Heavy grazing and trampling can lead to heavy degradation of pastureland. Shenako, Akhmeta Municipality. (Hanns Kirchmeir)

Remote Sensing as a Tool for Land Degradation Neutrality Monitoring (Georgia)

DESCRIPTION

Land degradation contributes to biodiversity loss and the impoverishment of rural livelihoods in Tusheti. Above all, however, land degradation are triggered by climate change as traditional land use practise might not be adapted to new climate conditions which can cause or speed up degradation processes significantly. On the other hand, degraded land often leads to low biomass volumes and this reduces the ecosystem capability to stabilise local climate conditions. The concept of Land Degradation Neutrality (LDN) and the method of using remote sensing for monitoring land degradation are tools to identify the need for local planning processes. This showcase describes the LDN monitoring concept, national targets and the technology to assess indicators, mechanism and incentives for LDN.

Purpose
The continuing global degradation of land resources threatens food security and the functioning of ecosystem services by reducing or losing their biological or economic productivity. Unsustainable land-use practices such as deforestation, overgrazing and inappropriate agricultural management systems trigger the loss and degradation of valuable land resources in Georgia. These effects are visible in all countries of the South Caucasus. About 35% of the agricultural land in Georgia is severely degraded, 60% is of low to middle production quality.

Land Degradation Neutrality (LDN)
LDN is a new international concept to combat the ongoing degradation of valuable soil resources. The LDN concept was developed by the UNCCD to encourage countries to take measures to avoid, reduce or reverse land degradation, with the vision of achieving a zero-net loss of productive land. To combat land degradation in Georgia, in 2017, the national LDN Working Group set voluntary national targets to address specific aspects of LDN, and submitted them to the UNCCD Secretariat.

To effectively set up counter measures to combat land degradation it is important to have detailed spatial information on land cover and land cover changes as well as on trends in degradation (like size of areas effected by erosion). Therefore a remote sensing toolset was developed and tested in the pilot are of Tusheti protected landscapes in the High Caucasus in Georgia. This region shows increasing soil erosion problems by uneven distribution of grazing activities and was selected for developing erosion control measures within the Integrated Biodiversity Management in the South Caucasus Program (IBiS) funded by the Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ).

Sensitivity Model
The Integrated Biodiversity Management in the South Caucasus (IBiS) project in cooperation with national experts in Georgia, developed and applied a remote sensing toolset called "Erosion Sensitivity Model". This remote sensing toolset helps to assess the current state and the general erosion risk. The sensitivity model is based on the RUSLE – Revised Universal Soil Loss Equation. The tool allows the calculation of erosion caused by rainfall and surface run-off. The RUSLE equation incorporates a combination of different input factors such as precipitation (R), soil type (K), slope (LS), vegetation cover (C) and protection measures (P). In this way, the estimated average soil loss in tonnes per acre per year (A) can be calculated as follows: A = R * K * LS * C * P.

LOCATION

Location: Tusheti region, Akhmeta municipality, Georgia

No. of Technology sites analysed: 2-10 sites

Geo-reference of selected sites
- 45.2009, 42.03922
- 45.63695, 42.3823

Spread of the Technology: evenly spread over an area (1000.0 km²)

In a permanently protected area?: Yes

Date of implementation: 2016

Type of introduction
- ☐ through land users' innovation
- ☐ as part of a traditional system (> 50 years)
- ☐ during experiments/ research
- ✓ through projects/ external interventions

The rainfall factor (R) results from a quotient from the monthly and annual mean value of precipitation. The data come from the data platform "CHELSA – Climatologies at high resolution for the earth's land surface areas". For the soil type factor (K), a soil map of 1:200,000 was taken. Then, depending on the soil type, different contents of sand, silt, loam and clay were used to calculate the K factor. The slope length and steepness factor (LS) is calculated from a digital elevation model (DEM) with a raster resolution of 10x10m. The DEM is derived from the topographic map 1:25,000. The global elevation model derived from SRTM data (Shuttle Radar Topography Mission) has a resolution of 30x30 m and is available worldwide free of charge. The land cover factor (C) describes the vegetation cover that protects the soil from erosion. The vegetation cover slows down the speed of the raindrops and reduces the erosive effect of the rain. It slows down surface water runoff and stabilises the soil through root systems. The main indicators, land cover and productivity, can be assessed by remote sensing. The data from satellites need to be classified and calibrated by field data (ground truthing). The technology for the assessment of these indicators with Sentinel 2 satellite images was developed and applied in 2016 to 2018 in the Tusheti region (Akhmeta municipality) in the framework of the GIZ-IBiS project. Based on spectral information from airborne or satellite images, the density of the vegetation was calculated and mapped. There are well developed vegetation indices and classification systems to derive different land cover types and vegetation densities (mainly described by the Leaf Area Index LAI or biomass indices). The LAI is the area of the leaf surface (in square meters) per square meter ground surface. Since the real surface area of the leaves is hardly measurable, the amount of biomass is a proxy for the LAI. The P-factor is rarely considered in large-scale modelling of soil erosion risk as it is difficult to estimate it with very high accuracy. Therefore, to refine the model, a more detailed DEM (digital elevation model) is required (e.g., from satellite images). Based on the input factors, a soil erosion risk map was calculated for the whole territory of the Tusheti Protected Areas (113,660 ha). Based on the different spectral bands of the Sentinel 2 satellite image, a land cover map was calculated using the Support Vector Machine (SVM) technology and spectral image information.
The results have been integrated in the development of pasture management plans ("pasture passports"). This maps and documents are indicating areas of high erosion risk that need to be excluded from grazing and the maximum number of livestock has been calculated based on the biomass maps and will be integrated into the lease contracts. The repetition of the remote sensing after some years (e.g. 5 years) will help to evaluate, if the measures in the pasture management have been successful to stop the degradation processes.

Figure 1: Loss of arable land due to riverbed erosion, Alazani River (Hanns Kirchmeir)

Figure 2: Pasture and soil erosion, Garabani municipality. Heavy grazing is reducing the vegetation cover and the top soil is exposed to wind and water erosion. (Hanns Kirchmeir)

CLASSIFICATION OF THE TECHNOLOGY

Main purpose

- ✓ improve production
- ✓ reduce, prevent, restore land degradation
- conserve ecosystem
- protect a watershed/ downstream areas – in combination with other Technologies
- ✓ preserve/ improve biodiversity
- reduce risk of disasters
- adapt to climate change/ extremes and its impacts
- mitigate climate change and its impacts
- create beneficial economic impact
- create beneficial social impact

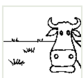
Land use

Land use mixed within the same land unit: Yes - Agro-pastoralism (incl. integrated crop-livestock)

Cropland

- Annual cropping: cereals - barley, root/tuber crops - potatoes

Number of growing seasons per year: 1
Is intercropping practiced? No
Is crop rotation practiced? No



Grazing land

- Transhumant pastoralism

Animal type: cattle - dairy and beef (e.g. zebu), sheep

✓ provide information to make a spatial-territorial planning

Is integrated crop-livestock management practiced? No

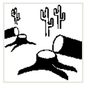
Water supply
- rainfed
- mixed rainfed-irrigated
- full irrigation
- ✓ rainfed and mixed rained-irrigation

Purpose related to land degradation
- ✓ prevent land degradation
- ✓ reduce land degradation
- restore/ rehabilitate severely degraded land
- adapt to land degradation
- not applicable

Degradation addressed

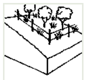

soil erosion by water - Wt: loss of topsoil/ surface erosion, Wg: gully erosion/ gullying


physical soil deterioration - Pc: compaction


biological degradation - Bc: reduction of vegetation cover, Bq: quantity/ biomass decline

SLM group
- pastoralism and grazing land management
- improved ground/ vegetation cover

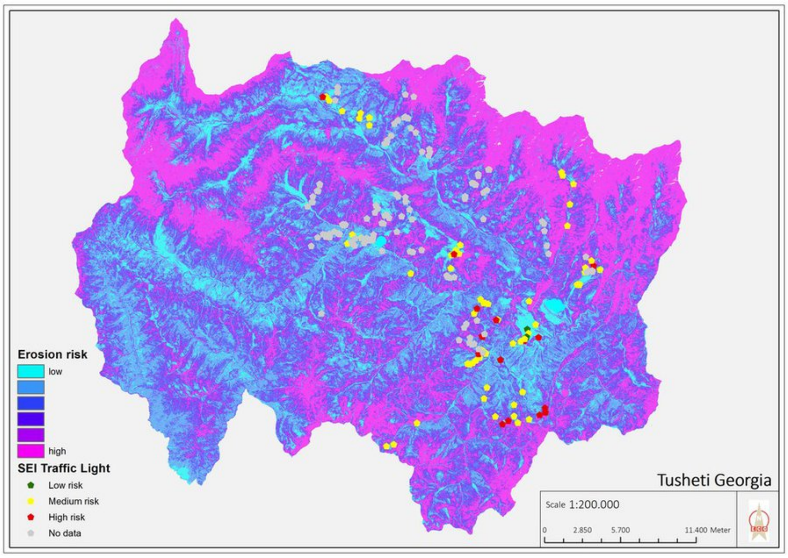
SLM measures


management measures - M2: Change of management/ intensity level

other measures - It is a monitoring technology to evaluate land management activities.

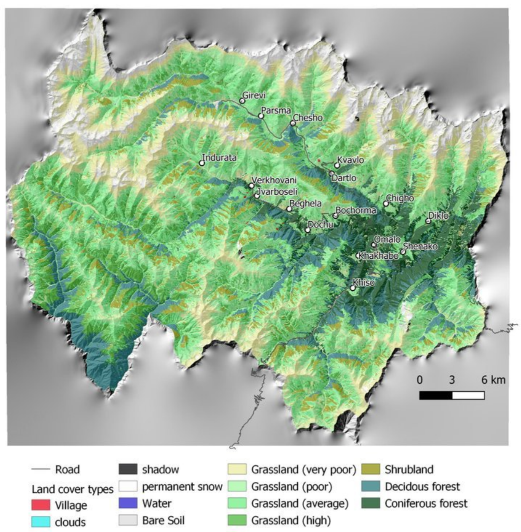
TECHNICAL DRAWING

Technical specifications
Map of erosion hot spots (pink colour) and the location of field sample plots for evaluation and ground truthing.



Author: Hanns Kirchmeir

Map of land cover classification derived from satellite images. The different grassland types are classified by their biomass as an indicator of productivity and current state. Repeating the satellite image classification with the same parameters after 5 or 10 years can give a clear picture of changes in the land cover.



Author: Hanns Kirchmeir

ESTABLISHMENT AND MAINTENANCE: ACTIVITIES, INPUTS AND COSTS

Calculation of inputs and costs

- Costs are calculated: per Technology area (size and area unit: **1000 km2**)
- Currency used for cost calculation: **USD**
- Exchange rate (to USD): 1 USD = n.a
- Average wage cost of hired labour per day: 100

Most important factors affecting the costs

Field sample collection; Remote sensing experts.

Establishment activities

1. National level. Baseline: Field assessment for remote sensing calibration (1x/20 years) (Timing/ frequency: 2017)
2. Sentinel satellite image classification (multi temporal data from 2017) (Timing/ frequency: 2017)
3. Statistical data from GEOSTAT Agricultural census (Timing/ frequency: 2014-2016)
4. Analysis of soil carbon content from existing profiles (Timing/ frequency: 2003 - 2006)
5. Conduct ongoing monitoring (Timing/ frequency: 5 years intervals)
6. Update sentinel satellite image classification (Timing/ frequency: 1x year)
7. Update statistical data from GEOSTAT Agricultural census (Timing/ frequency: 4x/year)
8. Resampling of soil carbon content near existing profiles (Timing/ frequency: 1x/5 years)
9. Municipal level. Spatial planning: Assessment of current stage of land degradation, anticipated gains and losses (Timing/ frequency: 1x/10 years)
10. Revision of spatial planning on Municipal level. (Timing/ frequency: 1x / 5 years)

Establishment inputs and costs (per 1000 km2)

Specify input	Unit	Quantity	Costs per Unit (USD)	Total costs per input (USD)	% of costs borne by land users
Labour					
Remote Sensing analysis by Sentinel Satellite data	person days	50.0	200.0	10000.0	
Collecting field data for satellite image callibration	person days	40.0	200.0	8000.0	
Soil sampling (for carbon content)	person days	20.0	200.0	4000.0	
Including results in spatial planning	person days	10.0	200.0	2000.0	
Total costs for establishment of the Technology				**24'000.0**	
Total costs for establishment of the Technology in USD				*24'000.0*	

Maintenance activities

1. Repeating the application of the calibrated remote sensing model for monitoring repitition (Timing/ frequency: with 5 years interval)
2. Repetition of soil samples for assessing soil carbon content (Timing/ frequency: with 5 years interval)
3. Analysing the results and integrate them in spatial planning and policy making (Timing/ frequency: with 5 years interval)

Maintenance inputs and costs (per 1000 km2)

Specify input	Unit	Quantity	Costs per Unit (USD)	Total costs per input (USD)	% of costs borne by land users
Labour					
Applying the calibrated remote sensing model for monitoring repetition	person days	20.0	200.0	4000.0	
Repetition of soil samples for assessing soil carbon content	person days	10.0	200.0	2000.0	
Analysing results and integrating in spatial planning	person days	10.0	200.0	2000.0	
Total costs for maintenance of the Technology				**8'000.0**	
Total costs for maintenance of the Technology in USD				*8'000.0*	

NATURAL ENVIRONMENT

Average annual rainfall

- [ ] < 250 mm
- [ ] 251-500 mm
- [ ] 501-750 mm
- [x] 751-1,000 mm
- [x] 1,001-1,500 mm
- [ ] 1,501-2,000 mm
- [ ] 2,001-3,000 mm
- [ ] 3,001-4,000 mm
- [ ] > 4,000 mm

Agro-climatic zone

- [ ] humid
- [x] sub-humid
- [x] semi-arid
- [ ] arid

Specifications on climate

Average annual rainfall in mm: 800.0

The climate is generally suitable for agriculture with an annual precipitation of up to 800 mm, with hot and humid springs, rainfall peaks in May and June with hot and dry summers.

Slope

- [ ] flat (0-2%)
- [ ] gentle (3-5%)
- [ ] moderate (6-10%)
- [ ] rolling (11-15%)
- [x] hilly (16-30%)
- [x] steep (31-60%)
- [ ] very steep (>60%)

Landforms

- [ ] plateau/plains
- [x] ridges
- [x] mountain slopes
- [ ] hill slopes
- [ ] footslopes
- [ ] valley floors

Altitude

- [ ] 0-100 m a.s.l.
- [ ] 101-500 m a.s.l.
- [ ] 501-1,000 m a.s.l.
- [ ] 1,001-1,500 m a.s.l.
- [ ] 1,501-2,000 m a.s.l.
- [x] 2,001-2,500 m a.s.l.
- [x] 2,501-3,000 m a.s.l.
- [ ] 3,001-4,000 m a.s.l.
- [ ] > 4,000 m a.s.l.

Technology is applied in

- [ ] convex situations
- [ ] concave situations
- [x] not relevant

Soil depth

- [x] very shallow (0-20 cm)

Soil texture (topsoil)

- [ ] coarse/ light (sandy)

Soil texture (> 20 cm below surface)

Topsoil organic matter content

- [ ] high (>3%)

- [x] shallow (21-50 cm)
- [ ] moderately deep (51-80 cm)
- [ ] deep (81-120 cm)
- [ ] very deep (> 120 cm)

- [x] medium (loamy, silty)
- [ ] fine/ heavy (clay)

- [ ] coarse/ light (sandy)
- [x] medium (loamy, silty)
- [ ] fine/ heavy (clay)

- [x] medium (1-3%)
- [ ] low (<1%)

Groundwater table
- [x] on surface
- [ ] < 5 m
- [ ] 5-50 m
- [ ] > 50 m

Availability of surface water
- [ ] excess
- [ ] good
- [x] medium
- [ ] poor/ none

Water quality (untreated)
- [ ] good drinking water
- [x] poor drinking water (treatment required)
- [ ] for agricultural use only (irrigation)
- [ ] unusable

Water quality refers to: both ground and surface water

Is salinity a problem?
- [ ] Yes
- [x] No

Occurrence of flooding
- [ ] Yes
- [x] No

Species diversity
- [ ] high
- [x] medium
- [ ] low

Habitat diversity
- [x] high
- [ ] medium
- [ ] low

CHARACTERISTICS OF LAND USERS APPLYING THE TECHNOLOGY

Market orientation
- [ ] subsistence (self-supply)
- [x] mixed (subsistence/ commercial)
- [ ] commercial/ market

Off-farm income
- [x] less than 10% of all income
- [ ] 10-50% of all income
- [ ] > 50% of all income

Relative level of wealth
- [ ] very poor
- [x] poor
- [ ] average
- [ ] rich
- [ ] very rich

Level of mechanization
- [x] manual work
- [x] animal traction
- [ ] mechanized/ motorized

Sedentary or nomadic
- [ ] Sedentary
- [x] Semi-nomadic
- [ ] Nomadic

Individuals or groups
- [x] individual/ household
- [ ] groups/ community
- [ ] cooperative
- [ ] employee (company, government)

Gender
- [x] women
- [x] men

Age
- [ ] children
- [ ] youth
- [x] middle-aged
- [ ] elderly

Area used per household
- [ ] < 0.5 ha
- [ ] 0.5-1 ha
- [ ] 1-2 ha
- [ ] 2-5 ha
- [ ] 5-15 ha
- [ ] 15-50 ha
- [ ] 50-100 ha
- [x] 100-500 ha
- [ ] 500-1,000 ha
- [ ] 1,000-10,000 ha
- [ ] > 10,000 ha

Scale
- [ ] small-scale
- [x] medium-scale
- [ ] large-scale

Land ownership
- [x] state
- [ ] company
- [ ] communal/ village
- [ ] group
- [ ] individual, not titled
- [ ] individual, titled

Land use rights
- [ ] open access (unorganized)
- [x] communal (organized)
- [x] leased
- [ ] individual

Water use rights
- [x] open access (unorganized)
- [ ] communal (organized)
- [ ] leased
- [ ] individual

Access to services and infrastructure

	poor			good
health		✓		
education			✓	
technical assistance			✓	
employment (e.g. off-farm)			✓	
markets		✓		
energy		✓		
roads and transport		✓		
drinking water and sanitation			✓	
financial services		✓		

IMPACTS

Socio-economic impacts

Socio-cultural impacts

Ecological impacts

Off-site impacts

COST-BENEFIT ANALYSIS

Benefits compared with establishment costs

	very negative							very positive
Short-term returns					✓			
Long-term returns							✓	

Benefits compared with maintenance costs

	very negative							very positive
Short-term returns					✓			
Long-term returns						✓		

The monitoring technology was applied for the first time to draw a baseline. Based on the results, activities have been planned and pilot measures have been implemented (exclusion from grazing, reforestation, regulation of grazing intensity). Future replications of the monitoring will show changes and evaluate success of measures. The technologies to control erosion are described separately in the WOCAT database (Community-based Erosion Control [Azerbaijan]; Pasture-weed control by thistle cutting [Georgia]; High-altitude afforestation for erosion control [Armenia]; Slope erosion control using wooden pile walls [Armenia]). The costs of the remote sensing approach have not been invested by the land owners but by GIZ and the Ministry. Therefore there are no direct negative impact caused by the investment. The maintenance will be covered by public authorities as well. The positive impact for the land users are the clearly delineated pasture unit giving the exact area of grassland and the accessible amount of fodder biomass. By this, the lease-rate can be found according to the productivity and the number of livestock can be adapted to the carrying capacity of the land within the lease contract.

CLIMATE CHANGE

Gradual climate change
seasonal rainfall decrease — not well at all ☐☐☐☐☑ very well — Season: summer

ADOPTION AND ADAPTATION

Percentage of land users in the area who have adopted the Technology
- [x] single cases/ experimental
- [ ] 1-10%
- [ ] 11-50%
- [ ] > 50%

Of all those who have adopted the Technology, how many have done so without receiving material incentives?
- [ ] 0-10%
- [ ] 11-50%
- [ ] 51-90%
- [ ] 91-100%

Number of households and/ or area covered
The technology is desigend to be applied by national or regional addministrations and not by land owners themselves.

Has the Technology been modified recently to adapt to changing conditions?
- [ ] Yes
- [x] No

To which changing conditions?
- [ ] climatic change/ extremes
- [ ] changing markets
- [ ] labour availability (e.g. due to migration)

CONCLUSIONS AND LESSONS LEARNT

Strengths: land user's view
- The monitoring technology can help to find erosion and degradation hot spots and based on this spatial information counter measures can be applied to save the productivity of land. As the income from agricultural activities and livestock breeding is of high priority in this pilot region, the protection of the productivity of land is of high importance to the local land users.

Strengths: compiler's or other key resource person's view
- The presented remote sensing technologies are a cost efficient and objective way to monitor land degradation and land use changes on large areas on long time periods. Based on this spatial data, land use regulations can be integrated in spatial planning and other legal and practical frameworks (e.g. pasture lease contracts) to counter act the degradation processes. The success of the measures and the development of degradation and rehabilitation can be monitored by the same toolset.

Weaknesses/ disadvantages/ risks: land user's view → how to overcome
- The technology is complex and cannot be applied by the land user her-/himself and is sometimes hard to understand. Therefore they might mistrust in the results and are not eager to accept regulations and measures to stop degradation. → Transparent documentation of the technology and regular field visits to evaluate together with the land owners and users the remote sensing results in the field.

Weaknesses/ disadvantages/ risks: compiler's or other key resource person's view → how to overcome
- The institutional setup on the national level for the regular application of the remote sensing technology and the storage and management of the monitoring data is not established yet. GIS, remote sensing and soil experts are of limited availability. → Institutional capacity building and academic training courses provided at the Georgian universities can help to overcome these limitations.
- Field data for calibration of satellite images (biomass volumes, classified land cover types, soil types, land management types) with exact information on the spatial location are rare and costly to be created. → Such data and information should be organised and gathered on national level across different sectors (agriculture, forestry, spatial planing, nature conservation ...). This would help to reduce significantly the costs and remote sensing could be applied on much larger areas.

REFERENCES

Compiler
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Full description in the WOCAT database
https://qcat.wocat.net/en/wocat/technologies/view/technologies_5488/

Linked SLM data
Approaches: Integrated Pasture Management Planning in Mountainous Regions
https://qcat.wocat.net/en/wocat/approaches/view/approaches_5490/

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Key references
- Land Degradation Neutrality 25.10.2017: https://e-c-o.at/files/publications/downloads/D00813_ECO_policy_brief_LDN_Georgia_171025.pdf

Links to relevant information which is available online
- Tools for satellite image analysis: http://step.esa.int/main/snap-2-0-out-now/
- UNCCD Good Practice Guidance on SDG Indicator 15.31. (Sims et al. 2017): https://www.unccd.int/sites/default/files/relevant-links/2017-10/Good%20Practice%20Guidance_SDG%20Indicator%2015.3.1_Version%201.0.pdf