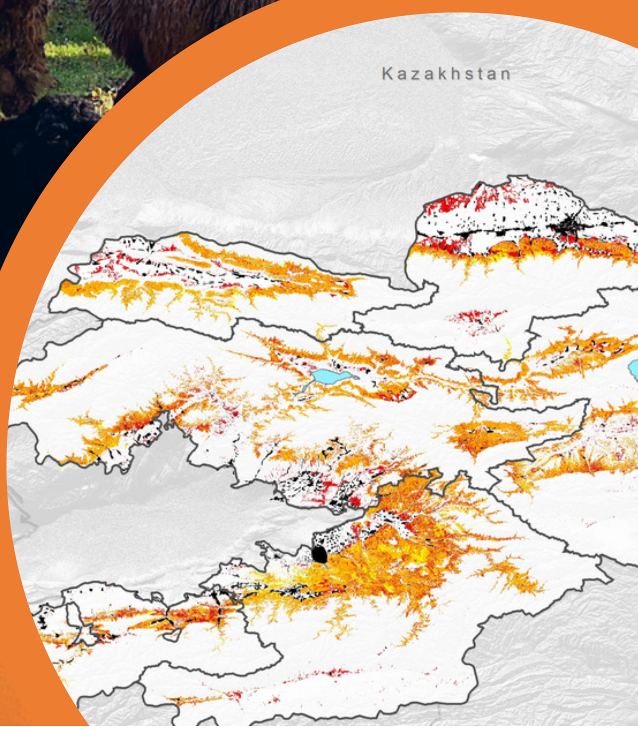




Technical note

# Pasture condition maps in Kyrgyzstan

climate resilience eo4sd

esa
European Space Agency

Германия кызматташтыгы
DEUTSCHE ZUSAMMENARBEIT

Published by:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

# Pasture condition maps in Kyrgyzstan

## TECHNICAL NOTE

Produced by the Climate Resilience Cluster of the Earth Observation for Sustainable Development (EO4SD CR) initiative, a programme of the European Space Agency, in partnership with the International Fund for Agricultural Development (IFAD) together with the project "Development of policy recommendations for reducing greenhouse gas emissions and climate risks in the land use sector as a contribution to the preparation of the Kyrgyz NDCs" (NDC SFF) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German federal enterprise for international cooperation) and the State agency on land resources under the Government of Kyrgyz Republic.

## ORIGINATORS

**Carlos Doménech** | EO4SD CR | GMV project manager | cdomenech@gmv.com

**Miguel A. Belenguer-Plomer** | EO4SD CR | GMV remote sensing analyst | miguel.belenguer.p@gmv.com

**Oliver Mundy** | IFAD technical officer | o.mundy@ifad.org

**Maya Eralieva** | Technical officer of the GIZ NDC SFF project | maya.eralieva@giz.de

**Almaz Abdiev** | Head of GIS and IT Department, State agency on land resources under the Government of Kyrgyz Republic | al.abdiev@gmail.com

## ACKNOWLEDGEMENTS

This work would have not been possible without the support from the European Space Agency (ESA) and IFAD's Adaptation for Smallholder Agriculture Programme (ASAP2). Valuable insights and data have been provided by Salamat Dzhumabaeva and Aliya Ibraimova from CAMP Alatoo as well as from Gulbahar Abdurasulova and Andreas Wilkes from the UNIQUE Company. The originators acknowledge the FAO PRAGA project for sharing field data. The originators also thank Ernst Kydyrmyshev from the Kyrgyz State agency on land resources for their support, as well as APIU and ARIS staff members of the IFAD-funded Livestock Markets Development Programme II. The originators also thank Samir Bejaoui, Nicolas Tremblay and Sebastien Subsol from IFAD for supporting this work, and Jyldyz Omorbekova from APIU (Agricultural Projects Implementation Unit) for translating this publication into Russian.

**Layout**: Rebecca Ferreira and Oliver Mundy | **Cover image**: Oliver Mundy

First published in **July 2021** – Revised in **December 2022**

## Introduction

A large part of Kyrgyzstan's land area serves as pasture for its 1.7 million cattle and 6.3 million sheep and goats. Many pastures are subject to degradation caused by overgrazing and exacerbated by climate change. Statistics on pasture conditions at country level are outdated. This technical note summarizes the results of a study that compares the average pasture conditions of 2000–2004 and 2016–2020 using remote sensing imagery. The note presents the maps and statistics, and explains how pasture conditions in Kyrgyzstan were assessed.

## Pasture degradation maps

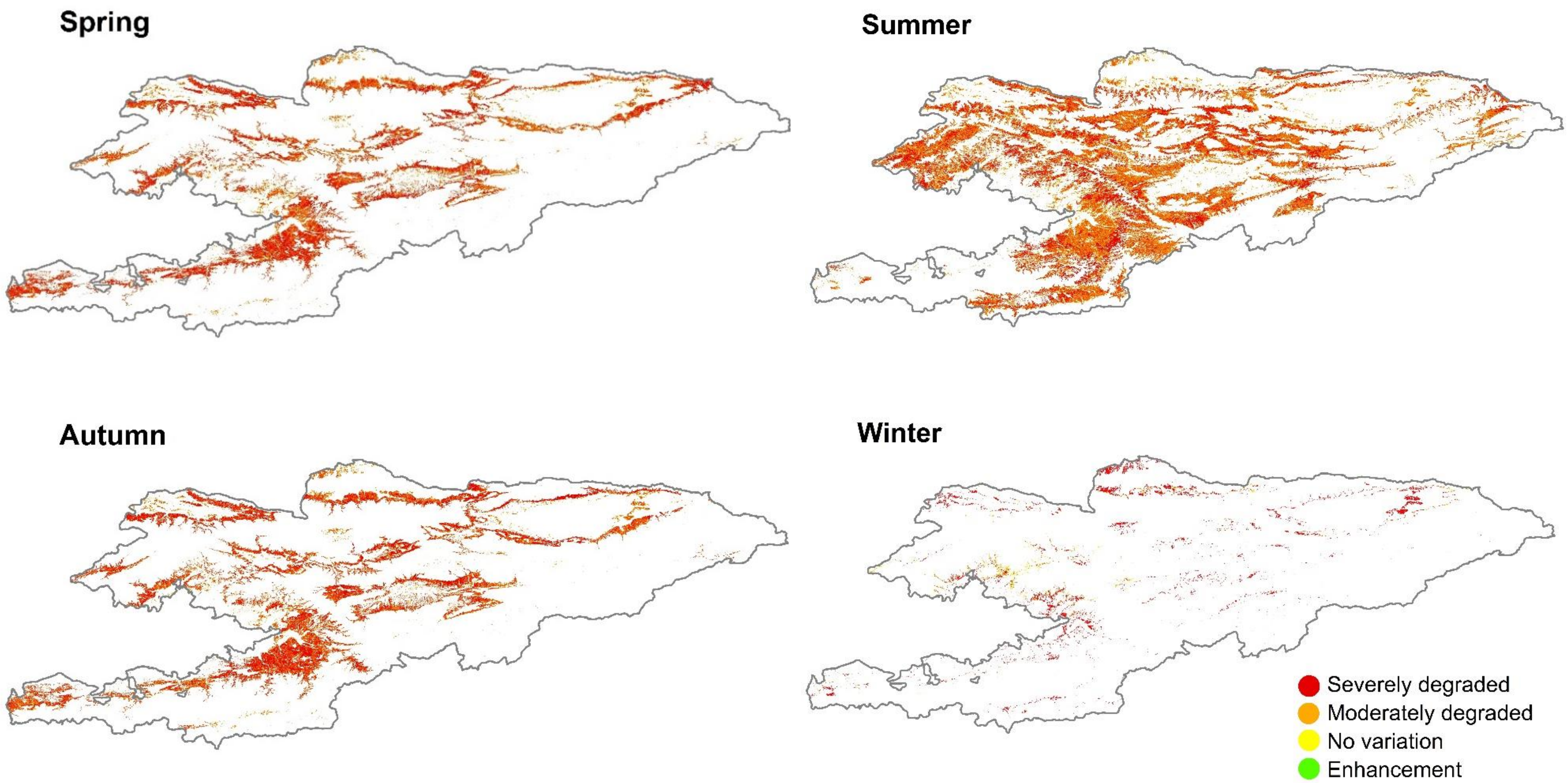
The study compared the average pasture conditions in the periods 2000–2004 and 2016–2020 using Landsat-based spectral indices and a digital elevation model. The remote sensing analysis took into account pasture types, grazing periods and altitudes, and a dataset of field measurements. Five-year timeframes were chosen to reduce the effects of seasons with statistically high or low rainfall or temperature. Changes of rangelands conditions were reported as degradation levels following IPCC's guidelines for grasslands degradation. The maps are available in raster format at 30 m resolution.

The results (Figures 1 and 2; Table 1) show that large areas of pasture were degraded moderately or severely between the start of the century and 2016–20. This study estimates that 87% of pastures (in total 85,531 km$^2$) have been degraded at least during one season (Figure 3).

**TABLE 1.** Seasonal area (ha) and percentage of total grazing area in that season, by rangeland condition

| Degradation level | Winter | | Spring | | Summer | | Autumn | |
|---|---|---|---|---|---|---|---|---|
| | ha | % | ha | % | ha | % | ha | % |
| **Severely degraded** | 533,598 | 81.5 | 1,276,714 | 33.0 | 3,347,111 | 43.0 | 1,127,757 | 28.9 |
| **Moderately degraded** | 80,723 | 12.3 | 2,116,978 | 54.7 | 3,906,920 | 50.2 | 2,427,628 | 62.1 |
| **No variation** | 38,512 | 5.9 | 470,001 | 12.2 | 525,241 | 6.7 | 349,016 | 8.9 |
| **Enhancement** | 1,802 | 0.3 | 4,328 | 0.1 | 5,803 | 0.1 | 3,462 | 0.1 |
| **Total** | **654,635** | **100** | **3,868,022** | **100** | **7,785,076** | **100** | **3,907,863** | **100** |

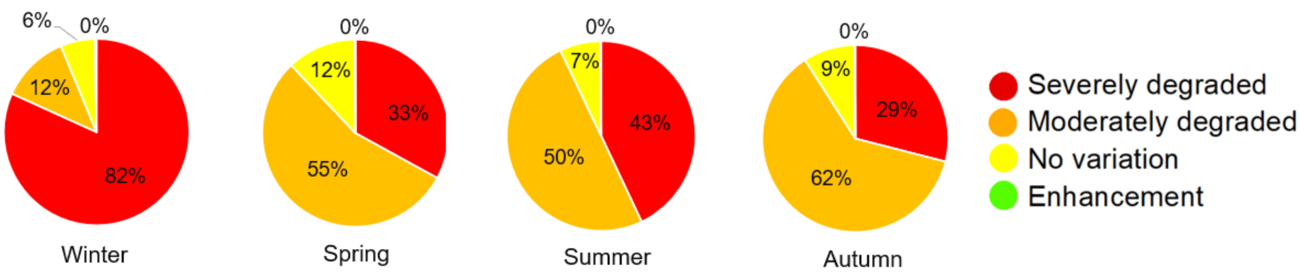
**FIGURE 1.** Seasonal maps of rangeland condition changes between the periods of 2000–2004 and 2016–2020 according to IPCC Guidelines of 2006



Over 40% of summer pastures have been severely degraded since 2000–2004. More than half of spring/autumn and summer pastures have been moderately degraded. Winter pastures are the worst affected, with 82% being severely degraded. Only a few areas of pasture have undergone an improvement in pasture conditions. The degradation levels per season and type of pasture are summarized in Table 1.

This study did not analyze the causes of degradation or to what extent overgrazing or the effects of climate change have contributed to pasture deterioration. The level of uncertainty can be reduced if more field data are available and pasture areas are better defined.

**FIGURE 2.** Percentage change in pasture condition between 2000–4 and 2014–20




## How to use the maps

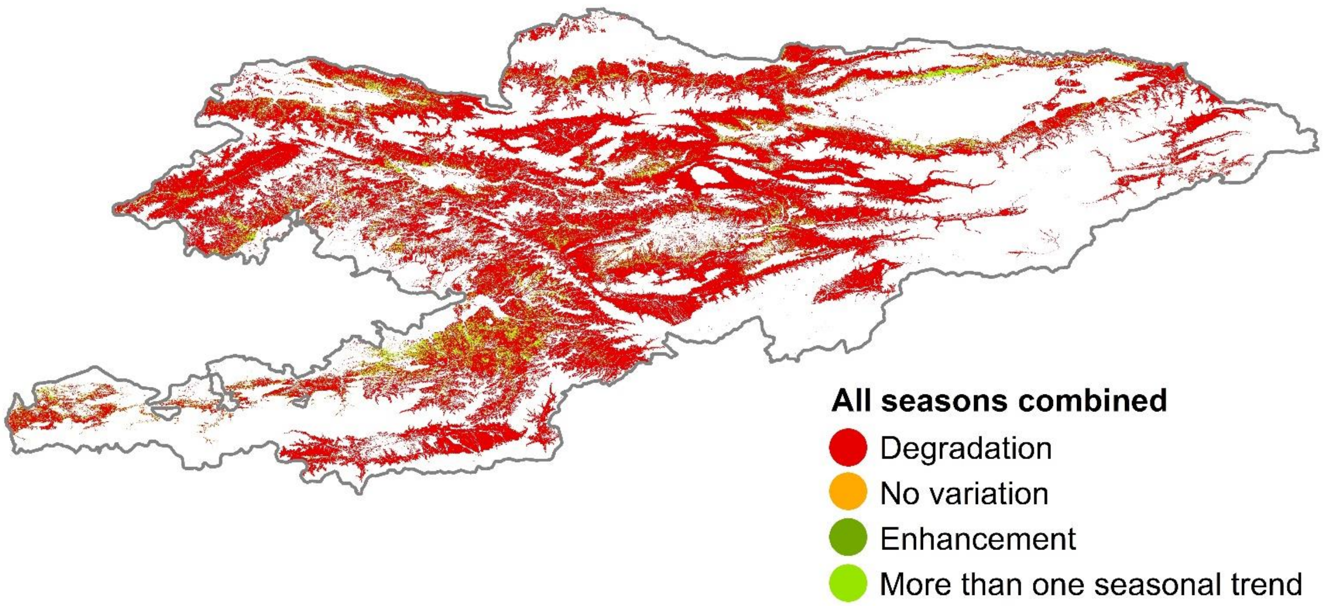
The pasture condition maps can be downloaded in raster format (links provided at the end of this note) allowing spatial statistics to be generated for different administrative levels using software applications such as QGIS.

The maps were used or can be used for the following purposes:

- **Informing climate policy**. The results of this study informed the 2021 update of the country's Nationally Determined Contributions (NDCs) (Kyrgyzstan's commitments to reducing emissions and adapting to changing climate in line with the Paris Agreement). Prior to the update of 2021, the pasture sector was not featured in the country's NDCs.
- **Identifying priority areas for pasture rehabilitation**. IFAD-funded projects and other donor or state-funded programmes can identify and prioritize areas where investments are needed to restore pasture health.
- **Pasture management plans**. Pasture user unions and the agencies supporting them can use the maps in the planning of pasture management in order to determine the need and extent of activities such as reseeding or reduced grazing.
- **Greenhouse gas inventory development**. The maps can also be used to quantify the greenhouse emission sources and associated emissions using standardized methods.

Maps and statistics of this study have been included in the 2021 report "Analysis of livestock and pasture sub-sectors for the NDC revision in Kyrgyzstan" by GIZ, FAO and IFAD.

**FIGURE 3.** Combined pasture condition map of all four seasons comparing the periods 2000–4 and 2014–20




# Recommendations

Pastoral systems, if well managed, are the best suited and adaptive form of agriculture for the majority of Kyrgyzstan's land area that is too dry, cold, or mountainous to practise crop farming. The production system relies on livestock mobility as a key strategy that allows herders to mitigate risks and manage pasture and water resources efficiently.

The literature indicates that unsustainable management practices are the major contributor to degradation. The new maps confirm an ongoing trend of pasture degradation. Between 2006 and 2020, the number of sheep and goats has increased by 55% and the number of cattle by 46% (National Statistical Committee of the Kyrgyz Republic).

## Better pasture & herd management

The high level of degradation that the maps reveal highlights the need for more effort to sustainably manage pastures and herd sizes. Good practices include pasture resting, rotational grazing on seasonal pastures, protection of water sources, and managing herd growth. A study of FAO and IFAD (2021) shows that it is possible to produce more meat and milk without adding more animals by breeding cows at an earlier age, improving the quality of feed, and providing better veterinary services.

## Pasture monitoring

In order to improve the quality of this analysis, more field measurements on pasture conditions are needed in different areas that can feed into the map computation. The locations of these field measurements need to be geographically referenced.

The authors recommend repeating the analysis in 2026 in order to analyze the next 5-year period.

# Computing the maps

The following section explains what data were used to produce the maps and how they were computed.

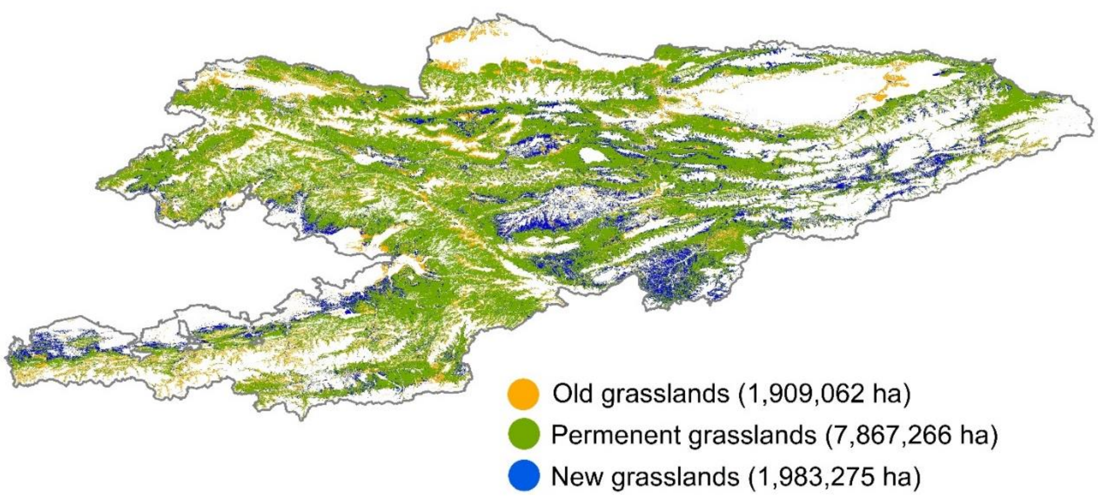
## Data inputs

The following data sets were used to compute the pasture condition maps.

**Landsat imagery**. The analysis used satellite imagery, atmospherically and radiometrically corrected, from Landsat 5, 7 and 8.

**Grassland maps**. The Food and Agriculture Organization of the United Nations (FAO) developed a land cover map at 30 m resolution for Kyrgyzstan in 2019. The study updated this product using information provided by CAMP Alatoo on grassland locations and characteristics. The improved map from 2019 was used to identify grassland areas and train an artificial intelligence-based model to develop a grassland map for the year 2000 from Landsat images. This was done because existing time series of global land cover maps are not detailed enough (i.e., pixel spacing is greater than 30 m) or do not cover the 2000–5 period. This approach captures grassland areas converted into cropland, bare soils or settlements and classifies them as degraded rangelands, if applicable, in the change map.

FIGURE 4. Computed grassland maps for 2000–4 and 2016–20 used in this study




**Pasture types and grazing periods.** Grazing practices in Kyrgyzstan differ by oblast, district or community. CAMP Alatoo provided information on grazing periods, seasonal-based altitudinal ranges for each administrative area (Table 2), plus grazing slopes and maximum distance of pastures to villages. Surface altitude was used to select the grassland areas used for grazing in every season.

**Elevation model.** The elevation was obtained from the Shuttle Radar Terrain Mission Digital Elevation Model (STRM-DEM) at 30 m.

**Field measurements.** For algorithm training and validating purposes, results from FAO's Participatory Assessment of Land Degradation and Sustainable Land management in Grassland and Pastoral Systems (PRAGA) project on the pastures state for different locations were used.

**TABLE 2.** Grazing periods and pasture types

| Oblast | District | Aiyl okmotus | Grazing periods | | | | Pasture types (altitude, m) | | | Distance to villages* |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Winter | Spring | Summer | Autumn | Winter | Spring/autumn | Summer | |
| **Jalalabad** | Aksy | Jergetal | 11 Nov–31 Mar | 1 Apr–20 May | 20 May–1 Sep | 1 Sep–10 Nov | 900-1000 | 1300-1500 | 1400-2200 | 500 m |
| | | Kerben | 11 Nov–31 Mar | 1 Apr–20 May | 20 May–1 Sep | 1 Sep–10 Nov | 1300 | 1500-1800 | 1700-3200 | 500 m |
| | Toguz-Toro | Atay | 16 Nov–31 Mar | 1 Apr–31 May | 1 Jun–31 Aug | 1 Sep–15 Nov | 1500-1800 | 1500-1900 | 1900-3100 | 200 m |
| **Osh** | Aravan | Too-Moun | 1 Dec–31 Mar | 1 Apr–30 May | 1 Jun–1 Oct | 1 Oct–30 Nov | 600-700 | 700-1600 | 1160-3000 | 200 m |
| | | Chek-Abad | 1 Dec–19 Mar | 20 Mar–30 May | 1 Jun–1 Oct | 1 Oct–30 Nov | 700 | 700-1200 | 2200-2400 | 700 m |
| | | Usupov | 1 Dec–19 Mar | 20 Mar–30 May | 1 Jun–1 Oct | 1 Oct–30 Nov | 700-800 | 800-1000 | 2100-2600 | 200 m |
| | Kara-Kulja | Kara-Guz | 1 Nov–31 Mar | 1 Apr–30 May | 1 Jun–1 Sep | 1 Sep–1 Nov | 1260-1900 | 1260-2300 | 1800-2800 | 100 m |
| | | Kara-Kochkor | 1 Nov–31 Mar | 1 Apr–30 May | 1 Jun–1 Sep | 1 Sep–1 Nov | 1300-2000 | 1300-2300 | 2300-2500 | 200 m |
| | | Kara-Kulja | 1 Nov–31 Mar | 1 Apr–30 May | 1 Jun–1 Sep | 1 Sep–1 Nov | 1200-2100 | 1200-2500 | 2500-3500 | 100 m |
| | Nookat | Kara-Tash | 1 Dec–31 Mar | 1 Apr–30 May | 1 Jun–1 Oct | 1 Oct–30 Nov | 1000-1300 | 1200-1300 | 1600-3000 | 100 m |
| | | Toolos | 1 Dec–31 Mar | 1 Apr–30 May | 1 Jun–1 Oct | 1 Oct–30 Nov | 1000 | 1000-2000 | 3000 | 100 m |
| **Batken** | Batken | Kara-Bak | Nov–Mar | Sep–Oct | Jun–Aug | Apr–May | 850-1200 | 850-1200 | 2700-3800 | 100m |
| | | Suu-Bashy | Nov–Mar | Sep–Oct | Jun–Aug | Apr–May | 1200-1600 | 1200-1600 | 1800-2000 | 100m |
| | Leilek | Beshkent | Nov–Mar | Sep–Oct | Jun–Aug | Apr–May | 650-1100 | 650-1100 | 650-1100 | 100 m |
| | | Katran | 21 Nov–9 Apr | 10 Apr–10 Jun | 11 Jun–20 Aug | 21 Aug–20 Nov | 1200-2000 | 1200-2000 | 1200-2000 | 100 m |
| **Naryn** | | | 1 Dec–1 Feb | 1 Apr–31 May | 1 Jun–31 Aug | 1 Sep–31 Nov | 2000-2500 | 1800-2500 | 2500-3300 | 500 m |
| **Issyk-Kul** | | | Dec–Apr | May–Jun | Jun–Sep | Oct–Nov | 1800-2200 | 1800-2500 | 2400-3300 | 500-1000m |
| **Chui** | | | Dec–Mar | Apr–Jun | Jun–Sep | Oct–Nov | 1000-1500 | 1000-2000 | 2000-3000 | 500-1000m |
| **Talas** | | | Dec–Apr | May–Jun | Jun–Sep | Oct–Nov | 1500-2000 | 1500-2200 | 2000-300 | 500-1000m |

*of winter pastures around villages

Source: Camp Alatoo

## Processing steps

Experts from GMV (the company leading the EO4SD CR cluster) developed the following methodology to compute the pasture condition maps using Python and QGIS.

**1. Satellite imagery corrections.** This step entails the atmospheric correction of satellite images and intercalibration of sensors. As spectral bands of the imagery from different sensors have distinct bandwidths, the first step was to adjust reflectances radiometrically in order to ensure time series consistency. Radiometrically stable targets, e.g., bare soil, were selected and used as reference for the intercalibration exercise.

**2. Calculation of Landsat-based spectral indices.** Vegetation, moisture and burn indices from Table 4 were calculated over Kyrgyzstan for every grazing period in each season in both five-year timeframes. The five-year average of 15-day spans in each seasonal grazing period were calculated to reduce the effect of meteorological-driven vegetation anomalies. The maximum value of the 15-day spans averaged indices in each seasonal grazing period were used as proxy to assess the pasture condition changes over time following the IPCC's guidelines (2006) of grasslands degradation (Table 3).

**FIGURE 5.** Shuttle Radar Terrain Mission Digital Elevation Model (STRM-DEM) at 30 m resolution

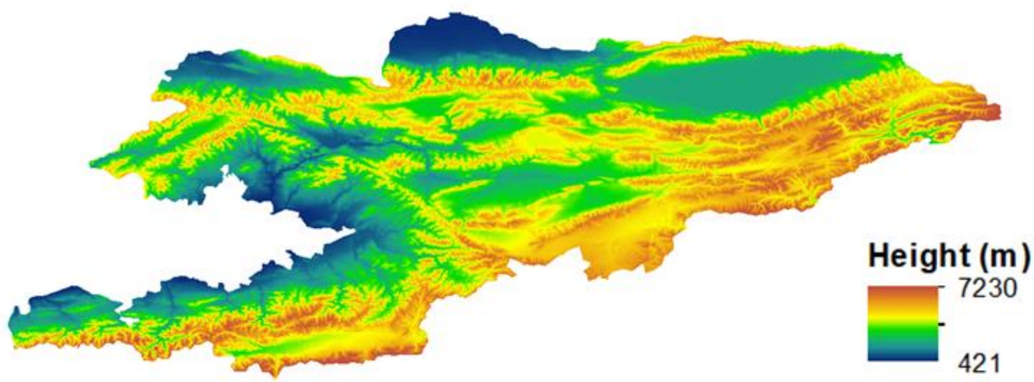



**TABLE 3.** Classes of rangeland condition changes from IPCC's guidelines from 2006

| Qualitative classes | Index variation of post-period with respect to pre-period |
|---|---|
| Severely degraded | <70% |
| Moderately degraded | 70.1–95% |
| Non-variation | 95.1–105% |
| Enhancement | >105% |

**TABLE 4.** Spectral indices used to estimate changes in rangeland condition

| Index | Formula* | Reference |
|---|---|---|
| **NDVI**<br>Normalized Difference Vegetation Index | $\frac{NIR - RED}{NIR + RED}$ | Rouse Jr et al. 1974 |
| **EVI**<br>Enhanced Vegetation Index | $G \times \frac{NIR - RED}{NIR + C1 \times RED - C2 \times BLUE + L1}$ | Liu and Huete 1995 |
| **SAVI**<br>Soil Adjusted Vegetation Index | $\frac{NIR - RED}{NIR + RED + L2} \times 1 + L2$ | Huete 1988 |
| **MSAVI**<br>Modified Soil Adjusted Vegetation Index | $\frac{2 \times NIR + 1 - \sqrt{(2 \times NIR + 1)^2 - 8 \times (NIR - RED)}}{2}$ | Qi et al. 1994 |
| **NDMI**<br>Normalized Difference Moisture Index | $\frac{NIR - SWIR_1}{NIR + SWIR_1}$ | Gao 1996 |
| **NBR**<br>Normalized Burn Ratio | $\frac{NIR - SWIR_2}{NIR + SWIR_2}$ | López-García and Caselles 1991 |
| **NBR2**<br>Normalized Burn Ratio 2 | $\frac{SWIR_1 - SWIR_2}{SWIR_1 + SWIR_2}$ | Key and Benson 2004 |
| **VCI**<br>Vegetation Condition Index | $\frac{NDVI_i - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$ | Kogan 1990 |
| **VHI**<br>Vegetation Health Index | $\frac{VCI + TCI}{2}$ | Kogan 1995 |

** BLUE, RED, NIR, $SWIR_1$ and $SWIR_2$ correspond to bands 1, 3, 4, 5 and 7 as well as 2, 4, 5, 6 and 7 for Landsat 5, 7 and 8, respectively.*

*For EVI and SAVI, G = 2.5, C1 = 6, C2 = 7.5, L1 = 1 and L2 = 0.2,*

*For VCI, $i$ refers to a specific date of a considered temporal period.*

*TCI = Thermal Condition Index, expressed as $(LST_i - LST_{min})/(LST_{max} - LST_{min})$, where LST is the Landsat-based Land Surface Temperature.*

**3. Analysing index-based degradation.** Changes observed by the spectral indices in the two periods for each sub-district were analysed. Indices showing redundant information were discarded. Results with observed similarity greater than 75% were discarded. The significance of each index to assess degradation is obtained by using a random forest model (feature importance calculation) with in-situ state of observed pastures from FAO's PRAGA project. This approach allowed estimating how effective each index is for representing condition changes in grasslands.

**4. Creating metric to assess pasture degradation.** A composite of the non-correlated index-based pasture condition changes was computed by weighting the results by their estimated significance and applying a weighted sum model (Equation 1).

$$Rangeland\ condition\ changes_i = \sum_{j=1}^{n} w_j c_{ji} \quad (1)$$

where *i* is a single geospatial observed unit (i.e., an image pixel), *n* is the number of considered indices, *w* is the weight of the index *j,* and *c* is the qualitative class of the rangeland condition change of the index *j*. This approach is widely used in geospatial applications (e.g., Belenguer-Plomer 2016; Rahman and Saha 2008). Additionally, a level of confidence product was also derived considering the weighted differences of each index-based product with respect to the combined result.

**5. Masking pasture areas.** The final step was to create and apply a pasture mask over the two grassland maps to target pasture areas. The mask followed the restrictions posed by the grazing practices gathered per district. These include grassland areas with non-steep slopes (i.e., below 45º), with close distance to villages for winter results and with DEM-based altitudes (see Figure 5) within the ranges given for season and per district.

The CHIRPS (Rainfall Estimates from Rain Gauge and Satellite Observations) precipitation product was used to discard areas where the coefficient of variation of annual precipitation exceeds 33% because greenhouse gas emission/absorption models cannot provide realistic results for higher values.

## Strengths and weaknesses

Box 1 summarizes the strengths and weaknesses of the methodology. The results of this assessment can be improved with:

- More field measurements of pasture conditions covering the whole country that are geo-referenced and standardized;
- More precise and complete information on grazing periods for each season (even at pasture user union level);
- Better definition of the location of pasture areas.

**BOX 1**. Strengths and weakness of the calculation methodology

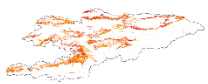
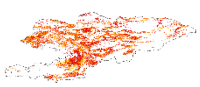
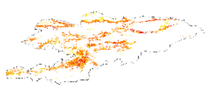
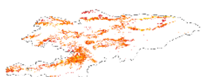
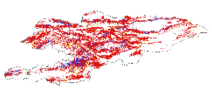
| Strengths | Weaknesses |
|---|---|
| ✓ Adaptability to specific regional-based grazing patterns<br>✓ Low-cost production when compared to field campaigns<br>✓ Replicability for some other time periods or regions | ☒ Precise local information is required. The method is not applicable to areas where no grazing information is available.<br>☒ Unbalanced availability of satellite data depending on the period. The more recent, the more data available.<br>☒ Local measurements on rangeland status are required to calculate the weights in the index composite. |

# Download maps and further information

The following products listed in Table 5 have been developed. All products can be downloaded here: https://www.ifad.org/en/web/knowledge/-/pasture-condition-maps-in-kyrgyzstan

A presentation and webinar recording on how the pasture conditions maps were calculated are available under this link: http://eo4sd-climate.gmv.com/content/capacity-building-kyrgyzstan

**TABLE 5.** List of mapping products

| Thumbnail | Product name | Description |
|---|---|---|
|  | EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_WinterDegradation_winter.tif | Winter rangeland condition changes |
|  | EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Winter.tifUncertainty_winter.tif | Winter rangeland condition changes uncertainty |
|  | EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_SpringDegradation_spring.tif | Spring rangeland condition changes |
|  | EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Uncertainty_sSpring.tif | Spring rangeland condition changes uncertainty |
|  | EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_Degradation_sSummer.tif | Summer rangeland condition changes |
|  | EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Uncertainty_sSummer.tif | Summer rangeland condition changes uncertainty |
|  | EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_ADegradation_autumn.tif | Autumn rangeland condition changes |
|  | EO4SD_KGZ_RangelandConditionUncertainty_2000-2004vs2016-2020_Uncertainty_aAutumn.tif | Autumn rangeland condition changes uncertainty |
|  | EO4SD_KGZ_RangelandConditionChanges_2000-2004vs2016-2020_AllSeasonspasturelands_status.tif | Combined rangeland condition changes considering all seasons |
|  | EO4SD_KGZ_Grasslands_2000-2004 | Grassland map 2000-04 |
|  | EO4SD_KGZ_Grasslands_2016-2020 | Grassland map 2016-20 |

**About the Earth Observation for Sustainable Development (EO4SD) initiative**

The programme funded by the European Space Agency aims to promote the usage of Earth observation-derived information in sustainable development. The initiative is organized in seven thematic consortia of companies that provide geospatial tools, data and services to international finance institutes such as IFAD. The “Climate Resilience” cluster of the programme has supported IFAD’s portfolios in Kyrgyzstan, Tajikistan and Lesotho. The cluster holds expertise on geospatial assessments on climate change adaptation and hosts a data platform called ADAM. The collaboration between IFAD and the Climate Resilience cluster of the programme started in 2019. Click here for more information.

## References

Belenguer-Plomer, Miguel Ángel. 2016. "Detección de Problemas en la Localización de Usos del Suelo Mediante SIG y AHP: El Caso de Riba-Roja de Túria (Valencia)." *GeoFocus. Revista Internacional de Ciencia y Tecnología de La Información Geográfica* (18):3–24.

FAO and IFAD. 2021. "Estimating the future impact of the Resilient Regional Pastoral Communities Project on greenhouse gas emissions. Contribution to the update of Nationally Determined Contributions (NDC) of Kyrgyzstan." Rome.

Gao, Bo-Cai. 1996. "NDWI—A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water from Space." *Remote Sensing of Environment* 58(3):257–66.

Huete, A. R. 1988. "A Soil-Adjusted Vegetation Index (SAVI)." *Remote Sensing of Environment* 25(3):295–309. doi: 10.1016/0034-4257(88)90106-X.

GIZ, FAO, IFAD. 2021. "Analysis of livestock and pasture sub-sectors for the NDC revision in Kyrgyzstan." Bishkek.

IPCC 2006. "2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme." Volume 4. Agriculture, Forestry and Other Land Use. Chapter 6 Grassland. Published: IGES, Japan.

Key, Carl, and Nate Benson. 2004. "Ground Measure of Severity, the Composite Burn Index; and Remote Sensing of Severity, the Normalized Burn Ratio." Pp. 1–51 in *FIREMON: Fire Effects Monitoring and Inventory System*, edited by G. T. R. RMRS-GTR-164. Ogden: USDA Forest Service, Rocky Mountain Research Station.

Kogan, F. N. 1990. "Remote Sensing of Weather Impacts on Vegetation in Non-Homogeneous Areas." *International Journal of Remote Sensing* 11(8):1405–19. doi: 10.1080/01431169008955102.

Kogan, F. N. 1995. "Application of Vegetation Index and Brightness Temperature for Drought Detection." *Advances in Space Research* 15(11):91–100. doi: 10.1016/0273-1177(95)00079-T.

Liu, Hui Qing, and Alfredo Huete. 1995. "A Feedback Based Modification of the NDVI to Minimize Canopy Background and Atmospheric Noise." *IEEE Transactions on Geoscience and Remote Sensing* 33(2):457–65. doi: 10.1109/tgrs.1995.8746027.

López-García, M. J., and V. Caselles. 1991. "Mapping Burns and Natural Reforestation Using Thematic Mapper Data." *Geocarto International* 6(1):31–37.

Qi, J., A. Chehbouni, A. R. Huete, Y. H. Kerr, and S. Sorooshian. 1994. "A Modified Soil Adjusted Vegetation Index." *Remote Sensing of Environment* 48(2):119–26. doi: 10.1016/0034-4257(94)90134-1.

Rahman, R., and S. K. Saha. 2008. "Remote Sensing, Spatial Multi Criteria Evaluation (SMCE) and Analytical Hierarchy Process (AHP) in Optimal Cropping Pattern Planning for a Flood Prone Area." *Journal of Spatial Science* 53(2):161–77. doi: 10.1080/14498596.2008.9635156.

Rouse Jr, J_W, R. H. Haas, J. A. Schell, and D. W. Deering. 1974. "Monitoring Vegetation Systems in the Great Plains with ERTS." Pp. 309–17 in *NASA. Goddard Space Flight Center 3d ERTS-1 Symp*. Vol. 1.

Sharpe, N., Mwangi, P., Isakov, I. and Onyango, V. 2022. Application of the participatory rangeland and grassland assessment (PRAGA) methodology in Kyrgyzstan – Baseline analysis, remote sensing, field assessment and validation report. Rome, FAO.

Investing in rural people

International Fund for
Agricultural Development
Via Paolo di Dono, 44
00142 Rome, Italy
Tel: +39 06 54591
Fax: +39 06 5043463
Email: ifad@ifad.org
www.ifad.org

facebook.com/ifad
instagram.com/ifadnews
linkedin.com/company/ifad
twitter.com/ifad
youtube.com/user/ifadTV

July 2021