Integrated Biodiversity Management, South Caucasus

Integrated Erosion control measures in Ismayilli, Azerbaijan.

Remote Sensing Concepts on Erosion Control and Pasture Management

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Report

11/2016

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

The Programme „ Integrated Biodiversity Management, South Caucasus “ is financed by the German Federal Ministry for Economic Cooperation and Development (BMZ) and co-financed by the Austrian Development Agency. It is implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

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Executive summary

The present report focuses on the development of first concepts on how remote sensing can help to assess current erosion and erosion risk, current landslides and maximum carrying capacities for livestock breeding based on the available biomass and suitable pastures. These concepts should provide a sound basis for discussion with national partners to develop final plans and strategies on the national level. The long-term objective is the provision of reliable and relevant spatial data for decision-making in sectoral administrations. Maps will serve as a tool for awareness raising and for explaining and exploring benefits and uses of the tool for national stakeholders. They will help the regional administration to identify sensitive erosion hot-spots and they form base information for sustainable natural resource management planning.

Methodology for assessment of current status of eroded areas based on remote sensing information

The methodology is proposed to prepare maps indicating which areas are affected by erosion. This information will help to develop strategies to adapt land-use to control erosion and to monitor the progress of erosion process. The time series could be used to monitor changes in erosion. On the one hand the success of erosion control measures can be monitored on a national level. On the other hand, new sites or increase of spatial cover of erosion can help to prioritize activities.

Methodology for erosion risk mapping (including wind erosion risk in lowlands)

The objective of this methodology is to develop and implement a remote sensing technology to produce maps of erosion risks in order to give a spatial information on erosion risks (the potential of soil loss) and to provide techniques and methods which are reproducible and can be used for monitoring changes in erosion risks.

Methodology for an assessment of landslide risks

Knowledge about landslide dynamics is crucial for planning of roads and settlements, identification of potential hazard zones and for planning and prioritizing erosion mitigation measures. The proposed methodology will help to build up a landslide inventory. The assessment delivers a digital map of existing and historic landslide areas. The maps help to develop strategies for mitigation measures and for optimal infrastructure planning and to support local or regional decision-making.

Methodology for an assessment of maximum stocking units based on the erosion assessment.

Estimation of existing fodder biomass and estimation of biomass productivity of different landscapes is the basis to calculate the maximum number of livestock that can be sustained by an ecosystem without depleting the pastures on long term. An assessment will be provided for pastures of each municipality (classification of pasture types according to productivity in ha, maximum of sustainable livestock units per type).

Changing erosion risks from a climate change perspective

It is proposed to develop a methodology for modelling changing erosion risks with regards to climate change based on biotic and abiotic factors (vegetation change, temperature, precipitation) for long-term strategic and spatial planning. The methodology includes the preparation of high resolution maps modelling climate-change induced changes in land-cover and vegetation types.

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List of Abbreviations

ADC	Austrian Development Cooperation
BMZ	German Federal Ministry of Economic Cooperation and Development
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GPS	Global Positioning System
IBiS	Integrated Biodiversity Management, South Caucasus
IEC	Integrated Erosion Control [Project]
M&E	Monitoring and Evaluation
MZ	Modulziel
NPSAP	National Biodiversity Strategy and Action Plans
NGO	Non-governmental Organization
RBM	Result based monitoring
ToR	Terms of Reference
NBSAP	National Strategy and Action Plan on Conservation and Sustainable Use of Biodiversity

1. Introduction

The biodiversity of the South Caucasus is of global importance, but the huge variety of species and the proper functioning of the ecosystems are under threat. There is considerable pressure from the exploitation of natural resources by the local population, private industry and governments.

IBiS follows up on the achievements of the programmes "Sustainable Management of Biodiversity, South Caucasus" and "Integrated Erosion Control in Mountainous Areas, South Caucasus", and is due to last four years (from December 2015 to November 2019). The programme is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry of Economic Cooperation and Development (BMZ).

In framework of the programme assessments and technical analysis to identify suitable erosion control activities have been done. Interventions started with the screening mission in the pilot region of Ismayilli (June 2014) and concepts of direct measures at village level have been developed in the project pilot village of Ehen, Ismayilli rayon.

Beside the implementation of erosion control measures on the local level also strategies on the national level on erosion control should be developed within the IBiS program.

This assignment is focusing on the development of first concepts on how remote sensing can help to assess current erosion and future erosion risk, current landslides and maximum carrying capacities for livestock breeding.

This concepts will provide a basis for discussion with the national partners to develop final plans and strategies on the national level.

1.1 Expected outputs according the ToR

The consultant will prepare concept drafts for further discussion with national partners on the following topics as defined by GIZ:

- Description of methodology for assessment of **current status of eroded areas** based on remote sensing information (including potential data to be used).
- Description of methodology for **erosion risk mapping**/sensitivity model including an assessment of wind erosion risk in lowlands (overview of available/needed data).
- Methodology for an assessment of **landslide risks**
- Methodology for an assessment of **stocking units** based on the erosion assessment.
- Changing **erosion risks from a climate change** perspective

2. Results

The Result section of this report describes the five above mentioned thematic concepts. Some of the activities are closely linked to each other and significant synergies can be potentially reached. At the end of this chapter we summarize these links and possible synergies.

Each chapter is structured the same way: it is started by a description of the general problem setting followed by an overview on the main objectives of the specific remote sensing concept. The main section with the technical approach will give a short review on the state of the art in the specific field and tries to argue the method recommended.

The outputs of the proposed approach are listed in the result section. At the end of each chapter needed resources (including needed data and human resources) are drafted.

This concepts should be discussed with the AZ-Stakeholders in the Ministry (and related authorities) to refine them prior to implementation.

2.1 Concept 1: Assessment of current status of eroded areas based on remote sensing information

The core result of such a spatial analysis is a map indicating areas, which are already affected by erosion classified into different erosion categories. This can be based on a remote sensing implementation concept dealing with the assessment of eroded areas based on satellite images.

2.1.1 Problem setting

Erosion in general is the gradual wearing away of land surface materials (rocks, sediments and soils) by the action of water, wind, or a glacier. For human agricultural activities, the erosion of soil is of high interest, as the soil is a crucial production factor for plant growth. Loss of soil means loss of productivity of land. Natural regeneration of soil is a very slow process taking centuries to develop a view centimetres of productive soil layer.

To keep up productivity of land (agriculture, pastoralism, forestry) it is important that the soil layer is protected against erosion.

From a land management perspective, the following questions are of interest:

- Is there erosion of soil layers taking place?
- What is the spatial dimension of these erosion processes (where is erosion located)?
- Is the degree (intensity, size of affected area) changing over time?

2.1.2 Main objective

Having maps available which indicate which areas are affected by erosion will help to develop strategies to:

- Adapt land use to control or decrease erosion
- Monitor the development of erosion sites
- Gain knowledge about correlations between relief, climate or soil types with erosivity of land surface.

2.1.3 Technical approach

The assessment of erosion by remote sensing is closely related with assessment of vegetation cover as erosion is directly correlated with vegetation cover. Sites covered by dense vegetation are usually free from erosion. Vegetation protects soils from being washed out as a good vegetation cover reduces the impact power of rain drops and slows down the speed of surface water run-off.

The degree of erosion can be estimated via the density of vegetation cover.

Based on spectral information from airborne or satellite images the density of vegetation can be calculated and mapped. There are well developed vegetation indices and classification systems to derive different vegetation types and vegetation density (manly described by the Leaf Area Index LAI or biomass indices). These classification systems are based on the fact, that living (green) biomass reflects light in a specific wavelength. Modern airborne or satellite mounted multispectral scanners have different sensors to precisely monitor these specific wave length bands. The ratios of amount of reflected light within this different bands is used to classify different vegetation types and land cover units.

The ground resolution of the images used for the classification is limiting the minimum size of vegetation patterns that can be determined. The ground resolution varies from pixel size of 0.01-0.05m (1-5 cm) from local Unmanned Aerial Vehicles (UAV's), 0.1-0.5m from airborne images to 0.5-60m from satellite images.

For a GIZ-Study on vegetation cover in Higher Caucasus (Tusheti) the new Sentinel-2 satellite images were already used and the results are very promising (Mikeladze & Nikolaeva 2016).

The Sentinel-2 mission was started in spring 2016. It delivers images for 13 different bands and the data is provided by the European Space Agency (ESA) for free. The resolution of the used spectral bands is 10 and 20 m per pixel. The same spatial extent is scanned by the satellite every 5 days, which gives high flexibility in selection of images without clouds, producing time series or analyse data for a specific season. The width of the scan is 290 km, which enables to analyse large territories with data of the same day.

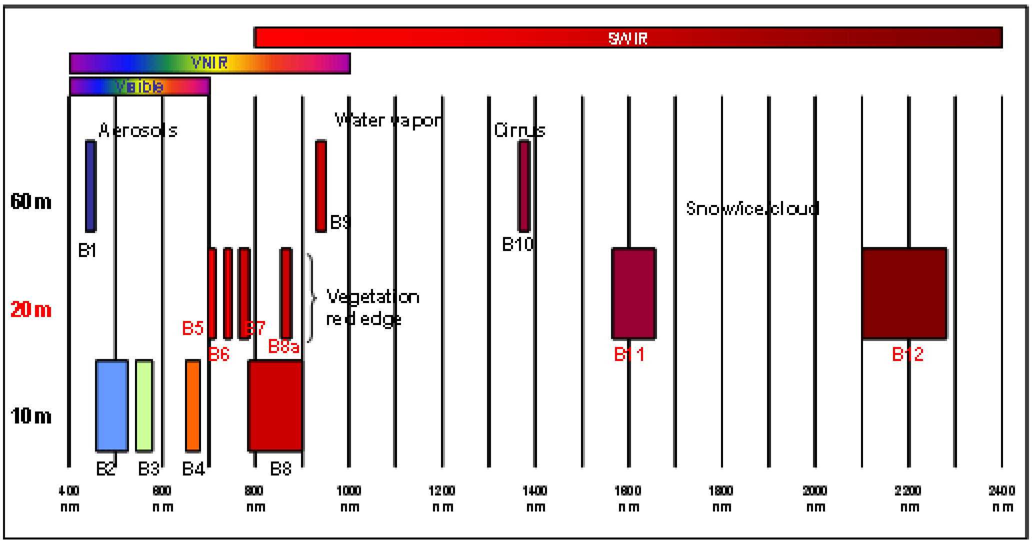

Figure 1: Sentinel-2 spectral bands (Source: http://www.cesbio.ups-tlse.fr/us/index_sentinel2.html)

Not all areas uncovered by vegetation are sites where ongoing erosion processes occur. Water surfaces, buildings and human infrastructure as well as rock surface or glaciers might not be assessed as eroded sites.

For a correct spectral classification, atmospheric correction must be completed before interpretation. Data for atmospheric correction is provided by Sen2Cor processor from the Sentinel Application Platform (SNAP, http://step.esa.int/main/snap-2-0-out-now/).

For the classification of vegetation cover different algorithms can be used. SVM (Support Vector Machines) are one tested option to develop and calibrate a regression model based on classified field data as training basis of the model.

Additionally, digital elevation models with similar spatial resolution as the classified spectral images help to explain different reflections caused by different exposition and shading effects.

The focus of the assessment of erosion should focus on sites with bare soils or soils without dense vegetation cover. The degree of vegetation cover can be used to rate the degree of erosion. It is important to classify open soil from rock or scree fields without soil cover.

To calibrate the remote sensing images field samples are needed. Based on a first analysis and classification of the images a stratified sampling design should be worked out for collection of field verification data. Size of field sample plots must correlate with the pixel size of the classified image and the precision of the spatial position of the sample plot. By using hand-held GPS devices for getting the coordinates of the sample plot, an accuracy of 10-15m can be reached.

2.1.4 Results

The assessment should deliver a digital map in the scale of 1:25.000 showing sites of erosion. We would recommend to start in 1-3 districts with pilot mappings and field verification in a first phase (first year) and scale up to national level in a second phase (year

2 & 3). The resulting map will give the spatial dimension of eroded sites and the degree of erosion in 3-5 classes (no erosion – heavily eroded). The minimum size of eroded land pattern that can be displayed in the map would be around 20x20 meter. Eroded areas significantly smaller than 20x20 might not play an important role on the overall productivity in municipalities. If smaller patches occurring frequently, this will have impact on the spectral composition of the satellite image. Results of frequent small patches of erosion will be detected as sites with lower phyto-biomass. Results from the Georgian pilot study are given in the annex.

The map can help to identify eroded landscapes and to develop strategies to change land uses to avoid further damage of vegetation or to introduce activities to rehabilitate vegetation.

It is of uppermost importance to recognize erosion at a very early stage. In early stages of erosion, while vegetation cover is still 90-70% but top soil already starting to be washed out, rehabilitation can be done by simple and quick measures without high investment. As an active soil layer is still present, self-rehabilitation processes of the vegetation can be used. This could for instance mean an adaptation of land uses to an adequate intensity, which simultaneously protects the productivity of the land.

If erosion cannot be stopped in the early stage, costs of rehabilitation increase significantly. In the case of a lost top soil layer, the process of re-establishing a productive land for grazing, agricultural or forestry use, is very long lasting and cost extensive.

Having this in mind, the erosion assessment should be very sensitive in detecting early stages of erosion.

Based on the same methodology, a time series can be started and be used to monitor changes in erosion. On the one hand the success of erosion control measures can be monitored on a national level. On the other hand, new sites or increase of spatial cover of erosion can help to prioritize activities.

Knowledge on the current spatial distribution is a valuable information for the development of erosion risk models. Based on the location of eroded sites, correlations with other site factors like inclination, soil type, geology and climate can be calculated. This information will help to improve erosion risk models and to adapt land use before damage to vegetation and soil occurs.

2.1.5 Required resources

The multispectral features of the remote sensing data are relevant for the classification of vegetation or erosion while the resolution (pixel size) is determining the finale scale of output maps and minimum size of assessable erosion sites.

Annex 1 (Geodata) of the IEC-Baseline study provides an overview about existing Airborne or Satellite images and digital elevation models (Kirchmeir 2014). The national expert for the data review in Azerbaijan was Ceyhun Zeynalov from INTEGRIS company.

Following the data-review from 2014, Airborne images are available in different resolution from 0.15 to 1m (0.15 m for urban areas, 0.25 for agriculture areas, 1 m for mountain areas).

Satellite images are available from different satellites:

Category of data type	Costs	Resolution	Description of content and attributes	Author of data
Rapid eye	commercial	5 m	RGB + Red Edge + NIR	Black Bridge
World View 2	commercial	0.5,	9 bands (RGBY, NIR1/2,Pan, Coastal)	Sovzond (Russian), Euro Space (Germany),
GeoEYE 1	commercial	0,4 m (Pan) 1.65 m (multispectral)	1,3, 5, 7, 9 and uninterrupted band tiff images	Sovzond (Russian), Euro Space (Germany)
Sentinel	free	10/20 m	13 Bands	ESA
Landsat 8	free	30m	9 Bands + 2 Thermal Infrared	NASA

Figure 2: Types of available satellite images and respective characteristics

To achieve better classification results, a digital elevation model (DEM) is recommended. The 30m resolution of the SRTM-Model is too coarse for this purpose. DEM with 10m resolution or less seems appropriate. DEM with resolutions of 2-8m calculated from high resolution satellite images can be purchased from commercial data providers by 15-100 USD per km^2. An alternative could be the generation of DEM from topographic maps (e.g. 1:50.000 Russian top maps). But usually only resolutions from 20m can be derived from topographic maps of scale 1:50 000. The classification of different vegetation types can be performed by interpretation of satellite images even without DEM. But results can be improved, if relief information is available in similar resolution as the satellite image.

The pilot study in Tusheti/Georgia showed good results with new sentinel data for maps in scale of 1:25 000, which seems meaningful for district or national maps.

For classification GIS-specialists and specific software are needed. They might be found in academic research institutions (University, Academy of Science) or in private companies/NGO’s (R.I.S.K., INTEGRIS etc.).

The development of the land cover assessment in the Tusheti Pilot Area in Georgia took about 150 workdays without field sampling. The field sampling depends on accessibility of the test area. In Georgia, we made 5-7 samples in remote mountain areas (1800-3000m) which were only accessible by food and horseback.

Involvement of universities seems meaningful to integrate knowledge and experience into education and training of students.

2.2 Concept 2: Erosion risk mapping & vegetation cover

In comparison to the assessment of erosion (concept 1) the erosion risk map should indicate areas, that are exposed to different categories of erosion risk, even if erosion is not visible at present. While vegetation cover or open soil is the main indicator for the erosion assessment, the erosion risk needs additional co-variables like run-length of a slope, soil structure, precipitation to calculate the potential erosion risk of a spatial unit. As for the calculation of the erosion risk a map of vegetation cover is needed, we integrate the classification of vegetation cover into this concept.

2.2.1 Problem setting

Some parts of the landscape are more susceptible to erosion and are more likely to lose their productive soil layer by impact of rain or wind.

For planning of land use, it is a valuable information to know, which parts of the landscape have low or high erosion risk. Sites with high erosion risk should be handled with special care to avoid damage of vegetation and to decrease productivity of land by erosion.

There are two main natural drivers for erosion in the Caucasus region: water and wind (Khresat et al., 1998). Raindrops have a reasonable energy when hitting the ground which can mobilise small fragments of the top soil layer if it is unprotected by vegetation cover. Surface water run off transport mobile soil fragments and wash out the productive soil layer. Similar impacts can be observed by wind, by blowing away bare top soil if not protected by vegetation.

2.2.2 Main objective

The objective of the assignment is to:

- Develop and implement a remote sensing technology to produce maps of erosion risks
- The results should help to
  - give a spatial information on erosion risks (the potential of soil loss)
  - develop a methodological approach, that can be up scaled to the national level of Azerbaijan
  - develop techniques and methods which are reproducible and can be used for monitoring changes in erosion risks

The long-term objective is the provision of reliable and relevant spatial data for decision-making in sectoral administrations.

2.2.3 Technical approach

To make use of existing tools, it is recommended to implement the erosion model as developed by GIZ in Georgia and to adapt the tool for the use in Azerbaijan. A report on the Georgian Erosion Risk Model was published in November 2016 (Mikeladze & Nikolaeva 2016).

The existing model does not include the assessment of wind erosion risk. For this purpose, a new model should estimate the risk of wind erosion should be developed.

Step 1: Set up of a Geographic Information System

The following data sets are necessary to be integrated:

- Satellite Images
- Digital Elevation Model (DEM) (min. resolution 10x10m)
- Spatial extrapolation of precipitation (monthly means, if available daily maxima)
- Soil map or extrapolation by geological maps and/or relief information derived from DEM
- Land cover information (derived from satellite image)
- Date on wind directions and intensity
- CHELSA climate data (www.chelsa-climate.org)

Step 2: Develop a remote sensing approach for assessing the rain erosion risk

The RUSLE (Revised Universal Soil Loss Equation) that was used in Georgia is one meaningful approach to set up a model on soil erosion risk caused by rain and surface run-off. It has to be adapted to the specific situation in Azerbaijan and is based on a dataset of different existing digital maps (K- and LS-factor from DEM, Geological Map and Soil Map) and meteorological data (R-factor) as well as some remote sensing analysis of satellite imagery. The remote sensing data uses a NDVI-Index based on Landsat 7 ETM+ images or Sentinel-2 satellite images (C-factor). These findings could help to analyse the spatial distribution of erosion risk and its correlation with abiotic factors like altitude, exposition and geology or zoo-anthropogenic factors such as grazing intensity or infrastructure development.

Special focus should be put on the interpretation of the satellite images to come up with a Land Cover Map that is a crucial input for the USLE-Model (C-Factor). The classification should comprise the following land cover types:

- Forest areas with trees
- Forest areas with shrubs
- Grassland with high biomass (90-100% vegetation cover, good growing conditions)
- Grassland with poor biomass (50-90% vegetation cover, poor growing conditions)
- Open vegetation types (10-50% vegetation cover)
- Rock and scree (less than 10% vegetation)
- Glacier and snow fields
- Water bodies
- Human infrastructure (buildings, settlements)

Multitemporal data from different seasons would help to differentiate agricultural land from other land use types.

Beside the satellite images, other information sources can and should be used. The scale of the erosion risk and land cover map should be at 1:25.000. The minimum resolution of output raster data sets is 10x10m.

Step 3: Develop a remote sensing approach for assessing the wind erosion risk

The most important factor to calculate the risk of soil erosion caused by wind are wind speed and vegetation cover (Aslan 2003). The erosive transport capacity of wind is determined by the horizontal wind speed close to the soil surface and duration of wind. Wind speed is usally measured 10-12 m above ground to reduce the influence of turbulences at ground level.

Wind speed at soil level is heavily influenced by vegetation height and density. Vegetation causes micro turbolences and is reducing wind speed close to the ground surface.

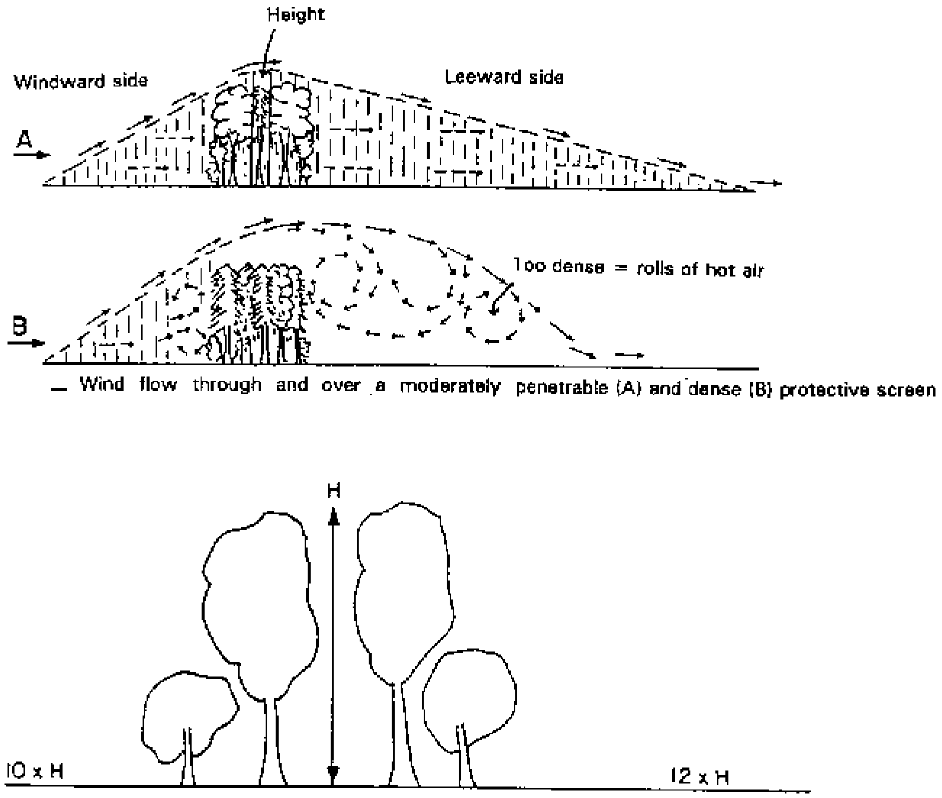

Figure 3: Wind patterns near at natural barriers such as wind protection hedges (http://www.fao.org/3/a-t1765e/t1765e0t.htm)

High vegetation patterns like forests or hedges have a significant effect on wind reduction even in the neigbouring areas (Figure 3). But also closed gassland vegetation can slow down wind speed effectivly at the soil surface.

Wind erosion can be monitored in the field by Fryrear field dust samples (Fryrear 1986) which should be covered by a rain hood (compare Leys et al. 2001).

Leys et al (2001) are describing different factors usable for modelling wind erosion. Soil texture and soil moisture, vegetation cover and surface roughness are used in combination with climate data like rainfall, evaporation and wind erosivity.

McTainsh et al. (1998) developed the “Et model” based on average monthly meteorological data to model dust storm occurrence in eastern Australia. The approach was further developed to distinguish natural and accelerated wind erosion (McTainsh & Tews 1999). This approach was used for the National Collaborative Program on Indicators of Sustainable Agriculture (NCPISA). GIS based models described in Leys et al. 2001 are based on the following input factors:

- Vegetation height (from vegetation maps)
- Leaf Area Index (from satellite images (NVDI))
- Soil particle size distribution (from soil sample database)
- Soil moisture (modelled by precipitation and evaporation)
- Wind speed and duration (spatial interpolation from climate stations)

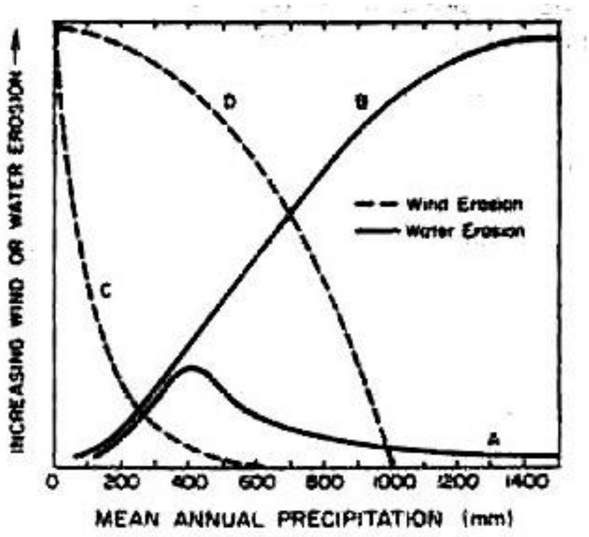

Figure 4: Relationship between water erosion (continuous lines) and wind erosion (broken lines) with mean annual precipitation. A and C represent natural vegetation cover, B and D represent bare ground conditions (based on Marshall 1973).

As shown in Figure 4 by Marshall 1973 there is an interlinkage between precipitation and the risk of wind or water erosion. Based on this relationship a combination of the two risk models (rain water & wind erosion model) can be calculated. In mountainous regions with higher precipitation rates the risk of the water erosion model will have high importance while in the semi-desert in the low lands wind erosion will have more significant impact.

Step 4: Ground verification

Based on the first draft results of the model, a stratified sampling design should be developed to select a representative set of samples for ground verification. The ground verification should get data from the field to validate and calibrate the data obtained from GIS-data sources. Site factors like altitude, aspect and slope should documented, the exact coordinates of the sample as well as soil type, soil structure, geology and the current degree of erosion. Information on the current vegetation cover (percentage of vegetation cover, vegetation height or number of herbs, grass, shrub and tree species) should be assessed.

Step 5: Calibration of the model and preparation of maps and reports

After the collection of field data, the developed models on erosion risk can be calibrated. Assumptions and classification tables used for the risk assessment will be updated by the experiences made in the field. The more field data available, the more accurate the models can be.

After integration of the field evaluation data in autumn, the final maps (Land cover, erosion risk) and reports are ready to be delivered.

2.2.4 Results

The expected outputs are erosion risk and land cover maps such as

  - Maps containing vegetation information ("Land cover") based on the satellite images
  - Maps for water and wind erosion
  - Combined erosion risk map (scale is 1:25:000)
  - Maps will be delivered as printable PDF versions. GIS-Datasets will be delivered as Esri-Shapefiles and/or TIFF-Raster-datasets (georeferenced)

- *Submission of a report with the following information:*
  - Documentation and description of classification and methodological procedures for further use and replication (Technical part).

Maps will serve as a tool for awareness raising and for explaining and exploring benefits and uses of the tool for national stakeholders. They will help the regional administration to identify sensitive erosion hot-spots. They form base information for sustainable natural resource management planning.

2.2.5 Required resources

Required resources are the same as for concept 1 (erosion maps), but additional information on wind erosion is needed. Rationalised maps on wind directions and intensity of wind as well as on seasonal patterns need to be obtained from meteorological stations.

2.3 Concept 3: Assessment of landslide risks

2.3.1 Problem setting

The structure of the landscape, climate and infrastructure makes Azerbaijan Republic vulnerable to number of natural disasters like earthquakes, seasonal floods and landslides. Every year floods and landslides particularly cause significant damage to agriculture in rural areas and to infrastructure in urban areas as well as serious human casualties. Occurrences of landslides during heavy rains cause significant damage to human settlements, industry, farms and roads. Large landslides and instable soil layers are for instance visible in the district of Ismayilli.

Particularly landslides have great relevance for spatial planning in rural mountainous areas. Knowledge about landslide dynamics is crucial for

- planning of roads and settlements
- identification of potential hazard zones
- for planning and prioritizing erosion mitigation measures

2.3.2 Main objective

Having maps with current landslides and instable soil layers available to support the development of strategies to

- map erosion and landslide risks
- integrate landslide risk areas into spatial and infrastructure planning
- develop and prioritize erosion control measures
- model high risk zones for infrastructure and settlement planning

2.3.3 Technical approach

Remote sensing approaches are mainly based on relief information and can detect areas which are already in a movement. However, remote sensing cannot give detailed information on stability of terrain for construction like houses or roads (but can deliver a first risk assessment for spatial planning).

Characteristics of landslides

The figure below shows the typical topographic characteristics of slides and other forms of erosion. Obviously, different types of erosion show typical features which allow for identification (either in the field, via GIS-analysis or interpretation of aerial/satellite images).

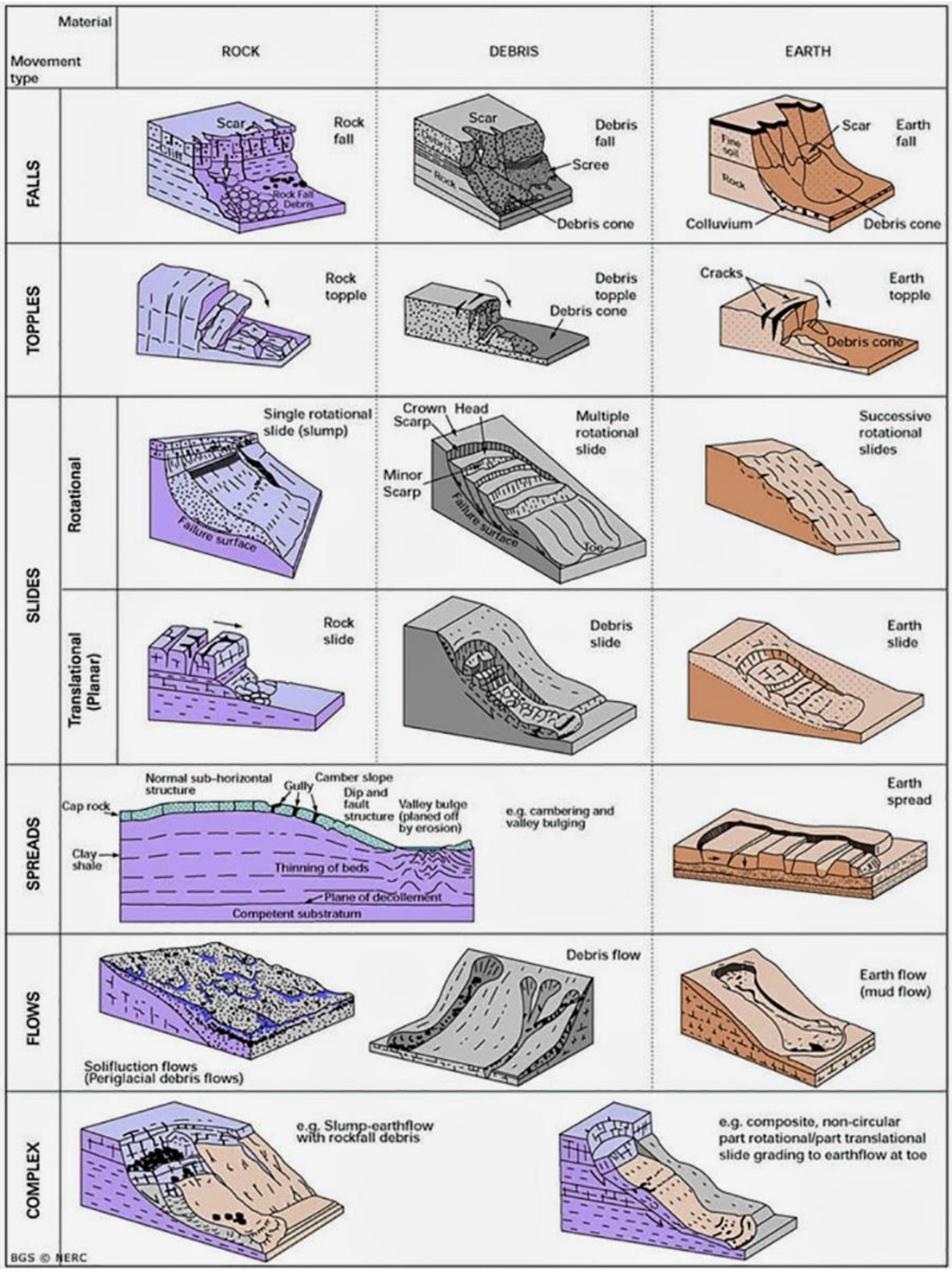

Figure 5: Different types of erosion and slides (www.lampre-project.eu)

There are numerous triggering factors for slope movements such as (Malet & Maquaire based on Van Asch et al. 2007):

Increase in shear stress

- Erosion and excavation at the toe of the slope
- Subterranean erosion (piping)
- Surcharging and loading at the crest (by deposition or sedimentation
- Rapid drawdown (man-made reservoir, flood high tide, breaching of natural dams)
- Earthquake
- Volcanic eruption
- Modification of slope geometry
- Fall of material (rock and debris)

Decrease in shearing resistance

- Water infiltration (rainfall, snowmelt, irrigation, leakage of drainage systems)
- Weathering (freeze and thaw weathering, shrink and swell weathering of expansive soils)
- Physico-chemical changes
- Fatigue due to static/cyclic loading and creep
- Vegetation removal(by erosion, forest fire, drought or deforestation)
- Thawing of frozen soils

Possible increase in shear stress and decrease in shearing resistance

- Earthquake shaking
- Artificial vibration (including traffic, pile driving, heavy machinery)
- Mining and quarrying (open pits, underground galleries)
- Swinging of trees

Recognition of landslides

Remote sensing for landslide investigation is applied for three main groups of activities (Scaioni et al. 2014):

- landslide recognition, classification and post-event analysis
- landslide monitoring (monitoring the activity of existing landslides)
- landslide susceptibility and hazard assessment

An important step is thus the preparation of a landslide inventory with the following underlying assumptions (Scaioni et al. 2014):

- landslide events leave visible marks on the territory. Thus, visual image interpretation of (stereoscopic) photographs, satellite images may help the recognition process
- Visually observed variations in terms of image intensity, pattern, texture, shape needs to be related to the expected ground conditions and landforms indicating possible slope instabilities and typical landslide morphology.
- *"The past and present are keys to the future"* – Landslide inventory maps are often used as background for further analysis, landslide susceptibility analysis or hazard zonation as failures observed under specific conditions in the past, are likely to occur in future in the same areas or under similar conditions.

Conventional landslide inventories are based on both visual interpretation of aerial photos and analysis of field surveys. Furthermore, in recent years automated landslide recognition made considerable progress in basically 3 directions:

- High resolution digital elevation models (HR-DEM)
- Automation of feature extraction and analysis of images including panchromatic, multispectral, hyperspectral and synthetic aperture radar (SAR) data and
- Integration of different kinds of RS data.

Alizade et al. (2016) emphasized the impact of vegetation cover on the dynamics of landslides and the risk level.

Vozenilek (2000) used a basic data input of previous landslides, geomorphological data and basic topographic information for modelling, mainly focusing on the following parameters:

Table 2: Coding of categorical data for modelling

Factors	Codes	Values
Slope angle	1	0 – 2°
	2	2 – 15°
	3	15° and more
Lithology	1	fluvial sediments
	2	Neogene sands, flysh sandstones, claystones and conglomerates
	3	loess and clay
Aspect	1	South-east – S, SE, E, NE and plains
	2	North-west – N, NW, W, SW

$$P\ (landslide) = f\ (slope\ angle,\ lithology,\ aspect),$$

Figure 6: Classification of landslide modelling according to Vozenilek (2000)

Feizizadeh et al. (s.a.) used the following parameters for landslide analysis:

Table 2. Pairwise comparison matrix for landslide analysis

Factors	1	2	3	4	5	6	7	8	Eigen Values
(1) Distance to stream	1								0.045
(2) Distance to road	1	1							0.036
(3) Aspect	1/3	1/3	1						0.020
(4) Slope	6	5	7	1					0.122
(5) lithology	8	7	9	4	1				0.300
(6) Distance to fault	1/2	3	5	1/3	1/4	1			0.063
(7) Precipitation	7	6	8	3	1/2	4	4		0.207
(8) Land use	7	6	8	3	1/2	4	4	1	0.207
Consistency ratio: 0.064									

Figure 7: Factors used for landslide analysis according to Feizizadeh et al.

Hadi (s.a.) used a more complex approach to prepare a landslide hazard map:

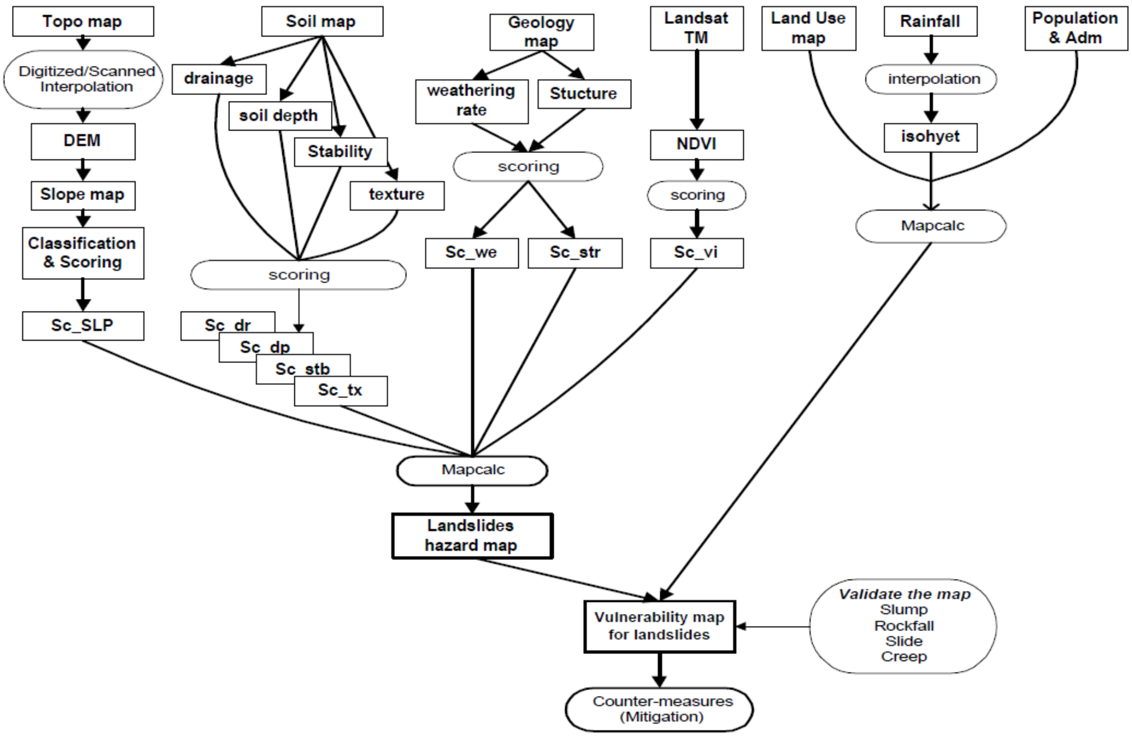

Figure 8: Flow diagram of the landslide hazard modelling according to Hadi (s.a.)

Hadi used the following classifications:

Table 1. Class and Score for Slope map

Criteria		Class	Score
Description	Steepness (°)		
Flat	0 -- ≤8 °	Very good	1
Flat to modetare	8 - ≤15 °	Good	2
Moderate	15 - ≤25 °	Fair	3
Steep	25 - ≤45 °	Bad	4
Very steep	>45 °	Very bad	5

Van Zuidam and Cancelado (1985)

Table 2. Scoring for NDVI

No.	cover density	NDVI	Score
1	Dense	> 0.4	1
2	Fairly dense	0.2 - 0.4	2
3	Bare land & water	(-0.2) - 0.2	3
4	unclassified	< -0.2	3

(Hadi, 2003)

Table 3. Scoring for soil texture

No.	Class	Score
1	Loam	1
2	Loamy clay, Loamy silt	2
3	Loamy sand	3
4	Heavy clay	4
5	Sandy clay	5

ILACO (1981), Fletcher & Gibb (1990)

Table 4. Scoring for depth of soil

No.	Class	soil depth (cm)	Score
1	Very shallow	0 – 30	1
2	Shallow	30 – 60	2
3	Moderate	60 – 90	3
4	Deep	90 – 150	4
5	Very deep	> 150	5

FAO Guidelines for Soils Profile Description (1968, in Worosuprojo & Jamulya , 1991)

Table 7. Scoring for rock structure

No.	The inclination of rock structure (°)	*Class*	Score
1	Horizontal, flat (0–3°)	very good	1
2	vertical, sloping on flat-undulating landform (>3-8°)	good	2
3	Non structural on steep slope (>20°), sloping on undulating landform (>8-14°)	fair	3
4	Sloping on undulating landform (>8-20°)	fair-bad	4
5	Sloping on heavy rock on undulating landform (>20°)	very bad	5

Misdiyanto (1992, modification by PSBA UGM 2001)

Table 6. Score for soil-rock weathering

No.	Degree of weathering	Description	Score
1	Slightly weathered	Bedrock have slightly changed in color	1
2	Moderate	Bedrock have slightly changed in color & some of the portion have weathered to be soil	2
3	Moderate-high	Bedrock have changed in color & more than half of the portion have weathered to be soil	3
4	High	all portion of rock have been decomposite, mostly weathered, but some of original rock still there	4
5	very High, completely weathered	All the rock have been completely decomposite, and weathered to be soil	5

Fletcher and Gibb (1990)

Table 9. Scoring for Land Use

No.	Land use	Score
	Water bodies (lake, river)	1
1	Forest	2
2	Mixed garden	3
3	Dry land agricultural	4
4	Paddy field	4
5	Settlement	6

(Worosuprodjo *et al*.., 1992; modification)

Group	Data layer and types	Relevance for landslide susceptibility and hazard assessment
Digital Elevation Data	Slope gradient	Most important factor in gravitational movements
	Slope direction	Might reflect differences in soil moisture and vegetation
	Slope length, shape, curvature	Indicators for slope hydrology
	Elevation	Important in relation to rainfall and exposure.
	Flow accumulation	Used in slope hydrological modeling
	Distance to ridges	In small scale assessment as indicator for type of terrain.
	Exposure	Windward & Leeward side of the island, is important in relation to rainfall
Geology & Geomor-phology	Rock types	Lithological information
	Weathering	Depth of profile is an important factor
	Structural geology	Geological structure in relation with slope angle/direction
	Faults	Distance from active faults or width of fault zones
	Geomorphology	Genetic classification of main landform building processes
Soils	Soil types	Engineering soils with genetic or geotechnical properties
	Soil depth	Soil depth based on boreholes, geophysics and outcrops
	Geotechnical prop.	Grainsize, cohesion, friction angle, bulk density
	Hydrological prop.	Pore volume, saturated conductivity, PF curve
	Stream network	Buffer zones around streams
Landuse	Land use map	Type of land use/ land cover
	Land use changes	Temporal varying land use/ land cover
	Roads	Buffers around roads in sloping areas with road cuts
	Buildings	Slope cuts made for building construction

Figure 9: Relevant parameters to determine landslide risk based on the Carribbean Handbook on Risk Information Management, http://www.charim.net/datamanagement/23 (2016).

Proposed technical approach

As a full terrestrial mapping and soil and geological analysis is required for predicting complex natural processes such as landslides, the identification of existing landslide areas is considered a feasible and important first step for a national landslide inventory and a major basis for regional spatial planning.

Thus, a combination of visual identification, collection of historic information and field verification is proposed to build an initial landslide inventory, which supports regional spatial planning processes and supports long term infrastructure planning. Specific focus should be given to the parameters mentioned above and particularly focus on slope gradient, direction, elevation, vegetation cover/land-use and whenever available soil and geological information.

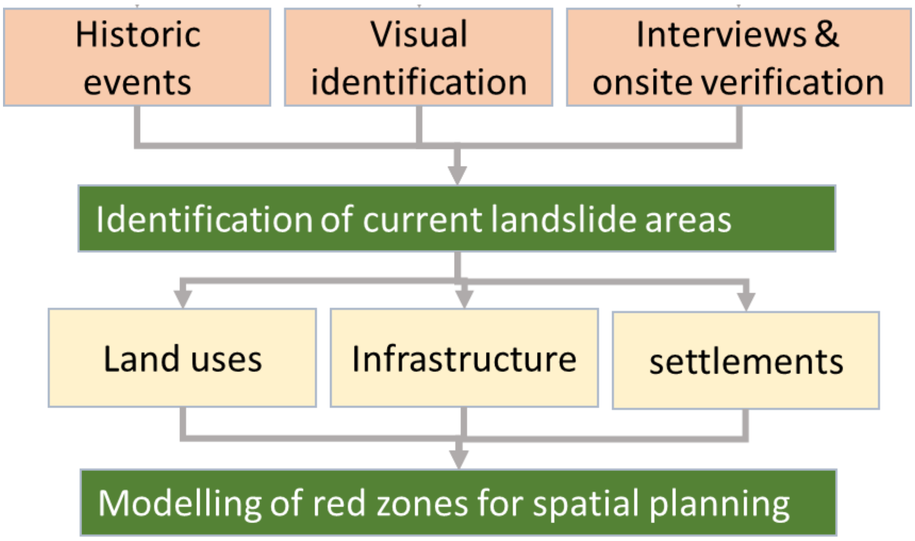

Figure 10: Technical approach for establishing a landslide inventory as a basis for natural hazard planning (Authors draft)

This comprises the following worksteps:

- Data collection and screening: Collect historic information, conduct interviews to identify existing landslide areas, furthermore collect spatial information on topography, geology, soils, hydrological information etc.
- Bring all data into a GIS-Sytem and identify common features of landslides
- Use the parameters to identify additional landslide areas and verify in the field
- Complete landslide inventory
- Model hazard zones by combining spatial information on settlements and infrastructures with existing landslide areas as a basis for spatial planning and decision making.

2.3.4 Results

The assessment should deliver a digital map in the scale of 1:25.000 of existing and historic landslide areas. To test the proposed technical approach and to build local capacity to carry out this type of assessment, it is recommended to start in one district. Within the first year this comprises the collection of data from historic events, the visual identification on existing aerial / satellite images and interviews and on-site visits for verification.

The results will be used for displaying all recognizable and existing landslide areas and further on modelling of high risk zones for spatial and infrastructure planning (low/no risk – medium – high risk). By an in-depth analysis of the topographic characteristics of the existing sites, a model for identification of further risk areas could be developed. The minimum size of eroded land pattern that can be displayed in the map would be around 20x20 meter. In further steps, the methodology can be upscaled to other districts (from year 2/3 onwards).

The map is supposed to help to identify areas where landslides are frequently occurring or occurred in the past to develop strategies for mitigation measures and for optimal infrastructure planning.

The proposed approach is a rather low-tech approach, which can be easily replicated. However, it has to be emphasized that landslides strongly depend on edaphic and geological conditions. Thus, this methodology does not replace a sound technical planning foundation for instance for road construction neither does it allow for a comprehensive prediction of landslides outside the indicated areas (e.g. where no landslide has been occurred so far). Nonetheless, it provides important information about existing risks in certain areas and can be a very relevant information for local or regional decision-making processes.

Knowledge on the current distribution of landslides is a valuable information for the development of erosion risk models and all future natural hazard risk planning. On the long run, the maps developed can be frequently updated (e.g. new landslides) and become an inventory of existing landslides. Based on the location of erodes sites, correlation with other site factors like inclination, soil type, geology and climate can be calculated.

2.3.5 Required resources

Similar datasets as used for the RUSLE model are required.

Additionally, field work is an integral part of the verification process (visual identification, interviews, historic events). Accompanying capacity building and training activities are required for visual identification of landslides (on aerial images as well as on site).

GIS-specialists and specific software are needed. They might be found in academic research institutions (University, Academy of Science) or in private companies/NGO's (R.I.S.K., INTEGRIS etc.).

Involvement of Universities seems meaningful to integrate knowledge and experience into education and training of students.

The Institute of Soil Science and Agro-chemistry at the Academy of Science in Baku might be a be a very valuable partner for this task as well as the Central Asia and Caucasus Disaster Risk Management Initiative (CAC DRMI) could provide relevant data and expertise.

2.4 Concept 4: Assessment of max livestock units.

Based on land cover maps and calibrated biomass estimation from remote sensing the carrying capacities of pastures can be calculated. Given the immense increase of sheep and cattle in the last two decades, the information on maximum carrying capacities would be an important base information for regulations, spatial planning or incentive base change of land use.

2.4.1 Problem setting

In mountainous regions (summer pastures) as well as in semi desert areas (winter pastures) grazing is an important economic factor. Livestock breading and milk production is an important contribution to food security in Azerbaijan. The output of livestock breeding in regards of meet and milk production is directly linked to the amount and quality of fodder. The main amount of fodder is produced by vegetation growth on pastures and hay meadows and can be calculated by biomass productivity per hectare and year.

In the case of overgrazing, the productivity can be temporarily (vegetation damage) or permanently (soil damage) decreased. To avoid overgrazing and permanent damages in fodder productivity (and loss in meat and milk productivity), the livestock numbers must not exceed the carrying capacity of grazing areas.

2.4.2 Main objective

The assessment of existing biomass and estimation of biomass productivity of different landscapes will enable to calculate the maximum number of livestock that can be sustainable fed by the ecosystem (without making harm to the ecosystem and reducing productivity on long term).

2.4.3 Technical approach

Based on the vegetation cover classification described in the concepts for erosion and erosion risk mapping different pasture types are classified by remote sensing.

The differentiation between pastures and hay meadows is not major importance, as both areas contribution to fodder production of livestock. Agricultural land can be classified by multitemporal assessment. Shrub land and forest should be clearly separated from other land cover types by the spectral characteristics.

Biomass samples (harvesting of $1m^2$ of above ground biomass) will be taken from different pasture types and altitudes to calibrate the remote sensing data to absolute biomass values (given in dry weight of biomass per hectare). Beside the coordinates of the biomass samples a visual assessment of livestock browsing and hay cutting has to be done in the field to classify biomass extraction.

A regression model based on the existing biomass assessment of field plots, the Leaf Area Index calculated from satellite images and climate information as well as altitude will be developed to calculate fodder biomass productivity of different pastures and hay meadows.

In the GIZ pilot study in Tusheti (Georgia) (M#) several vegetation indices have been calculated from the Sentinel-2 Satellite data (NDVI (Normalized Difference Vegetation Index), Red Edge NDVI (rNDVI), LAI (Leaf Area Index) and leaf chlorophyll content (LAI_cab), FAPAR (Fraction of Absorbed Photosynthetically Active Radiation). The comparison with the biomass samples from the field showed, that the leaf chlorophyll content (LAI_cab) had the best explanation rate of the biomass variability. As further field works are planned in 2017 in Tusheti, additional calibration data and calculation algorithms is expected that might provide relevant information to the model development in Azerbaijan.

For proper calibration of the biomass productivity model approximately 50 field samples for each pasture type are needed (Lillesand & Kiefer 1994) which lead to a total number of 200-250 samples for a pilot district.

2.4.4 Results

Based on the remote sensing data and calibration with field data

- The assessment is addressed on pasture land and will give for each municipality:
- Classification of pasture types based on productivity (deci-tons of dry biomass per hectare)
- The number of hectares of per pasture type
- Maximum number of livestock units that can be sustainable grazed on this area within the municipality

The results can be provided by digital biomass maps for a district or municipality showing the spatial distribution of biomass on pastures and as tables showing the hectares of different pasture types, the total fodder biomass production and the maximum sustainable livestock numbers per municipality.

2.4.5 Required resources

Satellite images and digital elevation models as well as climate data as described in concept 2 (erosion risk and vegetation cover).

Human resources as descried there as well.

2.5 Concept 5: Changing erosion risks from a climate change perspective

2.5.1 Problem setting

Climate change is likely to have considerable impacts on the erosion risks in Azerbaijan requiring future adaptations in spatial planning, land use and use of natural resources. Impacts on the hydrological systems such as increased water-run-off in spring and earlier spring peak discharge in snow-fed rivers, earlier greening of vegetation in spring and longer thermal growing seasons have already been observed (IPCC WGII Fourth Assessment). Even though regional climate prediction models are available, no data in higher resolution is available.

Temperature data from Azerbaijan's National Hydrometeorology Department of MENR for 10-year period 1991-2000 indicate a rise of temperature by 0.41 C or three times higher than that of the 30-year period 1961-1990. With regards to the South Caucasus, the highest rise will be observed in the middle and higher mountainous zones of the Great Caucasus. Models indicate that rainfall in 2021-2050 will increase by 10-20% compared to the period 1961-1990. Even though this might be beneficial for pastures, their area will most likely diminish due to soil erosion, changing land uses and increased evaporative demands due to higher temperatures.

A concrete methodology for modelling these changes is beneficial for the Azeri authorities to have a proper foundation for future (spatial) planning of land-uses and for the prioritization of anti-erosion measures and climate change mitigation measures.

2.5.2 Main objective

- Elaboration of a methodology for mapping changing erosion risks with regards to climate change based on biotic and abiotic factors (vegetation change, temperature, precipitation) for long-term strategic and spatial planning.

Having high resolution maps modelling changes in land-cover and vegetation zones due to current climate change models to support the development of strategies to

- map probable changes in vegetation types based on temperature and precipitation changes
- integrate ecosystem changes into land-use planning
- develop and prioritize erosion control and climate change mitigation measures

Climate change is likely to shape and change land-uses in Azerbaijan in future. Knowledge about potential changes is crucial for

- Identification of future pastures for land-use planning
- Identification of areas with a high desertification potential

- Understanding forthcoming changes in the landscapes and the land-use potential at district level

2.5.3 Technical approach

Climate modelling is amongst the most challenging tasks from technical point of view. Regional climate models are available. Particularly, WWF was working a lot on this topic providing a good basis at Caucasus regional level.

To approach the task, we propose to model the shift of potential natural vegetation due to changing precipitation and temperature predictions. Taking the parameters of regional climate change models would allow to model the shift in the potential natural vegetation types.

Furthermore, several changes are likely to occur but go beyond the RUSLE model. This includes changes in time of snow cover, changes in permafrost layers, changes of the hydrological regime and changes of spatial patterns of temperature and precipitation.

The main changes that are likely to directly influence the degree of erosion are as follows:

- Changes in R (Precipitation)
- Changes in C (Vegetation cover, land-use types)

Particularly, vegetation cover is furthermore strongly determined by temperature and precipitation. Given the fact that vegetation cover is an essential factor for protection against soil erosion, particular attention will be paid to this factor.

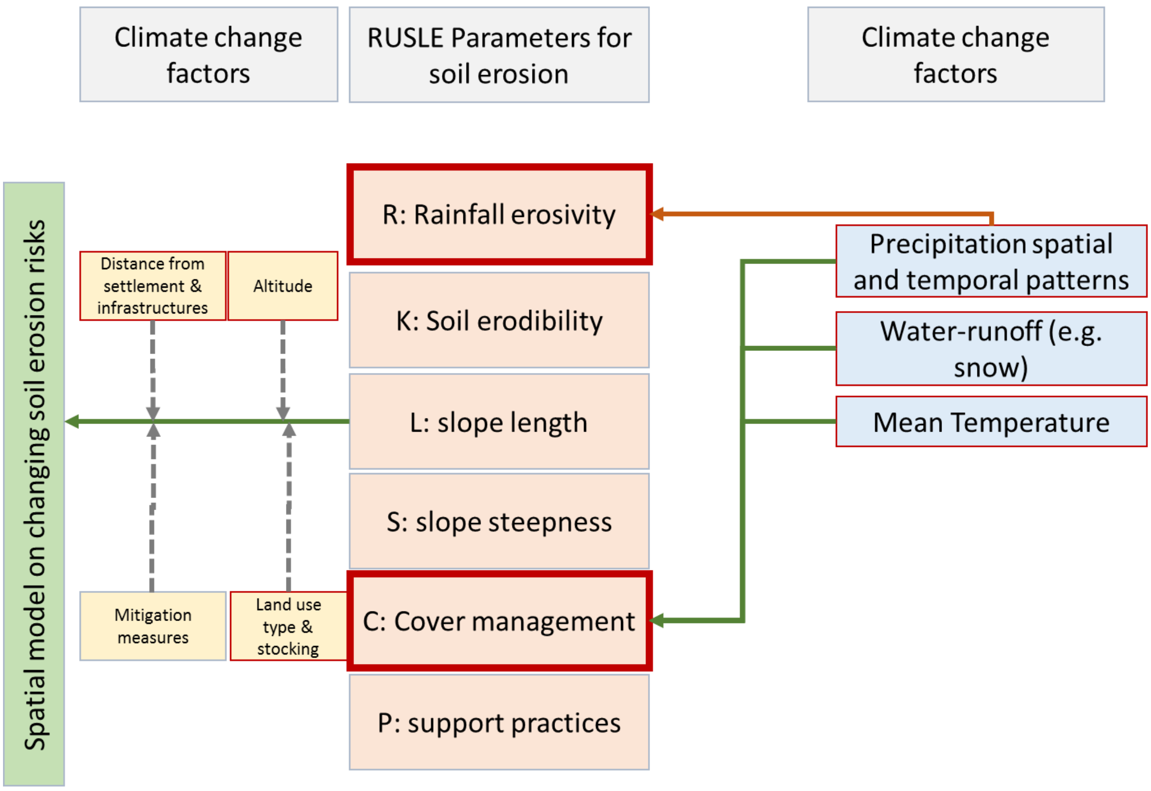

Figure 11: Technical approach to integrate climate change scenarios into erosion risk modelling (Authors' draft)

A good indicator to model these changes could be the changes of the potential natural vegetation as modelled by Bohn et al. (2004). They draw a map of the natural vegetation of Europe covering the three South Caucasus countries as well. Considering changing precipitation and temperature conditions, changes will become visible and influence erosion risk (e.g. different vegetation types, share of open soil, risk of overgrazing due to more adverse pasture conditions). This is also a critical issue for predicting desertification processes (and is thus linked to the United Nations Convention to Combat Desertification (UNCCD)).

To meet this complex topic, the follow approach is proposed:

- Data collection: Collect climate relevant data, spatial data on vegetation cover, vegetation types and land-uses
- Data processing: Homogenize datasets
- Modelling of changes from the status quo based on the RUSLE model, temperature and precipitation predictions and the vegetation map of Bohn et al.
- Elaborate maps illustrating the likely shifts of vegetation cover and erosion risk
- Preparation of guideline/manual for processing data
- Institutional integration (identification of relevant institutions and capacity building)

2.5.4 Results

The assessment should deliver two digital maps in the scale of 1:25.000 indicating the present situation and a future scenario. We would recommend to elaborate the map for one district in a first phase (first year) and scale up to national level in a second phase (year 2 & 3). Once the methodology is defined, the GIS analysis can be easily accomplished for other areas.

The resulting maps will give the spatial dimension of changing vegetation covers and types and derived information on changes on erosion risk (based on the RUSLE model). The map can help to identify areas which will have an increased risk for erosion due to climate change as well as areas which will potentially require land-use changes in future. Thus, these maps provide supporting information for long-term land-use planning and the development and prioritization for erosion control and climate change mitigation measures (e.g. planting of counter erosion hedges against wind erosion, vegetation cover supporting projects or land-use changes).

It is of uppermost importance to recognize local at an early stage. This is particularly relevant for land-use: If climatic conditions change, this is likely to have direct impact on the carrying capacity of individual pastures, for instance. If planned on the long term, self-rehabilitation processes of the vegetation can be used by adapting land use to an adequate intensity and productivity of the land can be protected. Once overgrazed and the soil layer is lost, the process of re-establishing a productive land for grazing, agricultural or forestry use, is very long lasting and cost extensive.

The integration of climate change parameters into erosion risk models will support the stakeholders in strategic long-term planning processes and the development of local land-use strategies. This information will help to improve erosion risk models and to adapt land use before damage to vegetation and soil occurs.

2.5.5 Required resources

GIS-specialists and specific software are needed. They might be found in academic research institutions (University, Academy of Science) or in private companies/NGO's (R.I.S.K., INTEGRIS etc.). Cooperation with institutions involved in climate change such as WWF could be beneficial.

The modelling of vegetation type changes should be supervised by an international expert and involve discussions with vegetation ecologists and climate change specialists. Thus, the involvement of Universities seems meaningful to integrate knowledge and experience into education and training of students.

Required data

- Regional climate change forecasts (precipitation, temperature)
- All RUSLE parameters
- Bohn 2004: potential natural vegetation of Europe
- Landcover data (CORINE or similar)
- CHELSA climate data (www.chelsa-climate.org)
-

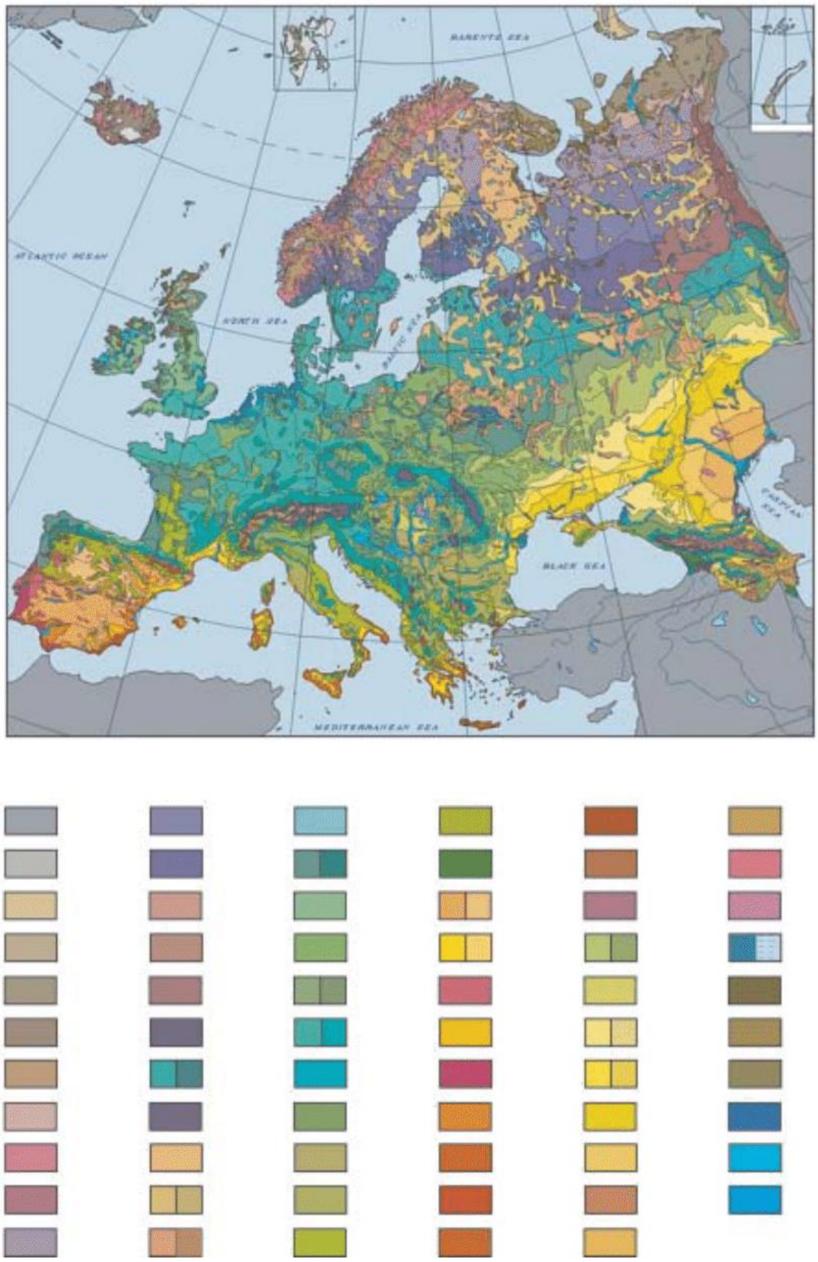

Figure 12: Map of potential natural vegetation of Bohn et al. (2004).

3. Interdependencies and synergies between concepts

Although the 5 concepts are described separately, there are a lot of synergies and interdependencies in the input data and human resources needed.

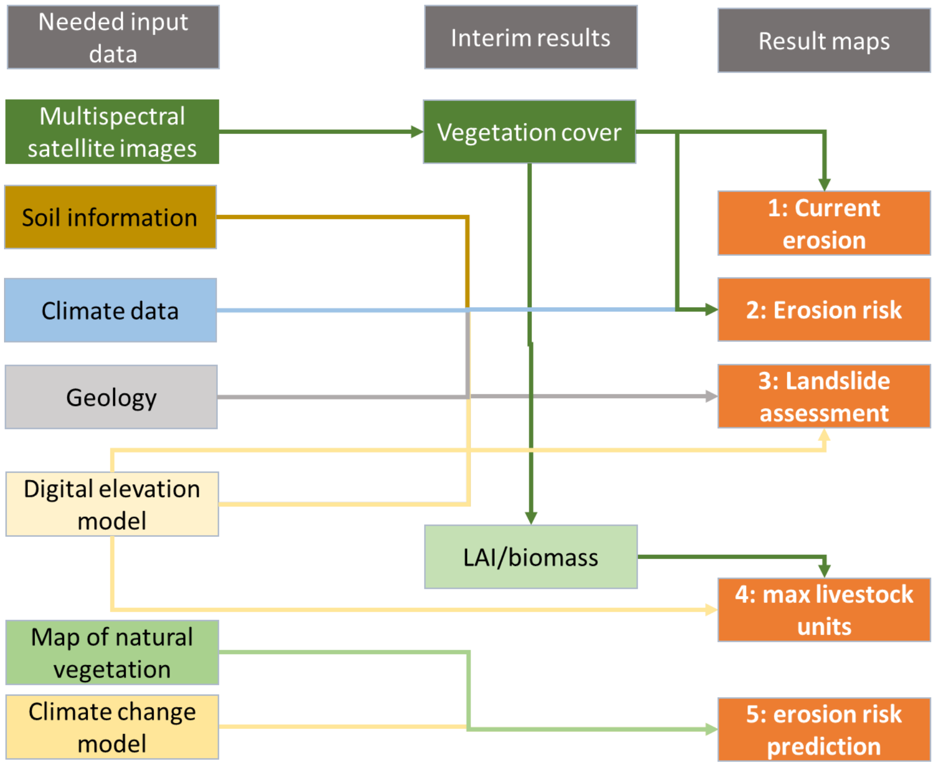

Figure 13: Relationship between input data, interim results and final output maps. (Author's draft)

It is recommended to develop and test the models in the Ismayilli District in 2017 and then upscale to the national level.

Within the pilot phase institutional and human capacities can be built up. First results on variability of the models will help to estimate the number of field plots required for validation and calibration.

Based on the results in the pilot area, discussions about the strategic integration of such data at national level could be discussed with national partners at ministerial and District administration level.

The pilot phase for one district is supposed to last for 1 year. Upscaling to the national level will take another 2 years. The most time-consuming part for upscaling is the field validation for calibration of different ecosystems other regions of Azerbaijan.

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5. Annex

5.1 Examples from Georgian Pilot Study

Within the GIZ-IBiS program a pilot project on remote sensing of erosion risk and land cover assessment was implemented in 2016 in the Gometsari Gorge (Tusheti Protected Areas in the high Caucasus, Georgia). The pilot area is at an altitude range from 1600 to 3300m in subalpine and alpine elevation belt. The main human land use in the area is livestock grazing. The purpose of erosion risk and vegetation cover analysis is to provide data for the spatial planning procedure and for natural resource management.

The objective was to deliver three main results:

1. A map showing erosion risk
2. A map showing different vegetation cover
3. A map showing phyto-biomass (amount of fodder)

5.1.1 Erosion risk map

The erosion risk map was calculated on the approach of the revised Universal Soil Loss Equation. This concept works for erosion driven by rainfall and surface water run off. Erodibility of soil, vegetation cover and shape of the landscape (relief) are the main factors beside the amount of precipitation (see Figure 14).

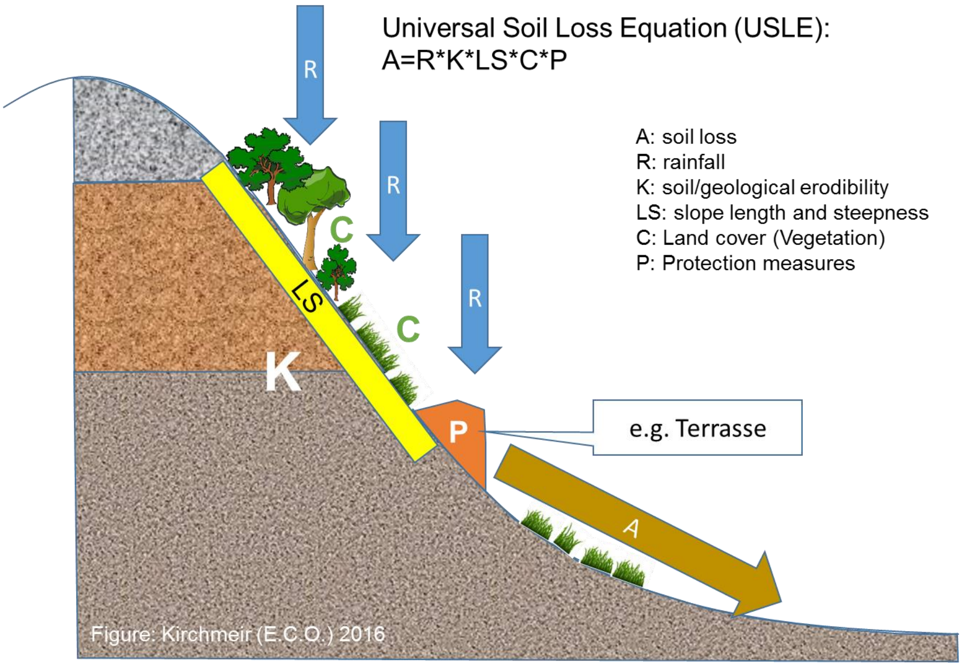

Figure 14: Schematic description of the factors of the Universal Soil Loss Equation.

In Tusheti the precipitation (P-factor) data was used from "CHELSA – Climatologies at high resolution for the earth's land surface areas" data platform. This data is derived from downscaling of the ERA interim global circulation model and is freely available at the Chelsea-climate.org. The spatial resolution is 30 arc seconds (ca. 1 km) and data covering a time scale from 1979 to 2013. The data sets include monthly mean temperature and mean precipitation.

The information on soil (K-factor) came from a soil map in the scale of 1:200 000, classifying the Tusheti area into 10 main soil types.

Relief information (LS-factor) is derived from a digital elevation model, which was generated from the topographic map (Russian topo map) in the scale of 1:50 000.

The vegetation cover (C-Factor) was created from Sentinel-2 satellite images from August 2016. For classification, the reNDVI (Red Edge Normalised Difference Vegetation Index) was calculated from ration of Red Edge and Red spectral information provided by the Sentinel sensors (B4 (10m) & B5-B7(20m)).

Support factors (P-factor) like man made erosion control measures (drainage, terraces) have not been included in the calculation in Tusheti.

Result map is a raster map with 10x10m resolution.

5.1.2 Vegetation cover

The vegetation map was also based on the classification of Sentinel-2 satellite data. The Jeffries-Matusita, Transformed Divergence algorithm was used for classification (after atmospheric correction of data). Based on the date 12 different classes have been distinguished:

- Villages/Farms
- Clouds
- Shadows/No data
- Permanent Snow
- Water
- Bare Soil
-
- Grassland - very poor biomass
- Grassland - poor Biomass
- Grassland - average Biomass
- Grassland - high biomass
- Shrub land
- Deciduous forest
- Coniferous forest

Result map is a raster map with 10x10m resolution.

5.1.3 Biomass map

Biomass was classified by the same Sentinel-2 data. It was shown, that the Leaf Chlorophyll Content (LAI_cab) calculated from the image had the best correlation with the biomass data from field samples. The field data was used, to calibrate the different LAI_cab values to dry biomass values available for grazing or hay making. The biomass was only calculated for grasslands (forests, shrub lands and water bodies were taken out of this calculation).

5.1.4 Result maps

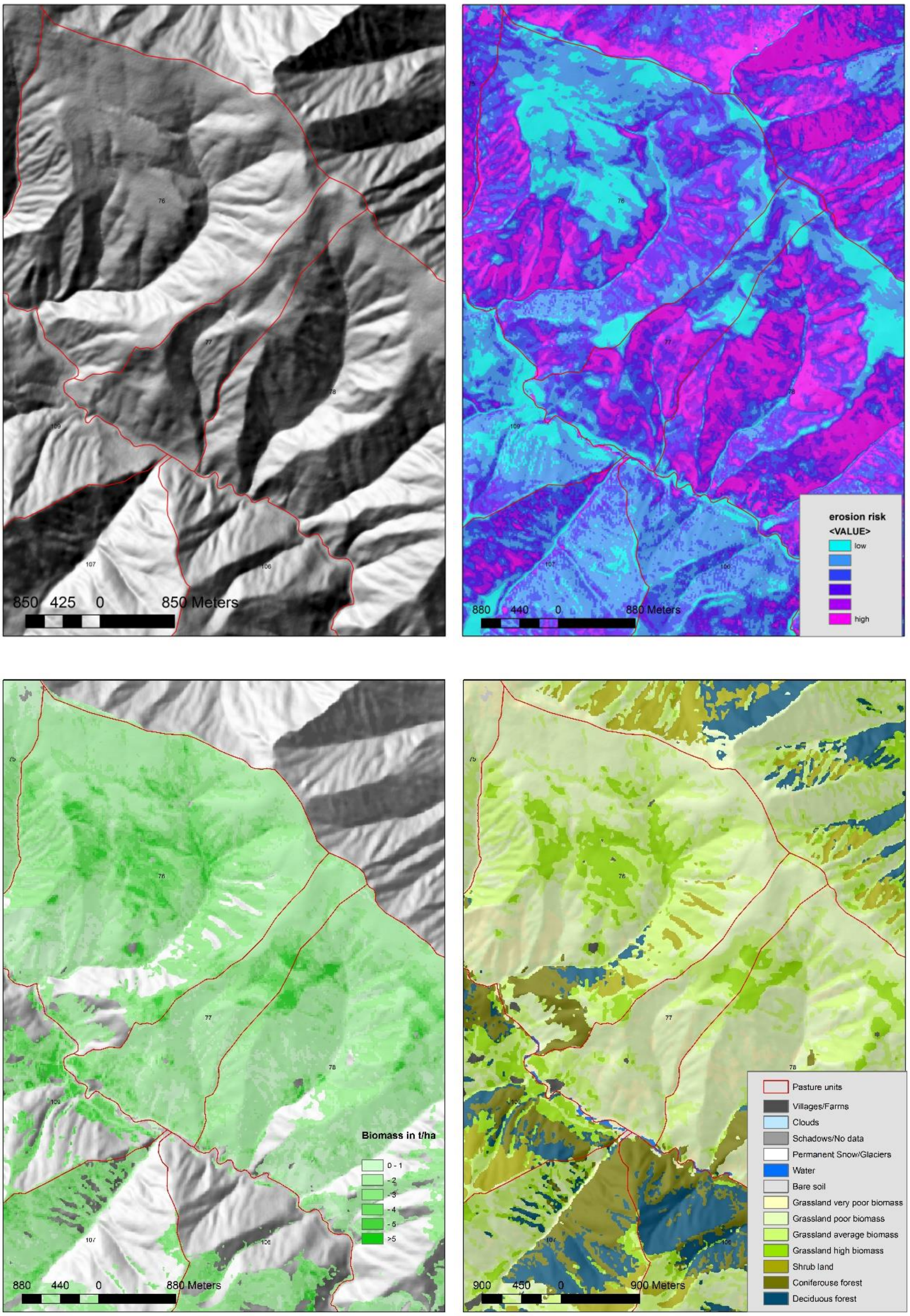

Figure 15: Upper left: relief, upper right: erosion risk, lower left: biomass, lower right: land cover; red outlines indication the boarders of pasture lease units

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