5 Conclusion and relevance for decision makers, scientific users and those concerned

The determination of people's risk of natural disasters is of crucial importance in all phases of a disaster or crisis management. The demands on data describing populations at risk concerning accuracy, timeliness and spatial resolution varies significantly according to the application the generated information product is designed for. International governmental and non-governmental organisations need to base their decisions on global or regional / continental datasets at relatively course but sub-national resolution and relatively low accuracy with a yearly temporal update. Public administration, development and humanitarian aid programs and any community or interest group acting at local level need fine resolution data of the best accuracy and in a case of a crisis ideally with a daily production repetition. However, their spatial area of interest is limited.

Beside these disparities the risk determination at various scales has in common that:

1. The populations' vulnerability is the most difficult parameter to assess due to the complexity of the issue and the number of components characterising it. Limitations for measuring populations' vulnerability include the frequency of update and quality of many of the potential indicators. Those indicator data available for global assessments usually do not feature a finer (sub-national) resolution. At local scale the appraisal of vulnerability lacks standards, is time consuming and difficult to repeat.
2. Data on the potential of hazard occurrence is mostly only available with strong restrictions regarding liability and spatial accuracy.
3. Population data is available but they are mostly lacking any accuracy information and they are often out-of-date.
4. In general it can be stated that the amount and accuracy of available country wide data sets is decreasing with lower development status. Hence, it is more difficult to generate vulnerability information for those countries that are the most likely to suffer a disaster when a hazard strikes.
5. The potential of Earth Observation data as source for datasets with direct or indirect relevance for vulnerability assessment is far from being exhausted. There is a growing number of satellite images with global coverage free available online and – at least in the case of Landsat – even existing for various years. These data could be more intensively used for identifying trends and changes detectable at medium scale and of importance for populations' vulnerability. The number of activities enhancing disaster emergency response worldwide and the amount of satellites receiving more frequently data of high and very resolution is growing constantly. Both can lead to a better population distribution and vulnerability data generated immediately after a hazard stroke. However, there is a need for more transparency and standardisation of processes regarding data management and distribution, quality assessments, vulnerability measurements, and map production.

There are a number of issues to be addressed regarding the existing approaches towards global risk and in particular global vulnerability assessments:

- Due to the lack of data and indicators available worldwide for a vulnerability estimation, most of the studies dealing with risk of natural hazards in larger areas look at the impact of past hazards in order to describe populations' vulnerabilities.

This approach exhibits several disadvantages, to name but a few: the lack of standards for reporting impacts caused by hazardous events, the difficulty to define temporal and spatial extent of a hazard impact and the absence of the possibility to repeat assessment procedures.

- The two most well-known studies for risk assessment and risk hot spot identification with a global or near global coverage rely both on the EM-DAT data base. This dataset has several constraints, of which two of the most important are (1) the lack of reports of hazardous events in least developed countries and (2) the lack of distinction between 'no data' and 0 at least for all those events registered before 2000.
- The methodology for a global risk assessment developed in the context of this work has the advantage to look at the populations' vulnerability most currently possible. It is independent from a certain disastrous event in the past and trends can be identified since the statistical procedure for the vulnerability assessment can be repeated quite easily. However, evidently the method has its own disadvantages such as the subjective decisions to be taken within the statistical process for the composite indicator generation.
- Regardless the methodology that a risk assessment is based on, the presenting scientists have a great responsibility when publishing their work and making it available to decision makers. The way the results are visualised is crucial for the interpretation of the outcomes and often underestimated in its impact. The risk of manipulation – consciously or unconsciously – is high. Classification, mapping and visualisation of the final results significantly influence their appearance and their perception by the user. In particular the set of class thresholds and the colour choice for presenting results in maps and ranking lists is important. Therefore it is emphasised that (1) any populations' vulnerability assessment is always to some extent *simplistic and relative* and (2) the visualisation of the results of a vulnerability estimation should be done in the most objective manner possible and the procedure of class threshold selection should be made transparent.

There are several aspects to be mentioned concerning the modelling population distribution at fine sub-national scale:

- The here presented work for the case study Zimbabwe has proved that the developed methodology could successfully be applied. A transfer of the methodology and applied procedures to other countries requires reasonable efforts for the adaptation of datasets and weighting factors to the area-specific characteristics. Obviously, the quality of the results increases with the accuracy of the input data and the amount of previous or local knowledge.
- Within the scope of this work, the modelling of population densities is the field with the greatest potential for the application of new technologies such as EO data and GIS.
- There is still a significant lack of:
    - Generic approaches, which take into account the climate, topographic, cultural and historical varieties of a country. The development of a base set of input data layers such as land use, roads and settlements would be useful. Within a standardised population density estimation model these input data layers could represent a fixed framework. The adjustment to the local or national specifications would be accomplished by the choice of weighting factors based upon local / expert knowledge.

- Standardised EO data interpretation methods for the generation of the crucial input layer land cover / land use. Ideally such methods would take advantage of reliable remote sensing data sensors with a long year life span and guaranteed data access.
- Methodologies to use active remote sensing sensors for generating required input data for tropical areas, where optical sensors are limited in their usefulness due to the cloud coverage.

There are various concrete suggestions for future activities regarding worldwide risk studies. They are allocated to the three main input data layers and listed below:

- Vulnerability
  - A universal agreement on the definition of vulnerability and related basic terms should be pursued in order to allow faster progress in quantified estimations of populations' vulnerability. This requires an accord not only within the 'disaster management community' but beyond, for example with the 'climate change community'. There is an increasing awareness of the correlation between growing numbers of hydro-meteorological hazards and global warming but the cooperation between experts from the respective research communities is weak. Not surprisingly, there are significant differences in the terminology used by disaster managers and climate change experts.
  - The worldwide compilation of important indicators such as the GDP at sub-national scale should be enforced (minimum at admin level 2, the provincial level) and the management of these data should be centralised.
  - Datasets describing physical objects of relevance for vulnerability determination such as earthquake safe housing should be collected worldwide in a standardised way, starting with 'hot spot' areas and countries.
  - A collection of local and regional vulnerability studies could support the development and validation of potential future global vulnerability estimations.
  - The UN branches dealing with disasters or vulnerability could take a leading role in these required activities.

- Hazard
  - The collection of data on natural hazard probability of occurrence at global level is still ongoing. Information on a hazard's magnitude, frequency, spatial extent etc. is only partly available for certain types of hazards. Activities for the standardisation of disaster data have been initiated and the development of a Global Unique Disaster Identifier Number (GLIDE) has been supported by a number of worldwide acting institutions including ReliefWeb-OCHA, ISDR, UNDP, WMO and IFRC. These efforts need to be pursued in order to improve disaster data bases.

- Exposure / population
  - According to the collection of indicators such as GDP at sub-national level, a centralised data base could serve as stock for population census data at provincial or district level. The pre-requirements for this compilation are

spatial datasets of administrative boarders of the respective administrative level to which the population data can be allocated.

- Following a bottom-up approach, evolving GIS technology and new EO sensors could be exploited for the generation of worldwide population datasets. This activity requires a generic and widely accepted standard of modelling population distribution in grid layers of fine resolution.
- For hot spot areas with a high potential of future critical events population distribution datasets of best possible accuracy and spatial resolution could be generated based on the here proposed methodology BEFORE an event occurs. In an evolving crisis situation these datasets could immediately be made available for decision-making of humanitarian and political relevance (for example this could have been possible and would have been very useful in the Darfur region of the Rep. of Sudan).

The majority of these proposed actions rely to some extent on a strong international institutional setting. It can only be hoped that the growing awareness of the increasing number of natural hazards and global climate change create the momentum for international cooperation, agreements and action.

It is debated if the number of natural hazards is increasing but there is no doubt that the number of vulnerable people is growing and will be growing over the next decades. Upcoming challenges are the very vulnerable group of migrating people (which will increase with growing effects of global climate change) and the partition of population groups with varying level of vulnerability in built-up areas.

It is time to act now.