The project is funded
by the European Union

Empowered lives.
Resilient nations.

Clima East Pilot Project "Sustainable management of pastures and forest in Armenia to demonstrate climate change mitigation and adaptation benefits and dividends for local communities" UNDP/EU

Stocktaking and vulnerability assessment of mountain ecosystems

- Approach and methodologies

August 2014

Essi Ulander

The project is funded by the European Union
and co-funded by the UNDP

ClimaEast

Content

1. Task outline 3
1.1. Scope of work 3
1.2. Approach – Detailed work plan 3
2. Stocktaking and vulnerability assessment – Theoretical background 5
2.1. Stocktaking of mountain ecosystems – Static baseline 5
2.2. Vulnerability under changing conditions – Moving baseline 6
2.2.1. Theoretical background for climate change vulnerability assessment – Conceptualization of vulnerability 6
3. Review of methodologies to assess vulnerability and selection of appropriate methodologies for the target area 9
4. Assessment of vulnerability - Pastures 11
4.1. Scope of work for the assessment of current conditions – Stocktaking of the target area 11
4.2. Scope of work for the assessment of future conditions and vulnerability 13
5. Assessment of vulnerability – Forests 18
5.1. Scope of work for the assessment of current conditions – Stocktaking of the target area 18
5.2. Scope of work for the assessment of future conditions and vulnerability 20
6. Draft terms of reference – Vulnerability assessment of mountain ecosystems 24

1. Task outline

1.1. Scope of work

Under the UNDP / EU Clima East Pilot Project "Sustainable management of pastures and forest in Armenia to demonstrate climate change mitigation and adaptation benefits and dividents for local communities", the scope of this report is to record the results of the following tasks:

1. Undertake the initial research and accurate analysis of existing approaches related to mountain ecosystem vulnerability assessment to ensure proper advice for the project implementation with specific focus on the project's first component on stocktaking and vulnerability assessment of project target area.
2. Define the approach/methodology best applicable for the country based on the desk review of existing approaches/methodologies for vulnerability assessment of mountain ecosystems, particularly considering current climate conditions and natural hazards, future climate change risks and expected/potential impacts;
3. Develop detailed scope of work (including required input and outputs) for conducting vulnerability assessment of mountain rangeland and forest ecosystems to support in reaching the project objective;
4. Provide substantial input in development of respective term of reference for conducting vulnerability assessment of selected sites in mountain rangeland and forest in Vardenis sub-region of Gegharkunik Marz in Armenia.

Based on the first four tasks a final and fifth task will be completed following an in-country mission and revision of suggested approaches based on stakeholder consultations:

5. Develop detailed guideline for conducting vulnerability assessment of mountain rangeland and forest ecosystems in Vardenis sub-region of Gegharkunik Marz in Armenia considering climate change risks and taking into account that the assessment results will serve as a basis for future development of pasture and forest rehabilitation pilots;

1.2. Approach – Detailed work plan

In accordance with the tasks outlined above, a detailed work plan, which has guided the work reported here, is described in the table below.

Task	Approach	Date of delivery
Undertake the initial research and accurate analysis of existing approaches related to mountain ecosystem vulnerability assessment to ensure proper advice for the	Revision of recent scientific peer-reviewed journal articles and reports of appropriate organizations related to vulnerability assessment of pastures and forests	August 25, 2014

project implementation with specific focus on the project's first component on stocktaking and vulnerability assessment of project target area	Revision of global and regional examples of pasture/forest vulnerability assessments	
Define the approach/methodology best applicable for the country based on the desk review of existing approaches/methodologies for vulnerability assessment of mountain ecosystems, particularly considering current climate conditions and natural hazards, future climate change risks and expected/potential impacts	Evaluate methodologies based on their data and time requirements Evaluate methodologies based on the ecosystems covered by them Assess available data in the target country and region - Identify potential constraints in the application of specific methodologies - Assess project requirements in terms of development of forest and pasture rehabilitation pilots Select most appropriate approaches for further stakeholder discussion	August 25, 2014
Evaluate the suitability of selected methods based on in-country mission and stakeholder discussions	Clarification of the scale of the vulnerability assessment, definition of sampling methods, sample size, target areas Finalize selection of methodologies	August 29, 2014
Develop detailed scope of work (including required input and outputs) for conducting vulnerability assessment of mountain rangeland and forest ecosystems to support in reaching the project objective	Develop scope of work based on chosen methodologies and approaches	Draft August 25, 2014 Final August 29, 2014
Provide substantial input in development of respective term of reference for conducting vulnerability assessment of selected sites in mountain rangeland and forest in	Outline tasks and requirements for the development of the respective terms of reference	Draft August 25, 2014 Final August 29, 2014

Vardenis sub-region of Gegharkunik Marz in Armenia		
Develop detailed guideline for conducting vulnerability assessment of mountain rangeland and forest ecosystems in Vardenis sub-region of Gegharkunik Marz in Armenia considering climate change risks and taking into account that the assessment results will serve as a basis for future development of pasture and forest rehabilitation pilots	Based on selected and revised methodologies, develop detailed implementation strategy for the vulnerability assessment of forests and pastures in the target area	September 14, 2014

2. Stocktaking and vulnerability assessment – Theoretical background

2.1. Stocktaking of mountain ecosystems – Static baseline

Methods for ecosystem inventory are well established. Past descriptions of ecosystem conditions rely on site indices developed based on environmental conditions describing the production potential of a site and respective growth and yield tables. These indices are based on assumption of static environmental conditions, which might not hold in the future. Nevertheless, they reveal a great amount of information and the current condition of the ecosystems assessed through more traditional inventory methods can be used as a starting point for the assessment of potential impacts also under changing climate conditions. A rigorous inventory of the target ecosystems is necessary to determine the current condition and integrity of these ecosystems. With a specific focus on enabling a vulnerability assessment, the inventory of the target area should include an assessment of ecosystem composition, biodiversity and integrity, assessment of the productive capacity and yield, evaluation of soil conditions and factors such as erosion and degradation, and based on the aforementioned factors, assessment of the current carbon sequestration potential of the target ecosystems. Importantly, a thorough inventory of the target ecosystems is necessary to determine the sustainability of the current level of utilization of the target ecosystems. Based on an inventory of the target areas, also a baseline development of the target ecosystems may be developed using modeling approaches, as suggested below in chapters 3, 4 and 5. The methodologies for the suggested stocktaking of the target ecosystems are described in chapters 4 and 5.

Climatological factors as well as biotic factors, such as pests and weeds, play a great role in the development of ecosystems also under current climate conditions. Thus, a stock taking of the target ecosystems has to include assessment of factors such as frequency of wildfires and pest outbreaks. Furthermore, an inventory is necessary to evaluate processes such as erosion and land degradation taking place already under current conditions.

The target ecosystems are greatly affected not only by climatological factors, but also by anthropogenic pressures. Thus the stocktaking of the target ecosystems has to include assessment of factors such as grazing pressure, utilisation of wood and timber as well as utilisation of non-wood forest products. The lack of up-to-date management plans for the target ecosystems suggests that qualitative methods are most appropriate for the assessment of these factors. To further assess the

The project is funded by the European Union
and co-funded by the UNDP

utilisation and value of the target ecosystems as well as the adaptive capacity of the communities dependent on pastures and forests in the target area, an assessment of the socio-economic conditions of the adjacent communities is necessary.

2.2. Vulnerability under changing conditions – Moving baseline

2.2.1. Theoretical background for climate change vulnerability assessment – Conceptualization of vulnerability

Instead of working with expectedly static environmental conditions in natural ecosystems, climate change forces users of natural ecosystems to consider the potential changes that the changing climate conditions might induce in the target ecosystems in order to ensure sustainability of natural resource management in the future. Ecosystem management under climate change entails acknowledging the potential changes in natural ecosystems induced by changes in the climatic conditions as well as the respective effects of these changes on the delivery of the desirable goods and services by the ecosystems. It is thus necessary to identify potential changes in the climatic conditions going beyond the inter-annual and inter-decadal variability present under static conditions. Accordingly, it is necessary to identify potential changes in natural ecosystems following the changes in the climatic factors.

Respectively, assessment of the vulnerability of an ecosystem to climate change begins with the identification of expected changes in the climatic conditions and consequent changes in both abiotic and biotic impact factors affecting the ecosystem. When the impact factors have been identified it is possible to analyse the potential impacts in the ecosystems. Understanding how and to what extent the different impact factors induced, strengthened or altered by climate change affect the target ecosystem – or in other words how vulnerable the ecosystem is to climate change – requires knowledge and assessment of the sensitivity of the ecosystems to climate change as well as assessment of its ability to respond to the changes in the environment, or its adaptive capacity. Also the adaptive capacity of ecosystem managers should be considered so as to identify their capacity to take actions to assist different ecosystems to respond to the environmental changes or resists the impacts of climate change.

These components – exposure to climate change and different climatic, abiotic and biotic impact factors, sensitivity of the system as well as its adaptive capacity – define according to the widely adopted definition of IPCC the vulnerability of a system to climate change. It is also the theoretical and conceptual framework on which the suggested vulnerability assessment of mountain ecosystems to climate change is built in this report. A short description of this theoretical background is provided below.

Conceptualization of vulnerability - Components of ecosystem vulnerability to climate change

According to the definitions given in the IPCC Fourth Assessment Report, the vulnerability of a system to climate change is a function of its exposure to changing climate variables and impact factors influenced by climate change as well as the sensitivity of the system to the impact factors and its adaptive capacity or resilience. Exposure is an external factor posed on the system, while sensitivity and adaptive capacity are internal factors of the system. Following definitions given e.g. in the IPCC Fourth Assessment Report and other scientific reports, the different components of vulnerability can be defined in the following manner:

Impact factors can be climatic, physical or biological variables that are influenced by the changing climate conditions. These include factors such as mean climate characteristics (temperature, precipitation), climate variability, abiotic disturbances (including occurrence, frequency and magnitude of e.g. storms and wildfires) and biotic disturbances (e.g. pests and pathogens). **Exposure** is defined as the projection of climate change affecting the system, its degree, duration, and extent of deviation in climate to which a system is exposed.

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate change or variability. The **impacts of climate change** in a system are defined as a function of exposure and sensitivity. The effects of climate change can be either direct or indirect, including for example effects of changing temperature or effects of increased disturbances. Many climatic factors such as changes in temperature and precipitation or more frequent heat waves and droughts, as well as the rising atmospheric CO_2 concentration itself, will directly affect eco-physiology in mountainous pastures and forests under climate change. Wind storms, wildfires and mass movements are examples of indirect abiotic factors, which can become more frequent and intense under changing climate conditions with consequent significant effects on mountain ecosystems. Additionally, biotic factors, such as pests, will also be affected by the new conditions. Pest species may benefit from both the new climate as well as the weakened condition of plant species following direct and indirect climatic stresses, which can lead to more frequent pest outbreaks. Weed and other less desired plant species may expand their ranges under the changing conditions. The complex interplay of the direct and indirect stress factors can make the impacts of climate change on mountain ecosystems both more severe as well as more difficult to predict. The ecological characteristics of an ecosystem affect the sensitivity of the ecosystem to the different impacts factors posed by climate change. Furthermore, the sensitivity of a natural ecosystem affects the extent to which mechanisms, such as plant growth and mortality, are affected by the different impact factors.

A risk is the potential adverse outcome of a particular impact. Respectively, **an opportunity** is the potential beneficial outcome of a particular impact.

Adaptive capacity of a system is the ability to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. In the context of natural ecosystems, the adaptive capacity can be further divided into the inherent adaptive capacity of an ecosystem as well as the socio-economic adaptive capacity of the natural resource management sector. The **inherent adaptive capacity** consists of the evolutionary mechanisms and processes, which enable ecosystems to adjust to changing environmental conditions. Adaptation in natural ecosystems is thus an autonomous reactive process, which happens through biological responses to climate stimuli. These include acclimation through phenotypic plasticity or genetic changes within a population due to natural selection. In natural ecosystems, the ability to adapt to climate change and variability is influenced by characteristics such as existing biodiversity in the system, the successional ecosystem state, strength of selection, fecundity of the species present, fragmentation of the landscape as well as site characteristics such as topography. Generally species with a very narrow range of suitable conditions (specialist species) might be less able to adapt compared to generalist species able to occupy a wider variety of locations and conditions. The ability of specific species to respond to climate change by migrating to new locations depends among others on the seed dispersal ability of the species, availability of seed sources, sexual maturity age of the species, soil conditions as well as biotic interactions. Species with short seed dispersal distances, low seed production and complex breeding systems are at greater risk under climate change. Importantly, land-use, landscape connectivity and existence of built environment affect greatly the ability of species to disperse and migrate to new habitats. E.g. in the case of forests, the long life-span of trees might hamper their ability to sufficiently adapt to climate change impacts *in situ*, and it is unclear whether migration rates are sufficient to allow for adaptation in the face of rapid climatic changes. Furthermore, migration and seedling recruitment in new locations are hampered e.g. by habitat fragmentation. As the ability of different species to migrate to suitable conditions varies from each other, it is likely that climate change will induce opening of gaps within current vegetation zones and cause fragmentation in species distribution rather than lead to uniform zonal shifts. This can be especially significant in mountainous environments, which are characterised by variable microclimates and deep environmental gradients.

When **assessing adaptation in the entire ecosystem** as opposed to the adaptation of individual species, the focus is on the functionality of the system: on the ability of the system to maintain its main functions and provision of ecosystem services under climate change. In natural ecosystems, the inherent adaptive capacity depends on the levels of genetic variability within but also among populations as well as on the species richness within functional groups. This functional group diversity provides material for natural selection and enables continued provision of the ecosystem services by the ecosystem, the functionality of which is ultimately maintained despite changes in the environmental conditions and consequent changes in e.g. species composition.

The **socio-economic adaptive capacity** consists of the social and financial capacities of the natural resource users defining the ability to alter the utilization and management of the resources. In human systems adaptation can be an autonomous process, where the system adapts when it is forced to, as well as a planned process. Planned adaptation to climate change means reducing the vulnerability of a system through specific measures, which aim to reduce the sensitive and enhance the adaptive capacity of the target system. The capacity of natural resource users to identify and to implement specific planned adaptation measures depends on their human and social capital. This includes e.g. the level of education and training as well as the capacity of the users to understand and predict potential changes in the target ecosystems under climate change and to design options to manage the risks or take advantage of opportunities related to climate change. In addition to the human capital, the ability to implement adaptation options is also highly dependent on the economic setting and the financial capital available. The wider socio-economic and institutional system as well as the political setting also affect adaptive capacity. Decisions made at the local level are directed by the national legislation and national policies. An important factor affecting the adaptive capacity is the flexibility of related policies and management processes. In regards to the social setting, also for example public support to specific management options can affect the acceptability of certain adaptation measures. Furthermore, the intensity of ecosystem management and the general level of activity in the natural resource management sector, which often affect also for example the level of technological development and the availability of technical capital in the sector, as well as the market conditions and demand for ecosystem products and services can affect the adaptive capacity of resource users. Also factors such as land ownership structure can affect the adaptive capacity.

As a function of all of the above mentioned, **vulnerability** is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.

The vulnerability to climate change in natural ecosystems can be exacerbated by **other (anthropogenic) stresses**. Thus it is very necessary to take also the wider context into consideration when evaluating the vulnerability of a system to climate.

The vulnerability of a system can vary at different spatial and temporal scales. Thus, it is highly important to consider the impacts of scale on the assessment of vulnerability and especially on the uncertainty related to climate change projections.

The assessment of vulnerability starting from the different components described above will help to understand which systems and species are likely to be most strongly affected and why they are most vulnerable to climate change. A thorough and rigorous assessment of vulnerability will provide also a sound basis for designing natural resource management options under climate change. The assessment of vulnerability will provide natural resource users information about which ecosystems and locations are most sensitive to climate risks, where the risks are already evident or most urgent, and where are climate change effects expected to be highly damaging. Likewise, a vulnerability assessment might indicate that the risks are lower in some places or that adaptation in a specific location would be very costly.

3. Review of methodologies to assess vulnerability and selection of appropriate methodologies for the target area

Most assessments of vulnerability, like assessments of ecosystem development under static conditions, are conducted today with the assistance of model simulations. Models can be used to simulate potential future ecosystem conditions and expected provision of ecosystem goods and services under a projected future climate. Furthermore, models can be used to assess the consequences of alternative management scenarios (no measures, business-as-usual, adaptive management) in terms of their potential to alter ecosystem vulnerability and to mitigate climate change impacts. Several different types of modelling approaches have been developed to serve different purposes and different aspects of vulnerability assessments. The vulnerability of specific species can be assessed based on estimations of the shifts in the suitable range of the species using bioclimatic envelope models built on geo-referenced empirical observations. Potential changes in ecosystems, such as pastures and forests, at managerial levels (forest plot level, field level) can be assessed using biophysical process based models. Many models are available and are readily usable with full instructions for model parameterization to new conditions. Reviews and comparisons of different models and modelling approaches can be found elsewhere.

All model simulations contain inherent uncertainty, but at the same time they are able to model the complex relations present in natural ecosystems. An integral part of model simulations has to be the assessment of uncertainty related to the simulation exercise. Additionally, as a part of appropriate use of models in any application, model simulations have to be assessed always also qualitatively and in terms of their biological realism. Due to remaining uncertainties in both predictions of future climate conditions and underlying mechanism of ecosystem responses, the results of model simulations should not be seen as predictions, but rather as representation of the potential direction, magnitude and range of change. Importantly, to assess and reduce the uncertainty related to model projections, it is recommendable to use multiple models, or ensemble modelling, to enable comparison of modelling results and assessment of potential range of change.

Using modelling approaches sets requirements in terms of input data. Data is required for the parameterization of models for the target region as well as for model runs. The level of uncertainty in model predictions is greatly affected by the quality of input data and the assigned parameters. Regardless, modelling tools can be helpful in the identification of the most critical factors affecting vulnerability and in the assessment of the potential range of change. Thus, it is recommendable to further investigate the possibility to use some modelling approaches both in the assessment of the vulnerability of pastures as well as the vulnerability of forests also under the current project. Furthermore so, as the initial model simulations are highly useful in the identification of future research needs. The modelling approach in the current context could be that of an investigation of a smaller, exemplary area, where input data could be obtained through the field assessments to be conducted under the current project. The suggested approach guides the selection of possible models to plot level (small scale) biophysical models (as opposed to e.g. regional level empirical-statistical bioclimatic envelope models). Selected models assessed to be suited for the current purposes are listed in respective chapters below.

As was described above, regardless of the use of model simulations, a qualitative assessment is required to evaluate ecosystem vulnerability under changing climate conditions. The validity of the

The project is funded by the European Union
and co-funded by the UNDP

modelling results needs to be assessed, but also the overall vulnerability has to be assessed using qualitative evaluation and possibly exposure, sensitivity and vulnerability indices derived from available data. This requires an assessment of the sensitivity of defining ecosystem characteristics to climatological factors and identification of climatological threshold levels using best available scientific knowledge combined with local knowledge and observations. The qualitative data can be projected geographically with mapping tools against the projections of future climate conditions at different temporal scales to identify the most vulnerable areas. By overlaying projections of different pressures, an overall qualitative assessment of vulnerability can be obtained.

Considering past trends and observed impacts in forest ecosystems through the assessment of observational data and consultation of local stakeholders are important aspects in understanding potential climate change induced impacts in natural ecosystems. Furthermore, analysis of past climatic variability and consequent ecosystem responses can cast light on the adaptive capacity and vulnerability of the target ecosystem and might assist in identifying most vulnerable areas. In addition to the analyses of what is known in this context, the assessment should target issues, which are unknown in regards to ecosystem response to climate change. Local knowledge is also highly valuable in validation and verification of model simulation results. Furthermore, past observations should be utilised to assess model suitability to local conditions by comparing observations to model runs for the same period.

In the current context qualitative assessments combined with quantitative, science-based indices of ecosystem sensitivity to climatic impact factors play a significant role in ecosystem vulnerability assessment. Model simulations support this qualitative-quantitative assessment of ecosystem vulnerability. The definitions given above in chapter 2 for the components of ecosystem vulnerability to climate change form the science based concepts which are the starting point of the vulnerability assessment methodologies suggested in this report. This report suggests an assessment of mountain ecosystem vulnerability where best available science based knowledge is utilized to assess the different components of vulnerability, especially ecosystem sensitivity, in the context of mountainous ecosystems of Armenia. This approach enables also the identification of uncertainties and potential ranges of changes related to climate change impacts in mountainous ecosystems. As was outlined in the previous chapter, the assessment of vulnerability of mountain ecosystems requires analyses of the present conditions and assessment of e.g. productivity, carrying capacity, growth and annual increment as well as the development of natural resources under different management pathways. It is necessary to identify the risks and vulnerabilities and also the opportunities posed by climate change at different temporal scales to the target ecosystems and their development, as well as to ecosystem health, biodiversity and provision of ecosystem services.

The development of both quantitative and qualitative vulnerability assessments requires the best available quantitative data of expected climate conditions at scientifically sound geographical and temporal scales. Furthermore, due to the uncertainties in climate change projections especially at finer geographical scales, it is recommended that a range of scenarios is considered in the process of vulnerability assessment. This is a prerequisite for a rigorous assessment of vulnerability. Projections of climate conditions enable the quantitative assessment of exposure to be combined with the quantitative and/or qualitative assessments of ecosystem sensitivity and adaptive capacity. Projections of climate data are required at different altitudes and for model simulations at required time steps. Seasonal climatological data is important for the assessment of vulnerability due to respective changes in e.g. regeneration and growing season. Furthermore assessment of the occurrence and frequency of extreme weather events and climatological hazards is required. Like above, also the climate projections especially at finer scales need to be qualitatively assessed and an assessment of what is unknown and uncertain about climatic responses has to be conducted. This is especially important in the targeted mountainous terrain, where high variability in climatic conditions is experienced at the fine scales.

In order to receive an overall assessment of vulnerability, the potential changes in the target ecosystems have to be combined with expected management pathways. It is necessary to obtain estimates of expected changes in the socio-economic conditions affecting e.g. grazing pressure and wood collection through energy prices. Several development pathways might have to be developed for the socio-economic conditions.

A component in all of the assessments outlined above should be the consideration of the impact of the different pressures on the climate change mitigation potential of the ecosystems. Estimates of carbon sequestration potential and sinks and sources of carbon should be calculated based on expected growth and accumulation rates under the different scenarios.

4. Assessment of vulnerability - Pastures

4.1. Scope of work for the assessment of current conditions – Stocktaking of the target area

The assessment of vulnerability of pastures in the target area requires assessment of the current condition of the pastures. The stocktaking of the pastures in the context of the vulnerability assessment should be combined to possible extent with the other stocktaking activities planned under the project.

Assessment of the current condition and vulnerability of the pastures requires information of the current ecological condition of the pastures, their extent and location, their usage as well as information on both biotic and abiotic factors currently affecting the pastures together with information of other anthropogenic factors affecting the pastures. To obtain this information, it is necessary to combine field inventories with review of existing data, such as maps, management plans etc., as well as with consultation and interviews of local stakeholders.

The **approaches** suggested in this report for the gathering of the necessary information are outlined in the following table. Some of the approaches might not be viable in the local context, if the outlined information is not available. Accordingly, the approaches should be revised following a stakeholder discussion. **Methodologies** including e.g. sampling size and design are subject to clarification following a more specific definition of the study design and selection of the study areas. The methodologies should be reviewed also in the context of other stocktaking activities, which are planned to be conducted under the project.

Scope of work	Approach / Input	Output
Inventory of pastures in the target region	Review of existing maps (possibly remote sensed data if available), mapping exercise (generation of digital maps), GPS tracking of specific study areas for GIS (if applicable)	Area and location of pastures, Topographic and altitudinal description of pastures Description of infrastructure - Access to pastures - Watering sites - Shelter

The project is funded by the European Union and co-funded by the UNDP

	Review of existing descriptions / data of the target pastures Field inventory of selected sites, Approaches either: - General, statistically representative description of the whole project area - Statistically representative assessment of selected sites Soil sampling and laboratory analyses Laboratory treatment of vegetation to estimate productivity (calculation of dry mass of vegetation)	Description of site indices, classification, vegetation, degradation/erosion, soil types Vegetation (Cover and type, species) - Site indices - Estimation of naturalness of the vegetation - Nutritional content / changes in vegetation Productivity and carrying capacity - Amount of vegetation (dry mass) - Amount of fodder (dry mass) - Number of livestock units supported Degradation/erosion Soil conditions - Site indices Calculation of carbon pools
Assessment of anthropogenic pressures on pastures	Interviews, stakeholder consultations	Grazing pressure - Number of animals (expressed in livestock units) - Fodder requirements - Grazing period / pen period - Grazing areas - Areas for harvesting winter fodder Animal health Other anthropogenic pressures - Utilisation of vegetation, species and amount collected Other land use pressures - On-going and planned activities

The project is funded by the European Union and co-funded by the UNDP

		Identification of current methods for the management of the pasture areas Ownership structure
Assessment of biotic pressures on pastures	Interviews, stakeholder consultations Past records	Pest and pathogen outbreaks
Assessment of abiotic pressures on pastures	Interviews, stakeholder consultation Past records	Frequency and extent of wildfires Frequency and impact of landslides, mud flows and other mass movements Frequency and impact of droughts and other extreme weather events
Evaluation of climate change mitigation potential and carbon sequestration	Calculations based on field inventory and mapping data	Carbon in carbon pools, sequestration rate, sources

The completion of the tasks outlined above requires:

- Collection, evaluation and analyses of existing data
- Generation of digital maps
- Setting up a field inventory with appropriate statistically sounds study plot design (to be clarified based on the size and characteristics of the study area)
    - Measurement of
        - Vegetation, composition: ocular estimation using standard plots
            - Evaluation of nutritional values
        - Vegetation, productivity: clip and weigh –method, calculation of carrying capacity
        - Soil, depth and composition: measurements, sampling and laboratory analyses
        - Soil, erosion and degradation: ocular, field measurement and laboratory analyses
    - Calculation of mean values based on inventory data
    - Calculation of carbon sequestration based on inventory data
- Conducting interviews
    - A combination of standardised questionnaire forms and free interviews of selected stakeholders
- Assessment of available data on abiotic and biotic pressures.

4.2. Scope of work for the assessment of future conditions and vulnerability

As outlined in chapter 3 of this report, the suggested approach for the assessment of vulnerability of pastures under climate change in the context of the current project is a combination of qualitative and quantitative methods. It is suggested that three different approaches are used to assess the climate change vulnerability of pastures:

The project is funded by the European Union
and co-funded by the UNDP

1. Qualitative assessment of past observations of ecological changes in the context of historical climate records and climate variability (long-term records, extreme events),
2. Qualitative-quantitative, science-based evaluation of the most significant impact factors and exposure, ecosystem sensitivity and threshold levels for the pastures using representative indicator species (or assemblage of indicator species) and the field inventory data obtained under the stocktaking activities, development of vulnerability indices based on the assessment,
3. Quantitative assessment of the potential range and direction of climate change impacts using modeling approaches for selected exemplary areas, identification of most significant factors altering the vulnerability and adaptive capacity of the target ecosystems
    a. Qualitative assessment of the biological realism of the results, stakeholder validation.

The **approaches** suggested in this report for the assessment of the vulnerability of pastures are outlined in the following table. Like above in the case of the approaches suggested for stocktaking, some of the approaches might not be viable in the local context. Accordingly, the approaches should be revised following a stakeholder discussion. A separate assessment of the projected changes in the climate is required for the vulnerability assessment. The overall vulnerability can be derived by evaluating the agreement and potential ranges of change suggested by the different approaches.

Scope of work	Approach / Input	Output
Assessment of climatological conditions	Ensemble modelling Downscaling methodology (including elevation model)	Projections of the climatological conditions at suitable spatial and temporal scales (assessment of uncertainty of local scale projections) - Different climatological trajectories (including assessment of related uncertainty) Exposure to different climatological impact factors - Long-term trends - Variability and climatological hazards and extreme events - Projections of seasonal climate conditions and variability - Projections of climatological conditions at different altitudes
Evaluation of observed changes	Interviews and stakeholder consultations	Identification of past changes related to climatic conditions

The project is funded by the European Union and co-funded by the UNDP

	Review of past climatological records and statistical data	Identification of historical fodder production levels, causes for variability Assessment of critical factors of ecosystem sensitivity and vulnerability
Assessment of future ecosystem conditions and adaptive capacity	Model simulations (e.g. CENTURY ECOSYSTEM MODEL)	Projection of future ecosystem conditions under different climate change trajectories Description of potential changes in - Vegetation - Pasture productivity and carrying capacity - Carbon sequestration potential Assessment of different management pathways and their impacts
Assessment of climate change mitigation potential, carbon sinks and sources	Carbon pool calculations Qualitative assessment of factors affecting carbon accumulation (productivity, decomposition etc.)	Assessment of carbon pools based on model simulations Identification of critical factors for carbon accumulation
Assessment of ecosystem vulnerability	Science based assessment of climate change sensitivity of biophysical processes and adaptive capacity (*in situ, ex situ*) of target ecosystems using indicator species as proxies for habitats/areas Assessment of sensitivity to biotic and abiotic impact factors Identification of climatological threshold levels and calculation of indicators relevant for pasture ecosystems (e.g. growing degree days, soil water availability / evapotranspiration, frost	Identification of most critical climatological factors Identification of potential impacts of climate change on ecosystems and ecosystem services, including grazing potential and winter fodder production Identification of most vulnerable ecosystem types and pasture areas Identification of areas most vulnerable to climatological hazards and biotic pressures, erosion and degradation, risk of mass movements

	events) (Utilisation of e.g. FAO CropWat model to assess water requirements) Science based assessment of potential climate change impacts as a function of sensitivity and exposure considering also adaptive capacity - Impacts on ecosystem conditions - Impacts on critical outcome variables of concern (ecosystem function, fodder production) Development of quantitative vulnerability indices based on the science-based analyses, assignment of indicator values to management level plots Mapping exercise, projection of vulnerability indices, overlaying different components of vulnerability at different temporal scales Verification of indices through stakeholder consultations	Identification of range shifts of species, assessment of the potential of species to move in response to climate change by assessing landscape connectivity, other physical barriers to movement, dispersal abilities and breeding productivity
Assessment of socio-economic vulnerability	Stakeholder consultation, interviews Statistical and economic analyses, assessment of food, commodity and energy prices and expected development of the economic situation	Estimation of future numbers of cattle (livestock units) - Estimation of grazing area required to support the LU's Estimation of livestock health (e.g. impacts of heat stress) Estimation of climate change impacts on grazing infrastructure (access to pastures etc.)

The project is funded by the European Union and co-funded by the UNDP

		Estimation of the number of people relying on the agricultural sector for their income - Share of subsistence farmers Estimation of social adaptive capacity

The completion of the tasks outlined above requires:

- Obtaining or conducting analyses of future climate conditions and projection to suitable spatial and temporal scales
    - Calculation of exposure to different impact factors
- Conducting model simulation
    - Obtaining relevant data
    - Parameterization of model and model validation
    - Appropriate model runs
        - Management options
        - Time scale
        - Target outputs
    - Verification of modelling results
- Identification of most significant indices for sensitivity, exposure and adaptive capacity
    - Qualitative assessment of the indices against projected climate conditions
        - Key biophysical processes and their climatological threshold levels
            - Phenology, photosynthesis, primary production, decomposition rates etc.
                - CO_2, water use efficiency, water availability, nutrient accumulation,
        - Key factors for in situ adaptive capacity
            - Seed production, regeneration etc.
        - Key factors affecting ability to move
            - Dispersal ability, landscape connectivity etc.
    - Development of vulnerability indices and assignment of indices to target area based on field inventory data
- Identification of most important factors affecting socio-economic adaptive capacity
- Designing interview plan and relevant questionnaires, conducting stakeholder interviews in regards to
    - Past observations re changes in vegetation, extreme events, hazards, fodder production levels, animal health
    - Socio-economic situation and adaptive capacity
    - Future number of livestock
- Assessment of overall uncertainty, comparison of results of different approaches to vulnerability assessment
    - Assessment of uncertainty

The project is funded by the European Union
and co-funded by the UNDP

5. Assessment of vulnerability – Forests

5.1. Scope of work for the assessment of current conditions – Stocktaking of the target area

The approach for the assessment of the vulnerability of forests in the target area suggested in this report follows a similar structure as was outlined above for pastures. Prior to the assessment of vulnerability under future conditions, stocktaking of the target ecosystems should be conducted to assess the current ecological condition of the forests. Again, the stocktaking exercise should be combined or be conducted jointly with other planned stocktaking activities under the project.

The forest inventory should include assessment of the current ecological condition of the target forests, forest area and location and current utilisation of the forests. Additionally information on both biotic and abiotic factors currently affecting the forests should be collected together with information on other anthropogenic factors affecting the forests. In addition to a field inventory of selected sites in the target area, the approach entails collection and review of existing data as well as consultation and interviews of local stakeholders.

The **approaches** suggested in this report for the gathering of the necessary information are outlined in the following table. Some of the approaches might not be viable in the local context, if the outlined information is not available. Accordingly, the approaches should be revised following a stakeholder discussion. **Methodologies** including e.g. sampling size and design are subject to clarification following a more specific definition of the study design and selection of the study areas. The methodologies should be reviewed also in the context of other stocktaking activities, which are planned to be conducted under the project.

Scope of work	Approach / Input	Output
Inventory of forests in the target region	Review of existing maps (possibly remote sensed data if available), mapping exercise (generation of digital maps), GPS tracking of specific study areas for GIS (if applicable)	Forest cover and location of forests Topographic and altitudinal description of forests
	Review of existing inventory data of and management plans developed for the target forests	Description of site indices, tree species composition and stocking density, soil types, ecosystem integrity, degradation/erosion
	Field inventory of selected sites, Approach either: - General, statistically representative description of the whole project area - Statistically representative	Above ground biomass (stand structure and age, stocking density, number/height of trees, species composition and forest biodiversity) - Site indices - Estimation of naturalness of the vegetation Regeneration

The project is funded by the European Union and co-funded by the UNDP

	assessment of selected sites Soil sampling and laboratory analyses	Assessment of growth rates Estimation of degradation/erosion Soil conditions - Soil depth - Site indices Susceptibility to disturbances Signs of anthropogenic pressures
Assessment of anthropogenic pressures on forests	Interviews, stakeholder consultations	Other anthropogenic pressures - Utilisation of vegetation, species and amount collected - Managed timber harvesting, wood collection - Unmanaged wood collection - Grazing (at forest border) Other land use pressures - On-going and planned activities Identification of current methods for the management of the forest areas Ownership structure
Assessment of biotic pressures on forests	Interviews, stakeholder consultations Past records	Pest and pathogen outbreaks
Assessment of abiotic pressures on forests	Interviews, stakeholder consultation Past records	Frequency and extent of forest fires and wildfires Frequency and impact of landslides, mud flows and other mass movements Frequency and impact of wind storms Frequency and impact of droughts and other extreme weather events

Evaluation of climate change mitigation potential, carbon sequestration	Calculations based on field inventory and mapping data	Carbon in above and below grounds carbon pools, carbon sequestration rate, sources

The completion of the tasks outlined above requires:

- Collection, evaluation and analyses of existing data
- Generation of digital maps
- Setting up a field inventory with appropriate statistically sounds study plot design (to be clarified based on the size and characteristics of the study area)
    - Measurement of
        - Stand structure (age, number of trees, DBH, height), species composition, calculation of stocking density: measurements using standard plots
        - Soil, depth and composition: sampling and laboratory analyses
        - Soil, erosion and degradation: ocular, field measurements and laboratory analyses
        - Regeneration: ocular estimation in addition to measured plot level data, number of seedlings
    - Calculation of mean values based on inventory data
    - Calculation of carbon sequestration based on inventory data
- Conducting interviews regards to current management and utilisation, abiotic and biotic pressures, current climatological hazards
    - A combination of standardised questionnaire forms and free interviews of selected stakeholders
- Assessment of available data on abiotic and biotic pressures.

5.2. Scope of work for the assessment of future conditions and vulnerability

Also the suggested approach for the assessment of vulnerability of forests follows the approach outlined above for pastures. It is suggested that three different approaches are used to assess the climate change vulnerability of forests:

1. Qualitative assessment of past observations of ecological changes in the context of historical climate records and climate variability (long-term records, extreme events),
2. Qualitative-quantitative, science-based evaluation of the most significant impact factors and exposure, ecosystem sensitivity and threshold levels for the target forests using representative indicator species (or assemblage of indicator species) and the field inventory data obtained under the stocktaking activities, development of vulnerability indices based on the assessment,
3. Quantitative assessment of the potential range and direction of climate change impacts using modeling approaches for selected exemplary areas, identification of most significant factors altering the vulnerability and adaptive capacity of the target ecosystems
    a. Qualitative assessment of the biological realism of the modeling results, stakeholder validation.

The **approaches** suggested in this report for the assessment of the vulnerability of forests are outlined in the following table. The suggested approaches might not be viable in the local context. Accordingly, the approaches should be revised following a stakeholder discussion. A separate assessment of the projected changes in the climate is required for the vulnerability assessment. The overall vulnerability can be derived by evaluating the agreement and potential ranges of change suggested by the different approaches.

Scope of work	Approach / Input	Output
Assessment of future climatological conditions	Ensemble modelling Downscaling methodology (including elevation model)	Projections of the climatological conditions at suitable spatial and temporal scales (assessment of uncertainty of local scale projections) - Different climatological trajectories (including assessment of related uncertainty) Exposure to different climatological impact factors - Long-term trends - Variability and climatological hazards and extreme events - Projections of seasonal climate conditions and variability - Projections of climatological conditions at different altitudes
Evaluation of observed changes	Interviews and stakeholder consultations Review of past climatological records and statistical data	Identification of past changes related to climatic conditions Assessment of critical factors of ecosystem sensitivity and vulnerability
Assessment of future ecosystem conditions and adaptive capacity	Model simulations (e.g. GOTILWA+ MODEL, 3-PG MODEL)	Future ecosystem conditions under different climate change trajectories Evaluation of potential changes in: - Forest composition - Growth rates and yield - Carbon sequestration potential Assessment of different management pathways

Assessment of climate change mitigation potential, carbon sinks and sources	Carbon pool calculations Qualitative assessment of factors affecting carbon accumulation (productivity, decomposition etc.)	Assessment of carbon pools based on model simulations
Assessment of ecosystem vulnerability	Science based assessment of climate change sensitivity of biophysical processes and adaptive capacity (*in situ*, ability to move) using indicator species as proxies for habitats/areas Identification of climatological threshold levels and calculation of indicators relevant for forest ecosystems (e.g. growing degree days, soil water availability / evapotranspiration, frost events) (potentially utilisation of FAO CropWat modelling tool) Assessment of sensitivity to biotic and abiotic impact factors Science based assessment of potential climate change impacts as a function of sensitivity and exposure considering also adaptive capacity - Impacts on ecosystem conditions - Impacts on critical outcome variables of concern (ecosystem function and ecosystem services, timber production, biodiversity) Development of quantitative vulnerability indices based on the science-based analyses,	Identification of most critical climatological factors Identification of potential impacts of climate change on ecosystems and ecosystem services, including e.g. carbon sequestration, timber production, biodiversity, water retention, soil protection, protection from mass movements Identification of most vulnerable ecosystem types and forest areas Identification of areas most vulnerable to climatological hazards and biotic pressures Identification of range shifts of species, assessment of the potential of species to move in response to climate change by assessing landscape connectivity, other physical barriers to movement, dispersal abilities and breeding productivity

The project is funded by the European Union
and co-funded by the UNDP

	assignment of indicator values to management level forest plots Mapping exercise, projection of vulnerability indices, overlaying different components of vulnerability at different temporal scales Verification of indices through stakeholder consultations	
Assessment of socio-economic vulnerability	Stakeholder consultation, interviews Statistical and economic analyses, assessment of energy prices and development of the economic situation	Estimation of future pressures on forests Estimation of social adaptive capacity - Estimation of impacts of potential changes in forest ecosystems on other sectors, such as agriculture Estimation of dependency on non-wood forest products Estimation of fire wood collection rates

The completion of the tasks outlined above requires:

- Obtaining or conducting analyses of future climate conditions and projection to suitable spatial and temporal scales
  - Calculation of exposure to different impact factors
- Conducting model simulation
  - Obtaining relevant data
  - Parameterization of model and model validations
  - Appropriate model runs
    - Management options
    - Time scale
    - Target outputs
  - Verification of modelling results
- Identification of most significant indices for sensitivity, exposure and adaptive capacity
  - Qualitative assessment of the indices against projected climate conditions
    - Key biophysical processes and their climatological threshold levels
      - Phenology, photosynthesis, primary production, decomposition rates etc.

        - CO_2, water use efficiency, water availability, nutrient accumulation, temperature
    - Key factors for in situ adaptive capacity
        - Seed production, regeneration etc.
    - Key factors affecting ability to move
        - Dispersal ability, landscape connectivity etc.
  - Development of vulnerability indices and assignment of indices to target area based on field inventory data
- Identification of most important factors affecting socio-economic adaptive capacity
- Designing interview plan and relevant questionnaires, conducting stakeholder interviews in regards to
  - Past observations re changes in forest composition and regeneration, extreme events, hazards
  - Socio-economic situation and adaptive capacity
- Assessment of overall uncertainty, comparison of results of different approaches to vulnerability assessment
  - Assessment of uncertainty

6. Draft terms of reference – Vulnerability assessment of mountain ecosystems

Below, initial aspects for the terms of reference to be drafted are listed.

- Duties and responsibilities:
  - Stocktaking of forests and pastures in the target area to assess the current ecosystem condition and current anthropogenic, climatological and biotic pressures the forests and pastures in the area are facing. It is envisioned that the stocktaking will include conducting rigorous field inventories applying statistically sound sampling methods as well as qualitative approaches including interviews and stakeholder consultations and gathering, evaluation and analyses of existing data.
  - Vulnerability assessment of pastures and forests in the target area using three approaches:
    - Qualitative assessment of past observations of ecological changes in the context of historical climate records and climate variability (long-term records, extreme events),
    - Qualitative-quantitative, science-based evaluation of the most significant impact factors and exposure, ecosystem sensitivity, threshold levels and adaptive capacity using representative indicator species (or assemblage of indicator species), assessment of potential impacts of changing climate conditions based on the field inventory data obtained under the stocktaking activities, and development of vulnerability indices based on the assessment,
    - Quantitative assessment of the potential range and direction of climate change impacts using modeling approaches for selected exemplary areas, identification of most significant factors altering the vulnerability and adaptive capacity of the target ecosystems, including qualitative assessment of the biological realism of the results, stakeholder validation.
  - The vulnerability assessment includes also obtaining and / or conducting analyses of future climate conditions and projection to suitable spatial and temporal scales.

- Required qualifications:

- Education: Background in biology, ecology, environmental sciences, environmental management, agriculture or forestry
- Experience: Strong experience in vulnerability assessment, and climate change research, experience in environmental management, experience in ecosystem-based climate change adaptation and mitigation, strong understanding of the ecosystem conditions in Armenia
- Technical skills: Strong skills within the MS Windows Suite, good understanding of statistical approaches, knowledge of GPS and GIS, knowledge of mapping tools, understanding of modeling approaches

The project is funded by the European Union
and co-funded by the UNDP