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# Towards Applying Climate Change Adaptation

## *Hacia la adaptación al cambio climático*

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### Abstract

Climate change adaptation has been growing in importance since the beginning of the 21<sup>st</sup> century. Historically adaptation, not to climate change but to extreme events, was deeply rooted in many societies and their land-use structures. With industrialization, and especially the increase in globalization since the 1990's the importance of appropriate adaptation has slowly decreased, leading to increased exposure and risks of human settlements in areas potentially affected by climate change impacts (e.g. sea level rise) and / or extreme events (natural hazards). In order to implement climate change adaptation sustainably feasible solutions should be identified, i.e. viable and acceptable from socio-economic point of views. The identification of such feasible solutions goes beyond pure scientific analysis but incorporates stakeholders, decision-makers and local knowledge.

**Keywords:** Climate change; natural hazards; vulnerability; risk; adaptation; land use; communication.

### Resumen

La adaptación al cambio climático ha ido cobrando importancia desde comienzos del siglo actual. Históricamente la adaptación, no al cambio climático sino a los eventos atmosféricos extremos, estaba profundamente arraigada en muchas sociedades y en su forma de ocupar el territorio. Con la industrialización y especialmente con el aumento de la globalización desde los años noventa del pasado siglo, la importancia de una adecuada adaptación al territorio ha ido perdiendo protagonismo, lo que ha aumentado la exposición y el riesgo de los asentamientos humanos en áreas potencialmente afectadas por los impactos del cambio climático (p.e. subida del nivel de mar) y/o por eventos extremos (peligros naturales). Para desarrollar medidas de adaptación al cambio climático es necesario identificar soluciones viables, es decir, viables y aceptables desde el punto de vista socioeconómico. La identificación de estas soluciones factibles va más allá del análisis científico puro puesto que incorpora a todas las partes interesadas, incluidos los responsables en la toma de decisiones y el propio conocimiento local.

**Palabras clave:** Cambio climático; peligros naturales; vulnerabilidad; riesgo; adaptación; usos del suelo; comunicación.

## 1. Introduction

Since the beginning of the 21<sup>st</sup> century most countries, and many regions and municipalities have started to develop and implement climate change adaptation strategies and plans. Since concrete adaptation measures must be planned and conducted at the local level, a major challenge is to actually implement adaptation to climate change in practice. One challenge is that scientific results are mainly published on international or national levels, and political guidelines are written at transnational (e.g., European Union), national, or regional levels - and these scientific results must be downscaled, inter-

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preted and adapted to local municipal or community levels. The challenges for implementation are also based on a large number of uncertainties, ranging from long time spans to matters of scale, as well as varying economic, political, and social interests. Especially time scales are a crucial issues, because most climate change impacts occur rather slowly, i.e. over decades and centuries, while local decision makers are engaged with daily business over much shorter time spans.

The challenges to implementing adaptation measures to climate change are related to three major groups of uncertainties: First, uncertainties about the development of our future climate, which include the climate sensitivity of the earth's climate system to anthropogenic greenhouse gas emissions, the reliability of emission scenarios and underlying storylines, as well as inherent uncertainties in climate models; Second, uncertainties about anthropogenically induced climate impacts (e.g., long-term sea level changes, changing weather patterns, and extreme events); and third uncertainties on the future socioeconomic and political development, including policies related to climate change mitigation and legislative frameworks. (Schmidt-Thomé & Kaulbarsz, 2008).

There have been very good achievements in developing climate change adaptation strategies on several levels (from over-regional to national and local). But the concrete implementation of adaptation measures is often lagging. Examples of mal-adaptation, starting from current climate and climatic extreme events, as well as potential climatic changes, prevail, unfortunately all too often despite better knowledge. Besides slow changes, e.g. changing sea levels, climate and vegetation zones, extreme events (natural hazards) are a factor of major importance for climate change adaptation. Many societies and their socioeconomic systems are not properly adapted to their current climate zones (e.g., intensive agriculture in dry zones) or to extreme events (e.g., housing built in flood-prone areas). Adaptation measures can be successful only by gaining common societal agreement on their necessity and overall (socio-economic) benefit. Ideally, climate change adaptation measures are combined with disaster risk reduction measures to enhance resilience on short, medium and long time scales.

The role of uncertainties and time horizons is addressed by developing climate change adaptation measures on local, or community, level and in close cooperation with local actors and stakeholders, focusing on strengthening the resilience by addressing both current and emerging vulnerability patterns. Successful adaptation measures are usually achieved by developing so-called "no-regret" measures – in other words measures that have at least one function of immediate social and/or economic benefit as well as long-term benefits. To identify socially acceptable and financially viable adaptation measures it is useful to employ participatory tools that give all involved parties and decision makers the possibility to engage in the process of implementing adaptation measures that best fit collective needs.

## 2. Methods: Options for climate change adaptation

This article reviews the definition and political demand for adaptation versus historical adaptation practices and their change over the past decades. Sea level rise and hydrometeorological hazards are closely linked to climate change impacts and thus play an important role in this review, but also geohazards are analyzed for important land-use policy implications. The article is based on a literature review and practical examples of implementing feasible climate change options derived from several implemented projects.

### 2.1. The context of adaptation

IPCC's climate change adaptation options to adapt to sea level rise are either to *accommodate*, *protect* or *retreat* (Intergovernmental Panel on Climate Change [IPCC], 1990). These are applicable also to adapt to natural hazards (i.e. extreme events), such as floods, droughts, storms, etc. as humans need to choose options to safely *accommodate* people, their assets and economic structures (e.g. agriculture); and/or to *protect* those (e.g. by technological solutions such levees (floods), water storage (droughts)); and/or to *retreat* (partly or totally).

Historical adaptation examples can be found from ancient settlements, many of which have been further developed towards modern climate change adaptation policies and implementations. But all-too-often, historical events and protection measures have either been forgotten or otherwise lost. The reason for inadequate adaptation of many modern settlements is manifold, ranging from population density pressures to economic interests. Observing the location of the original founding sites of historical old towns, it

is noticeable that these were originally accommodated to avoid impacts of extreme events. For instance, the ports of the important coastal cities in Southern Europe were located at the sea shore, meanwhile the city centers were founded at a certain distance to the shoreline to prevent from diseases (e.g. malaria) and storm surges. Ancient churches and other buildings prevail to stand nowadays in earthquake prone areas as they were built on hard rock, instead of soft soil (liquefaction). Coastal settlements in, e.g. Castro on the Island of Chiloe (Chile) and in the Ton Le Sap Lake (Cambodia) remain to be built on high pillars to give room to daily or periodically changing tides, respectively, as well as floods.

There is a globally observable pattern that new buildings (often 21<sup>st</sup> century) are situated on soft soils and in, or close to, flood prone areas, meanwhile the old city foundations are located in more safe areas. The pressure of the growing population as an argument justifying buildings in hazardous areas is only partly true. Hazardous areas are also being built up in Europe, which in fact faces population decline. One major reason for increasing vulnerabilities is the continuing urban population in (coastal) urban areas (Olcina, Hernández, Rico & Martínez, 2010; Schmidt-Thomé & Klein, 2011; United Nations, 2014; Olcina, Saurí, Hernández & Ribas, 2016).

In the example of coastal protection, modern policies or strategies react differently to adapt to extreme event and climate change impacts. The City of Hamburg (Germany) actively discusses accommodation with the support of different flood compartments (Knieling and Schaerffer, 2013). On the other hand the first master plan for coastal and flood protection of the German Federal State of Mecklenburg-Vorpommern acknowledges that retreat is an option as it mentions that the coastline is a mosaic in space and time, its character is variation (Ministerium für Bau, Landesentwicklung und Umwelt Mecklenburg-Vorpommern, 1993). Indeed, in some areas of Mecklenburg-Vorpommern sea walls are removed, re-creating salt marshes as flood retention areas. The New York City Special Initiative for Rebuilding and Resiliency (2013) on the other hand states that “The city cannot, and will not, retreat” (p. 7). On the other hand New York City does not aim for complete protection as the report also outlines concepts of “living with water”.

Due the rather short time span (since approximately 2007) of climate change adaptation strategies, the concrete implementation of climate change adaptation measures on local level is often still lagging. The problem with many generalized politically and institutionally demanded climate change adaptation measures is their lack of practical applicability at the local level. Another challenge are the ongoing uncertainties in emission scenarios, climate models, climate sensitivities and effects on, e.g. extreme event patterns to climate change. One often mentioned argument by stakeholders and decision makers involves our need to react and adapt “now” and “before it is too late” – a near mantra that has infused the basic content of most discussion about climate change and its effects. Whereby these mantras are seldom underpinned with applicable and viable adaptation measures, not even mentioning financial means.

Climate change impact assessments usually conclude that there are far more negative than positive impacts (e.g. Hitz & Smith, 2004, IPCC, 2014). On the other hand, measurements show that anthropogenic GHG emissions have already surpassed “worst case” IPCC emission scenarios by 2004 (Raupach *et al.*, 2007; Le Quére, *et al.* 2009) (see also below). In June 2015 the National Oceanic and Atmospheric Administration [NOAA] and the United States Environmental Protection Agency [EPA] (2015) reported that the global GHG concentration in the earth’s atmosphere have surpassed 400 ppm (from 280ppm in 1850). Following the argumentation that anthropogenic GHG emissions strongly increase the atmosphere’s greenhouse effect this means that continuous global warming will continue, at least for several decades (e.g. Archer & Brovkin, 2008). Therefore humans will inevitably have to adapt to rising temperatures, and the consequences (IPCC, 2001, 2014). The comparatively little amount of literature on the benefits of global warming (for example in the respective IPCC assessment report chapters by Smit, *et al.*, 2001; Smith, *et al.*, 2014) induces that it seems not politically correct or ethically acceptable to openly discuss potential positive effects of climate change. But why should stakeholders and investors only focus on the potentially negative effects of climate change and not also debate the opportunities that a changing climate makes available at the local level on a broader basis? As it is scientifically proven that the climate is changing, it could also be very well considered to publically evaluate and discuss the potential benefits of climate change, while discussing adaptation measures. In light of seeking funds for necessary adaptation measures, there is justification to discuss more intensively not only what negative consequences climate change might lead to but also how the potentially positive impacts from climate change can be used beneficially, e.g. from a socio-economic point of view. The interests of investors could have positive influences or spin-off effects for adaptation measures. For example investments in tourism can be tied

to adaptation measures, e.g. investments adjacent to flood prone areas must include flood prevention measures. Investments in the food sector might lead to the development of crops that are better adapted to climate variability, etc.

## 2.2. Background: Uncertainties and timescales

Stakeholders and decision makers of all kinds, as well as investors and representatives of the private sector, tend to ask these questions in climate change adaptation meetings: How reliable are the emission scenarios and climate change models, and how high are the uncertainties? How reliable are derived climate change impacts on the living environment and hydro-meteorological extreme events?

One aspect of the uncertainties is that IPCC reports (2007a, 2014) usually state what impacts might happen, underlying the statements with high, medium or low likelihoods, certainties and agreements. However, the reports seldom state that these effects might as well not happen. Even though there is a so-called scientific consensus (IPCC, 2014) that human GHG induced climate change appears to lead to unprecedented rates of climatic changes, these must still be seen in the human (geologically very short term) perspective - because there is also evidence of natural rapid climatic changes (Rial, *et al.*, 2004). Meanwhile any abrupt climate changes most likely have a strong impact on socio-economic systems (Claussen, 2008) the timeframe of such (geologically rapid) changes are yet not comparable to the even shorter timeframes of day-to-day politics, decision making and investments.

Investments lead to jobs and subsequently tax income - on which municipalities eventually depend. Decision makers, stakeholders and local private sector actors certainly also want to protect their communities and areas as well as their investments from potential damages. But they are also in a constant competition with other municipalities and need to remain attractive for investments to secure their own socio-economic development. Many discussions with local stakeholders have shown that there certainly is awareness of climate change and its potential impacts. But there is also knowledge about the uncertainties and the time span perspectives. It definitely plays a major role for a municipality when investments to prevent potential future hazard patterns are politically or scientifically required on the one hand but encounter financial thresholds or resistance on the other hand. The question is thus how adaptation to climate change can be planned and implemented, respecting both inert uncertainties and economic developments.

On the other hand there are numerous examples of mal-adaptation practices, not only to climate change impacts, but also to current extreme event patterns, scarce natural resources, and agricultural practices. Therefore, this recommendation: Analyze human vulnerabilities and adaptabilities to local climates from a general perspective, with examples of mal-adaptations, before developing and implementing climate change adaptation measures.

## 2.3. Analysis: Human adaptability, mal-adaptation and accepted risks

As a species, humans are spread more widely across the climate zones of this world than any other mammalian species. Humans have been permanently and self-sufficiently settling into all climate zones and on all but one continent, from the Arctic over all climate zones north and south of the equator and in nearly all altitudes from below sea level (e.g. Dead Sea) to over 4000m above sea level (e.g. Andes). Since the first appearance of humans, climate also has undergone several changes, including several Quaternary glaciation cycles.

The IPCC definitions of climate change adaptation are based on human-induced climate change and are certainly justifiable within the concept of recent climate changes in the Holocene, especially in connection with anthropogenic GHG emissions. But it can be argued that these definitions do not fully grasp adaptation in its entire complexity. The overall definition mentions the “moderation of harm” or the exploitation of “beneficial opportunities” which presupposes that humans had a clear knowledge of both the climatic changes to be expected as well as their potential impacts. This definition somehow skips one of the most essential parts of adaptation to climatic stimuli: the ability of nature and humans to spontaneously and promptly adjust to (changing) climatic and environmental conditions and maintain a living environment, including necessary food supplies. The mention of “various types of adaptation” (IPCC, see above) even stronger presupposes human knowledge about potential impacts in climatic changes and optimal adaptation measures, might these be anticipated, planned or spontaneous. From a purely theo-

retical point of view these definitions might be correct. But as humans adapt to be able to live in certain climatic settings they all too often increase their own vulnerabilities by putting their assets and lives, as well as vital natural resources at risk by mal-adaptation practices. Examples can be found in nearly all climate zones and cultures, and independently from economic conditions.

Examples include settlements in hazardous areas, mal-adapted agricultural practices, and overuse of natural resources, etc. These examples enlarge the contextual frame of climate change adaptation and interlink it with vulnerability and risk, especially with the concept of acceptable risk. Over millennia any human society in any place of the world has somehow adapted to a certain climate and climatic changes. Despite excellent information, experiences, statistical records and scientific knowledge on underlying hazards and vulnerabilities and resulting risks, examples of mal-adaptation are continuously found within nearly all societies.

Presently climate change adaptation is mainly discussed in the context of recent Holocene climatic changes but it should be analyzed and understood in a broader context. This broader context should include earlier (rapid) climate changes, human reactions to those, as well as adaptation to extreme events, scarce natural resources and respective mal-adaptation practices. Human vulnerabilities and their exposure to adverse characteristics of their living environment and extreme events play a key role in understanding risks. To understand risk patterns it is crucial to assess social vulnerabilities and their many variables (Cutter, Boruff & Shirley, 2003), as well as motivations and capabilities of local actors and networks. Most importantly these vulnerabilities need to be assessed on several levels, e.g. from the national and the local level (Cutter, Mitchell & Scott, 2000) and should not only be assessed from a purely damage oriented approach (e.g. losses calculated by insurance companies).

When analyzing and developing climate change adaptation options and strategies one question needs to be asked:

*How well are humans adapted to the current climate of a specific region, including extreme events?*

Before analyzing the ability to adapt to changing climatic stimuli, both, the resilience of societies and the vulnerability to extreme events should be analyzed. Factors such as availability and use of natural resources should also be taken in to consideration. Human beings tend to blame disasters related to mal-adaptation practices on other reasons or circumstances besides their own mismanagement.

Growing overall losses and rising local vulnerabilities related to natural hazards and subsequent disasters (e.g. Munich Re, 2015) cannot only be attributed to climate change impacts (e.g. IPCC, 2011; Barredo, 2009, 2010; Pielke, *et al.*, 2008). Losses grow, because people continue to settle, and expand settlements in hazardous areas, not only in poor regions with a potential shortage of land due to expanding populations, but also in richer countries. Despite knowledge on rising sea levels urban agglomerations continue to grow strongly in coastal areas globally (United Nations, 2014). After a disaster the one to blame is searched for - usually elsewhere than in one's own wrong-doing.

Per definition extreme events occur only seldom (from a human perspective). Still, their impacts are often disastrous. The problems, obstacles and/or negligence in adapting to such events leads to the conclusion that it would be feasible to discuss (mal-) adaptation to the (current) climate, and its extremes first, before heading straightforward into climate change adaptation. The message on climate change conveyed by IPCC's summary for policy makers (2007b and 2014) is that hydro-meteorological natural hazards will, with high confidence, increase on nearly all continents, in both, intensities and frequencies. Therefore the statement above might also be asked the other way round:

*If everything is to be really bad in the future, does that imply that everything is going really well at the moment? In other words: Do we not experience disasters caused by natural hazards nowadays?*

Since many societies are obviously unwilling or unable to adjust properly to the current climate and its extremes, why should they suddenly be able or willing to adjust to potential changes that might occur in the future? Instead of solely arguing about the potential climate change impacts, much could be learned from current mal-adaptation practices. Vulnerabilities and risks are often neglected despite better knowledge and because of perceived benefits that outweigh the risks.

Humans have always settled in areas affected by natural hazards. After disasters hit settlements were rebuilt, often on the very same spot. There are virtually no examples of any larger city that was given up or relocated due to risks related to hydro-meteorological hazards. Adopted protective measures, might they be engineering solutions such as dams, or regulative ones such as zoning can certainly not mitigate

all risks. People accept risks because the perceived benefits of locations outnumber the potential risks. The nature of extreme events, i.e. their seldom appearance often catch societies off-guard and cause substantial disasters. The extent of disasters is caused by several, often overlaying factors. For example certain flood heights have never been recorded in human history, or they have simply been forgotten. Upstream changes in river catchments, e.g. deforestation, sand mining and riverbed straightening, change flood patterns. If hazards (floods, droughts, etc) do not occur for a longer time frame (from a human perspective), development takes place in hazardous areas. And when disasters do occur the search for someone (or something) to blame starts.

Since people perceive great benefits from settling in potentially hazardous areas and accept the risks rather than avoiding them, a feasible solution is thus to try to minimize the risks whilst allowing maximum benefits. Even though tsunamis are not related to climate change impacts, valuable input on the debate on adaptation concepts can be derived from the coastal reconstruction along the Indian Ocean following the tsunami in 2004. An international expert meeting in the aftermath of the tsunami in Bangkok/Thailand counted with the presence of the then Thai Minister for tourism. A large group of geoscientists pledged that due to the tsunami hazard the tourism industry should not be allowed to rebuild damaged installations on the coast but only in higher, flood proof areas. Such a relocation of tourist industries would lead to substantial losses from this important source of income for Thailand, especially since Malaysia had already announced that it would not retreat from beach resorts. After a hefty debate the expert group agreed on the proposal to regulate the land use in such a way that tourist installations remain on the beaches remain, but that rescue and other vital infrastructures would be located on higher grounds. Local people would be trained on the tsunami hazard, evacuation routes would be planned and installed and a tsunami early warning system would be set up. The tsunami hazard land use and emergency regulations follow those of Hawaii (Johnston & Dudley, 2009). The former Thai Minister for Tourism was satisfied with this proposal and accepted it. In the meantime said regulations have been implemented in Thailand (Johnston & Dudley, 2009). It would be advisable to follow such examples of disaster risk reduction and carefully consider financial and other benefits of local economies also in climate change adaptation practices. This tsunami related disaster risk management also serves as a good example on the potential to build synergies with mutual benefits between the two concepts of disaster risk management (DRR) and climate change adaptation (CCA) (Pollner, Kryspin-Watson & Nieuwejaar, 2008; IPCC, 2012; Solecki, Leichenko & O'Brien, 2011).

### 3. Results: Sustainability of climate change adaptation measures

Since adaptation measures are finally implemented on the local level, the local stakeholders, decision makers and the private sector need to understand uncertainties, agree on local vulnerabilities and resulting risk patterns, to be able to develop acceptable, and thus sustainable, solutions. To be successful, implemented measures must fit into local cultural and political settings and be financially bearable. The development of climate change solutions should follow and respect local legislations, regulations, cultures and interests. The implemented measures will only be sustainable, if they are perceived as beneficial to the local socio-economic and cultural settings, because local people will ensure their maintenance. It has been proven that so-called no-regret measures present the most feasible solutions, even though IPCC (2014) criticizes this as non-sufficient for climate change adaptation. No-regret measures are of benefit immediately after their installation, even in the absence of climate change impacts. Such measures can for example protect areas from current floods, and from future, potentially higher floods (e.g. Petersell, *et al.*, 2013). Some flood retention areas are designed multi-functionally, e.g. as a recreational park, which raises the overall value of the entire neighborhood (e.g. Rimkus, Kažys, Stonevičius & Valiuškevičius, 2013). No-regret measures to protect from current and potential future urban flood patterns can be designed to improving local living environments (Jarva, *et al.*, 2014). No-regret measures are thus win-win solutions that are best achieved by interdisciplinary communication.

Experience has shown that it is easier for decision makers to invest in adaption measures to current problems, i.e. extreme event patterns, rather than investing into climate change effects that might take place in 50 years or more. While investing to protect from current hazard patterns, it is possible also take potential climate change impacts into account. Ideally, climate change adaptation measures have social acceptance right from the start. If local climate change adaption measures also protect from current

hazard patterns and also improve living conditions decision makers can easily justify investments and achieve two goals at the same time.

Once climate change impacts to hazard patterns become visible and start to affect livelihoods, these protective measures can be re-designed gradually. The analysis of sea level rise impacts on shallow groundwater aquifers in the City of Hanko (Finland) yielded the results that the current water intakes are vulnerable to sea level rise and consequent salinization (Luoma, Klein & Backman, 2013). An Analysis with local waterworks did not lead to the immediate decision to relocate groundwater intakes merely because of potential future risks. Part of the discussions took into account the future socio-economic and population trends of this city: How will local industries develop, will water demand grow or decrease and how many people will live in this city in a couple of decades? Currently no decisions or investments on relocating water intakes have been taken. This example shows that it is certainly valuable to conduct both vulnerability and risk analysis under climate change scenarios, but to also keep future uncertainties in terms of socio-economic developments in mind, before taking decisions hastily that might lead to futile investments.

Timescales strongly affect stakeholder's points of views and are important for decision making. Some geo-hazards and related geo-risks may never occur during a human lifespan, others might occur rather frequently. The periodicity, geological processes and impact delays are therefore a very important issue in the communication of geosciences. It is often forgotten that climate change is an ongoing, slow process and its impact occurs steadily, and not suddenly, e.g. at the end of the 21<sup>st</sup> century. Human impacts on the living environment and the exploitation of natural resources are often stronger than climate change signals and occur quicker than climate change impacts. It is certainly possible that climate change contributes to adverse impacts, but it is also possible that these might never occur. Climate change impacts might end up being completely different than currently estimated, due to uncertainties of models as well as due to human impacts. It is therefore very important to keep timescales and changes to land use and socio-economical and political frameworks in mind. For example, some investments that yield short term revenues might possibly never be affected by climate change - and if, they might as well be decommissioned in case of adverse climate change effects. It is thus one important part of climate change adaptation to keep the time-scales of anthropogenic and geological processes in mind.

There are possibilities to decrease the effect of uncertainties in climate change adaptation measures by developing adaptation measures on community levels that focus on local vulnerability patterns and thus inherently lead to improvements of adaptive capacities and local resilience (van Aalst, Cannon & Burton, 2008). Optimally such vulnerability analyses include on disaster potential caused by extreme events, as these are usually commonly remembered and the potential impacts are empirically based. Derived disaster risk management options further be used to develop, e.g. protective or adaptive measures to cope also with changing climatic patterns (intensifying cloudbursts, longer dry spells, etc). In such a way also mutual benefits and cross-feeding between, the politically and institutionally demanded, disaster risk management and climate change adaptation can be achieved (e.g. Pollner, *et al.*, 2008; IPCC, 2012). There are numerous examples of successful adaptation practices from the community level. In such so-called bottom-up approaches (versus top-down approaches) local people evaluate their local environments' and socio-economic settings' vulnerabilities to climate change impacts. Such community based climate change adaptation practices usually use participatory approaches to develop tailored adaptation measures (van Aalst, *et al.*, 2008).

#### **4. Discussion: Implementing participatory tools for the development and implementation of climate change adaptation measures**

Participatory approaches strongly focus on governance issues as the involvement of citizens in decision-making practices is becoming more important from a basic democratic and social justice perspective. By involving various interest groups a more complex understanding of the issues at stake may be achieved, as well as socially accepted solutions to problems may be found, by taking into account the various interests, motivations and expertise. Early integration of manifold expertise and interests minimizes the risk of costly adjustments at a later stage, even though it might seem time consuming and challenging (Slocum, 2003; Wollenberg, Edmunds & Buck, 2000). In addition, the integration of relevant stakeholders reduces the amount of potential resistance and therefore leads to an overall quicker implementation

of measures (e.g. Rimkus, *et al.*, 2013; Petersell, Suuroja, All & Shtokalenko, 2013). The integration of local stakeholders and interdisciplinary approaches in participatory tools have proven very effective to successfully develop and implement climate change adaptation measures (Hinkel, Bisaro & Swart, 2016) and may lead a way to mainstreaming climate change adaptation in practice (Schmidt-Thomé, Klein, Nockert, Donges, & Haller, 2013; Schmidt-Thomé, Nguyen, Pham, Jarva, & Nuottimäki, 2014).

Decision making under changing climatic conditions often requires weighting between different adaptation options to reach an agreement of a best-fit and socio-economically viable solution. There are many participatory approaches to weight non-mathematical variables and options, for example the Delphi Method, Cost-Benefit Analysis (CBA) and Multi Criteria Decision Analysis (MCDA). Experience has shown that these have been applied for several decision making processes, involving different options and opinions of various stakeholders, decision makers and local people. Many of these tools do not necessarily require an immediate interaction between the persons involved, e.g. they can be conducted online. In order to reach agreements acceptable to all involved experience has also shown that the endorsement of communication and fostering on the interaction of different interest groups can prove to be most valuable. Sustainable climate change adaptation solutions can be reached by achieving a generally accepted understanding of all involved interest groups and stakeholders (etc) of the necessity of any given area or place to adapt to changing climatic conditions. This acceptance can be reached by the joint evaluation of options and their respective pros and cons. Among the great variety of participatory tools scenario workshops have proven to be generally very successful and therefore light is shed on this tool exemplarily.

Scenario workshops are a participatory tool that supports communication among stakeholders, scientists and decision makers and thus scenario workshops are good choice for climate change adaptation projects. According to Slocum (2003) scenario workshops are useful when dealing with uncertainties related to climate change. They are useful to improve overall preparedness and long-term decision making as well as to develop alternative options for future developments. Scenario workshops develop long-term story lines of possible future developments and are thus suitable to integrate natural hazards and climate change impacts into land-use planning. Such storylines are used to identify potential future developments and to react timely by taking early measures. The goal is to safeguard economic development and social safety by early decision making on appropriate adaptation measures. Each new scenario workshop requires careful planning and fine-tuning to the local conditions. This fine-tuning is necessary because of different physical settings such as geographical features and data availability of a certain area and also because of differing cultural settings, such as education levels, planning systems and motivations of stakeholders.

Three different types of scenario workshops can be identified. The first workshop type focuses on *informing* about changes and their potential impacts. In this case the scenario workshop is used to inform about possible scenarios and to present possible solutions which are discussed during the workshop. The second workshop type is used to tackle a *specific* problem. The scenario workshop is then used to develop various solutions to the presented problem. The aim is to reach consensus on the understanding of the problem and to identify one best solution. The third workshop type is used to *develop several solution scenarios*. In this case the total amount of stakeholders is too large to participate in the workshops; therefore a representative stakeholder group identifies different development options. These options are then discussed or voted for at a stakeholder summit, which should conclude on a final decision.

The aim of each workshop may differ. A workshop might be of an *informative* nature, i.e. the result is broader knowledge of important issues. The discussions among and with the stakeholders are used to draw up different scenarios and/or to receive feedback on proposed solutions to problems. A scenario workshop might also be used for problem solving, i.e. to reach an *agreement* on how to handle a specific threat by an extreme event or pollution. A scenario workshop might also be used to *change* land-use patterns and building regulations. The differences in aims also affect the planning system. Is the issue at stake focusing on informing stakeholders about necessary changes to maintain current public services and safety? In this case the workshop is used to ensure stakeholder knowledge about adaptation options at an early stage. Or is the aim to have a broader involvement of stakeholders to tackle a particular issue and ensure that all beneficiaries are involved? In this case the adaptation option might have a larger impact on a municipality and the workshop is used to ensure that all interests of relevant stakeholders are taken into account in order to come up with the most feasible solution. Finally it is possible that the

question at stake is so complex that changes in current land-use patterns might have to be considered (i.e. changes in building codes or retreat from hazardous areas).

Ideally, all possibly involved or affected stakeholders should be invited to scenario workshops. While this is not always possible for practical reasons, great care should be placed on inviting representatives of the most important stakeholder groups of a particular issue at stake. It is also recommendable to invite stakeholders that have a potential to obstruct measures and investments. By involving critical persons from the beginning it is possible to avoid resistance at a later stage.

It is most important to prepare sufficient and concise workshop material at an early stage and provide this to all workshop participants for preparation. If possible, feasibility studies and/or cost estimations of potential investments should also be made available. The workshop is most effective when participants have a good understanding of the issue and the necessary background information to focus mainly on the matters to be discussed and are not distracted by other explanations. A briefing meeting prior to the workshop makes sense in case the participants are not familiar with the issue.

## 5. Conclusions

Climate change adaptation largely takes place in an environment characterized by inherent uncertainties of climate models. It has proven most successful to use current extreme event patterns to analyze local vulnerabilities and resulting risks to achieve an understanding of adaptation needs, challenges and potentials.

The future is and will remain uncertain, no matter how sophisticated models might be one day. It is virtually impossible to foresee economic or climatic developments and their variances over longer time spans. General trends and their impacts on the other hand can be estimated. These estimates can serve as valuable sources to derive climate (change) adaptation policies and measures. Since climate change adaptation measures are mainly implemented at the local level, it will always remain crucial to tailor the measures according to current and short term socio-economic interests and demands. Adaptation measures have to respect local conditions and should support local development otherwise they might be socio-economically unbearable. If adaptation measures are too costly they might be counter-productive by leading to economic downturns and making themselves obsolete.

There are many potential futures which do not only depend on climate change. Local politics and economics, as well as social decision making are also future shaping factors. Climate change models are most valuable tools, but communication is the most important factor in decision making on climate change adaptation measures. In order to achieve the implementation of sustainable climate change adaptation measures the integration of a large amount of stakeholders, decision makers and the private sector is key. Solutions should be structured in a way that climate change adaptation measures are not investments into a distant future. A close cooperation, where feasible, with natural hazard mitigation and disaster risk management also supports the justification of climate change adaptation measures, such as land use restrictions, investments in protective measures and many others. Immediate benefits should be palpable despite of potential climate change impacts and ideally, no-regret measures serve and improve current living conditions and are generally perceived as beneficial to the living environment of an area.

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