. In Jakarta, the generated information is aimed to support regular monitoring of stability of high-rise buildings, coastal defence infrastructure as well as management of ground water extraction (the main cause of land subsidence). In Ho Chi Minh City, information on its subsidence will be integrated into the flood management plans being prepared.

For urban risk assessments, EO is not only a source of reliable information about natural hazards, but also an extremely effective method to communicate potential risks, hence to influence the dialogue with the stakeholders to convey the importance of prevention and/or mitigation efforts. It allows to focus resources on priority interventions such as monitoring of stability of buildings, coastal infrastructure, installation of gauges to more accurately assess the sea-level rise trends, on conducting precise measurement of terrain elevation to model flood propagation.

Another EO application in the disaster risk management area pertains to the protection of high-value agriculture and rural infrastructure from the damage caused by droughts and flooding. The project implemented by the World Bank in the Mekong River Basin demonstrated that with the right EO-based information it is possible to better characterize hazards and quantify the exposure of assets (crops, buildings, roads) to floods, droughts, and other extreme weather events. Thanks to wide-area synoptic observation which takes into account the transboundary character and hydrological connectivity of the Mekong basin, thousands of buildings and infrastructure features as well as thousands of square kilometres of crop yields were mapped in a way that can offset time-consuming and expensive field trips and airborne surveys.

1b



1b. Example of different precise motion products delivered within the framework of eoworld projects. Credit: Altamira Information (Georgetown, Alexandria, Jakarta, Ho Chi Minh City, Yogyakarta), TRE (Tunis), Hansje Brinker (Rio de Janeiro) for ESA, World Bank. Data used: ERS, ENVISAT, ALOS, COSMO SkyMed, TerraSAR-X.

Urban Development

Cities in the developing and emerging world are growing in size and increasing in numbers at an extraordinary rate. Urban populations are expected to double, adding additional two billion people over the next two decades. Whilst urbanization advances, there is a growing need for quality data to better understand the distribution and expansion of urban land cover at the global and regional scale as well as the evolution of urban densities, the percentage of natural areas being converted to urban land, and other land use trade-offs at the level of individual cities.

"The access to EO data, when combined with traditional layers of spatial data, geo-referenced survey data, and essential non-spatial urban data, has paved the way for a deeper understanding and a richer analysis of urban growth. Given the rate, scale and complex nature of urban expansion in Asia, access to this type of technology and data can provide a foundation for valuable preemptive analysis that can improve and shape billions of dollars of infrastructure investment, urban design and land use strategies".

Arish Dastur,

Urban Specialist,
East Asia Pacific Region, World Bank

One of the major benefits of the use of EO-based monitoring for urban planning is the ability to produce detailed and cost-effective digital urban maps, while ensuring that the most up-to-date and accurate data is made available on a regular basis. Moreover, EO datasets facilitate measurements that are conducted in a harmonized and standardized manner, allowing global assessment as well as spatially and temporally-consistent comparisons. In addition, advances in technology allow new observations which were not available in the past including more precise vegetation cover, urban water supply and sanitation, waste management, air quality monitoring, urban heat islands measurements as well as 3D stereoscopical mapping.

Within the framework of the World Bank's South Asia Megacities Improvement Program, EO data was used to analyze 20 years of urban expansion in the metropolitan areas of Delhi, Mumbai and Dhaka. EO services applied in this project enabled measuring of the qualitative and quantitative aspects of urban transformations such as the changes in urban land use, urban fabric growth rate, distribution and density of urban sprawl, and its effect on urban area classes evolution, the drivers of land consumption as well as the sprawl of informal settlements outside of the cities administrative boundaries (Fig. 2).

From the policy perspective, it is important to have the tools that allow to accurately assess and manage urban development. The growth of built-up areas and infrastructure can be managed more effectively with appropriate information in hand. The advantage of EO in comparison to traditional sources of data collection is that it provides objective observations, which are fast, independent of administrative-level reporting and can be obtained remotely to verify the accuracy of the existing data without conducting costly in-situ surveys. Moreover, digital datasets allow flexible aggregation with other types of socio-economic information to derive relevant analysis of urban realities. For instance, for the three megacities,

"The type of detailed EO data produced for the three cities represents a very useful base for evidence-based dialogue with government agencies regarding long-term as well as short-term urban development policies and initiatives. To guide a city's continued growth, it is important to know where the city is coming from, and how it has evolved to date.
The spatial assessments also help highlight and address challenges with regard to metropolitan governance arrangements. Application of this type of technology should always be considered in preparation of city development strategies and larger urban infrastructure projects supported by the World Bank".

Mats Andersson,

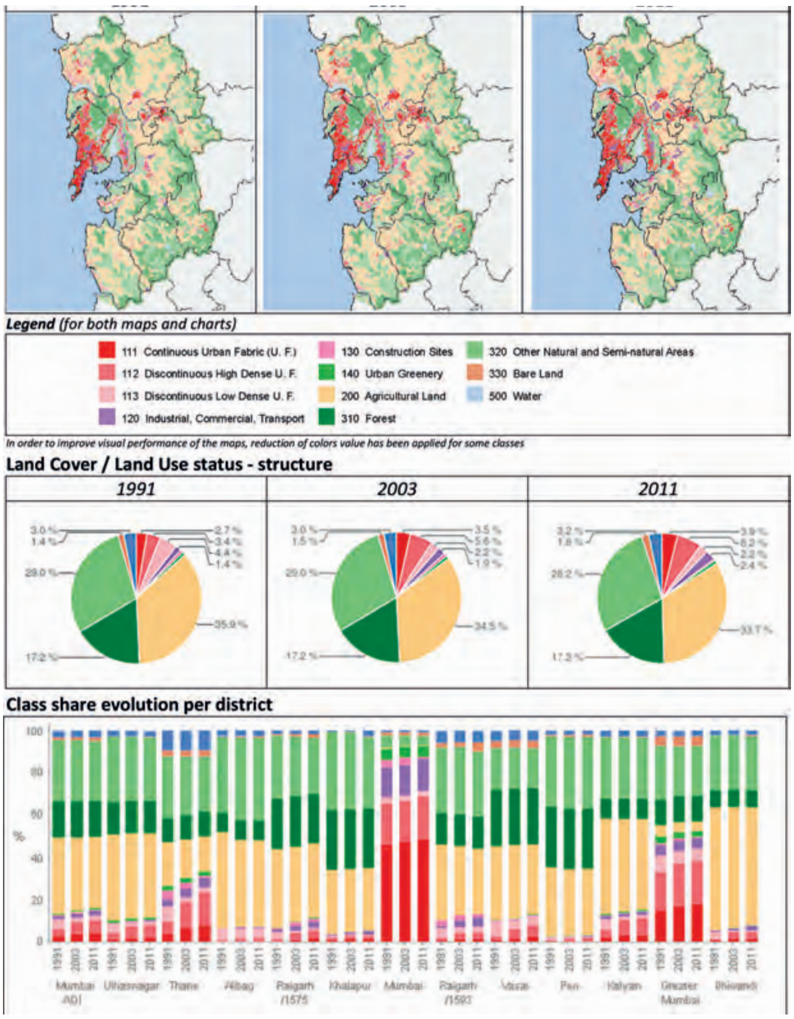
Senior Urban Specialist,
Former World Bank Staff

the combination of EO with population datasets revealed the correlation between the ratio of population growth and urban sprawl at the sub-district level. Other indicators, such as the proximity and accessibility of green urban areas and the ratio of green urban areas per inhabitant can also be obtained with the use of in situ data.

The analysis conducted for the years 2010/11 revealed that the land cover and land use composition in three metropolitan areas of Delhi, Mumbai and Dhaka. In Delhi National Capital Region the land use is dominated by agriculture (73%). Urbanized area represent there only approximately 20% of land cover. In the Metropolitan Region of Mumbai only 15% area is urbanized, the share of non-urbanized area is divided between the agriculture land (34%), (semi-)natural vegetation (28%) and forest (17%). In Dhaka Statistical Metropolitan Area urbanized area stand for 48%, but large part of that is occupied by rural settlements and scattered built-up (18%) surrounded by groves of trees. Non-urbanized area is dominated by agriculture land (43%). The study also found that urban sprawl in Dhaka is clearly dominated by residential built-up, while in Delhi and Mumbai, the urban sprawl is accelerated by industrial development (in 2003-2010 period mainly for Delhi). Large increase of construction sites also indicates that this trend will continue in the future.

The results of the analysis conducted for Delhi, Mumbai and Dhaka inspired further use of EO-derived spatial information as a part of the World Bank's Urbanization Flagship Reports in South Asia and East Asia and of the national urbanization review studies in the countries of the Middle East and North Africa region. The World Bank has also benefited from the spatial data portal for custom-made analysis which was developed as part of this *eoworld* project, and which significantly improved the approach to analysing and reporting collected information.

2a



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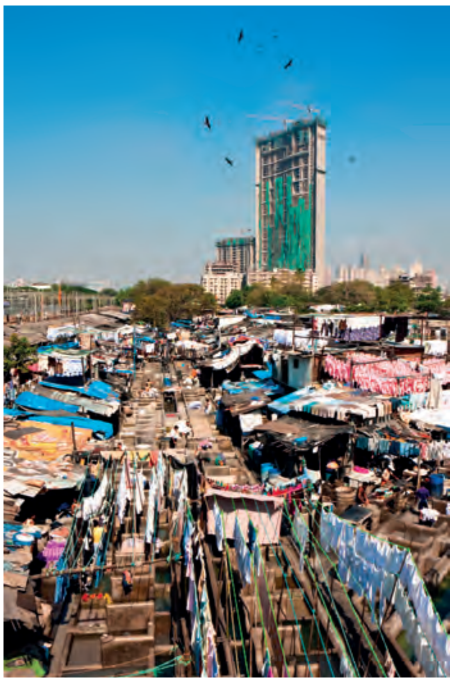


2a. Land cover analysis overview for Mumbai. Credit: GISAT
2b. In Delhi and Mumbai the urban sprawl is accelerated by industrial development. Photo: Mumbai, India by Simone D. McCourtie / World Bank

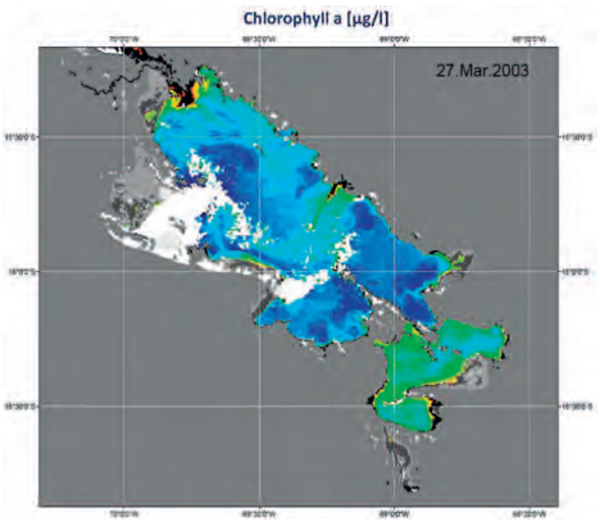
Water Resources

Earth Observation is a very powerful tool to improve the understanding and management of water resources especially in these regions of the world which lack the ground data to systematically evaluate the status of water bodies or which are unable to develop effective measures to counteract the threat of water scarcity caused by population growth, climate variability, economic development, agriculture production or urbanisation. While increased pollution threatens lakes, rivers, estuaries, and groundwater bodies around the world, EO offers independent, area-wide, standardized, and long-term observations to help address all of these challenges.

The use of Earth Observation tools for integrated water resources management (WRM) was demonstrated in World Bank's projects implemented in the Lake Titicaca basin and the Zambezi River basin, where the key environmental challenges are related to unsustainable land use and WRM practices. EO data were used to assess the evolving status of the water bodies, hot-spot areas, land erosion, and causative links between the origins of pollution and changing land use patterns.

Lake Titicaca basin is a UNESCO World Heritage Site on the border of Peru and Bolivia. It suffers from many different pollution sources caused by fertilizers and pesticides runoff, urban waste, as well as heavy-metal contamination related to mining. To help manage these challenges the *eoworld* project provided an independent evaluation of the key water quality indicators such as chlorophyll and total suspended matter concentrations. Innovative use of higher resolution sensors revealed important pollution hot-spots, and optimized planning of future surveys (Fig. 3a). Moreover, a detailed analysis of land use trends provided striking evidence of the status and evolution of the lake extent over time. The results prominently indicated that between 2003 and 2010 the size of Lake Titicaca has decreased by 650 square kilometers (7% of the lake area was lost). It also documented that lands protected under the RAMSAR Convention as important wetlands and breeding grounds for endemic species, are facing unprecedented degradation: the fast emergence of shrubs/grassland, agriculture surface types and bare soil. These findings were a new discovery for the local authorities as well as for the scientific community at large.

3a



"This is the only existing land cover dataset since more than ten years of this specific area in Bolivia/Peru, and definitely the first one with 5m spatial resolution. Because of the unique high-spatial-resolution and quality of the data for this particular region, it is an invaluable resource for detailed research on vegetation dynamics and land cover change within this data-sparse region, which faces many future challenges in climate and resource management".

Marco Otto,

Department of Echology / Chair of Climatology, Technical University of Berlin

What came into focus in the Zambezi River basin was the added value of using satellite EO to upgrade ground-based inventories of small water bodies which are an important part of Zambia's irrigation system. Zambia is a large country with a fairly small population concentrated in the urban areas. The network of ground measurements is, therefore, sparse and difficult to maintain. The use of EO tools allowed mapping of over a thousand small reservoirs, thus optimizing ground measurements/field surveys. It set the basis for a modern water resources information system that is currently being implemented by the World Bank and which will integrate ground-

3b

3c

based hydro meteorological observations with satellite products. ESA has also provided two pilot hands-on training sessions for the Zambian users which resulted in the decision to set up a series of six intensive two week trainings over a period of three years. This professional training program for the Zambian institutions responsible for water resources management was organized at the request of the Zambian government and incorporated in the World Bank Water Resources Development Project. It will cover the assessment of water resources (water storage infrastructure monitoring, reservoir state, water volumes based on optical and radar data, quantification of water usage (evapotranspiration, ET), land cover classification, including crop types of irrigated areas, and flood monitoring and flood vulnerability mapping) as well as the production of integrated information for decision making.

From a broader perspective, the application of EO technology to water management tasks at regional or even global scale is very promising. EO cannot substitute all observations, which still need to be carried out using in-situ sampling, however, it is extremely useful for collecting data over large areas and extended periods of time. In case of trans-boundary basins, it helps to offset some of the difficulties in managing water bodies under the jurisdiction of different national institutions, as well as for comparing information collected by different countries, which often use different methodologies to quantify their facts and figures. The availability of factual, transparent and objective data holds the key to effective ecosystems management and sharing of scarce resources. The demand for training and capacity building is also evident as freely available EO data is under-utilized due to the lack of staff capacity for processing and accessing data in the majority of developing countries.

3d

3a. Chlorophyll concentration in Lake Titicaca. Credit: EOMAP.
3b. Lake Titicaca, the largest lake in South America, appears to be a majestic pristine body of water. But it is quickly becoming contaminated, endangering the lives of indigenous people all along its shores across Bolivia and Peru. Photo: Noah Friedman-Rudovsky / Pulitzer Center for Crisis Reporting.
3c. Puno, on the Peruvian side of Lake Titicaca is the largest city on its shores. Recently the Peruvian government has stepped up efforts to reduce contamination from garbage and sewage after the bay became filled with duckweed. The plant growth which resulted from an overabundance of nutrients caused by household sewage run-off, creates a lack of oxygen in the water and chokes off much life below the surface. Photo: Noah Friedman-Rudovsky / Pulitzer Center for Crisis Reporting
3d. Training in Water Resources Management in Zambia. Photo: NEO/TU Delft.

Coastal Zones Management

Coastal areas are important for a whole range of economic activities such as trade, tourism, fisheries, oil and natural gas fields, harbours and transport links. However, fragile coastal ecosystems become threatened by increased water pollution due to agricultural runoff, urban sewage and industrial discharges. Coastal zones also bear the burden of global warming: worsening weather conditions erodes shorelines, rising sea-levels affect coastal marshes and swamps, turning estuaries and groundwater more saline. Of particular concern is the increased vulnerability of coastal land to disasters, including high valued assets located close to the shores (e.g. coastal cities, embankments, ports). Therefore, access to information that can help manage risks associated with coastal erosion and sea-level rise is critical.

"Generated maps have served as an input to policy discussions on improved spatial planning in the coastal areas of Sao Tome and Principe - and also to serve as a reminder of the irreversible impacts of coastal sand extraction in small island systems".

Sofia Bettencourt,

Lead Operations Officer, Africa Region,
World Bank

The World Bank has a vast portfolio of investments that addresses Integrated Coastal Zones Management (ICZM) and has been actively assisting governments in building their national capacity for implementation of comprehensive coastal management. At the same time the World Bank must expand its capacity to provide cutting edge advice to clients concerning climate change and sea-level rise. A step toward this goal is exploring the use of satellite imagery to generate, in a cost effective manner, consistent and reliable regional-scale maps of sea-level rise, as was documented in the eoworld project on coastal changes in West Africa. Satellite EO offers a unique source of data to foster understanding of oceans and coastal variability to support routine monitoring and global predictions of the state of coastal zones.

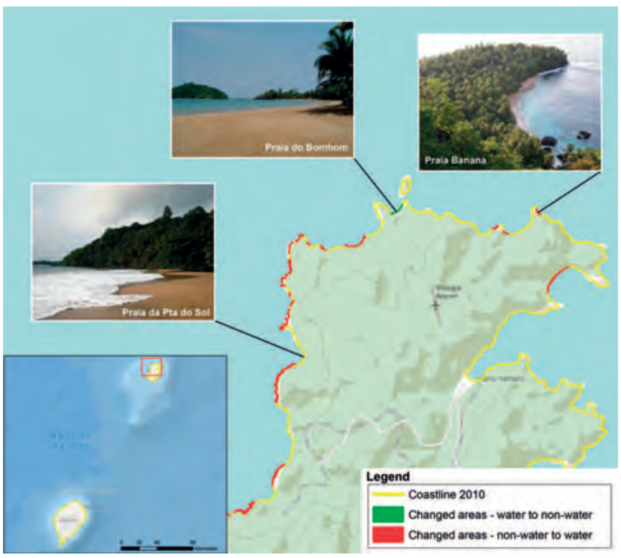
The mapping activities focused on Sao Tome and Principe,

"The geoinformation products have an invaluable importance for our efforts to counter coastalerosion on the beaches of the Sao Tome Island and to mitigate climate change effects. Currently, these products serve as an important baseline and communication tool for the participatory risk planning with local communities. It is now foreseen to receive training on the utilization of such digital information products to the maximum extent possible and to integrate them in our administration procedures".

Arlindo de Ceita Carvalho,

Director General of Environment,
Sao Tome and Principe

the Gambia, Senegal, Benin and Nigeria. The results provided an analysis of two types of factors: recent and historic coastline maps for three reference years (1990, 2000, and 2010) including the loss and gain of coastal areas in decadal sequences, and the satellite altimetry-derived sea-level rise maps, including ocean currents. Collected data revealed critical erosion hot-spots (identified in Gambia and Senegal), accession areas (documented in the Lagos lagoon in Nigeria), as well as sea-level rise of approximately 3mm a year in that region.



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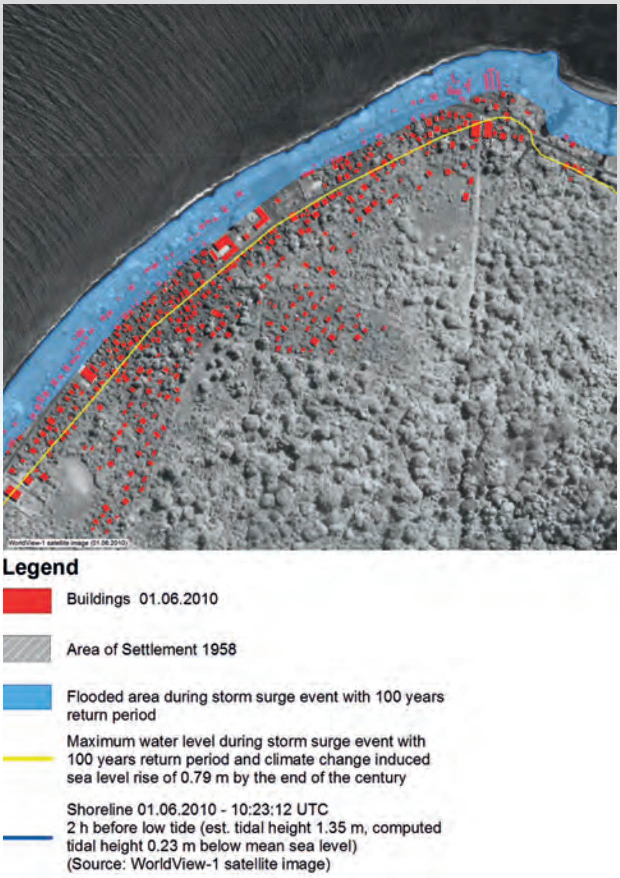


Satellites can track the process of coastal erosion through archived satellite data indicating location of high value ecosystems or settlements under threat. While acquiring in-situ information regarding coastal changes over vast areas can be costly and time consuming, satellite-based maps offset these costs by providing wide scale synoptic observations. A single satellite pass may take a high-definition image of the area equivalent to the entire Mozambique Channel in a matter of seconds. This information allows identification of long term trends and allows for prioritization of interventions to prevent further degradation (i.e. indicate the localization of hot-spot areas). In West Africa, for example, the study confirmed that the entire coastline length is decreasing. The sea-level datasets generated for this project did not allow for a definitive conclusion that the sea-level rise is in fact responsible for coastal change trends (the altimetry-derived sea-level rise maps provide a synoptic view of the area, but not a high enough coastal resolution). Nevertheless, it was evident that in the three out of the four test areas, rising sea-level might be linked to coastal erosion, among other contributing factors (i.e. sand mining). As a result, for the countries considered to be highly vulnerable to the effects of climate change and sea-level rise, such as Sao Tome and Principe, coastline monitoring became an integral part of the Bank-financed project focused on adaptation to climate change. Dedicated technical activities which followed the *eoworld* project were designed to monitor erosion hotspots and to engage target communities and authorities. The activities were focused on adaptation to climate change through better planning of the location of critical infrastructure and managed expansion of settlements towards less vulnerable sites. Highly accurate topographical information generated from satellite imagery with long-term, homogeneous, continuous and validated observations can also be used to model possible outcome of a rising sea-level, and assist with the planning of countermeasures.

4c

4d

4a. Sao Tome costal change maps.
4b. Sao Tome - roofprints of buildings and stormsurge induced sea flood scenario for Santa Catarina. Credit: Geoville for World Bank.
4c. Waters off the coast of Ghana. Ghana. Photo Curt Carnemark World Bank.
4d. Training in Sao Tome. One of the primary recipients of project results were country-level end users. Photo by Geoville

Marine Environment Management

Oil spills are serious threats to marine environment. They can affect marine resources in several ways including surface contamination (coastline contamination, water quality) and disruption of natural marine cycles, including a wide range of subsurface organisms that are linked in a complex food chain that includes human food resources (fisheries, coral reefs ecosystems, etc.).

The main objective of the Western Indian Ocean (WIO) Marine Highway Development Project implemented by the World Bank in the Mozambique Channel was to strengthen the capacity of the countries in the region (South Africa, Seychelles, Comoros, Mauritius, Madagascar, Mozambique, Kenya, Tanzania and La Reunion (France)) to respond to oil spill emergencies. The maritime surveillance system implemented as a part of the eoworld project offered them highly advanced satellite-based monitoring tools to help manage ship-based environmental contamination.

The Western Indian Ocean (WIO) is at high-risk of pollution from ship-borne and off-shore sources. Approximately 30% of world's crude oil is transported through WIO waters by five thousand oil tankers carrying 500 million tons of oil products each year. As the area encompasses thirteen major commercial ports, illegal discharges and spills originating from port operations represent an additional risks of pollution. At the same time, the WIO is home to biologically complex ecosystems including the Aldabra Atoll in the southwest Seychelles (a UNESCO World Heritage Site since 1982 and an official RAMSAR site since 2010), and the small islands of Mayotte (France), Rodrigues (Mauritius), and Tulear (Madagascar).

The use of EO services enhanced the tactical and operational capability of the national authorities to protect these fragile ecosystems and conduct their law enforcement activities to prevent and manage oil spills. The monitoring system covered a total of 17.5 million square kilometers and a combined coastline of 13,300 kilometers. Equipped with this near real time information, national coast guard authorities were able to dispatch interception vessels (boats, airplanes) in order to collect ground evidence faster and more effectively. In the course of 5 months of operations and service delivery, 38 potential slicks were detected and investigated (Fig 5). Moreover, the ability to gather reliable, evidence-based information concerning potential illicit or harmful activities turned out to have an important deterrent value to all shipping companies operating in the region.

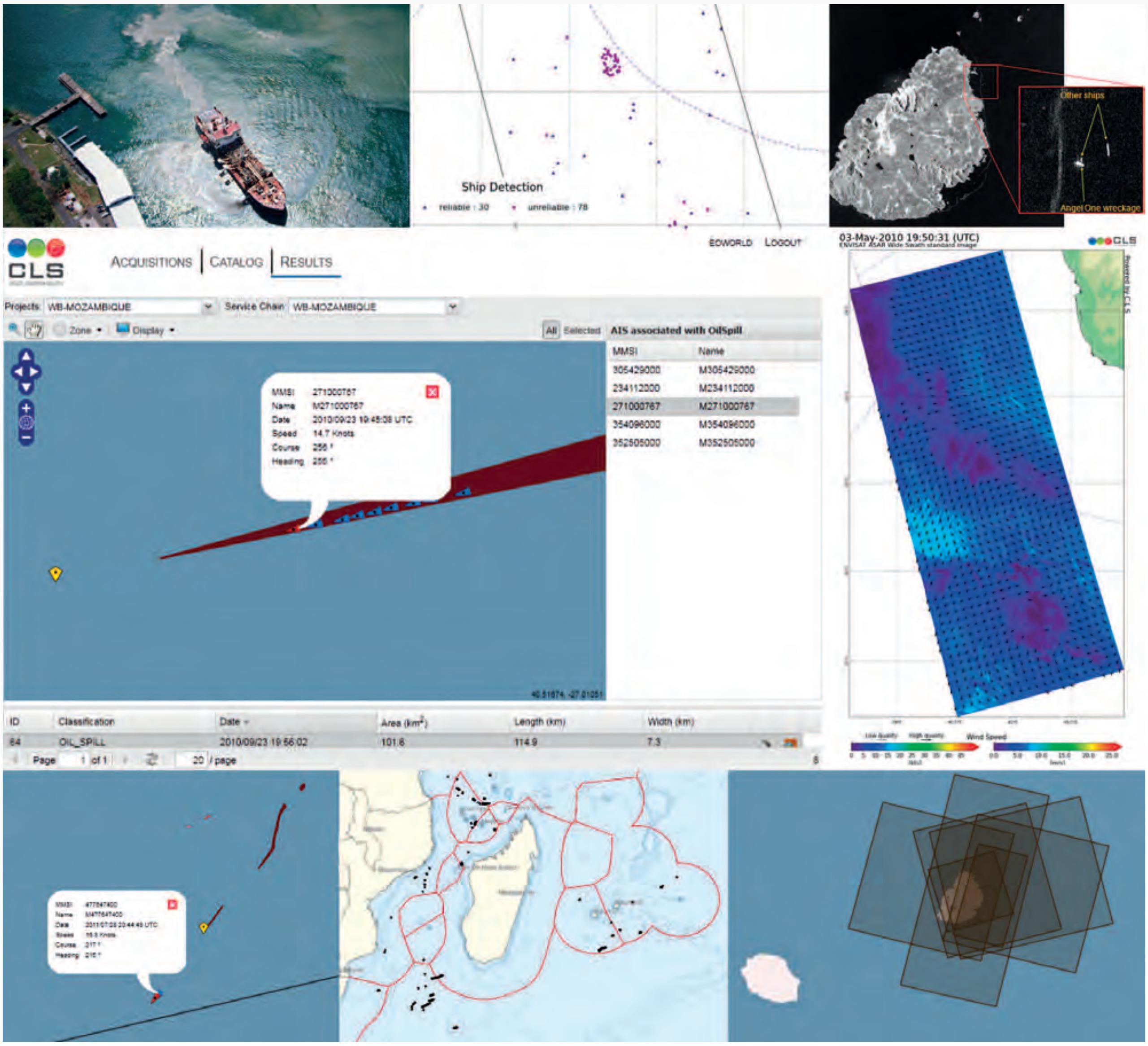
"The feedback from the users is extremely positive. The agencies involves in marine protection, shipping operations and marine and port control really felt that this information was so unique, so available and so accessible that they really changed their perception on how they can manage the oil pollution and the contamination of the oceans. And this is a revolution. For the national users this is the point of flection concerning the possibilities that they have. They can now identify the polluters, take action and conduct inspection of the contamination incidents. There are changes in behavior that are happening with this application".

Juan Gaviria,

Transport Sector Manager,
Europe and Central Asia Region,
World Bank

The EO data have also contributed to managing environmentally sensitive areas in a number of selected sites in the Mozambique Channel. High-resolution optical data was used to map coral reef extent and its evolution over time while sea-surface temperature, suspended sediment concentration, water transparency, chlorophyll concentration, and significant wave height information were used to assess major stress indicators. These observations revealed a massive loss of coral zones over the period of 1962-2012 at the Grand Recife de Toliara (GRT) site, clearly revealing modifications of geomorphological zones and the loss of coral communities. It was assessed that between1962 and 2011, 77% of the initial coral stripes surface was lost. These changes were attributed to various factors, such as sediment dynamics, cyanobacteria development as well as erosion of dead coral framework; however the biggest cause of the changes was correlated with destructive fishing practices. The use of EO in this case enabled optimization of the in-situ inspection regime, and increased focus on the protection of the most valuable areas.

5



5. The image of the catalog of satellite acquisitions and the pattern of detected pollutions. A shipwreck off the coast of Mauritius and deployed oil spill contingency. Credit: CLS

Agriculture and Rural Development

The use of satellite mapping services provides many opportunities for the management and verification of the environmental practices associated with agricultural production. EO data are used for planning and assessing land suitability and productivity, and generating land use scenarios, i.e. to ensure that agricultural practices have no negative effects on the environment. Through unique EO products, it is possible to map vegetation and land use, distinguish between crops, and crop varieties, changing planting dates (identify when crops were planted, how they are developing), decreased productivity due to pests, disease or reduction of water. For these reasons EO is an effective method of collecting information for areas with little ground information. In many countries EO data are routinely used to collect statistics on crop yields and production, and to monitor the implementation of agricultural policies, including subsidies (subsidy allocation and administration, monitoring of farming systems and actual crops planted and harvested), and certification systems, monitoring of concession licenses for energy and cash crops, or to facilitate production shift (licenses for conversion of forest to agricultural land) or monitoring of potential conflict between different land uses.

"From the Bank's perspective the involvement in oil palm sector financing is controversial. For this reason the SADP strives to make a convincing case that sustainable production is possible and enforceable. We are very satisfied with the delivered results. It is clear that EO is a helpful tool. The service will be used as baseline information for the ground activities which have just started".

Mona Sur,

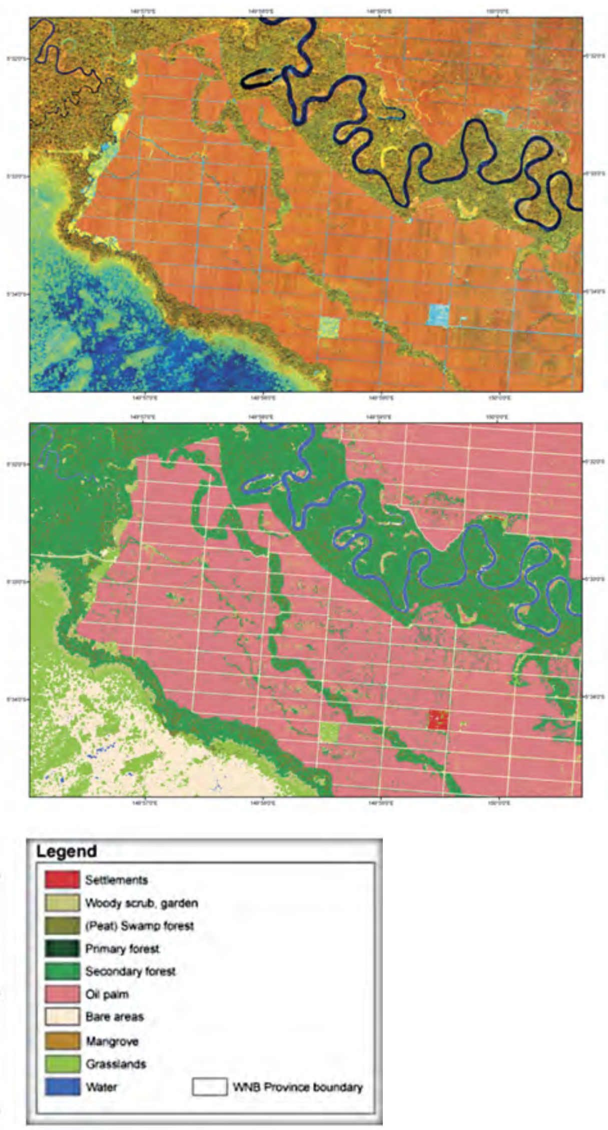
Senior Agriculture Economist,
East Asia and the Pacific Region,
World Bank

The use of EO within the World Bank Smallholder Agriculture Development Project (SADP) in Papua New Guinea demonstrated how satellite based monitoring can help manage risks associated with smallholder oil palm cultivation to ensure that the active infill planting and rehabilitation of existing plantations is taking place only in eligible areas and does not affect primary forest or high conservation value areas. Special attention was placed on monitoring buffer zones along rivers, springs, and streams to ensure they are maintained (Fig. 6). New techniques were tested for the monitoring of mangroves, wetland, and remnant swamp areas.

"The eoworld results struck me. I was impressed that the results are far more useful than expected. The strategic value is far greater than thought at the start of this project. We would like to see continuity!"

Ian Orrell,

PNG Palm Oil Council



6

"Eoworld project provides new information previously unavailable and highlighted some information, for example concerning wetlands that the SADP did not focus on before. We like to see that project developing further and get additional information".

Mike Scott,
Oil Palm Industry Corporation

Introducing these monitoring tools for improved land use practices for palm oil sector was needed and timely. In 2011 the World Bank Group had lifted its 18-months-long moratorium on palm oil investment financing and voiced the need for evidence-based instruments to strengthen policy and regulation for sustainable agricultural production. The SADP project in Papua New Guinea is one of the first projects put in place since the memorandum was lifted. The project is actively promoting the environmental and social sustainability of oil palm production while ensuring that the expansion of plantation areas and the construction of new roads do not distress the primary forest or the protected buffer zones along rivers and conservation areas. To this end, EO-based monitoring documented that the World Bank-financed investments are in compliance with the Roundtable on Sustainable Palm Oil (RSPO) guidelines.

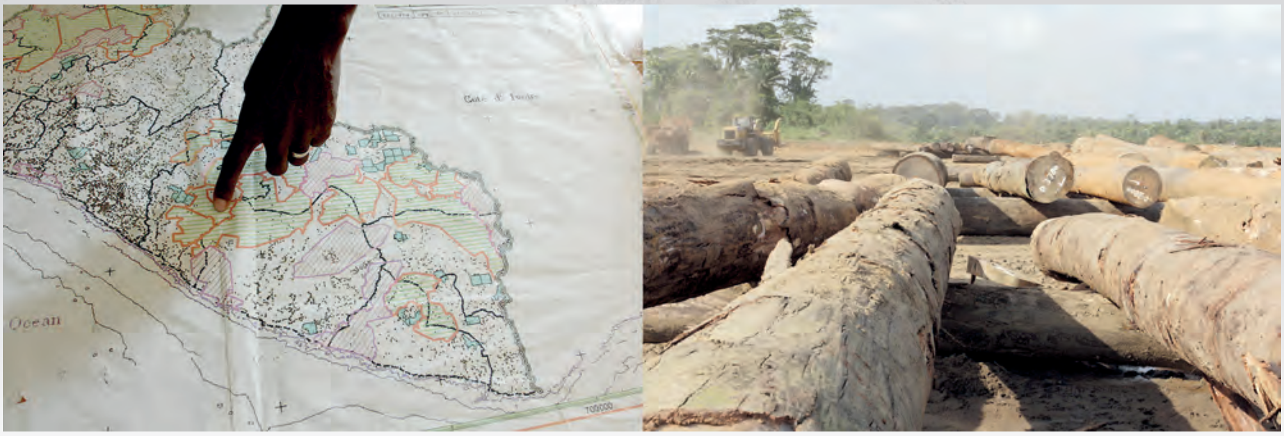
The project also revealed that factual, evidence-based information over thousands of smallholder plantations is a unique instrument not only for practical management of the plantation process but also for transparency, awareness raising, and communication of results to the wide community of stakeholders: local landowners, oil palm industry, and civil society (e.g. local NGO's) concerned with environmental conservation. With such accurate and independent information in hand it is now possible to more effectively engage in the debate concerning the sustainability of bank investments in this form of agricultural production.

EO data allow optimization of ground resources and the overall planting management processes. Previously, there was a need to conduct time-consuming, expensive and frequent field trips to check on the progress of investments. Satellite observations offer a reliable source for initial assessment to prioritize ground-truthing. EO tools are planned to be subsequently implemented periodically for monitoring purposes once an objective and transparent baseline is established. Similar tools can be put in place anywhere where there is controversy surrounding agricultural practices or other activities leading to soil degradation, reduced biodiversity, unsustainable water extraction, groundwater depletion, and agrochemical pollution or causing conflicts with existing natural habitats (i.e. rainforests encroachment or threats to endangered species).

6. Location of buffer zones can be easily measured. Credit: SarVision. Photo by Niels Wielaard.

Forestry

7a



Forest management tools rely heavily on satellite imagery for establishing historical baselines and assessing evolution over time. EO data can be used to identify forest boundaries, distinguish tree species, estimate biomass, and quantify forest health. EO data is also integral to monitoring forest governance through identification of illegal activities, forest harvests, forest fires, the state of secondary growth, and settlements and agriculture. Finally, EO data is integral in supporting operational decisions, such as allocation of forest concessions, and classification of forests parcels.

"The maps show there is no deforestation taking place in the two concessions areas. These findings are very comforting but they caught us by surprise as there was no accurate information available before concerning the richness of Liberian forests. We hope we can move ahead and cover the entire Liberia".

Paola Agostini,

Senior Economist,
Africa Region, World Bank

The World Bank assists many governments in the evaluation and implementation of policies regarding the sustainable management of forests. In doing so the Bank focuses on containing deforestation, promoting conservation, fostering forest carbon sequestration benefits, and encouraging community participation in forest management as some of the key development objectives. In the course of the *eoworld* project it was demonstrated that forest management can be substantially improved by the use of a forest monitoring system based on a combination of EO-based analysis and field data collection.

Satellite mapping focused on two selected locations in North-West Liberia (Gbarpolu & Grand Cape Mount) where the Bank has been engaged since 2004 (Fig. 7). Liberian authorities had long struggled with accurate assessment of the county's forest base, especially since the knowledge of Liberia's forests was drastically reduced as a result of uncontrolled logging activities and during the civil wars. By 2004 most of the existing maps were outdated or fragmented and could not provide a complete picture of the current forest inventory. To assist the government in addressing these information gaps, the *eoworld* project demonstrated the use of the state of art satellite techniques to provide comprehensive land use mapping and forest baselines. As a result, the most accurate assessment of deforestation trends in North-west Liberia was delivered to the government and to

7b

the national forest authority. One of the immediate benefits of the collected datasets was the validation of various contradictory reports, verification of the existing databases, and clarification of forest and land use definitions. The new datasets have also supported an assessment of the forest concessions allocation process (i.e. which areas are best fitted for agricultural concession, commercial forestry or carbon sequestration, and biodiversity conservation).

The project helped to clarify the way forward and identify options for national land use reform. It is now being extended to cover the entire country as a baseline for creating a nation-wide forest and land cover map aimed to steer its national Reducing Emissions from Deforestation and Degradation (REDD) activities. This national baseline will improve the efficiency of field surveys and monitoring of illegal logging, as well as the timely assessment of forest and land cover with the objective to contribute to the future national forest inventory.

The results were shared with and utilized by the national Liberian Forestry Development Agency (FDA) which is now working toward improving its own national forest information system based on the systematic use of EO. A suite of activities envisaged within the Liberia Forest Carbon Partnership Facility (FCPF) grant will help build internal technical capacity for accessing and analyzing data and mapping products. In parallel the World Bank has supported FDA in implementing "the chain of custody system" which allows for precise tracking of logs intended for export from Liberia. This includes geolocation technologies to tag and track timber products.

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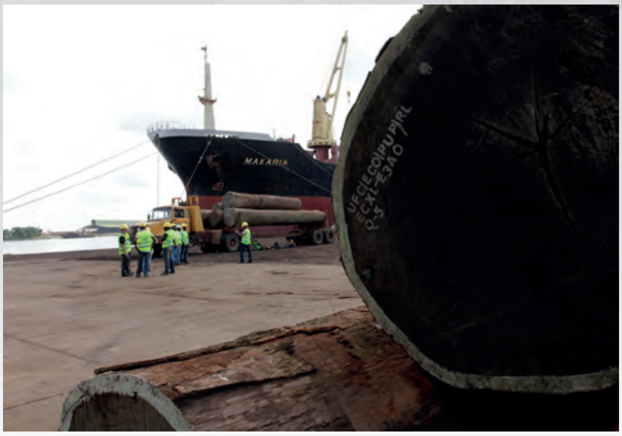

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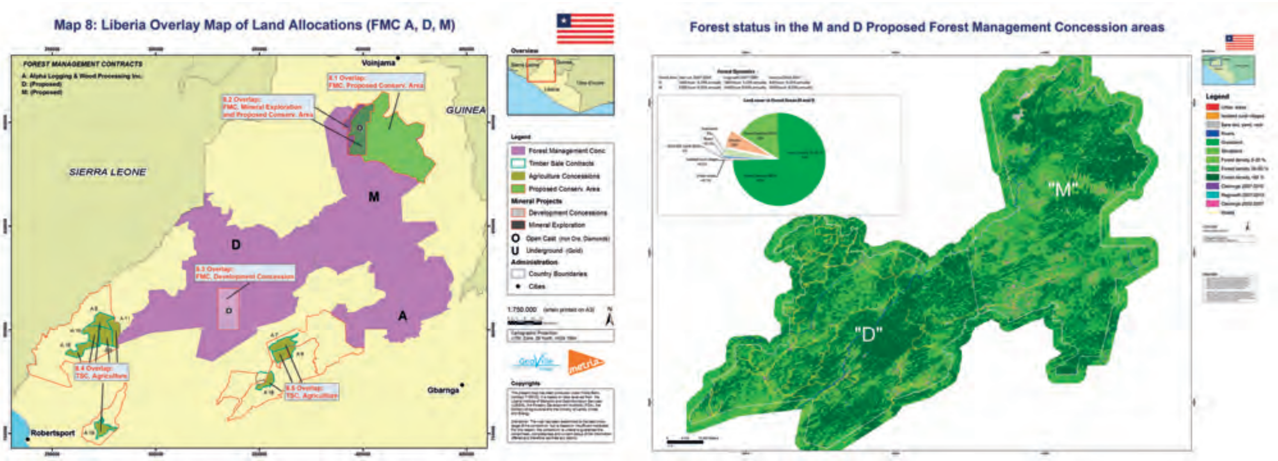

7a. Forest Concessions on a map of Liberia. Logs at the Buchanan logyard in Liberia. Photos by Flore de Preneuf/PROFOR.
7b. Liberia is currently implementing a modern chain of custody system which uses tracking and mapping applications. That tracking system, known as the LiberFor, is seen by experts as one of the few bright spots in a Liberian forest sector that has struggled to repair the damage done by years of mismanagement, corruption and over-exploitation under President and warlord Charles Taylor. Photo: Flore de Preneuf/PROFOR.
7c. Caption: Liberia's efforts to re-start logging operations for export were challenged by the dilapidated state of road and port infrastructure in the aftermath of the war. The port of Buchanan returned to operations in 2009. Photo: Flore de Preneuf / PROFOR.
8. Forest Concessions allocation assessment and satellite forest cover map for Gbarpolu & Grand Cape Mount areas (concession areas D and M). Credit: Metria/Geoville.

Climate Change Adaptation

Counteracting climate change poses a challenge for the design and appraisal of World Bank projects. Design of dams and seawalls, disaster risk management systems, flood control infrastructure, sustainable river, land and coastal management practices have to take into account the changing and future climate conditions. In ESA - World Bank partnership, particular emphasis has been placed on demonstrating the added value of using EO data to support climate change adaptation in coastal areas: coastal cities in North Africa, coastal lowlands in South Asia, and coral reefs in the Caribbean.

"There was very little scientific evidence of the subsidence that has been taking place along the Nile Delta coastline, and whether the city of Alexandria had been affected as well. We therefore very much appreciated EO filling this gap as an important input to the study we carried out on climate change adaptation and natural disaster preparedness in the coastal cities of North Africa".

Anthony Bigio,

Senior Urban Specialist, Urban and Disaster Risk Management Department, World Bank

Cities and Climate Change

Adaptation of cities to climate change is essential in preparing for natural disasters such as floods, heat waves, or water scarcity - all of which can be measured with the use of Earth Observation tools (i.e tools to assess precipitation and temperature anomalies, heat waves, urban heat islands effects, flood risk, urban green cover, etc). The contribution of EO data to support the World Bank study "Adaptation to Climate Change and Natural Disaster Preparedness in the Coastal Cities of North Africa" was primarily focused on geological risks and the location of subsidence and uplift zones in Alexandria and Tunis. While traditionally such measurements relied solely on geodetic in-situ surveying techniques, new EO techniques allow for measurement of deformation with much higher precision, and provide the basis for the design of adaptation measures which in these two locations were mostly related to flood vulnerability and relative sea-level rise.

Coastal lowlands and Climate Change

In Bangladesh, EO data helped resolve issues related to the scientific debate around the status and coastal dynamics in the coastal region. More specifically, EO data measured the changing nature of the Ganges river delta and associated sediment aggregation rates. The Ganges' morphology is constantly changing, with sediment deposits of over a billion tons per year. Understanding the processes that guide this sediment deposit is critical to

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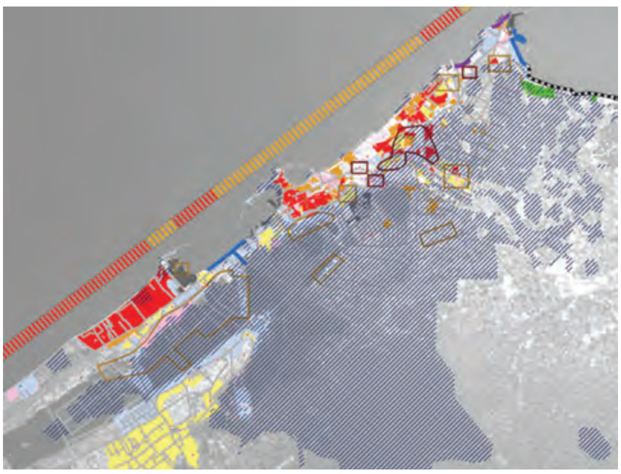

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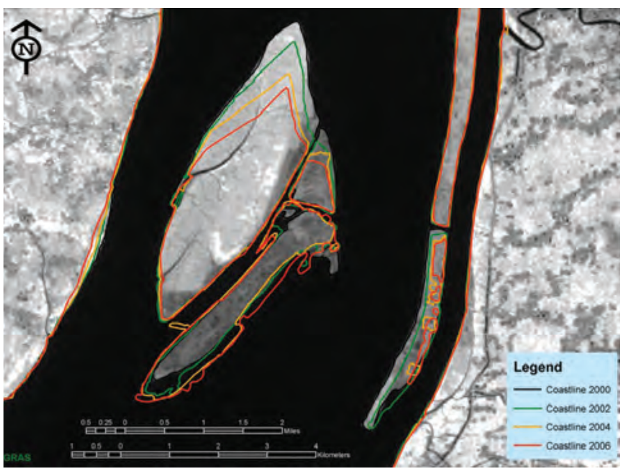

9a. The map highlights Alexandria's critical vulnerabilities identified by the Word Bank "Coastal Cities" project. Credit: World Bank.
9b. Coastline migration in Bangladesh from 2000 to 2006 identified by manual interpretation. Credit: GRAS.

assessing the real impacts of sea-level rise on the flood plains. In combination with other data (such as sea-level rise, storm surge, wave statistics, and subsidence evolution over the last 20 years) EO evidence of coastal sediment transport was considered an important step toward developing a more comprehensive understanding of the geomorphology of Bangladesh's coastal areas to better plan for adaptation measures.

"The coastline of Bangladesh is extremely dynamic, making it difficult to predict how sea-level rise may impact the southern part of the country. These preliminary results from EO are interesting and merit further investigation into the accretion and erosion processes occurring".

Winston Yu,

Senior Water Resources Specialist,
South Asia Region,
World Bank

Coral reefs and Climate Change

In recent decades scientists have become increasingly aware of the fact that climate change will have profound impact on the health and biodiversity of coral reefs. Coral bleaching - the whitening of corals during periods of exceptionally warm sea temperature – is causing rapid deterioration in many fragile marine ecosystems. As much as 30% of coral reefs are already permanently lost and if current trends continue, particularly in combination with overfishing and pollution, a further 30% are at risk of being lost by 2050.

The pilot eoworld project conducted off the coast of Belize incorporated the use of various satellite products to measure the biological stresses related to climate change. Earth Observation techniques offered a solid scientific base to support traditional environmental monitoring and management of coral reefs. EO's main strengths are cost, synoptic view, and simultaneous evaluation of several recognized stressors for the establishment of relevant links. Satellite monitoring of sea surface temperature is remarkably effective at predicting where and when bleaching, one of the main sources of coral stress, will take place. Understanding the patterns of the thermal regime may further assist in locating hot-spots to maximize the reef's resilience and recovery. Moreover, information concerning chronic and acute thermal regimes can be used by the local marine reserves management authorities to reduce some causes of biological stress, such as overfishing.

"Space-based observations are an essential element of climate monitoring in Latin America and a complement to ground-based stations. ESA instruments and observation protocols are particularly applicable to the type of information that needs to be collected over time in the Americas".

Walter Vergara,

Former Lead Engineer, Latin America and Carribean Region, World Bank

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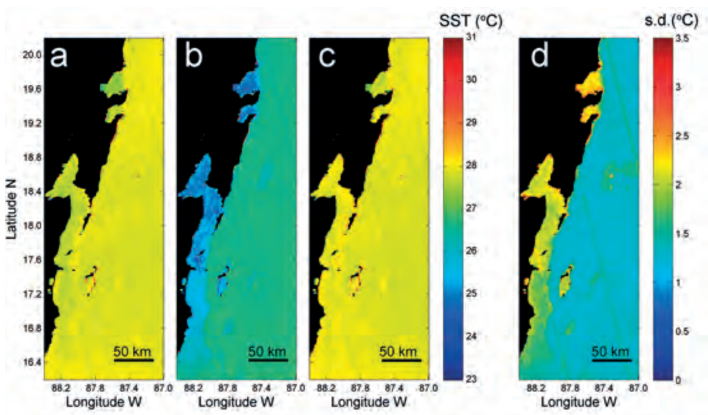


9. Sea surface temperature patterns for the Belize area (a) average (b) minimum monthly mean (c) maximum monthly mean (d) standard deviation. Credit: MSEL, ENVISAT data (c) ESA.

3. EVALUATION OF IMPACTS

Following the implementation of the *eoworld* projects, the objective was to evaluate their impacts based on four factors: availability, usefulness, reliability, and affordability of the EO services as delivered. This process was mainly based on the feedback from the World Bank teams and their country-level clients, and three other sources of information: final reports and operational documentation delivered by each of the project teams; World Bank project information documents (PIDs), and field-based case studies associated with the individual projects; as well as interviews with the World Bank managers and staff involved in the collaboration. This evaluation aimed to assess the prospects for wider use of EO information services across a greater number of Bank operations and across different sectors. It was made by comparing the performance of EO-based services in comparison to alternative sources of information. Moreover, recommendations for improvements of EO services and additional information requirements were captured.

The outcome of this process revealed a significant demand for EO-based services both at the World Bank and in its client countries reflecting their relevance to the World Bank operational needs, data collection, knowledge generation, and institutional strategy. The implementation of the *eoworld* portfolio has brought to the forefront the value of training and capacity building to achieve the desired development objectives at the local level.

Operational needs

Many Bank managers highlighted their fundamental need for quality data and information, especially in view of multimillion dollar investments in new infrastructure, forest stocks, environmental conservation, and water resources. Therefore, from the operations perspective, the use of EO-based information for projects' design and implementation was regarded as essential to strengthening the strategic relevance and technical quality of the proposed and on-going World Bank projects. EO-based information is particularly important in view of implementing, coordinating, and monitoring large-scale infrastructure investments, and long term strategic planning (i.e. definition of priority interventions or understanding risks and vulnerabilities, especially in view of climate change). Moreover, the access to tested and validated geo-information services with known accuracies and limitations was particularly useful in cases where there was a need to upgrade the reliability of available datasets to create a more favourable decision-making environment. The ability to manage operational risks and mitigate the possibility of making poor decisions based on inaccurate or outdated data makes EO an important tool in operational processes (i.e. decisions related to location of settlements in risk-prone areas, designs of irrigation systems, concessions allocations) was considered essential.

The *eoworld* projects confirmed that the availability of factual, evidence-based information is a unique instrument for transparency and awareness-raising in order to develop an informed community of stakeholders and to effectively engage them in a dialogue on the issues of common interest. In Indonesia, for example, the precise assessment of subsidence trends enhanced an on-going World Bank dialogue with DKI (Daerah Khusus Ibukota Jakarta or Special Capital City District of Jakarta) and the National Agency for Disaster Management (BNPB) and prompted the creation of a national-level community of practice with local authorities and agencies responsible for the management of the urban areas affected by subsidence. In Papua New Guinea, satellite based monitoring helped bring together local government, industry, and civil society in setting transparent baselines for future bi-annual environmental audits. Generated information has also greatly improved the dialogue with all of the stakeholders involved in forest management in Liberia. The results of the EO project were also presented at a high-level meeting with the Government, and informed discussions concerning options for the national land use reform.

Overall, in the course of implementing the *eoworld* portfolio some bigger sectoral information needs have been identified by different World Bank units. For example, collaboration with ESA highlighted the need for greater utilization of EO data for independent forest assessments to ensure that Bank-led investments in the forestry sector are effectively contributing to overall improved forest management This is particularly important given that the World Bank is the largest source of multilateral financing for forests, and a hub for a number of key global forestry efforts, such as the Forest Carbon Partnership Facility (FCPF), and the Forest

Investment Program (FIP) of the Strategic Climate Fund (SCF) within the Climate Investment Funds (CIF).

Similarly, EO was considered as critical source of information to aid the World Bank agenda for healthy and productive oceans which involves doubling the coverage of marine protected areas and setting tangible targets for improvement of the management of marine and coastal environments, while mitigating the negative effects of pollution and climate change on ocean ecosystems.

Concerning urban development, historical analysis of urban growth was identified as critical input to better manage the World Bank infrastructure investment activities but was also acknowledged as an essential element for producing and delivering global knowledge products on urbanization processes worldwide. The World Bank's Water Partnership Program (WPP) has highlighted the need to create a new task on remote sensing and water to provide technical assistance to project managers on how to incorporate EO-based information into World Bank's project design and implementation.

Data and information supply

EO techniques proved to be applicable to critical Bank research and generation of data that is later integrated into operational work. Satellite EO technology offers a unique capability to collect and analyse information, and improve the effectiveness of existing methods of collecting information especially in cases where traditional in-situ surveys are restricted for logistical reasons, or are too expensive to be conducted over large areas. The use of EO was deemed particularly useful in those areas of the world where databases are poorly maintained, or where the existing data collection methods do not exist or are insufficient.

For example, in the Lake Titicaca basin where in-situ water quality stations are often out of order, EO filled in data gaps and provided reliable and affordable options for long term basin-wide environmental observations. In Jakarta, where the problem of urban subsidence was well known to the public but have not been fully measured, EO-based interferometry provided a complete analysis of subsidence trends on the level of single infrastructure elements, dramatically increasing the number of measurement points (from approximately 80 GPS/extensometers ground-based stations to over 5 million points using very high resolutions (VHR) satellite sensors) in order to more effectively assess the problem of collapsing terrain. In the overwhelming majority of test cases the application of satellite observation helped to optimize the use of limited in-situ or ground assets. In Zambia and Malawi EO tools enabled verification and consolidation of available official regional databases and will be further used to optimise in situ surveys.

One of the most difficult tasks facing developing countries is to create sustainable options for collecting information and monitoring of large areas with limited resources. While ground-based, air-based, and ocean-based monitoring devices usually serve as a primary source of information, in many places of the world these tools are not always readily available. This was highlighted by the *eoworld* project implemented in the Mozambique Channel where counties have long struggled to overcome limitations associated with insufficient number of vessels (air and seaborne) for the detection, tracking and monitoring of oil spill pollution. The use of remote sensing technologies was ground-breaking for their ability to adequately track contamination accidents in the entire region, and effectively monitor hundreds of thousands of square kilometres, in a non-intrusive and reliable manner.

In the Mekong River basin EO has also provided wide-area synoptic datasets which have taken into account the trans-boundary character and hydrological connectivity of river basins to map thousands of buildings and infrastructure features as well as thousands of square kilometers of fields and crop yields. This data collection method helps to offset the time-consuming, expensive and frequent field trips and airborne surveys which otherwise would have had to be conducted. EO measurement also allows for periodic updates of geospatial inventories of assets as they develop over time. In the case of rice crop monitoring, satellite radar data offered a unique capability to assess rice growth patterns which would not be available from other sources.

Knowledge Management

Some of the World Bank sectors (i.e. water, disaster risk management, forestry) have more experience in working with Earth Observation technology, while others still need to develop such capacity. The application of EO technology to water management tasks as well as to forestry and ecosystem assessment is particularly promising. Moreover, the World Bank's Global Facility for Disaster Risk Reduction and Recovery (GFDRR) has leveraged remote sensing for one of its core activities – Post Disaster Needs Assessment (or PDNA). The World Bank East Asia and Pacific Region (EAP) has championed the use of EO data for urban risk assessment. A number of strategic publications and regional guidebooks were issued in 2012 and reported on the use of *eoworld* services for disaster risk management (See Box 1). The EAP Urban team has also led the way in the development of dedicated tools for urban analysis via the upcoming Platform for Urban Monitoring and Analysis (PUMA).

One of the key institutional challenges of the ESA-World Bank partnership has been the capturing and systematically organizing available spatial data and information generated within *eoworld* projects, but also more broadly the management of geospatial datasets developed in the framework of Bank activities. Many Bank investment operations have generated a significant wealth of comprehensive spatial information datasets. However, this information is often generated in a fragmented way without clear guidance concerning standards and technical specifications (metadata, data formats and structures in which spatial data are organized and accessed). Many activities occur in relative isolation from one another, risking duplication of efforts.

To help overcome these limitations a spatial data portal called GeoWB has been built and launched by the Sustainable Development Network Information Services (SDNIS) as a mean of organizing and sharing spatial information across the institution. This is a major step toward providing greater access to information in line with the Bank's "Open Data, Open Knowledge, Open Solutions" reforms. In this context, the "Earth Observation for Development" initiative encouraged a downstream use of generated information products by the end users.

One of the key objectives of the ESA-World Bank partnership has been to encourage the use of EO across the World Bank Group as a standard reference technology

BOX 1

Tools for Building Urban Resilience: Integrating Risk Information into Investment Decisions. Pilot Cities Report – Jakarta and Can Tho, World Bank Publication

...With the advanced satellite-based monitoring techniques it is possible to monitor displacement trends and follow them building-by-building and other single infrastructure points especially. This high precision monitoring can then provide unique inputs to rehabilitation and maintenance of flood control infrastructure...

Strong, Safe, and Resilient: A Strategic Policy Guide for Disaster Risk Management in East Asia and the Pacific, World Bank Publication

...Integrating satellite earth observation for high-resolution risk identification: [...] EO imagery allows the extraction of hazard information (flood risk area, subsidence, and landslide) and exposure (buildings, roads, dams) at very high resolution for a detailed local-level analysis. Regional projects in Ho Chi Minh City, Jakarta, and Yogyakarta have already benefited from cutting-edge EO. One of the most promising applications is interferometric synthetic aperture radar–based persistent scatterer interferometry (InSAR-based PSI), known for providing detailed measurements of surface displacements for measuring hazards associated with earthquakes, volcanoes, and landslides, as well as subsidence and deformations of flood defense structures in coastal lowlands...

10

in monitoring, assessment and implementation of projects. Significant progress has been made to date to bring this vision closer to reality. The World Bank has embarked on an effort to scope its information needs to be addressed by systematic use of Earth Observation tools. However, there is still a need for targeted technical assistance, awareness-raising, capacity building and knowledge exchange activities. The Second Phase of ESA-World Bank partnership is intended to contribute further in this area.

The role of capacity building in Earth Observation

The quality of the engagement with the local stakeholders made a real difference when it came to the operational use of EO services, and their impacts on the ground. The projects that actively involved user communities in the production, dissemination, and assessments of the services have better prospects for sustainable use of the generated information, and they also resulted in a greater developmental outcome. Moreover, in those cases where operational user communities were involved in training and capacity building, the respective national agencies were keen on applying EO methodologies in their day-today operations, and developing further expertise.

The Coast Guard agencies of the countries in the Western Indian Ocean trained in the use of the early warning have noticeably improved methods for managing marine contamination. This experience led them to improved regional collaboration, the refinement of delivered tools to better meet their specific operational requirements, and the upcoming incorporation of this state-of-the-art EO-based maritime surveillance system into a Regional Coordination Center for Oil Spill and Chemical Spill prevention to be hosted by the South African Maritime Safety Agency. Currently, the Western Indian Ocean is the only area outside of Europe and North America where such advanced oil spill management tools are being put into practice. This project is also an example of EO opening new areas of engagement with the World Bank country-level clients. It significantly expanded the objectives of

10. Snapshot of GeoWB portal.

the World Bank activities in the region, enhancing the Bank's competitive advantage as an institution focused on delivering cutting edge solutions and brokering knowledge exchange across countries.

The series of technical exchanges, training courses, seminars, workshops, and "on-line" advice underscored the fact that the Bank has an important role to play in global capacity building in Earth Observation. In Rio de Janeiro, the results of the vulnerability study were reviewed by Rio Prefeitura's Publics Works department (SEOBRAS), the State Geological Survey (DR/RJ), Rio State Institute of Environment (INEA), GeoRIO, RioÁguas, and the Federal University of Rio de Janeiro as well as by the Operational Centre of Rio de Janeiro, which received a working-level hands-on training concerning the use of the EO information in their urban planning and disaster risk management operations. The training was also provided to national level agencies and organizations responsible for water resources management in Zambia. It led them to incorporating Earth Observation tools in the country strategy for water sector assistance. Subsequently, the World Bank and the Zambian Government agreed to integrate and fund a national level EO training program of six training courses over the next three years to enhance the capacity at the national and regional level to better address the challenges related to water resources management.

Satellites provide an enormous amount of quality data and the access to openly available imagery is only going to expand in the future. However the value of this wealth of information can only be realised through the ability of users to access, analyse and use the information on an operational basis. This is why expanding and improving the knowledge and skills in remote sensing applications is critical to making the most of these opportunities. This transfer of knowledge and skills to users in developing countries (i.e. national-level and regional authorities, implementing agencies as well as universities) through specialized training has been identified as a key element of the ESA-World Bank collaboration to ensure long-term and sustainable flow of quality data and innovations to developing countries.

As capacity building is a long term process that requires targeted efforts, there is an opportunity for the World Bank to take advantage of the partnership with ESA to become a global connector of knowledge and innovation by providing these opportunities to its clients. Education and training in Earth Observation is at the heart of ESA activities which has developed a vast experience in EO capacity building as well as a variety of training materials to support it. For example, through the Tiger Initiative ESA has trained over 200 African scientists in advanced EO tools for water resources management. Under the DRAGON program ESA is supporting a large Chinese scientific community in developing a dvanced EO applications in land, oceans, and atmosphere.

Eoworld projects have also highlighted the crucial role of capacity building in transferring high-impact knowledge products to the users in developing countries. The World Bank clients usually needed practical instructions on interpretation of satellite imagery in order to know how EO can be of use. Therefore the most positive feedback from the local institutions involved in this collaboration was provided to those *eoworld* projects which delivered training and capacity building. Such hands-on training activities not only enhanced the uptake of EO products at the local level, but have also

11a

11a. Training in Sao Tome. Photo by Geoville.

11b

increased the users' ownership of these knowledge products and their operational use. Moreover, these capacity building activities has resulted in new requirements and requests by the client governments for the continuation of technical assistance. Some of these requests were incorporated in World Bank regional operations, such as the monitoring of seven hot-spot locations in Sao Tome and Principe with the use of very high resolution data to establish local expertise to manage and update a comprehensive digital geo-database for the islands. Similar capacity-building was also implemented in Zambia and it will continue over the course of the next three years during which ESA and the World Bank provide a specialized series of workshops to enhance the capacity of the local institutions to use EO for the management of the country's water resources.

These examples have highlighted individual strengths of both institutions in addressing key development objectives while leveraging each other's core competencies: the ESA's technology transfer to developing countries, and the Bank's role focusing on the long-term sustainable capacity building of government users. Overall, the *eoworld* capacity building component was an important element of expanding access to EO data and information to a broader community of users especially in view of the growing potential of Earth Observation to support decision making.

11b. Training at Indian Ocean Commission concerning marine surveillance system. The local users received on-site training on the principles of radar remote sensing and the use of on-line system and interpretation of the pollution reports. Photo by CLS.

4. MILESTONES AND NEXT STEPS

Institutional agreements

The pilot phase of collaboration between ESA and the World Bank (2008 – 2010) was the result of projects-based agreements whereby ESA agreed to providing pro-bono EO services to specific Bank teams which were seeking technical support for on-going or new engagements. The key milestone for the launch of the fully-fledged first phase of formal collaboration (2010-2012) was an exchange of letters between the ESA's Head of Science, Exploitation and Future Technologies Department in the Earth Observation Programmes Directorate and the World Bank Director of the Urban and Disaster Risk Management Department of the Sustainable Development Network issued respectively on July 26, 2010 and on August 5, 2010. The letter exchange was followed by the establishment of an Earth Observation Coordination team at the World Bank's Urbanization and Disaster Resilience Department to coordinate and connect with ESA and World Bank project teams, and to promote a dialogue on issues of common interest. The Earth Observation team promotes the Bank-wide use of EO, consistent with World Bank international strategic framework as well as strategic partnerships.

In October 2011 ESA has formally established an on-site presence at the World Bank Headquarters via the secondment of a staff member who integrated the Earth Observation Coordination team. In November 2011, a Progress Report was released to highlight the on-going achievements of the first phase of collaboration, and to further stimulate EO awareness and knowledge sharing. In February 2012, a high level delegation chaired by the ESA's Director for Earth Observation Programmes participated in the World Bank Sustainable Development Network Forum – the prime learning and knowledge sharing event across the institution. The joint session highlighted the strategic directions for current and future use of EO information technology and applications at the World Bank in an effort to establish a longer-term adoption of such services in its operations. In June 2012 a dedicated website: *www.worldbank.org/earthobservation* was launched.

Mainstreaming the use of EO at the World Bank

In March 2012, the World Bank's Sustainable Development Network Information Services department (SDNIS) with the support and involvement of Earth Observation Coordination team launched a spatial data portal – GeoWB – which facilitates exchange, sharing, access, and use of spatial data across the institution. Currently, GeoWB serves as a framework for developing advanced geospatial applications and creating unique opportunities to communicate development results. Data products from the *eoworld* initiative have been integrated and actively explored using the GeoWB.

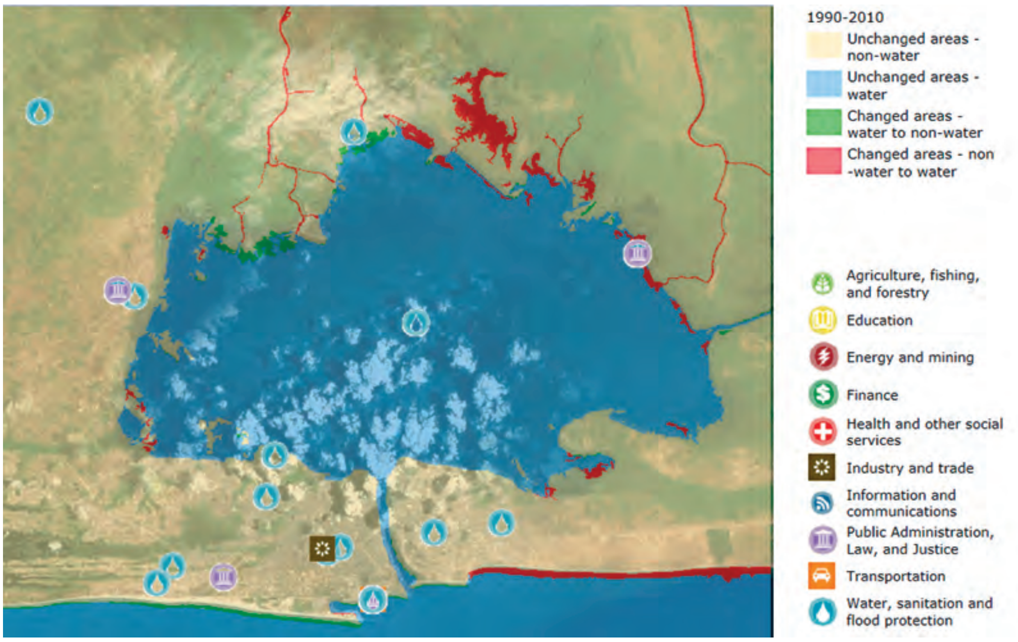
By logging the geospatial information from the *eoworld* projects in the GeoWB, the projects can be combined with other data to create unique online maps and applications. For example, the Mapping for Results (M4R) initiative maps the locations of all the World Bank projects to improve the transparency of aid flow and monitoring of results. Some of the *eoworld* products (i.e. the assessment of the long term coastal erosion trends in West Africa) have been overlaid with Mapping for Results data to visualize the locations of Bank-financed projects to get a better understanding of the types of World Bank (and other development) interventions in this area and if they correspond to the environmental issues affecting this region. The image in Figure 12 showcases the *eoworld* project results in Benin where long term erosion hot-spots were detected and overlaid with Mapping for Results data. This analysis revealed that the majority of the World Bank projects in this area are related to water, sanitation and flood protection which is a positive correlation with *eoworld* findings. This sort of analysis can provide added value to the World Bank business development strategy. For example this area in Benin could potentially also attract more investments in integrated coastal zones management.

Mainstreaming geospatial knowledge involves not only sharing data, information, and analytic tools but also best practices, experiences, and lessons learned. Satellite applications offer numerous benefits to World Bank teams: improved decision-making processes, access to more detailed information, faster information retrieval time, and increased quality and quantity of development data. As a result, certain missions operate more effectively and are more optimized for their tasks. The level of openness and transparency introduced by satellite platforms has the potential to deliver evidence-based and data driven solutions to many development challenges. Furthermore, as EO applications are relevant to operational effectiveness, they can be translated into policy recommendations, can be used as a data collection method in locations where projects are difficult to monitor and evaluate (remote areas, fragile, conflict- or disaster- affected states), introduced as "best practice" assessment tools in selected sectors (i.e. in forestry, water, urban development, coastal zones management), and can act as standard reference technology in cases where data gathering is only available through space-based observations (i.e. maritime surveillance, fisheries monitoring, terrain motion, land subsidence, flood hazard assessment based on historical observations or case-specific methodologies for water resources management).

The ESA-World Bank collaboration has inspired a review of current practices concerning the use of EO within the Bank and in its client countries. This review revealed that in some areas the World Bank has been a leader in EO implementation. For example, in 2003 the Bank commissioned a study on the Dynamics of Global Urban Expansion, based on the use of MODIS500 and Landsat data, which provided one of the most important global assessments of urbanization and urban growth models. While the Bank has lead the way in certain projects, overall, only a limited amount of Earth Observation information is used in the preparation and implementation phase of investment projects. At the same time, various operational units in the World Bank have voiced a need for accurate and reliable spatial information. It may indicate a growing demand to inform project design and monitoring of outcomes using EO data and tools.

Moreover, methodologies often vary from project to project preventing comparative analysis. Sectoral standardized approach to spatial information and methodologies would enhance Bank's overall operational effectiveness. For example, the World Bank Water Partnership Program (WPP) has already recognized the importance of providing technical assistance to project managers on how to incorporate EO-based information to project design and implementation. The WPP is currently embarking on a new global initiative that promotes the mainstreaming of remote sensing technologies in water resources management. The objective is to improve the quality of water resources management planning and project design by promoting a menu of remote sensing products. The foundation of the new initiative lays in evaluating of the demand and operational use of remote sensing products across World Bank regional teams, followed by provision of expert support to country teams on application of specific tools, analytical work concerning development of new tools, as well as regional capacity building.

12



12. Coastal erosion trends in Benin (Credit: Geoville). The results are overlaid by Mapping for Results layer. Courtesy of GeoWB team.

The portfolio of *eoworld* projects has thoroughly documented technical specifications of EO services: procurement of data, delivery formats and systems, as well as metadata standards, desired accuracies, etc. This portfolio can be considered a best practice in this field and consequently could be used by the World Bank as a reference when developing its own technical guidance notes.

Finally, to contribute to the expanding knowledge base about Earth Observation techniques, all tools developed as a part of the ESA-World Bank collaboration have been presented to the wider World Bank audience via a series of dedicated Training and Learning Events which took place between November 2011 and December 2012. One of the key objectives of these results-focused presentations was to demonstrate the usefulness and applicability of the mapping products as well as to show that even complex and highly specialized EO applications are in fact affordable and easy to use, dwarfing the costs of in-situ data collection. These events offered an opportunity to further develop internal capacity and know-how concerning practical applications of EO services for the Bank's operations and also to demonstrate the global applicability of EO methods.

Global outreach and dissemination of results

One of the main objectives of the ESA-World Bank partnership from the onset has been to reach EO know-how users in developing countries through the World Bank's global reach and presence. The outputs of the *eoworld* portfolio have been presented during the Services Utility Review meetings conducted in collaboration with the World Bank Country Offices in Brazil, Papua New Guinea, Zambia, Indonesia and the Headquarters of the Indian Ocean Commission. The local institutions were trained in the use of information products, data analysis, and interpretation of the results.

In December 2011 the World Bank Office in Port Moresby, Papua New Guinea organized a meeting which involved the presentation of the results to the Oil Palm Research Association of PNG (PNGOPRA) and to the Oil Palm Industry Corporation (OPIC), which are the implementing agencies of the World Bank-financed Smallholder Agriculture Development Project (SADP). From the technical standpoint, the use of very high resolution RapidEye data considerably improved the detail and scope of the information available as compared with Landsat-resolution map products which were occasionally used by SADP in the past. The *eoworld* maps are now slated to be incorporated into the locally managed geographic information systems.

In February 2012, the Zambian Water Board of the Ministry of Energy and Water Development hosted a training session which was attended by 40 participants representing different government and development

EO Learning Events (2011-2012)

- Monitoring of Water Quality and Land Use Changes in the Lake Titicaca Basin November 22, 2011
- Historical Assessment of Spatial Growth of Built-ups and Metropolitan areas of Delhi and Mumbai in India, and Dhaka in Bangladesh, January 10, 2012
- Forest Resources Management in Liberia, January 11, 2012
- Building Exposure Maps of Urban Infrastructure and Crop Fields in the Mekong River Basin, January 11, 2012
- Satellite Tools for Building Flood Defence Systems in Guyana, February 21, 2012
- Analysis of Land Subsidence in the Agglomeration of Jakarta, February 21, 2012
- EO Support to Multi-Hazard Vulnerability Assessment in Ho Chi Minh City and Yogyakarta February 22, 2012
- Monitoring of Coastal Vulnerability and Coastal Change Trends in West Africa, February 23-24, 2012
- Sustainable Oil Palm Production in Papua New Guinea, December 11, 1012

agencies. It was followed by a dedicated "Capacity Building workshop on Advanced EO Methods in Water Management" that took place in November 2012 in Lusaka within the framework of TIGER activities which have trained 20 additional professionals from several government organizations. The training included interactive sessions, keynote lectures on state-of-the-art Earth Observation, theoretical lectures on microwave remote sensing with emphasis on synthetic aperture radar (SAR), workshops on accessing satellite data, SAR data processing, and flood and small water body mapping. This was the first time that ESA cooperated with the World Bank in delivering a training course in Africa. It resulted in World Bank financing of six additional training courses over the next three years.

13a

13b

The Indian Ocean Commission hosted the Monitoring of Environmentally Sensitive Areas in the Mozambique Channel, Real-time Oil Spills Detection & Polluter Identification project meeting on March 15-16, 2012. The workshop gathered a community of users to discuss the outcomes of the project and recommendations for future steps. The participants included Indian Ocean Commission, South African Maritime Safety Agency, Mozambique's INAMAR - National Maritime Authority, Comoros's Centre des Opérations de Secours Et de la Protection Civile (COSEP), La Réunion's Action de l'Etat en Mer (AEM), Centre Régional Opérationnel de Surveillance et de Sauvetage (CROSSRU), Madagascar's Organe de Lutte contre l'Evènement de Pollution (OLEP), Mauritius' Albion Fisheries Research Center, Ministries of Public Infrastructure, (Land Transport & Shipping) and Fisheries, Mauritius' Oceanography Institute (MOI), National Coast Guard (NCG) and Seychelles' Ministry of Environment. Later on, the continuity of the Oil Spill Detection service in the Mozambique Channel was secured within the second phase of the World Bank's GEF-financed Marine Highway Development and Coastal and Marine Contamination Prevention Project, which includes a dedicated training of key staff in operational sites.

The results of the Jakarta land subsidence study were first presented at the Flood Risk Management and Urban Resilience Workshop in Jakarta on May 2-3, 2012 organized by the World Bank, with the support of the Republic of Korea and the Global Facility for Disaster Reduction and Recovery (GFDRR). Attendees included representatives from Indonesia, China, Lao PDR, Philippines, Thailand,

"The results of the EO world for Indonesia had attracted a lot of interest. We hope we can continue facilitating discussion among stakeholder like DKI Jakarta government to have more regular subsidence monitoring program which incorporate the use of ESA technology ".

Iwan Gunawan,
Senior Disaster Risk Management Specialist,
World Bank Country Office, Jakarta

13a. The results of the project in Papua New Guinea were presented to the local stakeholders. Photo by SarVision.
13b. TigerNET workshop participants receive Certificates.

and Vietnam, as well as various development partner organizations. One of the workshops sessions was dedicated to the problem of disaster risk management in Jakarta and aimed at presenting new approaches and technologies, including the PSI-based subsidence assessment conducted in the framework of the *eoworld* project. The Jakarta Workshop was followed by a dedicated meeting with Indonesia's Disaster Management Agency (BPBD) in June 2012. The audience was composed of about 40 participants in total representing agencies responsible for spatial planning and environmental management, public works, energy, industry, marine, fisheries, as well as academia and other experts from the local government responsible for planning, community protection, environmental management, social affairs and resettlements, among others.

Moreover, to facilitate broader global outreach as well as greater coordination of the existing initiatives ESA and the World Bank have been actively exchanging their expertise through a series of professional events.

The ESA TIGER Initiative Workshop organized in December 2011 in South Africa offered the opportunity to discuss the World Bank's perspectives regarding the role of information technology in supporting African countries in their water resources management. A major component of the TIGER Initiative is devoted to supporting African scientists, technical centres and water authorities to develop the scientific skills and the technical capacity to make the best use of EO technology. EO can be used to assess and monitor the status of the water resources in Africa and assess the potential impacts of climate change on water resources to establish a sound scientific basis for developing effective adaptation and mitigation measures across the continent.

"The World Bank is a key development partner for Africa to strengthen water-related information, institutions, and infrastructure at a scale that can have transformative impact at local, national, and regional levels… Evolving Earth Observation tools can provide significant opportunities to accelerate Africa's sustainable development"

Harshadeep Rao,
Senior Environment Specialist,
Africa Region, World Bank,
Tiger Workshop, 2011

13c

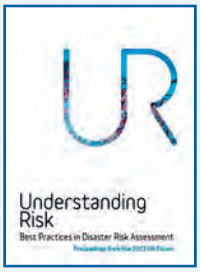
13c. Understanding Risk Forum, 2012 Cape Town, South Africa. From left to right: Philippe Bally (ESA), Jane Olwoch (SANSA), Hicham Ezzine, Regional Centre for Disaster Risk Reduction (RCDRR), Egypt, Paida Managara (SANSA), and Guido Van Langenhove, National Hydrological Services, Namibia.

BOX 2

Scientific and Technical Memorandum of The International Forum on Satellite EO and Geohazards, 21-23 May 2012, Santorini Greece, ESA/GEO Publication

...EO, combined with other data sources can be a very powerful tool, with important opportunities to support risk management. There is need for information on hazards but also assets and their vulnerability. Many applications are still to be explored (flood extent monitoring, etc.) but upcoming missions should open new area for investigation. [...] Cost, continuity and sustainability must be carefully considered when considering applications in developing countries. Data preparedness is key to accelerate risk assessment activities, build in-country capacities...

Francis Ghesquiere, Head of GFDRR Secretariat, ESA's International Forum on Satellite EO and Geohazards, 2012



Best Practices in Disaster Risk Assessment Publication, GFDRR Publication

...In the next few years, the ESA Sentinel satellites will be launched as a part of the joint European Union-ESA GMES program. The GMES program aims to ensure long-term continuity of acquisitions with global observations that are conducted in a systematic fashion with free and open access data policy. This has the potential to enable local users and policy-makers in African countries to enhance their ability to use satellite EO for DRM...

Philippe Bally, ESA's Science, Exploitation and Future Technologies Department, GFDRR's Understanding Risk Forum, 2012

ESA has also participated in the first Annual Meeting of the Global Partnership for Oceans (GPO) convened by the World Bank in April 2012. The event involved more than 100 governments, international organizations, civil society groups, and private sector representatives, all committed to addressing the threats to the health, productivity and resilience of the world's oceans. While Earth Observation can address many of the main concerns of the GPO, such as overfishing, pollution, and habitat loss, ESA's capabilities were considered to maximize the contributions from remote sensing applications via its on-going and planned activities, and to support the achievement of GPO objectives.

In June 2012, ESA participated in the Understanding Risk Forum organized by the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) in Cape Town on Mapping Global Risk. The Agency has co-chaired there a dedicated session on Satellite Earth Observation and Disaster Risk Management along with the South African Space Agency (SANSA). The session included speakers from Nigeria, Egypt, Namibia, South Africa and the World Bank who discussed the innovation in risk assessment. The participants concluded that the current and planned EO missions are providing unprecedented varieties and volumes of data along with tools and techniques to transform them into geophysical measurements directly relevant to disaster risk reduction. This finding resonated with the conclusion of the International Forum on Satellite Earth Observation and Geo-Hazard Risks, organized by ESA and attended by the GFDRR in May 2012, which has also offered a platform to discuss the use of Earth Observation in tectonics, coastal lowland subsidence and flood defence, landslides, seismic hazards and other hydro-geological risk assessment (such as groundwater management and inactive mines) (See Box 2).

In September 2012 the World Bank organized its 6th Urban Research and Knowledge Symposium in Barcelona "Rethinking Cities: Framing the Future". As part of the symposium a dedicated session was organized on Earth Observation and Urban Development which was the

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participation of experts from ESA, Columbia University, GISAT (an European EO service provider) and ICT Netherlands.

Finally, in April 2013 ESA took part in the third annual WAVES (Wealth Accounting and the Valuation of Ecosystem Services) Partnership meeting at the World Bank which brought together more than 100 experts who are at the forefront of advancing work on natural capital accounting). ESA also organized in collaboration with WAVES an international user consultation Workshop in Washington DC concerning the expansion of Earth Observation for ecosystem services assessment which took place at the World Bank Headquarters.

Building on success and deepening the partnership

In 2013 ESA and the World Bank are entering into the Second Phase of the Partnership intended to broaden the initial scope of the Earth Observation for Development initiative. Within this framework ESA will extend its capacity (financing and technical supervision) to produce and deliver EO information services to a focused set of sectors identified by the World Bank as having the biggest potential for transformative outcomes. A series of consultations across the Sustainable Development sectors and units have resulted in a joint decision to prioritize four areas for the second phase of the collaboration, namely: urban development, disasters risk management, oceans, and forestry.

The reinforced partnership will provide a platform for identifying opportunities to include new areas of strategic importance which have not yet been explored, such as operations in fragile and conflict-affected states, ecosystem's services, extractive industries, renewable energy, and the insurance and reinsurance sector. The widening portfolio of World Bank's activities in climate change also presents an opportunity for a broader use of EO applications; especially in cases where operational climate information services may not yet exist.
The second phase of the ESA – World Bank partnership will build upon the existing collaboration. It will continue to provide a platform for services expansion

14. Ecosystem Services Workshop, 2013 Washington DC.

with an objective of taking the Partnership beyond the initial technology demonstration phase and toward a consolidation of EO technology usage in the World Bank knowledge, information and services delivery systems. This new approach will not focus exclusively on the demonstration projects negotiated on individual basis, but rather aim to build a strategic partnership that takes the full advantage of the technological capabilities of the European Space Agency, European national satellite missions, in particular the Global Monitoring for Environment and Security (GMES) Program, and the innovation opportunities they offer to the user communities around the world.


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The upcoming Sentinel satellites being developed under Europe's Global Monitoring for Environment and Security (GMES) programme will continue to provide operational data to global organisations like the World Bank. The European Space Agency is developing five families of Sentinel which will offer a depth and breadth of coverage not previously possible with most sensors on a single platform, resulting in an unprecedented increase in the amount of Earth Observation data available to the users while guaranteeing continuity of observations for the next two decades. Sentinel-1 will acquire imagery over an area which is 200 times the size of Malawi - every day - at high spatial resolution, regardless of weather conditions, and it will deliver them within an hour of acquisition – a major improvement over existing synthetic aperture radar systems. The Sentinel missions will benefit numerous EO services, including oil-spill monitoring and ship detection for maritime security, monitoring land-surface for motion risks, mapping for forest, water and soil management and mapping to support humanitarian aid and crisis situations. For applications requiring optical data, Sentinel-2 (A and B) will provide complete global coverage at 10m resolution every five days. Data from Sentinel-2 will benefit services associated with land management (delivering land-cover maps, land-change detection maps and geophysical variables that use, for example, leaf area index, leaf chlorophyll content and leaf water content), disaster control and

SENTINELS OVERVIEW

Sentinel-1 is a polar-orbiting, all-weather, day-and-night radar imaging mission for land and ocean services. The first Sentinel-1 satellite is planned for launch in 2013.

Sentinel-2 is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring providing, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 will also deliver information for emergency services. The first Sentinel-2 satellite is planned for launch in 2014.

Sentinel-3 is polar-orbiting, multi-instrument mission to measure variables such as sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The first Sentinel-3 satellite is planned for launch in 2014.

Sentinel-4 is a payload that will be embarked upon a Meteosat Third Generation-Sounder (MTG-S) satellite in geostationary orbit scheduled to be launched in 2019. Sentinel-4 is dedicated to atmospheric monitoring.

Sentinel-5 is a payload that will be embarked on a MetOp Second Generation satellite, also known as Post-EPS, to be launched in 2020. Sentinel-5 is dedicated to atmospheric monitoring.

15. A simulated Sentinel-1 image of Indian Head in Canada, one the three major sites investigated intensively during the AgriSAR 2009 campaign. The various colours reflect the radar brightness of each field at different times. Fields growing the same crops generally display the same colour radar data. These data can therefore be used for crop classification. Radarsat image ©MDA.

humanitarian relief operations (images of floods, volcanic eruptions and landslides), or coastal zones management.

Many public policy areas will be served, especially multilateral environmental agreements such as the Rio conventions. Sentinels' operations will also significantly increase EO capacity for agricultural monitoring in terms of resolution, revisit frequency and coverage. Data products developed using Sentinel-2 will include estimates of crop area extent, crop type and crop state for different regions of the Earth (status mapping in the frame of food security) as well as precision agriculture. In forestry, improved estimation of forest distribution and change, and an improved quantification of regional and global biomass will help in reducing uncertainties in calculations of carbon stocks and fluxes in the terrestrial biosphere.

The EO community is currently moving towards providing a long-term sustainable data flow, forming the basis for operational use of EO. Technical capabilities are improving continually, with radical improvements taking place in the range, quality, quantity and reliability of earth observation. This decade will see the deployment of many more sensors, increasing global Earth observation capabilities at a very high spatial resolutions (<1m to 2.5m), and providing new spectral capabilities using infrared (IR), multispectral and hyperspectral sensors to spot heat sources, highlight features of vegetation, determine vegetation species, and identify materials and environment conditions. State-of-the-art radar missions will provide data to support a variety of tailored applications offering a range of high spatial resolutions, polarisations and operating frequencies, as well as improvements in interferometric capabilities, allowing 3-D imaging and quantification of surface deformation with subcentimetric accuracy.

Demand for accurate geo-information has increased enormously over the past decade. Geospatial data and geographic information systems (GIS) including satellite remote sensing are becoming increasingly commonplace in development as a large number of United Nations agencies and other organizations in the international development community have been developing GIS/EO capacity to support their operations. For example, UNOSAT - United Nations Satellite Operations Center launched in 2003, with direct support from ESA, and now operates 24 hours a day, 365 days a year, providing rapid mapping service for UN-led humanitarian operations. The World Food Program's Emergency Preparedness and Response Branch has also begun using tested EO approaches to support its field operations: joint logistics centre, contingency plans, and emergency response. Similarly, in 2011 the US Agency for International Development (USAID) set up its GeoCenter to employ satellite imagery and other spatial datasets to support its Missions and Operating Units in overall planning, monitoring, evaluation, and communication of development work.

The World Bank may be the single largest, indirect generator of spatial data in the world; but it is not easy to quantify this claim as these investments are not tracked directly in the Bank's accounting system. What is certain is that the use of spatial data as well as the awareness of remote sensing techniques has grown alongside the development of geospatial information systems across World Bank units. In environmental policy research, for instance, Development Research Group uses GIS to calculate the probable effects of climate change, with overlay mapping techniques to track the spatial distribution of potential environmental impacts. The World Bank Climate Change Knowledge Portal created in 2012 provides the public with visualization tools for exploring openly available climate models alongside country level dashboards focused on national level impacts of climate change. Moreover, a specialist GIS team at the Global Facility for Disaster Reduction and Recovery (GFDRR) – so called GFDRR Labs – has piloted a number of open geospatial platforms for risk assessment (InaSafe) under its Open Data for Resilience Initiative (OpenDRI). All new World Bank projects are also now geo-referenced under the Bank's Mapping for Results program to ensure that development planners can geo-locate on-going aid flow.

However, while the Bank has begun to embrace the geospatial revolution it is still at the early stages of exploring the opportunities provided by satellite Earth Observation and the specialized services it offers for more informed decision making. The need to invest more in the awareness raising efforts, staff training, long term capacity building, and IT infrastructure, to ensure that the EO information is generated when needed and put to operational use, both at the World Bank and in the client countries has been clearly recognized. The partnership with ESA, now entering its second phase, will support this on-going process and accompany it into the next generation of results.

5. PROJECTS SUMMARY

THREE EARLY PILOTS (2008–2009)

Climate Change Adaptation	Adaptation to Climate Impacts in Coastal Zones in the Caribbean: Monitoring of Coral Reefs in Belize
Coastal zone management	Monitoring of the Coastal Change Trends in Bangladesh
Climate Change Adaptation	Climate Change Adaptation and Natural Disasters Preparedness in the Coastal Cities of North Africa

FIRST PHASE COLLABORATION PROJECTS (2010–2012)

Disaster Risk Management	Assessing Vulnerability in the Metropolitan Area of Rio de Janeiro
Urban Risk Management	Building Flood Defence Systems in Guyana
Urban Risk Management	Multi-Hazard Vulnerability Assesment in Ho Chi Minh and Yogyakarta
Urban Risk Management	Analysis of Land Subsidence in Jakarta
Disaster Risk Management	Building Exposure Maps of Urban Infrastructure and Crop Fields in the Mekong River Basin
Water Resources Management	Watershed Mapping for Water Resources Management for the Zambezi River Basin
Water Resources Management	Monitoring of Water Quality and Land Use Changes in the Lake Titicaca Basin
Coastal Zone Management	Monitoring of Coastal Vulnerability and Coastal Change Trends in West Africa
Marine Environment Management	Monitoring of Environmentally Sensitive Areas in the Mozambique Channel
Urban Development	Historical Assessment of Spatial Growth of Metropolitan Areas of Delhi, Mumbai and Dhaka
Agriculture and Rural Development	Sustainable Oil Palm Production in Papua New Guinea
Forestry	Forest Resources Management in Liberia

Adaptation to Climate impacts in Coastal Zones in the Caribbean: Monitoring of Status and Health of Coral Reefs in Belize

Users

World Bank Unit:
Sustainable Development Department, Environment and Water Resources Unit, Latin America and the Caribbean Region

Local Stakeholders:
Caribbean Community Climate Change Center, Belmopan, Belize

Other Users:
GEF Coral Reef Targeted Research & Capacity Building for Management

EO services provided

Coral Reef monitoring using remote sensing techniques to assess thermal stress regimes, wave exposure areas and reef connectivity (for larvae dispersion)

Service providers

Marine Spatial Ecology Lab, University of Exter (UK)

ESA Technical Officer

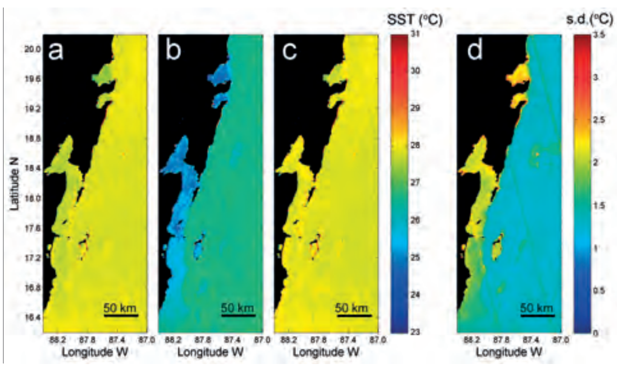
Pierre-Philippe Mathieu
European Space Agency
Science, Applications and Future Technologies Department, Exploitation & Services Division, Industry Section, Directorate of EO Programmes
Tel: +39 06 94180568 | pierre.philippe.mathieu@esa.int

WB Task Team Leader

Walter Vergara
The World Bank Group
Former Lead Engineer, Environmental and Social Sustainability Development Department (LCSES), Latin America and the Caribbean Region

Ecosystem services provided by the coral reefs provide important monetary and non-monetary values to the local communities. They protect of coastal landscapes and water quality, and provide employment opportunities such as fishing and tourism. At the same time, reef systems are increasingly threatened by a range of biological, chemical, and physical stresses all over the world, chief amongst these being climate-change related coral bleaching, overfishing and pollution.

1



1. Remotely sensed derived all-day SST patterns for the study area (a) average, (b) minimum monthly mean (c) maximum monthly mean (d) standard deviation based on ERS, ENVISAT (ATSR, AATSR) Data (c) ESA, temporal coverage: 1991-2008, spatial resolution: 1 km. Credit: Marine Spatial Ecology Lab (MSEL), University of Exter.

The decline and loss of complex coral ecosystems can have significant social, cultural, economic consequences; therefore there is a need to understand their major stressors and promoting better management and conservation. The eoworld project demonstrated that systematic collection of data using on remote sensing techniques yields important information concerning health and resilience of the coral reefs systems. Such tailored monitoring and early warning tools can adequately support protection efforts and the scope of their potential recovery.

The project covered the areas of the second longest Barrier Reef System in the world - Mesoamerican Barrier Reef System (MBRS) which extends off the coasts of Belize, Mexico, Guatemala, and Honduras. The central theme of the trial focused on monitoring of coral reefs status (reefs habitats, reef extent), and main stress indicators (sea surface temperature patterns, chronic and acute thermal regimes, wave exposure - a proxy for potential macroalgae growth, and coral connectivity among reefs).

This demonstration confirmed that EO data can be used to map reef habitats and assess their change overtime, and to identify regions which are more vulnerable and likely to experience coral bleaching. Moreover, the project provided a review of state-of-the-art remote sensing capabilities giving away useful recommendations concerning the use this technology to improve reef conservation (resistance and recovery from disturbances) and management.

Sea surface temperature patterns

Thermal regime of the sea surrounding the reefs ecosystem determines the environmental setting of the coral communities and their variability in bleaching response. Satellite monitoring of sea surface temperature (SST) is remarkably effective at predicting where and when bleaching, one of the main sources of stress, will take place. In the MBRS shallow waters, at the Bays of Ascension, Espiritu Santo and Chetumal, as well as the channel between the barrier reef and Belize's mainland

and the atoll lagoons, all experience colder average SSTs, colder winters and broader temperature variation. Warmer waters, on the other hand, and more frequent thermal anomalies are experienced in areas of slow flow, as discovered in the south of the study area, as well as in the shallow and sheltered regions on the internal side of the bays and atoll lagoons. (Fig. 1)

Chronic and acute thermal regimes

As the oceans continue to warm, episodes of coral bleaching are set to become more frequent. The response of corals to thermal stress depends on the temperatures that they are acclimated to (chronic stress) and the prolonged, elevated temperatures that they experience during disturbance events (acute stress). Such acute stress conditions were experienced by Belize's reefs during the mass bleaching in 1998, which was the most significant warning event in the region, exacerbated by a catastrophic hurricane which has caused a 50% reduction in coral cover in Belize.

In general, reefs can be classified according to their past temperature patterns into the following categories (Fig. 2):

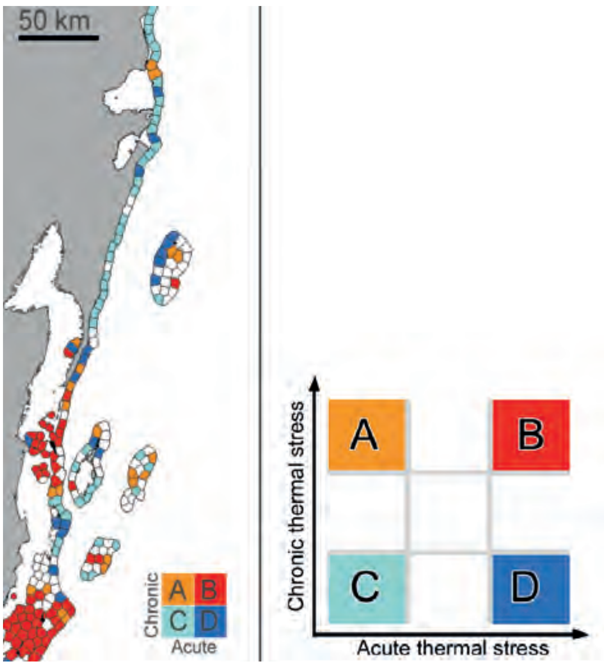
A. high chronic (thus acclimated) and low acute stress, expected to cope best with rising temperatures,
B. high chronic and high acute stress, where the selection for more thermally-tolerant genotypes would be greatest,
C. low chronic and low acute stress, not acclimated to any thermal stress and expected to be fair badly if subjected to unusual warming, and
D. low chronic and high acute stress, likely to be the worst-affected by climate change.

In MBRS, the areas that are predicted to fare better under future climate change (A) are rare and scattered across the study area, mainly in the barrier reef and the atolls. These are predicted to have the most bleaching-resistant coral communities - acute stress tends to be low in these locations and the corals' acclimation to high chronic thermal stress implies a degree of natural resistance against elevated temperatures. Also, the diversity of corals in (A) regimes is expected to be relatively high and the size distribution of corals - broad because of the successful progression of colonies through successive size classes.

Areas with high selection pressure (B) are located in sheltered areas within the barrier reef and the Gulf of Honduras. These may have some natural resistance to bleaching conditions by virtue of their acclimation to high chronic temperature, but their exposure to acute warming during frequent bleaching events is likely to cause significant mortality.

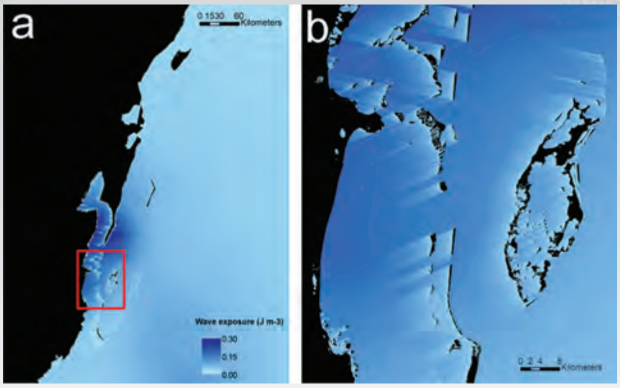
Sites with low chronic stress (both C and D) are found throughout the entire latitudinal range, mainly in areas where there is a change in bathymetry and thus increased water flow, for example in the north of the study area. Sheltered areas near Belize City that are located behind the barrier reef have high acute stress due to lower wave exposure and reduced mixing of the water column during summers. Corals in the (C) regime are predicted to benefit from a lack of severe bleaching events but their acclimation to cooler conditions is likely to increase their vulnerability to even short periods of rapid warming. They will be moderately healthy but mortality rates due to acute disturbance will be greater than those occurring in regime (A). Corals in regime (D) (low chronic and high acute stress) are predicted to

2



2. Categorization of coral reefs in MBRS by thermal stress regime. Empty (white) polygons are unclassified, falling between thermal regimes. Credit: MSEL.

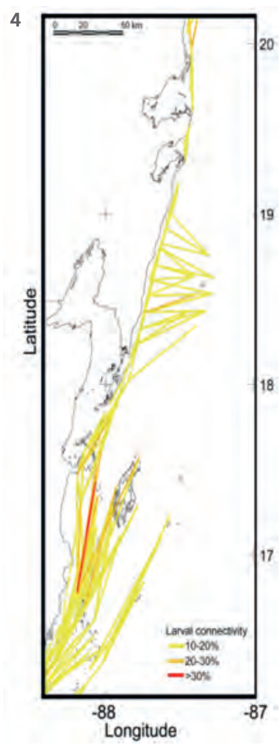
3



experience severe mortality because of their lack of acclimation to severe thermal stress resulting in acute bleaching and disease.

Interestingly, although it has been suggested that as a general rule higher sea surface temperature variability may be associated with lower vulnerability to bleaching and associated mortality, in the MBRS this is not the case. Following the 1998 bleaching event, coral bleaching was recorded across the whole spectrum of environment in the MBRS. However, mortality was only observed in lagoon areas, where the temperature regimes are most variable.

4



Wave exposure patterns

Wave exposure is a degree of wave action on an open shore. At the regional scale, the exposure pattern is dominated by the wind statistics. In the MBRS case the regional variations in wave exposure are characterized by lesser exposure in the south and higher exposures at the north of the barrier reef, between Ambergris Cay and Belize City, where the winds are strongest (Fig. 3). Variation in exposure at local scales is well represented in the exposure map in the Figure 3b. The dominant effect of the north-easterly trade winds can easily be seen with land masses shadowing western regions due to limiting the attainable fetch along the trade wind direction. Moreover, the seaward side of the atolls and the barrier reef experience higher exposures unless they are shadowed by a reef structure to the east. These areas are more likely to experience higher water mixing and elevated microalgae growth rates. They are most vulnerable to algal blooms if the reefs are also depleted of herbivorous fishes, which are currently the most commonly caught fish in the region. This fact is important for conservation efforts because the areas with high wave exposure and faster algal growth have a reduce rate of coral recovery. However, due to the complexity of the study area, which is characterized by shallow waters and a large number of small islands and atolls, the wave exposure map generated within the framework of this study should be interpreted only as a relative measure of exposure to waves, not as a quantitative evaluation.

Coral larval connectivity

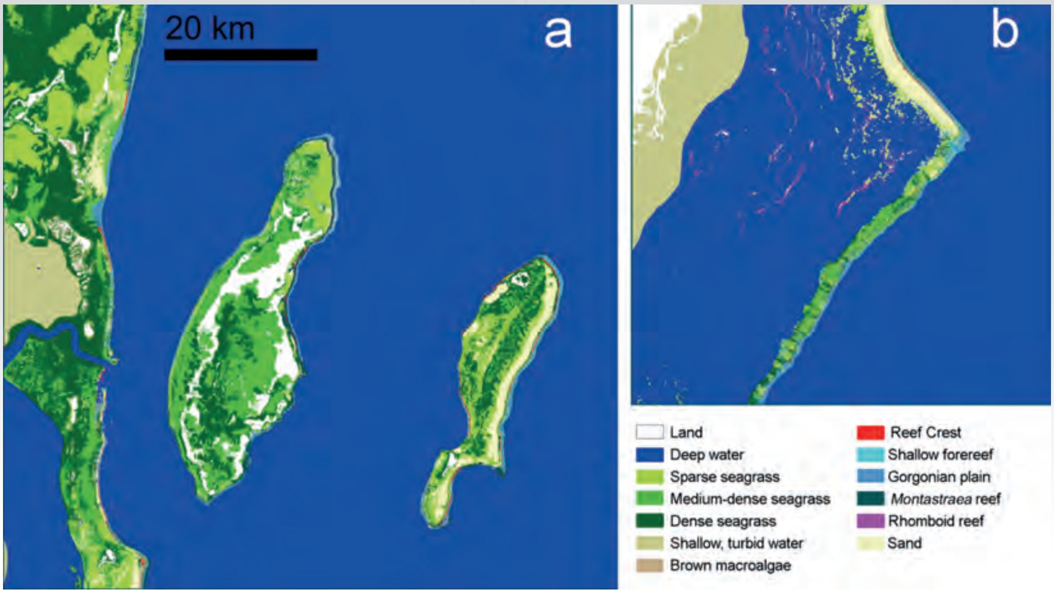
Following disturbance events, coral reefs persistence and recovery depends not only on coral growth, but also upon the arrival of larvae to reseed the population. Larval transport is driven by a general pattern of sea currents in the area, with most of the connections between pairs of reefs running parallel to the coastline. In the MBRS case the reefs at the latitudinal extremes of the study area exhibit some isolation from the offshore atolls which serve mainly as sources of larvae. On the other hand, the sites in the middle of the barrier reef have the highest number of connections. Figure 4 represents the sample of the connectivity network (various levels of larval exchange (proportion surviving) between each of the reef site) for coral populations in the study area. This assessment is based on the sample data - evaluation of a longer time period would produce more general patterns that can be reliably taken into account within conservation and management plans.

Habitat maps

Habitat maps enable the estimation of the coverage of different coral communities within an area and the

3. (a) Exposure map for the study area. Land and reef crest are black. Relative exposure measures ranges from 0 to 0.3 J/m3 (b) detailed region showing shading effects. Data source and resolution: remotely sensed derived winds (AMI), coastline and reef crest locations (Landsat) 25 m. Credit: MSEL.

5



establishment of links among different ecosystems. Two sections of the MBRS were mapped in this project: (1) offshore Belize city, Turneffe Islands and Lighthouse Reef, and (2) Southern Barrier Reef. The maps provided ten habitat classes: sparse, medium-dense and dense seagrass, brown macroalgae, reef crest, shallow forereef, gorgonian plain, Montastraea reef, rhomboid reef and sand.

The regions mapped within the project are covered mainly by seagrass and sand in shallow areas. Coral reefs are located in the seaward side of the barrier reef, around the atolls (mainly in the seaward side) and within the complex region at the south of the study area, dominated by the presence of rhomboid reefs (Fig. 5). Within the Barrier, reefs are rare in the south, in the Gulf of Honduras, where the shallower, slow-flow areas are dominated by seagrass beds (Fig. 5b). reefs are also scarce around the deep shipping channel south of Belize City (Fig. 5a), where the water quality diminishes.

Overall, Earth Observation techniques provide a solid scientific base that can be designed to support traditional environmental monitoring and the management of coral reefs. In some cases they provide a good alternative to field-surveys - their mains strengths being cost-effectiveness, synoptic view, and simultaneous evaluation of several putative stressors for the establishment of causative links. Information concerning the patterns of the thermal regime may further assist in locating hot spot locations to maximize the scope for coral resilience and recovery. For example, information concerning chronic and acute thermal regimes can be used by the local marine reserves management to reduce some forms of biological stress, such as overfishing (one of the main problems in the region), thereby minimizing the overall stress that occurs due to coral and algal competition. This is particularly important in view of the fact that coral bleaching increases the vulnerability of reefs to the negative effects of a cyclical phase shift: changing from a coral-dominated to a macroalgae-dominated state, if herbivores are absent.


6

4. Connectivity network for coral populations in the study area for various levels of larval exchange (proportion surviving) between each reef site. Data provided by Claire Paris, RSMAS/AMP, University of Miami. The dataset was produced using three dimensional high resolution models of larval transport. The model was parameterized using oceanographic data for August 2003. Credit: MSEL.
5. Maps of the main marine habitats for (a) the area offshore Belize city and around the Turneffe islands and Lighthouse reef.
6. Coral reef. Photo by Marine Spatial Ecology Lab.

Monitoring of the Coastal Change Trends in Bangladesh

Users

World Bank Unit

- Environment and Water Resources Unit, South Asia Region
- Agriculture and Rural Development Unit, South Asia Region

EO services provided

- Mapping of the development of the coastal zone in the Ganges Delta (long term trends and change zones, interannual change zones, and single event change zones) using medium and high resolution optical imagery
- Monitoring of a coastal change using long range of EO data (Landsat archives from 1962 to 2007)

Service providers

GRAS (Denmark)
planquadrat Geoinformation (Germany)

ESA Technical Officer

Pierre-Philippe Mathieu
European Space Agency
Tel: +39 06 94180568 | pierre.philippe.mathieu@esa.int

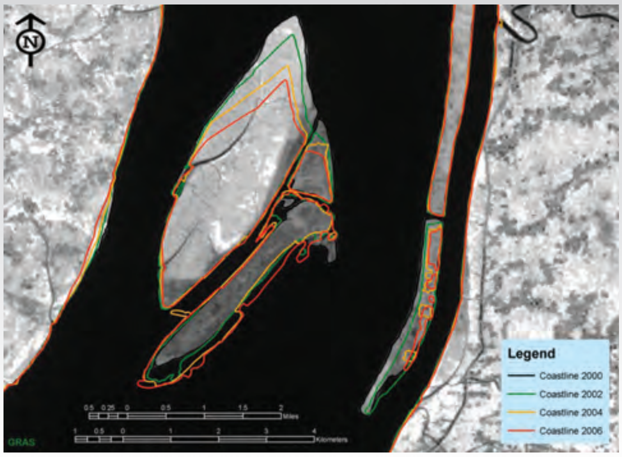
WB Task Team Leader

Winston Yu
The World Bank Group
Senior Water Resources Specialist,
Agriculture and Rural Development Unit, South Asia Region

In the context of changing climate many projections for Bangladesh estimate a rise in sea level of around 1 meter by the year 2100. This would mean an inundation of approximately 18% of the land surface of the country. However, what these estimates fail to recognize is the extremely dynamic and changing nature of the river delta. The river morphology is constantly changing, depositing over a billion tons of sediment a year into the delta. These processes are crucial for renewing the fertility of the flood plain – Bangladesh's backbone for economical and societal stability.

The EO services were aimed at contributing to the scientific debate on the net result of high accretion and deposition rates which add land surface, against the erosion and compaction rates which reduce the land surface.

The rates of loss or gain of land are usually calculated by comparison of satellite images acquired at different points in time. The difficulty with applying this approach in Bangladesh lied however in the existence of strong tidal range (difference between water levels at low tide and high tide) which in combination with flat coast morphology in the Ganges Delta could have resulted in misinterpretation of the extended tidal flat areas as land loss or gain. Therefore the project was a proof-of-concept to develop two new methodologies.



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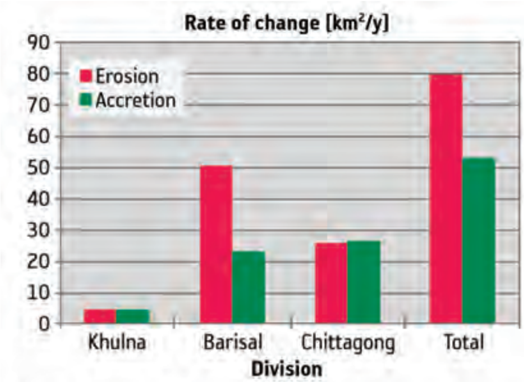

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Table 3. Erosion and Accretion from 2000 to 2007 for total area as well as for division demarcated areas.

Division	Erosion [km²]	Accretion [km²]	Net change [km²]	Rate of change [km²/y]
Khulna	28	29	1	0.14
Barisal	355	159	-196	-27.93
Chittagong	179	183	4	0.59
Total	**562**	**372**	**-190**	**-27.20**

1. Coastline migration from 2000 to 2006 identified by manual interpretation. Credit: GRAS.
2. Erosion and accretion trends from 2000-2007. Credit:GRAS.

3

The first study by planquadrat Geoinformation developed a nearly automatic method based on the analysis of time series (1990, 2000, 2009) of more than 160 satellite images of freely available Landsat data, 90% of which were at the time of high tidal water level. These were further used to derive Land/Water masks using the mid-infrared spectral band (5) of the Landsat ETM+ satellite sensor. Those Land/Water masks were combined to time series datasets and classified into trend zones for erosion, accretion and tidal flats.

A study by GRAS analyzed the impact of geometric resolution and very long time comparisons on the results. Data of different pixel resolution from 0,6m to 32m were tested and the time span of the EO imagery ranged from 1962 to 2007. Semi-automatic object-based segmentation and classification methods were applied as well as visual interpretation of the imagery (Fig. 1 and 2).

The results of this pilot project highlighted the added value of the analysis of EO data for the monitoring of coastline dynamics. For a large study area, this method provided useful baseline information on locations with tendency to erosion and locations with tendency to accretion (Fig. 3 and Fig. 4). Additionally it provided robust and reliable annual average rates of erosion and accretion in decadal intervals. The analysis confirmed however that the tidal effect (the water level at time of data acquisition by the satellite sensor) has a significant impact on the results. To resolve this problem, semi-automatic methods can be applied to multi-spectral data while panchromatic data should be visually interpreted. For more detailed information on rates of erosion and accretion, higher resolution EO data combined with detailed and exact digital terrain data of the coastal area and the tidal zones, as well as the exact tidal water levels along the coastline at the various points in time of the EO data acquisition, is required.

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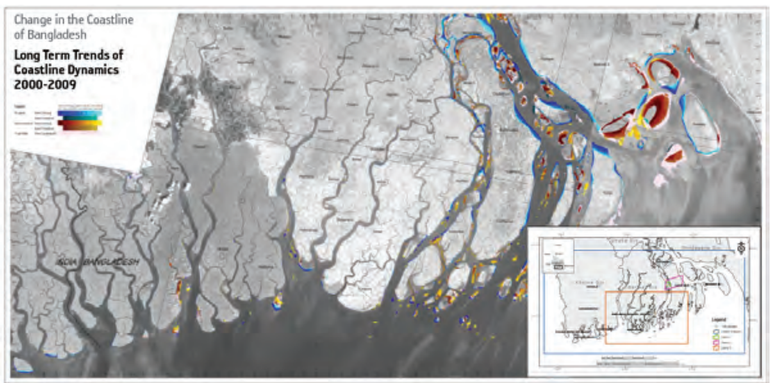

3. Planting crops. Bangladesh. Photo: Thomas Sennett / World Bank

4. Long term trends in the coastal dynamics. Classificationof the study area is done using the slope intercept approach. Colour scheme according to the slope-intersect matrix provided in the study: blue and blue-green areas are erosion areas, brown to yellow areas are accumulation areas, mid gray areas are tidal flats. Credit: planquadrat Geoinformation. Smaller image on the lower right shows the location map of Bangladesh and division boundaries and areas of interest covered by the service. Credit: GRAS.

Climate Change Adaptation Natural Disasters Preparedness Study in the Coastal Cities of North Africa

Users

World Bank Unit:
Urban and Social Development Unit, Middle East and North Africa Region; Marseille Center for Mediterraean Integration

Local Stakeholders

- In Egypt:
  - Egyptian Environmental Affairs Agency
  - Arab Academy of Science, Technology and Maritime Transportation
- In Tunisia:
  - Ministry of Environment and Sustainable Development
  - Ministry of Development and International Cooperation
  - Municipality of Tunis

EO services provided

- Historical mapping of terrain deformations in Alexandria (Egypt) based on interferometric technique using Synthetic Aperture Radar (SAR) data
- Historical mapping of terrain deformations in Tunis (Tunisia) based on interferometric technique using Synthetic Aperture Radar (SAR) data

Service providers

- TRE (Italy)
- Altamira Information (Spain)

ESA Technical Officer
Philippe Bally
European Space Agency
Science, Applications and Future Technologies Department, Exploitation & Services Division, Industry Section, Directorate of EO Programmes
Tel: +39 06 94180537 | philippe.bally@esa.int

WB Task Team Leader
Anthony Gad Bigio
The World Bank Group
Senior Urban Specialist, Urban Development Unit, Coordinator, Earth Observation for Development

The eoworld project conducted in the framework of the World Bank study on "Climate Change Adaptation and Natural Disasters Preparedness in the Coastal Cities of North Africa" aimed to identify and assess natural risks and vulnerabilities in Alexandria and Tunis. The contribution of EO data was primarily focusing on terrain deformation mapping to provide precise indications on the location of subsidence and uplift zones in support to surveys concerning land stability and seismic issues. The study analyzed potential ground movements in both cities between 1993-2000 and 2003–2009.

Figure 1 showcases the multi-risk map created for the World Bank "Coastal Cities" report which highlights Alexandria's critical vulnerabilities. The large shaded area indicates low-lying, flood-prone lands; red represents

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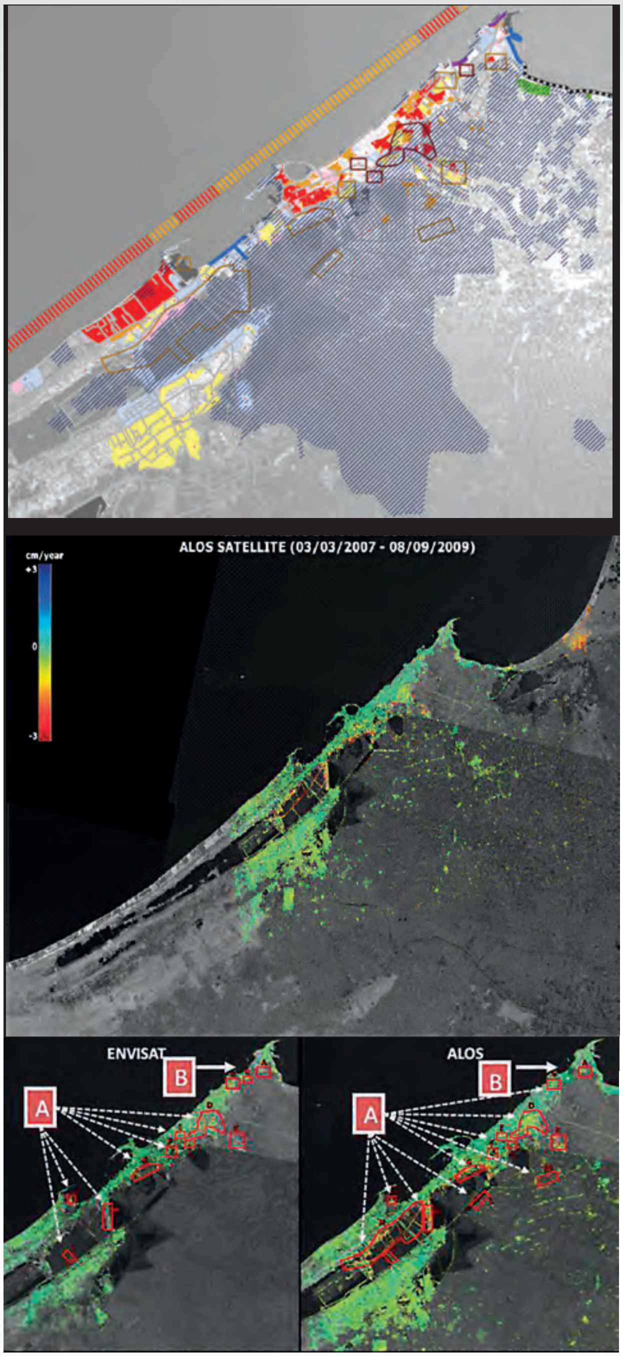

1. Upper map highlights Alexandria's critical vulnerabilities identified by the Word Bank "Coastal Cities" project. Credit: World Bank. The lower images indicate Alexandria's historical terrain motion patterns provided by Altamira Information as a contribution to World Bank study. ENVISAT ASAR image data © ESA 2003-2009.

high-density residential areas; yellow shows slums and informal settlements; blue shows areas most subject to marine submersion. The diagonal line of the coast represents different degrees of coastal erosion risk.

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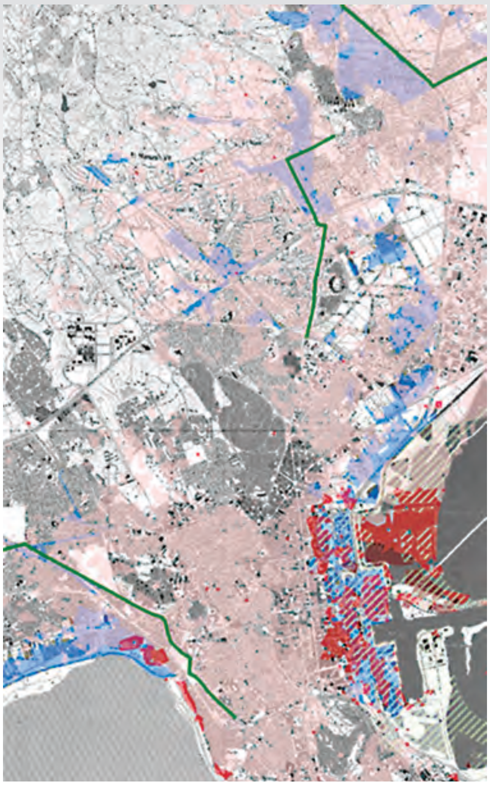

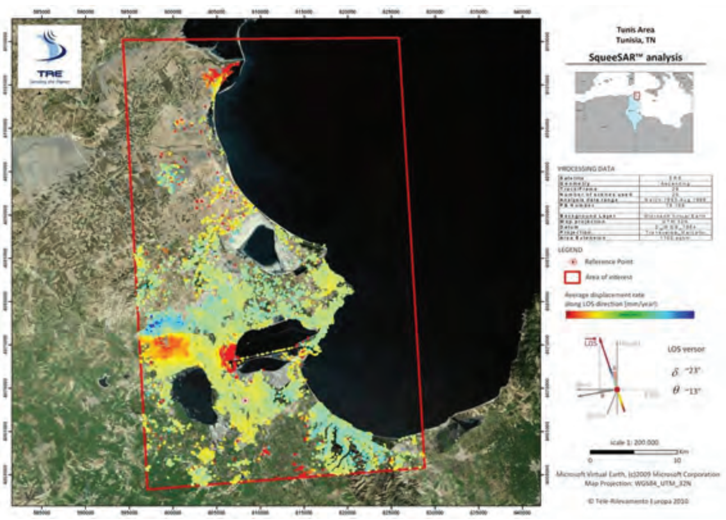

Historically, the region of Alexandria was affected by geological hazards such as seismic activity, tsunamis and offshore landslides. Satellite data was used to reconstruct monthly historical ground displacement in the urban and rural areas of Alexandria over the period 1992 to 2009. The Persistent Scaterrers Interferometry (PSI) analysis found that the terrestrial ground uplifting and ground subsidence in the urban and rural zone of Alexandria and Idku regions were ranging from maximum of -3 cm/year (ALOS) via -1.5 cm/year (ERS, ENVISAT) to maximum uplift 0.9 cm/year (ALOS) via 0.5 cm/year (ERS, ENVISAT). The maximum of this ground motion is mainly located in the northern border of the Al Bouhayra and Mariut lakes located in the south of the city and in the central area of Idku city.

In Tunis, terrain motion analysis found that in central part of the city, former and present industrial areas on the southern shore of the lake and port of Rades have experienced significant subsidence patterns undermining city's resilience to storms, seismic risks and extreme weather. In economically important central Tunis, subsidence (indicated in red) combined with flooding risks (indicated in blue) multiply potential disaster impacts as illustrated in Figure 2a. Major storms overwhelm the center-city drainage, inundating streets and buildings. This finding implies the need for infrastructure strengthening to better manage water levels, or upgrading of sewage and drainage structures.

2. The findings of the World Bank study. In economically important central Tunis, subsidence indicated in red combines with flooding risks indicated in blue to multiply potential impacts. Major storms overwhelm the center-city drainage, inundating streets and buildings. Left: SqueeSAR analysis of ERS ascending data identified more than 70000 measurement points, with a density of about 70 PS/km2. For each point, the average rate of deformation and time history of movements were estimated. Positive values (blue) suggest uplifting movement, while negative values (red) indicate a subsidence phenomena affecting the area. Credit: TRE, ERS ASAR data © ESA

Assessing vulnerability in the Metropolitan Area of Rio de Janeiro

Users

World Bank Unit:

Urban, Water and Disaster Risk Management Sector Unit, Latin America and the Caribbean Region

Local Stakeholders:

- Government of Rio de Janeiro State (Rio Prefeitura), Secretariat of Public Works (Obras)
- CEPERJ (Fundação Centro Estadual de Estatística, Pesquisa e Formação de Servidores Públicos do Rio de Janeiro)
- Fundação GEO-RIO for landslides (Instituto de Geotécnica do Município do Rio de Janeiro)
- Rio-Águas for floods (Subsecretaria de Gestão das Bacias Hidrográficas)
- Geological Survey of Rio de Janeiro State (DRM/RJ)
- Rio State Institute of Environment (INEA)

EO services provided

DEM-derived slope maps, urban mapping of infrastructure & buildings based on VHR Optical data (1:10 000 scale) complemented with Digital Elevation Model (DEM) generated using VHR Optical data

Additional analysis:

1: Flood simulation product based on land use data, DEM and historical meteorological data

2: Landslide susceptibility mapping based on interferometric terrain deformation technique using Synthetic Aperture Radar (SAR) data

Service providers

Flood risk:

- Critical Software (Portugal)
- NOA (Greece)
- Hidromod (Portugal)
- INPE (Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research)) (Brazil)

Landslide risk:

- NEO (The Netherlands)
- Hansje Brinker (The Netherlands)

ESA Technical Officer

Philippe Bally

European Space Agency

Tel: +39 06 94180537 | philippe.bally@esa.int

WB Task Team Leader

Alessandra Campanaro

The World Bank Group

Senior Infrastructure Finance Specialist,

Latin America and the Caribbean Region

The State Government of Rio de Janeiro has recently taken steps to improve city's spatial planning in view of better management of urban environment and disaster risk. One of the objectives is to develop robust disaster risk management tools to address and respond to the hydrological and geological hazards in the Rio metropolitan region. Of particular concern is to ensure that the future urban growth that will be taking place under constrained territorial conditions characterized by a fragile environment and high vulnerability to natural disasters does not result in increased exposure of assets and population to geological and hydrological threats.

The eoworld project was aimed to demonstrate the added value of using satellite data to support Rio's disaster risk management operations. A particular focus was on generating information that supports urban risk assessment to assist better planning of new housing development while mitigating risk of settlement pressures in hazard-prone areas. The project delivered three types of information products:

- base maps indicating the status of urban development urban assets exposed to floods and landslides including EO-generated Digital Elevation Model,
- analysis of selected flood events taking place in Rio Grande and Rio Anil watersheds as well as land use options that take into account the impacts of different land cover scenarios on flood propagation,
- landslides susceptibility analysis indicating landslide prone areas using EO-based terrain deformation information that can be early indicator of a landslide threat.

The mapping products were transferred to the Operations Center of Rio de Janeiro (OC-Rio) which integrates about thirty institutions of the city administration to support crises management as well as other public bodies of the municipality responsible for civil protection, water resources management (Rio-Aguas), and geological services (the Institute of Geotechnics Foundation of the Municipality of Rio de Janeiro - Geo-Rio).

Urban mapping

The project provided detailed analysis of the morphological features of the urbanized area in the Rio de Janeiro agglomeration including residential areas, commercial and industrial units, favelas located on the hills as well as a large majority of vegetated land (Fig. 1). This information was used to expound urban reality of Rio's build-up area, in particular to identify any vacant, under-utilized or industrial areas that could be redeveloped or used for infill to accommodate Rio's growing population

Disaster Risk Management

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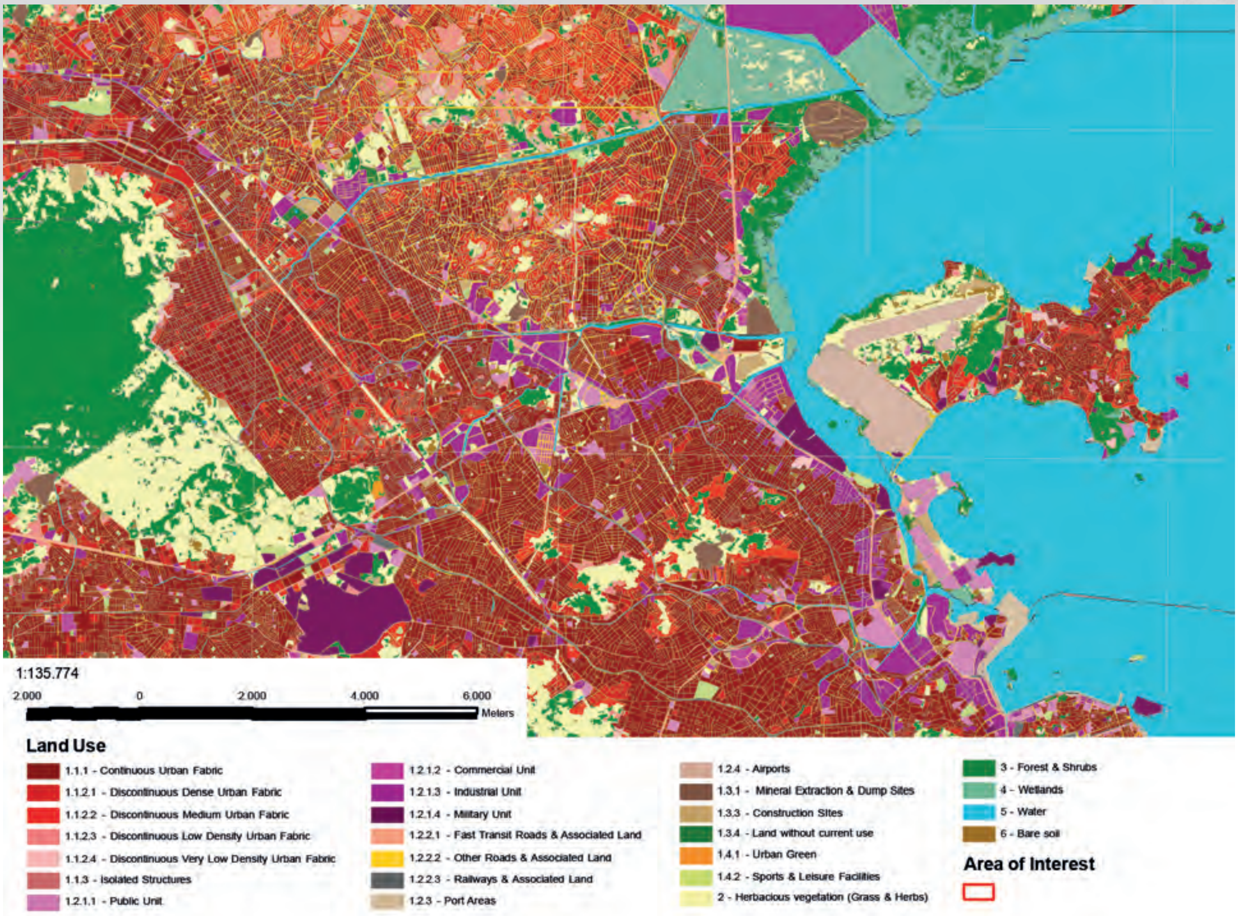

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while taking into account the risk information. As a result, the project produced a first order approximation of land potentially available for such redevelopment and located in the areas which are not prone to natural disasters. Moreover, the locations that could potentially be converted to other land uses were delineated taking into consideration the proximity of new transport investments and the need to protect existing forests,

1. Land Use map of Rio de Janeiro based on the exploitation of Very High Resolution (VHR) satellite imagery - SPOT5 optical data at 2,5m resolution - with geometric accuracy of 1:135.774 scale. Thanks to the use of VHR imagery single buildings, streets, ports, residential block density, etc. were identified with very high accuracy (up to 95%). Credit: Critical Software, NOA and INPE. SPOT5 Data © Astrium Geoservices.
2. Potential vacant land (in red). The smaller image indicates in detail land with high redevelopment potential 'Bare soil' (blue), and lower vacant potential: 'Herbaceous vegetation outside parks & protected areas' (light green) and 'Forest & shrubs outside parks and protected areas' (in darker green). Credit NEO, SPOT Data 2010 © Astrium Geoservices.

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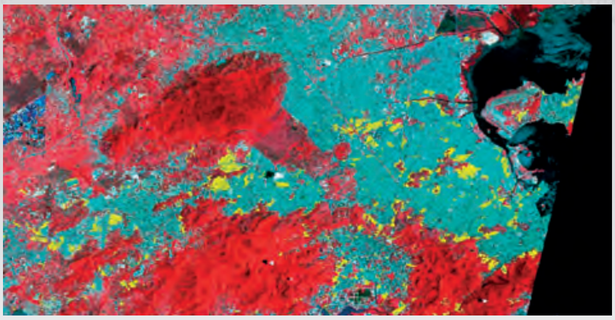

parks, and recreation areas which provide valuable ecosystem services to the city (Fig. 2.)

In this context the project demonstrated the advantage of Very High Resolution (VHR) EO data vs. traditional surveys for urban land use mapping. According to the users the cost of EO data is on average less than the data acquisition through aerial / in-situ campaigns because EO offers fast wide area coverage and affordable data handling. Satellite-based mapping is in fact a very unique way to keep up with the dynamic expansion of Rio's agglomeration through easily updatable inventories of buildings and infrastructure. It can be used for a wider set of objectives associated with sustainable urban development such as monitoring of controlled urban sprawl and associated fragmentation of communities through informal settlements, loss of green urban spaces, degradation of landscapes, or to support crises operations by providing information on demand. Moreover, in course of this project some of the rapidly sprawling informal settlements which were not previously mapped were located and georeferenced (Fig. 3).

The critical factor of building urban resilience to natural disaster is a good understanding of the types and characteristics of hazards facing the city. The use of innovative Earth Observation techniques can improve such assessment of hydro-meteorological and geohazards hazards and contribute to risk assessment for threats related to floods and landslides.

Flood scenarios

Four different flood scenarios were generated for the city to model different impacts of the same flood event when facing different land cover status. The analysis concluded that while a very dense urban area increases the fast propagation of the floods, the introduction of natural vegetation in the lower slopes, downstream the watersheds, may delay the peak of the water flow for about 2 hours (Fig. 5 and 5). In a pristine scenario, where the watershed is fully covered by vegetation, the peak of the water flow would hypothetically be delayed by about 6 hours. This type of information is crucial in formulating disaster prevention strategies enabling authorities to make informed decisions on adding green and recreational areas where the most vulnerable assets are located. It can also support proactive environmental protection strategies supporting development of natural urban landscapes. Already now Rio de Janeiro is home to the largest urban forest worldwide with plans to reforest up to 1,300 hectares of degraded land by 2016. Going forward, the city planners can take advantage of using this type of information to identify areas that are most suitable for planting of urban greenery to benefit flood mitigation strategies.

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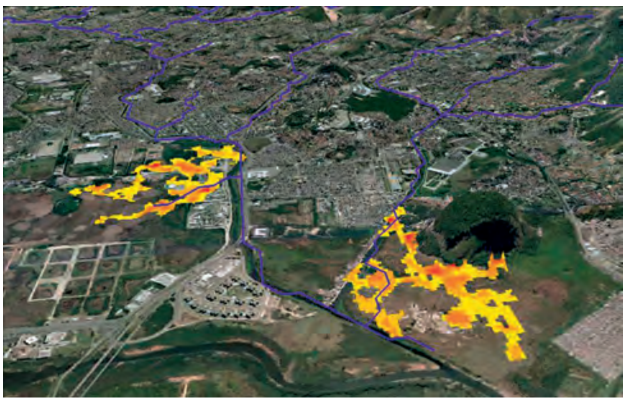

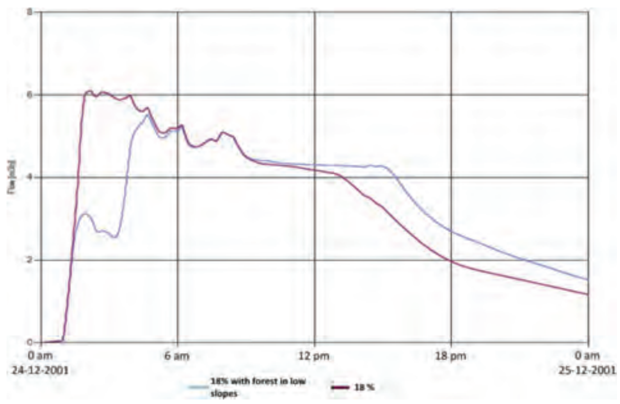

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3. Example of the map locating favelas. Credit: Neo, SPOT Data 2010 © Astrium Geoservices.
4. Example of the flood simulation product. Credit: Hidromod.
5. Flood scenario calculation (Rio Grande). Credit: Hidromod.

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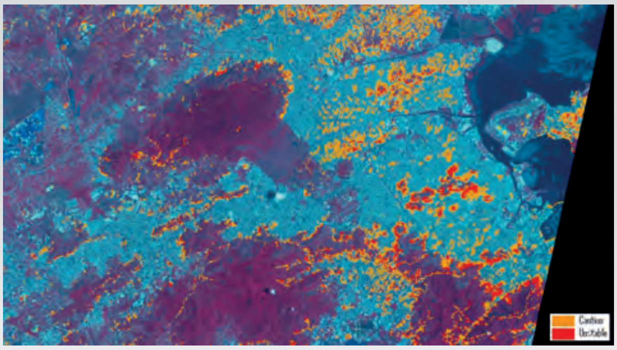

Landslides risk assessment

Since the devastating landslides which affected Rio de Janeiro in January 2010, Geo-Rio (the Rio's Geotechnics Institute) has achieved a major progress in terms of reduction in the casualties and damages from landslides as well as mapping of risk areas.

The eoworld project contributed to this process with a landslide susceptibility analysis. The landslide susceptibility map exemplified in Figure 6 is a first order classification that indicated vulnerable areas based on relations between slope steepness, flow accumulation, and urban land use. This analysis was further enhanced by adding precise terrain deformation information using radar-based Permanent Scatterer Interferometric SAR (or PS-InSAR). The deformation analysis covered the period of 2007-2011 (Fig. 7).

This type of information was provided for the first time to the city of Rio de Janeiro. It enabled the authorities to identify unstable hot-spots located the southern slopes of the hills and in coastal areas near Lago de Freitas and a polder area in North-East Rio. These coastal lowlands located on the soft clay terrain and former mangroves forests are subsiding with over 1 cm per year. This soil characteristics coupled with urban settlement pressures can potentially be a cause of subsidence however expert interpretation and interconnection with geological and geomorphological data is necessary to take the best advantage of this analysis (and to conclude the assessment of the contributing factors).

Overall, the PS-InSAR information was regarded as potentially greatly contributing to understanding of the existing landslide risk in Rio's built-up areas, especially if generated twice a year for hot-spot locations. The future EO capabilities will be well suited to provide this type of support to civil protection. With the launch of ESA's Sentinel-1 satellite the users around the world will have access to very large volumes of data to enable operational landslide monitoring services. Such identification of landslide risk and monitoring will be available on the local, regional and global scale through detecting landslide-induced surface features and land motions. Moreover, to meet the different operational needs higher resolution sensors such as COSMO-SkyMed, TerraSAR-X and Radarsat-2 already now provide a key contribution to monitoring at-risk areas with tailored observations. The use of such advanced systems however depends on the capacity of the national users to generate, validate and/or integrate this information to their national disaster risk management strategies. Even in case of Rio de Janeiro, where the disaster preparedness systems are more mature then elsewhere in developing world, there is still a need to develop outreach programs, capacity building and technical assistance to facilitate integration of EO based information to the day-to-day decision making processes.

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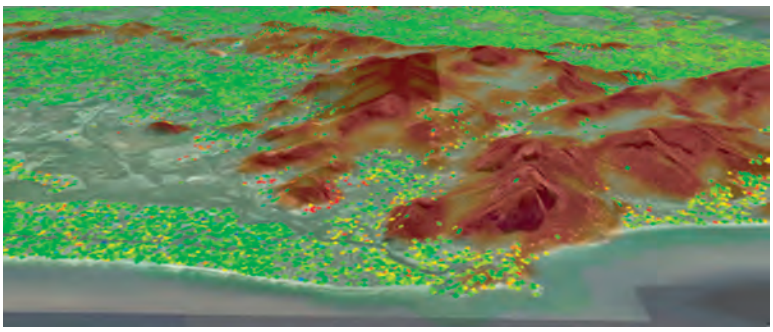


6. Landslide Susceptibility Map I showing locations that are susceptible for landslides. It is a combination of instable slopes and land use classes that have an effect on the stability as favelas and residential areas. Credit: NEO, SPOT Data 2010 © Astrium Geoservices.

7. Overview of precise deformation map. In several hundred thousand locations scattered across the city and surroundings, a point measurement of the local deformation is derived from the radar images. Credit: Hansje Brinker, Radarsat data © MDA.

Building Flood Defence Systems in Guyana

Users

World Bank Unit:
Urban, Water and Disaster Risk Management Sector Unit, Latin America and the Caribbean Region

Local Stakeholders:
Guyana national disaster preparedness and emergency management sector.

EO services provided:

- PS-InSAR mapping/monitoring of historical terrain deformations based on VHR SAR data.
- Urban mapping of infrastructure & buildings based on VHR Optical Data (1:10 000 scale).

Additional analysis:
1: High resolution Digital Elevation Model (DEM) based on VHR SAR data
2: Sea level height
3: Past Flood Analysis

Service providers:

- Altamira Information (Spain)
- Eurosense (Belgium)

ESA Technical Officer
Philippe Bally
European Space Agency
Tel: +39 06 94180537 | philippe.bally@esa.int

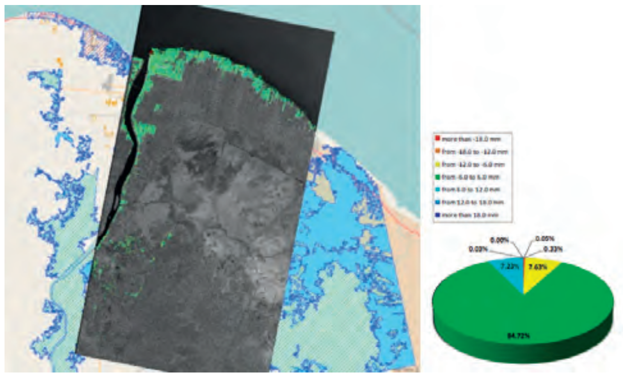
WB Task Team Leader
John Morton
The World Bank Group
Senior Urban Environment Specialist
Urban, Water and Disaster Risk Management,
Latin America and the Caribbean Region

The World Bank is currently implementing a Conservancy Adaptation Project with the objective to reduce the vulnerability to Guyana's low-lying coastal areas to catastrophic flooding. Guyana has repeatedly experienced a number of damaging floods in the past. Frequent and violent storm surges and the threat of sea level rise pose additional risk related to climate change. Therefore improving the resilience of Guyans's flood defence infrastructure is critical to reducing of the existing vulnerabilities. Selected interventions include increasing of drainage performance, revitalization of sluices and drainage canals, monitoring the safety of dikes and seawalls, as well as strengthening of the capacity of national emergency sector.

The main objective of the eoworld project was focused on the estimation of a potential land subsidence in the coastal lowland of Guyana, in particular the state of the old dyke system along the East Coast Demerara and the stability of the seawall located in the capital city - Georgetown. The terrain deformation study was complemented with up-to-date digital urban reference mapping and analysis of the assets exposed to floods based on the selected historical flood events.

Land subsidence

The majority of Guyana's population and most fertile agricultural land are located on the coastal plains which are protected from flooding by a system of sea defenses consisting of dikes, drainage canals, seawalls, and sluices. This infrastructure requires continuous maintenance and reinforcement however in discussions related to Guyana's resilience to natural disasters it has been postulated that the land itself is subsiding threatening the integrity of the infrastructure. Advanced mapping and engineering analysis was required to resolve this question, and the



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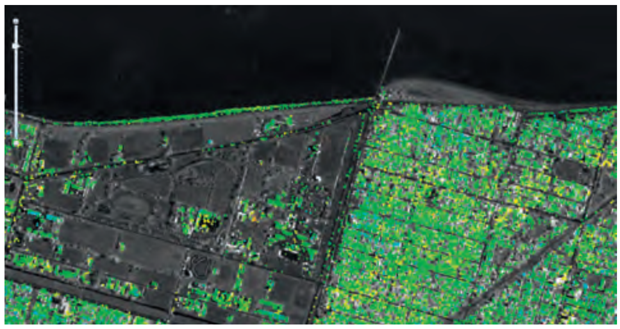

1. Percentage of measurement points in function of the magnitude of deformation. Satellite.. Credit: Altamira Information.

use of EO techniques to measure land stability provided crucial inputs to this investigation.

Potential subsidence in the coastal lowland has been evaluated using the Permanent Scatterer Interferometric SAR (or PS-InSAR) technique based on Very High Resolution radar data acquired over the 8-month period between August 2010 and April 2011. It allowed to detect terrain deformations with millimetric precision and the results have shown that the investigated area of interest is globally stable- no large scale deformation patterns have been identified (Fig.1).

Figure 1 shows the percentage of measurement points in function of the amplitude of the deformation. 84% of points were stable over the monitoring period (accumulated displacement varying between -6 and 6 mm), while about 16% of points are affected by displacement of low magnitude.

Seawall Stability

The PS-InSAR analysis was also used to investigate the condition of the Georgetown's seawall - a part of the sea defense system built to prevent coastal flooding. The analysis revealed subsidence up to -20 mm over the 8 months period. Figure 2 shows the eastern edge of the seawall, close to the Ogle Kocker, which is used to control the flow of water in the drainage canals (trenches) in the city. The color coded points indicate deformations of the concrete structure at this location which is stretching for over about 1 km. The time series of points located in this portion of the seawall are displayed in Figure 3. It is worth noting that in this pilot project ground motion is evaluated at very high resolution but over a short period of time (8 months). While it was sufficient to provide accurate measurements longer monitoring period would allow to determine the annual displacement rate of the structure, in order to clearly identify and localize potential anomalies.

Moreover, the PS-InSAR analysis is particularly useful for monitoring of flood defence infrastructure which consists of solid cover such as rubble mounds and concrete. Guyana's sea defences measuring 430 km long in the North and flood control dams in the South are however partly covered by grass posing some challenges to this monitoring technique. Installing corner reflectors would allow to overcome this problem offering important opportunities for monitoring of hundreds of kilometres of sea defence systems (Fig. 4). This solution is applicable to all coastal areas which are threatened by eroding and aging of coastal defence infrastructure especially if they require constant maintance and monitoring as in the case of Guyana.

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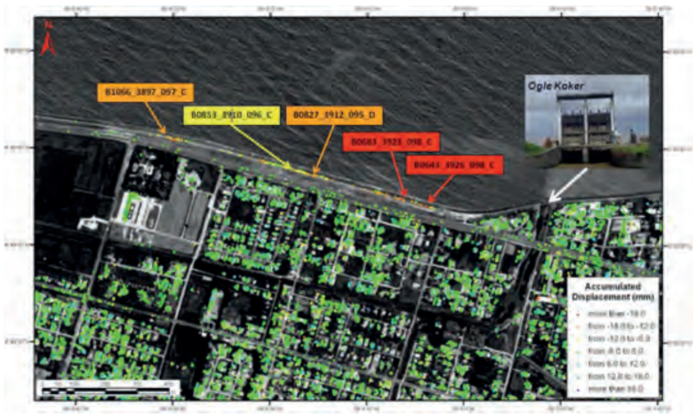

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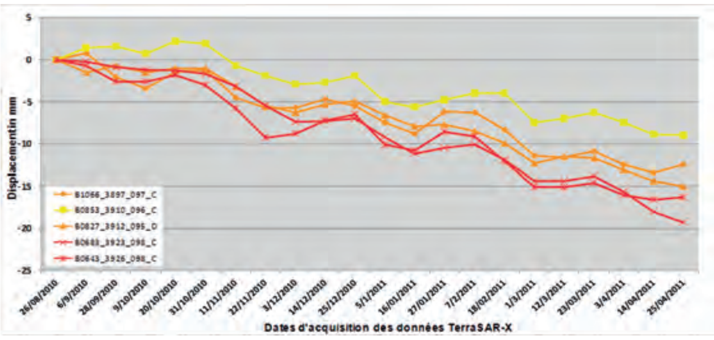

2. Accumulated displacement on the eastern edge of the Georgetown seawall – The measurement points for which time series are displayed in Figure 3 are identified by their codes. Credit: Altamira Information.

3. Time series of the measurement points located on the seawall (Figure 2) and affected by displacements of different magnitudes. Credit: Altamira Information.

4

Flood risk assessment

Strengthening the national flood emergency management sector has long been a paramount for Guyanese government as approximately 90% of Guyana's population lives on the coastal plain, which lies about 1.4 meters below mean high tide. The ability to identify and quantify the extent of the potential flooding and affected areas is fundamental for flood management. Earth Observation can greatly enhance the ways to understand and manage the impact of weather related disasters by providing in information about assets, terrain's hydrological characteristics as well as severity of past flooding to identify zones at risk.

In this context, the eoworld project helped to generate baseline information to create the inventory of main assets with a special focus on the flood infrastructure (Fig. 6). Approximately 700 km roads, 350 km of drainage canals and 2581 building blocks have been charted revealing urban density, buildings' material, distance, footprints, height, floor area and distance to drainage systems for each building block. This information can be now easily updated to monitor the status of urban development, to support emergency activities or to support proactive urban and housing development strategies.

Moreover, to better understand flood hazard the historical flood map was generated. It was based on the available archive of high resolution imagery covering the flood event of 2005, which was one of the most devastating floods in Guyana estimated to cause damages equal to 60 % of GDP for the year 2004 (Fig. 8). The combination of detailed urban maps, and available socio-economic data it served as an input to flood risk analysis. Resulting risk maps provided essential information for disaster preparedness: potential flood extent and economic losses in case of major events or dam failures (Fig. 9).

Overall these mapping products have significantly improved the accuracy of flood risk information available to date and based on the Dartmouth Flood observatory data (Fig 10).

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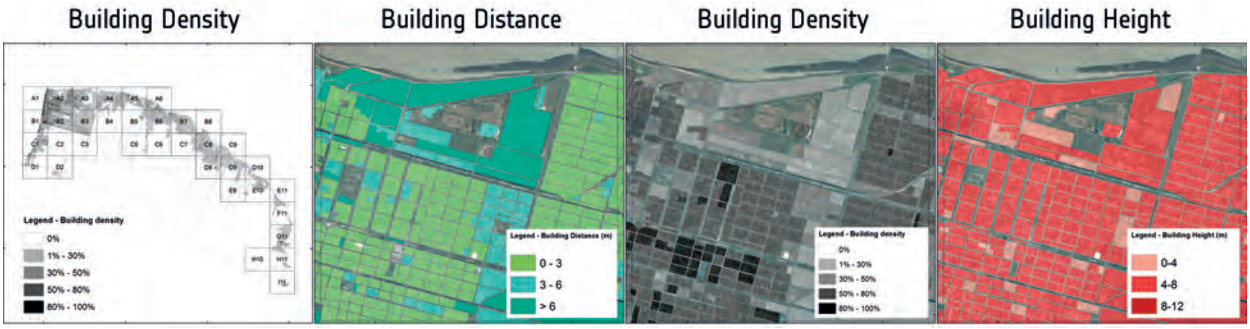

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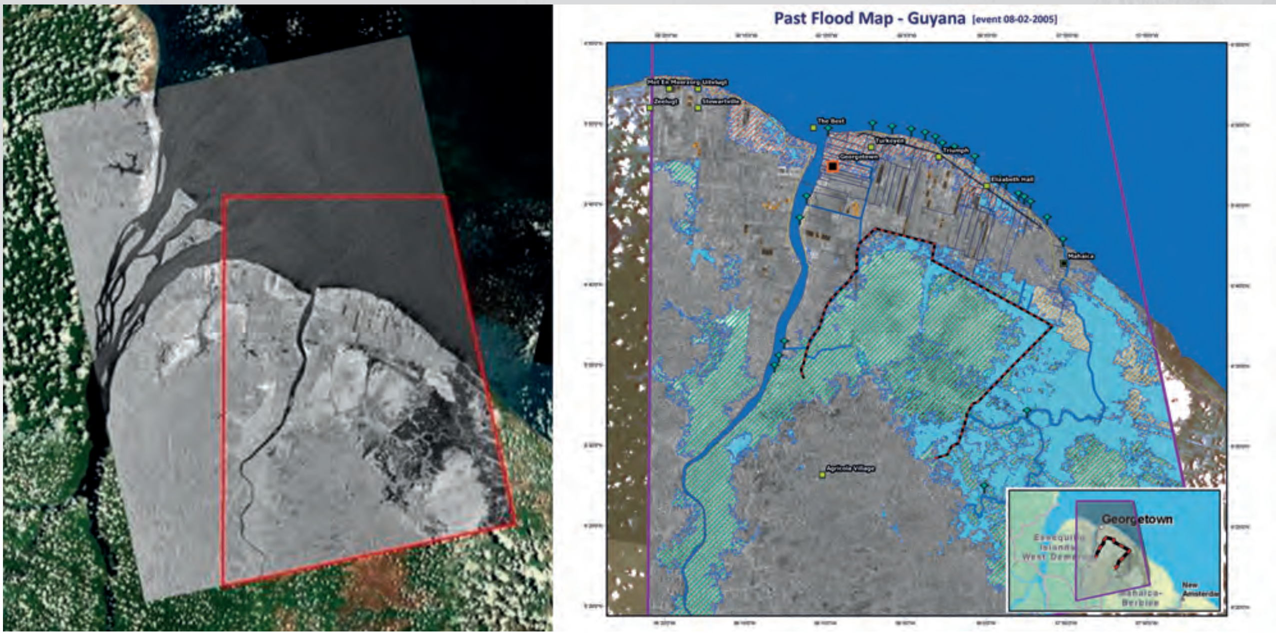

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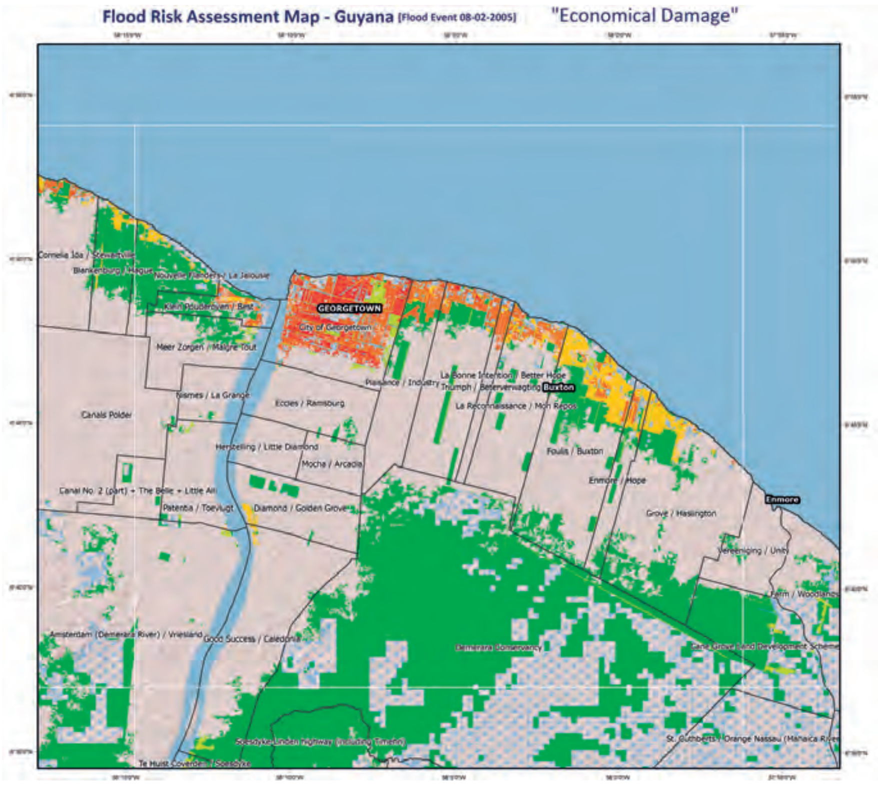

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4. Image of a corner reflector which allows to reflect radar signal.
5. An extract from Georgetown's land use map showing building's density. Credit: Eurosense.
6. The example of different construction parameters derived from EO analysis. Credit: Eurosense.
7. Past Flood map based on Radarsat imagery. Credit: Eurosense.
8. Flood risk assessment map for Georgetown. Credit: Eurosense.
9. The Flood defense system.

Multi-Hazard Vulnerability Assessment in Ho Chi Minh City and Yogyakarta

Users

World Bank Unit:
Urban, Water and Disaster Risk Management Sector Unit, East Asia and the Pacific Region.

EO services provided

- Urban mapping of infrastructure and building inventories based on Very High Resolution (VHR) Optical data (1:10 000 scale).
- Historical mapping of terrain deformations based on interferometric technique using Synthetic Aperture Radar (SAR) data.

Additional analysis:

1: Precise Digital Elevation Model (DEM) generated using VHR Optical data providing building height for an enhanced urban mapping
2: Multi-hazard vulnerability mapping addressing the risks of subsidence and flooding
3: Flood risk analysis (past flood mapping, flood hazard mapping and flood risk assessment)

Service providers

- Altamira Information (Spain)
- Eurosense (Belgium)
- Center for Environmental Engineering (Vietnam)

ESA Technical Officer
Philippe Bally
European Space Agency
Tel: +39 06 94180537 | philippe.bally@esa.int

WB Task Team Leader
Fatima Shah
The World Bank Group
Senior Urban Specialist, South Asia Region

Zuzana Stanton-Geddes
Operations Analyst, East Asia Pacific Region

"The foundation for Disaster Risk Management is understanding the hazards, and the exposure and vulnerability of people and assets to those hazards. By quantifying the risks and anticipating the potential impacts of hazards, governments, communities, and individuals can make informed prevention decisions. Such information can be used to set priorities for development and adaptation strategies, sector plans, programs, projects, and budgets."

The World Bank Sendai Report, 2012

The World Bank has promoted a number of analytic risk management tools to help local policymakers to assess their cities' susceptibility to natural hazards. One of them is Multi-Hazard City Risk Index (MHCRI) – city-focused metric system aimed to assess their susceptibility to risks, over time and relative to other cities. MHCRI was developed to stimulate the process of urban risk assessments and raise awareness concerning the importance of developing adequate disaster risk management plans.

There are many factors contributing to risks cities face. East Asian cities, for example, are particularly vulnerable to the impacts of extreme weather events, climate change and sea level rise. Taking into account their rapidly increasing population and the fact that high density urbanized areas are often situated on coastal flood-plains or the low-lying deltas their exposure and vulnerability to flooding is particularly high.

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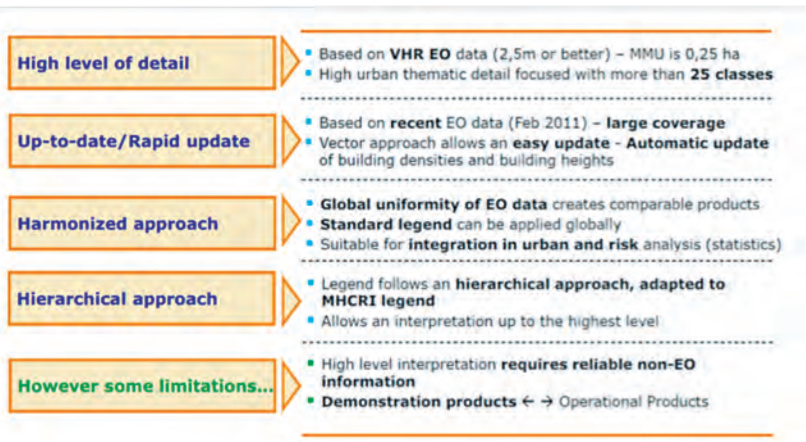


Moreover, due increases in temperature and precipitation patterns they are expected to experience even more severe shocks as a result of climate change.

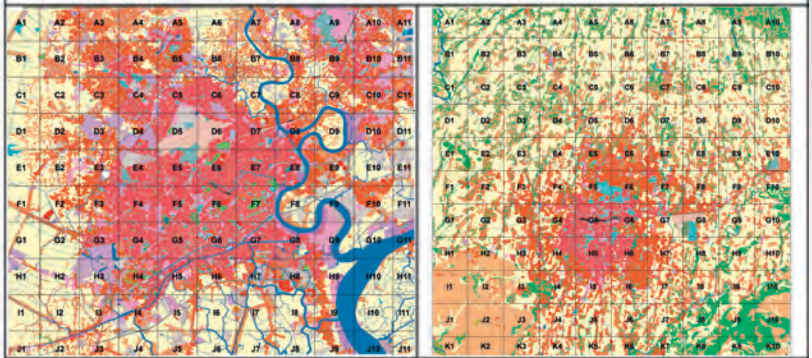
The existing risks are often amplified by poor urban risk management practices. This can manifest in allowing concentration of the poorest and most vulnerable populations in the risk prone areas or anthropogenic changes to the urban landscape, such as ground water extraction

Table 1

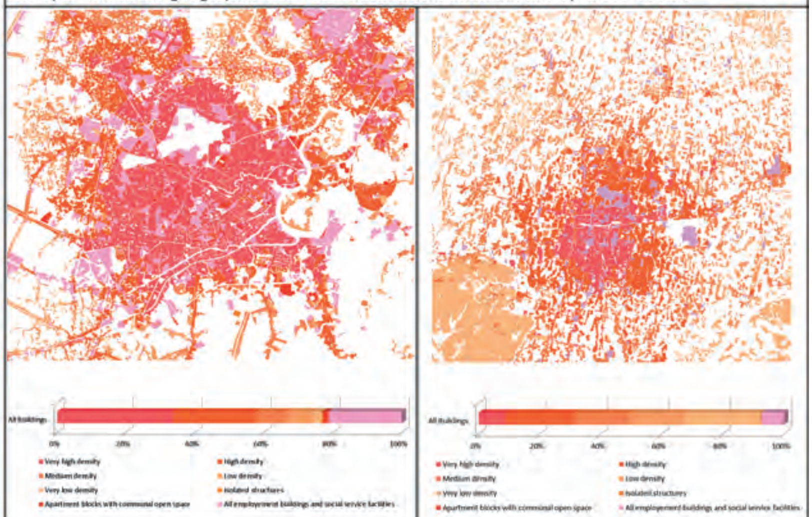
Legend Urban map

- 1000 All buildings
- 1100 All residential
- 1120 Very low density
- 1130 Low density
- 1140 Medium density
- 1150 High density
- 1160 Very high density
- 1170 Apartment block with open communal space
- 1180 Isolated structures
- 1200 All employment buildings and social services
- 1210 All employement buildings
- 1211 Commercial area
- 1212 Industrial area
- 1220 All social service facilities
- 1221 Education
- 1222 Health
- 1223 Sport and leisure facilities
- 1224 Other public military and private services
- 2000 All infrastructure
- 2100 All energy and power
- 2200 All flood control infrastructure
- 2210 Canals
- 2600 All road transport
- 2610 expressways and highways (incl. overpasses and viaducts)
- 2620 Other roads
- 2630 Bridges
- 2700 All public transport (incl. inter-city rail)
- 2720 Inter-city rail
- 2721 Passenger railway stations
- 2722 Freight marshalling yards
- 2800 All air transport
- 2820 International airports
- 2830 Aircargo facilities
- 2900 All water transport infrastructure
- 2910 Passenger terminals
- 2920 Bulk cargo terminals
- 2930 Liquid cargo terminals
- 2940 Container terminals
- 2950 Drydock
- 3000 All environmental sensitive areas
- 3100 Public open space
- 3200 Wetlands
- 4000 Agricultural areas
- 5000 Forest and semi-natural areas
- 5100 Forest
- 6000 Water
- 7000 Mine and construction sites
- 7200 Construction sites
- 7300 Land without current use

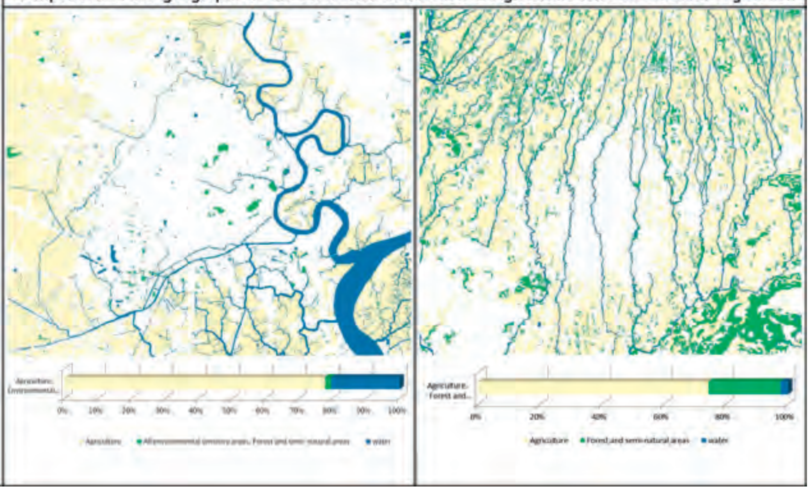
URBAN MAP in scale 1:10.000 in Ho Chi Minh City (left) and Yogyakarta (right) MMU in urban area = 0.25 ha, MMU in rural area = 0.5 ha



Comparison of the geographical and statistical distribution of build-up areas classes



Comparison of the geographical and statistical distribution of Agriculture land and natural vegetation



1. The benefits of urban mapping of infrastructure and building inventories for Multihazard City Risk Index. Credit: Altamira Information / Eurosense.
Table 1. Mapping of Ho Chi Minh City and Yogyakarta based on EO-derived information using Urban Atlas methodology (Eurosense for European Space Agency/World Bank, 2011)

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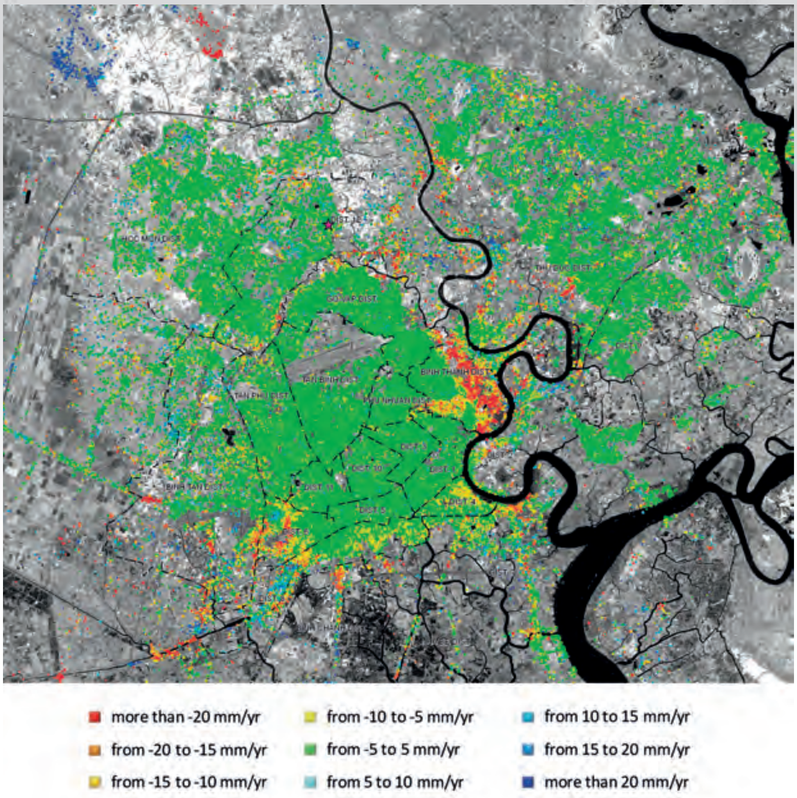

that leads to land subsidence which account for a great share of the damage cost from flooding. Therefore the development of the reliable measures to better quantify the exposure of urban areas taking into account a whole range natural and man-made risks is paramount. In this context, eoworld project contributed to this multi-hazard risk identification with two elements:

- a scalable methodology for using satellite data to advance hazards identification and characterization with a special focus on hydro-geological hazards (such as floods, urban subsidence, mudflows and landslides)
- multi-hazard vulnerability analysis based on the combination of hazard information, information about location and distribution of assets and socioeconomic data.

The methodology was demonstrated in two South East Asian cities: Ho Chi Minh City (HCMC) in Vietnam and Yogyakarta in Indonesia. These two cities were selected because currently their municipal governments seek innovative risk management strategies. In Ho Chi Minh City the main concern is flood risk management. In Yogyakarta, which is particularly exposed to the damages caused by Merapi volcano eruptions and associated lahars (mudflows), which in 2010 have caused a displacement of app. 350.000 people, the civil protection authorities need better risk management and preparedness tools.

The hazard vulnerability analysis is a process which involves a collection of various input data concerning hazards (flood, landslides, subsidence) and exposure factors (location and characteristics of urban infrastructure, buildings, population, critical facilities, etc.). In this case EO-based information was primarily used for analysis of terrain deformations and past floods and for creating buildings and infrastructure inventories.

Infrastructure and building inventories

The urban maps for Ho Chi Minh City and Yogyakarta have been produced at the scale 1:10,000, over an area of about 1400 square kilometers in total. Approximately 1000 kilometers of roads, 580 kilometers of waterways and almost 4000 residential building blocks have been

3

2. Terrain Deformation measurements in HCMH City based on the PSI analysis of ERS and ENVISAT ASAR data (1996-2010). The results are overlaid on a SPOT 5 multispectral image acquired on Feb. 14th, 2010. Credit: Altamira Information, ENVISAT ASAR image data © ESA.

3. Example of the terrain deformation analysis in Binh Than District. Bing© maps serve as a background image.

mapped in HCMC and approximately 500 kilometers roads, 500 kilometers of waterways and over 3000 building blocks in Yogyakarta. The classification rules and the description of each land use class is showcased in detail in Table 1.

Before the completion of this study only limited data concerning urban infrastructure and building inventories was available for both cities. The eoworld project demonstrated that urban classification, especially if conducted for multiple cities and in comparative perspective can be successfully derived from optical satellite imagery by automatic classification offsetting the limitations of alternative field/on site research which would have been a more difficult and time consuming process (Fig.1)

Historical mapping of terrain deformations

In HCMC rapid urban development coupled with groundwater extraction resulted in land subsidence that is considered one of the risk elements in the city and a factor that affects flood resilience. Some previous studies indicated that terrain deformations in the city vary from 1 cm/year to, in some places, 5 cm/year, on average being between 1 and 3 cm/year, however, the exact rate of subsidence was not known. The use of Persistent Scatterer InSAR (PS-InSAR) technique allowed, for the first time, to evaluate these trends in greater detail.

The map in Figure 2 and 3 represents the evolution of terrain deformation in HCMH betwveen February 1996 and April 2010. Several affected areas were clearly identified. As the motion is mainly visible at the location of the water pumping stations and wells it is likely that it is caused by the uncontrolled ground water extraction. The most important subsidence was detected in Binh Than District. The mean deformation rate reaches -47 mm per year in the area closer to the Thu Thiem Bridge that crosses the Saigon River. The deformation continues towards the North up to -32 mm/ year at the border with Go Van District. Deformation patterns have also been identified around the Nhieu Loc-Thi Nghe Canal where measurement indicates a subsidence of -6.5 mm/year. The districts Go Vap, Tan Phu, Tan Binh, Phu Nhan, 1, 3, 5, 10 and 11 were detected as stable.

In Yogyakarta the problems with terrain motion manifests itself in the form of landslides. While the analysis of land stability in Sleman, Kodya (Yogyakarta City), Bantul and Kulon Progo Regencies indicated that the locations are generally stable, some deformations leading to the occurrence of landslides could have been clearly identified and color-coded in yellow and red (Fig. 4). These findings were based on three independent studies based on three different sensors (ENVISAT/ ASAR, ERS and ALOS) which have been conducted to

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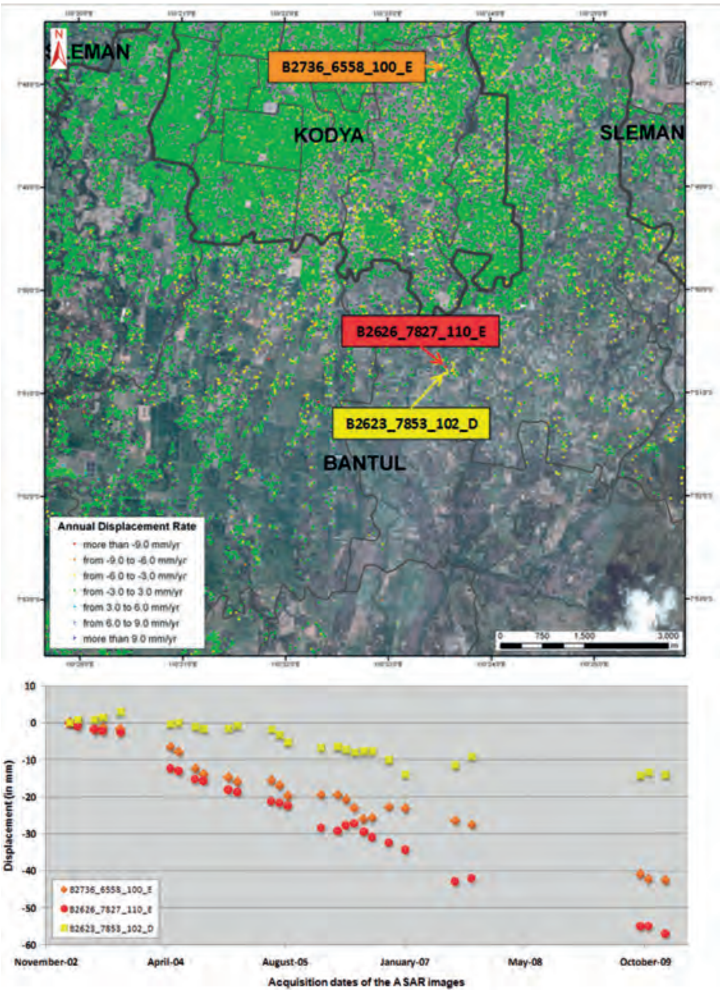

4. Terrain deformation in Yogyakarta City and Bantul Regency derived from the analysis of ASAR data (2003 - 2009). Credit: Altamira Information.

assess terrain deformations over the period of 15 years (1996 – 2011).

Flood Risk Analysis

The analysis of EO archive data can provide information on flood risk: location of permanent water bodies, extent of past floods (maximum), flood duration/frequency per area, the type of flooded land cover, and a probability that the area is going to be flooded.

The historical flood information over the HCMC was derived from satellite observation of a flood event from October to November 2001 at the time when the Mekong River Delta in southern Vietnam was flooded

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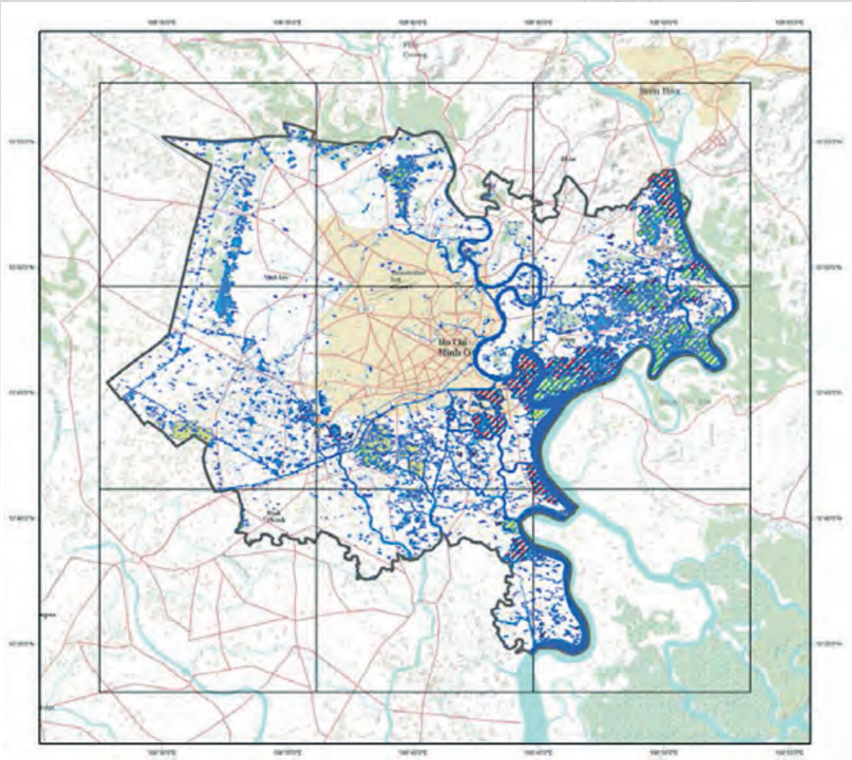

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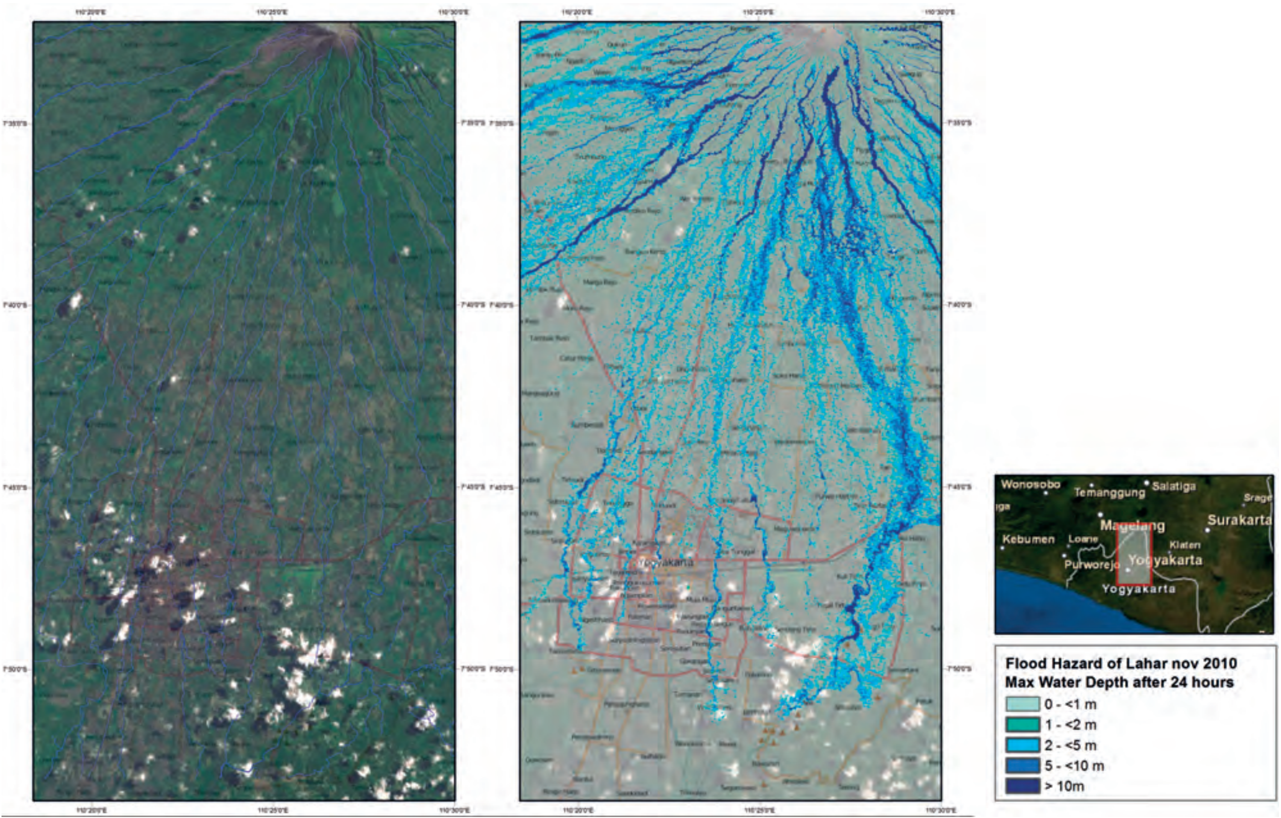
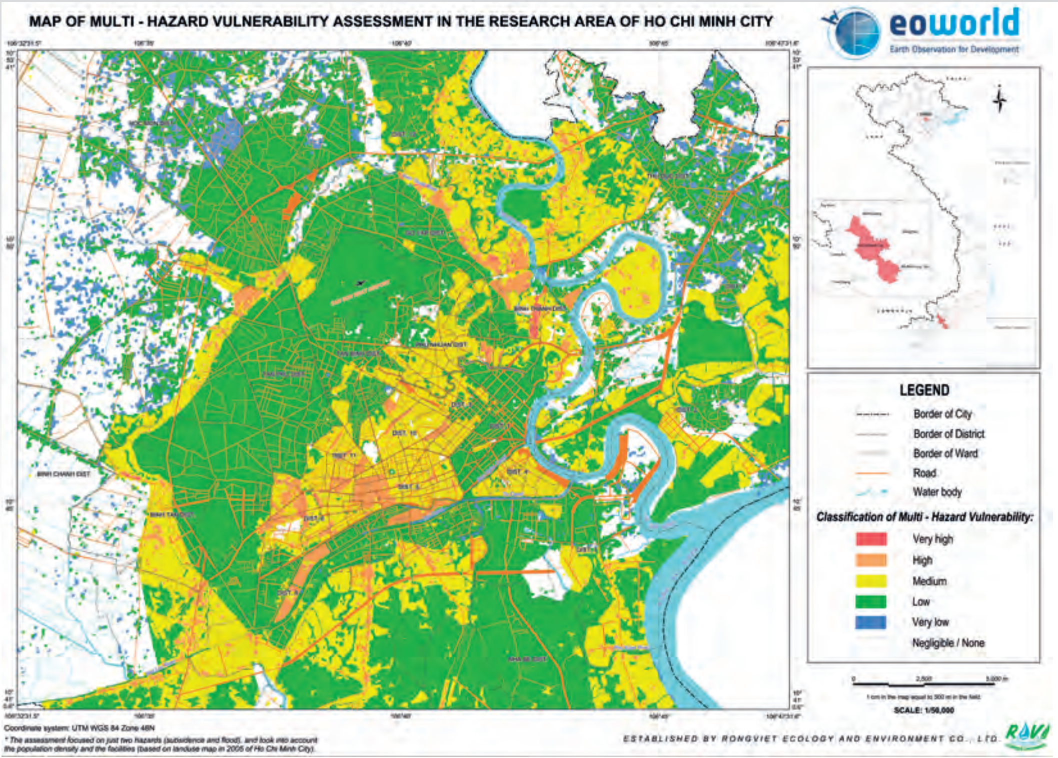


5. Past flood map in HCMC.

6. Flood hazard simulation corresponding to the Merapi lahar flood of November 2010. The image on the right represents flood simulation: the extent of flood and a water depth. The image on the left has additional layer of information indicating the affected urban land cover. Credit: Eurosense.

7



after the monsoonal rains (Fig. 5). The provinces most seriously affected were Long An, Dong Thap and An Giang. In late October water levels in lower Tien and Hau rivers were on the rise due to the appearance of the spring tide which has submerged larger areas in Kien Giang, Vinh Long, Tien Giang, and Ben Tre provinces and some suburban districts of Ho Chi Minh City.

In Yogyakarta the flood risk assessment was developed based on the simulation of the lahar event of November 29-30, 2010 following the eruption of Marapi volcano. In Yogyakarta floods are commonly caused by the flow of cold lava (lahar flood). They occur during and after heavy rainfall when the debris of the eruption (due to the sedimentation of lava in the river) are driven by flash flood current. The eruption of Mount Merapi on 25 October 2010 in combination with heavy rain fall caused such a flooding event. Figure 6 shows the water extent of the rivers flowing downstream from Mount Merapi to Yogyakarta and surroundings (in blue). The window on the right shows the water extent and water depth after 24h simulation of the event.

Multi-Hazard Vulnerability Mapping

The urban maps, terrain motion maps and past flood maps were the key inputs to Multi-Hazard Vulnerability Mapping which combined hazard information (floods assessment and subsidence information) with available socio-economic data.

The map in Figure 7 is the first order of analysis conducted for Ho Chi Minh City and indicating that the most vulnerable area of Ho Chi Minh City is located in Binh Than District which is located in flood-prone area, heavily urbanized and affected by high rate subsidence. The vulnerability assessment was computed using flood and subsidence information and resulting exposure of population and assets to these hazards. Moreover, many other areas show a similar level of vulnerability. For example in Districts 5, 8 and Go Van, which are located in close proximity to rivers and canals, are vulnerable to flooding.

Vulnerability is relatively moderate in Districts 10, 11, Phu Nhuan and Binh Chan which experienced some flooding in the past but are not affected by subsidence.

7. Multi-Hazard Index map at the scale 1:50,000 derived from the Multi-Hazard Index and Exposure. Credit: RAVI.

Analysis of Land Subsidence in Jakarta

Users
World Bank Unit:
World Bank, Indonesia Country Office (Jakarta)
Local Stakeholders:
DKI local government of Jakarta

EO services provided
PS-InSAR mapping/monitoring of historical terrain deformations based on VHR SAR (Cosmo-SkyMed) and other SAR data (ALOS PALSAR)

Additional analysis:
Thematic analysis of the causes of possible land deformation over Jakarta

Service providers
Altamira Information (Spain)
ITB Bandung Institute of Technology
(Jakarta - Indonesia)

ESA Technical Officer
Philippe Bally
European Space Agency
Tel: +39 06 94180537 | philippe.bally@esa.int

WB Task Team Leader
Fook Chuan Eng
Senior Water and Sanitation Specialist, Sustainable Development Department,
World Bank Country Office, Jakarta, Indonesia

Arlan Rahman
Infrastructure Specialist,
World Bank Country Office, Jakarta, Indonesia

Jakarta is highly vulnerable to the impacts of natural disasters. The greatest risk facing the city, one that imposes very high human and economic loss, is related to flooding. Particularly in the north part of the city, the local neighborhoods are extremely vulnerable to damages from sea water intrusion and coastal inundation. This is largely because the flood risk is aggravated by rapid land subsidence. The existing evidence shows that if sustained at the current pace, it would result in coastal defences sinking to 4 to 5 meters below sea level by 2025, resulting in some industrial and residential areas and ports to be completely submerged in the next decades.

To help address the situation, the World Bank is currently implementing a flood mitigation project in collaboration with Jakarta's local municipal government (DKI) and the Indonesian Ministry of Public Works. This includes revitalization of Jakarta's drainage canals and flood retention ponds, establishment of a Flood Management

"Previous information on subsidence were largely based on terrestrial sample point monitoring, and do not offer anywhere the resolution, quality or timeliness possibilities offered by this analysis. This study provided much recent and more comprehensive and encompassing information and at higher resolution than previously available. It was suitable for use: both to update on previously available data on Jakarta's subsidence, and particularly as a means to achieve higher sense of urgency when communicating the issue to Jakarta decision makers and stakeholders. The Government is implementing a World Bank supported flood mitigation project targeted at restoring existing flood channels. The information on subsidence at local level provides the knowledge to enable a better idea of infrastructure reconfiguration needs going forward in the long term flood mitigation efforts in Jakarta. The high resolution analysis provides for a more compelling justification for projects and better impact when in project discussions and dialogue with the authorities and stakeholders. The timeliness and relatively quick analysis provides for the possibility to shorten the project preparation timeframe."

Fook Chuan Eng,

Senior Water and Sanitation Specialist,
World Bank Jakarta Country Office

Information System, and increasing the capacity of the existing hydraulic networks. Collection of detailed geospatial information concerning land subsidence patterns greatly contributed to this process.

Understanding long term subsidence

Land subsidence in Jakarta is largely caused by uncontrolled ground water extraction – withdrawal of underground water through deep wells to compensate for the lack of

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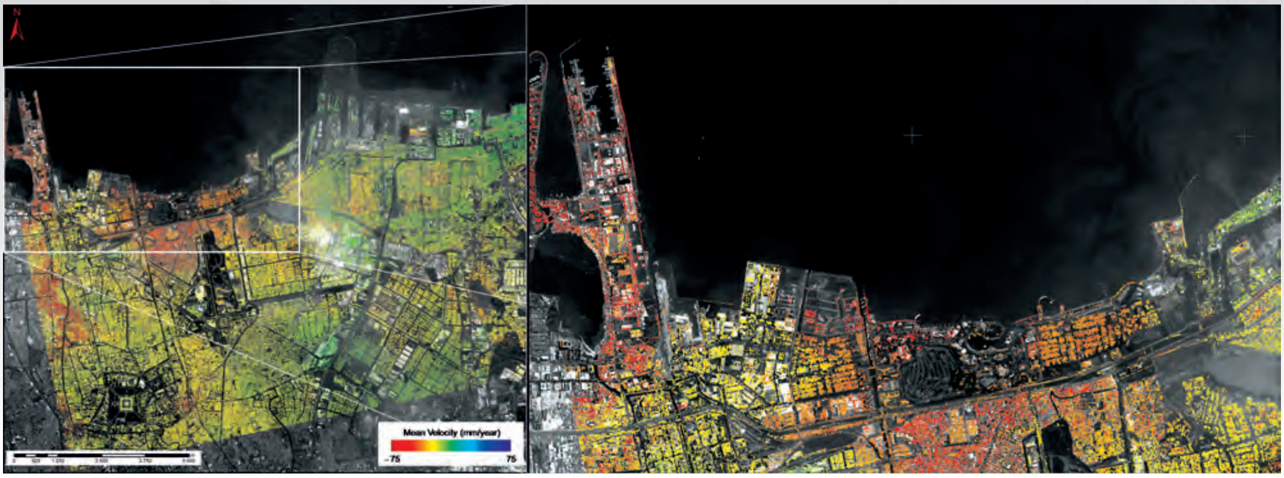


access to piped water. It is estimated that 20% of such well are over 100 meters deep often causing aquifers to collapse. Other contributing factors include heavy constructions exacerbated by the fast paced urban development, as well as the natural consolidation of soil and tectonics.

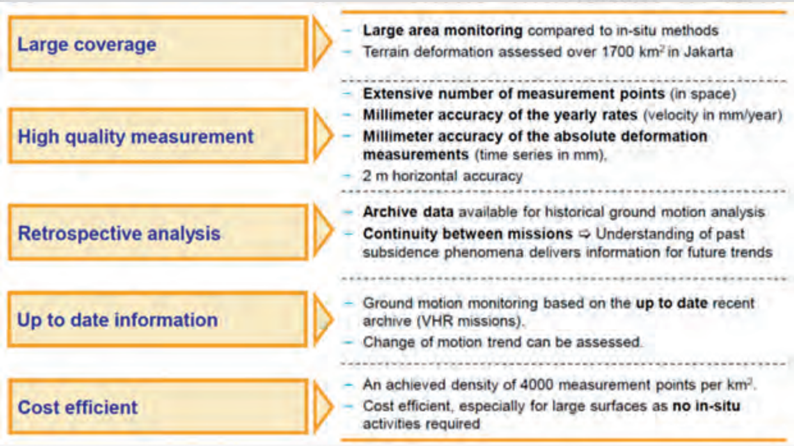
In this context Earth Observation offered a unique insight into past trends as well as state-of the art tools for monitoring of present and future terrain deformations. The EO results revealed that the sub-districts of Penjaringan, Cengkarang, the South Center of Jakarta and the suburban district of Cikarang are affected by strong subsidence rates. In the Jakarta Bay (District of Penjaringan (Fig. 1), where a system of sea walls, water draining channels, canals, and water reservoirs protecting the land from sea flooding are located, the maximal detected subsidence rate is more than -15 cm/yr, resulting in a deformation of more than -60cm over the period of 4 years.

With an archive of imagery with good spatial and temporal coverage spanning the past two decades, EO data yielded land motion information at an unprecedented level of detail and accuracy. Two parallel InSAR studies from two different satellites were conducted using:

- Very High Resolution (VHR) COSMO-SkyMed data gathered over the six months period from October 2010 to April 2011 which yielded very high spatial and temporal density of measurements in the specific constructed areas.
- High Resolution (HR) ALOS archived data from January 2007 to end of February 2011 which provided information concerning terrain motion of higher amplitude and over the period of 4 years.

Data were processed through the Persistent Scatterer Interferometry (PS-InSAR) technique - a method that accurately estimates the near vertical terrain movement with sub-milimeter accuracy. Figure 2 and 3 show the terrain deformation maps generated within the framework of the study. Figure 1 represents the map of deformation rates over Jakarta derived from 12 Cosmo-SkyMed images acquired over 6 months, between October 2010 and April 2011. Figure 2 shows terrain motion of higher amplitude and over the period of 4 years using High Resolution (HR) ALOS archived data from January 2007 to the end of February 2011.

1. Subsidence as measured by COSMO-SkyMed in Jakarta harbor and Panjaringan district where water draining channels, canals, and water reservoirs protecting the land from sea flooding are located. Credit: Altamira Information.; COSMO-SkyMed data Credit: e-Geos.



The use of satellite imagery has significantly expanded the knowledge of land subsidence in Jakarta, which was detected for the first time in 1920's and initially measured by repeated levelling surveys. These measurements were unfortunately discontinued for fifty years, until 1978, when lowering of groundwater-level, increased inland-sea water intrusion and land subsidence began to significantly impact permanent infrastructure causing the expansion of flooding areas. Since then several techniques were used to assess the magnitude of the problem (e.g. levelling surveys, extensometer measurements, ground water level observations, GPS surveys, and InSAR) (Fig. 6). However, while these datasets were of high quality, they had a number of limitations, in particular little spatial distribution and low frequency of measurements. In comparison, EO-based observations provided a very high motion accuracy and wide area coverage corresponding to the satellite image (40x50km2 for Cosmo SkyMed and 70x100km2 for ALOS PALSAR used in this project) and much greater number of measurements points which expanded exponentially from 80 (GPS and extensometer stations) to 1.3 million points with ALOS and 5 million points with COSMO-SkyMed. This in turn allowed very detailed assessments, including at the level of single infrastructure elements. Moreover, the combination of independent measurements from different satellite sensors became the basis of calculation of land motion of different magnitudes and in various environments - built-up and rural areas alike - identifying the zones which are at risk of subsidence and which were not previously evaluated by in-situ techniques.

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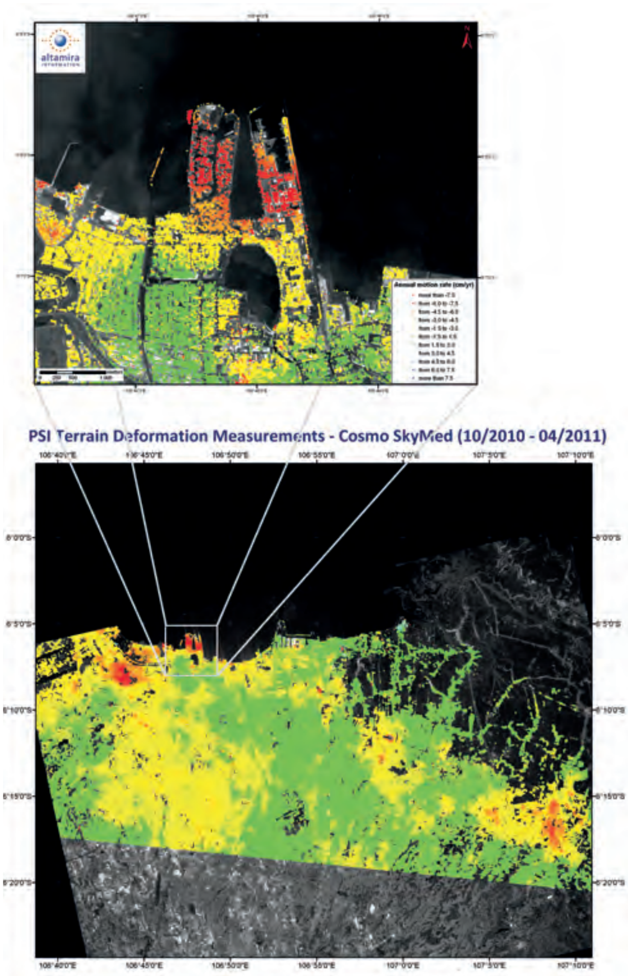


Monitoring of deformations

One of the key achievements of the eoworld project was a demonstration of the operational monitoring capability, which was designed to understand a behavior of single infrastructure elements in Jakarta and to evaluate changes (improvements or deterioration) in the affected areas. Thanks to high-resolution sampling and the fast repeat cycle of COSMO-SkyMed satellite (in this case every 16 days) it was possible to derive very precise information regarding the terrain movement and trends evolution (acceleration and slowdown) over the 6 month monitoring period. This type of monitoring is particularly

2. Land deformation map over Jakarta at the scale 1:30.000 derived from the analysis of COSMO-SkyMed data acquired from October 2010 to April 2011 – Some sectors of Jakarta Bay show an accumulated subsidence of more than 60 mm. Credit Altamira Information.

Higher spatial resolution of Very High Resolution SAR (radar) data

- More precise information on the spatial evolution of the subsidence
- Assessment of how single infrastructure (building, historical monument....) are affected
- Identification of zones at risk where terrain deformation has still not been evaluated by in-situ techniques.

Higher temporal distribution of measurements achieved with the high revisit rate of the Very High Resolution SAR mission

- Precise information on the change of subsidence trend (deceleration, stabilization, uplift...)
- Monitoring of fast motion

High revisit rate of the Very High Resolution SAR mission:

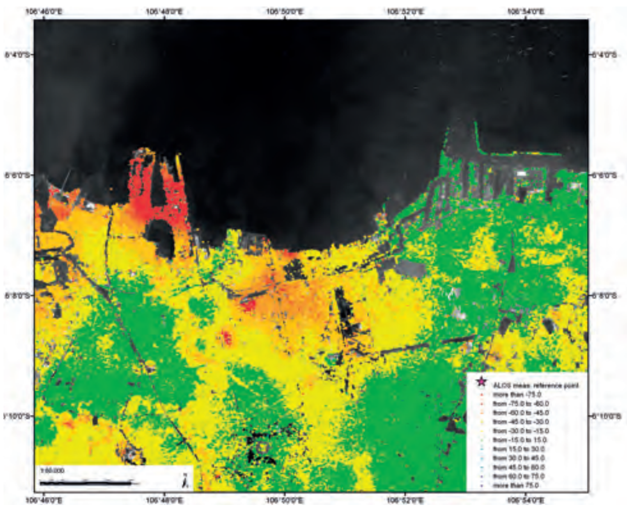
- Fast building of the suitable data archive for monitoring.
- Up-to-date information on the changes in areas affected

useful to measure not only fast subsidence but also the stabilization of infrastructure providing an insight into the effectiveness of the applied mitigation measures (see Fig. 4 and 5).

The benefits of eoworld mapping products go beyond improvements in resolution and detail in comparison to alternative techniques. In fact, the use of EO was extremely useful in framing a World Bank dialogue with the local government to convey the importance of prevention actions. The occurrence of severe subsidence was relatively well known to the public in the past and yet, despite alarming figures it was largely unaddressed as a risk factor. Institutional fragmentation as well as the absence of effective mechanisms for metropolitan coordination hindered the local government's ability to act preventively on the policy and technical level. The unique insight offered by the EO results gave the opportunity to raise the profile of land subsidence problem and bring it back to light from an entirely new perspective.

This type of operational information was not previously available to the stakeholders. With EO-data it was possible to demonstrate that it is feasible to analyze the problem accurately and objectively, in a consistent manner and offering a common analytical framework to improve the coordination of institutions that are impacted by subsidence and involved in the management of the affected zones (port authorities, agencies responsible for transport, water resources, housing and settlements, and disaster risk management.) It immeditely highlighted the importance of integrating subsidence data to the city spatial planning and to evaluate the type of necessary interventions (i.e. monitoring the stability of high-rise buildings and Jakarta coastal defense infrastructure, or controlling ground water extraction). The capacity to use these products is however yet to be explored. These techniques require IT infrastructure capable to handle large volumes of complex data as well as the capacity to analyze it and to set information requirements for a monitoring system. For this reason it is necessary to invest more in awareness raising efforts, capacity building with specialized geological survey institutes as well as information technology infrastructure to make sure that the risk information is put to operational use.

3



3. Land deformation map over Jakarta at the scale 1:60.000 derived from the analysis of ALOS data acquired from January 2007 to February 2011. Credit: Altamira Information

Building Exposure Maps of Urban Infrastructure and Crop Fields in the Mekong River Basin

Users

World Bank Unit:
Urban, Water and Disaster Risk Management Sector Unit, East Asia and the Pacific Region

Local Stakeholders:
- Mekong River Commission
- Cambodia's National Committee for Disaster Management (NCDM)

EO services provided
- Urban mapping of buildings and infrastructure based on Very High Resolution (VHR) Optical data and enhanced by in-situ data collected in the field
- Crop types and acreage mapping based on Synthetic Aperture Radar (SAR) data

Additional analysis:
Historical flood and drought hazard mapping

Service providers
GeoVille (Austria)

ESA Technical Officer
Philippe Bally
European Space Agency
Tel: +39 06 94180537 | philippe.bally@esa.int

WB Task Team Leader
Henrike Brecht
The World Bank Group
Disaster Risk Management Specialist, East Asia and Pacific Infrastructure Unit

The World Bank is currently implementing the Integrated Water Resources Management (IWRM) Project in the Lower Mekong Basin to establish examples of and mainstream the best IWRM practices in the region. One of the key objectives is to support disaster risk management to address naturally occurring hazards such as floods, flash floods as well as droughts. With climate change they are expected to become more frequent and less predictable in this area posing additional risk to people inhabiting flood prone plains which are often one of poorest rural communities relying on seasonal rains and the natural flooding of low-land croplands for rice cultivation.

As a part of disaster resilience strategy in the Mekong Basin the Bank proposed a suite of disaster resilience tools including risk management information platform as well as a multi-hazard open-source modeling tool for probabilistic risk assessment. In this context, EO data was used to demonstrate the added value of satellite remote sensing to characterize the types of hazards occluding in the basin (floods) and their variability (droughts), and to building up the inventory of exposed assets. The study was piloted over the selected areas in Cambodia, however as currently such geospatial data is not widely available for the Mekong region, a particular emphasis was put on the scalability of this approach to the entire basin (including Vietnam and Laos).

Hazard risk analysis relies heavily on the availability and quality of the exposure data showing pre-disaster characteristics of assets potentially exposed to hazards. The required minimum information is usually pertaining to the location and characteristics of infrastructure, buildings, as well as crops, and crop cultivation patterns when considering predominantly rural areas.

Inventory of buildings and infrastructure

In the Mekong basin existing data and information collection systems were long deemed inadequate to

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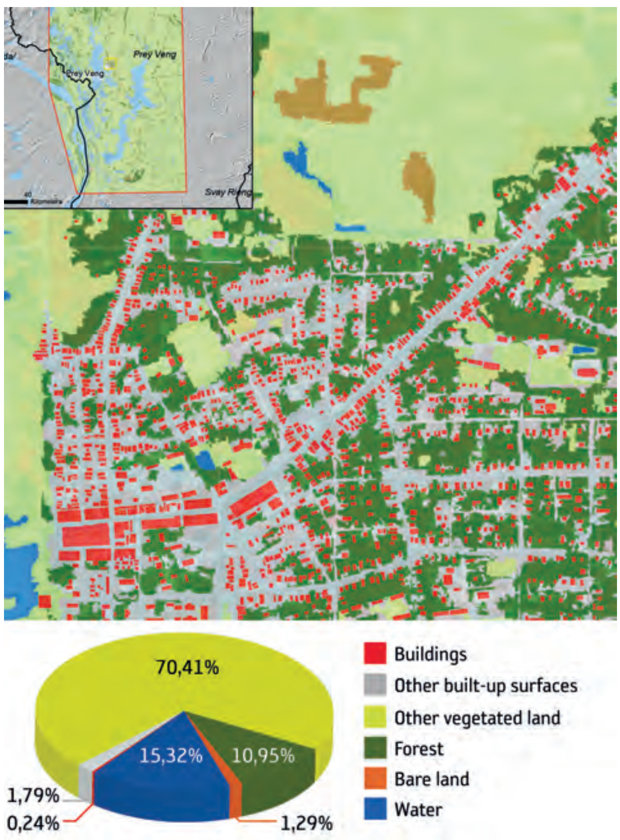
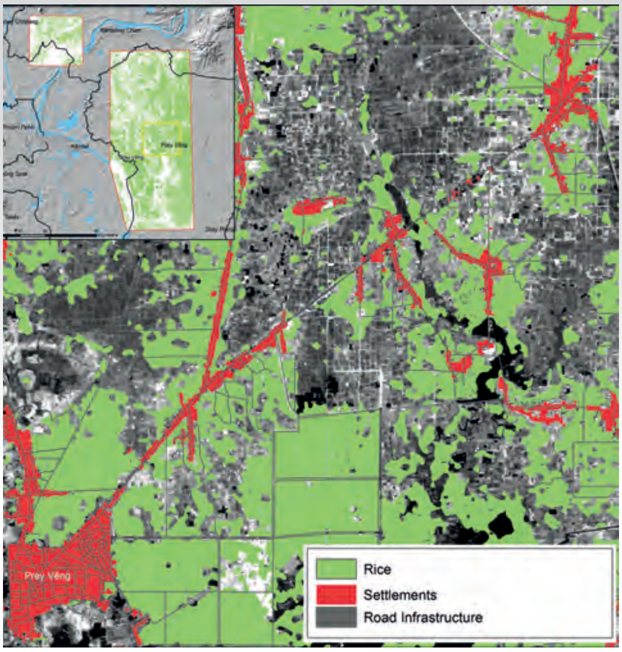


1. Detailed map of building footprints and other general land cover types. Credit: Geoville.

2



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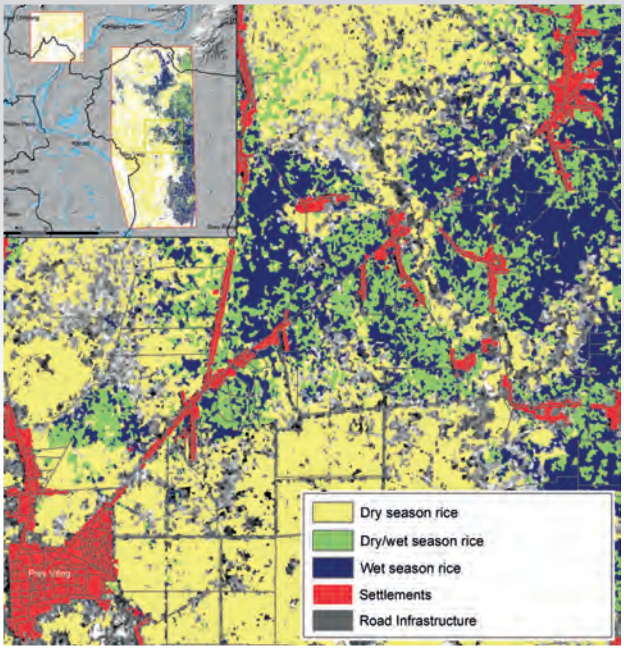
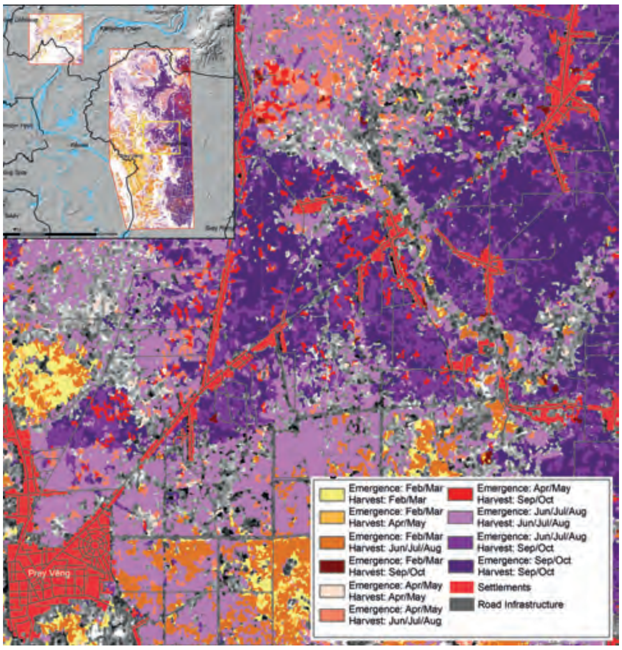


capture the complexities of the basin, given its size, seasonal variability, transboundary character and the rapidly increasing concentration of people exposed to disasters. EO data is a very effective tool to provide objective and synoptic observations of elements at risk. The eoworld project provided comprehensive inventory of buildings and infrastructure with 115,000 buildings, 5,100 building blocks and 3,200 km of road network which were mapped and geolocated. Figure 1 represents sample results of this classification showcasing land use patterns and detailed information concerning urban and rural settlements, including building footprints, building location, distances from building to building and building count. In addition, the inventory contains information collected from the field and revealing construction classes at building block level, including building material, building height (number of stories) and floor area.

The statistical analysis revealed the predominant rural settlement structure of the project area. Only 5% of the area is used for settlements and 1% of land for transport infrastructure. More than 80% of the area is cropland and other vegetated land. 86% of the buildings are consisting of small structures with a ground area of less

3a

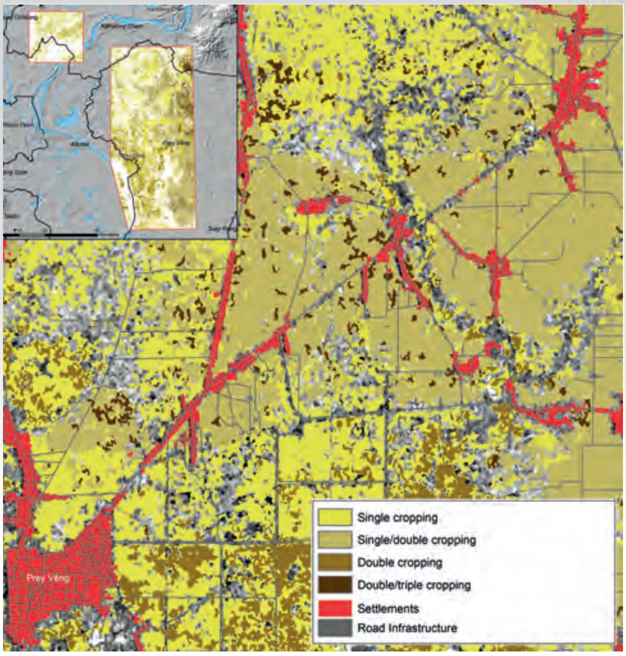


2. Rice acreage map generated using multi-temporal multi-temporal ENVISAT ASAR from Feb to Oct 2011 (ENVISAT-ASAR) and extension to Dec 2011. MMU: 1 ha. Credit Geoville, data © ESA.

3a. Indicator for planted rice under SRI (System of Rice Intensification) ENVISAT ASAR imagery from Feb to Oct 2011 (ENVISAT-ASAR) and extension to Dec 2011. MMU: 1 ha. Credit Geoville, ENVISAT data © ESA.

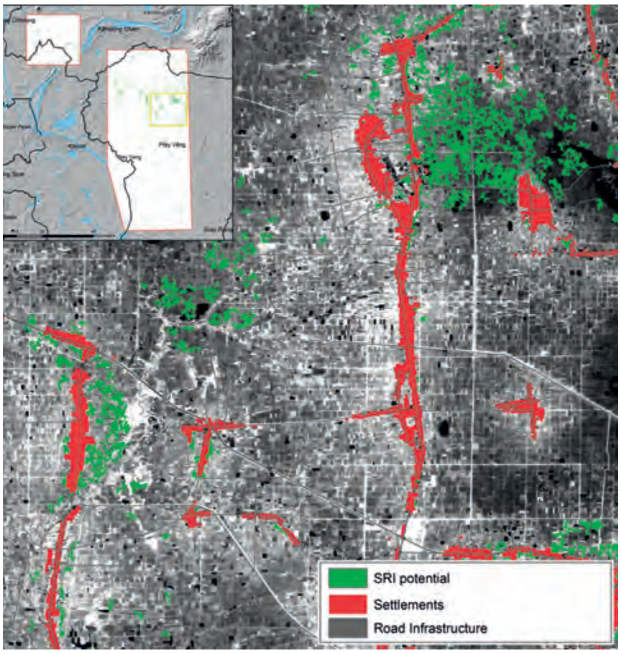
3a. Rice cropping system generated using multi-temporal ENVISAT ASAR imagery from Feb to Oct 2011 (ENVISAT-ASAR) and extension to Dec 2011. MMU: 1 ha. Credit Geoville, ENVISAT data © ESA.

3c



than 100 square meters, and 90% of the settlement area is characterized mainly by low density stilt-houses with two stories and a distance of less than 100m to road networks.

3d



Inventory of crops

Thanks to the use of all-weather radar imagery with dense temporal sampling it was possible to provide continuous monthly monitoring of rice fields including monitoring date of emergence and harvest of rice (Fig. 2). In this case radar imagery was used to assess the extent of rice cultivation areas and to identify rice cropping system. For the observed time period between February to October 2011 total rice acreage was estimated to amount to 1376.93 square km representing 74.64% of the total agricultural production in the area. Dry season irrigated rice area is more widespread (60.5% of the cultivated land) than wet season rainfed rice (23.4%). The remaining 16.2% is cultivated with dry as well as wet season rice. Figure 3 represents map which is differentiates major cropping systems (wet-season vs. dry season), crop cycles (single/double/ triple crop per year), date of emergence/ harvest and the distinction between rice planted under intensive (SRI) vs. regular rice cultivation techniques.

Hazard and exposure assessment

To conduct exposure analysis information on crops, buildings and infrastructure was overlaid on hazard maps to identify flood and drought prone areas and potential damage.

Reconstruction of past flood events using EO data is a valuable step to understand flood risk, especially if no other data sources are available which is often the case of the flooding events covering hundreds of thousands of square kilometers. In this case the past floods maps were developed based on the analysis of the ERS-2 satellite scenes covering a flood event that impacted Mekong basin between August and November 2001 (Fig. 4). The flood impact analysis indicated that 79% of the identified selected settlement areas in the Lower Mekong basin, and 88% of the road network, are threatened by high-water levels in case of a severe flood event similar to the one that has affected the area in 2001. In such case, more than 90% of the cropland would be also be threatened by high water levels.

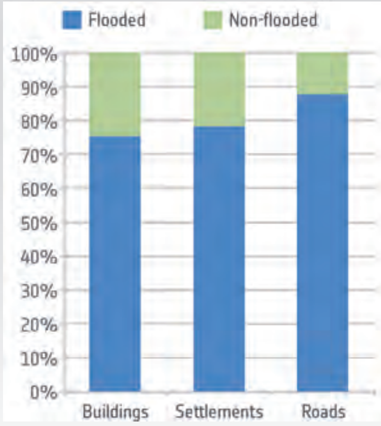
3c. Crop cycle map generated using multi-temporal ENVISAT ASAR imagery from Feb to Oct 2011 (ENVISAT-ASAR) and extension to Dec 2011. MMU: 1 ha. Credit Geoville, ENVISAT data © ESA.

3d. Indicator for planted rice under SRI (System of Rice Intensification) generated using multi-temporal ENVISAT ASAR imagery.

Disaster Risk Management

Furthermore, while evidence of historical floods is rather well documented in the Mekong basin, this is not the case concerning occurrence and impacts of droughts. Using EO-derived Normalized Difference Vegetation Index (NDVI) based on SPOT5 observations it was possible to assess the conditions of 2002 drought and estimate the exposure of crops to similar events. The findings indicated that 99% of the cropland in the study areas would be affected for a period of at least 1 month and that almost 50% of cropland would experience such drought conditions at the drought peak.

Overall this data collection method helps to offset time-consuming and expensive nature of frequent field trips and airborne surveys. It also allows for periodic updates of geospatial inventories of assets, their spatial extent, location and development over time. In case of rice crops monitoring, satellite radar data offered a unique capability to assess rice growth patterns, which would not be available from other sources. The analysis was conducted entirely remotely without any utilization of in-situ information and yielded accurate results (the average overall accuracy for maps amounts to 86.1%.) However, while EO provides a wide range of information with known levels of precision and accuracy, in-situ measurements are still needed to identify specific exposure parameters (e.g. load bearing structures of buildings, detection of specialized rice cultivation techniques and so on).



The main benefit of satellite Earth Observation for the users at the Mekong Basin lays in the fact that it allows collection of data in consistent and objective manner, as well as sharing, consolidating and validating information generated by different national institutions to facilitate regional integration. All of the mapping products were transferred to the Mekong River Commission (MRC) and the Cambodian National Committee for Disaster Management (NDCM) where results served as an input to disaster resilience planning at various administrative levels. Both MRC and NCDM plan to use it to better quantify assets exposure to the range of hazards and optimize investments to minimize potential damage or loss. Such GIS-ready, quality controlled geoinformation products have a high replicability potential to other regions along the Mekong River.

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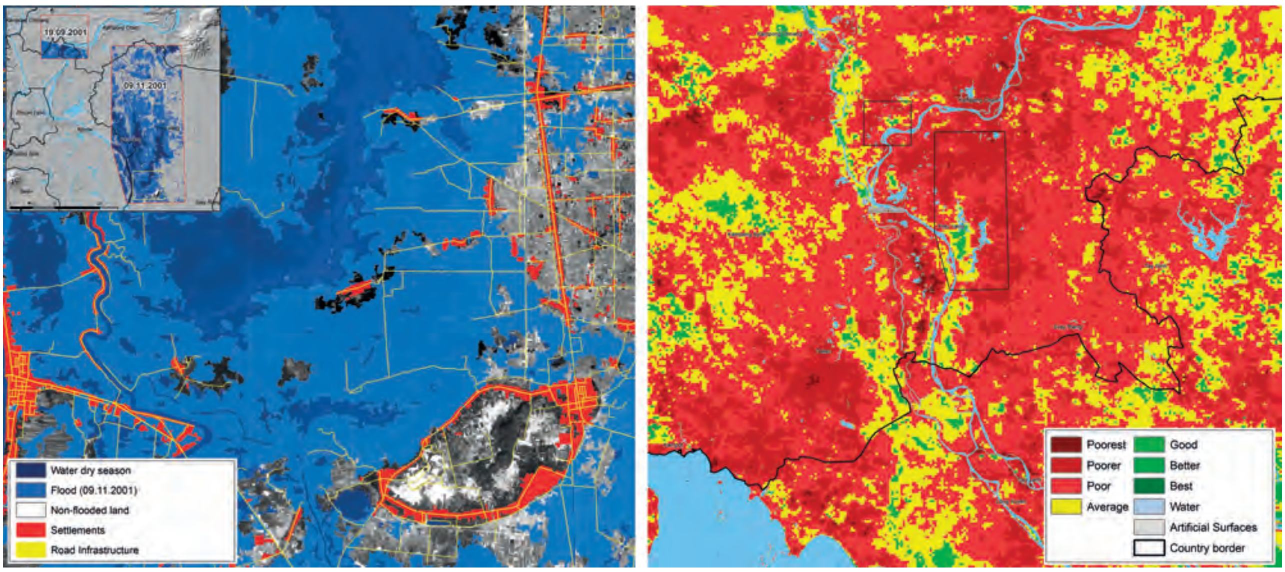

4. Flood hazard map. Credit: Geoville.

Watershed Mapping and Water Resources Management in the Zambezi River Basin

Users

World Bank Unit:

Environment and Natural Resources Management Unit, Africa Region

Local Stakeholders:

World Bank Country Office in Lusaka, Zambia

EO services provided

- Small-scale water bodies mapping based on SAR (Synthetic Aperture Radar) data to identify small (minimum 1ha) water bodies, reservoirs and lakes extensions and evolution over time
- Lake Malawi water quality products, including lake surface temperature as well as historical water level records
- Soil lost and erosion estimation using VHR Optical data (SPOT5)

Service providers

- NEO (The Netherlands)
- Technical University of Delft (The Netherlands)
- Water Insight (The Netherlands)

ESA Technical Officer

Diego Fernández Prieto

European Space Agency

Science, Applications and Future Technologies Department,

Directorate of EO Programmes

Tel: +39 06 94180676 | Diego.Fernandez @esa.int

WB Task Team Leader

Nagaraja Rao Harshadeep

The World Bank Group

Senior Environmental Specialist, Africa Region

The World Bank supports the implementation of an integrated framework for development and management of water resources in Zambia. The project beneficiaries are rural communities who will benefit from improved small scale water resources infrastructure. In this context, the eoworld project provided the demonstration of advanced EO tools to assist in mapping of small water bodies in Southern Province of Zambia, as well as additional information products to assess water quality of Lake Malawi and erosion pattern in selected locations in Malawi's Shire river basin.

Small reservoirs mapping

Small reservoirs have traditionally been one of the most important sources of irrigation to rural communities in Zambia, also used for watering cattle, fishing, recreation, and to supply households. The existing inventories of small water bodies are however often incomplete which hinders the ability of local authorities to manage these resources in a timely and comprehensive manner. In this context the eoworld project explored the use of remote sensing in identification and mapping of small reservoirs (0.5 hectare and higher) in regular intervals and assess their storage evolution over time.

The base maps covered the entire Southern Province of Zambia providing an overview of 1022 small reservoirs and their spatial distribution (Fig. 1). During the validation exercise the products showed a good agreement with in-situ information (Fig. 2). Even though some limitations apply when it comes to the detection of reservoirs smaller than 0.5 ha, this capability proved to enhance the traditional data collection methods through the optimization of ground surveys.

The images in Figure 3 showcase the possibilities for extraction of additional information from such base maps. New methods were tested to assess the evolution of small reservoirs water extent over time, including automatic classification based on radar (SAR) imagery. Within the reach of the footprint of one newly acquired radar scene 131 reservoirs where visibly filled with water (out of 268 reservoirs from the base map classified based on combination of optical and radar date). The project has however found that this is difficult to reliably assess the declining sizes of the small reservoirs during the dry season.

During the implementation of this project a specialized training session was provided to Zambian authorities March 2012 and subsequently taken aboard of the existing ESA "TIGER Initiative" which is dedicated to providing innovating information services to support water resources management in the Africa region. Based on the request from the Zambian Department of Water Affairs, an additional training for the Zambian authorities was organized in October 2012. As a result of this technical assistance and capacity building support from the ESA and the World Bank, EO techniques were included in the proposed World Bank project targeting water resources development in Zambia. To accomplish

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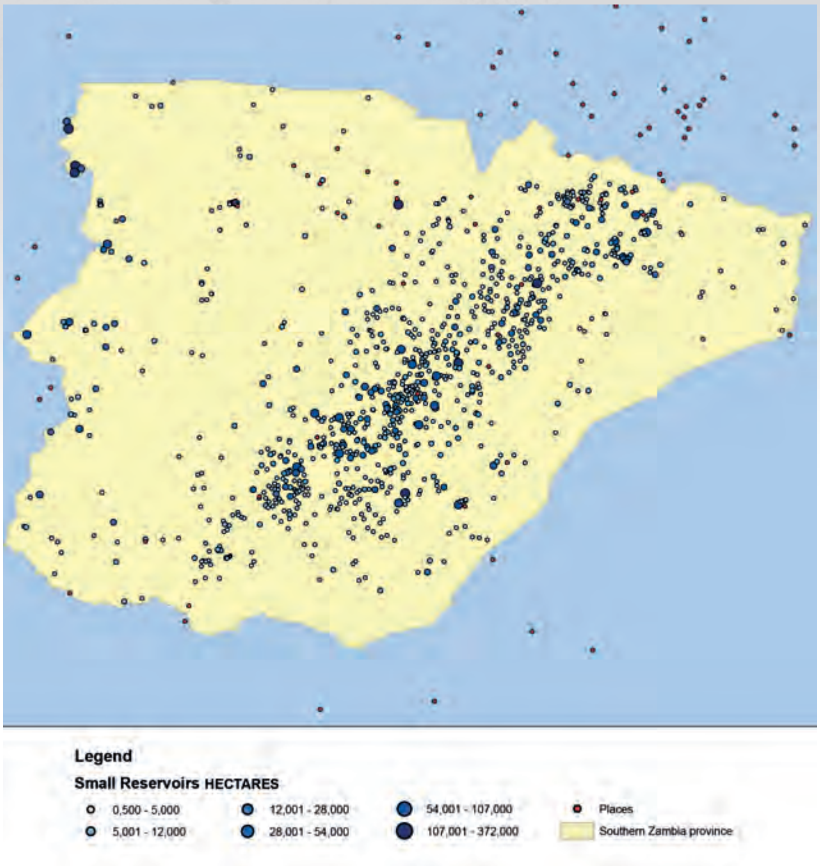

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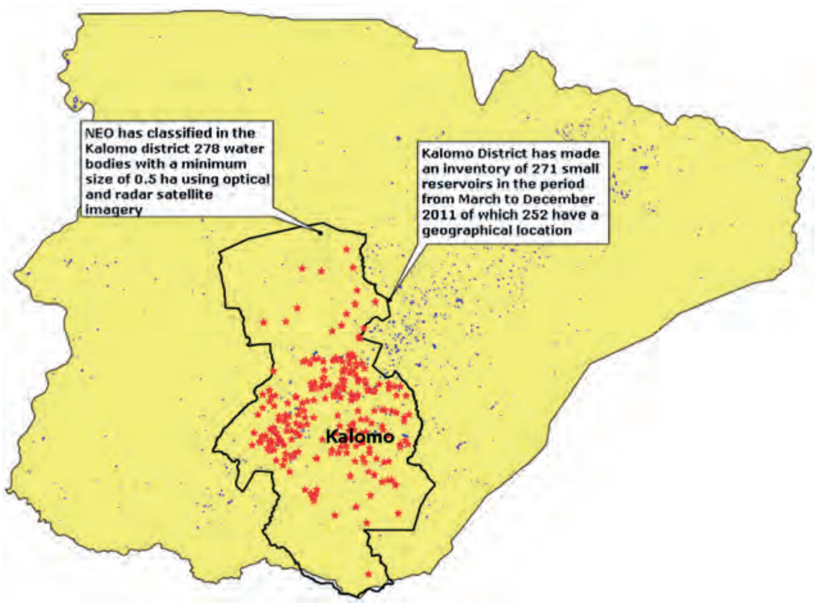


this, the Bank plans to collaborate with ESA and to design an extended three year training program focused on earth observation information tools.

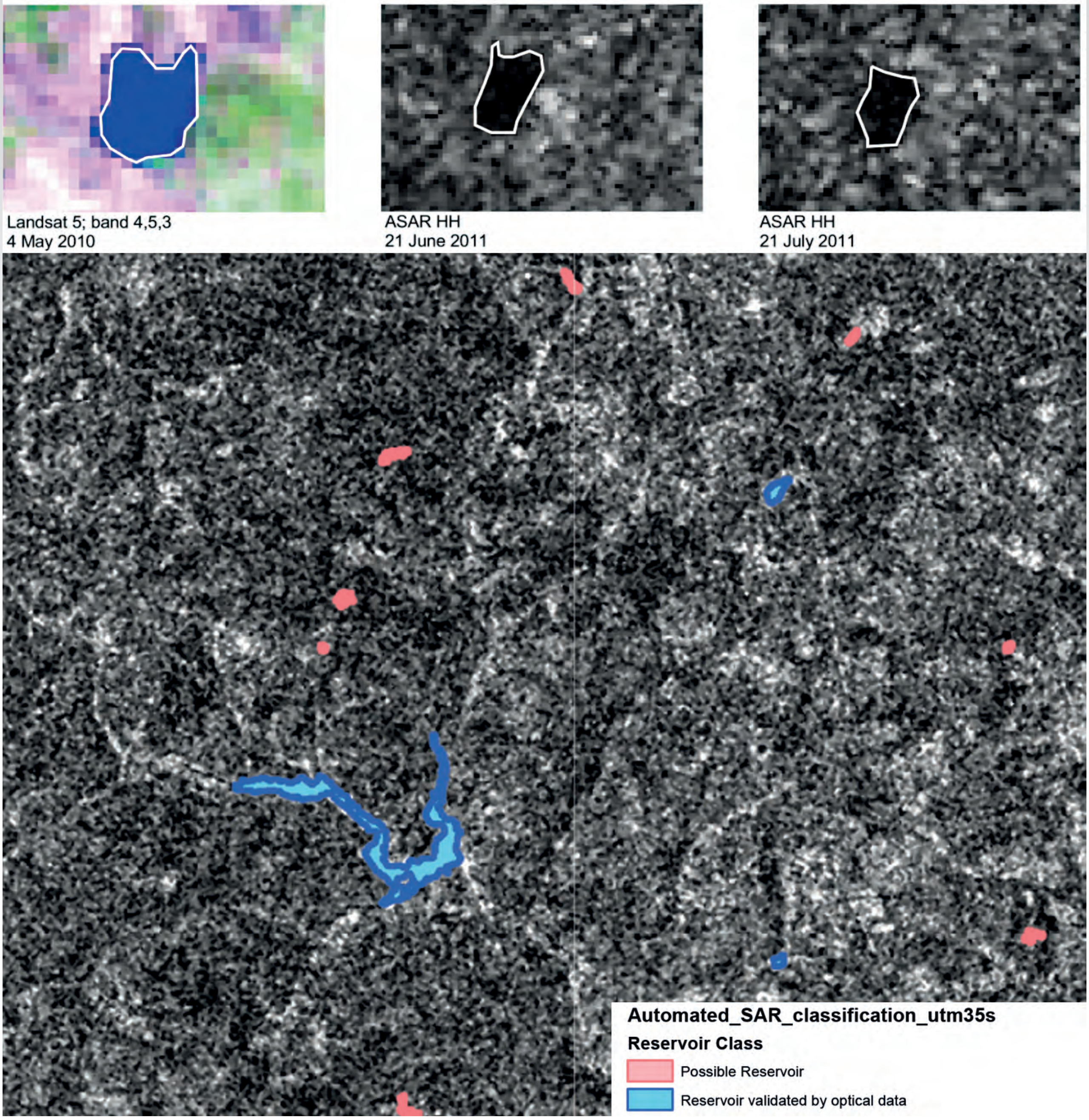
Monitoring of Lake Malawi

There is little quantitative information available concerning spatial and temporal dynamics of water quality in Lake Malawi, and the nearby lakes - Malombe and Chilwa. The existing in situ methods of water quality monitoring are deemed inadequate to capture the variability in water circle. There are also limited ways to evaluate the impacts of deforestation on increased erosion in the lake catchments, as well as on increased sediment and nutrient loads. As the same time, the accurate assessment of the sediment loads of lakes and rivers as considered critical by the Department of Water Resources because high sediment loads have caused severe problems in hydroelectric power stations in the last few years.

The greatest value in satellite derived water parameters lies in its ability to provide a viable substitute for in situ measurements to asses hydrological status of the basin. The data can be gathered entirely remotely which is important from the perspective of the cross-boundary water management issues, and harmonization of available datasets.

1. A base map using Landsat data covered the full Southern Province of Zambia providing an overview of 1022 small reservoirs and their location. Credit: NEO.
2. Red stars are showing locations of reservoirs inventoried by the Kalomo district authorities. Blue outlines are showing water bodies classified using EO technology. The accuracy is striking: 278 water bodies classified and geolocated using optical and radar imagery vs. 271 small reservoirs mapped using ground surveys.

3



To help assess the state of the Lake Malawi, Lake Malombe and Lake Chilwa water bodies, ENVISAT-MERIS data was used was evaluate key water quality parameters including chlorophyll-a (as proxy for biomass) and Total Suspended Matter (TSM) concentrations as well as Kd (attenuation coefficient) (as proxy for turbidity / transparency) and Coloured Dissolved Organic Matter (CDOM) as proxy for the presence of humic substances.

The results indicated that Lake Malawi has very clear waters with low chlorophyll-a and TSM concentrations. Monthly mean maps however show some hot spots in the Southern part of the lake, and along the South-Western lake shore suggesting "hot-spot" locations

3. The monthly evolution of the small reservoir updated with the use of the ENVISAT ASAR HH and HV polarization modes. Image on the left is based on the manual classification, image on the right shows the possibilities of automatic extraction. Credit: NEO.

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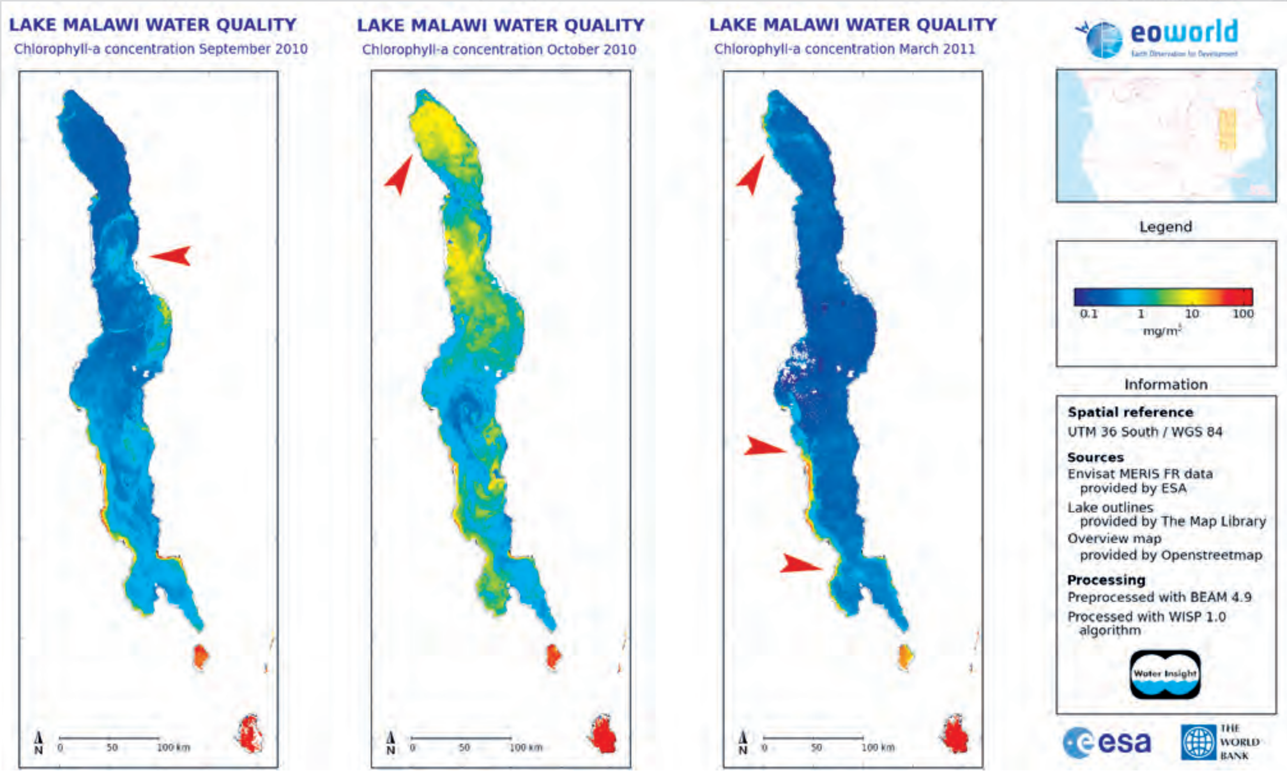

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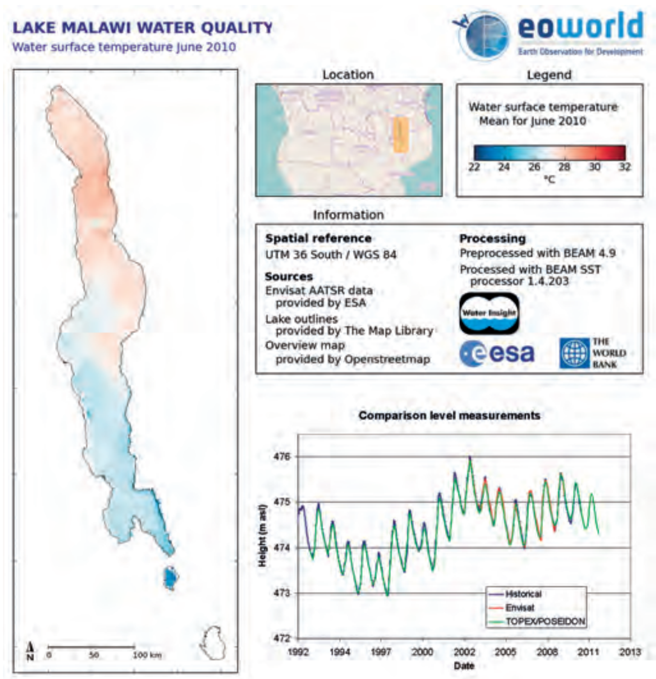

and the need for more detailed monitoring. Small peaks in chlorophyll-a could also be observed at the end of the rainy season, indicating effects of surface run-off carrying nutrients into the lake (Fig. 4). These are indicators of anthropogenic eutrophication, most likely caused by urbanization and intensification of agricultural use of lands surrounding the lake which put pressures on the lake ecosystem. Moreover, a peak in chlorophyll-a concentration indicating an algae bloom was observed in October 2010. A similar event may have also occurred in October 1999 coinciding with massive fish kills. In addition to water quality, the analysis included temperature time series which compared well with existing historic measurements and showed a tight coupling of water temperature with the yearly summer-to-winter progression and climatological phenomena such as the presence of trade winds (Fig. 5).

In nearby Lake Malombe, the chlorophyll-a concentration is much higher than reported historical

4. Red arrows points to chlorophyll-a plumes caused by riverine influx. Credit: WaterInsight.

values, which provided an indication that some improvements in Lake monitoring may be necessary. Lake Chilwa has also detected high values of chlorophyll concentration, most likely cause by its enclosed nature and shows a trend wise increase of chlorophyll-a from 2010 to 2011.

EO services have been shown to provide high temporal and spatial coverage of the lakes. However, not all parameters (such as anion and cation content and pH values) that are included in-situ measurement programs can be derived from EO information. Nevertheless, EO-derived information can be considered as supplementary and can be used for guiding targeted in-situ measurements.

Erosion in Shire Basin

In Malawi, soil erosion has been a major concern dating back to the colonial era. Population pressure increased the exploitation of natural resources. The studies conducted in the 1990's by the University of Arizona (UoA) have shown an increase of 243% in land allocated as pasture and agriculture in Southern Malawi. It also reported decreases in forested areas and progressing soil erosion leading to the higher sediment load discharching to the River Shire. However, UoA study was the last comprehensive assessment documenting the environmental impacts of changing land use patterns. At the same time, recent increase of the profitability of tea and tobacco production greatly intensified pressures on land and its adaptation for agricultural purposes.

In this context, the eoworld project provided the most accurate and up to date land use, land use change information available for the area. It has been used to prioritize World Bank interventions in the four selected catchments under the Shire River Basin Management Program and will be further be integrated into monitoring activities.

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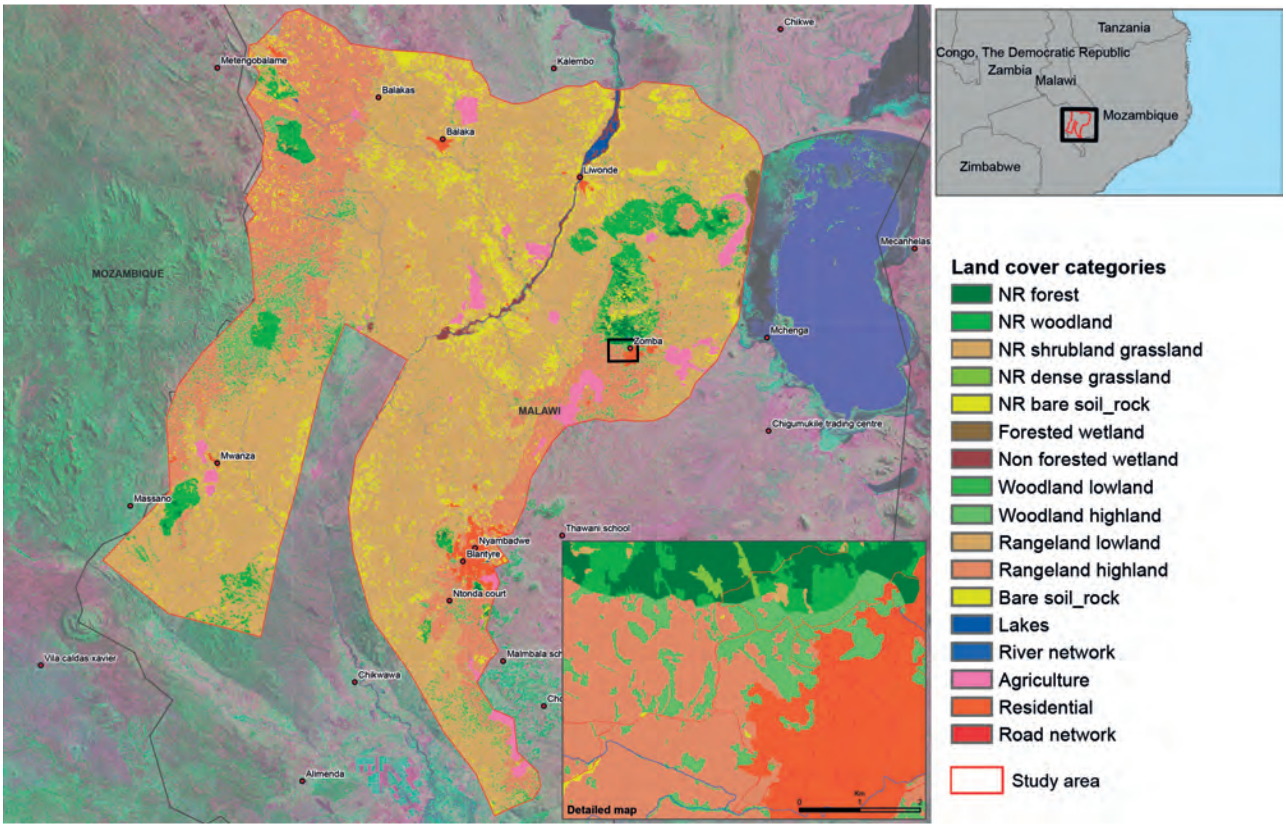

6. Land cover map for Shire Basin. Credit: NEO.

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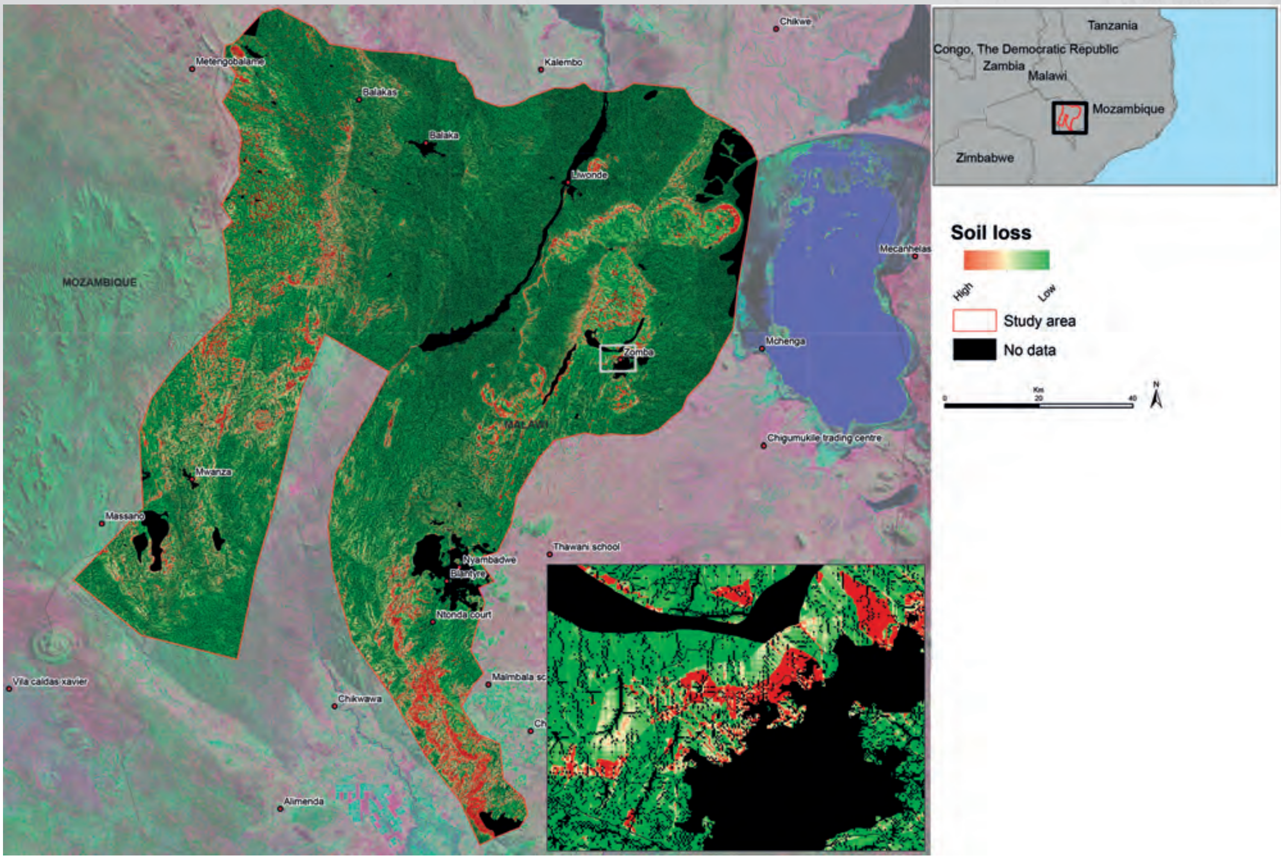

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The estimation of soil lost and erosion within Malawi's Shire river basin was based on SPOT5 acquisitions form the period 2005 to 2010 and covering 10798 km2 in 17 land use classes. It revealed that 24% of the area underwent change from 2005-2010. The changes are related to deforestation (in the Natural Reserve (NR) classes one can see a change in land cover from Forest to grassland – shrubland and also woodland.), increase of agricultural areas: (growing rate of 9% in the period of 5 years), development of new settlements around larger built-up areas (up 10%) and wetlands (the forested wetland decreased in size in favour to non-forested wetland). The assessment of these changes did not however account for seasonality (Fig. 6).

An erosion map was also produced to indicate areas with an erosion potential which is influenced by the topography and rainfall erosivity. The accuracy of the proposed methodology to estimate soil losses depends however,on the good qualitative and quantitative information on soil type, rainfall events, grown crops, related crop calendars and farming practices (Fig. 7).

7. Erosion map in the Shire sub basin (red: high erosion risk). Credit: NEO.
8. Workshop in Zambia gathered local authorities which were trained in the use of EO data for water resources management.

Monitoring of Water Quality and Land Use Changes in Lake Titicaca Basin

Users

World Bank Unit:
Urban, Water and Disaster Risk Management Sector Unit, Latin America and the Caribbean Region

Local Stakeholders:
Autoridad Binacional Autónoma del Lago Titicaca (ALT) in Bolivia
Ministerio de Culturas in La Paz, Bolivia

EO services provided

- Water quality monitoring using medium resolution imaging spectrometers, primarily Medium Resolution Optical data sources (e.g. ENVISAT MERIS)
- Land use and land change with a special focus on wetlands /crop type derived from high to very high resolution imaging optical sensors

Service providers

- GAF (Germany)
- EOMAP (Germany)

ESA Technical Officer

Benjamin Koetz, Dr. sc. nat.
European Space Agency
Science, Applications and Future Technologies Department, Exploitation & Services Division, Industry Section, Directorate of EO Programmes
Tel: +39 06 94180653 | Benjamin.Koetz@esa.int

WB Task Team Leader

Miguel Vargas-Ramirez
The World Bank Group
Senior Water and Sanitation Specialist, Africa Region

John Morton
The World Bank Group
Senior Urban Environment Specialist, Urban, Water and Disaster Risk Management, Latin America and the Caribbean Region

Lake Titicaca's watershed is very complex. The lake basin is located on the border between Peru and Bolivia and comprises of the high-altitude hydrological system of approximately 140,000 square kilometers. Sharp population increase, fast-pacing urbanization, and the fact that most of the agricultural activities are located in the areas around the lake, make the watershed system very vulnerable, particularly to pollution problems. The main environmental concerns are organic and bacteriological contamination caused by improper agriculture practices (fertilizers and pesticides runoff), urban wastes (solid waste, sewage discharge and lack of secondary waste water treatment which generates the process of eutrophication) as well as mining (dumping of wastewater from mines which is considered a principal cause of heavy metal contamination and alarming concentrations of cadmium, arsenic, and lead in various parts of the lake.) UNEP estimates that by 2025, the volume of wastewater in the basin will double, which in turn may lead to the disappearance of fish and aquatic life, among other potentially adverse environmental impacts. At the same time local communities depend on the lake resources for their economic livelihoods and well-being. Therefore the protection of the long-term water quality and ecological integrity is one of the long term priorities for its sustainable development. The central concern is to reduce the flow of nutrients and pollutants, and reverse some of the adverse environmental damage sustained in the past.

One of the biggest challenges concerning management of Lake Titicaca basin is related the persistent lack of reliable data on the water parameters and land use patterns, as well as incomplete inventories of pollution

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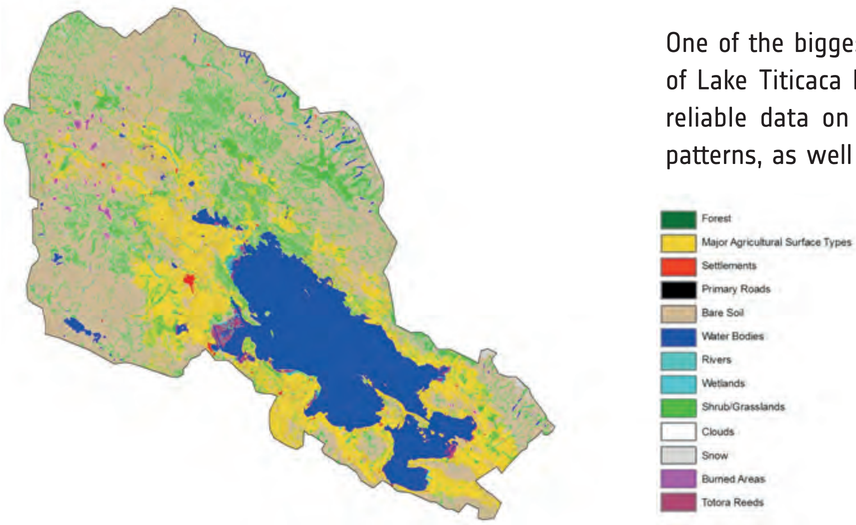

1. Example Land Use Map 2010. Credit. GAF.

hot spots and outdated water resources management plans. The creation of a Bolivia-Peru Binational Autonomous Authority of Lake Titicaca (ALT, Autoridad Binacional del Lago Titicaca Bolivia-Perú) in 1996 has addressed some of these problems. Nevertheless a number of challenges remain to be resolved. This includes improving data collection and data dissemination, refurbishing some of defunct water-quality monitoring stations and laboratories, providing platforms for sharing and consolidating available information, and promoting standardization of data generated by different national institutions.

In this context the eoworld project demonstrated the feasibility of setting up a satellite based monitoring system for a systematic collection of information concerning temporal and spatial dynamics of the lake ecosystem. Satellite monitoring covered the entire sub-basin for the year 2010/11 with high resolution (5m) and provided land use change detection for the period 2003-2010/11. Moreover, standardized and comparable water quality products were generated from 2003 to 2010 for improved understanding of lake dynamics, identification of pollution sources, and early warning indicators for algal bloom. Hot spots, natural sources of pollutants such as river inflows as well as other spatial peculiarities in the water bodies could also clearly be identified.

The project was specifically designed to look at ecological and environmental borders of the Lake Titicaca basin, rather than its administrative boundaries. It facilitated synoptic observations, it set forth validated options for the future consistent and cross-boundary data collection method to facilitate regional integration and collaboration of Bolivian and Peruvian water authorities as well as ALT.

Monitoring of long term trends in land use

The observations covered 47,000 square kilometers of the basin territory creating the most comprehensive and detailed land cover inventory produced for this area to date. Collected information allowed to address three major environmental concerns related to land use (Fig. 1):

- soil erosion,
- land degradation and
- loss of lake water body.

Results revealed that expansion of agricultural activities affects valued vegetation and ecosystem types such as rivers, wetlands and forests (Table 1). This trend can be associated with the fact that while the majority of crop production in the region takes place in the areas surrounding the lake, only 17% of land is suitable for agriculture.

Table 1

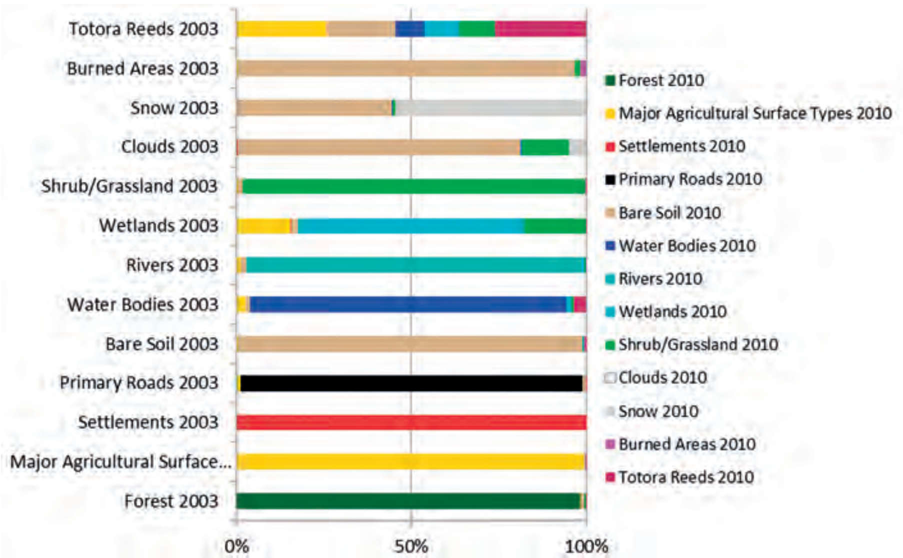

Table 1. Change Statistics for Land use between 2003 and 2010. Credit: GAF.

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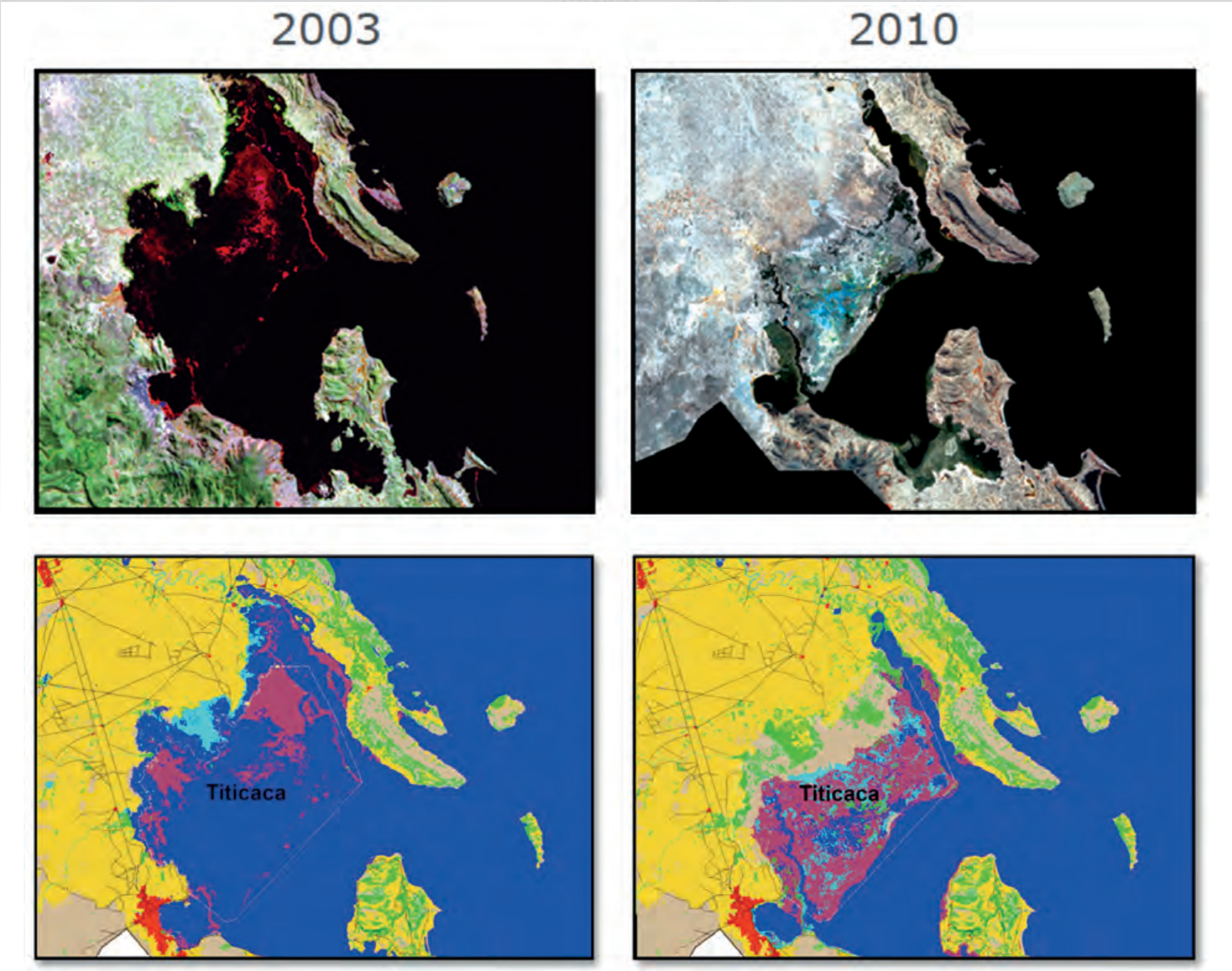

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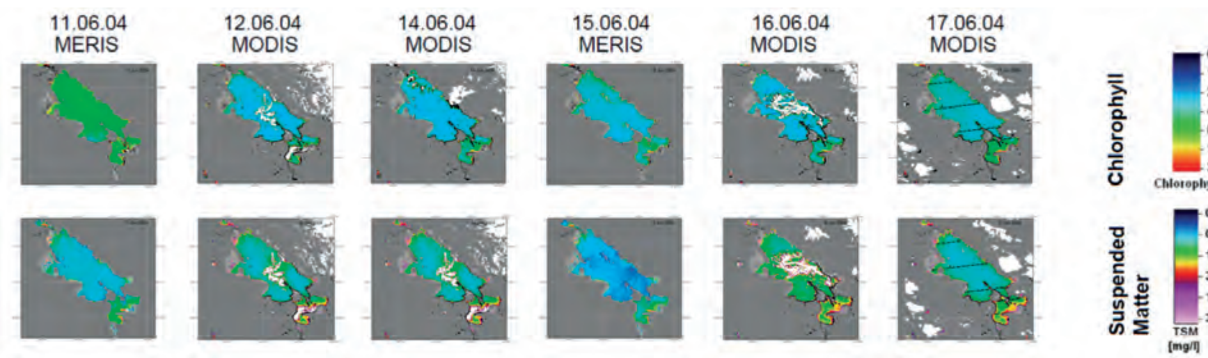
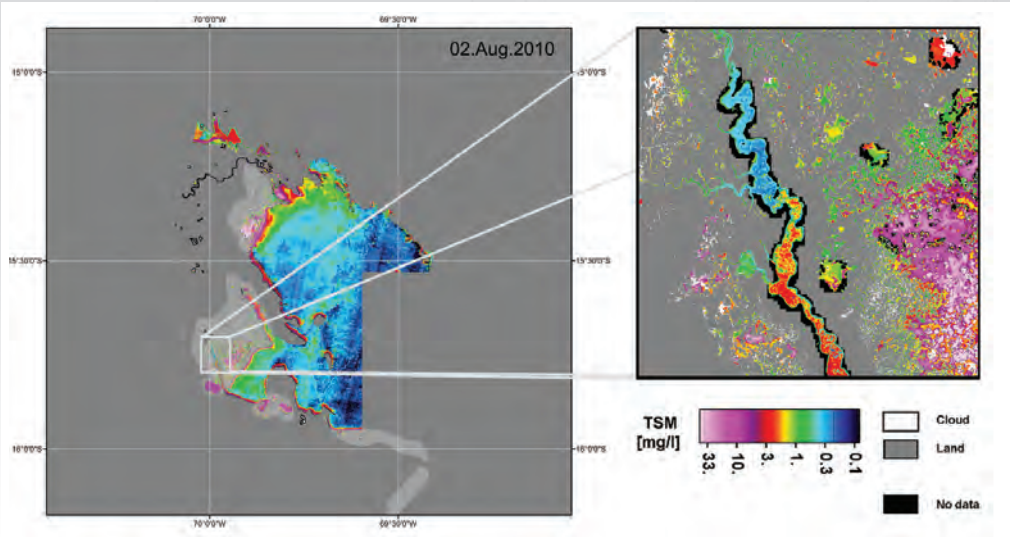


2. Example Land Use Change 2010/2003 for Reserva Nacional – Titicaca and Land use change statistics for Puno Bay. Credit. GAF.

3. Examples of satellite MERIS and MODIS retrieved products for Chlorophyll and Suspended Matter concentration. Credit: EOMAP.

4



Moreover, EO data provided the first evidence of the alarming rate of receding lake water levels and succession of water bodies by wetlands, reeds and agricultural land. The estimated loss of the shoreline amounts to as much as 100km - an equivalent of the 7 percent of the lake extent. This has a direct negative impact on the biodiversity hotspots – coastal wetlands and Tortora reeds. The project documented, for the first time, that the Reserva Nacional del Lago Titicaca at the Puno Bay – which is an area protected as a RAMSAR Convention and an important wetland/breeding ground for endemic species– is facing unprecedented transformation: fast emergence of shrubs/grassland, agriculture surface types and bare soil (Fig. 2).

Water quality monitoring

The project also provided harmonized water quality information including the assessment of the flow of nutrients, pesticides and other pollutants to the lake. The EO-based water quality monitoring is a very powerful tool used to improve the understanding of the impact of sediment-bound nutrient and contaminants on the aquatic ecosystems as well as managing pollution hot spots. It can detect eutrophication sources and mechanisms, nutrient concentrations, pollution, turbidity, sediment and phosphorus flows into the water bodies. Key water quality parameters, such as phytoplankton and chlorophyll, total suspended matter and turbidity were provided using different sensors such as ENVISAT MERIS, MODIS Aqua/Terra (500m and 300m resultion) and RapidEye (5m, 50m scale resolution) (Fig. 3).

The innovative use of higher resolution sensors (Rapid Eye, 5m) significantly increased the spatial and temporal resolution of the measurements, and optimized the survey planning by integration with standard ground truth sampling methods. As a result, the EO data provided an independent, area-wide long-term monitoring instrument with standardized and comparable water quality products, which can be generated independently on ground truth data thus offering important tool for monitoring, entirely remotely, of the status of the lake as well as verification of the applied countermeasures (Fig. 4).

Pollution hotspots

The leading cause of organic pollution in the Lake Titicaca is poor waste disposal stemming from urban centres as well as coastal villages surrounding the lake. The most polluted areas are known to be located on both the Peruvian side (within the Puno's interior bay, the Torococha River and the lower course of the Coata River) as well as the Bolivian side (for instance within the Cohana Bay, northwest of La Paz). The satellite-based analysis of chlorophyll concentration confirmed the

4. Examples of satellite RapidEye retrieved total suspended matter in 50m (left) and 5m (right) resolution for the northern and central part of Lake Titicaca. Credit: EOMAP.

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alarming trends of eutrophic process in the Puno Bay frequently associated with the disposal of the untreated sewage as well as agricultural run-off carrying fertilizers (Fig. 5). In the South Eastern, Bolivian, part of the lake, some regression in water quality was also observed, for example, in the area of Lake Huiñaymarca, which includes Cohana Bay and its tributaries: Rio Seco, Pallina and Katari. Increased nutrient concentrations are also frequent in Golfo de Achacachi and the Ramis River Delta.

Moreover, in the Lake Titicaca watershed there are many environmental and health concerns with regard to toxic waste and mineral residues inflow to the lake. This is usually correlated with sediments being flushed out from the mines up the river streams or with dumping of the industrial wastewater. According to UNEP Ramis River and River Suches are particularly affected by physical (suspended solids) and chemical (heavy metals) contamination. Satellite Total Suspended Matter (TSM) analysis is often used to measure sediments and other depositions originating from the rivers that are characterized by high particles concentration, which are present in case of various pollutants, including heavy metals. Such TSM analysis indeed revealed spatial peculiarities in Ramis and Suches rivermouths, having transboundary effect on the entire lake (Fig. 6) A dedicated field campaign would however be necessary to provide a definitive verification of these observations.

The combination of water quality information with detailed analysis of land use trends provided a clear indication of changing land use patterns and the evolving status of water bodies setting up a baseline for various land management and planning tasks. Moreover, the project demonstrated that EO can provide an

5. During the dry season, from May through November, Rio Seco is just a trickle fed by wastewater from homes, slaughterhouses, tanneries and mining operations. Along its course through El Alto, the river runs red with blood, vivid green with algae, black with oil and a thick brilliant rust color from mineral processing. Image by Noah Friedman-Rudovsky. Bolivia, 2011. Credit: Pulizer Center on Crisis Reporting.

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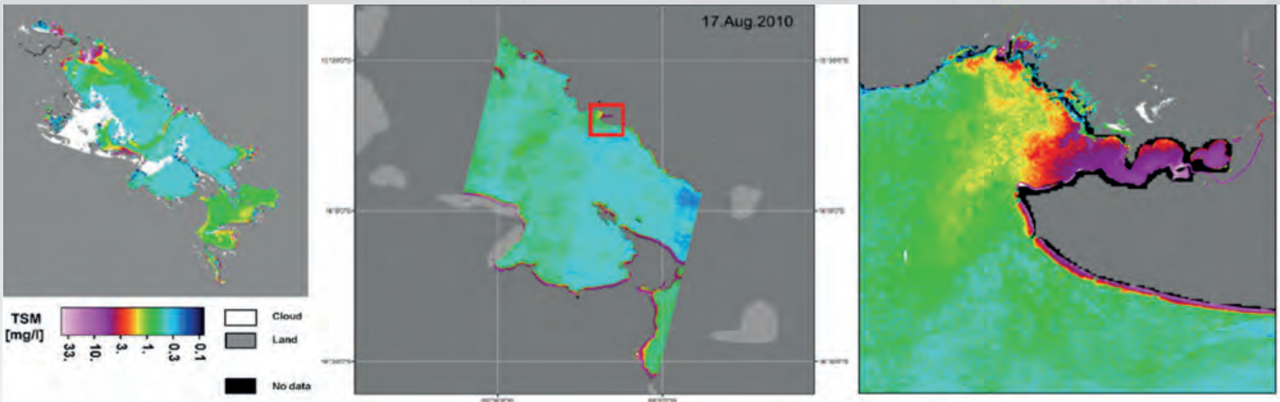

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independent evaluation of the key water parameters and indicate the degradation of water quality as well as associated causes. This is the first time this level of information has been generated for the Lake Titicaca basin in terms of detail, accuracy and direct relevance to the national authorities. Such information can be used in evidence-based environmental monitoring addressing the key policy issues: land use practices, location of the hot spot areas, causative between the origins of pollution, and adverse impacts on the ecosystem and the effectiveness of the applied mitigation measures. As such generated datasets have filled the critical information gaps and provided options for setting up an operational monitoring system for counteracting negative environmental and population impacts of the degradation of land and decreasing water area.

6. TSM analysis on Lake Titicaca revealed spatial peculiarities in Ramis and Suches rivermouths, having transboundary effect on the entire lake. Credit: EOMAP.
7. Water runs down from Bolivia's glaciers, through rivers that pass the city of El Alto, and finally arrive at Lake Titicaca. Photo: Noah Friedman-Rudovsky
8. Aymara women cross a bridge of rocks on the shores of Lake Titicaca. The lake's water is increasingly contaminated by rivers that pass through the industrial city of El Alto. By the time the water reaches the lake it is highly contaminated, affecting the ecosystem and local residents. These communities produce crops and supply fish that Peru and Bolivia depend on to help feed their populations. Urban growth is not the only threat to traditional lakeshore life: increased mining, cattle operations and overfishing also put the lake at risk. Photo: Noah Friedman-Rudovsky.
9. Aymara fisherman at dawn on Lake Titicaca near the city of Puno, Peru. Pollution and overfishing are killing off the fish population of the lake. Photo: Noah Friedman-Rudovsky.

Monitoring of Coastal Vulnerability and Coastal Change Trends in West Africa

Users
World Bank Unit:
Environment and Natural Resource Management Unit, Africa Region
Local Stakeholders:
- World Bank country office in Dakar, Senegal
- World Bank Country Office in Lusaka, Zambia

EO services provided:
- Coastal change maps
- Sea level height and ocean currents

Service providers:
- CLS (France)
- GeoVille (Austria)

ESA Technical Officer
Gordon Campbell
European Space Agency
Science, Applications and Future Technologies Department, Exploitation & Services Division, Industry Section, Directorate of EO Programmes
Tel: +39 06 94180406 | Gordon.Campbell@esa.int

WB Task Team Leader
Sofia Bettencourt
Lead Operations Officer, AFTEN | The World Bank Country Office, Lusaka, Zambia

Denis Jordy
Senior Environmental Specialist, AFTEN | The World Bank Country Office, Dakar, Senegal

The eoworld project in West Africa provided important assessment of the vulnerability of West African coastal areas to climate change and erosion. The chosen test sites were located in Sao Tome and Principe, Senegal and Gambia, Cotonou (Benin) coastline and Lagos (Nigeria). The assessment included analysis of past changes (10 to 20 years) due to erosion (coastal change maps) and changes in sea level height.

Coastal change maps

Coastline maps were produced for three different points in time - 1990, 2000 and 2010 - using multi-spectral and panchromatic LANDSAT (30 m resolution) and SPOT satellite imagery (10 and 20 m resolution). They represent an analysis of the individual coastline maps for various reference years and depict actual changes of coastal areas that have happened between these dates to quantify the total area of erosion and accression rates.

Figure 1 and 2 represent sample change maps of the coastline near the city of Bakau (11 km west of Gambia's capital Banjul) for the years 1990, 2000 and 2010. The red line shows the coastline for 1990, which retreated strongly until 2000 (green line, partly below yellow line). Some sand banks were present in the year 2000 (green oval lines), but finally disappeared until 2010. While the estuary largely remains unchanged over 20 years, significant changes occur at the shoreline near the land tongue in the northern part of Bakau.

Appropriate interpretation of the underlying driving factors of these changes was conducted in collaboration with local experts. Some examples of trends interpretation is given in Figure 4 where the signs of sand build-up near Micolo between 1990 and 2010 can be clearly identified and correlated with the local community decision to forbid sand extraction in mid-1994.

The project has found that this type of information is typically not readily available from public databases in the countries covered within this project. While terrestrial field work may deliver more accurate results for limited areas, satellite data allow creating easy-to-understand maps, at different levels of accuracy from low-to-high in order to balance the benefits of general trends assessment with detail monitoring of hot spots (Fig 5). In the latter case EO data can be further used by local experts to plan field visits, to support the definition of countermeasures and to support further geospatial analyses. Moreover the unique added value of satellite observation is the ability to utilize image archives of 30-40 years to identify past trends, compare them to other locations and continuously track the recent development of coastlines.

Sea level height

When it comes to obtaining accurate and operationally relevant sea-level rise information, typically it is gathered through ground base tide gauges. However in case of West African coasts such gauges are very sparsely located and only one or two have data for more than 5 or 6 years. Therefore EO-based altimetry is the only reliable way for assessing the regional mean sea level rise in this area. The altimetry-derived maps provided

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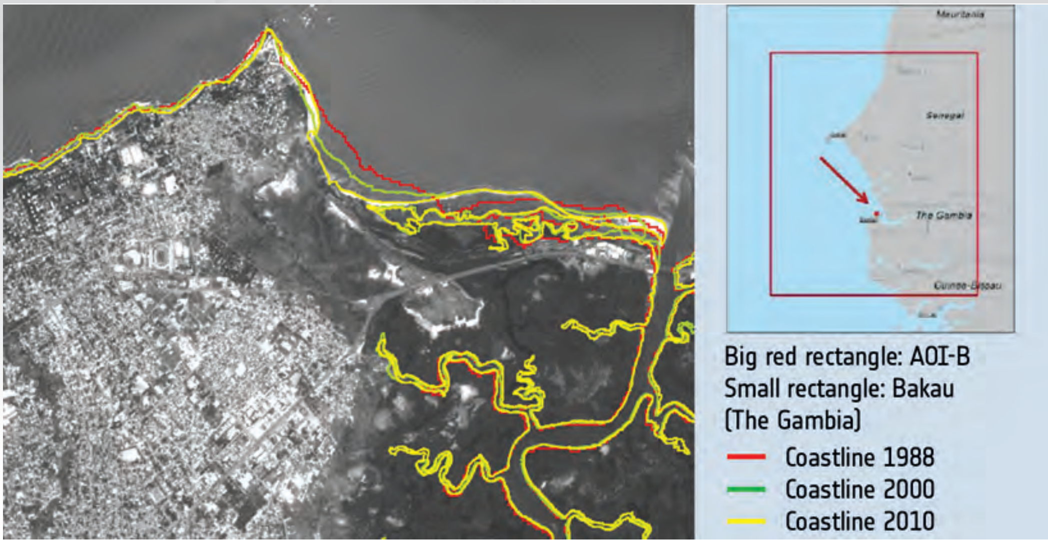

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synoptic view of sea level rise trends. Data are homogeneous (they are intercalibrated across different sensors), continuous and validated, and provide the long term assessment for the region. A complete set of maps and data covering Senegal and Gulf of Guinea revealed mean sea level trends, associated geostrophic currents, and tide amplitude as well as tidal and wind-driven currents.

Both areas show an elevation of the sea level (slightly less than the global sea level rise for the Senegal, about the same rate for the Gulf of Guinea). However, this elevation is certainly not wholly due to climate change, but in part to interannual variability, since the monitoring period is not long enough.

1. Coastline maps from 1988, 2000 and 2010 for the city of Bakau in The Gambia (for complete project area see upper right image). Credit: Geoville.
2. Coastal change map for Bakau, Gambia, and Delta du Saloum, Senegal for the time period 2000 to 2010. Credit: Geoville.

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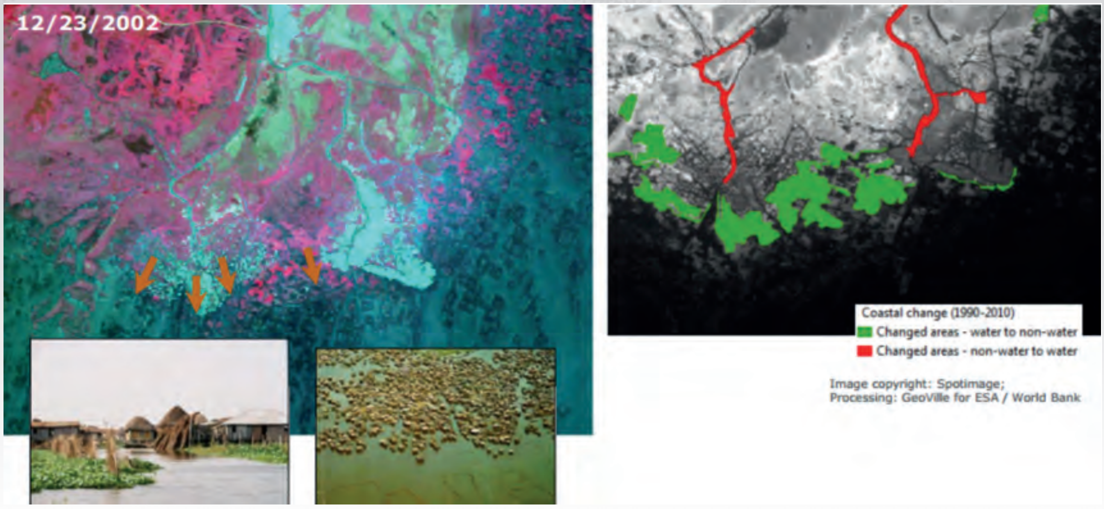

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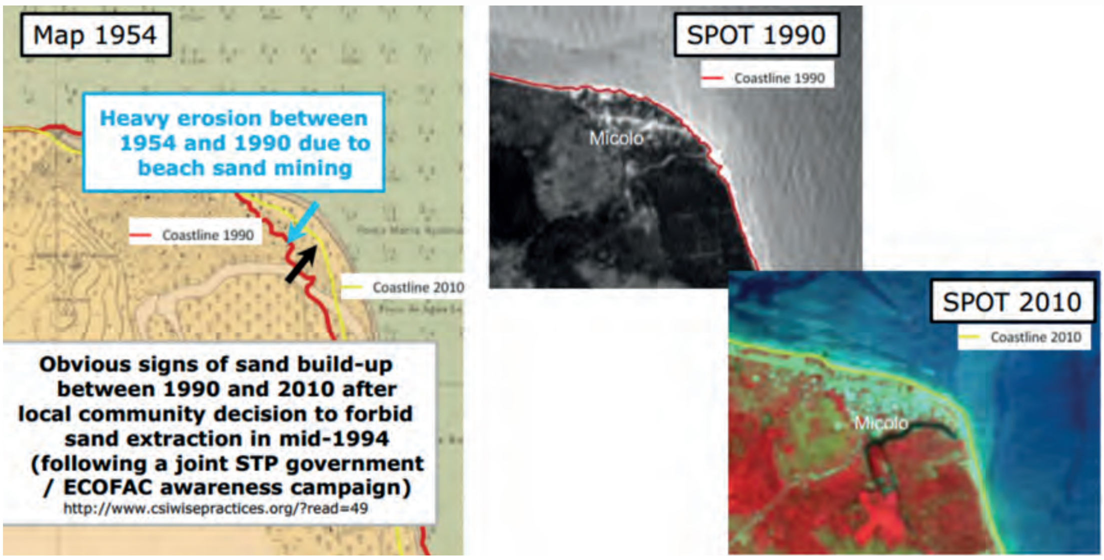

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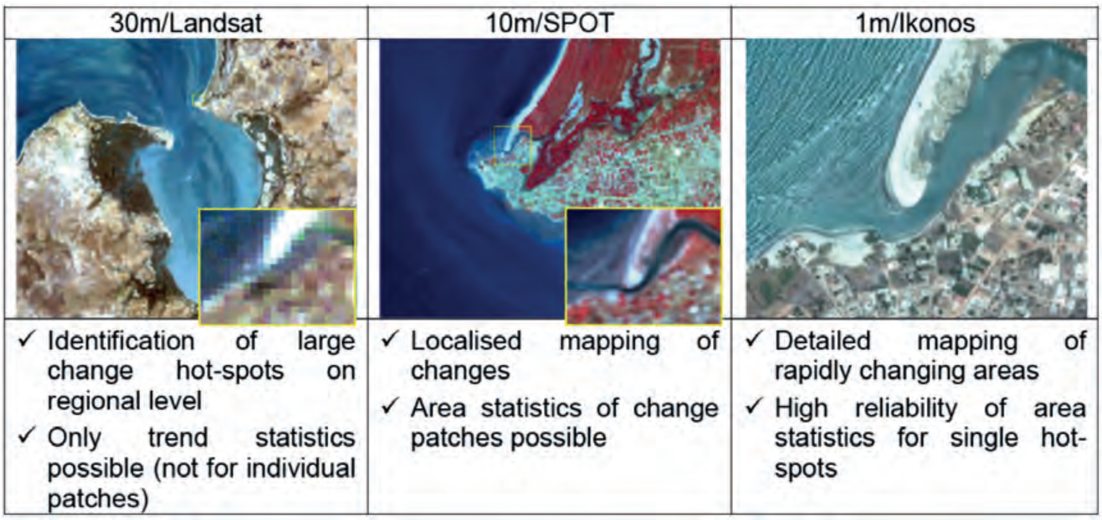

3. Land reclamation by aquafarming and stilt housing Ganvié – Lake Nokoue(Benin). Credit: Geoville.

4. Coastal erosion caused by beach sand mining near Micolo (São Tomé). Credit: Geoville.

5. Examples of results that can be achieved at different levels of accuracy.

Coastal Zone Management

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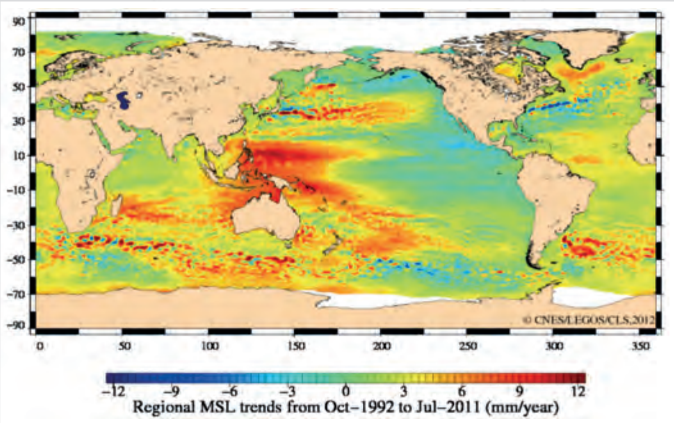

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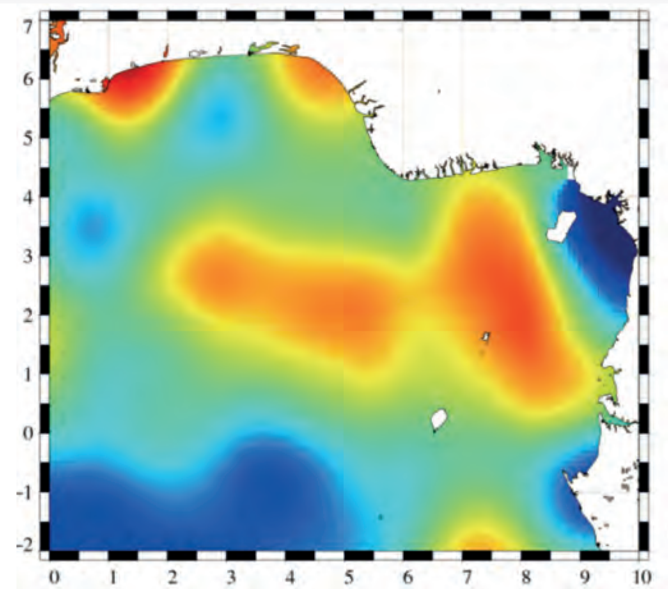

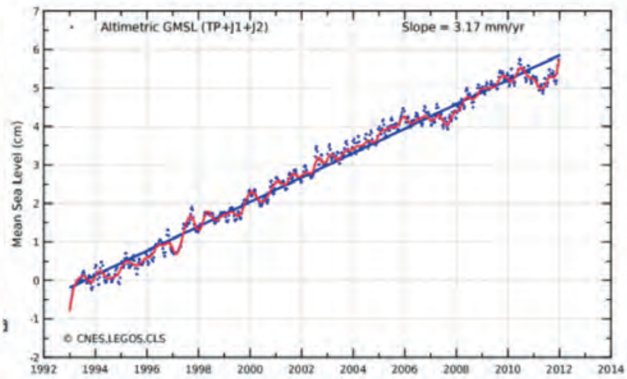

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6. Regional sea level rise trend. Credit: CLS.
7. Training in Sao Tome. Photo by Geoville.
8. Waters off the coast of Ghana. Ghana. Photo Curt Carnemark World Bank.

Monitoring of Environmentally Sensitive Areas in the Mozambique Channel, Real-time Oil Spills Detection & Polluter Identification

Users

World Bank Unit:
World Bank, South Africa Country Office (Pretoria)
Environment and Natural Resources Management Unit, Africa Region

Local Stakeholders:
South African Maritime Safety Agency (SAMSA)
National maritime institutions and port authorities from:

- Seychelles,
- Mauritius,
- Mozambique,
- Madagascar,
- Tanzania,
- Kenya,
- Comoros

for the oil spill surveillance service as well as Indian Ocean Commission for the coral reef monitoring service.

EO services provided

- Real time oil spill detection and polluter identification
- Coral reef health– status and evolution observation

Service providers

- CLS (France)
- IRD (France)

ESA Technical Officer

Gordon Campbell
European Space Agency
Tel: +39 06 94180406 | Gordon.Campbell@esa.int

WB Task Team Leader

Juan Gaviria
The World Bank
Sector Manager, Transport Unit, Europe and Central Asia Region

The World Bank is actively engaged in development of active pollution management measures involving eight countries in the Western Indian Ocean (WIO) region: South Africa, Seychelles, Comoros, Mauritius, Madagascar, Mozambique, Kenya, Tanzania and France (Reunion). This includes hydrographic surveying for the main maritime routes, enhancing maritime surveillance as well as protection of sensitive mangrove and coral ecosystems from contamination due to maritime transport. The aim is to reduce the amount of pollution from collisions and groundings and to develop reactive measures to address any threats to ecosystems in case of accidents. Earth Observation services contributed to these activities in two important areas – the timely detection of oil spills by ships and assessment of the status and health of priority coral ecosystems to detect deterioration caused by marine traffic.

Potential damage due to accidental spills and illegal discharges from ships or ports would have disastrous consequences to the unique and ecologically vulnerable ecosystems of the Mozambique Channel. This area contains a number of protected marine and coastal reserves including the UNESCO's World Heritage site of Aldabra Atoll in Seychelles as well as two of the six Large Marine Ecosystems located in Africa: Agulhas and Somali Current. Moreover, extensive coral reefs as well as mangrove forest and internationally significant wildlife

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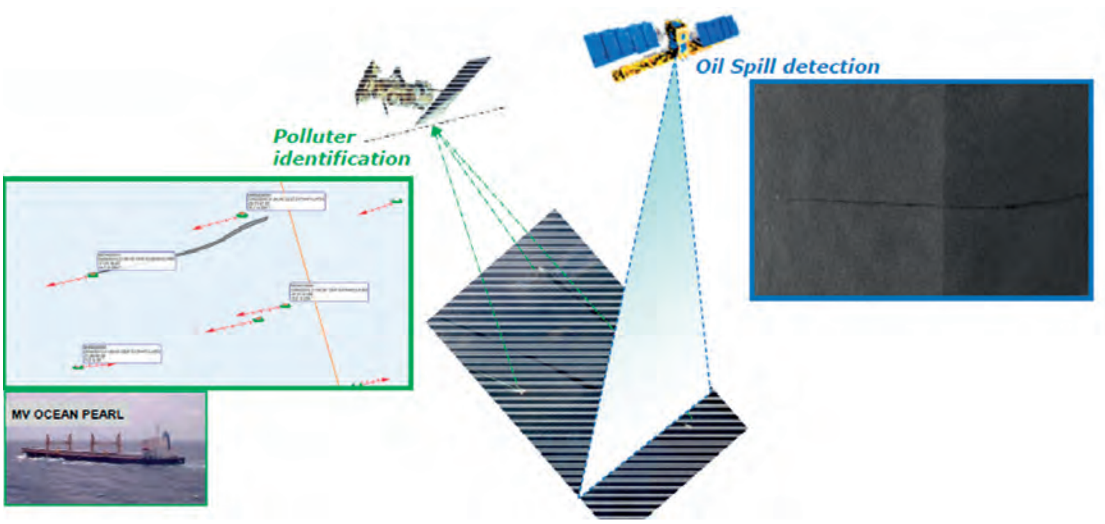

1. Fusion of SAR imagery (e.g. ENVISAT-ASAR, Radarsat) with vessel identification data from satellite-based Automatic Identification System (or SatAIS). Credit: CLS.

are prevalent in Mozambique, Madagascar, Tanzania, South Africa, Comoros, and Mauritius. These countries largely depend on tourism and aquaculture as a major source of their income. Therefore improving marine environmental protection and the capacity to respond to disasters is one of the priorities for the regional development.

Oil spill detection and polluter identification

The oil spill monitoring system has been design as a continuous, near-real time delivery of information in support of anti-pollution operations, as well as polluter identification and backtracking. The program of observation covered a total 17.5 million square kilometers of the Mozambique Channel geographic area and combined coastline of 13,300 kilometers. As a result of the 5 months of operations from July to December 2011, 38 potential slicks were detected and investigated. 23 of them were classified high degree of confidence as 'oil spills'. Moreover six potential polluters were identified thanks to their AIS signal collected by satellite, leading to an identification rate of 26% per spill.

These results were groundbreaking. This is the first time that such state of the art monitoring system was implemented in the area other than Europe and Northern America and it significantly upgraded the ways of conducting maritime safety operations in Western Indian Ocean.

The concept of operations was based on the use of wide-swath satellite radar imagery delivered in real time and fused with vessel identification data from satellite-based Automatic Identification System (or SatAIS) (Fig 1). Resulting "oil pollution report" was delivered to the appropriate coast guard authorities and port authorities between 30 min and 1hr from data acquisition via a dedicated web portal. The entire service has been visualized using a user friendly, comprehensive web interface

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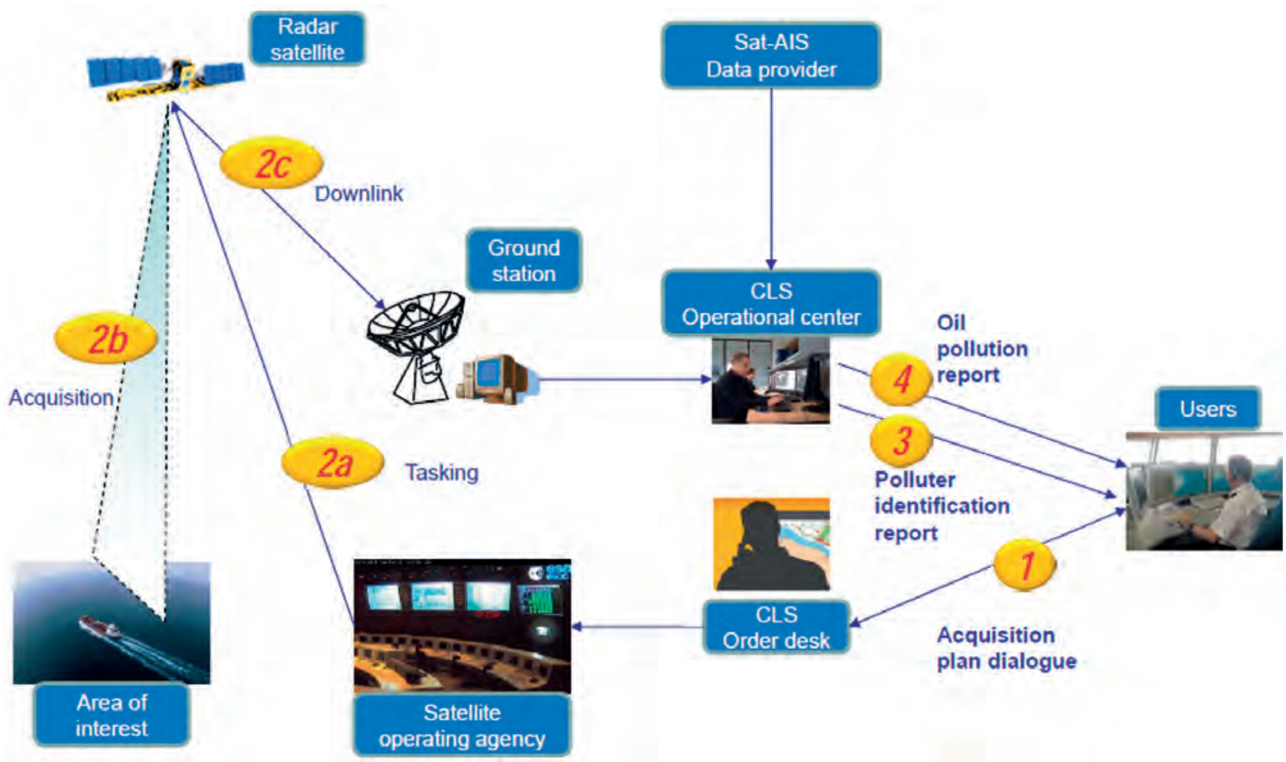

2. Concept of operations – service chain. (1) Acquisition planning - users browse available scenes and send wish list to the service operator, (2) Satellite tasking, image acquisition over the area of interest and data downlink, (3) Oil pollution report, (4) Pollution notification and polluter identification if oil spill is detected. Credit: CLS

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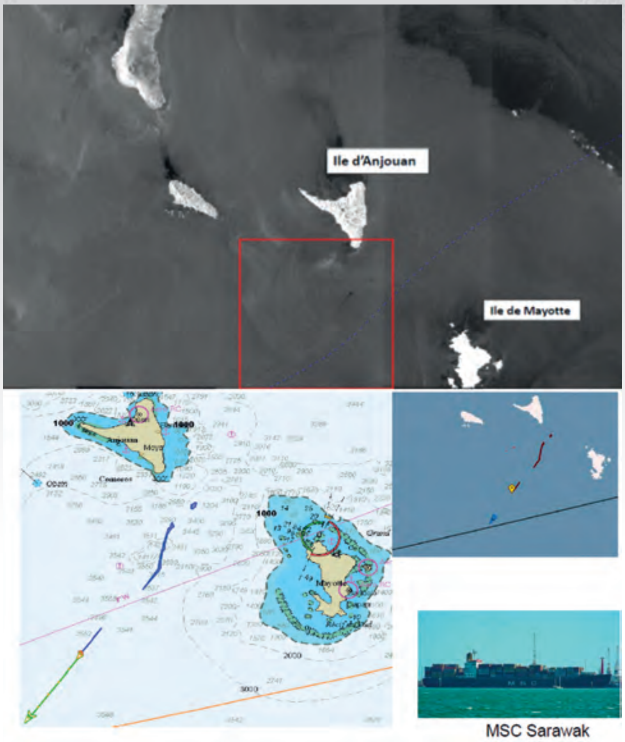

providing a description of the event: image footprint, acquisition time, slick location and extent, environmental conditions, and polluter identification (Fig. 2)

Satellite radar technology (SAR) is a key tool used for oil spill operational surveillance due to its wide area coverage, and day and night monitoring capability which is independent of cloud cover. A single satellite pass may image the area equivalent to the entire Mozambique Channel area in few seconds. In the best possible configuration satellite-based observations are combined with aerial surveillance to optimize the aerial reconnaissance missions which are sent directly on the polluted sites. A good example of this type of end-to-end service delivery is represented in Figure 3 which showcases a large oil spill (more than 50 km long) discovered on July 28, 2012 at 19:32 UTC between Mayotte and Comoros. The spill was captured in the satellite imagery. The AIS message broadcasted by the vessel and collected by the communication satellites allowed polluters non-ambiguous identification. Following this notification, the reconnaissance aircraft was dispatched from Mauritius to fly on-site to check on the situation. Suspected polluters were later on boarded for inspection while in port transit in South Africa.

The same concept of operation was applied in support of crisis management off the coast of Mauritius to mitigate potential pollution risks and provide early warning during an accident taking place from August 30 to September 9 when very large crude carrier vessels run aground. Seven high resolution images were acquired within short notice to monitor the status of wreckage, look for signs of oil leaks and to support the oil spill contingency plan activated after the shipwreck. Fortunately, no spill occurred during the rescue operations (Fig. 4).

Monitoring of environmentally sensitive areas

Given the proximity of shipping lanes to sensitive habitats even small volumes of mineral oil could harm surrounding marine ecosystems. Therefore the combination of oils spill detection and with coral reef observations established a basis for a highly effective and easily accessible database which supported to conventional monitoring and surveillance capabilities in the area.

Long term protection of the regional coastal and marine environments and their rich biodiversity from damage is one of the priorities in the region. The EO data contributed to the existing maps of environmentally sensitive areas with analysis of the environmental stress conditions of coral reefs. This was based on the estimation of the reefs morphology as well as main stressors such as sea-surface temperature, suspended sediment concentration, water transparency, chlorophyll concentration, and significant wave height (Fig. 5). Detailed analysis using very high resolution (VHR) data was conducted for four coral reefs study sites: Aldabra Atoll in the southwest Seychelles (a UNESCO World Heritage site since 1982 and an official RAMSAR site since 2010), Mayotte (France), Rodrigues (Mauritius), and Tulear (Madagascar) providing habitat maps (detailed geomorphological zonation) and assessing their evolution between 2000 and 2011. The basic elements of the reef system were delineated and characterized. The map products

3. Screenshots of the visualization system which shows an oil spill detected between Comoros and Mayotte (using radar imagery) and its connection to the polluter vessel (as identified by its AIS message signal collected by satellite). Credit: CLS; ENVISAT ASAR data © ESA.

included, in their full complexity, as much as 26 classes representing the geomorphological diversity of the studied sites, and for some classes, additional information on benthic cover.

This information offered an important insight into the state of the coral reef systems and surrounding environment, which was complemented with the analysis of their long term evolution. For example, observations revealed massive loss of coral zones over the period of 1962-2012 at the Grand Recife de Toliara, GRT, site (Fig. 6) as well as changes in Mayotte's seagrass zones. For the GRT the time series of images clearly reveal modifications of geomorphological zones and the loss of coral communities. Between1962 and 2011, 77% of the initial coral stripes surface was lost. These changes are resulting from various factors, such as sediment dynamics, cyanobacteria development as well as erosion of dead coral framework. However, the biggest cause of the changes is due to destructive fishing practices, with a high frequentation of fishermen tramping over, breaking and moving coral colonies in search of benthic invertebrates.

Follow on

The added value of Earth Observation to the existing instruments for data collection and pollution control in the region has been groundbreaking. After the 5 month demonstration the services were taken up as an integral part of the World Bank-implemented Western Indian Ocean Marine Highway Development project. In the first phase of the transition of the service to the local authorities the coverage was extended to include all of the coastal waters of South Africa, coastal waters of Mauritius including Rodrigues and the marine route between La Réunion and south of Madagascar. The local users of the services received on-site trainings on principles of radar satellite remote sensing , use of the on-line system and interpretation of the reports as well as recommendations for coordinated space/ground operations (acquisition planning and how to conduct

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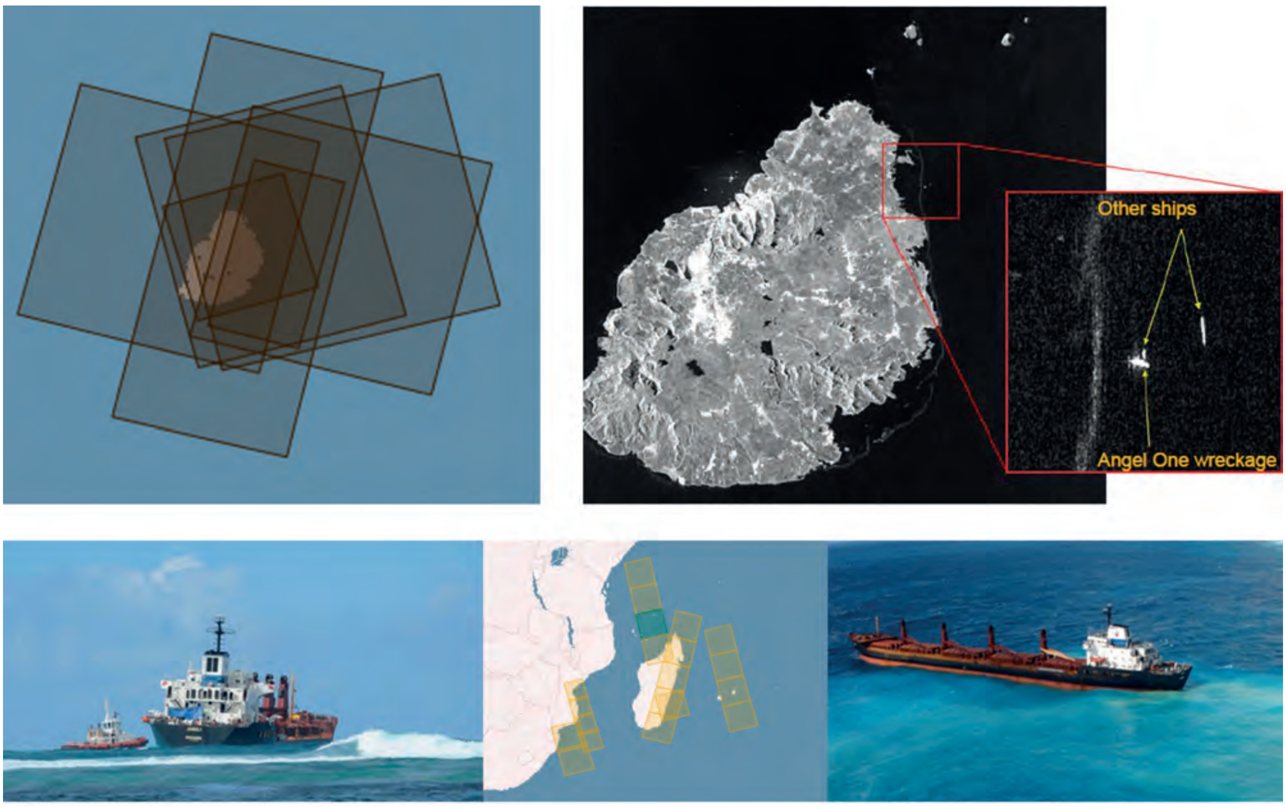

4. Support to crisis management after Angel One carrier run aground. Credit: CLS.

on-site validation). In this transition phase, ESA continued to provide radar satellite images for analysis. Moreover, a number of improvements were proposed to user interface, including the integration of the coastal AIS network operated locally, integration of maps of sea-surface current and sea-surface swell to the system as well as development of the tailored application suitable for mobile devices (tablets, smartphones, satphones, etc.). In the long run the aim is to integrate these services to the Regional Coordination Center for Oil Spill and Chemical Spill Prevention which is planned to be hosted by South African Maritime Safety Agency (SAMSA). Coral reef monitoring will continue in collaboration with the Mauritius Oceanographic Institute, partially implemented within the framework of the European Union MESA (Monitoring of Environment and Security in Africa) project which will additionally study coral reef stress indexes with the objective to provide 10 to 20 maps per year. If required, field surveys could be carried out to allow the inference of more complex products (reef states, species, etc.)

From the technical perspective, the availability of Earth Observation satellites, particularly near-real-time radar data covering, is essential for the long-term sustainability of this type of operational maritime monitoring and surveillance services. The guaranteed long term access to appropriate satellite observations in support of this and other environment- and security-related monitoring projects will be enabled by the operation of ESA's new satellite missions. In particular, the Sentinel-1 satellite will ensure the continuity of the ENVISAT radar observations on which the Mozambique Channel surveillance service was based. Moreover, as the services are gradually adopted by the local authorities, the timeliness of delivered information will be greatly improved when using the local satellite receiving antenna based in La Réunion (SEAS-OI, Surveillance de l'Environnement Assistée par Satellites dans l'Océan Indien, satellite receiving station). This will allow direct downlink of the data after their acquisition and the reduction of time from detection to notification of the potential events to less than 30 minutes.

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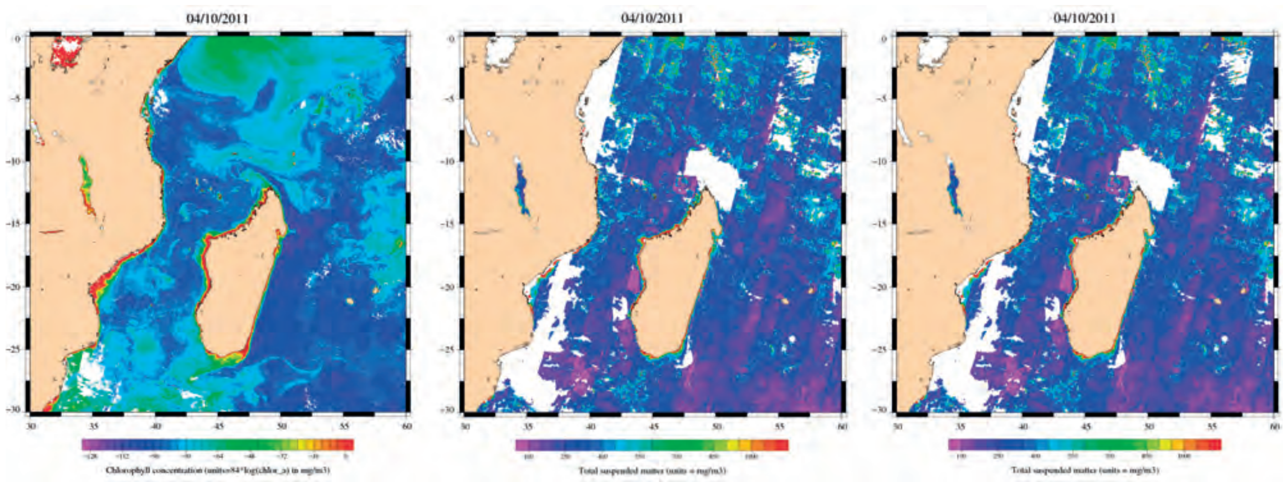

5. Maps of chlorophyll concentration (left) and sea surface temperature (SST) (right). Credit CLS.

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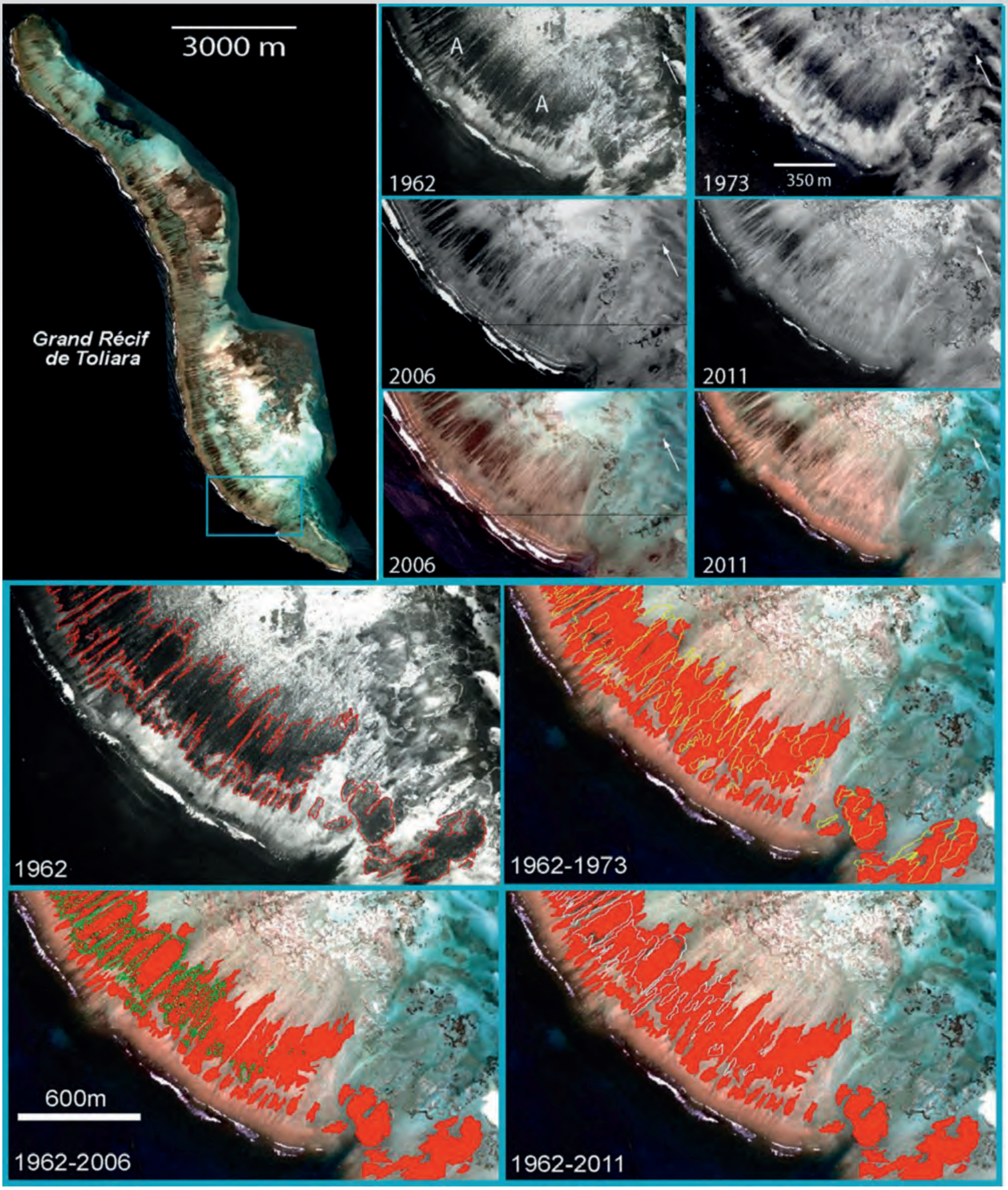

6. GRT area processed for change detection between 1962 and 2011 is shown on the lower images. All available imagery for change detection are shown on the upper right. Credit: IRD.

Historical Assessment of Spatial Growth of Built-up and Metropolitan areas of Delhi, Mumbai and Dhaka

Users
World Bank Unit:
World Bank Urban Development Department,
South Asia Megacities Improvement Program
Local Stakeholders:
Dhaka: municipalities & local engineering department
Mumbai: metropolitan development agency
Delhi: several state governments including main capital planning board

EO services provided
Accurate historical land cover/use mapping by exploiting the High Resolution (HR) Optical data archive: providing a sequence of land use datasets monitoring urban growth in 1992, 2003 and 2011.

Service providers
GISAT (Czech Republic)

ESA Technical Officer
Benjamin Koetz, Dr. sc. nat.
European Space Agency
Tel: +390694180653 | Benjamin.Koetz @esa.int

WB Task Team Leader
Songsu Choi
The World Bank Group
Former Lead Urban Economist, Urban Development Unit, South Asia Region

Within the framework of the South Asia Megacities Improvement Program, the eoworld project focused on mapping 20 years of urban expansion in the metropolitan areas of Delhi (the Delhi National Capital Region (South-East part)), Mumbai (the Metropolitan Region of Mumbai) and Dhaka (the Statistical Metropolitan Area). The analysis of high-resolution satellite data provided spatially-explicit information about the current state and previous development of land use and land cover resources, including:

- Structure of the land cover and land use stock;
- Spatial and temporal distribution of land use and land use change over the past two decades; and
- Comparison between metropolitan areas in space and time.

The observations covered a total of 18,000 square kilkometers.

Structure of the land cover and land use stock

The analysis conducted for 2010/11 revealed that the land cover and land use composition in the three

Major benefits on EO data level	Major benefits on EO based information level	Major benefits on EO based service level including dissemination via the Web Tool platform framework
▪ time-space comparable contents ▪ synoptic and consistent mapping around the globe, including remote locations ▪ multi-scale (global, regional, local) and multi-sensor (high res/low res) solutions ▪ long temporal archives ▪ free data or competitive pricing ▪ represents cost effective solution comparing to in-site survey or mapping	▪ spatial explicit information on land cover/land use evolution ▪ state-of-the art image analysis techniques (e.g. object oriented approaches) ▪ harmonized contents for large areas over long time ▪ information on spatial/temporal patterns, quality and intensity of changes ▪ information comparable between cities ▪ consistent analytical framework - insight into urban related processes and drivers ▪ past trends / forecasting ▪ identification of priority areas ▪ retrospective potential	▪ easy exploration tool for complex data ▪ instant integration of various presentation modes in easy-to-use integrated environment ▪ integration of spatial and socio-economical data ▪ multiple views across multiple themes ▪ predefined or user defined analytical units ▪ support to collaborative work, data analysis and reporting

megacities is quite distinct. In Delhi National Capital Region (South-East part) the land use is dominated by agriculture (73%). Urbanized area represent only 20% of the land cover. In the Metropolitan Region of Mumbai only 15% area is urbanized, while the share of non-urbanized area is balanced between agriculture land (34%), (semi-)natural vegetation (28%) and forest (17%). In Dhaka Statistical Metropolitan Area the urbanized area is 48%, but large parts of that is occupied by rural settlements and scattered built-up areas (18%), surrounded by a specific class of groves of trees. Non-urbanized area is dominated by agriculture land (43%) (Fig. 1)

Structure and intensity of change

Satellite-based monitoring is an extremely effective method of identifying the rate, location and the characteristics of urban sprawl which takes place outside of administrative boundaries of cities as well as other types of urban expansion. As a monitoring method it can offset any missing or inaccurate

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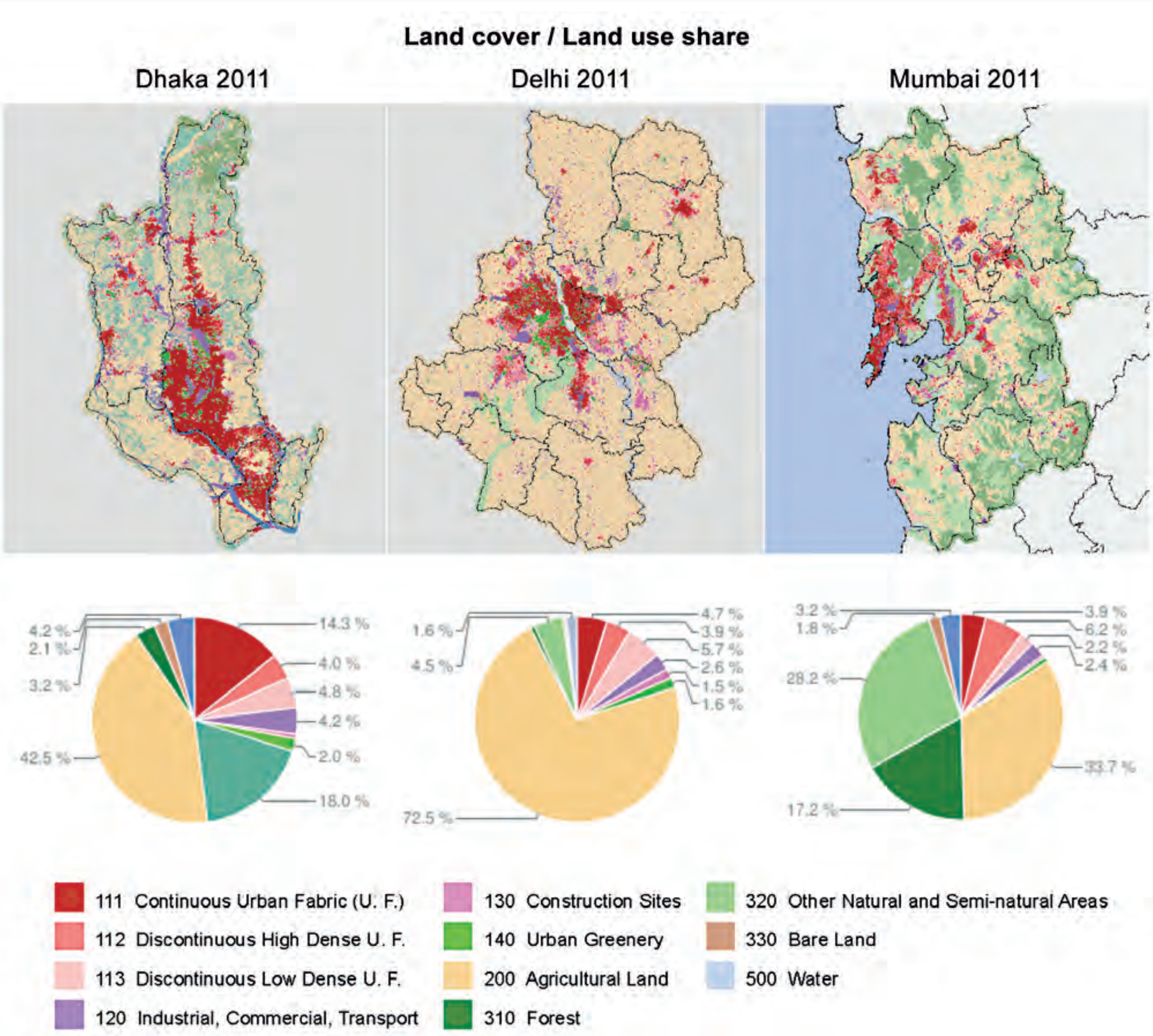

1. Example of the land use maps developed for the year 2010/2011 and statistical information derived from spatial data analysis. Credit: GISAT.

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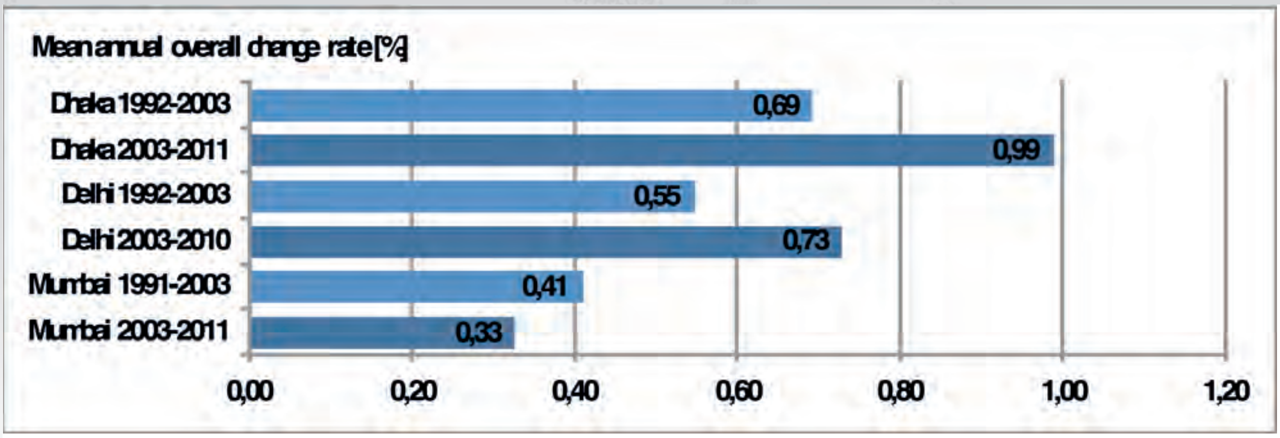

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2. Example of the land use maps developed for the year 2010/2011 and statistical information derived from spatial data analysis. Credit: GISAT.
3. Overall change type in all three megacities. Credit: GISAT.

information and track the de facto trends occurring often outside of control or supervision of local authorities. The ability to collect this type of information is particularly important in view of the lack of a consensus regarding the administrative borders of the 100 largest urban areas in the world.

As seen in Figure 2, the overall change rate in the three megacities studied is high (0.3%-1% of total area per year (i.e. 5-8 times more than the average in Europe (0.11%)), which confirms that all areas are under dynamic development. Except in the Mumbai area, the change rate is also increasing.

In addition, Figure 3 below shows that in all three megacities the increase of artificial surfaces is by far the most dominating type of change in comparison to other land transformations (i.e. extension/reduction of urban greenery, rural settlements, recultivation, etc.). The study also assessed the structure of a massive urban sprawl (land uptake by residential, commercial and industrial buildings together with associated services

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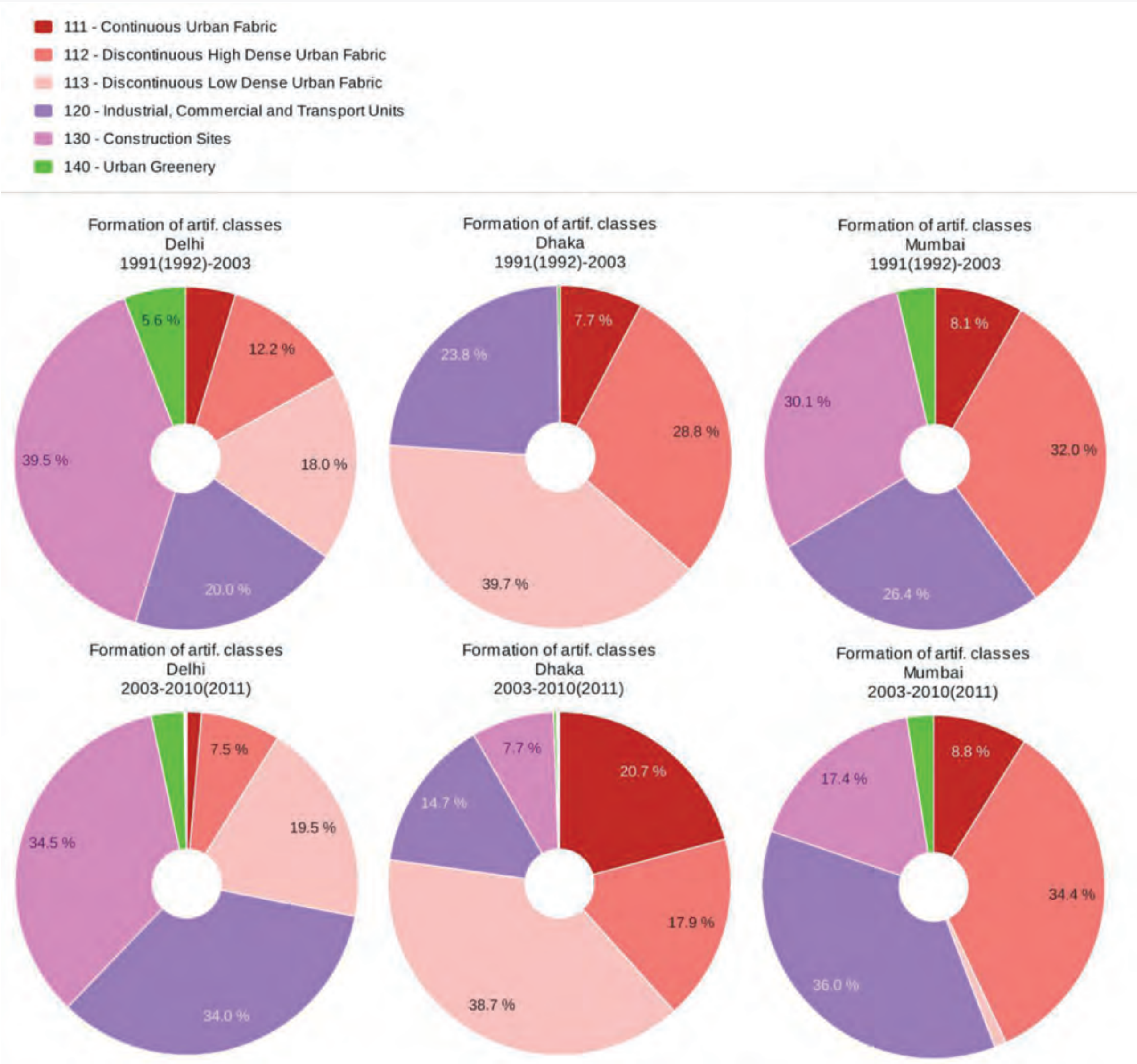

4. Overall change type in all three megacities. Credit: GISAT.

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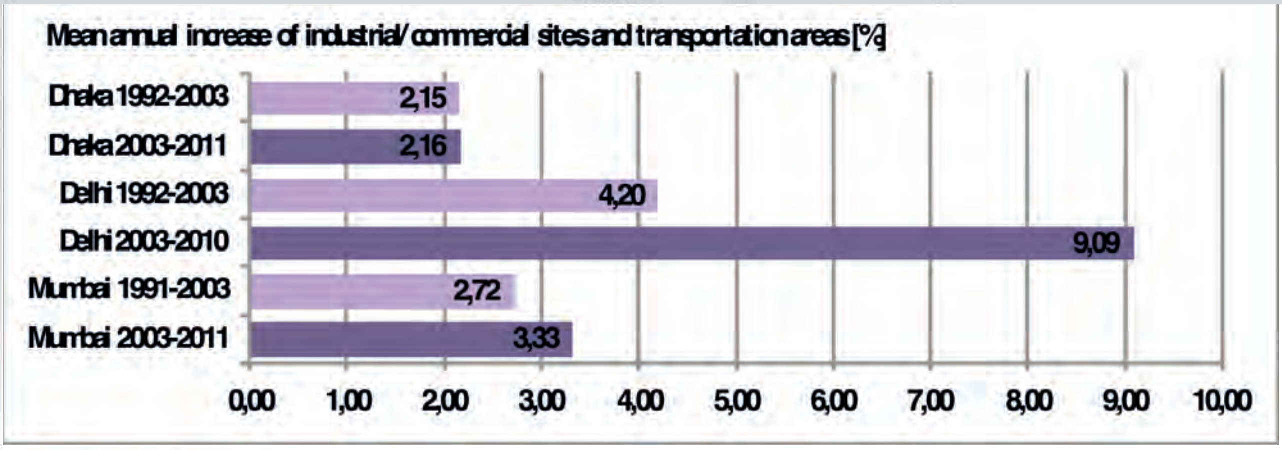

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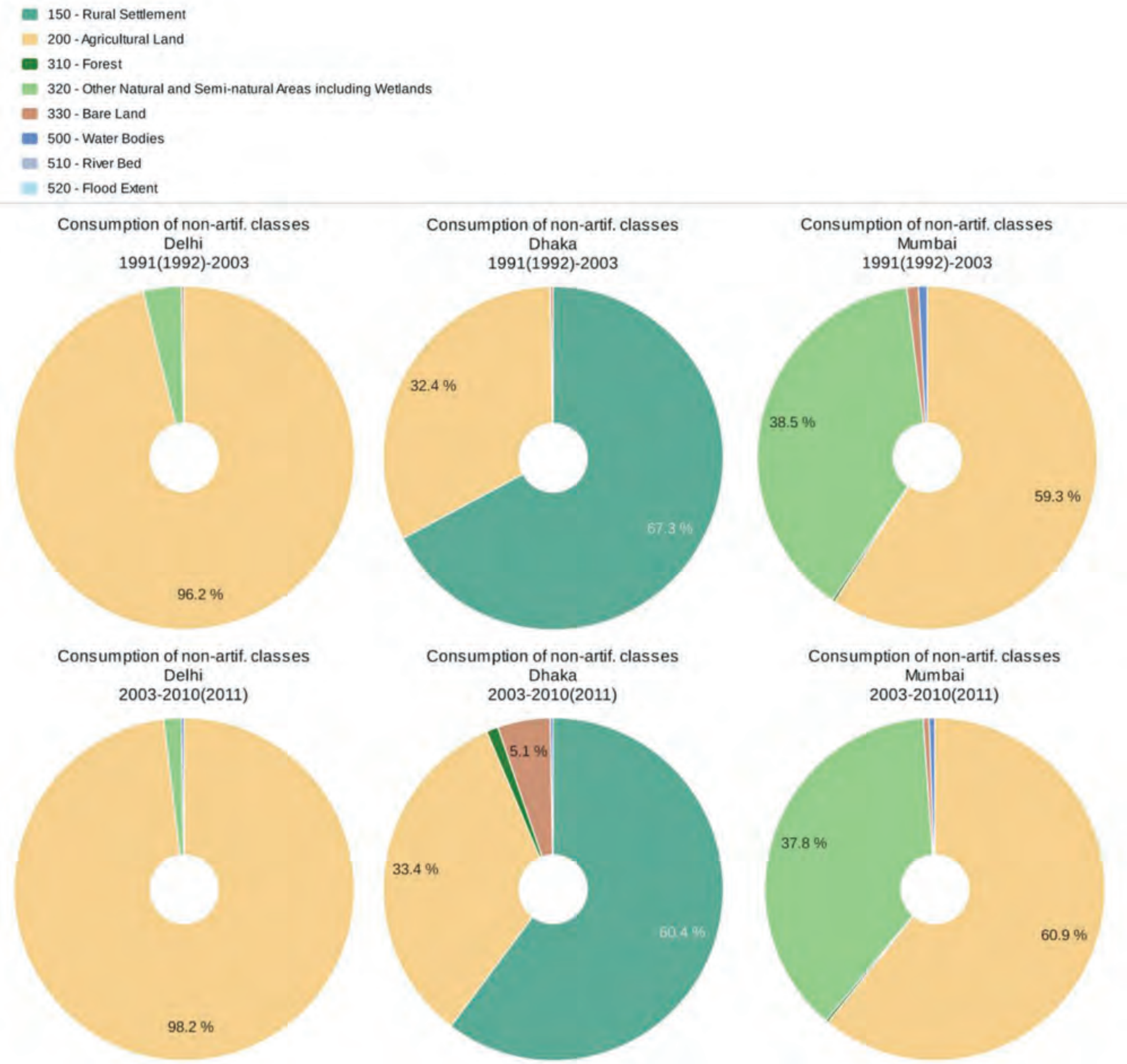

5. Annual increase of industrial, commercial and transportation areas (class 12*) in percent of initial area and its trend in all three megacities. Credit. GISAT.
6. Non-artificial land consumption (due to artificial land uptake) structure and its trend in all three megacities. Credit: GISAT.

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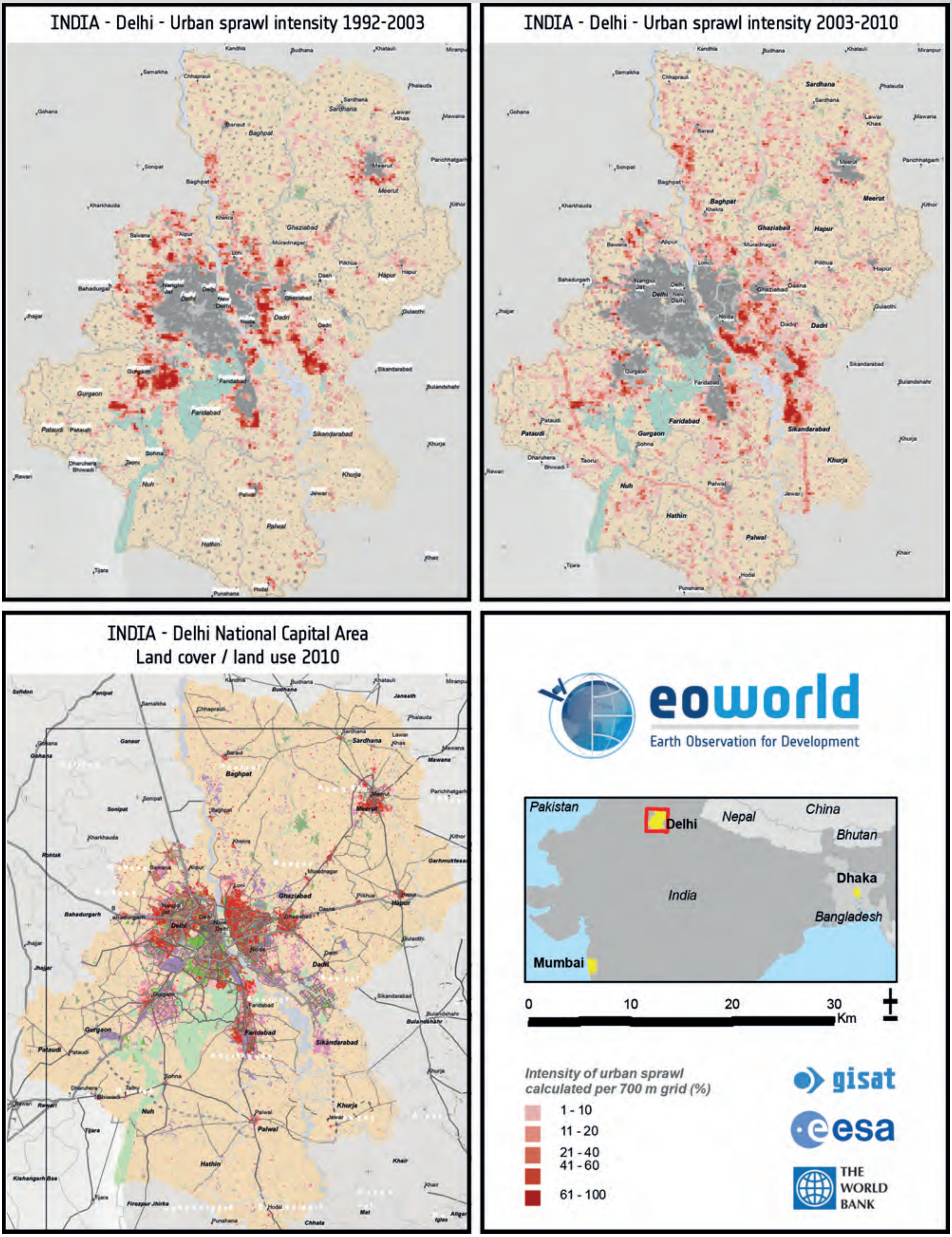

7. Overall change type in Delhi. Credit: GISAT.

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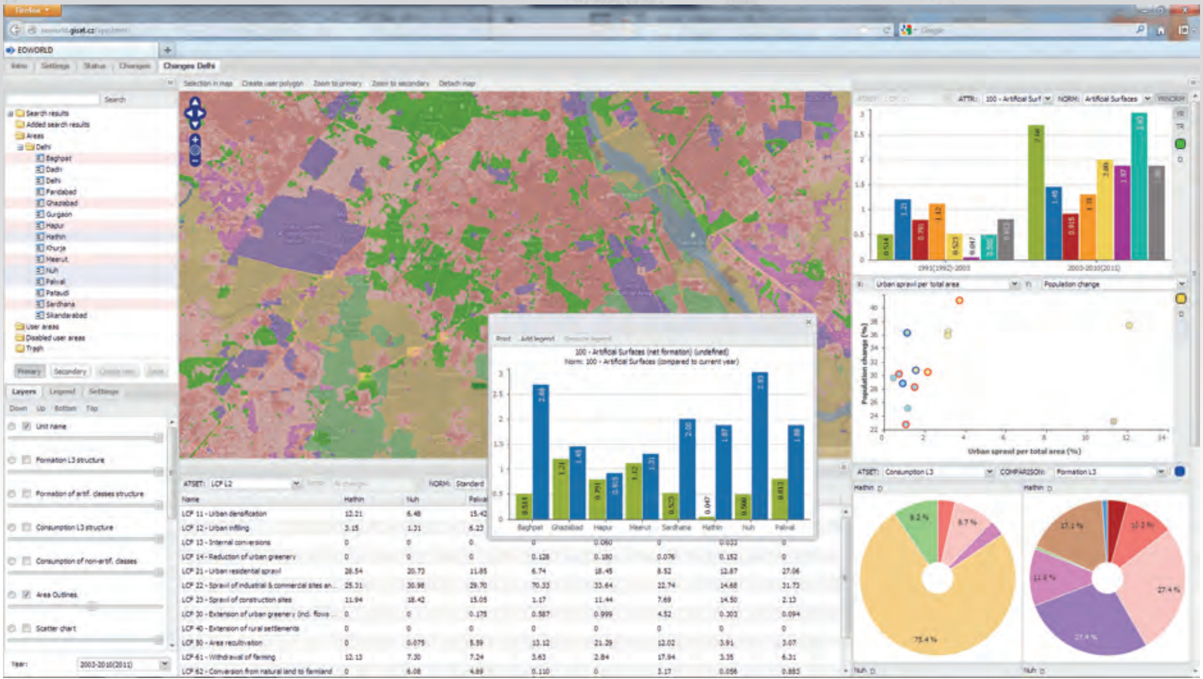

and urban infrastructure) taking place since 1991/1992, including the changes between residential, commercial and industrial zones (Fig. 4). In Dhaka it is clearly dominated by residential built-up, while in Delhi and Mumbai, the urban sprawl is accelerated by industrial development (during 2003-2010 predominantly for Delhi) (Fig. 5). Large increase of construction sites indicates that this trend will likely continue in the future.

Impact on the surrounding environment

Urbanization in the form of new constructions projects, residential quarters, new industrial and commercial facilities or transport infrastructure, changes the functions of the surrounding environment. If occurring in uncontrolled manner, rising percentages of the ground sealing levels may lead to a number of challenges to sustain the urban development, such as

9

9. In Delhi and Mumbai the urban sprawl is accelerated by industrial development. Photo: Delhi, World Bank

10

uptake of the arable land, reduction in soil permeability, and drainage capacity among others. EO is a very powerful tool to identify the extent of urban impact on the natural areas and assess potential conflict between them. The eoworld study revealed that while agriculture land is taken almost exclusively in Delhi area (>95%), in Mumbai, large share of land turned to urban is represented by (semi-)natural land (~38%). In Dhaka, land consumed by urban sprawl is dominated by rural settlements. The latter is a sign of gradual densification of rural settlements leading to disappearance of surrounding high vegetation and small gardens (Fig 6).

Finally, insight into the spatial distribution and intensity of changes within the monitored areas was also provided. As seen in Figure 7, spatial distribution of urban sprawl has a different pattern in each megacity. In Dhaka the urban sprawl is mostly concentrated in central-north part of the area, while in Mumbai in the central/central-west part. In Delhi low density urban sprawl is distributed almost equally over the whole megacity territory.

Working with data: better visualization, comparison and analysis

In addition to the core mapping outputs, the project provided a state-of-the-art data exploitation Web Tool which facilitates spatial data integration with other in-situ datasets to support collaborative work, data analysis, and the use of data in reporting. The Web Tool can be accessed at the dedicated Urban Portal (https://eoworld.gisat.cz).

The advantage of working with digitalized spatial data lays in the possibility to analyze datasets at the level of different administrative units: metropolitan level, city level, district level, sub-district level, as well as other city catchment (non-administrative) units depending on information needs. Such datasets allow flexible aggregation. For instance they can provide information concerning the ratio of population growth correlated with urban growth rate, the proportion of sprawl by district, the distribution and density of urban sprawl, urban area class evolution, the drivers of urban change, and so on. In addition, in combination with available environmental or socio-economic data it is possible to measure different city indicators, such as compactness (as a function of city density), the ratio of green urban areas per inhabitant, or the proximity and accessibility of green urban areas, among others.

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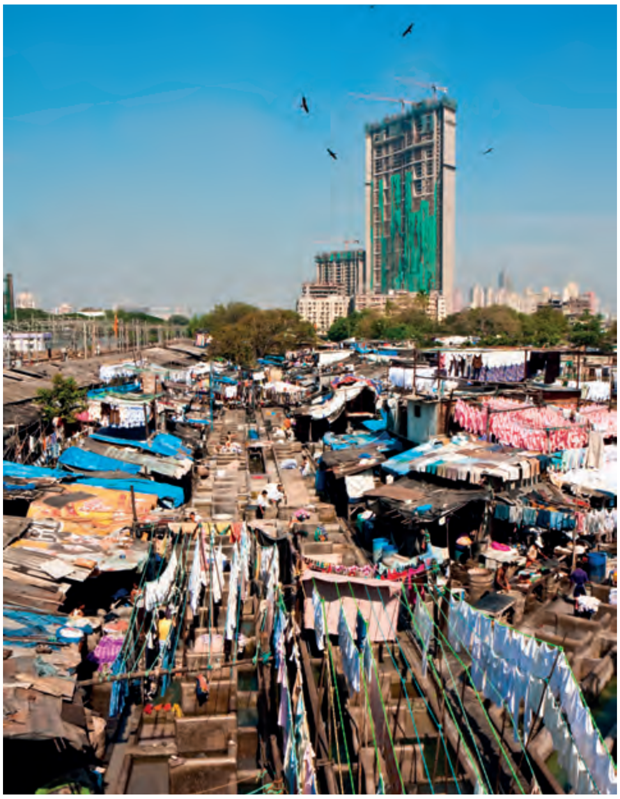

10. The study found that urban sprawl in Dhaka is clearly dominated by residential built-up areas. Photo: World Bank
11. In Delhi and Mumbai the urban sprawl is accelerated by industrial development. Photo: Mumbai, India by Simone D. McCourtie / World Bank

Sustainable Oil Palm Production in Papua New Guinea

Users

World Bank Unit:
World Bank PNG Country Office (Sidney, Australia)
Local Stakeholders:
- Provincial government of the PNG Orto and West New Britain provinces
- Oil Palm Industry Corporation (OPIC)
- PNG Oil Palm Research Association (PNGOPRA)

EO services provided
- Forest mapping for three points in time 2005-2009-2011 using High to Very High Resolution (HR/VHR) Optical sensors
- Land cover mapping for 2011 using High to Very High Resolution (HR/VHR) Optical sensors

Service providers
SarVision (Netherlands)

ESA Technical Officer
Benjamin Koetz, Dr. sc. nat.
European Space Agency
Tel: +39 06 94180653 | Benjamin.Koetz@esa.int

WB Task Team Leader
Mona Sur
Senior Agriculture Economist, Pacific Islands Sustainable Development Department, East Asia and the Pacific Region | The World Bank Country Office, Sydney, Australia

Oil palm agriculture production is one of the most important sources of cash income for rural households in Papua New Guinea (PNG). The smallholder oil palm blocks support between 180,000 and 200,000 people. In this context, the Smallholder Agriculture Development Project (SADP) funded by the World Bank and PNG Sustainable Development Program Ltd (PNG SDP) aims to increase, in a sustainable manner, the level of involvement of targeted communities in their local development through measures aimed at increasing oil palm revenue and local participation.

Environmental and social sustainability of oil palm cultivation is a priority for SADP. The project adopted sustainability principles & criteria reflecting the key mechanism for certifying palm oil as sustainable - the Roundtable on Sustainable Palm Oil (RSPO) to mitigate environmental impacts of the main project activities which include infill planting of 9000 of hectares of new village oil palms and rehabilitation of 550km of the existing rural roads to facilitate local communities' access to critical social services and markets.

Moreover, SADP promotes measures to prevent smallholders from displacing their food gardens into protected areas. A special attention is paid to ensure that the buffer zones along rivers, springs and streams are maintained and that the patches of mangroves, wetland and remnant swamp areas remain undisturbed (i.e. there is no construction or renovation of drainage channels in adjacent oil palm blocks or roads).

The key added value of satellite mapping services in support of implementation of the SADP project concentrated on a reduction of a number of investment risks. It provided new opportunities for verification of the planting process and supported project management with innovative options for effective monitoring of potential stresses due

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1. Oil palm production is one of the most important sources of cash income for rural households in Papua New Guiney. Smallholder oil palm blocks support between 180,000 and 200,000 people. Photo(s): Mona Sur / World Bank to planting or road construction. It demonstrated that tangible and factual information concerning the status of oil palm plantations, forests and other types of land cover can be provided objectively and on the regular basis.

Investment planning

EO mapping supported the investment planning by creating the baseline map showcasing the current land use to make sure that the active planting is taking place only in eligible areas, and that the planting does not affect primary forest or high conservation value areas (HCVA). The baseline mapping focused on in two SADP locations - Oro Province and West New Britain Province and provided the most spatially and thematically detailed land cover maps of Oro and WNB to date, the most recent and up-to-date forest cover change (deforestation) map of Oro to date. It also upgraded the roads dataset. They were significantly improved in terms of accuracy and detail in comparison to the previously available data from 2009. The new road datasets also allowed to accurately assess the location and length of (access) roads for project planning and compliance monitoring purposes (Fig. 5 a/b).

Land use trends

The presence of both the established mature oil palm estates as well as smallholder areas dominates the agricultural landscape in Oro Province (Fig 1). However, there is no evidence of the oil palm plantation expansion into primary forest after 2005 and, consistently with this, the encroachment to secondary forest is driven by selective logging, logging for road development and small clearings for small subsistence agriculture and food gardens (< 0.5 ha) rather than clearing for palm oil production.

Moreover, the examination of the forest cover and deforestation rate between 2005and 2011 clearly indicated that the rate of deforestation in that area is minimal. The net forest loss during that period amounts to 15,481 ha which equals to 1.8% of the total forest cover in 2005. The map in Figure 2 based on the RapidEye 5m satellite image mosaic for the year 2011 (left) shows how EO-based information was used for identification of small clearings (blue spots), secondary forest (dark brown), smallholder oil palm (dark orange) as well as other land cover types. The forest cover change map on the right (at 30m resolution) shows deforestation of secondary forest during 2005-2009 (orange),

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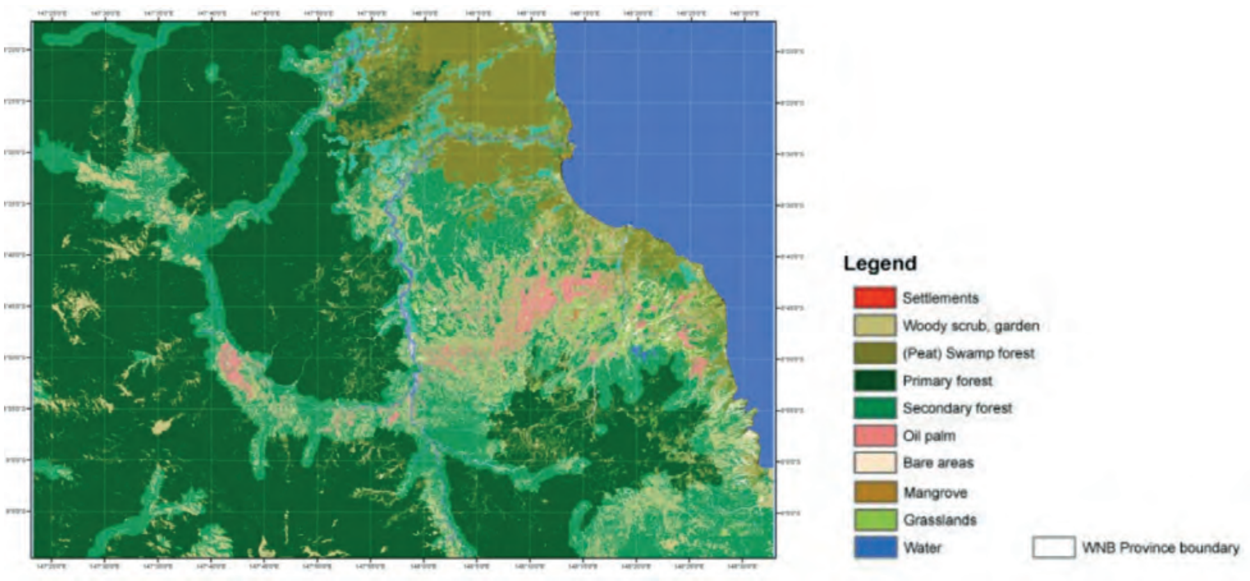

2. Land cover map for Oro Province. Credit: SarVision.

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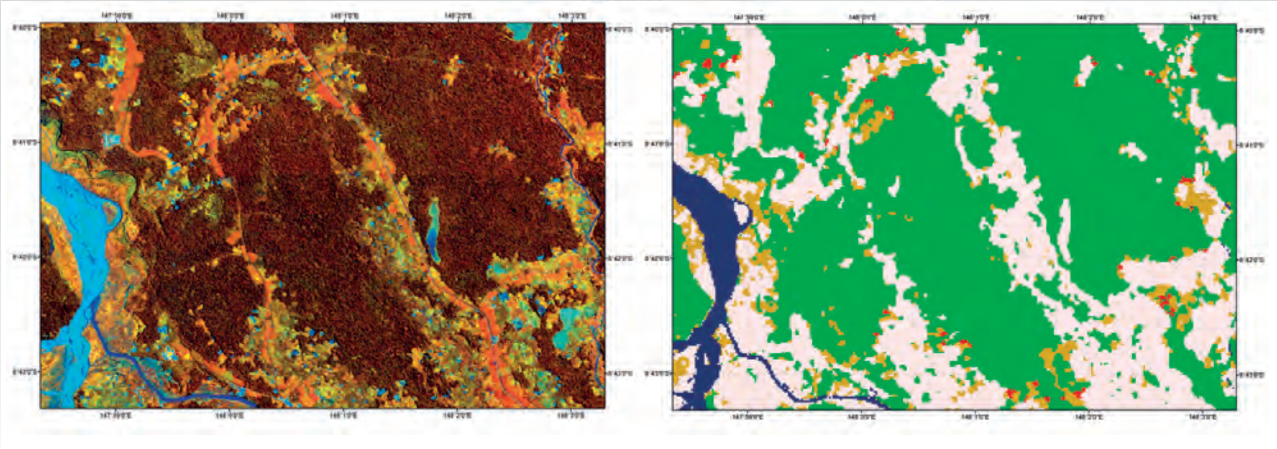

deforestation of secondary forest during 2009-2011 (red), in addition to secondary forest (green), rivers (blue), and non-forest including oil palm (white).

The forest cover change map product provided information for assessment of compliance with deforestation monitoring requirements resulting from SADP and RSPO sustainability Principles and Criteria. The detailed assessment of forest change trends is exemplified in Table 1. The largest noticeable area of deforestation in primary forest was found to be 3,832 hectares during 2005-2009. This forest loss appeared to be caused by a cyclone that hit PNG in 2007 which decimated forested areas by spawning numerous landslides and causing rivers to change course. The map in Figure 4 illustrates the landslides effect in area ‘A’, while area ‘B’ is an area

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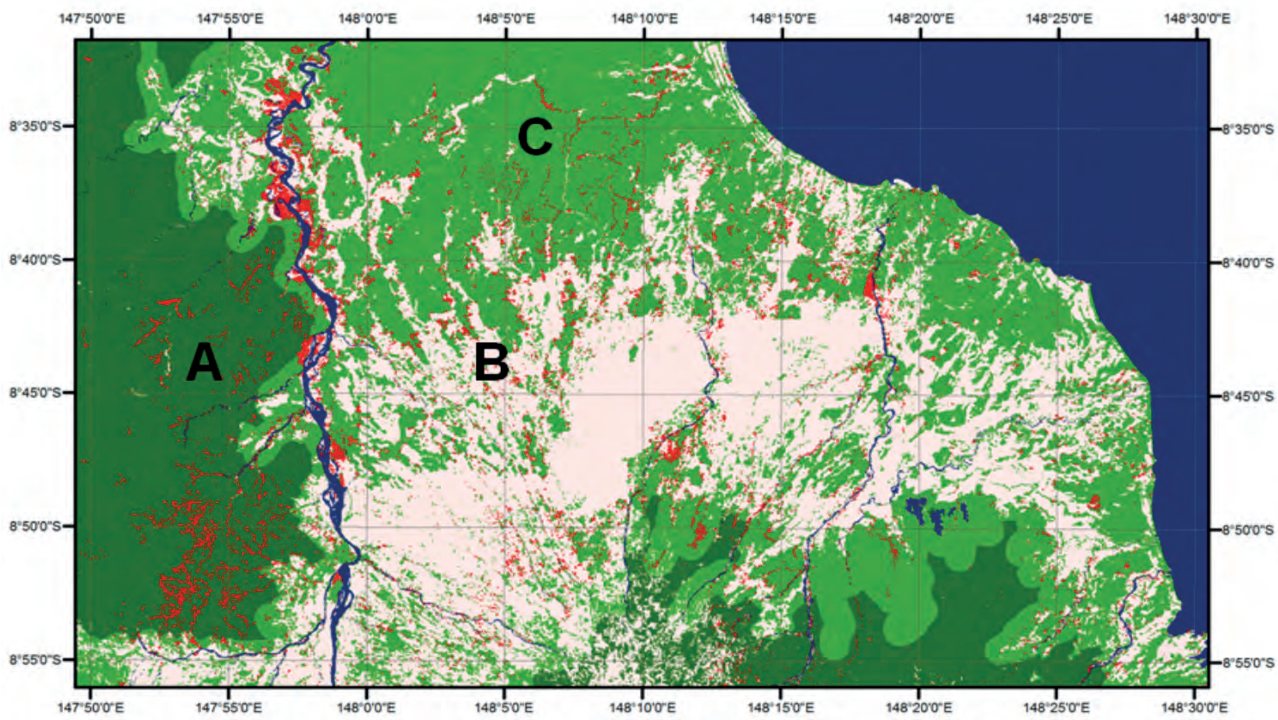
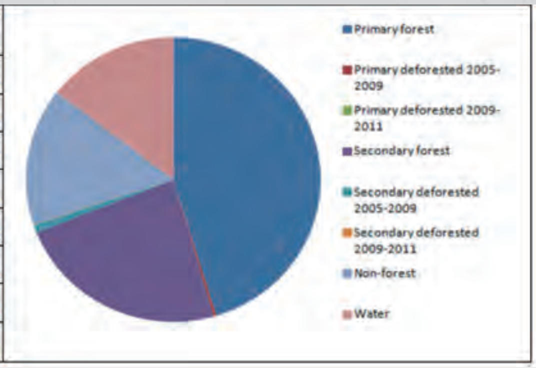


3. Detail of 5m RapidEye image (left) and 30m Forest Cover Change map (right) showing small clearings for food gardens/subsistence agriculture in Oro. Credit: SarVision, EO data © RapidEye, 2011.

4. Subset example of cumulative Forest Cover Change map 2005-2011 for Oro province. Dark green: Primary forest (dark green); Secondary forest (light green); Deforested 2005-2011 (red); Non-forest (white); Water (blue). Credit: SarVision.

Table 1

Forest cover class	Hectares
Primary forest	556,893
Primary deforested 2005-2009	3,832
Primary deforested 2009-2011	22
Secondary forest	286,963
Secondary deforested 2005-2009	10,712
Secondary deforested 2009-2011	915
Non-forest	192,480
Water	178,014



with small-scale clearing for good gardens and agriculture. Area 'C' is an area of logging along the road networks.

The landscape of West New Britain Province is quite different from Oro. It is mostly dominated by industrial oil palm estates, while extensive tracts of remaining secondary forest are subject to selective logging (Fig. 4). RapidEye 5m satellite image mosaic on the left shows older logging roads in white and more recent selective logging gaps and logging roads in blue tones. The land cover map product (right) indicated such logging activities as bare (white), while also showing secondary forest (green), woody shrub (light olive), and oil palm (light pink), among others.

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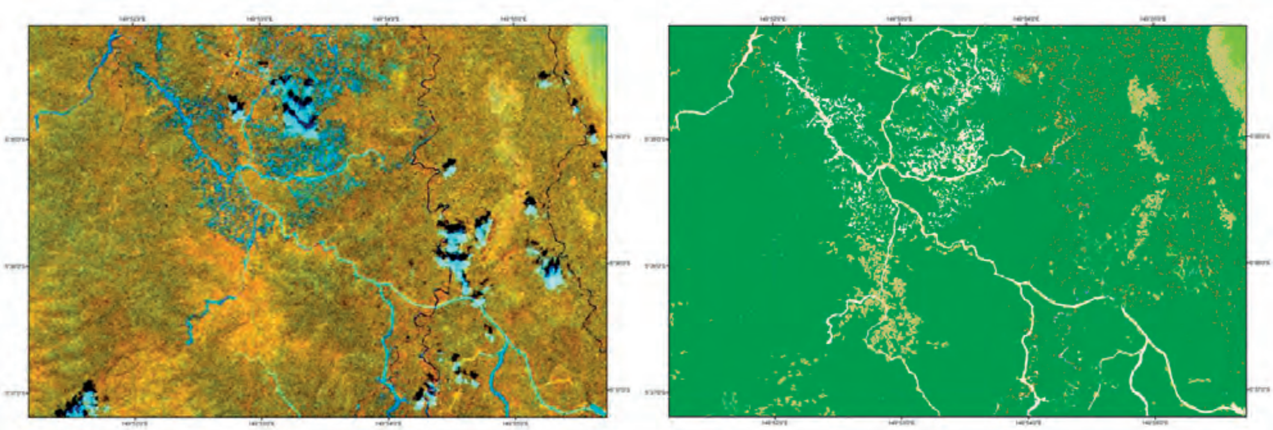

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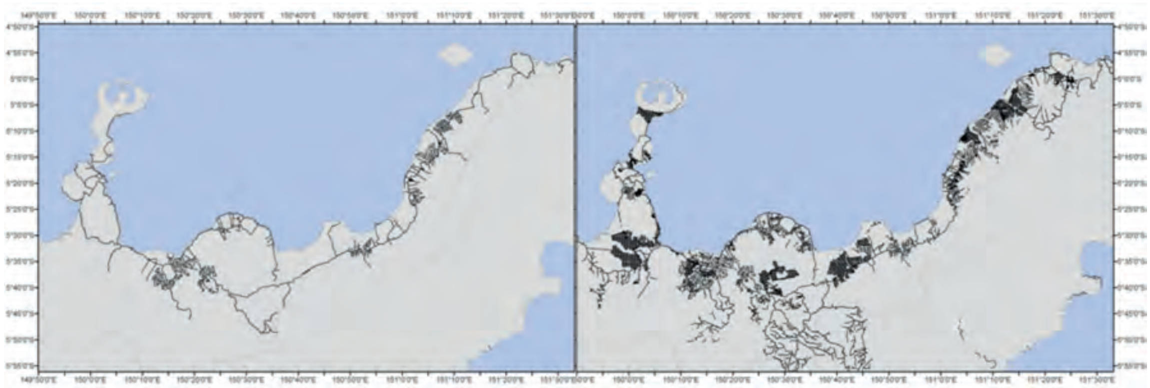

Table 1. Forest status information Oro province project area. Credit: SarVision.
5. Example of land use information and logging patterns in West New Britain. Credit: SarVision. EO Data © RapidEye, 2011.
6a. Example of detailed road dataset produced for West New Britain. Previously available roads dataset released in 2009, courtesy of the PNG Remote Sensing Centre (left), and more detailed and up-to-date road network dataset for 2011 produced during the eoworld project (right). Credit: SarVision.

Protecting High Value Conservation Areas (HVCA)

Land cover maps showing environmentally sensitive areas (e.g. wetlands) are now available as tangible proof that operational procedures for robust spatial planning and monitoring of environmental safeguards are under development and being implemented. Radar sensors such as ALOS PALSAR, or ESA's upcoming Sentinel-1, can provide unique information on the location and status of wetlands and wetland forests.

In the framework of the eoworld project ALOS data was used to demonstrate how these EO can be used to assess the extent of large tracts of intact (peat) swamps still found in the North-Eastern part of Oro (indicated in brown at 'A') and regularly flooded riparian forest (white at 'B') (Fig. 6). While the initial examination confirmed that human influence seems to be limited there - roads or oil palm areas were not found within the area - overall, to enhance the assessment of the of potential conflicts between high value ecosystems and anthropogenic activities additional information from ancillary data sources and field surveys concerning protected areas, species, the conservation status, erosion risks, and local community dependence on forests is necessary.

The information generated in the framework of the eoworld project will be integrated in the Smallholder Information System maintained by the PNG Oil Palm Industry Corporation (OPIC) - one of the key SADP stakeholders, and the key local user this information. In the future EO is planned to be incorporated in the

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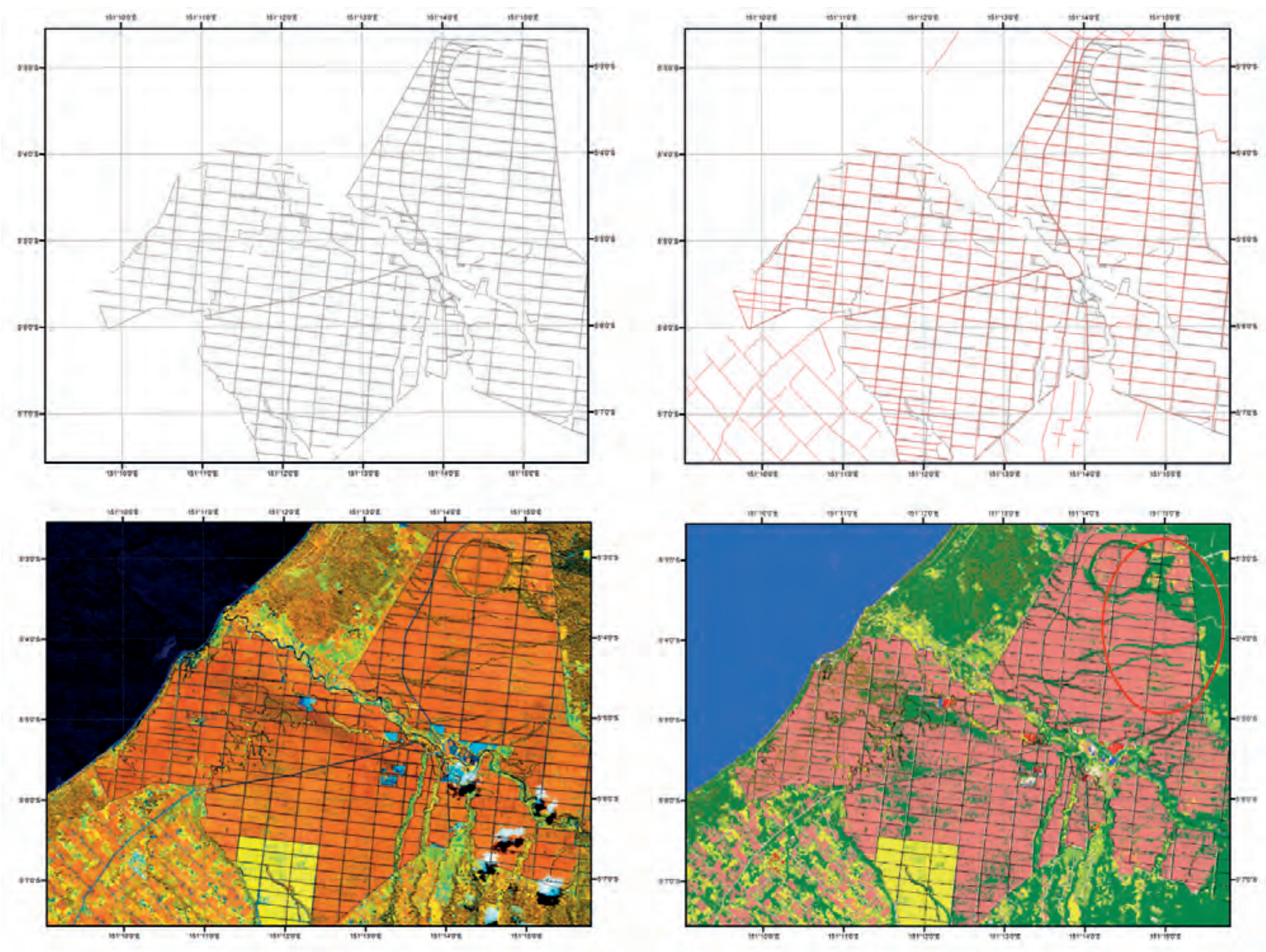

6b. Roads datasets in one of the plantations in West New Britain. Previously available dataset (left) and dataset produced in the framework of eoworld project (right) overlaid on the satellite data (bottom row). Credit: Sarvision.

framework of SADP bi-annual environmental and social audits which are aimed to assess whether necessary measures have been successfully taken to comply with the Bank's safeguards policies.

Moreover, the successful implementation of the project resulted in the interest to provide more dedicated training and capacity building to the local experts and auditors, to extend the mapping to other SADP locations as well as to test new applications to support the coffee and cocoa plantations monitoring. In the future technical developments will allow to (semi-)automate the production of forest and land cover change information maps over the eoworld PNG locations as well as over much larger areas. Systematic provision of such information can be further improved after data from ESA's Sentinel- 1 (radar) and Sentinel-2 (optical) satellites become available in 2013-2014 timeframe.

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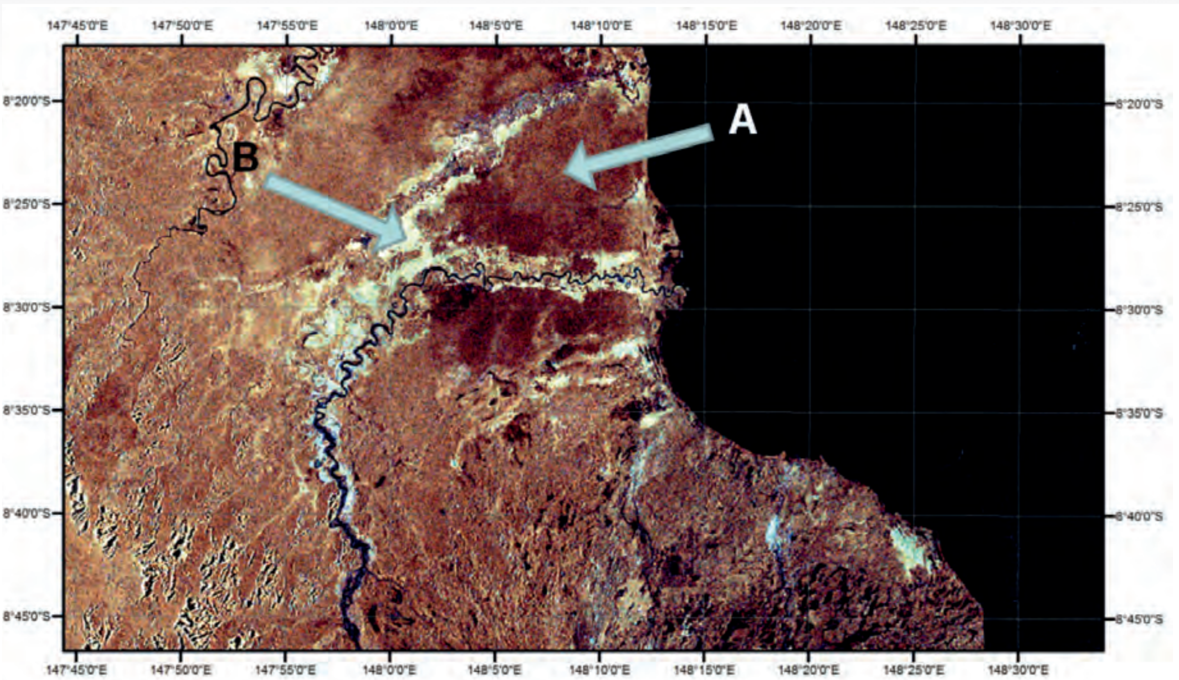

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7. Example for Oro province based on ALOS PALSAR 100m multitemporal image composite using data collected every 46 days for a full season between 2010 and 2011. Credit: SarVision, ALOS data © JAXA.

8. The Roundtable on Sustainable Palm Oil (RSPO) was formed in 2004 with the objective of promoting the growth and use of sustainable oil palm products through credible global standards and engagement of stakeholders. Photo: Anna Burzykowska / World Bank.

Forest Resources Management in Liberia

Users
World Bank Unit:
Environment and Natural Resources Management Unit, Africa Region, Liberia Forestry Program
Local Stakeholders:
- Liberian National Forestry Development Authority (FDA)
- FAO's Liberia Forest Initiative (LFI) Partnership

EO services provided
- Forest mapping in North-Western Liberia for 2002, 2006, 2011
- Land cover and terrain mapping for 2011

Service providers
- Metria (Sweden)
- GeoVille(Austria)

ESA Technical Officer
Benjamin Koetz, Dr. sc. nat.
European Space Agency
Tel: +39 06 94180653 | Benjamin.Koetz@esa.int

WB Task Team Leader
Paola Agostini
The World bank
Senior Economist, Africa Region

Unsustainable depletion of natural resources is a serious problem in many developing countries. Fortunately for Liberia, deforestation and forest degradation remained low during the last decade despite the pressures to allow greater forest resources exploitation. At present, the main challenge is to reconcile different visions for the forest sector development which would take into account the needs of export-oriented commercial timber industry, with conservation and community needs.

The issues related to forest management in Liberia are very complex. Liberia's forest is rich in biodiversity and a recognized global hotspot for conservation. At the same time timber sector is very important for country's social and economic development. Whereas timber production can become a significant source of GDP, most of the country's rural population is dependent on forests as well as various forests products and ecosystem services for their day-to-day livelihoods (i.e. ecotourism industry, soil conservation, and protection of water resources). Moreover, the establishment of an international mechanism to compensate countries for reducing emissions from deforestation and forest degradation (REDD+) offers an opportunity for Liberia to benefit from the carbon market. Liberia's participation in REDD + was formally submitted in May 2011 with the objective to introduce a range of new priorities and instruments for forest conservation and management.

In view of this, the need for adequate geo-data to assess the state and evolution of Liberia's forest is immense. The eoworld project demonstrated that the assessment as well as control of the use of forest resources can be much improved with a use a monitoring system based on a combination of EO analysis and field data collection. In addition, a parallel study was conducted to provide an independent validation of various contradictory reports on Liberia forest base, in particular the accuracy of forest assessments conducted in the past, and potential overlaps of land allocation concessions. The results supported the World Bank dialogue with the government concerning land use reforms and were transferred to the national Liberian Forest Authority to inform discussions concerning different land uses and the allocation of concessions (i.e. which areas are more suitable to be designated for agriculture concession, commercial forestry or kept for carbon and biodiversity conservation.)

Independent verification and concessions mapping

Over the years, several forest assessments were conducted in Liberia including a nation-wide forest mapping in 2004 which constituted the basis for allocation of forest concessions. A recent reevaluation of the country's forest resources indicated however, that a national forest type map series is outdated, that the previous maps are not compatible, and that there are some methodological problems in the earlier forests assessments (i.e. regarding definitions of land cover classes and the estimation of forest cuttings and re-growth which were not accounted for). This independent verification has also revealed serious overlaps of existing concessions for timber, agriculture, conservation, and mining. The mapping of concession areas based on the government level data indicated that several proposed Forest Management Concessions (FMC) – (B, C, D, H, M, ULF) and Timber Sale Contracts

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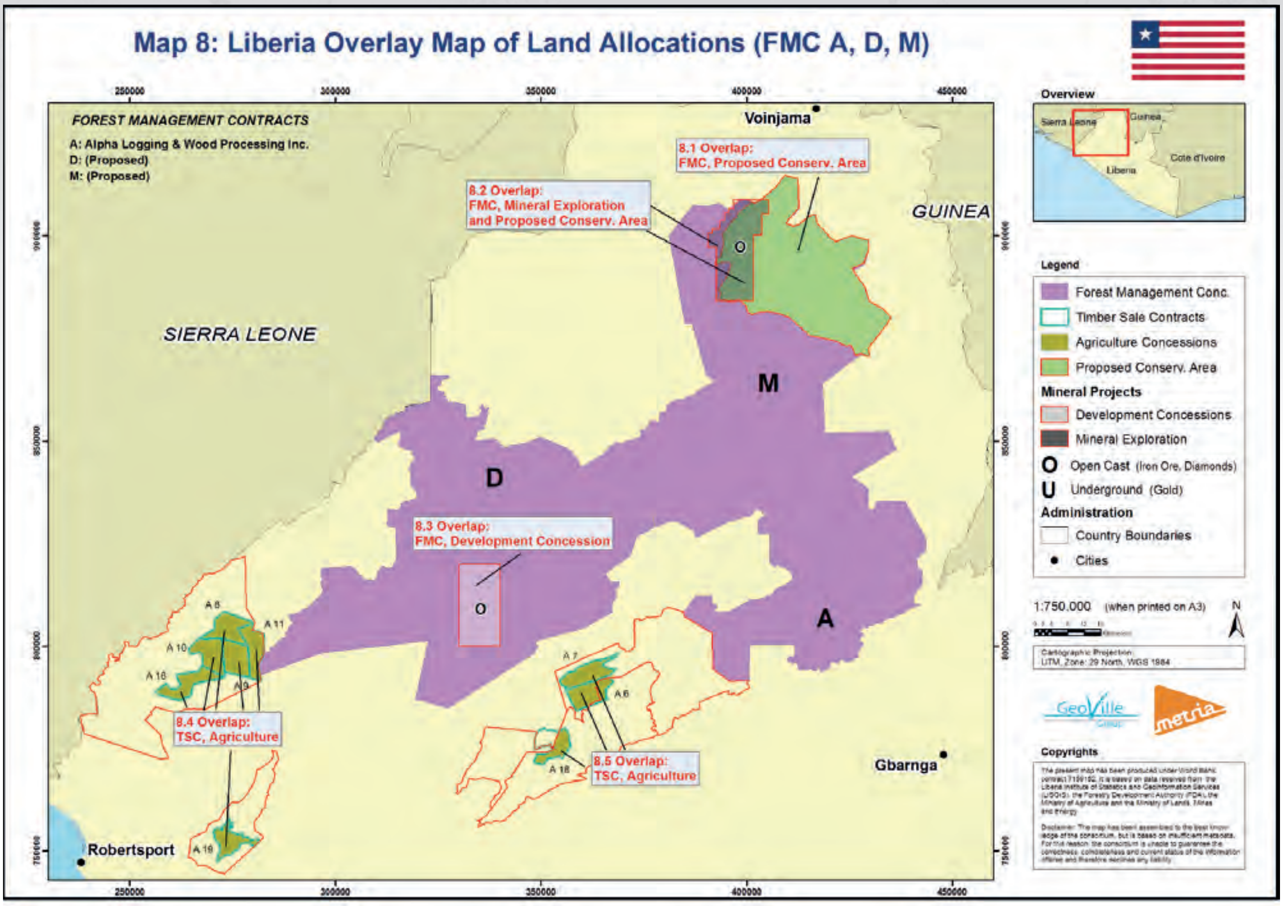

extensively overlap with Mineral Project Exploration Concessions (in one case these overlaps affect 100% of the mineral concession site). There were also major overlaps between Forest and Agricultural Concessions found in the sudy areas. In addition, some Forest concessions coincided with Proposed Conservation Areas (Fig. 1)

This independent verification confirmed the need for a new comprehensive study to support forestry and land use planning decisions in Liberia and consequently, potential land use tradeoffs. The World Bank recommendation was to conduct a new assessment of the location, extent and main characteristics of the remaining forests – a process which was initiated through the World Bank –ESA partnership for two pilot locations in Northwest Liberia, and is planned to be carried over nation-wide through the newly awarded Liberia Forest Carbon Partnership Facility Grant.

Forest cover

The analysis of forest cover begun with two biggest proposed Forest Management Concessions (M and D) in North-Western Liberia (Gbarpolu & Grand Cape Mount) which was completed for the years 2002, 2007 and 2010 covering approximately 75,000 ha of forest and identifying the rate of deforestation and net re-growth between these years. It yielded the most accurate information of the forest and land use in that area to date setting the basis for creating a country-wide forest and land cover map in view of future REDD activities (Fig. 2).

The analysis was based on the data derived from two sensors: Landsat TM (30m), SPOT5 (2,5m - 20m) and RapidEye (up to 5m). With the use of these latest satellite datasets and enhanced processing techniques the mapping accuracy was greatly improved. In comparison to the

1. Overlay map of land allocations. Credit: Metria/Geoville.

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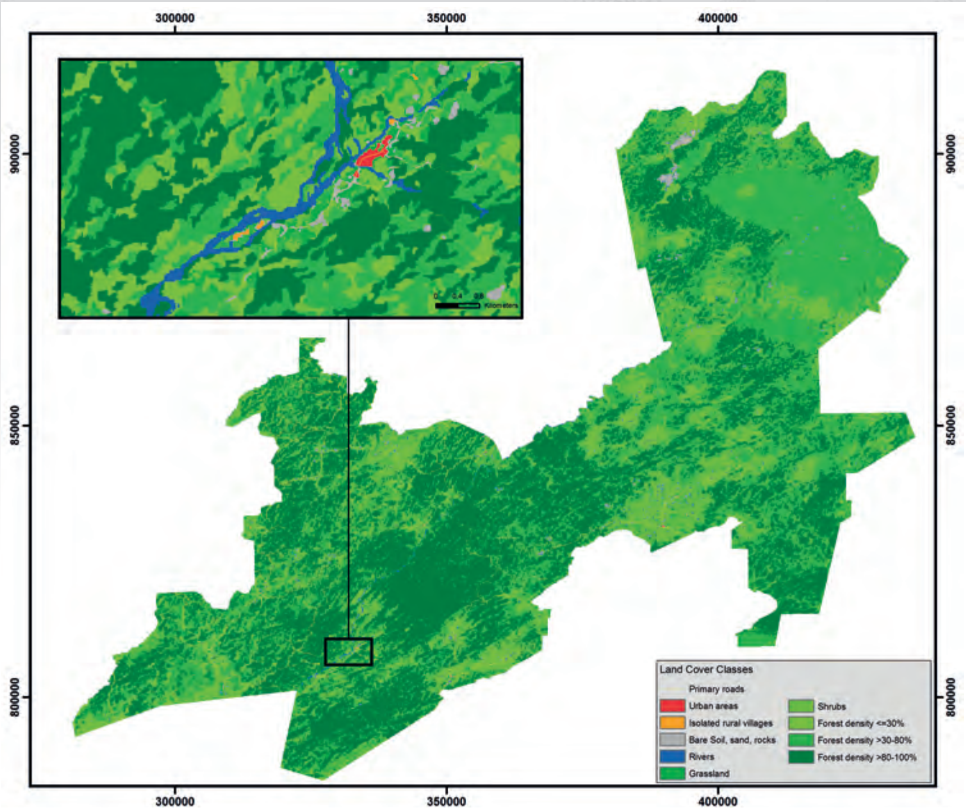

best previously available analysis the minimal mapping unit (MMU) came down to less than 1 ha as compared to the previous assessments of Liberian forest dated to 2006 and conducted at the scale of 1000 ha (Fig. 2).

	Clearing	Re-growth	Clearing
Forest Area	2002-2007	2007-2009	2007-2009
"D"	-0,15%	0,53%	-0,28%
"M"	-0,29%	0,66%	-0,35%

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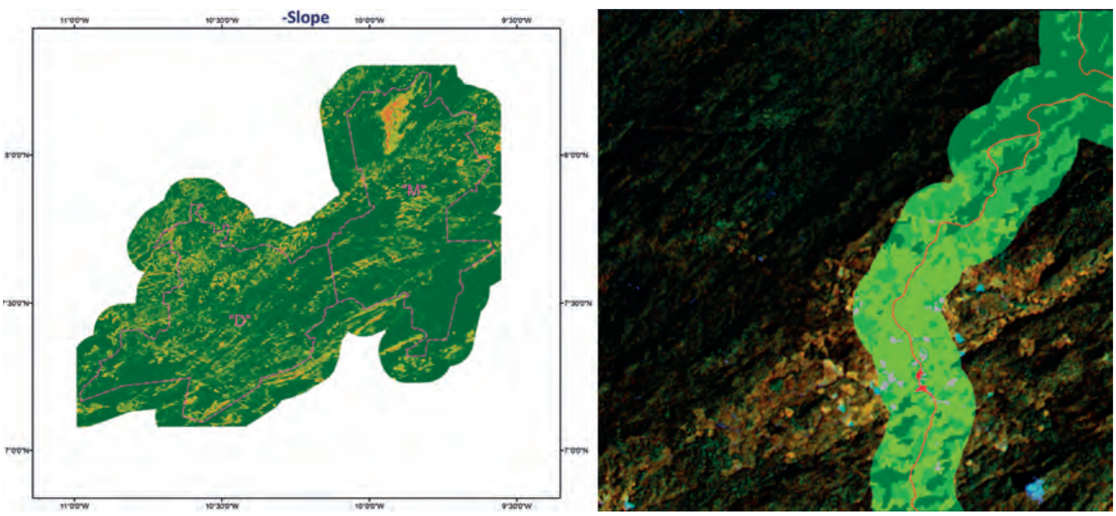

2. Land cover map over the M and D areas in North Western Liberia. Credit: Metria/Geoville.
5. Slope calculations based on the DEM SRTM and ASTER GDEM and an example of indication of harvestable areas along the road networks. Credit: Metria/Geoville.

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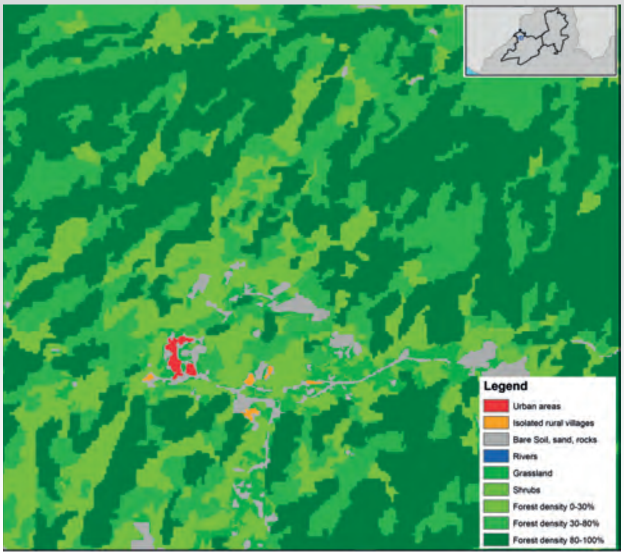

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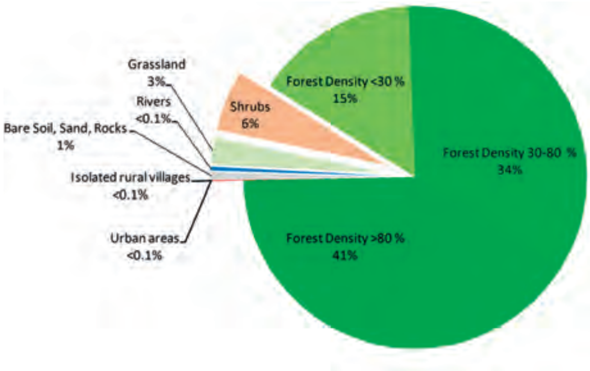

The results proved that rate of change in forest cover in Gbarpolu and Grand Cape Mount is relatively small with a net regrowth of approximately 0.20 %. The annual deforestation rate between 2002 and 2007 was respectively 0.15 % and 0.3 % (Fig. 4). Deforestation, if at all, was mainly taking place close to populated areas and likely as a result of traditional agricultural practices, which did not encroach into the surrounding dense forest (Fig. 3).

Moreover, there was no evidence of timber harvesting taking place in the investigated time period, despite the presence of visible timber roads in the imagery from 2002. Such little-exploited forest areas have presumably high biodiversity and conservation value despite the fact that the presence of timber roads may indicate that some selective cuttings could have been taking place.

The study analyzed the state of the forest resources in the areas where logging should be restricted - along the rivers' buffer zone of 200 meters. It was estimated that almost 70% of the land within 200m from rivers is forest with a density of 30 % or higher and that most of it is intact. Moreover, forest map was enhanced with terrain mapping using Digital Elevation Model (ASTERGDEM exploited together with the SRTM DEM at 15m vertical resolution). Such elevation model gives information about topographic characteristics other then land use, such as the course of river valleys, mountain ridges, and depressions. This information is essential for an effective and efficient planning of infrastructure elements as roads or power transmission lines (Fig. 5).

Land use assessment

In addition to the assessment of forest cover, detailed land use and land cover maps were provided for the year 2010 with 11 thematic classes revealing forest areas as well as primary roads, grassland, shrubs, urban areas, isolated rural villages, base soil, sand rocks and rivers (of minimum width of 10 meters) (Fig. 6). The study found that 90% of the area is covered by forest (of different densities), 5% by shrub land, and almost 5% indicates human activities such as housing, infrastructure, or farming.

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6. A detail from land cover mapping from 2010 with a MMU of 1 ha. Credit: Metria/Geoville.
7. Land cover status map and area distribution of Forest areas D and M. Credit: Metria/Geoville.
8. Painting numbers and letters in large white print so they can be easily read from afar. Photo by Flore de Preneuf/PROFOR.

Service providers

Altamira Information	Contact Project Manager: **Fifame Koudogbo** Altamira Information, C/ Corcega, 381-387 E-08037 Barcelona, SPAIN Tel: +34931835750 fifame.koudogbo@altamira-information.com | www.altamira-information.com
CLS - Space Oceanography Division	Contact Project Manager: **Olivier Germain** CLS, 8-10 Rue Hermes, 31520, Ramonville Sait-Agne, FRANCE tel. +33 561 394 856, ogermain@cls.fr www.aviso.oceanobs.com | www.altimetry.info
Critical Software	Contact Project Manager: **Ricardo Armas** Critical Software, Campus do Lumiar - Edificio M8, Estrada do Paço do Lumiar 1649-038, Lisboa, PORTUGAL Tel: +351 239 989 100 rgoncalves@criticalsoftware.com | www.criticalsoftware.com
EOMAP	Contact: **EOMAP** Sonderflughafen Oberpfaffenhofen, Friedrichshafener Str. 1, D-82205 Gilching, GERMANY Tel.: +49 (0) 8105 370778 0 info@eomap.de | www.eomap.de
Eurosense	Contact Project Manager: **Jolijn Leen** Eurosense, Nerviërslaan 54, B-1780 Wemmel, BELGIUM Tel.: +32 2 460 70 00 info@eurosense.com | www.eurosense.com
GAF	Contact Project Manager: **Rainer Fockelmann** GAF, Arnulfstrasse 197 80634 Muenchen, GERMANY Tel: +49 89 121528-43 rainer.fockelmann@gaf.de | www.gaf.de
GeoVille	Contact Project Manager: **Juergen Weichselbaum** GeoVille, Sparkassenplatz 2 A - 6020 Innsbruck, AUSTRIA Tel: +43-512-562021-17 weichselbaum@geoville.com | www.geoville.com
GISAT	Contact Project Manager: **Tomas Sykup, GISAT** GISAT, Milady Horakove 57, 107 00 Praha 7, CZECH REPUBLIC Tel: +420270003735 tomas.soukup@gisat.cz | www.gisat.cz
GRAS	Contact: **Geographic Resource Analysis & Science Ltd.** c/o Institute of Geography and Geology, University of Copenhagen, DK-1350, Copenhagen K, DENMARK Tel: +45 35 32 41 75 gras@gras.ku.dk | www.gras.ku.dk
Hansje Brinker	Contact Project Manager: **Mathijs Schouten** Hansje Brinker, Oude Delft 175, 2611 HB Delft, NETHERLANDS Tel: +31 15-8200225 mathijs.schouten@hansjebrinker.com | www.hansjebrinker.com
HIDROMOD	Contact: **Hidromod** Rua Rui Teles Palhinha nº 4, 1º.2740-278, Porto Salvo, PORTUGAL Tel: +351 218 486 013 hidromod@hidromod.com | www.hidromod.com

Service providers

IRD	Contact: **Institut de recherche pour le développement** Le Sextant 44, bd de Dunkerque, CS 90009, 13572 Marseille cedex 02, FRANCE Tel: +33 (0)4 91 99 92 00 www.ird.fr
Marine Spatial Ecology Lab, University of Exter	Contact Project Manager: **Peter Mumby** College of Life and Environmental Sciences, University of Exeter, Stocker Road, Exeter, EX4 4QD, UK Tel: +44 (0) 1392 723798 | http://msel.ex.ac.uk/gis/belize
Metria	Contact Project Manager: **Eric Willen** Metria, P-O Box 24154, 104 51 Stockholm, SWEDEN erik.willen@metria.se | www.metria.se
NEO	Contact Project Manager: **Corne van der Sande** NEO, Utrechtseweg 3E, Postbus 2176, NL-3800 CD Amersfoort, NETHERLANDS Tel: +31334637433 corne.vandersande@neo.nl | www.neo.nl
NOA	Contact Project Manager: **Haris Kontoes** National Observatory of Athens, Institute for Space Applications and Remote Sensing Vas. Pavlou & I. Metaxa, 15236 Penteli, GREECE Tel: +30-2108109182 | www.space.noa.gr
Planquadrat Geoinformation	Contact: **Christophe Dreiser** Planquadrat Geoinformation Brüsseler Str. 12, D-13353 Berlin, GERMANY Tel: +49-30-49803849 info@plan-quadrat.de | www.plan-quadrat.de
SarVision	Contact Project Manager: **Niels Wielaard** SarVision Agro Business Park 10, 6708 PW Wageningen, NETHERLANDS Tel: +31 317 452310 wielaard@sarvision.nl | www.sarvision.nl
Technical University of Delft	Contact: **Nick van de Giesen** Water Management, Civil Engineering & Geosciences, TU Delft Stevinweg 1, 2628 CN Delft, Room 4.73, PO Box 5048, 2600 GA Delft, NETHERLANDS Tel: +31 (0)15 2787180 giesen@tudelft.nl | www.wrm.tudelft.nl
TRE	Contact: **Alessandro Ferretti** Telerilevamento Europa srl, Ripa di Porta Ticinese, 79, 20143 Milano, ITALY Tel: +39 02 4343 121 info@treuropa.com | www.treuropa.com
Water Insight	Contact: **Steef Peters** WaterInsight, Marijkeweg 22, 6709PG Wageningen, NETHERLANDS Tel: +31 317 210004 info@waterinsight.nl | www.waterinsight.nl

Earth Observation satellite missions used in the eoworld projects

The *eoworld* initiative took the opportunity to showcase the capabilities of European and Canadian satellites, ESA and national missions, and also harnessed a variety of other missions' datasets. The plethora of data used reflected the needs of the ESA-World Bank projects which relied on a combination of EO data from different sources, both to increase sustainability of services provision and to complement the range of observation parameters. In addition, ESA have been early in discussions with mission operators to anticipate new data acquisition for the majority of the twelve ESA-World Bank projects.

The services are largely based on ESA's own Earth observing satellites – the ERS-1&2 and ENVISAT missions. Moreover, ESA provided access to the so-called 'ESA Third Party Missions' (ESA TPM) - satellites operated by organizations (public and private) other than ESA, both European and non-European. These are often the missions to which ESA contributes financially (usually through sharing of Ground Segment facilities or operations) or for which ESA assumes a data distribution responsibility to a European or worldwide user community.

The ESA TPM scheme currently includes over 50 instruments on more than 30 missions serving a wide range of users globally, including Africa, Asia, and South America. The most prominent examples of ESA TPM used in the framework of the *eoworld* initative are SPOT1-4, Landsat, Kompsat, ALOS, and Ikonos. The service providers were granted a Category 1 user status, which allowed them to access TPM data at cost of reproduction.

Concerning EO data not covered by the ESA TPM scheme, these were procured commercially by the service providers (i.e. RapidEye, SPOT5, SPOT DEM, Cosmo SkyMed, TerraSAR-X, Radarsat, GeoEye, Quickbird and WorldView). In case of the European national missions

ESA was in a fruitful dialogue with the operators concerning planning, programming and acquisition of new data to stimulate their active involvement in data procurement.

Data Policy

European Space Agency's Earth Observation Data Policy is based on free and open access principles and it was defined by the ESA Member States with the objective of maximizing the beneficial use of ESA and of TPM data and to facilitate balanced development of science, public utility and commercial applications.

ESA is moreover dedicated to advancing international trends for full and open access to EO data, in line with inter-governmental Group on Earth Observation (GEO) data sharing principles, setting the context for future data policies. In case of non-ESA missions used in the framework of eoword projects, the underlying image data licensing conditions vary. This is in particular relevant to the data available commercially for which data licenses usually depend on the applicable Terms and Conditions (rights and obligations of the users).

Future ESA Missions: GMES Sentinels

With the start of the European flagship space program-GMES (Global Monitoring for Environment and Security) European Union and ESA provide the framework for the development of the operational Earth Observation system of a new generation.

ESA is developing five families of new Sentinel missions specifically for the GMES programme, the first of which is scheduled to be launched in 2013/2014. The Sentinels will provide a unique set of observations, starting with the all-weather, day and night radar images from Sentinel-1 to be used for land and ocean services, followed by Sentinel-2 which will deliver high-resolution optical images for land services, Sentinel-3 for services relevant to the ocean and land and Sentinel-4 and Sentinel-5 for atmospheric composition monitoring from geostationary and polar orbits, respectively. Sentinel missions will provide worldwide carpet coverage resulting in an unprecedented increase in the amount of Earth Observation data available to the users while guaranteeing a long-term continuity of observations for future decades (25+ years).

Along with the Sentinels, there are around 30 existing or planned missions contributing to the GMES programme. These include missions from ESA, their Member States, Eumetsat (European Organization for the Exploitation of Meteorological Satellites) and other European and international TPM.

Sentinel Data Policy Principles includes full and open access to Sentinel data to all users. Overall, with GMES operations in place ESA is aiming for maximum availability of data in support of increasing demand of EO data in context of climate change initiatives and for the implementation of environmental policies, also resulting in many humanitarian benefits to international development community.

GMES is all about delivering products and services to manage and protect the environment and natural resources, and ensure civil security. The GMES services fall into six main categories: services for land management, services for the marine environment, services relating to the atmosphere, services to aid emergency response, services associated with security and services relating to climate change, including downstream sector providing information based on these core thematic areas and offering tailored solutions to specific regional or local needs, as well as the needs of the specialized global users. The monitoring capacity of GMES will be used for the benefit of the international community with the objective to support effective environmental policy-making for a more sustainable future.

ENVISAT (ESA)

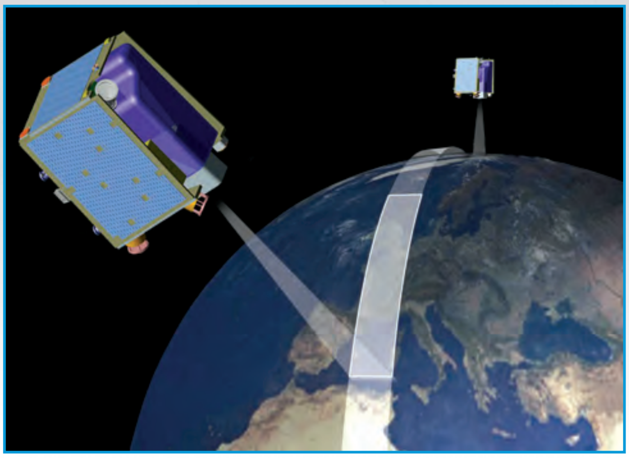
Launch date: 2002
Type: Optical and radar
Envisat is the largest Earth Observation spacecraft ever built. The instruments address four major areas: (i) radar imaging, (ii) optical imaging over oceans, coastal zones and land, (iii) observation of the atmosphere, and (iv) altimetry. The Envisat data are used in many fields of Earth science, including atmospheric pollution, fire extent, sea ice motion, ocean currents and vegetation change, as well as for operational activities such as mapping land subsidence, monitoring oil slicks and watching for illegal fisheries.
www.esa.int/esaEO

ERS 1-2 (ESA)

Launch date: ERS-1 (1991-2000), ERS-2 (1995-2011)
Type: Radar
ESA's first Earth Observation satellites carried a comprehensive payload including an imaging Synthetic Aperture Radar (SAR). Both ERS satellites (ERS1&2) were built with a core payload of two specialised radars and an infrared imaging sensor. The two spacecraft were designed as identical twins with one important difference - ERS-2 included an extra instrument designed to monitor ozone levels in the atmosphere.
www.esa.int/esaEO

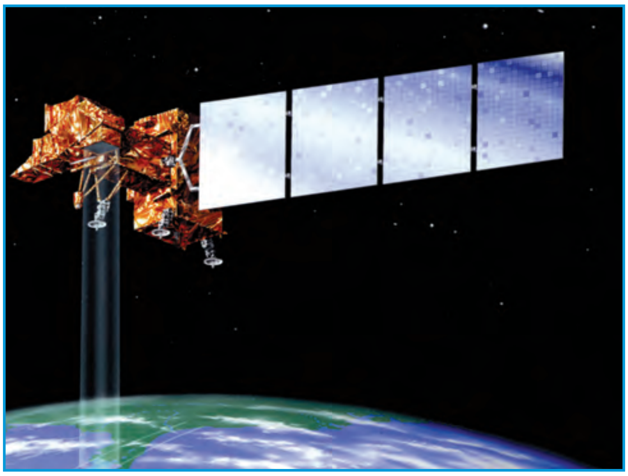
SPOT 1-5 (CNES / Spotimage)

Launch date: SPOT 1 (1986-1990), SPOT 2 (1990-2009), SPOT 3 (1993-1997), SPOT 4 (since 1998), SPOT 5 (since 2002)
Type: VHR and HR Optical (2,5m – 20m res)
The SPOT system was designed by the French space agency (CNES) and it is operated by Spot Image. SPOT imagery comes in a full range of resolutions from 20m down to 2,5m, for work on regional or local scales (from 1:100 000 to 1:10 000). Thanks to the constellation of SPOT satellites and their revisit capabilities, it is possible to obtain an image of any place on Earth, each day. A SPOT DEM is a digital elevation model produced by automatic correlation of stereopairs acquired by the HRS instrument on SPOT5 with 10 to 20m vertical accuracy.
www.spotimage.com



RAPIDEYE (RapidEye AG)

Launch date: 2008
Type: HR Optical (5m res)
RapidEye - a German constellation of five identical EO satellites at 5m spectral resolution - provides multispectral optical data since 2009 with five spectral bands, including the near infrared, which is very valuable for land use/ land cover applications. Other main areas of applications is agriculture, forestry, energy & infrastructure, environment and security & emergency management. Together, the 5 satellites are capable of collecting over 4 million km² with a revisit date of 1 day. The system is operated by RapidEye AG.
www.rapideye.de

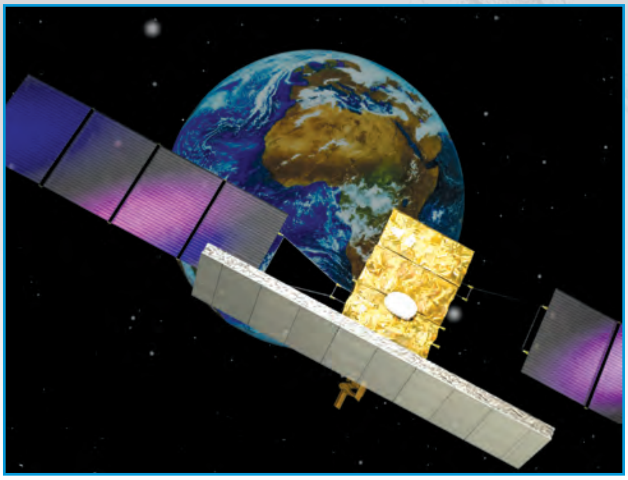


LANDSAT (NASA)

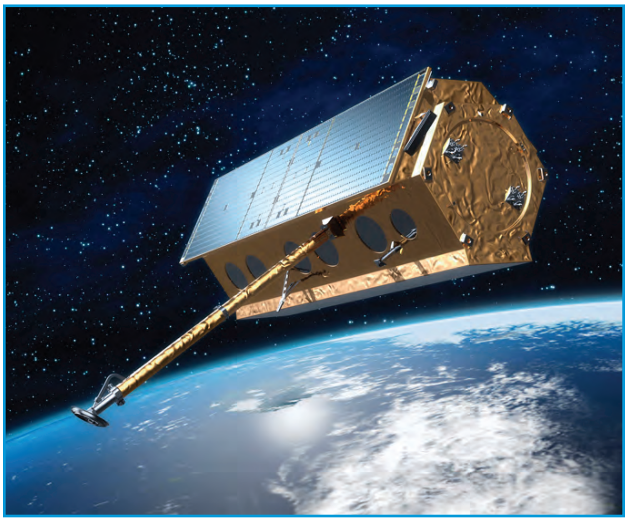
Launch date: 1972
Type: Optical (30m res)
Landsat imagery accounts for the largest parts of Earth's surface displayed on web mapping services. NASA-owned the vast majority of Landsat data is made available free of charge for any use by different web services like the USGS Landsat archive. Landsat is ESA's Third Party Mission.
http://earth.esa.int/TPMDAG/landsat.html

KOMPSAT-2 (KARI)

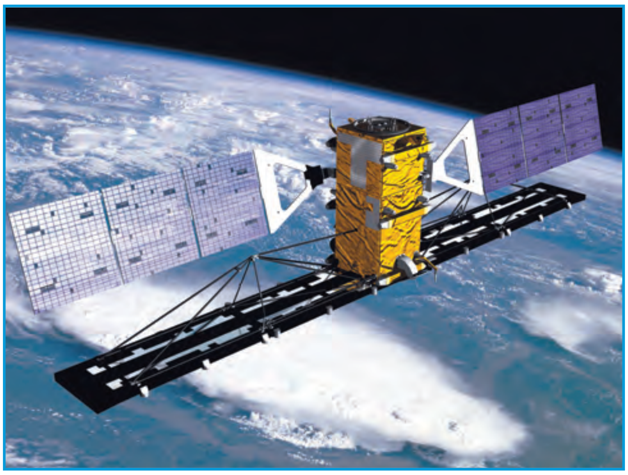
Launch date: 2006
Type: VHR Optical (1m res)
Kompsat-2 was developed in South Korea by KARI (Korea Aerospace Research Institute). The main mission objectives of the KOMPSAT-2 system are to provide a surveillance of large scale disasters and support disaster response, acquisition of independent high resolution images for GIS (Geographic Information Systems), composition of printed maps and digitized maps for domestic and overseas territories and survey of natural resources. Kompsat is ESA's Third Party Mission
www.esa.int/esaEO



COSMO SkyMED (ASI / e-geos)
Launch date: 2007
Type: VHR Radar (up to 1m res)
COSMO-SkyMed (Constellation of Small Satellites for Mediterranean basin Observation) is a 4-spacecraft constellation, conceived by ASI (Italian Space Agency) and funded by the Italian Ministry of Research (MUR) and the Italian Ministry of Defence (MoD). Each of the four satellites is equipped with the SAR-2000 instrument operating in the X band and is capable of operating in all visibility conditions at high resolution and in real time. The primary mission is to provide services for military and civil (institutional, commercial) community for land monitoring, territory surveillance, management of environmental resources, maritime and shoreline control, law enforcement, topography as well as scientific applications.
www.egeos.it

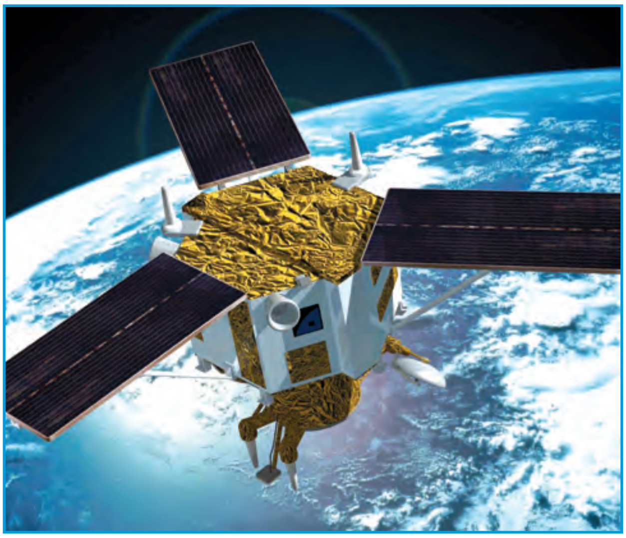


TERRA SAR-X (DLR / Infoterra GmbH)
Launch date: 2007
Type: VHR Radar (up to 1m res)
TerraSAR-X Earth Observation satellite system was designed by the German space agency (DLR) and is operated by Infoterra GmbH. TerraSAR-X acquires high-resolution all-weather SAR (Synthetic Aperture Radar) data in the X-band for research and development purposes as well as scientific and commercial applications. A second sister satellite, TanDEM-X launched in early 2010, makes the two satellites acting as a pair and producing a Digital Elevation model featuring a vertical accuracy of 2m (relative) and 10m (absolute), within a horizontal raster of approximately 12x12 square meters. Global Digital Elevation Model (DEM) of an unprecedented quality, accuracy, and coverage will be soon available for the Earth's complete land surface.
www.infoterra.de



RADARSAT 1-2 (CSA / MDA)
Launch date: Radarsat-1 (1995), Radarsat-2 (2007)
Type: VHR Radar (up to 2m res)
Equipped with a powerful synthetic aperture radar (SAR) instrument Radarsat satellites acquire images of the Earth day or night, in all weather and through cloud cover, smoke and haze. The system has three main uses: maritime surveillance (ice, wind, oil pollution and ship monitoring), disaster management (mitigation, warning, response and recovery) and ecosystem monitoring (forestry, agriculture, wetlands and coastal change monitoring). The system is operated by the Canadian company MDA. Radarsat-2 is ESA's Third Party Mission.
www.gs.mdacorporation.com
http://earth.esa.int/TPMDAG/radarsat_sar.html

ALOS (JAXA)
Launch date: 2006-2011
Type: VHR Optical (2,5-10m res), HR Radar (up to 20m res)
The Advanced Land Observing Satellite "DAICHI" (ALOS) has been developed by the Japanese Space Agency - JAXA - to contribute to the fields of mapping, precise regional land coverage observation, disaster monitoring, and resource surveying. ALOS is ESA's Third Party Mission.
http://earth.esa.int/TPMDAG/alos_palsar.html



IKONOS (GeoEye)
Launch date: 2000
Type: VHR Optical (0,8m res)
The world's first commercial satellite able to collect black-and-white (panchromatic) images with 82-centimeter resolution and multispectral imagery with 4-meter resolution. Imagery from both sensors can be merged to create 1-meter colour imagery (pan-sharpened). It is being used for national security, military mapping, air and marine transportation, and by regional and local governments. Ikonos is ESA's Third Party Mission.
http://earth.esa.int/TPMDAG/ikonos.html

GEOEYE 1 (GeoEye)
Launch date: 2000
Type: VHR Optical (0,4m res)
GeoEye offers unprecedented spatial resolution by simultaneously acquiring 0,41-meter panchromatic and 1,65-meter multispectral imagery allowing for a number of applications in every commercial and government sector.
www.geoeye.com

USEFUL LINKS

Coastal water monitoring
CoastColour
www.coastcolour.org

Combating desertification
DesertWatch
www.coastcolour.org

Satellite-derived wind-wave and swell data
GlobWave
www.globwave.info

Satellite monitoring in support to early warning of volcanic risks
GlobVolcano
www.globvolcano.org

Global Land Cover
GlobCover
www.ionia1.esrin.esa.int

Support to the implementation of the RAMSAR Convention
GlobWetland
www.globwetland.org

Global Snow monitoring
GlobSnow
www.globsnow.info

Global Aerosol monitoring
GlobAerosol
www.globaerosol.info

Earth Observation for Epidemiology
Epidemio
www.epidemio.info

Urban heat island information
www.urbanheatisland.info

European association of Remote Sensing Companies
Epidemio
www.epidemio.info

Committee on Earth Observation Satellites
CEOS
www.ceos.org

Group on Earth Observation
GEO
www.ceos.org

ACKNOWLEDGEMENTS

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The Paraná River cuts through this image of southern Brazil In the area pictured, the river marks the borders of the Brazilian states of Mato Grosso do Sul to the north and west, São Paulo to the east and Paraná to the south. Agricultural structures are evident in the surrounding land. Near the centre of the image, smoke from a fire was captured blowing southwest from its source. Copyright ESA

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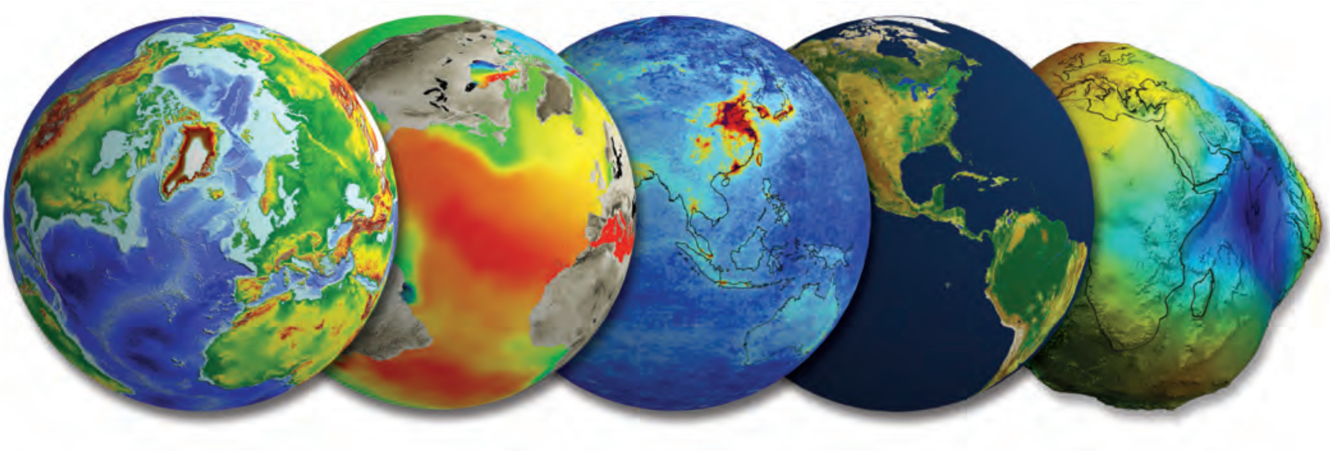

Lake Malawi in the Eastern Rift of the Great Rift Valley, a geological fault system of Southwest Asia and East Africa. One of the world's few ancient lakes, Lake Malawi, also known as Lake Nyasa, is the third largest lake in Africa. Copyright ESA

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www.worldbank.org/earthobservation
www.vae.esa.int