Differentiating Anthropogenic Modification From Climate-driven Change In Kazakhstan

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Background

- Dryland Asia's grasslands are experiencing significant changes in their structure and function.
- Increased intensity in anthropogenic activities, and climate regime shifts are causing extreme biodiversity and ecosystem function losses.
- However, little is known about how complex human–environmental interactions are shaping these semiarid ecosystems.
- Hence, it is important to distinguish anthropogenic climatic contributions to vegetation productivity changes.
- While livestock numbers are available at country/provincial level in Kazakhstan (KZ), significant knowledge and data gaps regarding their density and distribution exist at the grid/county level.
- We used time series of 250m resolution satellite data to detect vegetation trends and attribute them to land use and climatic factors.

Research questions

1. What are the spatiotemporal distributions and trends of livestock densities - LSK_D (sheep & goats and horses) across KZ?
2. Which SES drivers help explain the LSK_D distribution across KZ?
3. What is the relative contribution of land use, climate change, climate variability and CO2 to vegetation changes in KZ?

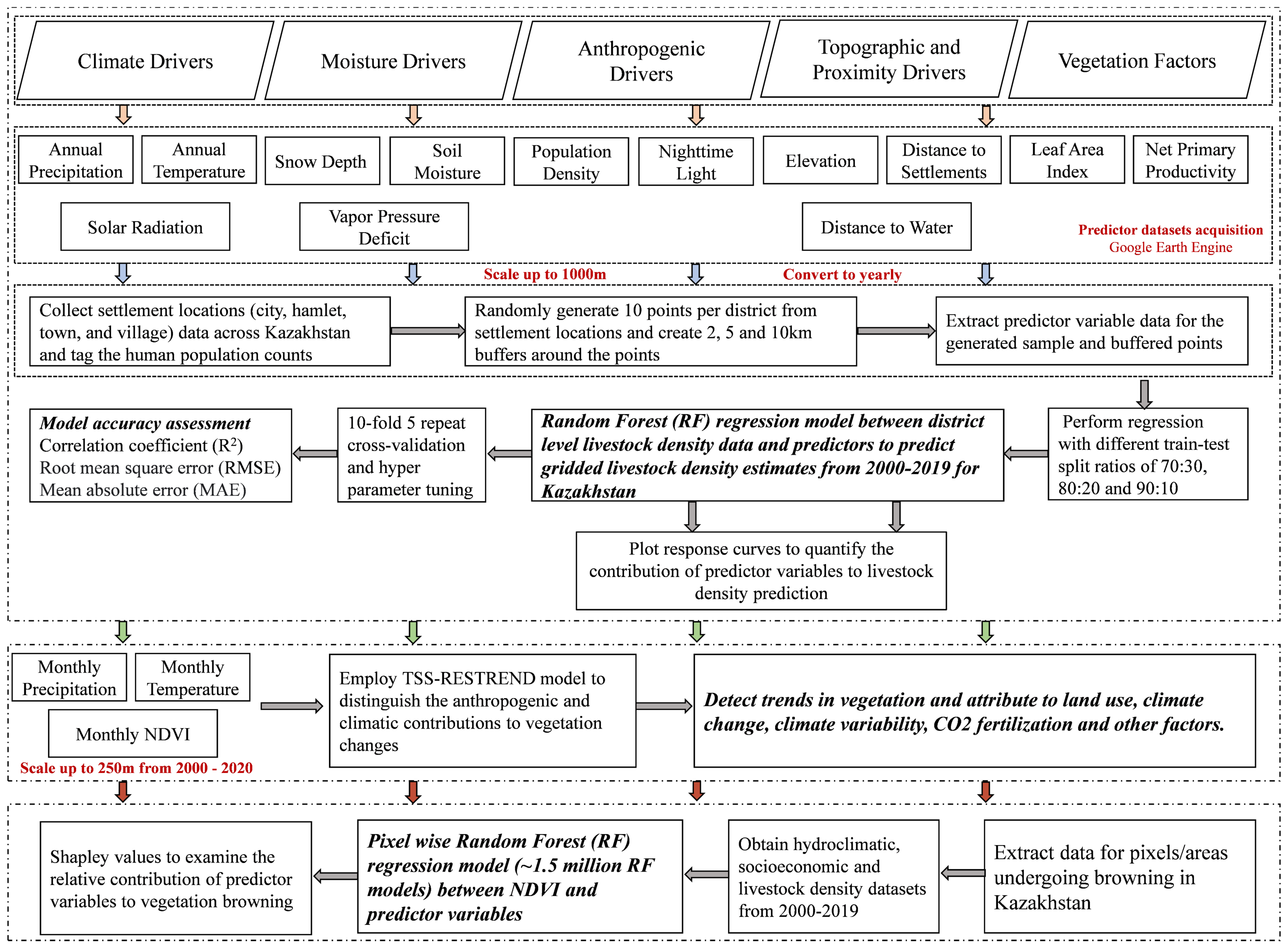

Fig 1. Schematic diagram of workflow for predicting livestock density and contribution various climatic and anthropogenic factors to ecosystem changes across Kazakhstan

Objectives

1. To employ Random Forest (RF) regression model to spatially disaggregate district-level livestock numbers into gridded estimates of LSK_D.
2. To develop high-resolution (1 km) gridded LSK_D maps for Kazakhstan (2000-2019) using vegetation proxies, climatic, socioeconomic, topographic and proximity drivers.
3. To detect spatiotemporal trends using Mann-Kendall and Sen's slope
4. Time Series Segmented Residual Trends (TSS-RESTREND) to detect vegetation productivity changes at a high resolution (250m) and attribute them to climate and anthropogenic factors.
5. To employ a pixel-wise fitted RF model and identify region-specific key socio-environmental system (SES) drivers causing ecosystem functional losses in Kazakhstan.

Findings

- We developed LSK_D distribution database for two decades in KZ.
- Elevation, population density, precipitation and nighttime lights were the top predictors.
- High-density clusters or hotspots were found in southern, southeastern provinces and near settlements in western and northern provinces of KZ.
- Trends and slopes showed a significant increase across country, concentrating more on southern provinces of KZ (South Kazakhstan, Zhambyl and Almaty).
- TSS-RESTREND results showed that 56% of KZ (1.52 million km²) experienced significant browning evident in southern and western provinces.
- We found that land use change is the predominant contributor to vegetation changes (26.4%), followed by climate variability (24.7%), climate change (4%) and CO2 fertilization (0.9%).
- Pixel-wise fitted RF (~1.5 million RF models) and fixed effects model will be employed to account for space-time effects and investigate key SES drivers causing vegetation changes in KZ.

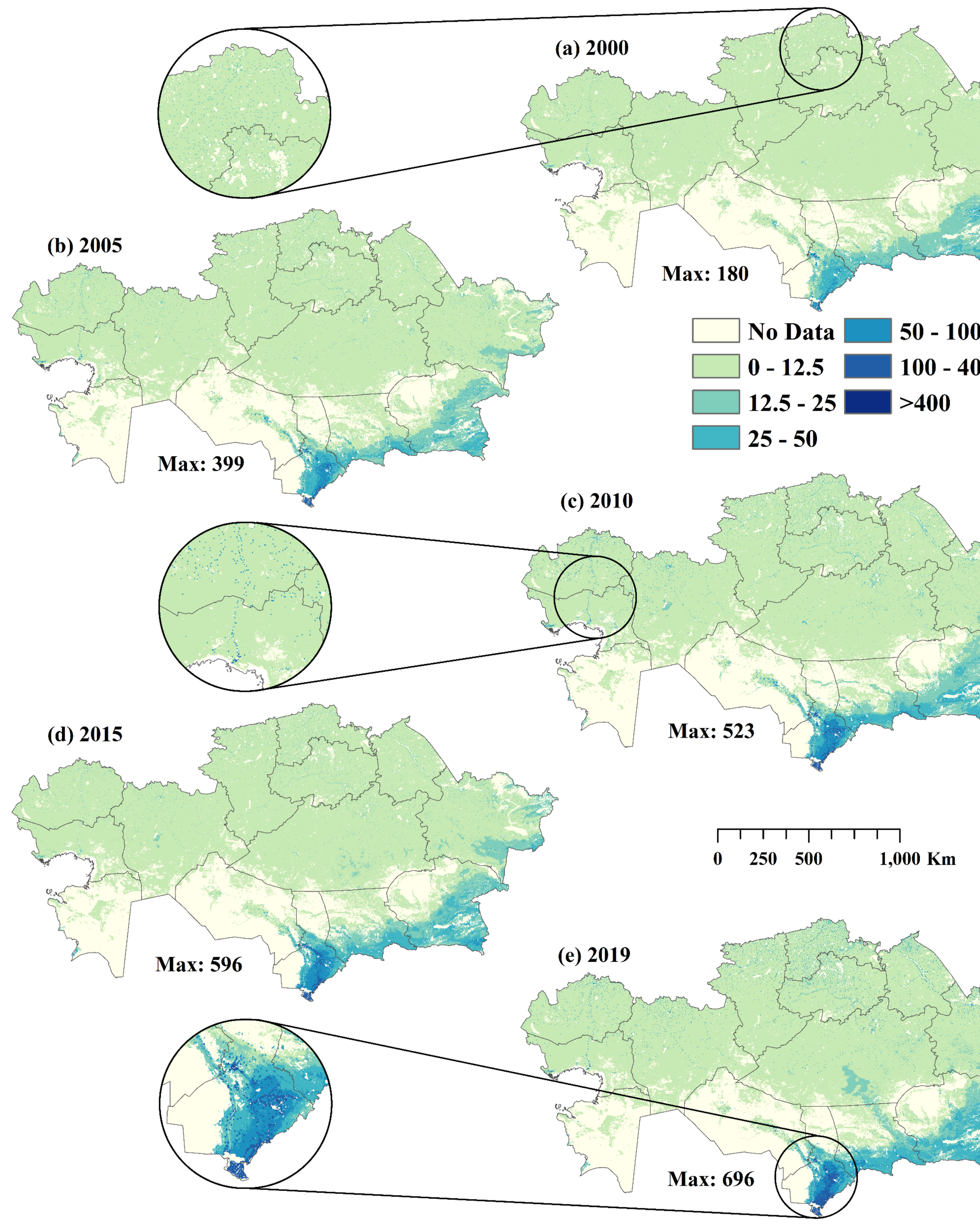

Fig 2. Spatial distribution of sheep and goat density across Kazakhstan for the years (a) 2000, (b) 2005, (c) 2010, (d) 2015 and (e) 2019.

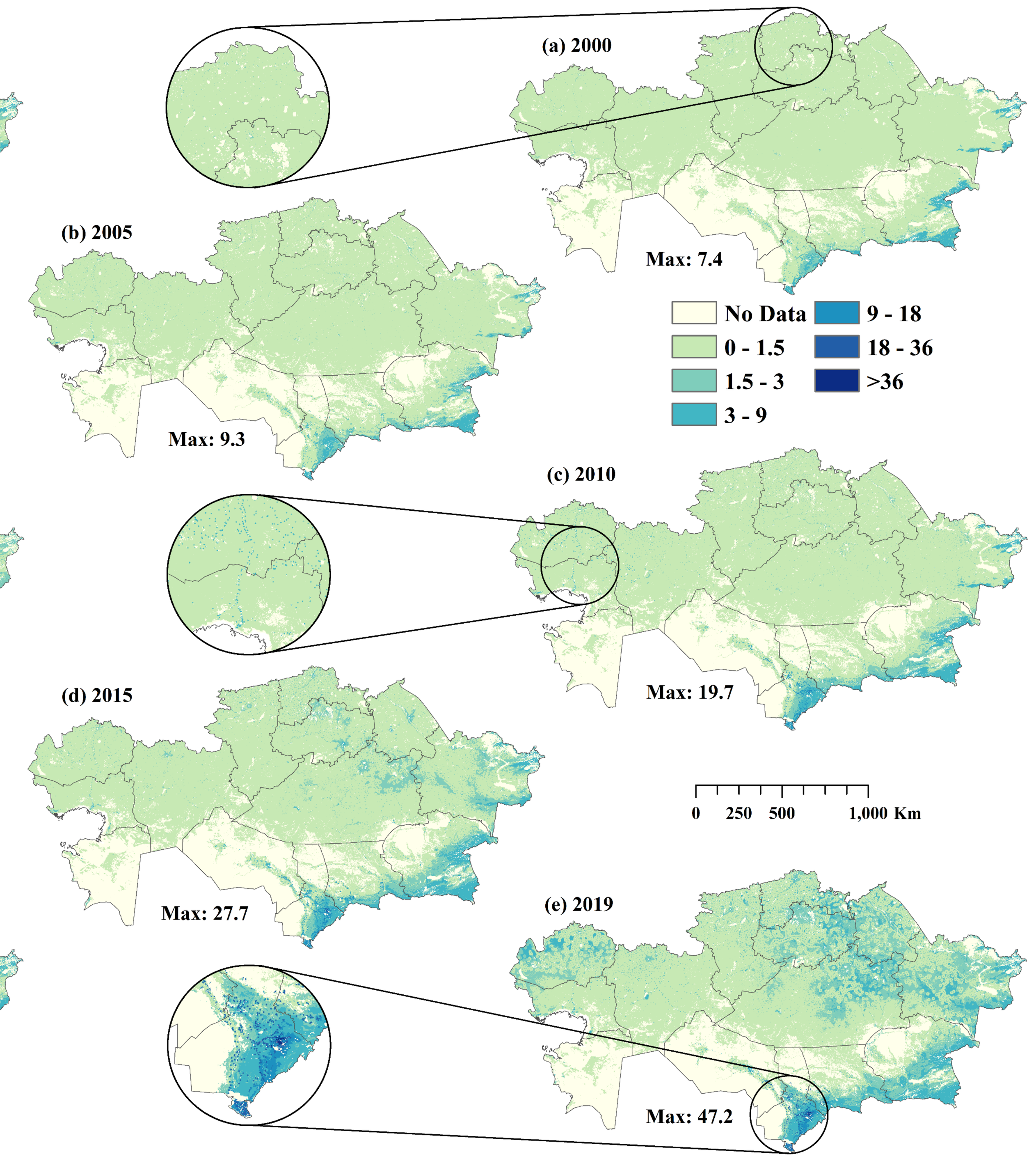

Fig 3. Spatial distribution of horse density across Kazakhstan for the years (a) 2000, (b) 2005, (c) 2010, (d) 2015 and (e) 2019.

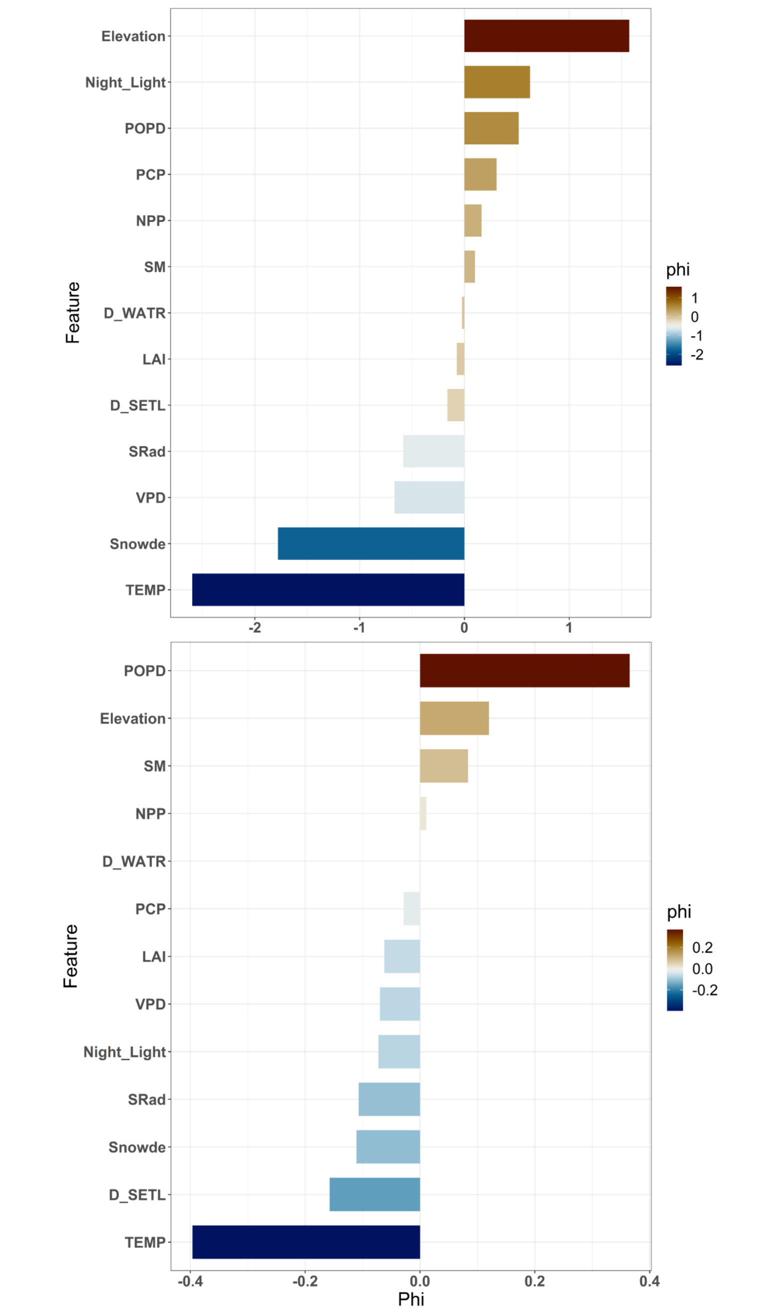

Fig 4. Shapley values for sheep & goat (top panel) and horse density (bottom panel) predictions. X-axis → SHAP values; Y-axis → variable contribution to increased or decreased LSK_D.

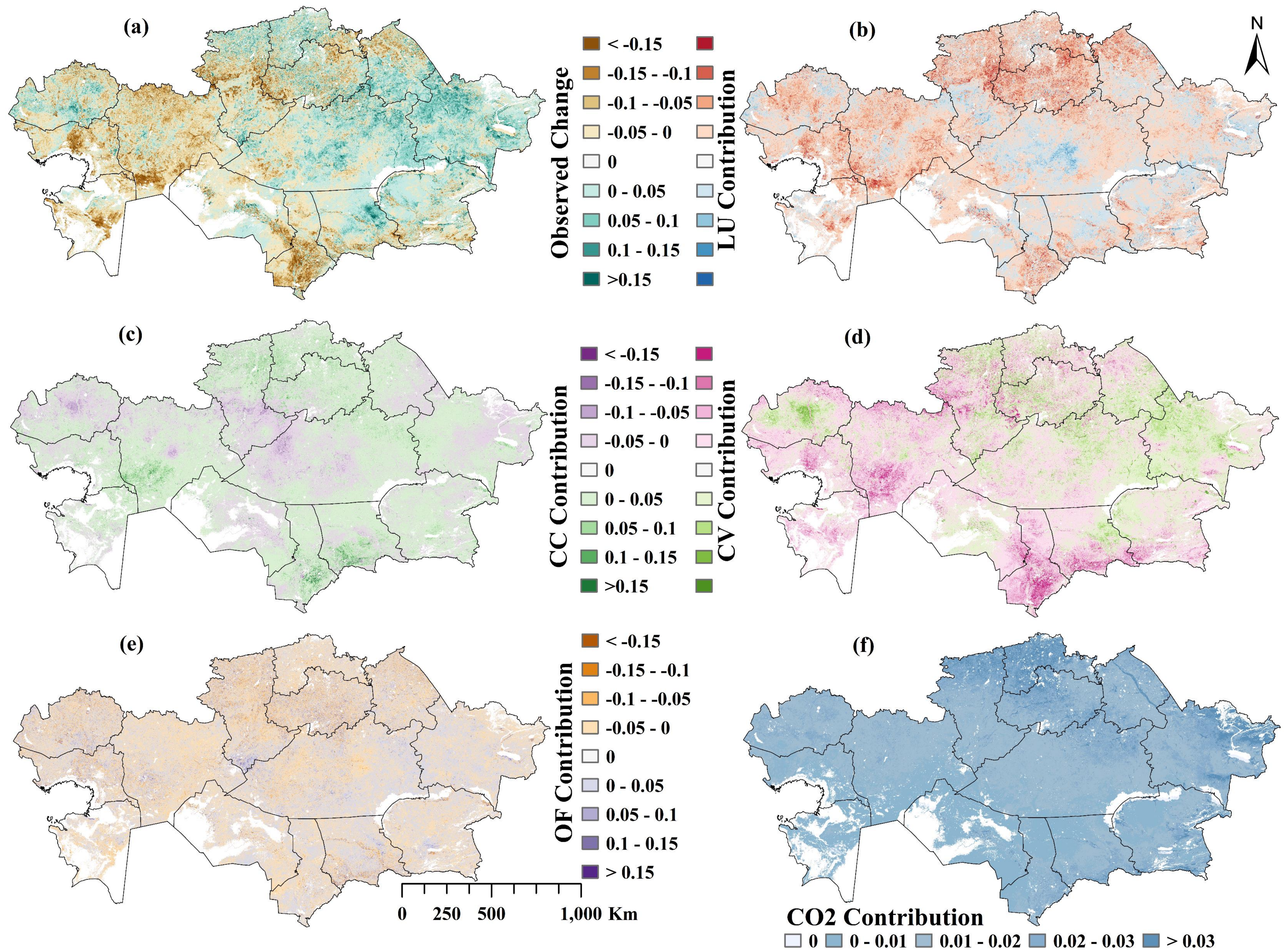

Fig 5. Observed changes in NDVI (a) between 2000 and 2020 attributed to land use [LU] change (b), climate change [CC] (c), climate variability [CV] (d), other factors [OF] (e) and CO2 fertilization (f) in Kazakhstan at 250m resolution.

Prediction results for sheep & goat density		Prediction results for horse density	
R^2	RMSE	R^2	RMSE
0.63 – 0.93	5.1 - 18	0.53 – 0.8	0.43 – 2.86

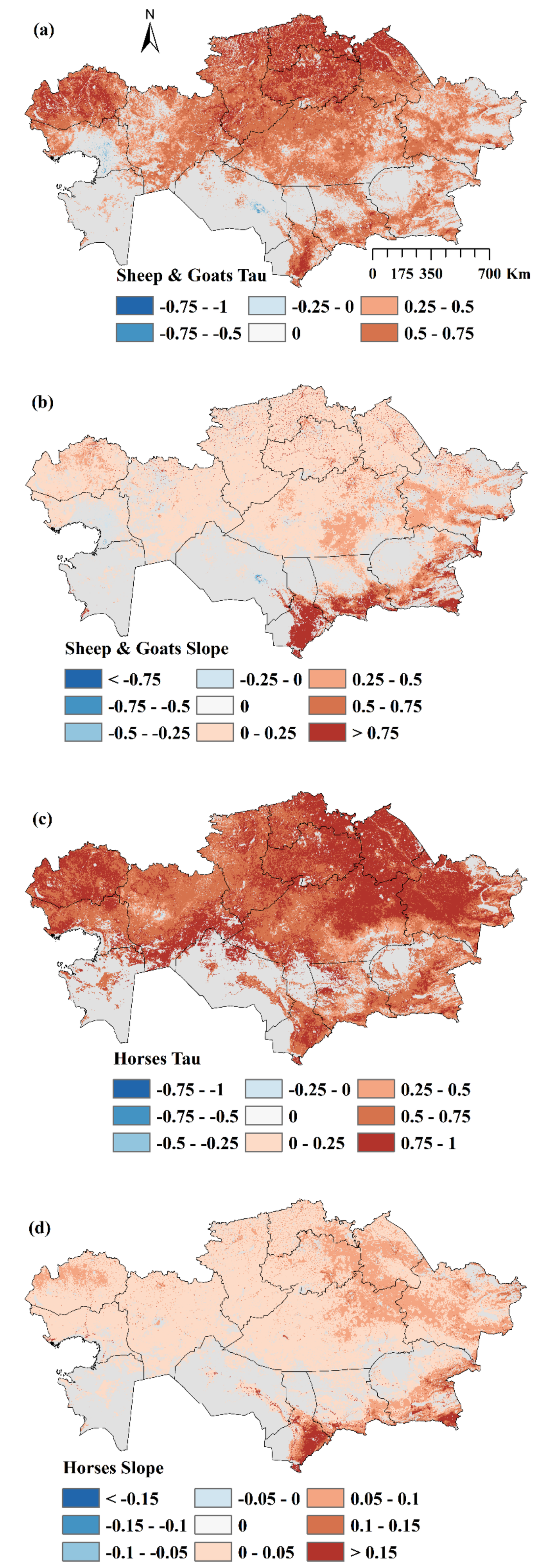

Fig 6. Spatial distribution of Kendall's Tau and Sen's slope for Sheep & Goats (a & b) and horses (c & d) from 2000 - 2019