Visual Summary

This summary intends to provide a short and visual overview of the key topics and findings of my PhD research

PhD Thesis
Dr. Stefan Kienberger

Spatial vulnerability assessment

Methodology for the community and district level applied to floods in Búzi, Mozambique

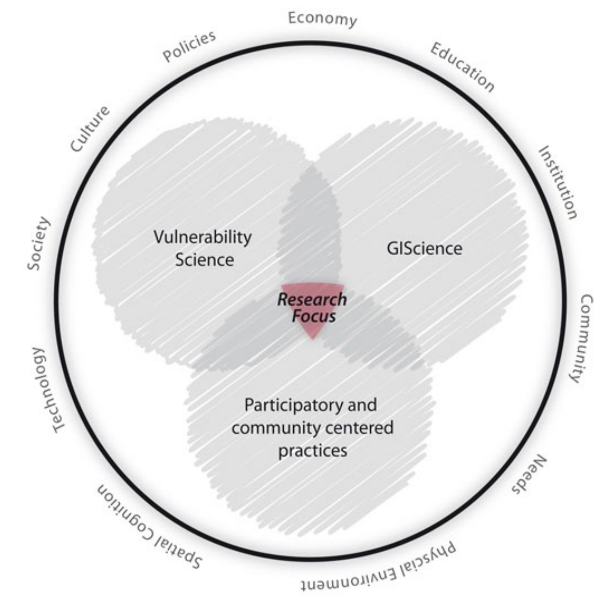
UNIVERSITÄT SALZBURG Z_GIS

Objectives

>> To **conceptualise vulnerability** within a **spatio-temporal** and **multi-dimensional framework** which allows the characterisation and definition of a vulnerability assessment for **different scale levels**

>> To **develop a methodology** which supports disaster risk reduction measures at the **community level** through the identification of **vulnerability factors** and **spatially enhanced risk mapping** in a **participatory manner**

>> To **develop a methodology** for assessing (and with the possibility of monitoring) **vulnerability to floods** in a multi-dimension framework for decision making at the **district level**



Research Questions

Overall research question

>> How can **vulnerability** to **river floods** be **captured and mapped** at the interlinked local **community level** and at the empowered **district level**?

Specific research question

>> How can the concept of vulnerability and the spatial-temporal scale issue be linked, to provide a framework which allows for the characterisation of vulnerability assessments on different scale levels?

>> What is the relevance of PGIS practices at the community level to contributetowards a community-based disaster risk reduction framework?

>> How can vulnerability issues be addressed in a sound spatial manner at the community-level and the integration of participatory approaches be achieved?

>> Which indicators are able to capture vulnerability and which methods are able to derive an integrated measurement of vulnerability for regular monitoring purposes at the district level?

Acknowledgments

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The PhD thesis has been submitted to the University of Salzburg, Austria and supervised at the Centre for Geoinformatics (Z_GIS) by Prof. Thomas Blaschke. Special thanks go to Peter Zeil for valuable input, Prof. Mark Pelling for the positive review and last but not least the colleagues at CIG-UCM in Beira.

Defining vulnerability

***RISK* = Vulnerability x Hazard**

The concept of vulnerability has not yet achieved a common understanding. For this work the following approach has been defined:

***RISK**: The expected probability of harmful consequences or losses resulting from interactions between natural or anthropogenic hazards and vulnerable conditions and its (human) exposure (working definition of the MOVE project, adapted from UN/ISDR 2009b).*

$$R = f(H,E,V)$$

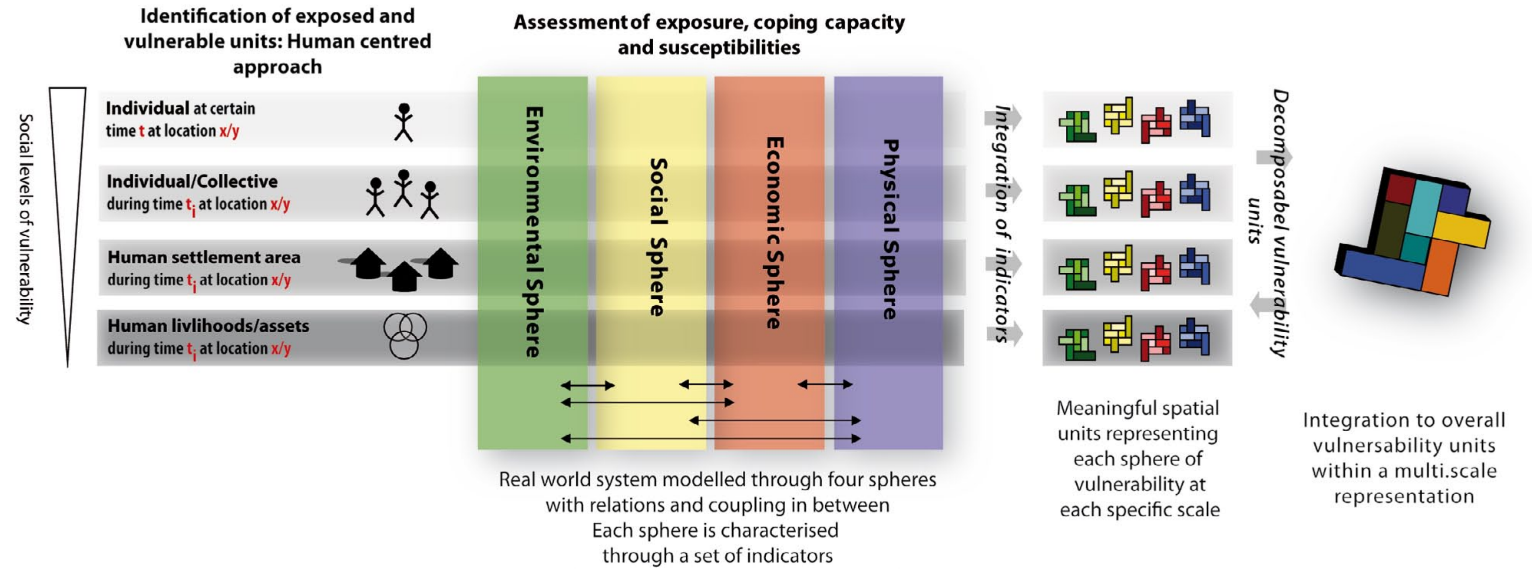
where R is defined as risk, H as hazard, E as exposure and V as vulnerability.

***VULNERABILITY**: The definition builds on the BBC-Concept (Birkmann 2006), but adapts it accordingly. Generally vulnerability is defined as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard". Vulnerability is characterised through different dimensions such as economic, social, environmental and physical. It is also noted that vulnerability has 'human-centred' characteristics, which also underlines the notion that there are no 'natural disasters'. It can be defined as a function of susceptibility and adaptice capacity. Vulnerability is characterised through factors which increase (negative) or decrease (positive) its degree. Additionally, vulnerability has been assessed within a environmental, social, economic and physical dimension .*

$$V = f(SU, AC)$$

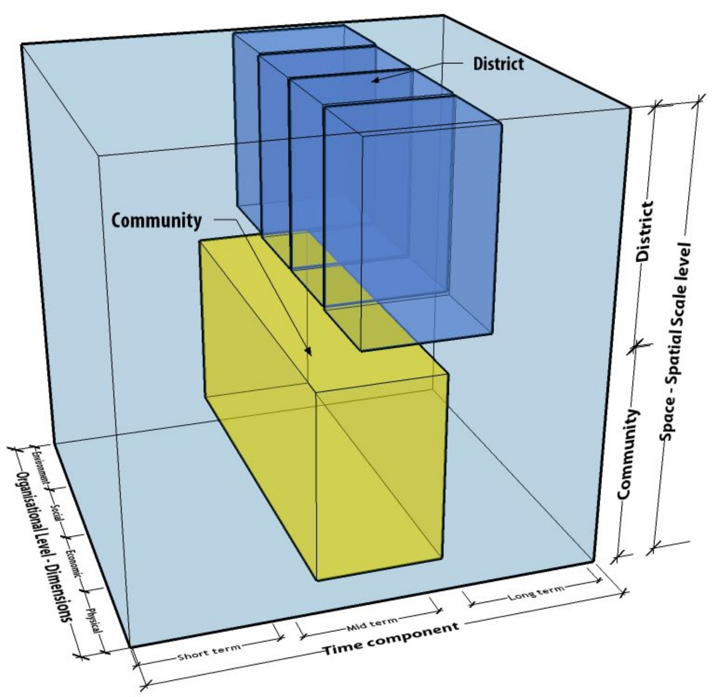
where SU defines the susceptibility and, AC Adaptive Capacity.

>>> See chapter I and IV.1



Vulnerability - in space + time

Vulnerability Cube



Having in mind the definition of vulnerability, important characteristics can be defined, which help to integrate the framework into a GIScience relevant context:

*>> **Where**: Vulnerability differs spatially*
*>> **When:** Vulnerability changes within time*
*>> **What:** Vulnerability has different dimensions (environmental, physical, economical, social, etc.)*
*>> **Why:** Vulnerability assessments are policy oriented with the overall objective of mitigating/avoiding the negative impacts of disasters*
*>> **How:** Vulnerability is currently measured indirectly and is described through specific indicators which allow for representing and monitoring the different dimensions of vulnerability*

*The proposed **Vulnerability Cube** helps to structure and conceptualise different assessments according to the following ,axes':*

*>> **Time** – Revealing event or process (e.g. daily, monthly, yearly, decadal etc.)*
*>> **Space** – Scale of vulnerability (local to global)*
*>> **Organisational Level** – Dimensions of vulnerability*

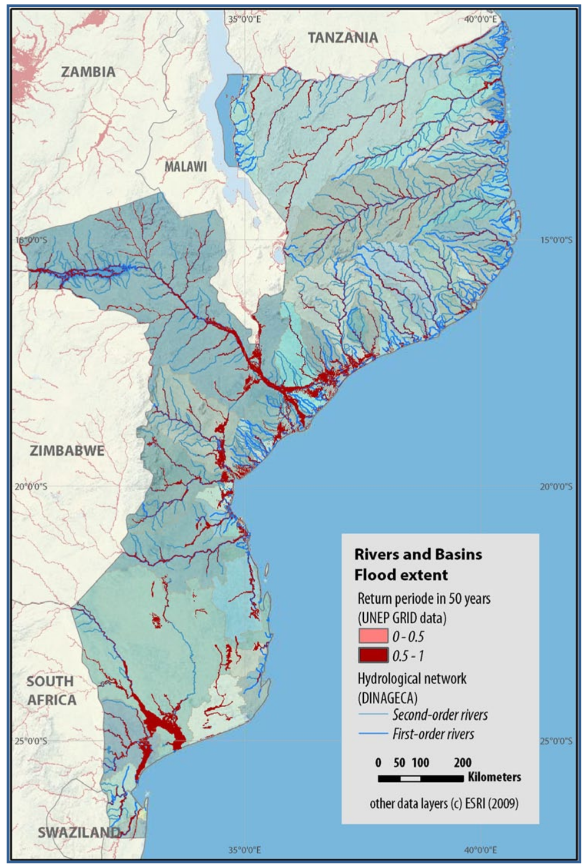
>>> See chapter IV.1.1

Modelling units in space and time

The 'phenomenon' of vulnerability exhibits a hierarchical structure . As vulnerability can be seen as a human centred issue (see the notion that there are no 'natural disasters'), we can define which 'human system' is to be addressed.
*Theoretically, the vulnerability of an **individual** could be assessed, defined by a specific location at a specific time. This vulnerability could be brought into relation to the different dimensions of vulnerability. However, the individual level might be for this purpose the most complex one and one which might not be 'relevant' for policy support. Actually we find here a strong link to psychological issues though this would step into quite a different domain, but can be simplified to examples such as physical vulnerability (e.g. ability to swim) or issues related to the social status of a person (e.g. income, education) which determine the susceptibility or coping/adaptive capacity.*
*At a next level individuals could be 'aggregated' to a '**collective**' such as population in general. Here the location of the population can be determined in a spatio-temporal relationship which might be not as 'chaotic' as an individual but still exhibits diurnal fluctuations (e.g. living vs. working places). This question is manifested in already identified research needs, where the daily and diurnal occupation of certain areas with people/population should be more closely investigated. This spatio-temporal distribution, which characterises the spatio-temporal exposure of the population as well, is defined through the different 'attributive' dimensions of vulnerability, such as physical issues (e.g. being within a house at a certain time and place which is less earthquake resistant) or socio-economic conditions which characterise certain 'groups' of the population (which links to the social science definition of exposure).*
*A possible next level, the **human settlement area** (which is in the German literature referred to as the 'Dauersiedlungsraum') could be of interest. Here the temporal dimension is more stable (fewer time fluctuations) compared to the lower level and involve a longer period of time (such as years). The spatial dimension therefore is 'wider' and includes next to the real 'housing locations' the surrounding area which is of use to people.*
*This approach can then be extended to what is here referred to as the **livelihoods approach**, where categories of land use and/or assets are still integrated and play a key role.*

>>> See chapter IV.1.2

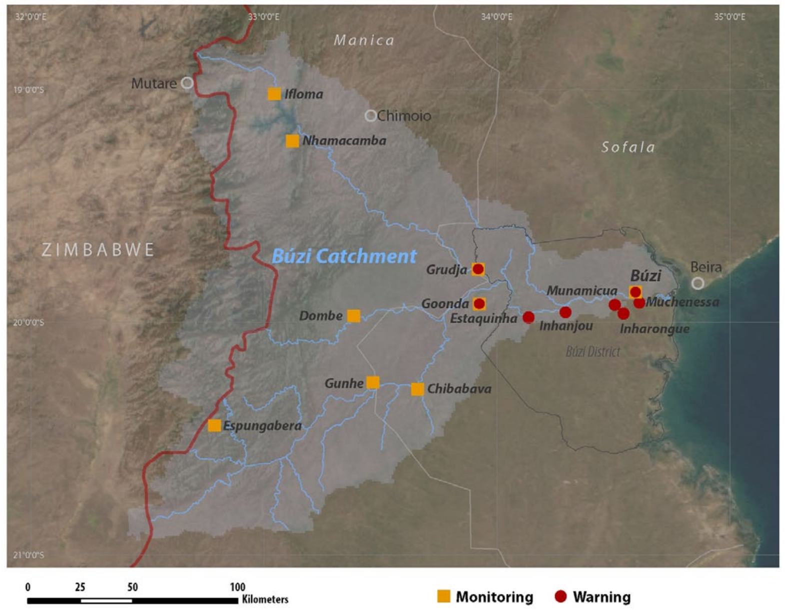
Case Study - Búzi



Mozambique

Due to its ***geographical location*** and its climate, characterised by the ENSO and within the tropical climate of the Indian Ocean, Mozambique is prone to hydro-meteorological hazards. Major hazards include droughts, floods, cyclones and also earthquakes.
Floods have certain characteristics and are linked to severe rainfall patterns (which is also dependent on the ENSO) but also triggered by tropical cyclones. The ***flood risk***, in connection with deficits in socio-economic characteristics, became very visible when, in February/March 2000, the highest amounts of precipitation for 50 years, in combination with four cyclones, led to a flood disaster of unknown extent. Reaching from the Rio Maputo in the south to the Rio Púngue in Sofala, vast parts of the south and centre of the country were struck. Between 700 and 800 people died, and many thousands lost their belongings and houses. 4.5 million people in total were affected.
These events showed the ***high vulnerability of Mozambique*** and highlighted at that time missing institutional response mechanisms. The severe floods in 2000 led to a strong engagement of various organisations in disaster risk reduction and management. This was accompanied by foreign technical cooperation when donors changed their policy focus from reaction to prevention. This and through the strong commitment and collaboration by national institutions, significant improvements could be made in recent years, which has been successfully demonstrated in recent disaster events which could have been delt with without any external support.

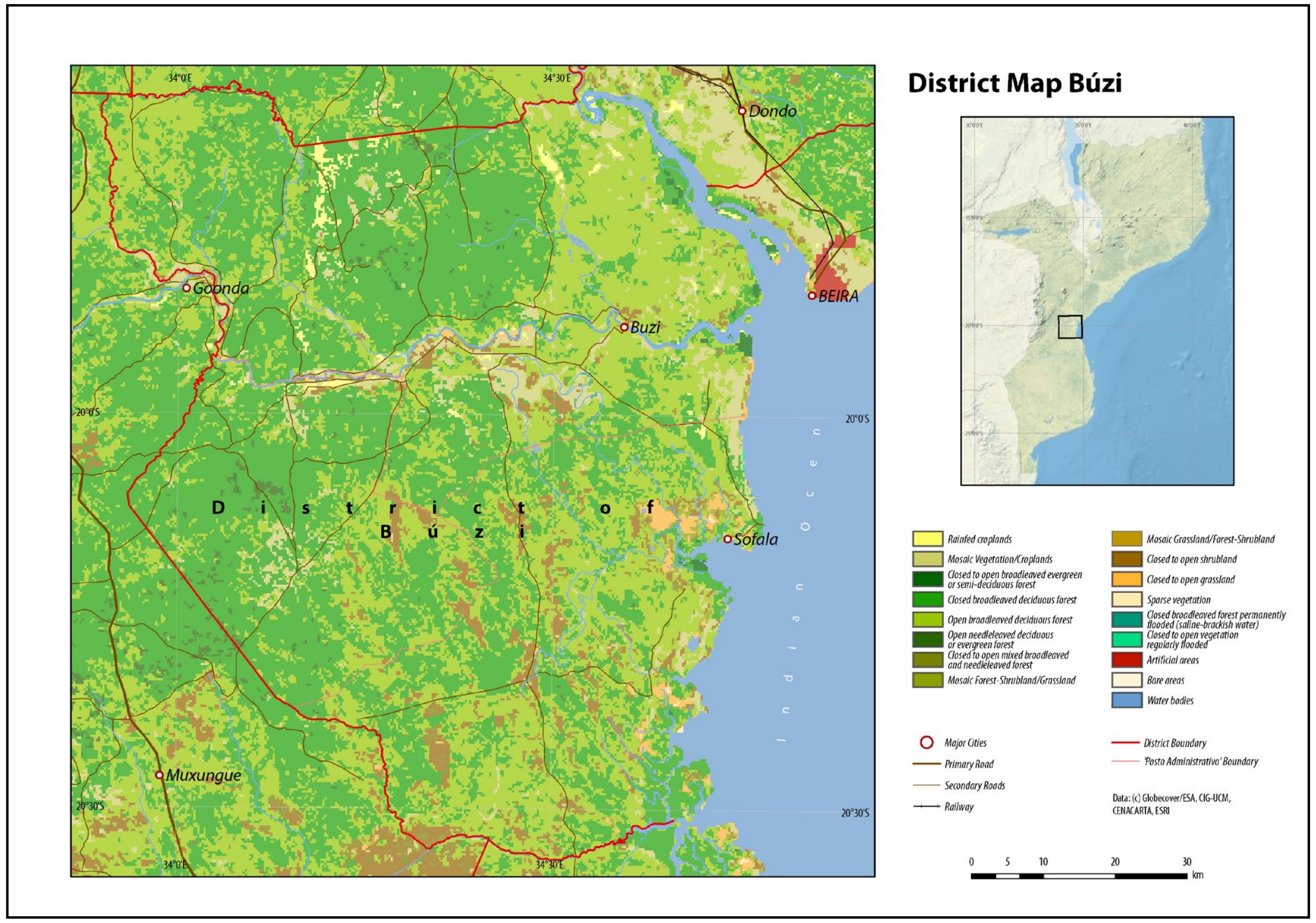
>>> See chapter III.1



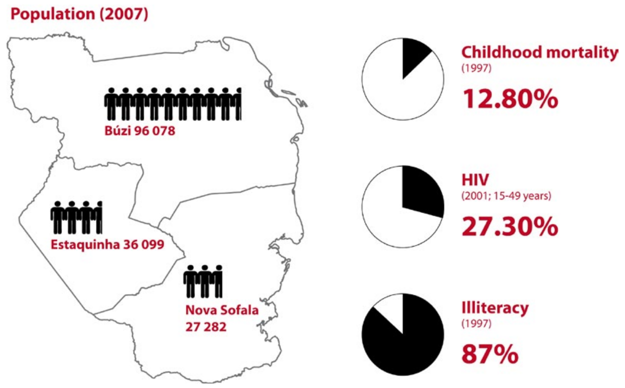
Community based Early Warning

Within one focus of the GTZ-funded project PRODER, a central element has been the establishment of local ***Disaster Risk Management commitees*** *(GRC - (Comités locais de Gestão de Risco de Calamidades). Thereby volunteers were identified (between 6-10 people; such as teachers, traditional leaders, other respected individuals) which were specifically trained and assigned certain tasks (responsibility for early warning via the radio, warning of community members, organisation of transport and evacuation measures, first aid etc.). These committees received the necessary equipment such as radios, boats, bicycles and flags which represent the early warning stage.*
Based on these committees, an ***early warning system on floods*** *was initiated (SIDPABB - Sistema Inter-Distrital de Pré-Aviso pela Bacia do Rio Búzi). Here warning is received from WMO by INAM and INGC and are then transmitted to the local level, which use different coloured banners (blue, yellow and red) raised by local committees. The early warning system SIDPABB works in a similar way, in which precipitation and water level measurements are carried out upstream of the Rio Búzi, which are then transmitted to the local warning centre in Búzi and then transmitted via radio to the possible affected communities. The warning centre in Bùzi also receives information from INAM in Beira. The warning at the local level is then carried out again by the GRCs. Currently 14 committees have been established and are supported through the GTZ and the Munich Re Foundation.*

>>> See chapter III. 2

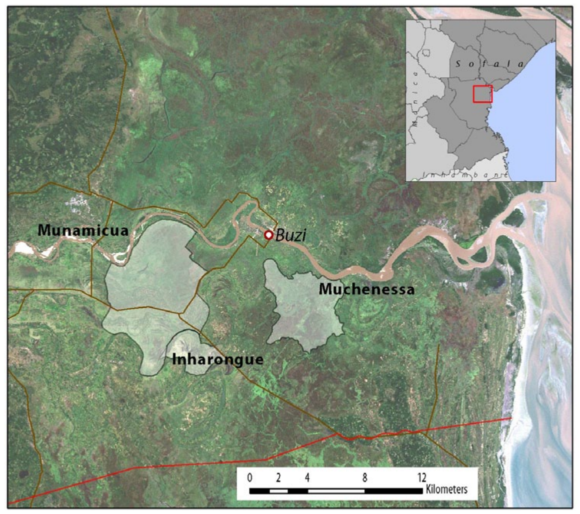


General Characteristics



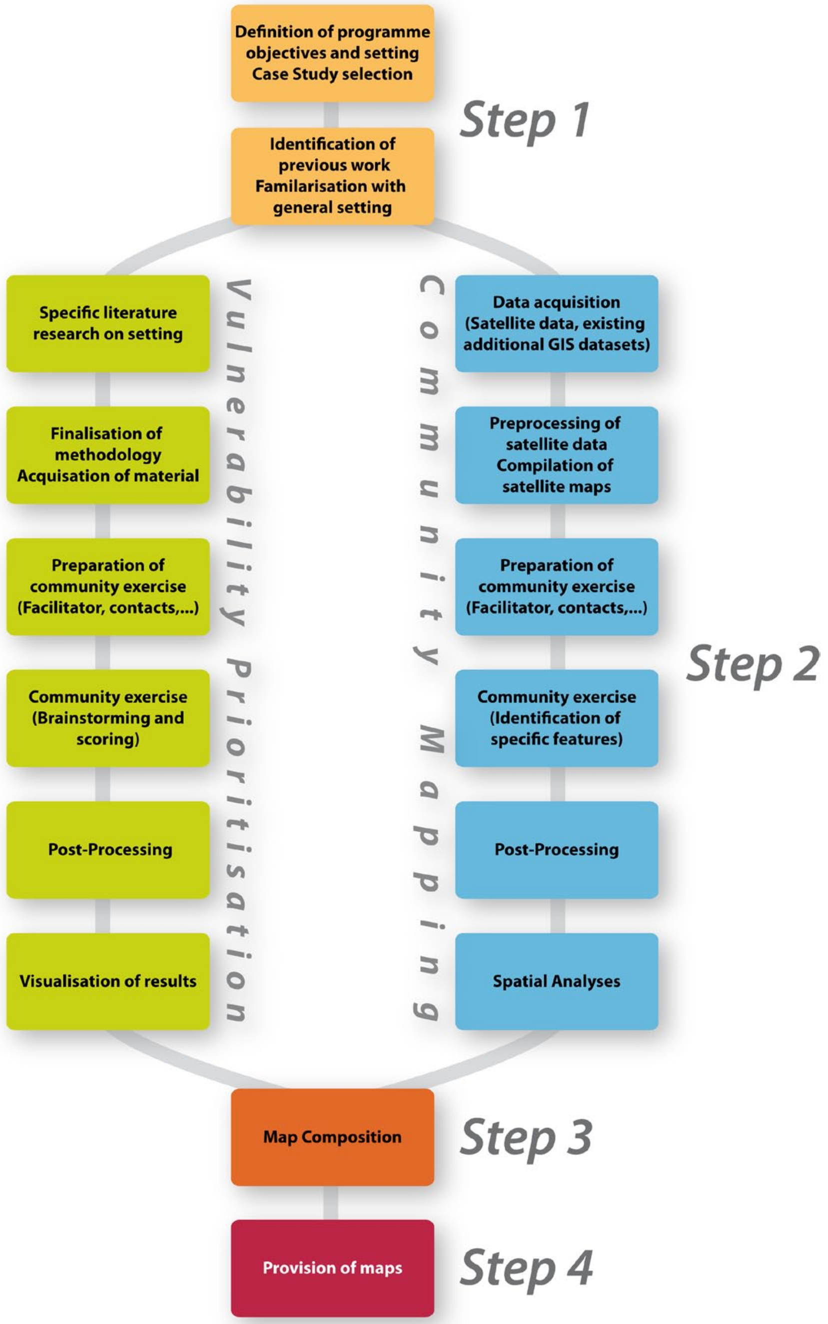
The district is characterised by a tropical semi-humid coastal ***climate*** *influenced by the Intertropical Convergence Zone (ITCZ), which leads to a wet season between December to February/March and the dry season between April and October/November. Strong rainfalls, and to a certain extent, upstream ams (Rio Revue in Manica), influence the hydrological regime of the river Búzi and numerous seasonal tributary rivers are created during the rainy season.*
Topographically*, the district is composed mainly of lowland plains with higher areas (formed by erosion of granite and limestone) in the west. The highest elevation point can be found near Grudja at around 130m above sea level. Additionally the landscape is in certain parts characterised by the final extent of the East African Rift valley which reaches the Indian Ocean between Búzi and Beira. The potential* ***vegetation*** *of grass savannah and tropical forest/shrub land is strongly over-shadowed by anthropogenic influences (slash and burn, monoculture). Most of the district is drained by the river Búzi and in the north by the river Púngue. The south-eastern area of the district is made up of smaller basins such as the Rio Chissamba, Rio Mabuto and Rio Donda, which directly drain into the Indian Ocean.*
The ***population*** *is mainly distributed primarily along the river Búzi with local centres distributed across the district. Larger uninhabited areas include the area between the Rio Búzi and Púngue which are regularly flooded in the rainy season and then turn into marshland. The total population of Búzi, according to the census results of 2007, is 159459 inhabitants, whereby 58.1% are below 25 years old. 47.1% of all inhabitants are male. A significant decrease between the age of 20 to 34 can be observed of which only 42.4% are male, which clearly shows the impact of HIV (with an HIV rate of 29.3% between the age group of 15-49 years for 2002 in the District of Búzi; INE 2007).*
Most of the population depends on subsistence farming as there are no other major employment opportunities available. These are concentrated around the district capital and some of the larger localidades. The capital Búzi is well connected to the Beira corridor which is the major development gateway in Central Mozambique (around 1.5 to 2.5 hours drive depending on road conditions). Areas beyond the river depend on the availability of a small ferry, otherwise a detour to the national highway (>7 hrs) has to be taken.
Land pressure *and resulting conflicts over land occur in parts of the district, especially over fertile land close to the river Búzi. Conflicts over or shortages of resources (firewood, water, land) occur in the most densely populated areas around the district such as the capital Búzi, the lands of the former sugar cane factory, in Bândua and partly Nova Sofala. This is amplified through resettlement programs as a consequence of flood response measures.*

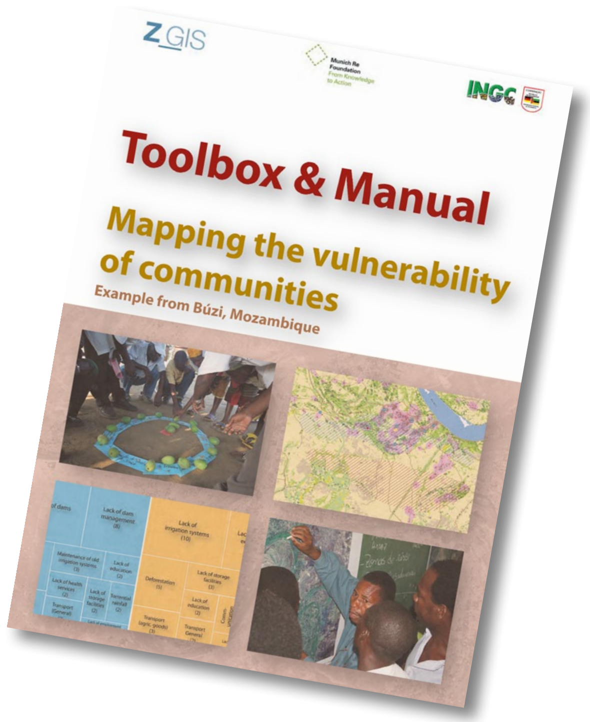
>>> See chapter III. 2



Investigated communities

Community Mapping + Assessment

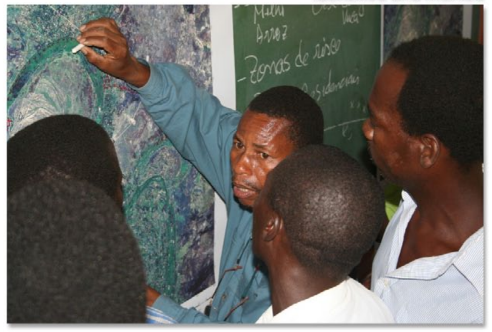




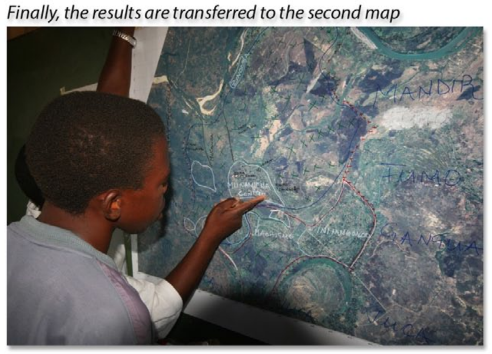

A school building is well-suited to conduct the exercise

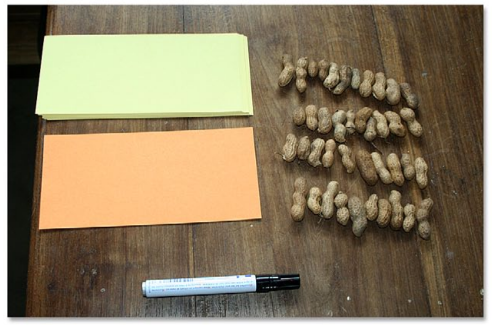

Participants should have the possibility to orientate themeselves on the map

With the help of a local facilitator features are identified and marked



Finally, the results are transferred to the second map




Required material: moderation cards, seeds as scores, and a pen


The facilitator conducts the brainstorming exercise and collects the factors/issues

Community members discuss the scoring of the different identified factors

Final result of the exercise, the scores should be noted on the cards

*The methodology to **assess, identify and quantify vulnerability** and hazards at the community level has been embedded in the research part, funded by the Munich Re Foundation. As a result of this project a **toolbox and manual** has been developed which describes the methodology in depth for future implementation at the practitioner's level. The manual has already been adapted and applied in a training workshop in Assam/ India, Bangladesh, Madagascar, Malawi and Mozambique and will be published later this year through ICIMOD (International Centre for Integrated Mountain Development).*

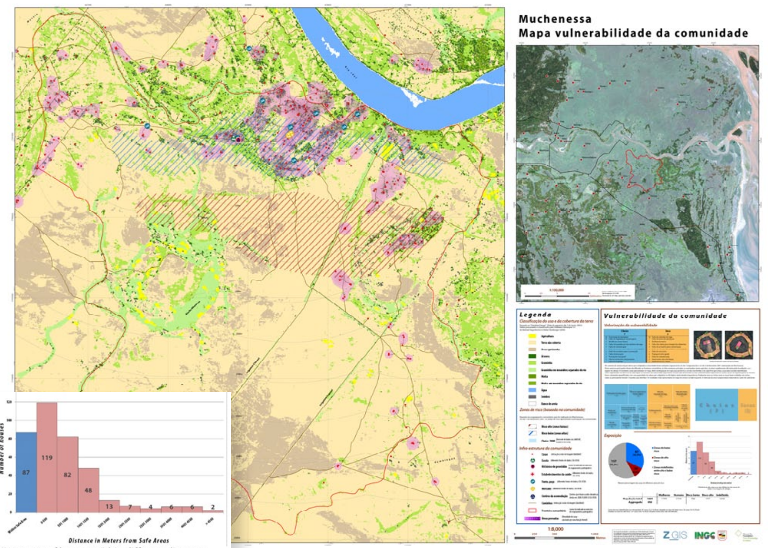
*The major aim of the developed approach is to provide community members with the **appropriate decision support** and **awareness tools** to identify and reduce their own vulnerabilities. A central element is the provision of community maps, which should significantly assist the community within their decision making. Answering the central **questions of 'where' and 'what',** is essential in dealing with challenges in a general community planning context, and especially in the case of disaster risk reduction. However, a 'map' is not a solution on its own, as it also requires certain structures, commitments and technical expertise. Therefore, the developed workflow/manual can contribute significantly to the support of community-based disaster risk reduction measures, but has to be embedded in the context of an integral disaster risk reduction program.*

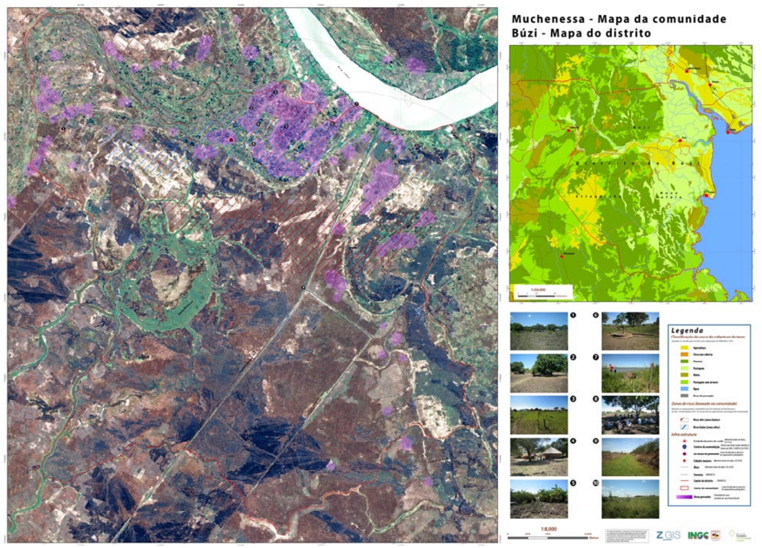
Specific objectives have been:
*>> the compilation and design of a **community vulnerability map** which should assist the community members within their disaster risk reduction measures*
*>> to map the community according to the needs of the communities in a **participatory manner***
*>> to define, analyse and prioritise the **driving forces of vulnerability** according to the perception of the communities*
*>> to enhance the 'maps' through **spatial analysis** results for different community characteristics related to disaster risk reduction*

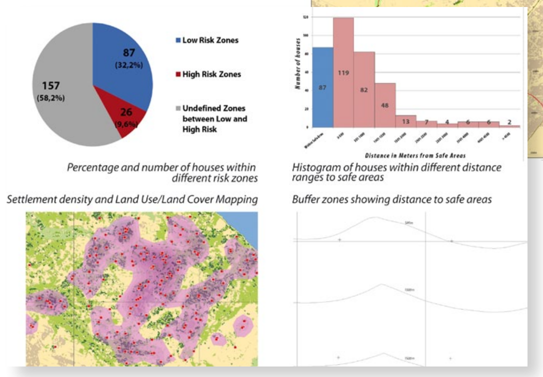
*The overall workflow is shown in the figure above and comprises four major steps, whereas the steps 2 – **community mapping** and **vulnerability prioritisation** – are described in more detail in the manual and thesis.*

>>> See chapter IV. 2.1

Results Community







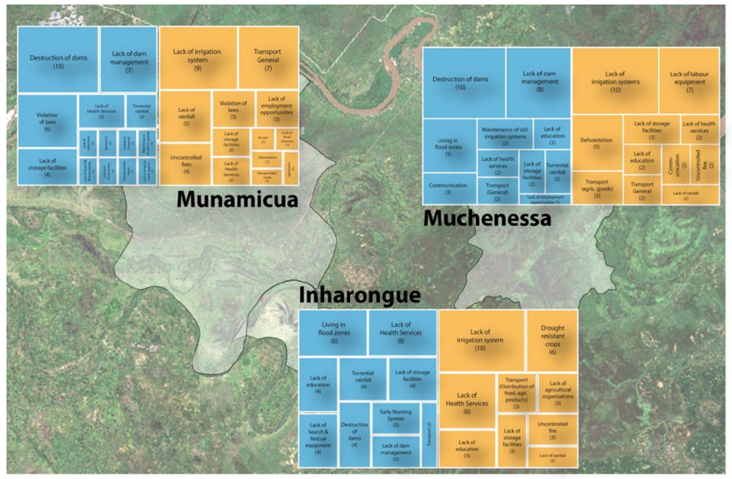
Mapping

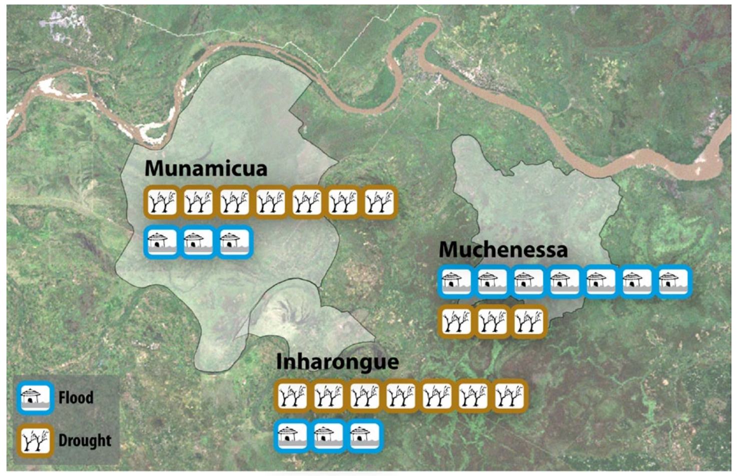
*For **each community** a **vulnerability/hazard map** and a **satellite/district map** were made available on A1 paper format and on scales of 1:8000 (Muchenessa, Inharongue) and 1:14000 (Munamicua), depending on the size of the community.*
The community vulnerability map integrates results of the mapping exercise, information on different community infrastructure features, results of the vulnerability prioritisation and a map of the wider surrounding area of the community. The map should serve as the central element for addressing disaster risk reduction measures.
The satellite and district map should additionally support the understanding of the community vulnerability map. As the community vulnerability map integrates a Land Use/Land Cover map, which might already be very abstract because of its classification and colour coding, the satellite map, which displays the environment in a natural RGB composition, should help to understand the LULC classification. Additionally a district map is supplied and georeferenced photographs of characteristic community spots have been added to enhance the educational value of the maps

The community maps include the following elements:

>> Community infrastructure, community boundary, cettlement area, risk zones, flood zones, results of vulnerability identification, buffer zones indicating the distance to the safe areas, analysis of exposure, different infrastructure, georeferenced photos of characteristic community spots, Quickbird satellite image

>>> See chapter IV. 2.1.3





Flood factors	Nr.	Values	Std.Dev.
Destruction of dams	3	8.00	2.83
Lack of dam management	3	6.00	2.16
Living in flood zones	3	4.00	2.16
Lack of Health Services	3	3.67	1.70
Lack of storage facilities	3	3.33	0.94
Torrential rainfall	3	2.67	0.94
Lack of education	3	2.33	1.25
Transport (General)	3	1.67	0.47
Lack of Search & Rescue equipment	2	2.50	1.50
Maintenance of old irrigation system	2	2.00	1.00
Lack of employment opportunities	2	1.00	0.00
Violation of laws	1	6.00	0.00
Communication	1	3.00	0.00
Transportable roads	1	1.00	0.00
Ignorance	1	1.00	0.00
Early Warning System	1	1.00	0.00

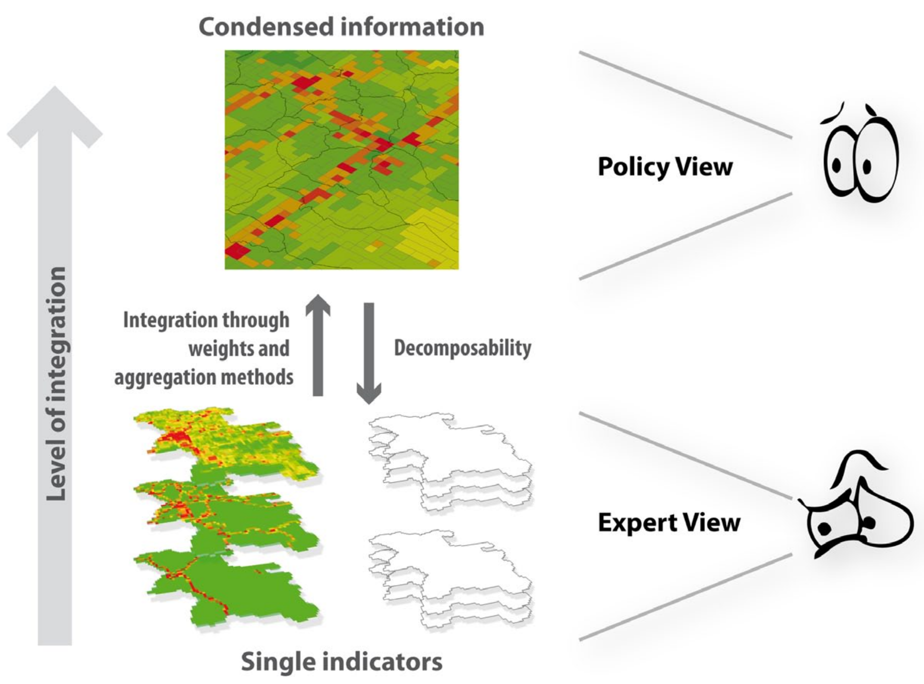
Drought factors	Nr.	Values	Std.Dev.
Lack of irrigation system	3	9.67	0.47
Lack of Health Services	3	3.33	1.89
Uncontrolled fire	3	3.00	0.82
Lack of rainfall	3	3.00	1.41
Lack of storage facilities	3	2.67	0.47
Transport (General)	2	4.50	2.50
Lack of education	2	3.00	1.00
Deforestation	2	3.00	2.00
Transport (Food; agri. Products)	2	3.00	0.00
Lack of labour equipment	1	7.00	0.00
Drought resistant crops	1	6.00	0.00
Lack of employment opportunities	1	3.00	0.00
Violation of laws	1	3.00	0.00
Lack of agricultural associations	1	3.00	0.00
Communication	1	2.00	0.00
Transportable roads	1	1.00	0.00
Ignorance	1	1.00	0.00
Access	1	1.00	0.00
Lack of food reserves	1	1.00	0.00

Prioritisation

*The results of the vulnerability prioritisation are summarised in **tree maps** which are shown on the left and aggregated in table. Issues/factors which have been identified for both hazards comprise general livelihood characteristics such as the lack of health services, lack of storage facilities for agricultural goods, lack of education and the availability of transport.*
This also underlies again the strong relationship between disaster risk reduction and poverty related issues. With respect to floods, the highest priorities have been assigned to hazard and exposure related issues such as the destruction of dams which protect the communities against river floods, the lack of upstream dam management and settlement in flood zones.
Within such exercises it is additionally interesting to note what has been identified in single communities, as this provides specific insights and might raise issues which are often neglected. In the case of floods the issue of 'violation of laws' has been raised for instance, which actually recognises the presence, and to some extent, the acceptance of laws which are not obeyed. Interestingly, the availability of drought resistant crops was mentioned only once, whereas this is an issue which is specifically targeted through different donor-driven and food security related programs.
*Interesting results arose from the scoring of **floods and droughts**, where ten points could be distributed between the two hazards. For two communities (Munamicua and Inharongue) droughts are more significant than floods. Muchenessa on the other hand, scored floods as their major issue. It is important to consider that the scoring exercise was held during a major drought season, so the results might be biased as the communities wanted to raise awareness of the drought issue. It is also interesting to note that the two communities with the drought priority also have the highest rate of houses exposed to floods.*

>>> See chapter IV. 2.1.3

District Modelling



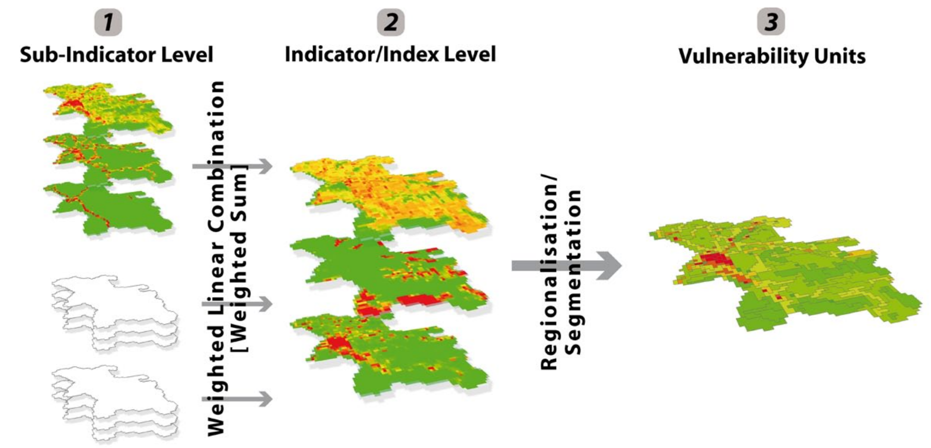
Policy Relevance

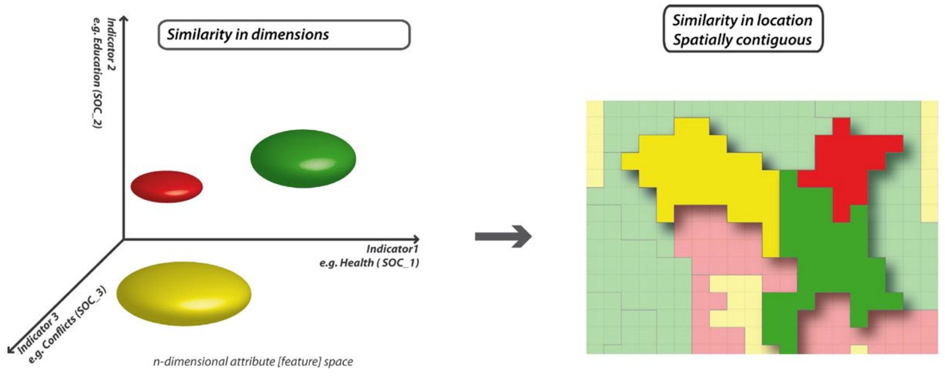
Next to the specific design and development of vulnerability/hazard maps at the community level, the ***district*** *is seen as another central level for the development of an appropriate vulnerability assessment approach. The need for this is outlined in chapter III2.4, where it was identified that within current legislation structures, the district level is the* ***target level for identifying and implementing measures of disaster risk reduction****. In this sense, it is aimed at supporting the district level with an integrated modelling of vulnerability which takes expert and community knowledge into consideration. Therefore the central objectives of district modelling are:*

>> To provide the district level with an ***integrated, spatial modelling*** *of the different* ***dimensions of vulnerability at a sub-district level***
>> To allow for ***decomposition of vulnerability*** *and for exploration of the underlying factors of vulnerability*
>> To ***integrate the knowledge of experts*** *(researchers, decision makers, district managers etc.) and of* ***local communities*** *in identifying appropriate measures and weights for representing vulnerability*

An essential element is the decomposability of the developed arpproach at the district level . The aim is to provide policy and decision makers, with an ***easy-to-grasp assessment*** *which communicates and represents vulnerability in an effective way, while being suitable for their decision making. Information could be aggregated on administrative boundaries, but the geon approach allows the representation to identify levels of vulnerability within area relevant for decision making. To allow an exploration of the underlying factors and indicators, the baseline information should be available for experts to provide the possibility for reasoning and the identification of causal relationships. Therefore it is aimed that the integration of* ***Vulnerability Units*** *(VulnUs) is transparent and can be followed through the evaluation of indicators. Additionally this provides decision makers who have to implement and target specific activities in their priority areas with relevant information.*

>>> See chapter IV. 2.2



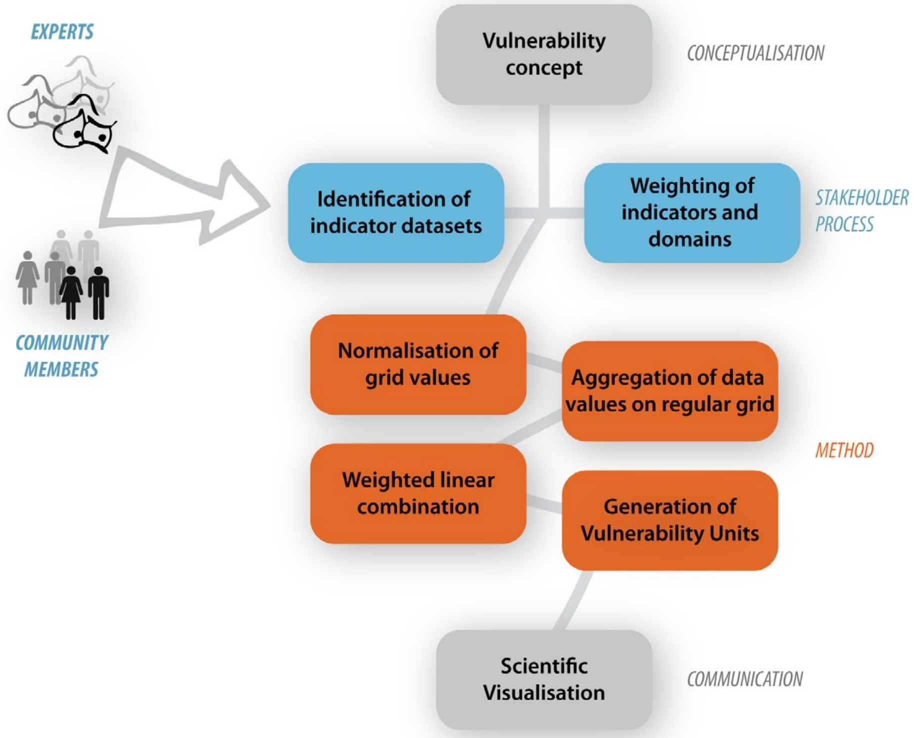


Method

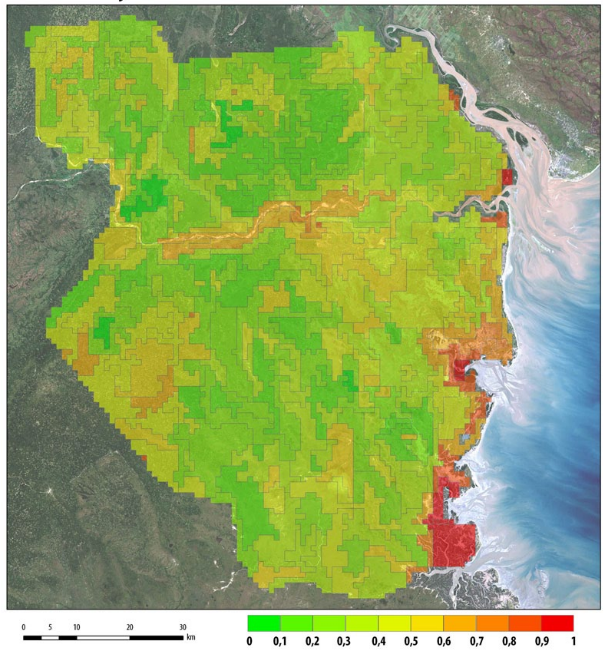
A specific aim of the developed methodology is to derive spatial homogenous units of vulnerability as a specific case of a geon set. Considering the fact that vulnerability is ***not directly measurable*** *and due to its complex dimension and social construction, an expert-based approach was chosen. Established methodologies such as Multicriteria Decision Analysis, Delphi exercises and new approaches are being integrated to model the spatial distribution of this complex phenomenon.*
The ***overall workflow*** *to model vulnerability units is presented in Figure on the left side. At the top of this workflow the concept of vulnerability is addressed. As no common understanding of the notion of vulnerability yet exists, it is required to choose an approach which is appropriate for the context in which the assessment is embedded (e.g. climate change, hazard/risk related).*
An essential step is the ***identification of indicator datasets****, the weighting of the different indicators and, if required, domains/subdomains. Within this research undertaking, expert interviews were carried out (October 2007; see Annex II which helped on the one hand, to identify an appropriate vulnerability concept and the choice of indicators. Different* ***experts*** *in Mozambique were interviewed within a brainstorming exercise to identify different causes, roots and triggers of vulnerability to floods and droughts in Central Mozambique. A discussion on the results and the finally identified indicators is provided in chapter 2.2.2).*
Additionally, the input and results identified during the vulnerability prioritisation at the community level were integrated. After having identified a final list of appropriate indicators, which next to the expert choice is in practice strongly influenced by the availability of data, experts were asked to anonymously weight the indicators. Here the same experts, who were interviewed, were contacted again. A total number of 11 experts provided their input. The averaged ***weights*** *of the experts' scores are then used to integrate the different indicators to model vulnerability units for the different dimensions. The methodology is outlined specifically in chapter IV 2.2.3 and builds on the methodology developed by Kienberger et al. 2009. The method applies besides established approaches of Multi Criteria Analysis (MCA) a regionalisation algorithm which should help to delineate the VulnUs.*

For integrating the different indicator data (see above) and for aggregating them on a sub-domain level within certain dimensions Multi Criteria Evaluation or Analytical Hierarchy Process (AHP) were applied. Multi Criteria Evaluation combines information from several criteria to create a single index.
From the single indicators, and, in certain cases, the index datasets, the vulnerability units for each dimension are derived applying the experts' weights in the ***regionalisation algorithm****. To this end we used regionalisation techniques applied to multidimensional data, as in object-based image analysis (OBIA). Borrowed from the domain of remote sensing image segmentation, a region-based, local mutual best fitting approach was applied that merges image segments according to the gradient of degree of fitting.*

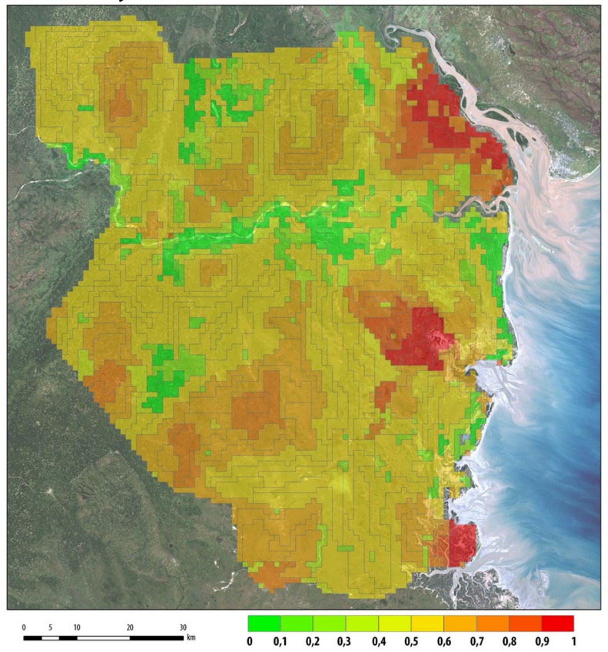
>>> See chapter IV. 2.2



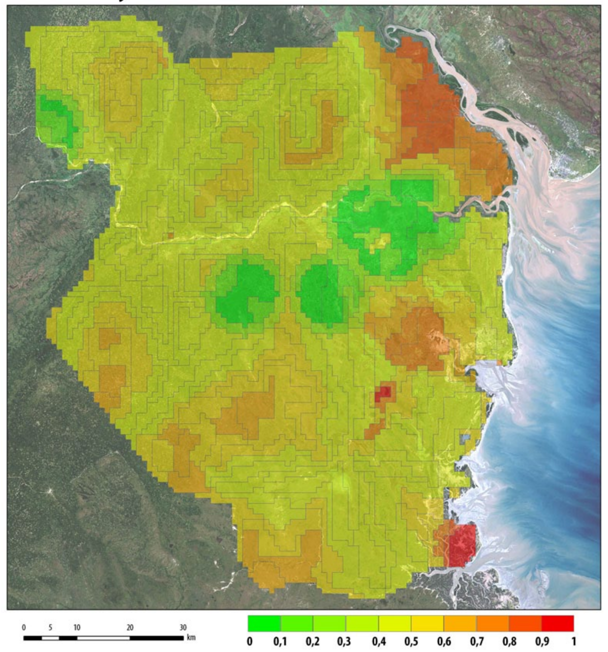
Vulnerability Búzi - Environmental Dimension



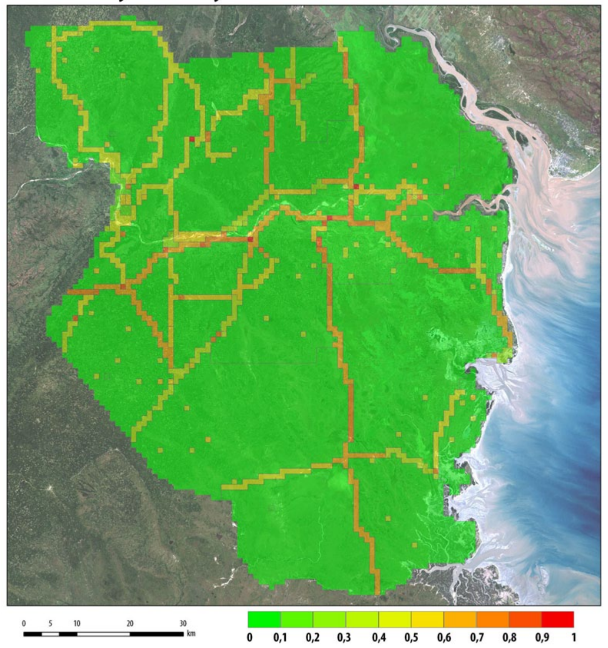
Vulnerability Búzi - Economic Dimension



Vulnerability Búzi - Social Dimension



Vulnerability Búzi - Physical Dimension



The results of the vulnerability modelling are presented in the figures above.

*The **environmental dimension** is reflected through high values in certain coastal areas which is here reflected because of the state of biodiversity (reflected through indicator ENV_1), a higher biodiversity loss (ENV_3) and the high values in the ecosystem service classes (ENV_4). From a general perspective it can be noted that those areas which contain larger population or are influenced by human activities, such as the agricultural areas along the River Búzi, have medium to high vulnerability values. Biodiversity loss (ENV_3) impacts the values in areas which are affected by slash-and-burn agriculture such as the central region north of the River Búzi. Low values are indicated for areas which are less impacted by humans and are somewhat remote from settlements.*

*The **social dimension** shows a different picture in which the presence and availability of the early warning system characterises a specific area in the centre of the district (SOC_5). Due to the modelling of a buffered Kernel density, this is visible here through somewhat rounded circles. The reason for that is also that this indicator obtained a rather high value during the expert weighting and is now reflected in the modelling results accordingly. The indicators from the distance algorithm (SOC_1, SOC_2, SOC_4 and SOC_6) clearly characterise the vulnerability conditions for the other areas, which show higher values for those areas which are not very close or are limited in their access conditions and availability of schools, wells, accommodation centres and health facilities. The conflict issue plays in this modelling a secondary role as it gained the lowest weight by the expert scoring. A different picture arises when the modelling is based purely on the community indicators and weights (see right). The smaller high peak unit in the southern central area reflects a quite remote and inaccessible area which is locked between different river courses and has thus obtained one of the highest values.*

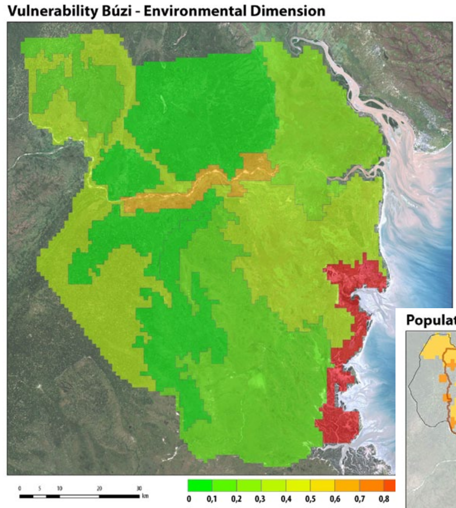
*The **economic dimension** has similar characteristics because of the integration of similar distance and 'access to' indicators (ECO_1, ECO_4 and ECO_5), but also reflects the lower vulnerability along certain coastal areas and along the River Búzi. These are also the main areas where agriculture takes place and where most of the markets and road infrastructure exist. The area along the river Búzi is also characterised by the lowest level of economic vulnerability as it has in addition to the agricultural characteristic the best access options in the district. Also the south-western and north-western clusters of low vulnerability reflect access to roads and the availability of agricultural land. The economic dimension is also for certain areas the opposite of the environmental dimension, which reflects the human activity and environmental impact arising there. Only the north-eastern region has high vulnerability values in all dimensions which is due to its remoteness and unsuitability of land (regular floodplain, swamp). It has to be noted again that this modelling is a human centred approach, as vulnerability is being defined in this context, and reflects a relative measure within the district (see discussion IV 2.2.5).*

*The **physical dimension** shows quite a different picture, as this is based purely on infrastructure and therefore reflects those regions/areas with a concentration of it. Higher values are a result of the density per raster grid, which is for road infrastructure higher than for certain point locations. Additionally this reflects the weighting results made by the experts, who rated road infrastructure with the highest score value. Hot spots arise here in settlement areas which are of course characterised by a concentration of the different infrastructure types.*

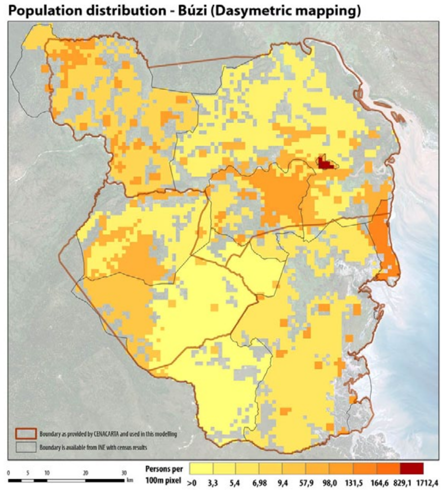
>>> See chapter IV. 2.2.4

Results District

Vulnerability Búzi - Environmental Dimension



Population distribution - Búzi (Dasymetric mapping)



*In the final results (very left) for the different dimensions a detailed approach was used, but this could be **more generalised and coarser regions** having common vulnerability characteristic might be identified. This relates to the scale debate where the appropriate detailedness might be chosen for the appropriate group of policy and decision makers.*

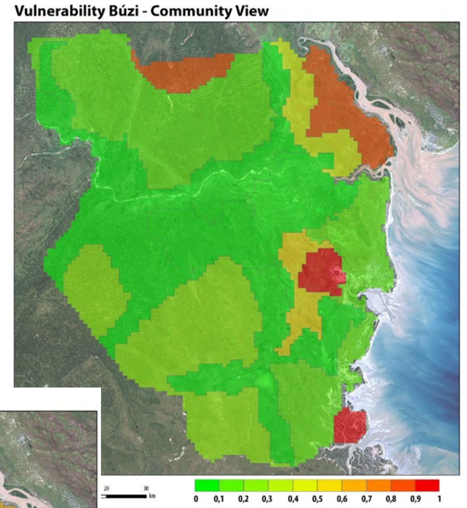
*The **modelling of the population distribution** was carried out in an experimental manner, where data from the national statistical institute (INE) was used and disaggregated based on land cover data and buffered village locations. The data represent only intermediary results from the census data collection and still inherit some incorrectness, especially in the boundary of the district.*

>>> See chapter IV. 2.2.5

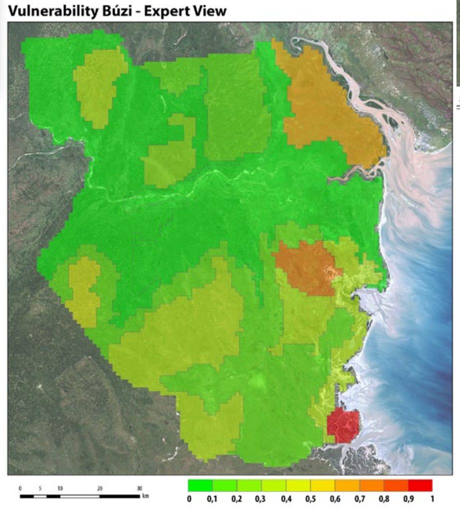
*In an **experimental approach** the indicators were integrated following the choice and weighting done by the **experts and the community members**. With this experimental approach it is underlined that the modelling of vulnerability underlies a strong perception and definition, which is seen in a specific context. These issues need to be considered and it might be dangerous at this step to present such maps as a final and true result. However, the visualisation of the results of the two different groups allows the exploration and ,visual exploration' of the differences. Therefore the map can be seen as a visualisation of different perceptions, which can then be used to further explore intervention options.*

>>> See chapter IV. 2.2.5

Vulnerability Búzi - Community View



Vulnerability Búzi - Expert View



Summary + Conclusions

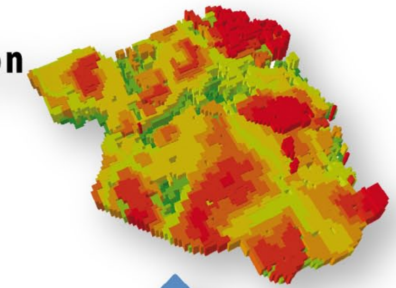
Expert knowledge

District Level

District Atlas
Spatial indicators
for planning purposes

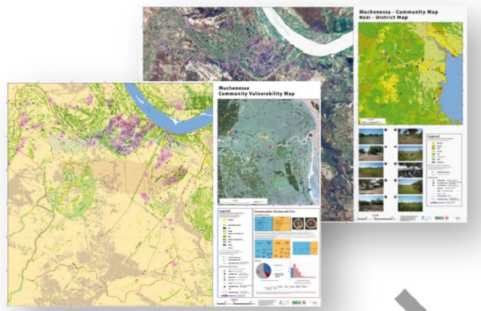
Integration

Vulnerability District Map
Hot spots of vulnerability
for different dimensions (VulnUs)

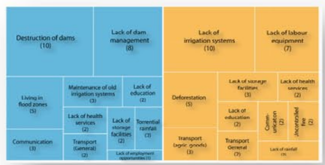


‚Upscaling' of priorities
and weights

Community (Hazard) Maps
For risk and hazard identification



Community Vulnerability Prioritisation
Identification and quantification
of vulnerability factors

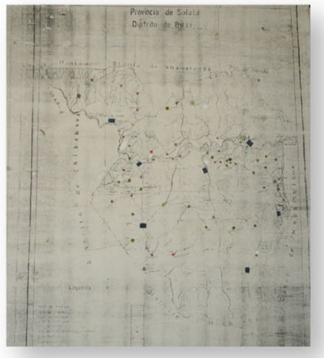


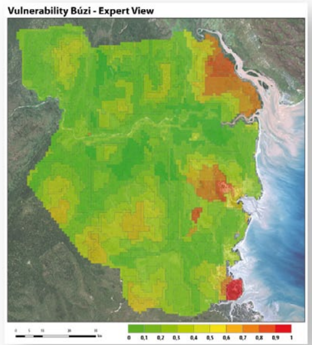
Learning and sensitisation
Process driven (self-assessment)

Community Level

In the proposed and developed methodology it has been demonstrated that the ***assessment of risks*** *through the integration of community knowledge in a spatial manner through the application of paper-based satellite images is valid. For community members it was easily to orientate themselves on the maps and to draw and highlight the essential features related to hazards in the community. It is clear that such mapping approaches, which include a representative group of a community, has to be seen as a snapshot. But for the purpose of a* ***participatory approach*** *it is appropriate to start such a process within the community. This has been highlighted through the identification of vulnerability factors and their weights, which may also be applied in a monitoring sense for project implementers to assess their objectives within community-based disaster risk reduction programs. Results of course have to be* ***critically interpreted*** *again as there might be biases due to the facilitator's input or just because of the composition of different groups or certain characteristics of specific communities. However, this actually represents a* ***cost-effective approach****, to obtaining an understanding of the needs, challenges and priorities from a community-perspective, which might, on the other hand only be possible through long-lasting research and field works, which are practically not implementable in current project designs. It has to be noted, and this point is taken up specifically in the district approach, that such assessments of course to some extent reflect* ***fuzzy boundaries*** *which also underlie different accuracy levels than a sophisticated risk delineation based on numerical and physical models. Having this in mind, which is quite an important prerequisite, it is possible to communicate to other stakeholders. and to enhance decision making within the community. Also the verification and grounding of vulnerability assessments for other levels (e.g. the district level) profits from this developed approach, which tries to identify indicators arising from the perspective of the community members. Essential here is also the appropriate integration within a project design which commits itself to the use of maps as a decision support tool in communities, and maintains the transfer and integrity from traditional sketch mapping towards real-world coordinate based PGIS maps.*

>>> See chapter V





Indicators *were constructed based on expert feedback and the integration of community knowledge. It has been shown that some factors/indicators were identified by both groups (experts & communities) whereas others were perceived separately. This provides ground for discussion of which indicators represent the different dimensions adequately and provides ground for the different policy levels to coordinate amongst their vulnerability models. The methodology developed represents vulnerability as homogenous regions which share a common property of vulnerability for the different dimensions and seems to be a valid approach to modelling such an integrative phenomenon. Of course* ***data availability*** *plays a critical role which determines the accuracy of such approaches and highlights again the need for the identification of basic data needs for vulnerability assessments and its continuous availability over different time periods. Again here it must be realised that vulnerability reflects a human constructed concept which is currently not commonly agreed upon in the scientific community. It is essential to follow established methodologies for indicator selection or within statistical analysis. However, it has to be clear that major* ***uncertainties*** *arise still from the concept and also through the accuracy of data. This is an essential point which has to be borne in mind with the interpretation of such modelling results. However, with this approach and with the possibility of changing different scale levels and identifying finer or coarser regions of vulnerability, concepts may be validated through a spatial reasoning. The issue of validation and the unavailability of accuracy estimations (which are currently not of central research focus within an interdisciplinary vulnerability science) are still the most critical issues with such approaches. However, it is not seen here that the spatial mapping is limited by this per-se, but provides a significant basis to really capture and understand vulnerability based on location – which of course integrates different feedback loops. The figure below tries to reflect the difference between the currently available map for planning purposes at the district level and one result within this modelling approach. It is obvious that such complex and integrative maps need specific support when implemented at the district level. It is also essential to provide access to the underlying datasets and simple indicators which allow for the exploration and reasoning of vulnerability, and again feedback loops for the modification of such results. It is here also proposed that in addition to such a vulnerability mapping approach, it is required to focus on the capacities at the decision making level, as well as the availability of general planning tools which reflect the characteristics of the district (such as a district atlas).*
Compared to the situation 10 years ago, data is increasingly becoming available in Mozambique with improving quality, coverage and level of scale. However, human and technical resources able to manage these amounts of data are still inadequate. Lacking or inappropriate database management hinders the implementation of the GIS in fields typically reserved for GIS applications. The image change of GIS as a map printing tool will still require a lot of educative work. Only to some extent have 'insiders' in Mozambique realised, that GIS/Remote Sensing in fact means information management, spatial analysis and most importantly the nucleus of a decision support system. Incorporating this understanding also means opening solutions to database management deficiencies and raising awareness at different levels.

>>> See chapter V