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Geo-communication for risk assessment and catastrophe prevention of flood events in the coastal areas of Chennai

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Abstract: Risk assessment of environmental stressors in the context of information and communication technologies is an emerging field of scientific research, for example to gain an understanding of how floods will develop. Geo-information technologies are accepted as powerful tools in crisis situations. To be successful in risk assessment and catastrophe prevention, it is essential to follow an interdisciplinary approach combining natural scientific, socio-economic and technical knowledge. At the same time it is important to combine top down (planning, official institutions) with bottom up views of the affected people. Interconnecting computational resources, human interdisciplinary expertise and local knowledge, following a top down / bottom up approach, can yield significant benefit in catastrophe prevention. Once the scientific understanding has been gained, a second phase is necessary in which geo-visualisation is important: The message has to be communicated effectively. This article explains how geo-communication and geo-visualisation can foster successful catastrophe prevention to arbitrate between different stakeholders supporting decision making processes. With these policy goals in mind the research results of this study were merged in an ogc-conform, server-based geo-communication portal using several flash based visualisation techniques. Thereby, the use of web-based mapping systems and an interactive participatory mapping tool proved to be an effective technique for risk evaluation.

Keywords: catastrophe prevention, participation, decision-making, geo-communication, geo-visualisation

1. INTRODUCTION

Flooding is one of the most widespread climatic hazards and poses multiple risks to humans. In the south Indian megacity Chennai, disastrous tropical monsoons linked with excessive precipitation frequently lead to wide-spread floods. Caused by rapid urbanisation, the population in urban and periurban areas is more and more affected by these events. Besides the marginalised population living in disfavoured areas, increasingly also the more wealthy population that settles in flood prone areas is affected. The situation is characterized by complex interrelations of anthropogenic and ecological factors that were analysed through an interdisciplinary risk and vulnerability assessment by an international team of scientists.

Much of the data, information and knowledge for risk assessment are geospatial in nature. Preventing, preparing for, responding to, and recovering from natural and human-induced disasters all require access to geographic, climatological, as well as socio-economic data. Increasing data heterogeneity, fragmentation and volume, coupled with complex connections among specialists, researchers, planners and affected people in disaster

response, mitigation, and recovery situations, demand new approaches for information technology to enable long-term catastrophe prevention [Tomaszewski, 2007]. For this, extracting relevant content and information visualisation techniques are necessary to facilitate visual exploration, analysis, synthesis and especially processes (e.g. of land use changes, impacts of urbanisation or changing adaptation mechanisms) and in order to interact with, to combine and to exchange complex data sets and information. To meet scientific as well as planning and social needs, geo-visualisation and geo-communication can be considered as an auspicious approach. It is a research field that develops visual methods and tools for information preparation and presentation. One aim is to encourage collaboration between researchers and to make research results relevant to the tasks at hand. But above all, geo-visualisation and geo-communication can encourage participative processes and foster communication, support knowledge exchange and decision making between different stakeholders required for successful catastrophe prevention.

2. GEO-COMMUNICATION AND GEO-VISUALISATION – CONNECTING PEOPLE AND DATA THROUGH INFORMATION EXCHANGE

Geo-communication is quite a new research field. It includes different disciplines, like geography and cartography, as well as information and communication sciences, visualisation techniques and multimedia design. One of its major interests is to communicate geographical knowledge and spatial information across to a recipient using methods of information transfer. To implement these specific methods of communication, visualisation plays an important role. Visualisation means “exemplification”, and generally stands for all techniques that process and visually represent abstract data and coherences to support an effective data analysis. Visualisations try to activate the visual skills and tendencies of humans. This leads to better and easier identification of correlations, and an extraction of essential information not immediately coherent out of crude data. Above all, visualisation in sciences is a powerful tool for exploration, analysis, synthesis and presentation of research results, and can support scientific research processes in visual-mental activity and communication. To get an ideal data presentation, visualisation includes research cognitions of human data processing. Visualisation is an especially promising approach to transferring and exchanging information and knowledge to laities, because it can scale down complex circumstances to clear structures.

Rapid advances in web-cartography and geographic information systems, as well as in information and communication technologies, have created a potential for dynamic and interactive visualization methods which are increasingly used by decision makers and planners. Especially using current web2.0-techniques in geo-communication portals enables decision-makers to make their decisions through exploring a broad range of data. Meanwhile a wide set of tools have been developed that allow for visual exploration. These allow for processes to interact, to combine and to exchange complex data sets and information. Providing effective tools for geo-communication is not only a technical challenge. In particular Lars Brodersen [2005, 2007] has developed an important geo-communication model based on established theories of communication science. These specific spatial communication models need to be developed further to provide effective geo-communication tools and portals.

Recognizing the importance of understanding between different pressure groups for successful catastrophe prevention, geo-visualisation was used as a communication interface for intermediation. Information and knowledge exchange between heterogeneous groups is always associated with problems, especially in developing countries. The communication and information transfer in both directions often fail, due to a lack of communication channels. The visualisation approach offers an auspicious opportunity to combine both local views, by applying a bottom-up approach, as well as institutional perspectives, following a top-down approach. Furthermore, expert information can be expressed in varying levels of abstraction to fit the needs of the respective user, and to make it more useable and intelligible. The multi-media based preparation and presentation of the research results combine information and attitudes of stakeholders on various levels to support mutual solution-finding processes. This proved to be an effective technique to support decisions-making in catastrophe prevention.

3. THEORETICAL FRAMEWORK AND METHODOLOGY

3.1 Workflow: Flood risk assessment using an interdisciplinary approach

As mentioned, both flood risk assessment and prevention need a holistic approach regarding human and environmental aspects. The conceptual framework (Figure 1) shows the multi-layered approach of this study combining physio-geographic analysis, remote sensing and socioeconomic data.

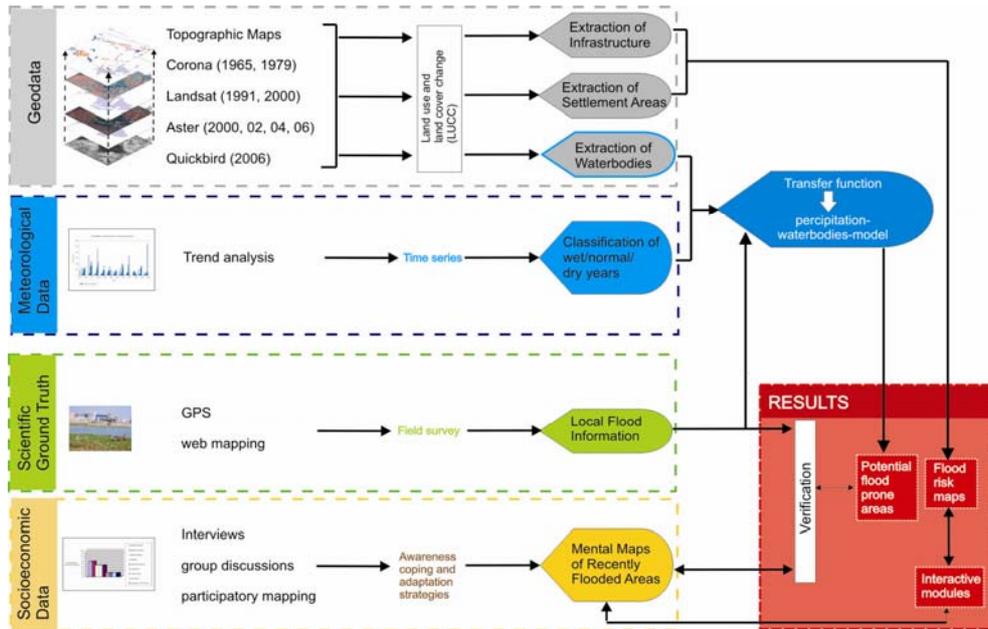


Figure 1: Workflow diagram - Interdisciplinary approach

Remote sensing data in different resolutions, (e.g. spectral and temporal ranges) were used to analyse the changes in settlement areas, infrastructure and the extent of water bodies from different periods of time since the 1960's up to now.

Early Corona-images from 1965 and 1979 were used to identify the state of natural water bodies and the dimensions of the former settlement. Multi-temporal Landsat images from 1991 and 2000, as well as repeated images from Aster, taken in 2000, 2002, 2004 and 2005, were used to receive time-dependent information about the dynamics of the main water body, the marshland in the South of Chennai. These were combined with long-term meteorological precipitation data to build a regression-based transfer function, showing the relations between rainfall and the extent of the water bodies in dry, normal, wet and extreme-rainfall years. Local flood information was gathered in transect walks and through a web-based mapping system, which also was used for verification.

In order to learn about risk perception and management, a multilevel approach was selected. This means focusing on quantitative macro-level information such as census data, but also on qualitative micro-level information for example, key-informant-interviews, group discussions and participatory mapping. An explorative, multi-methodological approach on different levels covers the complexity of attitudes and responses. Mental maps represent people's perception of their own environment and provide additional insights in local cognitions of flooding. The mapping was started by identifying community boundaries and infrastructure. In order to learn about the historic dimensions of floods, time-lines were selected. In doing so, outstanding floods of the last twenty years were

demarcated. Based on this information, discussion took place about response strategies used before, during and after floods. The mapping activities proved to be very helpful in communities with low literacy since the visualisation enabled the participants to overcome barriers of communication.

3. 2 Theory: Flood risk assessment using a risk and vulnerability framework

Flood risk assessment is theoretically embedded in a risk and vulnerability framework. Risk and vulnerability concepts are not new in disaster research. In the past, researchers acknowledged the fact that it is not sufficient to look at environmental exposure and stressors only, since this leaves out information about different human response strategies, as well as impacts [Bohle, 2001]. Turner *et al.* [2003] developed an expanded vulnerability framework, which sets the focus on the multifaceted synergies and linkages between human and environmental aspects. This framework takes into consideration that in case of a disasters, such as floods, vulnerability is not determined by exposure to risk only, but also by the sensitivity and resilience, as well as by coping and adaptation strategies of those affected. This interdisciplinary approach provides information about the complexity of human-environment systems.

Within the framework, a hazard, e.g. floods, is a threat to a system. The impact of a hazard depends on the exposure of a system. Exposure can be the frequency, magnitude and duration of floods. Sensitivity means the consequences for a population considering their human conditions – e.g. human capital and endowment - as well as environmental conditions – e.g. climate and soil. Resilience patterns are developed depending on the sensitivity. This includes coping as well as adaptation strategies. According to Turner, social vulnerability can be defined as the combination between exposure, sensitivity and resilience of a system [Turner *et al.*, 2003; Glaser *et al.*, 2006]. The interdisciplinary analysis of the complexity of risk and vulnerability is crucial for this study. The focus lies on the exposure to floods in PM, risk perceptions of those affected as well as their coping and adaptation strategies. The results are combined and visualised in the conclusion using a table based on Turners framework.

The Turner model visualises the linkages and dependencies between causes and consequences of floods in Tamil Nadu (Figure 2). The framework visualises the linkages and dependencies between causes (highlighted in red) and consequences (highlighted in black) of floods in Tamil Nadu. Hereby, three levels are covered: the international (green background), the national (yellow background) and the local level (blue background). Global socio-economic changes reflect in national population growth and labour-migration, environmental changes result in changing monsoon patterns and climate variability. These developments highly impact on local planning capacities of the government. The sensitivity of those exposed to floods varies. It reflects in the frequency and intensity of vector and water born diseases, loss of income, loss of schooling and psychological stress. Depending on the livelihood background (especially the financial and social resources) different coping and adaptation strategies are selected by the affected communities. However, on a household level strategies are limited. Although sustainable prevention measures and proper city planning would be needed, the government only offers rehabilitation services. The lack of national and local strategies increases the vulnerability to current environmental as well as socioeconomic changes, at the same time these changes put a burden on government authorities.

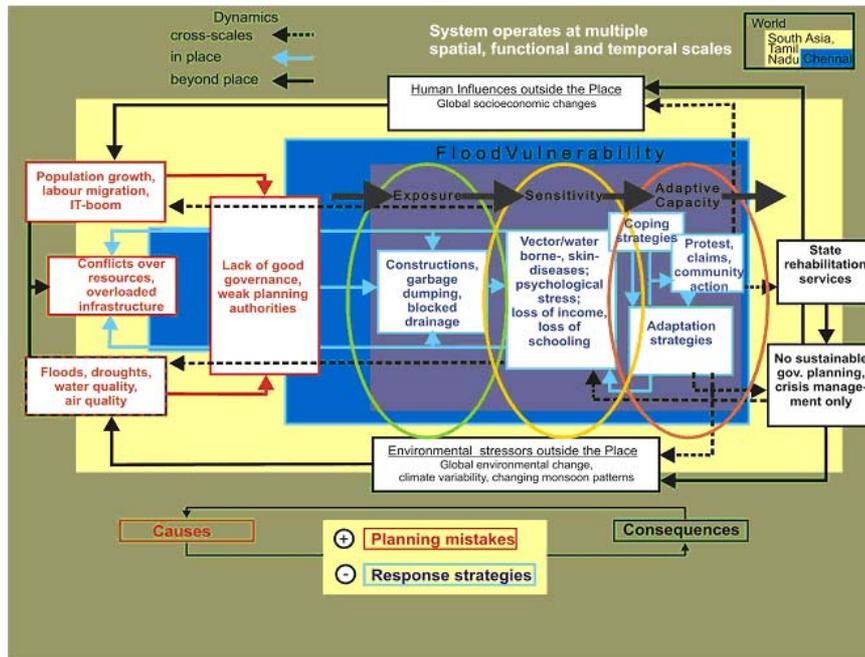


Fig. 2: Modified framework according to Turner et al. [2003]

4. GENERAL RESEARCH RESULTS OF THE STUDY

The analysis of the meteorological data clearly shows that there is an outstanding year-to-year variability, but also medium-term fluctuations on a decadal scale over the last 200 years on the eastern coast of India. But in the long-term perspective, there are no significant upwards nor downwards trends during the last 200 years [Walsh et al., 1999]. The last 30 years are characterised by a decrease of annual precipitation, while the number of floods affecting the inhabitants of Chennai is increasing. The reason for these floods is the high monthly total precipitation that may exceed the total yearly rainfall. In some cases, even the daily total rainfall exceeds the average monthly amount. But most importantly, the statistically derived relation between the extent of the water body and the rainfall amount gives clear evidence that the flood risk in the south of Chennai is increasingly due to man-made mismanagement in the area of the Pallikaranai Marsh. Building activities in and around the Marshland cut off the water run off, and therefore aggravated the frequency and intensity of floods, even though the precipitation amounts are decreasing. Without a sustainable planning strategy, especially facing the natural run-off due to single strong rainfall events, Chennai will suffer from more devastating floods in the future.

The socio-economic analysis of risk perceptions and management strategies underline the interrelated reasons for floods, which are embedded in a broader context of economic globalisation, labour migration and rapid urbanisation. The pressure on cities and their planning authorities grows as the number of their inhabitants increases. The demand for developing new areas leads to the ecological destruction of the marshland close to Chennai. Planning authorities are not reacting accordingly. Illegal as well as legal garbage dumping into the wetland is also an increasing hazard. Existing infrastructure are not properly maintained. Canals are dysfunctional; storm water drains are not cleaned regularly; water bodies are not maintained. Uncontrolled construction of IT-companies and construction of private citizens, both legal and illegal, are in complete ignorance and violation of the norms and rules of the government. The combination of these various factors is resulting in a collapse of natural drainage systems.

5. VISUALISATION OF THE RESULTS - A KNOWLEDGE-BASED GEO-COMMUNICATION PORTAL FOR DECISION-MAKING IN CATASTROPHE PREVENTION

The results of this study were merged and visualized in an information portal that is publicly accessible, and can be expanded by the project partners in Chennai (compare Figure 3).

Technically it is based on a Flash-WebGIS- and a Mapbender-WebGIS-Client using the ogc-standards and services web-map-service (WMS) and transactional web-feature-service (WFS, WFS-T). ogc is a nonprofit, international standards organization that is leading the development of standards for geographic data related operations and services. By the use of these specifications the exchange of geo-information between different systems is assured. They also provide interfaces to web-services for data maintenance and supply. The consideration of ogc-standards guarantees a sustainable use and durable free access to data, as well as a transparent integration of heterogeneous, distributed geodata services. For data storage a PostGIS database is used.

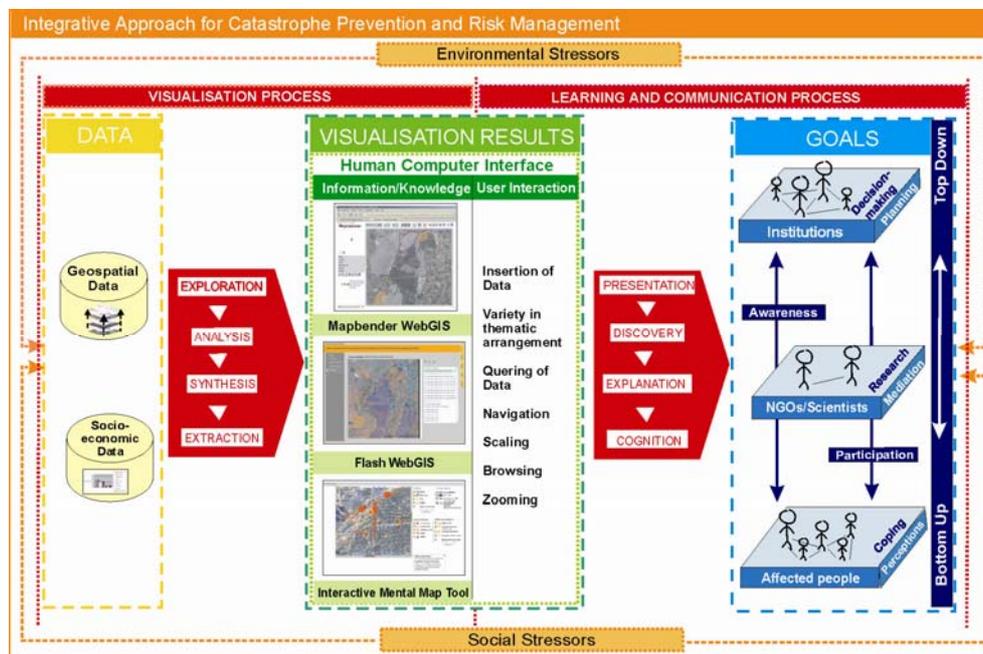


Figure 3: Visualisation process and resulting learning and communication processes

The visualisations are implemented with the authoring software Adobe Flash, which is specialised in developing interactive web content. The integrated programming language Action Script enables wide scope for designing interactive dynamic maps. The developed animations can be presented via the internet, or as offline solution. Flash is platform independent and can be used as browser plug-in, but also as a stand-alone solution. The Flash-Plug-in is available on 98% of users' computer desktops – more than any other similar plug-in technology. It is also easy and quick to install. Additionally, map files (.SWF files) are up to about 25% smaller than equivalent Java-based files, which contributes to a faster user experience. The widespread accessibility and the easy usability of the Flash plug-in turns Adobe Flash into an interesting visualisation tool, especially for use in development cooperation. It also features the use of vector and raster graphics, which is important for working with geographic data.

The geoportal can be divided in two parts: The first part is based on two WebGIS-Applications (5.1). The second part of the information portal offers different flash-based web-animation techniques, to provide an understanding of the processes and results of the

project. This part of the portal also includes a data page for accessing all acquired data, including original hand drawn mental maps, results of interviews and group discussions. In addition, a media page is integrated with an image database, with video and audio sequences of key informant and group interviews from the research area. A flash animation based on satellite images and geographic data gives an easy access to the quiet impressive land use and land cover change in the region. The interactive mental map tool (5.2) proved to be especially useful for stakeholder communication.

5.1 Mapbender and Flash WebGIS-application

Mapbender is an open source WebGIS-application implemented in PHP and JavaScript for managing spatial data that are standardized following the ogc specifications. Data storage is organized with a PostgreSQL, PostGIS or MySQL database. The framework implements user management, authentication and authorization. Management interfaces, depending on authorization and demand of the user, are stored as configurations in the database. The Mapbender client-software can be used to display, overlay, edit and manage geodata.

The implementation of this tool is a response to the difficulty of obtaining satellite images that are taken at the time of flood events. To overcome the missing data, local stakeholders were familiarised with the program. The capacity building process enabled, and still enables, local partners to give their input of the exact area where floods are happening. After the transfer to the database in Freiburg, using ogc-compliant Web Services, the geodata can be accessed directly from expert tools, as well as any client-application qualified for working with GIS-web-services. So it can also easily be integrated in the research analysis. Through this process the acquisition and integration of the knowledge of local project partners were made possible.

For getting access to all acquired geodata, we provided a flash based mapping solution giving users the possibility to discover, explore and visualise different thematics, like for example: settlements, water bodies, infrastructures from different years, as well as land use and land cover change documented by the remote sensing data.

5.2 Flash based interactive mental map tool

Geo-information technologies have long been accepted as being important for catastrophe prevention. Although the advantage of working with participatory maps is known, in the past visualisation techniques were rarely used for information preparation und presentation of hand drawn mental maps. In our project we developed an interactive mental map tool, by combining multiple sources of hand drawn maps with various geographical and socioeconomic data. In order to get insights into local views and understandings of flooding, mental maps drawn by affected community members were used. Hereby, existing infrastructure, as well as flood related time lines were demarcated. The time lines aimed at illustrating the historical dimensions of outstanding floods within the last twenty years. During the mapping activity, discussions about response strategies used before, during and after floods were initiated. Mental maps proved to be particularly helpful for illiterate community members who could visualise, reflect and communicate their local knowledge and experiences. The obtained hand drawn mental maps were then transferred in a digital version for more useful and precise analysis. Following cartographic rules, a comprehensive and generally understandable legend was defined by translating information from group discussions and the hand drawn information into icons, symbols, lines, polygons and points. The digital mental maps proved to be a very accurate transformation of the original information into digital readable elements. To compare the mental maps with the topographic reality we used a Quickbird satellite image as an overlay. The combination with geo-referenced highly resolved satellite imagery showed an astonishing accordance. The ground-truthing functioned as an additional source of verification of the basic information. This successful translation from raw data, such as hand drawn mental maps, digital mental maps and satellite images, did result in an interactive mapping tool that merges interdisciplinary data on infrastructure, local perceptions, coping and

adaptation strategies, with remote sensing data and modern map making technology. The integration of manifold information in one interactive mapping tool led to a more realistic presentation of the situation. The interactive character of this mapping tool proved to be very efficient and effective in communicating research results. It initiated bottom-up information exchange on various levels, from community members up to city planners, and therefore helped to improve and support sustainable planning and decision making processes.

6. CONCLUSION

These results, especially the geo-communication portal, had been presented at two policy workshops in Chennai, India and in Freiburg, Germany. The aim was to bring together different stakeholders, representatives of planning authorities, administrative managers, resident welfare organisations, as well as community members who are personally affected by the problems that have been identified throughout the research, to address the issue of the Pallikaranai Marsh.

The visualisation of the research results helped enormously in expanding the awareness of many participants of the extent of local problems, especially for politicians and city planners. Additionally, they provided new insights and arguments for human rights activists and conservationists. Generally, it was pointed out during the workshop that a better accessibility of reliable data was crucial for the improvement of planning all over India. In this context, the information portal with publicly available data is a very useful tool that could serve as an example for future projects.

A second important achievement of this study was the interdisciplinary approach that has succeeded in offering new possibilities of looking at land use conflicts, their possible resolutions and catastrophe prevention. Another goal of the project was to establish a sustainable tool for flood risk assessment in Chennai, which allows a continuous integration of new data, even after the research had been finished. The chosen digital setting gives the involved experts, under the supervision of the NGO Care Earth, the chance to monitor future flood events, and to suggest appropriate action on site and provide in-time information to relevant authorities. In order to guarantee sustainable processes, continuous capacity building of the local partners was initiated and implemented during the application of the Mapbender client software.

In order to understand and communicate scientific approaches more effectively, and to enhance the level of understanding between different stakeholders, geo-communication is a fundamental approach and geo-visualisation an essential technology.

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