Final Report for project 18.2062.0-003.00 in the frame of programme “Management of natural resources and safeguarding of ecosystem services for sustainable rural development in the South Caucasus”

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1. List of abbreviations

BR	Biosphere Reserve
DEM	Digital Elevation Model
DTM	Digital Terrain Model
ECOserve	Management of natural resources and safeguarding of ecosystem services for sustainable rural development in the South Caucasus
EMA	Ethiopian Mapping Authority
GD	Group discussion
GDEM	ASTER Global Digital Elevation Map – free of charge
GEE	Google Earth Engine
GIS	Geographic Information System
HM	Hydrologic modelling
IDI	In-depth interviews
LSU	Landscape Units
LULC	Land Use Land Cover
MLA	Machine learning algorithm
NDVI	Normalized Difference Vegetation Index
PRA	Participatory Rural Appraisal
RF	Random forest classifier
RS	Remote Sensing
TWI	Topographic Wetness Index

2. Introduction

The German programme "Management of natural resources and safeguarding of ecosystem services for sustainable rural development in the South Caucasus" (ECOserve) aims at sustainable use of natural resources in the South Caucasus incorporating political partners, like the Ministry of Agriculture (MoA) in Azerbaijan. The following report is located under this umbrella programme.

Grassland areas in Azerbaijan are under heavy anthropogenic pressure. To support the Ministry of Agriculture (MoA) in management decisions to sustain the ecosystem services and bride the gap between different claims on land, a countrywide baseline on grassland was developed by the predecessor programme of ECOserve. In cooperation with the Aerospace Center (DLR) the "Grassland extent and condition mapping of Azerbaijan" (GRAZE) developed a 1. grassland/non-grassland map; 2. Estimation of grassland productivity and condition and 3. Degradation of grassland areas.

In general, the objective of this study is a detailed analysis of the generated GRAZE outputs. The approach of GRAZE was to derive information of the spatial extent, the productivity and status of degradation of all pasture types with remote sensing methods from spatiotemporal satellite imageries. While the development of a grassland mask was straight forward based on recent Sentinel2 imageries (2018)[1] with satisfactory accuracy results, the analysis of condition and degradation was based on historical imageries (1987, 2000, 2006, 2010, 2015, 2018)[2] using the Normalized Difference Vegetation Index (NDVI), which is widely employed to assess vegetation conditions and productivity. Linear regression overall years failed to show a statistic significant trend for degradation. As a result, only the year 1987 and 2018 was compared.

To verify the GRAZE results, we collected sample points in all grassland types, which we used to verify the spatial extent (grassland, non-grassland) and present degradation. To estimate the degradation, we used a two-sided approach in the field (see Figure 1: General work flow). Degradation is a process over time caused by disturbances from which the ecosystem cannot recover. The drivers of pasture degradation are associated with specific social, economic, political, and environmental conditions. In general, the relationship between pasture degradation and intensity/frequency of natural disasters (landslides, fire, drought), poor income distribution, marginalization of rural populations, land ownership conflicts, concentration of small farms, regional political instability, health problems, and unsustainable land use, when livestock and forest conversion to pasture are used as a mechanism for land speculation.

To evaluate the degradation state without having high resolution temporal in-situ plots, we decided to ascertain the pasture condition conducting semi-structured interviews with herders[3]. The collection of stratified random sample plots with the sampling of indicator species for grazing and application of Etzold&Neubert monitoring system (2016), was used for verification and evaluating the newly developed degradation system.

[1] According the GRAZE report (p.26) recent grassland cover was derived from Sentinel2 Sensor.
[2] According to GRAZE report (page 2), the time time series (change detection) was performed on Landsat8, Landsat5, Landsat4 Sensor.
[3] Precondition for selecting interview partner was the grazing at least for 5 years of the same pasture.

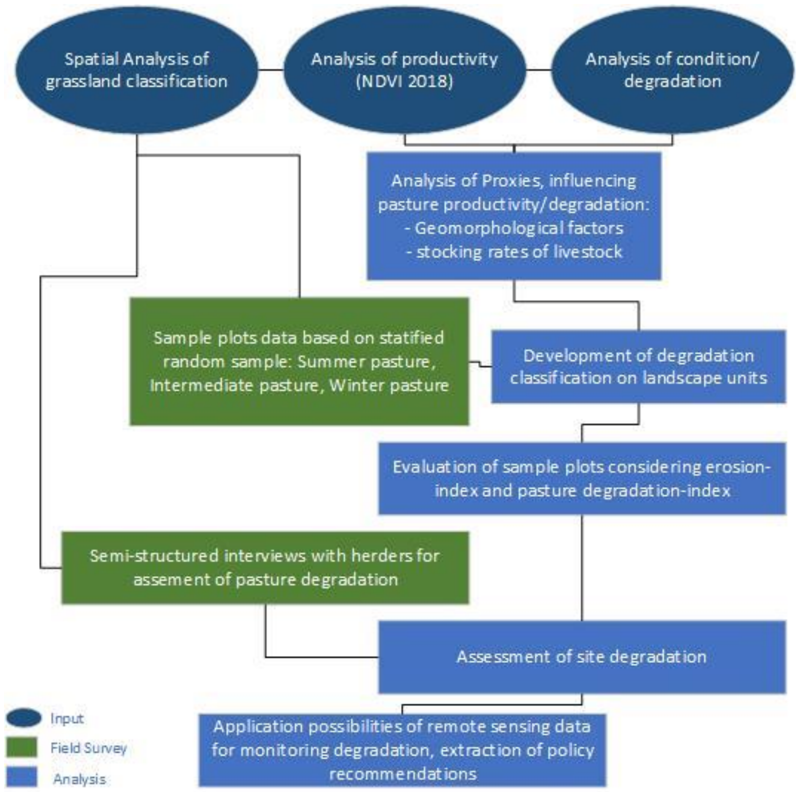


Figure 1: General work flow

a. Interviews with herders

A combination of data collection instruments was used in this study. A semi-structured questionnaire was used to collect data on spatiotemporal grazing pattern, livestock numbers, development of grazing quality since visiting the summer/winter pasture. Main purpose of conducting interviews with herders was to understand the temporal dimension in pasture development. As there was no historic data able to be referred as baseline of pasture, we tried to capture this component with interviews.

In total 10 interviews were collected in different ecosystems. Due to the small number, a quantitative evaluation was not possible. Anyhow, qualitative information was used to broaden the view for finding additional proxies explaining pastures' degradation. Taking more samples in the future could improve the spatial distribution and probably reveal differences in spatiotemporal movements according to different ecosystem complexes in Azerbaijan.

b. Sample plots

To have a second instrument for evaluating the condition of pastures, we used the monitoring manual for summer and winter pastures from Etzold and Neudert (Etzold, 2013; Etzold *et al.*, 2017). In total we captured 17 plots, thus the evaluation scheme recommended in the manuals had to be slightly adopted to low numbers. The number of samples is too low to satisfy the requirements for statistical significance (Falissard, 2012). They were used to show the potential of described degradation classification 4 (page 15). Results of all plots can be found in the appendix (chapter 10.i; page 31).

3. Evaluation and use recommendation of GRAZE data

Due to the cooperation between GIZ and MoA a countrywide grassland baseline was developed. The follow up programme ECOserve extended the information with grassland type and condition mapping in Azerbaijan. The "Deutsches Zentrum für Luft- und Raumfahrt" (DLR) with the research project "Grassland extent and condition mapping in Azerbaijan" (GRAZE) derived the spatial extend of Azerbaijan's grassland and its condition from historic and recent satellite imageries. The time series was built on 5-year time steps beginning in 1987 up to 2018 and used for interannual Normalized Difference Vegetation Index (NDVI) comparison purposes[4]. The result generation (preprocessing, classification, change detection) was performed with the cloud-based platform google earth engine (GEE). Apart from selected outputs in raster format the complete GEE code is attached in the report. A complete re-run for the actual study was not possible due to missing training samples for the supervised grassland classification. The used classification method is widely known as neural network analysis. Based on specific training areas (defined during the run of the model), the neural network creates a set of decision trees from randomly selected subset of training sets. It then aggregates the votes from different decision trees to decide the final class of the test object. A rerun is only possible with the exact same points, otherwise it will generate different outputs. As stated in GRAZE report (p. 4), 60% of the biomass data points were used for calibration of the model while 40 % of the samples were hold back for accuracy issues it was not possible to use the whole biomass assessment samples. In the case, a rerun of a model or script is conceivable, it is recommended to stipulate deliveries also including input variables.

a. Grassland mask

According to the GEE code, a complete landuse classification was performed by using a pixel-based supervised random forest (RF) machine learning algorithm (MAL) using ground samples from the ECOserve field mission (Aug – Oct 2018). The random forest classifier (RF) applied, is an integrated package in the machine learning (ML) functions of the GEE[5] and widely applied in LULC classification (Collins, Newell and Mellor, 2018; Teluguntla *et al.*, 2018; Zurqani *et al.*, 2018). According to GRAZE, the grassland was derived from the optical sensor Sentinel2 with a spatial resolution of 10m. The provided geodata representing the actual grassland (2018) have a spatial resolution of 30 m.

It was not clear why the classification from Bayramov et al (Bayramov, Buchroithner and Bayramov, 2016) was not used. The overall accuracy with 87% was even higher for year 2015. It is recommended to compare the results from Bayramov with those of GRAZE. This was not possible in so far due to a lack of geospatial data.

i. Accuracy

The error matrix indicates an overall accuracy of 83 % and Kappa coefficient of 0.82. The lowest accuracy is between the classes "grassland" and "bushland" (6.7%) with omission errors (9 pixels

[4] Due to the controversial discussion in scientific reports whether time-series of NDVI are appropriate to capture pastures' degradation we decided to work on the latest image (2018) and compare the potential NDVI of one LSU. Apart, mythologically it seems to be important only to include the vegetation period for estimating the NDVI. The spatial outputs of the GRAZE study included only accumulated means per year.

[5] GEE explanation: https://developers.google.com/earth-engine/classification (visited on 28.10.2019)

should have been classified as “grassland” were omitted from that category) underestimating the extent of grassland. Misclassification happens in both directions as shown in Table 1.

“Bushland” classified as “grassland”	“Grassland” classified as “bushland”
	
Western steppe Zone of Mingachevir Reservoir with bushland and Juniper woodland, classified as grassland (47°2'23,059"E 40°52'35,287"N)	Mountain steppe close to Iranian border (48°23'13,818"E 38°39'47,559"N)

Table 1: Misclassification of "grassland" with "bushland" and vice versa

It is recommended to revise the “bushland” classification, as suggested in GRAZE with an enlargement of “bushland” samples. The fact that both classes in nature have fuzzy borders to each other should be concerned. This and the spatial resolution of 10 m (Sentinel2) might impede a good class distinction.

For the evaluation of the pasture condition, the fact that both classes intermingle does not affect the result. According to personal communication with J. Etzold (27.08.2019) and visual detection in the field, grazing is practiced in both landcover classes.

The GRAZE pasture types were derived with a post classification method, based on a free digital elevation model (DEM)[6]. Accordingly, the grassland types are:

Pasture type	altitude	Size (ha)	% of total land use[7]
Summer pasture	>1800 masl	295,387.1	4.3
Intermediate pasture	>800 masl <1800 masl	459,237.6	6.5
Winter pasture	< 800 masl	2,204,843.5	31.8

Table 2: Grassland extend and grassland type classification according to GRAZE (own calculation)

The Table 3 is a summary of grassland types used in international literature. The grassland type “intermediate pasture” introduced by GRAZE is not described. The term is neither used by the MoA and the questionnaires with herders reveal a local classification in “summer”, “winter”, and “village” pasture. The term “village” pasture is also present in literature. According to expert information, instead of “intermediate pasture” the term “spring pasture” is sometimes used. The heterogeneity of terms and semantic addresses a need to set up a country wide classification scheme on pasture types.

Source	Landuse	Size (ha)	% of total land use
(Etzold, 2015)	Pasture	2,576,500 ha	29.7 (8641500 ha)
	Hayfields	109,600 ha	1.3
Aliyev 1965; found in:	Summer pasture	859,221 ha	9.95 (86374409368 ha)

[6] SRTM - Shuttle Radar Topography Mission, Open data

[7] Percentage is based on study boundary “GRAZE”

(Neudert, 2016)	Winter pasture	1,902,692 ha	22
Mamedov 2003; found in (Neudert, 2016)	Summer pasture (>1700masl)	600000 ha	7
	Winter pasture (< 700 masl)	1700000 ha	20 (8500000 ha)
(Kosajev and Guliev, 2006)	Summer pasture (>1600masl)	600000 ha	7
	Winter pasture (< 700 masl)	1780000 ha	20,5

Table 3: Grassland types in AZ according to literature

International literature of pasture referring on “winter pasture” and “summer pasture” (Succow, 2009; Etzold, 2013, 2015; Neudert, 2016; Etzold *et al.*, 2017); Leeuw *et al.*, 2019) and “village pasture” (Etzold, 2013; Neudert, 2016), while “intermediate pasture” is not described.

It is recommended to harmonize the sematic of pasture types (also the altitudinal border for separation). Instead of using “intermediate pasture” the term could be substituted by “village pasture” (by using a spatial buffer around villages). Interviews in the field with herders show, that the altitudinal border to divide between “summer” and “winter” pasture is often at lower altitudes starting sometimes from 1550 masl. This seems to match with the classification introduced by Kosajev and Guliev 2006 (see Table 3).

Due to different country or study borders, neither the spatial extent of pastures in the whole, nor the different pasture types are comparable from GRAZE and literature. As GRAZE reports a total share of 32% land coverage for only winter pasture, Etzold 2015 give a number of 30% land coverage for all pasture types. It is recommended to harmonize the pasture mask with the extend used by MoA or always prepare two numbers (whole country, study area).

The GRAZE study researched the change of vegetation intensity but not the change of land use and spatial extent of pasture land during the years. For the time series, a grassland mask of 2018 was used. It is recommended to include this kind of analysis because land use change from pasture land to agriculture is happening and a very dynamic process.

Field visit, recent land conversion from pasture to agriculture (9.09.2019 | 48°25'9,604"E 38°47'10,547"N)	Satellite imagery from 06.10.2019 showing whole extent of land conversion (photo taken at green marker).
	

Table 4: Land conversion (pasture land towards agriculture)

According to personal communication with Hartmut Müller (26.08.2019), the land conversion is happening to a bigger extent especially in former steppe (used as winter pasture). In recent satellite imageries, it is possible to detect new land conversions which are irrigated according to their pregnant spatial pattern. Further studies on the land use dynamic seem to be important and could help to identify a trend or revealing a bottleneck effect for pasture land in specific districts.

b. Information on productivity (intra-annual analysis)

The productivity of grassland in GRAZE is derived from the mean NDVI of all Sentinel2 scenes in the year 2018 aggregated every month. The NDVI reflects vegetation density or greenness of the land cover and thus can be viewed as a holistic indicator of plants' development condition. The period for NDVI calculation was selected from January to December ('2018-01-01', '2018-12-31'). This method is used also in other studies in the Caucasus region and Asia (Jiang *et al.*, 2006; Wessels, Bergh and Scholes, 2012; Karnieli *et al.*, 2013; Eckert *et al.*, 2015; Wiesmair, 2016; Shahidian, 2018; Zhumanova *et al.*, 2018). In general, the productivity derived from NDVI can show areas with high values within the ration between 1 and -1, while high values indicate photosynthetically active biomass and high vegetation coverage degree in one pixel.

According to the classification (grassland - non-grassland) the distinction between bushland and grassland is not possible. Concerning the availability for grazing purposes, this misclassification is not crucial – grazing is possible in both land cover classes. When it comes to the potential productivity, the misclassification is influencing the result. Due to a different spectral reflectance of bushland (e.g. Artemisia spec.) carrying more lignified material, the NDVI values are significantly lower than for grassland. Furthermore, the phenology has a very different characteristic (prolonged vegetation period for bushland). For a deeper understanding between the NDVI characteristic of bushland and grassland and its influence on the overall productivity, it would need more research. Anyhow, it seems to be important to be aware of that fact when comparing the mean NDVI value among different land cover classes.

The monthly scatterplot in the GRAZE report (Figure 12; Figure 13; Figure 14) for all different pasture types highlights the shifted vegetation period in between the "summer", "winter" and "intermediate" pasture which coincides with empiric data and literature. While the "winter" pasture has its vegetation peak between February – April. As Neudert 2016 describes "winter pastures are usually grazed from the beginning of October to the beginning of May" … The mean NDVI of the whole country is lowest in October. According to interviews, all herders have to leave the summer pasture due to harsh weather condition in October. Accordingly, October is a kind of bottleneck month concerning vegetation quantity. Interviewed herders described also, if fodder scarcity in winter pastures is severe, they provide additional fodder (mostly locally-produced forage, barley grain, Alfalfa, hay).

The scatterplots show clearly a 2-week retardation after precipitation peak. Due to the very heterogenous interannual and spatial precipitation pattern and the strong relation between NDVI and precipitation (Xie and Sha, 2012; Kawabata, Ichii and Yamaguchi, 2014), it seems to be very important to integrate the distribution of precipitation in Azerbaijan in the evaluation scheme of grasslands productivity.

The summer pasture (GRAZE report Fig. 13/14) has its highest vegetation peak in June and the lowest vegetation provision from January till April. Interviews indicate that this period, most of the time pasture is covered by snow. Intermediate pasture shows a similar pattern like summer pasture, except the highest vegetation peak is in May. To compare the variance with the annual mean it is suggested to select the time frame only during the vegetation period for the different pasture types.

Otherwise, the absolute NDVI values within a pasture type is not comparable. The high spectral albedo of snow will generally cause the NDVI of a snow-covered pasture to be lower than the value for snow-free conditions. If NDVI is aggregated around the year, summer pastures not covered by snow, indicate higher NDVI values and could provoke misinterpretation. According to interviews, snow is a very important factor for the recovery of intensely grazed pastures. Furthermore, the evaluation of productivity would need, beside their altitudinal range, additional landscape stratification as performed in comparable studies, like (Reeves and Baggett, 2014; Jucker *et al.*, 2017; Zhumanova *et al.*, 2018) on biotic and abiotic factors. Pixels belonging to the same Landscape strata are considered to have the same ecological condition, and their NDVI is considered to be comparable. A proposed stratification on different factors is described in detail in section 4.4. "Proposed classification of grassland condition" on page 15.

Interpretations on only one year (2018) comparing the overall intensity values with each other have to be interpreted very carefully due to the different vegetation period [8].

In summary it can be stated that using the NDVI for addressing pastures' productivity, following aspects have to be taken into concern:

- High values (representing high productivity) result from photosynthetically activity of biomass. The ability to graze is not only restricted on biomass which is photosynthetically active but also on hay like meadows (close to senescence).
- The misclassification of bushland (as grassland) is crucial in terms of determining pastures productivity. As bushland with e.g. Artemisia spec. has other spectral characteristics (generally lower NDVI due to lignified branches) and other phenology (vegetation period is prolonged) which influences the mean (annual) NDVI.
- Since precipitation is one of the main influencing factors for high NDVI values, the model to show productivity should include precipitation for comparison of mean NDVI values.
- It seems to be important to compare only those NDVI values of similar biotic and abiotic preconditions. A possible methodology which is scientifically accepted, is the application of landscape units (LSU). LSU are defined on similar conditions (in this study) based on aspect, elevation and slope.
- In general, the raw NDVI values are solely not sufficient for explaining the productivity. Further research should be done on the influence of the NDVI anomalies of different land cover classes in Azerbaijan and furthermore link the biomass data towards the raw NDVI values.

c. Information on grassland condition (inter-annual analysis)

To draw conclusion about the grasslands condition and probable degradation, the GRAZE study researched the mean NDVI from a time series between 1987 – 2018. While 1987 – 2015 were covered by the Landsat sensor (with a spatial resolution of 30 m) and 2015 – 2018 by Sentinel2 data (with spatial resolution of 10 m). There are different studies showing that remote sensing can be

[8] GRAZE (page 9): *"An in-depth analysis for the year 2018 reveals that the largest percentage of low intensity pastures is located in the eastern region of the country, in particular within the districts of Absheron and Qobustan. On the other hand, higher intensity grasslands can be observed in the North Eastern part of the country (where most of the summer pastures are located) in particular within the districts of Quba and Qusar"*

used to analyze quantitative changes in vegetation cover. As the NDVI represents the “greenness” of a pixel, it is a straight forward analysis to differentiate between non-vegetation and vegetation, or “a lot” of vegetation and “less” vegetation, but it is more challenging to study changes in vegetation composition, as pasture degradation includes changes in vegetation productivity, native vegetation cover and phenology (Zhumanova *et al.*, 2018). Additionally, results from NDVI analysis are difficult to interpret, because NDVI values do not distinguish signs of degradation/conservation from impacts of adverse/beneficial natural processes.

In general, the GRAZE study indicates that there is not a statistically significant trend [9], but anyhow there are results, indicating *“that grassland intensity has been increasing for all pasture types over the years (…)”* and accordingly highest increments were observed in intermediate pastures and lowest gradual increments were observed in winter pastures.

Different studies on pasture development in Azerbaijan and the Caucasus Region in general stress degradation as a widespread phenomenon as a consequence of long-term impacts of inappropriate management practices and ongoing environmental changes (Succow, 2009; Tagieva, 2012; Neudert, 2016).

The discrepancy between the studies result and the observed pasture degradation can be explained partly by the fact that Vegetation phenology shifts in degraded mountain steppe pastures. The remote sensing study of *Zhumanova et al* (2018) in a similar setting in *Kyrgyzstan and Karnieli et al* (2013) in Mongolia researched qualitative changes in pastures using the NDVI. In the study, the presence and amount of unpalatable species were used as indicators towards degradation. While in degraded pastures, the amount of unpalatable species is statically higher than in non-degraded pastures the study revealed that the change of species composition has an influence in the annual cycle of vegetation phenology. Their model results showed that the NDVI values tended to increase with increasing degradation level. It would be interesting to research the annual green up and scene sense of the time series researched in GRAZE. Monthly mean NDVI were so far not provided as output data.

Other studies showed a shift in the growing season due to climate change (Beever and Belant, 2011; Olsen *et al.*, 2015). Considering the herders interviews, 6 of 9 observed an earlier green up on summer pastures but 2 of 9 observed an earlier senescence also. Due to the low number of interviews (n=9) a statistical significance is not given. Anyhow, this effect of shifted phenology seemed to be a well-known phenomenon among the herders.

The studies above contradict the general assumption that the higher the vegetation index value, the better the grazing conditions. This effect should be researched for Azerbaijan as well to estimate the scope of using NDVI for each grassland type.

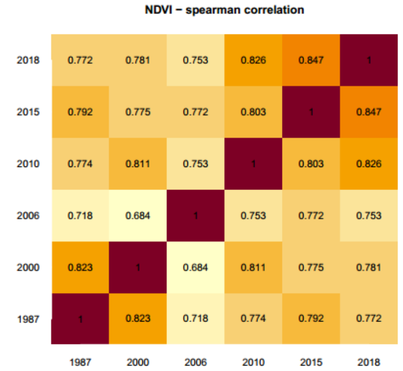
For explicit results on degradation, GRAZE uses only the NDVI values from 1987 and 2018 without any stratification. To give information about degradation, NDVI values were subtracted pixel-wise while negative values should indicate a degradation and positive values show potential areas. In the report it is stated that this method is highly explorative. Due to the fact, the NDVI is very sensitive concerning precipitation (Kawabata, Ichii and Yamaguchi, 2014) it is advised to include annual

[9] GRAZE (page 6): *“Linear regression analysis over all investigated years, which were also tested, did not yield statistically significant trends due to the low number of samples (n=6).”*

precipitation. The selection of reference years should offer the same condition or should be transformed to limit the influence of precipitation. According to herders' interview, there were severe drought years in 2015 – 2016 and 2018. The named drought periods effected in fodder scarcity. A spearman correlation on the NDVI within all years could show significant differences in 2006 (according to Imanov et al 2012 a drought year) of the GRAZE time series.

Table 3. *SPI* values for spring in the Lankaran region

Years	Lankaran	Astara	Yardimly	Goy tepe	Kalvaz
1998	−1.08	−0.90	−1.77	−0.72	1.22
1999	−0.11	0.02	0.86	0.79	−0.68
2000	−0.51	−0.42	−0.06	−0.49	−0.27
2001	−1.59	−1.90	−1.42	−1.28	−1.90
2005	−0.07	0.10	−0.64	−0.86	0.78
2006	−0.84	−0.75	−0.46	−0.73	−1.49



Source: "Investigation of droughts in the Lanjaran region of AZ", F. Imanov et al (2012)

Own source

Table 5: Anomalies in weather phenomenon

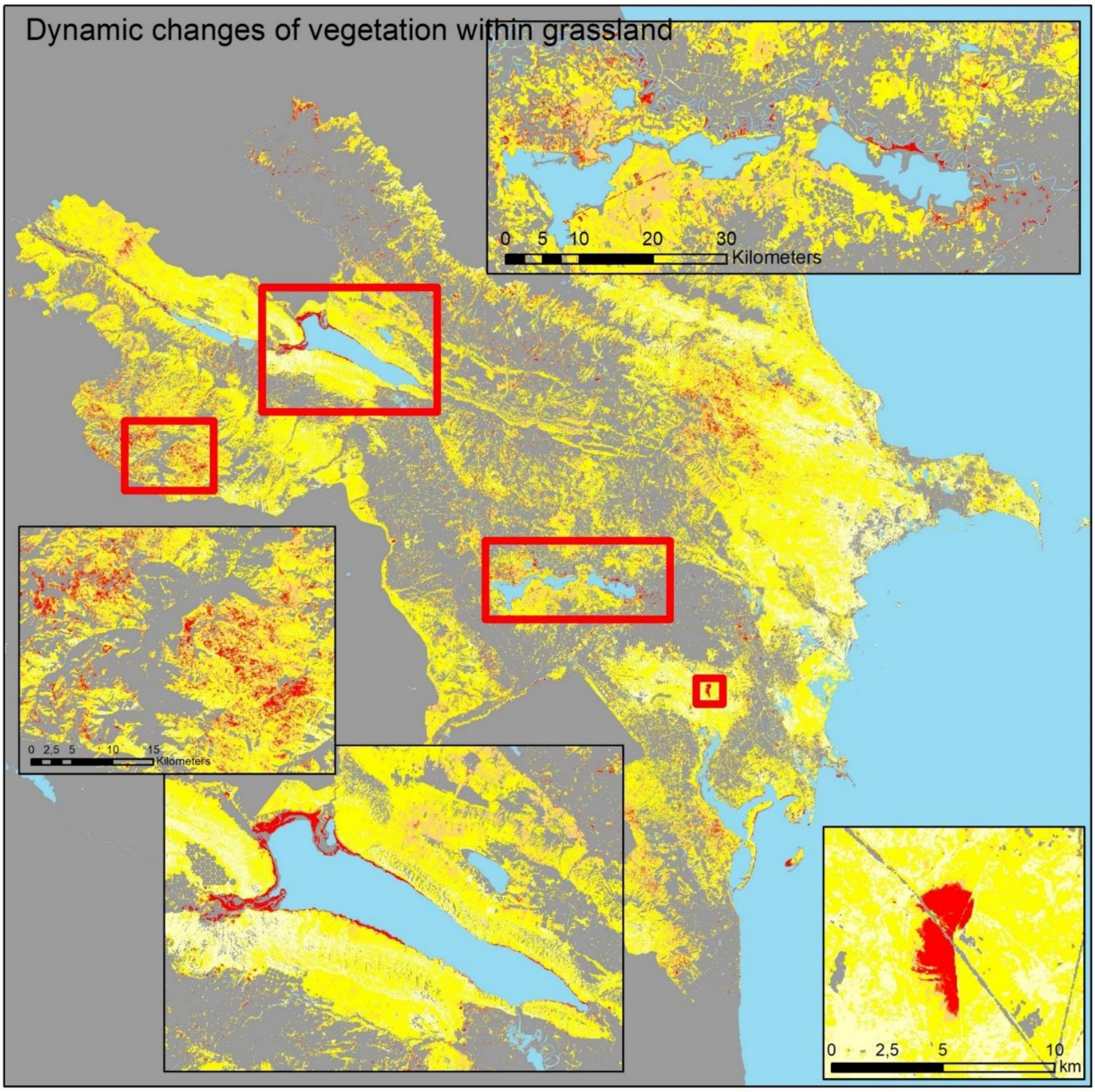
Conclusively, it can be summarized:

- To detect an interannual change in pasture condition, years with dry and normal conditions have to be evaluated separately
- To compare mean NDVI values it is important to stratify the data and identify similar sites exhibiting comparable climatic and vegetation production characteristics
- Higher vegetation index values do not automatically indicate better grazing conditions
- Research should be done on probable phenological shifts in pasture land
- The intra-annual variation of the mean NDVI could gain important information concerning degradation of pasture land

d. Derivatives from GRAZE data

i. Variance – interannual / intra-annual

We calculated the variance of all years of the mean NDVI separated for all pasture types.



Map 1: Variance of mean NDVI from GRAZE time series within the grassland mask (in red the outliers; Q_{75} – Q_{25} from mean NDVI)

According to expert interviews (GIZ, 04.09.2019) outliers surrounding inland water result from differences in water levels. Actually, these areas are recommended to be removed from the grassland mask.

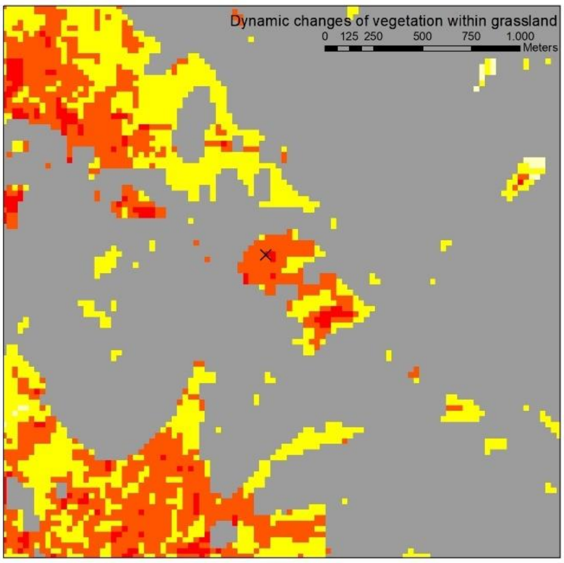
Layer	min	max	mean	std
summer	0	0,0681	0,0051	0,0041
inter	0	0,1432	0,0058	0,0041
winter	0	0,1640	0,0045	0,0052

The variance for winter pasture is lower than for summer and intermediate pastures. This highlights the importance of a landscape stratification especially in higher altitudes. The Spearman correlation underlines the strong dependency between variance of NDVI and altitude.

	var	aspect	slope	height
var	1,00000	-0,00907	0,00228	-0,10202
aspect	-0,00907	1,00000	0,34455	0,26832
slope	0,00228	0,34455	1,00000	0,66485
height	-0,10202	0,26832	0,66485	1,00000

Actually, a general conclusion cannot be drawn on the multidirectional changes but the variance from year to year could give a good impression on changes and indicate those areas important to visit. During the field visit we could observe at those spots showing a high variance, during the last 20 years a conversion of land use occurred.

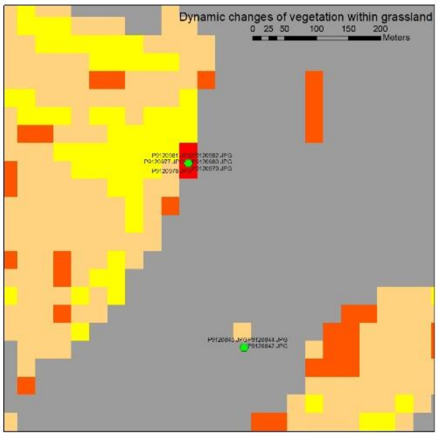
Map of variance indicating a high variance at plot



Photos of the plot; indicating land cover change from forest to grassland (45°49'25,087"E 40°32'16,308"N)

Figure 2: Variance of interannual NDVI and in-situ findings (land use change)

The effect of interannual variance could be useful to detect land cover changes. It is recommended to perform this analysis on the whole study border and not only on the grassland mask to be able to catch also LC changes beyond the actual grassland. The plot of Table 4: Land conversion (pasture land towards agriculture) is not showing a higher variance than random. It has to be taken into concern that LC change might be shown also on (small scale) erosion as shown in the following example. But other studies mostly in arid to semi-arid environments conclude also those areas and times where and when values differ significantly from random, are worthy of further investigation (Paruelo and Lauenroth, 2014; Waylen *et al.*, 2014).

Small scale pattern of high variance	Small scale erosion on the southern slope of village pasture (45°38'12,622"E 40°35'38,325"N)
	

As interannual NDVI variance has to be further researched to gain more understanding about the direction of change, the intra-annual NDVI variance is widely used. On a monthly base it could be a good proxy for estimating the pastures degradation. The studies of Zhumanova et al (2018) and Huang et al (2009), showed that pastures with homogenous communities (dominated by unpalatable species) show less variation in NDVI values than heterogenous pastures.

4. Proposed classification of grassland condition

As discussed before, the reason for change in NDVI values within the time series from 1987 – 2018 is not completely understood, a different approach for detecting and classifying levels of vegetation degradation from satellite based NDVI data was tested.

The stratification of pastures on different biotic and abiotic factors should result in almost homogenous units, where vegetation is facing the same condition and thus similar productivity is expected. This approach is also applied for identifying degraded grassland/ pasture in Reeves et al (2014) and Juncker (2017) (Reeves and Baggett, 2014; Jucker *et al.*, 2017). Since this study was conducted in pastures under long- term grazing, there were no undisturbed pasture areas, thus fenced areas like private property or hay meadows play a significant role in estimating the productivity potential.

a. Introduction

For the degradation assessment, we analyzed the variance of the annual average NDVI for 2018 within different landscape units, which we identified based on pasture type (elevation), aspect, and slope steepness parameter. Pixels pertaining to the same LSU are considered to have the same ecological conditions, and their raw NDVI is considered to be comparable. To identify the LSU with aspect and slope, we used the freely available Digital Terrain Model (DTM) of ASTER imagery with a 30-m resolution.

Landscape units (LSU)

In general, a LSU is a more or less homogenous patch in the landscape referring to a specific research object. With this approach the abiotic factors influencing the NDVI are similar and the NDVI becomes comparable.

We used a different approach for identifying LSU in summer or intermediate pastures and winter pastures. The landscape of summer and intermediate pastures is dominated by different slope and aspect classes. Aspect and slope features were derived from the 15-m resolution DTM freely available from NASA[10]. Slopes were classified into four categories based on the guidelines for soil description of the United Nations Food and Agriculture Organization (FAO) with: flat (0-10%); sloping (10-15%); steep (15-30%) and very steep (30-100%). Aspect was classified into 5 categories (north, east, south, west, flat) as well as two categories (north, south). Both aspects will be tested as input for the NDVI variance analysis to get more homogenous landscape units.

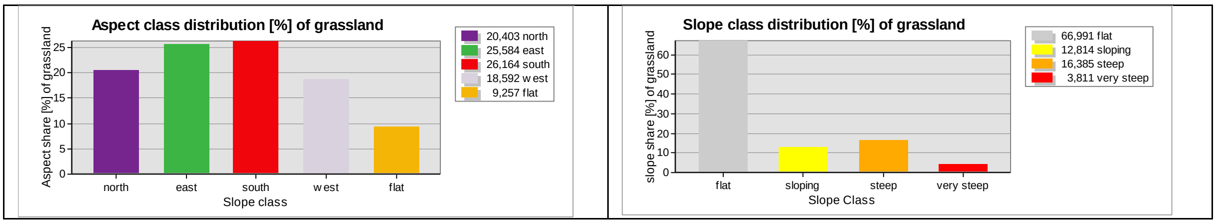


Table 6: Distribution of grassland on slope and aspect classes

Evaluation of degradation

Each pixel is classified according to its degradation level on a scale of 1 (heavily degraded) to 4 (potential). Classification is achieved by comparing each pixel's average NDVI value with the distribution of values on the same LSU

Landscape units for summer and intermediate pastures

First of all, we produced LSU for summer/intermediate pastures based on slope and aspect. We used a minimum size of 9 pixel for representing a single LSU. For summer and intermediate pasture we used the same LSU classification scheme.

The winter pastures seem to have other landscape elements which shape the representation of vegetation intensity (e.g. most of the area is flat), e.g. climatic factors. It is assumed that the winter pastures have multipurpose land use, though the questionnaire with herders could not prove that (2 out of nine use the winter pasture additionally for fodder production). If the assumption is correct that land use in winter pastures is fuzzy, this will bias the proposed potential of production for those landscape units. To limit this effect, we worked out a stratification method based on the NDVI variance.

Landscape units for winter pastures

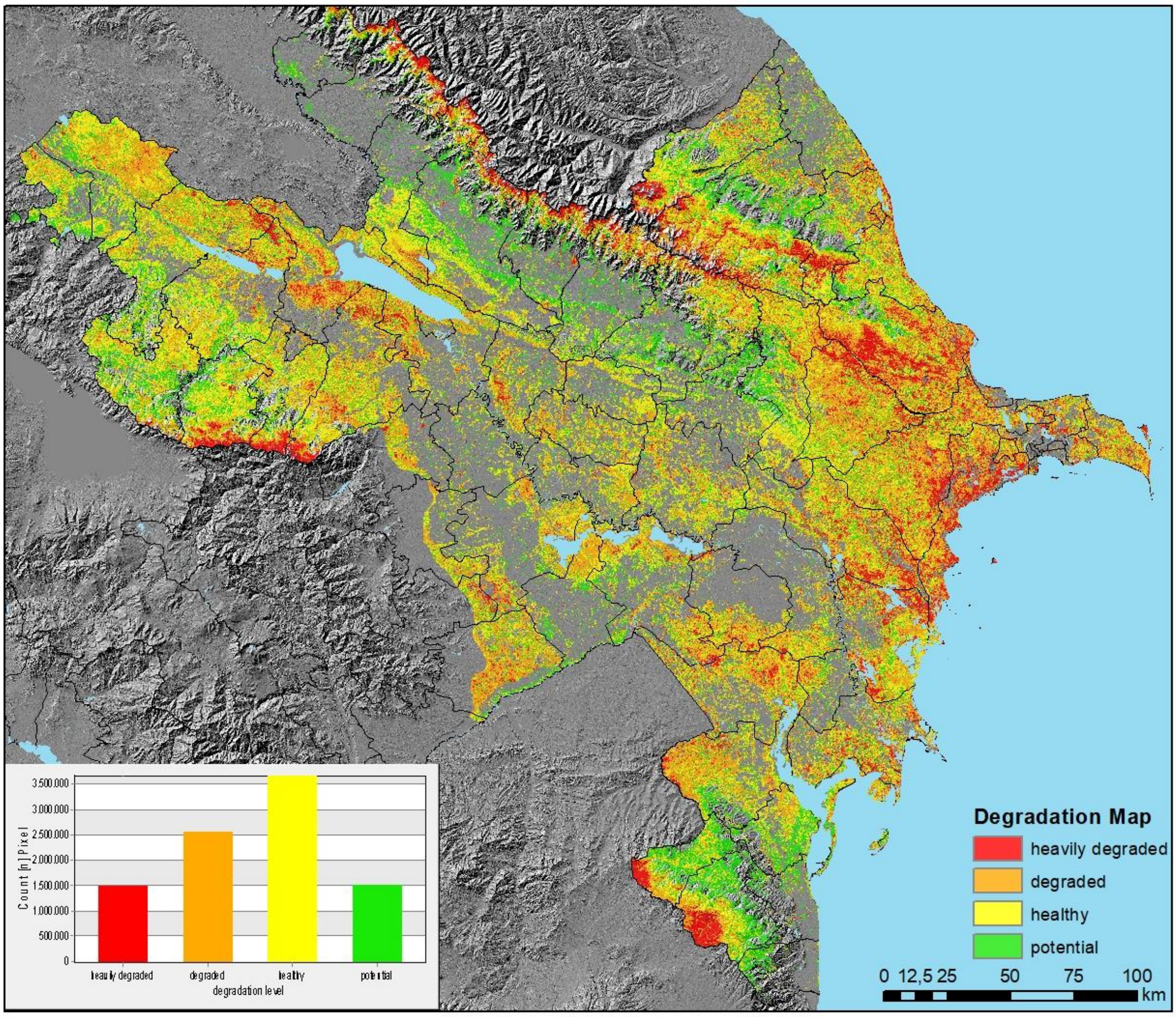
To eliminate areas of land use change (pasture -> agriculture; water -> land) and other spatially explicit changes (irrigation sites, recession farming) with high variances in NDVI we stratified the data according to five classes on their natural inherent breaks after Jenks and Caspall (1971) and masked out the two classes with highest variation. They are not regarded as grassland. The remaining classes were used as units for mean value calibration. The class with medium to low changes were found to

[10] GDEM – ASTER DTM: https://gdemdl.aster.jspacesystems.or.jp/

be misclassified grassland (crops) in the grassland mask of DLR. The LU are compared to the mean NDVI (2018) and classified according the distance towards the mean in four classes. Lastly, the classified LU were generalized according to a sieve and majority filter.

b. Results

During the field survey we were able to collect 17 plots according to the method proposed by Neudert and Etzold for summer and winter pastures (Etzold, 2013; Etzold *et al.*, 2018). There developed classification scheme had to be modified due to the scale of study[11]. The number of samples is not able to statistically prove findings or give an accuracy. It is solely useful to show if findings in the ground match the degradation classes and if this approach is promising for further research.



Map 2: Degradation Map based on average mean NDVI for 2018 by landscape unit stratification

[11] Manual description foresees multiple plots on single pasture. According to limited time frame, this was not realistic.

The classification was tested with the degradation parameters described by Neudert and Etzold, namely the susceptibility to erosion-index (SEI)[12] and the pasture degradation-index (PDI)[13].

GPS	Degradation level after NEUDERT&ETZOLD			Degradation Level on LSU	Visual Interpretation of PLOT	
Plot ID	SEI	PDI	Stocking rate	degradation level	veg. State of site	comments
1	5	5	8 SU/ha	potential	good	winter pasture
2	5	5	8 SU/ha	healthy	good	winter pasture, little cattle faeces, no signs of grazing, very nice plot
3	5	5	8 SU/ha	heavily degraded	medium	winter pasture, no green up so far
4	2,5	5	6 SU/ha	potential	good	pasture, former forest
5	0	5	4 SU/ha	potential	good	
6	5	5	8 SU/ha	potential	good	beside highly eroded areas, creek nearby
7	0	2,5	2 SU/ha	degraded	bad	totally browsed
8	5	2,5	6 SU/ha	degraded	medium	heavily browsed
9	5	5	8 SU/ha	potential	good	winter pasture, probably for hay, no sheep/cattle faeces
10	2,5	2,5	4 SU/ha	degraded	medium	summer pasture close to basecamp
11	5	5	8 SU/ha	healthy	medium	heavily browsed, livestock tracks
12	5	2,5	6 SU/ha	potential	bad	former wetland, huge cracks, phragmites remnant
13	0	5	4 SU/ha	potential	good	private pasture without fence, surrounded area even more degraded, former
14	2,5	0	2 SU/ha	heavily degraded	bad	very steep, only used for transition, lot of cattle faeces around, nearby plot was fenced and looked nicely
15	2,5	5	6 SU/ha	potential	good	perfect meadow, nicely
16	2,5	5	6 SU/ha	potential	medium	heavy landslides 10 years ago
17	5	2,5	6 SU/ha	potential	bad	winter pasture, not vegetative at the moment

Table 7: Plot evaluation after NEUDERT & ETZOLD compared to classification result and visual impression of the plot

The PDI of NEUDERT & ETZOLD in comparison to the classification result of NDVI mean show a good match for the evaluation of summer pastures (detailed plot description in appendix). In fact, winter pastures were difficult to evaluate due to the phenological state when visited. This might bias the PDI, additionally winter pastures were found to be used as well for agriculture (as well irrigated). This can lead to a shift in naturally predominant NDVI values for this LSU, hence mean NDVI for this LSU is shifted. In that case it seems to be reasonable to use different threshold settings (Jucker *et al.*, 2017).

[12] „created from physical site conditions that are independent from the impact of livestock. This index reflects the potential erosion on a site."

[13] „Traces of erosion and the state of the pasture vegetation contribute to the Pasture Degradation-Index (PDI). The presence of livestock directly impacts all nine variables recorded. The index therefore reflects the current state of a pasture.

	Non – to slightly degraded	Severely to extremely degraded
Alpine ecozone		
GPS	48°23'19,174"E 38°39'45,811"N	48°19'25,728"E 41°10'38,695"N
Mountain steppe		
GPS	49°0'32,46"E 40°51'40,194"N	45°43'53,245"E 41°3'53,827"N (ECO field campagne)
Semi desert		
GPS	47°8'9,056"E 40°49'52,153"N	46°12'21,363"E 40°44'42,868"N (ECO field campagne)

Figure 3: Characteristic plant communities by ecozones and degradation status. Photos were taken during the field campaign (September 2019)

Degradation was tested according to the following explanatory variables: slope, aspect, altitude, distance to roads, elevation and distance to the country border.

# Layer	1	2	3	4	5	6
1	1,00000	-0,01524	-0,06802	-0,08567	-0,50424	0,04471
2	-0,01524	1,00000	0,33034	-0,01733	0,24971	0,00951
3	-0,06802	0,33034	1,00000	0,08026	0,65445	-0,09424
4	-0,08567	-0,01733	0,08026	1,00000	-0,00522	-0,06060
5	-0,50424	0,24971	0,65445	-0,00522	1,00000	-0,22162
6	0,04471	0,00951	-0,09424	-0,06060	-0,22162	1,00000

1=degradation level; 2=aspect; 3=slope; 4=distance2roads; 5=DTM; 6=distance2border

Table 8: Correlation Matrix with explanatory variables influencing degradation level

The correlation matrix shows a negative relation of degradation level and elevation. That means, there is a relation between altitude and degradation level (the higher the altitude, the higher the degradation level) and stocking density (see chapter 5.a, page 23). The relation of all other tested variables is not very strong. It could be interesting for management purposes researching further variables influencing the degradation (e.g. duration of lease agreement with herder, precipitation, temperature).

Unfortunately, it was not possible to relate the result of GRAZE directly with our findings because the degradation data were not provided in geodata format (only static map, included in the report).

c. Improvements

Different threshold settings to classify pixels according to their degradation level should be tested. We employed the comparison to the mean while other scientific reports described better results for the comparison between best and worst situation (Jucker *et al.*, 2017).

For verification purpose, a higher amount of field samples has to be applied. As we employed the evaluation scale proposed by Neudert and Etzold for monitoring degradation, we were not able to incorporate samples of the ECO field champagne due to missing parameters.

For the estimation of average NDVI within a LSU it was highly important to include pasture enclosures. As this management tool was not established, we used private pastures or hay meadows to calibrate the mean NDVI on that. All areas we used for calibration were fenced.

Figure 4: Fenced versus non-fenced area (1225 m.a.s.l.; Lerik district close to the Iranian border; 48°23'19,174"E 38°39'45,811"N)

i. Additional proxies for determining degradation of pastures

As indicated in Table 8: Correlation Matrix with explanatory variables influencing degradation level, the variables slope, aspect and distance from road or country border are not useful to explain the degradation level. Only elevation can be seen as proxy for the degradation level. It would be interesting to include further variables.

Field observation could show that the position of camps in the summer (and intermediate) pastures had an impact on the surrounding vegetation development. It is recommended to identify the position of camps and use this as a proxy indicator of grazing intensity. To calibrate the degradation model, it is necessary to identify the extreme levels of grazing intensity (fenced areas for non-degraded sites; heavily degraded sites close to camp sites). In the timescale below, the succession of a pasture under heavy grazing pressure becomes visible.

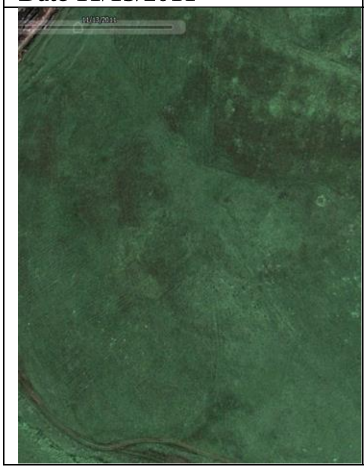
Date 11/13/2011	Date 10/13/2019	Photo (40.451438° | 46.064668°)
		

Figure 5: Degraded pasture land close to summer camps on google maps (historic without camp 2011 versus camp site in 2019)

Azerbaijan's complex orography produces a distinct pattern of precipitation (Mamedov, Safarov and Safarov, 2009).

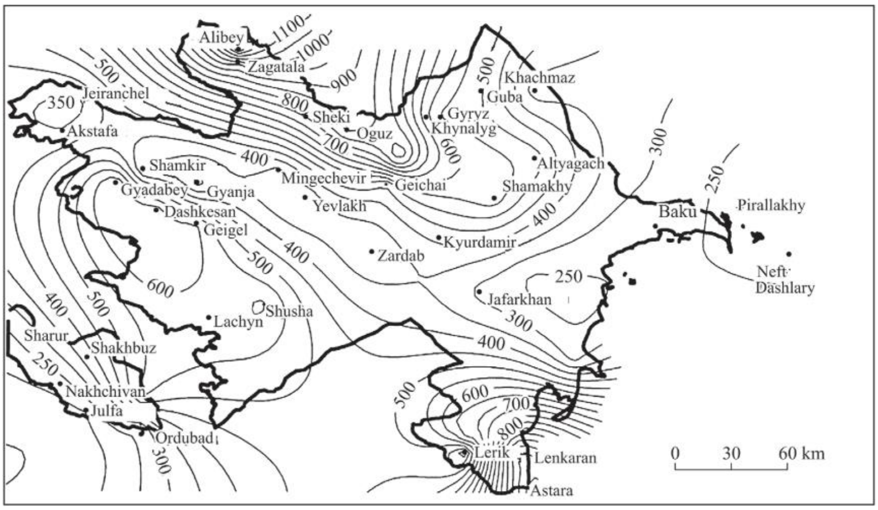


Figure 6: Distribution of the yearly averaged amount of precipitation (1961 - 2006); from Mamedov et al 2009

The distinct form of precipitation distribution is an important factor influencing the potential of vegetation production. In our model, we assumed equal precipitation for all Azerbaijan but this should also be taken into concern when stratifying the LSU.

As described under chapter 3.d.i (page 12) the interannual NDVI variance might give insights about the species composition and possible degradation.

5. Information on district level and management recommendations

In this chapter we give some facts about the different districts concerning the responsibility to pasture management.

The 10 highest districts with pasture (all pasture types) coverage (own analysis based on grassland/non-grassland mask; pasture types derived from ASTER GDEM; official district borders provided by GIZ):

District NAME	Area share of pasture land [%]	Area covered by pastures [ha]	No of pasture types covering
Gobustan	90,4	127495,2	2
Absheron	85,5	169828,4	1
Khyzy	81,8	149784,2	3
Kelbejer	78,5	172,5	1
Siyezen	78,5	55628,6	2
Jebrayil	76,1	942,5	1
Agstafa	71,1	108548,8	2
Yardymly	69,3	46042,9	3
Dashkesen	62,9	63774,9	3
Garadagh (Baku)	60,5	67584,7	1

If applicable, it is recommended to establish permanent plots in all pasture types and different precipitation regimes to record the succession without grazing. Those area enclosures can help to estimate the potential of nature without pressure and selective grazing for regeneration, biomass productivity and species composition. A district offering all pasture types is Khyzy, covering winter pasture and on the western side also summer pasture.

According to pasture type, the five most covered districts (own analysis based on grassland/non-grassland mask; pasture types derived from ASTER GDEM; official district borders provided by GIZ):

District NAME	Pasture type	Area share of pasture type [%]	Area covered by pastures [ha]
Zagatala	summer	11,0	14842,1
Balaken	summer	9,6	8820,3
Gebele	summer	8,9	13958,0
Gakh	summer	6,5	9654,6
Goranboy	summer	5,9	10620,6
Fizuli	winter	55,1	50636,0
Tovuz	winter	52,7	100392,6
Salyan	winter	51,1	94140,8
Samukh	winter	50,8	70901,9
Gazakh	winter	49,7	33892,7
Shemkir	intermediate	14,0	23348,7
Gusar	intermediate	13,3	20436,7
Goranboy	intermediate	9,5	17217,8
Ismayilli	intermediate	8,9	18528,4
Astara	intermediate	8,2	5098,0

According to our degradation map, the districts show very different degradation levels. The districts with highest degradation are the following:

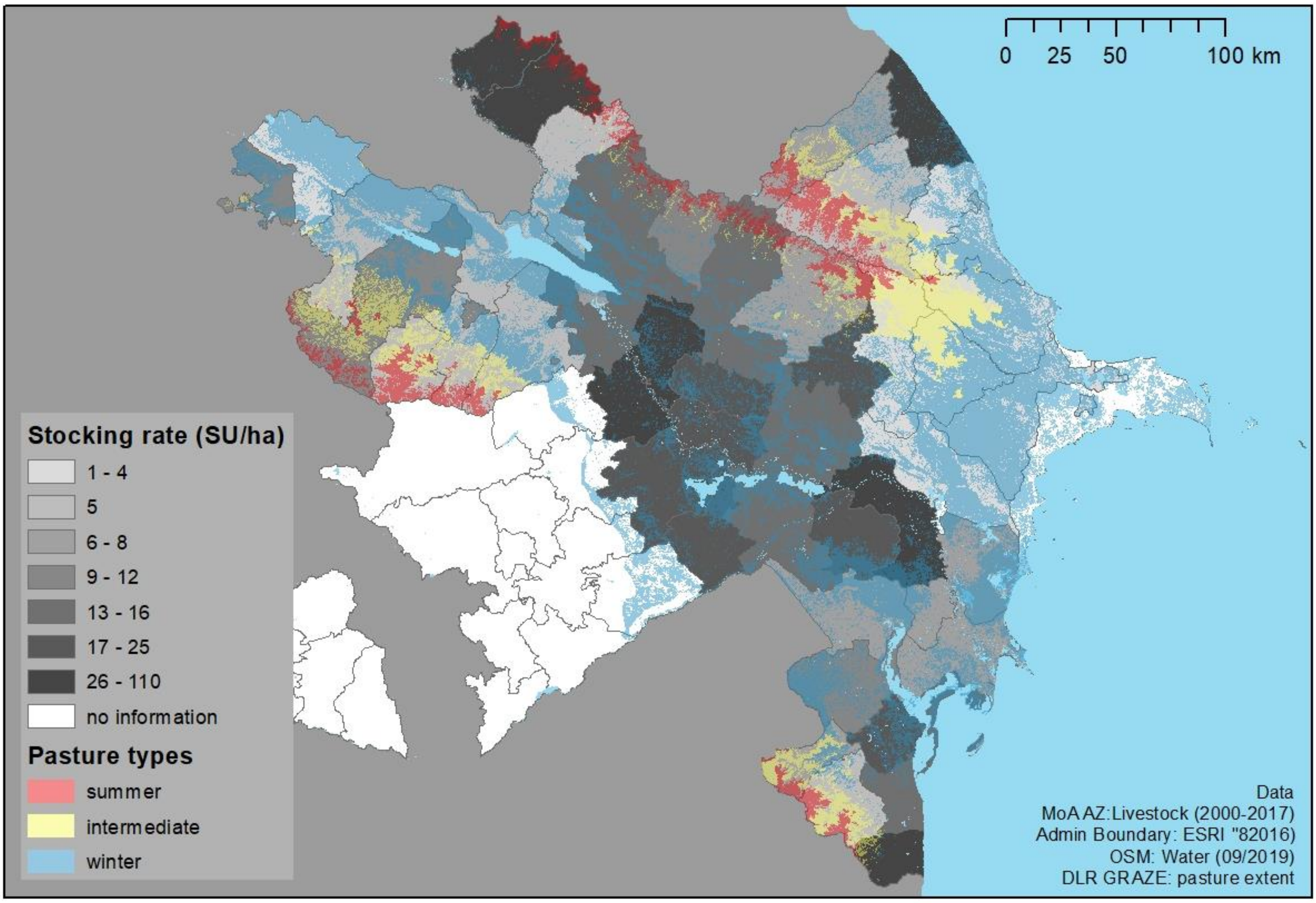
Districts with lowest degradation are namely:

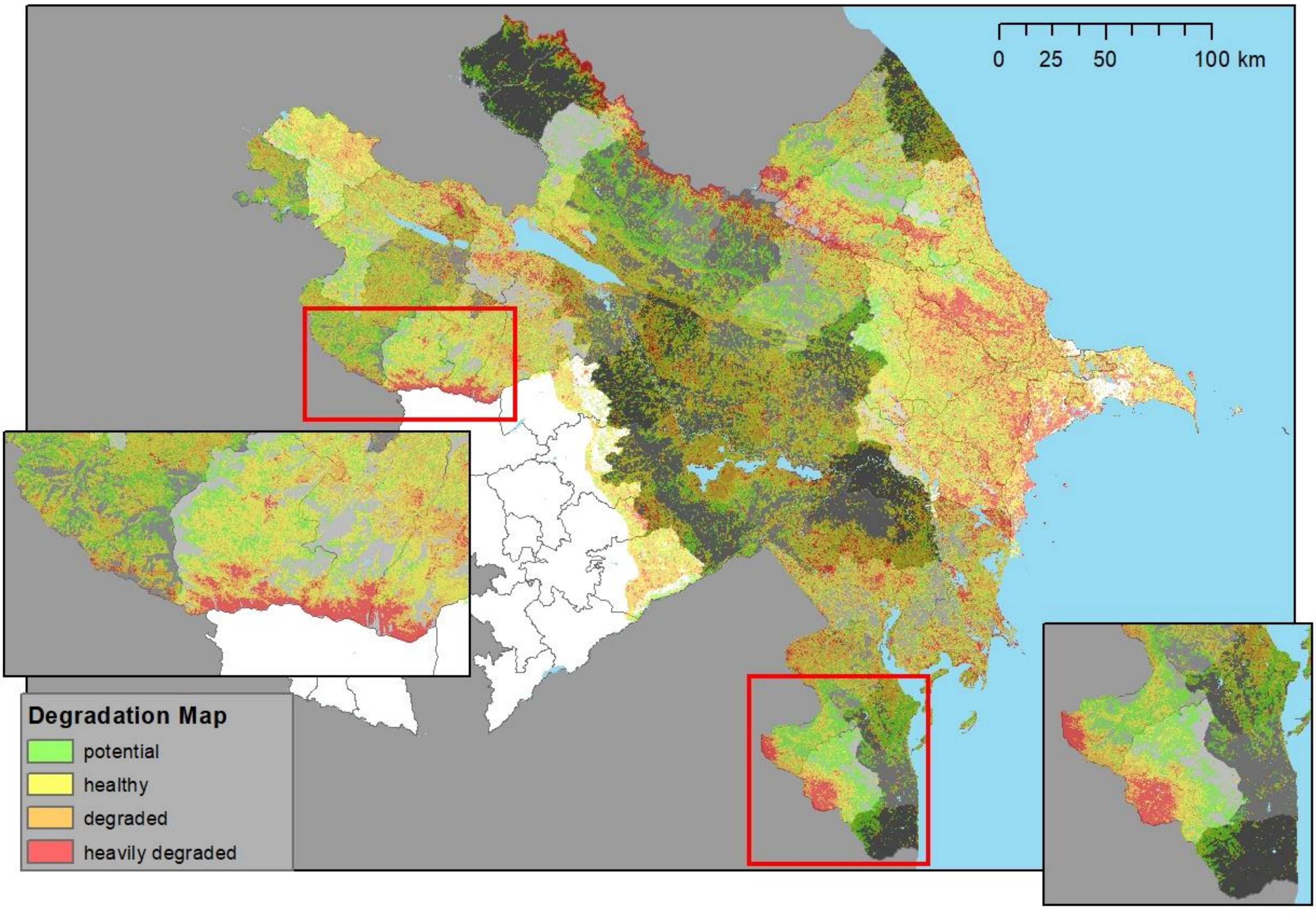
a. Livestock data (State Statistical Committee) in relation with degradation

Livestock data were provided by the MoA ranging from 2000 up to 2017. The map shows the stocking rate per ha. For calculating the stocking rate, for livestock to sheep units the following conversion factor was used: sheep x 1; goats x 0.7 ; cattle x 6 ; described in (Etzold, 2013) and buffalo x 7.2[14]. To estimate the real number per district, only the area covered by pasture in each district was concerned in the calculation. Only those districts located completely within the GRAZE boundary were used, due to total livestock numbers per district.

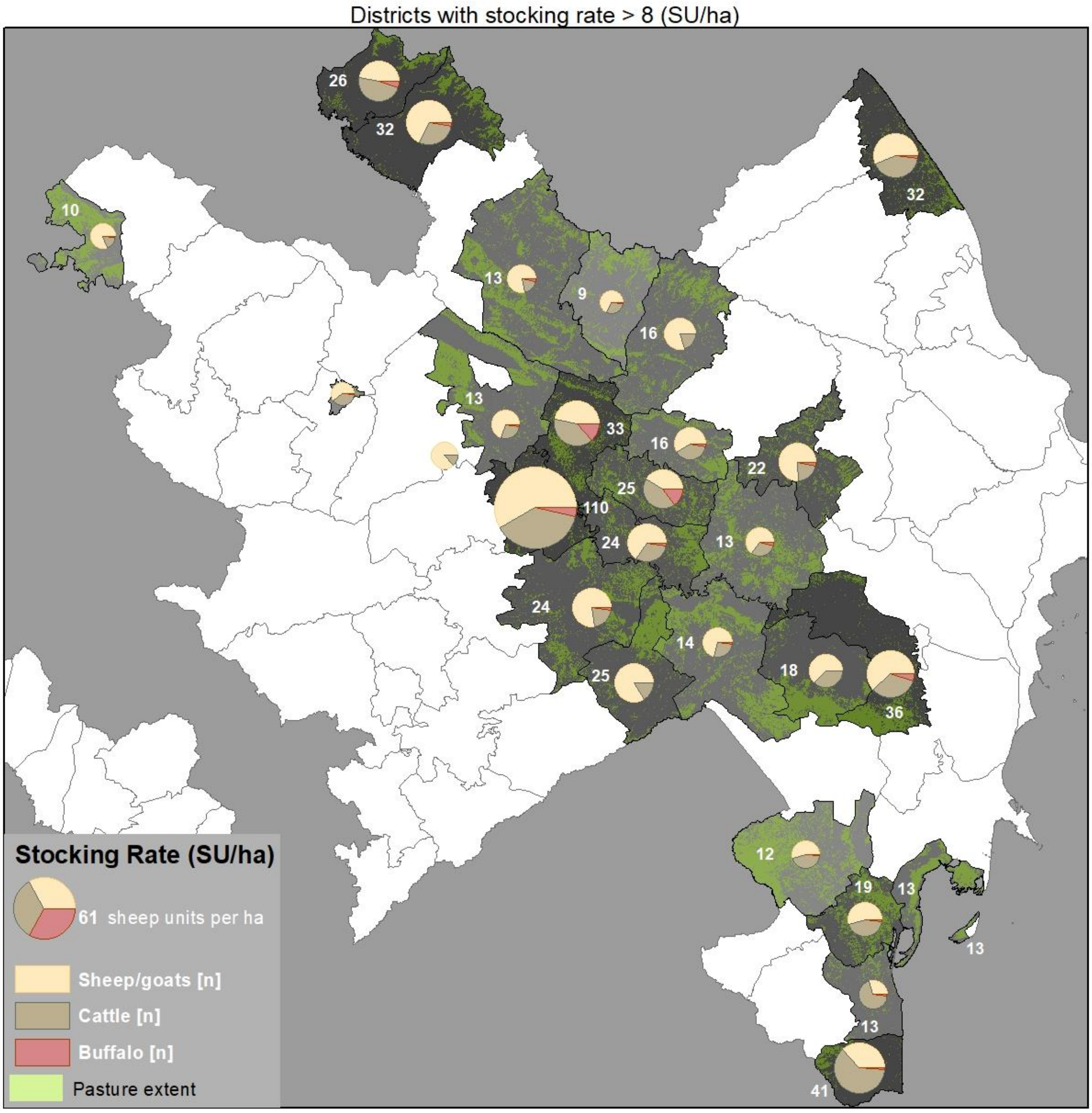
[14] According to buffalo weight from FAO (http://www.fao.org/3/ah759e/AH759E16.htm, visited 25.09.2019)

Livestock (sheep units/ha) on district level for 2017





The stocking rate per district shows alarming rates in some parts and exceeds by far the recommended stocking rate proposed by MoA with 8 sheep per hectare for summer pasture sites[15]. In total, 26 districts have higher livestock rates than 8 SU/ha, while Barda has a stocking rate of 110 SU/ha. These very high stocking rates might indicate as well that livestock is not only kept in pasture areas. Barda rayonu has according to the GRAZE grassland mask only 6,907 ha pasture area with 140,503 sheep/goats; 92,537 cattle and 8,434 buffalo. Assuming the pasture area is bigger, the stocking rate decreases. A complete list of stocking rates can be found in the Appendix Table 9: Stocking rates (SU/ha) for all Districts, page 40.



Map 3: Districts with stocking rate 2017 with more than 8 sheep units per hectare

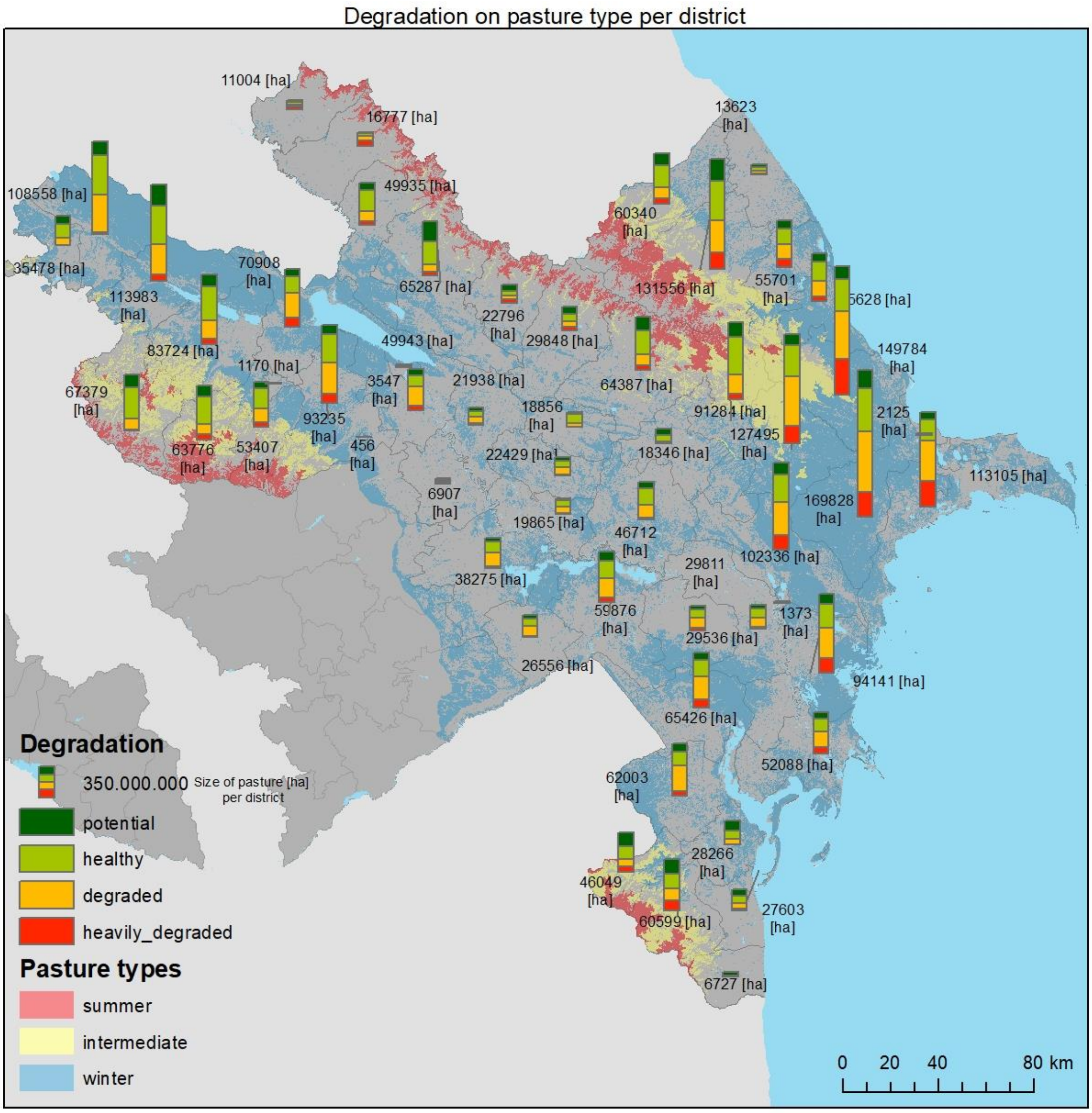
[15] Found in: (Neudert, 2016)

With multiple geographically weighted linear regression we tested the dependency of stocking rate and percentage of degradation levels within a district. Accordingly, stocking rate and degradation level have a strong correlation (R^2=0.24; σ=15.2).

A recommendation, especially for districts with very high stocking rates are lower stocking levels.

b. Classification of degradation level on district level

Heavily degraded pasture area can be found in all pasture types (summer, winter, intermediate) as in all districts.



Map 4: Degradation on pasture type per district

Since degradation in mountainous areas is hardly reversible it is recommended to focus on the heavily degraded areas and try to establish different grazing regimes or lower the livestock density at least for the time of recovery.

6. Recommendations

Recommendations are derived from literature review, field work and statistical and spatial analysis of provided (GRAZE, GIZ, MoA) and free available data.

Policy recommendations on improved management related to different areas and grassland use types

1. As described in chapter 5.a (page 23), the stocking rate of livestock exceeds by far the recommended 8 sheep units per hectare in specific districts (Table 9: Stocking rates (SU/ha) for all Districts, page 40). Considering the relation to pasture degradation, it is recommended to adopt the stocking rates. Furthermore, the calculated stocking rates are still underestimating real stocking rates. The grassland mask of GRAZE does not qualify if pasture land is private and fenced. Thus, those areas are used for sheep unit projection but de facto they are not available for transhumance grazing. Main focus according to own analysis are all districts exceeding 8 sheep units (Map 3: Districts with stocking rate 2017 with more than 8 sheep units per hectare, page: 25). It is recommended to adjust stocking rates. For better acceptance of adjusted stocking rates, awareness creation among all stakeholders concerning sustainable land use seems to be important. Establishing new market for non-meat products could also help to diversify the income of herders while decreasing sheep numbers.
2. Land conversion is happening. This dynamic process has to be integrated into pasture degradation measures. The analysis of Bayramov et al (Bayramov, Buchroithner and Bayramov, 2016) indicates a decrease in area from 28,229 to 24,925 km2 for grassland. Accordingly, land cover dynamics were mainly driven by agricultural activities. Land conversion could be observed during the field visit especially in Lerik district (Table 4: Land conversion (pasture land towards agriculture), page 8), but it needs to be researched more systematically. It is recommended to establish incentives for pasture protection like a payment system for ecosystem services, which compensates local land users for safeguarding these services as described in Neudert (2016).
3. It seems to be important to homogenize the pasture classification and semantics. As described in chapter 3.a.i (page 6). There is a discrepancy in defining summer and winter pasture (altitudinal border) and the use of the term “intermediate pasture”. Using different classification scheme could lead to differing numbers of extent, hinder comparison of scientific research and lead to misinterpretations. The widely used term “village pasture” has a more or less spatial explicit border but is used in varying time windows and by different user groups. The official integration as pasture type (beside summer and winter pasture) would require a more sophisticated classification scheme (than only using the altitudinal border). It seems feasible to define a spatial buffer around and assign the intersecting pastures to “village pasture”. This could also lead to a less fuzzy use right of pastures.
4. According to our degradation analysis considering the productivity, most severe degraded areas are located in summer pasture (19.8% of summer pasture is heavily degraded). But especially the sub-alpine ecosystem is extremely vulnerable and restoration demand resource intense efforts. It is found (Neudert 2016) that the giving pasture lease agreements for summer pasture nowadays prefer annual terms (mostly regulated by high prices). This method seems to be counterproductive in awareness creation concerning sustainable land

use. A more promising approach is to create ownership and responsibility. This is only possible with stable and long term lease agreements. Furthermore, as Etzold and Neudert recommend, a simple monitoring of pasture land should be done for all pasture management units. Monitoring guides are existing for winter and summer pastures, also in Azerbaijan language.

7. Lessons learned

This chapter deals with direct experience during the preprocessing of the data, the field work and postprocessing. It could give valuable information on study design with similar focus on remote sensing.

1. It was challenging to estimate the pasture potential and/or degradation in the time frame of the study. The summer pasture was close to senescence (most herders were already on track and left the summer camps). Winter pasture were not in green up phase so far (missing precipitation). The provided database of ECOserve, ESTOK and Azercosmos could only be used to a limited extend due to missing attributes. It is recommended to synthesize all in-situ samples form field campaigns and administer those in a field sample database.
2. To be able to capture the differences in between the different pasture types and regions, it is recommended to take as much interviews as new information is expected with the next interview. For gaining an overall view on pasture development, it could be helpful to take interviews two times a year (between May-September in summer pasture and November – April in winter pasture). While based in summer pastures, traveling time should not be underestimated.
3. Sample plot size [n] to capture vegetation should satisfy the question addressed. To capture degradation on pastures, the sapling design of Etzold and Neubert suggest six plots on each selected pasture unit (managed by one herder)(Etzold, 2013). We minimized the plots to only one per pasture unit due to resource limitation thus could not capture the heterogeneity of one unit.
4. For verification purposes of remote sensing techniques, it is recommended to take at least 30 samples per feature to be able to calculate the accuracy of classification results. In the case of the developed degradation map this would mean at least 120 plots for verification (each degradation class 30 samples) (Green and Congalton, 2009).
5. If the study design foresees to take interviews with herders, it is important to make sure if the interview partner has enough time. Furthermore, it is important to use appropriate methods of collection (personal conduction).
6. To be able to interpret the NDVI in a better way, it would be very helpful to identify area enclosures in all LSU to estimate the potential of pasture land without or less disturbance. In the study, all areas representing pasture land were included. Especially hay meadows and other private fenced areas were helpful to calibrate the mean NDVI within a homogenous LSU.

8. Conclusions

The process developed to relate scientific findings (GRAZE study) to the operational management unit, is based on literature review, field work, statistical assessment of provided data and own analysis. The idea to formulate recommendations on improved management taking into consideration the actual degradation status based on the GRAZE report had to be refused due to the nature of applied exploratory methods. Instead, we developed an own degradation classification based on LSU. The use of reference conditions to develop standards or benchmarks, against which pixel value can be compared are necessary for reliable results. As precipitation is a main stressor for vegetation growth in Azerbaijan, it is assumed that the best model consists of a hybrid strategy which uses reference area or conditions combined with rainfall use efficiency measures may be effective for detecting trends in degraded productive capacity. Due to resource limitation and phenological plant characteristics it was not possible to verify the degradation classification to a sufficient point but it can show a straight-forward way for quantifying the status of pasture productive capacity relative to reference conditions.

The use of remote sensing techniques is promising to estimate the pasture condition, but explicit recommendation only comparing historical data with present information do not imply recommendations on the management level. As described in chapter 3.b (page 9) due to climate change (or annual weather phenomenon) and adaptation of the ecosystem to grazing pressure the green up and senescence could be shifted, which affects the NDVI. Thus, the solely raw NDVI is not appropriate to distinguish between different pasture production classes. The raw NDVI values have to be linked to empiric, quantitative biomass data.

The development for criteria influencing pastures degradation was mainly based on literature information and handbooks for monitoring pasture in Azerbaijan. Reed et al (2011) suggested a degradation analysis should include a social and economic analysis involving the appropriate stakeholders. In that manner it could be helpful to start an extensive process for choosing indicators of sustainability where stakeholders are engaged through workshops. As mentioned in the GRAZE report, the degradation concept has to be clearly defined with all stakeholders. As the “gradual change in the grassland cover extent” was not researched in GRAZE, additional research should take place.

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10. Appendix

i. Questionnaire with herders

Questionnaire for assessing pasture condition Date:

GPSname:	Altitude:
Name of Summer Pasture:	
Name of interview partner:	

1. General information

1.1 For how many years do you personally come to this summer pasture? _______________years

1.2 When do you usually arrive on this summer pasture and when do you leave?
Arrival date: Departure date:

1.3 Why do you select those times?

Migrating start from winter pasture	Migrating start from summer pasture
[ ] livestock owner or other person decides	[ ] livestock owner or other person decides
[ ] individually, due to weather condition	[ ] individually, due to weather condition
[ ] not enough fodder/grass left	[ ] not enough fodder/grass left
[ ] lease agreement contains fixed date	[ ] lease agreement contains fixed date
[ ] veterinary care	[ ] veterinary care

Other:

---

2. Winter pasture

2.1 Where does the livestock kept on this pasture stay in winter?
[ ] Winter pasture | Name of rayon:
[ ] Village | Name of village:

2.2 On winter pasture do you offer additional fodder? [ ] NO [ ] YES, please differentiate

[ ] locally-produce forage [ ] barley grain [ ] straw [ ] chaff or wheat

Other:

2.3 Do you use the winter pasture in combination with cultivation? [ ] NO [ ] YES
If YES, please differentiate what kind of cultivation:

---

3. Livestock

3.1 How much livestock is kept on the summer pasture? (fill in total number)
Sheep: Goats: Cattle:

3.2 How did the livestock develop in the last years?
[ ] became more [ ] stayed the same [ ] became less

3.3 What influences the survival rate/weight of your lambs? Please rank from the most important (1) to less important (6)
[ ] strength of mother [ ] weather condition [ ] available fodder (quantity)
[ ] quality of fodder (species)

4. Species composition (species collection should be done on the way to the camp)

4.1 Could you please order the plants according to your livestock favors' and dislikes'.
(show all collected species and let the interviewer order the plants or groups of plants from very favoured (1) ←----------------→ unpalatable (x)

Number the species and make a picture of the collection!

Is something missing, which frequently grows on your pasture? *(if name is missing, let you show and take a picture)*

____

5. Pasture condition

5.1 Of the collected species, could you tell us what we can mostly find on your pasture? (*please, note numbers)*: ______________________________________

5.2 How to you apprise the condition of this pasture compared to neighboring pastures?

[ ] better [ ] same [ ] worse

If the pasture condition is better or worse, please explain why:

5.3 Did the condition of this pasture change during the last 10 years?

[ ] better [ ] same [ ] worse

5.4 Did the species composition change within the last 10 years? (refer to the collected species)
More of (please, note the numbers):
Less of (please, note the numbers):

5.5 Did you recogise the following trends on your pasture:

[ ] earlier greenup [ ] YES NO [ ]

[ ] later greenup[ ] YES NO [ ]

[ ] earlier senescence [ ] YES NO [ ]

[ ] later senescence [ ] YES NO [ ]

5.6 Is the pasture area big enough for the livestock kept here?

[ ] more than enough [ ] just enough [ ] not enough

5.7 What measures do you use to improve the condition of this pasture?

5.8 In general: Are there degradation problems on summer pastures in this region?

[ ] not at all [ ] few problems [ ] severe problems

5.9 Do you remember an exact year with extremely bad conditions for your livestock?

[ ] NO [ ] Yes, If YES, please specify the year and reason:

Due to:

[ ] drought summer, in year __________

[ ] wet summer, in year________________

[ ] pest (locusts/grasshoppers), in year_______________________

[ ] disease of livestock, in year___________________

Other:

5.10 If you could choose a summer pasture, how would your ideal site look like, concerning:

5.10.1 aspect [ ] southern slope [ ] northern slope [ ] doesn't matter

Why:

5.10.2 land cover [ ] grassland [ ] bushland [ ] other:

Why:

5.10.3 Specific species composition (refer to the collected ones and note numbers):

[ ] doesn't matter

Why:

5.10.4 Proximity to winter pasture [ ] close [ ] far [ ] doesn't matter

Why:

5.10.5 Other reasons:

ii. Plot description

Plot ID	Altitude m		slope d	aspect d	topo position	slope configuration	bedrock	GC d baresoil	GC rubble	GC rocks
1	84	winter pasture	0	0	valley bottom	staight	soft, breakable by hand	1	non visible	non visible
2	104	winter pasture	0	0	valley bottom	staight	soft, breakable by hand	non visible	non visible	non visible
3	216	winter pasture	0	0	valley bottom	staight	soft, breakable by hand	2-5	non visible	non visible
4	1447	former forest (10-20 yr ago)	12	40	middle slope	concave	soft, breakable by hand	non visible	non visible	non visible
5	1514	village pasture, former forest (< 30 yr)	50	225	upper slope	staight	medium solid, not breakable by hand but when thrown on rock	non visible	1	non visible
6	1959	pasture	10	80	middle slope	concave	soft, breakable by hand	non visible	1	non visible
7	2012	pasture	45	180	middle slope	convex	soft, breakable by hand	>50	2-5	non visible
8	2223	summer pasture	3	320	upper slope	convex	solid, not breakable by hand neither when thrown on rock	6-10	2-5	non visible
9	1185	abandoned meadow	12	350	lower slope	concave	medium solid, not breakable by hand but when thrown on rock	non visible	1	non visible
10	1713	summer pasture	10	220	lower slope	convex	soft, breakable by hand		1	non visible
11	1753	summer pasture	10	120	valley bottom	convex	solid, not breakable by hand neither when thrown on rock	2-5	1	non visible
12	-18	summer pasture; on dry wetland; in soviet time agriculture	0	0	valley bottom	flat	soft, breakable by hand	26-50	non visible	non visible
13	1125	ter pasture, private, probably used as agriculture in future	45	350	upper slope	convex	soft, breakable by hand	2-5	1	non visible
14	1551	migration route, no real pasture	55	300	upper slope	straight	solid, not breakable by hand neither when thrown on rock	26-50	11-25	1
15	1361	pasture, enclosure, good condition	12	175	middle slope	straight	soft, breakable by hand			
16	699	pasture, transition pasture	25	90	upper slope	convex	soft, breakable by hand	2-5	non visible	non visible
17	-20	former agriculture	0	0	valley bottom	straight	soft, breakable by hand	6-10	non visible	non visible

Plot ID	GC livestocktracks	GC erosiontracks	physiognomic feature	Veg height MAX	Veg height average	standing crop	vegetation provided water
1	none visible	non visible	meadow-like	50	20	a lot	well
2	none visible	non visible	meadow-like	60	30	a lot	well
3	none visible	non visible	tussocks	25	7	few	badly
4	none visible	1	short growing lawn	10	6	a lot	well
5	none visible	non visible	short growing lawn	15	10	medium	medium
6	1	non visible	meadow-like	35	15	a lot	well
7	11-25	non visible	short growing lawn	35	10	few	medium
8	11-25	non visible	short growing lawn	30	2	medium	medium
9	none visible	non visible	meadow-like	70	20	a lot	medium
10	2-5	1	short growing lawn	20	8	a lot	medium
11	1	1	short growing lawn	10	4	medium	well
12	none visible	11-25	meadow-like	4	2	medium	well
13	1	1	short growing lawn	15	5	medium	well
14	none visible	11-25	tussocks	100	20	few	badly
15							
16	6-10	6-10	short growing lawn	7	2	medium	badly
17	1	non visible	short growing lawn	20	0,5	few	badly

Plot ID	Bush cover	Tree cover	Thistles	Rhododendron	Juniper thorny bush	thorny plants	poisonous aromatic plants
1	non visible	non visible	non visible	non visible	non visible	non visible	non visible
2	non visible	non visible	non visible	non visible	non visible	non visible	non visible
3	non visible	non visible	non visible	non visible	non visible	non visible	non visible
4	non visible	non visible	non visible	non visible	non visible	non visible	non visible
5	non visible	non visible	1	non visible	non visible	1	non visible
6	non visible	non visible	1	non visible	non visible	non visible	non visible
7	non visible	non visible	1	non visible	non visible	non visible	non visible
8	non visible	non visible	non visible	non visible	non visible	non visible	non visible
9	non visible	non visible	2-5	non visible	1	non visible	1
10	non visible	non visible	1	non visible	non visible	non visible	non visible
11	non visible	non visible	non visible	non visible	non visible	non visible	non visible
12	non visible	non visible	non visible	non visible	non visible	non visible	non visible
13	non visible	non visible	non visible	non visible	non visible	non visible	non visible
14	6-10	non visible	non visible	non visible	2-5	11-25	2-5
15							
16	non visible	non visible	non visible	non visible	non visible	non visible	non visible
17	non visible	non visible	non visible	non visible	2-5	non visible	11-25

Plot ID	sum GIS	Flowering plants	no plant species
1	0	a lot	36
2	0	a lot	40
3	0	medium	25
4	0	medium	11
5	2	medium	12
6	1	medium	30
7	1	few	12
8	0	few	10
9	3	a lot	40
10	1	few	18
11	0	medium	16
12	0	few	8
13	0	few	12
14	3	few	25
15			
16	0	few	22
17	2	few	13

iii. Livestock density for all districts

District name	Sheep/goats [n]	Cattle [n]	Buffalo [n]	District Area [ha]	Pasture Area [ha]	Stocking Rate [SU/ha]
Bərdə rayonu	140503	92537	8434	95246	6907	110
Astara rayonu	24164	40866	734	61911	6727	41
Sabirabad rayonu	223480	120395	17121	148869	29811	36
Ağdaş rayonu	89991	76195	25040	103879	21938	33
Zaqatala rayonu	139816	61013	4940	135309	16777	32
Xaçmaz rayonu	74649	57114	2177	104203	13623	32
Balakən rayonu	36376	36581	4342	91780	11004	26
Beyləqan rayonu	300803	58785	842	114943	26556	25
Ucar rayonu	55346	59100	19846	85152	22429	25
Ağcabədi rayonu	331134	88543	10041	171017	38275	24
Zərdab rayonu	113477	54678	5037	86338	19865	24
Ağsu rayonu	138869	38162	6102	101894	18346	22
Masallı rayonu	90002	72611	3108	74622	28266	19
Saatlı rayonu	112992	67548	1518	113601	29536	18
Göyçay rayonu	58607	38049	2931	72792	18856	16
Qəbələ rayonu	190737	46326	1216	156428	29848	16
İmişli rayonu	254721	94769	5762	177522	59876	14
Kürdəmir rayonu	135861	64785	9729	163840	46712	13
Şəki şəhəri	313372	71508	11756	240091	65287	13
Yevlax şəhəri	172630	67575	7489	154810	49943	13
Lənkəran şəhəri	22943	52433	1222	108876	27603	13
Cəlilabad rayonu	122987	99391	3631	143747	62003	12
Naftalan şəhəri	2608	422	8	1071	456	11
Qazax rayonu	147469	31135	2909	68287	35478	10
Oğuz rayonu	51082	23811	907	104326	22796	9
Gəncə şəhəri	2005	1296	36	8517	1170	9
Gədəbəy rayonu	255552	49748	160	125900	67379	8
Şəmkir rayonu	299568	61407	1251	166649	83724	8
Neftçala rayonu	140673	42822	2665	148478	52088	8
İsmayıllı rayonu	180620	51709	774	207090	64387	8
Mingəçevir şəhəri	4677	2517	635	12210	3547	7
Biləsuvar rayonu	138927	41298	2475	140065	65426	6
Salyan rayonu	186442	62680	2505	184165	94141	6
Yardımlı rayonu	86689	28537	150	66511	46049	6
Qusar rayonu	89371	41039	4	153790	60340	6
Lerik rayonu	111171	36640	94	107062	60599	5
Göygöl rayonu	154519	20251	231	97163	53407	5
Goranboy rayonu	202469	40909	862	179281	93235	5
Quba rayonu	258777	62256	410	262266	131556	5
Samux rayonu	155222	24222	1704	139535	70908	4
Qax rayonu	65238	22314	2080	147631	49935	4

Tovuz rayonu	199939	43860	1172	190684	113983	4
Daşkəsən rayonu	109176	25081	247	101401	63776	4
Şabran rayonu	50717	24542	2591	102954	55701	4
Hacıqabul rayonu	136906	38798	2221	171614	102336	4
Ağstafa rayonu	170730	26448	4833	152821	108558	3
Şamaxı rayonu	138941	26811	818	151751	91284	3
Qobustan rayonu	190973	30096	302	141060	127495	3
Siyəzən rayonu	54462	13090	536	70842	55628	2
Abşeron rayonu	107693	21644	16	198733	169828	1
Xızı rayonu	77261	9582	16	183090	149784	1

Table 9: Stocking rates (SU/ha) for all Districts