The Vulnerability Sourcebook Annex

Content

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1. Template for the implementation plan for vulnerability assessments (VA implementation plan)

VA implementation plan: general information and scope

Excel sheet available online at:
https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Vulnerability assessment implementation plan	
General information	
Title of the VA	(Tentative) Title of your vulnerability assessment
Context	Describe the general context of your VA (Module 1; Step 1) in terms of: • What are related processes? • What knowledge is already available? • Which institutions play a role? • What resources are available? • Which external developments are important?
Objectives	Describe the general objective of your VA (Module 1; Step 2): • Which specific process shall be supported? • What is the information gap? • Who is the target audience?
Expected outcomes	Describe the expected outcomes of your VA (Module 1; Step 2): • How shall the results of your VA be presented?
Scope of the vulnerability assessment	
Thematic scope	Describe the specific topic of your VA (Module 1; Step 3): • What exactly is your vulnerability assessment about?
Already identified impacts / vulnerabilities	Possibly refer to potential climate impacts that shall be addressed in the VA (Module 1; Step 3): • Do you already have potential climate impacts and vulnerabilities in mind?
Geographical scope	Describe the spatial scope of your vulnerability assessment (Module 1; Step 3) • What is the geographical scope of your assessment?
Temporal scope	Describe the temporal scope of your VA (Module 1; Step 3): • What is the time period addressed in the assessment?
Methodological approach	Outline the methods foreseen for the assessment (Module 1; Step 3): • What are the right methods for your VA?

Source: adelphi/EURAC 2014.

VA implementation plan: knowledge

Excel sheet available online at:
https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Vulnerability assessment implementation plan						
Existing knowledge (Module 1; Step 1)						
		Date of publication	**Scope / Sector of study**	**Key information / Impacts**	**Knowledge gaps**	**Remarks**
Existing studies and information						
	Study 1					
	Study 2					
	Study 3					
	Study 4					
	Study 5					
	Study 6					
	Study 7					
	Study 8					
	Study 9					
	Study 10					

Source: adelphi/EURAC 2014.

VA implementation plan: resources & partners

Excel sheet available online at:

https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Vulnerability assessment implementation plan						
Conditions and resources for implementation (Module 1; Step 1)						
		Financial	Human	Technical	Available time	
Own resources available						
		Needs / interests in VA	Functions	Resources	Available time	Potential conflicts of interest
Partners	Partner 1					
	Partner 2					
	Partner 3					
	Partner 4					
	Partner 5					
	Partner 6					
	Partner 7					
Key stakeholders	Stakeholder 1					
	Stakeholder 2					
	Stakeholder 3					
	Stakeholder 4					
	Stakeholder 5					
	Stakeholder 6					
	Stakeholder 7					
	Stakeholder 8					

Source: adelphi/EURAC 2014.

VA implementation plan: processes & external developments

Excel sheet available online at:
https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Vulnerability assessment implementation plan				
Processes and external developments (Module 1; Step 1)				
		Key goals	Possible synergies/ Overlaps	Remarks
Related processes in the field of adaptation	National Adaptation Plan			
	Process 2			
	Process 3			
	Process 4			
	Process 5			
	Process 6			
	Process 7			
	Process 8			
External developments		Influence on the subject of the VA	Remarks	
	External development 1			
	External development 2			
	External development 3			
	External development 4			
	External development 5			
	External development 6			
	External development 7			
	External development 8			

Source: adelphi/EURAC 2014.

VA implementation plan: objectives and scope

Excel sheet available online at:
https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Vulnerability assessment implementation plan	
Objectives and expected outcomes (Module 1; Step 2)	
Objectives	Which specific process(es) shall be supported by the vulnerability assessment?
	What is the information gap?
	Who is the target audience?
Expected outcomes	How shall the results of the vulnerability assessment be presented?
Scope of the Vulnerability Assessment (Module 1; Step 3)	
Thematic scope	Describe the specific topic of your vulnerability assessment:
Already identified impacts / vulnerabilities	Possibly refer to potential climate impacts that shall be addressed in the vulnerability assessment:
Geographical scope	Describe the spatial (geographical) scope of your vulnerability assessment:
Temporal scope	Describe the time period of your vulnerability assessment:
Methodological approach	Outline the methods foreseen for the vulnerability assessment:

Source: adelphi/EURAC 2014.

VA implementation plan: schedule and responsibilities

Excel sheet available online at:

https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Vulnerability assessment implementation plan

Activity & time plan

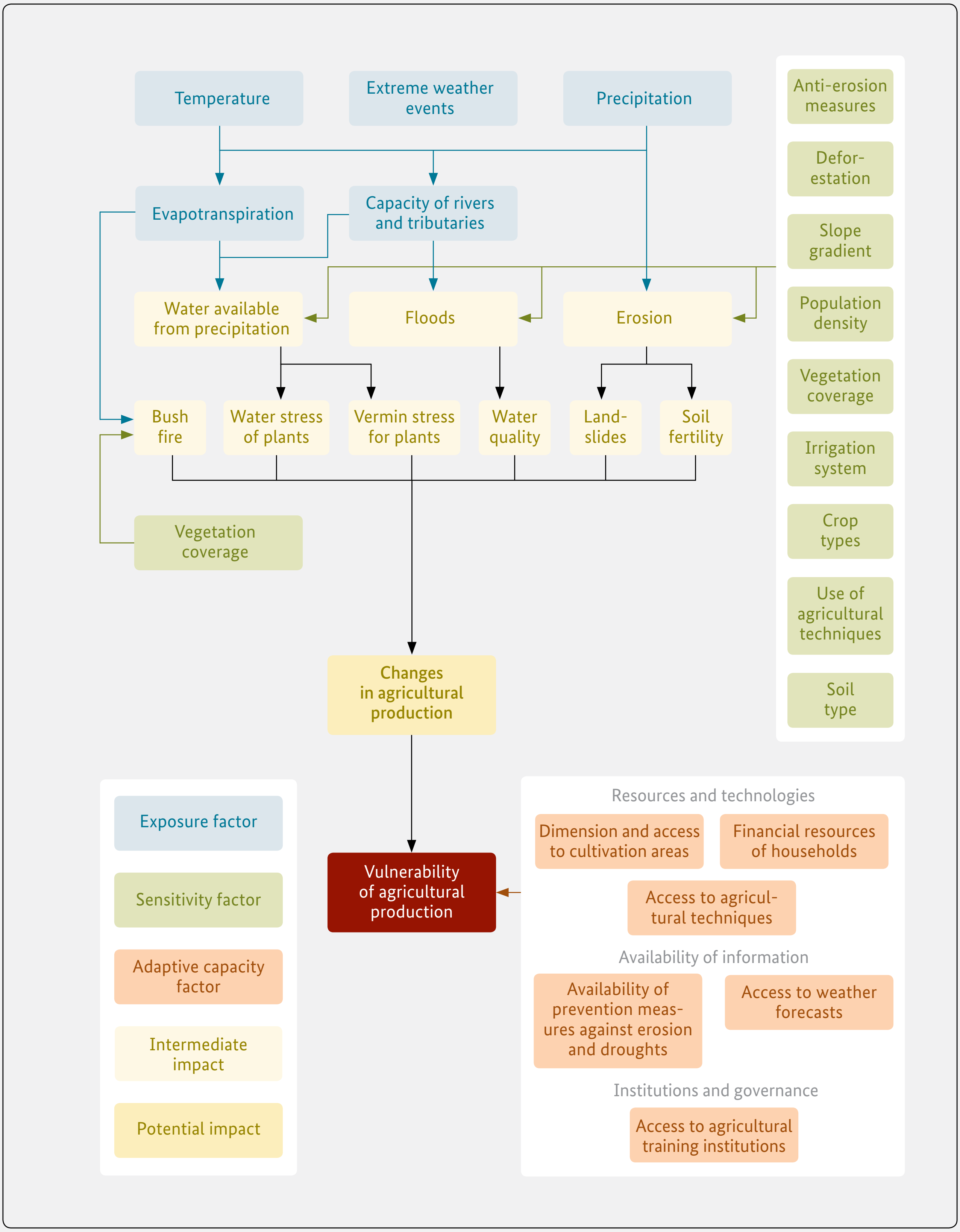
Module 1: Preparing your vulnerability assessment									**Time plan**				
	#	Task	Status	Date	Responsible	Parties involved	Input/Resources	Output	Month 1	Month 2	Month 3	Month 4	...
Step 1: Understand the context of the VA	1.1												
Step 2: Identifiy objectives and outcomes	1.2												
Step 3: Determine scope of the VA	1.3												
Step 4: Prepare VA implementation plan	1.4												

Module 2: Developing impact chains									**Time plan**				
	#	Task	Status	Date	Responsible	Parties involved	Input/Resources	Output	Month 1	Month 2	Month 3	Month 4	...
Step 1: Identify potential impacts	2.1												
Step 2: Determine exposure	2.2												
Step 3: Determine sensitivity	2.3												
Step 4: Determine adaptive capacity	2.4												
Step 5: Brainstorm adaptation measures (optional)	2.5												

Source: adelphi/EURAC 2014.

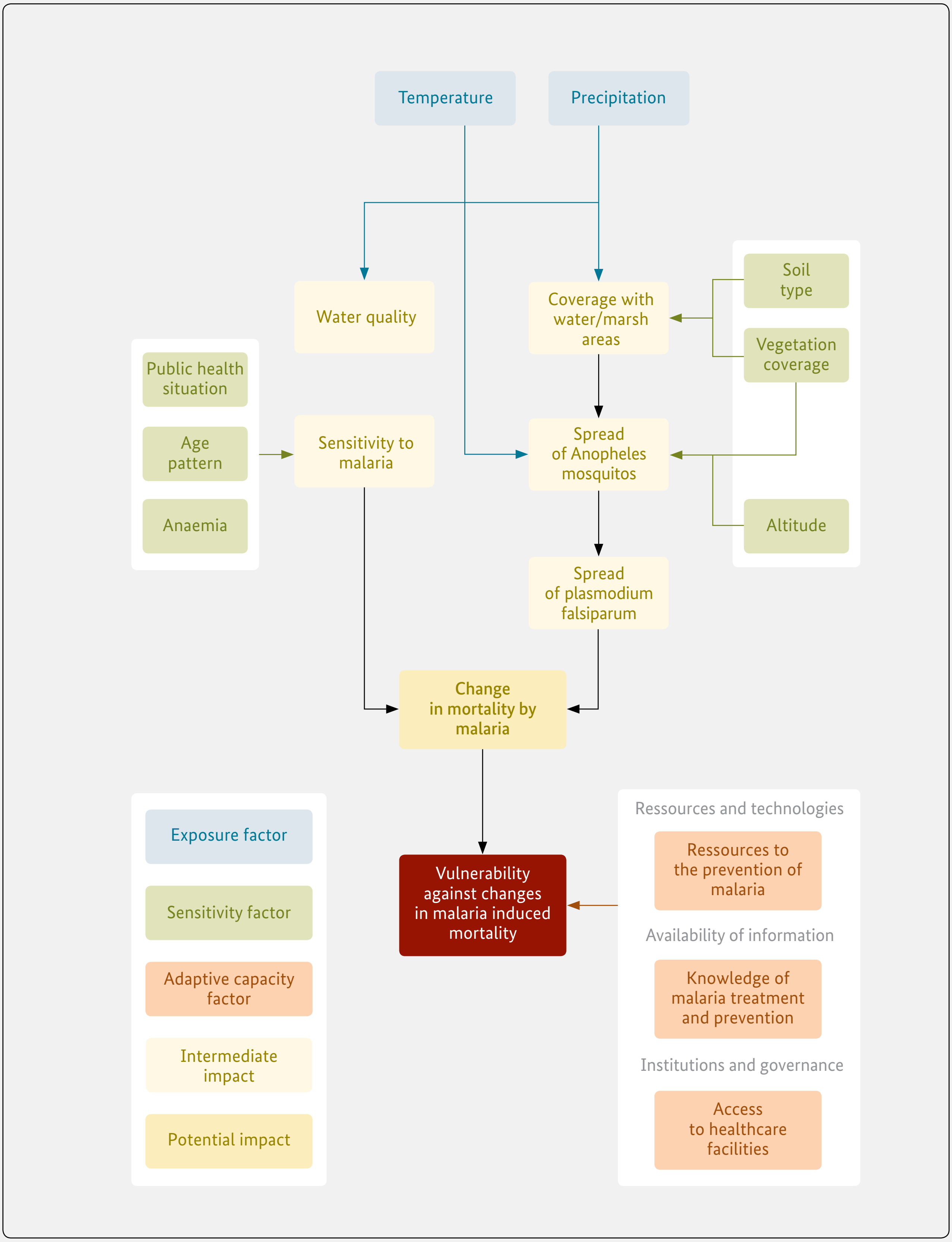
2. Sample impact chains

Sample impact chain for the agriculture sector (as used in a vulnerability assessment in Burundi)



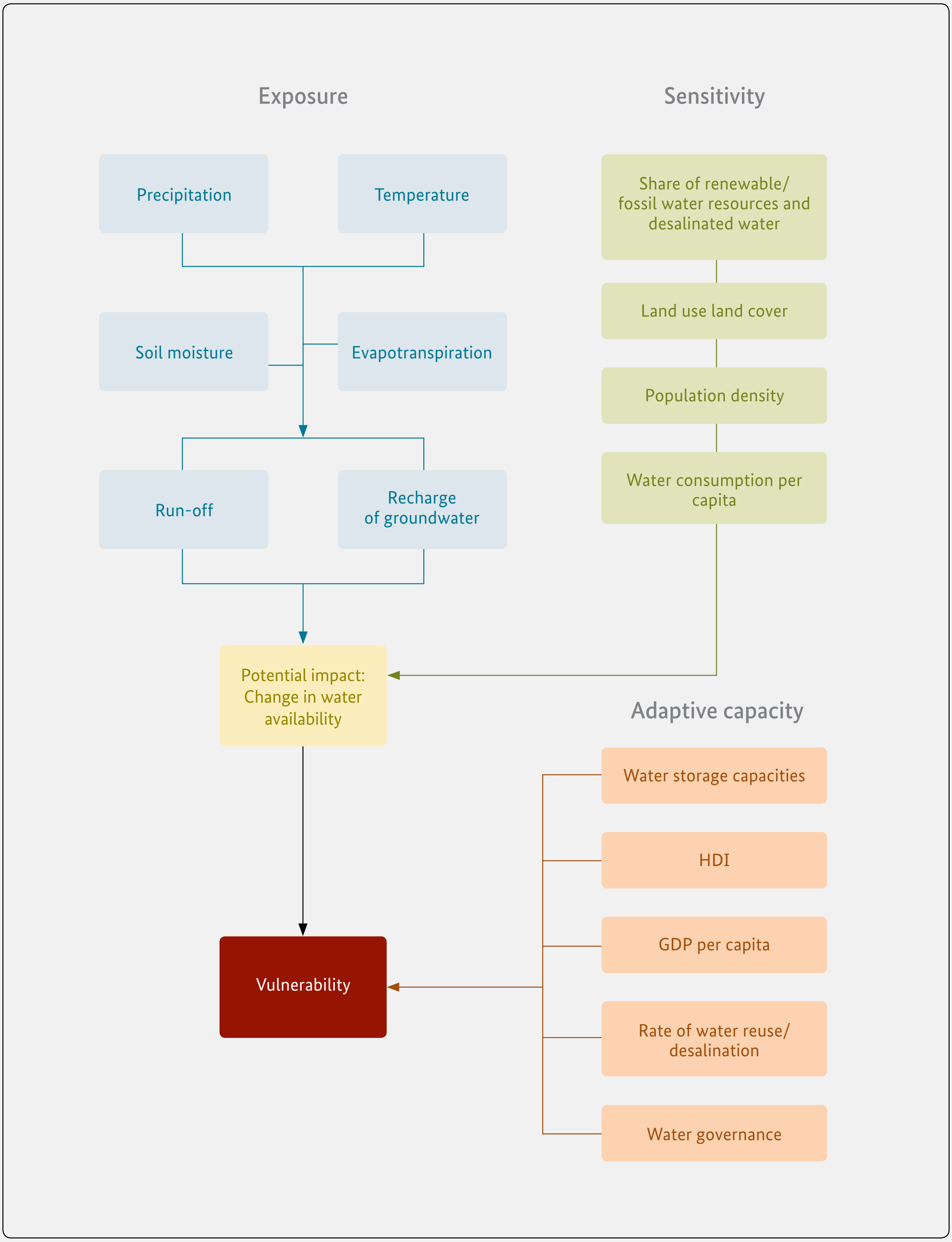
Source: adelphi/EURAC 2014.

Sample impact chain for the impact 'change in mortality caused by malaria' (as used in a vulnerability assessment in Burundi)



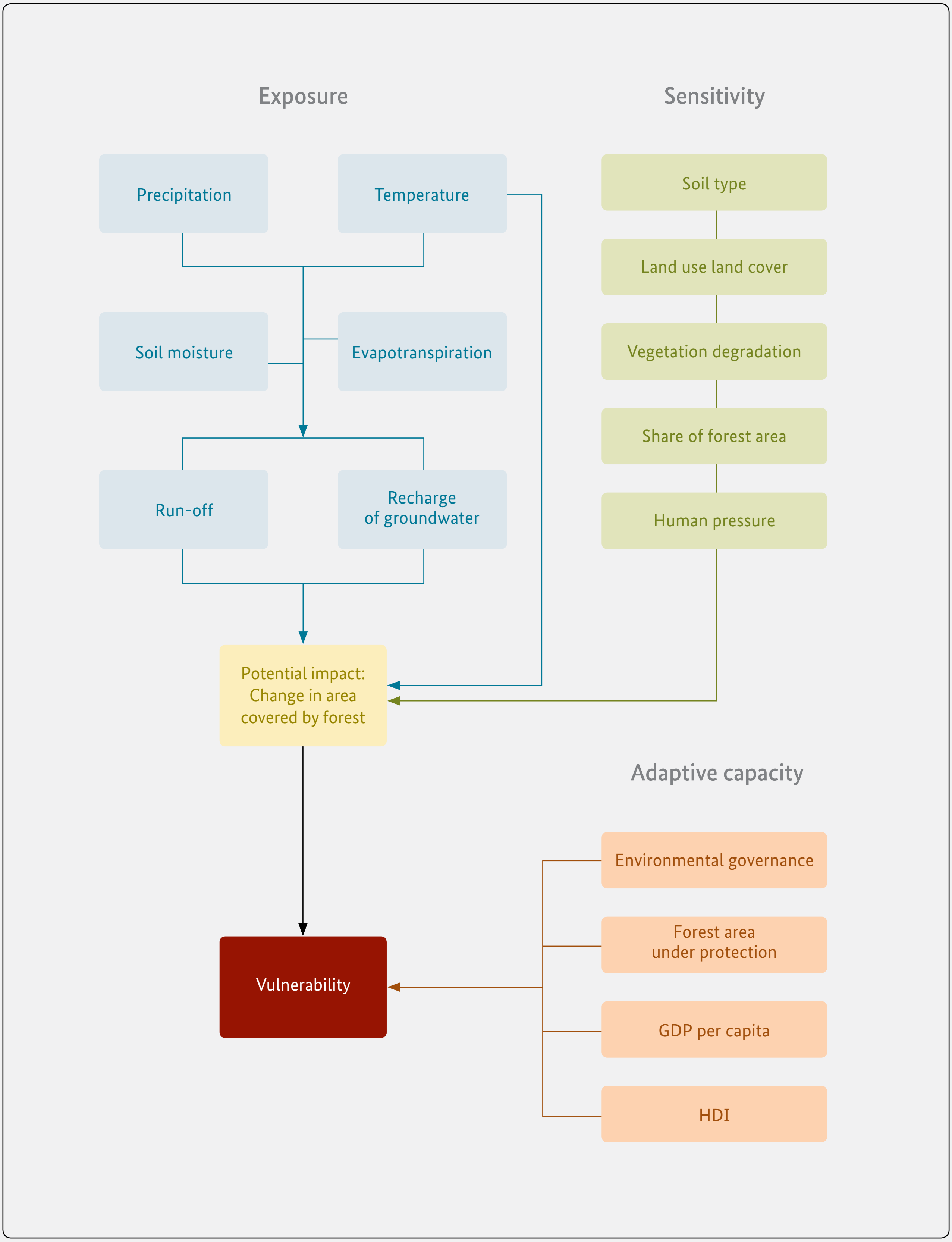
Source: adelphi/EURAC 2014.

Sample impact chain of a trans-boundary vulnerability assessment on the potential impact 'change in water availability'



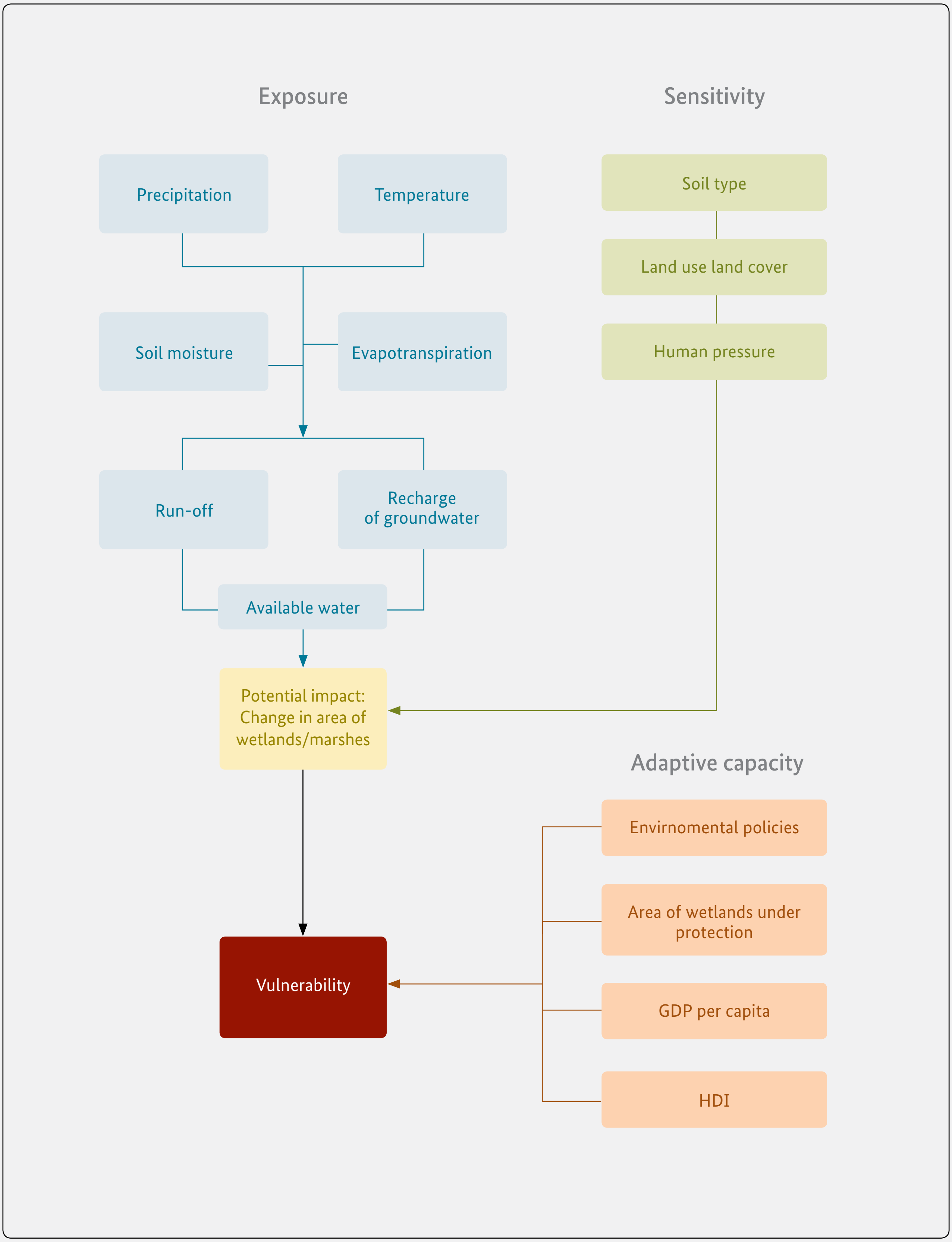
Source: adelphi/EURAC 2014.

Sample impact chain of a trans-boundary vulnerability assessment on the potential impact 'change in area covered by forest'



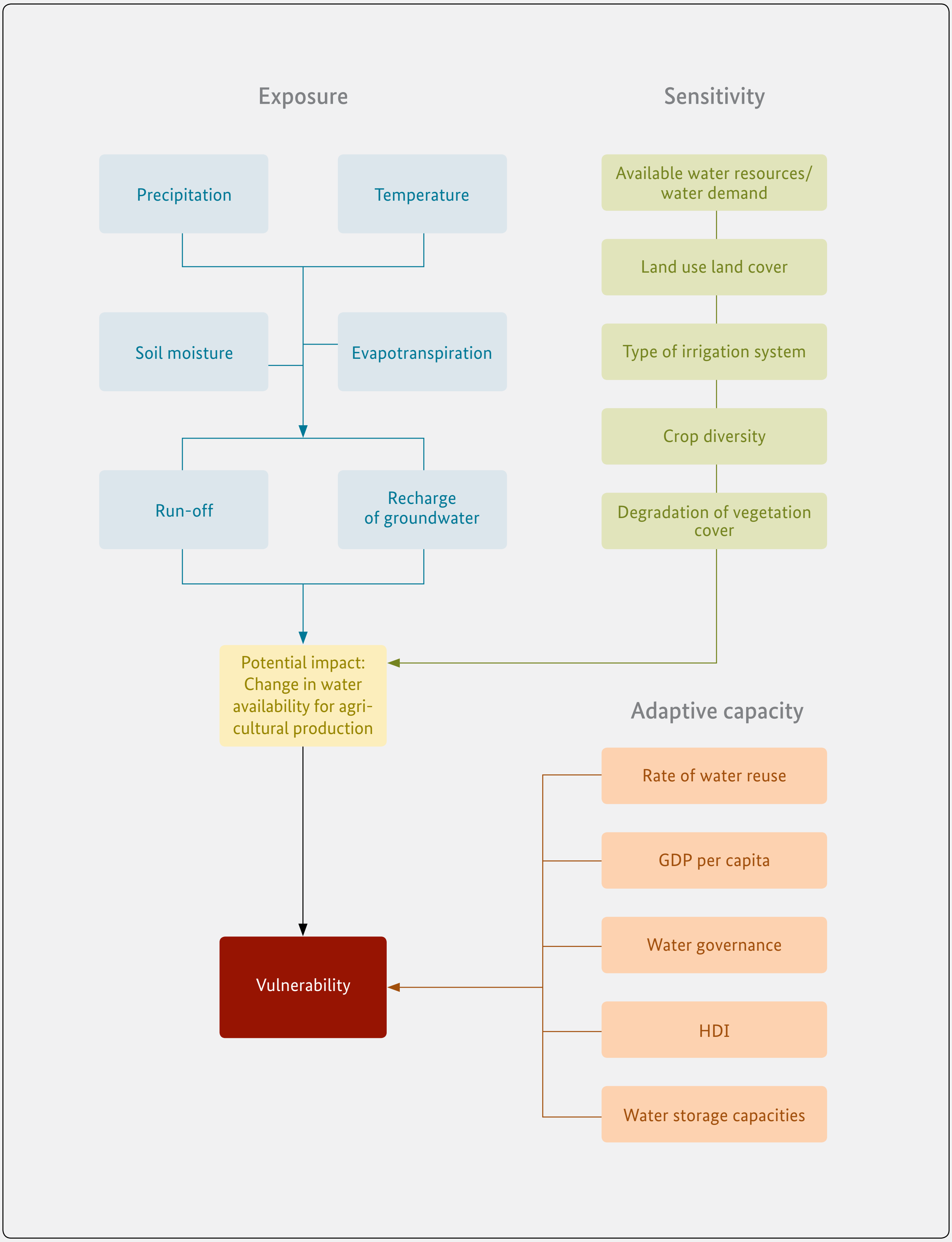
Source: adelphi/EURAC 2014.

Sample impact chain of a trans-boundary vulnerability assessment on the potential impact 'change in area covered by wetlands'



Source: adelphi/EURAC 2014.

Sample impact chain of a trans-boundary vulnerability assessment on the potential impact 'change in water available for agricultural production'



Source: adelphi/EURAC 2014.

3. Selected indicators for vulnerability assessments

Sample indicators for vulnerability assessments

Vulnerability component	Indicator categories	Example indicator	Possible data source	Methods
Exposure	Climatic stimuli	• Number of nights with T(min) above 25°C • Number of extreme rainfall events • Number of days with T(max) below 0°C	• Met. offices, global circulation models (GCMs), regional circulation models (RCMs)	• Data analysis/GCMs, RCMs, trend analysis
		• Percentage of flooded area (100 yr event) • Frequency of (experienced) storm events	• Statistical office, national disaster or loss databases • Met. offices	• Data analysis/GIS analysis/hazard models • Data analysis/survey/ hazard models
Sensitivity	Bio-physical characteristics	• Land cover data • Crop type • Irrigation system	• Statistical office/geodetic institutes/intern. orga. • Geodetic institutes/ statistical offices • Statistical office/ experts/target population	• Remote sensing • Remote sensing/survey • Survey
	Socio-economic characteristics	• Population density • No. of people in 100 yr flood zone	• Statistical office • Statistical office/ hazard maps	• GIS analysis • Survey/GIS analysis
Impact	Loss indicator	• Loss in agricultural production • Potential flood damage	• Value functions (e.g. loss function)	• Empirical • Synthetical
	Potential impact indicator	• Potential storm impact	• VA indicators: exposure and sensitivity	• Geometric aggregation
Adaptive capacity	Socio-economic characteristics	• Level of education • Income • GINI Index • Access to efficient irrigation technology • Access to health facilities	• Statistical office/target population/intern. orga. • Statistical office/target population/intern. orga. • World Bank • Literature/target popula-tion • Statistical office/target population	• Survey/literature study • Survey/literature study • Data analysis/literature study • Literature study/survey • GIS analysis/survey
	Policy indicators	• Change in land use planning policies • Governance indicator	• Literature/exp. interviews • Literature/exp. interviews/ intern. orga.	• Literature study/ques-tionnaire • Literature study/ques-tionnaire

Source: adelphi/EURAC 2014.

Indicators from the vulnerability assessment for Germany

(By the Vulnerability Network [Netzwerk Vulnerabilität])

For the progress report of the German Adaptation Strategy (DAS) in 2015 a standardised assessment covering the whole of Germany was needed and commissioned by the Inter-ministerial Working Group on adaptation in 2011. It covers all sectors of the DAS and also investigates cross-sectoral relationships to enable the comparison of vulnerabilities and to identify spatial and thematic hot-spots for the prioritisation of adaptation needs. To initiate this process, a network of 16 different public authorities and agencies, the so-called 'Vulnerability Network' (Netzwerk Vulnerabilität) was founded, which is supported by a scientific consortium. In a cooperative manner the scientists develop the methodology, collect the available knowledge, prepare the assessment, and work with the scientific officers of the respective authorities, who support the scientists with their expert knowledge and by taking the normative decisions to focus the assessment on most relevant aspects.

Please find below an excerpt of the sensitivity and impact indicators used for the German assessment:

Sensitivity indicators by sector

Sector	Indicator
Building industry	Buildings and infrastructure in flood prone areas
	Building density
	Population density
Transport	Position of civil airports
	Position and amount of transport infrastructure (roads and railways) in flood prone areas
	Position and amount of roads, railways and airfields in frost prone areas
Human health	Proportion of population at the age of 60 years plus (which is highly sensitive against heat)
	Number of hospitals, medical practitioners and ambulances per county
Coastal and marine protection	Land use at the coast
Water	Position of barrages
	Position of wastewater treatment plants
Energy	Position and output of thermal power plants
	Proportion of hydro power
	Position of power supply lines, gas and oil pipelines
Tourism	Position of touristic infrastructure
	Amount of overnight stays and accommodations in counties
	Position of spa towns
Industry and commerce	Position of chemical parks
	Industrial water use
	Percentage of industry and commerce of the total gross value per county

Source: Adelphi/EURAC 2014, Plan and Risk Consult, 2013.

Sector	Indicator
Building industry	Changing potential damages at buildings and infrastructure through flood
	Changing indoor climate
	Changing urban heat island
Transport	Changing number of days with potential icing of aircrafts
	Potential flood damages at roads and railways
	Potential frost damages at roads, railways and airfields
Human health	Changing number of days with potential heat stress for humans
	Changing number of days with weather causing breathing difficulties
	Changing number of medical consultations per county
Coastal and marine protection	Changing building loads through rising sea levels
	Potential damages at coasts through rising sea levels
Fishery	Changing range of fish species
	Changes in growth, reproduction and mortality of fish
	Changes in fishing conditions due to extreme weather events
Water	Changing flow rates
	Changing number and amplitude of floods
	Quality and availability of surface water
Energy	Changing demand of heating/cooling energy
	Changes in the regional hydro power capacity
	Changing availability of cooling water for thermal power plants
	Potential damages at power supply lines, gas and oil pipelines
Finance and insurance sector	Amount of insured losses due to storm and hail
	Changing requirements for insurance and premiums
	Changing decisions concerning investments and credits
Tourism	Changing number of bathing days
	Potential damages at touristic infrastructure due to storm
	Changing number of days with extreme heat in spa towns
Industry and commerce	Potential flooding of chemical parks
	Potential damages at long-distance transport infrastructure due to storm
	Changes in the availability of water for industrial production
Biodiversity	Potential distribution of invasive species
	Changes in ecosystem areas
	Changes in ecosystem services
Soil	Changes in water balance
	Changes in soil erosion and deflation
	Changes in soil functions
Forestry	Changing number of days with risk of forest fires
	Changes in heat and dry stress
	Changes in wood production
Agriculture	Changing growth phase of plants
	Changing yield
	Potential losses due to extreme weather events

Source: adelphi/EURAC 2014.

4. Examples for adaptive capacity indicators

Indicator	Description	Method/ Data
GDP per capita (US$/PPP)	Measurement of the total economic activity /economic overall wealth of a country. Indicates on the ability to finance and sustain adaptation projects.	National data, World Bank - World Development Indicators (WDI)
GINI index	Measurement of a country's income distribution (inequality) and indication of asymmetries for financial burden sharing and social cleavages.	National data, World Bank (WDI)
Ease of doing business index	Assessment of economic regulations and property rights in a country and a ranking of all 189 states. Indicates the potential for economic viability and development potential.	National data, www.doingbusiness.org
Agricultural import quantity index	Quantity indices for the aggregate agricultural and aggregate import of food products. Leads to assumptions on food dependency and vulnerability against world market prices and vulnerability in cases of weather extremes.	National data, FAO Statistics Division
Job sectors per household , as relative number of different job-sectors per household	Reflects the ability of households to react to changes in their income situation. In addition, certain industries are, by nature, safer and more likely to provide better social organisation.	Household-level survey
Mobile cellular subscriptions (per 100 people)	Access to mobile cellular telephone networks serves as proxy for access to an infrastructure of services and information.	National and local data, World Bank (WDI) and local mobile provider.
Improved water source, rural (% of rural population with access)	Percentage of the rural population with access to improved (piped, public taps, protected springs, rainwater collection) drinking water sources preventing infections.	World Bank (WDI)
Improved sanitation facilities (% of population with access)	Percentage of the rural population with access to improved (flush/ pour flush, ventilated, latrine, composting toilet) sanitation indicating resilience to diseases.	World Bank (WDI)
Access to electricity (% of population)	Percentage of the population with access to electricity. Access to electricity is a basic necessity to various activities connected with adaptive efforts.	World Bank (WDI)
Hospital beds (per 1,000 people)	Hospital beds available in public, private, general or specialised hospitals serve as proxy for preparation against diseases and general access to curative and preventive care.	World Health Organization (Global Health Observatory Data Repository), national statistics
Value lost due to electrical outages (% of sales)	Value lost due to electrical outages is the percentage of sales lost due to power outages and serves as a proxy for the vulnerability of power grid and economic potential.	World Bank (WDI), national statistics
Average time to nearest market (minutes)	Average time it takes the households to get to the nearest market.	Local data, survey question 'How long does it take you to get to the nearest market?'
Average time to nearest health facility (minutes)	Average time it takes the households to get to the nearest health facility.	Local data, survey question 'How long does it take you to get to the nearest health facility?'
Voice and Accountability Index	Part of the World Bank's 'Worldwide Governance Indicators'. Captures perceptions on basic freedom and participation rights.	National data, World Bank (WGI)

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Indicator	Description	Method/ Data source
Civil Society Index	Assesses the health and vitality of national civil societies in a 4 dimension approach (Structure, Space/Environment, Values, Impact) measuring the political civic culture and political culture in general.	National data, CIVICUS index
Number of local cooperatives/social organisations per 1000 inhabitants	Households rely on a social network that often acts as a substitute for insurance, savings or as a secure livelihood during disruption in an emergency. Social organisations act as a proxy to the level of social organisation and the potential to provide material or non-material assistance during recovery.	Local data, project data bases of institutions dealing with civic support , survey
Fraction of villages with NGO activity	NGO are considered part of civil society organisations and serve as a proxy to the participatory environment and the degree that different groups of people are able to shape the priorities of (local) government.	Local data, project data bases of institutions dealing with civic support , survey
Riots and conflict, as fraction of villages with at least one riot	Measure the capacity of a society to solve its conflicts internally and without external pressure (political, administrative, militarily). Internal conflict solving is a main reason for strong social ties within communities and facilitates other forms of support.	Local data, survey, Fund For Peace CAST Conflict Assessment Framework
Health expenditure, total (% of GDP)	The sum of public and private health expenditure in relation to the GDP employed as a proxy for commitment on general public interest.	National data, World Bank (WDI), national statistics
Central government debt, total (% of GDP)	All obligations and liabilities of the government to others, serving as an indicator to fiscal freedom of the given country.	National data, World Bank (WDI), national statistics
Internally displaced persons (number, low estimate)	People who have to leave their homes and have not crossed borders. Used as an indicator for internal conflict and administrative burdens.	National data, World Bank (WDI)
Dependency ratio	Ratio of the non-working vs. working population (<15 years and >65 years vs. age 15-65), measuring the economic burden for social policy, care but also intrapersonal networks.	National data, local data, survey question 'Please list the age and sex of every person that sleeps and eats in this house'.
Internet users (per 100 people)	Access to WorldWideWeb serves as an indicator for a general access to information networks.	National data, World Bank (WDI)
Public spending on education, total (% of GDP)	The total public expenditure (current and capital) on education expressed as a percentage of the Gross Domestic Product (GDP) in a given year. Indicates commitment to general education.	National data, World Bank (WDI)
Number of farmers trained on improved irrigation techniques	The number of farmers trained in improved irrigation techniques is an indicator to the general provision and maintenance of improved irrigation systems. It further serves as a proxy to the spread of know-how and awareness about irrigation techniques and irrigation issues.	Local data, project data bases of institutions dealing with water issues, survey
% of income available for investment into new crop types	Indicator on the capacity to plant more resilient crops. To invest in new crop types is an important ability in facing environmental changes.	Local data, project data bases of institutions dealing with crop/agrarian issues, survey
Number of local water cooperations	A proxy to measure institutional capacity to improve water distribution.	Local data, project data bases of institutions dealing with water issues, survey
Number of households that practice improved land management methods such as improved ploughing or anti-erosive measures	A proxy to measure the capacity to improve land management.	Local data, project data bases of institutions dealing with soil/agrarian-issues, survey

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Indicator	Description	Method/ Data source
Adult literacy rate, both sexes (% aged 15 and above)	Percentage of the population ages 15 and older who can, with understanding, both read and write. Needed to access basic information channels and networks.	UNDP Human Development Reports
Pupil-teacher ratio, primary education	The number of pupils enrolled in primary school divided by the number of primary school teachers. Endowment of schools is a main indicator for school and education quality.	National data, local data, World Bank (WDI), national statistics
Research and development (R&D) expenditure (% of GDP)	Expenditures for research and development in relation to the GDP measuring the overall innovation potential and possible technological adaptive capacities.	National data, World Bank (WDI)

Source: Adelphi/EURAC 2014, Plan and Risk Consult, 2013.

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5. Examples for gender-sensitive indicators

Indicator	Unit	Description
Adult literacy rate: female	%	Percentage of females able to read and understand texts.
Gender Inequality Index (GII), 2012		Composite index measuring gender inequality along three dimensions: reproductive health, empowerment, and labour market participation, ranking all participating nation-states. Obtainable through UNDP Human Development Indices.
Gender-Related Development Index (GRDI)		Composite index measuring gender gaps in life expectancy, education, and incomes. Obtainable through UNDP Human Development Indices.
Gross school enrolment ratio - primary + secondary: female	%	Total of female enrollment in primary + secondary education as a percentage of the female population of official education age. Data obtainable by World Bank (WDI), UN and national statistics.
Ratio of girls to boys in primary and secondary education	%	Percentage of girls to boys enrolled at primary and secondary levels in public and private schools. Data obtainable by World Bank (WDI).
Ratio of female to male tertiary enrollment	%	Percentage of men to women enrolled at tertiary level in public and private schools. Data obtainable by World Bank (WDI).
Progression of females to secondary school	%	The share of female pupils enrolled in the final grade of primary education progressing to secondary school. Data obtainable by World Bank (WDI).

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Indicator	Unit	Description
Infant mortality	Total per 1,000 live births	High infant mortality has a negative impact on household income with disproportionate effects on women (compared to men) in particular. Data obtainable through World Health Organization (WHO) Mortality Database.
Maternal mortality ratio	%	The maternal mortality ratio represents the risk associated with each pregnancy due to insufficient health care and/or information and gender priorisation. As such exposure is a risk exclusively to women. Data obtainable through WHO.
Percent of female-headed households	%	Female-headed households are subject to several disadvantages (higher dependency, fewer assets and less access to resources, greater history of disruption, less income, diversification and mobility). Percentage of households where the primary adult is female. If a male head is away from the home >6 months per year the female is counted as the head of the household. Data obtainable by survey or questionnaire.
Percent of households with family member with chronic illness	%	Chronic illness is a major risk for poverty, making women very vulnerable both as persons affected or caring. Percentage of households that report at least 1 family member with chronic illness. Chronic illness is defined subjectively by respondent. Data obtainable by survey.
Percent of households with family member working in a different community	%	Working migration is an important source of income diversification. Due to their lower mobility women have additional duties to perform. Percentage of households that report at least 1 family member who works outside of the community for their primary work activity. Data obtainable by survey.
Percent of households with orphans	%	Orphans and their upbringing impose additional obligations and resources to their respective household. Percentage of households that have at least 1 orphan living in their home. Orphans are children <18 years old who have lost one or both parents. Data obtainable by survey.
Civic organisations and associations active in the area (opt.: concerned with gender issues)	Absolute number/ %	The number of associations serves as an approximation to the ability to voice opinions and concepts and to participate in decision making and agenda setting in the public sphere. Possible extension could be the number of associations focusing on gender/female issues. Data obtainable by survey or questionnaire.
Share of issued land titles held by women	ha/ acreage/ %	Measurement of proportion of issued land titles that are held by women. In some countries or cases, land titles are more difficult for women to obtain or inherit. Data obtainable by survey or national statistics.
Share of women in wage employment in the non-agricultural sector	%	The share of female workers in wage employment in the non-agricultural sector (industry and services) expressed as a percentage of total wage employment in that same sector. Wage employment has often been the preserve of men in less developed countries, except in agriculture. Data obtainable by World Bank (WDI) and FAO.
Women's share of total labour force	%	Female labour force as a percentage of the total. Shows the extent to which women are active in the labour force. In the light of women's participation in the informal sector and housework, the share of labour force is used as a proxy for general participation in social live and entry points in the public sphere. Data obtainable by WB (WDI), International Labour Organization (ILO) and national statistics.

Source: adelphi/EURAC 2014.

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6. Indicator factsheet

Template indicator factsheets

FACTSHEET: Number of factsheet (e.g. IMP #1)

Excel sheet available online at: https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Indicator	
Indicator:	Name of the indicator *Water available from precipitation.*
Vulnerability component:	Which vulnerability component is described by the indicator? *Impact.*
Description (position in the impact chain):	Further description of the indicator *Calculated indicator for the impact 'water available from precipitation';* *Output for: 'water available from irrigation' and 'water supply for crops'.*
Additional comments:	
Data	
Sources of data:	Who provides data? *University La Paz, Department of Agriculture.*
Availability and costs:	What are the conditions to obtain the data? *Official request by the Ministry of Agriculture; no costs.*
Type of data:	In which format are the data available? *Geo-data (shape file).*
Spatial level:	Coverage and scale of the data *National coverage, 1 value per district.*
Statistical scale:	Which statistical scale do the data have? *Metric.*
Unit of measurement:	In which unit are the data provided? *Runoff in m^3 / sec.*
Method of calculation:	Which method has been applied for calculation? *Semi-physical model based on the methodology of Mello 2008.*
Input-indicators needed:	Are sub-indicators needed? Which? *For current situation: no.* *For 2050: re-run of the model necessary with new input values for daily precipitation and evapotranspiration.*
Time reference and frequency of measurement:	For which year(s) are the data available? *1990-2010, yearly.*
Expected trend without adaptation:	Trend of climate change impact *Decrease.*
Classes and thresholds:	Which classes or thresholds are proposed or determined? Is this a common used classification? *Proposed thresholds: more than 100 mm; 100 to 0 mm; 0 to -100 mm; less than -100 mm.*
Rating:	Which scale or classes should be used for the assessment? *Scale from 0 to 1 (using 200 mm precipitation as zero-point).*
Additional comments:	

Sources: Ministry of Environment and Mineral Resources 2012, Plan and Risk Consult 2013.

Sample indicator factsheets

Used in a vulnerability assessment in Pakistan (see Annex 10)

Poverty line

Indicator	
Indicator:	Name of the indicator *Poverty line.*
Vulnerability component:	Which vulnerability component is described by the indicator? *Adaptive capacity.*
Description (position in the impact chain):	Further description of the indicator *Poverty is increasing in Pakistan. Impact on food security and livelihood options.*
Additional comments:	*Poverty increased from 23% in 2008 to 37.4% in 2011. Standard of living has reduced due to less spending in social sector. Increase in inflation, prices and shortage of commodities have further burdened millions of people and pushed them down to poverty line.*
Data	
Sources of data:	Who provides data? *1. Ministry of Finance.* *2. Planning Commission of Pakistan.* *3. Economic Affairs Division.* *4. Pakistan Institute of Development Economics (PIDE).* *5. NWFP Economic Report, World Bank (2005).*
Availability and costs:	What are the conditions to obtain the data? *Written request. Normal cost of the copy of the report.*
Type of data:	In which format are the data available? *Reports, tables, graphs.*
Spatial level:	Coverage and scale of the data *National, provincial.*
Statistical scale:	Which statistical scale do the data have? *Metric.*
Unit of measurement:	In which unit are the data provided? *% of population.*
Method of calculation:	Which method has been applied for calculation? *Economic survey.*
Input-indicators needed:	Are sub-indicators needed? Which? *Not applicable.*
Time reference and frequency of measurement:	For which year(s) are the data available? *2011. No such data has been released for the last 3 years.*
Expected trend without adaptation:	Trend of climate change impact *More people pushed down below poverty line.*
Classes and thresholds:	Which classes or thresholds are proposed or determined? Is this a common used classification? *Based on government current minimum monthly wage of Rs 10,000 for a family of 8 persons, which comes to RS 40 dollar per day.*
Rating:	Which scale or classes should be used for the assessment?
Additional comments:	*No coherent definition for 'poverty line' is followed in Pakistan and no authentic and straight forward data is forthcoming.*

Source: ADMC and adelphi/EURAC 2014.

Access to health services

Indicator	
Indicator:	Name of the indicator *Access to health services.*
Vulnerability component:	Which vulnerability component is described by the indicator? *Adaptive capacity.*
Description (position in the impact chain):	Further description of the indicator *Access to health services depends upon the number of health services centers, cost of medicine, allied services and affordability which in turn depends upon the economic situation of the country.*
Additional comments:	*Government health facilities are available in all districts of the province. Similarly number of private health services centers has increased but quality of service has declined as a result of which a person has to pay visits again and again. Moreover cost and quality of laboratories and medicines is also questionable, further burdened millions of people and pushed them down to poverty line.*
Data	
Sources of data:	Who provides data? *1. Provincial Health Department.* *2. Pakistan Social and Living Standard Measurement Survey.* *3. Provincial Bureau of Statistics.*
Availability and costs:	What are the conditions to obtain the data? *Written request. Normal cost of the report.*
Type of data:	In which format are the data available? *Reports, tables.*
Spatial level:	Coverage and scale of the data *National, provincial, local.*
Statistical scale:	Which statistical scale do the data have? *Metric.*
Unit of measurement:	In which unit are the data provided? *% of persons who have access/ no access.*
Method of calculation:	Which method has been applied for calculation? *Survey and public sector infrastructure development reports.*
Input-indicators needed:	Are sub-indicators needed? Which? *Not applicable.*
Time reference and frequency of measurement:	For which year(s) are the data available? *Annual Review Report (2012-13).* *Annual Monitoring & Evaluation Report (2011-12).*
Expected trend without adaptation:	Trend of climate change impact *Access to health services will be severely affected.* *Increase in various kind of diseases and population growth will cause decrease in access to health services.*
Classes and thresholds:	Which classes or thresholds are proposed or determined? Is this a common used classification? *% of persons covered by the facility.* *Control of contagious/infectious diseases.*
Rating:	Which scale or classes should be used for the assessment?
Additional comments:	*There is a whole range of health facilities ranging from allopathic to indigenous and all have their clients in large number.*

Source: ADMC and adelphi/EURAC 2014.

River discharge

Indicator	
Indicator:	Name of the indicator *River discharge.*
Vulnerability component:	Which vulnerability component is described by the indicator? *Impact.*
Description (position in the impact chain):	Further description of the indicator *Discharge of main rivers at given outlets (Output) , in response to rains / snow recorded at observatories across the catchments (Input) are forecasted by WAPDA through stochastic model per decades observation to manage/ regulate water for irrigation and flood waning.*
Additional comments:	
Data	
Sources of data:	Who provides data? *WAPDA.*
Availability and costs:	What are the conditions to obtain the data? *Official request has to be made to WAPDA; no costs.*
Type of data:	In which format are the data available? *Digital sheets.*
Spatial level:	Coverage and scale of the data *National coverage (values per major catchment).*
Statistical scale:	Which statistical scale do the data have? *Metric.*
Unit of measurement:	In which unit are the data provided? *Runoff in m^3 / sec.*
Method of calculation:	Which method has been applied for calculation? *The rainfall-discharge data series recorded over decades are statistically correlated towards developing input-output relationships.*
Input-indicators needed:	Are sub-indicators needed? Which? *For current situation: no.* *For 2050 and 2100: re-run of the model necessary with new input varies for daily precipitation and evapotranspiration.*
Time reference and frequency of measurement:	For which year(s) are the data available? *Updated once per decade.*
Expected trend without adaptation:	Trend of climate change impact *Seasonal variation. More water in the initial years may fall after receding of glaciers.*
Classes and thresholds:	Which classes or thresholds are proposed or determined? Is this a common used classification?
Rating:	Which scale or classes should be used for the assessment?
Additional comments:	

Source: ADMC and adelphi/EURAC 2014.

7. Examples for evaluation of indicators

During a workshop in Bujumbura/Burundi with 10 local experts from various disciplines, the values of several indicators were allocated to five different classes representing the range from very negative to very positive situations. This class allocation was supported by:

1. A map visualising the data distribution over the country;
2. A precise question that ensured that the experts evaluated the indicators in the context of the impact at stake;
3. The minimum and maximum values of the dataset (where appropriate).

The following figures display some of the evaluated indicators used in the Burundi vulnerability assessment.

Example 1: evaluation of the 'crop type' indicator

Which crop type is / is not resistant towards water scarcity?

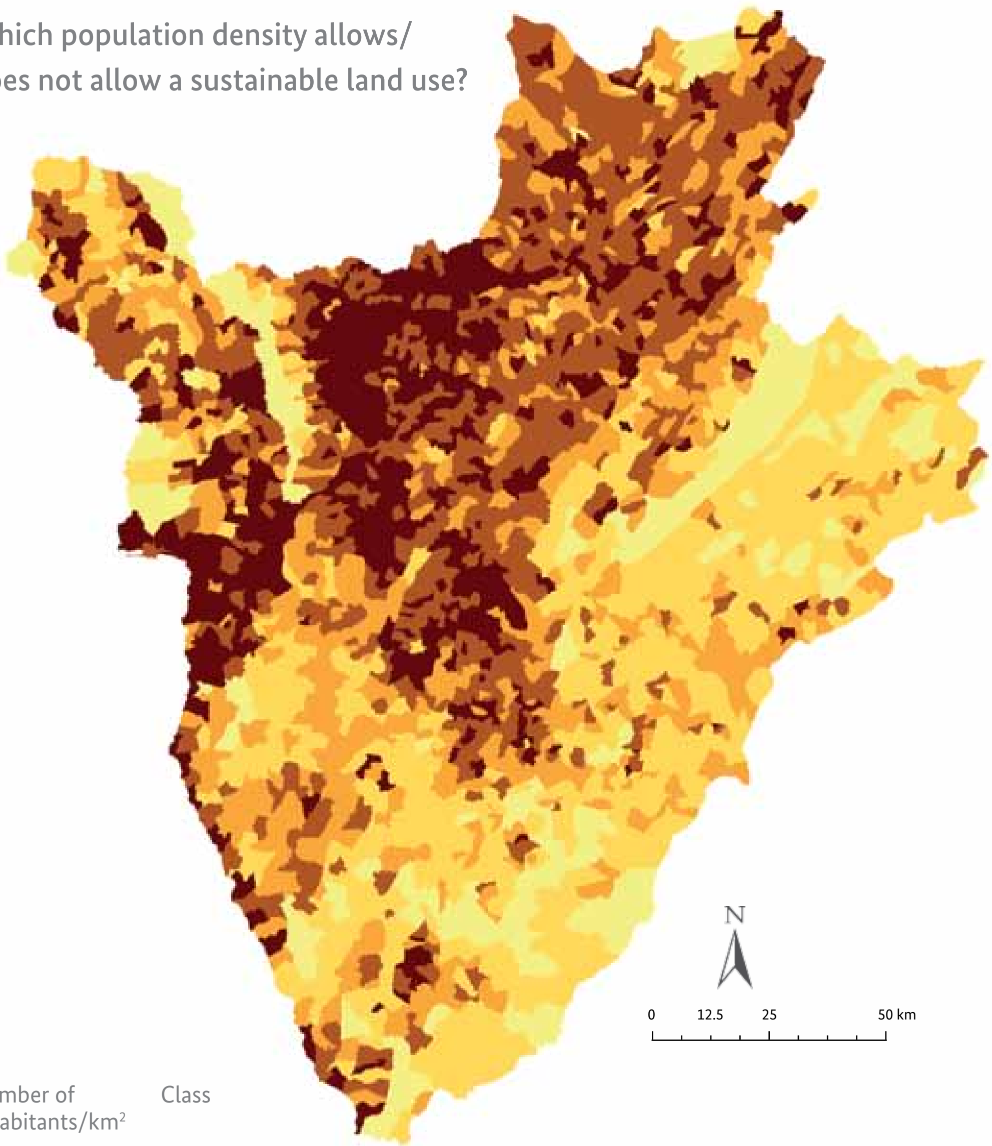
Crop type	Class	Crop type	Class
Natural forest	1	Degraded soil	1
Plantation	1	Rocky mountain ridge	1
Annual plants	1	Pasture	2
Perennial plants	1	Rice cultivation	5
Wetlands	5	Sugar cane	5
Savanna	3	Urban	4
Water body	4		

1 – very resistant / 5 – not resistant

Source: adelphi/EURAC 2014.

Example 2:
evaluation of the 'population density' indicator

Which population density allows/
does not allow a sustainable land use?



Number of inhabitants/km²	Class
< 101	1
101 – 200	2
201 – 300	3
301 – 450	4
> 450	5

1 - allows sustainable land use / 5 - does not allow sustainable use

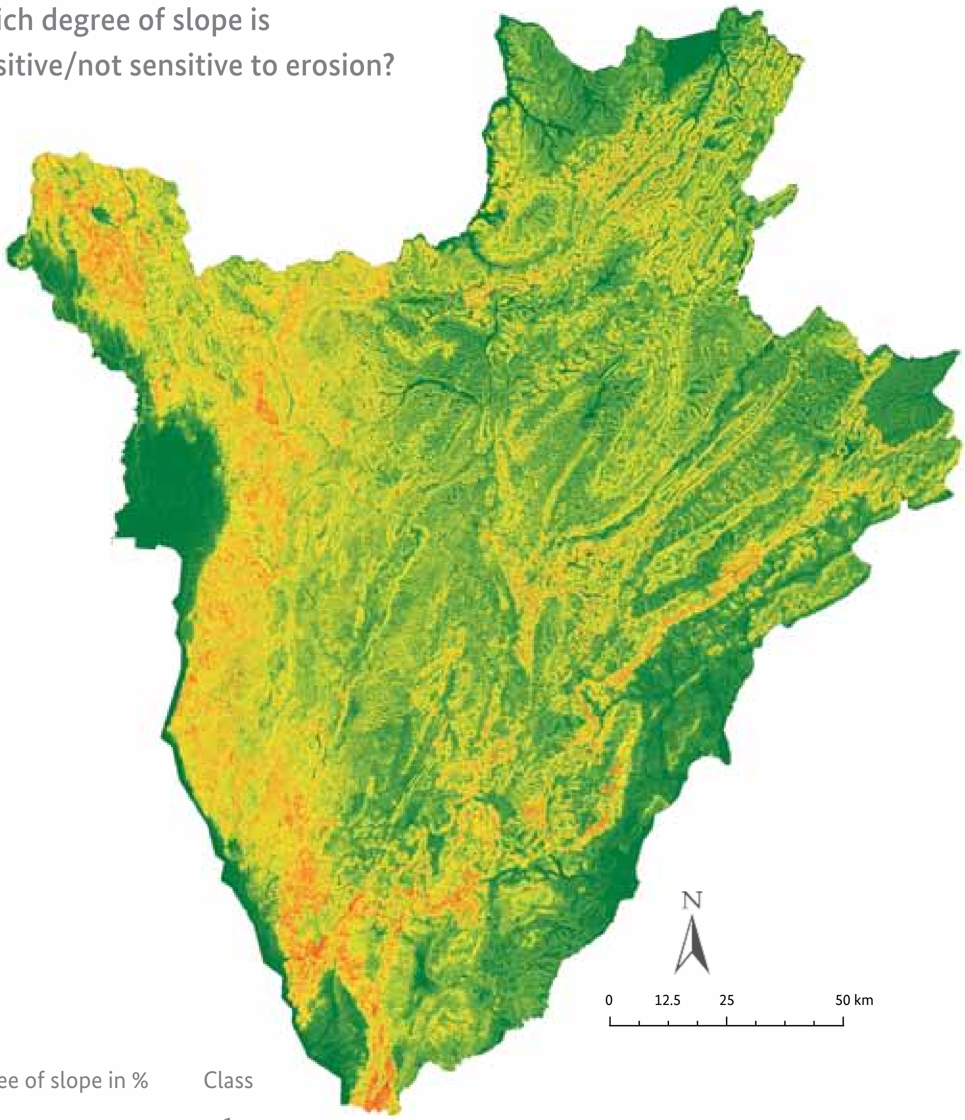
Population density per km², average per colline

< 50 | 50 – 100 | 101 – 200 | 201 – 400 | 401 – 500 | > 500

Source: adelphi/EURAC 2014.

Example 3: evaluation of the ‘degree of slope’ indicator

Which degree of slope is sensitive/not sensitive to erosion?



Degree of slope in %	Class
< 6	1
6 – 10	2
11 – 30	3
31 – 60	4
> 60	5

1 – not sensitive / 5 – very sensitive

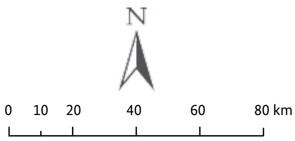
Type of slope in °

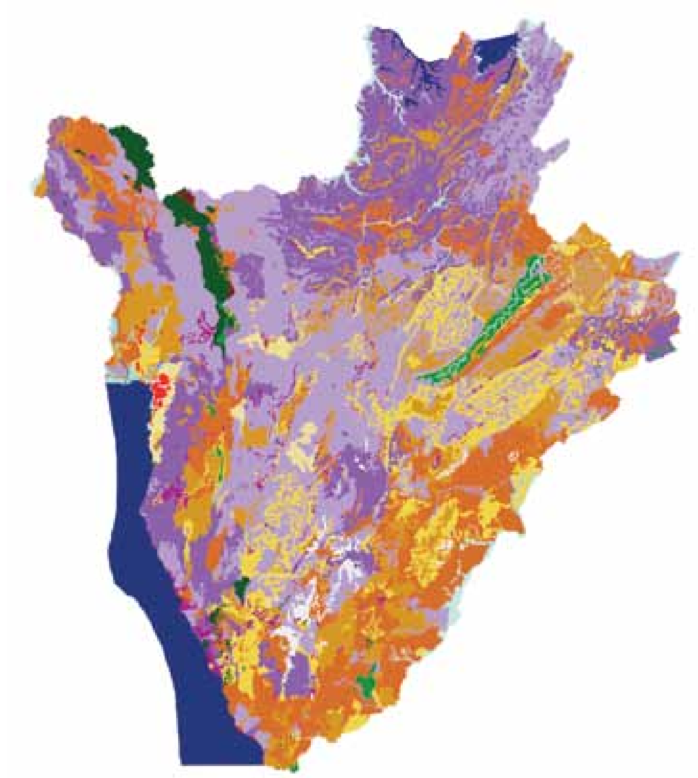
< 6 | 6 – 10 | 11 – 20 | 21 – 30 | 31 – 40 | > 40

Source: adelphi/EURAC 2014.

Example 4: evaluation of the ‘vegetation cover’ indicator

Which vegetation type supports the prevalence of mosquitos?





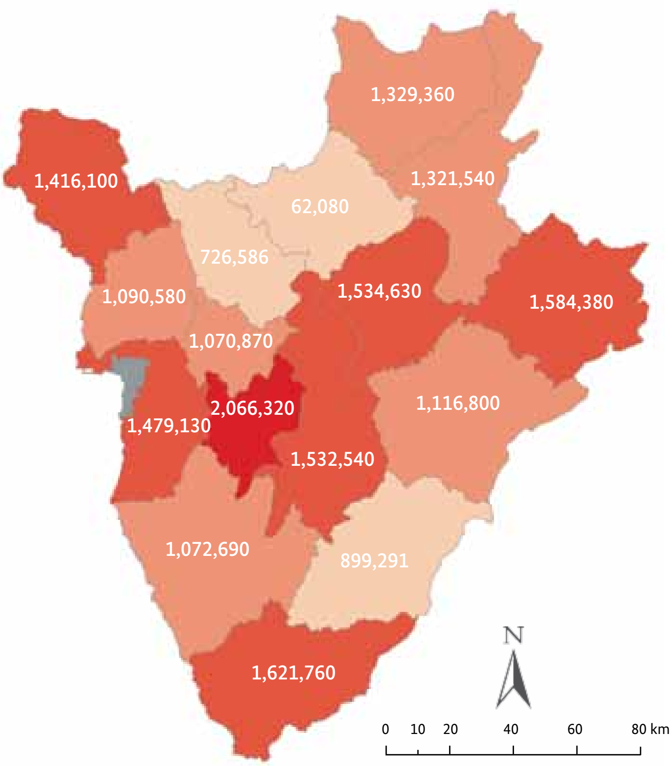
- Forest plantations and tree plantations
- Shrub crop
- Herbaceous crops
- Vegetated urban areas
- Forest
- Woodland
- Closed woody vegetation
- Open woody vegetation
- Thicket
- Shrubland
- Tree savannah
- Shrub savannah
- Grassland
- Sparse trees
- Sparse shrubs
- Sparse herbaceous vegetation
- Fields rice
- Closed swamp
- Open swamp
- Woody vegetation on flooded land
- Shrubs on flooded land
- Herbaceous vegetation on flooded land
- Artificial surfaces
- Bare soil
- Water bodies
- Snow

Vegetation cover	Class
Natural forest	1
Plantation	1
Annual plants	1
Perennial plants	1
Wetlands	5
Savanna	3
Water body	4
Degraded soil	1
Rocky mountain ridge	1
Pasture	2
Rice cultivation	5
Sugar cane	5
Urban	4

Source: adelphi/EURAC 2014.

Example 5:
evaluation of the 'household income' indicator

Which monthly income allows for adaptation?



Average farmer
household revenue (Fbu)

- no data
- 0 – 726,586
- 726,587 – 1,116,800
- 1,116,801 – 1,416,100
- 1,416,101 – 1,121,760
- 1,121,761 – 2,066,320

Classification: Natural breaks (Jenks)

Province	FBU/year	FBU/day	class
Bubanza	1,090,582	3063	5
Bujumbura rural	1,479,129	4155	4
Bururi	1,072,687	3013	5
Cankuzo	1,584,383	4451	3
Cibitoke	1,416,099	3978	4
Gitega	1,532,542	4305	3
Karuzi	1,534,630	4311	3
Kayanza	726,586	2041	5
Kirundo	1,329,355	3734	4
Makamba	1,621,757	4555	3
Muramvya	1,070,867	3008	5
Muyinga	1,321,536	3712	4
Mwaro	2,066,318	5804	3
Ngozi	620,080	1742	5
Rutana	899,291	2526	5
Ruyigi	1,116,795	3137	4

1 – does allow to adapt / 5 – does not allow to adapt

Source: adelphi/EURAC 2014.

8. Excel template for aggregating indicators of exposure, sensitivity, adaptive capacity and vulnerability components

		Description of factor	Indicator	Assessment scale		Observed value	Normalised value
				Lowest value	Highest value		
Exposure							
	Example	**Extreme rain events**	**Number of extreme rain events in the last 5 years**	**0**	**10**	**3**	**0.3**
	1						0
	2						0
	3						0
	4						0
	5						0
	6						0
	7						0
	8						
Sensitivity							
	Example	**Deforestation**	**% deforestation**	**0**	**100**	**20**	**0.2**
	1						0
	2						0
	3						0
	4						0
	5						0
	6						0
	7						0
	8						
Adaptive Capacity							
	Example	**Law enforcement**	**Satisfaction level**	**0**	**4**	**1**	**0.25**
	1						0
	2						0
	3						0
	4						0
	5						0
	6						0
	7						0
	8						

Excel template available online at:

https://gc21.giz.de/ibt/var/app/wp342deP/1443/index.php/knowledge/vulnerability-assessment/vulnerability-sourcebook/

Weighting factor for each indicator	Total	POTENTIAL IMPACT	Weighting factor for potential impact	ADAPTIVE CAPACITY	Weighting factor for adaptive capacity	IMPACT TO VULNERABILITY
1	**0.3**					
	0					
1	**0.2**					
	0	0	1	0	1	0
1						

Source: adelphi/EURAC 2014.

9. Sample structure of a vulnerability assessment report

1. Introduction (Refer to Module 1)

- What is the context of the VA? (Module 1; Step 1)
  - E.g. is the VA part of a superior process? Which institutions want to conduct the VA, who is involved, who are main target users? Are particular climate change challenges already identified?
- What are the objectives of the VA? (Module 1; Step 2)
  - E.g. is the VA supposed to contribute to concrete adaptation planning? Is the main objective to identify cross-sectoral hotspots? Or is it supposed to identify particularly vulnerable population groups?
- What are the topic(s), areas and time periods covered by the VA (Module 1; Step 3)?
  - In short: Who is vulnerable (or which system?), to which climate change impact and where? (The system can be understood as an economic sector, livelihoods, segments of population etc.)
  - E.g. which sectors, segments of populations, livelihoods etc. are the focus of the VA? On which spatial or administrative level does the VA take place (e.g. on the level of villages, communities, regions, etc.)? Does the VA concentrate on present vulnerability or does it include a forward-looking vulnerability analysis?
- Understanding of vulnerability and its components applied for the VA (refer to Conceptual Framework)
  - How is vulnerability understood in the analysis? Here, please refer to the Vulnerability Sourcebook's approach to vulnerability and highlight and explain any differences in the concept used (if applicable).
- Stakeholders involved in the preparation and implementation of the VA (Module 1; Step 1)
  - Who contributed to the VA, which institutions where involved, which civil society actors or affected communities were involved, etc.?

2. Understanding of climate change impacts (Refer to Module 2)

- Which factors contribute to climate change vulnerability? (specific to the system the VA is concentrating on) (Module 2; Steps 1 to 4)

  - Factors should be clustered (according to the Vulnerability Sourcebook's approach) in exposure, sensitivity, potential impact and adaptive capacity.
  - Apply and describe impact chains as analytical and visualisation tool.

- What are the underlying cause-effect-relationships? For instance, how are exposure, sensitivity and adaptive capacity interlinked to form the vulnerability of the system? (Module 2; Steps 1 to 4)

3. Assessment methodology (Refer to Modules 3 – 7)

- Key information on the overall implementation process of the VA
  - E.g. work plan, time needed for the implementation, number of field missions conducted.
- Which indicators were selected for which vulnerability factors? (Module 3)
  - How were the indicators selected? (E.g. based on the impact chains using a participatory approach, based on a literature review).
  - What does the indicator express?
- What is the data/information base of the VA? (Module 4)
  - Which methods are used to quantify the indicators (e.g. models, statistics, survey, but also expert judgement)/which data sets and information were used?
  - What were data quality challenges and how were they coped with?
- How is data normalised? (Module 5)
  - Explain normalisation technique (e.g. min-max-normalisation)
- Which thresholds were identified for different indicators? (Module 5)
  - How where these thresholds determined? E.g. expert judgment, thresholds from the literature.
- How were indicators weighted? (Module 6)
  - Explain if indicators are assigned equal ('equal weighting is also weighting') or different weights
  - Outline method for weighting, e.g. using a certain participatory approach, based on expert knowledge, literature review.
- What are the aggregation rules on the level of vulnerability components? (e.g. arithmetic aggregation as recommended in the Vulnerability Sourcebook) (Module 6)
- What is the aggregation rule for calculating vulnerability from its components? (Module 7)

4. Outcomes of the VA (Refer to Module 8)

- What are the key findings from the VA related to its objective?
- Which recommendations can be drawn from the VA results?
  - E.g. for adaptation planning, strategy development, priority areas for action.
- What are central lessons-learned from the implementation of the VA?
  - What are limits and opportunities of the VA?
  - Which advises can be given to the future use of VAs in similar processes?

5. Annex

- Key documents and files used for the implementation, e.g. documentation of workshops, transcripts of interviews, questionnaires used, tables and maps developed.
- List of data used including meta data (see template of data factsheet above)
- Additional background information and literature

10

10. Applying the Vulnerability Sourcebook: vulnerability assessment in Khyber Pakhtunkhwa, Pakistan

Participants of the vulnerability assessment in Pakistan

Source: adelphi/EURAC 2014.

adelphi

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List of contents

Background of the vulnerability assessment

Pakistan is ecologically unique and is one of the main biodiversity hotspots worldwide. It is home to many varieties of endemic wildlife and is rich in indigenous crop diversity with an estimated 3000 taxa and cultivated plants.

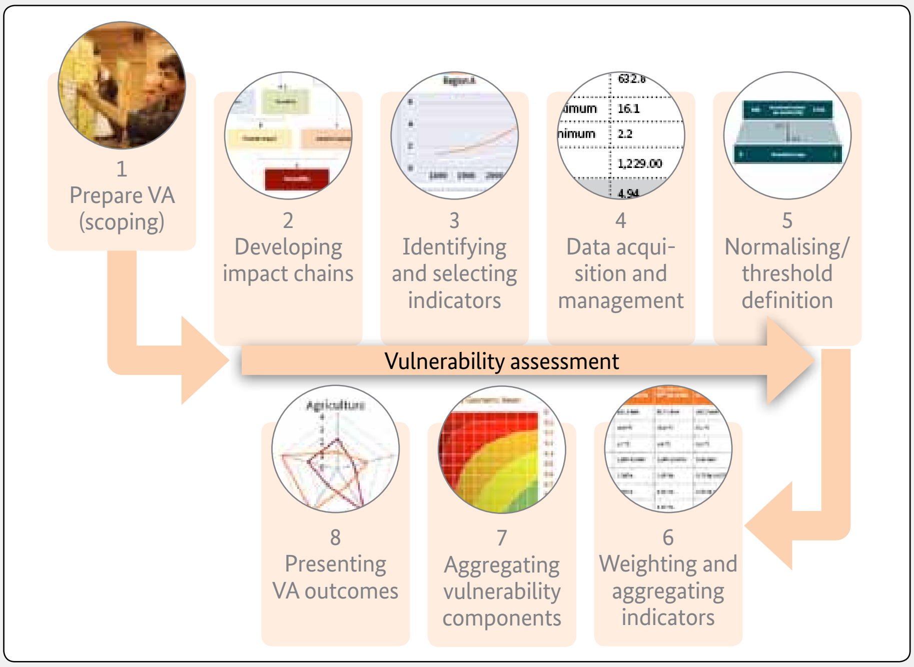
The ecosystems and their biodiversity are not only ecologically important, but they also play an essential role for economic development. Ecosystems and the services they provide to humans are crucial for the over 3.5 million people living in Khyber Pakhtunkhwa province. However, these resources are seriously threatened by human made factors such as the overuse of natural resources, which is further reinforced by population growth as well as an influx of refugees and internally displaced persons. Moreover, natural hazards and negative effects of climate change such as heavy rainfall events, floods and earthquakes considerably affect livelihoods in Khyber Pakhtunkhwa province. The impacts of climate change on the living conditions of the population and the loss of biodiversity have also been acknowledged by the Pakistani government and are perceived as a threat to national economic and social development.

Against this background, GIZ is currently implementing the project ‘Conservation and Sustainable Management of Biodiversity in Khyber Pakhtunkhwa (BKP)’, on behalf of the Federal Ministry of Economic Cooperation and Development (BMZ). The project aims at improving the capacity of the Khyber Pakhtunkhwa government in considering biodiversity (agro-biodiversity) as a core element of sustainable policy development. Moreover, it comprises the identification and implementation of community-driven and ecosystem-based adaptation measures to climate change. The project focuses specifically upon the two districts of Swat and Chitral, where the implementation of pilot measures and best practices intend to benefit the local communities directly.

Applying the Vulnerability Sourcebook in Pakistan

An explorative vulnerability assessment was carried out that assessed the climate vulnerability of Swat and Chitral in a standardised way. The objective of the VA in the two districts was to (a) raise awareness, (b) identify suitable adaptation measures at the community level, monitoring and evaluating their effectiveness and (c) provide policy advice. The assessment primarily followed the modules outlined in the Vulnerability Sourcebook and are described in greater detail in the following sections (see also Figure 1).

Figure 1: The eight modules of a vulnerability assessment according to the Vulnerability Sourcebook



Source: adelphi/EURAC 2014.

The explorative VA was implemented during a 3 day stakeholder workshop in December in Islamabad, consisting of two parts. During the first 1 1/2 days, the concept of the Vulnerability Sourcebook was introduced to a wide range of about 35 stakeholders from national, provincial and district level, and their expertise on climate change vulnerabilities and possible data sources for such an assessment was gathered. During the final 1 1/2 days, the explorative VA was prepared together with the implementation teams and BKP project staff for the two pilot areas. The implementation teams consisted of agricultural and forestry experts from districts' administrations. These implementation teams will be responsible to carry out additional explorative VAs together with local communities in Swat and Chitral subsequent to the workshop and to oversee the implementation of the identified adaptation measures.

Preparing the vulnerability assessment (Module 1)

In line with Module 1 of the Vulnerability Sourcebook, the explorative vulnerability assessment was prepared by assessing the context of the analysis, defining its objectives and making key decisions on scope and topics.

To gain a solid understanding of the context in which the VA was implemented, a local consultant was commissioned in advance to prepare a scoping study. This provided information on the case study areas of Chitral and Swat and their climate vulnerabilities. Moreover, it covered ongoing activities on adaptation and vulnerability and already identified possible data sources and availability. In total, about 30 person days were invested in the scoping study to lay the groundwork for the vulnerability assessment. It proved to be a very useful input for the workshop and the conduction of the VA.

During the workshop, the key attributes of the VA in Pakistan were further defined together with the implementation teams from Swat and Chitral and GIZ project staff. This included the definition of the objective of the VA, its spatial and temporal scale, reference group, methodological approach, required resources, partners and stakeholders, as well as key topics.

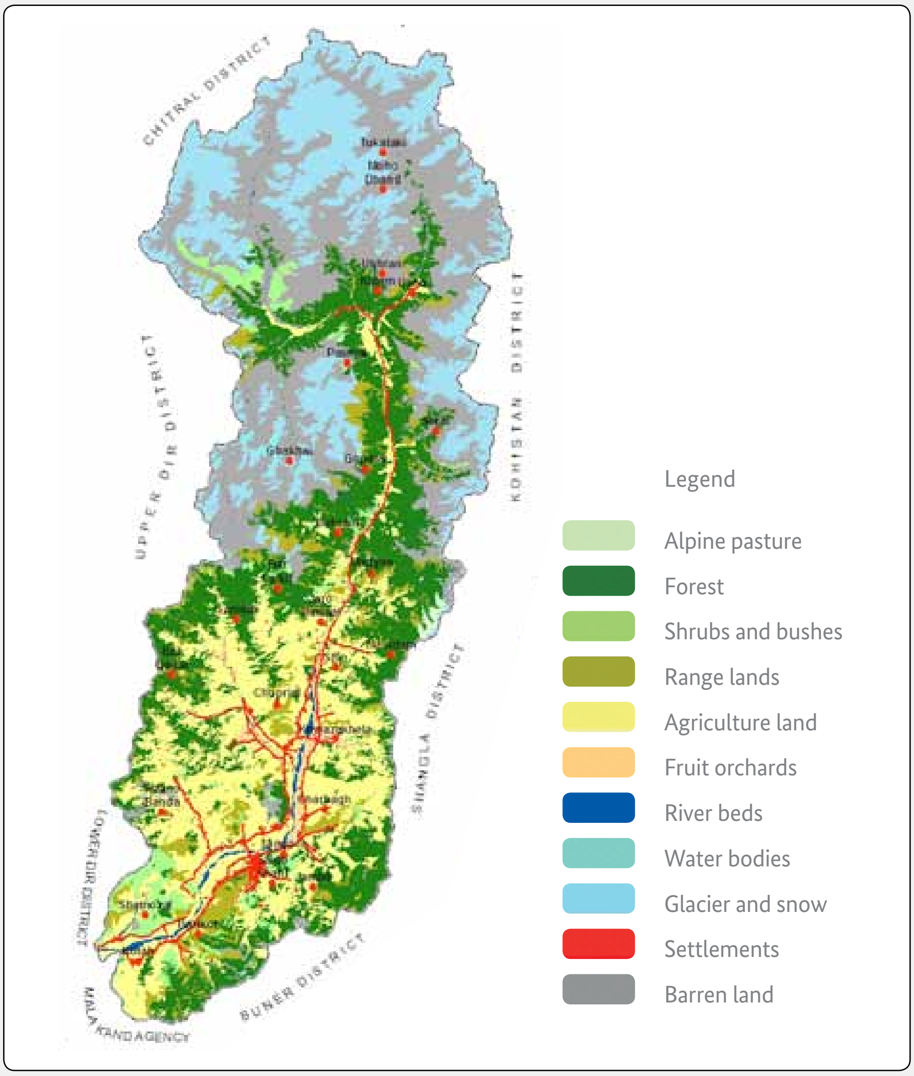
Understanding the context of the vulnerability assessment (Module 1; Step 1)

Case study areas

The Swat district (see Figure 2) can be divided into lower Swat and upper Swat. Lower Swat is affected by monsoons and offers a sub-tropical to temperate climate. Crops of all kinds, especially vegetables and fruits, are cultivated here. This part of Swat is known for its high quality walnuts and deemed particularly suited for commercial agriculture. With new, exclusively commercial species being introduced there is a fear that indigenous species might become extinct. On top of that, there are rising concerns about new diseases and vermin (especially new fruit flies). Both developments are partly also caused by changing climatic conditions such as warmer temperatures.

In contrast, Upper Swat is very rich in biodiversity, mostly consisting of high mountain ranges and remote valleys. It is a dry region that mostly experiences winter rain, as it is shielded from monsoons by the Pamir Mountains. Upper Swat has mostly subsistence farming and vegetables (off-season products) and is also known as a famous hunting ground for trophy animals. Both regions differ substantially in their topological, meteorological and therefore biological conditions. They do share similarities though, the most noteworthy being the decrease in yield, a change in crop patterns and the increase of invasive species.

Figure 2: The Swat district



Source: adelphi/EURAC 2014.

Last but not least, both of the Swat areas incorporate a large number of rivers, tributaries and melt water reservoirs, which are responsible for several flash floods over the last years, creating concern over erosion and the growing damage as a result of such floods. Flood risk might be further enhanced due to shifts in precipitation patterns as well as anthropogenic land use change.

Chitral is a high altitude valley-district that borders Afghanistan. It is one of the remotest areas of Pakistan and almost inaccessible during wintertime. Except for one highway, its roads are closed during winter, secluding the valley from the outside. Famed for its wildlife, it is rich in biodiversity yet comparably poor in economic terms. The economy is determined by subsistence farming and trophy hunting. 9 % of its surface is covered by forests (a famous oak forest is found in Chitral), providing habitat for a rich diversity of indigenous species and making up one fifth of the entire Khyber Pakhtunkhwa province's forests.

Figure 3: Regional expert showing steep slopes with deforestation and unsuitable cultivation which is prone to erosion

Source: adelphi/EURAC 2014.

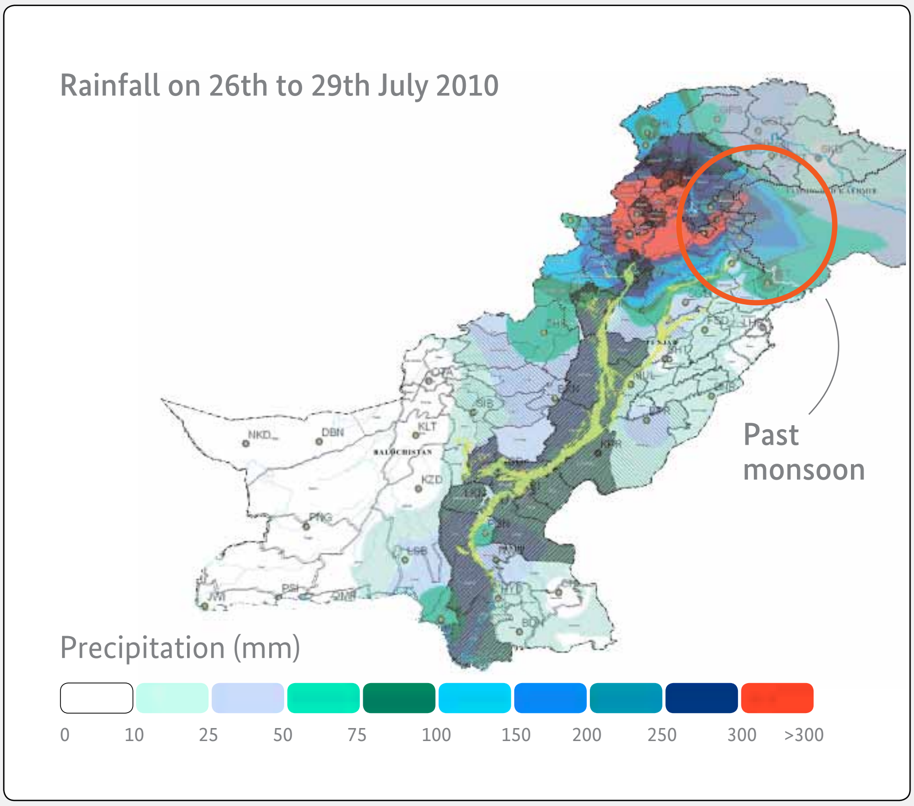
The lower parts of Chitral only get a fraction of the monsoon rain, leaving the northern part quite dry. Crop patterns include mono-crop situated up from Buni/Booni and double-crop situated below this fertile floodplain on the banks of the Mastuj River. There are some spots in Chitral that are suitable for growth of winter vegetables, but it is small scale farming (0.5 acres/household) that is predominant in the district, with the most prominent fruit species being pears and walnuts. The thin population density, scarcity of arable land and difficult working conditions make Chitral an area affected by high poverty and dominated by landlords. High transportation costs are a primary reason for the low export orientation of agricultural products. Chitral can thus be characterised as a region of high food insecurity, especially due to seasonal road and tunnel closures. Deforestation and the cultivation of unsuitable plants pose an added threat to the ecosystem which is accelerated by climate change making the need for adaptation even more important (see Figure 3). In addition, Chitral experiences landslides, erosion and degradation which pose a threat to both ecosystems and subsistence farmers.

Climate vulnerabilities

In line with the Vulnerability Sourcebook's terminology, climate vulnerability was assessed with respect to exposure, sensitivity and adaptive capacity to get a clearer understanding of the area under review.

In terms of exposure, over the last century, a temperature increase of about 0.06°C per decade has been observed in Pakistan, showing increased acceleration over recent decades. Precipitation trends also seem to have shifted, as indicated by late winter rains, heavy snowfall and a shift in monsoon patterns. Over the last 60 years, monsoons have shifted by about 80-100km from the northwest of the country towards the northeast of the country (see Figure 4).

Figure 4: Monsoon shift in Pakistan based on the records of the past 60 years



Source: Pakistan Meteorological Department.

Various studies of the Global Change Impact Studies Centre (GCISC) and the Pakistan Meteorological Department (PMD) indicate that temperatures in the mountain areas are increasing at a faster rate than in the other parts of the country. While this may be seen as an opportunity rather than a threat, especially since these areas are short of heat, any increase in temperature will be beneficial for enhanced agriculture productivity and vegetation growth. However, increasing temperatures may shift conifers northwards and thus could be replaced by fast-growing, invasive species that occupy a larger area and may endanger biodiversity. Simultaneously, the precipitation pattern is expected to change with more intense monsoons and winter snowfalls causing hazards that include soil erosion, flash floods, avalanches and Glacier Lakes Outburst Floods (GLOFs). The frequency of hydro-meteorological disasters has already increased in Pakistan, particularly in the mountain regions, which are fragile and inaccessible, and under increasing pressure due to rising population and unsustainable agricultural practices. Thus mountain communities are already suffering from high climatic risks today.

Figure 5: Landslide and soil erosion in the case study area

Source: GIZ 2013.

In terms of sensitivity, the country suffered from a reduction of about 25% of its forests during the last two decades, mostly in the mountain areas, aggravating the problem of soil erosion (see Figure 5). Furthermore, there is an ongoing loss of fertile top soil due to surface and gully erosion due to heavy rainfalls and events causing auxiliary extinction of species, habitat, and agricultural land productivity. This pattern of overall natural resource degradation is not only affecting the livelihoods of the poor people who depend on them but also poses serious environmental threats to the mountain ecosystems.

While Pakistan is heavily affected by climate change impacts, it has a low adaptive capacity due to its high dependency on natural resources that have largely degraded and the carrying capacity of these resources having declined over time. Moreover, the majority of the rural poor lives in highly vulnerable areas, traditional coping mechanisms often have become ineffective due to changing climatic conditions, land holdings are small and the mountain people lack alternative sources of income. The recurring flash floods have further deteriorated their resource base. In addition, there are limited resources allocated for research and extension on climate-related aspects, and institutional capacities to deal with associated challenges are low. All these aspects hold especially true for mountain areas such as Swat and Chitral.

Resources

The following resources were available for the preparation and implementation of the VA in Pakistan (second part of the workshop). During the stakeholders' workshop in Islamabad, a vulnerability assessment in the two pilot regions was prepared, as well as the implementation of an explorative VA. Participants consisted of rural extension workers and GIZ BKP technical advisors. Moreover, a local consultant and two international consultants from adelphi and EURAC were involved.

Following the workshop, additional explorative VAs will be conducted in the pilot areas, focusing on additional bio-diversity related topics over a period of three to four months. The implementation teams responsible for conducting the VA, which also participated in the workshop, consist of approximately 16 team members, including technical advisors of the GIZ BKP project team as well as technical experts from local authorities and institutions. Furthermore, a local consultant and possibly two international experts from adelphi/EURAC will provide backstopping. The overall time frame for the field surveys was estimated roughly at 2 days per valley. Two to three years after completion of the BKP project, the success of the implemented measures shall be assessed by repeating the vulnerability assessments at the end of the project.

Objective of the vulnerability assessment (Module 1; Step 2)

The objective of the VA in the two districts was to (a) raise awareness, (b) identify suitable adaptation measures at the community level, monitoring and evaluating their effectiveness and (c) provide policy advice. The VA's overall objectives were derived from the targets set by the project and an understanding between the relevant stakeholders, which was achieved during the workshop.

a)
Raising awareness was the first and foremost objective as it served as the basis for further action on adaptation. The aim was to have stakeholders understand the different range and varying forms of vulnerability to climate change within the BKP project area, especially related to biodiversity issues.

b)
Closely related to highlighting awareness on climate change vulnerabilities was the VA's focus on interventions. The VA was used to identify suitable adaptation measures together with the stakeholders, experts, district-representatives and the BKP project staff. A repeated VA shall furthermore be used to monitor and evaluate adaptation effectiveness at the end of the BKP project.

c)
Attention was given to provide tangible policy advice to local authorities and representatives of the people concerned. The main aim here was to identify suitable climate change adaptation elements, which can be proposed within the Biodiversity Action Plan for Capacity, and to support specific adaptation measures.

Determine the scope of the vulnerability assessment (Module 1; Step 3)

Selection of key topics

Important factors for the four vulnerability components exposure, sensitivity, impact and adaptive capacity were first gathered by the presentation of the scoping study.

These factors were pinned on boards and presented to the workshop participants, who were then invited to add additional factors (see Figure 6).

Figure 6: Results of the participatory session

Source: adelphi/EURAC 2014.

Using this large collection of possible impacts as a basis, all workshop participants were then asked to identify the key impacts for the two case study areas. To do this, each participant received three red dots signifying prioritised impacts for Swat and three blue dots signifying prioritised impacts for Chitral (see Figure 7). This exercise resulted in the participants' identification of the following key impacts (see also Figure 8):

- Land degradation: Erosion, landslides, flash floods
- Agriculture: Change in yield (+ and -), change in fodder for livestock, options for new crops due to climatic changes
- Indirect effects of climate change on population and behaviour: Climate migration into the Swat/Chitral region, increasing fuel wood requirements, movement from flood plains to slopes due to increasing risk of floods
- Ecosystems: Shift in ecosystems, invasive species, reduction of indigenous species, change in species richness
- Water: Seasonal droughts, critical droughts

Figure 7: Participants assessing and budgeting impacts

Source: adelphi/EURAC 2014.

Figure 8: Result of the selection of potential impacts to be considered within the vulnerability assessment

Source: adelphi/EURAC 2014.

Spatial and temporal scale and reference groups

As previously mentioned, the VA analysed communities (valleys) at a local level in two Pakistani districts. Two pilot valleys, one from Swat and one from Chitral were focused on during the workshop. 2 to 3 pilot-communities (valleys) in each district will be examined in the additional VAs that will be carried by the implementation teams subsequent to the workshop. It was also decided that the temporal scope of the VA covers current vulnerability and thus takes climatic data of the past 30 years into account. The reference group is the total population of the respective valley/village, although sub-groups and gender aspects must also be taken into account.

Methodological approach

Considering the objective of the VA, its time-frame and the resources available, it was decided to implement an explorative VA that predominantly relies on expert judgment and participatory approaches. During the workshop, the expertise of the participating stakeholders was used to conduct the VA. For future implementation of additional explorative VAs in the pilot valleys, questionnaires and participatory rural appraisal techniques such as village meetings and focus group discussion will be used, possibly including any available census data as well as spatial data (such as land use or soil maps).

Developing an impact chain (Module 2)

In line with Module 2 of the Vulnerability Sourcebook, impact chains were used to visualise and structure the cause-effect-relationships of vulnerability towards soil erosion in the two pilot regions. The impact chains were also used to brainstorm on possible adaptation measures.

During the second part of the workshop, an impact chain was developed for one of the prioritised impacts: vulnerability towards land degradation, erosion and landslides. As described in the Vulnerability Sourcebook, impact chains are used to systemise the factors assumed to affect the vulnerability of a system and visualise cause-effect relationships. Hence, all factors that contributed to the different vulnerability components (exposure, sensitivity, adaptive capacity) were identified and systematically ordered in terms of cause-effect relations, as described in Steps 1 to 4 of Module 2 of the Vulnerability Sourcebook.

We once again followed a stepwise procedure. Starting from the potential impact, the different factors of exposure, sensitivity and adaptive capacity contributing to vulnerability towards soil erosion were discussed with the implementation teams. The expert-knowledge, specific know-how and varying perspectives of the stakeholders proved to be an invaluable asset. Figure 9 depicts the subsequently developed impact chain for soil erosion, landslides and land degradation vulnerability. Exposure is bound to the factor 'erratic but intensive precipitation events'. Sensitivity towards soil erosion was thought to be influenced mainly by the factors 'deforestation', 'overgrazing', 'unsuitable cultivation of steep slopes' and 'soil type'. Adaptive capacity was defined by the factors 'effectively enforced land management', 'high dependency on natural resources', 'small land holdings' and 'farmers' knowledge of proper land management'.

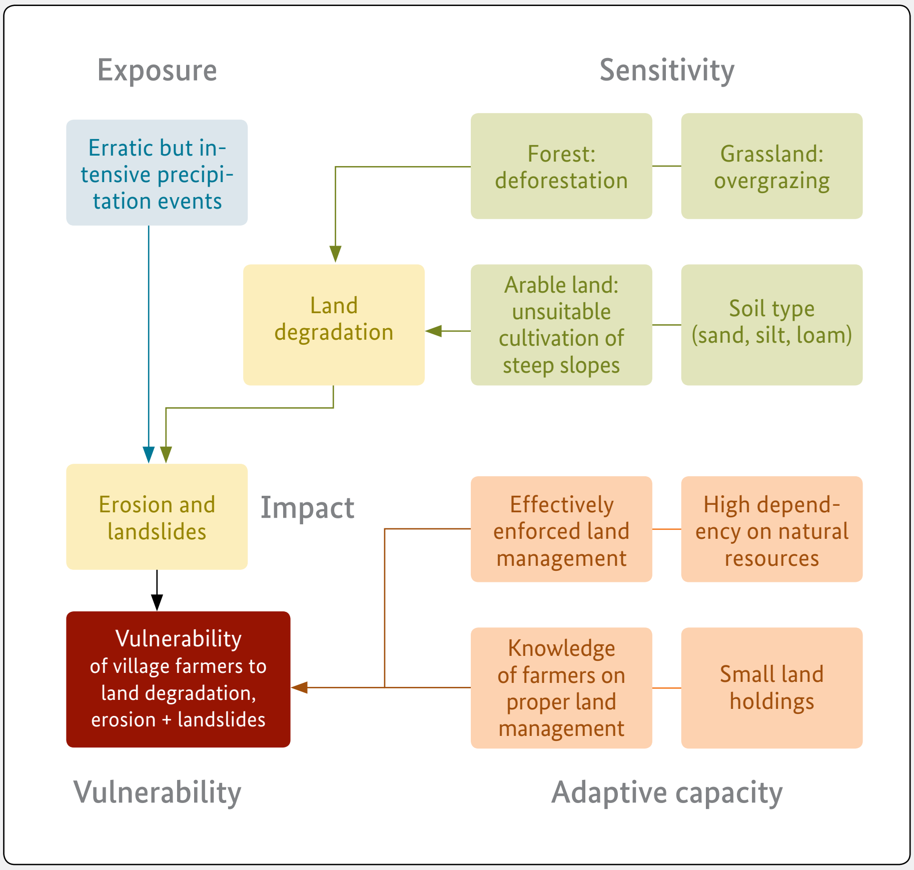
Brainstorm adaptation measures (Module 2; Step 5)

Impact chains are already one important result of a vulnerability assessment, as they represent a conceptual model of all identified important relationships and already enable adaptation planning and awareness raising. Adaptation options can either decrease sensitivity or increase adaptive capacity. In our case, participants brainstormed on potential adaptation measures that could reduce deforestation and unsuitable cultivation, or increase law enforcement and/or farmers' knowledge of proper land management. Adaptation options proposed to decrease sensitivity factors were:

- Forest/deforestation: Afforestation with indigenous species
- Grassland/overgrazing: Pasture management plan to restrict grazing
- Unsuitable cultivation of steep slopes: Plant suitable crops such as wild rhubarb

Adaptation options proposed to increase adaptive capacity were providing training for farmers, policy advice, broadcasts on land management in the farmers' radio, as well as sermons on biodiversity in mosques during Friday prayers. Impressions from the brainstorming exercise during the workshop using Metaplan are shown in Figure 10.

Figure 9: Impact chain for vulnerability towards 'land degradation, erosion and landslides'



Source: adelphi/EURAC 2014.

Figure 10: Impressions from the brainstorming exercise on adaptation options to reduce sensitivity factors (left) and increase adaptive capacity (right) to vulnerability towards soil erosion

Source: adelphi/EURAC 2014.

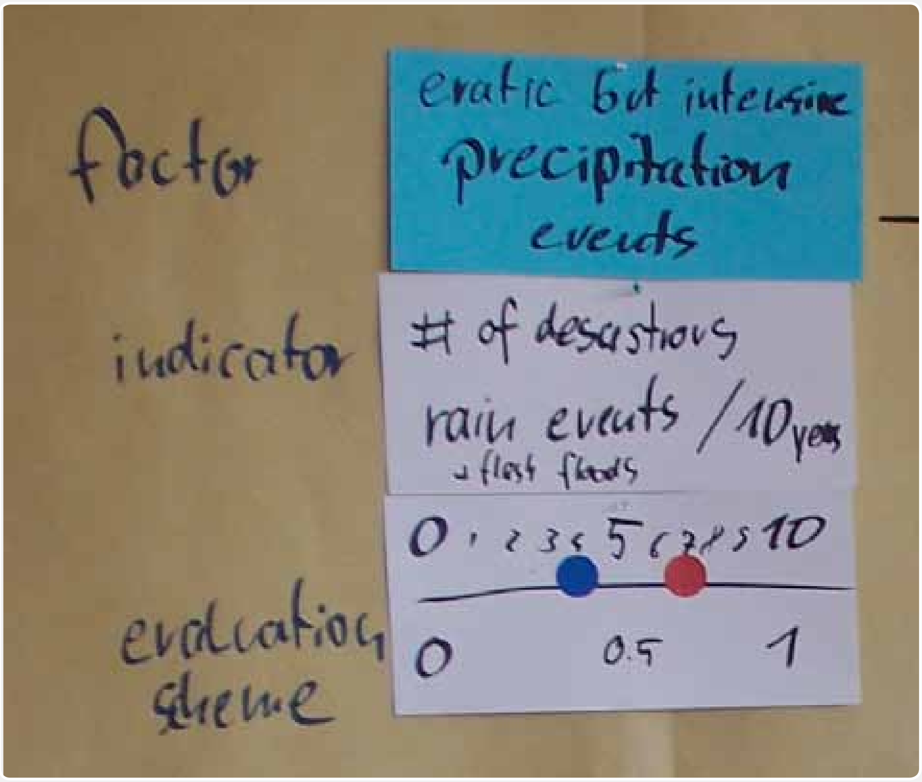
Identification of indicators and methods for quantification (Modules 3 to 5)

In line with Module 3 of the Vulnerability Sourcebook, the creation of impact chains allowed for the selection of indicators and the preparation of indicator data according to the methods outlined in Module 4.

Selecting indicators for the three vulnerability components (Module 3; Steps 1 to 4)

A further step was to identify suitable indicators that can be used to quantify the factors of the impact chain (see Figure 11). Again, this was carried out through intensive consultation with the implementation teams. It was moreover decided to develop indicators only for the two most important factors influencing sensitivity (deforestation/unsuitable cultivation) and adaptive capacity (law enforcement/ farmers knowledge). It was felt that these two factors sufficiently capture sensitivity and adaptive capacity respectively, towards soil erosion.

Figure 11: Example for an exposure factor, a suitable indicator and the respective evaluation scheme



Source: adelphi/EURAC 2014.

During the selection of indicators it was kept in mind that as they were quantified through expert knowledge or participatory approaches, they therefore needed to be formulated in an easy and comprehensive way. The following indicators were identified and agreed upon by the workshop participants (see Figure 12):

Exposure:

- # of days where catastrophic rain events took place in the last 10 years

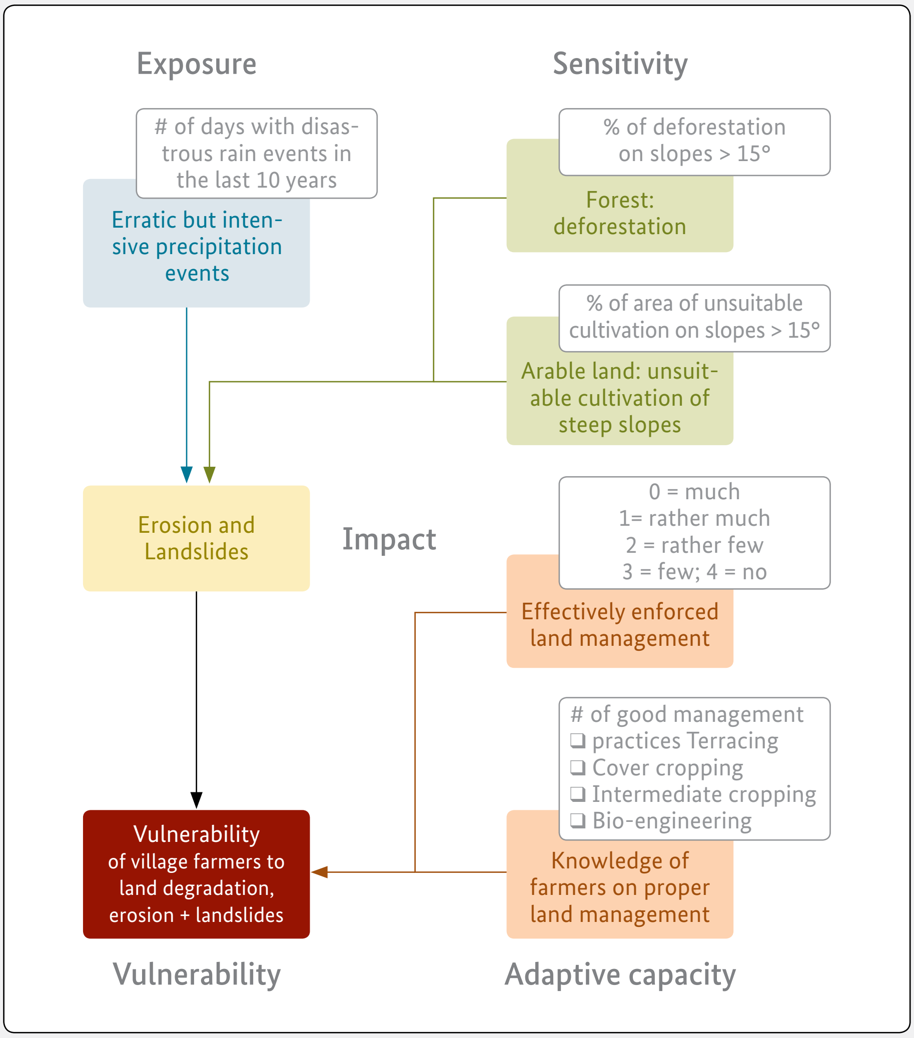
Sensitivity:

- % of deforestation on slopes > 15°
- % of area of unsuitable cultivation on slopes >15°

Adaptive capacity:

- Villagers satisfaction with law enforcement
- # of good management practices

Figure 12: Indicators for the impact chain ‘land degradation, erosion and landslides’



Source: adelphi/EURAC 2014.

Evaluation of indicators (Module 5)

In line with Module 5 of the Vulnerability Sourcebook, the indicators were then normalised to a common unit-less scale from 0 to 1.

To be able to perform a vulnerability assessment, each indicator needed to be evaluated in accordance with a standardised assessment scheme from 0 to 1 with:

- '0' in the context of exposure, sensitivity and adaptive capacity
  - An exposure value (climate, weather) which does not pose any harm to the system.
  - A sensitivity value, which does not sensitise the system to climate or weather related exposure under average conditions (the system is 'climate proof').
  - An adaptive capacity indicating social or economic conditions, or available adaptation options, which do not enable adaptation and would harm a system in such a magnitude that it seriously threatens the system.
- '1' in the context of exposure, sensitivity and adaptive capacity
  - An exposure value (climate, weather) which harms a system in such a magnitude that it seriously threatens the system, and cannot be entirely compensated by low sensitivity or high adaptive capacity. Extreme events/years in the past where catastrophic impact has taken place might serve as a reference.
  - A sensitivity, which does not provide any buffer to exposure and leads to a high potential impact, even under low exposure.
  - An adaptive capacity indicating an optimal capacity to adapt, i.e. social or economic conditions, or available adaptation options, which enable adaptation without harming the system (but which may still not compensate a very high impact).

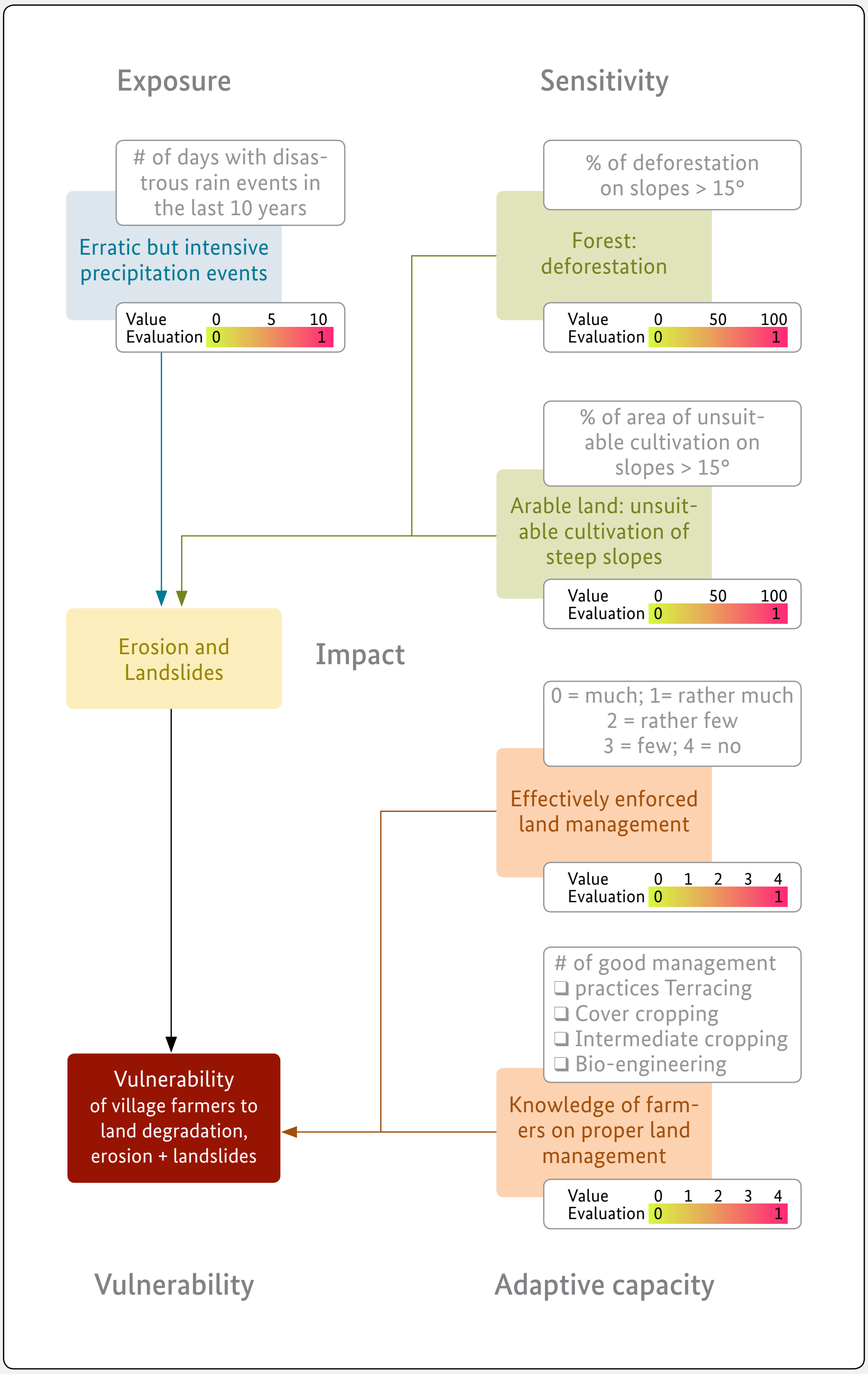
To that end, an evaluation scheme for each indicator was developed together with the participants. In terms of the adaptive capacity indicator 'effectively enforced land management', for instance, it was agreed that a rating from 0 (= much enforcement) to 4 (= no enforcement) will be applied, which has then been transferred (normalised) to the scale from 0 to 1 (see 'law enforcement' in Figure 13). The evaluation schemes for all indicators are provided in the following illustration (see Figure 13).

Subsequently, the expert teams from both districts evaluated each indicator for two selected valleys: Chel Valley in Swat and Rambur Valley in Chitral. The evaluation provided by the participants is shown in Figure 14.

The evaluation revealed that individual factors of the two valleys in Swat and Chitral differ significantly: While exposure to intensive rain events is higher in the Swat region, which is affected by monsoons, in Chitral sensitivity is greater due to high deforestation rates and high percentages of unsuitable cultivation on steep slopes.

Regarding adaptive capacity, both regions attained similar assessments, with a moderate to low adaptive capacity due to only moderate knowledge of good land management practices and low satisfaction levels with law enforcement in the field of land management.

Figure 13: Evaluation scheme and indicators for the simplified impact chain 'land degradation, erosion and landslides'



Source: adelphi/EURAC 2014.

Aggregating indicators and vulnerability components (Modules 6 and 7)

In accordance with the Vulnerability Sourcebook's concept, weighting and aggregation of individual indicators to vulnerability components (Module 6) to overall vulnerability (Module 7) was carried out in three steps.

First Step:
Aggregation of individual vulnerability component indicators (exposure, sensitivity, adaptive capacity)

- All individual exposure indicators were aggregated to one value for the vulnerability component 'exposure'.
- All individual sensitivity indicators were aggregated to one value for the vulnerability component 'sensitivity'.
- All adaptive capacity indicators were aggregated to one value for the vulnerability component 'adaptive capacity'. Since equal weighting was applied to all indicators, the aggregation equation was simply:

Formula 1:

$$\textit{vulnerability component index} = \frac{I_1 + I_2}{2}$$

Second Step:
Aggregation of exposure and sensitivity to potential impact (again using weighted arithmetic mean aggregation).

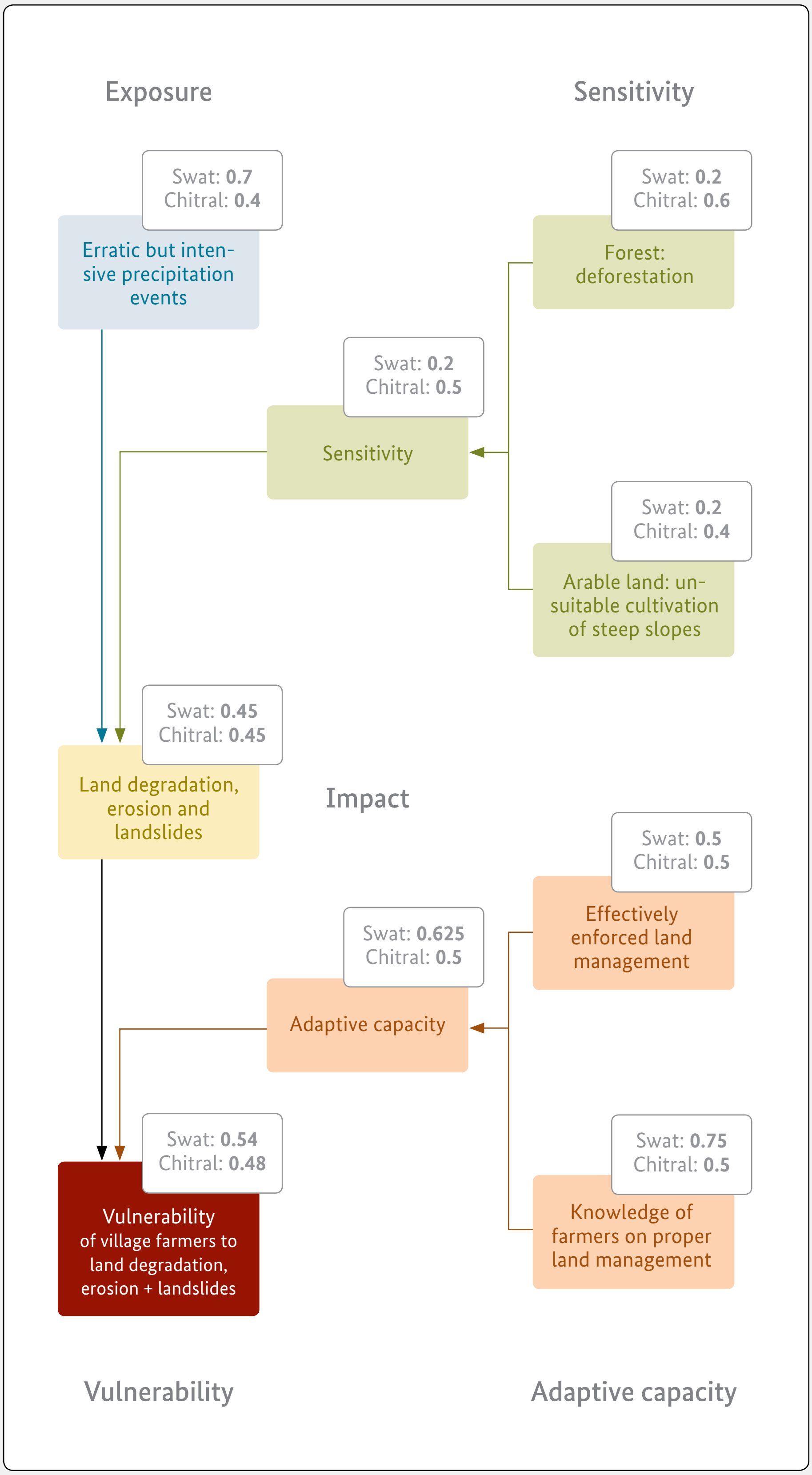
Third Step:
Aggregation of impact and adaptive capacity to vulnerability. Here, again a weighted arithmetic mean aggregation was applied.

Formula 2:

$$V = \frac{I + AC}{2} \quad \text{with } V = \text{Vulnerability } I = \text{Impact } AC = \text{Adaptive Capacity}$$

The result of the aggregation procedure is presented in Figure 14.

Figure 14: Aggregation of indicators and vulnerability components for assessing vulnerability to soil erosion in Pakistan



Source: adelphi/EURAC 2014.

Outcomes of the vulnerability assessment

Key findings, recommendations and next steps (Module 8)

The explorative VA in Pakistan provided several key insights: Chel Valley in Swat is more exposed to erratic but intensive rain events than Rambur Valley in Chitral. At the same time, Chel Valley is less sensitive, since it has suffered less deforestation and even the degree of unsuitable cultivation on steep slopes is lower. Variations within the two vulnerability components 'sensitivity' and 'exposure' between the two districts results in an identical potential impact for both valleys. This again highlights the importance of also considering individual vulnerability components and even individual indicators when interpreting the results of a VA. Adaptive capacity is somewhat higher in Rambur, due to a slightly higher level of law enforcement. Overall vulnerability in both regions is medium with a slightly higher level of vulnerability in Chel Valley.

Most interesting is identifying the weak points within the system, since these are the entry points for adaptation options. For instance, the high degree of deforestation in Rambur should be mentioned, which could be tackled by afforestation, for example with indigenous plants. Unsuitable practices on steep slopes could be addressed by providing training courses, or by broadcasting information on sustainable practices over the farmers' radios. Follow-up steps for the implementation teams in line with the explorative VA include:

- Developing impact chains for other impacts related to biodiversity
- Finding appropriate indicators which can be included in the Participative Rural Appraisal (PRA) at village level
- Agreeing on an evaluation scheme for each factor/indicator of the newly developed impact chains
- Performing field surveys
- Analysing and reviewing the results
- Documenting the VA
- Communicating results
- Identifying adaptation measures
- Implementing suitable adaptation measures

Once the measures have been implemented, adaptation effectiveness shall be monitored and evaluated (M&E) by repeating the vulnerability assessment at the end of the BKP project life span. The documentation requirements for Monitoring and Evaluation can be found in detailed explanations within the M&E Chapter of the Vulnerability Sourcebook and include:

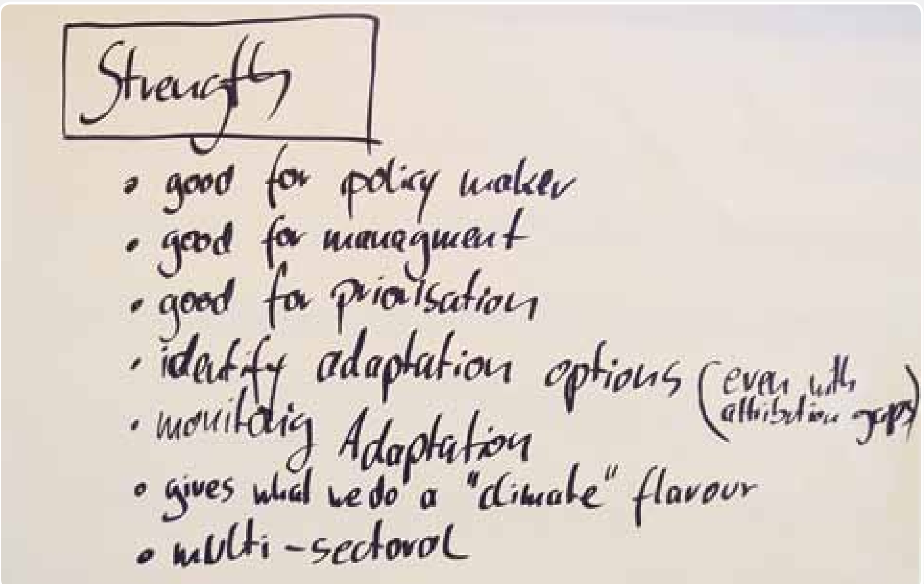
- A thorough documentation of the entire VA and its related processes
- Ensure reliability of indicators
- Describe procedures for quantifying indicators
- Keep assessment rules constant

Lessons learned

Several of the lessons learned came as a result of applying the Vulnerability Sourcebook in Pakistan. In particular, the application of the Vulnerability Sourcebook can generate valuable results for adaptation planning within a short period of time. In Pakistan, it was possible to implement an explorative VA, based on a participatory approach, within a 3 1/2 days workshop. This explorative VA can, if applicable, be up-scaled and broadened further by including additional factors, data sources and impact chains. While the first explorative VA predominantly relied on expert judgments, it could be later decided to e.g. use data from statistical bureaus and meteorological offices. Possible data sources and data holding institutions were already identified in the scoping study.

The impact chains proved to be a very useful tool and a result in itself. The tool allows for intuitive, yet substantial and easy, access to information on vulnerability in a given area. Their use in identifying possible entry points for adaptation measures was appraised by the participants of the workshop. Moreover, it was perceived as a very good tool for raising awareness and stimulating discussions both among policy makers and within local communities (see Figure 15).

Figure 15: Feedback from the workshop participants on the strengths of the vulnerability assessment approach



(*good for policy maker, *good for management, *good for priorisation, *identify adaptation options [even with attribution gaps], *monitoring adaptation, *gives what we do a ‘climate’ flavour, *multi-sectoral).

Source: adelphi/EURAC 2014.

A drawback noted by a participant from the policy making level was that the VA does not quantify any monetary terms, just a 'mere' vulnerability number. It was argued that this can make it difficult to convince policy makers to provide funding for an adaptation project. In the case of Pakistan, this decision is very much based on assumed cost and benefits. On the other hand, it was argued that the VA can help to overcome this very technical planning approach in order to achieve a more holistic and outcome-oriented planning. This is precisely the objective of the BKP project.

Annex

List of participants and respective organisations

Nr.	Name	Position	Organisation
1	Mr. Naveed Mustafa	Scientific Officer	CAEWRI, National Agriculture Research Centre (NARC), Islamabad
2	Mr. Muhammad Ijaz	Scientific Officer	Global Change Impact Studies Centre (GCISC), National Centre for Physics, Islamabad
3	Ms. Nuzba Shaheen	Scientific Officer	Global Change Impact Studies Centre (GCISC), National Centre for Physics, Islamabad
4	Dr. A. D. Khan	Director (Hydrologis)	Pakistan Council of Research for Water Resources (PCRWR)
5	Dr. Mona Hagras	Post-Doctoral Fellow	Pakistan Council of Research for Water Resources (PCRWR)
6	Dr. Muhammad Abdullah	Director (Saline Agriculture)	Pakistan Council of Research for Water Resources (PCRWR)
7	Dr. Shaukat Zaman	Director	Pakistan Bureau of Statistics, Islamabad
8	Mr. Syed Zuhair Bokhari	Deputy Director General	Space Upper Atmosphere Research Commission (SUPARCO), National Space Agency of Pakistan, Islamabad
9	Mrs. Annette Lisy	Project Manager	Federal Institute for Geosciences and Natural Resources, Assessment of Geohazards in Pakistan, c/o Geological Survey of Pakistan
10	Mr. Simon Sadiq	Assistant Director	Geological Survey of Pakistan.
11	Mr. Tayyab Shahzad	Coordinator Land Use Planning	Sustainable Land Management Project, Climate Change Division, Islamabad
12	Mr. Khursheed Ahmed	Project Officer	Swiss Development Cooperation (SDC)
13	Mr. Mohmand Hidayatullah	Director	Soil Survey Regional Office Peshawar

continued on next page

Nr.	Name	Position	Organisation
14	Mr. Fazli Rabbi	Provincial Census Commissione	Pakistan Bureau of Statistics, Peshawar
15	Mr. Syed Mushtaq Ali Shah	Director	Regional Meteorological Centre Peshawar
16	Dr. Ishaq A. Mian	Deputy Director	Soil and Environmental Sciences, K.P Agriculture University, Peshawar
17	Mr. Tehsil Zaman	Assistant Chief Agriculture & Environment	Soil and Environmental Sciences, K.P Agriculture University, Peshawar
18	Mr. Sanaullah Khan	Director/ Conservator Forest	Planning & Development Department, Peshawar
19	Mr. Shabir Hussain	Deputy Chief Conservator	Forest Department, Peshawar
20	Dr. Ehsan Ullah	Senior Research Officer	Agriculture Research Institute, Mingora
21	Mr. Syed Fazal Baqi	Deputy Conservator Wildlife	Wildlife Department
22	Mr. Sher Zada Khan	District Director	Agriculture Extension Department, On-farm water management
23	Mrs. Shamsu Nihar	Social Mobiliser	Chitral Gol national park, Forest Department,
24	Mr. Jan Mohammad	District Director	Agriculture Extension Dept.
25	Dr. Mohammad Naseer	Director	Agriculture Research Center
26	Dr. Marc Zebisch	EURAC	Head of Department
27	Dr. Philip Bubeck	Adelphi	Project Manager
28	Dr. Syed Sajidin Hussain	ADMC	Consultant
29	Mr. Shaukat Ali	ADMC	
30	Mr. Wolfgang Hesse	BKP	GIZ
31	Ms. Veronika Utz	BKP	GIZ
32	Mr. Asghar Khan	BKP	GIZ
33	Mr. Fayaz Muhammad	BKP	GIZ
34	Ms. Nighat Ara	BKP	GIZ
35	Ms. Shaista Zarshad	BKP	GIZ

11

11. Applying the Vulnerability Sourcebook: vulnerability assessment of smallholder farmers in the community of Chullcu Mayu (Bolivia)

Source: adelphi/EURAC 2014.

Programa de Desarrollo Agropecuario Sustentable (PROAGRO) GIZ Bolivia

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Jose Luis Gutiérrez

Feb, 2014

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Preparing the vulnerability assessment (Module 1)

Understanding the context of the vulnerability assessment (Module 1; Step 1)

The Sustainable Agricultural Development Program (PROAGRO, for its acronyms in Spanish) is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in Bolivia. The Program, co-financed by the Swedish International Development Agency during its second phase covering 2011-2014, focuses on strengthening small-holder farmers' resilience to climate change in dry areas of Bolivia.

In this context, the Program promotes together with national and subnational stakeholders the implementation of so-called Management Models, successful experiences on agricultural development at a local level, documented to promote its scaling up and knowledge management. One of this Management Models is the 'Technified Irrigation for a more efficient use of water in agriculture' (from now on, Technified Irrigation), as a response to water scarcity and low efficiencies of the traditional irrigation systems in rural communities of dry areas. Even more, erratic rainfall reduces the potential for agricultural production, consequently small-holder farmers living in dry areas are highly vulnerable to climate change, and the sustainability of its livelihoods is at risk due to low production levels, hence low agricultural incomes. To cope with this challenge, the Management Model aims to apply new technologies for improving the intake, conveyance, distribution and application of water into crops with a localised irrigation, to increase the irrigation area with the same water source, and to increase the frequency of irrigation, which eventually allows crop diversification, rise in yields and higher incomes.

Agricultural development projects need to integrate climate change adaptation into its planning, in order to reduce the climate vulnerability of farmers, especially in arid and semiarid regions, where producers with scarce livelihoods are highly exposed to climate risks due to erratic rainfall and rise in temperatures. In order to improve the understanding of the vulnerability components in these agricultural areas for a better adaptation planning, PROAGRO is interested to learn to what extend the small-holder farmers´ vulnerability to climate change is reduced by implementing the Technified Irrigation management model.

Objectives of the vulnerability assessment (Module 1; Step 2)

PROAGRO promotes a Technified Irrigation management model for a more efficient water use in agriculture, as a measure for climate change adaptation of smallholder farmers' vulnerability to climate change.

Farmers in the Chullcu Mayu community have implemented this type of project, hence, the objective of the assessment is to quantify to which extent climate vulnerability was reduced with the technification of the community's irrigation system.

Determine the scope of the vulnerability assessment (Module 1; Step 3)

The lands in Chullcu Mayu are suitable for agriculture (see Figure 1), however the low water availability for irrigation is a constraint for increasing the agricultural production. Therefore, in 2005 a gravity fed irrigation system was designed in order to improve the livelihoods of the families. This community is located in the region of inter-Andean valleys characterised by an uneven physiography, with precipitation levels between 400 – 800 mm, and soil losses due to erosion. The water scarcity is an obstacle for this fertile part of the country.

The problem for agricultural production in this region is water scarcity due to erratic rainfall and low efficiency in their traditional irrigation systems. Therefore, the main potential climate change impact is the reduction of the cropping area under optimal irrigation.

Figure 1: View of Chullcu Mayu community (Cochabamba, Bolivia)

Source: adelphi/EURAC 2014.

In this context, a semi-quantitative vulnerability assessment was conducted in the community, considering vulnerability factors before and after the implementation of the Technified Irrigation system. The assessment focuses on the present vulnerability, considering climate average conditions before implementing the project (period 1960-1990), and after (period 1991-2011) project implementation. In this special case study the vulnerability assessment was thus conducted to compare two historic periods, one with adaptation and one without as an approach to evaluate the success of the adaptation measure (see Module 1; Step 3 about possible different time periods for vulnerability assessments and Chapter IV for monitoring and evaluation of adaptation measures with a VA).

In order to develop a better understanding of the system, additional assessments were made on the impact of climate variability in the traditional irrigation system, considering extreme events of lowest precipitation (year 2000) and highest precipitation (year 1986). Likewise, an assessment was made as to how future climate conditions (trends for 2030) according to the PRECIS climate regional model could affect the irrigation system. Table 1 explains the temporal scales of the VA.

The spatial scope is the Chullcu Mayu community, part of the Tiraque municipality, located in the Department of Cochabamba (Bolivia). Its geographic location is between 65°32’30” to 65°33’30” of West Longitude and 17°29’55” to 17°27’30” South Latitude, located at 3,486 meters above sea level (see Figure 2), at a distance to the closest department capital city (Cochabamba) of 75 km through a paved highway. Specifically the spatial scope of the assessment includes the potential agricultural area of 61 ha in the community Chullcu Mayu, which is inhabited by 97 peasant families.

Table 1: Temporal scales of the vulnerability assessment

Period or year	Explanation
2000	Climate conditions of the extreme event with lower precipitation (10th percentile of historic precipitation data)
1986	Climate conditions of the extreme event with higher precipitation (90th percentile of historic precipitation data)
1960 – 1990	Average climate conditions in the Chullcu Mayu community, before the implementation of the Technified Irrigation project
1991 – 2011	Average climate conditions in the Chullcu Mayu community, after the implementation of the Technified Irrigation project
2030	Future climate conditions[1] generated by the regional climate model -PRECIS (‘Providing Regional Climates for Impacts Studies’) developed by the Hadley Centre in the United Kingdom’s Meteorological Office. Data was based on ECHAM4, under the emissions scenario A2 (considering the period of period 2001-2030 as future time and the period of 1961-1990 as present time). This model provides the following climate changes for 2030: Temperature increase in 1.6 °C Precipitation variations: During dry periods, precipitation reduction of 26%. During wet periods, precipitation increase of 26%.

Source: adelphi/EURAC 2014.

Stakeholders interested in the results of the assessment are the following: Smallholder farmers from inter-Andean valleys, public and private institutions in the region working on agricultural development with irrigation systems, authorities and local technicians from the Vice-Ministry of Water Resources and Irrigation in Bolivia, PROAGRO personnel, and also other organisations and international cooperation agencies.

The partners directly involved in the VA within this case study were PROAGRO, GIZ and EURAC Research.

[1] Source: Ministry of Environment and Water (2009), Second National Communication of the Plurinational State of Bolivia to the UNFCCC, Page 133.

Figure 2: Location map of the Chullcu Mayu community

Source: © Fotolia - Arid Ocean, Guillaume Le Bloas.

Developing an impact chain (Module 2)

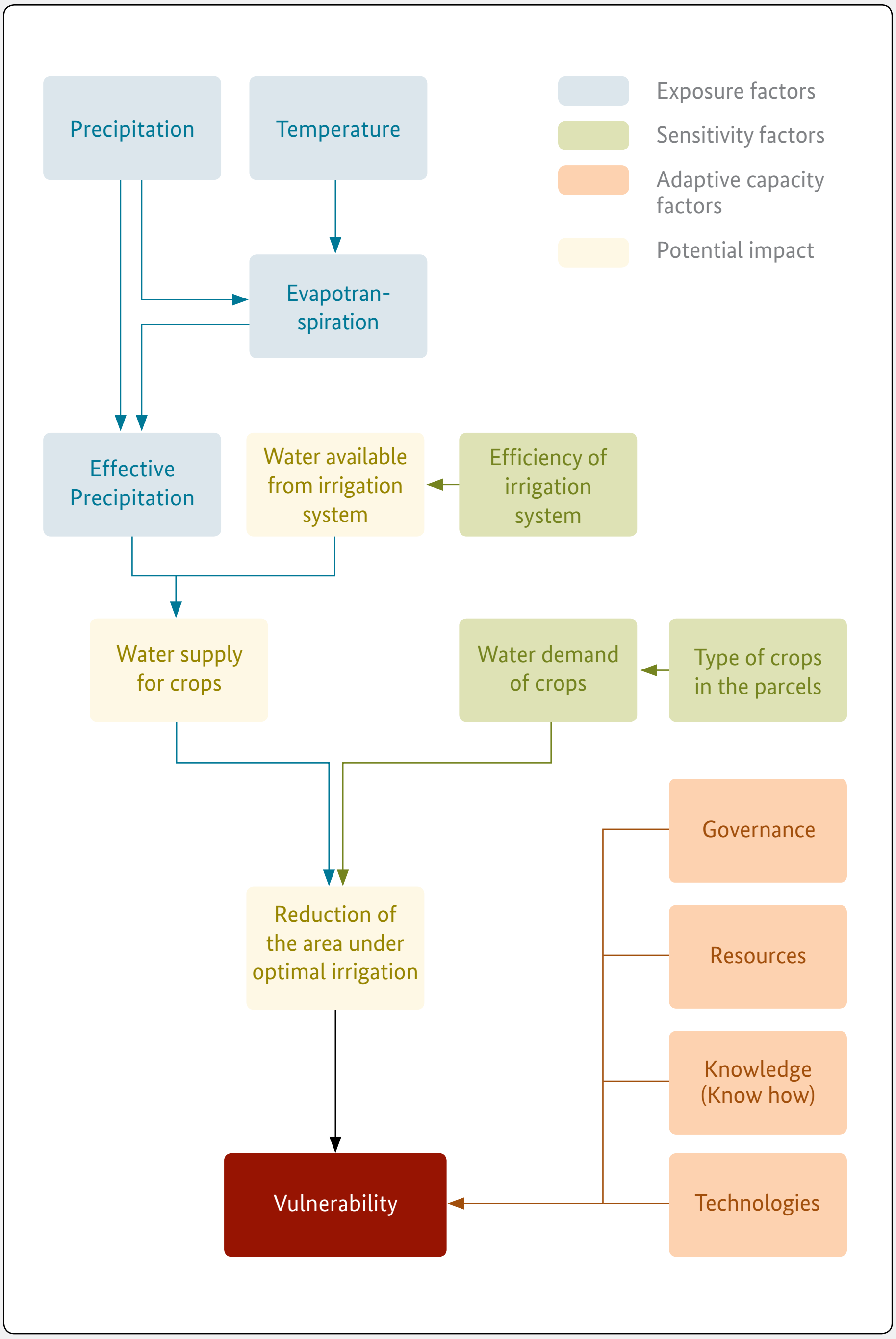
The conceptual framework for the VA follows the IPCC (AR4) where vulnerability is the degree to which a system is susceptible to, or incapable of, confronting adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change, as well as variations to which the system is exposed, its sensitivity and adaptive capacity.

In order to understand the potential climate change impact in the community, an assessment of the impact chain was developed, being an analytical tool that systematically enables an assessment of the vulnerability factors and its cause-effect relations. The assessment starts with the identification of the main potential impact to the system assessed, as outlined below, following Steps 1 to 4 of Module 2.

During a consultation process with PROAGRO experts in irrigation systems, it was identified that small-holder farmers are vulnerable to low water availability for crops. This implies that changes in climate conditions could affect the water supply for crops which require a higher demand for water; therefore, reducing the cropping area under optimal irrigation.

Once the potential climate impact had been assessed, the factors related to the farmers' adaptive capacity were identified. These factors were clustered in the following categories: governance, resources, knowledge and technologies. For each category, sub-factors were selected to assess the adaptive capacity in this specific community, considering the analysed productive activity. Figure 3 shows the impact chain for this case study.

Figure 3: Impact chain for the case study in Chullcu Mayu community



Source: adelphi/EURAC 2014.

According to this impact chain, climate vulnerability in the Chullcu Mayu community is determined by:

- Exposure: Temperature and precipitation variations affect evapotranspiration and effective precipitation levels.
- Sensitivity: The agricultural production system in Chullcu Mayu is sensitive to climate variations due to low efficiency in the traditional irrigation system and the type of crops cultivated in the parcels, being aspects that determine the crops' water demand.
- Climate change potential impact: The reduction of the area under optimal irrigation (soil moisture) is the main climate impact identified in the Chullcu Mayu community, which depends on the balance of water supply and demand for crops. According to this balance, the cropping area under optimal irrigation in the system can be estimated.
- Adaptive capacity: Aspects like the level of governance or social organisation, resources available in the community, farmers' specific know how on crop management and productive systems or technologies available for agricultural production are factors that determine the farmers' capacity to cope with potential climate impacts in their system.

Assessment methodology (Modules 3 to 7)

Key information on the overall implementation process of the vulnerability assessment

This type of vulnerability assessment applied for the Chullcu Mayu pilot application is focused on a very specific topic and uses a mixed method approach. A purely quantitative approach is applied for assessing exposure, sensitivity, and impacts. A semi-quantitative approach is applied for assessing adaptive capacity, based on the criteria of 'expert opinion', using proxy indicators that consider aspects clustered in the following categories: governance, resources, knowledge, and technology.

The process started with a visit from the EURAC Research team to Bolivia in order to explore the opportunities for a pilot application of the Vulnerability Sourcebook, where a workshop was developed with PROAGRO personnel. As a result, the irrigation project in Chullcu Mayu was selected for the VA, since it had been implemented a few years ago, and it would be interesting to measure or quantify the results regarding beneficiary farmers' vulnerability.

The resources used for the VA included the ABRO software (acronym in Spanish for Area under Optimal Irrigation), a tool officially used in the Bolivian water sector for designing irrigation projects financed by public funds, the regional climate model PRECIS and historical meteorological records. After a first evaluation of the available data, a consultant was hired to support the statistic modeling of the meteorological data, introduce new climate data, run the ABRO software, and assess adaptive capacity. Three workshops and a field visit including personal interviews with farmers were conducted with the PROAGRO team linked with the Technified Irrigation project in this community. Two additional workshops were carried out to present the results to the same team. Additionally, the EURAC Research team made a second visit to Bolivia to backstop the process and learn about the results on the application of the Vulnerability Sourcebook. In total, about four months were needed to implement the VA.

Identification of indicators (Module 3)

Together with the PROAGRO and EURAC Research team, a visit was made to the Chullcu Mayu community to get to know the area and obtain key information from the local farmers involved. With this information, a first impact chain was built. From that proposal, the PROAGRO team finalised construction of the impact chain based on the factors that determine the small-holder farmers' vulnerability in this community.

According to the local perceptions of the farmers interviewed in the field visit, in this community the main climate hazards are deficit and erratic precipitations, as well as extreme events like hail, frost and heat waves. From all these, the deficit of precipitation has the most significant impact due to the low water availability for agriculture, and consequently a reduction in production levels, food security and agricultural income levels. Therefore, it was identified that the main potential impact was the reduced water availability for agriculture in the community.

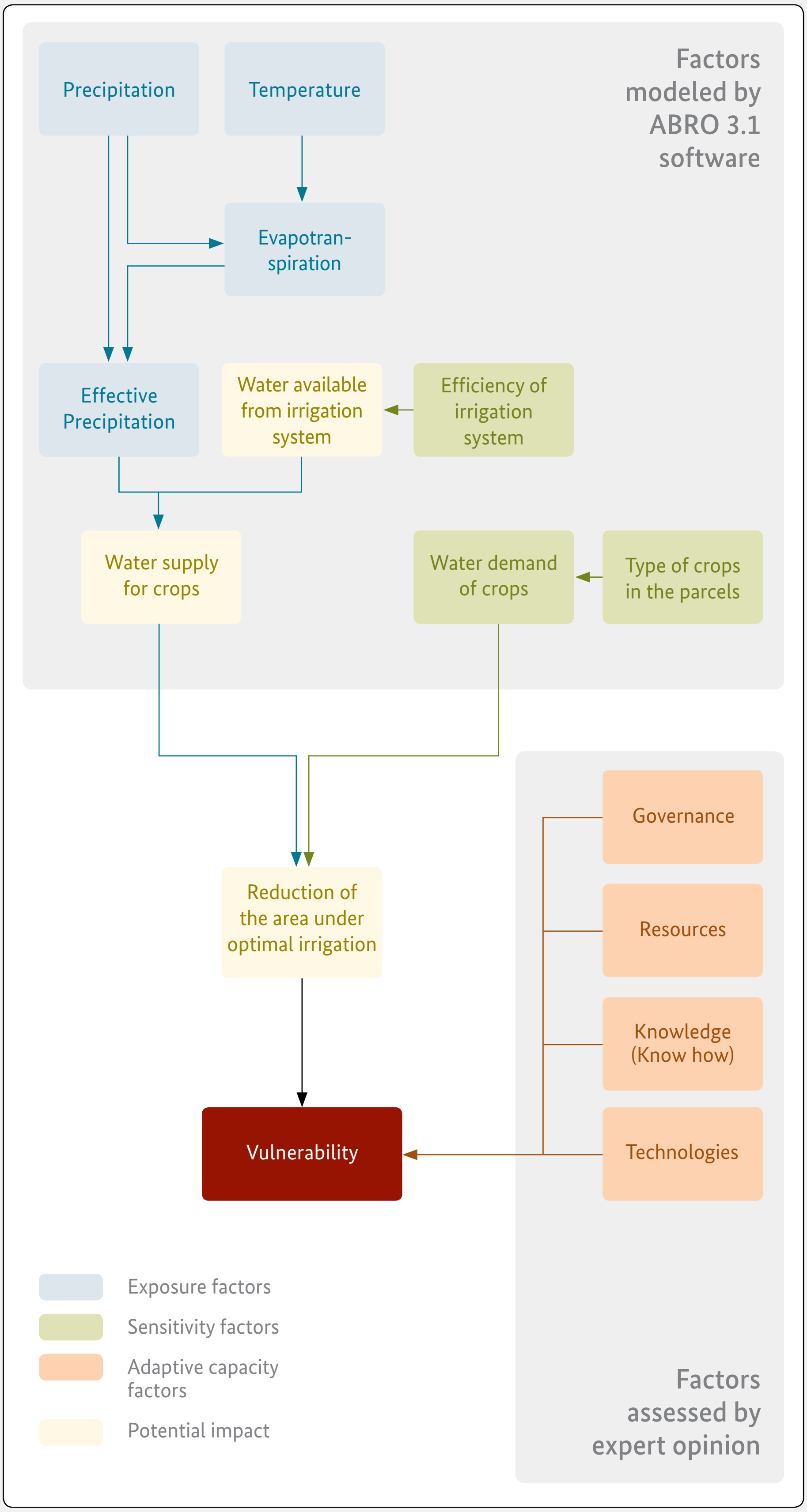
Once the potential impact to be assessed was identified, the team realised its difficulties to measure it directly; hence, a proxy indicator was identified: the area under optimal irrigation (soil moisture). The rationale for this is that a reduction in the availability of water due to less precipitation implies that the area under optimal irrigation would reduce.

Identification of methods for quantifying the indicators (Module 4)

The methods to assess the climate vulnerability components are presented in the following illustration (see Figure 4): to assess the impact, the software ABRO is used; to assess the adaptive capacity, the expert opinion elicitation is used.

Tables 2 and 3 provide detailed information on each of the vulnerability components (exposure, sensitivity and adaptive capacity), including their calculation and additional information, such as measurement, frequency, source and owner of data.

Figure 4: Methods to assess vulnerability components



Source: adelphi/EURAC 2014.

Table 2: Factors related to exposure

Factor *(Unit of measurement)*	Method of calculation	Comments
Precipitation *(mm)*	Direct measurement	These two factors are needed as input data in order to run the model ABRO 3.1 The frequency of the measurement is monthly. The owner of the data is SENAMHI (National Service of Information on Meteorology and Hydrology). In order to use temperature and precipitation records of more than 30 years, these data were estimated with statistical models (linear regression) from the Tiraque meteorological station (with data from 1960 to 2011) to complete the same number of records for the Toralapa meteorological station (used for the project design).
Temperature (max and min) *(°C)*	Direct measurement	
Evapotranspiration *(mm/day)*	ABRO 3.1 Model	Calculated by ABRO 3.1, with max and min temperature, data modeled for Toralapa station, based on data of Tiraque station.
Effective Precipitation *(mm)*	ABRO 3.1 Model	Calculated by ABRO 3.1., according to the climate conditions of the highlands, where Chullcu Mayu community is located. Input data for model ABRO 3.1
Water available in the irrigation system *(m^3)*	ABRO 3.1 Model	The information used for the calculation derives from measurements of water flow in the year 2007, in the water sources of the existent irrigation system and the projected sources that would increase the water flow for irrigation.
Water available for crops	ABRO 3.1 Model	Corresponds to the sum of effective precipitation and water availability in the system, intended for crop irrigation.

Source: adelphi/EURAC 2014.

Table 3: Factors related to sensitivity

Factor	Method of calculation	Comments
Crop Parcels	Input data for ABRO 3.1	The provided information is the type of crop, the month of sowing and the area cultivated.
Crop water demand	ABRO 3.1 Model	Calculation based on the composition of crops in the parcels.
Irrigation system Efficiency	Input data for ABRO 3.1	Calculation based on the efficiency of the components of the irrigation system: intake, conveyance, distribution and application of water in parcels.

Source: adelphi/EURAC 2014.

The potential climate impact for small-holder farmers in Chullcu Mayu is assessed based on the indicators mentioned above for exposure and sensitivity. The proxy indicator for this purpose (area under optimal irrigation) is validated with the criteria explained below (see Table 4):

Table 4: Criteria to verify the appropriateness of the proxy indicator

Criteria	Comments
Validity	The land surface area under optimal irrigation depends on the water provided by the irrigation system, the precipitation levels and temperatures (max and min), therefore it shows the impact of climate variables in the amount of hectares that can receive an optimum irrigation. This amount of hectares will be reduced when there is less rainfall than expected and higher temperatures that increase the water demand, regardless of the source that provides water for the system.
Precise meaning	Technicians that elaborate irrigation projects use the area under optimal irrigation as a parameter of design of the projects, applying the ABRO software. PROAGRO experts agree that this proxy indicator is useful, considering that there are no direct measurements representing in a better way the climate variations in agricultural production with the available information in Bolivia.
Applicability	The ABRO software, which calculates the area under optimal irrigation, has the versatility to keep constant some parameters of the irrigation system operation (e.g. composition of the types of crops in the parcel, quantity of water to feed the system, etc.) and allows to change the climate conditions like precipitation and temperature, hence, it shows how the system responds to different climate conditions through time.
Reliability	The ABRO software has been developed based on various experiences in irrigation systems design in Bolivia, and its use is extended throughout the national territory. Therefore, the measurement of the land surface area under optimal irrigation calculated by this software is reliable.
Practicability	The use of the ABRO software to calculate the area under optimum irrigation as an indirect indicator of climate change does comply with the criteria of practicability, affordability and simplicity, since it is a software of simple application that includes a manual for is installation in any computer which has a basic hardware configuration. It is affordable since it can be downloaded from the web free of charge.
Sensitivity	The sensitivity of the ABRO software to detect small variations of climate conditions is not very high, which is a limitation for climate change vulnerability assessments. However, due to the lack of information to feed more sophisticated and possibly more sensitive models, the current case study is obliged to use the ABRO software, considering this limitation.

Source: adelphi/EURAC 2014.

The adaptive capacity factors have been selected, considering how these aspects help the farmers cope with the low water availability for agriculture in the community of Chullcu Mayu. The factors are the following (see Table 5):

Table 5: Factors related to adaptive capacity

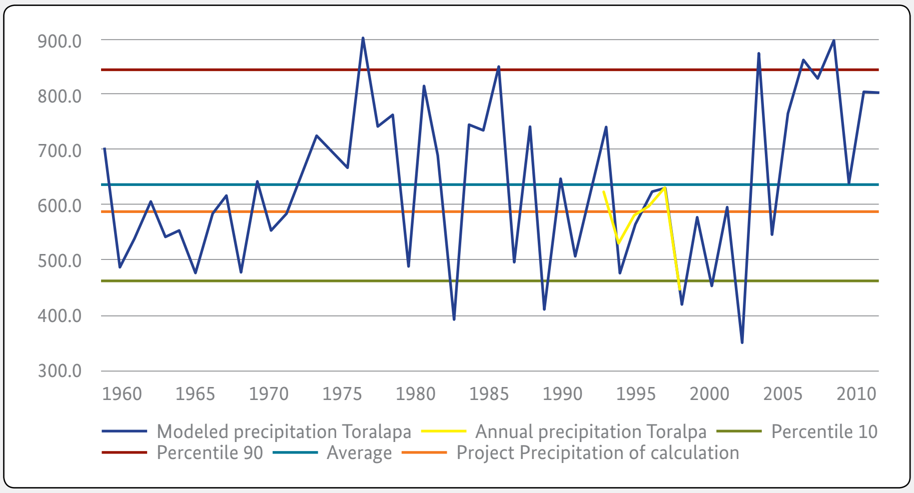
Factor	Method of calculation	Observation
Gover-nance	Expert opinion	Assessment of Chullcu Mayu farmers' social and productive organisation conditions in regards to the irrigation system, including: · Organisation of producers related to the irrigation system rights to water access, as defined by them. · Rights to water access (as defined by organisation of producers)
Resources	Expert opinion	Assessment of the community's available resources which may improve the agricultural production, including: · Chullcu Mayu producers' land availability · Chullcu Mayu producers' access to institutional support (mainly referred to technical assistance) · Chullcu Mayu producers' access to information technology and services · Community's proximity to trade channels
Knowl-edge	Expert opinion	Assessment of Chullcu Mayu producers' knowledge (know how), which may improve agricultural production, be it traditional or introduced (through contemporary techniques), including: · Introduction of new crops · Crop management · Adjustment to the agricultural calendar
Techno-logies	Expert opinion	Assessment of Chullcu Mayu producers' application techniques to improve the agricultural production, including: · Technology for soil management · Technology for seed management · Technology for plague and disease control

Source: adelphi/EURAC 2014.

It is important to mention the constraints faced when accessing data for the assessment. The project mainly used data from the meteorological station in Toralapa, which only had records for a 10 year period. Therefore, a statistical model was developed to increase the number of records. Hence, the climate information used corresponds to historical series statistically modeled with linear regression techniques for the Toralapa Station; having used the precipitation and temperature (max and min) of the Tiraque Station, located in the same basin, with historical records of 52 years. It was verified that the correlation coefficients and the p-value have a significant statistical association between the records of both stations, which guarantees reliability on the Toralapa Station's modeled data.

Figure 5 shows historical records of the annual precipitations modeled for the Toralapa Station. The graph shows a high variability with five peaks where the level of precipitation is either greater than the 90th percentile of total records (850mm) or below the 10th percentile (461mm) of precipitation records. Additionally, it can be observed that the annual precipitation used to design the irrigation system (590mm) is below the average annual precipitation for the period between 1960 and 2011 (640mm). Therefore, the irrigation system can be considered to be adapted even to low precipitation years.

Figure 5: Annual precipitations modeled for the Toralapa meteorological station



Source: adelphi/EURAC 2014, based on data from the Bolivian National Service of Information on Meteorology and Hydrology – SENAMHI

Weighting of indicators (Module 6)

The ABRO software was used to calculate the potential climate impact before the implementation of the irrigation measure and after the implementation (see Table 6). The results of the model show that with average climate conditions and without implementing the project, the traditional irrigation system supplied water for only 4.94 ha of cropping area; and with the implementation of the Technified Irrigation project, the cropping area was increased up to 56.12 ha under optimal irrigation.

In order to estimate the adaptive capacity in the community of Chullcu Mayu, expert opinion was used, by allocating a specific weight to each factor according to the experience and criteria of the experts that participated in the assessment. With this purpose, a meeting was held with four technicians from PROAGRO to analyse the existing capacities for agricultural production among the producers of the community; based on certain elements referred to governance, resources, technologies and knowledge applied to agricultural production. An analysis was made for each of these factors to find out which are the most important aspects that determine a greater area under optimal irrigation, in a scale between 0 and 100 (scale: 0 = inexistent adaptive capacity, 100 = high adaptive capacity). Based on the expert opinion it was defined that the factor of 'governance' was worth 35 points (main element), both 'resources' and 'technologies' were worth 25 points and 'knowledge' 15 points. These groups of values are the criteria used to assess the adaptive capacity.

Table 6: Area under optimal irrigation for climate conditions before and after the implementation of the project

Factor		1960 – 1990 (without project)	1991 – 2011 (with project)
Annual precipitation (mm)		632.8	650.8
Average annual temperature (°C)	Maximum	16.1	17.0
	Minimum	2.2	1.9
Annual evapotranspiration (mm)		1,229.00	1,295.77
Area under optimal irrigation (ha)		4.94	56.12

Source: adelphi/EURAC 2014.

As a next step, adaptive capacity elements were determined for each of the categories defined (e.g. governance, resources; see Table 7). For example, to assess the 'technologies', it is considered that the producers in Chullu Mayu practicing soil and seed management as well as plague control can better cope with adverse climate impacts. Each one of these factors has been given a weight as shown in the following table.

Table 7: Weighting of factors for adaptive capacity

Factor	Weight	Comments	Weight
Governance	35	Farmer's irrigation organisation	100
Resources	25	Land availability	40
		Institutional support (technical assistance)	10
		Access to information	25
		Proximity to trade channels	25
Knowledge (know how)	15	Knowledge on introduction of new crops	30
		Crop management knowledge	30
		Adjustments to agricultural calendar	40
Technologies	25	Soil management	30
		Seed management	35
		Plague and disease control	35

Source: adelphi/EURAC 2014.

Normalisation and evaluation of indicators (Module 5)

Once the factors, indicators and calculation parameters were established, the next step was to normalise the data in order to transform it in comparable aggregated units of measurement. Since the calculation of the potential impact is made on a metric scale and the calculation of adaptive capacity is made on an ordinal scale, the data had to be normalised in order to achieve a measurement of vulnerability that is both standardised and comparable throughout time (see Module 5 of the Vulnerability Sourcebook). Therefore, a normalisation technique was used when calculating the impact of climate change in Chullcu Mayu's productive system, before and after the Technified Irrigation system was implemented.

Acknowledging the fact that Chullcu Mayu has 61 ha for potential agricultural production, climate impact was analysed using Formula 1:

Formula 1:

$$Climate\ Impact = \frac{61\ ha\text{-}Area\ under\ optimal\ irrigation\ in\ ha}{61\ ha} * 100$$

The value of 61 corresponds to the total land surface available for agricultural production. Therefore, the greatest expected impact is equal to 100 points, which would imply that the area under optimal irrigation would be 0 ha, since the climate conditions would be so adverse that not enough water would be supplied for an optimal irrigation. On the contrary, a result of 61 ha under optimal irrigation would imply that the climate conditions have no impact whatsoever (equal to 0 points). Table 8 shows the application of this equation.

Table 8: Climate impact assessment in Chullcu Mayu

Situation	Period (years)	Area under optimal irrigation (ha)	Climate impact (points)
Without project	1960 – 1990	4.9	91.9
With project	1991 – 2011	56.1	8.0

Source: adelphi/EURAC 2014.

This implies that without the project, in the past, there was a high climate impact (91.9 points). Presently, as of the implementation of the project, climate impact

Table 9: Data normalisation for adaptive capacity calculation in the Chullcu Mayu community

				Assessment (scale from 0 to 3)		Normalisation (scale from 0 to 100)		Arithmetic aggregation	
Factor	Value	Sub-factor	Weight	Before TI	After TI	Before TI	After TI	Before TI	After TI
Govern-ance	35	Farmer's irrigation organisation	100	1	3	33.3	100.0	**33.3**	**100.0**
Resources	**25**	Land availability	40	1	1	33.3	33.3	**50.0**	**50.0**
		Institutional support (technical assistance)	10	1	1	33.3	33.3		
		Access to information	25	1	1	33.3	33.3		
		Proximity to trade channels	25	3	3	100.0	100.0		
Knowl-edge (know-how)	**15**	Knowledge on intro-duction of new crops	30	1	2	33.3	66.7	**33.3**	**66.7**
		Knowledge on crops management	30	1	2	33.3	66.7		
		Adjustment to agricultural calendar	40	1	2	33.3	66.7		
Techno-logies	**25**	Soil management	30	1	1	33.3	33.3	**33.3**	**33.3**
		Seed management	35	1	1	33.3	33.3		
		Plague and disease control	35	1	1	33.3	33.3		
Total	**100**			**Adaptive capacity**				**37.5**	**65.8**

Source: adelphi/EURAC 2014.

is lower in Chullcu Mayu (just 8 points), because there is a larger surface of land under optimal irrigation (56.1 ha instead of 4.9 ha).

Based on the identified factors and the establishment of criteria for its evaluation, the adaptive capacity was estimated for the situation before the implementation of the project and the situation after its implementation. To do this, each of the sub-factors was assessed on a scale from 0 to 3. The corresponding values are 0= 'inexistent adaptive capacity', 1= 'low adaptive capacity', 2 = 'medium adaptive capacity' and 3= 'high adaptive capacity'. The qualification for each factor was developed in conjunction with the PROAGRO team discussing the arguments for the assigned qualifications. The results are presented in Table 9. Once the values were assessed according to the weighted scale, the data was normalised and combined using arithmetic aggregation. This enables to have an absolute value of the adaptive capacity for the cases with and without Technified Irrigation project implementation.

The information in the previous table denotes that before the Technified Irrigation system was implemented, there was a low adaptive capacity among the producers of the community, which increased with the implementation of the project. This is because the project strengthened farmer's organisation for the irrigation system, promoted introduction of new crops, management of crops, and adjustments to the agricultural calendar. Notwithstanding, the farmers in the community require to improve their knowledge and practices in regards to soil management, and probably access to seeds, as well as control of plagues and diseases.

Aggregation of indicators and vulnerability components (Module 7)

For the calculation of climate vulnerability with and without implementation of the Technified Irrigation system, a mathematical relation was identified to link the climate change impact data and the adaptive capacity, both measured on a scale from 1 to 100. The mathematical equation is the following (see Formula 2):

Formula 2:

$$Vulnerability = Impact - Adaptive\ Capacity$$

When aggregating climate change impact and adaptive capacity, it must be considered that both factors have different directions in terms of influence on vulnerability (high adaptive capacity reduces vulnerability, high impact increases vulnerability). Therefore, the adjustment of this equation is as follows (see Formula 3):

Formula 3:

$$Vulnerability = 100 - \frac{((100 - Impact) + Adaptive\ Capacity)}{2}$$

Note: According to the Vulnerability Sourcebook, all indicators are already aligned in the direction in Module 5. In this case, there is no need to calculate the inverse of the 'impact' as it is done in Formula 3. Table 10 shows the results of the formula's application on this case study.

Table 10: Calculation of climate vulnerability to climate change

Situation	Impact	Adaptive Capacity	Vulnerability
Before Technified Irrigation	92	38	77
After Technified Irrigation	8	66	21

Source: adelphi/EURAC 2014.

With the implementation of Technified Irrigation, the vulnerability of Chullcu Mayu's small-holder farmers has reduced because, on one hand the adaptive capacity has increased, and on the other hand, the impact has been reduced in a great magnitude with the supply of secure water through the technification of the irrigation system.

It is important to remark that for the situation of 'with project', even though the adaptive capacity further improved (which would imply 100 points), vulnerability is not reduced to zero. Vulnerability reduces in magnitudes from 77 to 21 points; showing that to cope with climate change, it is important to implement strategies to reduce climate sensitivity. For example, it is important to implement strategies to reduce the sensitivity of the system, like adjusting the type of crops, in order to reduce water deficit, and consequently reduce climate vulnerability of producers to extreme events.

Outcomes of the vulnerability assessment (Module 8)

Key findings

The Technified Irrigation Management Model has efficiently contributed to reduce the climate vulnerability of small-holder farmers in the community of Chullcu Mayu through the following:

- Reduction of the sensitivity in the system, through adjustments in the type of crops and the dates for sowing, with the certainty of secure water supply and with a greater efficiency in the parcels, which has increased the land surface under optimal irrigation.

- Increase of adaptive capacity, through strengthening the farmers' organisation for the irrigation system, an effective use of the available resources (optimal use of the land, proximity to trade channels), a greater access to knowledge (introduction of new crops, adjustments to the agricultural calendar), and application of production technologies (with soil and seeds management, and plague control).

In the past, climate variability had a more severe impact than the climate change in the agricultural activities of the Chullcu Mayu community. This negative climate impact was substantially reduced with the implementation of the Technified Irrigation project, because the greater water supply increased the cropping area under optimal irrigation, and this contributed to improving food security and agricultural income. As observed in Table 10, the project, having reduced the vulnerability of the producers (from 77 to 21 points), proved to be an efficient measure for climate change adaptation.

The reduction of vulnerability to climate impacts of small-holder farmers with Technified Irrigation is due to an increase in the adaptive capacity and reduction of the potential climate impact. As this situation is known, the following sections show results as to how the project has reduced the potential climate impact to extreme events and to future climate change.

Climate impact under extreme precipitation conditions

The impact of climate variability was analysed in the production area of the Chullcu Mayu community, with a meteorological historical data series, where it was identified that in the year 2000 the area had the lowest precipitation level (close to the 10th percentile), and on the other extreme, in 1986 records show the highest precipitation level (close to the 90th percentile). These data were introduced in the ABRO software in order to model the land surface under optimal irrigation (indirect indicator of climate change impact), on both extreme events. The results are shown in Table 11.

In Chullcu Mayu, extreme climate events are caused by the variations in precipitation levels (among the two extreme events occurred in 1986 and 2000 there is a difference of 402mm, equivalent to 88%). Temperature (and evapotranspiration) variations are very slight.

When analysing the situation in Chullcu Mayu without the project, it is observed that extreme variations in precipitation determine the increase or decrease of the land surface under optimal irrigation. For the situation with the implementation of the project, on the other hand, the land surface under optimal irrigation is not affected by the level of precipitation, be it high or low, since the Technified Irrigation system is in operation, which complements water supply under any precipitation deficit. In fact, the Technified Irrigation project increases the irrigation system's efficiency, and therefore reduces the climate sensitivity of the system.

In conclusion, the project allows the reduction of climate variability impact: variations in the precipitation do not affect the area under optimal irrigation. By increasing the efficiency of the irrigation system with technification, climate sensitivity of the system is reduced, and there is available and secure water supply for agricultural production.

Table 11: Area under optimal irrigation for extreme precipitation conditions in Chullcu Mayu

Year		**A. 1986**	**B. 2000**	**C. Difference**
Analysis		Precipitation – 90th percentile	Precipitation – 10th percentile	(1986 with respect to 2000)
Annual precipitation		857.5 mm	455.3 mm	-402.2 mm
Average annual temperature	Maximum	16.8 °C	16.9 °C	0.1 °C
	Minimum	1.4 °C	1.7 °C	0.3 °C
Annual evapotranspiration		1,300.25 mm	1,294.81 mm	-5.44 mm
Area under optimal irrigation <u>without</u> the project	Potato (early)	1.85 ha	1.14 ha	-0.71 ha (-62.28 %)
	Fava bean (dry)	0.80 ha	0.49 ha	-0.31 ha (-63.27 %)
	Carrot	0.43 ha	0.27 ha	-0.16 ha (-59.26 %)
	Oat (fodder)	0.80 ha	0.49 ha	-0.31 ha (-63.27 %)
	Gladiolus	0.49 ha	0.30 ha	-0.19 ha (-63.33 %)
	Potato (late)	4.37 ha	2.69 ha	-1.68 ha (-62.45 %)
Area under optimal irrigation <u>with</u> the project	Potato (early)	18.61 ha	18.51 ha	-0.10 ha (-0.54 %)
	Fava bean (green)	10.15 ha	10.10 ha	-0.05 ha (-0.50 %)
	Carrot	5.92 ha	5.89 ha	-0.03 ha (-0.51 %)
	Oat (fodder)	8.46 ha	8.41 ha	-0.05 ha (-0.59 %)
	Gladiolus	8.46 ha	8.41 ha	-0.05 ha (-0.59 %)
	Total area	51.60 ha	51.32 ha	-0.28 ha (-0.55 %)

Source: adelphi/EURAC 2014, based on ABRO software and modeled data from the Toralapa Station.

The potential climate change impact in the future

Information was used from the regional model 'Providing Regional Climates for Impacts Studies' (PRECIS) to analyse future potential climate change impact on the productive activity of Chullcu Mayu. This model considers the time from 1961 to 1990 as present and 2001 to 2030 as future period. In the present time, an average of the precipitation and temperature was made and future climate conditions were calculated. The model projects a temperature rise of 1.6 °C and a mixed trend for precipitation. The rainfall is projected to be reduced during dry season by 26% and increased during rainy season by 26%.

It must be noted, that the climate information projected towards the future shows a good consistency in both increase and magnitude of precipitation and maximum temperature in relation to the historically recorded data. However, the trend of the minimum temperature is contrary in relation to the recorded data. In the future, the minimum temperature has a tendency to increase, however historical registries show a tendency to descend. Despite this fact and the uncertainty the climate change model implies, the results of the PRECIS model were presented in the II National Bolivian Communication to the UNFCCC; therefore, till this moment the data pertains to the country's official information. Climate data for the present and the future have been introduced to the ABRO model in order to observe climate change impact on the land surface under optimum irrigation for Chullcu Mayu.

Table 12 shows, that the projected future climate conditions are: a greater annual average precipitation of 129 mm, increase of the minimum average temperature from 2.2°C to 3.8°C, and an increase of the maximum average temperature from 16.1°C to 17.7° C. In general this could signify overall improved climatic conditions for agricultural production in Chullcu Mayu. However, the increase in temperature implies an increase in evapotranspiration, which will increase water demand for crops, and in turn compensates precipitation increase, resulting in a net increase of only 72 mm.

Evapotranspiration increase in the future implies a special attention in considering which crops are adequate for future climate conditions that will optimise water and soil use for a sustainable agricultural production. Therefore, in the future, a strategy to reduce climate change vulnerability consists in sowing different types of crops, considering water demand, with the purpose of reducing climate sensitivity of the agricultural system.

Without the Technified Irrigation project, presently the Chullcu Mayu community would only posess 5 ha for production under optimal irrigation, and in the future may attain up to 6 ha (column A and B, mid-section), due to precipitation increase, which is almost proportionate to increase of the cropping area.

Table 12: Area under optimal irrigation with present and future climate

Note: The boxes with shadow correspond to simulated cases which do not exist in the reality.

Year or period		**A. 1960 – 1990**	**B. 2001 – 2030**	**C. Difference**
Reason for analysis		Present climate conditions	Future climate conditions	(Future in relation to present)
Annual precipitation		632.7 mm	752.4 mm	128.7 mm
Average annual temperature	Maximum	16.1 °C	17.7 °C	1.6 °C
	Minimum	2.2 °C	3.8 °C	1.6 °C
Annual evapotranspiration		1,229.00 mm	1,285.62 mm	56.62 mm
Area under optimal irrigation without the project	Potato (early)	2.09 ha	2.55 ha	0.46 ha (+22.01 %)
	Fava bean (dry)	0.90 ha	1.11 ha	0.21 ha (+23.33 %)
	Carrot	0.49 ha	0.60 ha	0.11 ha (+22.45 %)
	Oat (fodder)	0.90 ha	1.11 ha	0.21 ha (+23.33 %)
	Gladiolus	0.56 ha	0.68 ha	0.12 ha (+21.43 %)
	Potato (late)	4.94 ha	6.05 ha	1.11 ha (+22.47 %)
Area under optimal irrigation with the project	Potato (early)	20.87 ha	18.79 ha	-2.08 ha (-9.97 %)
	Fava bean (green)	11.38 ha	10.25 ha	-1.13 ha (-9.93 %)
	Carrot	6.64 ha	5.98 ha	-0.66 ha (-9.94 %)
	Oat (fodder)	9.48 ha	8.54 ha	-0.94 ha (-9.92 %)
	Gladiolus	9.48 ha	8.54 ha	-0.94 ha (-9.92 %)
	Total area	57.85 ha	52.10 ha	-5.75 ha (- 9.94 %)

Source: adelphi/EURAC 2014, based on ABRO software, modeled data from the Toralapa Station and projections from the PRECIS Regional Model.

The situation with project implementation shows that under present climate conditions, there would be 57.9 ha under optimal irrigation; however with future climate conditions only 52.1 ha would have been achieved (column A and B, lower section). Even if the average annual precipitation has increased by 20%, throughout the year and particularly during the rainy season, there are various months in which the projected monthly precipitation level will be lower than in the same months of the present time. According to this lower precipitation and a higher evapotranspiration due to high temperature levels in the future, the area under optimal irrigation with the project would be almost 10% less in the future than in the present time.

Additionally, the ABRO exercise for the future did not adjust introduction of different types of crops for the new climate conditions, and as a consequence available water is not optimised. Therefore, it would seem that the area under irrigation is reduced in the future, when in reality it only responds to having used the same types of crops in the ABRO system as in the present time. If technological adaptation measures had been taken into account in the model, there would be a greater area under optimal irrigation; however in this case study, climate effect on the cropping area is observed.

This shows that a strategy to reduce potential climate change impacts on the cropping area, would consist in reducing the effects of increased evapotranspiration and taking advantage of increased precipitation in some months of the year, through the following: i) adjustments to types of crops sown, introducing crops with less water requirement and adequate to future climate conditions, and ii) adjustments to the agricultural calendar.

Recommendations drawn from the vulnerability assessment

Based on the climate records of precipitation and temperature used in this case study, the constant change in climate conditions is evident, and these have often negative impacts for the agricultural activity. However, as long as the Technified Irrigation system is working, and adaptive capacities are strengthened (for example making adjustment to the agricultural calendar), these impacts would not be significant for Chullcu Mayu farmers. A strategy for reducing the potential climate impact in the cropping area would be to reduce the effects of increased evapotranspiration, and take advantage of precipitation increase in some months of the year, through the following: i) adjustments to types of crops sown, introducing crops with less water requirement, and ii) adjustments to the agricultural calendar. This shows the need to include an integrated technical assistance in project designs in order to make adjustments according to climate variations, as well as the importance of monitoring climate conditions to adjust measures for agricultural development and optimise resources.

Even though the implementation of Technified Irrigation in Chullcu Mayu, has reduced climate vulnerability under lower levels, there is still a residual impact under the present climate conditions, which could be reduced through adjustments to types of crops sown and measures taken to strengthen the farmers' adaptive capacity in the community.

Therefore, it is important to acknowledge the vulnerability determinants of the analysed system, since the adaptive process to climate change requires various strategies in different areas, such as: i) productive system management (at infrastructure level and human capacities to maintain an efficient system), ii) in the area of productive organisation to improve negotiation capacities which allow the group access to resources, technologies and knowledge, and iii) in the area of integral technical assistance to farmers around diverse infrastructures that normally consist of external service (municipal or national) in order to guarantee technical assistance to public sector investments.

Therefore, the implementation of productive projects require an integrated focus that improves adaptive capacity and reduces climate sensitivity, considering climate factors and their influence on natural resources output (water, soil, crops). Hence, monitoring these climate factors and achieved outputs is essential to make the necessary adjustments to the system and optimise resources.

In order to take advantage of the Technified Irrigation system in the community, the farmers' adaptive capacity should be strengthened. This may not be possible in some areas, for example, the farmers in Chullcu Mayu have limited access to available land and this will not change in the future. However, aspects such as knowledge and technologies, as well as access to technical assistance, could be optimised, reducing farmers' vulnerability to climate change. This does not imply that they require external assistance, but that farmers need to strengthen their networks and alliances to achieve better negotiation conditions with the municipality, non-governmental entities, and governmental rural programs, in order to have better services for their crops. Also, they require more information on prices and markets, products and agricultural inputs, which could be achieved through a strong social-productive organisation in the community.

Even though, the irrigation system reduces vulnerability to precipitation and temperature changes, it has a limited effect on avoiding or reducing negative impacts of frosting on agricultural production. Therefore, it is necessary to establish adaptive strategies in order to avoid damages and losses due to frost. Likewise, a similar analysis should be made for hailstorm.

Considering that in this case study the area under optimal irrigation has been used as an indirect indicator of climate change, maintaining the other variables of the irrigation system constant, it is necessary to periodically monitor the following: efficiency and water quantity harbouring the Technified Irrigation system, verifying that these are not below the design levels.

Lessons learned from the implementation of the vulnerability assessment

In order to develop the vulnerability assessment, it is important to understand the impact chain, since it provides a clear view on the cause-effect relation in the system analysed, and allows identification of entry points for adaptation measures. Therefore, this analysis of the impact chain with participative methods to involve diverse actors is useful in improving comprehension regarding the vulnerability of the system and the need to adapt. It is to say, that this tool not only provides the guide to progress with assessment, identifying the vulnerability factors, but can also be used to increase awareness on the need to adapt to climate change and develop capacities.

For quantitative, date driven approaches there will normally be a breach between the information required to follow through a vulnerability assessment and the available information, be it historical or future models. Furthermore, the level of uncertainty will be high. Therefore, it is important to find a balance between the effort of a data driven approach and explanatory power of quantitative results. Often, the value added of the assessment will be the comprehension of the system's vulnerability, identification of entry points for adaptation and the definition of the indicators for monitoring and tracking adaptation measures.

A pending element in the Chullcu Mayu case study was to give feedback from the assessment results to the farmers that benefitted from the Technified Irrigation Project, which was not possible due to lack of time. However, the recommendation is to consider feedback to the local actors as a fundamental input for results to be implemented by the users involved in the system analysed.

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