Abstract code: B06

Exposure analysis while combining EO-derived mapping results with available information for data poor regions (use case: flood in Albania)

Steve Kass[1], Davide Poletto[2], Dominik Reisinger[1], Clemens Holzer[1], Leonhard Suchenwirth[1], Jan Militzer[1], Andreas Walli[1]

[1]GeoVille Information Systems GmbH, Sparkassenplatz 2, 6020 Innsbruck, Austria
[2]UNESCO Regional Bureau for Science and Culture in Europe, Venice, Italy

Corresponding author details:
GeoVille Information Systems GmbH, Sparkassenplatz 2, 6020 Innsbruck, Austria; email: kass@geoville.com

Keywords:
IncREO, asset mapping, Pleiades, Albania, Shkodra, flood, exposure, affected population, land cover, monetary value

Risk analysis remains challenging, especially in regions with poor data availability. The main reason is that essential information to analyse the risk, combining hazard occurrence probability and intensity information, identifying location of elements at risk as well as their vulnerability to a given hazard are often only partly available or even completely missing.
The approach developed within IncREO may be considered as a significant example of a synergic convergence of science for disaster risk reduction with a multi-stakeholder participation. The approach targets an improved dialogue between the scientific community and the emergency responders in Albania and aims for a successful integration of IncREO products into the national operational system (DEWETRA), which is a system for reference data at national level.
The developed approach uses Earth observation (EO) data in combination with in situ information from the region as well as freely available data (e.g. open street map) for a detailed exposure analysis.
In the beginning a detailed land cover/land use (LC/LU) mapping in the Shkodra region was carried out based on very high resolution optical satellite imagery (Pléiades). Delineated block structures (e.g. residential, industrial) were refined with the help of population statistics. The population distribution on administrative level was disaggregated to the LC/LU classification considering EO derived imperviousness degrees as a weight factor. Monetary values were finally associated to the mapped structures referring to the asset map BEAM (Basic European Assets Map). The harmonized result is a refined asset map at regional level.
In addition, valuable information on location of critical infrastructure (e.g. schools, hospitals, etc.) have been collected and harmonized based on information from the Military Geographical Institute of Albania (MGI) and open street map (OSM) to be integrated in a later stage.
As a last step, flood inundation areas were derived using EO-based radar data. With a threshold mapping procedure as well as post-processing steps for refinement, flood extend area have be delineated. Therefore, existing flood extend maps derived from TerraSAR-X satellite data produced by DLR/ZKI have been used as well as modelled dam failure scenarios (SECO/KESH) from 2006.
Combining all derived data, a comprehensive exposure analysis was conducted for flood event and dam failure scenarios. This resulted in maps of potentially affected

LC/LU areas, population and monetary values on administrative district level and on the European Environment Agency (EEA) one square kilometre reference grid. Furthermore, exposed critical infrastructure and vulnerability hotspots were identified and mapped within the whole region.
The results were evaluated by the IncREO users (UNESCO, General Directorate of Civil Emergencies – Ministry of Interior of Albania and affiliated Ministries). The results were seen as highly beneficial for reporting obligations, planning of risk mitigations and fund raising. Therefore, the information are currently implemented into the DEWETRA system. The concept follows an approach of regional exposure analysis and can be easily implemented at European level, especially in areas which have been mapped by the EC Urban Atlas**.**

INTRODUCTION

Due to dramatic river flooding within recent years for several regions of Europe, the damage has reached unprecedented proportions causing numerous causalities. Lugeri et al. (2006) identify two basic reasons for this: a) the increased frequency of extreme weather events, likely due to modifications of the climate regime, b) built-up areas (e.g. urbanisation and infrastructures) continue to grow mainly in flood prone areas[1]. The combination of these two elements is particularly worrying since changes in land use associated with urban development affect flooding in many ways. Urbanisation generally increases the size and frequency of floods and may expose communities to increasing flood hazards (Konrad 2003). Altogether, these trends contribute to an unsustainable development pattern, with an increasing exposure to natural hazards in large regions of Europe (Lugeri et al. 2006).
To support the transition from traditional flood defence strategies to a flood risk management approach at basin scale in Europe, the EU has adopted a new Directive (2007/60/EC) at the end of 2007. De Moel et al. (2009) give an overview of existing flood mapping practices in 29 countries in Europe and show what maps are already available and how such maps are used.
At the global level, the Hyogo Framework for Action[2] (HFA) recognizes the role of Earth Observation as a component of the priority of action 2: Identify, assess and monitor disaster risks and enhance early warning with particular reference in the field of capacity, information and management exchange. The need for EO derived application in DRR is also re-confirmed on the way to Sendai[3] as stated by the zero draft document for post-2015 framework for disaster risk reduction, recently submitted by the Preparatory Committee to the UN GA[4]. The use of EO is recognized as a key element to understand Disaster Risk and to support disaster risk reduction at all levels.
It is a matter of fact that the advancement of science and technology applied to EO and their derived products, at the basis of IncREO project main applications, are potentially offering solutions which may bring substantial benefits to local communities and to end users. In particular, the combined use of earth observation (EO) products and geo information systems (GIS) has become an integrated, well developed and successful tool in disaster risk

[1] As stated by the recently issued IPCC Summary for Policymakers (Fifth Assessment Report), a most likely record of increased number and intensity of heavy precipitation, combined with the sea level rise will imply greater risks of flooding whose impact is expected to cause increased exposure and risk both to ecosystems and human settings including urban settlements located in the proximity of exposed areas. This has particular implications for low income countries, where substantial infrastructural mitigation measures are hardly affordable.

[2] The HFA is a UN led 10-year International Strategy for Disaster Reduction endorsed by the UN General Assembly in the Resolution A/RES/60/195 following the 2005 World Disaster Reduction Conference held in Hyogo, Japan.

[3] At the Fourth Session of the Global Platform for Disaster Risk Reduction in May 2013, The Government of Japan announced it would host the World Conference in Sendai. The proposed dates are 14-18 March 2015.

[4] United Nations General Assembly.

management. Van Westen CJ (2008) provides an overview of the use of spatial data with emphasis on remote sensing data, and of the approaches used for hazard assessment.
However, product developers and scientists investing in cutting edge technology should find a way to be effectively linked and to interface with policy makers and emergency responders in particular in low income countries, where benefits may actually be broader, encompassing, for instance, the areas of urban, land use planning and rural development. Therefore, linking successfully outer space to ground space is the key factor to determine both effectiveness and sustainability of EO derived products in the entire Disaster Risk Management Cycle and in several additional societal benefit areas.
This interconnection between science and society in EO as also required by the very nature of the phenomena to confront, and as recommended in the HFA, has made disaster risk preparedness an important entry point of UNESCO's strategy. UNESCO, which by mandate deals with cross-cutting issues, has mobilised all its internal resources in building upon a culture of disaster risk resilience through its constitutive components: education, science, culture and communication (Disaster Preparedness and Mitigation UNESCO's Role, 2007). The need for an effective combination of scientific and technological derived products, with the access of in situ data, monitoring and management systems involving a wide array of stakeholders on field, has presented a challenging and nevertheless successful ground work for the UNESCO Regional Bureau for Science and Culture and Geoville, a specialised geo-information applications and satellite earth observation company. This PP[5] partnership, in the frame of the demonstration component related to the IncREO project in Albania, made possible to translate such theoretical approach into practice.
Albania as other neighbouring countries in the Balkans have not yet fully matched the challenge of implementing an integrated set of Geographic Information Systems (GIS) as well as Earth Observation (EO) applications in environmental monitoring and management. As pointed out at the Post-GEO Plenary Workshop on Earth Observations for the Social Benefit of the Balkans held in Istanbul (18-19 November 2012), the deficit in the implementation of GIS and EO applications as well as their use in different societal benefit areas are manifested through the limited synergies among national and regional institutions, ineffective technological means and discontinuous record of participation to international organizations and committees. It has to be reported that Albania with other Balkan countries are not members of the GEO (Group on Earth Observations)[6], therefore IncREO target activities in the Skhodra region with the involvement of national governmental and scientific institutions, have contributed to facilitate the process of strengthening their capacity in GIS and EO applications of Albanian Civil Protection Dept. within the European context.
The city of Shkodra and its surroundings (North-West part of Albania) were chosen as test area (see Figure 1) in order to analyse exposure in Albanian flood plains[7].

[5] Public/Private.

[6] The World Summit on Sustainable Development and the G8 launched in 2002 a call for the constitution of the Group on Earth Observation (GEO) with the aim of coordinating efforts to build the Global Earth Observation System of Systems (GEOSS), the structure that proactively links together existing and planned observing systems around the world and support the development of new systems where gaps currently exist.

[7] The transboundary lake of Shkodra, the largest lake of the Balkan Peninsula, was chosen by the GDCE of Albania as the demonstration site for the IncREO project due to its recurrent inundations. A state of emergency on 7 January 2010, following heavy rainfall during November and December 2009 caused water levels to rise in the lakes and consequently downriver on the Drini and flooding the Shkodra and Lezha regions. Reportedly more than 1200 buildings/houses (some partially) were flooded. About 12,000 people had to be evacuated from their homes in northern Albania while 14,000 hectares of land surrounding the swollen lake with their inhabitants were inundated and cut off from communication

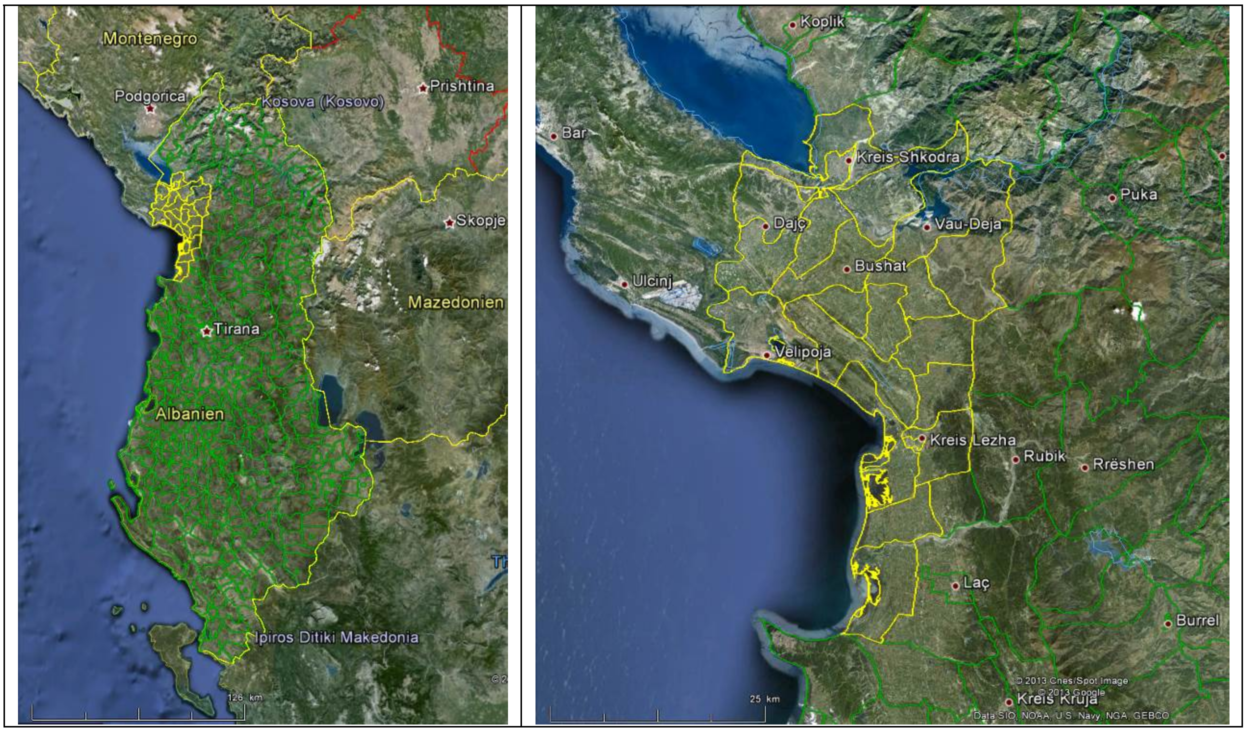

Figure 1. The city of Shkodra and its surroundings as area of interest (left) within the North-West part of Albania (right).

This extended abstract describes the potential of using Earth Observation (EO) data in combination with in situ information and other available data (e.g. open street map) in order to derive several exposure analyses as contribution for an increased preparedness and resilience. The first part is dedicated to the methodological approach, illustrating and describing the refinement of EO derived information with other available data in order to assess essential information for exposure analysis. The second part highlights main results of conducted exposure analysis as well as their implementation into an operational system. The last part concludes with the potential of the derived products and an outlook.

METHODS

According to UNISDR (2009), exposure is defined as people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. In order to analyse therefore exposure, two essential information are necessary. The hazard zones, as well as the elements or structures, being subject to these. Both information can be assessed with remote sensing data and complemented as well as refined with additional information.

Elements or structures being subject to potential losses, were derived with an EO based mapping approach. This processing chain compromises the collection and harmonization of relevant geo-spatial input information (see Figure 2), preparing available Information like CORINE land cover classes (Copernicus Land Monitoring Services), the High Resolution Imperviousness layer (Copernicus Land Monitoring Services) as well as the adjustment, optimization and refinement of the road network out of in situ and open street map (OSM) data. The mapping procedure follows the Urban Atlas approach (EU, 2011) considering a new acquisition of VHR2 imagery (Pléiades satellite constellation; 2m multispectral resolution) as input source and guaranteeing therefore up to date land cover information.

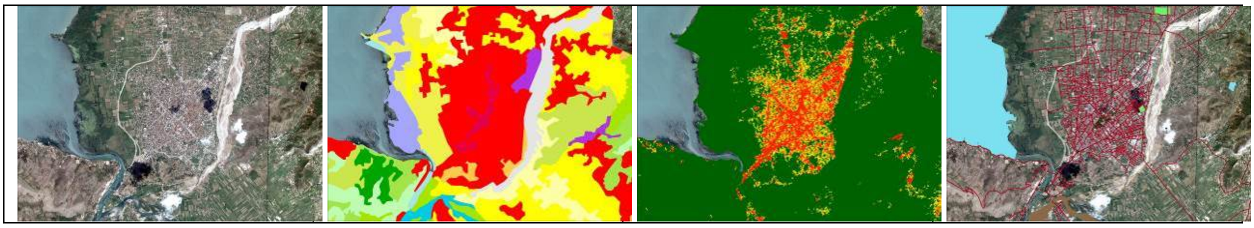

Figure 2. Considered input data for the land cover / land use classification (From left to right: VHR2 imagery, CORINE land cover 2006, Imperviousness degrees 2009, adapted road network)

Derived segments from an object-oriented classification approach, having been fused with previous relevant input information and labelled accordingly, were visual adapted and refined by interpretation. By considering topographic and thematic information from the Military Geographical Institute of Albania (MGI), an optimization of land use differentiation as well as better structural delineation could be achieved. The final land cover/land use (LC/LU) classification resulted in classes (e.g. residential, industrial), being delineated as block structures (see Figure 3).

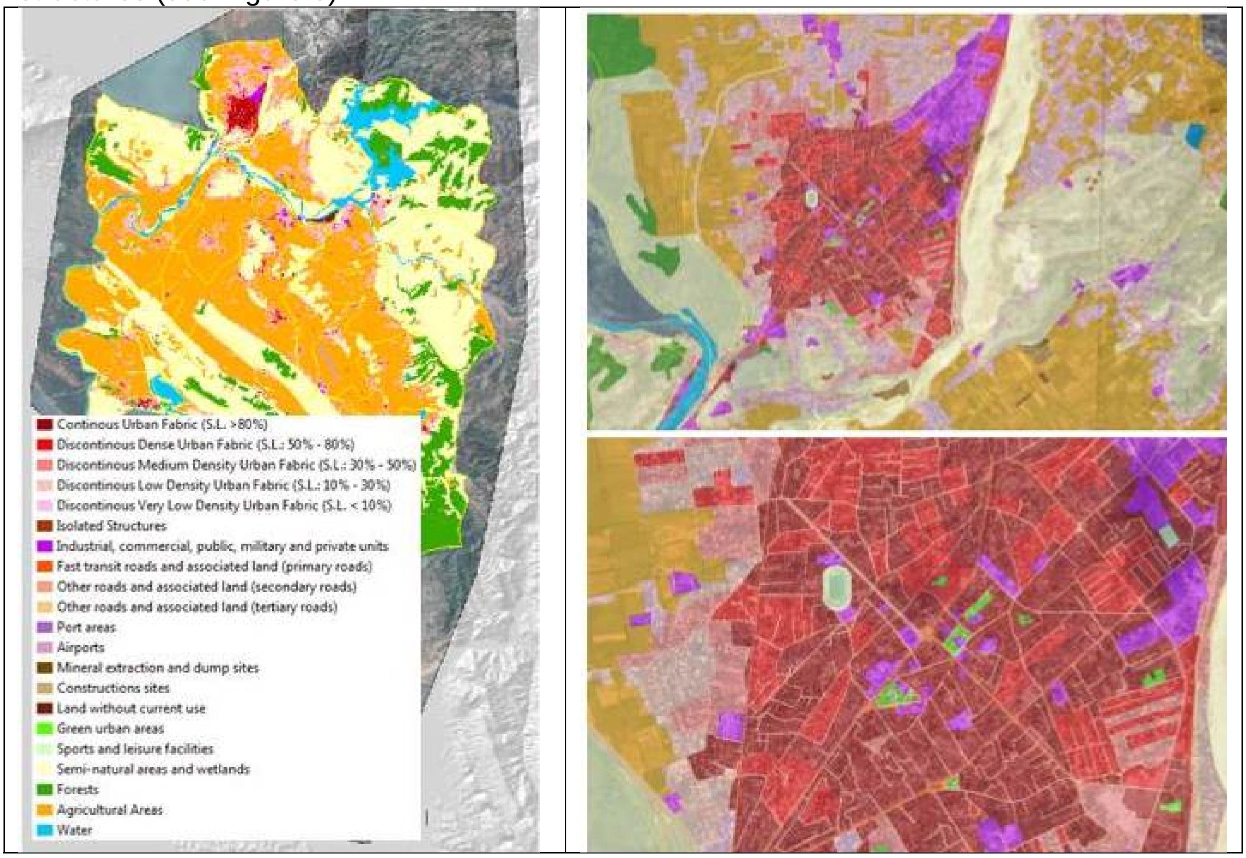

Figure 3. Land cover / land use (LC/LU) classification with integrated socio economic information while zooming to Shkodra city (left)

Asset information was implemented to land cover / land use (LC/LU) classification while referring to economic information (monetary values) out of the Basic European Assets Map (BEAM) product from SAFER (GMES Emergency Response Service project). The implementation took place considering a zonal statistic approach. In addition, up to date population distribution were considered while referring to the census review of 2011 provided by the Institute of statistics of Albania (INSTAT). The Population distributed on administrative

levels was disaggregated to the land cover / land use (LC/LU) classification considering earth observation (EO) derived imperviousness degrees (from EC GIO land) as weight factor. The approach follows a refined methodology of DECUMANUS (EU-FP7 project). As a consequence of the VHR EO data-based building block delineation, location of population distribution and monetary values reflected the distribution more precisely and realistic.
The institutional role played by UNESCO in cooperation with the General Directorate for Civil Emergencies and the Albanian National Commission for UNESCO, in order to set up informal mechanisms to enhance relevant stakeholders[8] dialogue and consultations was at the basis to acquire the available data in situ, validate the IncREO product in progress as well as to build up a sense of ownership of the project activities and related products, in view of their later sustainability. The first inter-ministerial roundtable set in place at the early phase of the project among different scientific and institutional stakeholders of Albania gave an important footprint in this sense.
At the technical level, considering topographic and thematic information from the Military Geographical Institute of Albania (MGI) as input data source, it becomes apparent that these data are only partially available. Thus missing infrastructure were complemented and enriched with data from open street map (OSM), resulting in below considered critical infrastructure:

- Accommodation *(hotel, motel, hostel)*
- Energy supply *(electric cabin, electro pumps, fuel supply, high/low voltage line)*
- Financial services *(bank)*
- Gastronomy *(café, bar, restaurant, pub)*
- Health facilities *(hospital, pharmacy)*
- Place of worship *(church, mosque, other places)*
- Public institutions *(public building, school, university, library, station, police station, post office, fire-station, college, museum)*
- Infrastructure *(bridges)*

As second essential information to conduct exposure analyses, hazard zones have to be identified. Within this case study, the hazard flood was analysed. Flood inundation areas can be derived by using Synthetic-aperture radar (SAR) based EO data. Using a threshold mapping procedure and post-processing steps for refinement, flood extend maps can be derived. Within this use case, already existing flood extends from January 2010 derived from TerraSAR-X satellite data by DLR/ZKI through the project SAFER were utilized. In addition, simulated dam break and flood wave analysis out of a study (SECO/KESH) from 2006 were taken into account for the exposure analysis. This resulted finally in four different flood inundation zones. One corresponding to the flood event of the 9th January 2010 derived from radar (SAR) based EO data, and three resulting out of modelling approaches of different dam break scenarios. Figure 4 illustrates the coverage of the different inundation zones. The fourth scenario is not shown as it correspond to the combination of the two dam break scenarios (vau dejes flood; matt flood) reflecting the worst case scenario.

[8] The following private-public entities were involved in the multi-stakeholders consultation: Military Geographic Institute of Albania, INSTAT, CIMA research foundation, Institute of GeoSciences, Environment, Water, and Energy (IGEWE), Shkodra Prefecture, National Committee on High Dams, Pöyry Switzerland Ltd., Albanian hydropower corporation, Center of agricultural technology transfer, Ministry of Civil Affairs, Ministry of transport and infrastructures, Albanian National Commission for UNESCO.

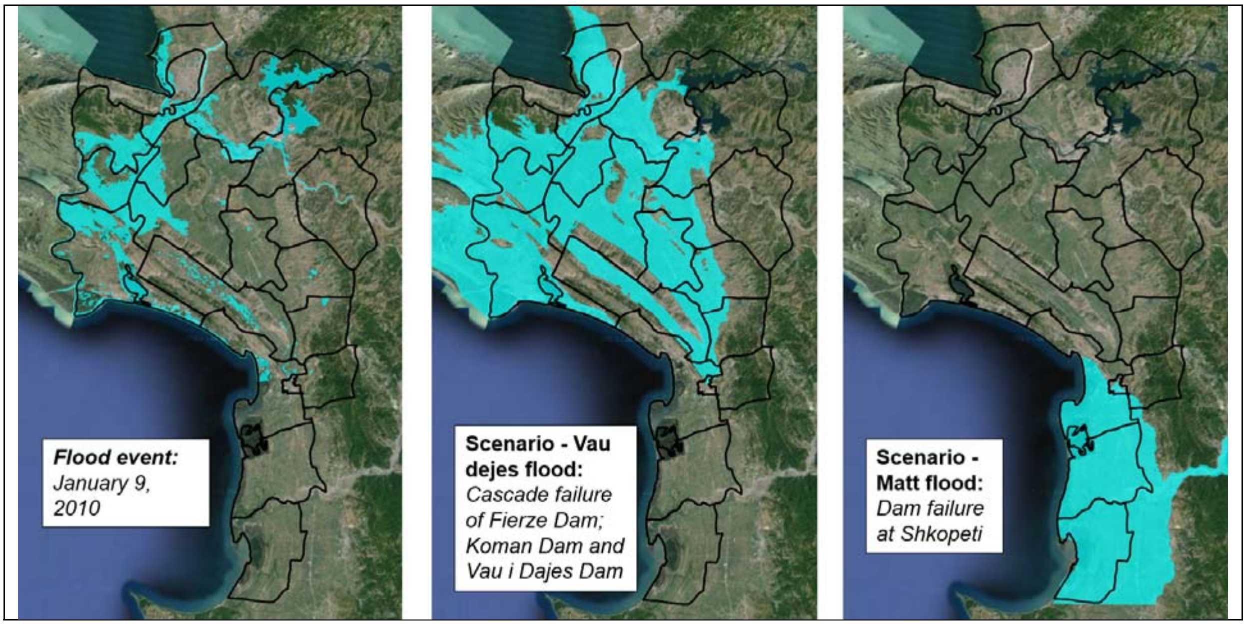

Figure 4. Considered flood hazard (left: flood event from January 2010, middle and right: dam failure scenarios)

Exposure analyses were conducted while analysing quantitatively (absolute and relative) as well as qualitatively potentially affected structures. A quantitative evaluation was performed by associating exposure measures to reference units. The used reference units are provided administrative units (districts) and uniform one square kilometre grids (EEA reference grids).
The exposure measures compromised analyses of potentially affected:

- Population
- Land cover / land use areas (residential, commercial and industrial, agricultural and infrastructure (roads, railways)
- Monetary values (potentially affected)

The results were associating to the reference units (districts, 1km²) with absolute and relative values of potentially affected measures (population, land cover / land use areas, monetary values). A qualitative evaluation took place while flagging the considered critical infrastructure with exposed (1) or not exposed (0) when analysing their location with the flood hazard zones and dam failure scenarios

RESULTS

The validation of the final results comprises quantitative and qualitative (plausibility) verifications of the input data and the considered processes. A quantitative verification of the derived land cover / land uses classification achieved 91% overall accuracy. Due to the fact that no comparable analyses could be considered regarding the evaluation of the exposure analyses, feedback from the local authorities and civil emergencies had to be considered as qualitative verification feedback. Quantitative and qualitative verification were finally positive and reflected experiences and expectation from local stakeholders and the scientific institutions involved.
As final results, a set of 38 maps illustrating and highlighting potentially affected areas, population, monetary values and critical infrastructure as well as a GIS database package with all derived analyses and harmonized data set was hand out to the General Directorate of Civil Emergencies of Albania (GDCE). Due to the amount of generated products and results, only a selective illustration of derived maps is provided within this result section. The figure below (see Figure 5) illustrates a subset of the exposure map highlighting potentially

affected population at EEA one square kilometre reference grid due to the flood event of January 2010. Note that in consequence of scale issue, the area of the upcoming legend pie chart do not reflect one to one the illustrated area within the map subset and should therefore only be considered as visualization legend

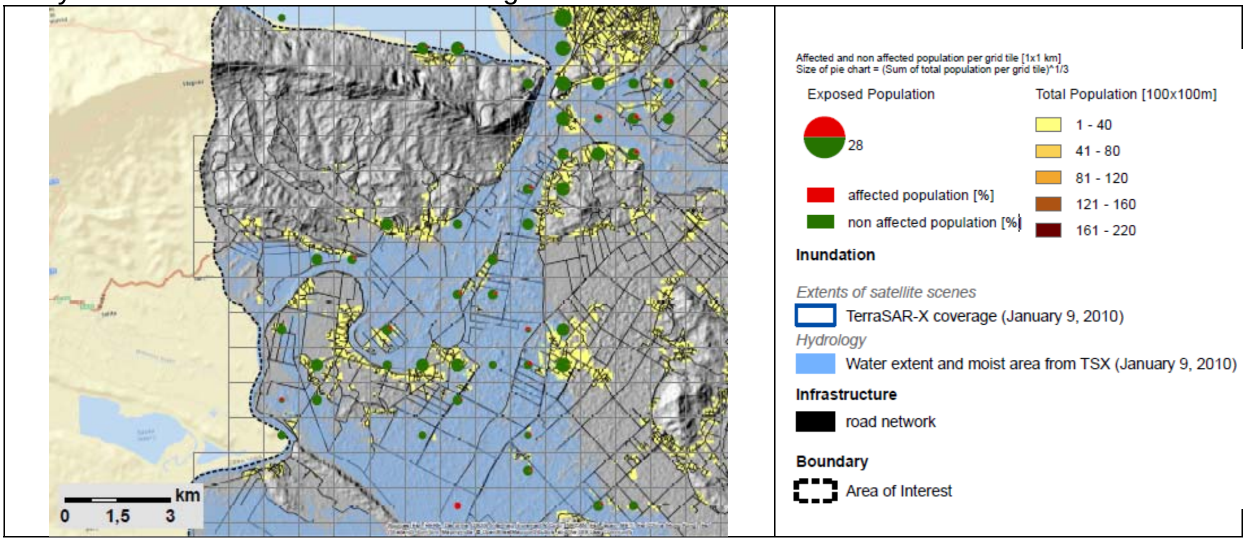

Figure 5. EEA one square kilometre reference grid with exposure analyses of potentially affected population for the flood event of January 2010

Figure 6 shows the amount of potentially affected monetary values on district level caused by the dam failure scenario "Vau dejes flood".

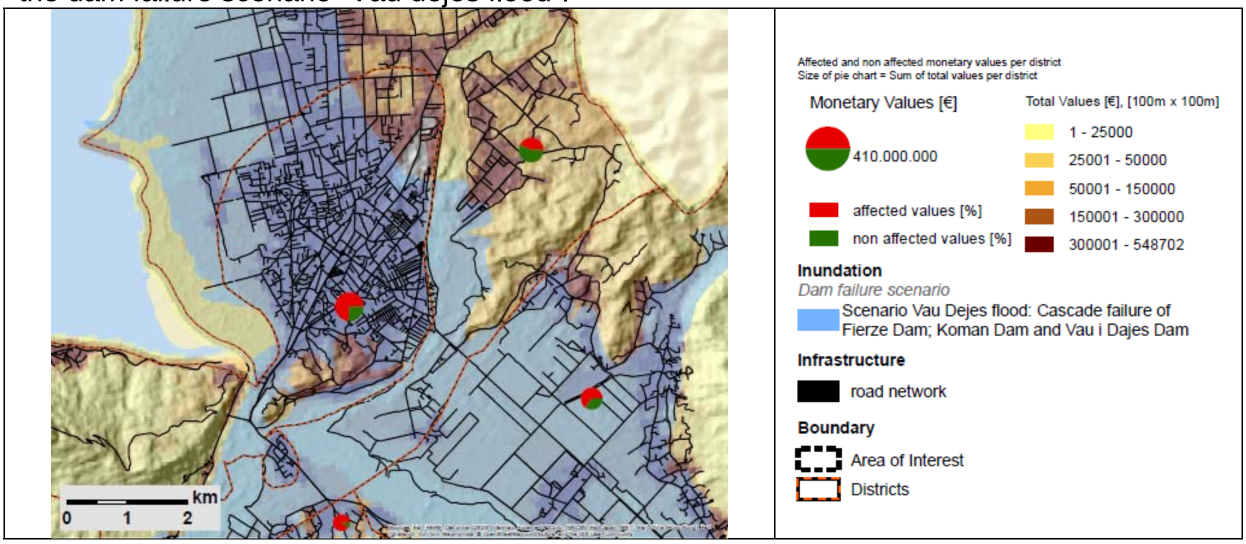

Figure 6. Administrative units (districts) with exposure analyses of potentially affected monetary values for the dam failure scenario "Vau dejes flood" (Cascade failure of Fierze Dam; Koman Dam and Vau i Dajes Dam)

Figure 7 shows potentially affected land cover and land use areas for the flood event of January 2010 on district level. The area analysis is illustrated within histograms, indicating absolute and relative affected area statistics.

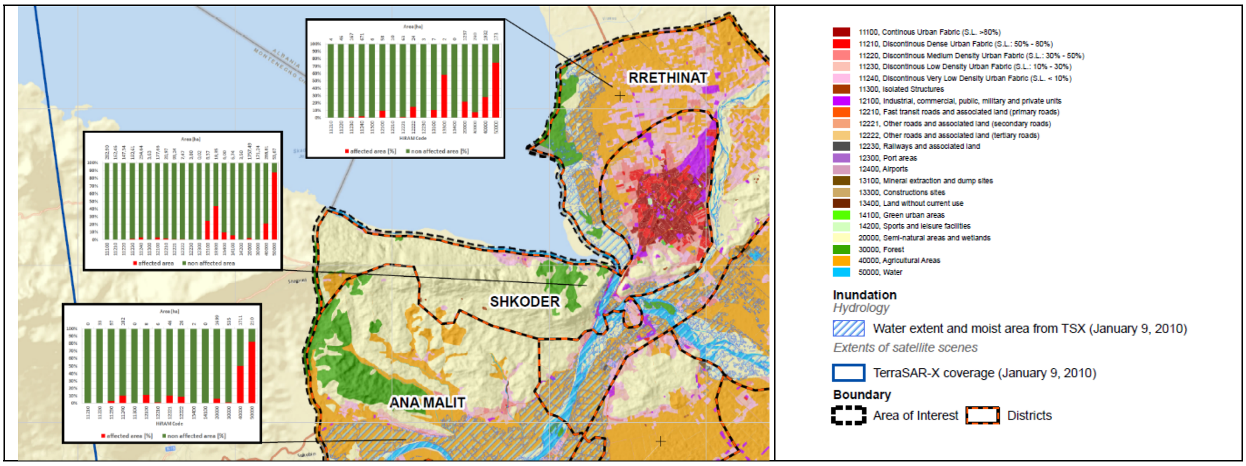

Figure 7. Administrative units (districts) with exposure analyses of potentially affected land cover and land use areas for the flood event of January 2010

A qualitative evaluation took place while considered critical infrastructure and identifying exposed hot spots. In the figure below (see Figure 8), a subset illustrated all considered critical infrastructure by highlighting the hot spot in red and non-exposed critical structures in green.

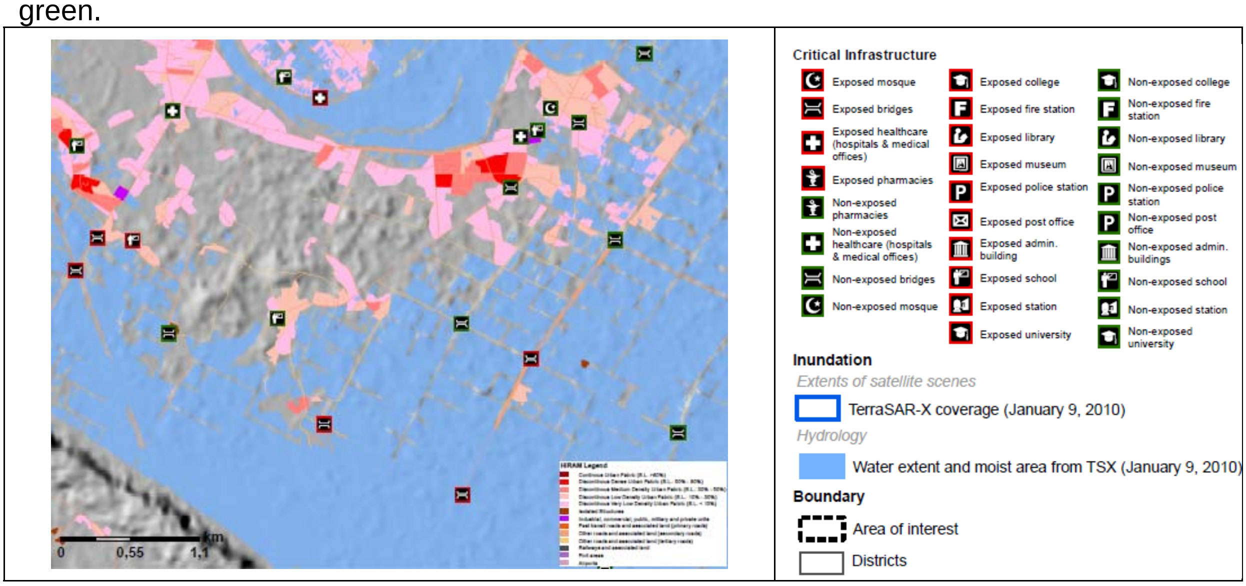

Figure 8. Exposure analyses of potentially affected critical infrastructure for the flood event of January 2010

In addition of providing the results in form of maps and a GIS database package, the maps are now under implementation into DEWETRA[9], the real time monitoring, prediction and prevention of natural risks system operated by the Institute of Geoscience, Energy, Water and Environment of Albania (IGEWE). This was considered a necessary step to be undertaken in the attempt to secure ownership and sustainability through a full fledge operationalization of the developed products. The following figure (see Figure 9) illustrates

[9] On March 25 2014, the Head of the Civil Protection Department Franco Gabrielli and WMO Secretary-General, Michel Jarraud signed a memorandum of understanding under which DEWETRA will be made available internationally to requesting Countries as an open source instrument. DEWETRA is from this moment recognized by the World Meteorological Organization as being one of the most advanced systems for hydro-meteorological risk management within the Global Framework for Climate Services (GFCS).

screenshots of the system with integrated IncREO products for operational use at General Directorate of Civil Emergencies of Albania (GDCE)

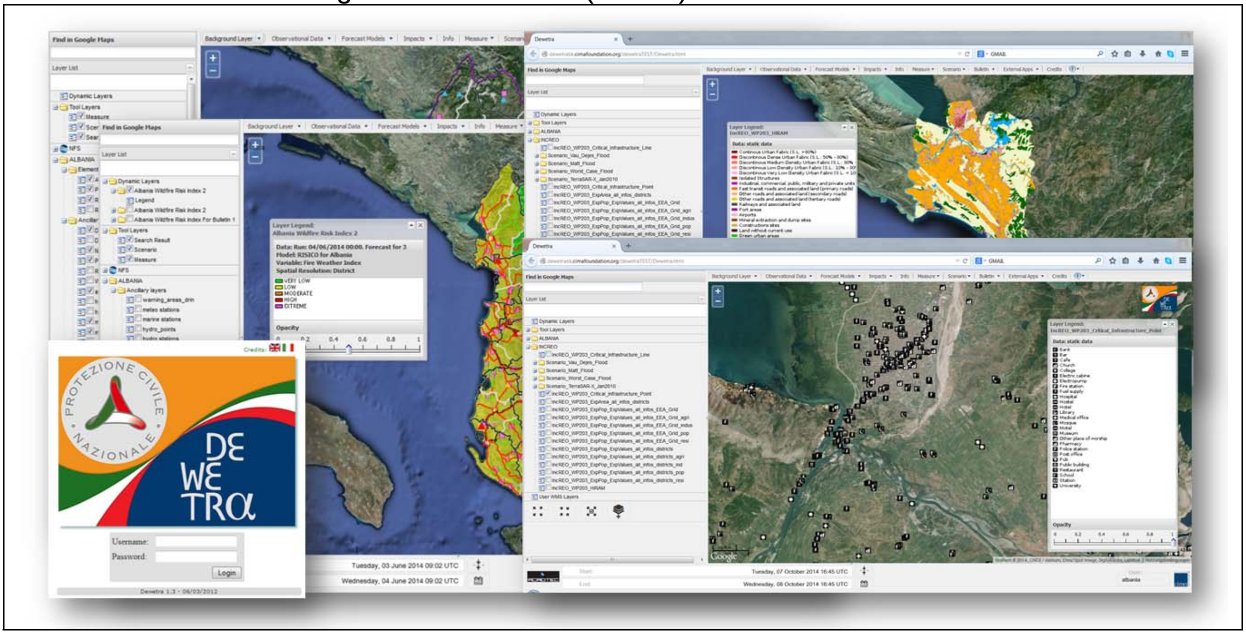

Figure 9. Implemented results within the DEWETRA system

CONCLUSIONS

The considered approach illustrated the combination of both technical and institutional interplay and their reinforcing benefits to achieving relevant technical results with a higher degree of sustainability. As to the technical level, the undertaken actions stressed out the potential of EO derived information, contributing to exposure analysis (population, land cover / land use areas, monetary values) at different scales and reference units (administrative units, uniform grids) and therefore provide simple indicative measurements for tendencies and hot spot detection. The EO derived products can be refined and adjusted with additional information, resulting in better delineation or differentiation. In addition, they can be complemented with statistical information and in situ data made available, as far as an effective multi-stakeholders consultation and engagement at the national level are secured. These data are then merged with the remotely derived products for their ultimate enhancement. Considering this easy reproducible approach, a monitoring procedure could be envisaged, providing basic exposure measurements at different levels (reference units) by updating the structures with newly acquired EO data (e.g. Sentinel) and available, updated statistical values.
The derived information were evaluated by the IncREO end users (General Directorate of Civil Emergencies- Ministry of Interior of Albania) and the most appropriate scientific partners dealing with the environmental monitoring and forecasting system and affiliated Ministries. Particular efforts were put to secure a certain level of consistency between the developed products and the users ‘needs and their technical requirements. At the final stage of this process, the achieved products were successful implemented into the DEWETRA system, securing the most immediate operationalization and degree of ownership of the IncREO products in Albania.
The concept follows and it is inspired by the Internationally recognised strategies in DRR, underpinning community leadership and engagement in DRR, in order to get both an easy implementable approach of regional exposure analysis, being applicable and implementable

at the European level, particularly in areas which have been mapped by the EC Urban Atlas efforts in combination with flood extend maps (e.g. JRC, EMS) and associating these information to defined units (e.g. nuts regions or EEA reference grids).

ACKNOWLEDGEMENT

The authors would like to express their gratitude to the General Directorate of Civil Emergency of Albania and to Dr. Marco Massabo and Dr. Miranda Deda from CIMA Research Foundation, for the technical feedback received during the implementation of IncREO activities in Albania and foremost for the important role played in interfacing the DEWETRA system with the IncREO products. Finally, a debt of gratitude is to Ing. Alan Edwards and Ing. Felix Oberrauch from Pöyry Switzerland Ltd., for the relevant contribution in gathering the data necessary for the development of the IncREO dam failure scenarios in the Shkodra lake.

REFERENCES

De Moel, H., van Alphen, J., and Aerts, J. C. J. H., (2009) *Flood maps in Europe - methods, availability and use*, Nat. Hazards Earth Syst. Sci., 9, 289–301.

European Union (EU), (2011) *Mapping guide for a European Urban Atlas*. Available from: http://www.eea.europa.eu/data-and-maps/data/urban-atlas#tab-methodology [Accessed: 6th November 2014].

United Nations, IPCC Fifth Assessment Synthesis Report, 1 November 2014.

Konrad C. P., (2003) *Effects of Urban Development on Flood*, U.S. Department of the Interior, U.S. Geological Survey, USGS Fact Sheet FS-076-03.

Lugeri, N., Genovese, E., Lavalle, C., & De Roo, A., (2006) *Flood risk in Europe: analysis of exposure in 13 Countries*. DG Joint Research Centre, Institute for Environment and Sustainability. Luxembourg: Office for Official Publications of the European Communities.

National Research Council of the National Academies, (2008) *Earth Observations from Space, the first 50 years of Scientific Achievements*, The National Academies Press, Washington DC.

Preparatory Committee of the Third United Nations World Conference on Disaster Risk Reduction, *(*2014) United Nations GA, *Post-2015 framework for disaster risk reduction Zero draft*. *(*20 October 2014)

SECO/KESH, (2006) *Consultancy Services for the Dam Safety Survey for Hydropower Plants located on Drin and Mat River Cascades Republic of Albania*. Zürich, Switzerland

United Nations Educational, Scientific and Cultural Organization UNESCO, (2007) *Disaster Preparedness and Mitigation UNESCO's role*

United Nations Office for Disaster Risk Reduction (UNISDR), (2007) *Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters*

United Nations Office for Disaster Risk Reduction (UNISDR), (2009) *Terminology on DRR*. Available from: http://www.unisdr.org/we/inform/terminology [Accessed: 6th November 2014].

Van Westen CJ (2008) *Remote Sensing and GIS for Natural Hazards Assessment and Disaster Risk Management*. Thesis report.