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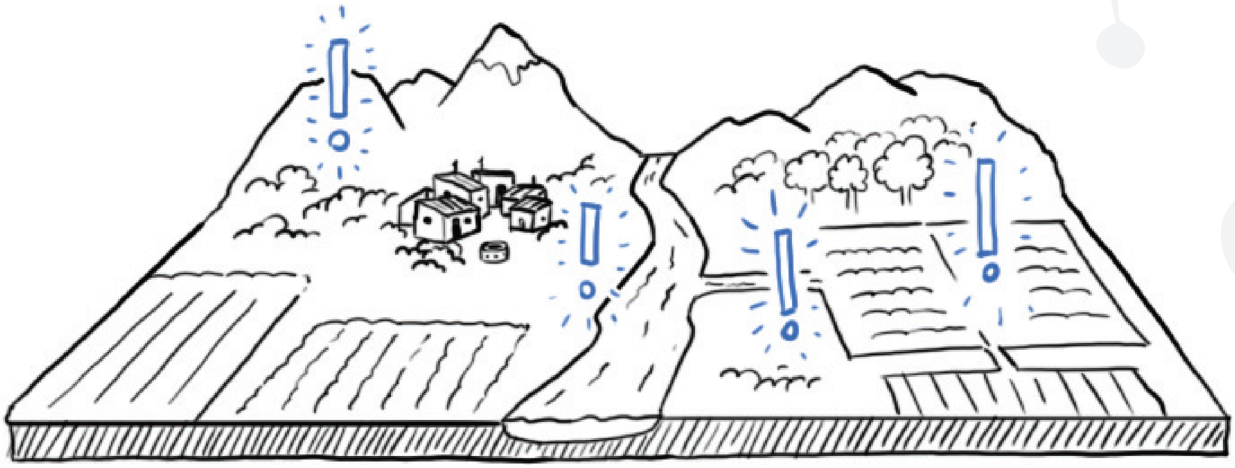

Comparative analysis of climate change vulnerability assessments: Lessons from Tunisia and Indonesia

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Competence Center for Climate Change

T +49 6196 79-1903
F +49 6196 79-801903
E info@giz.de
I www.giz.de

Authors
Anne Hammill, Livia Bizikova, Julie Dekens, Matthew McCandless (International Institute for Sustainable Development)

Contributions by
Nadia Manasfi, Nana Künkel

Responsible
Timo Leiter

Design elements
Climate Media Factory, info@climatemedia.de

Layout & Design
Ira Olaleye, Eschborn

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Content

Abbreviations and Acronyms

AHP	Analytic hierarchy process
CBD	Convention on Biological Diversity
CCA	Climate change adaptation
GCM	General Circulation Model
GIS	Geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
MDG	Millennium Development Goal
McLMSA	Micro-level multi-sectoral approach
MsLMSA	Meso-level multi-sectoral approach
PIK	Potsdam Institute for Climate Impact Research
RPJP	Short-term development plan for Tarakan City
RPJM	Long-term development plan for Tarakan City
RTRW	General spatial plan for Tarakan City
SRES	Special Report on Emissions Scenarios by the IPCC
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VA	Vulnerability Assessment

Executive Summary

Vulnerability assessments (VAs) are central to shaping climate change adaptation decisions. They help to define the nature and extent of the threat that may harm a given human or ecological system, providing a basis for devising measures that will minimise or avoid this harm. Yet the wide variety of VA approaches can be confusing for practitioners, creating uncertainty about the "right" way to assess vulnerability. In an effort to provide some guidance on designing and conducting VAs, this paper reviews and compares VAs undertaken in Indonesia and Tunisia to distill key approaches, components and lessons. It begins with a general overview of definitions, approaches and challenges with conducting VAs, and then proposes a framework for analysing and comparing them. The framework looks at four components of VAs:

- **Framing** of the VAs: Where do we come from?
- **Process** of conducting the VAs: how does it work?
- **Inputs**: What is needed?
- **Outputs**: What does it tell us?

The framework is then applied to analyse the assessments carried out in Tunisia and Indonesia, from their respective framings of vulnerability to the outputs from the process. The report then concludes with observations on differences and similarities between the VAs, as well as lessons-learned that can inform the design and execution of future assessments.

Vulnerability assessments help to define the nature and extent of the climate change threat that may harm a given system, providing a basis for devising measures that will minimize or avoid this harm – i.e. adapt

1.0 Introduction

Now more than ever, the observed and anticipated impacts of climate change are recognised as a development challenge. Higher temperatures, changing precipitation patterns, more frequent and/or extreme events, and rising sea levels will change the distribution of water resources, the productivity of food systems, the spread of human and animal diseases, as well as strain critical infrastructure and networks, disrupting ecosystems, livelihoods and economies around the world. In an effort to minimise loss associated with climate change, decision makers at all levels – from households to national governments – are taking steps to adapt to its impacts, making adjustments in the way resources are managed so that development objectives can still be achieved.

Vulnerability assessments (VAs) are a central component of adaptation action. In short, they are important mechanisms for gathering information on "what to adapt to and how to adapt" (Füssel and Klein 2006: 5). They help to define the nature and extent of the threat that may harm a given system, providing a basis for devising measures that will minimise or avoid this harm. Vulnerability assessments for climate change adaptation build on work from several disciplines, which has served to both enrich and confuse their execution. While the different approaches, objectives and results of these assessments continue to be explored, debated, and documented in the scientific literature, policy makers – and the roster of researchers and consultants that support them – must carry on with the task of commissioning these assessments in order to facilitate adaptation planning. Yet the wide variety of VA approaches can be confusing for practitioners, creating uncertainty about the "right" way to assess vulnerability.

The **Inventory of Methods for Adaptation to Climate Change** (IMACC) is a global initiative that seeks to reduce confusion and uncertainty around adaptation planning. Financed by the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in collaboration with the Potsdam Institute for Climate Impacts Research, IMACC partners are working to apply and advance existing tools and methods for adaptation in its seven countries [1] and to facilitate South-South exchange through a Community of Practice (AdaptationCommunity.net). National inventories of methods are being set up to systematically compile and share established methods, tools and experiences in the four topics:

- climate services and information,
- vulnerability assessment,

[1] IMACC partner countries are: Grenada, India, Indonesia, Mexico, Philippines, South Africa and Tunisia.

- mainstreaming adaptation,
- monitoring and evaluation.

By making such methods more readily accessible, the project will strengthen the capacity of decision-makers and their technical support structure to undertake robust adaptation planning.

In an effort to contribute to the Inventory of Methods, the International Institute for Sustainable Development (IISD) undertook a comparative analysis of VAs in two of IMACC's partner countries – Indonesia and Tunisia – to distill key approaches, components and lessons for conducting VAs. The aim was to draw from practical applications and experiences in countries to offer guidance on designing and conducting VAs under different circumstances, and reduce uncertainty around finding the "right" approach to assessing vulnerability. The specific objectives of this work were threefold:

1 Articulate a common conceptual foundation and analytical criteria for conducting vulnerability analyses.
2 Give practical recommendations on choice of methods.

This report starts with some theory, but quickly goes into practical applications. It begins with a summary of definitions, approaches and challenges with conducting VAs, and then proposes a framework for analysing and comparing them. The framework is then applied to analyse the assessments carried out in Tunisia and Indonesia, from their respective framings of vulnerability to the outputs from the process. The report then concludes with observations on differences and similarities between the VAs, as well as lessons-learned that can inform the design and execution of future assessments.

2.0 Background: Climate change vulnerability assessments

2.1 Defining vulnerability and approaches to its assessment

Vulnerability is a term so intuitive yet vague that it defies a single, unified definition. Susceptibility, sensitivity, defencelessness, weakness, propensity to be wounded – these have all been used to describe vulnerability. In its most basic sense, vulnerability refers to a potential for being harmed by something, this 'something' often being referred to as a hazard, perturbation or stressor (Füssel 2007; Kasperson et al. 2005; Preston et al. 2011).

Vulnerability assessments (VA) are employed to systematically understand how socio-ecological systems may be affected by a source of harm. In climate change adaptation research, vulnerability assessments are used to understand how the effects of climate change may harm a given system, providing a basis for devising measures that will minimise or avoid this harm.

Finding a technical definition of vulnerability that lends itself to systematic analysis is challenging – i.e. what data and information can represent the potential for being harmed? Attempts at developing a one-size-fits-all definition of vulnerability have generally been dismissed and most researchers agree that it is more important to define the term within the context of a specific analysis than seek a single theoretical definition (Wolf 2011). Clarifying the '**what**' in vulnerability assessments – vulnerability **of what** (e.g. people, regions, ecosystems, economic sectors) and vulnerability **to what** (e.g. storms, sea level rise, temperature extremes – to use climate-related examples) – is a good first step to framing an assessment. Füssel (2007) identifies four aspects to describing a vulnerable situation:

✓ **System:** The social/socio-ecological system being threatened by a hazard (e.g. geographic region, economic sector, ecosystem)
✓ **Attribute of concern:** The valued feature within the vulnerable system that may be harmed by a hazard (e.g. specific crop , hydropower potential, human health)
✓ **Hazard:** Potentially damaging influence – perturbation, stress – that may adversely affect a valued attribute of a system

✓ **Temporal reference:** The time period of interest, including whether it is current vulnerability or future vulnerability that is being assessed.

Indeed, the more one can explicitly define the situation being assessed, the better one can focus (i.e. design, implement, and communicate) the assessment.

In addition to the specific systems and attributes being assessed, VAs are defined by different theories of what causes and constitutes vulnerability – i.e. factors that determine the potential for a system to be harmed. Broadly speaking, these factors are usually described as 'external' or 'internal' to the system being assessed and biophysical (e.g. climate, topography) or socioeconomic (e.g. demography, governance, cultural practices) in character (Füssel 2007; Preston et al. 2011). Different disciplines have combined these vulnerability factors to propose different conceptual approaches for explaining how vulnerability is shaped and therefore how it can be reduced. The approaches that have most directly influenced climate change adaptation research include the Risk-Hazard, the political economy, and the integrated approach (Eakin and Luers 2006; Füssel and Klein 2006; Füssel 2007):

I. **Risk-Hazard (RH) approach,** which describes vulnerability in terms of the consequences (losses) that might be expected when exposed people and/or property are sensitive to a particular (external) hazard. In other words, vulnerability is the outcome of a somewhat linear process where a hazard interacts with an exposed entity, and the sensitivity of the entity to the given hazard/stressor leads to consequences (impacts), as depicted in Figure 1 (Turner et al. 2003; Preston et al. 2011).

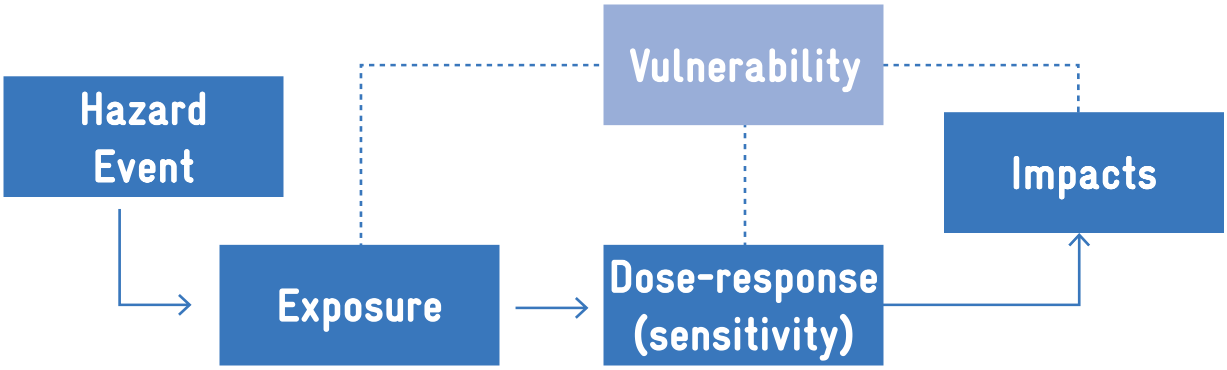


Figure 1: Vulnerability in the risk-hazard approach (recreated from Tuner et al. 2003)

While 'vulnerability' is not usually explicitly defined its realisation is the residual or net impacts of a hazard after adaptive measures are implemented (Eakin and Luers 2006; Kelly and Adger, 2000; O'Brien et al., 2004).[2]

Confusingly, the risk-hazard approach is associated with the formula: **Risk = Hazard * Vulnerability,** which implies that vulnerability is not an outcome, as stated above, but a factor that shapes an outcome, in this case 'risk,' (or impacts, expected losses of a hazard.) However, vulnerability in this formulation denotes a hazard-loss or dose-response relationship, which is typically captured by the term 'sensitivity' in IPCC terminology. Thus, the formula could be revised to I**mpact = Hazard * Sensitivity**, which is along the lines of what is expressed in Figure 1.

Within the context of climate change, the risk-hazard approach is typically associated with '**top-down**' or scenario-driven vulnerability assessments, where global climate projections are applied (sometimes downscaled) as the 'source of harm' to assess impacts on physical or natural exposure units, such as watersheds, infrastructure (Dessai and Hulme 2004). Thus, a VA drawing heavily from the risk-hazard approach will focus on the expected net impacts of climate change, including their distribution over time and space; it is useful for describing the extent of the problem, whether in terms of financial costs, ecosystem damage, or human lives lost (Kelly and Adger 2000; O'Brien et al. 2004; Füssel 2007).

[2] The understanding of vulnerability as both sensitivity to and impacts of hazards leads to the 'conflation of causal processes and conditions with outcomes', which can be confusing (Eakin and Luers 2006: 369)

II. **Political economy approach**, which was developed in large part in response to criticisms of the risk-hazard approach, focuses on the socio-economic processes that lead to differential exposure, impacts, and capacities to deal with impacts. This focus on human agency and capacity is important, as they can amplify or reduce impacts of hazards. Vulnerability in this approach is seen as a dynamic, *a priori* condition, determined by sociopolitical, cultural and economic factors.

Climate change VAs drawing from the political-economy approach tend to be characterised as '**bottom-up**', since the unit of analysis is typically smaller and more localised, such as households or communities. The emphasis is more on current and short-term time scales, where vulnerability to current climate variability serves as a starting point for understanding vulnerability to future climate conditions. Unlike risk-hazard style assessments, which describe to what systems are vulnerable, what kind of impacts may occur, when and where, VAs using a political economy approach will focus their analyses on why systems or populations are vulnerable (i.e. drivers of vulnerability) and why some groups are more affected by climate hazards than others (i.e. differential vulnerability) (Eakin and Luers 2006; Füssel 2007; Cutter et al 2009). In so doing, one can identify measures for reducing vulnerability, including the necessary capacity and barriers to the implementation of such measures.

III. **Integrated approach:** The Intergovernmental Panel on Climate Change (IPCC) draws from both of the previously described approaches, where vulnerability is defined as:

The degree to which as system is susceptible to, or 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 variation to which a system is exposed, its sensitivity, and its adaptive capacity (McCarthy et al., 2001).

Here the potential for a system to be harmed is shaped by its exposure to (external) changes in climate (i.e. temperature, precipitation, extreme events) and its (internal) sensitivity to such changes and capacity to moderate or recover from the impacts of such changes. While the integrated definition of vulnerability is a tribute to the multidisciplinary nature of the problem, operationalising it – i.e. identifying appropriate metrics for each of exposure, sensitivity and adaptive capacity, and combining them to construct a compelling policy narrative on how to adapt to climate change – remains challenging (Preston et al. 2011).

Thus, defining the situation being assessed, as well as the conceptual understanding of how vulnerability is shaped is important to designing and ultimately communicating the results of a VA. The decision of which conceptual approach to vulnerability to use in undertaking an assessment will be shaped by a number of factors including the specific policy and research questions being asked, the disciplinary training of those undertaking the analysis, as well as available resources and capacities. More important than selecting one conceptual approach over another is being clear and upfront about it in the analysis, i.e. reflecting on how the chosen approach shapes the results.

2.2 Purposes of vulnerability assessments

In addition to specifying the 'what' that is being assessed, the purpose and objectives – i.e. the 'why' – of a VA must also be clearly articulated since there are a range of reasons for undertaking an assessment, each of which play a role in shaping its design and execution. These days, the overarching goal of climate change vulnerability assessments is to inform policies that will facilitate adaptation. But this is not always the case – the purpose of VAs within the context of climate change has evolved alongside developments in science and policy. Different authors have identified a range of purposes for assessing vulnerability (Füssel and Klein, 2006; Hinkel, 2011; Patt et al. 2009):

- **Setting mitigation targets:** Evaluating the impacts of climate change on a given system under different emissions scenarios in order to devise targets and timelines for avoiding "dangerous anthropogenic interference with the climate system" (Article 2 UNFCCC).
- **Allocating resources**: Identifying people, places and sectors that may be most affected by climate change so that research activities and relevant (financial and technical) assistance can be channelled accordingly. Assessments for this purpose lend themselves to comparison and prioritisation exercises;
- **Designing adaptation policies:** Understanding the vulnerability and capacity of socio-ecological systems to

(current and future) climate in order to devise specific strategies that will minimise its exposure and sensitivity and/or increase its adaptive capacity.

- **Monitoring adaptation policies:** Evaluating whether or not specified adaptation policy is actually reducing vulnerability. This particular objective is less common, as the development of adaptation policies is nascent and changes in vulnerability would only really be observed in the distant future.
- **Raising awareness about climate change:** Highlighting the causes, effects, and ways to address climate change through the identification of people, places, sectors that may be affected by it. This is usually a secondary objective in undertaking a VA and usually targeted at decision makers who tend to have a limited understanding of climate change.
- **Conducting scientific research:** Understanding vulnerability is about testing and refining methodologies, understanding system functioning, developing a better theory of vulnerability, and seeing if it can be applied elsewhere. Similar to the previous point, benefits to the scientific community are more likely to be cited as secondary to the policy objectives.

The first four decision-making contexts are more often cited and currently most relevant to climate change policy discussions, with monitoring and evaluation being a relatively newer area of interest among decision-makers. VAs for setting mitigation targets and allocating resources are often supported by top-down, impacts-driven assessments – i.e. understanding of the extent and severity of impacts to shape the scale and urgency of mitigation action, or understanding the distribution of the burden of impacts to dictate resource flows. But impact-driven assessments are not usually suited to. the development of adaptation policies for a number of reasons, including the uncertainty about future climate and socio-economic conditions, misalignment of scales between climate models and adaptation decision-making, the narrow range of adaptation options considered in most impact models, and limited consideration of the adaptation process itself – which may have important obstacles that prevent the uptake of adaptation measures – as well as the broader development policy context (Burton et al. 2002; Carter et al. 2011). Given this, the design of adaptation policies should be informed by assessments that account for current conditions and development priorities, generate information that is usable for more local-level decision-making, and consider the full range of socio-economic and political factors that not only shape people's vulnerability to current and future climate hazards, but also incentivise or impede adaptation action.

Moreover, vulnerability assessments can support two distinct but related processes for developing adaptation policies (Preston et al. 2011):

i. **Problem orientation**, where the aim is to build an understanding of the nature of vulnerability, including its magnitude and extent, causes and effects, as well as the institutional and governance context within which it exists. Methodology development and testing can also be included in this category (i.e. include secondary objective of conducting scientific research.)

i. **Decision-support**, where the aim is to identify and select strategies for managing vulnerability. More recently, it has also been acknowledged that VAs can provide a basis for monitoring and evaluation of adaptation.

Assessments that focus on problem-orientation use a range of methods for gathering information about current and future vulnerability, impacts, and adaptive capacity; assessments that focus on decision-support incorporate methods for identifying and evaluating adaptation options and/or methods for integrating assessment results into relevant policies.

In many vulnerability assessments, the aims of problem-orientation and decision-support are often conflated under the assumption that problem orientation will inevitably contribute to decision-support – i.e. describing and explaining vulnerability will lead to policy decisions to reduce it. But this understanding of policymaking is oversimplified and inaccurate. Policy processes are often complex, non-linear, and 'messy' and lack of information is not necessarily the key barrier to decision-making (Naess et al. 2011). Thus, assessments that truly aim to provide decision support should not only include steps for identifying adaptation measures and evaluating them against a set of criteria, but also need to be generated and communicated in such a way that they have actual policy impact.

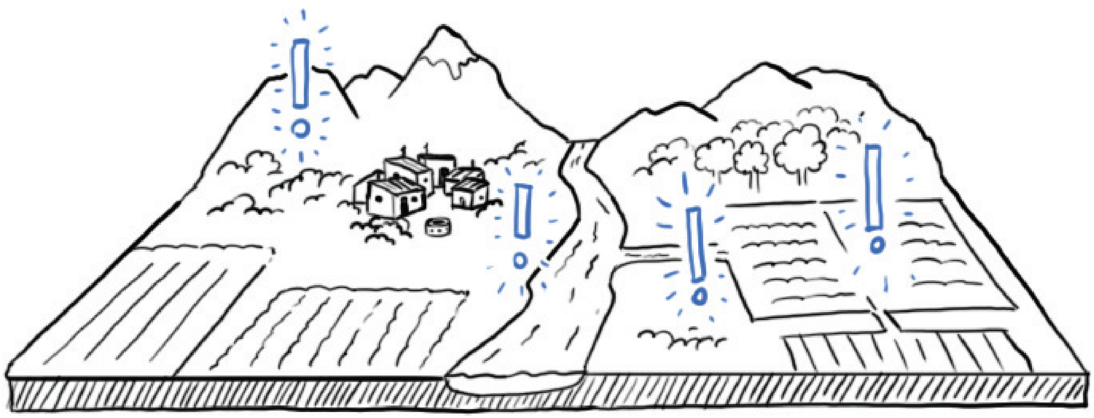
Finally, in addition to developing appropriate and robust adaptation actions, decision-makers are becoming increasingly interested in measuring their effectiveness. The questions of 'what works' and whether particular actions have actually supported adaptation are engendering the development of monitoring and evaluation (M&E) frameworks and tools. While this particular decision-making context is relatively new, the role of VAs in supporting M&E of climate adaptation is clear – they can provide a baseline against which adaptation effectiveness can be measured, whereby vulnerability before and after an intervention would point to the success of a given intervention. As expected, the challenge is in the details, where those establishing the M&E framework must clearly

articulate their 'theory of change' regarding how vulnerability is reduced by an adaptation action, but also select appropriate metrics or indicators that characterize the vulnerability of the system in question (Spearman & McGray, 2011).[3]

2.3 Inputs: Data and information for vulnerability assessments

Because climate change vulnerability assessments look at how future climate may affect coupled socio-ecological systems, they typically require some information on future climate conditions for a defined area and a combination of quantitative and qualitative data and information to characterise how socio-ecological systems may be affected. The level of detail and degrees of emphasis placed on different types of information largely depends on a number of factors – many of which were described in the previous section – including the definition of vulnerability being used, the vulnerable situation being assessed, the scope and purpose of the assessment, as well as the availability of resources.

An assessment that is structured around a specific definition of vulnerability with identified components, such as the IPCC definition where vulnerability is a function of exposure, sensitivity, and adaptive capacity, will influence the kind of information sought. Continuing with the IPCC definition as an example, exposure, sensitivity and adaptive capacity would themselves need further defining, then appropriate proxies might be identified for each, and information for these proxies gathered accordingly. The selection of proxies would depend on the system, attribute, climate hazard, and timeframe being considered in the assessment. Thus, understanding exposure could mean finding information on rainfall distribution in 2030 or sea level rise for 2050 for a given area (i.e. the system); sensitivity might be inferred through attributes such as crop yields (for subsistence agricultural households) or river flow (for hydropower stations) under future climate; adaptive capacity could be captured through socio-economic census data (e.g. access to electricity, water, highest education level attained, disability) or other human development indices, such as UNDP's Human Development Index. The real challenge is of course combining the different types of information to discern an overall picture of vulnerability for a given situation. Further examples of information that could be used in a VA are presented in Table 1.



[3] For a guidebook on designing adaptation projects and results-based monitoring systems see Olivier & Leiter, 2012.

Table 1: Examples of data and information that can be used in a vulnerability assessment

Vulnerability aspect	Examples of information to describe or represent the vulnerability aspect
Hazard Potentially damaging influence – perturbation, stress – that may adversely affect a valued attribute of a system	● Quantitative (computer-generated) models that represent projected changes in precipitation and temperature at different scales ● Quantitative (computer-generated) models used to understand the consequences of temperature and precipitation changes, such as droughts, floods, sea level rise, changes in the occurrence of pest and disease outbreaks ● Qualitative information, such as expert judgement and stakeholder consultations, can enhance or validate information about local-level climate hazards
Exposure The presence of people and assets in areas where hazards may occur (Cardona et al 2012)	● Hazard maps depicting the location and distribution of people, infrastructure, ecosystems in areas that are or will be affected by hazards
Sensitivity The degree to which people and assets are affected, either adversely or beneficially, by climate variability or change (IPCC 2007)	● Database information on previous impacts of hazards – e.g. crop loss, economic loss, human and animal deaths, ● Models to estimate the impact of past or future climate hazards on crops, livestock, ecosystems, etc. ● Maps depicting the location and distribution of fragile or poor quality housing, land, infrastructure. as well as degraded ecosystem and marginal populations (while these may depict exposure at a local level, aggregated they can characterize sensitivity at a higher spatial – i.e. district, country – level ● Local observations, experiences with climate hazards
Adaptive Capacity The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences (Millennium Ecosystem Assessment 2005)	● Development data and indices (population, inequality, debt, economic productivity, trade flows, education levels, foreign direct investment, disease patterns, etc.) ● Ecosystem goods and services ● Census data, household surveys ● Institutional capacity assessments ● Local coping and adaptation strategies

Assessments that see vulnerability in terms of consequences or impacts – i.e. using a Risk-Hazard approach – tend to draw heavily from quantitative (biophysical and econometric) and top-down sources of information, including computer-generated climate projections and impact models. Here, a useful distinction can be made between indicator-based approaches and model-based approaches, the latter requiring more data and analysis, whereas the former relies on available proxies. Located somewhere between indicator-based and model-based approaches is the use of impact chains, where cause-effect relationships between different components of a systems are depicted. This approach has been used in Germany, informing an indicator system for the German Adaptation Strategy. It builds on impact chains, thus it presents very simple models indicating the relations between components. These relationships could help identify critical factors of vulnerability (which, in turn, could be used as proxy indicators).

Those using a political economy approach tend to use more qualitative (socio-economic, anthropological), bottom-up information, particularly when the analysis is more localised at the community or household level. Information of this nature is critical to understanding the capacities that people have at particular locations, how they are utilized to reduce vulnerability, and what more can be done to reduce their vulnerability in the face of further, future climate change. Table 2 presents a simple typology of VAs according to these aspects.

Table 2: Simple typology of VAs according to modelling approaches and respective inputs

Approach	What?	Inputs -Typically used data	Inputs - Methods	Inputs - Time and effort required
Quantitative, model-based approaches	Modeling the system in view of climate change	Meteorological/ climate data, biophysical	Climate/bio-physical Modeling	Usually high
Impact chain approaches	Deriving a qualitative model of the system	Can go potentially without data, or subsequent modeling	Expert judgement, or quantitative modeling	From low to high
Indicator-based approaches	Representing a system based on proxy-indicators	Socio-economic, biophysical, meteorological/ climate data	Literature review; statistical analysis	From medium to high
Bottom-up approaches	Describing the broader development context/ stressors on livelihood, climate only one of them	Historical data of weather & hazard impacts, livelihood data	Participative, qualitative (e.g. consultations, focus groups)	From low to high

There is a growing interest and effort to use both qualitative and quantitative information at multiple scales for more integrated assessments, and some guidance has been developed accordingly (Bizikova et al. 2011).

Despite great efforts at clearly defining vulnerability and the theory behind how it is shaped, the ultimate determinant of what information is used in a VA could be availability and capacity. In many developing countries, high quality, reliable information simply does not exist – either it has not been systematically gathered and documented, or it has but not extensively or consistently enough for the purposes of a particular VA. In other cases, the information may exist but be difficult to access; it may be managed by government departments or academic institutions that are not prepared to share such information or will only do so at reasonable cost. Finally, the information may be accessible, but it is not in a format that can be easily understood or analysed; the level of technical expertise and time required to verify and translate data and information may be a barrier to its application in a VA.

2.4 Outputs from vulnerability assessments

Assessments can yield a range of knowledge and information products, depending on the target audience. The most common output from VAs is research reports, summarizing the assessment methodology, results, and relevant policy recommendations. These reports can go on to inform the development of policy planning processes and documents, including those linked to the UNFCCC such as National Communications, National Adaptation Programs of Action (NAPAs), National Adaptation Plans (NAPs), or a country's own national climate strategy or action plan. As part of an effort to feed into the processes to develop these policies, VA research reports may be further synthesised and translated into derivative products targeted at specific audiences, such as policy briefs for decision-makers, or online resources for an interested and/or informed public. This translation of research into policy and public awareness is particularly challenging and therefore often involves engaging intermediaries who are familiar with the substance of VAs and the a complex set of issues as well as the awareness, literacy, and needs of the target audience.

Many VAs, particularly those focusing on ecosystems and natural resources, are usually accompanied by maps that depict the temporal and spatial distribution of different aspects or determinants of vulnerability – i.e. hazards, biophysical features or processes, socio-economic conditions, etc. Some VA methodologies overlay several different vulnerability factors to identify 'hotspots' or those areas that are especially vulnerable and therefore a policy or programming priority. While the use of vulnerability maps can be instrumental to supporting spatial planning and public awareness, they may introduce as many questions as they answer and lead to ineffective decision-making (Preston et al. 2011). Unless clearly explained, both in terms of the processes and methods behind the mapping, as well as the biases and limitations of what they depict, users may misinterpret or over-emphasize their contribution to adaptation decision-making. For example, a map with indicators of adaptive capacity may depict a particular population as having higher capacity to manage climate risk, leading to a false sense of security. But other intervening variables, such as multiple and interacting stresses (such as environmental degradation, disease outbreaks, commodity price volatility) may converge to overwhelm this capacity and leave the population worse off than those in other areas who were depicted as having lower adaptive capacity.

Turning VA reports and maps into policy influence remains a challenge. Because VAs are often undertaken by a mix of technical experts who may have limited understanding or interest in the political implications of their work, and the VA process itself can end up being a more resource-intensive and compartmentalised than expected (see next section), there is always a risk that the final outputs are submitted and practically abandoned, or its results not rendered usable for policy action. Patt et al. (2009) identify three criteria for increasing the likely policy impact of assessments:

i. **Salience:** The assessments must present information at temporal and spatial scales that match the temporal and spatial scales of particular decisions to be taken.

ii. **Credibility:** The information in the assessments must be packaged and delivered in a way that is believable to the target users. Personal and professional associations to key constituencies are often used to bolster credibility.

iii. **Political legitimacy:** Related to the previous point, information is more likely to be accepted if it comes from a source perceived to have social and political legitimacy; oftentimes, this can be linked to a source's perceived neutrality and objectivity. Universities and research institutes can be important in this regard, as they may be seen as less biased than, for example, for-profit enterprises or advocacy organisations.

Thus if policy relevance is the stated goal of a VA, the 'translation' process described above – i.e. of turning VA results into derivative products for different target users – must be accounted for in the design and execution of an assessment.

2.5 Process of conducting vulnerability assessments

Vulnerability assessments build on the knowledge and methods applied in several disciplines, combining different types of inputs to provide a range of outcomes. Participation is an integral part of conducting VAs, as it helps to ensure the relevance and legitimacy of identified vulnerability-reduction measures and therefore their successful implementation (Füssel 2007; Schröter et al. 2005). Participation can include engaging a diverse range of stakeholder groups, including sectoral and disciplinary experts, local stakeholders whose livelihoods are threatened by hazards, decision-makers involved in designing and implementing actions at different scales, and funding agencies that may have specific requirements on how the VA should be conducted including time frames, locations, applied methods and involved stakeholders. Given the complexity both in the applied methods and in the diversity of stakeholders that can be engaged, coordination is critical to making the process of conducting VA effective.

Schröter et al. (2005) propose eight key steps to conducting a VA. The steps emphasize the dynamic nature of vulnerability and the need to focus on both human and biophysical subsystems over different temporal scales (Füssel 2007). The key steps can be presented as follows (Schröter et al. 2005):

1 Define study area together with stakeholders to ensure that the chosen area reflects stakeholders' concerns and therefore increase their ownership of assessment results.
2 Get to know place over time to develop knowledge of the stakeholders, key trends and challenges in human and environmental systems, including the drivers of vulnerability.
3 Hypothesize who is vulnerable to what to narrow down the key attributes of concerns, hazards and frame the data collection, applied methods and outputs accordingly.
4 Develop a causal model of vulnerability to connect the attributes of concern in a system to identified hazards, highlighting drivers and impacts, and linking them to stakeholders' views on the situation. The model might include factors external to the system, such as commodity price fluctuations, as well as factors within the system, such as local power relationships.
5 Find indicators for the elements of vulnerability to measure key capacities, sensitivities, extent of the hazards within the defined focus of the VA.

6 Operationalize model(s) of vulnerability, identifying the data, models, qualitative approaches needed to assess the vulnerability as hypothesised in the model; in some cases it may be possible to operationalize the model through a single numerical model that uses the indicators as input variables.
7 Project future vulnerability to assess how vulnerability might change with progressing climate change, but also across a range of scenarios using the relevant socio-economic, environmental variables.
8 Communicate vulnerability creatively to reach both the decision-makers and stakeholders that need to implement vulnerability-reducing measures.

In a recent review of 45 VAs, Preston et al. (2011) pointed out the shortcomings associated with VA processes, especially when it comes to defining specific goals for the VA, paying enough attention to the up-take of results by decision-makers, and maintaining a balance between using top-down and bottom-up approaches. To address these challenges they emphasise the importance of (i) clarifying how a VA will be used and, more importantly, the specific ways in which the outputs can be used by decision-makers to avoid 'questionable assumptions regarding the utility of information for decision-making', (p. 20). Writing a synthesis report or producing a sophisticated map will not inherently benefit policy-making, as it is not a 'linear outcome of intelligence gathering' (ibid p. 5) they must be targeted and contextualised to the particular decision being made; and (ii) ensuring that both biophysical and socio-economic determinants of vulnerability are represented through combining the use of top down, often quantitative, information and bottom-up, qualitative information.

2.6 Challenges with vulnerability assessments

Considerable challenges remain in designing, implementing and comparing vulnerability assessments, complicating efforts to provide simple guidance on VAs. Oftentimes, stakeholders who are tasked with undertaking a VA can feel like they are starting from almost nothing, trying to navigate the different frameworks, methods and tools for understanding what climate change will mean for a given system. Some of the challenges in designing and conducting a VA include:

- ✓ **Terminology:** As mentioned above, efforts at defining concepts like vulnerability, exposure, sensitivity, risk, and impact, as well as articulating the relationships between them, can be a daunting process; with so many similar, but slightly different, interpretations of such concepts, it can impede the important task of clearly framing a VA.
- ✓ **Metrics:** A topic worthy of its own detailed analysis, the process developing and/or selecting indicators to represent a vulnerable system is as much an art as it is a science. Complex systems and processes are difficult to capture through a manageable number of indicators, and gaps and uncertainties are inevitable. As such, the process and rationale for selecting specific indicators for a VA should be clearly explained so that the limitations of the analysis are made clear.
- ✓ **Data and information availability:** Already mentioned under the 'inputs' section, the availability of high quality, usable data and information can be the biggest limiting factor to even a well-designed VA. Whether it is access to key policy documents (e.g. district development plans), critical gaps in time series data (e.g. historical rainfall), or gathering local observations (e.g. through community consultations), the challenges associated with collecting such information should be explained and accounted for in an assessment.
- ✓ **Multi-disciplinary analysis:** Because VAs are analyses of socio-ecological systems, they call on technical expertise from a range of disciplines that may not be accustomed to working closely together. Exacerbated by the tendency to assemble VA teams of individual technical consultants, assessments can become compartmentalised, comprised of mini, specialised, assessments focusing on a particular component of the overall causal model. The challenge is then weaving together the various components, emphasising their respective contributions to the model appropriately, and constructing an overall narrative of how a system may be affected by climate change and what can be done to minimize loss and damage.
- ✓ **Coordination:** Closely linked to the previous point, the process of assembling, managing, and synthesising analyses from different disciplines, at different scales, and involving a wide range of stakeholders throughout the process, requires significant coordination; having a dedicated focal point or agency for the process that tries to foster regular communication between the various actors, mobilize and deploy resources efficiently, and maintain an overall picture of the process, and what it is trying to achieve, are key to conducting a successful VA.
- ✓ **Comparability of results:** Due to the context-specific nature of VAs, their results can be difficult to compare. This links back to the issue of defining the purpose of a VA – comparability is mostly desired if the aim of a VA

is to identify populations, sectors, or regions that are especially vulnerable so that resources can be allocated accordingly; or if VA is meant for monitoring purposes; comparability is likely less of a priority if the aim is to devise vulnerability-reduction or adaptation strategies for a given system. Yet even when resource allocation is the purpose, unless VAs are designed using the same framing, conducted using similar inputs over the same period of time, there may be too many other intervening variables – e.g. change in government policy, global or regional shifts in commodity prices, the introduction of a particular technology – that explain differences and similarities in vulnerability.

2.7 Framework for comparing vulnerability assessments

Because vulnerability is so context-specific, it can be difficult to compare VAs and draw meaningful conclusions on how vulnerability is shaped and reduced in the face of climate change. But as Polksy et al. (2007) note, addressing this comparison challenge is important if "the vulnerability perspective is to represent not only an appealing conceptual framework but also a meaningful catalyst for empirical research" (473). For the purposes of this analysis, the VAs from Indonesia and Tunisia were reviewed and compared not necessarily to draw general conclusions about vulnerability to climate change, but to understand the similarities and differences in how vulnerability is being conceptualised and assessed in countries that are actively developing climate change adaptation policies. The VAs were 'unpacked' and their respective components categorized under the four themes based on the preceding discussion, presented in Box 1.

The VA components presented above are not listed chronologically and do not represent the steps in a VA process; rather, they serve to categorize the key considerations that must be elaborated when designing a VA. If you map these components against Schröter et al. (2005)'s VA steps you can begin to get a sense of where and when in the process you will be able to define these components (see Table 3):

Box 1: Framework components of vulnerability assessments

Case study: Disaster & Climate Risk Management in Agriculture Project – Bangladesh

1. Framing: How vulnerability is understood, interpreted, and defined. This involves specifying:

✓ Definition of vulnerability, including its components and how it is shaped
✓ The vulnerable situation being assessed – i.e. the system, attribute of concern, hazard, and timeframe for the VA
✓ The purpose and/or objective(s) of the VA, what it seeks to achieve
✓ The target audience for the VA results

2. Input: The types of data and information used for the analysis.

✓ Data and information sources
✓ Methods and tools used for data and information gathering and analysis
✓ Consideration of uncertainty

3. Output: The outputs and – if possible – the outcomes of the analysis, such as:

✓ Knowledge product (e.g. maps, tables)
✓ Ex-post impact chains
✓ Identified thresholds, where applicable
✓ Metrics/indicators
✓ Results and recommendations

4. Process: The 'who' (i.e. stakeholders) and 'how' (steps followed) of the assessment

✓ Main steps of the VA
✓ Actors, partners, institutions and their roles
✓ Level of participation
✓ Coordination

Table 3: Framework components of VAs linked to Schröder et al.'s (2005) steps in conducting a VA.

VA step	VA component
Define study area together with stakeholders	Framing: Select the spatial and temporal scale of the assessment Process: Initiate engagement and security participation with collaborators and intended beneficiaries/users of VA results Output: Think about the formats in which beneficiaries/users should receive results, including messaging, language/jargon, timing,
Get to know place over time	Framing: Study context to understand the socio-ecological dynamics that may influence vulnerability Input: Gather information through literature reviews and consultations on the dynamics that may influence vulnerability Process: Continued engagement with stakeholders
Hypothesize who is vulnerable to what	Framing: Select the climate hazard that will be analysed, along with the people, assets, and/or ecosystems services that may be harmed by the identified hazard. Input: Identify the data, information, analytical tools, time, and money needed to undertake the analysis. Defining this may further refine the focus of the assessment.
Develop a causal model of vulnerability	Framing: Elaborate a model explaining factors, and relationships among the factors, that lead to vulnerability. Input: Consultations Process: Stakeholders should be involved in developing, fine-tuning, validating the causal model.
Find indicators for the elements of vulnerability	Input: Metrics to characterise different parts of the causal model. Process: Consult with stakeholders for suggestions on metrics; ensure indicators are understandable by stakeholders; decision on what is quantifiable and what must be omitted – i.e. defining biases and limitations
Operationalize model(s) of vulnerability	Input: Weight and combine indicators to produce a measure of vulnerability; Overlay different indicators on a map Process: Coordination among researchers; engagement with stakeholders to validate vulnerability measures
Project future vulnerability	Input: Scenarios of the vulnerability variables reflecting trends and expert opinion. Clear explanation of assumptions and uncertainties around the scenarios. Process: Validation of the scenarios with appropriate stakeholders
Communicate vulnerability creatively	Output: Products from the VA, such as reports, maps, websites, photos, video/film, etc. Process: Communicate outputs to stakeholders, building on relationships and dialogue sustained throughout the VA process

In addition to providing a framework for comparison, the four categories and their respective elements presented in Box 1 may also serve as a starting template for designing VAs – i.e. stakeholders interested in conducting a VA can use the categories to define and focus the analysis, ascertain information needs and gaps for conducting the VA, identify experts and other key stakeholders that should be consulted, think about how the process will be coordinated, and the results presented and communicated.

3.0 Tunisia: Vulnerability assessments of selected agro-ecological systems

As part of a project supporting the implementation of the United Nations Framework Convention on Climate Change (UNFCCC), GIZ Tunisia and partners have been conducting five vulnerability assessments in different agro- and eco-systems of Tunisia at national and regional levels since 2009. The focus on ecosystems is aimed at creating synergies between the UNFCCC, the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD). IISD reviewed four assessments focusing on the impacts of climate change on (1) various ecosystems at national level (finalized), (2) grassland ecosystem at regional level (not finalized), (3) oak forest at regional level (not finalized), and (4) olive production at regional level (finalized) under present and future conditions.

3.1 Framing of the Tunisian VAs

The four assessments from Tunisia were conducted in two different stages. First, a general VA was conducted to identify the most vulnerable ecosystems at the national level. This was then used as a basis for undertaking more detailed assessments in grassland, oak forest, and alfa steppe systems within the country. The stated goals of the national, grassland, and oak VAs were to support both problem-orientation (including methodology development) by identifying the impacts of climate change on specific agro-ecological systems, and decision-support, by identifying adaptation options. The audience of the VAs was a combination of researchers, planners and decision-makers at national and regional levels. The vulnerability assessment of olive production was conducted in a different context where the aim was to pilot the "climate impact chains" methodology developed jointly by the Potsdam Institute for Climate Impact Research (PIK) and GIZ.[4]

Not all reports explicitly define the term vulnerability. Vulnerability was often measured as a function of the biophysical sensitivity of the system; in the case of the grassland and olive production assessments, vulnerability was a combination of biophysical sensitivity and some socio-economic factor/stress (e.g. overgrazing). In the VA of oak forest units, the effects of multiple stressors (e.g. fire, pastoral pressure) were included in the treatment of vulnerability, where areas experiencing one or more of these stressors could be understood as being more vulnerable to climate change.

The adaptive capacity of the system or specific attribute of concern within each VA was not really taken into account, largely due to time and resource constraints. For example, the team working on the oak forest VA would have liked to have found information on the presence of groundwater resources, as oak trees that have access to more groundwater supplies will be better able to survive prolonged droughts. The information exists at national level but is costly to access. However, the adaptive capacity of the broader agro-ecological system was assessed for the grassland and oak forest units by reviewing relevant existing initiatives and capacities on climate change adaptation. These two assessments also included an analysis of the indirect, socio-economic impacts of climate change on ecosystems services using the approach developed by the Millennium Ecosystem Assessment.

The overall approach used in all four assessments was top-down, often using different modeling tools combined with GIS to assess the direct impacts of future projected changes in temperatures and precipitation on the ecosystems. The studies tended to put more emphasis on the biophysical and environmental determinants of vulnerabil-

[4] For more information refer to http://cigrasp.pik-potsdam.de/about/impactchains

ity than on the socio-economic drivers. As mentioned earlier, the VA of the cork oak ecosystem was different from the others since it considered multiple stressors. The framing of the analysed Tunisian VAs is summarised in table 4.

Table 4: Framings of the Tunisian vulnerability assessments

Assessment	Purpose	Vulnerability	Approach	Audience
Ecosystems (National)	Identify ecosystems vulnerable to CC at national level	Vulnerability of ecosystems in Tunisia to climate change in 2000, 2020, 2050 Definition in report: IPCC (E, S, AC) In practice: V = biophysical sensitivity	Top-down, impacts driven VAs. Very little on adaptive capacity	Researchers, planners and decision-makers at regional and national levels
Grasslands (Sub-national)	Provide inputs into the development of adaptation measures/ plans for vulnerable ecosystems	Vulnerability of grassland units in the Medenine governorate to climate change today and in 2020 – 2050 V = biophysical sensitivity + anthropogenic perturbation (i.e. overgrazing)	Strong influence of RH approach where vulnerability is an outcome, largely attributable to a system's biophysical sensitivity to a hazard, overlaid with socio-economic stressor/factor.	
Oak Forest (Sub-national)		Vulnerability of oak forest units in 3 governorates to climate change today and in 2020 – 2050 V = biophysical sensitivity + stressors (fire and pastoral pressure)	The 3 detailed VAs incorporated socio-economic parameters in their definition of vulnerability	
Olive Production (Sub-national)	Develop methodological approaches for studying the vulnerability of ecosystems to CC	Vulnerability of olive production to climate change in Medenine governorate today and in 2020 – 2050 V = biophysical sensitivity + socio economic parameter (land tenure)		Mostly researchers

3.2 Inputs: Data and information used for the Tunisian VAs

The data used in the assessments were mainly quantitative data accessible at national and regional levels (climate, soil, land use, livestock, etc.). Other data accessed at the international level included climate data (WorldClim) and elevation data. Based on the data available in-country, the different methods used are relatively easy to replicate.

The modeling tools used varied according to the exact focus of the VA. The VA of ecosystems at the national level applied the ecological niche-based approach using the MAXENT software based on the Maximum Entropy Method to identify the most vulnerable ecosystems at national level and to assess the impacts of climate change on the grassland ecosystem at regional level. This approach provided a general understanding of whether or not certain species could exist in particular locations under certain conditions. MAXENT has the advantage of being relatively easy to use. The WorldClim database[5] already compiles all 19 MAXENT-required parameters into gridded cells for all locations on earth. However, it should be noted that the IPCC, among other sources, is largely critical of the use of the ecological niche based approach[6]. While this approach may be useful for higher-level, first-cut assessments, they should not necessarily be used to draw conclusions about specific climate change impacts, nor should they form the basis of adaptation decision-making, especially at sub-national levels. More detailed research is required. Because ecological niche models provide very coarse results, the treatment of error is all the more crucial.

In contrast to the ecosystem and grassland VAs, the assessment of cork oak forests did not use any specific modelling tools but focused on overlaying and weighting (based on expert judgement) various vulnerability factors (i.e., sensitivity to forest fire, overgrazing, and hydrological deficit) using GIS to classify forest units into different levels of vulnerability. The assessment of olive production used the water balance model, BUDGET, to assess the impact of climate change on olive trees. This appears to be a good choice of model as it examines water storage in the root zone and how trees will be affected by reduced water availability. However it cannot model how yields will be impacted.

Table 5: Inputs for the Tunisian vulnerability assessments

Assessment of	Data & Info Sources	Scenarios/Projections	Methods & Tools	Uncertainty
Ecosystems (National)	Global: Climate data from Worldclim, elevation, soil National: Vegetation, soil colour, population	Climate: HADCM3 A2 and B2 Socio-economic: Population growth projections for 2020 and 2050 considered	Habitat model MAXENT (Maximum Entropy Method)	Moderate
Grasslands (Sub-national)	Global: Climate data from WorldClim, elevation National: Climate; Soil depth, texture, salinity; vegetation zone maps; livestock density	Climate: HADCM3 A2 and B2 Socio-economic: No	Habitat model MAXENT (Maximum Entropy Method)	Weak, almost non-existent
Oak Forest (Sub-national)	Global: climate data from WorldClim National: National forest inventory; bio climatic maps, local climate and fire data;	Climate: HADCM3 A2 and B2 Socio-economic scenario using projections for: population, livestock, forest ageing	Weighting and mapping different vulnerability factors – forest fire sensitivity, overgrazing, hydrological deficit	Weak: "Results should be interpreted with caution..."
Olive Production (Sub-national)	Global: historical climate from www.tutiempo.net/en/ National: Climate; soil, ecozone, land use and land tenure maps;	Climate: HADCM3 A2 and B2 Socio-economic: No	Hydrological model BUDGET	Weak, almost non-existent

5 It should also be noted there is likely considerable error in the WORLDCLIM database of climate parameters used in those studies. If the error in the temperature prediction is greater than the predicted magnitude of climate change increase, it is not possible to reliably estimate climate change impacts. http://www.worldclim.org/

6 For example, it is discussed in different chapters of the IPCC Fourth Assessment Report (2007) including the "Food Fibre and Forest Products" chapter (page 287), the "Ecosystems, their Properties, Goods and Services" chapter (page 218), and the "New Assessment Methods and the Characterisation of Future Condition" chapter (page 137). Other recent examples include Wiens et al. 2009, accessible at http://www.pnas.org/content/106/suppl.2/19729.full.pdf; and Challinor et al. 2009, accessible at http://jxb.oxfordjournals.org/content/60/10/2775.full.pdf+html.

All studies only consider one possible future climate using the Global Circulation Model HADCM3 with two scenarios A2 and B2. Socio-economic projections (population, livestock) are only used for the oak forest ecosystem using national data. In all reports, the consideration of uncertainties (including a clear description of all assumptions) is limited or non-existent.

3.3 Outputs of the Tunisian VAs

The main outputs of the VAs in Tunisia are a series of technical reports with vulnerability or sensitivity maps. These maps are useful in providing an overview of the following:

- Potential distribution of various ecosystem types under present and future (2020 and 2050) conditions at the national level
- Potential distribution of different grassland ecosystem types under present and future (2020 and 2050) conditions in one governorate
- Location of oak forest units that may experience more water stress (due to climate change), more animal pressure, and more forest fire under present and future conditions (2020 and 2050) in three governorates
- Areas where olive trees may experience more moisture stress under present and future (2020 and 2050) conditions in one governorate

The results are useful for awareness-raising and identifying future research topics. One potential limitation in the outputs relates to their presentation and communication: the maps, as presented in the reports, are often illegible due to small and illegible font and can be difficult to interpret as the assumptions are not always explicitly described in the text. As such, there is a risk that policy and decision makers may not be able to put the presented results into their proper context. This may also undermine the dissemination of the results.

In addition to vulnerability and sensitivity maps, the grassland and oak forest ecosystems VAs yielded a review of existing initiatives (including relevant policies) and specific recommendations on adaptation options based on the results of the vulnerability assessment. For the grassland ecosystem VA, the report mainly highlights existing institutional and land-tenure issues, including the lack of national strategies for grassland and livestock management, which may serve as barriers to effective climate change adaptation. For the oak forest ecosystem, more concrete adaptation options are identified, as well as entry points for mainstreaming climate change adaptation into the national strategy for the sustainable development of oak forests, all of which can support decision-making.

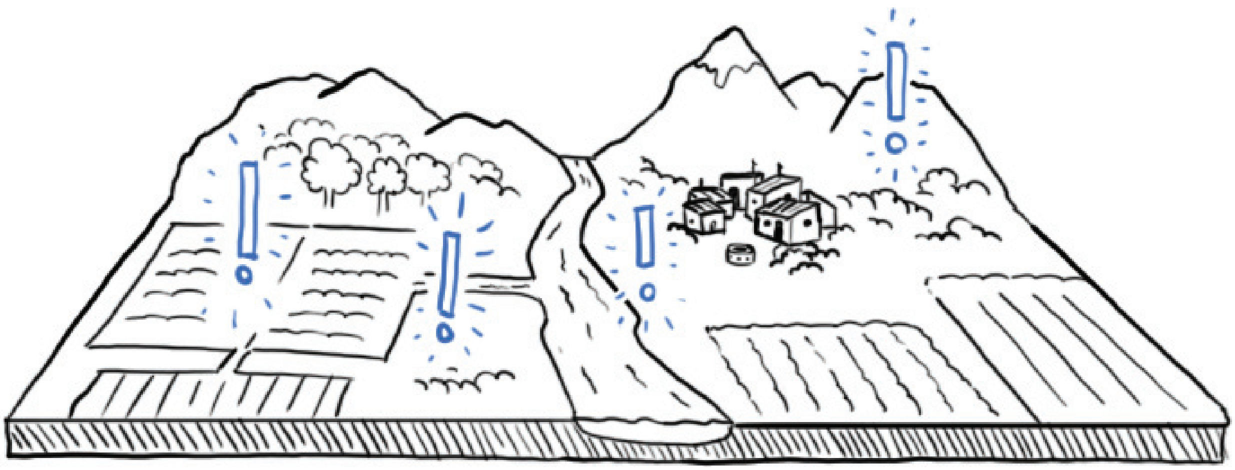
Table 6: Outputs from the Tunisian vulnerability assessments

Assessment of	Knowledge products	Impact chains, thresholds	Metrics	Observations/Recommendations
Ecosystems (National)	• Sensitivity maps for 4 ecosystems in 2000/20/50 • Map of temperature change severity index (2000/50) • Map of precipitation severity index (2000/50) • Map of CC severity index (2000/50)	• None	• Climate change: Temp & precipitation change • Biophysical sensitivity: distribution of species' environmental requirements for suitable conditions	• Reduced potential distribution areas for oak forest, alfa grass, *Rhanterium suaveolens* • Population pressure may render real distribution areas smaller, more fragmented
Grasslands (Sub-national)	• Vulnerability maps of steppe formations in 2005/20/50 • Economic valuation of key ecosystems services lost due to climate change • Review of key initiatives related to grasslands in the context of climate change	• Direct biophysical impacts and indirect socio-economic impacts • Very vulnerable species disappear by 2020, less vulnerable by 2050	• Climate change: Temp & precipitation change • Biophysical sensitivity: distribution of species' environmental requirements for suitable conditions • Anthropogenic perturbation: animal pressure (overgrazing coefficient)	• Different levels of vulnerability for different grasslands • But overall, grassland units have not reached critical thresholds • Need regulated, controlled management of grassland resources to avoid thresholds • Must develop strategy to increase resilience of pastoral ecosystem in line with national agriculture and economic policies • Adaptation options: mix of technical, political, legal measures, capacity building, research
Oak Forest (Sub-national)	• Vulnerability maps showing forest units that will experience different levels of: • - livestock pressure • - soil water deficit • - forest fire today • (in 2020/2050 under A2 and B2 scenarios) • Composite vulnerability maps, classifying forest units into different levels of vulnerability under A2 and B2 scenarios in 2020 and 2050 • Economic valuation of key ecosystems • Review of key initiatives related to oak forest in the context of climate change • Map of adaptation propositions (2050)	• Direct biophysical impacts and indirect socio-economic impacts • Decay threshold established based on the impacts of historical droughts on oak forest in Tunisia	• Climate change: temperature ↑ and precipitation ↓ • Biophysical sensitivity: soil water deficit • Socio-economic stressors: forest fires (number of hectares affected per year, constant), and overgrazing (ratio of fodder demand/ ha – itself based on population density – to fodder production/ ha)	• Results predict limited loss in 2020, limited loss of area between 2020 and 2049. Most losses would happen from 2050 onwards • Need to internalize CC-related costs in management decisions and conduct a cost-benefit analysis of adaptation to identify the best time to act • Adaptation options proposed according to the level of vulnerability of the different forest units (technical management measures) • Proposal for adding a CCA component in the current development strategy for oak forest

Assessment of	Knowledge products	Impact chains, thresholds	Metrics	Observations/Recommendations
Olive Production (Sub-national)	● Sensitivity (suitability) maps showing areas that can support olive cropping in 2010/20/50 ● Vulnerability Maps: Combining or overlaying sensitivity maps with socio-economic parameters (in this case, land tenure)	● Pre-analysis impact chain ● Influence diagram ● No thresholds identified ● None	● Climate (temperatures, precipitations) ● Soil (texture, depth, topography) ● Land use (current land use map for olive tree)	● N/A

3.4 Process of conducting the Tunisian VAs

In all studies, stakeholders (decision-makers, planners, researchers) at national and/or regional levels participated in the process through various workshops to facilitate data and information collection, review methods and tools used, and to validate the results, which sensitized key actors on the topic. In some cases, the assessments were done in collaboration with international research institutes.[7]



[7] Collaboration with PIK for assessing the vulnerability of olive production using the "impact chain approach" and with the Biodiversity and Climate Research Centre in Frankfurt (BiK-F) for assessing the vulnerability of ecosystems using the ecological niche modeling at national level

Table 7: Process of conducting the Tunisian vulnerability assessments

Assessment of	Main steps	Actors	Participation level	Resources (time, money)	Coordination, implementation
Ecosystems (National)	1. Framing with key partners 2. Data collection and modeling 3. First national workshop to present the suggested approach as well as the first results 4. Collection of additional data, preparation of sensitivity maps 5. Second national workshop, identification of pilot areas on the basis of the sensitivity maps provided 6. Collection of additional data for the pilot regions, third modeling approach to amend the sensitivity maps for the pilot regions 7. Third national workshop, presentation of more precise sensitivity maps	Biodiversity and Climate Research Centre in Frankfurt (BiK-F), GIZ, research institutes	Stakeholders at national level contributed to approach development and validation of results through various workshops	N/A	N/A
Grasslands (Sub-national)	1. Analysis of the current state of the ecosystem 2. VA to CC in 2020 and 2050 3. Analysis of strategies, programmes, projects related to the ecosystem in relation to CC 4. Proposition of strategic orientations in order to improve the development of programs and projects for the management of the ecosystem 5. Identification of adaptation measures	GIZ, development services, NGOs, research institute	Stakeholders at regional level were consulted to provide information and contributed to approach development and validation of results through various workshops	At least one year	Implemented by a team of three consultants (a rangeland scientist, from an international research center, a GIS specialist and an economist)
Oak Forest (Sub-national)	Same as for grassland ecosystem	Government decision-makers, local leaders, research institutes, development services	Same as above	At least one year	Implemented by a team of three national consultants (an ecologist, a GIS specialist, and an economist)
Olive Production (Sub-national)	1. Identification of the research question 2. Development of the research framework 3. Modelling 4. Analysis and results interpretation 5. Presentation of the results and identification of adaptation measures with partners in a workshop	PIK, regional research institute, GIZ	N/A	N/A	Implemented by a research institute based in the region (sub-national)

4.0 Indonesia: Vulnerability assessments of the city of Tarakan

The VA in Indonesia was not focused on the entire country but centred on Tarakan municipality and city of Tarakan, located in the north-east of Kalimantan Island , with a total area of approximately 657.33 km^2 (Figure 1)[8]. This study followed a series of previously-completed climate risk and adaptation assessments in Lombok (2008 – 2009) and the Indonesia Climate Change Sectoral Road Map (2009 – 2010) (Djoko Suroso, email communication, 16/11/2011).

Overall, the government of Tarakan is considered to be very visionary with a strong environmental commitment, which facilitated their interest in climate change and adaptation. In 2009, the city government used its local budget to conduct a preliminary climate risk assessment. This initiative was brought to the attention to the Ministry of Environment, which decided to support the next stages of the process with resources from a partnership between AusAID-GIZ-MoE (Djoko Suroso, email communication, 16/11/2011). This support led to the VA analysed in this report.

This VA is an ongoing initiative which started in 2009 and is expected to finish in 2012. IISD reviewed five published draft reports within this VA including: (1) a climate risk and adaptation assessment of the coastal sector (Latief et al., 2011); (2) sea-level rise and extreme event projections (Sofian, 2011); (3) a risk and adaptation assessment of the health sector (Sofyan and Agoes, 2011); (4) a climate risk and adaptation assessment of the water sector (Abdurahman et al., 2011); and finally (5) a climate risk and adaptation assessment using a micro-level multi-sectoral approach in Tarakan City (Suroso et al., 2011). The outcomes of the first four reports feed into to the fifth report, which is a synthesis report in which risks, hazards, vulnerability and adaptation options are assessed within the context of Tarakan.

4.1 Framing of the Indonesian vulnerability assessments

The vulnerability assessments in Tarakan were undertaken with the overall objective of designing adaptation policies, both sectoral adaptation strategies and integrating sectoral adaptation options into local development plans. With the exception of the sea level rise report, which was not a vulnerability assessment in any case, the sectoral VAs contributed to both aspects of developing adaptation policies – i.e. problem orientation and decision-support. On problem orientation, the assessments provided a basis for understanding the nature and spatial distribution of sector-specific vulnerability and risk; the water and health VAs explicitly listed methodology development and testing as an objective. In terms of decision-support, the studies went further than simply proposing a suite of adaptation options for each sector; they offer a basis for prioritizing adaptation options and identifying areas on Tarakan that should be paid particular attention. Moreover, the overall assessment process included identifying areas of overlap or convergence between the proposed adaptation strategies and local development plans and policies.

Vulnerability and risk were assessed using a so-called "micro-level multi-sectoral approach" (McLMSA), where the focus of analysis was at the local (i.e. lowest administrative) level and across multiple sectors – i.e. coasts, wa-

[8] Source of the Figure 1: http://en.wikipedia.org/wiki/Tarakan_Island

ter and health (Suroso et al., 2011; Latief et al., 2011). This approach was a detailed replication of the "meso-level multi-sectoral approach" (MsLMSA) that had been successfully developed and applied in a similar assessment of Lombok Island (Latief et al., 2011). The rationale for localising the MsLMSA was that the use of more specific climate projections, hazards, vulnerabilities and would yield more concrete adaptation options that could be integrated into local development strategies and policies.

The Tarakan assessments operationalised the concept of vulnerability from a risk management perspective using the understanding and definitions from the disaster risk reduction literature; the key approach to vulnerability could be defined as follows:

RISK (Potential Impact) = Hazards x Vulnerability

Vulnerability was understood to be an a priori condition, a function of physical, social, and economic factors (for the coastal VA) or exposure, sensitivity, and adaptive capacity (for the water and health VAs), each of which could be represented by a number of physical and socio-economic variables or indicators. The indicators were selected in consultation with sector experts and analysed using mostly quantitative methods (although expert judgement was used at certain steps). Those indicators for which data was available were normalised and categorised into levels of vulnerability – e.g. vulnerability of critical infrastructure to inundation, from very low to very high. The indicators were then weighted according to their sensitivity to hazards, then aggregated and mapped for an overall understanding of the distribution of different levels of (current and future) vulnerability for a given sector to a particular hazard. These vulnerability maps were subsequently overlaid with information about (current and future) hazard severity to determine (current and future) climate risk.

The audience for the Tarakan VAs was a combination of policy makers and the research community. The objective was to have the former use the VA results and outputs to design or mainstream adaptation options, while the latter would use them to fine-tune and replicate the assessment methodology.

Table 8: Framings of the Tarakan vulnerability assessments

Assessment of	Purpose	Vulnerability	Approach	Audience
Sea-level rise and extreme event projections	To provide a an information basis for resilient coastal area development in the face of future climate change	Vulnerability not defined or assessed per se; analysis of hazard – i.e. sea-level rise and extreme weather events until 2100 (in time slices of 2030, 2050 and 2080; baseline year 2010)	Quantitative analysis of sea surface temperature, sea level, and wave height using trend analysis, ocean general circulation model, wave model.	Researchers to analyze the outcomes of the sectoral studies and decision-makers at city and municipal level of the synthesis report; this study also serves as an example for potential replication in other jurisdictions
Coastal Sector in the Tarakan Municipality	To perform climate risk assessment of the coastal sector and formulate adaption strategy to be endorsed by local authorities	Vulnerability of Tarakan's coastal areas to inundation in 2010 and 2030. V= Physical + Social + Economic	Predominately quantitative analysis; vulnerability assessed as part of risk Vulnerability an a priori condition represented by both socio-economic and physical indicators, some of which change over time (dynamic vulnerability)	
Water sector	Identify vulnerability and risk assessment methods for the 3 sectors using McMSA approach Develop predictive sector models as part of national VA Guidelines	Vulnerability of Tarakan's communities to water to floods, landslides, and water shortage in 2010/11 and 2030. V= Exposure + Sensitivity - Adaptive Capacity		
Health sector	Assess and map vulnerability and risk to climate-related coastal zone, water and health hazards Build capacity of local sectoral stakeholders in vulnerability and adaptation Contribute to the Climate Change Adaptation and Vulnerability Database in Tarakan Help design adaptation strategies for each sector and integrate adaptation into government plans	Vulnerability of Tarakan's communities to dengue, malaria and diarrhea in 2008 and 2030 V= Exposure + Sensitivity - Adaptive Capacity	Vulnerability indicators aggregated and mapped for an overall picture of vulnerability of Tarakan to a specific hazard. Aggregate vulnerability to a given hazard overlaid with hazard severity to determine risk level (from very low to very high) on Tarakan	
Adaptation Strategies in Response to Climate Change for Tarakan Municipality	Assess risk, vulnerabilities and hazards for the area and identify adaptations	N/A		

4.2 Inputs: Data and information used for the Indonesian VAs

The assessment of risks and vulnerabilities in the Tarakan VAs was based mostly on quantitative approaches. Both climate scenarios and socio-economic scenarios were developed to assess the impacts of hazards presently and in the future. To describe current conditions, a baseline using 2010 data was used. Future conditions were described using climate projections based on the IPCC SRES A1B, B2 and A2 scenarios as well as the extrapolation of observed historical and observed data to 2100; however, most of the assessments focused on a time horizon to 2030 (Latief et al., 2011). Future socio-economic scenarios were based on trends in population growth, trends in changing property values based on economic growth, trends in land use based on the 2029 Spatial Planning strategy for Tarakan, and finally trends in infrastructure and critical facilities development based on the Short-Term Development Planning (RPJP), Long-Term Development Planning (RPJM), and Spatial Planning strategies (Sofyan and Agoes, 2011).

A number of models were used to analyse hazards; changes in climate conditions were translated into changes in water availability, flooding and landslides, coastal inundation and disease prevalence (overview of the models and data inputs is presented in Table 8). The hazards were then compared with socio-economic scenarios, and vulnerability assessed using a weighting method based on the analytic hierarchy process (AHP); this method was published in 1980 by Sally (overview is presented in Abdurahman et al., 2011).

Based on the vulnerability assessments, risks and adaptation needs were identified. Risk levels were determined by overlaying normalised levels of vulnerability and hazard severity, as presented in Figure 2 below:

Figure 2: Chart for risk analysis (Suroso et al. 2011)

	HAZARD					
VULNERABILITY		Very Low	Low	Moderate	High	Very High
	Very Low	VL	VL	L	L	M
	Low	VL	L	L	M	H
	Moderate	L	L	M	H	H
	High	L	M	H	H	VH
	Very High	M	H	H	VH	VH

These risk levels would be mapped according to the sector and hazard in questions, and used as a basis for devising adaptation options. Adaptation options were identified using the basic principle that the aim of such options should be to reduce vulnerability, which meant examining the vulnerability factors and finding ways to reduce exposure and sensitivity or increase adaptive capacity. Adaptation priority areas were identified according to the following general guidance (Djoko et al., 2011):

- For areas identified as being at high and very high risk today, either in a single sector or across multiple sectors, reactive adaptation is needed.
- For areas experiencing multiple or compounding risks, either currently or in the future, then reactive or anticipatory adaptation is needed.

Table 9: Overview of used models in the hazard analyses (summary of models listed in the reports)

Assessment	Hazard Type	Main Parameters and types of data	Scenarios and projections	Methods and Tools	Uncertainty
Coastal Sector	Inundation	Storm surge, La Nina effects, Tide, Wind wave, Sea-level rise	Climate: SRES A1B, A2 and B2 Socio-economic: scenarios based on population, property values, trends in land-use infrastructure development	Cumulative Inundation model and scenario	Uncertainty is considered in the climate projections
Water sector	Flood	Rainfall, Sea-level rise, Soil type, Land use change		HECRAS	
	Landslide	Rainfall, Soil type and Land use change		GEOSLOPE model	
	Water shortage	Rainfall, Temperature, Soil type and Land use change		Water balance model	
		Total Run-Off, Population and Land use		Water budget model	
		Aquifer geometry , Permeability, Groundwater storage		FEM WATER model	
Health sector	Dengue, Malaria, Diarrhea	Rainfall, Temperature, Disease incidence rate		Regression and correlation model	

4.3 Outputs from the Indonesian VAs

The key focus of the Tarakan VAs was to ensure the relevance of the outcomes for decision-making. This was accomplished by using socio-economic scenarios for Tarakan as well as by linking adaptation options with local development plans and policies. Such an approach provided opportunities for decision-makers to see how climate risks could be reduced through adaptation actions presented within the context of policy and strategic documents.

As with the Tunisian VAs, the main outputs from the Tarakan assessments were a series of research reports, accompanied by maps identifying the spatial distribution of different levels of climate-related vulnerability and risk in the coastal, water, and health sectors. The content of the reports included:

- Hazard analyses, which look at the character, magnitude, and rate of different hazards – i.e. sea level rise-induced coastal inundation, rainfall-triggered floods, landslides, water shortages, dengue, malaria and diarrhea – based on historical, current and projected climate conditions.
- Estimations of vulnerability to each of the hazards in 2008/2010 and 2030, based on socio-economic scenarios for the city of Tarakan, presented on maps.
- Analyses and estimations of climate risk for each of the sectors, derived from overlaying hazard and vulnerability maps.
- Identified number of adaptation options in each of the sectors including options focused on engineering solutions, ecosystems-based actions, capacity-development, monitoring and other 'soft' measures.
- Multi-risk assessments and maps to identify areas in Tarakan exposed to more than one hazard, thereby representing adaptation planning priorities.
- List of adaptation needs linked to current planning documents and identified performance indicators to monitor progress with adaptations.
- List of future adaptation needs to help reduce risks in medium time horizons.

Table 10: Outputs from the Indonesian VAs

Assessment of	Knowledge products	Impact chains, thresholds	Metrics	Observations/Recommendations
Sea-level rise and extreme event projections	• Summary report with multiple tables, graphs and maps depicting trends in sea surface and sea level rise , as well as wave height, globally, regionally and near Tarakan Island	• None identified	• N/A	• Sea level rise of about 14.7 cm ± 6.25 cm by 2030 relative to 2000 • Contribution of ice melting to sea level rise in 2030 – 14 cm to 56 cm • More frequent and longer La Nina projected, leading to stronger wind speed, increasing wave height, sea level rise, and greater flood risk
Coastal Sector in the Tarakan Municipality	• Hazard (coastal inundation) maps for six different hazard scenarios in 2030 • Maps of vulnerability elements for 2010 and 2030 (land use, population density, infrastructure and critical facilities) • Aggregate vulnerability map for 2008 and 2030 for coastal areas in Tarakan • Coastal risk map for 2030	• No impact chains • 2 m above mean sea level (MSL) threshold between high and very high hazard levels	• Physical vulnerability: elevation, slope, land use (dynamic) • Social vulnerability: urban population density (dynamic) • Economic vulnerability: critical infrastructure (dynamic)	• North coast – 236.836 ha inundated by 2030; moderate risk level; adaptation strategies – coastal forest restoration and accommodation-protection • West coast – high to very high risk level; adaptation strategies – accommodation-protection and mangrove restoration • East coast – high to very high risk level; adaptation actions – managed realignment, coastal setback, and hard and soft coastal protection) • Priority sub-districts identified
Water sector	• Current and projected hazard (water shortage, flooding, landslide) maps • Maps of baseline and projected (2030) vulnerability to water shortage, flooding, and landslide • Maps of baseline and projected water shortage risk, flood risk (for 12 watersheds), and landslide risk	• None identified	For **floods and landslides**: • Exposure: urban population density, land use • Sensitivity: Function and status of critical infrastructure • Adaptive Capacity: housing type, per capita income, drainage or road network For **water shortage**: • Exposure: water demand • Sensitivity: water resource type, quality • Adaptive capacity: housing type, per capita income, PDAM network	• Hard and soft adaptations organised around principle of integrated water resource management • **Water shortage** risk low in 2010, slight increase by 2030; Example adaptations – Increase reservoir capacity, desalinate, inter-basin transfers, rainwater harvesting • **Flood** risk levels increase slightly for a few watersheds in 2030; example adaptation – build sluice gate • **Landslide** risk in North Tarakan increase slightly to moderate level by 2030, West Tarakan to high; example adaptation – soil improvement, resettlement • Soft measures for all 3: re-shaping planning processes, linking water quality and quantity

Assess-ment of	Knowledge products	Impact chains, thresholds	Metrics	Observations/Recommendations
Health sector	● Hazard maps for dengue, malaria and diarrhea cases in 2030 ● Maps of existing vulnerability for dengue, malaria and diarrhea ● Maps for projected vulnerability to dengue, malaria and diarrhea in 2030 ● Maps for existing and projected risks for dengue, malaria and diarrhea	● Pathways by which climate change affect human health (general, Patz et al 2000) ● Relation between climate change stimuli and health hazard ● No thresholds identified	**Dengue** ● Exposure: urban population ● Sensitivity: water supply source, urban population density ● Adaptive Capacity: provision of health facilities **Malaria** ● Exposure: population near breeding site ● Sensitivity: distance from breeding site, housing type ● Adaptive capacity: provision of health facilities **Diarrhea** ● Exposure: urban population ● Sensitivity: household sanitation facility, water supply source ● Adaptive capacity: provision of health facility	● **Dengue:** High risks due to high population density, low piped water coverage. Risk levels will increase for 10/20 villages by 2030 ● **Adaptation strategies:** emergency response (e.g. emergency indoor spraying); recovery (e.g. breeding site reduction); long-term adaptation program (e.g. transgenic mosquitoes) ● **Malaria:** Higher risks north due to temporary housing; south and east regions due to proximity to breeding sites; risk expected to increase in 5/20 villages, decrease in 8/20 villages by 2030 ● **Categories of adaptation options:** vector control, environmental improvement, disease agent surveillance, human infection management ● **Diarrhea:** High population density a major contributor to high risk; risk levels expected to increase for almost half (9/20) villages by 2030 ● **Categories of adaptation options:** management of flood, environmental improvement, disease agent surveillance, human infection management

4.4 Process of conducting the Indonesian VAs

The climate risk and adaptation assessment was conducted using the following steps (Suroso et al., 2011):

i. **Formulation of problems and identification of vulnerable sectors to climate change**, using brainstorming, public consultations, and focus group discussions to gather stakeholders, identify focus sectors for the study, and articulate data needs among involved stakeholders and institutions;

ii. **Analysis of hazard due to climate change** where the character, magnitude, and rate of hazards were assessed based on current trends and future projections of climate change;

iii. **Analysis of vulnerability of sectors due to climate change impact**, by identifying vulnerability indicators, collecting data on these indicators, and then analysing data using GIS and producing vulnerability maps;

iv. **Analysis and evaluation of climate risk for sectors**, by overlaying estimated hazards and vulnerabilities from steps 2 and 3 to create risk maps;

v. **Formulation of adaptation strategies for sectors** based on the acquired understanding of the level of vulnerability and risk; options for vulnerability reduction and risk management;

vi. Multi-Risk assessment and adaptation prioritization to identify sub-districts or villages exposed to more than one hazard and narrow down and prioritize adaptation options in terms of risk level, population affected, existence of vital infrastructure and built areas, and size of wetlands and mangrove areas.

vii. Mainstreaming adaptation strategies into development policies

The assessments were done by multiple teams that were well coordinated so each of the sectoral assessments could be brought together and synthesised. The overall project was led by a team coordinator and weekly meetings were scheduled to synchronize and adjust the work done by each sectoral team. Further one-on-one discussions were organized by the coordinator and sectoral leaders to ensure consistency of the outcomes (Djoko Suroso, email communication; 16/11/2011). So far there is no specific report developed on the process, however based on the feedback from the coordinator and GIZ representative they are currently working on a report to document the process (Djoko Suroso and Tilman Hertz, email communication; 16/11/2011).

5.0 Observations from the case studies

The VAs in Tunisia and Indonesia provide enough detailed information to compare their respective framings, inputs, outputs and processes for conducting the assessments.

5.1 Framing of the VAs: Where do we come from?

The two studies had different overall approaches to their vulnerability assessments. The Tunisia cases assessed vulnerability as a standalone future condition, largely shaped by biophysical sensitivity to climate change, whereas the Indonesia VAs analysed vulnerability as part of current and future risk and was comprised of a number of biophysical and socio-economic variables. Both sets of VAs applied the IPCC definition of vulnerability (i.e. as a function of exposure, sensitivity and adaptive capacity); the Tunisian studies did not explicitly link their determinants of vulnerability to the IPCC components of vulnerability nor did they place much emphasis on adaptive capacity of the selected ecosystems. Most of the Indonesian assessments explicitly identified indicators for exposure, sensitivity, adaptive capacity within in each sector (system). The difference in the treatment of adaptive capacity may be a function of the systems being analysed; it can be more complicated and technical to capture the adaptive capacity of a natural system (i.e. natural adaptations of forests, grasslands), whereas the adaptive capacity of human systems – such as the socio-economic sectors assessed for Tarakan – are often described through more easily accessible development indicators. Both studies complemented the biophysical emphasis of their assessments by incorporating basic information on socio-economic trends, such as the number of livestock and overgrazing in Tunisia or urban population density, housing and infrastructure type in Indonesia.

In Tunisia, the VAs started from a country-level focus, as the main impetus was to support the implementation of the UNFCCC reporting guidelines. The subsequent assessments were focused at subnational, agro-ecosystem level, with the aim of feeding into a national overview and strategy on adaptation. The VAs in Indonesia, on the other hand, were largely driven by a city government with a strong environmental commitment that had completed their first preliminary climate risk assessment and had further interest in climate change, vulnerability, and adaptation. Because of the leadership provided at the local level, the VAs focused on the vulnerability and risks of multiple sectors on the island of Tarakan.

Based on their stated goals, both VAs aimed to support both problem-orientation (including methodology development and testing) by identifying the impacts of climate change on specific systems, and decision-support, by identifying vulnerable areas, sectors and needed adaptation options. The audience of the VAs was a combination of researchers, planners and decision-makers at national and regional levels. Because of the more localised focus on the VA in Indonesia, the linkages with decision-making were more explicit as the city and municipal government were one of the instigators of the study and planning documents, strategic development plans and projections were involved as input information for the VA.

5.2 Inputs: What is needed?

The salience and credibility of VA results can be tied directly to the inputs and methods applied in the assessments. Because VAs try to incorporate both biophysical and socio-economic issues over a number of temporal scales, gathering the necessary inputs can be challenging.

The VAs in Tunisia and Indonesia relied heavily on existing quantitative data available for the national and sub-national levels. In Tunisia, the data were accessed through international and national databases, whereas in Indonesia public and research databases were also used. Examples of data and information used to describe current vulnerability and trends, often linked to a specific baseline year (e.g. 2010 in Indonesia.) include:

- Climate data: temperature, rainfall, storm surges, la Niña, tides, wind waves, sea-level rise
- Biophysical data: soil information (type, depth, texture, salinity); vegetation zone maps; livestock types and density
- Water-related data: total run-off, groundwater storage, water quality, aquifer type
- Land use and land-use change: national forest inventory; bio climatic maps; agriculture map (denoting land tenure); fire data
- Socio-economic information: population; capital income; disease incidence (dengue, malaria, diarrhea); housing type; number of healthcare facilities in an area

In both countries, historical and current climate information was retrieved from international sources such as the IPCC Data Distribution Centre and the WorldClim database. Future vulnerability and risk were then assessed using climate projections and impact models for the assessed areas. The climate projections used to estimate the potential changes in precipitation and temperature until 2050 (Tunisia) and 2100 (Indonesia) were derived from the following SRES scenarios:

- **A1B** (Indonesia): More integrated world, with a balanced emphasis on all energy sources
- **A2** (Tunisia, Indonesia): More divided worlds
- **B1** (Indonesia – sea level rise): More integrated and ecologically friendly world
- **B2** (Tunisia): More divided but ecologically friendly world

Climate projections were complemented by some analysis of future change in other biophysical and socio-economic variables. In Tunisia, for example, population and livestock projections were used in one of the VAs, while in Indonesia, future trends in population, economic growth and property values, land use, and infrastructure development were drawn from local and regional planning documents

Various sectoral models were used to link projected changes in climatic variables with changes in predominately biophysical trends. In Tunisia, an ecological niche based approach using MAXENT was applied in two of the studies and a hydrological model – BUDGET – was used to assess the vulnerability of olive production. In Indonesia, specific models were used to cover each of the sectoral VA such as inundation model, GEOSLOPE model, HECRAS, water budget models and regression and correlation models to estimate occurrence of disease vectors in the context of climate change and their related health impacts. Some of these models had been already used by research teams involved in VAs to monitor changes in the sectors and some of them were new applications such as the MAXENT models and the regression and correlation models.

Most of the outputs from these models were presented in the form of maps, where multiple variables were overlaid and vulnerability and risk hotspots identified. However, in both countries, discussions on the limitations, uncertainties, and potential gaps related to data sources, future projections, and models were very limited. The issue of uncertainty was mostly discussed in the context of climate change projections by presenting ranges of potential temperature and precipitation changes and sea-level rise. The implications of uncertainty in climate projections and how they translate into uncertainty in outputs was not discussed.

5.3 Outputs: What does it tell us?

Both of the VAs produced a number of outputs describing different levels of vulnerability across selected ecosystems (Tunisia) and sectors (Indonesia), contributing to the process of problem-orientation in adaptation policymaking. The results from the VAs were presented in narrative reports with accompanying maps, which contained information such as:

- Different levels of sensitivity and sensitivity indexes of selected ecosystems
- Estimations of sectoral vulnerability to different hazards, as well as associated levels of risk
- Thresholds for extinction of certain key species at different levels of vulnerability
- Adaptation options in each of the sectors including options focused on engineering solutions, ecosystems-based actions, capacity-development, monitoring and other 'soft' adaptations
- Maps of single risks, multiple risks and spatial allocation of adaptation options over time

The narrative reports and maps also represented tangible results of different methods of data collection and analysis which might be replicated in other contexts, albeit with some modifications.

In terms of decision-support for adaptation policymaking, the assessments offered some very specific insights not only by making and strengthening the case for adaptation action (which is really the role of problem-orientation, as described through the outputs listed above) but by providing concrete, targeted next steps that decision-makers can consider in policy formulation and implementation. Examples included:

- Economic valuation of key vulnerable ecosystems, providing an economic justification for adaptation action (Tunisia)
- Identification of concrete adaptation actions (Tunisia and Indonesia)
- Prioritization of adaptation actions (Indonesia)
- Identification of entry points for integrating VA results into existing development strategies, policies, and plans (Indonesia)
- Identification of performance indicators to monitor progress with adaptation (Indonesia)

While assessments from both countries went as far as identifying a range of adaptation options to reduce vulnerability and/or manage risk, those for Tarakan went further by prioritizing adaptation options and identifying policy entry points (although the Tunisian studies were interim reports.) In both cases, the analyses were conducted for medium-term time horizons – i.e. 2020 (Tunisia) and 2030 (Tunisia) – in order to strengthen the saliency of the assessment results, as links could be drawn to current policy and planning processes.

The treatment of uncertainty was virtually non-existent in the presentation of VA results. In those cases where it was acknowledged in the data collection and analysis stages, it all but disappeared by the time the assessment results were presented. To increase and ensure the credibility of VA results, it is important to be as explicit as possible about the role of uncertainty in recommended adaptations. This can be done for example by highlighting those adaptations that may be robust across different levels of uncertainty. Communicating uncertainty and conveying a sense of urgency at the same time to a non-expert audience can be challenging, but this process could be facilitated by engaging a wide range of stakeholders during the entire VA process.

5.4 Process of conducting the VAs: How does it work?

The relevance, salience and legitimacy of VA outputs also depend on the level of stakeholder involvement and the effectiveness of the coordination among the different actors involved within the VA process. This process often takes time – a resource that is frequently underestimated during VA design. In Tunisia, for example, the different assessments were initially planned for a few months but took more than 12 months. Moreover, as explained in section 2.6 above, VAs often involve working across sectors and disciplines and at different levels. As such, the role of a coordinator is critical, as is some kind of platform which allows those involved in the VA to interact with each another on a regular basis.

In the analysed VAs, the studies were led by research teams that coordinated a number of sub-teams delivering specific system-based assessments. In all cases, there was an initial scoping workshop to identify key questions, the scope of the assessments, as well as data, information, and methodological needs. The process roughly followed the suggested steps outlined by Schröter et al. (2005) – from defining the study area, to developing causal models and identifying indicators – while also contributing to the different channels through which VAs can contribute to adaptation policies identified by Preston et al. (2011) – i.e. problem orientation and decision support).

Most of the studies were heavily centred on biophysical and quantitative data. Perhaps working with more stakeholders and experts beyond those involved in climatology, natural sciences and engineering could have helped in bringing in more qualitative inputs and recommendations. As most of the assessments are just being completed, it is critical that there are enough resources to effectively communicate the outcomes to decision-makers both at the higher-levels to ensure buy-in and at the medium and lower level to ensure that those who will be likely tasked with implementation of the outlined actions are informed as well. This may involve developing different products (booklets, policy brief, etc.) that are adapted to the target audience.

5.5 Recommendations

Based on the above analysis, as well as the authors' experience in designing and conducting other VAs, the following recommendations can be distilled for future climate change vulnerability assessments. Overall, there would be value in **systematically designing a VA**, whereby an assessment would be structured using the framework – or elements of the framework – described in Section 2.7 (Box 1), thinking in terms of VA framing, inputs, outputs, and process. This will help members of the VA team to systematically consider and clearly articulate what is being assessed, how, and by or with whom.

Looking at the four components of the VA framework, the following recommendations are offered:

Framing

1 **Be explicit about the conceptual approach to vulnerability.** Providing definitions and explanations about vulnerability is often viewed as an unnecessary academic exercise, somehow diverting attention away from the central analysis in a VA. Yet, as described in Section 2, vulnerability is understood in different ways and through different disciplines. As such, articulating how vulnerability is shaped is important for adaptation decision-making. This means explaining if, for example, vulnerability is about the net impacts of climate hazards on a system (and therefore adaptation is about avoiding or minimizing specific impacts), or if it is an a priori condition that shapes how it is affected by climate hazards (and therefore adaptation is about changing these a priori conditions); it also means going beyond presenting a vulnerability 'equation' (e.g. V=f(E, S, AC)), but describing what the different parts of the equation mean and how they come together to construct vulnerability.
Similarly, the link between an improved understanding of vulnerability and a policy outcome should be well-articulated. For example, how will understanding the geographic extent of the grassland ecosystem in the future inform policy decisions? Will such an analysis serve to better define a problem or will it lead to concrete management recommendations?

2 **Facilitate replication and repeated VAs, think about what somebody trying to design a VA needs and has available (in terms of data and time):** Given the sometimes considerable resources required for VAs, it is useful to think about comparability (across contexts and over time) at an early stage. If one of the aims of the VA is to test and fine-tune an assessment methodology so that it can be replicated in other contexts, then the methodology must be explained clearly and simply. Designing VAs in a way that they can be repeated at a later point in time, may be extremely valuable for purposes of monitoring and evaluation of adaptation and of climate impacts. Considering which data may be available over time is useful in this respect. Assumptions must be highlighted, along with gaps and limitations to the methodology. Certain steps, such as the weighting of vulnerability indicators or factors, should be given particular attention as they typically involve expert judgement for a subsequently conducted quantitative analysis.

3 **Deliver on decision-support if that is your objective:** If the results of a VA are to move beyond problem-orientation and offer decision-support to adaptation policymaking, then the assessment should include a step for evaluating and prioritising adaptation options. Similarly, if results are to be integrated into development strategies, policies and plans, then appropriate entry-points should be identified. That is, providing a list of options

at the end of a VA does not go far enough for providing decision-support – evaluating them and trying to plug them into decision-processes can help provide a bridge between assessment and action; so be sure to include these steps in your VA methodology.

Inputs

4 **Be aware of quality control, find (and communicate!) your quality 'comfort zone':** VAs in developing countries are often challenged by data and information limitations. Where data and information exist, quality can be a concern. Gaps in time series data, unclear data collection, organisation and storage methods, and even political biases associated with different databases, can affect the reliability of VA inputs, and therefore VA outputs. Those conducting VAs need to have a clear sense of minimum data and information requirements and be able to make judgement calls on what goes into a VA and what stays out. A VA can, after all, help legitimise data sets and information sources, so care must be taken in selecting and using them. If incomplete or questionable data and information sources are used –because the value of going through a VA process and building local capacity outweighs the reliability of final results, for example – then these limitations must be clearly communicated.

5 **Remember adaptive capacity in biophysically-focused VAs:** While many VAs these days use the IPCC`s definition of vulnerability – i.e. exposure, sensitivity and adaptive capacity – understanding adaptive capacity can feel like a separate assessment. This is especially true for ecosystem- or biophysically-focused VAs, where system sensitivity is the driving consideration in assessing vulnerability; capturing a system's adaptive capacity can seem either overly complex (e.g. adaptive capacity of grasslands?) or distant/secondary, since it is an attribute that is typically associated with aspects of economic development. Adaptive capacity could be captured through institutional assessments which determine if existing policies provide the operational space to implement new management decisions, or a review of organisational capacities to implement adaptation actions. The World Resources Institute's National Adaptive Capacity Framework provides a nice structure for querying this aspect of vulnerability (2009).

6 **Use multiple Global Circulation Models:** Different climate circulation models may generate different future scenarios, particularly in regard to precipitation. If a VA is based on a single model only it may leave other projections out of sight and therefore increase uncertainty. If available, data from numerous climate models should be compared to ensure the trend used for the VA is consistent across the models.[9] If no consistent trend exists between models this needs to be acknowledged in the analysis.

7 **Accept that there is no easy way to blend qualitative and quantitative information:** Since vulnerability can be so context-specific and shaped by a multitude of macro and idiosyncratic factors, qualitative information gathered through participatory research methods and stakeholder consultations can be important to VAs. How these are combined with more quantitative analyses such as hydrological model outputs can be somewhat haphazard. Expert judgement can be used to query or validate quantitative research results, or stakeholder consultations can be used to help evaluate or select adaptation options, but researchers and policy makers will have to be comfortable with the biases these processes introduce.

Outputs

8 **Accept the potential anti-climax of VA results:** The relatively complex and resource-intensive nature of VAs can contribute to an expectation that they will yield new and transformational results, that recommendations will enlighten decision-makers on policy options and investments never before considered. This may very well take place, but it is usually the exception rather than the rule. Because most VAs are embedded in current and short- to medium-term development priorities, they are more likely to yield recommendations that reinforce

[9] The climate diagram generator of the ci:grasp platform features a comparison of five different models: http://cigrasp.pik-potsdam.de/diagrams/compare

the achievement of these priorities through familiar measures. What's more, VA results may point to long-standing but largely unimplemented development recommendations, such as integrated watershed management or clarified land tenure, which can be frustrating to both VA researchers and the target audience. The value of a VA should not be judged on the 'newness' of its results.

9 **Treat and communicate uncertainty head-on:** Uncertainty is inherent in projections, whether scientific or socio-economic. When these projections are further projected, through the use of models, uncertainties are carried through, even amplified, but their explicit consideration is somehow lost. Uncertainties and their implications should be clearly stated in a VA, and, where possible, options for managing them should be presented along with the assessment results (e.g. resilience building approaches).

10 **Label and explain maps clearly:** A simple but important recommendation; maps are useful and powerful tools for effectively communicating results of VAs. Yet they can also teeter on the edge of oversimplification, where nuance and limitation are overlooked for the sake of visualisation. Titles should be descriptive, legends should be clear, and where possible, assumptions and uncertainties articulated so the user is aware of what the map does and does not represent.

11 **Explore alternative outputs:** While maps and reports are the most common and expected outputs of VAs, other formats for presenting the results should be explored where time and other resources allow (which is admittedly rare). The use of spider diagrams, for example, to depict the relative prevalence or importance of different factors in shaping vulnerability could be an effective way of communicating the causal model of vulnerability to decision-makers. Other formats and media, such as photos, film, 'citizen's guides', and interactive websites, could also be effective channels for communicating the vulnerability storyline of the assessment.

12 **Recognise assumptions around policy-uptake, know the audience:** Even the most effectively designed and executed VAs can end up unused and unnoticed by policy makers. The barriers to policy uptake can range from lack of capacity to understand VA results or recommendations, limited resources to implement recommendations, to lack of ownership of the VA process and therefore its results, and other political considerations such as low priority given to climate change adaptation issues or decision-making power. If these issues are considered at the outset of a VA, the process and outputs can be tailored accordingly, and resources and expectations managed appropriately. For example, if the targeted policymakers are championing a 'green growth' economic agenda, VA results and recommendations should be presented in these terms as much as possible.

Process

13 **Appreciate the politics of VAs:** Despite how some researchers may characterise VAs, particularly those relying heavily on quantitative analyses, VAs are political. They are commissioned by actors and institutions with particular agendas, carried out by actors and institutions with their own interests, and yield political recommendations. This can influence all of the components of a VA – i.e. its framing, inputs, outputs and process. Linked to the earlier point about the anti-climax of VA results, the political nature of VAs can contribute to their yielding familiar recommendations or suggestions for incremental changes to existing systems. If the objective of climate change adaptation is to keep development on a given trajectory, then the results of a VA will be tailored to that vision; recommendations for transformational changes that potentially disrupt the achievement of that vision, such as moving out of agricultural production, will be difficult to sell.

14 **Dedicating resources to coordination:** Due to the multi-disciplinary and multi-stakeholder nature of VAs, coordination can easily outweigh analysis in their execution. But this should not be viewed negatively; as sustained coordination is key to maintaining an overall perspective of the VA process and what it seeks to achieve or influence.

15 **Be realistic about time and money:** Depending on factors such as the level of expertise within the VA team, data and information availability, as well as the oftentimes iterative nature of VAs, assessments typically take longer and cost more money than anticipated. Linked to the previous point, budgets and work plans should allow for significant coordination and engagement efforts; getting the right people to do the analysis and care about the results can be a significant but ultimately worthwhile investment.

16 **Allocate money for immediate follow-up:** VAs are typically designed to yield recommendations that will be considered and hopefully implemented by targeted actors. Yet rarely are resources immediately mobilized and channeled towards implementation; VA recommendations are more likely to be parked and reconsidered when resources become available and investment decisions are being formulated. This can lead to a time lag between assessment and potential action, where VA results can become outdated. By the time resources for adaptation become available another VA may be commissioned, leading to a cycle of assessment and inaction, a common complaint among developing countries. One way of bridging the gap between assessment and action could be setting aside a discrete sum of money within a VA budget to support the implementation of at least some recommendations immediately after they are shared and considered; even if the money is for relatively simple action items like public awareness campaigns and training workshops (as opposed to new infrastructure projects), it will keep up the momentum of a VA and be a sign of good faith in the process and stakeholders.

17 **Document the process:** With so much interest and activity around VAs, it can be surprising that so many actors continue to seek guidance on how they should be designed and conducted. This speaks to the lack of documentation of VA processes, as oftentimes it is just the results that are published and shared. VA teams should be encouraged to properly document the approach, tools and methods, data, and stakeholders engaged in the assessment process. Successes, challenges, and lessons-learned should be noted, particularly if methodology replication is a stated objective of the assessment. . Efforts should be made to reach out specifically to the research community to share the 'story behind the VA' so that there is a more comprehensive understanding of the relative merits of different approaches.

18 **Expand the disciplinary reach of the VA team:** The VAs in Tunisia and Indonesia relied largely on experts with backgrounds in climatology, natural sciences, and engineering. Including more social scientist, as well as conducting regular consultations with stakeholders, may have provided more insights into vulnerability aspects such as adaptive capacity. Moreover, VA teams should also consider including a dedicated communications/ outreach or engagement expert, who can feed updates about the VA to interested stakeholders.

19 **Monitor, evaluate, and share the lifecycle of a VA:** Linked to the previous point of coordinating and documenting the process, VA teams should put in place mechanisms to monitor progress and evaluate the success of the assessment approach and methods.

20 **Think about and manage the legacy of VAs:** In addition to contemplating the longer-term impact of VA recommendations, assessment teams should also consider the capacities, identified needs, and expectations resulting from a VA process. Capacities could range from enhanced modelling skills to increased collaboration between different institutions. These should be anticipated, documented, and maximized where possible. A VA process may also identify problems such as poor data organisation or limited inter-departmental coordination. These should similarly be documented and addressed where feasible. Finally, VA processes can be influenced by the assessments that preceded them, both positively (where capacity was built, actions were taken) or negatively (where ownership was limited or lack of follow-up has led to 'assessment fatigue' among key stakeholders) An awareness of what took place before can help increase the uptake of VA results.

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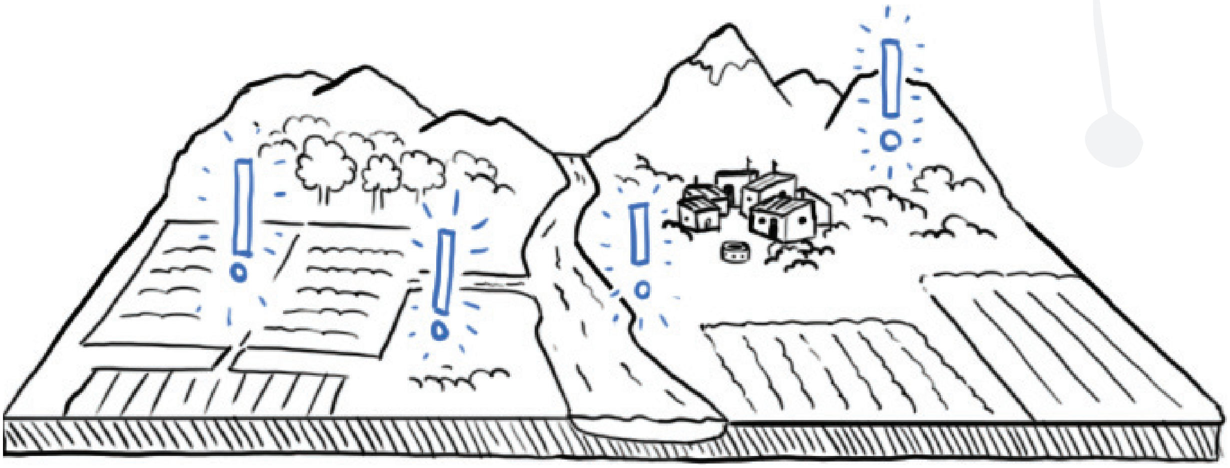

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Dag-Hammarskjöld-Weg 1–5
65760 Eschborn, Germany
T +49 61 96 79-0
F +49 61 96 79-11 15
E info@giz.de
I www.giz.de