Integrated Biodiversity Management, South Caucasus

Sensitivity Assessment of Pasture Lands based on Simulation Models and RS/GIS Techniques in Armenia

Report

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Executive summary

Soil erosion remains a large problem for pasture management in Armenia, in terms of both cattle productivity and degradation of ecosystems. There exists a need for improved pasture monitoring and management processes – at the local, regional and national level. The purpose of this report is to provide a general introduction to the sensitivity assessment, which combines the application of the soil loss model RUSLE, as well as the calculation of vegetation indices serving as biophysical indicators. Furthermore, the report shall serve as a reference document which describes the sensitivity assessment conducted in GIZ SMBP Armenia to monitor the state of pastures of Sisian region. Results of the assessment of Sisian Region reveal the grazing capacity for each raster cell of the studied area. Based on the generated data a maximum allowed number of cattle has been calculated accordingly. Assessed information shall be included into the planned PMIS of Armenia, in order to increase transparency and information exchange among various stakeholders on the state of pastures, and, hence, to influence decision making processes on the national, regional and local level (top-down management). Direct erosion control measures based on the results of the sensitivity assessment have not yet been implemented within the study area.

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List of Abbreviations

AM	Armenia
DEM	Digital Elevation Model
DTM	Digital Terrain Model
ETM	Enhanced Thematic Mapper
FMIS	Forest Management Information System
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
ha	hectar
IBiS	Integrated Biodiversity Management in the South Caucasus
km	Kilometer
l	Liter
LAI	Leaf Area Index
m	Metre
m2	Square metres
MFI	Modified Fournier Index
MS	Multi Spectral
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
PMIS	Pasture Management Information System
RA	Republic of Armenia
red	Visible Red
RS	Remote Sensing
RUSLE	Revised Universal Soil Loss Equation
SAVI	Soil Adjusted Vegetation Index
SLR	Soil Loss Ratio
SMB(P)	Sustainable Management of Biodiversity (Programme), GIZ
SPI-MU	State Pasture Index – Management Unit
SU	Stock Unit
T	Tonnes
UPP	Unpalatable Plants
USLE	The Universal Soil Loss Equation

1. Introduction

Soil erosion is one of the most important processes contributing to land degradation and desertification. It is a natural geological phenomenon during which soil particles are removed by water or wind. Generally, the most fertile soil (humus) is being eroded and deposited, resulting into the loss of arable land. Several factors contribute to soil erosion, such as steep slopes, climate, unsustainable land use, land cover patterns or ecological disasters, such as forest fires. Also, intrinsic factors of soil, such as silt texture, thin layer of topsoil, or low organic matter content, can make it more prone to erosion. To increase the understanding and knowledge of erosion processes it is interesting to look on the one site at the actual erosion rate of a specific area, and, on the other side, to assess the risk of potential erosion in the same area. Erosion models, which simulate soil erosion based on given indicators, can be couple with remote sensing data, which provides spatial information such as vegetation cover, biomass intensity, or land use (Ustin e al., 2004, Gitas et al. 2009).

The overall aim of this report is to give a short introduction and overview about erosion risk models, as well as remote sensing data in order to assess soil erosion and pasture degradation. The example of the “Sensitivity Assessment of Sisian region, Armenia” will serve as a practical example.

One of the visions of the current regional GIZ Sustainable Management of Biodiversity (SMB), as well as of the upcoming Integrated Biodversity Management in the South Caucasus (IBiS), programme, is the prevention of erosion and loss of soil fertility, especially in landscapes highly prone to erosion, degradation and desertification within the South Caucasus. The methodology for assessing the erosion severity of a specific area, presented in this report, shall serve as guidance for the three countries of the South Caucasus to identify areas with a high risk for erosion, so that pasture management processes can be improved, and cost effective biophysical erosion control activities can be planed accordingly.

The paper starts with a guidance on which factors need to be taken into account when choosing the right model for assessing erosion risk of a certain area (chapter 2). Further, it presents the Revised Universal Soil Loss Equation (RUSLE), as one widely used equation to simulate soil loss (chapter 3). The approach of the sensitivity assessment is explained in chapter 4. Part 5 presents the methodology of the sensitivity assessment of Sisian region, Armenia” as one example. Part 6 presents the methodology of calculating the state of pasture-index of one management unit.

2. Selecting Simulation Models for Soil Erosion

A large variety models to assess soil erosion risk exists. The models can be classified as: empirical and mechanistic models; static and dynamic models; deterministic and stochastic models; spatial dimension models; qualitative and quantitative models; long-term or event based models; single point or spatial distributed models (Gitas et al. 2009).

In order to be able to choose the right model for assessing soil erosion within a given study area, following factors should be considered.

(1) Type of erosion: different erosion types occur on different kind of areas. Wind erosion for example might occur on flat, coastal areas, while on mountainous, landlocked areas water erosion might frequently occur. For the different types of erosion different types of models exist (compare Shi et al., 2002);

(2) Geographical Scale: on which geographical scale do I want to assess soil erosion? Scales can, for example, differ between global, regional and local scales (compare table 1). Different models may apply for different scales;

(3) Accuracy: Is my objective to calculate accurate data of soil loss, or do I want relative comparison of data? Different models have different chances of errors. Depending on the individual objective, a simple and robust model might be more suitable than generating accurate data of exact soil loss rates;

(4) Time scale: What is your planned period of time that you want to assess? Time scales can vary between single storm/flood events and continuous time (daily values, monthly values, yearly values, seasonal);

(5) Data availability: different models require different input data. Which data do I already have? Which data is possible to obtain within my give time schedule? Note: the type of model is dictated by availability of data;

(6) Simulation Results: different erosion models can simulate different results such as: soil loss; runoff and soil loss; runoff, soil erosion and deposition; transport of nutrients and pesticides (etc);

(7) Software, Hardware, Human Capacity, Costs: before choosing a model, the availability of necessary software, hardware and human capacity should be assessed. Some models require expensive Geographic Information Systems (GIS) and Remote Sensing (RS) software (Klik et al., 2010¸ Gitas et al., 2009, Huete, 2004).

3. The Revised Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) has been developed as a field scale model and aims to predict the long-term annual rate of erosion on croplands or gently sloping topography based on rainfall pattern, soil type, topography, crop system and management practices. (Gitas et al.,2009). It is a model to predict water erosion, mainly on agricultural land. The RUSLE model is the modified version of USLE and became the standard tool for erosion prediction on disturbed lands. RUSLE follows the same formula (see chapter 3) as USLE, but got several improvements for the estimation of the values of the various factors and a broader application to different situations, including forests, rangelands, or grasslands. The aim of USLE and RUSLE is to serve as a tool for comparing soil loss of a specific area and management system to the tolerable soil loss rate (the tolerable soil loss rate is the rate that could occur indefinitely without adversely affecting soil productivity). Based on the result, alternative management systems and rehabilitation measures for the studied area could be evaluated (Wall et al., 2002). RUSLE is a computation method that can be applied for site evaluation and planning purposes. It does not only provide an estimate of erosion risk, but also numerical results that can validate the benefits of planned erosion control measures in risky areas. Hence its can also be seen as an assistance to decision process of selecting erosion control measures (Gitas et al., 2009). RUSLE can be calculated by using GIS interfaces such as IDRISI Kilimanjaro, or ArcGIS (for the latter an RUSLE calculation model has been developed by GIZ SMB AM). In comparison to other models, RUSLE is one of the least data demanding models and can be applied for widely at different scales due to its robust data (van der Knijff et al., 2000).The RUSLE equation can be seen as a combination of several general conditions, unique to any areas, which effect erosion by water. These are:

! climate ! soil ! topography ! vegetation or crop ! land use practices !

Each of the conditions is represented by a different factor or output layer (compare Figure 1) in the RUSLE equation as follows:

$$A=R*K*LS*C*P$$

in which:

- **A** represents the potential, average annual soil loss in tonnes per hectare per year.
- **R** is the rainfall factor
- **K** is the soil erodibility factor
- **L** and **S** are the slope length and steepness factors, respectively
- **C** is the cover and management factor
- **P** is the conservation or support practice factor

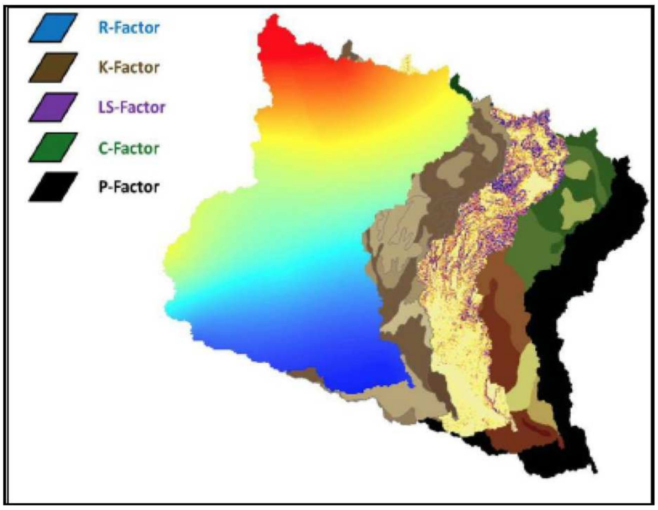

Figure 1: Overlay of the RUSLE Model (Source: Kim, 2014)

3.1 Advantages of RUSLE

RUSLE is a widely used model for estimating long term average annual soil loss. Widespread use has substantiated RUSLE's usefulness and validity. Though originally developed as a field scale model, it can be applied on various scales due to its relative simplicity and robustness. RUSLE predicts erosion potential through the amount of soil loss on a cell-to-cell basis and provides qualitative and quantitative data for the assessment of soil erosion intensity. Its ability to map soil erosion risk is viewed as very good, when considering the purpose of this model as a conservation tool. The equation enables the planner/land manager to predict the average rate of soil erosion for each of various alternative combinations of cropping systems, management techniques, and erosion control practices on any particular site. When applying with GIS, RUSLE can also be used to isolate and query the spatial distribution of soil loss and provide information about the roles of individual variables in contributing to the observed erosion potential value.

3.2 Obstacles

RUSLE predicts the amount of soil loss that results from water erosion and does not account for additional soil losses that might occur from gully, wind or tillage erosion, nor does it calculate sediment yield. Also the accuracy of RUSLE factor values is limited. Errors are similarly multiplied, because data input layers are being multiplied together. However, recognizing the inexact nature of the A-value, x-class ordinal ranking can be undertaken, so that the errors are then likely to be aggregated into one of the x designations (for example 5 classes). This categorization is consistent with the model's role as a conservation management tool, where relative comparisons among land areas are more critical then assessing the absolute soil loss in a particular cell. Original charts and tables containing approximate values of the RUSLE factors (Renard et al., 1997) are incomplete and inaccurate for conditions outside the U.S., where rainfall characteristics, soil types, topographic features, or farm practices substantially differ. Appropriate values need to be developed for individual conditions. Validation of the RUSLE model can and should be applied by field observation, satellite image interpretation, or the like.

3.3 Result of RUSLE

For each RUSLE factor a 30m raster output map can be created mapping the different values of each factor. From these five 30m raster outputs, a simple raster calculation can be computed to get the soil loss for each 30mx30m cell. This is the RUSLE risk and intensity map of potential average annual soil erosion (soil loss) (tonnes/hectare/year) caused by raindrop impact and sediment transport and by thin overland flow (no wind erosion).

These outputs can then be compared to the tolerable soil loss rate. A tolerable soil loss is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hill slope is adversely affected. The impact of erosion on a given soil type (and hence the tolerance level) varies, depending on the type and depth of soil. Generally, soils with deep, uniform, stone free topsoil materials and/or that have not been previously eroded are assumed to have a higher tolerance limit than soils which are shallow or previously eroded. Fine to medium textured soils tend to be more tolerant than coarser-textured soils, although this may vary depending on the specific characteristics and management of each soil.

These values provide only a relative indication of the impact that erosion has on different soil types and will vary depending on the site. The object of good soil management should be to keep soil erosion well below these “maximum” rates.

4. Sensitivity Assessment

The sensitivity assessment (compare Figure 2, step (3)) is a combined analysis of the results given by calculating the Revised Universal Soil Loss Equation (RUSLE) Model (1) and the results of the calculation of vegetation indices based on RS (2), which provide information on biophysical indicators, such as vegetation cover or biomass intensity. Remote sensing can serve as additional validation for RUSLE and/or serve as an input for more detailed analysis. Although within some RUSLE equations satellite images (NDVI Index) might already be included (C-factor), RS is of particular interest since information given from NDVI within the RUSLE equation will be strongly mitigated by the other factors. Also in many RUSLE applications the P-value might not be calculable due to lack of appropriate data. Here, vegetation indices can serve as a biophysical indication of land management practices and land cover, by indicating location of bare soil and rocks, cattle tacks, grazing sites, hay making sites, or unused areas with plenty of vegetation. Moreover, as a tool for validation of RUSLE, vegetation indices can support analyzing inconsistencies between RUSLE and RS maps. The simulated erosion potential map is then to be compared with the actual state of pastures. Hence, the sensitivity assessment is based on different methodological models reflecting both the simulated average annual risk potential of a given area, as well as the current state of erosion indicated by the vegetation indices. This information can be individually combined with more relevant information, for further analysis and management planning, and for formulating more accurate management advice (box with dashed line).

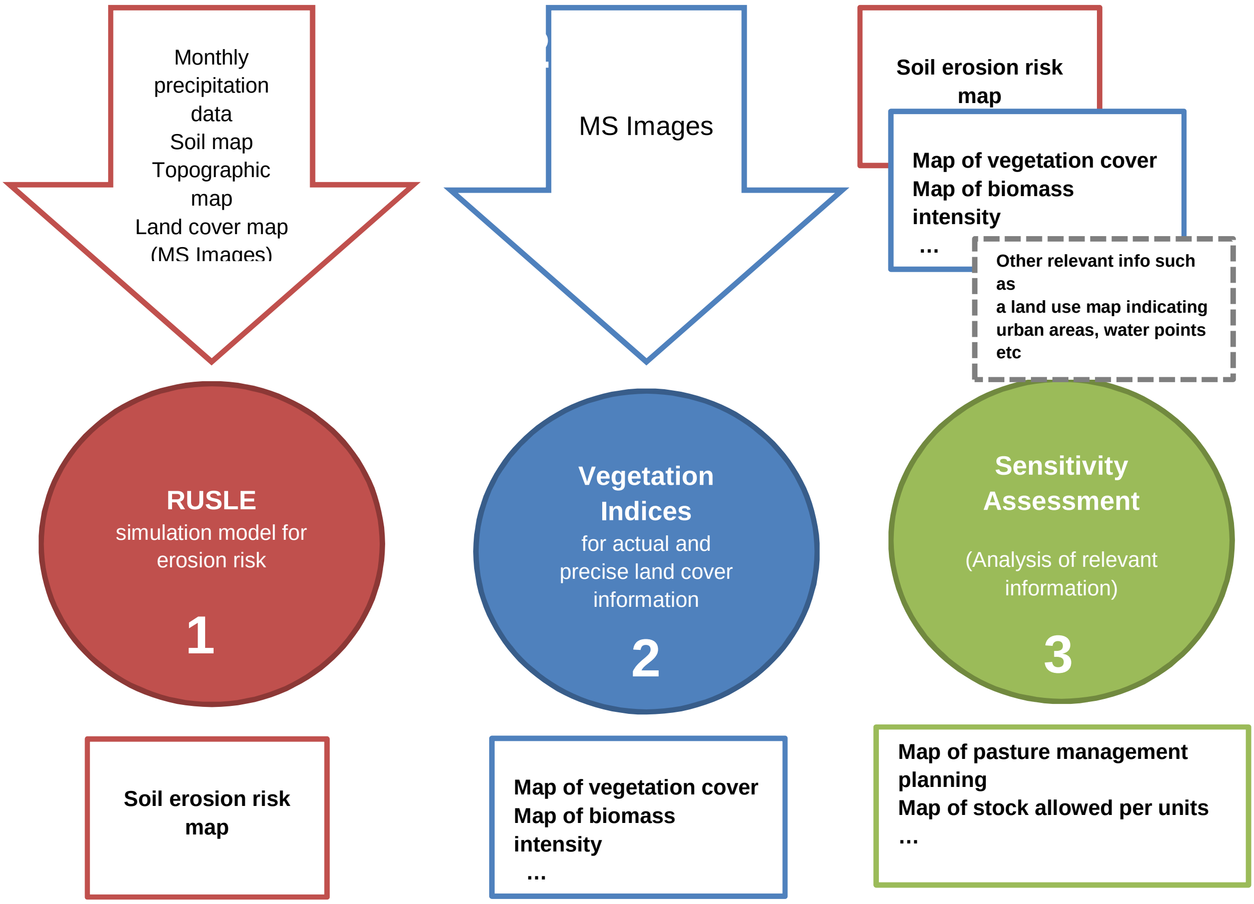

Figure 2: The Sensitivity Assessment

5. Sensitivity Assessment of Sisian Region, Armenia

The aim of the sensitivity assessment of pastures in Armenia was to produce an erosion risk map by calculating RUSLE, and to validate and further analyze its result with information received by biophysical indices based on RS techniques. Note: Results captured from RUSLE and RS data shall always be verified by field visits, e.g. on the ground pasture monitoring. The study area of the sensitivity assessment explained in this report is the area of Sisian region, Armenia, which comprises 21 470 hectare (Figure 3). The study has been conducted by an external consulted contracted by GIZ SMBP AM.

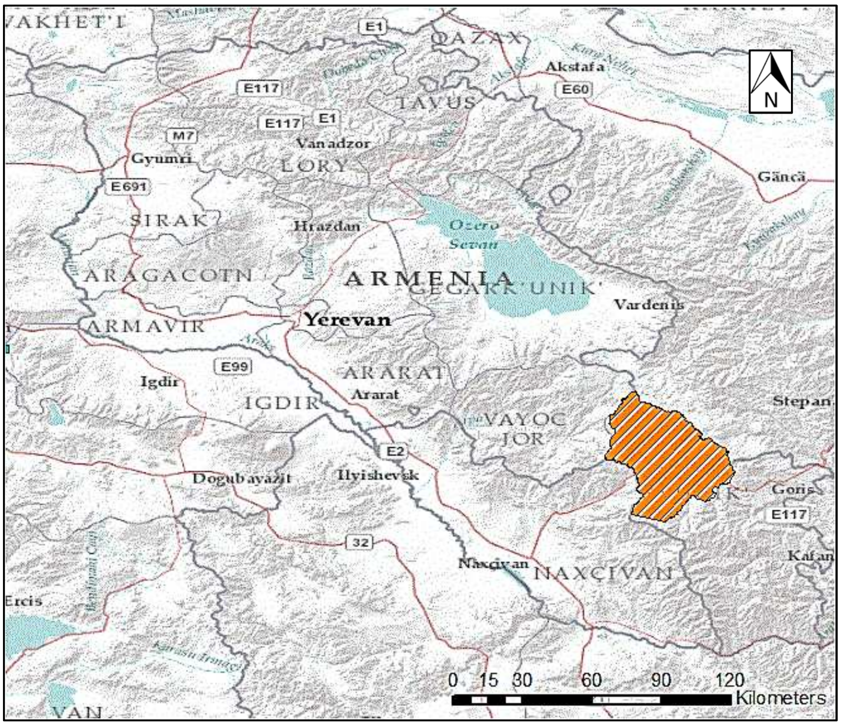

Figure 3: Location of Sisian Region, Armenia

5.1 RUSLE/ Susceptibility to Erosion-Index (SEI)

RUSLE has been chosen as the model to simulate soil erosion in the mountainous area of Sisian region, Armenia as a part of the sensitivity assessment, because of several factors. One factor is that in the study area water erosion rather than wind or gully erosion occurs. RUSLE with is wide applicability, is an appropriate model for geographical extent of the study area. Furthermore, expected results of RUSLE fitted with the objective of the study: to generate analytical data and support management decisions with solid and robust data. There was no necessity for assessing the absolute soil loss in a particular cell. For this reason occurring inaccuracies in resulting data are tolerated. As a next step, it has been checked, if necessary data, hardware, software and human resources to apply RUSLE were already available, or possible to obtain within given time frame. Finally, ArcGIS has been chosen as the software to calculate RUSLE, since the software and basic knowledge on it was already available within the partner structure.

As RUSLE and each of its factors are calculated by different formulas, an ArcGIS model for each equation has been built by using the *Model Builder* Tool of ArcGIS. For every RUSLE factor the final RUSLE equation can be calculated.

Data set available for RUSLE in Armenia

- Monthly climatic average observations derived from available meteorological stations
- Soil map on a scale of 1: 50 000
- DTM Model on a scale of 1:25 000
- Landsat Images acquired for August 2011

The calculation of each RUSLE factor with the ArcGIS model will be presented.

R-Factor:

Data needed: *Monthly precipitation average observations derived from metrological stations for the whole area* <u>*and*</u> *levels of altitude (if not available, prediction models can be applied, for example a simple linear regression).*

R is the rainfall and runoff erositivity index. Detailed information on both rainfall and rainfall intensity are needed to calculate the R-Value. Since, these data are usually not available from standard meteorological stations, a simplified approach to estimate R can be used. Often, the mean annual and the monthly rainfall amount have been used to estimate R-factor.

To develop the raster model of precipitation erosion index, it is necessary to have the long-term average monthly and annual precipitation data from at least three meteorological stations of the area, as well as data on altitudes of those meteorological stations (Table 1).

Table 1: The long-term average monthly and annual precipitation data of meteorological stations

Meteo. Stations	Month													Altitudes
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	YEAR	
Sisian	30	24.4	27.9	52	78.7	53.2	100	3.7	23.4	11.9	33.2	28.1	467	1581
Goris	46.8	38.5	66.7	58.1	119.2	169.5	44.2	17.3	38.5	47.8	59.2	54.6	760	1380
Ashtarak	26	30	34	51	58	32	18	11	11	36	28	30	365	1098
Talin	26	30	38	56	79	54	31	22	17	39	26	23	441	1635
Armavir	17	20	23	32	45	24	12	8	9	27	18	15	250	862
Aragats	77	82	109	123	114	81	61	50	38	81	95	89	1000	3239
Merdzavan	24	26	33	41	48	23	13	9	9	31	24	26	307	937
Eghvard	33	37	42	62	63	39	19	12	14	41	34	36	432	1329
Eratmber	79	84	99	93	90	71	46	33	34	63	70	69	831	3072
Yerevan	22	25	30	37	44	21	9	8	8	27	23	23	277	899

Due to the lack of a dense meteorological network in Armenia, in this study a the linear correlation is created between meteorological stations and the long-term average monthly and annual precipitation data, image 1 and 2

$$y=ax+c$$

where “a” and “c” are the coefficients of the linear equation.

For August the monthly a-coefficient is 0.0188, and the c-coefficient is -5.7144 (Figure 4). The annual a-coefficient is 0.2909, and the c-coefficient is 42.608 (Figure 5).

The correlation graphs can be drawn with Microsoft Office Excel.

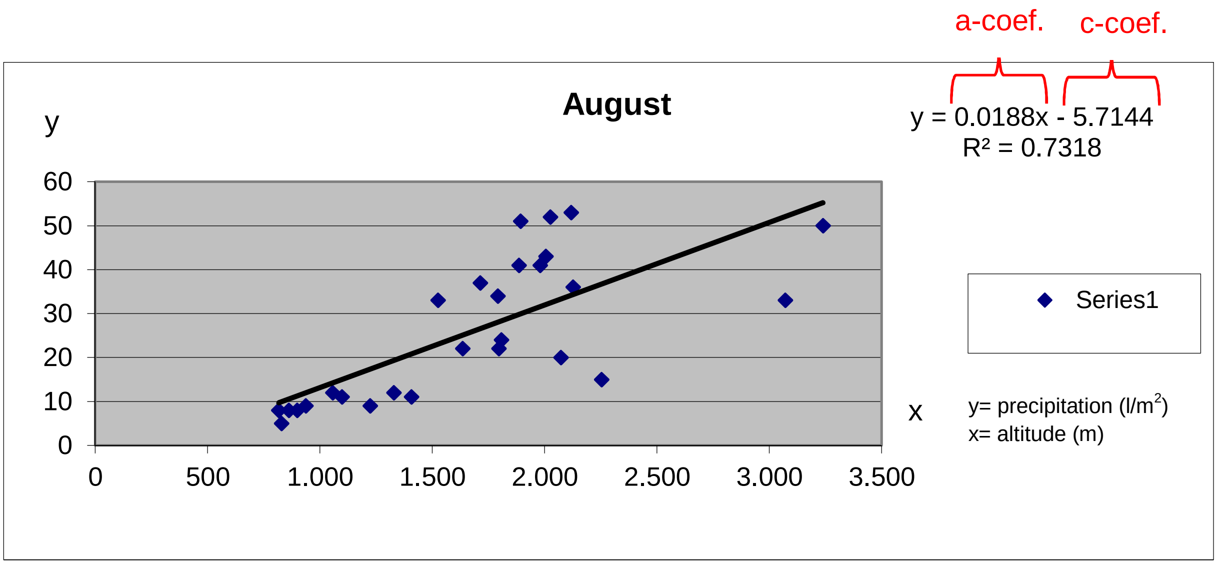

Figure 4: Linear regression model for Armenia, August 2011

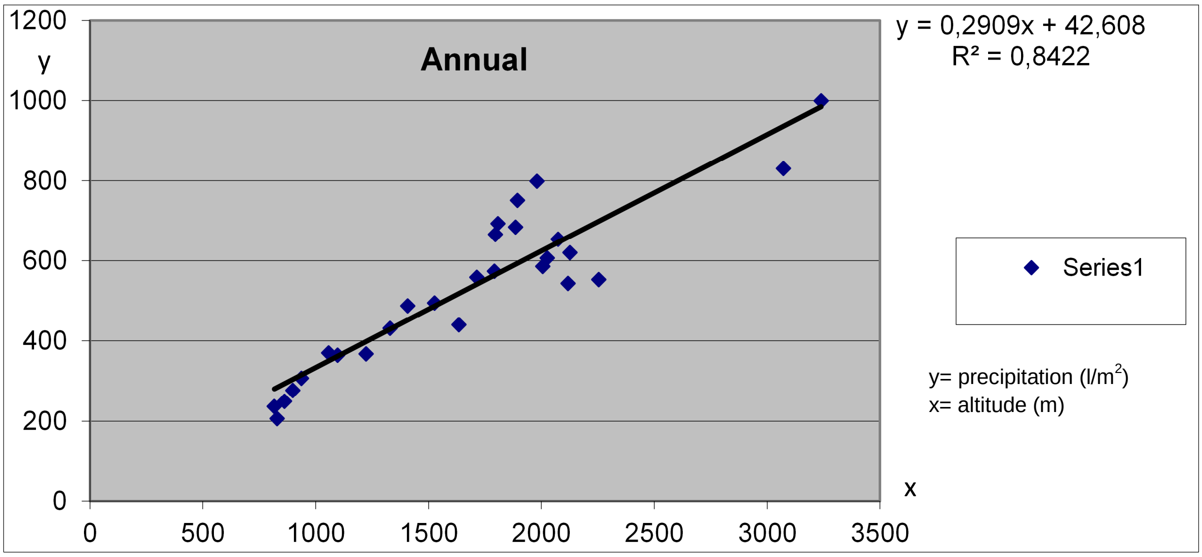

Figure 5: Linear regression model for Armenia, year 2011

With this equation the rainfall rate can be estimated for every altitude monthly or on an annual basis. For this study the annual and monthly coefficients have to be imported into ArcGIS (see Figure 6), together with the DEM for the study area.

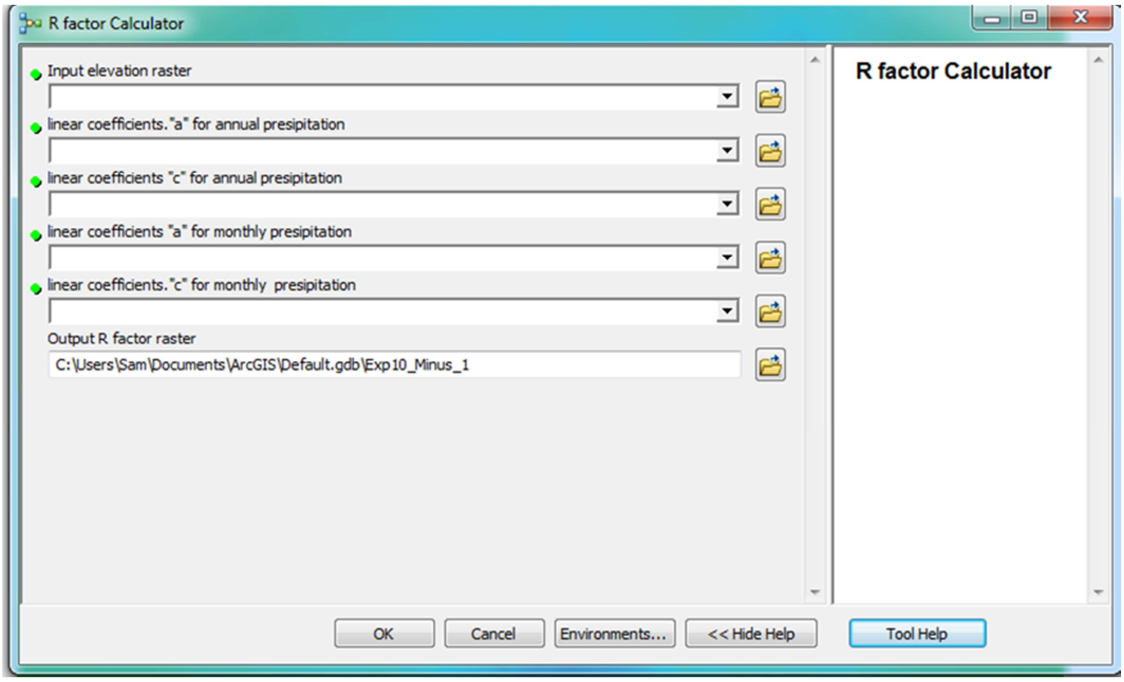

Figure 6: R-factor calculation in ArcGIS model

Result R-Factor Calculation

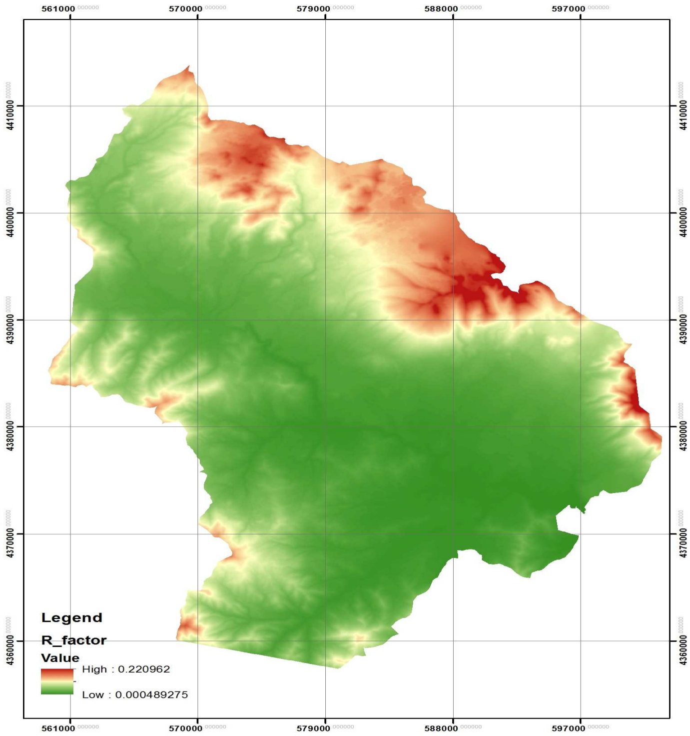

Figure 7: Result R-factor

Data needed: Digitalized geological map (scale 1:100 0000) (1cm : 1km), raster grid format

The K-factor is a quantitative measure of the influence of soil properties on soil loss during storm events on upland areas (Renard et al., 1997). Generally, it can be said that soil with a high percent of silt and very fine sand particles, a low organic matter content, poor structure and very low permeability, will be most erodible (based on soil characteristics only)

An analogue geological map, originated from the former Soviet Union, has been digitalized. Generally it can be said that maps from the former Soviet Union have good quality and are still valid. The digitalized version has been converted from vector to raster format. Then, a reclassification from geological material to soil texture classes has been performed using Table 2. For the Sisian region identified and reclassified soil texture map has been classified with k-values manually (Figure 8).

Table 2: Reclassification geological material, soil texture, k-values

Parent geologic material	soil texture*	k-values
Alluvial deposits	SL-L	0.15
Limestone	C or SiC	0.4
Peridotid	CL-C	0.5
Granite	S-SL	0.2
Schists	L	0.7
Gneiss	S or LS or L	0.3
Tertiary deposits	SL-L	0.15

* S: Sandy, L: Loam, Si: Silty, C: Clay

Result K-factor calculation

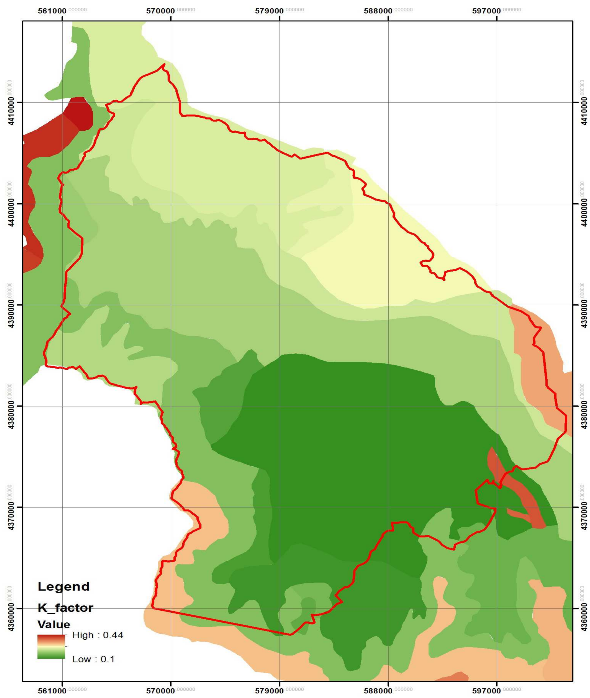

Figure 8: Results K-factor

LS-factor:

Data needed: Digital Elevation or Terrain Model (DEM/DTM) (30 or 90m resolution, for example ASTER or SRTM).

The LS factor represents

the effect of topography on erosion. The slope length (L) is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient deceases enough that deposition starts or runoff becomes concentrates in a defined channel. Figure 9 shows typical slope lengths.

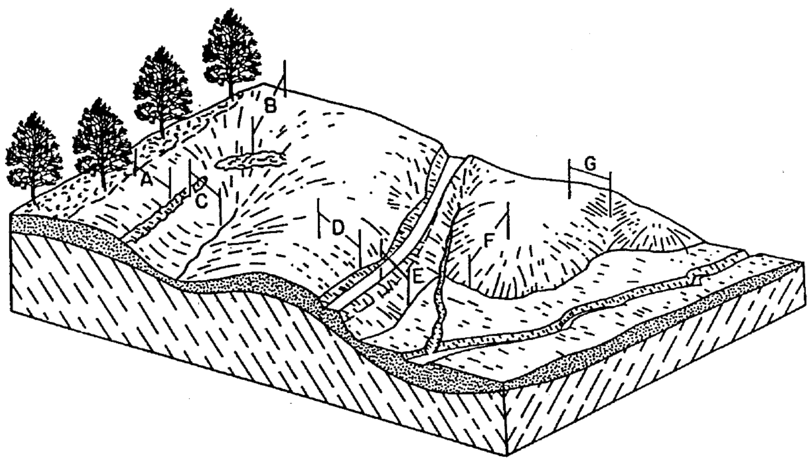

Figure 9: Typical slope lengths (Source: Renard et al., 1997)

Where **A**: If, undisturbed forest soil above does not yield surface runoff, the top of the slope starts with edge of undisturbed forest soil and extends down slope to windrow, if runoff is concentrated by windrow. **B**: Point of origin of runoff to windrow, if runoff is concentrated by windrow. **C**: From windrow to flow concentration point. **D**: Point of origin of runoff to road that concentrates runoff. **E**: from road to flood plain where deposition would occur. **F**: on nose of hill, from point to origin of runoff to flood plain where deposition would occur. **G**: Point of origin of runoff to slight depression where runoff would concentrate.

To calculate the LS-factor for pilot area, the ArcGIS model only requires the DEM in the form of a raster grid as input data. The LS-factor map will then be calculated automatically (Figure 10), (Figure 11).

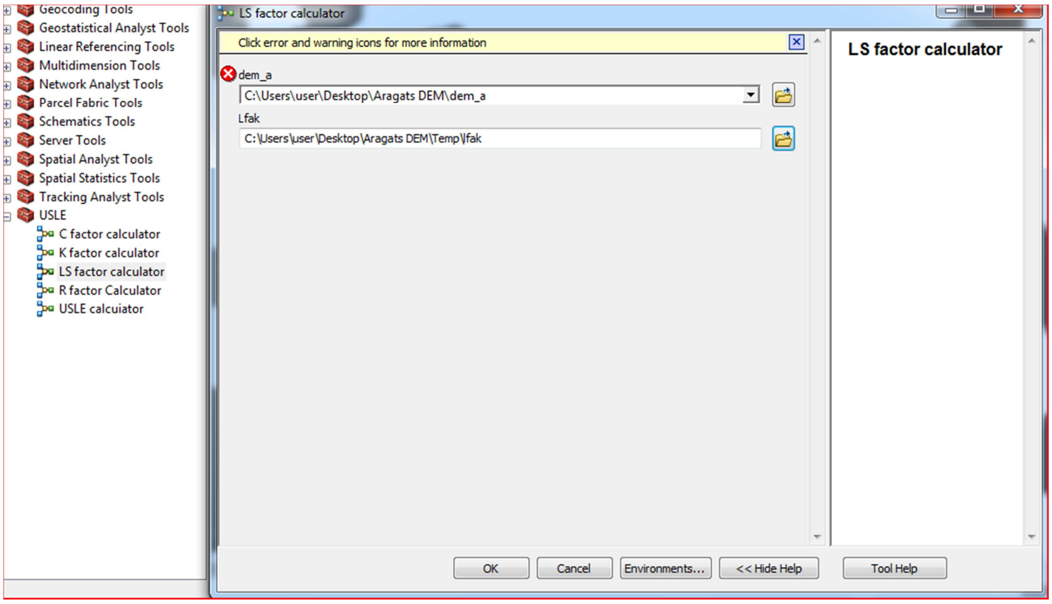

Figure 10: LS-factor calculation in ArcGIS model

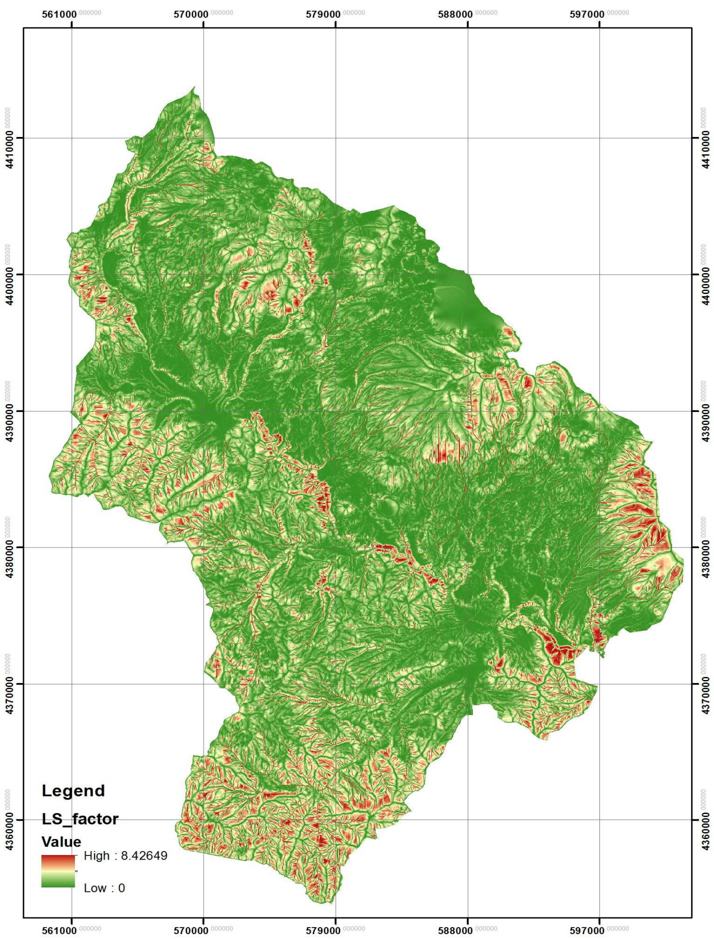

Figure 11: Results LS Factor

C-Factor:

Data needed: Landsat satellite images. They can be derived from the Glovis website (www.glovis.usgs.gov) for any specific time and area. Landsat 5, 7, and 8 are recommended for RUSLE C-factor.

For calculating the C-factor for Sisian region it was decided to apply the NDVI index. For the conventional calculation by estimating the SLR data availability was not sufficient. To calculate the NDVI Landsat 8 images have been downloaded, since they include NIR and IR bands or channels. The output raster for C-factor will be generated automatically, after selecting and uploading the right bands into the C-factor calculator (Figure 12), (Figure 13).

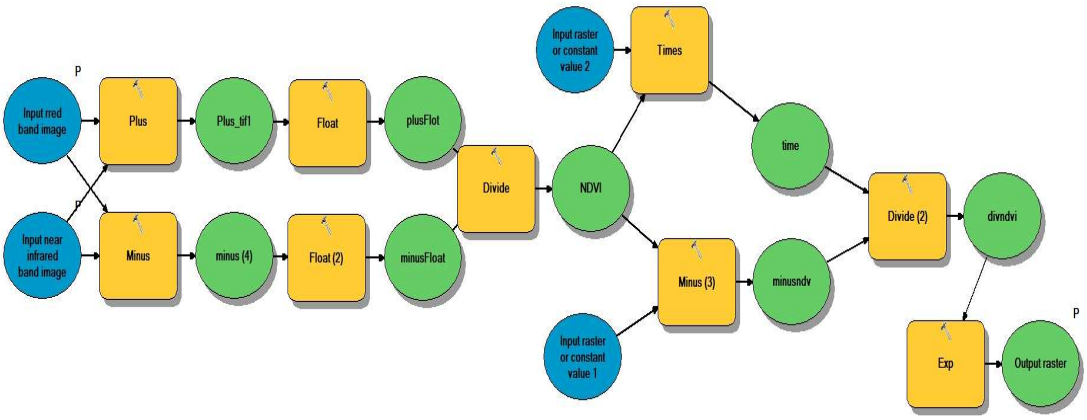

Figure 12: C-factor calculation in ArcGIS model

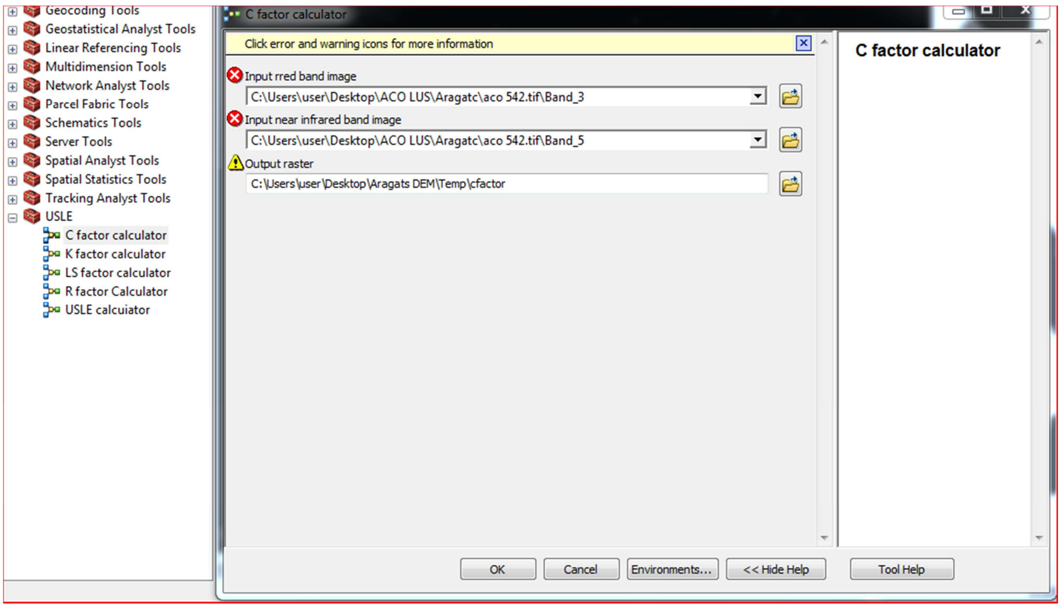

Figure 13: C-factor calculation in ArcGIS model

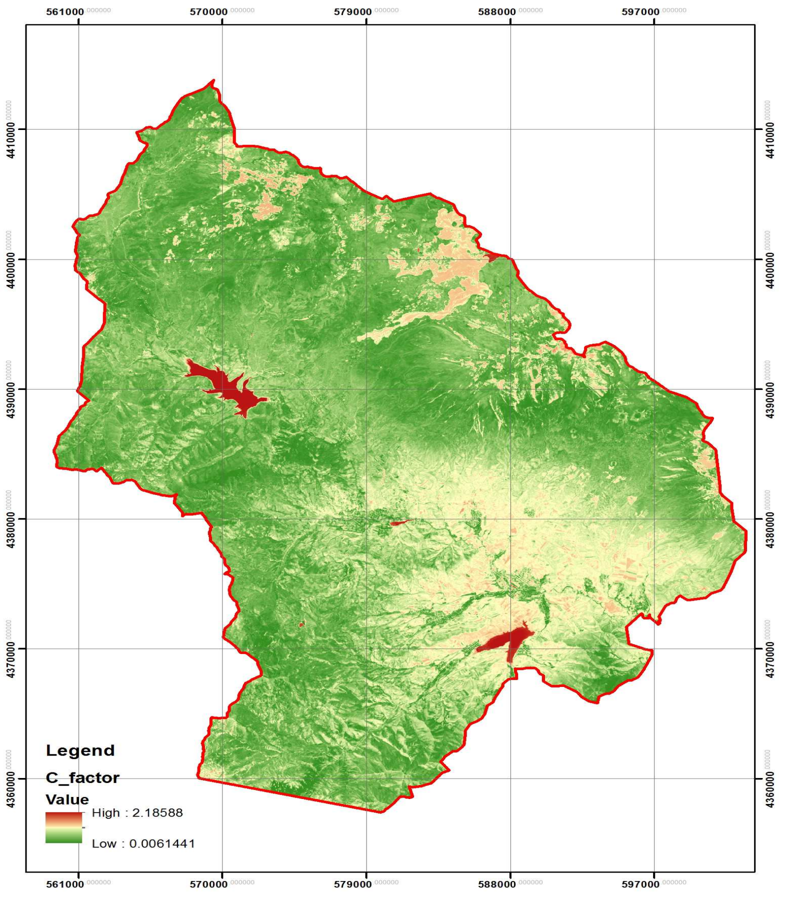

Figure 14: Results C factor

P-Factor

Data needed: Digitalized land cover or use map (1:100 000), raster grid format.

The P-factor accounts for the erosion control effectiveness of support practices. It underpins the C-factor within the RUSLE formula. The P-factor reflects the effects of practices that will reduce the amount and rate of the runoff water by modifying the flow pattern, grade, or direction of surface runoff, and thus, reduce the amount of erosion (Wall et. al., 2002).

A support practice is most effective when it causes eroded sediment to deposited far up-slope, hence, very close to the source. For example terraces or contour furrows reduce sheet and rill erosion by breaking the slope into shorter slope length, and hence increase their infiltration and the water holding capacity (see table 3 for more possible effects of different treatments. This table has been developed especially for rangelands) (Renard et al., 1997).

Table 3: Ratings of possible effects of rangelands treatment (Renard et al., 1997)

Possible effect	Treatment or implement [2] LP	PT	CH	BP	RP	RI	CF	BR	RD	TR	FL	BU
Incr. infiltration	3	3	1	2	3	1	3	2	1	3	1	0
Incr. percolation	2	2	1	1	3	3	3	1	0	3	0	0
Incr. pore space	2	2	1	2	2	3	3	1	0	1	0	0
Incr. water holding cap.	3	3	1	2	2	3	3	2	1	3	1	0
Incr. surface porosity	1	2	0	2	3	1	2	2	1	1	0	0
Incr. surface stability	3	2	1	2	2	1	1	3	1	1	1	0
Incr. roughness	3	3	1	2	2	1	2	3	1	1	0	0
Incr. seedling establish.	3	2	0	1	2	0	2	1	2	1	0	1
Decr. surface compaction	0	2	0	3	3	1	2	0	2	1	0	0
Decr. soil water evap.	2	1	1	1	1	0	1	2	0	0	3	0
Decr. surface runoff	2	2	1	1	2	1	3	1	1	2	1	0
Decr. erosion	2	2	1	1	3	2	2	1	1	2	1	0
Decr. canopy cover	3	2	2	2	2	1	1	3	0	0	3	3
Decr. competition	1	1	2	2	3	0	1	1	0	0	1	2
Treatment or implement used on:	LP	PT	CH	BP	RP	RI	CF	BR	RD	TR	FL	BU
Steep slopes	3	1	3	1	2	3	1	3	2	3	3	3
Rocky soils	3	1	3	1	2	1	2	3	2	3	3	3
Clay soils	2	2	3	1	3	3	2	2	3	3	3	3
Shallow soils	3	3	3	3	3	2	3	3	3	3	3	3
Woody shrubs	3	2	3	2	3	3	2	3	1	3	3	3
Herbaceous plants	3	3	0	3	0	0	3	0	1	3	0	3
Treatment longevity	3	1	3	2	3	3	2	1	1	3	0	2
Return/cost	3	1	3	1	2	1	2	1	3	3	1	2
Treatment or implement totals:	53	43	34	38	51	34	46	39	27	43	28	28

[1] LP = Land imprinter, broadcast seeding
PT = Pitting, broadcast seeding
CH = Chaining, cabling
BP = Brushland plow
RP = Rootplow, rangeland drill seeding
RI = Ripping
CF = Contour furrow, broadcast seeding
BR = Brush roller
RD = Rangeland drill (seeding)
TR = Terrace, broadcast seeding
FL = Flail
BU = Burning
[2] Ratings range from 0 = no effect, to 3 = greatest effect.

Values for the P-factor of rangelands are computed in RUSLE with the equation:

$$P = \frac{D_y}{D_e}$$

where D_y is the sediment transported from the slope, and D_e is the sediment produced on the slope by detachment. Compare Renard (1997) for the equation of D_y and D_e.

Several calculations of generalized P-values can be found in the literature. In table 5 the P-value has been estimated based on given equations from Renard (1997) and adapted to local circumstances (Gitas et al., 2009, Shi et al., 2002) (for examples see Table 4 and 5).

Table 4: Land management type, slope and P-factor (Shi et al., 2002)

Land use type	slope(%)	*P* factor
Agricultural land	0—5	0.11
	5—10	0.12
	10—20	0.14
	20—30	0.22
	30—50	0.31
	50—100	0.43
Other land	all	1.00

Table 5: Support Practice and P-factor (Gitas et al., 2009)

Support Practice	*P*-Factor
Up & Down Slope	1.00
Cross Slope	0.75
Contour farming	0.50
Strip cropping, cross slope	0.37
Strip cropping, contour	0.25

Generally it can be said, the lower the P-Value the more effectively the practice helps to cause deposition to occur close to the source. In case of none support practices, P assumes unity and equals 1 in the RUSLE. The P-value might be the least accurate factor within the RUSLE formula, because of a deficient data base compared to that for other factors.

The P- values can be used to re-classify the land use map to obtain the P-factor map of the study area.

!! The P-factor value has not been taken into account for calculating the RUSLE, because of the lack of necessary data (information of support practices).

RUSLE calculation

After calculating each RUSLE factor and receiving one respective output raster for each factor, the final RUSLE equation can be calculated (Figure 15). As it can be seen in Figure 16, the factors will be put uploaded into the final equation calculator and the RUSLE output raster will be given. The output shows the simulated average annual soil loss (Figure 17).

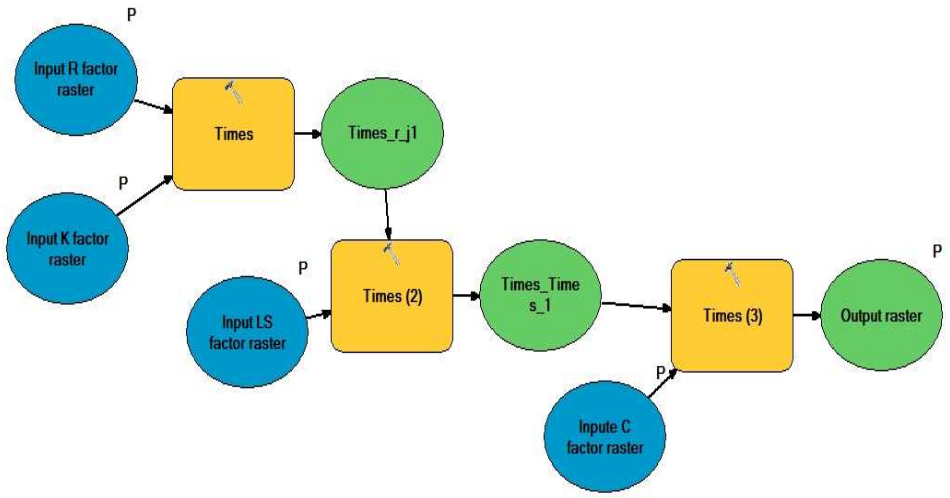

Figure 15: RUSLE tool in ArcGIS, developed by GIZ SMBP AM

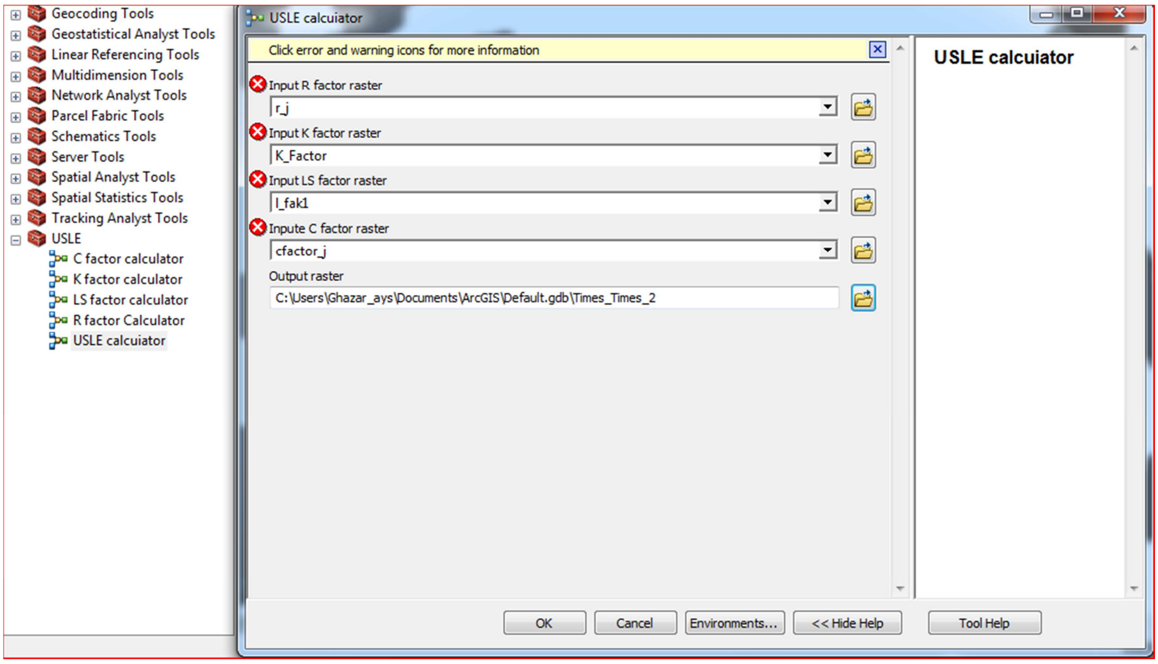

Figure 16: USLE calculation in ArcGIS model

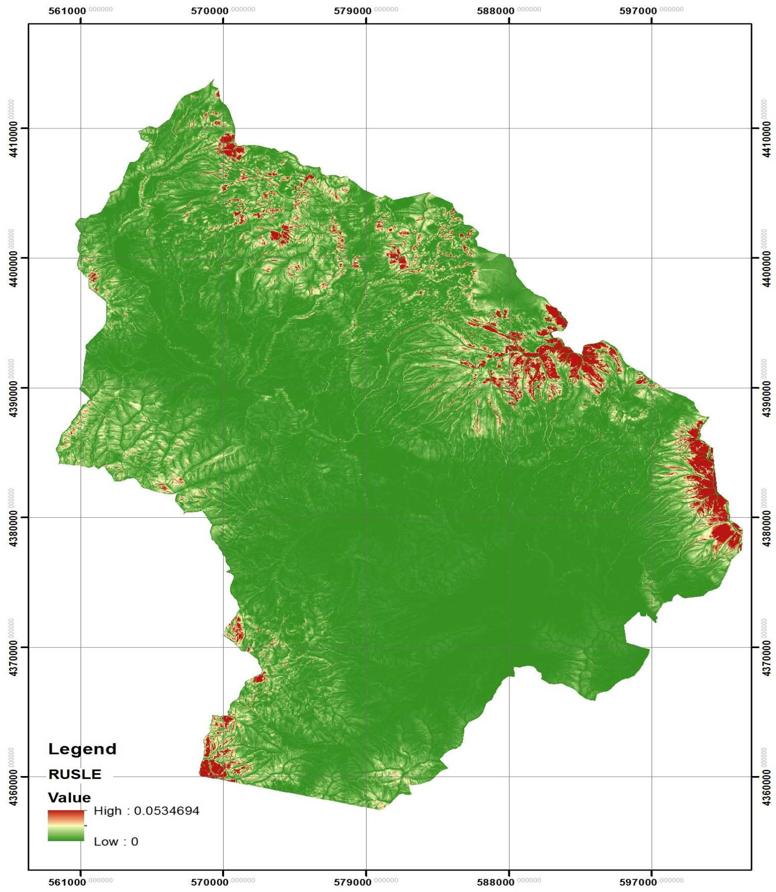

Figure 17: RUSLE output raster

The RUSLE output raster were changed to 0-100 range by applying developed scaling tools (Figure 18) with equation ((DN-min) / (max-min)*100), in ArcView raster calculator: ((Float ("%Input value raster%") - "%min%") / ("%max%" - "%min%")) * 100.

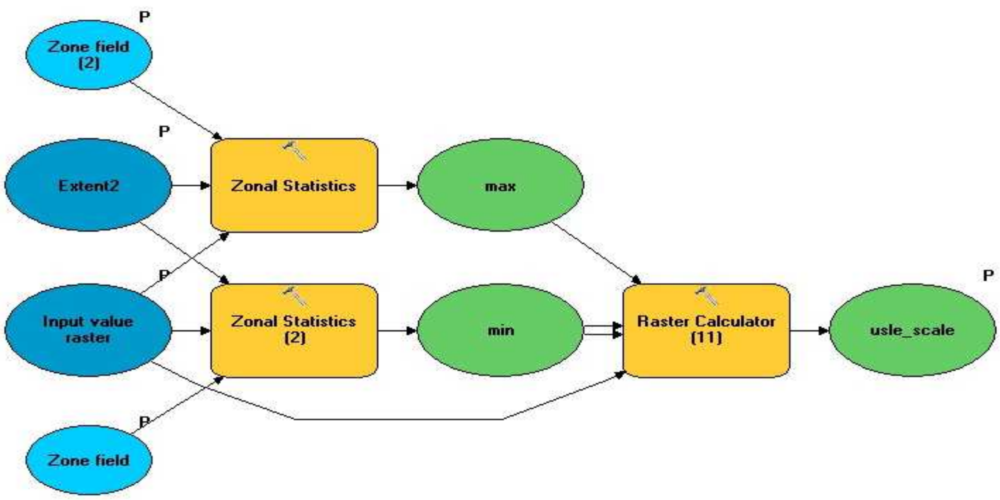

Figure 18: Scaling tools

The next step is normalizing of the scaled raster. The range of values was reclassified (reclassification tool (ArcGIS)) into the new single values (Figure 19) according to the table on weighting of erosion level (Figure 20).

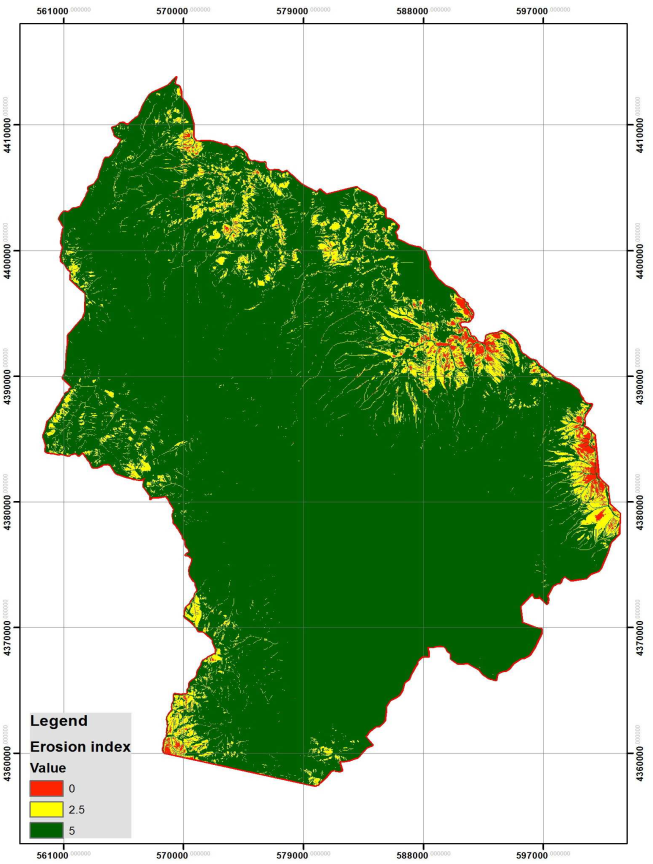

Figure 19: Erosion risk by 3 classes (low, middle, high)

Table 6: Classification of erosion risk

Index range	Risk to erosion level	Traffic light	Traffic light as numerical figure
68-100	Low risk	Green	5
34-67	Medium risk	Yellow	2.5
0-33	High risk	Red	0

The numeric values have been reclassified into 3 classes (low, middle, high) of erosion risk. As mentioned before, this reclassification is also used to regulate possible errors, by bringing the assessment of absolute soil loss in a particular location, into a relative and comparable ordinal ranking.

6. Calculating the state of pasture-index of one management unit

6.1 Remote sensing data

Spatial distribution of Leaf Area Index was estimated on the basis of one satellite image: Landsat 8 OLI (09.08.2013). The image was radiometrically and atmospherically corrected. The atmospheric correction was carried out applying the ATCOR-2 tool. All data sets were projected into the WGS-84 coordinate system. Several Spectral Vegetation Indices (SVI) were tested in order to obtain the spatial distribution of LAI from Landsat 8 OLI: Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI).

Vegetation index was calculated by using Raster Calculator (ArcView 10).

NDVI=(NIR-RED)/(NIR+RED) was calculated by using Raster Calculator (ArcView 10):

- (Float("%B5.TIF%" - "%B4.TIF%")) / (Float("%B5.TIF%" + "%B4.TIF%")).

Soil Adjusted Vegetation Index (SAVI) was calculated by using Raster Calculator (ArcView 10):

- ((Float("%B5.TIF%") - Float("%B4.TIF%")) / ((Float("%B5.TIF%") + Float("%B4.TIF%") + 0.5))) * (1 + 0.5)

6.2 Predicting LAI and its mapping

Leaf Area Index is one of the most crucial structure characteristics describing vegetation canopy structure and it is closely related to evapotranspiration, biomass, photosynthesis, primary productivity, interception and many other processes with significant influence on the exchange of matter and energy between ecosystem and the atmosphere. Accurate estimations of LAI are essential for biomass assessments which are necessary for the characterization of pasture ecosystems and rational management.

The models LAI-Spectral Vegetation Indices (SVI) for each date to predict LAI were evaluated according to Gong et al. (1995) methodology. LAI and Vegetation Indices were the dependent and the independent variables, respectively. For each date, the samples were split into two groups, predicting and testing. The predicting group was used in the coefficient estimation to establish the prediction equations, while the test group was used to calculate. Separation between samples of each group was made randomly.

The NDVI index was chosen as the best predictor of Leaf Area Index. The linear regression model presented in Figure 20 was used to estimate spatial distribution of LAI on the basis of Landsat 8 image:

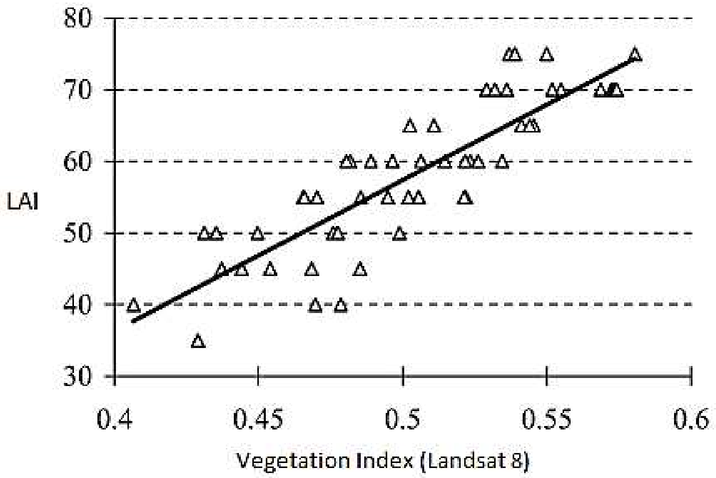

Figure 20: LAI developed on the basis of field measurements and NDVI and linear regression model (R^2=0.73).

Equation for linear regression model: LAI=21.828*NDVI-12.118

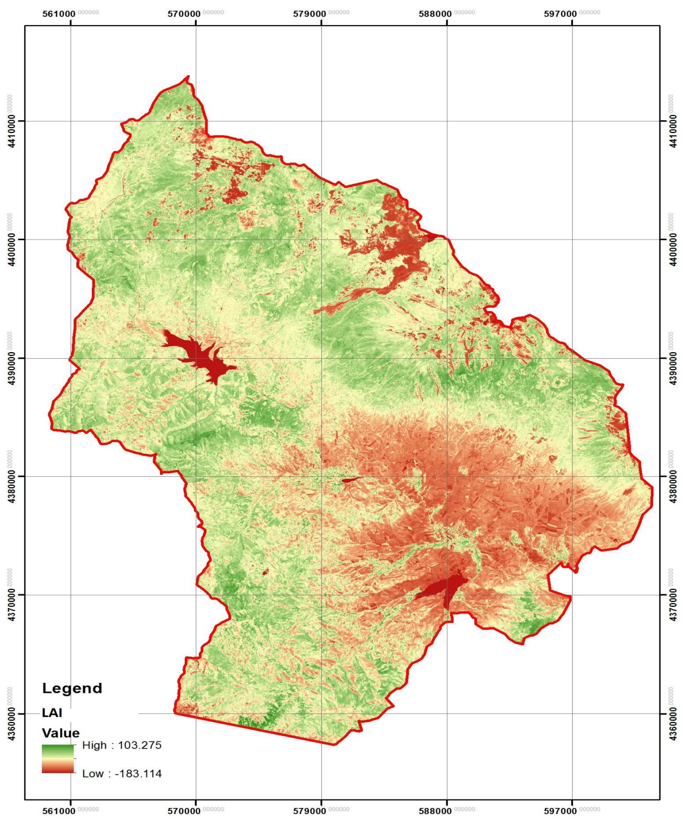

Figure 21: Map of LAI

6.3 Predicting SAVI/UPP and its mapping

A selective grazing lead to competitive replacement of palatable grasses by unpalatable grasses is based upon that the competitive ability of the palatable plants species is higher than the one of unpalatable plants species in absence of grazing.

The establishment of a regression model for PUG (Figure 22) followed the same procedure for LAI, based on collected data for unpalatable plants/UPP (dangerous and poisonous) var.19 percentage of economic elements (3.3.3) (according to the “Manual for Monitoring of Pastures, Armenia”) and processed SAVI (Landsat 8).

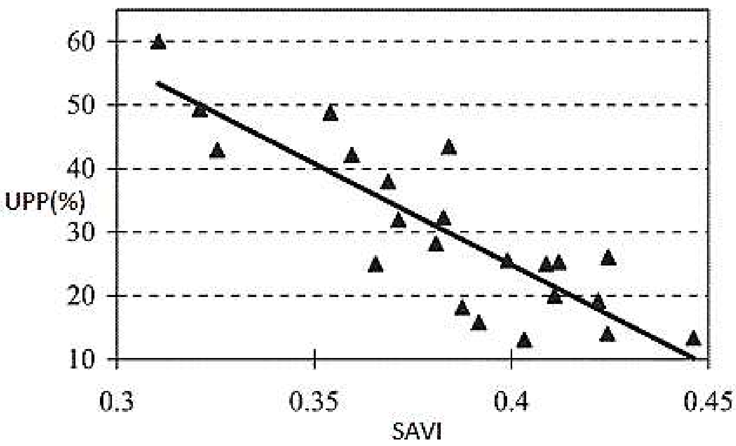

Figure 22: Linear regression model (R^2=0.71) of UPP (unpalatable plants %) developed on the basis of field measurements and SAVI.

Equation for linear regression model for SAVI/UPP=-318.26*SAVI+152.13 (R^2=0.73).

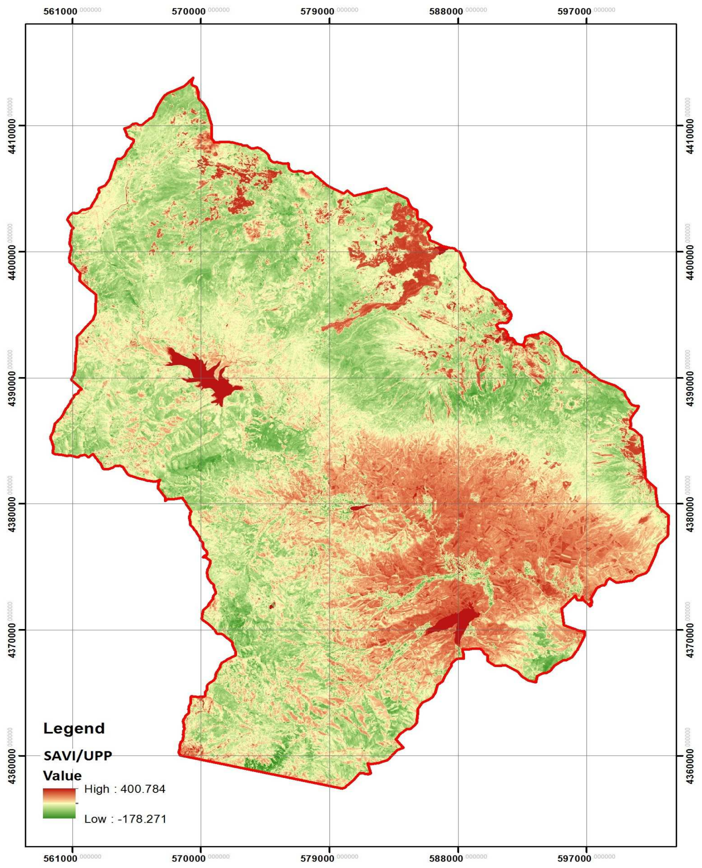

Figure 23: Map of SAVI/UPP

6.4 Direct LAI measurement- Field data processing

Field measurements were conducted by using a stratified sampling design during August, 2013. The sample sites were mainly located with considerable respect to travel distance and availability. Measurements were performed at 46 locations covering the most typical vegetation found in the research area. In every location sample plots were established according to community based pasture monitoring guideline. Handheld GPS receivers were used for localization of the measurement points.

"Ground-truth" data (canopy height (cm), canopy cover (%), above ground fresh biomass (g/m2), and the number and name of plant species) was collected and measured based on frame (1m^2 in size) of the sampling plot (Figure 24).

Figure 24: Grass cut off within the 1m^2 on sample occasion

On future in situ ground indirect measurements of LAI can be performed by using indirect non-contact LAI measurement methods: LAI 2000 Canopy Analyzer tool, using digital camera with Veg Measure software, etc.

6.5 Calculation of Pasture Degradation Index (PDI)

Pasture Degradation Index (PDI) is calculated by Leaf Area Index (LAI) and SAVI/UPP Indices processed by satellite images and integrated based on weighting requirements of “Manual for Monitoring of Pastures, Armenia”.

The LAI and SAVI/UPP maps independently produced were combined to form an overall map so that degradation could be assessed more efficiently (Figure 25).

$$DI = 0.5\ (1 - LAI) + 0.5\ SAVI/UPP$$

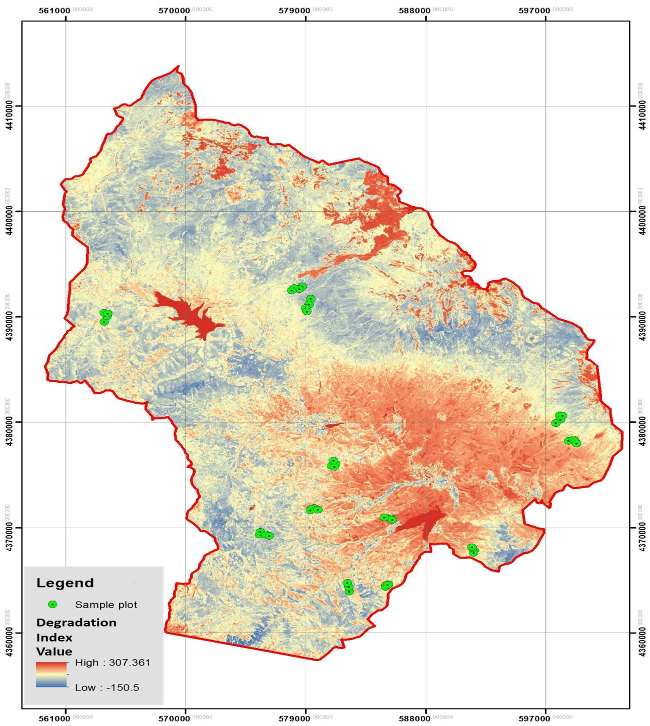

Figure 25: Degradation index

Degradation Index ranges of LAI and SAVI/UPP raster's were changed to 0-100 range by applying developed scaling tools (Figure9) with equation ((DN-min) / (max-min)*100), in ArcView raster calculator: ((Float ("%Input value raster%") - "%min%") / ("%max%" - "%min%")) * 100. (Fig. 26):

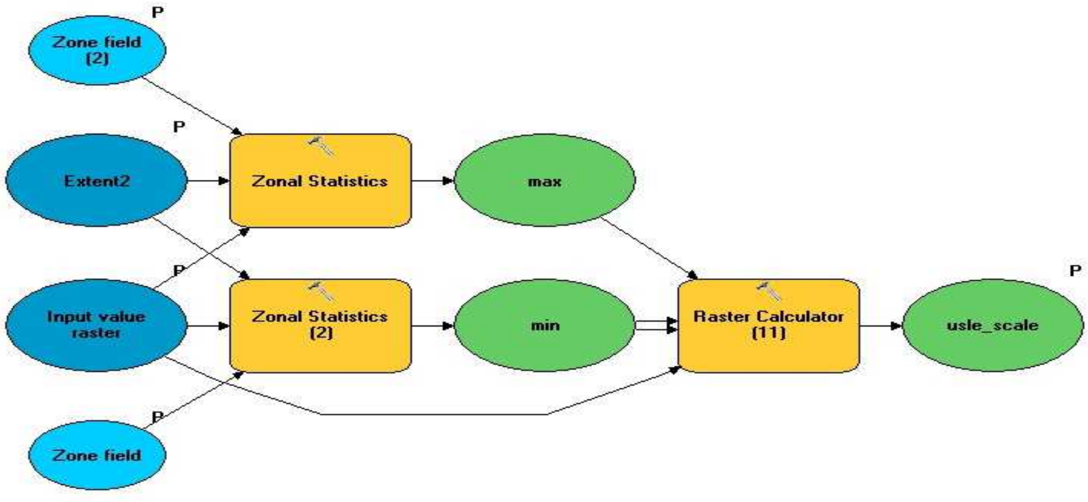

Figure 26: Scaling tools

The next step is normalizing PDI. The original raster with old range of values was reclassified (reclassification tool (ArcGIS)) into the new single values (Figure 27).

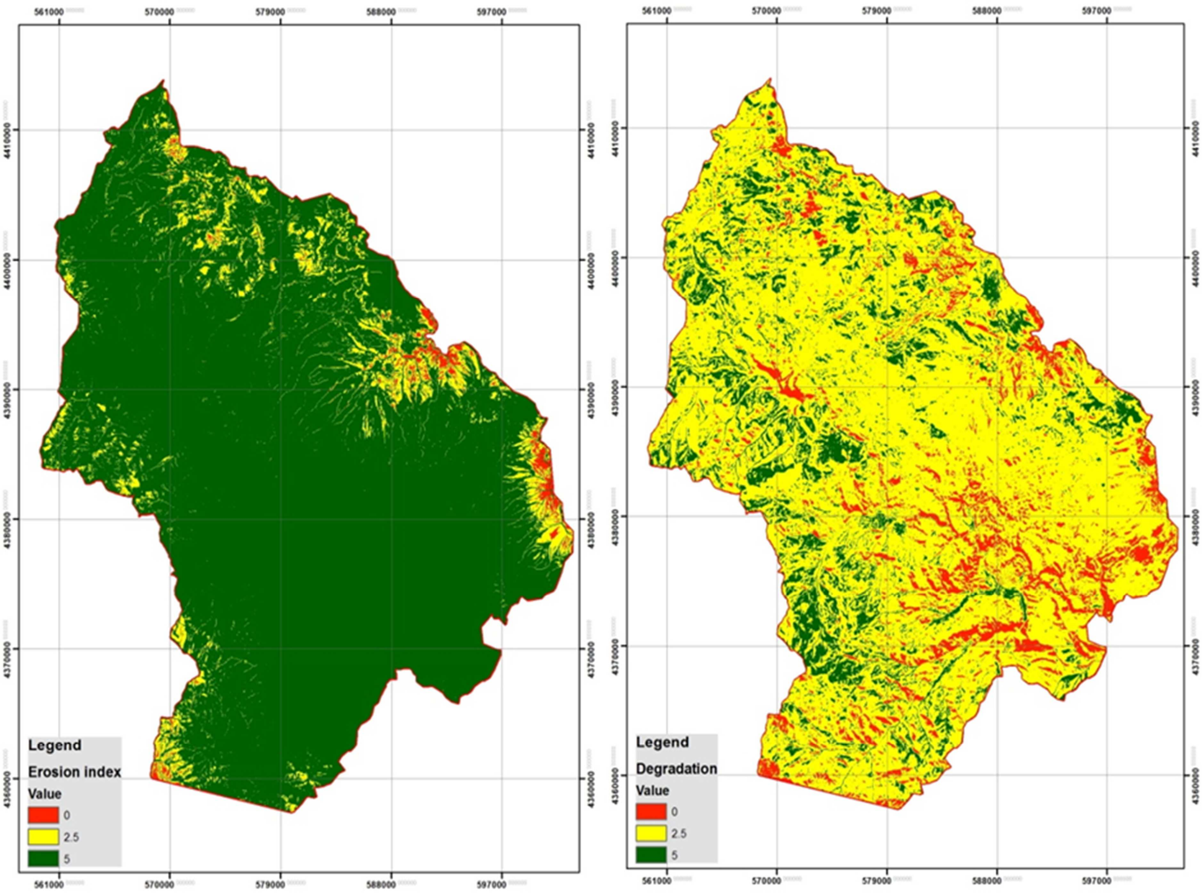

Figure 27: SEI and PDI maps

6.6 Calculating the state of pasture-index of one management unit (SPI-MU)

For giving management recommendations you combine both indices to calculate the State of Pasture-Index of one management unit (SPI-MU). This index is calculated as the sum of SEI-MU and PDI-MU (Figure 28.).

SPI-MU=SEI-MU + PDI-MU

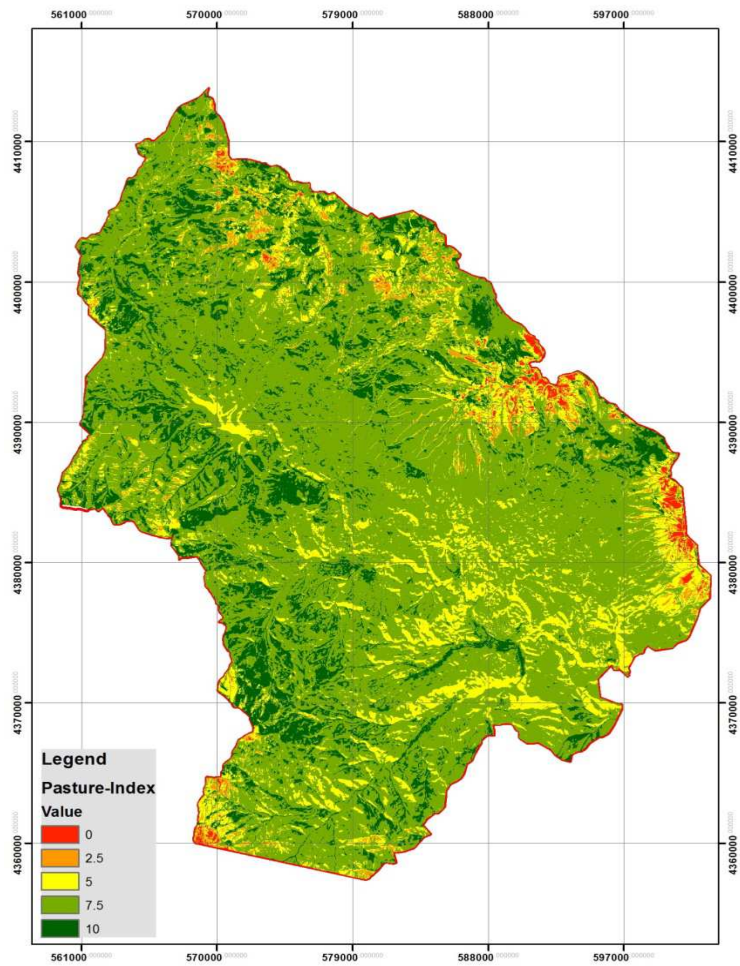

Figure 28: State of Pasture-Index

The stocking rates cattle units per ha (SU/ha) based on the possible SPI-MU values can be calculated and mapped by using raster calculator (ArcGIS) according to requirement of Table 7:

Con("%AIC%" == 10, 1, Con("%AIC%" == 7.5, 0.8, Con("%AIC%" == 5, 0.6, Con("%AIC%" == 2.5, 0.4, Con("%AIC%" == 0, 0))))) equation.

Table 7: Management Recommendation based on SPI-MU

Coefficient	Number of cattle (Stock Unit) per hectare
10	8 SU/ha
7.5	5 SU/ha
5	4 SU/ha
2.5	2 SU/ha
0	0 SU/ha

7. Conclusion

In conclusion, the sensitivity assessment and calculation the state of pasture-index of Sisian area revealed areas with low to high grazing capacity, based on which rotational grazing systems can be developed and rehabilitation measures planned by farmers or local municipalities.

This information has been shared by GIZ SMBP AM with the land management department of the RA Ministry of Agriculture.

One main purpose of this assessment was to supply the governmental partners with primary and processed information on the environmental condition of the study area. This information can then be used for planning and monitoring activities. It aims to change policy strategies in a way so that sustainable management of ecosystem will be improved (top-down management).

Another purpose of the assessment is to share results with a wider audience. Hence, a Pasture Management Information System (PMIS) is planned to be developed within GIZ IBiS AM (planned for 2016) in combination with the already existing Forest Management Information System (FMIS). It shall serve, inter alia, as a mean to facilitate information exchange, reporting and communication among various stakeholders and, therefore, create transparency on the conditions of pastures in Armenia. In particular, concerns of the quality of pastures shall be highlighted, which in turn shall influence and improve decision making processes with regard to sustainable pasture management and controlling of soil erosion. The sensitivity assessment represents only one part of the planned PMIS data base. The PMIS shall moreover include all necessary information on pastures in Armenia to allow transparent monitoring and planning of pasture lands.

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