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Urban flash flood vulnerability: Spatial assessment and adaptation – A case study in Istanbul, Turkey

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Abstract

The Ayamama River basin in Istanbul is a densely populated urban area that is frequently impacted by flash floods causing damage to people and infrastructure. The IPCC expects that under climate change conditions, more intense precipitation will occur, leading to a higher risk of flash floods. Approaches to assess vulnerability focus on particular hazards without relating to climate change; usually emphasizing either physical or social vulnerability. However, enabling governance systems to deal with risks due to climate change requires participation of local inhabitants and inclusion of local knowledge for planning effective climate change adaptation measures. This paper presents a framework for a spatial assessment of urban vulnerability to flash floods under climate change conditions. Qualitative interviews were conducted to capture local knowledge of citizens in the Ayamama area about flood events and climate change. Spatial multi criteria evaluation was applied to calculate vulnerability indices.

Keywords

[Urban vulnerability, spatial assessment, flash floods, local knowledge]

1. Introduction: climate change and urban vulnerability

Climate change constitutes a challenge for scientists, policy-makers, and common people since extreme weather events (floods, draughts, heat waves and sea level rise) seen as climate change impacts will harm people differently worldwide (IPCC 2007a). The IPCC (2007a) expects that, under climate change conditions, more intense short-duration precipitation in Europe will occur, leading to a higher risk of flash floods. In Mediterranean countries, where flash floods are more intense than in the rest of Europe (Gaume et al. 2009), certain urban areas, located nearby rivers, are considered to be vulnerable to this hazard due to their proximity to the riverbed, and their high and continuously increasing population and population density. In this sense, vulnerability arises as a complex and critical factor related to the impact of flash floods.

Vulnerability is an issue that has been broadly researched (Adger 1999; Bohle 2001; Cross 2001; Cutter 2003; Few 2003; Füssel 2007; Kelly and Adger 2000; Moss et al. 2000; Pelling 2003; Uitto 1998). In urban environments, vulnerability is understood as a condition that shows how deficient and susceptible the urban environment is to be damaged "due to social, biophysical, or design characteristics" (Rashed and Weeks, 2003, p.550). In relation to climate change, vulnerability is understood to mean the potential of people to be killed, injured or otherwise harmed by the direct or indirect impacts of climate change (Satterthwaite et al. 2009). Urban vulnerability assessment studies so far have focused on particular and specific hazards such as floods, identifying physical, and or social vulnerability (Ebert and Kerle, 2008, Marschiavelli, 2008, Wigati, 2008). These kinds of assessments are important for disaster management and adaptation planning since one can know where vulnerable areas and groups are located (Birkmann 2007).

In Istanbul, Turkey, various vulnerability studies have been conducted related to a particular hazard and following either a social or a physical approach. For instance, some studies focused on identifying social groups vulnerable to earthquakes and physically determining vulnerability of settlement areas to floods (Haki et al. 2004; Ozcan and Musaoglu 2010). Although these assessments have produced good results, none of them have incorporated both dimensions together, i.e. social and physical vulnerability. Moreover, available studies have not considered the hazard events in relation to climate change impacts.

In the paper, we present a framework for a spatial assessment of urban vulnerability to flash floods under climate change conditions. The framework integrates the social and physical dimension of vulnerability and is based on interviews in order to capture local knowledge about flash floods and climate change. The case study area is the Ayamama River Basin in the European part of Istanbul, an area that was recently struck by a huge flash flood in 2009 causing severe damage to men and materials.

Section 2 discusses current approaches to vulnerability assessment. In section 3, the case study area, Ayamama River basin, is presented. Section 4 contains the presentation and discussion of the assessment framework that is applied in section 5 to the case study area. The paper concludes in section 6 with a discussion on how to use the results for governing climate change adaptation.

2. Current approaches to assess vulnerability

The term “vulnerability” has evolved along the years (Pelling, 2003, UNDP, 2004, Birkmann et al, 2006). From a more limited conceptualization based only on the likelihood to experience damage; vulnerability has been widened including more concepts such as exposure, coping capacity, and is, in the present, a multidimensional term (Birkmann 2007). Bohle (2001) defines vulnerability as a double structure concept. Its internal side is related to the coping capacity needed to withstand the impacts of hazards; and its external side focuses on the exposure to risks. Therefore, vulnerability depends on the interrelationship between these two. Within a hazard and risk approach, Birkmann (2006) presents disaster risk as the core of the conceptualization, and vulnerability is seen as one of its four components together with hazard, exposure, and capacity and measures. Here, exposure and capacity do not seem to interact within the vulnerability component, and that represents an issue that has been covered by posterior approaches.

Focusing on climate change, vulnerability is understood as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity” (IPCC, 2007c, p.21). On the one hand, exposure refers to the frequency and magnitude to the climate–related hazard such as floods. It is considered as a “product of physical location and the character of the surrounding built and natural environment” (Pelling, 2003, p.48); therefore, it is studied by considering physical parameters such as topography, distances, temperature, precipitation, etcetera. On the other hand, sensitivity considers how a population is sensitive to changes in the climate (Ebi et al. 2006) due to its intrinsic structure such as demographic profile, for instance.

From the three components of vulnerability: exposure, sensitivity, and adaptive capacity, it is the latter the one which influences the most the degree of vulnerability. According to IPCC (2007c), adaptive capacity recalls on how capable a system adjusts itself to climate change by responding to its effects. In the case of a society, this condition depends on several factors such as socioeconomic conditions, technology and infrastructure, institutional framework, knowledge, among others (Metzger et al. 2005). These set the framework in which different adaptation actions, which are the materialization of adaptive capacity, are generated (Smit and Wandel 2006). For example, if two groups of people –A, with good education, access to information and a good economic condition; and B, with low education level, no access to information and a deficient economic condition- were equally exposed and sensitive to a hazard under climate change conditions, A would be less vulnerable than B due to its higher adaptive capacity: its good socioeconomic condition will make it respond and adapt better than B to the effects of climate change by either developing short or long-term actions.

Turner et al. (2003) coincide with the above definition of vulnerability; however, in their vulnerability framework, they have imported the term “resilience” from ecology to refer to the coping response or adjustment of the “human –environment system” to an event. Resilience, thus, is in this case nothing else but adaptive capacity. So far, vulnerability frameworks have focused on the interrelationships of the different concepts that compose them. Nevertheless, a special vulnerability framework is presented by Polski et al. (2007) who state that it is even more important the integration of methodologies from different research fields for assessing vulnerability to climate change. Therefore, their Vulnerability Scoping Diagram (VSD) constitutes a tool that enables comparability between vulnerability assessments and can be updated with local knowledge.

The Livelihood Vulnerability Index (LVI) proposed by Hahn et al. (2009) can be seen as an application of the VSD. Although the LVI does not use these exact terms of dimensions, components and measures, it uses the three levels of organization of the VSD. In the LVI, exposure is measured by natural disasters and climate variability; adaptive capacity by the demographic profile, livelihood characteristics, and social networks; and sensitivity by the state of food, water security and health status. Finally, Wilhelmi and Hayden (2010) focus on adaptive capacity but more from a methodological perspective. They address not only a sound conceptualization of the different elements that interact and compose vulnerability but also pay attention to the fact that a combination of quantitative and qualitative analysis will lead to a more appropriate vulnerability assessment. In their framework, vulnerability is influenced by external drivers such as climate change and urbanization which may increase exposure; and, is at the same time, affected by adaptation and response measures, which are directly related to adaptive capacity.

Vulnerability assessments join various methods, which come from different sciences, to identify how the relation of the three components mentioned above is, and they have been applied in multiple situations (Behringer et al. 2000; Belton and Stewart 2002; Dessai and Hulme 2003; O'Brien et al. 2004; Pittman et al. 2011). This variety depends on the scale and unit of analysis, time span, understanding of vulnerability, and selected tools (Dessai and Hulme 2003). While social approaches to assess vulnerability focus more in the analysis on the socio-economic characteristics such as demographic profiles and income of societies, physical approaches prioritize the analysis of physical exposure, and does not include human groups into their assessments (Dessai and Hulme 2003). Spatial multi-criteria evaluation, a method that incorporates different interrelated criteria in order to help decision–makers find the optimum alternative for a particular problem (Aceves-Quesada et al. 2007; Belton and Stewart 2002), is usually applied in combination with a GIS (Malczewski 1996) in order to estimate vulnerability in a spatio-temporal scale (Mendoza and Martins 2006).

In order to assess vulnerability at the local level, information -at the same level- is necessary but it is often unavailable from census data. Van Westen (2009) considers that working with local people in local communities will have as a result good information at local level since they are the ones who know the best the hazards that affect them, the elements at risk, the consequences of the events, as well as the adaptive mechanisms they employ. Therefore, this information could be incorporated into disaster management plans. Mustelin et al. (2010) addressed vulnerability related to coastal change by combining stakeholders' perceptions through interviews and vulnerability mapping, developing a management strategy for coastal forest areas. Peters-Guarin (2008) developed a Participatory GIS (PGIS) that required the involvement of communities in producing spatial data and decision-making. This is an innovative method that continues to be developed together with the application of GIS in many sciences.

Participatory methods have been included within vulnerability to climate change frameworks since these focus on people's adaptive capacity: the capacity to adapt to climate change effects starting from what people perceive about this topic (Behringer et al. 2000), and ending with a link to local level decision-making in the design of adaptation measures (Næss et al. 2006). In this line of work, Schröter et al. (2005) proposed and developed an eight-step methodology for vulnerability research starting from study area and stakeholders' selection, developing a vulnerability model and indicators and ending with communicating the results to everybody involved in the process.

3. Climate change and flash floods in Turkey - Ayamama River basin in Istanbul

Climate change is understood as a modification in the present condition of the climate by the "changes in the mean and/or the variability of its properties" which last for a period of time (IPCC, 2007b, p.667). For Turkey, models predict a change in the seasonality of precipitation meaning that they will either start one month in advance or one month later, requiring adaptations to this new "calendar" (Güven 2007). Because of that, Turkey has started to develop different measures to adapt to climate change effects which include an increase in participation and public awareness on disasters associated to climate change (Turkey: Ministry of Environment and Forest 2010).

Flash floods are characterized by a rapid and violent movement of water in a small spatial area produced by heavy rainfall. During a precipitation event, there is a short time span between the storm peak and the discharge stream peak. Urbanization reduces the infiltration capacity of soils and reduces the time period between the two peaks. Thus, flash floods are more likely to occur in urban areas, where soils have been progressively replaced with man-made features.

During the 1950 – 2010 period, Turkey has experienced 35 flood events (EM-DAT 2010). Part of Istanbul is located on flood–prone areas, where flood events have already occurred. Here, a combination of different factors such as unplanned urbanization, an increase in population density, weak construction control by the authorities (Yalçin and Akyürek 2004), deficient urban master plans and heavy rainfall have caused floods with severe economic and social losses (Dubovyk 2010; Einfalt and Keskin 2010; Yalçin and Akyürek 2004).

Flood events in Ayamama River basin happened in 1995, 2002 and 2009. The lack of mitigation measures and the lack of implementation of new disaster policies after the 2002 event have enlarged the negative consequences of September 2009's flash flood: 31 people killed (Reza 2009; Watson and Comert 2009) and a loss of more than $100 million (Yildiz n.d.).

The case study area is Ayamama River basin located in Istanbul, the largest city in Turkey with a total population of 12 915 158 inhabitants (Turkish Statistical Institute 2010). Ayamama River basin has an area of 62.27 km^2 and it encompasses 25 neighborhoods within the Bağcilar, Bahçelievler, Bakirköy, Başakşehir, Küçükçekmece, and Sultangazi districts (Figure 1). The river flow has a north-south direction and discharges into the Marmara Sea (Einfalt and Keskin 2010). In the upper part of the basin, the river presents more tributaries than in the middle and lower parts due to less built-up areas in the north. Also because in the middle and lower part it has been channelized, and in some sections covered for urbanization.

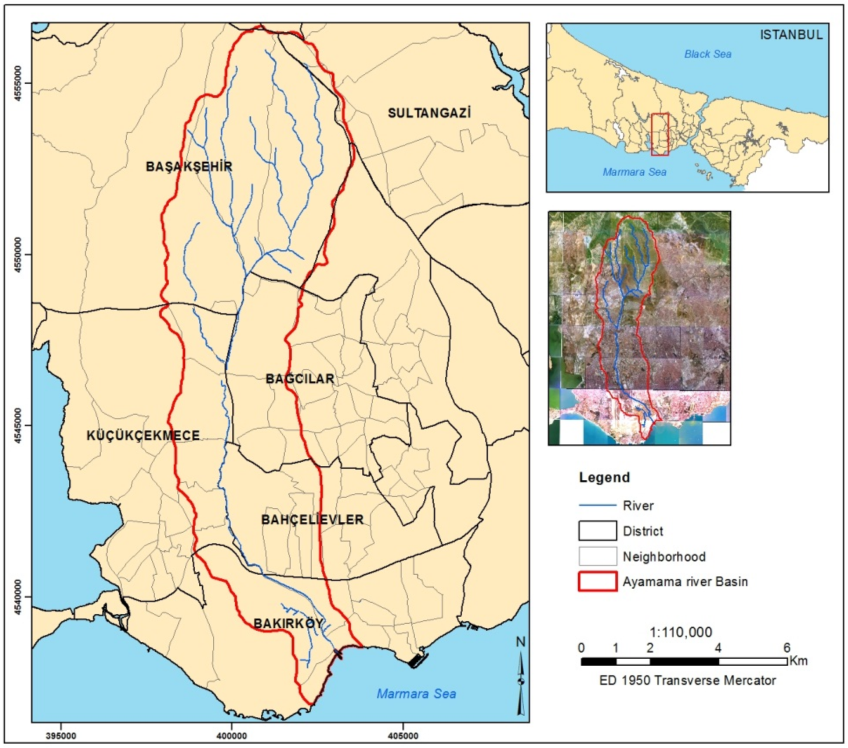

Figure 1. Ayamama River Basin.

Population within Ayamama River basin is approximately 799,556 inhabitants[1] (IMP, 2006), and the upper part of the basin is less inhabited since these neighborhoods are not completely urbanized and still have natural land cover. The area where the basin is located has experienced a process of rapid land cover change in the last decades: bare soil areas, grasslands and shrubs (some of them still present in the upper part of the basin) have been progressively replaced with built-up areas designed for densely residential (Figure 2) and industrial uses (Kaya and Curran 2006; Kucukmehmetoglu and Geymen 2009). This has been reported to constitute a threat since many of the industries located along the Ayamama River throw part of their wastes to the river, and people do the same with their solid garbage[2]. There is no specific information about the increase in built-up areas for the study area; however, for Istanbul, it has increased in 126.7% between 1987 and 2001 (Kaya and Curran, 2006).

[1] Population values given correspond to the values for the entire neighborhood and not just the portion of neighborhoods within the basin.

[2] This was observed during fieldwork in September, 2010.

Figure 2. Residential areas in Ikiteli Mehmet Akif and Ikitelli Atatürk neighborhoods, Ayamama River basin.

4. Assessment framework for flash flood vulnerability based on local knowledge

4.1. Findings from fieldwork in the case study area

Data collection in the study area was included with 30 interviews based on a questionnaire. The aim of the questionnaire was to gather information regarding vulnerability, flash floods, climate change, and adaptation measures from the inhabitants of Ayamama River area. Results from primary data collection were analyzed to build proxy indicators to be incorporated into the framework to assess urban vulnerability related to flash floods under climate change conditions.

Capturing local knowledge allowed an understanding of how people perceive their vulnerability in the study area. 21 interviewees considered that the neighborhood they live in *is* vulnerable to floods. Distance to the river was the most frequent reason mentioned, not only referring to Ayamama River itself but also to the tributaries dewatering into the main stream. Inhabitants perceive different negative consequences of flash floods; however, the one that most important people recall is the presence of water in basements and in the first levels of the houses. Moreover, the saturation of the underground drainage system contributed to flood the basements and to affect the street network.

The responsibility for the flood events, as stated by local people, is seen on the side of the local government because they gave authorization for building in what they call “wrong areas” meaning close to the river[3]. Any kind of improvements that should have been done along the river in order to avoid future floods, are also the responsibility of the local government..

Knowledge about climate change is poorly developed in the study area. Climate change is most commonly associated to “seasonal changes” meaning that the changes between seasons are different now in terms that they start later. This lack of knowledge may be explained by the education level of local inhabitants since less than 50% finished middle, high and superior education. This lack of a detailed knowledge about climate change and how it influences the

[3] This information coincides to what ARK TERA (2009) and Ozcan and Musaoglu (2010) have expressed about the amendment in urban plans in 1997 which turned this space into a residential area.

frequency of occurrence of flash floods in the area is related to the actions that they could do in order to reduce the consequences of floods.

What people would do to reduce the consequences of floods depends on how much knowledge they have about vulnerability to flash floods or on what they see as the main problem. People think that closing the top of the river to avoid the spill of water, widening the streambed because more water could flow, removing houses near the river because less houses would be flooded, and building infrastructure such as walls along the river, will reduce the consequences. They recognize the river and the distance to it as the main problem, which constitues the reason why they think these neighborhoods are vulnerable.

Preparation campaigns are seen as important because they help increase awareness and prepare people in case of a flood event. 28 out of 30 people agreed that neither Municipality nor any other institution organized preparation campaings prior to the flood in 2009.

Finally, to have people organized in local organizations and/or comittees to reduce impacts of flash floods is something they recognized as important. They argued that people are more efficient in groups than alone in case of an emergency such as in 2009, when they got organized and distributed food and other aid. Moreover, they think that organizations increase people's awareness since they can exchange experiences and knowledge between them.

4.2. Flash flood vulnerability assessment framework

The general structure of the framework (Figure 3) considers in first place a set of externalities (Wilhelmi and Hayden 2010) which affect the measures of the framework. For instance, migration to urban areas increases the number of inhabitants, and household size is modified. Likewise, it is the occurrence and severity of flash floods most likely increasing with ongoing climate change. The framework presents a three-level structure: dimensions, components, and measures because it is a didactic way to present and indicate that measures are part of components and these are part of dimensions. Measures constitute the concrete indicators that will allow the quantification of each component, and components are the main characteristics of each dimension. The structure allows a comparison between vulnerability assessments in different areas (Polsky et al. 2007).

While the dimensions are represented by exposure, sensitivity and adaptive capacity according to what the IPCC (2007c) proposes, the components include four characteristics proposed in the LVI: climate variability, natural disasters, demographic profile, infrastructure, and health (Hahn et al. 2009). The remaining physical conditions, access to information, economic level, institutions involvement, and awareness have been included due to their relevance for assessing vulnerability at the local level and their absence in previous frameworks as such. This is an optimum framework to assess vulnerability to floods; however, not all the measures could be incorporated into the assessment due to lack of data, logistic and time issues. In this sense and in the next paragraphs only those who were included in the assessment will be explained.

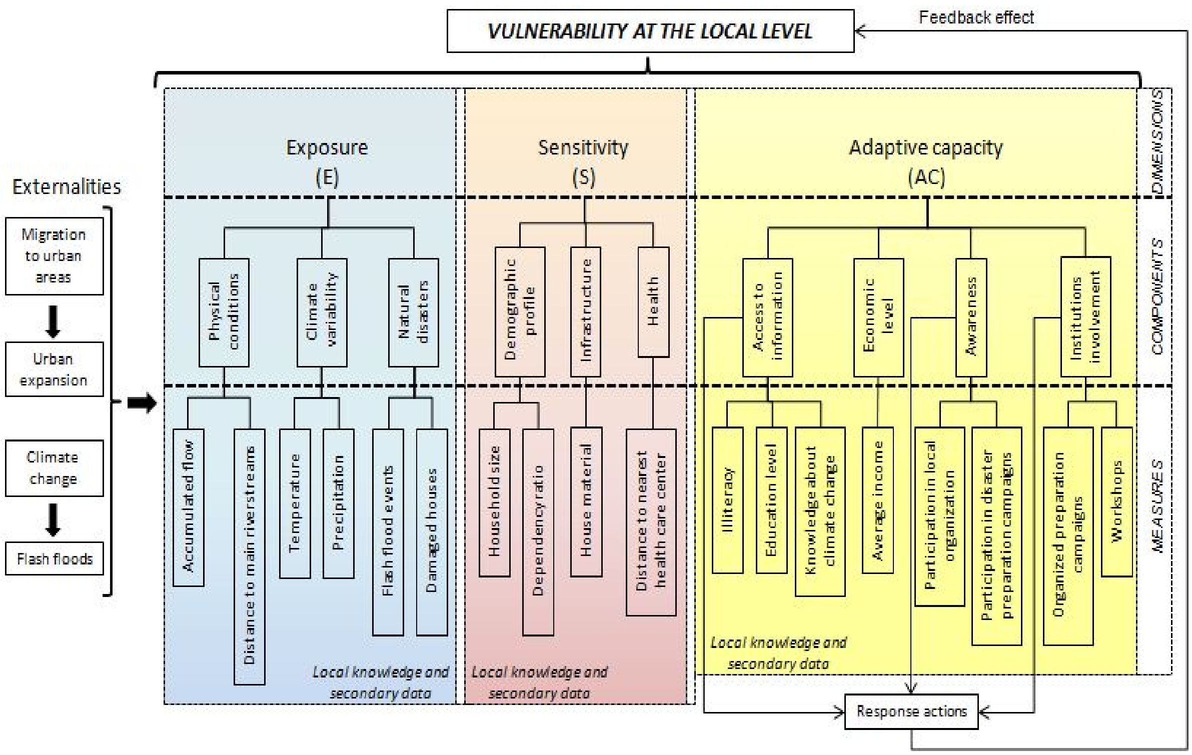

Figure 3. Urban flash floods under climate change conditions vulnerability framework.

4.2.1. Exposure

An area is more or less exposed to a flash flood event depending on the physical and hydrological conditions. In the absence of sufficient hydrological data to develop a hydrological model, these conditions are represented by key characteristics of the catchment expressed in the following two measures: accumulated flow, and distance to the main river stream. Accumulated flow represents the key flow patterns in the area, where for each spatial unit the accumulated flow that can be expected in the area is a strong indicator for the relative flow to be expected and the level of flood exposure. Distance to the main river streams is also considered since areas that are closer are more affected due to potential overflow, particularly those areas in the lower reaches of the basin. These parameters are derived from the Digital Elevation Model and a river map and produced through GIS analyses.

Climate variability addresses the influence of the changes in the climate expressed in temperature and precipitation in the area. Precipitation and temperature data of the last 30 years was collected from Florya gauge station, located in the lower part of the basin. The historic series were used to estimate standard deviation for the 1975-2009 -period as suggested by Hahn et al. (2009).

4.2.2. Sensitivity

Sensitivity groups characteristics that make a society or a household more prone to suffer from flash flood events. An area with very young or very old population will be more sensitive to flash flood events because they depend more on the rest of inhabitants: children and elderly cannot protect themselves so easily and need assistance from older and younger people, respectively. That is why it is important to identify a dependency ratio in order to see the relationship between the population under 15 plus over 65 years old, and the population between 19 and 64 years old (Hahn et al., 2009). The higher the dependency ratio, the higher sensitivity there is. Household size is an indicator of the number of people living in a household which can lead to knowing the distribution of people affected in case of a flash flood event. The larger the household size, the more sensitivity there is since the same quantity of resources such as income or food has to be shared between more people.

4.2.3. Adaptive capacity

The framework considers adaptive capacity as a combination of social, economic and institutional components that are enabling households to cope with the impacts of flash floods. The criteria illiteracy and education level are measures representing the access to information component. Illiteracy indicates the percentage of inhabitants older than 6 years old who know how to read and write. Education level is analyzed by the percentage of people in the neighborhood who attended primary, middle-high school, and superior education. The higher the percentage of people attending higher levels of education is, the higher capacity to cope with flood consequences there is. Average income represents the economic component of adaptive capacity. What an inhabitant earns determines his/her acquisition power and it serves as input to conduct practical actions to modify vulnerability and to cope with flash flood consequences.

5. Flash flood vulnerability in the Ayamama River basin

The vulnerability framework as developed in section 4 was applied to assess the entire area of the Ayamama River basin according to its vulnerability to flash floods under climate change conditions. Socio-economic data used to determine criteria for the sensitivity and adaptive capacity component of vulnerability was derived from a household survey conducted in Istanbul in 2006 by Istanbul Metropolitan Planning Agency (IMP). Spatial data for assessing the exposure dimension of vulnerability as well as the distance to health center criteria in the sensitivity dimension was prepared using a GIS based on data kindly provided by IMP.

The method applied to calculate the vulnerability index per spatial unit is spatial multi-criteria evaluation (SMCE). In SMCE each criterion included in the assessment is first transformed into a standardized utility score between 0 and 1, where a value of 0 e.g. means a very low resp. no exposure or a low sensitivity and a value of 1 stands for a very high exposure or sensitivity of this area. In the second step all standardized criteria are combined into one overall index applying a weighted summation, in which standardized utility scores are summed up based on the respective importance, i.e. their single weight. The results obtained are maps that show for each single spatial unit or cell of the case study area their respective degree of vulnerability on a scale between 0 and 1, 0 meaning not vulnerable at all and 1 meaning highest degree of vulnerability. Depending on the structure of the SMCE application also intermediate results in terms of maps for exposure, sensitivity and adaptive capacity are obtained, that allow interpreting the results in detail.

Resulting maps depicting the overall vulnerability in the Ayamama River basin as well as the three components of vulnerability are presented in figures 4a to 4d. The overall vulnerability (figure 4a) clearly shows that areas close to the main river and especially in the downstream part of the main river are the most vulnerable areas. Medium vulnerable areas (yellow colors in figure 4a) are located in a slightly higher distance from the river in the downstream part of the river, but also in the northern part of the basin, a rather mountainous area. The first is mainly because of the high exposure (figure 4b) of that area, while the latter is most likely influenced by the extremely high sensitivity (figure 4c) of that area, e.g. because of large distance to existing health facilities.

The sensitivity map (figure 4c) reveals a clearly distinct degree of sensitivity of the population in the Ayamama River basin. Neighborhoods in the south, located closer to the sea, are the least sensitive, whereas northern neighborhoods show a high degree of sensitivity. This is not only because of the higher distance to health facilities in the north but also because the dependency ratio that is much higher in the northern part. Most likely is the amount of elderly people per household here much higher.

The adaptive capacity does not reveal such a clear and distinct pattern in the spatial distribution of the household resilience towards flash floods. Obviously do households in the neighborhoods east of the river in the downstream part command over less adaptive capacity. This area contains a much higher degree of mixed industrial as well as residential land use that might explain the lower resilience in this area.

6. Conclusions: Governing climate change adaptation

Vulnerability and climate change constitute trans-disciplinary issues since they concern civil society, the scientific community and governments. Assessing vulnerability, therefore; requires the involvement of these groups with an approach that allows their participation during the whole process in order to translate this produced knowledge into policies that address adaptation to climate change impacts. Areas close to the main river and especially in the downstream part of the main river are the most vulnerable parts of the basin. Households living in this area that show a high sensitivity and/or low adaptive capacity therefore should be are among the first and most important groups of society to target in concrete adaptation measures.

The research demonstrates that local knowledge plays an important role in vulnerability assessments related to flash floods under climate change conditions. In the study area, people perceive that flash flood events will increase in frequency due to climate change; however, this is not jointly translated into adaptive actions. In fact, actions local inhabitants recall are more focused short-term and on the river itself, than on ameliorating their organization capacity and relationship with the local government. Not only is local knowledge useful for understanding the specific context regarding vulnerability in the study area, which constitutes a starting point for the assessment, but also a source of information from which context–specific parameters can be developed.

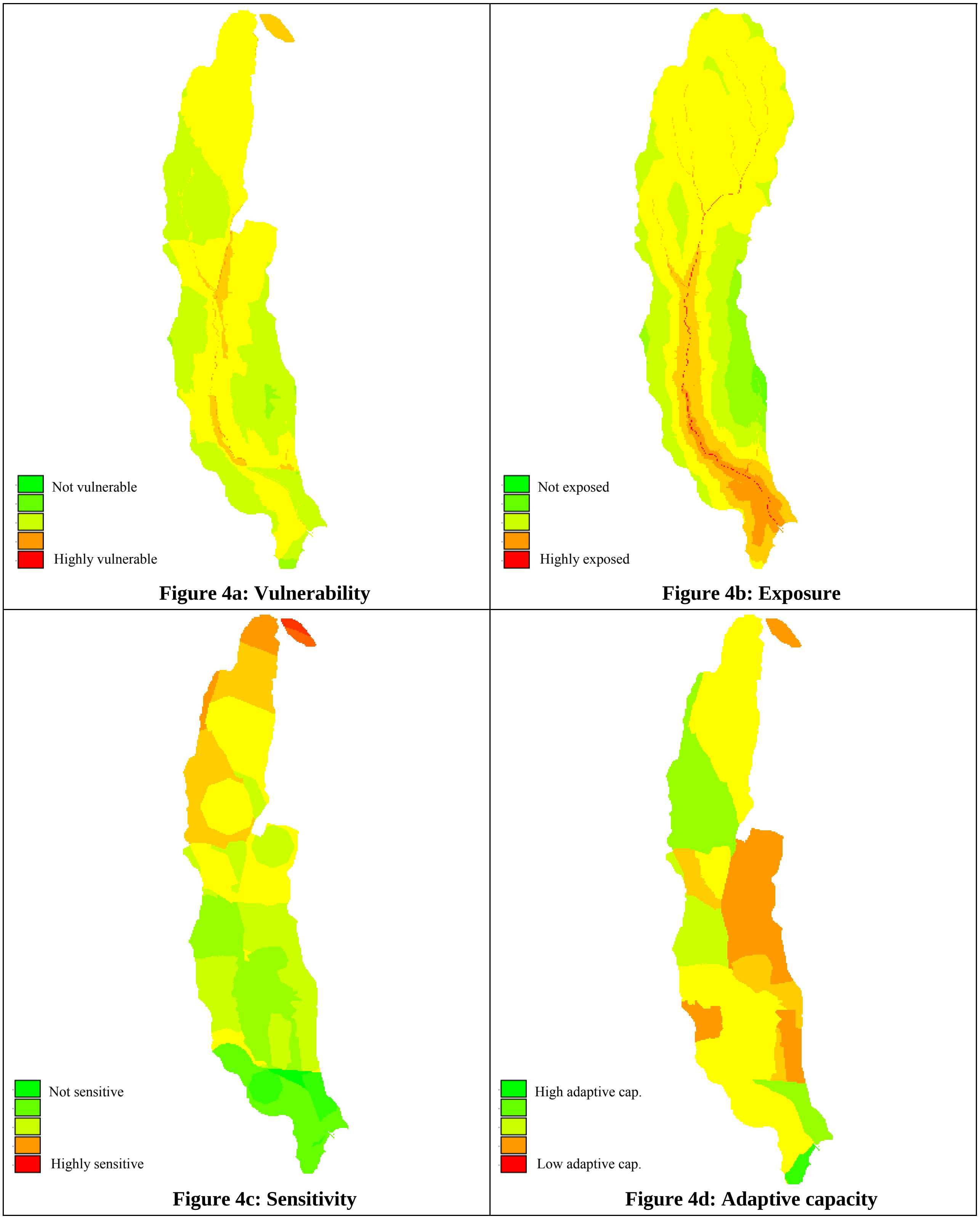

Figure 4a: Vulnerability

Figure 4b: Exposure

Figure 4c: Sensitivity

Figure 4d: Adaptive capacity

Figure 4. Urban vulnerability outputs

References

ACEVES-QUESADA, J., DÍAZ-SALGADO, J., and LÓPEZ-BLANCO, J. (2007). "Vulnerability assessment in a volcanic risk evaluation in Central Mexico through a multi-criteria-GIS approach." Natural Hazards, 40(2), 339-356.

ADGER, W. N. (1999). "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam." World Development, 27(2), 249-269.

BEHRINGER, J., BUERKI, R., and FUHRER, J. (2000). "Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture." Integrated Assessment, 1(4), 331-338.

BELTON, V., and STEWART, T. (2002). Multiple criteria decision analysis: an integrated approach, Boston; Dordrecht: Kluwer Academic Publishers.

BIRKMANN, J. (2006). "Measuring vulnerability to promote disaster-resilient societies: Conceptual frameworks and definitions", in J. Birkmann, (ed.), Measuring vulnerability to natural hazards: towards disaster resilient societies. Tokyo: United Nations University Press.

BIRKMANN, J. (2007). "Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications." Environmental Hazards, 7(1), 20-31.

BIRKMANN, J., FERNANDO, N., and HETTIGE, S. (2006). "Measuring vulnerability in Sri Lanka at the local level", in J. Birkmann, (ed.), Measuring vulnerability to natural hazards : towards disaster resilient societies. Tokyo: United Nations University Press.

BOHLE, H. (2001). "Vulnerability and Criticality: Perspectives from Social Geography"IHDP 2, 2001. Newsletter of the International Human Dimensions Programme on Global Environmental Change City.

CROSS, J. A. (2001). "Megacities and small towns: different perspectives on hazard vulnerability." Global Environmental Change Part B: Environmental Hazards, 3(2), 63-80.

CUTTER, S. L. (2003). "The Vulnerability of Science and the Science of Vulnerability." Annals of the Association of American Geographers, 93(1), 1 - 12.

DESSAI, S., and HULME, M. (2003). "Does Climate Policy Need Probabilities?". Norwich: Tyndall Centre Working Paper 34, University of East Anglia.

DUBOVYK, O. (2010). Spatio - temporal analysis of informal settlements development : a case study of Istanbul, Turkey, ITC, Enschede.

EBI, K. L., KOVATS, R. S., and MENNE, B. (2006). "An Approach for Assessing Human Health Vulnerability and Public Health Interventions to Adapt to Climate Change." Environmental Health Perspectives, 114(12), 1930-1934.

EINFALT, T., and KESKIN, F. (2010). "Analysis of the Istanbul Flood 2009"BALWOIS 2010 Scientific Conference on Water Observation and Information System for Decision Support. Ohrid, Republic of Macedonia.

EM-DAT. (2010). "The International Disaster Database, Center for Research on the Epidemiology of Disasters - CRED". Retrieved November 4, 2010, from http://www.emdat.be/database.

FEW, R. (2003). "Flooding, vulnerability and coping strategies: local responses to a global threat." Progress in Development Studies, 3(1), 43-58.

FÜSSEL, H.-M. (2007). "Vulnerability: A generally applicable conceptual framework for climate change research." Global Environmental Change, 17(2), 155-167.

GAUME, E., BAIN, V., BERNARDARA, P., NEWINGER, O., BARBUC, M., BATEMAN, A., BLASKOVICOVÁ, L., BLÖSCHL, G., BORGA, M., DUMITRESCU, A., DALIAKOPOULOS, I., GARCIA, J., IRIMESCU, A., KOHNOVA, S., KOUTROULIS, A., MARCHI, L., MATREATA, S., MEDINA, V., PRECISO, E., SEMPERE-TORRES, D., STANCALIE, G., SZOLGAY, J., TSANIS, I., VELASCO, D., and VIGLIONE, A. (2009). "A compilation of data on European flash floods." Journal of Hydrology, 367(1-2), 70-78.

GÜVEN, Ç. (2007). Climate Change & Turkey. Impacts, Sectoral Analyses, Socio-Economic Dimensions. Ankara: UNDP Turkey Office.

HAHN, M. B., RIEDERER, A. M., and FOSTER, S. O. (2009). "The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change--A case study in Mozambique." Global Environmental Change, 19(1), 74-88.

HAKI, Z., AKYUREK, Z., and DUZGUN, S. "Assessment of Social Vulnerability Using Geographic Information Systems: Pendik, Istanbul Case Study." Presented at 7th AGILE Conference on Geographic Information Science, Heraklion, Greece.

IPCC. (2007a). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA.

IPCC. (2007b). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA.

IPCC. (2007c). Summary for Policy makers. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

KAYA, S., and CURRAN, P. J. (2006). "Monitoring urban growth on the European side of the Istanbul metropolitan area: A case study." International Journal of Applied Earth Observation and Geoinformation, 8(1), 18-25.

KELLY, P. M., and ADGER, W. N. (2000). "Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation." Climatic Change, 47(4), 325-352.

KUCUKMEHMETOGLU, M., and GEYMEN, A. (2009). "Urban sprawl factors in the surface water resource basins of Istanbul." Land Use Policy, 26(3), 569-579.

MALCZEWSKI, J. (1996). "A GIS-based approach to multiple criteria group decision-making." International Journal of Geographical Information Systems, 10(8), 955-971.

MENDOZA, G. A., and MARTINS, H. (2006). "Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms." Forest Ecology and Management, 230(1-3), 1-22.

METZGER, M. J., LEEMANS, R., and SCHRÖTER, D. (2005). "A multidisciplinary multi-scale framework for assessing vulnerabilities to global change." International Journal of Applied Earth Observation and Geoinformation, 7(4), 253-267.

MOSS, R., MALONE, E., and BRENKERT, A. (2000). Vulnerability to climate change: a quantitative approach. Washington D.C.

MUSTELIN, J., KLEIN, R., ASSAID, B., SITARI, T., KHAMIS, M., MZEE, A., and HAJI, T. (2010). "Understanding current and future vulnerability in coastal settings: community perceptions and preferences for adaptation in Zanzibar, Tanzania." Population and; Environment, 31(5), 371-398.

NÆSS, L. O., NORLAND, I. T., LAFFERTY, W. M., and AALL, C. (2006). "Data and processes linking vulnerability assessment to adaptation decision-making on climate change in Norway." Global Environmental Change, 16(2), 221-233.

O'BRIEN, K., ERIKSEN, S., SCHJOLEN, A., and NYGAARD, L. (2004). What's in a Word? Conflicting Interpretations of Vulnerability in Climate Change Research. Oslo University, Oslo.

OZCAN, O., and MUSAOGLU, N. (2010). "Vulnerability Analysis of Floods in Urban Areas Using Remote Sensing and GIS"30th EARSEL Symposium. Paris, France.

PELLING, M. (2003). The vulnerability of cities : natural disasters and social resilience, London etc.: Earthscan.

PETERS GUARIN, G., FRERKS, G. P., VAN WESTEN, C. J. P., and DE MAN, W. H. E. P. (2008). Integrating local knowledge into GIS based flood risk assessment, Naga city, The Philippines, Wageningen University, ITC, Wageningen, Enschede.

PITTMAN, J., WITTROCK, V., KULSHRESHTHA, S., and WHEATON, E. (2011). "Vulnerability to climate change in rural Saskatchewan: Case study of the Rural Municipality of Rudy No. 284." Journal of Rural Studies, 27, 83-94.

POLSKY, C., NEFF, R., and YARNAL, B. (2007). "Building comparable global change vulnerability assessments: The vulnerability scoping diagram." Global Environmental Change, 17(3-4), 472-485.

RASHED, T., and WEEKS, J. (2003). "Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas." International Journal of Geographical Information Science, 17(6), 547-576.

REZA, M. E. (2009). "Flash Floods Nature's Vengeance". Retrieved September 30, 2010, from http://www.articlesbase.com/politics-articles/flash-floods-natures-vengeance-1294250.html

SCHRÖTER, D., POLSKY, C., and PATT, A. (2005). "Assessing vulnerabilities to the effects of global change: an eight step approach." Mitigation and Adaptation Strategies for Global Change, 10(4), 573-595.

SATTERTHWAITE, D., HUQ, S., REID, H., PELLING, M., and ROMERO, P. (2009) " Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low-and Middle-Income Nations", In J. Bicknell, D. Dodman, and D. Satterthwaite, (eds), Adapting Cities to Climate Change: Understanding and Addressing the Development Challenges. London, Sterling, VA: Earthscan.

SMIT, B., and WANDEL, J. (2006). "Adaptation, adaptive capacity and vulnerability." Global Environmental Change, 16(3), 282-292.

TURKEY: MINISTRY OF ENVIRONMENT AND FOREST. (2010). Republic of Turkey National Climate Change Strategy (2010-2020). Turkey: Ministry of Environment and Forest. General Directorate of Environmental Management Climate Change Department, Ankara.

TURKISH STATISTICAL INSTITUTE. (2010). "Databases". Retrieved August 9, 2010, from http://www.turkstat.gov.tr

TURNER, B. L., KASPERSON, R. E., MATSONE, P. A., MCCARTHY, J. J., CORELL, R. W., CHRISTENSENE, L., ECKLEY, N., KASPERSON, J. X., LUERS, A., MARTELLO, M. L., POLSKY, C., PULSIPHER, A., and SCHILLER, A. (2003). "A framework for vulnerability analysis in sustainability science." Proceedings of the National Academy of Sciences of the United States of America, 100(14), 8074-8079.

UITTO, J. I. (1998). "The geography of disaster vulnerability in megacities : A theoretical framework." Applied Geography, 18(1), 7-16.

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP). (2004). Reducing Disaster Risk: A Challenge for Development. A Global Report. UNDP-Bureau for Crisis Prevention and Recovery (BRCP), New York.

VAN WESTEN, C. (2009). Multi hazard risk assessment: United Nations University - ITC - DGIM.

WATSON, I., and COMERT, Y. (2009). "Istanbul buries dead after fatal floods", CNN.com/europe. Retrieved August 10, 2010, from http://edition.cnn.com/2009/WORLD/europe/09/11/turkey.floods/

WILHELMI, O. V., and HAYDEN, M. H. (2010). "Connecting people and place: a new framework for reducing urban vulnerability to extreme heat." Environmental Research Letters, 5(1), 1-7.

YALÇIN, G., and AKYÜREK, Z. (2004). "Multiple criteria analysis for flood vulnerable areas"24th Annual ESRI International User Conference 2004. City: ESRI: San Diego, CA.

YILDIZ, D. (n.d.). "Kent Hidrolojisi Hesapları Yapılmalı!". Istanbul.