Integrated Biodiversity Management, South Caucasus

Implementation of an Erosion Risk Assessment tool on pilot regions in the Southern Caucasus.

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Report

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1. Introduction

The key challenge in high mountain areas of the South Caucasus is the unsustainable use of pastures and forest areas that leads to erosion, degradation, desertification and loss of biodiversity. The programme "Integrated Biodiversity Management in the South Caucasus" (IBiS)" contributes to rehabilitation of degraded areas and conservation of biodiversity through the protection of natural resources from anthropogenic induced erosion processes.

To assess the current state and general risk of erosion, a remote sensing tool – the Erosion Sensitivity Model - was developed by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in cooperation with national experts in Armenia. The technology was also transferred to Georgia and Azerbaijan.

Experts from Armenia and Georgia worked on remote sensing tools to estimate the risk of erosion by adapting the **Revised Universal Soil Loss Equation (RUSLE)** to the Caucasian environment.

2. Sensitivity model

The sensitivity model is based on the RUSLE – Revised Universal Soil Loss Equation (Renard et al. 1996) and was implemented in numerous studies (Angima et al. 2003, Fu et al. 2005, Kim & Julien 2006, Kouli et al. 2009, Ma et al 2003, Mati & Veihe 2001, Millward & Mersey 1999 and many others). 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). That way, the estimated average soil loss in tons per acre per year (A) can be calculated [see Figure 1].

RUSLE: A = R*K*LS*C*P

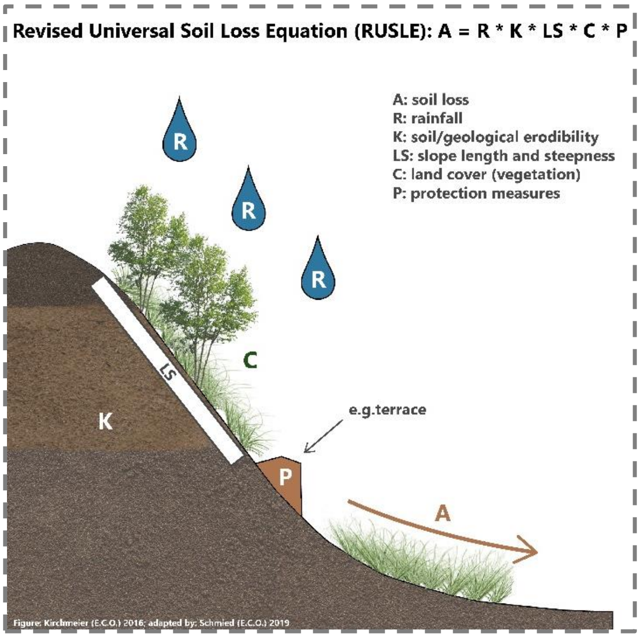


Figure 1: Main factors of the revised universal soil loss equation (RUSLE).

The “Erosion Sensitivity Model” can be used on different scales, while the accuracy mainly depends on the quality of the input data. It is therefore important to obtain as good and accurate data on precipitation, soil parameters, relief and land cover as possible. Some of the model inputs are subject to factors that cannot be influenced. These include precipitation and length and steepness of the slope, the main driving factors describing the energy of erosive water influence. The soil and the land cover factors, on the other hand, express the resistance that the soil and vegetation cover can provide against the erosive influence of water. Thus, the factor, which can be influenced by human activities the most, is the vegetation cover. If protection measures are available, they of course can influence the soil loss as well. In the following, the above-mentioned factors are briefly explained.

2.1 R – Rainfall factor

The R-factor is the rainfall-runoff erosivity factor derived from a quotient from monthly to annual mean precipitation.

The Armenian model used the data from 10 national metrological stations. To get the spatial information, a linear regression between precipitation and altitude was calculated from the metrological data (and altitude of the stations). This regression was applied to the digital elevation model and precipitation maps were derived. This is a meaningful and feasible approach, but there is no new spatial information added to the overall model other than the altitude of the elevation model.

In the Georgian approach (Mikeladze & Nikolaeva 2016) the precipitation (R-factor) data was used from the “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 *chelsa-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.

2.2 K – Soil Erodibility Factor

The K-factor is the soil erodibility factor which represents both the susceptibility of soil to erosion and the rate of runoff, as measured under the standard unit plot condition. Soils high in clay have low K values, about 0.05 to 0.15, because they are resistant to detachment. Soils having a high silt content are most erodible of all soils. They are easily detached; tend to crust and produce high rates of runoff. Values of K for these soils tend to be greater than 0.4.

Instead of the geological map 1:50,000, now the soil map 1:200,000 was used to derive the K-factor (GIZ 2015). While the classification of the former geological map 1:50,000 only led to two different soil types (and K-factors), the soil map 1:200,000 differentiates 12 different soil types in the project area. The different content of sand, silt, loam and clay are used to calculate a K-factor based on the soil type.

But still, the spatial information on the K-factor is very rough, as it is only available in 1:200,000 and the high variability on soils according to the micro-relief is not shown in the soil map.

The Georgian approach used the same source (soil map 1:200,000). In both approaches (Armenia and Georgia), the information on the K-factor seems to have a low spatial information value, as the input data is very coarse. It is not very likely, that there will be more precise soil maps (e.g. in scale of 1:50.000 or higher) available for mountainous regions in the Caucasus.

The same can be assumed for geological maps, that could be used as an alternative to derive K-factors.

Although no precise source for deriving a K-factor is available, it does not imply that the results are imprecise as well. The model might not calculate the amount of erosion (described in tons of soil loss per hectare and year) very accurately, but the spatial distribution of erosion risk will still be described quite clearly by the vegetation cover and the slope-factors derived from the elevation model.

Another option would have been to replace the coarse information from the soil map 1:200,000 by a constant factor (e.g. 0.5) in order to avoid artefacts caused by the rough resolution of the soil map.

2.3 LS – Slope length and steepness factor

L is the slope length factor and S the slope steepness factor, both representing the effect on erosion. Soil loss increases rapidly with slope steepness and with the length of the slope, as more water is accumulated on a long slope.

The slope length and steepness (inclination) are calculated from a digital elevation model derived from isohypses from a topographic map (1:10.000).

The same approaches were used in Armenia and Georgia. Besides the calculation of a digital elevation model (DEM) from the isohypses from the topographic map, other sources can be used. The global elevation model derived from the NASA Shuttle Radar Topography Mission data (SRTM, 2015) has a resolution of 30x30 m and is globally available for free. Other digital elevation models with higher resolution can be calculated from high resolution satellite images.

2.4 C – Land Cover Factor

The C-factor describes the vegetation cover, protecting the soil against erosion. The vegetation cover slows down the speed of raindrops hitting the ground, thus reducing the erosive energy of the rain. Additionally, the vegetation slows down surface water run-off and is stabilises the soil through the root system. The amount of vegetation cover is usually expressed by the Leaf Area Index (LAI). The LAI is the area of leaf surface (in square meters) per square meter ground surface. As the real surface of the leaves can hardly be measured, the amount of biomass is a proxy to the LAI.

The reflection of chlorophyll in the green leaves has a characteristic spectral fingerprint. By comparing the ratio between the visible red light and invisible near infrared, the amount of chlorophyll can be estimated. This effect is used to calculate different vegetation indices from multispectral satellite images. The Normalized Difference Vegetation Index (NDVI) is a commonly used index.

3. Technical adaptations and developments

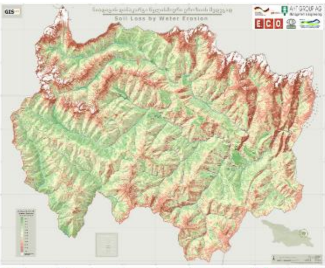
Through the implementation processes in Armenia and Georgia some further technological developments and improvements were tested and integrated into the model approach:

- **Additional and more detailed rainfall data:** With the Georgian approach of using the CHELSA data platform for the precipitation (R) factor, data with much higher spatial resolution, covering information from several decades can be incorporated into the model. In comparison to the linear regression of precipitation, as done in Armenia, the CHELSA-data bring additional spatial information and might show differences in precipitation on south and north exposed slopes.
- **Higher resolution and more accurate images from Sentinel-2 Satellite**: The application of the model began with the use of Landsat 7 data from 2011 in Armenia, later Landsat 8 data were used. In the Georgian pilot project, the Sentinel 2 satellite images were used which have the advantage of a higher resolution (visible band and near infrared 10m, and additional "red edge band" 20m) and a higher number of bands, especially in the red and near infrared spectral range (in total 6 bands: B4, B5, B6, B7, B8 and B8a). 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 analysing 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.
- **New by-products *land cover* and *biomass map***: Information on vegetation cover and available biomass was generated during the calculation of the C-factor. This spatial information is supposed to support land use planning and decision-making processes for better management of natural resources, especially pastures. In Georgia, land cover, biomass and erosion risk maps are now available for the whole pilot area. These layers were intersected with the pasture management units to calculate available biomass and maximum carrying capacities of livestock for each pasture unit. Overgrazed areas that are critical to erosion were detected and alternative grazing areas, which are currently unused, were identified.

4. Results

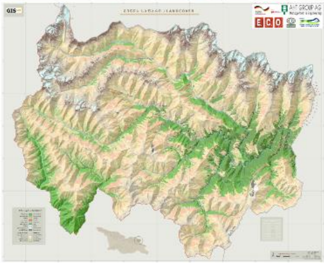
Within the IBiS activities, the technical approach developed in Armenia was transferred to Georgia and within the expert meetings and discussions the model process was further developed and described in several reports (see reference list) which were shared with the partners in Azerbaijan. The output of the activities is, on the one hand, the improved methodological approach and, on the other hand, the maps produced in the pilot areas in Armenia and Georgia.

Erosion risk map



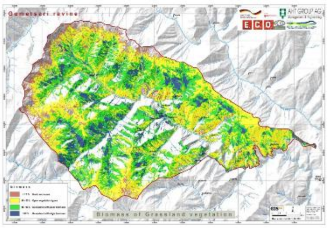
Derived from the input factors rainfall – soil type, length and steepness of slope and vegetation cover – erosion risk maps for 6 pilot municipalities around Mount Aragats (AM) and the territory of the Tusheti Protected Area (GE) was calculated. The maps indicate the risk of erosion by surface water runoff.

Land cover map



Based on the different spectral bands of the Sentinel 2 satellite image, a land cover map was calculated for the Tusheti region (GE). This was done by a Support Vector Machine (SVM) technology which was trained using sample plots classified by experts. The map classifies deciduous and coniferous forest, shrubland, grassland of different biomass content, bare soil, water, snow field/glaciers and villages.

Biomass maps and pasture degradation index



The spectral information from the Satellite was calibrated by 88 biomass sample collected on Tusheti in 2016 and 2017. The map gives the amount of above ground biomass in tons/hectare which is available as fodder for livestock. For the Armenian pilot villages maps indicating a Pasture Degradation Index and the maximal livestock stocking rate were delivered.

The Armenian results were shared with the local municipalities to integrate them into their pasture management plans developed within a CARMAC Project (Community Agricultural Resource Management and Competitiveness). In Georgia, the results were addressed on two levels: For each pasture unit, a pasture 'passport' was generated including the maps and data on the biomass volumes and carrying capacity for livestock. These passports are addressed to the shepherd managing the pasture unit. Additionally, the overall results were handed over to the municipality, responsible for the lease contracts in the Protected Landscape and to the Agency of Protected Areas (APA), responsible for the land use in the National Park.

This remote sensing approach was also integrated into the Georgian Land Degradation Neutrality Monitoring Concept (Huber et al. 2017, financed by REC Caucasus and BMZ via GIZ).

The lessons learned in Armenia and Georgia were summarised and distributed to the experts in Azerbaijan for further implementation.

5. References

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