BUILDING EXPOSURE MAPS OF URBAN INFRASTRUCTURE AND CROP FIELDS IN THE MEKONG RIVER BASIN

E. Haas [(1)], J. Weichselbaum [(1)], U. Gangkofner [(1)], J. Militzer [(1)], A. Walli [(1)]

(1) GeoVille, Sparkassenplatz 2, 6020 Innsbruck (Austria), Email: haas@geoville.com

ABSTRACT

In the frame of the Integrated Water Resources Management (IWRM) initiative for the Mekong river basin World Bank is collaborating with the Mekong River Commission and governmental organizations in Cambodia, Lao PDR, Thailand and Vietnam to build national and regional capacities for managing the risks associated with natural disasters, such as floods, flash floods and droughts. Within 'eoworld', a joint initiative set up by ESA and World Bank to foster the use of Earth Observation (EO) for sustainable development work, a comprehensive database of elements at risk in the Lower Mekong river basin has been established by GeoVille, including urban infrastructure and crops (primarily rice paddies). In the long term, this exposure information shall be fed into an open-source multi-hazard modeling tool for risk assessment along the Mekong River, which then shall be used by national stakeholders as well as insurance and financial institutions for planning, disaster preparedness and emergency management.

Earth Observation techniques can provide objective, synoptic and repetitive observations of elements at risk including buildings, infrastructure and crops. Through the fusion of satellite-based with in-situ data from field surveys and local knowledge (e.g. on building materials) features at risk can be characterised and mapped with high accuracy.

Earth Observation data utilised comprise bi-weekly Envisat ASAR imagery programmed for a period of 9 months in 2011 to map the development of the rice cultivation area, identify predominant cropping systems (wet-season vs. dry season cultivation), 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.

Very High Resolution (VHR) optical data from SPOT, KOMPSAT and QuickBird were used for mapping of buildings and infrastructure, such as building footprints, residential / commercial areas, industrial buildings, main infrastructure, and other public assets. A key input to this work was data collected by the project team in the field with the purpose of scoping information about buildings including material, height (number of stories), construction technique, and floor area. A high resolution satellite-based Digital Elevation Model was additionally generated to provide surface elevations of vegetation and man-made objects with a vertical accuracy of 10 m. By using this methodology thousands of buildings and infrastructure features were mapped, clearly indicating the location and characteristics of the assets. Exposure maps were complemented with the analysis of historical flood and drought events using ERS and Envisat ASAR radar data for historical flood mapping alongside with vegetation index data from SPOT-VEGETATION and NOAA-AVHRR, concerning drought events.

1. PROJECT BACKGROUND

The Mekong river basin is at high risk from multiple hazards mostly related to the water cycle. Severe floods induced by storms or typhoons associated with heavy rain and high seasonal discharge of the Mekong river on the one hand, and droughts have caused extensive losses and damages to livelihood, agriculture and infrastructure in the Lower Mekong river (LMB) basin in the past [1].[1] Due to the strong linkage between risk and poverty in developing countries like Cambodia, reduction of risk is one of the single most important steps to reduce poverty. One of the first steps in risk reduction is to identify the risk to raise awareness and allow pre-event planning in contrast to post-event damage reduction. Risk assessment forms the basis for financial solutions to reduce risk and taking appropriate mitigation measures [2].

The objective of the project was to establish a risk management platform and regional risk model for the Lower Mekong river basin, including the development of methodologies and a multi-hazard open-source modeling tool for probabilistic risk assessment.

The purpose of the project was to promote the application of integrated water resource management (IWRM) principles within the lower Mekong River basin and to build capacity for mapping the impacts for

[1] The IPCC expects an increase in occurrence of extreme weather events including heat waves and intense precipitation events particularly for South-East Asia. This leads to floods, landslides, and mud flows, while the number of rainy days and total annual amount of precipitation will decrease, causing severe impacts on the production of rice, maize and wheat.

Proc. 'ESA Living Planet Symposium 2013', Edinburgh, UK
9–13 September 2013 (ESA SP-722, December 2013)

floods, flash floods and droughts within the basin and ultimate to manage the sustainable basin development [3].

Moreover, an Open Risk Modeling System (ORMS) was under preparation in the frame of the Integrated Water Resources Management initiative, in order to improve the monitoring, assessment and management of water related disaster risks in the Lower Mekong River Basin [1]. This system is expected to be used in national planning, disaster preparedness and emergency management by local stakeholders, insurance and financial institutions involved in reducing the impact of disaster risk. The project specifically addresses risk and exposure in the region to strengthen the local capacity to predict and prepare for disasters, thus improving resilience and reducing risk and subsequent losses. The Open Risk Modeling System includes a data management, sharing and dissemination platform. It foresees the development of reliable hazard models and the population of the database with exposure and vulnerability data for operational risk modeling.

2. REQUIREMENTS OF GEOSPATIAL INFORMATION

While historical floods are well documented by the Mekong River Commission (MRC) and member countries, only limited information and impact assessments of droughts are available [4]. However, actual governmental or institutional practices remain focused primarily on responding after the occurrence of a disaster event instead of preparedness for disaster. In advance risk management and the estimation of potential losses and damages to housing, infrastructure or crops must take into account the exposure (total value at risk) and vulnerability of assets. At present, exposure and vulnerability data and tools for detailed risk assessments are not readily available.

Exposure data are critical for probabilistic risk analysis, providing disaster risk specialists and policy-makers with the necessary information to manage future disaster risk. As a first step towards modeling losses and managing impacts in the basin, it is necessary for the member states in the Lower Mekong river basin to build reliable exposure maps of basins at risk of floods, flash floods and droughts. More specifically, detailed inventories of buildings and infrastructure and of crops are needed to fully characterize exposure in the areas of interest. Minimum requirements for exposure mapping are building footprints and material, infrastructure, and agriculture (crops).

The required information also comprises the combination of exposure mapping and multi-hazard information, including both drought and flood, extracted from Earth Observation.

In the beginning of the project, no high-resolution map information on urban areas, infrastructure and crops was available. Even basic cartography and geo-information, e.g. administrative boundaries or hydrologic networks, was patchy and poor (especially for Lao PDR and Cambodia).

The derived information is therefore dedicated to prove the concept and build capacity within the government before applying the method to other areas. The methodology for capturing exposure information is scalable to the entire river basin.

3. INTERPRETATION OF THE RESULTS

The most cost-effective means of achieving inventories of buildings, infrastructure and crops across tens of thousands of square kilometres is to use EO satellite data as it provides a consistent data and information source across countries. The project has generated a self-contained demonstration for EO-based exposure and hazard mapping as critical input for the envisaged risk platform in the lower Mekong river basin. All products are available as digital (GIS-ready) or analogue thematic maps that can be further combined and analysed with other statistical or geospatial data.

The following services have been generated:

- Service 1: Urban mapping of infrastructure and buildings
- Service 2: Crop mapping (inventory map identifying crop type and crop acreage)
- Additional service: Flood & Drought hazard mapping of selected historic events

The Area of Interest (AOI) in Cambodia (Figure 1) comprised a large AOI-A with an area of 2,173 km² and a smaller AOI-B with an area of 413 km² in the provinces of Prey Veng, Kampong Chan and Kandal.

Figure 1. Area of Interest (AOI) in Cambodia

The services derived products that were for the largest part directly generated from Earth Observation images ("EO-standalone products"), and products that needed to be enhanced by in-situ information ("Enhanced in-situ products").

3.1 Inventory of buildings and infrastructure

Urban Mapping was split up into a Service 1a for EO stand-alone products, which are directly retrieved from very high-resolution optical satellite images (KOMPSAT-2 & QuickBird in 1 m resolution for settlements supported with a SPOT-5 coverage in 2.5 m resolution), and Service 1b for Enhanced in-situ products, which were produced from a combination of satellite data analysis and in-situ data collected in the field campaign.

The 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 geo-located. Figure 2 represents sample result 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.

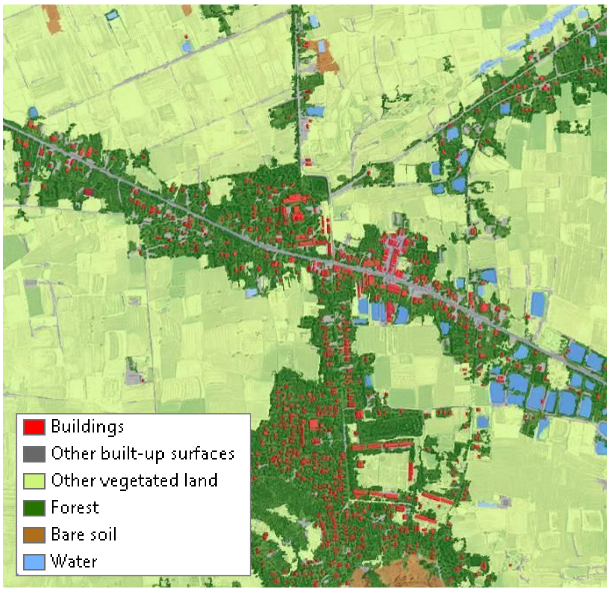

Figure 2. Land cover with building footprints

Statistical analysis underpins the predominant rural settlement structure of the project area, with only 5% of the area used for settlements and related functional areas and 1% of land for transport infrastructure. More than 80% of the area is cropland and other vegetated land. 86% of the buildings are small structures with a ground area of less than 100 m², and 90% of the settlement area is characterized mainly by low-density stilt-houses with two stories and a distance of less than 100 m to a road to prepare for regular flooding [5].

3.2 Inventory of crops

Crop Mapping was based on the direct analysis of multi-temporal radar satellite imagery of Envisat ASAR in 30 m spatial resolution (EO stand-alone products), without any utilization of in-situ information for map production. Based on this information it was possible to provide continuous monthly monitoring of rice fields including monitoring date of emergence and harvest of rice (Figure 3). Besides, an indicator for planes rice under SRI (System of Rice Intensification) was generated [6]. For the observed time period between February and October 2011 total rice acreage amounts to 1376.93 km² representing 74.64% of the total agricultural area present in the project area. Dry season irrigated rice with 60.5% of the cultivated area is more widespread than wet season rainfed rice with 23.4%. The remaining areas (16.2%) are cultivated with dry as well as wet season rice [5].

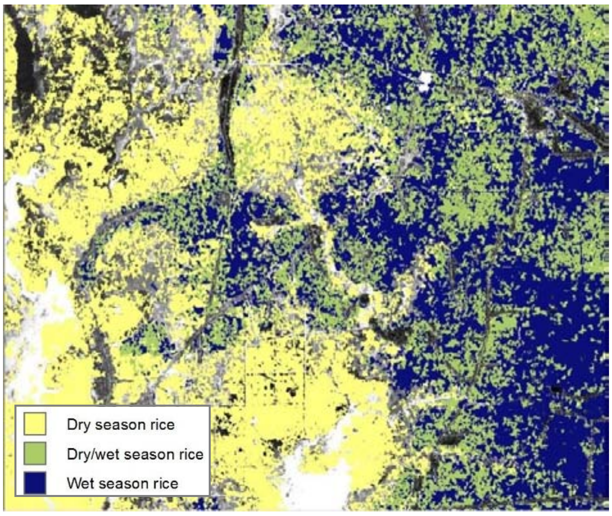

Figure 3. Rice cropping system (February to October 2011)

3.3 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.

Flood extent maps were generated using multi-temporal radar imagery of ERS-2 satellite (during and before / after flood) covering a flood event that impacted the Mekong basin between August and November 2001 (Figure 4). 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 kilometres. The flood impact analysis indicated that 79% of the settlement area and 88% of the road network are threatened by high-water levels in case of a severe flood similar to the 2001 event. More than 90% of the cropland would be threatened by high water levels.

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 SPOT-5 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 was exposed to the 2002 drought for a period of at least 1 month, and almost 50% of cropland was under heaviest drought conditions at the drought peak in April 2002 [5].

With the help of this data collection method time-consuming and expensive nature of frequent field trips and airborne surveys can be reduced. This allows periodic updates of geospatial inventories of assets, their spatial extent as well as their 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 etc.) [7].

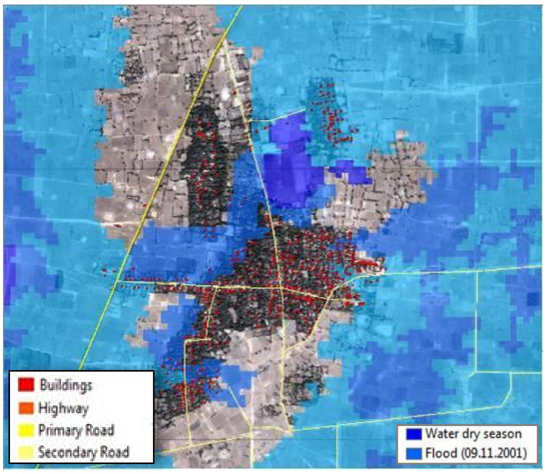

Figure 4. Detailed view of flooded settlement area and road infrastructure

4. CONCLUSIONS

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. It as well allows sharing, consolidating and validating the generated information 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 the Mekong River Commission and the Cambodian National Committee for Disaster Management plan to use the products to better quantify assets and exposure to the range of hazards and optimize investments to minimize potential damage or loss. Such GIS-ready, quality controlled geo-information products have a high reproducibility potential to other regions along the Mekong River [7].

Acknowledgement

This study was funded by ESA in the frame of 'eoworld', a joint initiative with the World Bank.
For more information please refer to:
http://www.esa.int/Our_Activities/Observing_the_Earth/ESA_and_the_World_Bank_join_forces

5. SAMPLE REFERENCES

1. World Bank Group (ed.) (2011): *Disaster Risk Management in the Lower Mekong Basin*. Development of an Open Risk Modelling Framework. Washington.

2. Polack, E. (2010): *Integrating climate change into regional disaster risk management at the Mekong River Commission*. Strengthening Climate Resilience Discussion Paper 4. Institute of Development Studies. Sussex.

3. Mekong River Commission (ed.) (2012): *Integrated Water Resource Management-based Basin Development Strategy*. Working Paper (2011-2015). Phnom Penh.

4. Mekong River Commission (ed.) (2012): *MRC Flood Management and Mitigation Programme. Available at:* http://www.mrcmekong.org/about-the-mrc/programmes/flood-management-and-mitigation-programme/

5. GeoVille (ed.) (2012): *Building exposure maps of urban infrastructure and crop fields in the Mekong river basin*. Final Report. October 2012.

6. Lam-Dao, N. et al (2009): *Towards an Operational System for Rice Crop Inventory in The Mekong River Delta, Vietnam Using Envisat ASAR Data*. In: 7th FIG Regional Conference Spatial Data Serving People: Land Governance and the Environment – Building the Capacity. Hanoi, Vietnam, 19 – 22 October 2009.

7. European Space Agency & World Bank (ed.) (2013): *Earth Observation for sustainable development*. Partnership Report. 70 – 73, June 2013.