Remote Sensing Study into Rangeland Condition in Kvemo Kartli and Samtskhe-Javakheti Regions of Georgia

Final Report

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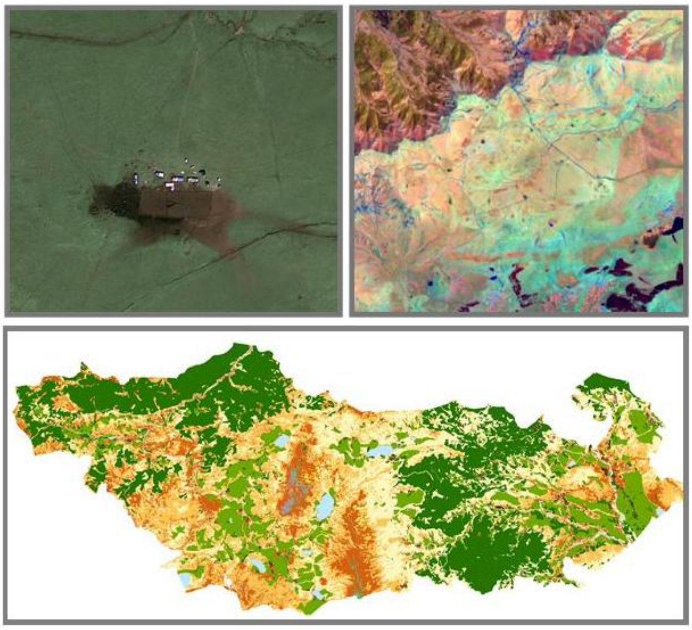

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Contents

Report prepared by

Mark Jarman, Stephanie Ties, Chris Finch and Steve Keyworth
Environment Systems Limited
11Cefn Llan Science Park
Aberystwyth
Ceredigion
SY23 3AH
UK
Tel: +44 (0)1970 626688
http://www.envsys.co.uk

With

AA International Limited
Ty Harbwr
Y Lanfa
Aberystwyth
Ceredigion
SY23 1AS
UK
Tel: +44 1970 613460/1
info@aainternational.co.uk

Glossary

ArcGIS	Geographic Information System (GIS) software
Atmospheric correction	The correction made to remotely sensed radiance to account for effects related to the intervening atmosphere between the Earth's surface and the satellite.
eCognition	Software for developing segmentations and rule-based classifications
DEM	Digital Elevation Model
EO	Earth Observation
GIS	Geographic Information System
Fuzzy logic	Considers that reasoning is approximate rather than fixed and exact
HRG	High Resolution Geometric
Landsat	Moderate spatial-resolution multi-spectral sensors that offer the longest continuous global record of the Earth's surface
MODIS	Moderate-resolution Imaging Spectroradiometer found aboard the Terra (EOS AM) and Aqua (EOS PM) satellites.
NDVI	Normalized Difference Vegetation Index
NIR	Near infrared
Orthorectification	A process of geometric referencing of an image to a map coordinate system that considers variations in the topography of the earth surface and the tilt of the satellite sensor.
Pre-processing	Ortho, atmospheric, topographic and other corrections to prepare imagery for classification.
Radiance calibration	Conversion of satellite image digital numbers to radiance.
Rangeland	Areas of vast natural landscape grasslands consisting of ephemeral grasses, either privately, collectively or state-owned. Endure little management from humans other than livestock grazing.
Rule base	A series of structured statistical rules (e.g. NDVI < 0.9) applied to satellite imagery, airborne imagery and/or thematic data layers to produce a user defined map.
Segmentation	Grouping of pixels based on similar values – a type of automated vectorisation (digitising).
Shapefile	A set of files used by ESRI ArcMap that contain points, arcs or polygons holding tabular data and spatial information
Spectral Reflectance	A quantification of the reflective characteristics of earth surface features measured as a function of wavelength and reflected and incident energy
SPOT	A French satellite supporting the HRG sensor
SWIR	Short Wave Infrared
Topographic shadowing	Shadowing of a surface by the surrounding topographic relief and as a function of solar angle.
Trimble	The company who own the eCognition software

Executive summary

Environment Systems was commissioned by Mercy Corps Georgia to undertake an assessment of rangeland condition across the Georgian regions of Kvemo Kartli and Samtskhe-Javakheti. The study was undertaken under the Alliances Programme, a market development programme working in the beef, sheep and dairy sectors, run by Mercy Corps and funded by the Swiss Agency for Development and Cooperation (SDC).

Rangeland condition is a key concern underpinning the traditional pastoral system. It has often been assumed that where livestock are present they cause rangeland degradation through overgrazing. This project aims to assess current rangeland condition, look at historical trends and identify factors contributing to condition. The study will provide a baseline from which to inform and guide programme policy and future interventions surrounding access to pasture and improved nutrition for small scale livestock producers. The overall aim is to help ensure the future sustainability of the livelihoods of the local rural population.

The study utilised Earth observation (EO) data, derived from the Landsat satellites, within remote sensing object-orientated rulebase classification techniques to map rangeland condition into three classes of good, moderate and poor, supported and confirmed by targeted ground truthing and discussions with local officials, farmers and graziers.

Key results showed:

1. There is no evidence of widespread current overgrazing, except locally along the transhumance routes and around the summer encampments. Rangelands in early summer generally have good or moderate vegetation cover with a good diversity of grass and forb (wildflower) species. On the higher peaks good condition occurs later in the summer, due to a later snow melt. If anything there has been an overall improvement in rangeland condition in early summer between the earliest available imagery (1984) and 2011; although with some regional variation.
2. There is evidence, from both imagery and ground truthing, of widespread seasonal change in rangeland condition, related to climate, with declining rangeland grazing quality through grass burn-off and die-back in mid to late summer. This is worse on the lower pastures, but does extend up into the higher pastures, especially where soils are shallow or very rocky.
3. There is some evidence, from both field observations and stakeholder consultation, supported by meteorological data that the climate in the study areas is becoming warmer and drier, contributing to greater seasonal change in rangeland condition.
4. There is a suggestion from the analysis that erosion may be occurring on some steeper slopes and valley sides, presumably the result of heavy rain falling on dry ground, which contributes to a degradation of rangeland condition.
5. There is some evidence from ground truthing of differences in rangeland quality and condition locally within the study area, reflecting intra-regional changes in bioclimate locally, which are difficult to map accurately and consistently.
6. There is evidence from the stakeholder consultations of increasing local stock numbers recently, particularly sheep, a consequence of better lamb prices, which may become an influence on rangeland condition (particularly on municipal pastures) in the future.
7. There is also evidence from the stakeholder consultations of changing ownership and access arrangements for both rangelands and municipal pastures, generally part of a drive by government for increased private ownership, which again may have an influence on rangeland condition in the future.

The key consequences of these results for rangeland management are:

1. The most productive summer grazing season is likely to start earlier and end earlier, and possibly become shorter, especially in dry years,
2. There is a longer period of seasonal grass burn-off and die-back, when there is less available grazing,
3. In drier years there is likely to be a higher risk of overgrazing and erosion.

If this trend to a drier and warmer climate continues, strategically there is a need to take more advantage of the time when rangeland and municipal grasses are at their most productive (spring/early summer) for both grazing and hay production. There may also be a consequence for both the timing (earlier in the season) and location (higher up the mountain) of summer transhumance.

It would be useful to test and confirm these conclusions in other areas of Georgia, especially in the east, where the winter grazing is located. It would also be useful to examine more closely seasonal change in rangeland condition within each year, related to climate and rainfall in particular, which can be achieved by utilising lower spatial resolution data, but which is more frequently available temporally, from MODIS imagery, which orbit the earth every one to two days. It is also possible to use EO techniques to help map the distribution of semi-natural habitats on the rangelands, and provide a better estimation of the extent of woodlands, both of which are necessary in preparing a comprehensive biodiversity resource assessment of the area.

1. Introduction

Environment Systems was commissioned by Mercy Corps in Georgia to undertake an assessment of rangeland condition across the Georgian regions of Kvemo Kartli and Samtskhe-Javakheti using Earth observation, supported by targeted ground truthing and discussions with local farmers and graziers. The study was undertaken under the Alliances Programme, a market development programme working in the beef, sheep and dairy sectors, run by Mercy Corps and funded by the Swiss Agency for Development and Cooperation (SDC).

Rangelands in Georgia form the southern extent of the vast steppe grasslands of central Russia, leading up to the peaks of the Caucasus Mountains. Part of the Lesser Caucasus, they constitute an integral part of the traditional pastoral agricultural system of Kvemo Kartli and Samtskhe-Javakheti, forming large expanses of open upland grasslands, generally above the lowland hay meadows and cropped land, merging in places into woodland and forestry. The rangelands are grazed in summer under traditional transhumance systems of livestock management.

Rangeland condition is a key concern underpinning the traditional pastoral system. It has often been assumed that where livestock are present they cause rangeland degradation through overgrazing. Georgia has undergone a significant amount of change over the last 25 years in terms of its social, political and economic structure and this project aims to assess current rangeland condition with regards to these changes. This is achieved by examining historical trends and identifying key factors contributing to rangeland condition. The study will provide a baseline from which to inform and guide programme policy and future interventions surrounding access to pasture and improved nutrition for small scale livestock producers and will be shared with the wider development community and both local and national government bodies. The overall aim is to help ensure the future sustainability of the livelihoods of the local rural population.

1.1 Aims and objectives

The overall aim of this research is to provide an evaluation of the current state of rangeland condition within the Samtskhe-Javakheti and Kvemo Kartli regions of Georgia and assess any evidence of historical change. Where possible factors contributing to rangeland condition will be identified and evaluated.

Mercy Corps have outlined the following specific questions to be addressed:

- Is rangeland being degraded, if so where?
- Is degradation being caused by livestock grazing practices?
- Is the rate of degradation in decline, accelerating or remaining the same?

In order to answer these questions the following key objectives were outlined:

- Establish a preliminary rangeland condition classification of the two regions using current satellite imagery and imagery acquired at regular intervals over the past 25 years,
- Conduct ground truthing in six focus areas, to assess, verify and help quality control the initial classification,
- Lead consultations with local stakeholders in-country to assess and verify assumptions on rangeland use, grazing practices, historical trends and local opinions not visible from imagery but necessary in order to fully understand the dynamics of rangeland management,
- Collate appropriate ancillary datasets and other contextual sources of information available including livestock, environmental and meteorological data to provide context to the remotely sensed data and help provide an understanding of the full extent of, and reasons for rangeland condition.

The project will deliver the following outputs to Mercy Corps:

- A spatial analysis of the current condition of rangelands across the study areas (identifying both areas that appear either over-grazed or under-utilised).
- An evaluation of change in rangeland condition over time in the study areas.
- An analysis and understanding, as far as possible, of the factors contributing to current rangeland condition

1.2 People, Farming and Rangelands in Georgia

Demographics

Generally, within Georgia, rural areas consist of a population dependent on agriculture, characterised by low disposable incomes, limited access to health care, poor housing and shortages of fuel and electricity. The main source of income is from agricultural activities and the desire to improve environmental situations is hindered by the fact that most people are more concerned with meeting basic needs.

Agricultural activities and systems

Prior to Georgian independence in 1991 agriculture was dominated by state ownership of all agricultural land and a concentration of production on large-scale collective farms, both arable and livestock. Large livestock herds were managed under extensive pastoral systems. Rangelands formed an important part of those pastoral systems, providing extensive areas of summer grazing in the higher land in the west of Georgia and areas of winter grazing in the warmer and drier east, with extensive seasonal transhumance in between. Arable land was extensively irrigated, with around 500,000 ha of land equipped for irrigation at the beginning of the 1980s (Food & Agriculture Org., 1997).

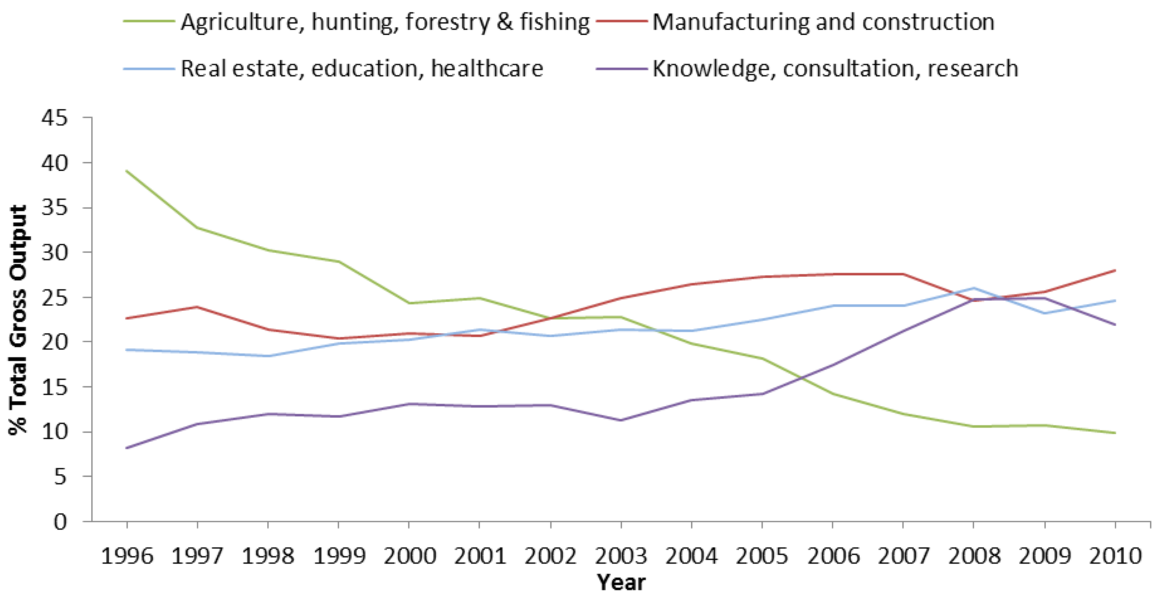


Figure 1: Changes in gross output in Georgia (Source: National Statistics Office of Georgia)

Following the collapse of the Soviet Union agriculture changed significantly. Much land was redistributed back to the rural population, although rangelands largely remained under state ownership. There was a significant decline in the productivity of agriculture (Figure 1) reflected in a sharp decrease in livestock numbers of both cattle and sheep in the 1990's (Figure 2)[1]. Traditional transhumance systems are still practiced (Figure 3), but not on the same scale as during the Soviet era. Mineral fertilizers, animal feeds and farming machinery are generally absent so animal production is limited by the natural productivity and carrying capacity of the environment.

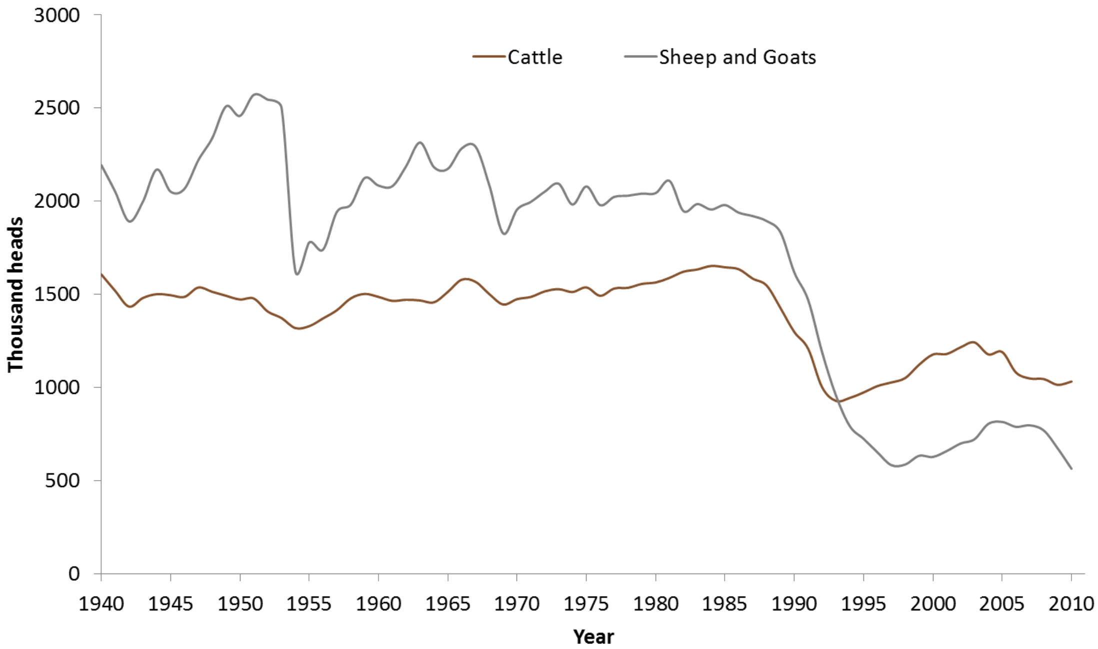


Figure 2: Changes in livestock in Georgia (Source: National Statistics Office of Georgia, 2010)

Figure 3: Current map of the location of winter and summer pastures in Georgia and transhumance routes (Source: National Food Agency)

[1] Although there is very recent evidence from our stakeholder consultations of some increase in both cattle and sheep numbers of individual herds, the latter especially through increased export opportunities for live lamb to the Middle East.

Rangelands

Rangelands in Georgia are vast natural landscapes in the form of grasslands consisting of semi-natural grasses and forbs. These areas are either unallocated state-owned land or, increasingly, privately owned. They may or may not be grazed and are subject to little management other than livestock grazing. They have a rich biodiversity including plants, birds and invertebrates. At lower levels the rangelands merge into municipal pastures around the main settlements and arable land. At higher levels they merge into areas of forestry and woodland. In 2002, over a third of the country's agricultural land was classified as pasture (Tsomaia *et al*., 2003). An estimated 1.1 million hectares of unallocated, state-owned land (neither privatised nor leased) was classified as pasture. Such land is generally used by communities for the pasturing of livestock and is composed mainly of mountain summer pastures and lowland winter pastures.

1.3 Previous rangeland studies

There are concerns for the condition of the rangelands from both agricultural and environmental perspectives.

Agriculturally, the rangelands support the economically important livestock sector. In spring 2011 Alliances Kvemo Kartli and Samtskhe-Javakheti (Alliances KK and SJ) conducted a number of regional focus group surveys to assess current agricultural activities and views of the local people with regards to rangeland condition and agricultural services. The Alliances programme is one of Mercy Corps' development programmes that aims to facilitate market change through engagement with key market players to address systematic market constraints. It is focused upon the development of the beef, dairy and sheep sub-sectors. The stakeholder consultations involved people chosen to reflect the varying demographics of the different regions. The survey found that the major income generating avenues in the regions are from dairy, meat and potatoes. The majority of people questioned expressed concerns over a lack of access to pasture, the quality of pasture available and believed that overgrazing appears to be a problem. The reason behind these problems, as viewed locally, seemed to be the privatisation of land which results in herds being concentrated on communal municipal land around settlements[2].

Environmentally the rangelands form an important national biodiversity resource. The Mountain Research Initiative (MRI) and the Global Mountain Biodiversity Assessment (GMBA) acknowledge that rangeland biodiversity in Georgia is under threat as a result of both human impacts and global climate change (Mountain Forum Bulletin, 2009). Overgrazing can increase the likelihood of land degradation and can cause an invasion of unpalatable plant species. This can culminate in an overall increase in vegetation density but a decrease in suitable grazing condition and biodiversity.

1.4 Earth observation

This study aims to provide an analysis of rangeland condition in Georgia through the use of EO data and analysis techniques,

EO is the 'earth-facing' discipline of remote sensing. It utilises both airborne and satellite systems that enable the mapping and monitoring of the surface of the Earth. This provides a wealth of knowledge, unobtainable by other means, including both topographic and thematic information. Although EO more commonly makes use of aerial photography, satellite-based EO has rapidly increased in popularity since 1972 with the launch of the first Landsat satellite. Since, there have

[2] Alliances Kvemo Kartli (2011) and Alliances Samstkhe-Javakheti (2011): Summary Market Analysis & Focus Group Survey Reports.

been progressive improvements in the spatial, temporal and spectral resolution across a range of mapping scales for a variety of mapping requirements.

EO data is not a universal panacea. Not everything can be mapped, all of the time. However, the array of imagery that is available provides field scale to the wider area perspective, as well as tracking cause, effect and change not directly possible with field work (particularly considering areas difficult to access on foot).

EO and Rangelands

EO is particularly suited to the evaluation and assessment of rangeland condition for three main reasons. Firstly, these areas are generally very remote and difficult to access on the ground and EO offers comprehensive large-scale but detailed resolution coverage over wide areas. Secondly, EO sensors provide the opportunity for consistent, objective mapping over time so that change can be monitored and evaluated. Finally EO enables an evaluation of characteristics of the landscape and vegetation that cannot be easily or quickly assessed even when access is possible.

Consequently, EO provides an effective tool for mapping rangelands that may be deployed to:

- Record a range of baseline landscape and vegetation features.
- Record changes in the landscape brought about by seasonality within each year.
- Record changes in the landscape over a period of years.

Previous attempts to assess, map and monitor the condition of rangeland areas have been reliant upon aerial photography and early satellite sensors such as Landsat and SPOT-5. These attempts have only sought to delineate heterogeneous vegetation and assess current condition. Advances in spectral and spatial capabilities within EO sensors, combined with the necessary expertise and processing techniques, offer the possibility to provide more insight into rangeland condition and answer questions regarding change in condition over time.

Currently, no evaluation into the condition of Georgian rangelands that utilises EO data has been carried out. This study presents an analysis of rangeland condition in Georgia by EO techniques.

1.4 The study area

This study focuses on the regions of Kvemo Kartli and Samtskhe-Javakheti (Figure 6), both rural areas in southern Georgia, where the main source of income is from agriculture. The regions cover approximately 12,900 km^2 and are mountainous, partly forested areas with natural pasture on the higher slopes. The study area follows the line of the Lesser Caucasus range, with the Likhi Ridge rising to 3000 m, forming a north-south boundary running between the two regions, connecting the Lesser Caucasus to the Greater Caucasus range. The Likhi Ridge forms an important bioclimatic boundary between east and west Georgia, shielding the eastern part of the country from the influence of the Black Sea, creating a continental climate to the east with colder winters, hotter summers and lower humidity.

Kvemo Kartli

Kvemo Kartli is the region due south of the Georgian capital Tbilisi that covers an area of approximately 6,480 km^2. It consists of seven administrative districts; Rustavi (the regional capital), Bolnisi, Gardabani, Dmanisi, Tetritskaro, Marneuli and Tsalka. The population is of mixed ethnicity where Georgians and Azeris comprise the larger proportion. It has good infrastructure links connecting the region to Tbilisi, Armenia and Azerbaijan. The main rangeland areas are on the border with Armenia and Azerbaijan and along the eastern side of the Likhi Ridge. Further east there is a large area of cropped agricultural land, following the valleys of the Algeti and Chrami rivers.

Climatically the region is characterised by temperate, dry, hot summers and cool winters. The majority of annual precipitation falls during April to June and temperatures reach their maximum in July and August, together with a pronounced reduction in precipitation.

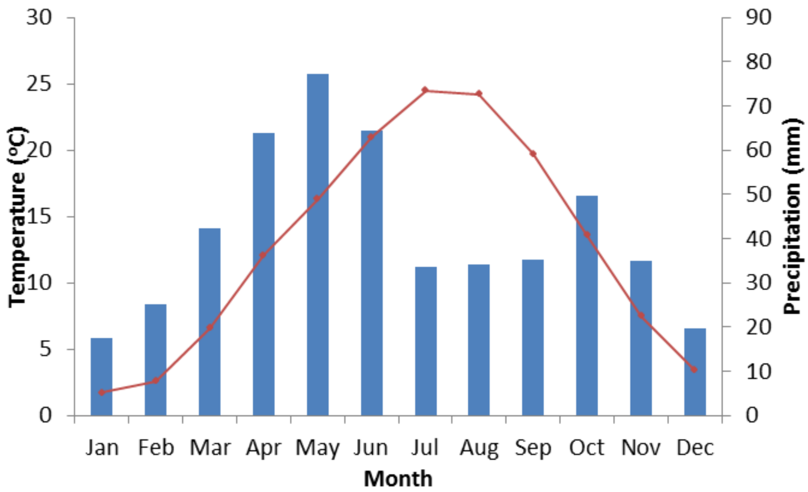


Figure 4: Monthly annual temperature and rainfall for Kvemo Kartli (average 1980-2010, source: National Environment Agency)

Samtskhe-Javakheti

Samtskhe-Javakheti lies to the west of Kvemo Kartli covering an area of approximately 6,420 km^2 and known for its dairy products and potatoes. It comprises six administrative districts; Akhaltsikhe (the regional capital), Adigeni, Aspindza, Borjomi, Akhalkalaki and Ninotsminda where the majority of the population are Armenian. The area is naturally isolated due to its location on a high volcanic plateau, dissected by the steep valley and gorge of the Mtkvari River. Rangelands occur across the volcanic plateau and along the western side of the Likhi Ridge.

Samtskhe-Javakheti experiences colder temperatures during the winter months and its summer months are cooler than those in Kvemo Kartli. The majority of precipitation falls during May and June, with a less pronounced reduction in the summer months.

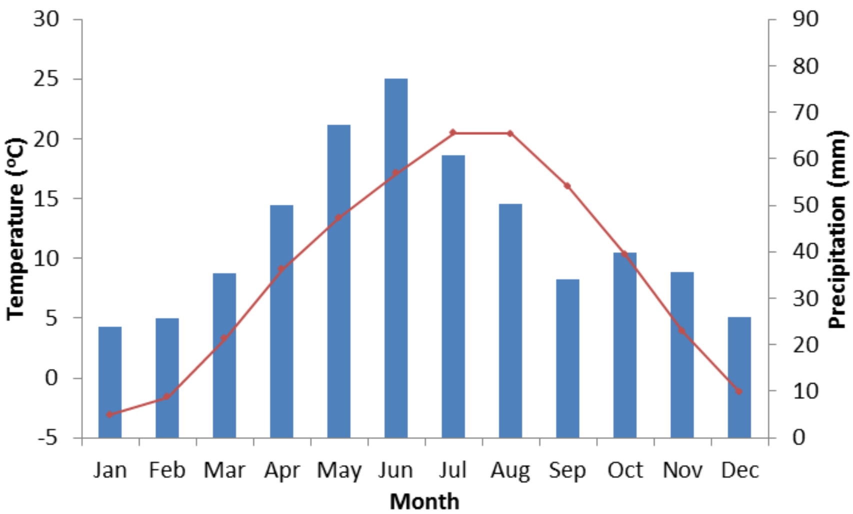
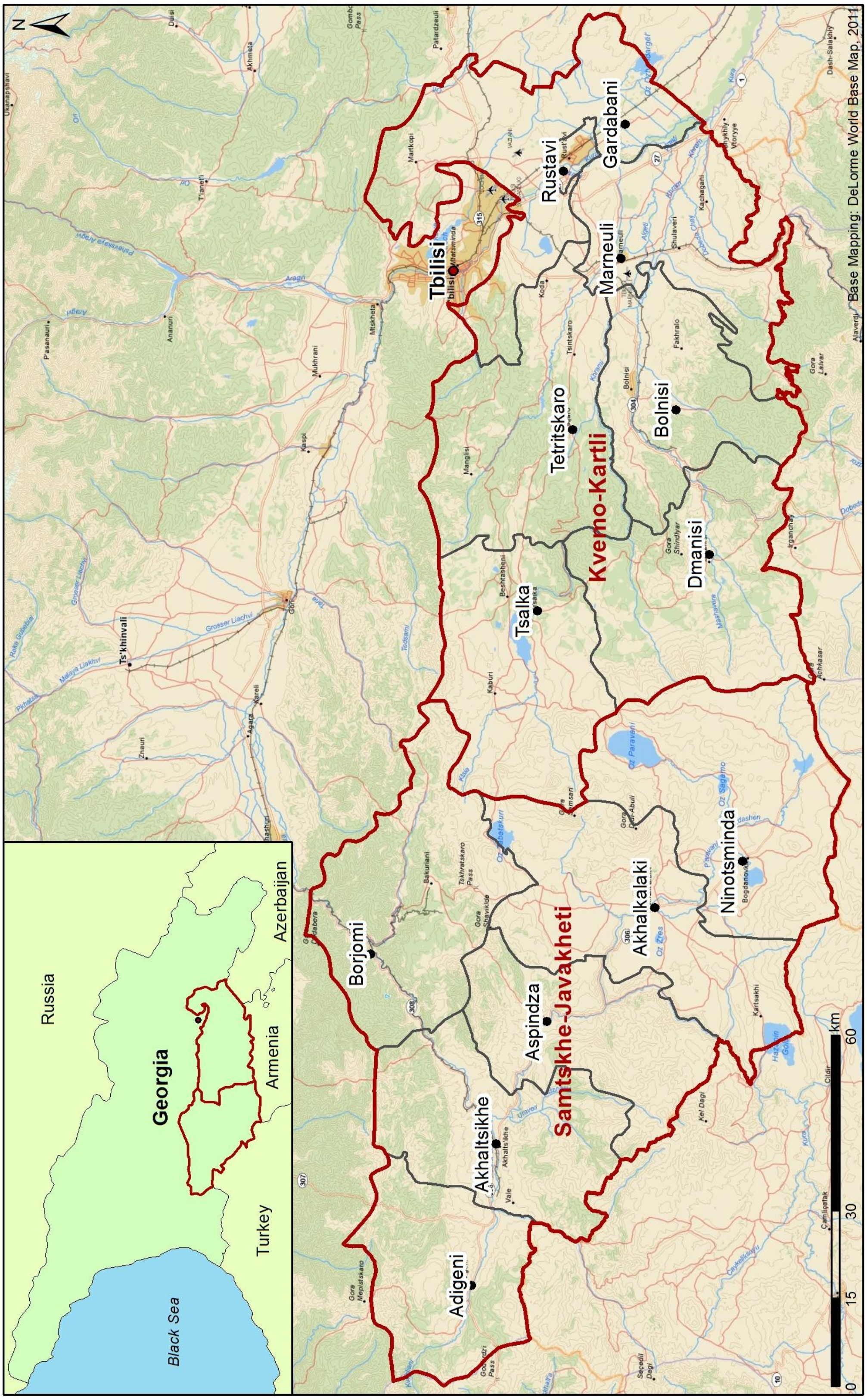


Figure 5: Monthly annual temperature and rainfall for Samtskhe-Javakheti (average 1980-2010, source: National Environment Agency)

Within both regions the rangelands are used as areas of summer grazing by farmers from the eastern parts of Georgia (especially Kakheti) moving large flocks of sheep (and to a lesser degree cattle) on seasonal migrations (transhumance) across the country in spring and autumn.

Figure 6: Kvemo Kartli and Samtskhe-Javakheti study area



2. Data

The main focus of this study is on the use of EO to assess rangeland condition. The project structure involved a number of stages:

1. Identification and acquisition of EO data
2. Collation of contextual datasets
3. Processing of EO data
4. Initial data analysis
5. Ground truthing and stakeholder consultation
6. Re-analysis and final reporting

These stages are illustrated in the process diagram at Figure 8.

2.1 Identification and acquisition of EO data

The primary EO data investigated were from optical (or passive) sensors i.e. where the satellite requires daylight to acquire an image. Optical multispectral sensors record the reflected solar radiation from the surface of the Earth, at specific frequencies across the electromagnetic spectrum. Different surface features exhibit characteristic spectral reflectance's which can be quantified by measuring the portion of incident energy that is reflected (Figure 7). In principle, a surface feature can be identified by its spectral reflectance signature as long as the sensing system has sufficient spectral resolution to distinguish it.

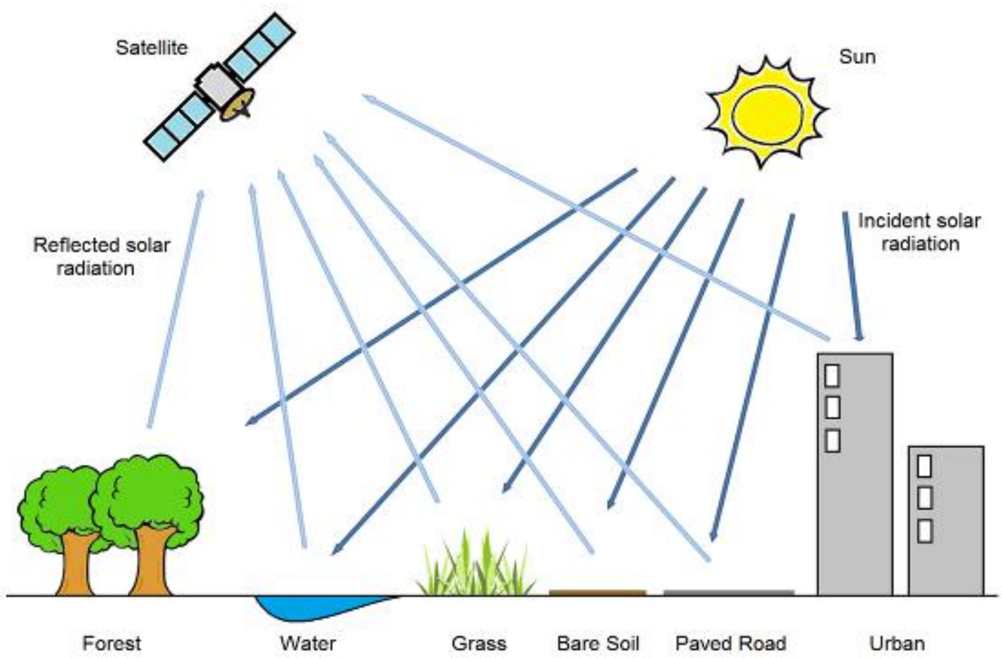


Figure 7: The concept of remotely sensed Earth observation data

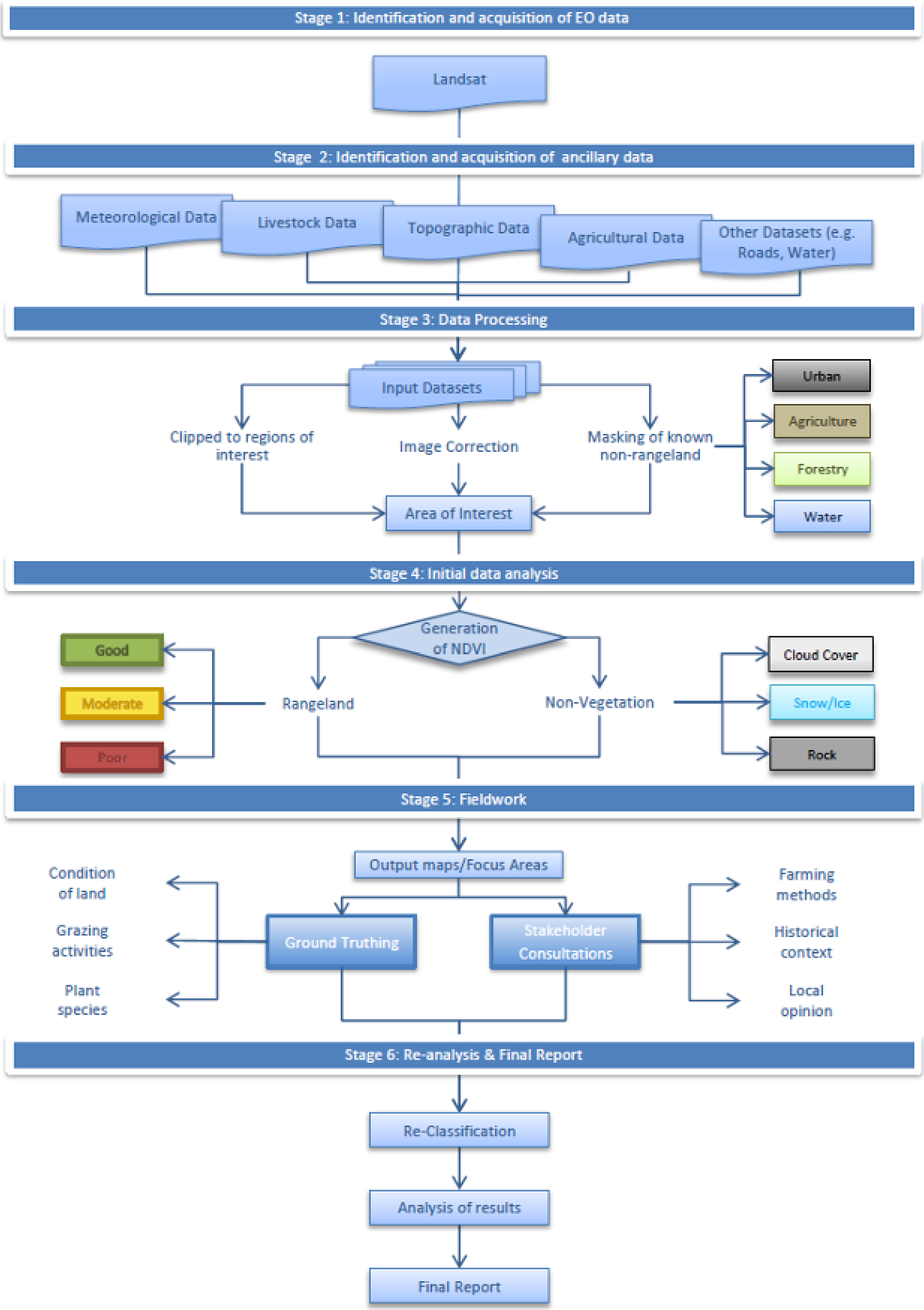


Figure 8: Project structure

It was important that the EO data utilised was of sufficient spatial resolution in order to accurately observe and map the rangelands under investigation. Based on accepted definitions, including those used by the EU Global Monitoring for Environment and Security (GMES), EO systems are categorised into four spatial resolution classes:

- Very High Resolution (VHR) ≤ 5 m
- High Resolution (HR) ≤ 30 m
- Medium Resolution (MR) ≤ 300 m
- Low Resolution (LR) ≤ 5 km

There is often a 'trade-off' whereby a higher spatial resolution typically means a smaller geographic footprint. Wider area coverage can be achieved by mosaicking several scenes together.

The optical sensors considered for this study included DMC, ASTER, SPOT and Landsat imagery (Annex 1). Since the task involved distinguishing between areas of productive rangeland and areas of overgrazing and degradation it was important to exploit data from the spring and summer periods, when vegetation is at its most productive and will exhibit a strong spectral response in the imagery.

For the purposes of this study Landsat imagery provided the best option. Landsat provides high resolution (HR) multispectral imagery and has been acquiring imagery globally since its initial launch in 1972. There are a number of Landsat satellites, of which the most relevant for this study, Landsat 4 and Landsat 5 have been acquiring imagery since 1982 and 1984 respectively. The most recent, Landsat 7, was launched in 1999. Landsat 'scenes' are generally 120 km by 120 km in size, taken as the satellite orbits the earth on its roughly SW to NE axis with a revisit time of roughly 16 days. Additional information with regards to Landsat can be found in Annex 5.

Image acquisition

Image scenes captured by the Landsat satellites 4, 5 and 7 were examined for their suitability. Key requirements were:

- Cloud-free or relatively cloud free images.
- Good availability of consistent image scenes over a 25 year period.
- Comparable seasonal dates of imagery to generate a composite image to cover the whole study area.

Table 1: Landsat imagery acquired

Year/month of composite map	Satellite	Specific date Kvemo Kartli	Specific date Samtskhe-Javakheti
2011 July	Landsat 7/5	27/07/2011	26/07/2011
2011 June	Landsat 5	01/06/2011	08/06/2011
2006/07 August	Landsat 5	29/08/2006	25/08/2007
2000 August	Landsat 5	12/08/2000	21/08/2000
1988/1990 June/May	Landsat 4/5	09/06/1988	29/05/1990
1984 June	Landsat 5	06/06/1984	13/06/1984

It was possible to obtain relatively cloud free images dating back to 1984. The study area requires two adjoining Landsat scenes for complete coverage. The orbit of the Landsat satellite means that these scenes will never be captured on the same day and may be up to 16 days apart (which means that the requirement for two adjoining cloud-free scenes at a similar time of year may not always be achievable within the same year as 1988/90 and 2006/07 show). Table 1 outlines the imagery acquired.

2.2 Collation of ancillary datasets

The datasets outlined in Table 2 provided further support in this study, assisting in the development of the classification, planning the field work and aiding in the understanding of the resulting condition maps. Specifically, a Georgian basemap supplied by Mercy Corps provided information on the spatial distribution of roads and some urban areas (e.g., buildings) while the digital elevation model (DEM) provided information on the terrain and landscape position. Datasets on forested areas and water bodies were also available and were provided by Mercy Corps.

Table 2: GIS map layers employed

Data	Source	Application
Summer/winter pasture location and Transhumance routes	Mercy Corps	Contributes to site familiarisation with supporting role in the development of rules.
Georgian basemap	Mercy Corps	Topographic structure –baseline year unknown (but of Soviet era, pre-1991).
DEM	Mercy Corps	Elevation, slope, aspect and orthorectified radar image data.
Forestry layer	Mercy Corps	Woodland masking to aid identification of the rangeland area on the ground – baseline year unknown.
Aerial photography	Google Earth	Site familiarisation and time series comparison.
Meteorological Data	National Environment Agency	Consists of current year (2010) and an average 1980-2010. Aids the understanding and interpretation of imagery from different times of year, and of change in condition (Annex 2).
Cropped agricultural land	Environment Systems*	Agricultural land masking to aid the identification of the rangeland area on the ground – baseline 2011

*It was agreed with Mercy Corps that a delineation of agricultural land would be undertaken by Environment Systems as part of the project in order to exclude such areas, which were confusing the identification of rangelands. This was created by utilizing current (2011) Landsat imagery to identify and digitise manually all areas that could be seen as cultivated land or hay meadows. In general these areas are the flatter land found in the base of valleys, extending in places, especially for hay, onto more sloping land along valley sides.

3. Methods

3.1 Image processing and data preparation

3.1.1 Pre-processing of EO data

Initial preparation of the satellite imagery involved two main technical processes, geometric and atmospheric corrections followed by a simple clip of the imagery. These processes allow alignment of the satellite images with other datasets (e.g. in a GIS), enabling a consistent application of classification techniques by removing any earth atmosphere effects from the imagery.

Geometric correction

The key priority is to register images acquired by sensors with different orbital and observing configurations (e.g., spatial resolutions, viewing angles). All imagery supplied was geo-referenced to the WGS 1984 UTM Zone 38N projection system, the best compromise for Georgia that achieves locally accurate referencing using an international standard.

Atmospheric correction

All imagery supplied was calibrated to radiance (W m^2 sr^{-1} μ^{-1}) and subsequently to top of atmosphere reflectance (%). It was vital that these stages were delivered accurately to ensure the successful development of the rule base. Our previous work has demonstrated that atmospheric correction of optical data to surface reflectance is a critical stage in developing consistent decision rules and classifications. The result of this processing is a set of imagery that has comparable reflectance data ready for classification, allowing;

- Comparison of reflectance data acquired by the sensor observing on different dates,
- Calculation of vegetation indices and end-member fractions,
- Removal of inconsistencies associated with the atmosphere.

Masking of imagery

As a part of the image processing the Landsat images were masked to the outline of each region. This removed a vast amount of data from outside of the study area which is of no interest to the study and helps to improve processing time during later stages of the study.

3.1.2 Pre-classification preparation

Choice of index to map vegetation condition

It was agreed with Mercy Corps at an early stage that rangeland condition would be assessed as the amount of vegetation cover, relative to bare ground. On this basis:

- Complete vegetation (grass) cover would equate to good condition.
- Large areas of bare ground, with little grass cover would equate to poor condition.
- Moderate condition would be assessed as a mix of good grass cover with some bare ground.

Bare ground of course can be present for a number of reasons:

- Naturally occurring on rocky soils,
- Due to overgrazing,
- Due to erosion, that may or may not be linked to overgrazing,
- Vegetation burn-off and die-back.

A suitable index was required to record rangeland condition. The performance and suitability of a particular index can generally be determined by the sensitivity of the index to the characteristic of interest. `The 'Normalised Difference Vegetation Index' (NDVI) was chosen as the indicator of condition most suitable for use. NDVI, the most widely used vegetation index separates green vegetation from other surfaces because the chlorophyll of green vegetation absorbs the red light for photosynthesis, and reflects in the near infrared wavelengths due to scattering which is induced by the internal leaf structure. A high NDVI value will therefore indicate high leaf biomass, canopy closure, or leaf area.

A consequence of using NDVI is that grassland that is not actively growing, either as a result of water stress or recent emergence from snow cover, will exhibit a reflectance signature similar to bare ground. This is particularly relevant in mid-late summer when some grasslands are showing signs of drought-stress, and in early spring, when some of the higher grasslands have only just emerged from snow cover. In these circumstances rangeland 'condition' is also a reflection of grazing quality, where poor condition can reflect a lack of grass growth (in an otherwise full cover of grass) as well as a lack of grass cover. Interpretation of the resultant maps needs to take account of these issues.

NDVI values were generated through using the fully processed EO data and applying band math procedures to each image within the Trimble eCognition software package.

Identifying rangelands

The Landsat scenes and ancillary datasets were collated within eCognition following a two tiered (multi-level) hierarchical approach. The first level (the Integration Level) brought together the non-rangeland datasets to enable the study to known areas of rangeland. This was achieved by synchronising the EO data with the GIS datasets, essentially overlaying the non-rangeland features onto the imagery. The area that remained after masking out urban infrastructure, water bodies, woodland and agricultural land, provides a good approximation of the full extent of the rangelands in the two study regions (Figure 9).

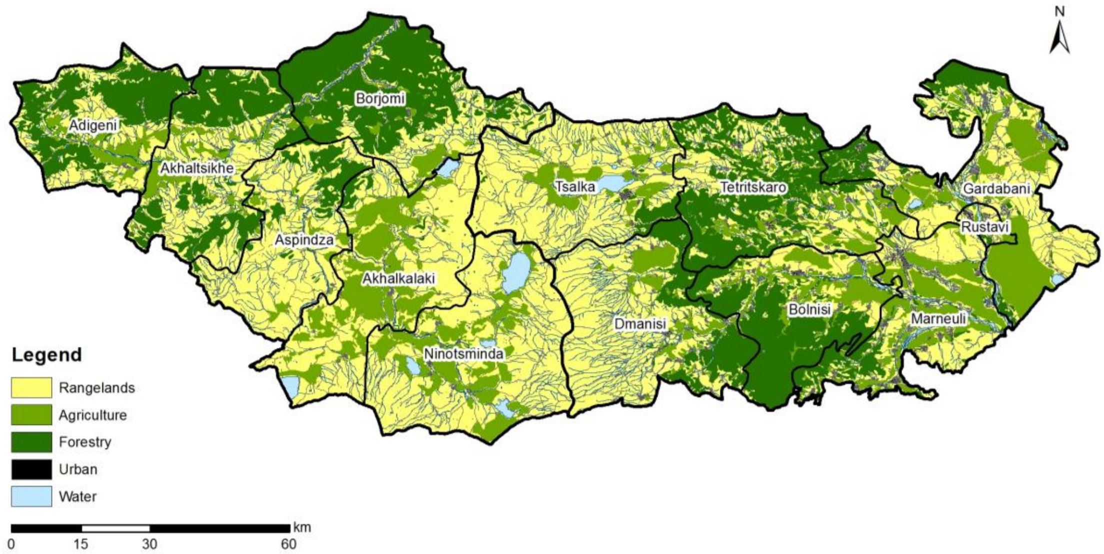


Figure 9: The rangelands of the study area

The second level (the EO Level) classified the 'rangeland' area into relative states of rangeland condition (good, moderate, poor). This was achieved by copying the Integration Level and re-segmenting the unclassified (rangeland) areas based upon their NDVI values. Classes were then developed from segmented data within this level.

3.1.3 Data analysis

Image segmentation

Segmentation techniques are a relatively new way of classifying remote sensing data. Historically, a process of manual digitisation of areas of interest following an extensive field campaign would be undertaken. However, with the increased necessity for high-spatial resolution imagery analysis, and the availability of commercial or non-commercial software packages, segmentation processes have become increasingly useful as these enable a rapid semi-automatic separation of image pixels, the basic unit of the satellite image, into a representative form of the real work component they depict.

Segmentation is essentially a semi-automatic way of digitising land with the same characteristics. In high spatial resolution imagery, pixels when grouped together can better represent the characteristics of land-cover groups far better than single pixels can. Therefore groups of adjacent pixels will be organised into objects which will in turn be treated as a minimum classification unit. These objects are defined as basic entities which are located within an image, where each pixel group is composed of similar digital values, and possesses an intrinsic size, shape, and geographic relationship with the real-world scene component it models. Therefore, the objects can be said to be spectrally more homogeneous within individual regions than between them and their neighbours.

The Trimble eCognition multi-resolution segmentation algorithm creates image or grid data segments which are primarily based upon three criteria: scale, colour and shape (smoothness and compactness). Scale is the heterogeneity acceptance within a segment whilst colour, smoothness and compactness are all variables that accentuate the segments spectral homogeneity and spatial complexity.

By emphasising the scale rather than compactness, it can allow for polygons to follow natural features more innately. When shape information was strongly emphasised instead of colour, the resulting polygons were unstructured and did not closely follow feature boundaries.

Development of a rangeland classification

In order to produce a suitable and informative classification of rangeland condition it was necessary to classify the imagery into an appropriate number of classes. Following the exclusion of non-rangeland (urban, forestry, water or agricultural based), the remaining (rangeland) areas were classified, based upon NDVI values into the classes outlined in Table 3. A 'traffic-light' system was employed to map condition, reflected in the rules used to classify the rangeland. Cloud and any associated shadow were identified as areas that had to remain un-mapped.

Rule based classification approach

A rule based classification was undertaken within eCognition to map the classes described above. A rule based approach permits knowledge of both the ecology and the content of the EO data to be incorporated into the classification process. Numerically derived rules can then be established based on noted differences and changes within the imagery, and thus used progressively to produce a classification.

Trimble eCognition allows both spatial and spectral information in high-resolution remote sensing imagery to be taken into account, enables the processing of a large remote sensing dataset, including ancillary information, and has fast execution. It is also robust, does not have any parameters that require detailed tuning, and is relatively easy to apply the output results in subsequent.

Table 3: Classification classes

Class	Description
Rock	Areas characterised by bare rock, gravel, scarps and other accumulations of rocky material, with little or no 'green' vegetation. Distinguishable by low NDVI values.
Snow/ice	Areas where remnant winter snowfall prevails characterised by a low NDVI.
Cloud cover	Areas of cloud (and its associated shadow), distinguishable by very low NDVI and high red and NIR values.
Good condition	Areas characterised by complete vegetation cover that is in a productive stage of growth thus exhibiting high NDVI values.
Moderate condition	Areas characterised by either; – A reasonable coverage of vegetation in a productive state – Dense coverage of vegetation in a less productive state
Poor condition	Areas of bare ground, with little coverage of vegetation, or where the vegetation is not actively growing either through water-stress or recent snow cover, thus exhibiting low NDVI values.

To undertake the rule based classification, thresholds were developed for each class making use of various spectral bands and from the derived NDVI index. For consistency, the decision rules were based on the opinion of a single skilled operator utilising knowledge acquired during previous projects of a similar nature. Rules for each class were acquired by obtaining upper and lower boundaries for the NDVI through using the 'feature view' function within eCognition. These boundaries were decided based upon 'fuzzy logic' whereby the differentiation between rangeland conditions is a transition rather than a fixed, exact change. This is reflected in the definition of the three classes.

3.2 Fieldwork

Six focus areas were identified within the overall study area (**Error! Reference source not found.**) ased on the initial classification of the 2011 imagery and input from Mercy Corps as areas reflecting parts of the two regions where rangelands were important. Three were chosen in each region; in Samtskhe-Javakheti these where Akhalkalaki, Akhaltsikhe and Aspindza. In Kvemo Kartli, Dmanisi, Tsalka and Tetritskaro were selected. Within each focus area a stakeholder consultation was held alongside ground truthing of pastures within the local area.

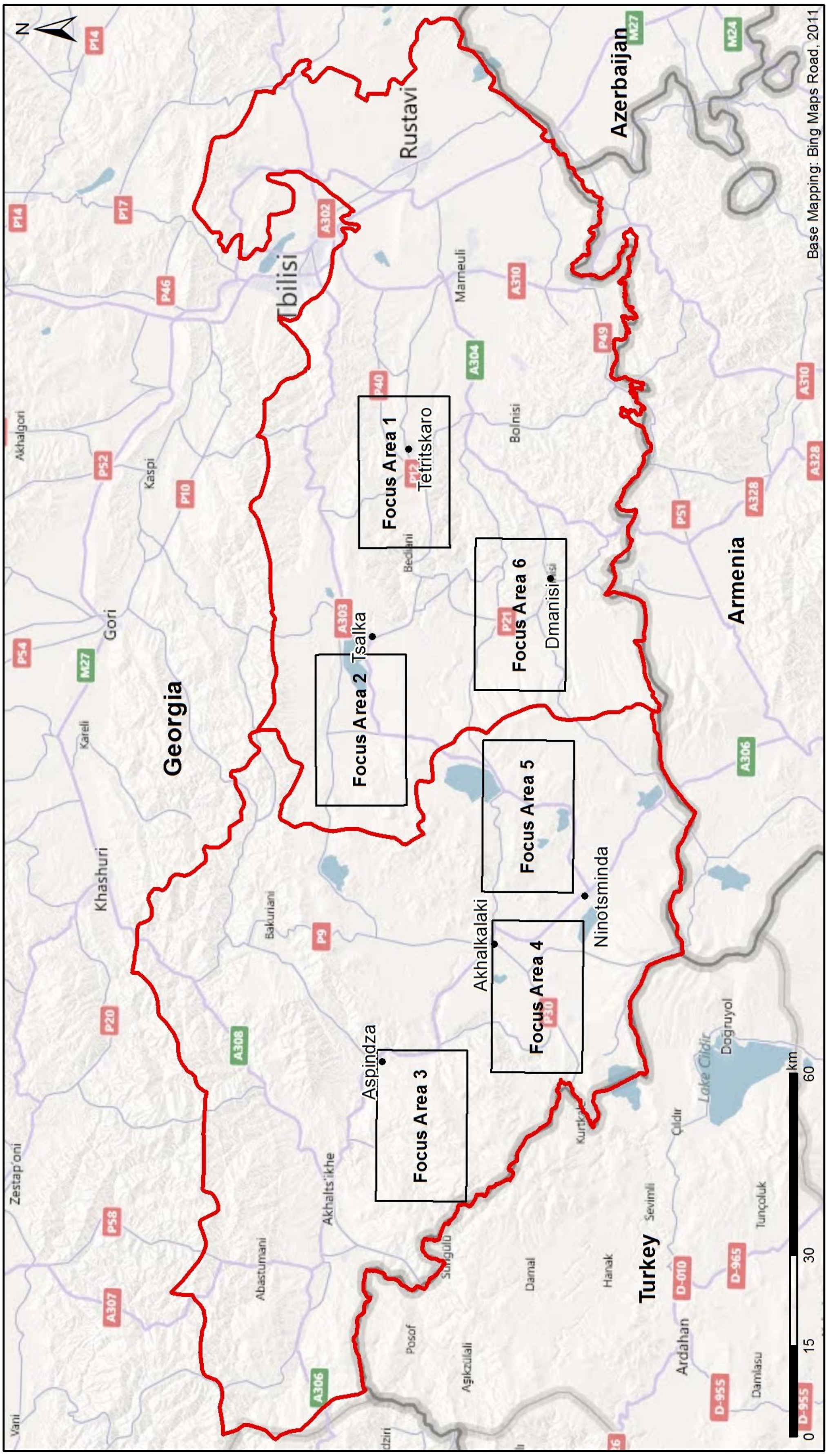
Stakeholder consultations

The stakeholder consultations were structured to imitate the focus groups conducted by Alliances Kvemo Kartli and Samtskhe-Javakheti earlier this year. They consisted mainly of farmers from the surrounding local areas in addition to community representatives. Mercy Corps staff assisted with local arrangements, particularly in Kvemo Kartli, and attended the meetings. Information was collected by an expert agricultural facilitator from AA International who led discussions around key topics. They each lasted around 3 hours and provided valuable information about the local situation with regards to rangeland condition and management. A full report on the stakeholder consultations is available at Annex 3.

Ground truthing

Field visits were made to a number of local and rangeland pasture sites by an expert ecologist, where a field assessment of pasture condition was made, and an in-situ assessment of grazing activities was made. In the time available this was restricted to sites reachable by an off road vehicle

Figure 10: The location of the six focus areas



within in a 2-3 hour period, which meant it was not generally possible to access the higher rangeland pastures. The aim of ground truthing was to check, confirm and amend the EO classification of the grasslands, based on an assessment of vegetation condition on the ground. A full report of the field assessment can be found at Annex 4.

3.3 Re-analysis

Following the initial classification and fieldwork a period of re-analysis was carried out on the initial rangeland assessment. This refined the rulebase as necessary, based on the results of the stakeholder consultations and ground truthing. In particular ground truthing revealed the rapid seasonal change in rangeland condition that is evident across the two regions and therefore guided the distinction between condition classes when comparing images acquired in different months. In particular it was decided to show, for 2011, two composite maps, one for early June and one for late July, which illustrate seasonal change in grassland condition in the study area over the key summer months. Finally the resulting classifications were brought into ESRI ArcMap (part of the ArcGIS software package) in order to evaluate the areas of rangelands as well as to conduct a change in rangeland condition analysis between the years 1984 and 2011.

4. Results and Discussion

In this section we have provided a number of illustrative maps that convey current and historical information on the distribution of rangelands and on the condition of rangelands in the study area. We also present a map that provides an indication of change in condition. These maps are supported by findings from the targeted ground truthing and stakeholder consultations undertaken in the study area. Each map is discussed individually in turn and a list of all the data generated, including GIS and satellite, from this investigation and available for distribution can be found in Annex 6. We have produced an interactive PDF which is available outside of this report for electronic viewing only.

4.1 Area of rangeland

An initial analysis identified the total area of rangeland in the study area. When other land uses are excluded, as Table 4 indicates, 7048 km^2 of the study area (55%) can be classified as rangeland.

Table 4: The area of the various land covers within the study area

Class	Area (km^2)	%
Forestry	3410	26
Urban	180	1
Agriculture	2041	16
Water	227	2
Rangelands	7048	55
Total	12906	100

4.2 Current condition

Two maps have been produced of current rangeland condition, for early June 2011 and late July 2011. For both these dates adjoining Landsat scenes close in time were available.

Map 1 shows current rangeland condition in early June 2011.

Interpretation:

June is probably the time of peak rangeland condition, particularly at lower levels. A large area of rangeland (37%) is in good condition, with 33% in moderate condition. In early June there is a residual amount of snow remaining on the highest peaks (especially on the Likhi Ridge), with the grassland immediately adjacent just emerging from snow cover and in poorer condition.

There is no evidence of widespread overgrazing, except along the transhumance route crossing through the districts of Gardabani, Rustavi, Marneuli, Tetritskaro and Tsalka (Figure 11). This route is visible in the Landsat image, where the large volumes of livestock that are moved from winter to summer pastures cause poaching and trampling damage to the vegetation.

Poor rangeland condition in northern parts of the Likhi Ridge reflects the very rocky landscape (Figure 12) which will always have a moderate or poor condition. There are smaller areas of rangelands in poorer condition around summer encampments in Samtskhe-Javakheti and on steeper slopes where some local erosion may have occurred.

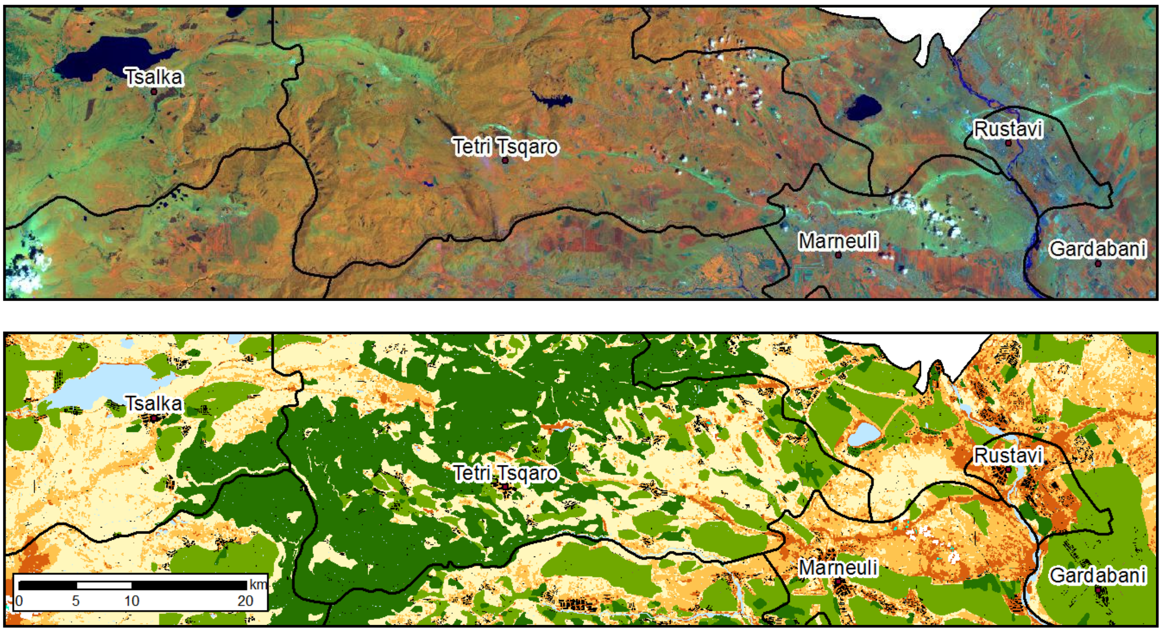


Figure 11: Transhumance routes visible in the imagery and classification

Climatically, April to June are months of peak rainfall which, coupled with the rising temperatures, provides suitable growing conditions for rangeland vegetation and explains why the majority of the rangelands in Map 1 are classified as being of suitable grazing condition.

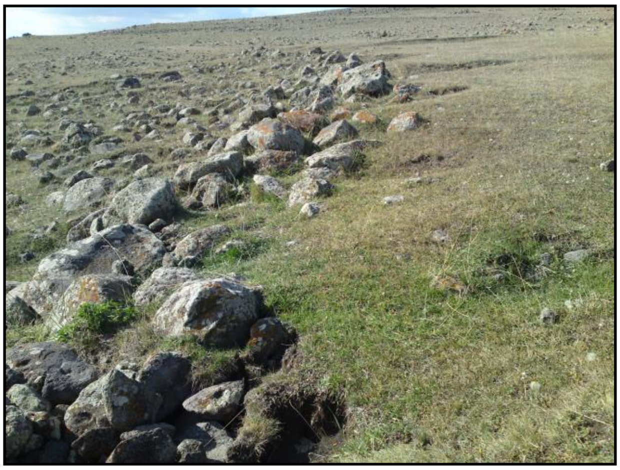


Figure 12: The rocky landscape common on the higher peaks of the study area

Map 2 shows current rangeland condition in late July 2011.

Interpretation:

By late July, temperatures are reaching their peak and rainfall has declined. The amount of rainfall received in both regions drops significantly in July. Rangelands at lower elevations have already begun to 'dry-out' indicated by the increase of areas classified as poorer in condition (34%). In particular, the eastern part of Kvemo Kartli demonstrates a much lower NDVI than that found in June and is more likely to be the result of its geographical position towards the east of Georgia where the climate shifts eastwards from humid subtropical to continental. Some of the steeper valley sides with shallow soils around Aspindza and Akhaltsikhe also show a poor condition, again probably a result of the drying out of the grassland vegetation. By mid-September 2011 the field survey confirmed this area as being very dry as the lack of rainfall continued into late summer.

On the higher ground of the Likhi Ridge and along the Turkish border the rangelands are in peak condition in July, reflected in the smaller area of land in good condition (11%).

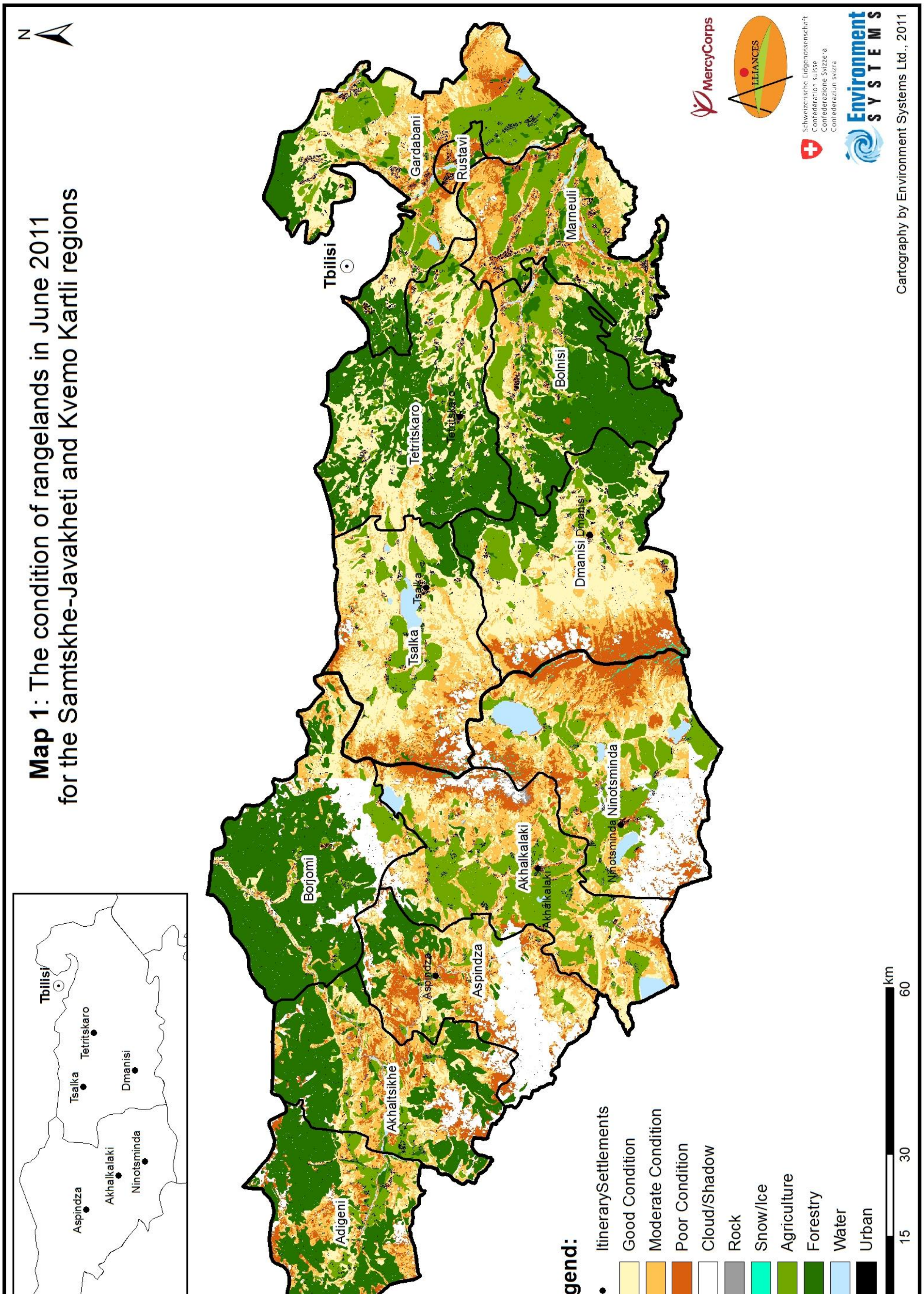
Map 3 indicates areas of under-utilised rangeland.

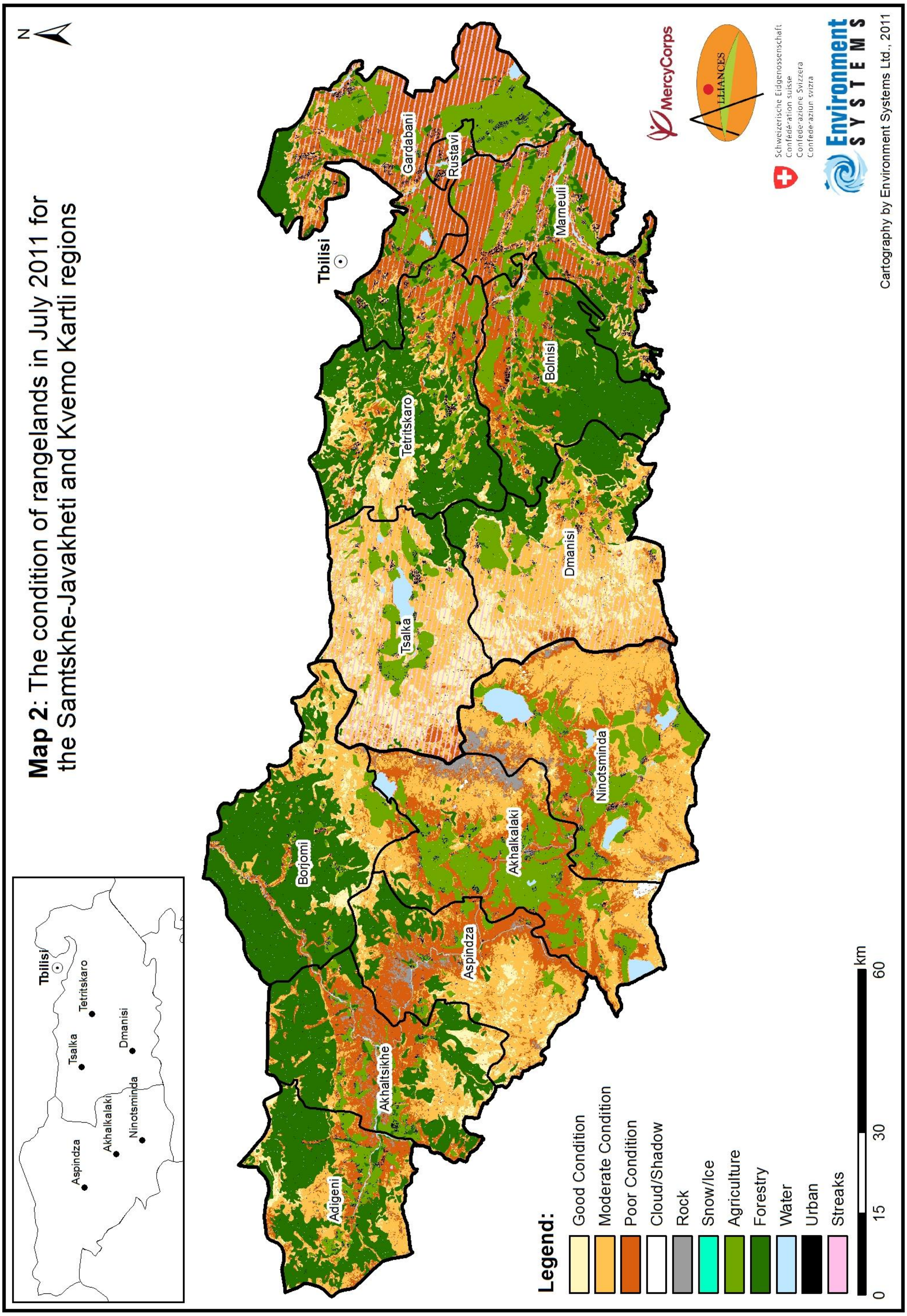
Interpretation:

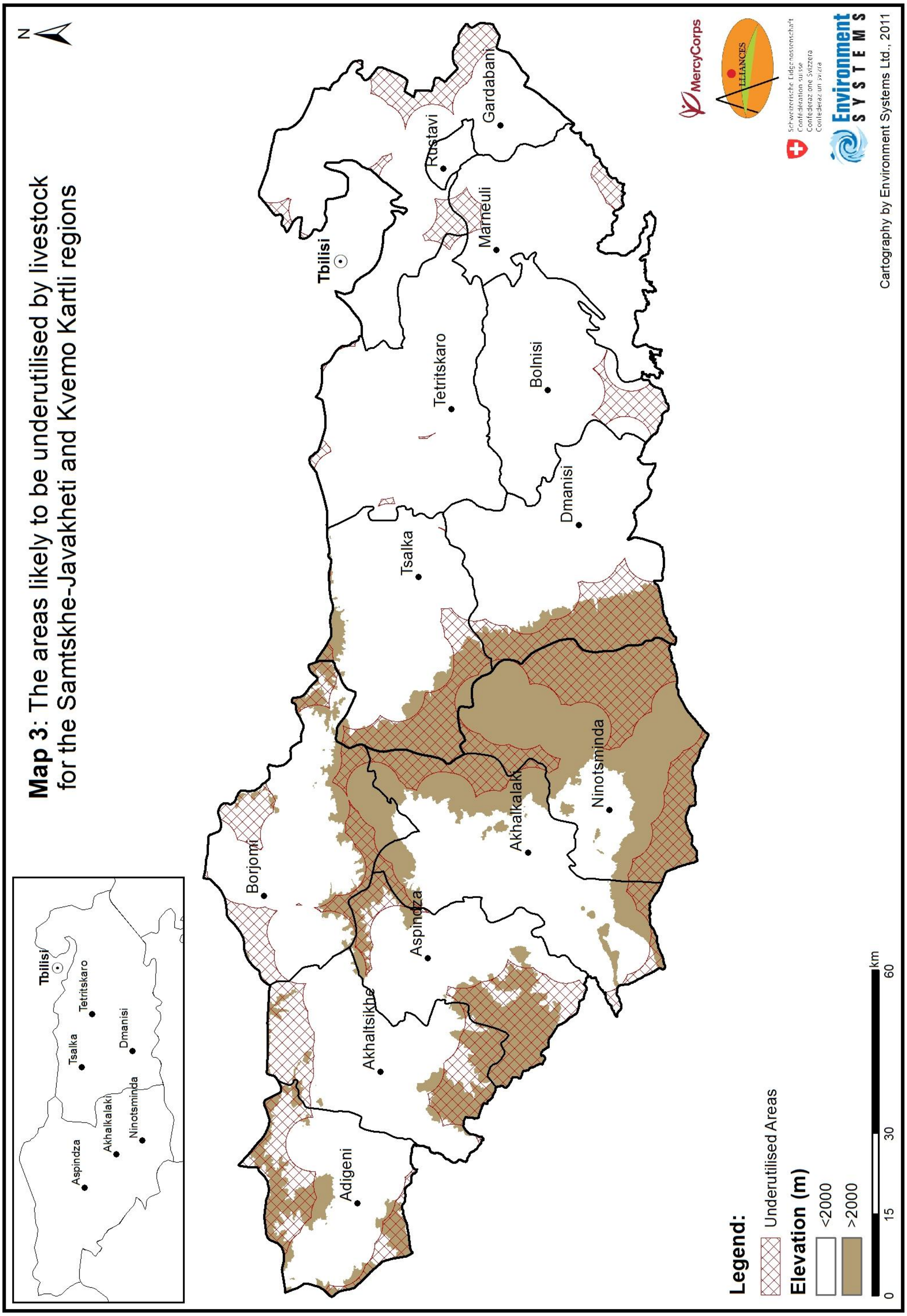
Grassland utilisation depends on the grazing management regime. It was difficult from the stakeholder consultations to identify the precise areas grazed by individual farmers. What was clear was that all stock are normally closely shepherded. Standard stock management involves taking stock onto the grazing pastures (both municipal and rangelands) during the day and returning to the village (or summer encampment) overnight. At night the stock are housed or corralled within enclosures. The consequence of this is that stock only graze the areas they can walk to, and back from, during the day. Consequently, based upon the findings of the Focus Groups conducted by Alliances and our own stakeholder consultations we have assumed that the areas within a 5 km radius of settlements and summer camps will be utilised by livestock. Outside of this 5 km buffer, pastureland is more likely to be underutilised. Map 3 has been produced on this assumption, whereby a buffer of 5 km has been mapped around known settlements. The areas outside of this buffer are unlikely to be grazed on a regular basis although do encompass summer pastures.

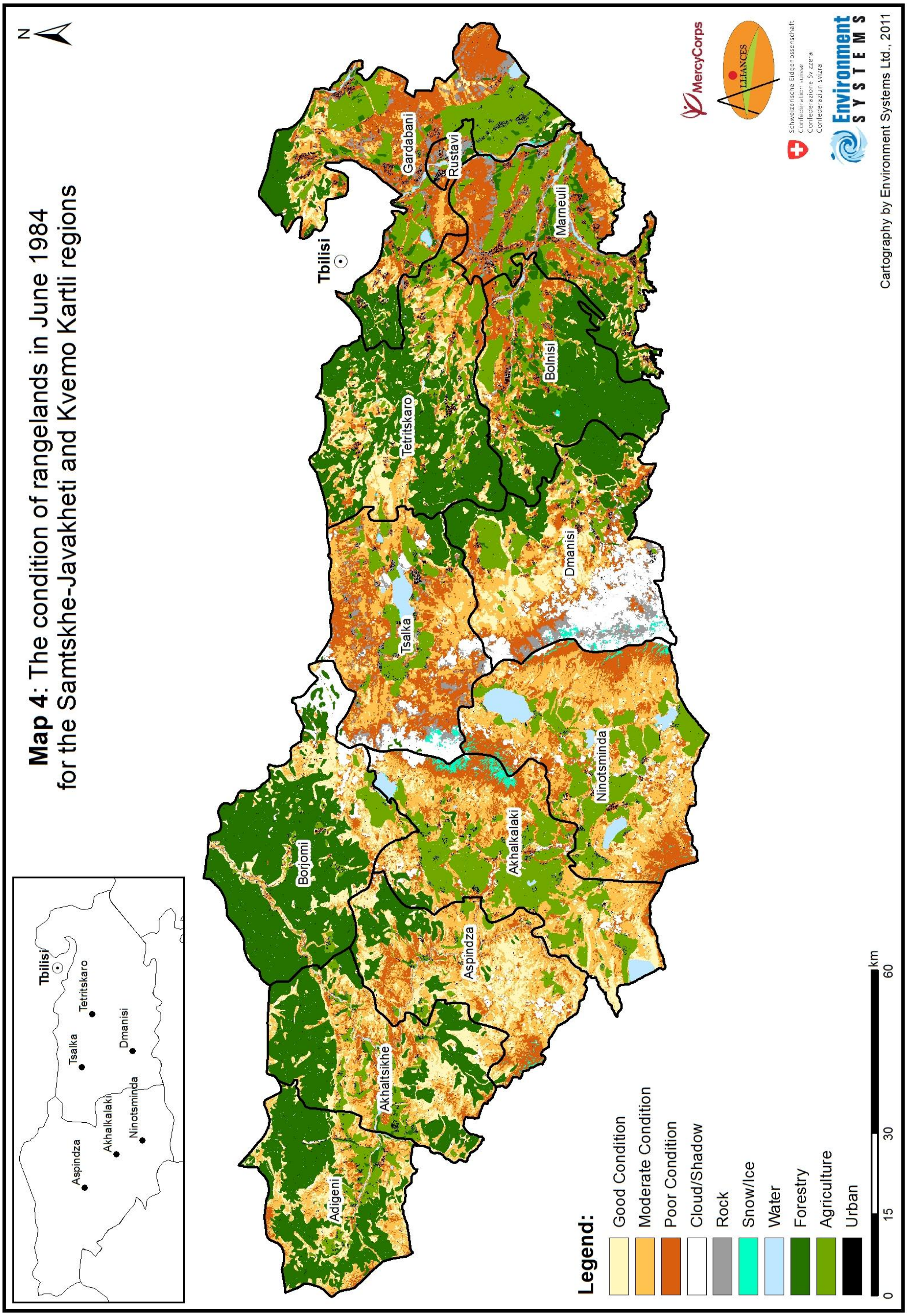
Whilst probably underestimating the number of settlements, especially in summer, the map does show areas of both regions likely to be under-utilised. The key feature to note with regards to Map 3 is that areas indicated as underutilised coincide with areas of higher elevations, particularly along the Likhi Ridge that lies between Samtskhe-Javakheti and Kvemo Kartli. Furthermore, on comparison with Maps 1 and 2, these areas are generally in a better state of condition as based on NDVI values.

The buffer provides an indication of the areas within easy reach of grazing livestock. Outside the buffer the assessment does provide a good indication of areas that are of significant distance from settlements and thus more likely to be underutilised.

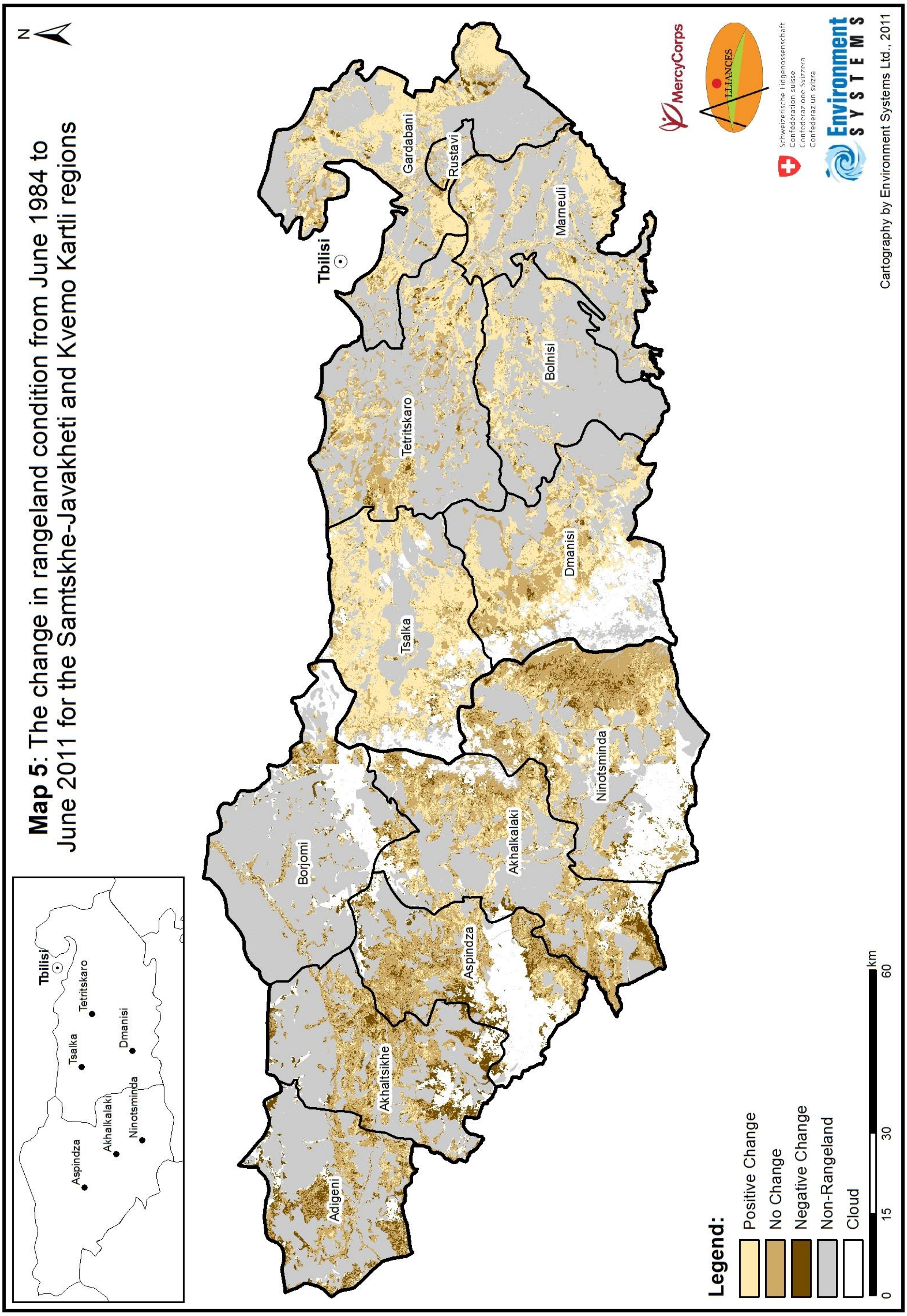

Map 1: The condition of rangelands in June 2011
for the Samtskhe-Javakheti and Kvemo Kartli regions
N
Tbilisi
Gardabani
Rustavi
Marneuli
Tetritskaro
Bolnisi
Dmanisi
Tsalka
Ninotsminda
Akhalkalaki
Borjomi
Aspindza
Akhaltsikhe
Adigeni
Legend:
ItinerarySettlements
Good Condition
Moderate Condition
Poor Condition
Cloud/Shadow
Rock
Snow/Ice
Agriculture
Forestry
Water
Urban
0
15
30
60
km
MercyCorps
ALLIANCES
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Environment SYSTEMS
Cartography by Environment Systems Ltd., 2011

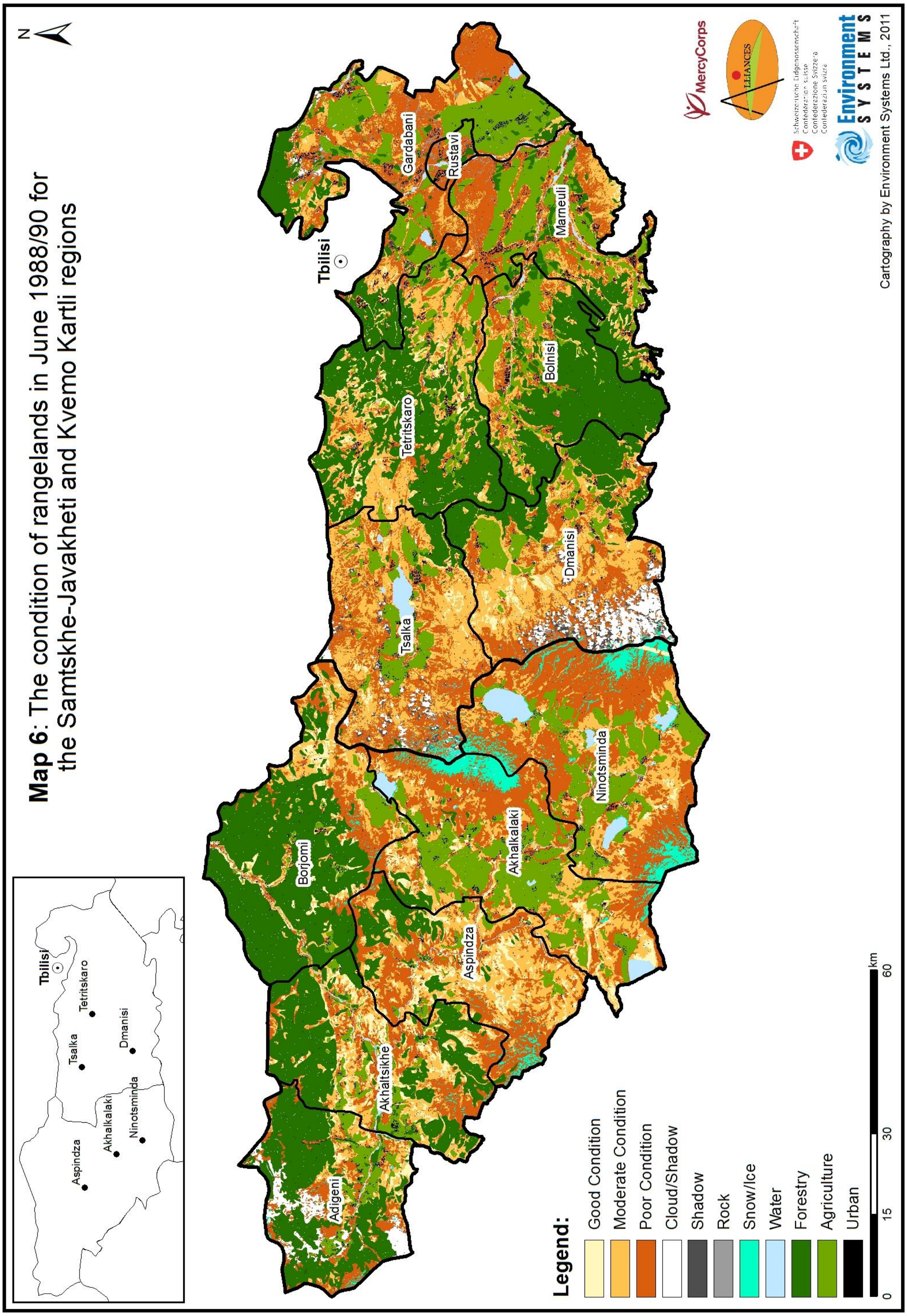

Map 2: The condition of rangelands in July 2011 for
the Samtskhe-Javakheti and Kvemo Kartli regions
N
Tbilisi
Gardabani
Rustavi
Marneuli
Bolnisi
Tetritskaro
Dmanisi
Tsalka
Ninotsminda
Akhalkalaki
Borjomi
Aspindza
Akhaltsikhe
Adigeni
Legend:
Good Condition
Moderate Condition
Poor Condition
Cloud/Shadow
Rock
Snow/Ice
Agriculture
Forestry
Water
Urban
Streaks
0
15
30
60
km
MercyCorps
ALLIANCES
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Environment
SYSTEMS
Cartography by Environment Systems Ltd., 2011


Map 3: The areas likely to be underutilised by livestock for the Samtskhe-Javakheti and Kvemo Kartli regions
N
Tbilisi
Rustavi
Gardabani
Marneuli
Tetritskaro
Bolnisi
Dmanisi
Tsalka
Ninotsminda
Akhalkalaki
Borjomi
Aspindza
Akhaltsikhe
Adigeni
Legend:
Underutilised Areas
Elevation (m)
<2000
>2000
0 15 30 60 km
MercyCorps
ALLIANCES
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Environment Systems
Cartography by Environment Systems Ltd., 2011

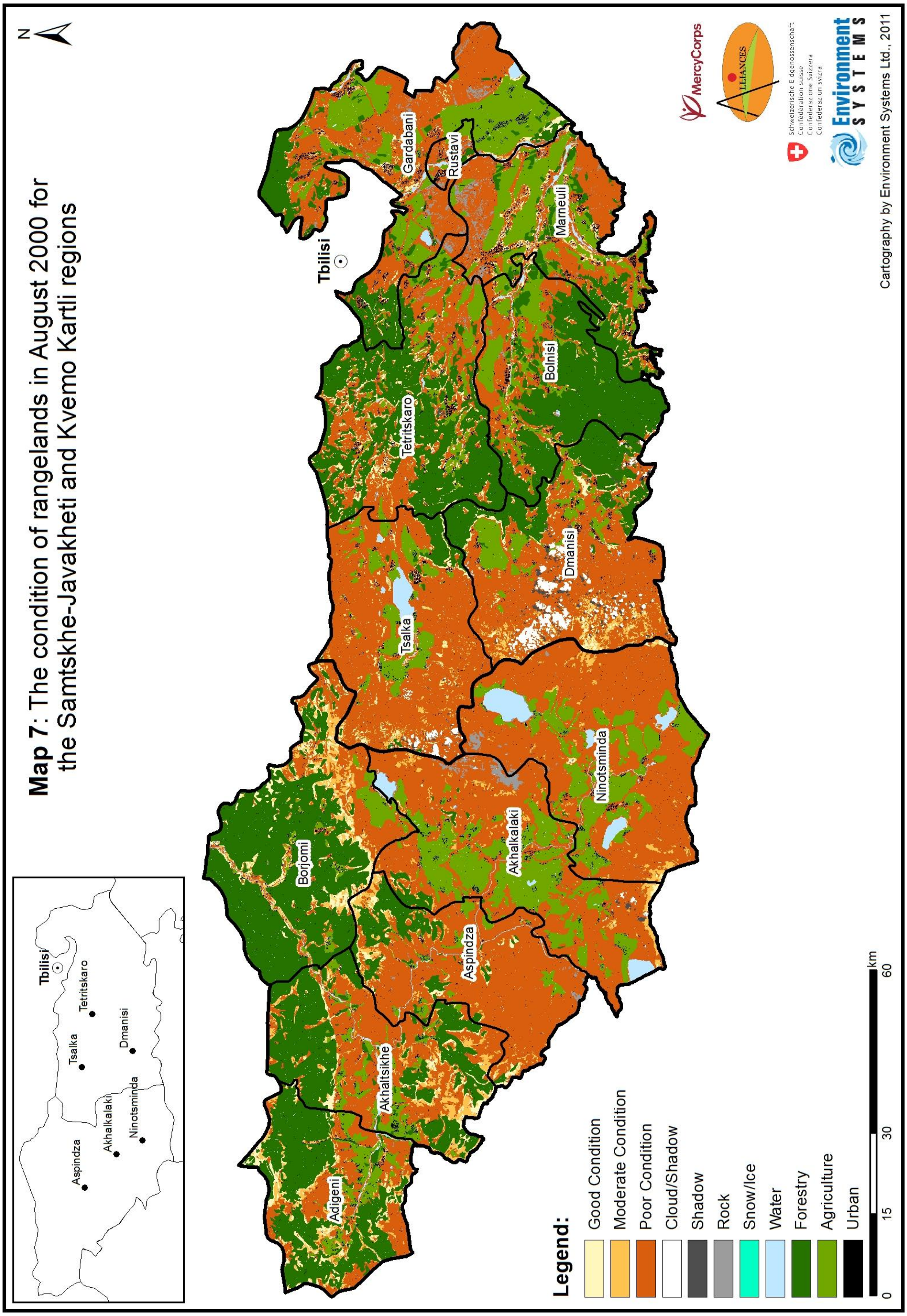


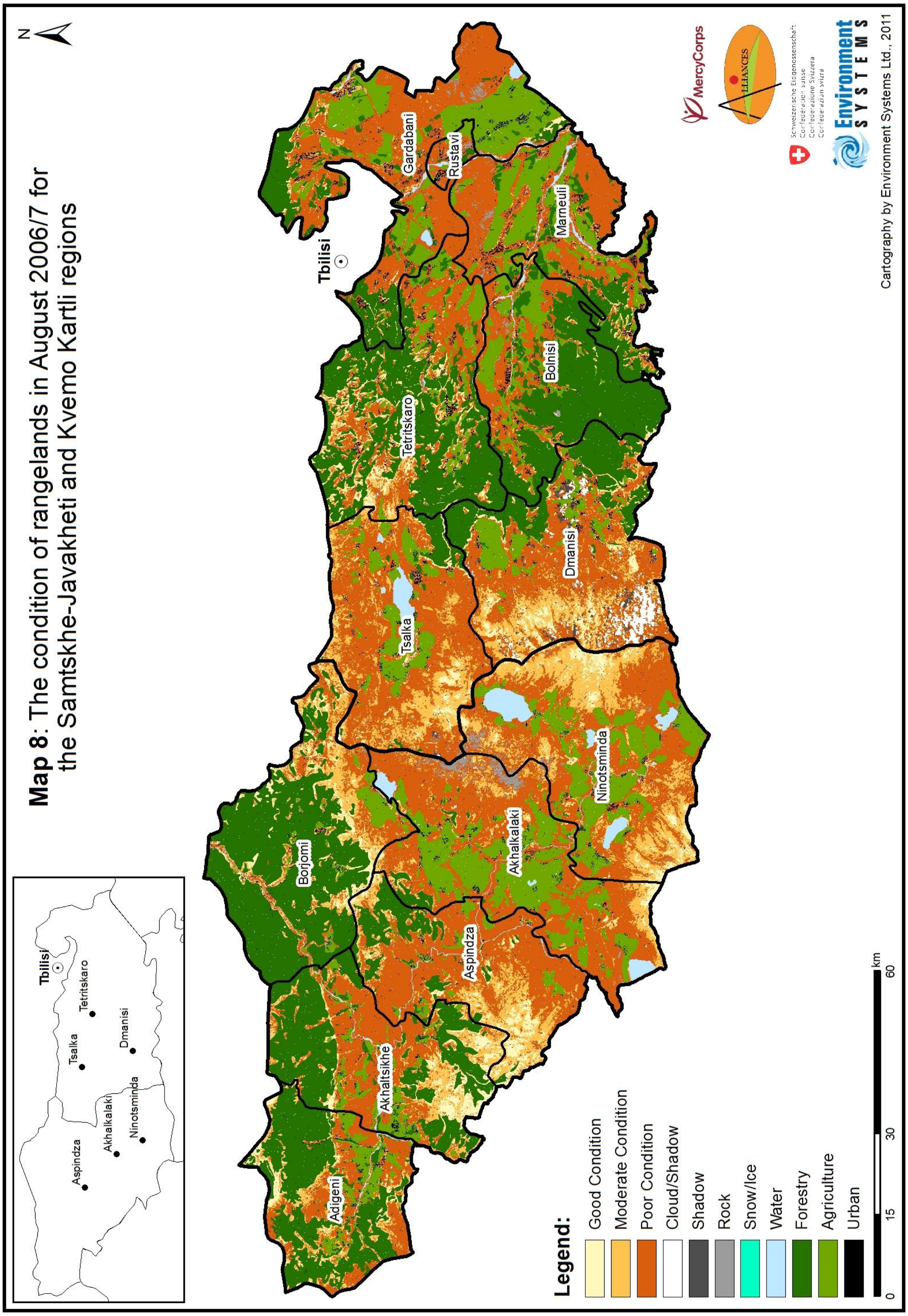
Map 4: The condition of rangelands in June 1984
for the Samtskhe-Javakheti and Kvemo Kartli regions
N
Tbilisi
Gardabani
Rustavi
Marneuli
Bolnisi
Tetritskaro
Dmanisi
Tsalka
Ninotsminda
Akhalkalaki
Borjomi
Aspindza
Akhaltsikhe
Adigeni
Legend:
Good Condition
Moderate Condition
Poor Condition
Cloud/Shadow
Rock
Snow/Ice
Water
Forestry
Agriculture
Urban
0 15 30 60 km
MercyCorps
ALLIANCES
Environment SYSTEMS
Cartography by Environment Systems Ltd., 2011


Map 5: The change in rangeland condition from June 1984 to June 2011 for the Samtskhe-Javakheti and Kvemo Kartli regions
N
Tbilisi
Gardabani
Rustavi
Marneuli
Bolnisi
Tetritskaro
Dmanisi
Tsalka
Ninotsminda
Akhalkalaki
Borjomi
Aspindza
Akhaltsikhe
Adigeni
Legend:
Positive Change
No Change
Negative Change
Non-Rangeland
Cloud
0 15 30 60 km
MercyCorps
ALLIANCES
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Environment SYSTEMS
Cartography by Environment Systems Ltd., 2011



Map 6: The condition of rangelands in June 1988/90 for the Samtskhe-Javakheti and Kvemo Kartli regions


Map 7: The condition of rangelands in August 2000 for the Samtskhe-Javakheti and Kvemo Kartli regions
N
Tbilisi
Gardabani
Rustavi
Marneuli
Bolnisi
Tetritskaro
Dmanisi
Tsalka
Ninotsminda
Akhalkalaki
Borjomi
Aspindza
Akhaltsikhe
Adigeni
Legend:
Good Condition
Moderate Condition
Poor Condition
Cloud/Shadow
Shadow
Rock
Snow/Ice
Water
Forestry
Agriculture
Urban
0
15
30
60
km
MercyCorps
ALLIANCES
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Environment SYSTEMS
Cartography by Environment Systems Ltd., 2011



Map 8: The condition of rangelands in August 2006/7 for the Samtskhe-Javakheti and Kvemo Kartli regions

4.3 Change in condition

Map 4 illustrates rangeland condition in June 1984.

Interpretation:

In 1984 Georgia was part of the former Soviet Union. Large collective farms dominated the area with much larger numbers of livestock present. In comparison with the similar month in 2011 (June), the NDVI classification shows that the relative condition of the rangelands was not as good (and by default has changed positively over the intervening period)

The map also shows the greater amount of snow present on the higher ground, with correspondingly larger areas of rangeland in poor condition surrounding the snow, and on other higher ground along the Turkish border, only recently snow free. This is consistent with winter being longer in 1984 when compared with 2011, but without detailed meteorological data for 1984, which is not currently available, this conclusion cannot be confirmed.

Overall in 1984 only 19% of the rangelands were classified as in good condition, with 38% in moderate condition and 29% poor.

Map 5 provides an assessment of the change in rangeland condition between June 1984 and June 2011.

Interpretation:

Map 5 was produced by comparing the condition of the rangeland in June 1984 to June 2011 and assessing the direction of change. Both maps show rangelands at a similar time of year, and seasonality, so should show real change, rather than a change in seasonality. Table 5 shows how the map was produced. If an area was classified as poor in 1984 and in 2011 had changed to moderate then this was logged as a positive change (Table 5).

Table 5: The change analysis classification classes

Change classification	1984 Classification		2011 Classification	Area of rangeland (km^2)	% of rangeland
Positive Change	Poor	→	Good	2410	34
	Poor	→	Moderate		
	Moderate	→	Good		
No Change	Poor	→	Poor	2326	33
	Moderate	→	Moderate		
	Good	→	Good		
Negative Change	Good	→	Poor	551	8
	Good	→	Moderate		
	Moderate	→	Poor		
Other		Cloud		1761	25
		Ice			
		Rock			

Map 5 provides a comparison of the change in NDVI values between the two dates during which the imagery was captured. It does not account for any fluctuations that may or may not have been experienced between these two dates and its interpretation is subject to a variety of influencing factors that may account for the differences observed.

On balance, when comparing Map 1 with Map 4 there is a strong indication based on the NDVI values that the condition of rangeland has improved since 1984. A large area of rangeland (just over 2400 km^2 or 45%) has experienced a positive change (Table 5). This could be the result of a number of reasons.

Kvemo Kartli appears to show more improvement than Samtskhe-Javakheti, where condition has largely stayed the same, with some decline.

The remaining 55% of rangeland (just over 2300 km^2) has neither improved nor degraded between the two dates. However, 11% has remained poor in both 1984 and 2011. The majority of these poor areas are found in Samtskhe-Javakheti along valley sides. These areas are not very big in size occupying only small pockets of land. This suggests that they could be the result of erosion along steeper sloping ground either caused by livestock movement up to higher pastures or from surface runoff of precipitation.

1984 and 2011 are simply two snapshots in time, from which it is difficult to derive firm conclusions about change. 1984 is simply the earliest year for which suitable imagery is available. 2011 is the current year. Since 1984 much has changed, both agriculturally and environmentally. Stock numbers generally have decreased, which should place less grazing pressure on the rangelands. The climate appears to have become warmer and drier, which will have the effect of producing an earlier snow melt (with an earlier start to grass growth in spring) and a more pronounced drying of the grasslands in summer, although this should not be evident until later in the summer.

It is difficult without more detailed analysis to assess the relative contribution of agricultural and environmental change on rangeland condition between 1984 and 2011.

4.4 Intervening years between 1984 and 2011

In between 1984 and 2011 imagery has been collated for 1988/90, 2000 and 2006/07 (Table 1).

Map 6 shows rangeland condition in May/June 1988/1990.

Map 7 shows rangeland condition in August 2000.

Map 8 shows rangeland condition in August 2006/07.

Interpretation:

Map 6 is a composite of two different years, of imagery early in the growing season. Imagery for Kvemo Kartli was captured in June 1988 while Samtskhe-Javakheti was captured in May 1990. This is a consequence of a lack of image availability. There are not cloud-free images for both regions for the same year.

There is snow still on the ground and a large area of rangeland, on higher ground around the snow, that has yet to recover from the winter (shown as in poor condition). Higher ground will experience warmer temperatures later than lower elevations and consequently is later to recover from winter snow cover.

In comparison to June 2011, although consistent in seasonality in late May/early June, the 1988/1990 does show rangeland in poorer condition (47% of the total) – consistent again with a warming of the climate generally and the earlier snow melt in 2011, with resultant earlier start to the growing season. This again can only be fully confirmed by detailed meteorological data for the 1988/90 years.

2000 was an acknowledged dry year, accompanied by much reduced arable yields, extensive crop losses and fourfold increases in fodder prices in Georgia (World Bank, 2006). This is reflected in the classification shown in Map 7 where the vast majority of the rangelands have been classified as being in poor condition (84%). Although August is likely to be, in normal years, a dry month, NDVI values in 2000 are significantly lower than would probably be expected. Since there was a lack of rainfall during this year it can be assumed with confidence that the condition of the rangelands is the result of the climate and not caused by overgrazing.

Map 8 again is a composite of two years, both perhaps more typical of August conditions in normal years. The map does show the extent of grassland in poor condition (69%), following dry conditions in mid-late summer. The higher peaks remain in better condition (29% in good or moderate condition), where the drying effects of high summer temperatures are less pronounced. Figure 13 illustrates (along the Likhi Ridge) the impact of altitude on rangeland condition between June, July and August.

June 2011 July 2011 August 2006/7

Figure 13: The effect of altitude on rangeland condition

What is clear from the time-series analysis and other research is that there has been enormous variability in climate between the 1984 base year and the 2011 current year. In addition to a number of dry years (especially 1999-2001) there was a particularly wet year in 2005, when heavy rainfall in April and May, coupled with a sudden onset of the seasonal snow melt, led to extensive flooding in lowland areas of Georgia and many landslides and mudflows in mountainous areas (WWF 2008, Climate Change in Southern Caucasus). All of these climatic influences would have an impact on rangeland condition.

Because of this variability in climate it is unlikely that there has been a consistent change in rangeland condition between 1984 and 2011. The overall improvement in condition shown on Map 5 has probably been masked by wide variation in condition in the intervening years.

4.5 Analysis of time-series classifications

Figure 14 illustrates the percentages of rangeland classified into each category for each analysis year. The charts illustrate more than anything the seasonal influence of climate on rangeland condition through the growing season.

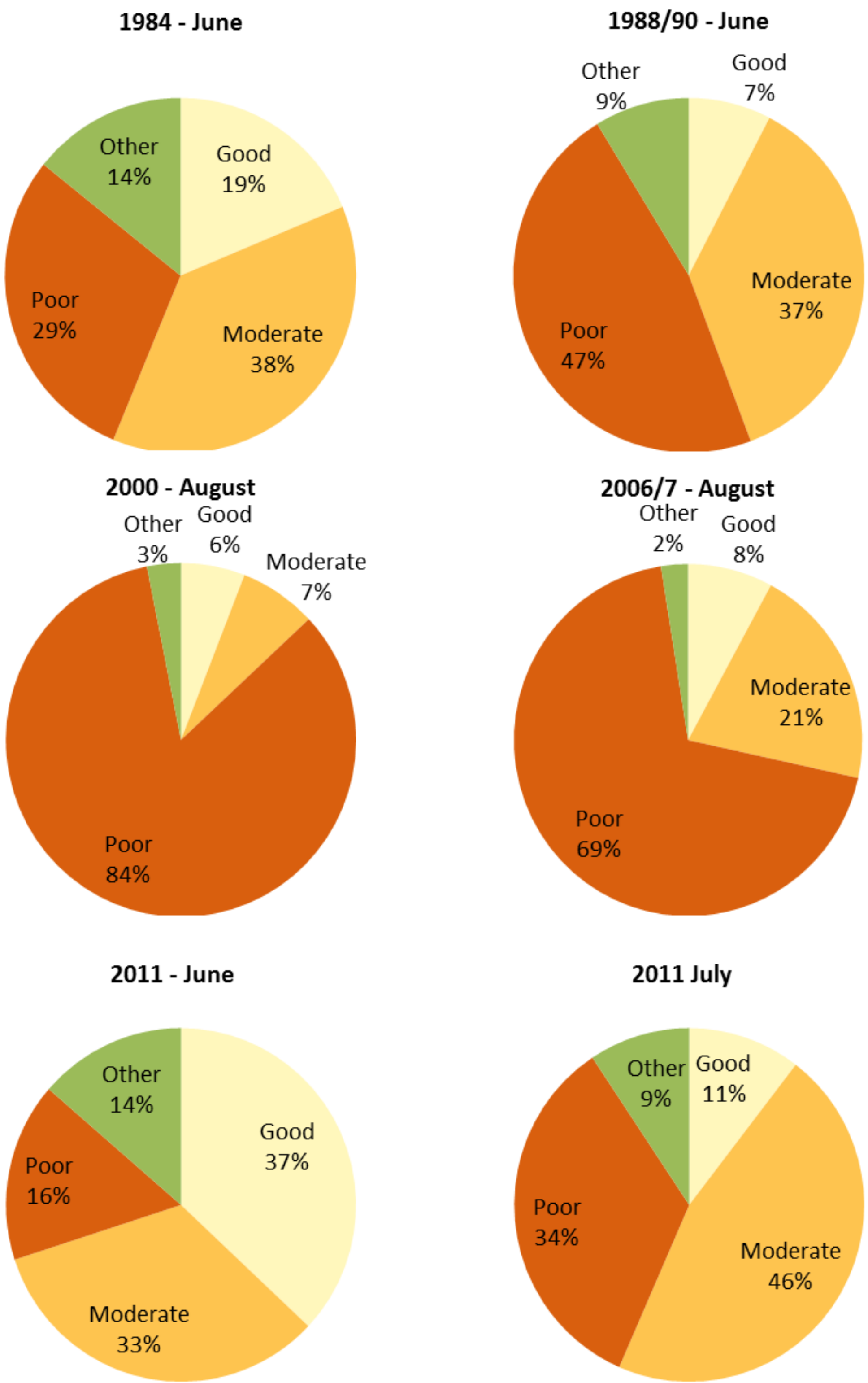


Figure 14: Percentages of rangeland in each condition category. Other includes snow, ice, rock and cloud.

4.6 Factors contributing to rangeland condition

From our research, stakeholder consultations, ground truthing and the resulting EO classifications we have identified a number of economic, agricultural and environmental factors that contribute to rangeland condition.

Economic factors

- Development of the economy

Since independence Georgia has experienced a decline in its primary sectors of activity, such as agriculture. This has been reflected in a decline in livestock numbers across the country. This suggests that there may well be less grazing pressure upon rangelands. However, in recent years an improved, more stable market has led to a rise in meat prices (particularly lamb) and increased stock numbers for those farmers interviewed in stakeholder consultations, which could lead to additional grazing pressure on rangelands in future.

- Land ownership

The majority of people involved with our stakeholder consultations, confirming the responses to the Focus Groups conducted by Alliances, expressed concerns over a lack of access to pasture, the major reason behind this being the distribution and ownership of land. Land privatisation began in 1992 driven by the government who want to increase private ownership. Under a private ownership system, where the owners are not local people, land is often less available to local populations to graze their stock, and then only as rented land.

Grazing pastures consist of both municipal land (local to settlements) and summer pastures (rangelands). There is no clear distinction between the two on the ground, since both are areas of open grazing, although municipal land tends to be closer to the villages and summer grazing pastures are located higher up the mountains. Both are subject to sale to private owners. Changing ownership may well have an influence of the utilisation of rangelands going forward into the future.

Agricultural factors

- Livestock management

Livestock systems in Georgia are largely traditional, based on self-supply. Mineral fertilisers, animal feeds and farming machinery are generally absent so animal production is limited by the natural productivity and carrying capacity of the environment. Despite an overall decline in stock numbers since independence, evidence from the consultations suggest that the numbers of livestock in local, privately owned herds are currently increasing, particularly with regards to sheep. An increase in flock numbers could potentially lead to increased pressure on areas of grazing,

Since there is no tradition of hedging or fencing in Georgia, everywhere is open. As a consequence, stock control involves close shepherding, often of community sheep flocks and cattle herds, throughout the year. The main grazing activity is municipal grazing around the village whereby a shepherd collects the herd in the morning and returns them at night. This grazing practice occurs throughout the year period within both winter and summer grazing areas. Summer grazing in the highlands is used mainly by farmers possessing larger herds although there are occurrences whereby smaller herds are combined and taken by a shepherd as part of a composite flock. The main livestock taken to graze within the highland areas are sheep. During the day the stock are generally closely shepherded whereas at night, stock are housed or corralled within enclosures.

Hay production is widespread in the study area, generally grown on lower, flatter ground but also on slopes and terraces along valley sides. It is cut late, often into September as this allows the grass to dry off naturally and makes the harvesting and subsequent collection and handling easier, particularly since this is usually done by hand and often by women. In late summer, when the grazing quality on higher pastures decline, livestock are grazed on the aftermath of lowland hay pastures or other arable land that has been harvested. This reduces the pressure on the municipal grazing areas and returns nutrients to the cultivated land. As a result of a shift in seasonality and increasing mechanisation hay can be cut earlier (and greener).

Table 6 illustrates a generalised grazing calendar for livestock farmers in the study area.

Table 6: Generalised grazing calendar for livestock farming in the study area

Area	Winter *Jan-Mar*	Spring *Apr-Jun*	Summer *Jul-Sep*	Autumn *Oct-Nov*
Rangelands	No grazing Snow cover	Good grazing after snowmelt Stock move up to summer pastures	Decline in quality of lower pastures, better grazing on high pastures Return to winter pastures in Sept	Local grazing only before snow returns
Municipal grazing	Some snow cover, grazing when snow free	Good grazing, pastures in best condition	Burn-off of some pastures especially in dry years	Better grazing as pastures recover
Hay meadows	Stock excluded	Stock excluded	Hay cutting Aug-Sep, followed by aftermath grazing	Aftermath grazing
Cropped land	Winter crops in the ground Stock excluded	Growth of winter sown crops - Spring sowing Stock excluded	Harvesting of winter and spring crops - aftermath grazing on arable land before autumn sowing	Aftermath grazing on spring sown land only

- Transhumance

There is a strong tradition of transhumance, the movement of stock from winter pastures to summer grazing in spring (May-June) and back in autumn (September) potentially up to 200 km, following traditional routes. In the study areas the main routes lead from the winter pastures in Kakheti in eastern Georgia to the summer pastures in the high upland plateaux of Kvemo Kartli and Samtskhe-Javakheti (Figure 3). Transhumance does not always fit easily with an increasingly modern lifestyle (of, for example, a more settled existence and busier roads) and also leads to conflicts with local farmers (over competition for grazing of local pasture en route and animal health issues). The transhumance routes seem to act as a funnel, with numerous routes across the summer pastures in the west, but coming together around Tsalka, to form a common pathway to Kakheti, recognisable on the imagery as a heavily-trafficked route with poor grassland condition.

Environmental factors

- Changes in climate and seasonality

Within the study area the climate and landscape varies considerably as a result of topography and geographical location, producing quite local biogeographic zones. There is a range landscape from high and steep alpine meadows, to open upland grassy plateaux, steep forested river valleys and flat and fertile cropped lowlands to areas of almost semi-arid grasslands and scrub.

In the study area the climate is of cold winters (with significant snowfall), followed by a wet spring/early summer and a hot dry summer and autumn. In summer grass burns off on slopes, especially those south-facing. The rangelands are green in spring/early summer, and become brown in mid-summer, generally recovering before the onset of winter. The higher ground retains better quality grazing through the dry summers due to increased humidity and cooler temperatures. Locally rainfall in particular seems to vary between different areas and reflect the differences in landscape. This makes the study area very diverse in terms of landscape, land cover and vegetation. It also means that there seem to be significant local differences in rangeland condition and grazing quality, based largely on summer rainfall. A key to this seems to be the Likhi Ridge separating the two regions, which forms a barrier to cloud movements and creates a distinct bioclimatic boundary.

Within this overall diversity the meteorological data show a warming and drying of the climate, when 2010 is compared to the 1980-2010 average for both regions. Such warming and drying is more pronounced in Samtskhe-Javakheti than in Kvemo Kartli. Local farmers and graziers at the stakeholder consultations have observed the climate becoming warmer and drier. This can have a positive impact, lengthening the grazing season in the higher pastures, as well as a negative impact, with lower grazing becoming much drier in the summer. From field inspection the 2011 weather seems to follow that of 2010.

Although there has been a wide variation in climate during the 27 years under study, should these changes to an overall warmer and drier continue, it is likely that there will be, especially in dry years:

- Less snow in winter and an earlier snowmelt
- An earlier spring flush of grass on rangelands of good grazing quality
- An earlier onset of drying and burn-off in summer in dry years
- A longer period of drying grass of poorer grazing quality
- The better grassland is retreating higher up the mountains, with lowlands suffering more burn-off and die-back in late summer and autumn.
- This trend seems more pronounced in Samtskhe-Javakheti than in Kvemo Kartli, which is borne out from the imagery.

A key impact of changing climate is likely to be on seasonality and on the start and duration of the growing (and hence grazing) season. An earlier start to the grazing season on the rangelands will affect the dates of transhumance. Lower down the mountain there will be impacts on the municipal pastures and on hay making.

This seasonality of rangeland condition is encapsulated in Table 7 below showing the typical annual seasonal cycle of grass growth and stock grazing on the rangelands:

Table 7: Typical seasonality of rangeland grass growth and stock management

Month	J F M A	M	J	J A	S O	N D
Grass condition	Snow cover	Snowmelt Grass recovering	Lush grass	Drying grass	Risk of burn-off in dry years	Grass recovery before winter
Grazing quality	No grazing available	Improving grazing quality	Good grazing	Grazing quality declining		Little grazing available
Stocking	No stock	Move to summer grazing		On summer grazing – peak stocking	Return to winter grazing	Local grazing only

5. Conclusions and recommendations

5.1 Rangeland condition

Our major conclusions are:

1. Through the use of NDVI as an indicator of rangeland condition there appears to be no evidence of widespread current overgrazing, except locally along transhumance routes and around the summer encampments and municipal pastures. Rangelands generally have good vegetation cover with a good diversity of grass and forb (wildflower) species. If anything there has been an overall improvement in rangeland condition between the earliest available imagery (1984) and 2011.

2. There is evidence from both imagery and ground truthing of pronounced seasonal change in rangeland condition, largely linked to climate and rainfall. This produces poorer rangeland grazing quality in mid to late summer through grass burn-off and die-back, especially on steeper slopes, rocky soils and where south-facing. The effect is worse on the lower pastures, but does extend up into the higher pastures.

3. There is some evidence, from both ground truthing and stakeholder consultation, supported by hydrometeorological data, that the climate in the study area is becoming warmer and drier. In dry years this means less grass is available for grazing in mid to late summer. There have been a number of dry years (in particular 1999-2001) observed from the hydrometeorological data as well as the imagery which cause fluctuation in rangeland condition over time.

4. There is some evidence from the imagery and targeted ground truthing of erosion on steeper slopes, presumably a result of heavy rain (such as for example in 2005), which contributes to a degradation of rangeland condition.

5. There is evidence from ground truthing of differences in rangeland quality and condition within the study area, reflecting small-scale changes in the local bioclimate, which are difficult to map accurately and consistently. There seems to be a more pronounced warming and drying in Samtskhe-Javakheti than in Kvemo Kartli.

6. There is evidence from the focus groups conducted by both Environment Systems and Alliances KK and SJ that local herds are increasing in size, especially with regards to sheep (reflecting better lamb prices), which may become an influence on rangeland condition. This is particularly true for the limited municipal pastures available to local people.

7. There is also evidence from the stakeholder consultations of changing ownership and access arrangements to both rangelands and municipal pastures, generally part of past governmental policies which have increased private ownership, which again may become an influence of rangeland condition in future.

The key consequences of these results for rangeland management are:

1. The most productive summer grazing season is likely to start earlier and end earlier, and possibly become shorter, especially in dry years,

2. There is a longer period of seasonal grass burn-off and die-back, when there is less suitable grazing areas available.

3. In drier years there is likely to be a higher risk of overgrazing and erosion.

If this trend to a drier and warmer climate continues, strategically there is a need to take more advantage of the time when rangeland and municipal grasses are at their most productive (spring/early summer) for both grazing and hay production. There may also be a consequence for both the timing (earlier in the season) and location (higher up the mountain) of summer transhumance.

It would be useful to test and confirm these conclusions in other areas of Georgia, especially in the east, where the winter grazing is located. It would also be useful to examine more closely seasonal change in rangeland condition within each year, related to climate and rainfall in particular, which can be achieved by utilising lower spatial resolution data, but which is more frequently available temporally, from MODIS imagery, which orbit the earth every one to two days.

5.2 The usefulness of EO data in analysing rangeland condition

EO data, in the form of Landsat imagery, enabled the generation of detailed land cover maps and the separation of varying rangeland condition levels in the regions Samtskhe-Javakheti and Kvemo Kartli in Georgia across a 27 year period. Accurate maps such as these are important for rangeland management and were generated in areas that are difficult to access on the ground. This reduces the need for traditional classification methodologies which in turn reduces time and labour costs and provides efficient, up-to-date information on the condition of rangeland environments.

Additionally, degradation can only be assessed in space and time simultaneously and therefore enforces the need for data available over decades rather than years. Landsat was able to provide this requirement spanning a 27 year period. However, given the susceptibility of optical sensors to cloud and other atmospheric phenomena a large range of scenes have to be assessed for suitability. Of the scenes available, a number were compromised by the extent of cloud cover. The majority are cloud free however, a number of the scenes utilised in this study have an element of cloud cover. Regardless, there was still a time-series of suitable satellite imagery available.

The temporal and spatial resolutions of NDVI data extracted from the Landsat imagery are suitable to capture differences in the seasonal growing cycles of the vegetation associated with rangelands. This provided information on the condition and phenological behaviour of the rangeland environment. In particular, there was evidence of an altitudinal delay in the behaviour of the flora in the two regions whereby vegetation at higher elevations flourished later on in the calendar year as a result of temperature gradients and remnant snow. There was also a significant indication that the climate experienced over the 27 years has changed both with regards to average monthly weather patterns and with regards to the onset of the different seasons. In order to fully understand the spatial and temporal dynamics of rangeland condition it is necessary to explore these influences in more detail.

5.3 Recommendations for future work

From discussion with and feedback from Mercy Corps and other stakeholders we recommend the following extensions to this work:

An extension of the methodology into other areas of Georgia

It is proposed that the use of EO for mapping and monitoring rangelands be extended across other areas of Georgia, especially the area of winter grazing in Kakheti outlined in Figure 3 which would provide a comparison in rangeland condition between winter and summer pastures. The major benefits would include establishing the current condition of the areas of winter grazing, the extent of transhumance and an assessment of the necessity of transhumance in order to enable winter pastures to recover.

An extension of the methodology to further examine seasonality in rangeland condition

From the available hydrometeorological data, there is some evidence for a change in climate experienced within the study area as well as a change in seasonality. It is suggested that the use of EO could be extended to explore the influence of climate upon seasonality. This might involve the use of MODIS imagery which, although of poorer resolution, provides more frequent imagery that could be utilised to investigate seasonal patterns across Georgia.

An extension of the methodology to provide semi-natural habitat mapping across the rangelands

This project has successfully assessed the condition of rangelands within Kvemo Kartli and Samtskhe-Javakheti. In order to understand the types of vegetation and habitats present on the rangelands the methodology employed can be extended to incorporate other vegetation indices and texture measure analysis techniques that would be able to differentiate rangeland species. The EUNIS (European Nature Information System) habitat classification has mapped habitats across the whole of Europe while the Phase I Habitat Classification provides a standardised system to record semi-natural vegetation and wildlife habitats in the UK. A similar classification system in Georgia would assist in the development of environmental impact studies and other ecological baseline surveys. This would be useful in establishing whether or not the invasion of unpalatable species is occurring as a result of overgrazing.

An extension of the methodology to improve the mapping of forest and woodland areas

The date of the forestry layer provided by Mercy Corps and utilised as a masking layer in this study is unknown and its extent is generalised. A visual assessment of the forestry layer against aerial photography suggests that many changes have occurred since the forestry layer was captured. Since woodland exhibits very high NDVI values, it is proposed that a more accurate (and current) delineation of the forested areas located within the Samtskhe-Javakheti and Kvemo Kartli regions (and further afield within Georgia) can be provided, using the Landsat imagery.

The further investigation of climate data

A lack of comprehensive historic climate data has restricted the confidence of some of the conclusions in this report. A more detailed study into the climate history of Georgia involving the acquirement of mean monthly values for precipitation and temperature across the country would assist in the interpretation of the trends and features visible in the imagery. Currently, the availability of hydrometeorological data for the years corresponding to the imagery is available at a cost of approximately £600 (900USD). It is recommended that a full record of hydrometeorological data is acquired and the trends in temperature and precipitation (both rainfall and snowfall) are investigated with regards to climate extremes (i.e. drought, floods) and shifts in seasonal patterns.

Capacity building in Georgian agricultural, environmental and rural development organisations

This project has created datasets providing information on rangeland condition during a number of years over the past 27 years, areas agricultural activity and on the indication of areas likely to be underutilised by livestock. These datasets did not previously exist and have the potential to aid the capacity and capability of key organisations in Georgia involved with environmental and rural development issues to analyse, understand and resolve such issues. Wide cooperation on ensuring data access, availability and updating is key to improving this capacity.

6. Acknowledgements

Environment Systems gratefully acknowledge the help received from Mercy Corps in particular Helen Bradbury, Davidson Highfill and their staff in both the provision of data and in the setting up of meetings in the focus areas. We are thankful to Chris Wardle of AA International for providing exemplary assistance in the field consultations. We also gratefully acknowledge the help received from our local project coordinator, Mr Vano Grigolashvili and his colleague in making local accommodation arrangements, providing transport, arranging meetings in the Samtskhe-Javakheti region and generally supporting the project on the ground.

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Annex 1: Satellite Image Assessment

In order to successfully distinguish between areas of productive rangeland and areas of overgrazing and degradation it is important to exploit data from the spring and summer periods as this is when the vegetation is at its most productive and thus will exhibit a strong spectral response in the imagery in contrast to areas void of vegetation. The imagery must also have a suitable historical coverage to allow for an assessment of change in rangeland condition over time to be made.

The main problems when obtaining the imagery included acquiring scenes that completely cover the two regions of interest and finding suitable scenes that are not spoilt by cloud cover. An assessment of available imagery from the satellites ASTER, SPOT, Landsat, IRS and DMC has been made as these were felt to offer the spectral and spatial detail required alongside the necessary historical detail to allow for assessment of rangeland change over time.

ASTER – (Advanced Spaceborne Thermal Emission and Reflection Radiometer)

ASTER imagery is acquired within 14 spectral bands with 15-90m resolution depending upon the bands used. (VNIR - 4band - 15m, SWIR - 6bands - 30m, TIR - 5bands - 90m). The satellite itself was launched in 1999 and has been collecting data since February 2000.

In regards to available image coverage, there is suitable imagery available between 2001 and 2010 across the summer periods. Individual scenes would be required per region to ensure complete coverage.

Satellite:	ASTER
Scene Size:	60x60 km (Full scene)
Resolution:	15-30 m
Spectral Coverage:	Green-SWIR + TIR

SPOT (Système Probatoire d'Observation de la Terre)

The satellite system has been collecting imagery since the launch of SPOT 1 in 1986. There have been a total of 5 SPOT satellites put up into orbit of which SPOT 4 and 5 remain in an operational state. Due to the spectral requirements of this study, only SPOT satellites 4 – 5 were chosen for the image searches due to the spectral capabilities of these satellites.

SPOT5

SPOT 5 was launched in 2002 at a 10 m resolution in four wavelengths (Green, red, NIR, SWIR). SPOT5 data is available at a variety of scene sizes. SPOT 5 is a suitable tool to use within the assessment of rangeland condition, but given the study area size and cost of the imagery, it was not used within this study.

Satellite:	SPOT5
Scene Size:	60x60 km (Full scene)
Resolution:	10 m
Spectral Coverage:	Green-SWIR

SPOT 4

SPOT 4 was launched in 1998 and collects imagery at a 20 m resolution in four wavelengths (Green, red, NIR, SWIR). The cost of acquiring enough SPOT 4 scenes to capture the full extent of the study region meant that SPOT 4 was not selected for use within this study.

Satellite:	SPOT4
Scene Size:	60x60 km (Full scene)
Resolution:	10m
Spectral Coverage:	Green-SWIR

Landsat

Landsat data has been collected since 1967 with the launch of Landsat 1. There has since been another 6 Landsat satellites launched, all of which with the exception of Landsat 6 have been operational over varying periods of time. Due to the spectral requirements of this study, only Landsat satellites 4 – 7 were chosen for the image searches due to the spectral capabilities of these satellites.

Landsat 4/5

Landsat satellites 4 and 5 were launched in 1982 and 1984 respectively. They sample from the visible through to the SWIR and TIR bands.

Satellite:	Landsat 4/5 TM
Scene Size:	(180*175 km)
Resolution:	30 m
Spectral Coverage:	Green-SWIR + TIR

Landsat 7 ETM+

Landsat 7 was launched in 1999 and samples from the visible through to the SWIR and TIR bands with the inclusion of a Panchromatic band at a 15 m resolution.

Satellite:	Landsat 7 ETM+
Scene Size:	(180*175 km)
Resolution:	30 m
Spectral Coverage:	Green-SWIR + TIR

IRS – (Resoursesat-1)

The IRS-P6 satellite operates within the green to SWIR was launched in October 2003and captures imagery with 23.5 metre spatial resolution. Suitable imagery was available covering the full study area for the years 2006 to 2008.

Satellite:	IRS-P6 LISS-III
Scene Size:	(140*140 km)
Resolution:	20m
Spectral Bands:	4 (Visible, NIR, SWIR)

DMC (Disaster Monitoring Constellation)

The Disaster Monitoring Constellation consists of a number of remote sensing satellites operated for a number of international governments (including the British) by DMC International Imaging. The satellites themselves operate within the Blue to NIR spectral region capturing data at a 20 metre spatial resolution. The first DMC satellite was launched in 2003.

There is full coverage for Samtskhe-Javakheti and partial coverage for Kvemo Kartli using this satellite source. Therefore it was decided not to use this imagery as part of this study, but this maybe a suitable source for future rangeland assessment.

Satellite:	UK-DMC-1
Scene Size:	(600*600 km)
Resolution:	30m
Spectral Bands:	4 (Visible, NIR)

Available imagery assessment

An assessment of available SPOT, ASTER, DMC and IRS imagery for the area of Samtskhe-Javakheti and Kvemo Kartli has been made. There is a much broader coverage of imagery for Samtskhe-Javakheti than is available for Kvemo Kartli.

Samtskhe-Javakheti

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000												
2001												
2002												
2003					SPOT4							
2004												
2005					ASTER	ASTER		ASTER				
2006						SPOT5		ASTER				
2007						DMC			IRS			
2008				IRS			ASTER	IRS ASTER				
2009								ASTER				
2010				SPOT5		SPOT5	ASTER					
2011						SPOT5						

Kvemo Kartli

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000												
2001												
2002												
2003												
2004				ASTER						ASTER		
2005				ASTER								
2006			ASTER									
2007						DMC	IRS			IRS		
2008					AST					AST		
2009												
2010												
2011												

Landsat afforded the best possibility for image coverage across the region with imagery available over a 27 year period. This will allow for a detailed assessment of change in rangeland condition to be possible.

Pairing	Year	Month	Region
1	1984	June	Samtskhe-Javakheti Kvemo Kartli
2	1988	June	Kvemo Kartli
Winter	*1989*	*January*	*Kvemo Kartli*
2	1990	May	Samtskhe-Javakheti
Winter	1999	*December*	*Kvemo Kartli* *Samtskhe-Javakheti*
		February	Kvemo Kartli
3	2000	August	Samtskhe-Javakheti Kvemo Kartli
4	2006 2007	August	Samtskhe-Javakheti Kvemo Kartli
5	2011	June	Kvemo Kartli Samtskhe-Javakheti
6		July	Kvemo Kartli Samtskhe-Javakheti

Annex 2: Climate data

2010 year meteorological data compared to the 1980-2010 average for Akhaltsikhe (Samtskhe-Javakheti) and Bolnisi (Kvemo Kartli). Source: Georgia Hydrometeorological Agency

Samtskhe-Javakheti

Akhaltsikhe	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Temperature, °C	1980-2010	-3.1	-1.6	3.3	9.1	13.4	17.1	20.5	20.4	16.0	10.3	3.9	-1.2
	2010	0.6	2.4	5.0	8.6	13.8	19.2	22.4	22.3	19.3	11.9	4.9	2.2
Average precipitation, mm	1980-2010	23.9	25.8	35.3	49.9	67.3	77.2	60.8	50.2	34.0	39.7	35.5	26.0
	2010	39.8	30.2	82.4	54.7	60.4	129.8	29.3	17.9	9.7	97.8	2.4	12.7
Number of rainy days	1980-2010	7.9	7.9	9.1	11.5	15.0	14.0	11.9	10.6	8.3	9.5	8.3	8.4
	2010	13	13	15	11	16	19	15	5	6	22	1	3
Average snowfall, sm	1980-2010	11.0	10.1	4.8	0.5	0.03	0	0	0	0	0	2.1	6.5
	2010	2	3	0	0	0	0	0	0	0	0	0	0
Number of days with snow	1980-2010	12.4	11.9	3.6	0.6	0.03	0	0	0	0	0	1.3	7.0
	2010	7	4	0	0	0	0	0	0	0	0	0	0

Kvemo Kartli

Bolnisi	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Temperature, °C	1980-2010	1.7	2.6	6.6	12.1	16.3	21.0	24.5	24.2	19.7	13.6	7.5	3.4
	2010	3.2	3.5	7.5	11.4	16.9	23.9	27.1	26.3	21.8	14.3	9.5	6.5
Average precipitation, mm	1980-2010	17.4	25.2	42.4	63.8	77.1	64.5	33.6	34.1	35.3	49.8	35.0	19.6
	2010	50.0	37.5	84.6	114.3	68.8	46.8	28.0	15.9	54.1	137.7	0.9	3.3
Number of rainy days	1980-2010	4.5	6.3	9.2	11.9	14.0	11.3	8.0	7.2	7.2	9.1	6.9	5.1
	2010	10	9	12	15	21	14	8	4	8	18	2	1
Average snowfall, sm	1980-2010	3.7	4.2	2.2	0.03	0	0	0	0	0	0.1	0.2	1.7
	2010	5	10	0	0	0	0	0	0	0	0	0	0
Number of days with snow	1980-2010	5.8	6.5	2.4	0.1	0	0	0	0	0	0.1	0.2	2.7
	2010	3	7	0	0	0	0	0	0	0	0	0	0

Annex 3: Stakeholder Consultations

Remote Sensing Study into Rangeland Condition in Kvemo-Kartli and Samtskhe-Javakheti Regions of Georgia Project, Mercy Corps.

Mission Report of Focus Group Meetings prepared for Environment Systems by Christopher Wardle, AA International Ltd

October 12th, 2011

AA International Ltd is a private company registered in the UK, Company No. 5507299.
Head Office: AA International Ltd, Ty Harbwr, Y Lanfa, Aberystwyth, Ceredigion, SY23 1AS, Wales.
Tel +44 1970 613460/1; Fax +44 1970 613462; email *info@aainternational.co.uk*

Executive Summary

Between September 18th and 24th 2011, AA International Ltd consultant Christopher Wardle, visited the Kvemo-Kartli and Samtskhe-Javakheti regions of Georgia to provide expertise in the preparation and delivery of in-country stakeholder engagement. AA International was also contracted to provide the services of Vano Grigolashvili for local liaison and translation services. Both were accompanied by Mr Chris Finch of Environment Systems during this period of engagement.

Focus Group Meetings were held in 6 Municipalities, 3 from each of these two regions. Most of the informants were men over 45 years in age of a mix of ethnic backgrounds. They were generally small farmers engaged in a mix of activities, with predominance given to livestock.

In summary, the conclusions drawn from these interviews are:

- Livestock are part of mixed farming system with most farms in both regions run as small, family farms.
- Livestock numbers have increased over the last 20 years.
- Migration of livestock to Summer grazing is still an important part of livestock farming.
- At the moment, overgrazing is not a major issue, especially in the Summer grazing areas but access and availability to grazing is an important issue for farmers.
- The condition of Summer pasture is relatively good but Municipal Lowland pasture is rated as poor or average.
- Access to land may get worse if the government auctions off its land which includes hay land in the lowland and Summer pasture.
- Climate change is apparently leading to a trend of warmer, drier weather.
- Little has been done by farmers to improve and manage the pasture.
- There is potential to develop the livestock sector and make it more productive.
- Many farmers still appear to be looking to others (government and donors) to address their needs and solve their problems.
- There is scope to improve market linkages and infrastructure for marketing livestock products.

1. Introduction

Environment Systems and AA International Ltd entered into an agreement on 16th September 2011 for the provision of consultancy services by AA International Ltd consultants to the Mercy Corps project “Remote Sensing Study into Rangeland Condition in Kvemo-Kartli and Samtskhe-Javakheti Regions of Georgia.”

Under this agreement, AA International UK supplied the services of a UK consultant Christopher Wardle to provide expertise in the preparation and delivery of in-country stakeholder engagement. AA International local consultant Vano Grigolashvili provided local liaison and translation services. Both were accompanied by Mr Chris Finch of Environment Systems during this engagement.

Between September 18th and 24th 2011, Christopher Wardle, visited the Kvemo-Kartli and Samtskhe-Javakheti regions of Georgia, accompanied by Vano Grigolashvili. Both were accompanied by Mr Chris Finch of Environment Systems during this period of engagement.

2. Scope of Work

As set out in the Tender and Project Initiation Documents received from Mercy Corps and the joint proposal submitted by Environment Systems and AA International, the objectives of this contract were to conduct key-informant and focus group interviews with land-users and stakeholders, to verify assumptions on grazing practices and historical trends.

Project Documents iterated that the consultation process would require the questioning of various individuals on elements such as:

- Current rangeland condition
- Their observations in change over time
- Changes in any livestock stocking patterns
- Changes in farming practices
- Any climatic change they have noticed?
- Any other elements that they feel have influenced changes in rangeland condition?

3. Progress Made on Scope of Work

3.1 Introduction

Focus Group Meetings (FGM) were held in the two southern regions of Kvemo-Kartli and Samtskhe-Javakheti in Georgia with stakeholders in the week of 19-23 of September 2011.

3.2 Methodology

The FGM were held in 6 Municipalities, 3 from each region. These were chosen by Mercy Corps as being representative of the region. Information was collected using a Questionnaire followed by discussions around key points.

The Stakeholder consultations consisted mainly of farmers from each locality, but in two they were also attended by community representatives. The FGM were complemented with interviews held with Municipal authorities (to get a broader picture of the livestock and grazing situation in that location) and some individual farmers and shepherds.

3.3 Profile of Stakeholders

Table 1 shows the numbers of farmers attending the Focus Group meetings. Some of the groups could have been larger, and women could have been better represented (though in one, there were more women than men).

Table 1: Focus group members

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Male	3	9	6	5	9	5
Female	5	0	0	0	3	1
Total	8	9	6	5	12	6

The majority of farmers (65%) were over 45 years of age. Only 9% were under 30 years of age. This suggests that currently, few young people are entering farming. This could have implications for the future of the farming and livestock sectors.

The ethnicity of farmers in each FGM is shown in Table 2. Most were Georgian, followed by Armenians (especially in the western region), Azeris and Greeks, in that order.

Table 2: Ethnicity of farmers

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Georgian	8	3	1	1	8	5
Armenian	0	6	5	0	2	1
Azeri	0	0	0	4	0	0
Greek	0	0	0	0	2	0
Total	8	9	6	5	12	6

The most important sources of family income come from a mix of livestock activities (especially dairy and rearing sheep) and crop production (mainly potatoes and vegetables). On the whole, livestock activities provide the greatest income, with income from dairying ranked the most important source by all but one Focus Group (Table 3).

Table 3: Ranking of sources of income

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Dairy	1	1	1	2	1	1
Beef	2	0	0	3	0	0
Sheep	3	0	0	0	2	2
Potatoes	0	1	0	0	0	0
Veg/Fruit	4	0	0	1	0	0
Other	0	0	0	4	0	0

Most farms are run as small family farms with tasks divided between the husband and wife. Women do the milking and cheese making but are also involved in other farming tasks.

3.4 Livestock Activities

Most farmers keep a mix of livestock, mainly dairy cows, a few sheep and sometimes a few goats and pigs. Rearing of sheep is more common in the drier, eastern region, while dairy farming and some beef production is more common in the western region.

The size of herds and flocks tends to be small, with most farmers keeping 2-5 dairy cows and a few sheep (Table 4). However, there is also a group of farmers who keep larger herds (20-60 cows and larger flocks of up to 200 sheep). The Focus Group members said that, in general, between 5-20% of all farmers in their villages were medium or large. These bigger farmers tended to be more predominant in the eastern region and largely involved in dairying.

Table 4: Size of dairy herds

# Cows	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
1-5	4	7	0	4	3	1
6-20	3	2	1	1	6	5
>21	1	0	5	0	3	0

Over the past twenty years, herd and flock sizes have increased considerably, often more than doubling or even tripling in size. This is partly because most farmers were given only a few animals when the USSR broke up in the early 1990's. The main reasons for the increase given by farmers were:

- They are profitable activities;
- They provide a regular source of income (especially dairy);
- The recent sharp increases in sheep prices (from a strong demand for exports to the Middle East);
- Modest increases in milk and cheese prices.

3.5 Grazing Activities

3.5.1 Types of Grazing

Farmers use several different kinds of grazing. These are defined using three different criteria:

a) Ownership
- Municipal land (common land around villages where most farmers graze their animals);
- Government land (pasture in the lowlands and upland Summer grazing which it rents to individuals (not necessarily farmers), who rent to the farmers at a higher price);
- Private land (all farmers have 1.5 ha of their own: some have managed to acquire more land).

b) Elevation
- Lowland (under 1,500 m);
- Highland/Rangeland (above 1,500 m, sometimes reaching 2,600 m).

c) Seasonality of Grazing
- Winter grazing;
- Summer grazing.

These definitions often overlap: e.g. some Municipalities have Summer as well as Winter grazing.

3.5.2 Where Farmers Graze

The main grazing for the smaller farmers is Municipal grazing around the village. A shepherd collects the farmer's livestock in the morning and takes them out for grazing, returning in the evening. They do this year round.

Less than 10% of farmers own private Lowland pasture beyond their allocated 1.5 ha. These few farmers tend to be the bigger farmers. Some farmers also rent land for hay from the government.

The Summer grazing in the Highlands is used mainly by farmers with bigger herds and flocks. However, some small farmers will pay shepherds to take their sheep to Summer grazing areas as part of a bigger flock (see section on Transhumance).

Locations where farmers graze their livestock have remained largely unchanged over the past 20 years.

3.5.3 Availability and Access to Grazing

Availability of grazing and access to it is major problem for many farmers.

All the Stakeholder consultations said their area of Municipal land and grazing has remained unchanged over the past twenty years (Table 5). With the increase in livestock numbers, these pastures are reaching their carrying capacity. This creates tensions when new farmers arrive in the village and limits the extent existing farmers can increase their livestock numbers.

Access to grazing is exacerbated by the increasing privatisation of Summer grazing. Most of this land is rented out by the government. The exception is where Municipalities own summer as well as winter grazing, which was the case in Aspindza and Tsalka. However, in these two areas, availability of Summer grazing is limited because nearly all the farmers use it.

Table 5: Access and availability to grazing: Main problems

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Lowland Municipal Grazing	1.Limited area	1. Poor quality 2. Lack of access to water	1. All FG used private land	1. Limited amount 2. Poor quality	1.Fixed/limited area	1. Limited grazing 2. Not good enough
Summer Grazing	1. Not enough	1. Privatisation/cost 2. Lack of infrastructure	1.Privitisat-ion/cost	1.Privitisat-ion/cost	1. Not enough	1.Privitisat-ion/cost

In the other areas, it tends to be the bigger farmers who use Summer grazing because they can afford it. The cost of renting Summer grazing has increased considerably in recent years, with shepherds reporting an increase from 3 lari/sheep to 20-25 lari over the last 5 years.

As a result, all the Stakeholder consultations said competition for grazing, both Winter and Summer, is increasing. In the case of Summer grazing, this is reportedly from other livestock coming in to their usual grazing areas. However, no Stakeholder consultations said that this has led to conflicts so far.

3.5.4 Elevation Grazed

Summer pasture is grazed up to 2,600m. Farmers say that snow cover is less of an issue than previously, due to shorter and less severe winters.

Table 6: Elevation grazed to

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Elevation (masl)	2000-2600	2000-2300	1900-2200	2200-2800	1500-1700	1500

3.6 Transhumance

As noted previously, it is mainly the bigger farmers that take their livestock to Summer grazing. Members of several families may combine their herds and flocks to take to them to the Summer grazing. Some of the smaller farmers may pay shepherds to take their livestock as part of a large composite flock.

The main livestock taken to Summer grazing are sheep, which move in large flocks of up to 1,000. A few cattle are taken, usually young-stock or non-milking cows. Most dairy cows stay in the Lowlands near the villages, though if Summer grazing is nearby, a few farmers in the western region take their whole herd to the mountains and make cheese from the milk.

The farmers and shepherds follow traditional transhumance routes which run east to west/north west. They stick to these routes, unless the weather is bad, in which case they may vary them a little.

Distances travelled from Winter to Summer grazing vary, and depend on the origins of the flocks (Table7). The Focus Groups in the eastern region travelled 20-100km, while those from the west travel a considerably shorter distance. The time taken is 1-6 days, depending on the distance.

However, it appears that some groups further east (near the border Azerbaijan) travel considerably further. We met a shepherd near Tetritskaro bringing his flock home. He had already travelled 6 days and expected it would take another 6 days to reach home. The total distance travelled would be around 200 plus km.

Table 7: Distance travelled to summer grazing

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Distance travelled (km)	10-50	1-10	1-10	50-100	20-50	20-35

The livestock are taken to the Summer grazing in late April/May and return in September/October. The dates depend on the weather and condition of the Summer grazing.

3.7 Condition of Pasture and its Management

3.7.1 Condition of Pasture

Five of the six Stakeholder consultations said the condition of this year's Summer pasture was good, mainly because rainfall was good. However, all said their Municipal Lowland pasture was only average or poor. This was mainly because it is inherently poor and little effort has been made to manage and improve it. Recently, drier summers have exacerbated the situation (Table 8).

Table 8: Rating of condition of pasture

	Aspindza	Akhalkalaki	Ninotsminda	Dmanisi	Tsalka	Tetritskaro
Municipal Lowland Grazing	Average	Poor	Average	Average	Poor	Poor
Summer Upland Grazing	Good	Good	Average	Good	Good	Good

The majority of farmers in the Stakeholder consultations felt that the condition of Lowland pasture had worsened over the last twenty years, mainly due to increased livestock numbers and, more recently, drier weather. In contrast, the majority felt that the condition of Summer grazing has not significantly changed over this period.

3.7.2 Management and Improvement of Pasture

According to the Stakeholder consultations, there is no formal management of Winter or Summer grazing. However, the shepherds who graze the flocks and cattle, tend to rotate grazing in an informal way, periodically moving the livestock to better grazing.

There has been little or no improvement made to pastures, both Winter and Summer. The main reasons given by Stakeholder consultations were:

- They don't own the land, so why improve it?
- Municipal land is common grazing and no one takes responsibility for managing and looking after it;
- Cost of improvement (e.g. reseeding) and on common land, not all farmers would be willing to contribute to this;
- Uncertainty of government intentions re: land it owns (will it sell it off and, if so, why improve it if is likely to be sold?).

There was one exception: the Tetritskaro Focus Group reported that a pilot reseeding project was carried out jointly by the Ministry of Agriculture and an international NGO in several villages in 2004/5. This considerably increased the productivity of the Municipal pasture in these villages, though the current rating of Municipal grazing by the Focus Group suggests this increase has tailed off.

3.7.3 Overgrazing

All Stakeholder consultations agreed that overgrazing was not an issue in Summer grazing areas they used. However, several of the Stakeholder consultations said it was an issue along transhumance routes, many of which pass over their land. This is due to the large numbers of livestock, mainly sheep, being moved.

In contrast, overgrazing is becoming an increasing issue in some of the Winter grazing areas. This is happening mainly on the Municipal grazing of those villages allocated relatively less land at the time of the break-up of the Soviet Union or who have had an influx of immigrants. One Focus Group (Tsalka) estimated that 70% of their Municipal land was overgrazed. The others said it was less severe, and tended to be localised, occurring mainly on pasture close to the villages.

3.8 Climate Change

All Stakeholder consultations agreed that, in recent years, the climate has been changing and that this is affecting the productivity of pasture and grazing patterns.

There was a consensus that the weather is getting warmer. Many Lowland areas are getting lower rainfall in summer and are consequently drier. This change is putting increasing pressure on Lowland grazing, especially on Municipal land. Also several Stakeholder consultations said that as a consequence, less hay is being made.

Conversely, the warmer weather has tended to lengthen the Summer grazing season, allowing shepherds to keep their livestock in the mountains for longer. However, the change in weather patterns can be erratic. According to one shepherd, this year, livestock are being moved off Summer grazing in some areas a little earlier than expected, due to unexpectedly cold weather.

3.9 Priorities for Livestock Development

Table 9 shows the priorities of the six Stakeholder consultations for development of livestock farming in their area. These are ranked in order of importance.

In most cases, the priorities listed by the Stakeholder consultations are similar, though the ranking may differ. The most common are:

Better marketing infrastructure especially more milk collection points and in Dmanisi, the need for slaughter facilities (they currently have to travel 80km). One constraint to increasing the number of collection points is the poor state of the roads (especially those to the more remote villages).

Access to improved breeds mainly of dairy cows. The current traditional breed only gives around 5 litres milk per day. Improved breeds would give 20 plus litres. However, the traditional cows are reportedly too small to give birth to improved breeds using AI. Also, improved breeds would need improved feeding to realise their potential.

Accesses to finance as currently, banks only lend for short term (1-2 years) and according to the Stakeholder consultations, interest rates are high. Farmers want access to long term, more reasonably priced finance to enable them to improve, grow and diversify the farms.

Assistance to improve pasture many farmers recognise that the poor quality of Lowland pasture is a major constraint to the number of livestock they can keep and their productivity. However, given the current land tenure system in Georgia, where much of the land is under common grazing, there is no incentive for individual farmers to improve the pasture. In addition, improving pasture is not cheap. As noted earlier, a pilot project to reseed Municipal land in several villages in Tetritskaro significantly improved pasture quality, though unless it is accompanied by proper management of the grazing, its impact does not last long.

Table 9: Priorities for livestock development[3]

Focus Group	Priorities
Aspindza	1. More milk collection points 2. Introduction of improved breeds 3. Access to finance to improve their farming 4. Help with reseeding pasture
Akhalkalaki	1. Access to finance to improve their farming and diversify 2. Introduction of improved breeds 3. Access to knowledge on improved farming methods 4. Better disease control
Ninotsminda	1. Machinery and finance to improve their pasture 2. Introduction of improved breeds 3. More technical knowledge of improved farming practices 4. Access to finance to invest in improving their farming
Dmanisi	1. More milk collection points 2. Slaughterhouse 3. Introduction of improved breeds 4. Access to machinery
Tsalka	1. Assistance to improve pasture 2. Introduction of improved breed 3. Improved veterinary services/means to control disease 4. Access to machinery
Tetritskaro	1. Improved veterinary services/means to control disease 2. Introduction of improved breeds 3. Assistance to improve pasture

[3] Many of these priorities agree with and confirm those found in the Alliances Focus Group surveys in Kvemo Kartli and Samtskhe-Javakheti earlier in 2011.

Better Disease Control: since Soviet times, coverage of veterinary services in rural areas has declined considerably. Stakeholder consultations reported difficulties in getting their livestock vaccinated or treated if they are ill. Vets are few and far between. Farmers also have little or no modern knowledge of treating sick animals. Disease control is particularly an issue for those villages through which the transhumance routes pass.

Access to knowledge as noted earlier, most farmers are still using traditional methods of farming. Few have been exposed to updated and modern methods and techniques of farming. This is partly because development of agriculture and livestock has not been a government priority until very recently.

Most members of the Stakeholder consultations expected others (e.g. government, donors) to address these areas, rather than taking some initiative themselves (either as individuals or together). The idea of farmers tackling their problems together does not seem popular either. However, there were exceptions. In Tetritskaro, where livestock diseases are a major problem, farmers have organised to find an unemployed vet and offer her a contract to vaccinate all their animals if she moves to their Municipality.

4. Conclusions

Based on the ground truthing exercise and according to the opinions of those involved with the stakeholder consultations:

- Livestock are part of mixed farming system and on the whole, the most important sources of income to farm families in the two regions.
- Most farms in both regions are small and run as family farms using traditional methods. As a result, productivity is low.
- Livestock numbers have increased over the last 20 years and in certain areas, mainly on Municipal grazing, land is reaching its carrying capacity.
- Migration of livestock to Summer grazing is still an important part of livestock farming, with large numbers of livestock (mainly sheep) moving each year west and north west to Summer pastures.
- At the moment, overgrazing is not an issue, especially in the Summer grazing areas (though there is some overgrazing on transhumance routes). However, it is beginning to be seen in some villages that were allocated relatively small Municipal grazing areas.
- Access and availability to grazing is more an issue for farmers. Increasingly, they are having to pay for Summer grazing, and areas of Municipal grazing have not increased.
- The condition of Summer pasture is relatively good but Municipal Lowland pasture is rated as poor or average. Its condition has worsened as livestock numbers have increased.
- Access to land may get worse if the government auctions off its land which includes hay land in the lowland and Summer pasture. Local farmers are unlikely to be able to bid as they do not have the money or access to the internet (over which bidding is likely to be done).

- Climate change is making the weather warmer and drier. This is having some positive impact (lengthening the Summer grazing season), as well as negative (Lowland areas are becoming drier in summer).

- Little has been done to improve and manage the pasture. This is mainly because much of it is common land. As a result, its productivity tends to be low. This is preventing the livestock sector from fulfilling its potential.

- Other contributing factors are poor breeding of stock, lack of access to veterinary services, lack of infrastructure (collection points etc.), access to finance for farmers to improve their operations and lack of knowledge of improved farming methods.

- There is potential to develop the livestock sector and make it more productive. Many of the changes needed were identified in the priorities for development listed by the Stakeholder consultations. Central to this, is the need to improve the quality and management of the pasture. However, the solutions to this are not easy given the current land tenure system, where much of the grazing land is held in common. Further research is needed to identify possible interventions.

- One drawback to bringing about change is that many farmers still appear to be looking to others (government and donors) to address their needs and solve their problems, rather than taking initiative themselves (either as individuals or together). However, the example of farmers in Tetritskaro coming together to address their animal health/disease problems suggests that sometimes farmers are able to come together to solve their problems.

- There is scope to improve market linkages and infrastructure for marketing livestock products. While some improvements could benefit all farmers (e.g. more milk collection centres), others might be better focussed on the medium sized farmers that tend to be owned by the younger, more progressive farmers.

Annex 4: Focus areas and ground truthing

Areas visited week beginning 19th September 2011

Kvemo Kartli

Dmanisi

- Largely municipal grasslands, with summer pasture rising to top of the Likhi Ridge
- Field inspection along the road from Dmanisi through Kamarlo, with large areas of hay meadows alongside the road
- Mountain peaks obscured by low cloud
- Field inspection accompanied by local agricultural official
- Generally the grasslands seen were very green, and in good condition – minor evidence of poor condition (sparse grass cover) close to Kamarlo and around the summer camps

Photo 1: Summer camp close to Kamarlo, looking west towards the uplands of the Likhi Ridge

Tetritskaro

- An area of mixed woodland and grassland, grazing areas below and above the natural, largely broadleaved woodland
- Mountain tops again obscured by low cloud
- Grasslands very green, good pasture, good condition
- Transhumance route passes close to the village – very trampled and poached

Photo 2: Transhumance - sheep and cattle en route to winter pastures, east of Tetritskaro

Tsalka

- By a large lake, with cropped land on flat land by lake, hay meadows on sloping land and terraces, with rangeland grasslands stretching up to the mountain tops
- Terracing extensive up hillsides, largely abandoned and unused
- Very open landscape, grasslands dry but generally in good condition
- Transhumance route passes close to the village – very trampled and poached

Photo 3: Terraces and abandoned cropped land on the slopes above Nardevani, west of Tetritskaro

Samtskhe-Javakheti

Ninotsminda

- High upland plateau and mountains
- Very open landscape with some planted shelter belts and small woodlands
- Very dry landscape with poor grazing quality, rocky in places, and rocky higher up on the mountain peaks.

Photo 4: High upland plateau near Ninotsminda, looking north towards Mt Didi Abuli, (3300 m) along the Likhi Ridge

Akhalkalaki

- Another area of upland plateau, higher mountains in the distance
- Very open landscape, some woodland planting, especially in narrow strips along roadsides
- Large area of cropped land, especially potatoes close to Akhalkalaki
- Field inspection accompanied by local agricultural official
- Grassland areas again very dry and of poor grazing quality
- Grazing seen largely aftermath grazing on cropped land

Photo 5: Rangelands on the Turkish border near Sulda, south of Akhalkalaki, with some forestry plantings.

Aspindza

- Rugged landscape to the south and west of the R Mtkvari valley
- Woodland on the steeper valley sides
- A very dry landscape with little grazing available
- From a vantage point near Ongora overlooking Aspindza, there was a noticeable difference in rangeland condition between the south-facing slopes of Mt Osora north of the Mtkvari (which appeared very dry and burnt-off) and the north-facing slopes, south of the Mtkvari, which appeared greener – and which get less sun.

Photo 6: Rangeland along the Mtkvari valley, north of Aspindza, looking towards Mt Osora (2600m), merging into woodland on the higher slopes.

Annex 5: Additional Landsat information

The Landsat programme

The Landsat programme offers the longest continuous global record of the Earth's surface and has collected spectral information for 39 years. Its historical archive is unmatched in quality, detail, coverage and length.

Table 1: The different Landsat systems

System	Launched	Retired	Instruments	Resolution	Revisit (Days)
Landsat-1 (ERTS-1)	1972, July 23	1978, January	RBV, MSS	80	18
Landsat-2	1975, January 22	1983, July	RBV, MSS	80	18
Landsat-3	1978, March 5	1983, September	RBV, MSS	30, 80	18
Landsat-4	1982, July 16	2001, June*	MSS, TM	80, 30	16
Landsat-5	1984, March 1	Operational	MSS, TM	80, 30	16
Landsat-6	1993, October 5	1993, October 5	ETM	30 (15 pan)	16
Landsat-7	1999, April 15	Operational	ETM+	30 (15 pan)	16

RBV –Return Beam Vidicon; an imaging system that operates in a single spectral range of 0.48 – 0.83 micrometres with 25 meter spatial resolution.

MSS – Multispectral Scanner; provides four bands in the visible and near infrared regions of the electromagnetic spectrum around a resolution of 80 meters.

TM –Thematic Mapper; a more sophisticated multispectral scanner that consists of 7 bands with the characteristics outlined in Table.

ETM – Enhanced Thematic Mapper; this would have collected data in the same seven spectral bands and at the same spatial resolution as the TM on Landsats 4 and 5. It also included an eighth panchromatic band with a spatial resolution of 15 meters.

ETM+ –Enhanced Thematic Mapper Plus; eight band multispectral scanner including a panchromatic band with 15 meter spatial resolution.

Unfortunately, Landsat 7 experienced a malfunction on its Scan Line Protector (SLP) which causes narrow bands on the images it takes. It loses approximately 22% on each image it acquires because the SLP is not operable. Landsat sensors carry a multispectral scanner. Landsat 4 and 5 carry the 'thematic mapper' (TM) scanner. All Landsat satellites provide multispectral data, outlined in Table that is suitable for an analysis of rangeland condition.

Table 2: The various bands available from the different Landsat systems

Band	RBV	MSS	TM	ETM+
1	0.48-0.57 μm green		0.45-0.52 μm blue	0.45-0.52 μm blue
2	0.58-0.68 μm red		0.52-0.6 μm green	0.53-0.61 μm green
3	0.69-0.83 μm IR		0.63-0.69 μm red	0.63-0.69 μm red
4		0.5-0.6 μm green	0.76-0.9 μm NIR	0.76-0.9 μm NIR
5		0.6-0.7 μm red	1.55-1.75 μm SWIR	1.55-1.75 μm SWIR
6		0.7-0.8 μm IR	10.4-12.5 μm TIR	10.4-12.5 μm TIR
7		0.8-1.1 μm IR	2.08-2.35 μm SWIR	2.08-2.35 μm SWIR
8				0.52-0.9 μm panchromatic

Table 3: Landsat spectral bands

Band	**Useful for:**
Band 1 – Blue	Distinguishing between soil and vegetation and deciduous from coniferous vegetation. Also identifies manmade objects such as roads and buildings.
Band 2 – Green	Emphasises peak vegetation as it shows the green reflectance of healthy vegetation. Differentiates between types of plants, plant health and identifies man-made objects.
Band 3 – Red	One of the most important bands for discriminating between different kinds of vegetation. Useful for delineating soil boundaries and geological formations.
Band 4 – NIR	Sensitive to vegetation biomass and bodies of water. Can distinguish between crops and soil.
Band 5 – SWIR	Sensitive to turgidity; the amount of water in plants. Useful in drought studies and is able to discriminate between clouds, snow and ice.
Band 6 – Thermal Infrared	This measures the infrared radiant flux (heat) emitted from surfaces thus discriminates geothermal activity, classifies vegetation and measures soil moisture.
Band 7 – Short-wave Infrared	Discriminates between rock formations such as hydrothermally altered rocks associated with mineral deposits.

Annex 6: Data deliverables

Data description	File name	Regions Covered	Format
Map 1	2011_June_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 2	2011_July_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 3	Underutilised_Rangeland	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 4	1984_June_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 5	Net_Change_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 6	1990_June_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 7	2000_Aug_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Map 8	2006_Aug_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Agricultural boundary	Agriculture_SJKK	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Grazed Areas	Grazed_Areas_SJKK	Samtskhe-Javakheti & Kvemo Kartli	Shapefile & Tiff
Interactive PDF	InteractivePDF_RngCon	Samtskhe-Javakheti & Kvemo Kartli	Adobe Acrobat Document