Vulnerability Assessment and Global Change Monitoring: The Role of Remote Sensing - Potential and Constraints for Decision Support

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Abstract – Global changes in social, cultural, economic and environmental systems converge in localities. Changes on the local scale contribute to the global change with its various linkages between systems and scales. It is still an unresolved task to predict and identify the various effects and linkages of global change.
Remote Sensing and Geographic Information Sytems can successfully contribute to the monitoring and assessment of change processes involved. However, satellite systems operating at a high technological standard alone are not sufficient. The network between data providers and users as well as the capacity to extract, deliver and receive information has to be developed.
Established and well-maintained local focal points are essential to ascertain the dissemination of information in an adequate format for local actors so that they can perform effectively.

Keywords: Vulnerability Assessment, Global Change, Remote Sensing, Monitoring, Developing Countries, Livelihoods, Decision Support, Institutional Requirements

1. INTRODUCTION

Some 75 percent of the world's population live in areas affected at least once between 1980 and 2000 by an earthquake, a tropical cyclone, flood or drought. From this, the observation was made that while only 11 percent of the people exposed to natural hazards live in countries with a low human development index, they account for more than 53 percent of total recorded fatalities. The destruction of infrastructure and the erosion of livelihoods are direct outcomes of disasters. But disaster losses interact with and can also aggravate other financial, political, health and environmental impacts. As a consequence such losses might make it difficult for many developing countries to meet the Millennium Development Goals by the year 2015.
Therefore disaster risk management needs to focus on the reduction of people's vulnerability. For this, compensatory and preventive policies are required to reduce contemporary and medium to long term risk.
Within this paper we present a concept on how to include Remote Sensing for a better decision support in regard to monitor and assess the vulnerability of a system in regard to global change. The identification of needs as a minimum catalogue will be provided whereas technical issues and other communication forms will be discussed.

2. FROM GLOBAL CHANGE TO VULNERABILITY

2.1 Global Change

The term "climate change" has made its way to the top agenda of scientific discussions and – at the same time - down to coffeehouse disputes. However, next to it another term has evolved in the scientific discussion which is often muddled up with climate change: global change.
The starting point for this is the integrated earth system. The earth system encompasses the climate system, and many changes in the earth system directly involve changes in climate. However, the earth system includes other components and processes, bio-physical and human, important for its functioning. Some earth system changes, natural or human-driven, can have significant consequences without involving any changes in climate.
Global change should thus not be confused with climate change; it is significantly more (Steffen, 2004).
As a result of this the interconnectedness and relationships between the different driving factors become very important and are a central starting point for further concepts. Furthermore it is essential to note that global changes in social, cultural, economic and environmental systems converge in localities. On the other hand changes on the local scale contribute to global change with its various linkages between systems and scales.
Examples for global driving forces are that the world's population has doubled since the 1960s, the global economy has increased since the 1950s by more than the factor 15 but the inequality is increasing, and so on.
To the present it is still an ongoing task to predict and identify the various effects and linkages of global change. The concept of "vulnerability" provides a useful framework to study and examine the consequences of global change and to understand and get aware of abrupt and creeping changes as well as surprises which might occur in the future.

2.2 The concept of Vulnerability

Vulnerability research and assessment is one of the major themes under the umbrella of sustainability science. Despite this, the term "vulnerability" has no universally accepted definition (Downing 2003). Social scientists often have a different understanding than e.g. climate scientists. Broadly speaking, the vulnerability of a system, population or individual to a threat relates to its capacity to be harmed by that threat. Vulnerability varies widely across peoples, sectors and regions. This diversity of the 'real world' is the starting point for a vulnerability assessment. Although assessments are often carried out at a particular scale, there are significant cross-scale interactions, due to the interconnectedness of economic and climate systems. Social scientists and climate scientists often mean different things when they use the term "vulnerability" (Adger, 2004).
So far different approaches have been identified (risk-based, vulnerability based). Recent definitions come from the IPCC (heavily discussed), Kasperson et al. (2001), Downing (2003) (proposing a nomenclature) and Turner et al (2003). Common findings are that it is adamant to assess vulnerability as an integral part of the causal chain of risk and to appreciate that changing

vulnerability is an effective strategy for risk management (Kasperson et al, 2001).
All evolves around the answers to the following questions:

- Who is vulnerable?
- To what are they vulnerable?
- What are the specific reasons for their vulnerability?
- Where are the vulnerable?
- How have they come to be vulnerable (or under what circumstances will they become vulnerable)?

A key research issue in seeking to understand vulnerability is the need to better grasp the causal structures (or maps) of current patterns of vulnerability and how these causal structures that shape immediate attributes of risk and vulnerability are embedded in the basic properties and processes of society, economy, and policy. As yet we know of few explorations, much less modelling efforts, of these causal "maps." Such maps will need to be complex enough to allow cross-scale analyses, to evaluate the multiple stresses on vulnerable regions and people which often emanate from higher larger scales as do societal forces. Characterising sequential coping, the drawdown of buffering resources, and the social learning involved in continuing encounters with stress is an essential task for the next generation of vulnerability research (Kasperson, 2001).
Recently Turner et al (2003) identified the following elements for inclusion in any vulnerability analysis, particularly those aimed at advancing sustainability:

- Multiple interacting perturbations and stressors/stresses and the sequencing of them;
- Exposure beyond the presence of a perturbation and stressor/stress, including the manner in which the coupled system experiences hazards;
- Sensitivity of the coupled system to the exposure;
- The system's capacities to cope or respond (resilience), including the consequences and attendant risks of slow (or poor) recovery;
- The system's restructuring after the responses taken (i.e., adjustments or adaptations); and
- Nested scales and scalar dynamics of hazards, coupled systems, and their responses.

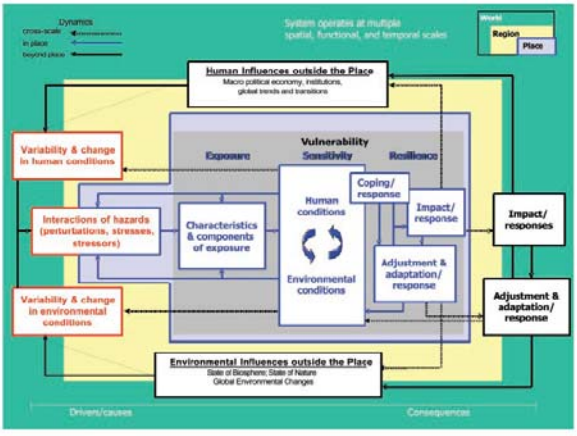

Figure 1. Vulnerability framework: Components of vulnerability identified and linked to factors beyond the system of study and operating at various scales (Turner, 2003).

The methodological challenge is to develop a reporting framework or system on vulnerability that can include both qualitative, quantitative as well as even visual data (photographs, sketches, maps) to flesh out a sophisticated appraisal of vulnerability that is at all times context-specific and linked to data on adaptive capacity. Ideally, vulnerability assessments should be continuously up-dated.
Additionally a set of vulnerability indicators has to be developed. The vulnerability indicators should be used to evaluate adaptive strategies and measures as well as should serve as the baseline for monitoring development. Selection criteria for indicators should comprise the use of existing and readily available data, the easiness and cost-effectiveness for applying them and the significance for different levels of vulnerability. An important issue is also the scale of the assessment (regional, national, local…). Additionally indicators should be relative rather than absolute as relative assessments are more useful for decision making: e.g. an assessment that the whole country is highly vulnerable to flooding is of little use in assessing priorities within the country.

2.3 Human security and the stability of livelihoods

Human security is understood as the coping capacity of individuals and /or societies suffering harm from risks of hazards in a deteriorating environment. Understanding the causes of vulnerability is a prerequisite for ensuring human security and decreasing human vulnerability. The global debate on re-conceptualising security (UN, 2004; EU, 2003; Madrid Agenda, 2005) recognizes the fact that stability will only be sustained if development in general (in economic and social terms) combined with the protection of the environment is seen as essential pre-condition. Environmental degradation and limited resource use reduce the coping capacity as well as the resilience of communities and societies when faced with the impact of terrorism or interstate conflicts. One of the ways out of this vicious cycle is to develop options for interventions based on monitoring changes in the environment. To strengthen monitoring capabilities, is the main objective of the European Initiative GMES (Global Monitoring for Environment and Security), and its future extension to the African Continent (African Monitoring for Environment and Sustainable Development AMESD). The challenge is to improve the tools, ascertain the availability of data, build the capacity to extract information, and guarantee its timely dissemination to facilitate the decision making process. For reducing vulnerability and strengthening coping capacity we need to integrate assessments at different levels and sectors - climate change, global change scenarios (Millennium Assessment), regional observations, national monitoring – and provide the synthesis in an appropriate format for local actors so that they can perform effectively.

3. THE ROLE OF REMOTE SENSING

3.1 The example of Buzi, Mozambique

Central Mozambique is often affected by different hazards. Droughts, cyclones and floods (Figure 3) can be identified as the major natural disasters which emerge from a regional to global scale. Despite this, the region also suffers from the consequences of the civil war which ended in the year 1992. Additionally epidemics such as AIDS, Malaria etc limit the development of the region significantly.
We take the community of Buzi (located to the West of t the City of Beira), District of Sofala, Mozambique, as an example to show the potential and constraints of Remote Sensing for decisions support in the context of Vulnerability Assessment and Global

Change. Various organizations and research institutions have been conducting activities in this region (Gall, 2002, Steinbruch, 2003).

Figure 2. Map showing the location of CIG-UCM and Beira

3.2 Capacity and Technical Limitations

For this region a GIS/Remote Sensing Centre already exists since 1998. The GIS-Centre (CIG-UCM) located at the Catholic University of Mozambique in Beira (Figure 2) serves as a germ cell to address the needs for monitoring and analyses of vulnerability and global change questions in Central Mozambique. In general, one of the main present obstacles is the lack of human capacity to deal with remote sensed data. Not only capacity is needed to apply the different tools and methodologies, but also to disseminate the results effectively to decision makers with the aim to sharpen the awareness about the hazards and risks.

Figure 3. Image above: August 1999 (dry season), Landsat 5; Image below: April 2000 (2 months after the floods), Landsat ETM

Such centers, as CIG-UCM, are important in this region to increase the capacity of people in regard to GIS/Remote Sensing and even more important to serve as a focal point to distribute and disseminate the appropriate information to the different agencies, organizations and stakeholders.

As datasets are still expensive (in terms of developing countries) and technical limitations (internet connections, hardware) exist, it becomes even more evident that such centers can serve as information technology focal points. Information for disaster management can only be produced reliably and timely by local institutions. Data bases on land cover, land use, socioeconomic indicators have to be updated regularly and require local knowledge. National centers for remote sensing and Geoinformation need the strong support by national governments. The staff requires continuous training and scientific exchange to improve information provision and apply new methodologies. In many cases the assistance by the international community is required to realise the establishment of these centers.

3.3 The Role of Institutions

In Buzi efforts have been made to integrate decision makers at the different institutional levels (Disaster Risk Management Project, PRODER-GTZ). Participatory disaster risk management concepts have been applied to train people in regard to preparedness and mitigation (contingency plans, prevention measures). What has still to be strengthened, are infrastructures such as early warning systems and monitoring facilities. For the affected area in the region of Central Mozambique, the GIS-Centre (CIG-UCM) provides the possibility to serve as the operating focal point for these instruments. However, what is still lacking are institutional agreements between the organizations in the countries itself and between regional organizations.

The experience has shown that the capacity building process of decision makers on how to use, apply and interpret the outcomes of analyzed remotely sensed datasets has to be continuously maintained and will only be sustainable when local experts are involved.

Relations among different institutions and their interactions with the general public are critical. Here is where ‘things fall apart’ when information flow and communication between responsible organisations, especially government agencies, and the population fails to work. In Mozambique, a weak monitoring and information system – in conjunction with a poorly developed culture of information sharing - limits the Government’s capacity to ascertain the security of its citizens. The effective use of Earth Observation (EO) data requires an efficient system with defined entry points for data and information. Only if clear requirements are forwarded and experts for processing and information production are in place, the full benefit of EO can be felt. Satellite systems operating at a high technological standard alone are not sufficient. The network between data providers and users as well as the capacity to extract, deliver and receive information has to be developed.

3.4 Better communication forms are needed

The distribution of information to decision makers for monitoring and analyzing vulnerability is effectively being done through web-based hazard and vulnerability atlases. Success was achieved with an online atlas in South Africa (http://sandmc.pwv.gov.za/atlas/) which was finally extended to the Southern African Region (http://edmc1.pwv.gov.za/sadc/). The advantage of such efforts is to provide necessary information timely and in a simple, understandable format to decision makers. However, experienced people are necessary to maintain and update such a system, as

well as sophisticated analysis and models have to be developed and integrated for the different regions and countries. For this local contact points are essential to process and prepare these inputs.

Additionally, alternative forms were used to communicate the concepts and outcomes of vulnerability assessments to local people. Participatory methods (such as Participatory GIS and other methodologies from the Participatory Rural Appraisal toolbox) have been used in this region but have still to be proofed and researched in regard to its methodology, relevance and success. Such methods give the opportunity to actively involve the local people in the decision making process and to open up the complex inter-linkages of the coupled human-environmental system to less well-educated people.

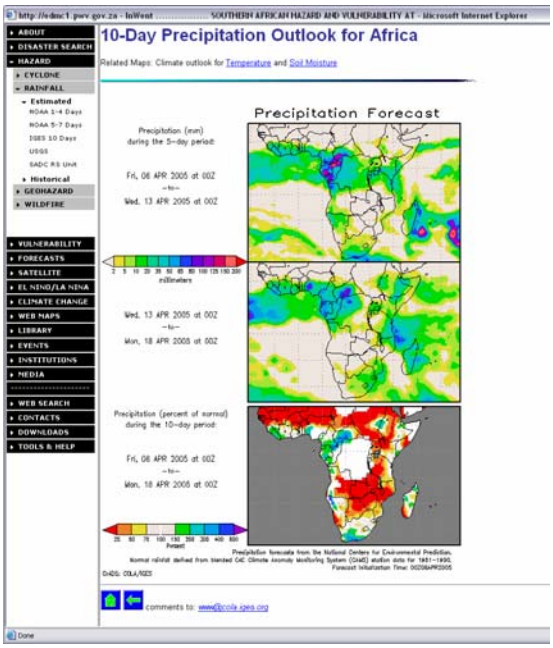

Figure 4. Southern African Hazard and Vulnerability Atlas, Precipitation Outlook (http://edmc1.pwv.gov.za/sadc/)

4. CONCLUSION

Satellite systems operating at a high technological standard alone are not sufficient. The network between data providers and users as well as the capacity to extract, deliver and receive information has to be developed.

One of the most critical aspects is the need to integrate ground information with remote sensing data, the availability of geographic information systems and trained local personnel to facilitate integrating those data quickly and efficiently within the regional context.

Datasets have to be provided to customers in developing countries in a cost-effective way (in terms of developing countries!).

To deliver the necessary and important information to decision makers and to local people in an efficent way, it has to be adapted which is taking into account the present limited capacities and limited access to state-of-art knowledge as well as the global scientific debate.

Still crucial is, and will be, the setting up of institutional structures, agreements and understanding, which are essential for facilitating the reduction of vulnerability and strengthen the development of affected societies.

3. REFERENCES

Adger, W. N., et al., 2004. New indicators of vulnerability and adaptive capacity. Tyndall Centre for Climate Change Research, Technical Report 7.

Downing, T. E., Patwardhan, A., 2003. Vulnerability Assessment for climate adaptation. Stockholm Environment Institute. Technical Paper 3.

EU, 2003. A secure Europe in a better world. European Security Strategy. Document proposed by Javier Solana and adopted by the Head of State and Government at the European Council in Brussels on 12 December 2003

Gall, M., et al, 2002. Distribution of relief supplies to flood victims in Mozambique – Can Remote Sensing effectively contribute to disaster risk management? 2nd Workshop EARSeL Special Interest Group on Remote Sensing for Developing Countries.

Kasperson, J.E., Kasperson, R. E., 2001: International Workshop on Vulnerability and Global Environmental Change. Stockholm Environment Institute.

Madrid Agenda, 2005. International Summit on Democracy, Terrorism and Security, Club de Madrid, 8-11 March 2005 http://english.safe-democracy.org/agenda/the-madrid-agenda.html

Steffen, W., et al., 2004. Global Change and the Earth System: A Planet Under Pressure. Springer-Verlag, Berlin Heidelberg New York.

Steinbruch, F., 2003. Hazard Risk and Vulnerability Assessment of the Buzi River Basin/Central Mozambique. PRODER-GTZ, Beira.

B. L. Turner II, et al., “A framework for vulnerability analysis in sustainability science,” PNAS, vol. 100 (14), p.p. 8074-8079, 2003

UN, 2004. A more secure world: Our shared responsibility Report of the High-level Panel on Threats, Challenges and Change” http://www.un.org/secureworld/