Contemporary Environmental Changes over the Dry Land Belt of Northern Eurasia and Their Consequences

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Abstract

Our presentation represents a brief overview of recent climatic and environmental changes over the Dry Lands of Northern Eurasia. The Dry Land Belt (DLB) in Northern Eurasia is the largest contiguous dryland on Earth. During the last century, changes here have included land use change (e.g., rapid virgin land development in the mid of the 1950s; cf. Figure 1), resource extraction, rapid institutional shifts (e.g., collapse of the Soviet Union), climatic changes, and natural disturbances. These factors intertwine, overlap, sometimes mitigate but sometimes feedback upon each other to exacerbate their synergistic and cumulative effects. Thus, it is important to document properly each of these external and internal factors and to characterize structural relationships among them in order to develop better approaches to alleviating negative consequences of these regional environmental changes. This paper addresses the climatic changes observed over the DLB in recent decades and outlines possible links of these changes (both impacts and feedbacks) with other external and internal factors of contemporary regional environmental change and human activities within the DLB.

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Introduction

The Dry Land Belt (DLB) in Northern Eurasia is the largest contiguous dryland on Earth. During the last century, changes here have included land use change (e.g., expansion of croplands and cities), resource extraction (e.g., coal, ores, oil, and gas), rapid institutional shifts (e.g., collapse of the Soviet Union), climatic changes, and natural disturbances (e.g., wildfires, floods, and dust storms). These factors intertwine, overlap, and sometimes mitigate, but can also feedback upon each other to exacerbate their synergistic and cumulative effects. Thus, it is important to properly document each of these external and internal factors and to characterize the structural relationships among them in order to develop better approaches to alleviating negative consequences of these regional environmental changes.

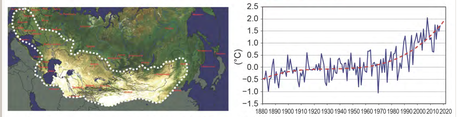
This presentation addresses the climatic changes observed over the DLB in recent decades and outlines possible links of these changes (both impacts and feedbacks) with other external and internal factors of contemporary regional environmental changes and human activities within the DLB.

Data/Methods

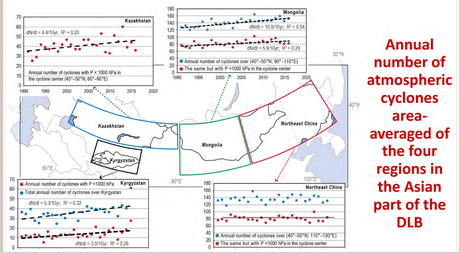
- Past findings within the Northern Eurasia Earth Science Partnership Initiative (NEESPI; http://neespi.org/)
- Time series of long-term in situ hydrometeorological observations within the DLB and its neighborhood
- MERRA 2 and ERA-Interim reanalyses and products based on them (precipitation, atmospheric cyclones' statistics)
- University of New Hampshire Water Balance Model coupled with country-based statistical socio-economic and demographic information
- Water Scarcity Index (WSI) that is the ratio of annual freshwater abstractions (i.e., system losses due to water consumption, evapotranspiration, and deep drainage) to the annual water availability
- Biospheric model simulations of dryland distributions coupled with the CMIP5 runs output (Parfenova et al. 2018)
- Land cover types and their recent changes within the Asian part of DLB based upon the MODIS land cover product (MCD12Q1V6; https://earthdata.nasa.gov/)
- The boreal ecosystem productivity simulator (BEPS; Chen et al. 2017)

Part 1. Changes in major hydrometeorological variables

Dry Land Belt of Northern Eurasia and surface air temperature anomalies for 1881–2017 area-averaged over it.

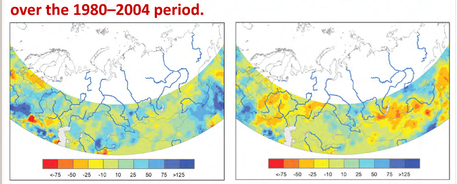


Surface air temperature across the DLB region had been stable from the beginning of the 20th century until mid-1960s, but has increased rapidly in the past five decades. These changes are mostly illustrated by changes during the winter and spring seasons with mean rates of change of 1.8°C (100yr)$^{-1}$ and 1.6°C (100yr)$^{-1}$, respectively. In winter, the temperature variability is higher with the 1.8°C (100yr)$^{-1}$ linear trend explaining 23% of the variation; whereas, a slightly smaller warming trend explains 37% of the variation in spring temperatures. For autumn and summer seasons, the warming signals have been much smaller with 0.7°C (100yr)$^{-1}$ in autumn and 0.4°C (100yr)$^{-1}$ in summer, **with the changes concentrated solely in the past three decades**.



Annual number of atmospheric cyclones area-averaged of the four regions in the Asian part of the DLB

Deviations of mean seasonal precipitation totals (mm) across the Dry Land Belt during 2005–2017 from a baseline average over the 1980–2004 period.

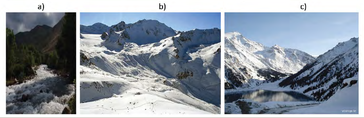


October through May. **June, July, August, and September.**

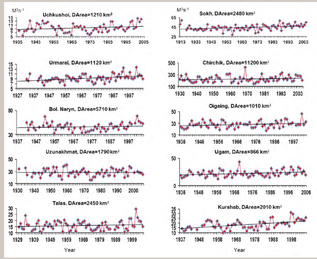
Estimates are based on the MERRA-2 reanalysis.

River discharge tendencies within three neighboring valleys in the Tian Shan Mountains (Zailijskiy Alatau)

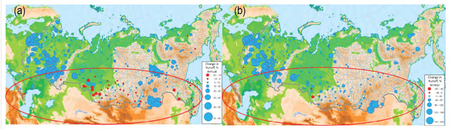
River Basin	Level of glaciation	Discharge tendency
Kaskelen	Low glaciation	Decrease
Malaya Almaatinka	Moderate glaciation	Moderate increase
Bolshaya Almaatinka	Extensive glaciation and buried ice	Very strong increase



Variation in annual discharge ($m^3 \times s^{-1}$) for rivers with minimal human impact in the Tian Shan Mountains



Anomalies of annual (a) and winter (b) runoff across the Russian Federation based on observational records from rivers minimally impacted by human activities during 1978–2010



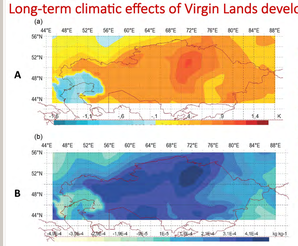
The deviations were calculated from mean runoff over previous observational period 1946–1977 and are shown in percent.

Part 2. Changes in water resources due to natural and anthropogenic factors

Long-term climatic effects of Virgin Lands development in Kazakhstan

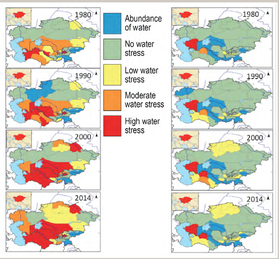
- One of the biggest episodes of land cover change over the steppes of the DLB was the so called **"Virgin Lands" development during 1954–1964**, when the area of arable land in Kazakhstan was expanded from 7–8 to 21–23 million hectares.
- The changes were also spread across the steppe zone of western Siberia and southern Russia but were centered over northern Kazakhstan. This massive conversion of grassland to cropland resulted in statistically significant increases of monthly surface air temperatures by 0.3° to 0.5°C during spring, summer, and autumn seasons and significant changes in evapotranspiration.
- Even within the interdecadal variability of the near surface temperature and humidity in this part of the world, the impacts of large-scale virgin land development are evident (see next picture).

Long-term climatic effects of Virgin Lands development in Kazakhstan (2)



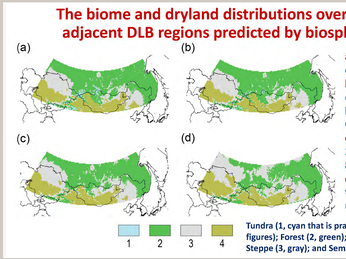
Differences of averaged near surface temperature (A) and near surface specific air humidity fields (B) between the years 1961–1970 and 1951–1960.

Dynamics of the Water Scarcity Index (WSI) for Central Asia based on combination of socio-economic data for administrative units with hydrological simulations



Left maps show WSI based only on available local water resources. Right maps account for both local water resources and outside river inflow.

The biome and dryland distributions over Siberia and adjacent DLB regions predicted by biosphere model

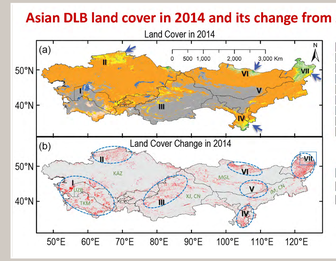


a. for the baseline climate of 1960–1990,
b. for the future climate in the 2080s by an ensemble of 20 GCMs under RCP 2.6,
c. by an ensemble of 20 GCMs under RCP 8.5, and
d. the ensemble of the five driest GCMs under RCP 8.5.

Tundra (1, cyan that is practically absent in these figures); Forest (2, green); Steppe (3, gray); and Semi-Desert/Desert (4, olive)

Part 3. Land use and human dimension changes

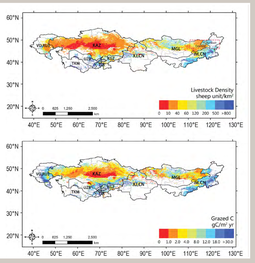
Asian DLB land cover in 2014 and its change from 2001 to 2016



Based on MODIS Product MCD12Q1 V6. The areas circled in blue dashed lines are hotspots for the land cover change.

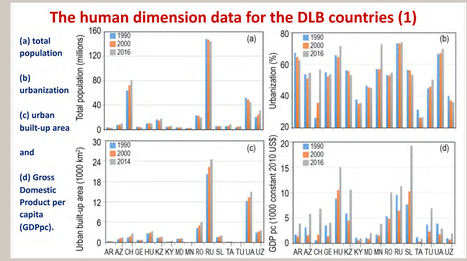
Spatial distributions of livestock density in the temperate Eurasian steppe

Spatial distribution of carbon ingested by grazing (C_{graze}) in the temperate Eurasian steppe.



The human dimension data for the DLB countries (1)

(a) total population
(b) urbanization
(c) urban built-up area
and
(d) Gross Domestic Product per capita (GDPpc).



The human dimension data for the DLB countries (2)

(a) total population
(b) urbanization
(c) urban built-up area
(d) Gross Domestic Product per capita (GDPpc)

- Country abbreviations are: AR—Armenia, AZ—Azerbaijan, CH—China Dry Land Region, GE—Georgia, HU—Hungary, KZ—Kazakhstan, KY—Kyrgyzstan, MD—Moldova, MN—Mongolia, RO—Romania, RU—Russia, SL—Slovakia, TA—Tajikistan, TU—Turkmenistan, UA—Ukraine, UZ—Uzbekistan
- China Dry Land Region includes four provinces: Gansu, Inner Mongolia, Ningxia, and Xinjiang
- Source for (a, b, and d) is http://databank.worldbank.org/, while the urban built up areas were computed using the 250-m resolution Global Human Settlement Layer product (http://ghsl.jrc.ec.europa.eu/datasets.php)

Conclusions

- Part 1 of this poster as well as previous findings (e.g., those provided in the overview by Groisman et al. 2017) report indisputable increases in surface air temperature, retreating cryosphere, and uncertainties in precipitation changes that have led to a generalized depletion of available water resources over most of the DLB.
- In the northern part of the DLB, which is presently occupied by forest, the large warming projected by general circulation models for the end of the century is expected to impact vegetation significantly and shift biomes northwards. In the southern DLB, presently occupied by steppe and semi-deserts, human activity has already interacted with climatic variation and extremes to impact both the environment and livelihood dependent on livestock.
- Current and projected environmental changes (higher temperature, more droughts, more fires), raise concerns about future food security. However, in the cold climate of the northern DLB, agriculture may benefit from climatic warming only after the necessary infrastructure could be developed and a larger rural population could be encouraged to move northward to this frontier.
- It is expected that increasing global and regional populations and a growing demand for land use and water resources will remain the major challenges for sustainable development in the DLB of Northern Eurasia. Therefore, in this part of the world, the role of conscientious human activity in land use, water management, construction, and consumption habits become a major factor responsible for environmental health and human well-being.
- Materials of this presentation were published on November 15, 2018, by Groisman, Bulygina, Henebry, et al. 2018 in Environ. Res. Lett. 13, 115008.

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