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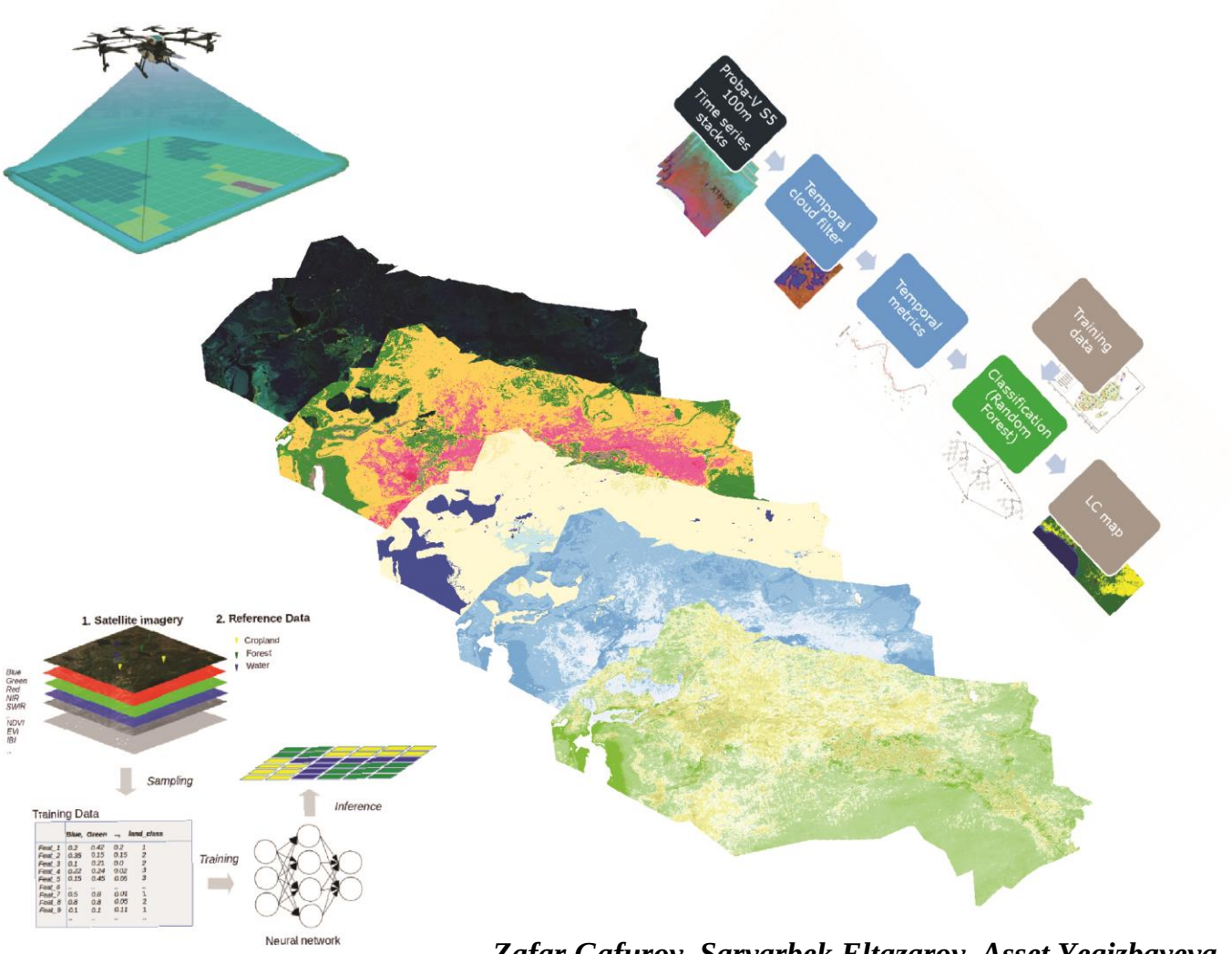
IWMI International Water Management Institute

Ecologically oriented regional development in the Aral Sea region program
Increasing water use efficiency in the Aral Sea Region

Geodatabase and Atlas: Kyzylorda region, Kazakhstan



Zafar Gafurov, Sarvarbek Eltazarov, Asset Yegizbayeva, Kakhramon Djumaboev, Sherzod Zaitov and Shavkat Kenjabaev

About GIZ

The German Society for International Cooperation (GIZ), as a service provider in the field of international cooperation for sustainable development and international education work, is dedicated to shaping a future worth living around the world. Having over 50 years of experience in a wide variety of areas, including economic development and employment promotion, energy and the environment, and peace and security, GIZ provides tailor-made, cost-efficient and effective services for sustainable development. GIZ has two registered offices in Germany, one in Bonn and one in Eschborn, near Frankfurt am Main. GIZ also operates from about 90 offices around the globe, some of which shared with other German development organisations.

About IWMI

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, policymakers, farmers, civil society, water managers, development partners and businesses to solve water problems and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services and products with capacity strengthening, dialogue and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a Research Center of CGIAR with offices in 15 countries and a global network of scientists operating in more than 55 countries.

About the "Ecologically oriented regional development in the Aral Sea region program"

Since 2020, the project has been supporting two Central Asian states (Kazakhstan and Uzbekistan) to improve the capacity of organisations and individuals, with the aim of enabling them to make climate-adapted and ecologically oriented investment decisions. For further details about the project, visit: https://www.giz.de/en/worldwide/93488.html.

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CONTENT

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/ spatial databases / atlases / digital elevation models / maps / satellite imagery / population dynamics / urban areas / rural areas / land cover / land use / soil types / soil density / soil organic carbon / soil salinity / clay soils / water resources / water supply / water demand / water-use efficiency / water user associations / irrigation canals / pumps / drainage systems / climate change / meteorological stations / precipitation / temperature / evapotranspiration / geographical information systems / remote sensing / transport / Kazakhstan /

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Acknowledgments

Geodatabase and Atlas: Kyzylorda, Kazakhstan is based on data and information generated and collected within the framework of the GIZ Program "Ecologically oriented regional development in the Aral Sea region". Data were also obtained from published and grey literature as well as spatial analyses carried out using publicly available sources. The authors would like to thank local project partners in Karakalpakstan for their valuable inputs and feedback when preparing the material.

This Geodatabase and Atlas was put together within the framework of activities implemented under the GIZ Program "Ecologically oriented regional development in the Aral Sea region" as part of the project "Increasing water use efficiency in the Aral Sea Region" implemented by the International Water Management Institute (IWMI) in collaboration with GIZ and local partners.

This work is mapped to the CGIAR Initiative on NEXUS Gains, which is grateful for the support of CGIAR Trust Fund contributors (www.cgiar.org/funders).

Donor

This project is funded by

This work was carried out as part of the GIZ funded regional project "Ecologically Oriented Regional Development in the Aral Sea Region" (ECO-ARAL) and commissioned by German Federal Ministry for Economic Cooperation and Development (BMZ)

Geodatabase and Atlas

Importance Geodatabase and Atlas

The information systems aimed at data and information management are becoming increasingly important with reference to the processes of decision making and strategic thinking in a newly emergent competitive economy setting. In addition to digital data types utilized in information systems, geospatial data have advanced significantly in recent years. Not only do these data include the geographic location of particular items on the planet, they also specify their shape and size. Spatial data including digital maps are the core component of a GIS. In order to help decision makers with the planning, design and prioritization of investment plans, these data are materialized in the form of files that are compiled into a single database.

Introduction

This Geodatabase and Atlas was developed by the International Water Management Institute (IWMI) in collaboration with regional partners as part of project activities under the GIZ project “Ecologically oriented regional development in the Aral Sea region”.

Capacity-building of micro-, small- and medium-sized enterprises as well as ministries and state agencies is one of the primary focuses of the project in order to enable their employees to make climate-adaptive and environmentally oriented investment decisions. Modern satellite imagery and technologies is one of the areas that create new opportunities for agricultural, forestry and water sector professionals to improve their skills and expertise in regional spatial planning. For instance, remote sensing techniques can be instrumental in identifying environmental or climate-related industrial risks and cases of degradation for targeted improvements at an early stage.

Data Accuracy and Reliability

This Atlas was created using open source GIS, remote sensing and other relevant information including databases, maps, research, analyses etc. publicly available from renowned international agencies, research organizations and projects.

Availability and Accessibility

The Atlas can be obtained in digital form for use by external parties. When using the Atlas, the authors and the institute should be credited.

Software Employed

This Atlas and the associated maps were created on a computer machine running Windows 10 Professional and using ArcGIS, QGIS and Google Earth Engine. End users should download the package that is most appropriate for the version of ArcGIS software that they are using. It is important to note that ArcGIS is not the only software that allows making use of the map package and associated geodatabase.

Aral Sea Basin

The Aral Sea, located in the Turan plain of Central Asia and once the fourth-largest inland sea in the world, has undergone many changes. Two major transboundary rivers, the Amu Darya and the Syr Darya, feed the Aral Sea. Their combined basin boundaries, which largely define the Aral Sea basin, cover a total area of 1.9 million km^2 (Xenarios et al. 2019) and extend over six countries: Kazakhstan, Turkmenistan, Uzbekistan, Afghanistan, Tajikistan and the Kyrgyz Republic. About 35 million people, two thirds of the combined population of these countries, live in the Aral Sea basin. Before 1960, about 60 billion cubic meters (BCM) (Xenarios et al. 2019) of water reached the sea annually. Today, the inflow of water has declined to 5-20 BCM annually and as a result, the level of water in the Aral Sea has dropped by almost 20 meters (m) and its area shrunk by two-thirds, from 67,000 km^2 in 1960 to 20,000 km^2 at present (Xenarios et al. 2019). The table in the following page provides some key features of the Aral Sea basin.

Table Key information on Aral sea basin, surface area and renewable surface water resources by basin countries

Country	Surface area			Renewable surface water resources			
	km²	% Aral sea basin	% Country area	Amudarya (km³)	Syrdarya (km³)	Aral sea basin (km³)	Aral sea basin (%)
Afghanistan	234800	12	36	6.18		6.18	5.3
Kazakhstan	540000	28	20		4.50	4.50	3.9
Kyrgyzstan	117500	6	59	1.93	27.25	29.18	25.2
Tajikistan	141670	7	99	62.90	0.40	63.30	54.8
Turkmenistan	466600	24	96	0.98		0.98	0.8
Uzbekistan	447400	23	100	4.70	4.84	9.54	8.3
Total	**1947970**	**100.0**		**76.69**	**36.99**	**113.68**	**98.3**
Aral sea basin				78.46	37.14	115.60	100.00

Source: FAO, 2003.

At present, the biggest challenges for the water sector in the region come from weak decision-making capacities of state water management organizations, and un-coordinated and competing interests of different stakeholders and public sectors across all levels of water management. These problems are the root causes resulting in bottlenecks and failures in implementing integrated water management approaches at river basin scale. Current water systems are in transformation, having the attributes of both past and present systems. However, an effective water administration needs to tackle both supply and demand needs, taking care of both the developing economy and the degraded environment (Xenarios et al. 2019).

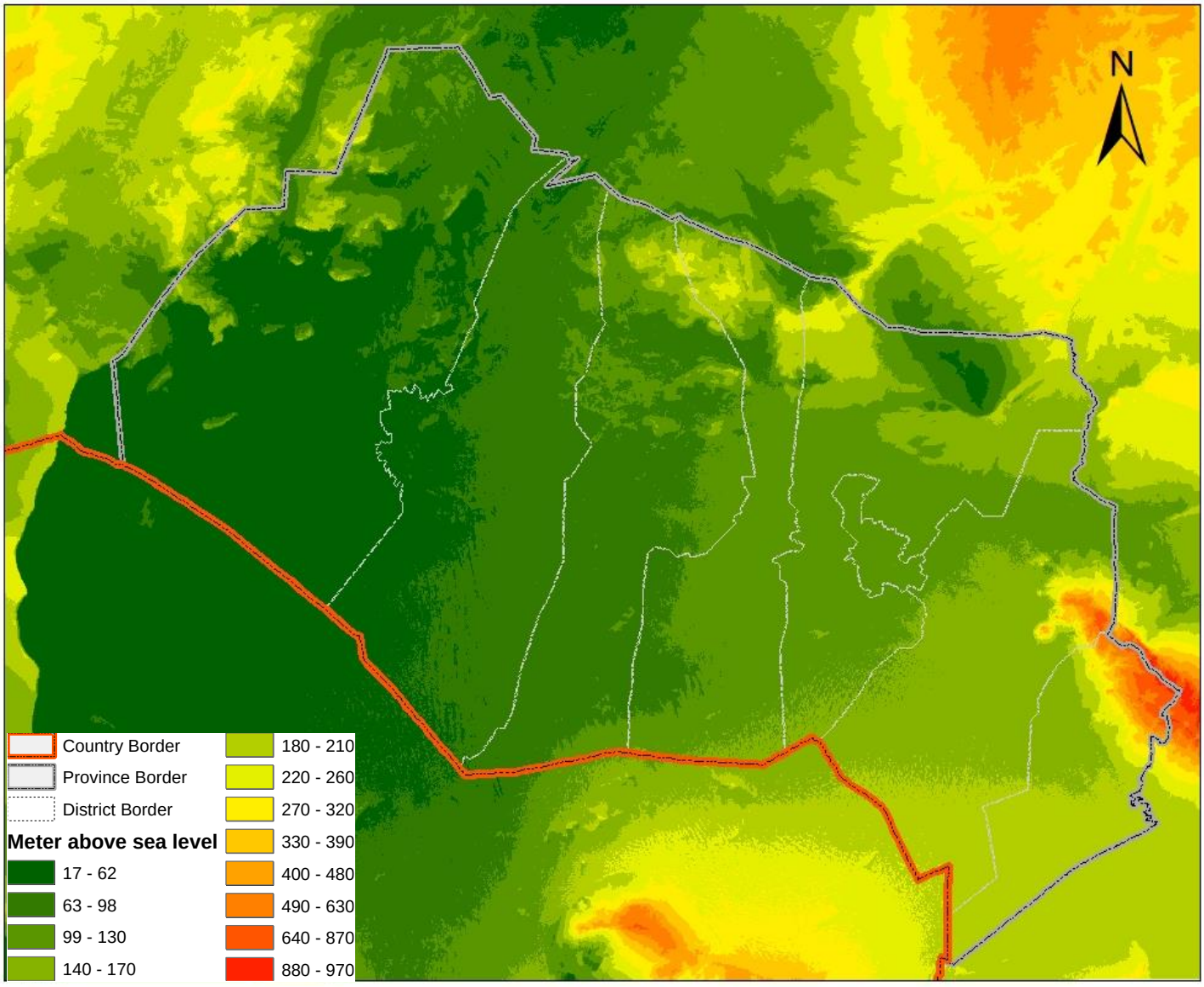
Satellite view of study area

Kyzylorda region, Kazakhstan

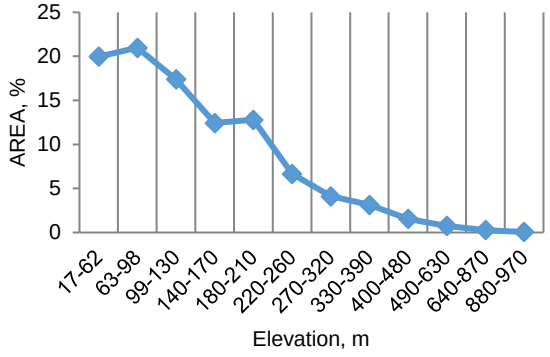
Kyzylorda is a region of Kazakhstan located in the southwestern part of Kazakhstan, along the river of Syrdarya. The capital is Kyzylorda, with a population of 234 73, region's population is 799533. The region borders the neighboring country Uzbekistan, as well as three other regions: Aktobe Region (to the west), Ulytau region (to the north), and Turkistan Region (to the east).

Kyzylorda region consists of Aral district, Zhalagash district, Zhanakorgan district, Kazaly district, Karmakshy district, Syrdarya district, Shieli district and the city of Kyzylorda. Kyzylorda region is of great agricultural and strategic importance in the country's food security. An extensive area of rice cultivation is concentrated in the central districts of the Kyzylorda region.

Digital elevation model



Max Elevation	970 meters
Min Elevation	17 meters
Mean Elevation	140 meters
Mean Slope	2 degrees

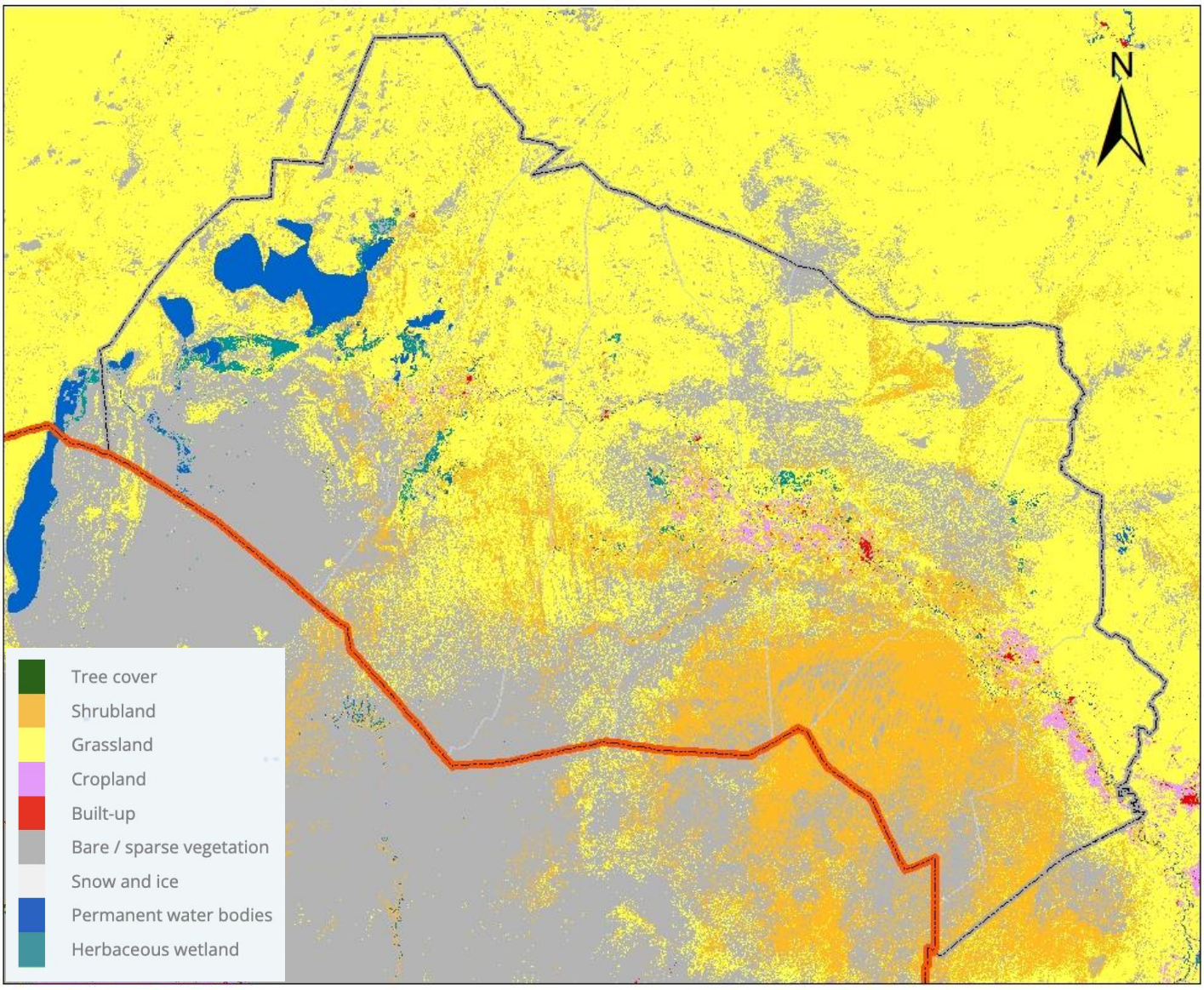


The digital elevation model of Kyzylorda region, Kazakhstan has been produced using the publicly available The Shuttle Radar Topography Mission (SRTM) digital elevation dataset. SRTM was originally produced to provide consistent, high-quality elevation data at near global scope. This version of the SRTM digital elevation data has been processed to fill data voids, and to facilitate its ease of use.

SRTM was originally produced to provide consistent, high-quality elevation data at near global scope. This version of the SRTM digital elevation data has been processed to fill data voids, and to facilitate its ease of use.

Source: Farr et al. 2007.

Land cover and use map



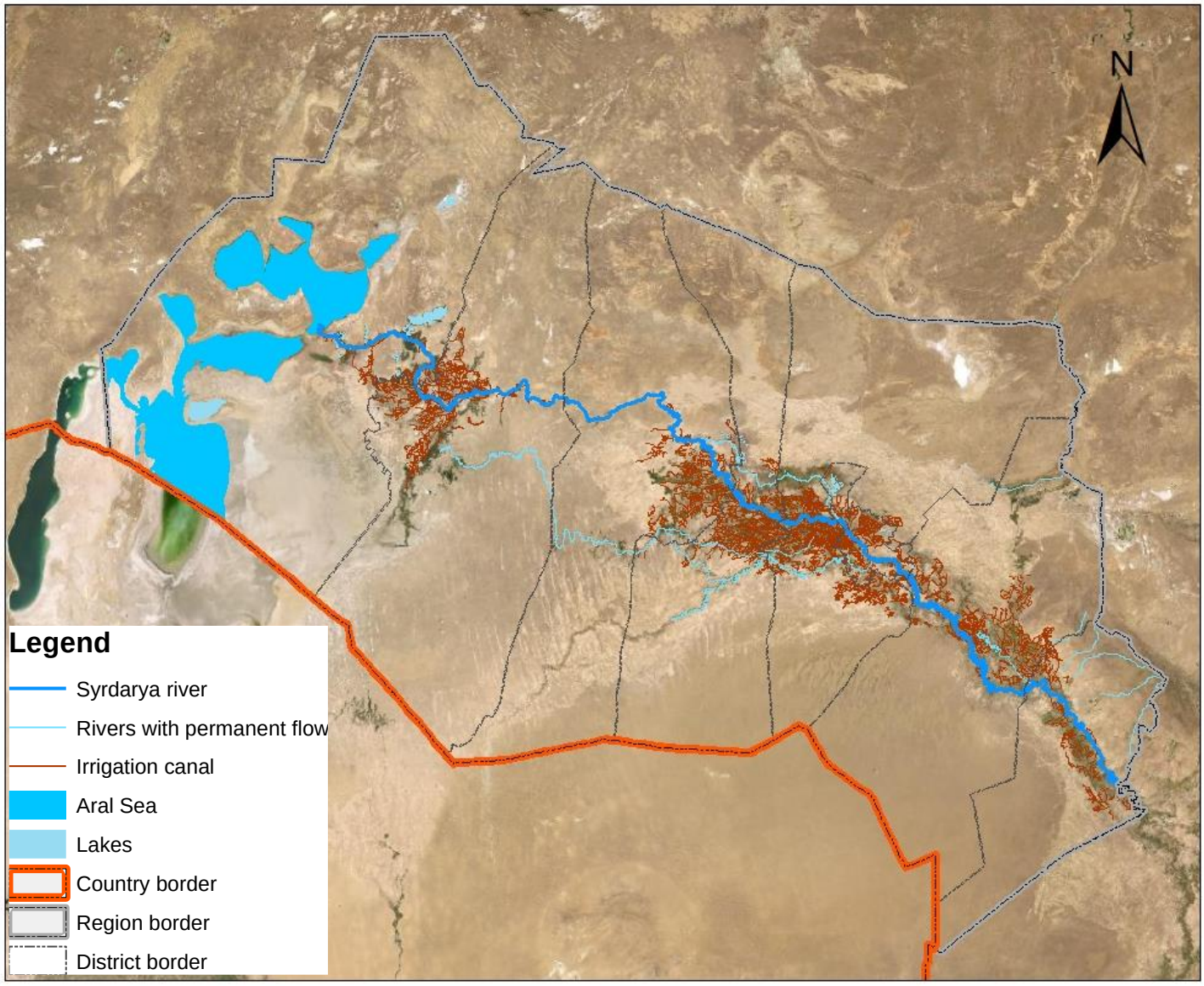
Source: ESA WorldCover product (Zanaga et al. 2021).

Class name	Area(%)
Tree cover	**0,02**
Shrubland	**17,35**
Grassland	**46,60**
Cropland	**1,87**
Built-up	**0,21**
Bare / sparse vegetation	**30,97**
Permanent water bodies	**2,08**
Herbaceous wetland	**0,91**

Total land area is 228 394 hectares. Of these, irrigated agricultural area is 1.87 %. Pasture area for livestock is 46.6% thousand hectares.

The European Space Agency (ESA) WorldCover product provides a global land cover map for 2020 at 10 m resolution based on Sentinel-1 and Sentinel-2 data. The WorldCover product comes with 11 land cover classes and has been generated in the framework of the ESA WorldCover project, part of the 5th Earth Observation Envelope Programme (EOEP-5) of the European Space Agency (Zanaga et al. 2021).

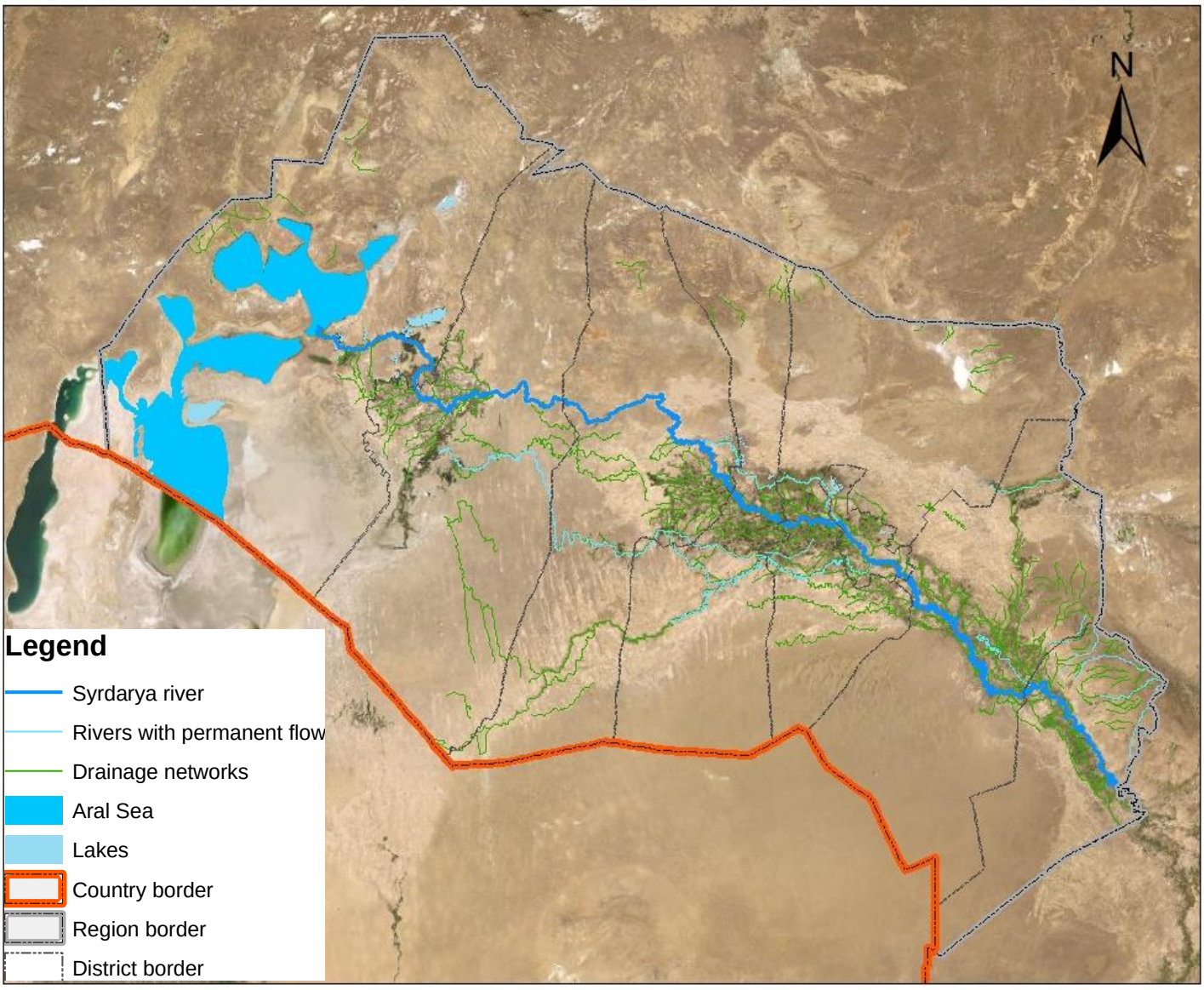
Irrigation canal networks



Kyzylorda Region in southern Kazakhstan relies on an essential irrigation system managed by "KazVodKhoz," a state organization responsible for water resources. The region's arid climate necessitates controlled water distribution to support agriculture, primarily along the Syrdarya River. This river serves as the main source for irrigation, enabling the cultivation of crops like cotton, rice, and wheat, crucial for food production and economic development.

KazVodKhoz not only sustains agriculture but also provides clean drinking water to residents in Kyzylorda Region and beyond. Managing water resources in this arid region poses challenges like water scarcity and environmental preservation. Efficient and sustainable water management practices are crucial for balancing agricultural and drinking water needs, ensuring the region's prosperity.

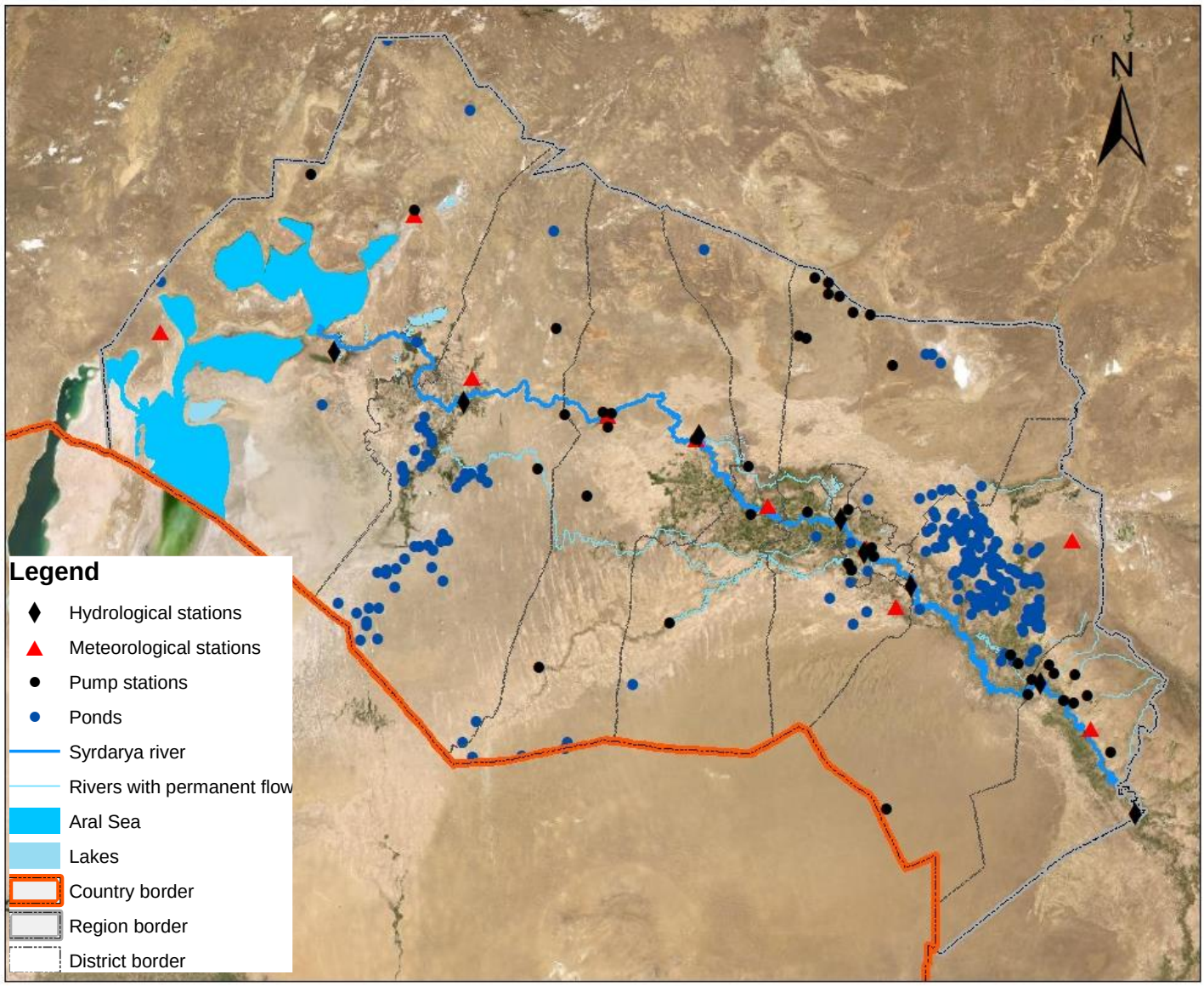
Drainage networks



The management of drainage water for irrigation is a critical aspect of agricultural sustainability in the Kyzylorda Region, with a primary focus on the Syrdarya River and its turbidities. Efficiently handling drainage water and integrating it into a comprehensive systemic management approach at the national level is a priority.

To streamline and optimize water resource management, there is an ongoing process of transferring asset ownership and operational responsibilities. These responsibilities, which include managing republican bulk water storage, transportation, and irrigation and drainage systems, are being consolidated under the authority of the Republican State Enterprise "KazVodKhoz" (KVK). This transition to centralized management through KVK represents a significant step in enhancing the efficiency and sustainability of Kazakhstan's irrigation and drainage systems.

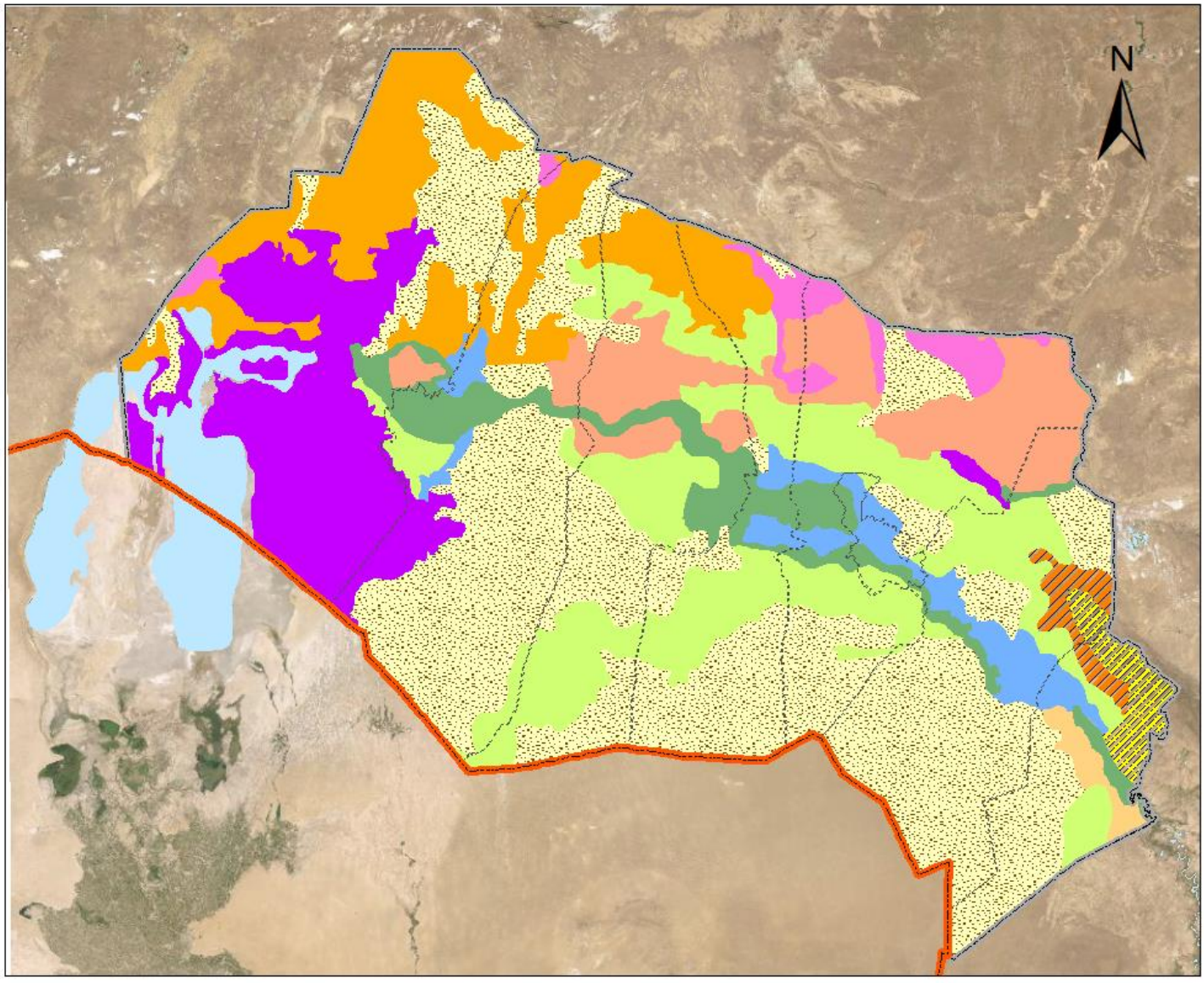
Irrigation pump stations and hydro-meteo posts



Source: THE NATIONAL ATLAS OF THE REPUBLIC OF KAZAKHSTAN, 2010 (https://ingeo.kz/?p=3643&lang=en)

The Kyzylorda region strategically places hydrological and meteorological stations along the Syrdarya River and in key populated areas. These stations serve critical roles in data collection and environmental monitoring. Hydrological stations track water levels, flow rates, and quality, vital for managing water resources, irrigation, and flood control. Meteorological stations offer essential weather data, including temperature, humidity, and precipitation, benefiting agriculture, climate studies, and disaster preparedness. This information aids farmers, water resource management, infrastructure planning, and ecological conservation. Together, these stations play a pivotal role in ensuring sustainable development and the well-being of the region's residents.

Main soil types



Legend

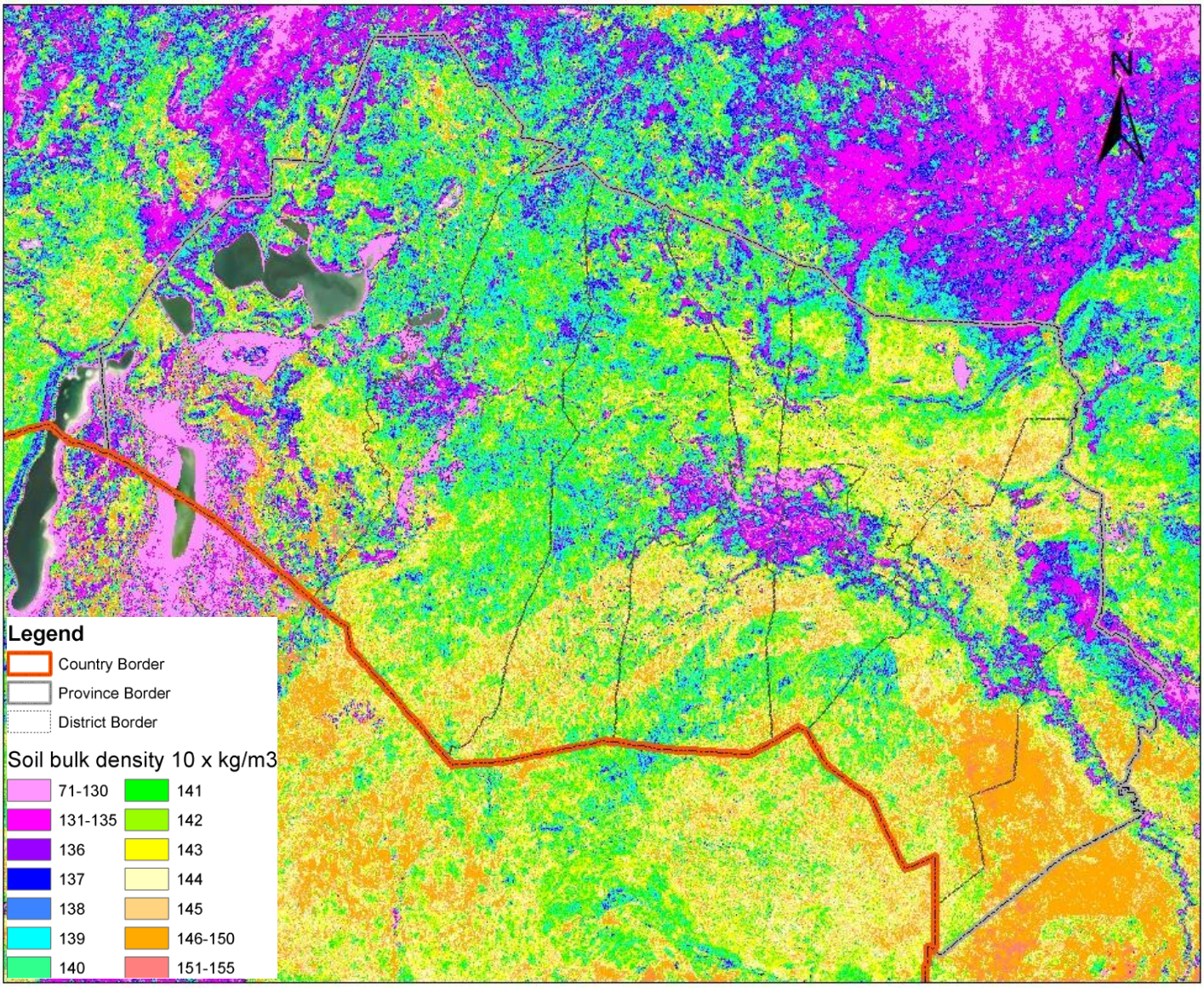
- Country Border
- Province Border
- District Border

Source: THE NATIONAL ATLAS OF THE REPUBLIC OF KAZAKHSTAN, 2010 (https://ingeo.kz/?p=3643&lang=en)

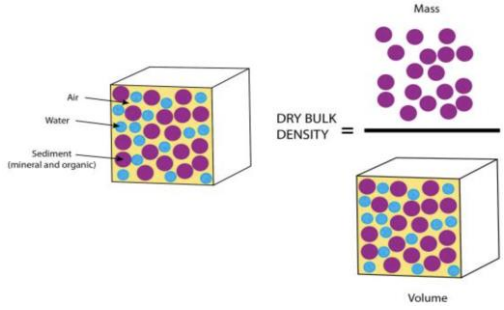
Soil type

- Brown desert soils
- Light brown desert soils
- Gray brown desert soils
- Takyr like soils
- Alluvial meadow
- Meadow boggy soils
- Solonetze
- Continental solonchaks
- Desert sands
- foothill brown soils
- foothill light sierozems
- Aral Sea

Soil Bulk Density



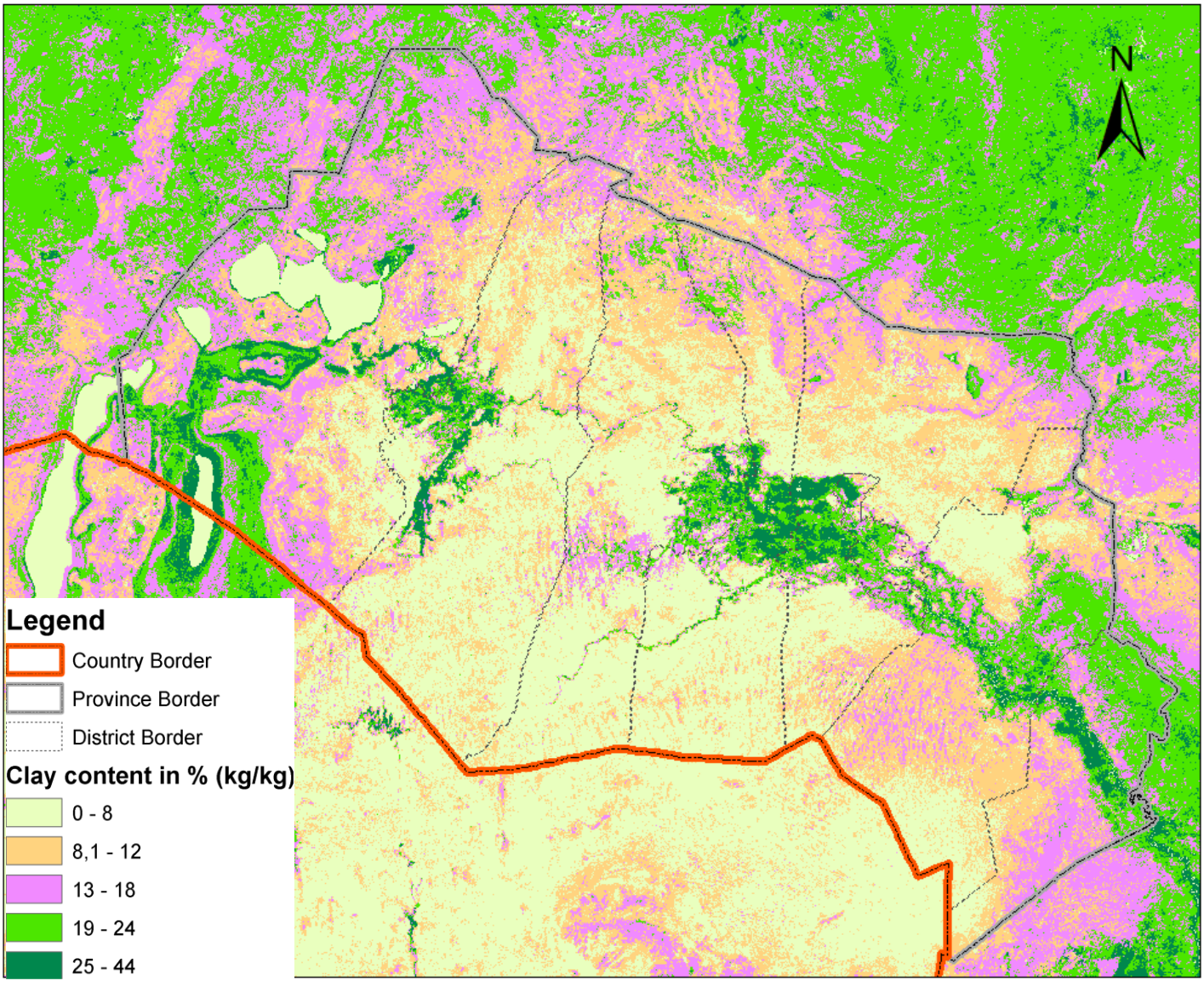
Source: OpenLandMap.org (Hengl 2018a).



The soil bulk density, also known as dry bulk density, is the weight of dry soil divided by total soil volume. The total soil volume is the combined volume of solids and pores which may contain air or water, or both. The average values of air, water and solid in soil are readily measured and are a useful indication of a soils physical condition.

OpenLandMap.org is a data portal to the world's environmental data representing land mask (land cover, vegetation, soil, climate, terrain data and similar). OpenLandMap.org is the web-mapping component of the OpenGeoHub GIS for land data (Hengl 2018a).

Clay content in soil

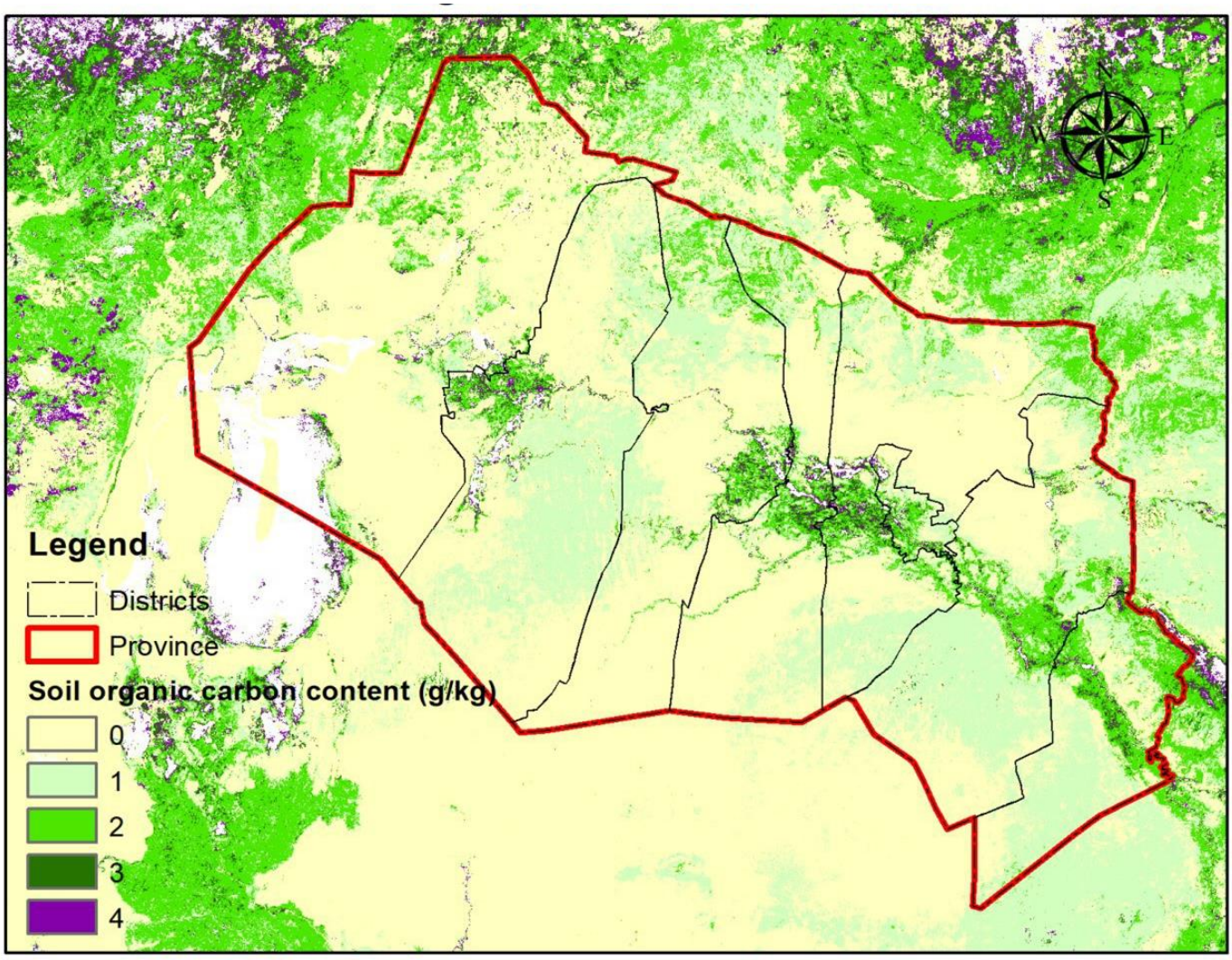


Source: OpenLandMap.org (Hengl 2018b).

Clay is a fundamental driver of many soil properties and in many ways defines what a soil is capable of growing and storing. The clay fraction in soils are any mineral particles less than 2 microns in size. As a result, the combined clay fraction has a significant surface area and therefore a large capacity for nutrient and carbon storage. The clay fraction also provides physical protection for soil microbes against predation.

OpenLandMap.org is a data portal to the world's environmental data representing land mask (land cover, vegetation, soil, climate, terrain data and similar). OpenLandMap.org is the web-mapping component of the OpenGeoHub GIS for land data (Hengl 2018a).

Soil organic content



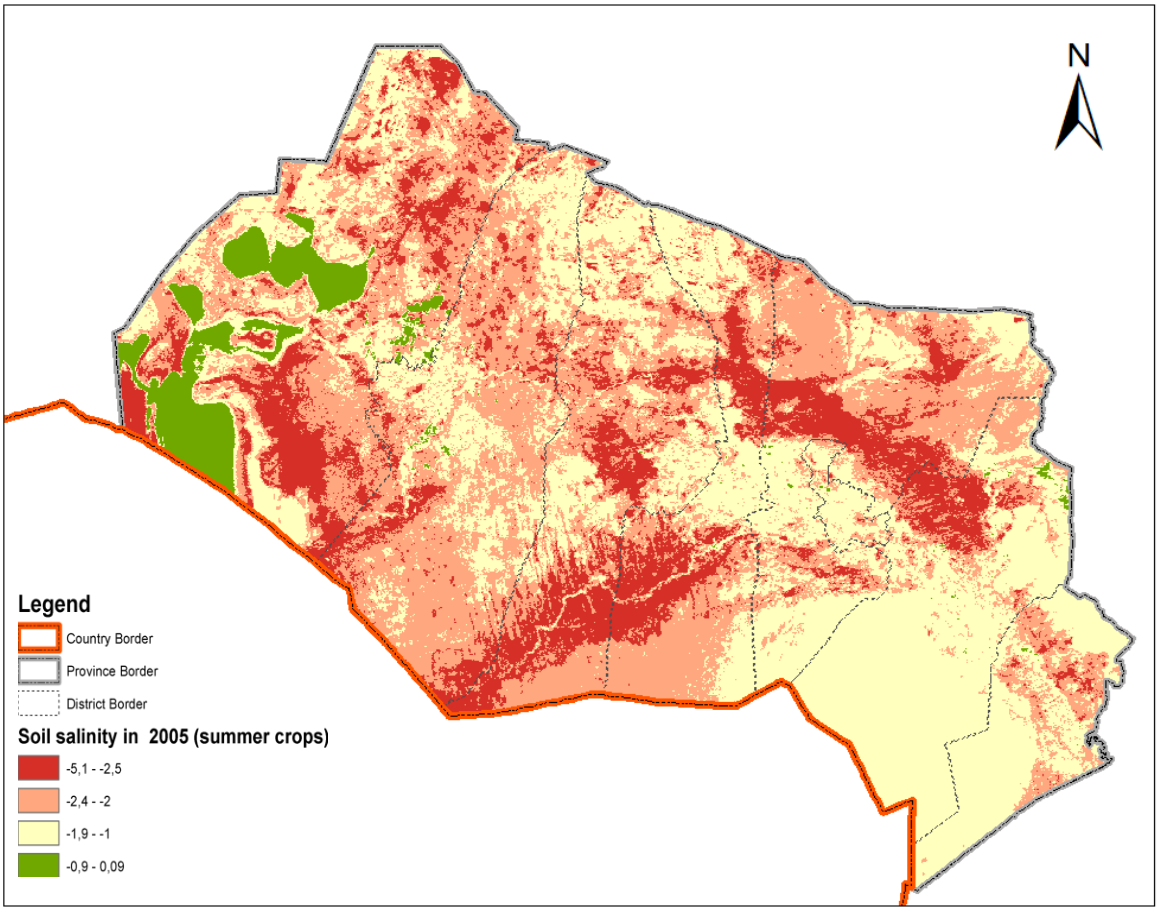
Source: OpenLandMap.org (Hengl and Wheeler 2018).

Soil organic carbon is a measureable component of soil organic matter. Organic matter makes up just 2–10% of most soil's mass and has an important role in the physical, chemical and biological function of agricultural soils.

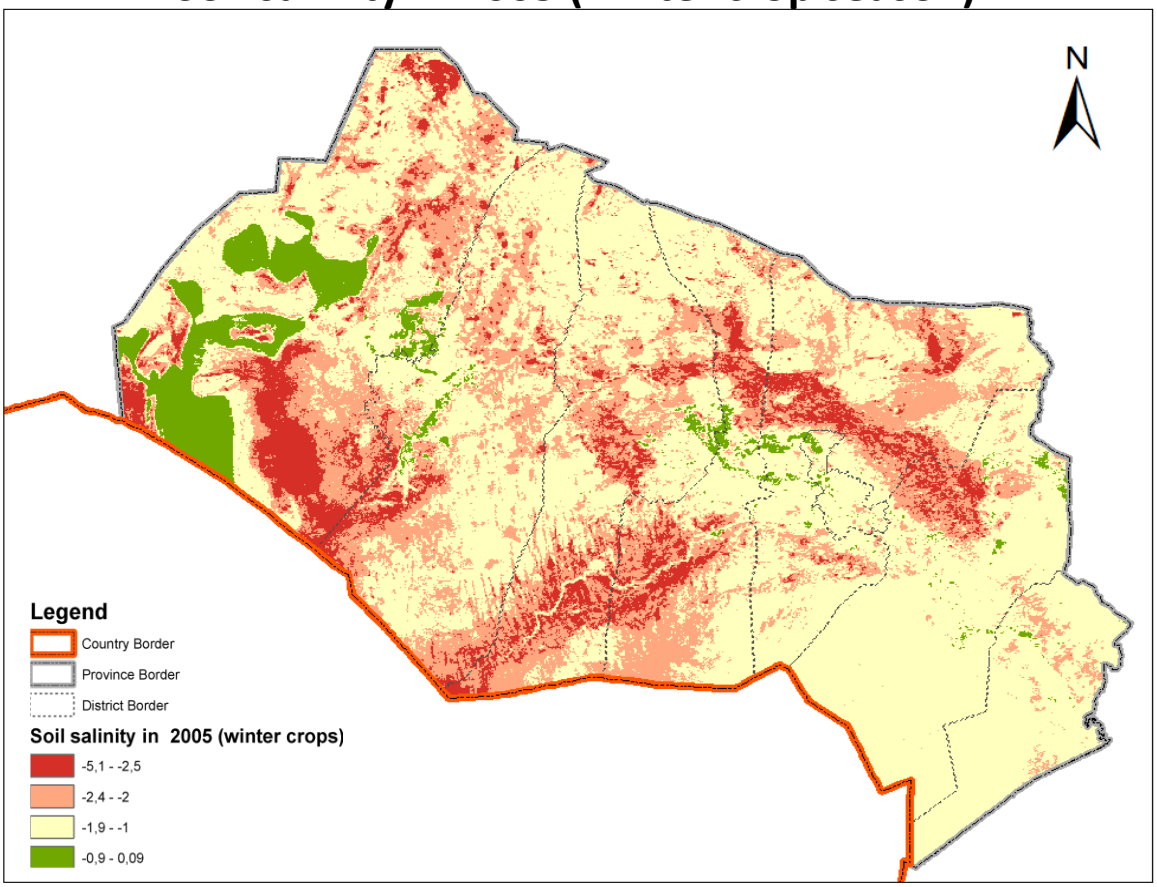
Organic matter contributes to nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, and carbon sequestration.

OpenLandMap.org is a data portal to the world's environmental data representing land mask (land cover, vegetation, soil, climate, terrain data and similar). OpenLandMap.org is the web-mapping component of the OpenGeoHub GIS for land data (Hengl 2018a).

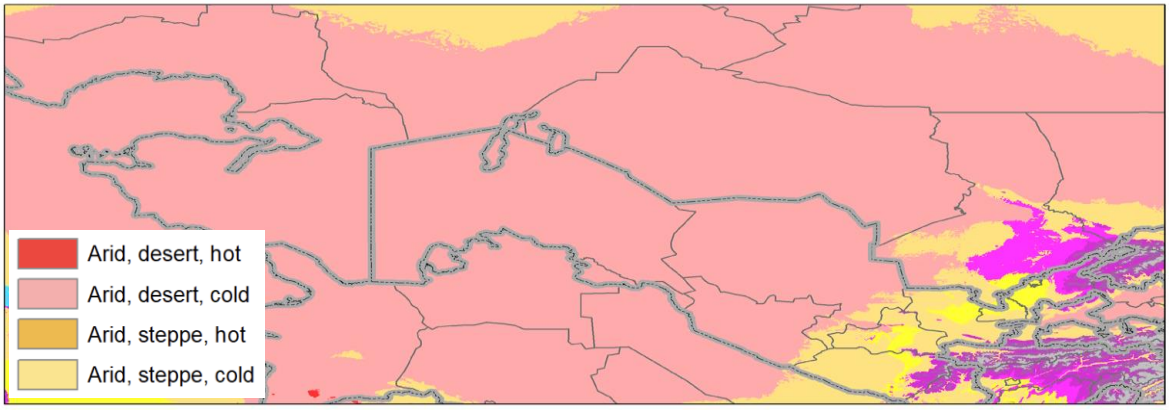
Soil salinity in 2005 (summer crop season)



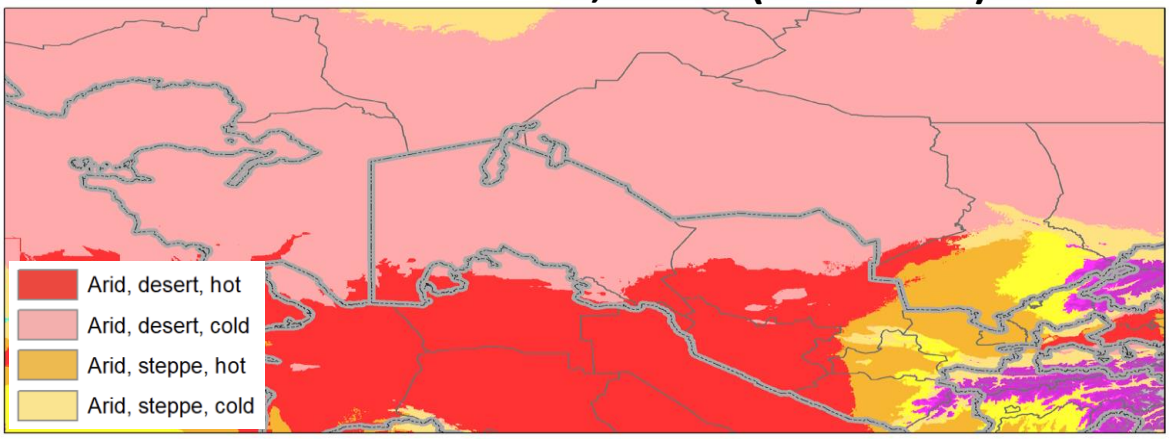
Soil salinity in 2005 (winter crop season)



Climate classification, present (1980-2016)



Climate classification, future (2070-2100)



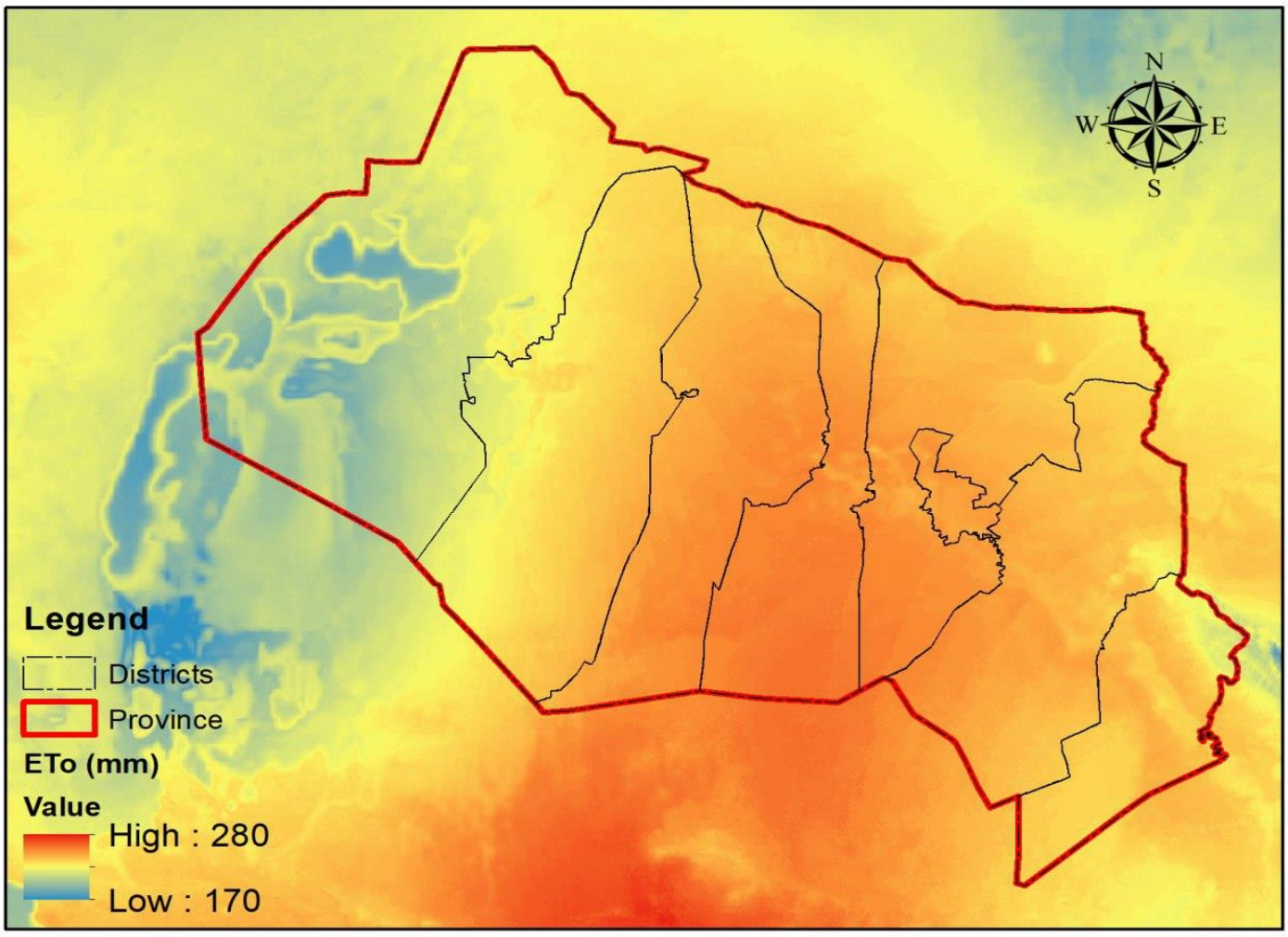
Source: Present and future Köppen-Geiger climate classification maps (Beck et al. 2018).

The climate in the study area is continental and arid, with an annual rainfall of about 120 mm. The climate of Kyzylorda falls into the BWwk Köppen-Geiger climate class (Peel et al. 2007). According to the ICARDA map of Agroclimatic Zones (Celis et al. 2007) the site belongs to zone 310 which is arid climates with cool or cold winters and warm or very warm summers. The area is characterized by sharply continental and dry climate (with hot summers and cold winters) with strong fluctuations of temperatures both daily and seasonally, with an annual rainfall of about 120 mm. Desert winds are common. Following the cold winter, spring is notoriously short and immediately followed by hot, dry and long summers (Glazirin et al. 1999).

Kyzylorda has an extremely continental and arid climate with hot, dry summers (average July temperatures of 25.9°C in the northwest and 28.2°C in the southeast) and relatively warm, snowless winters (around -9.8°C in the northwest and -3.5°C in the southeast in January). Precipitation is minimal, with about 100 mm near the Aral Sea coast in the northwest, the lowest in Kazakhstan, and up to 175 mm in the southeast foothills of Karatau. These climate conditions greatly impact agriculture, water resources, and local ecosystems.

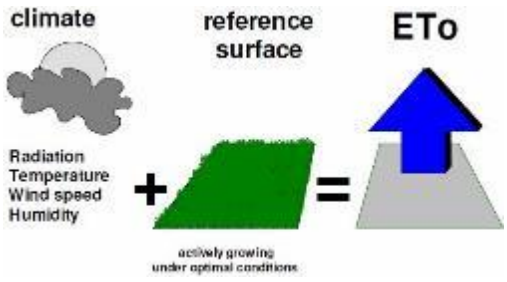
The Köppen-Geiger system classifies climate into five main classes and 30 sub- types. The classification is based on threshold values and seasonality of monthly air temperature and precipitation. Considering vegetation as “crystallized, visible climate”, this classification empirically maps biome distributions around the world: different regions in a similar class share common vegetation characteristics (Beck et al. 2018).

Reference Evapotranspiration in May



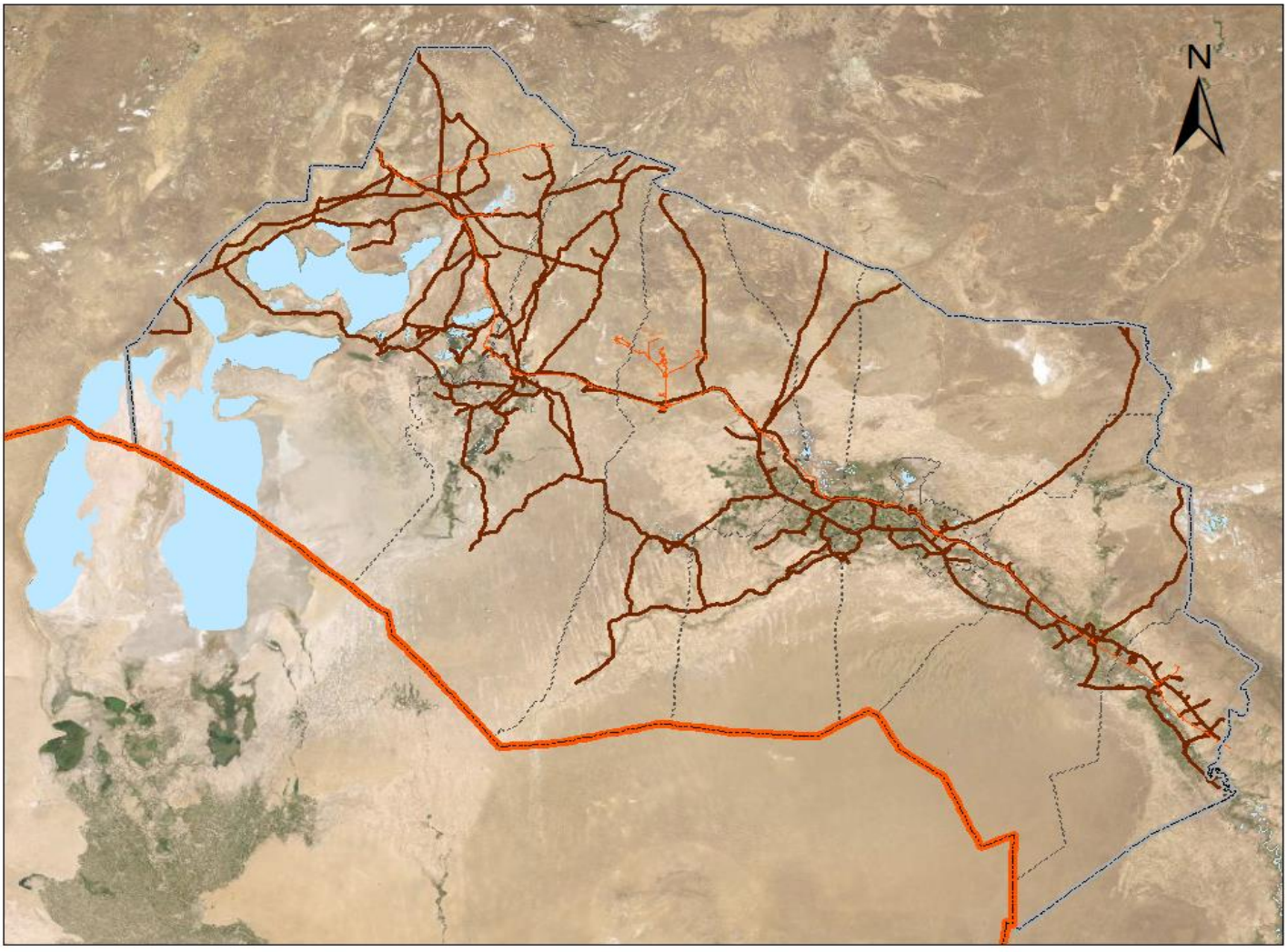
Source: TerraClimate (Abatzoglou et al. 2018).

Reference evapotranspiration (ETo) is the evapotranspiration rate from a clearly defined reference surface. The concept was introduced to allow the estimation of the evaporative demand of the atmosphere independently of crop type, crop development or management practices. ETo corresponds to the evapotranspiration from a hypothetical extensive well-watered field covered with 12 cm height green grass having an albedo of 0.23 under the given down-welling short-wave radiation.



TerraClimate is a dataset of monthly climate and climatic water balance for global terrestrial surfaces. It uses climatically aided interpolation, combining high-spatial resolution climatological normals from the WorldClim dataset, with coarser spatial resolution, but time-varying data from CRU Ts4.0 and the Japanese 55-year Reanalysis (JRA55) (Abatzoglou et al. 2018).

Transportation Infrastructures



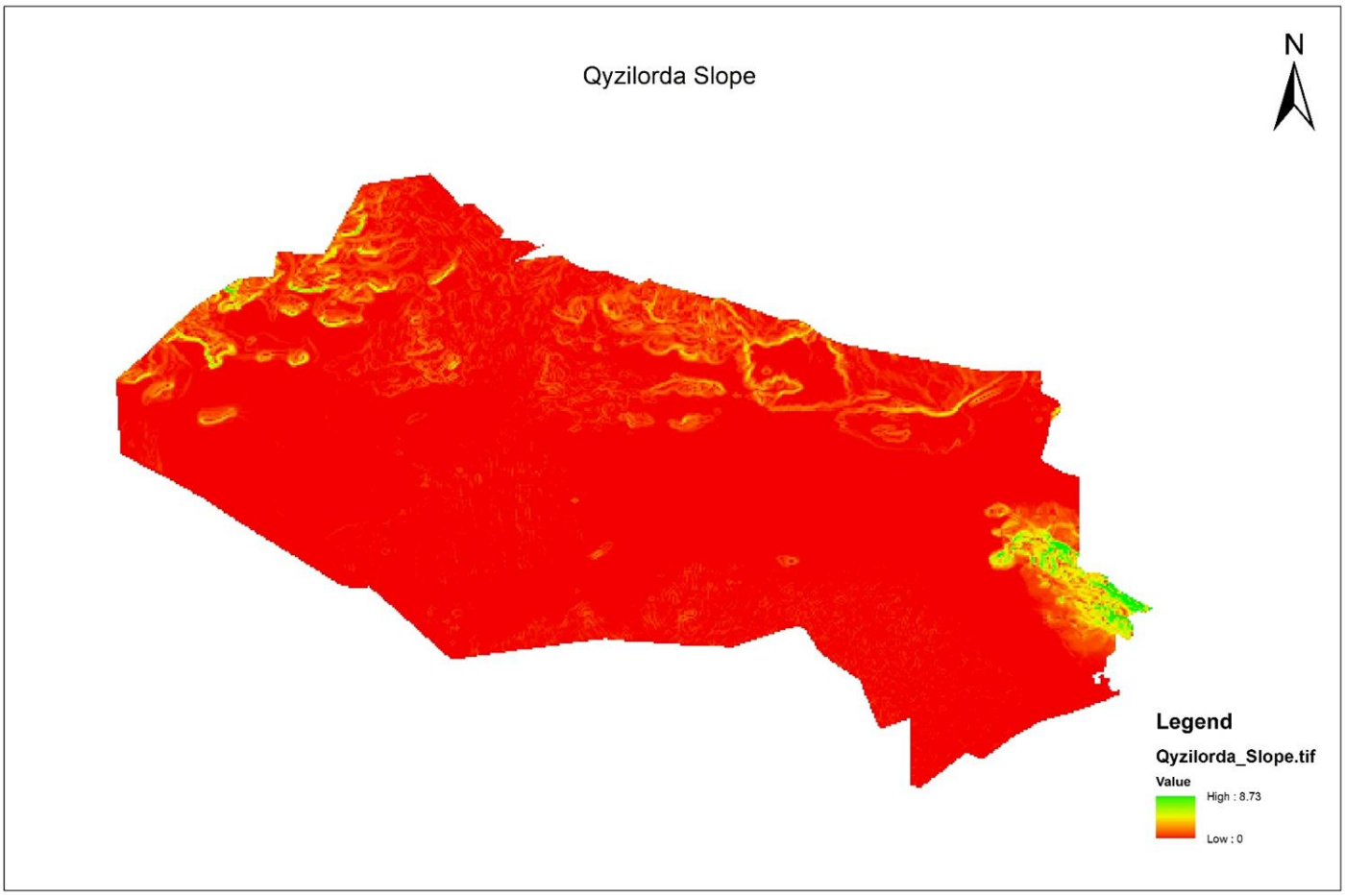
Source: THE NATIONAL ATLAS OF THE REPUBLIC OF KAZAKHSTAN, 2010 (https://ingeo.kz/?p=3643&lang=en)

Legend

- Country Border
- Province Border
- District Border
- Railways
- Roads

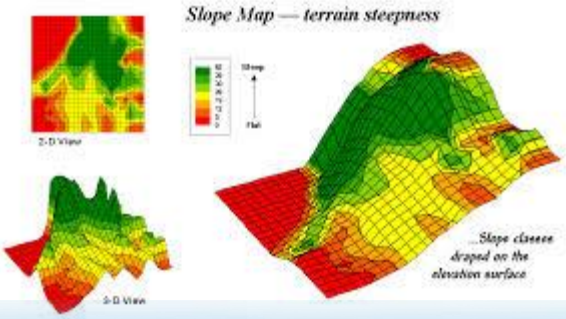
The transportation infrastructure in Kyzylorda has been meticulously designed to facilitate efficient connectivity for its residents. The road and railway networks have been strategically constructed to enable smooth and convenient travel between various locations. This well-planned infrastructure not only enhances mobility but also contributes to regional economic development by facilitating the transportation of goods and fostering trade. It plays a crucial role in connecting people, enabling them to access essential services, job opportunities, and cultural exchanges, ultimately improving the overall quality of life in the region.

Slope map



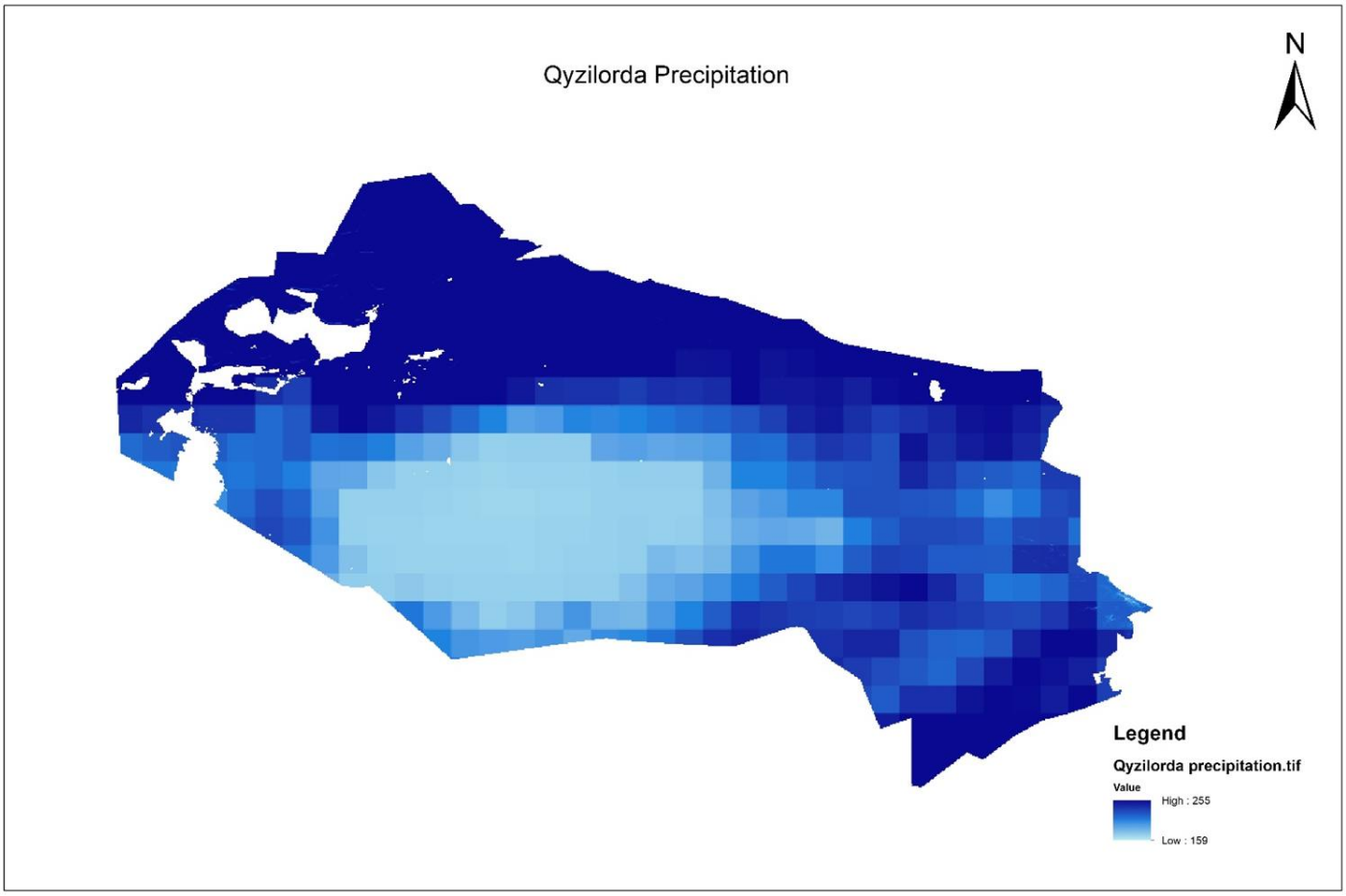
Source: Farr et al. 2007.

This map was created using DEM (Digital Elevation Model) data and subsequently colorized to depict the varying slopes found in the Kyzylorda region. These images provide a 3D view that vividly illustrates the steepness and topographical characteristics of the terrain in the area.



The colorized slope representation is a versatile tool that effectively communicates terrain steepness across a wide range of map scales. Its adaptability makes it suitable for integration into diverse applications and maps, enhancing the overall contextual understanding of the Kyzylorda region's topography. Whether used for local or regional assessments, land planning, environmental studies, or recreational purposes, this layer provides valuable insights into the ruggedness or gentleness of the terrain, facilitating informed decision-making and a deeper appreciation of the geographical features within the area. Its visual appeal and clarity make it a valuable addition to geographic information systems (GIS) and mapping applications.

Precipitation



We have used the developed tool in Climate Engine platform and through scripting we analyzed Climate Hazards Group Infra Red Precipitation with Station data (CHIRPS) to map annual precipitation in selected study area for 2020. Data is provided for each 0.05^0 grid sizes and produced as maps.

Data comes directly from the Climate Hazards Center

Historical period: 1988 – 2018

Source: https://chc.ucsb.edu/data/chirps

CHIRPS is a 30+ year quasi-global rainfall dataset. Spanning 50°S-50°N (and all longitudes), starting in 1981 to near-present, CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

Dataset Availability

1981-01-01T00:00:00 - Present

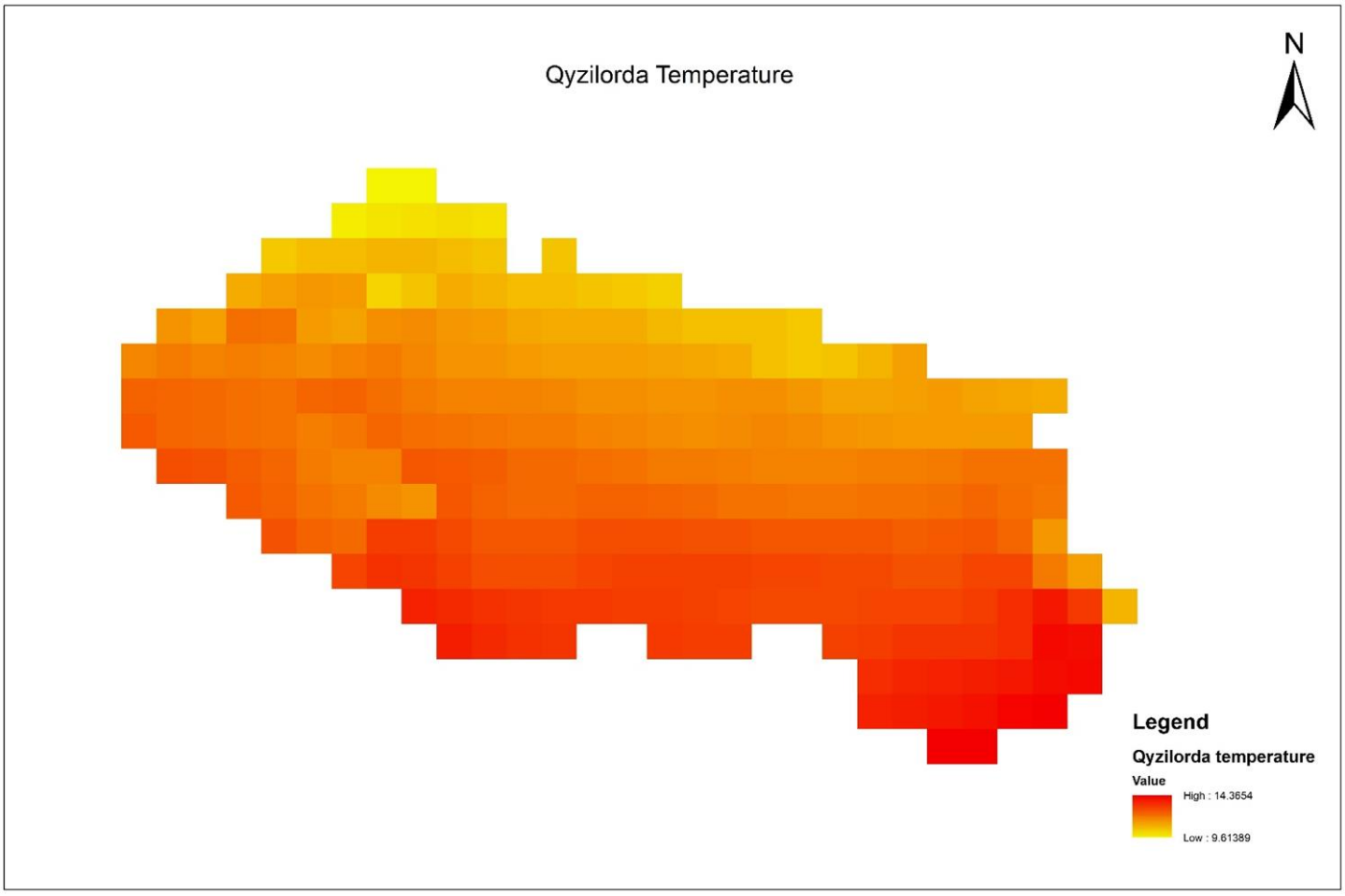
Dataset Provider

UCSB/CHG

Earth Engine Snippet

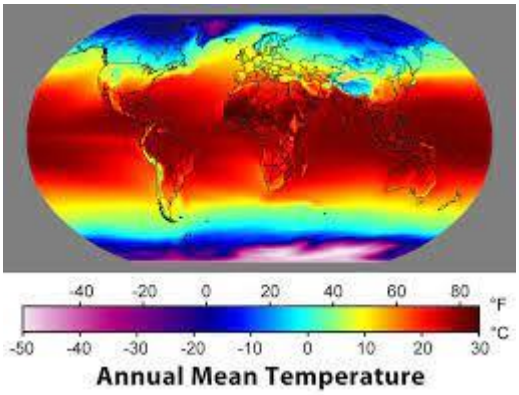
Climate Engine

Temperature



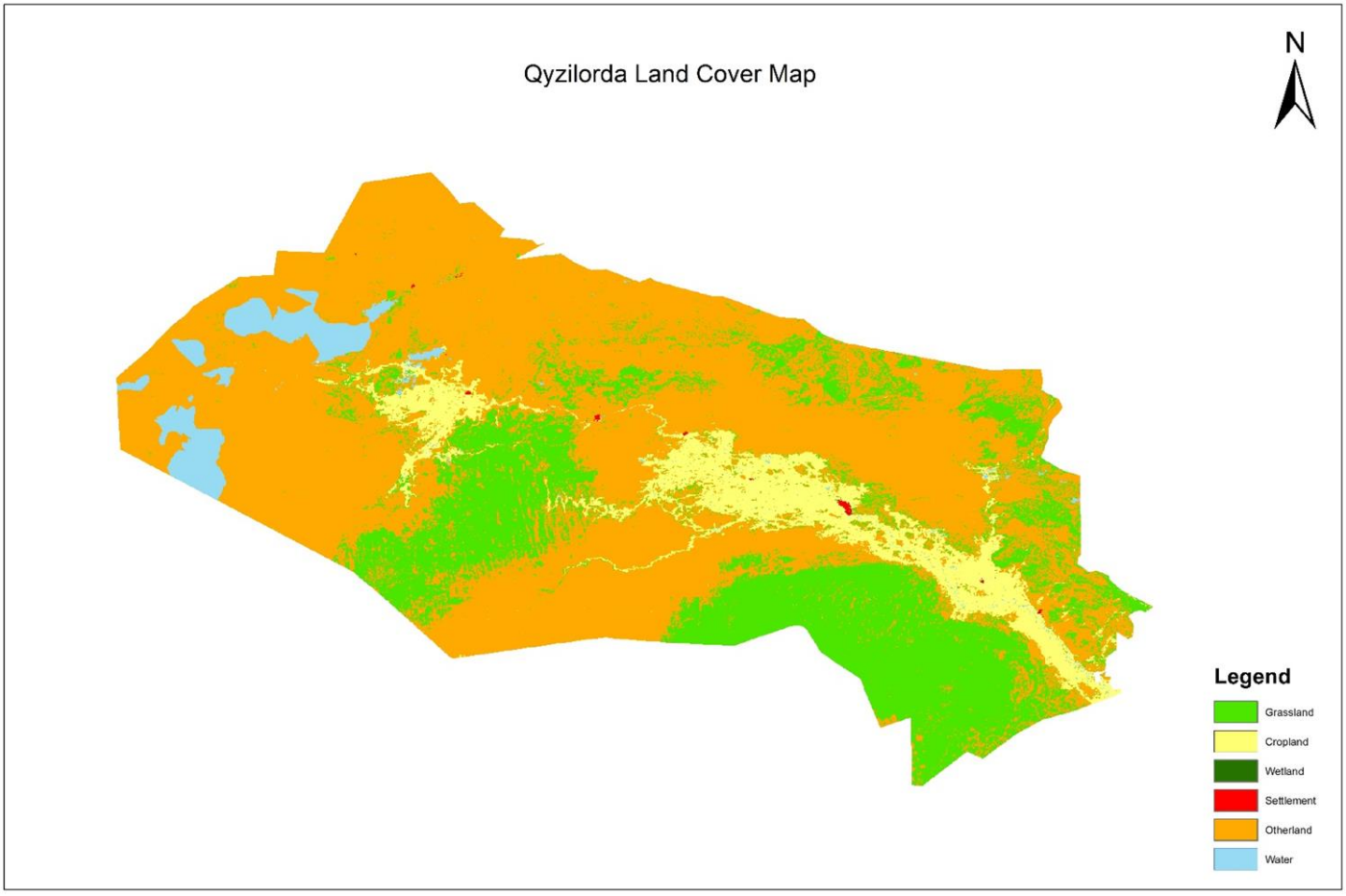
We successfully utilized the developed tool within the Climate Engine platform. Through scripting, we conducted an in-depth analysis of the NCEP Climate Forecast System Reanalysis dataset to map annual temperature variations specifically for the year 2020. Our analysis covered a selected study area and provided high-resolution data, with information available for each 0.050 grid size. The resulting temperature maps, which offer comprehensive insights into temperature patterns, were generated. It's important to note that the data we used originates directly from the reputable source, the Climate Hazards Center. This process underscores the power of combining advanced tools, scripting, and reliable data sources to gain a deeper understanding of climate dynamics within the specified area of interest.

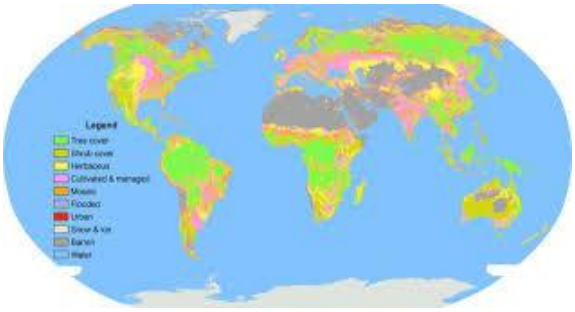
Source: https://chc.ucsb.edu/data/chirps



Climate Engine

Land cover

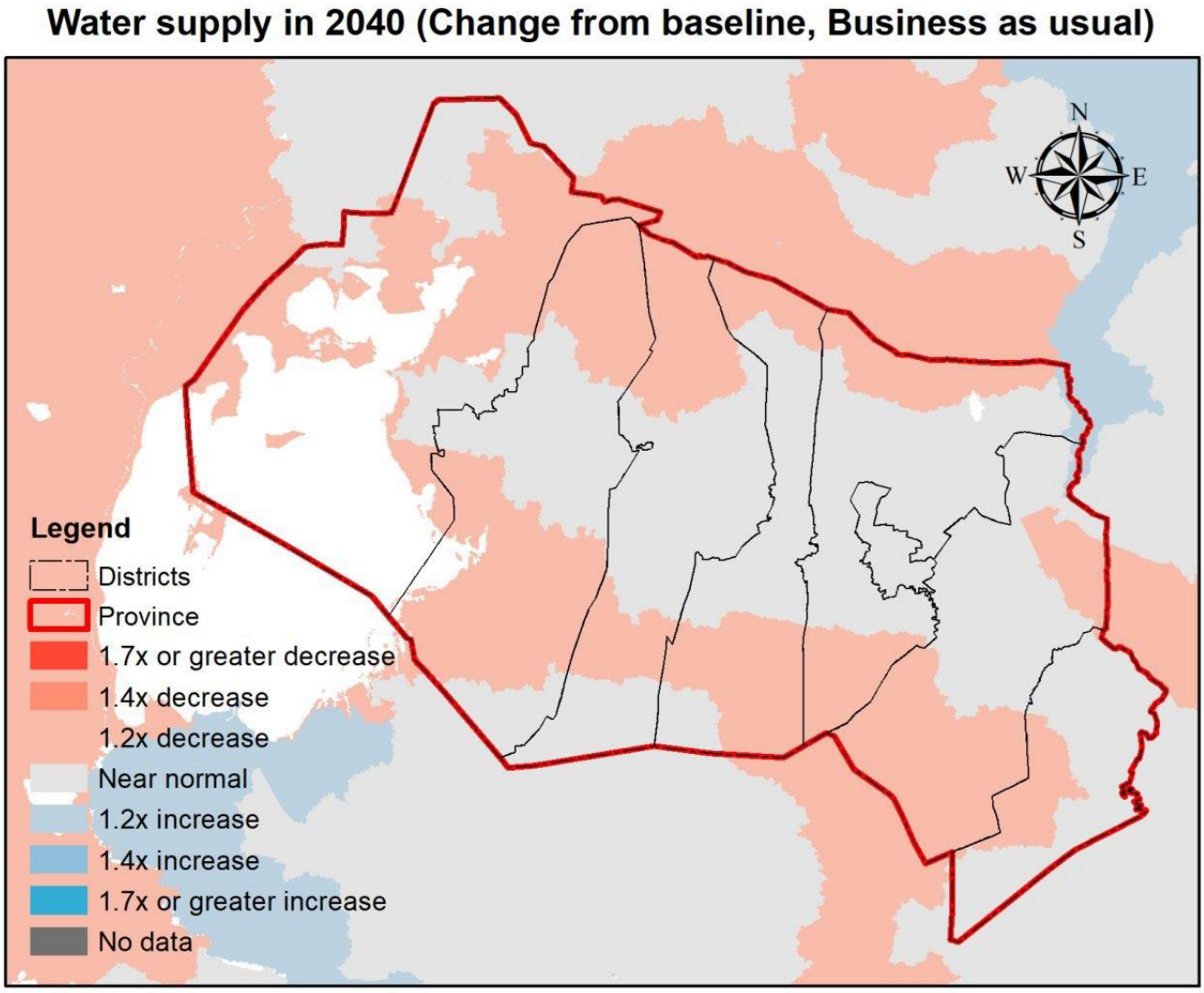




https://esa-worldcover.org/en

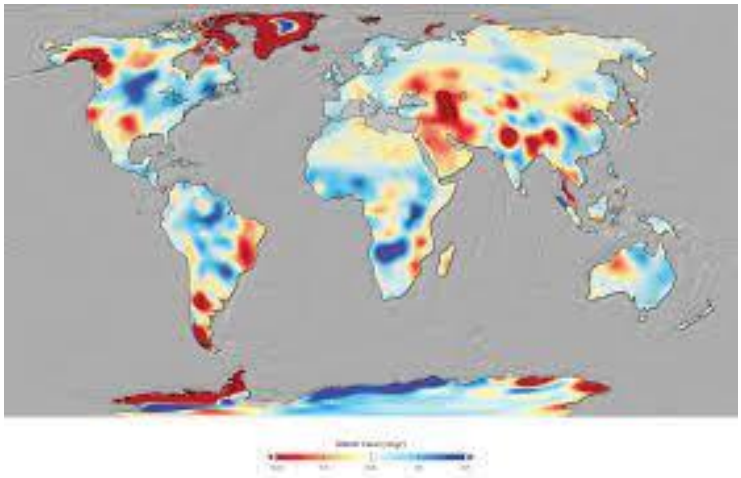
The land cover map was created by utilizing the MODIS NDVI (Normalized Difference Vegetation Index) product, and the entire data processing was carried out using the Google Earth Engine platform. This approach demonstrates the capability of harnessing remotely sensed data, such as NDVI, through a robust and efficient processing environment like Google Earth Engine. The resulting land cover map provides valuable information about the distribution and health of vegetation in the specified area, serving as a valuable resource for ecological, environmental, and land management studies.

Water supply



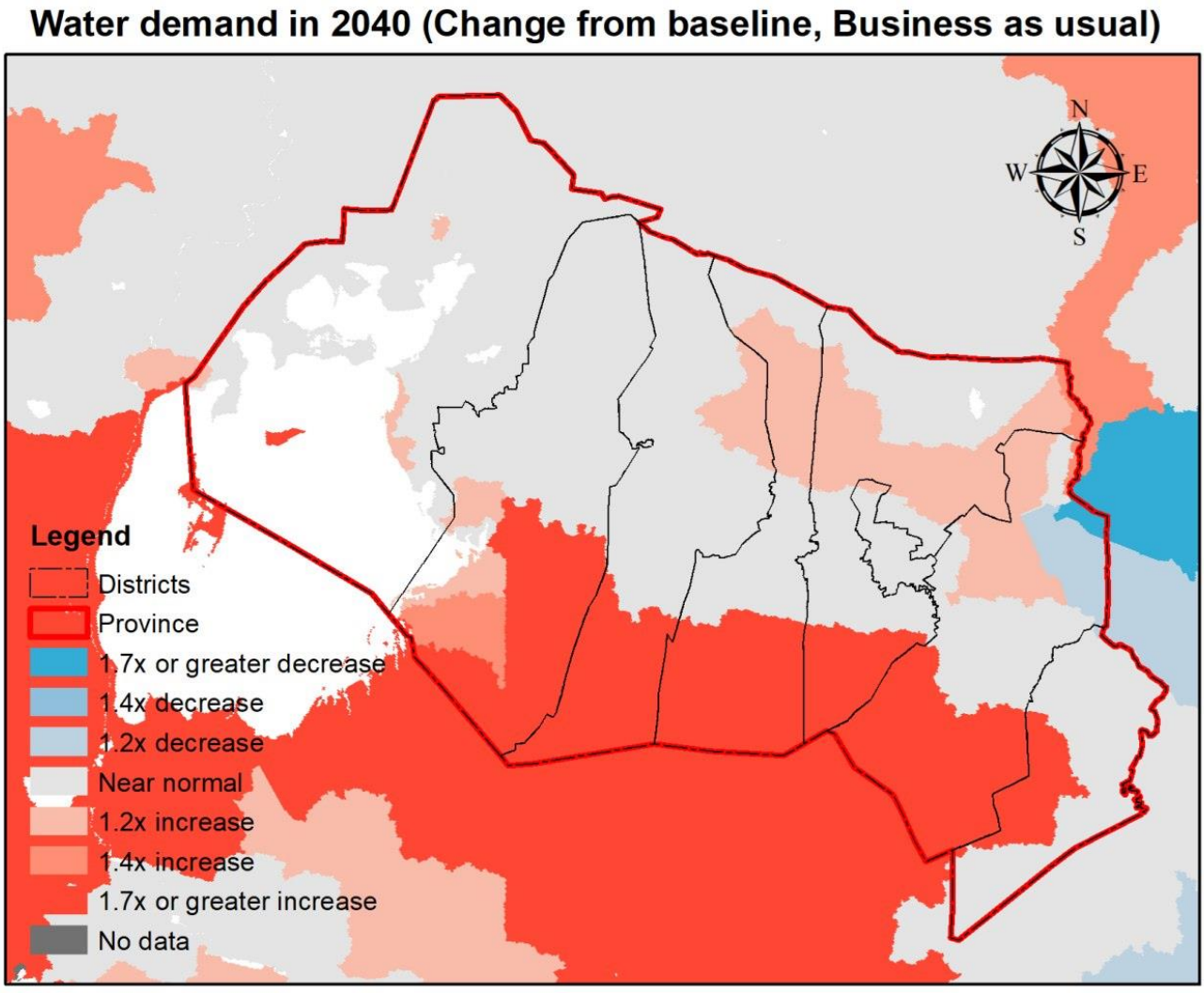
WATER SUPPLY

Total blue water (renewable surface water) was our indicator of water supply. Projected change in total blue water is equal to the 21-year mean around the target year divided by the baseline period of 1950–2010.



Source: WRI Aqueduct, 2015

Water demand



Water demand was measured as water withdrawals. Projected change in water withdrawals is equal to the summarized withdrawals for the target year, divided by the baseline year, 2010. Since irrigation consumptive use varies based on climate, we generated unique estimates of consumptive and non-consumptive agricultural withdrawal for each year. Estimates for consumptive and non-consumptive agricultural withdrawal for each ensemble member, scenario, and target year are the mean of the 21-year window around the target year.

Source: WRI Aqueduct, 2015

References

Abatzoglou, J.T.; DobrowskiS.Z.; Parks S.A.; HegewischK.C. 2018. Terraclimate, a high-resolution global dataset of monthly climate and climatic water balance from 1958-2015. Scientific Data 5:170191, doi:10.1038/sdata.2017.191.

Beck, H.E.; Zimmermann, N.E.; McVicar, T.R.; Vergopolan, N.; Berg, A.; Wood, E.F. 2018. Present and future Köppen-Geiger climate classification maps at 1-km resolution. Scientific data, 5(1), 1-12. doi:10.1038/sdata.2018.214.

Climate Hazards Group Infra Red Precipitation with Station data (Chirps), https://chc.ucsb.edu/data/chirps.

Celis, D.; De Pauw, E.; Geerken, R. 2007. Assessment of land cover and land use in Central and West Asia and north Africa. Part 1. In: Land Cover/Land Use–BaseYear. 1993. International Center for Agricultural Research in Dry Areas (ICARDA).

FAO, 2003. Review of World Water Resources by Country. Water Reports 23, https://www.fao.org/4/Y4473E/y4473e11.gif.

Farr, T.G.; Rosen, P.A.; Caro, E.; Crippen, R.; Duren, R.; Hensley, S.; Kobrick, M.; Paller, M.; Rodriguez, E.; Roth, L.; Seal, D.; Shaffer, S.; Shimada, J.; Umland, J.; Werner, M.; Oskin, M.; Burbank, D.; Alsdorf, D.E. 2007. The shuttle radar topography mission. Reviews of Geophysics, 45, RG2004. https://doi.org/10.1029/2005RG000183.

Glazirin, G. E., Chanishev, S. G., & Chub, V. E. 1999). Brief outlines of climate in Uzbekistan. Chinor ENK–Galaba, Tashkent, 29.

Hengl, T. 2018a. Soil bulk density (fine earth) 10 x kg / m-cubic at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution (Version v02) [Data set]. Zenodo. 10.5281/zenodo.1475970.

Hengl, T. 2018b. Clay content in % (kg / kg) at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution (Version v02) [Data set]. 10.5281/zenodo.1476854.

Hengl, T.; Wheeler, I. 2018. Soil organic carbon content in x 5 g / kg at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution (Version v02) [Data set]. Zenodo. 10.5281/zenodo.1475457.

National atlas of the republic of Kazakhstan, 2010. https://ingeo.kz/?p=3643&lang=en.

Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. Hydrology and earth system sciences, https://hess.copernicus.org/articles/11/1633/2007.

References

Water Resources Committee of the Ministry of Agriculture of the Republic of Kazakhstan (KazVodKhoz), https://qazsu.kz/en.

Worldwide land cover mapping, https://esa-worldcover.org/en.

World Resources Institute (WRI) Aqueduct, https://www.wri.org/aqueduct.

Xenarios, S.; Schmidt-Vogt, D.; Qadir, M.; Janusz-Pawletta, B.; Abdullaev, I.; Smakhtin, V. 2019. The Aral Sea Basin: Water for Sustainable Development in Central Asia (Introduction). In The Aral Sea Basin: Water for Sustainable Development in Central Asia (pp. 1). Routledge. https://doi.org/10.4324/9780429436475.

Zanaga, D.; Van De Kerchove, R.; De Keersmaecker, W.; Souverijns, N.; Brockmann, C.; Quast, R.; Wevers, J.; Grosu, A.; Paccini, A.; Vergnaud, S.; Cartus, O.; Santoro, M.; Fritz, S.; Georgieva, I.; Lesiv, M.; Carter, S.; Herold, M.; Li, L.; Tsendbazar, N.E.; Ramoino, F.; Arino, O. 2021. ESA WorldCover 10 m 2020 v100.

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