Environmental Changes, Migration, and Remittances Affect Pastoralist Communities in Montane Central Asia

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Table 24-2 | The amount of information supporting conclusions regarding observed and projected impacts in Asia.

Sector	Topics/issues	North Asia		East Asia		Southeast Asia		South Asia		Central Asia		West Asia	
	O = Observed impacts, P = Projected Impacts	O	P	O	P	O	P	O	P	O	P	O	P
Freshwater resources	Major river runoff	/	x	/	/	/	/	/	x	x	x	x	x
	Water supply	x	x	x	x	x	x	x	x	x	x	x	x
Terrestrial and inland water systems	Phenology and growth rates	/	/	/	/	x	x	x	x	x	x	x	x
	Distributions of species and biomes	/	/	/	/	x	x	x	/	x	x	x	x
	Permafrost	/	/	/	/	/	x	/	/	/	/		
	Inland waters	x	x	/	x	x	x	x	x	x	x	x	x
Coastal systems and low-lying areas	Coral reefs	NR	NR	/	/	/	/	/	/	NR	NR	/	/
	Other coastal ecosystems	x	x	/	/	x	x	x	x	NR	NR	x	x
	Arctic coast erosion	/	/	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Food production systems and food security	Rice yield	x	x	/	/	x	/	x	/	x	x	X	/
	Wheat yield	x	x	x	x	x	x	x	/	x	x	/	/
	Corn yield	x	x	x	/	x	x	x	x	x	x	x	x
	Other crops (e.g., barley, potato)	x	x	/	/	x	x	x	x	x	X	/	/
	Vegetables	x	x	/	x	x	x	x	x	x	x	x	x
	Fruits	x	x	/	x	x	x	x	x	x	x	x	x
	Livestock	x	x	/	x	x	x	x	x	x	x	x	x
	Fisheries and aquaculture production	x	/	x	/	x	/	x	x	x	x	x	x
	Farming area	x	/	x	/	x	x	x	/	x	/		
	Water demand for irrigation	x	/	x	/	x	x	x	/	x	x	x	x
	Pest and disease occurrence	x	x	x	x	x	x	x	/	x	x	x	x
Human settlements, industry, and infrastructure	Floodplains	x	x	/	/	/	/	/	/	x	x	x	x
	Coastal areas	x	x	/	/	/	/	/	/	NR	NR	x	x
	Population and assets	x	x	/	/	/	/	/	/	x	x	x	x
	Industry and infrastructure	x	x	/	/	/	/	/	/	x	x	x	x
Human health, security, livelihoods, and poverty	Health effects of floods	x	x	x	x	x	x	/	x	x	x	x	x
	Health effects of heat	x	x	/	x	x	x	x	x	x	x	x	x
	Health effects of drought	x	x	x	x	x	x	x	x	x	x	x	x
	Water-borne diseases	x	x	x	x	/	x	/	x	x	x	x	x
	Vector-borne diseases	x	x	x	x	/	x	/	x	x	x	x	x
	Livelihoods and poverty	x	x	/	x	x	x	/	x	x	x	x	x
	Economic valuation	x	x	x	x	/	/	/	/	x	x	x	x

Key:
/ = Relatively abundant/sufficient information; knowledge gaps need to be addressed but conclusions can be drawn based on existing information.
x = Limited information/no data; critical knowledge gaps, difficult to draw conclusions.
NR = Not relevant.

I. Central Asia is a "Great Unknown"

Sufficient information (O/P) on Permafrost

Knowledge Gaps in Asia from WGII report from IPCC AR5

Sufficient information (P) on Farming area

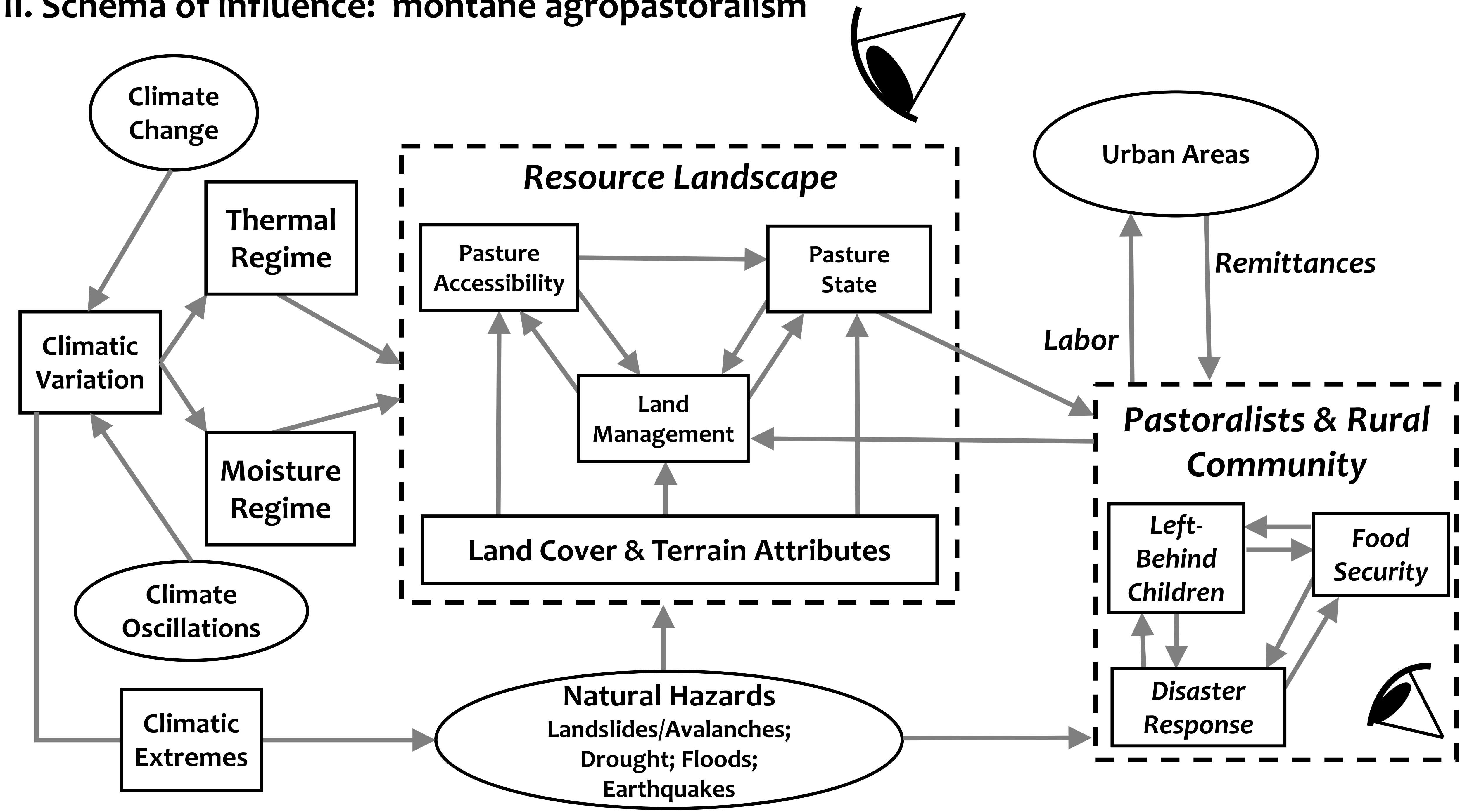
In Central Asia, every other topic has limited information/no data yielding critical knowledge gaps making it difficult to draw conclusions about observed and potential impacts of climate change

Hijioka *et al.* 2014. Asia. Chapter 24 of WGII report of AR5

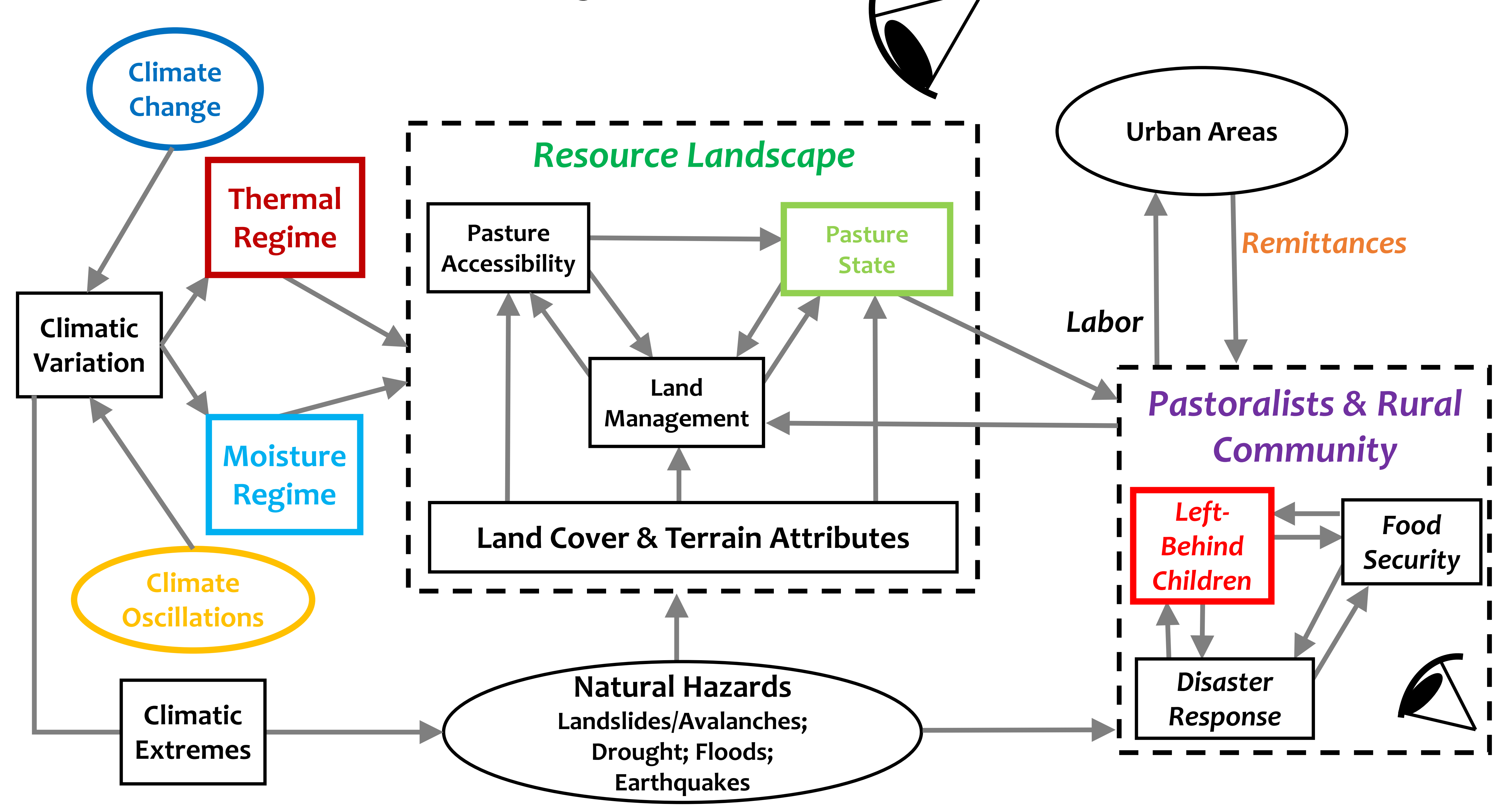
The Caucasus and Central Asia

https://en.wikipedia.org/wiki/Geostrategy_in_Central_Asia#/media/File:Caucasus_central_asia_political_map_2000.jpg

II. Schema of influence: montane agropastoralism



II. Schema of influence: montane agropastoralism



III. Trends in water vapor transport into Central Asia

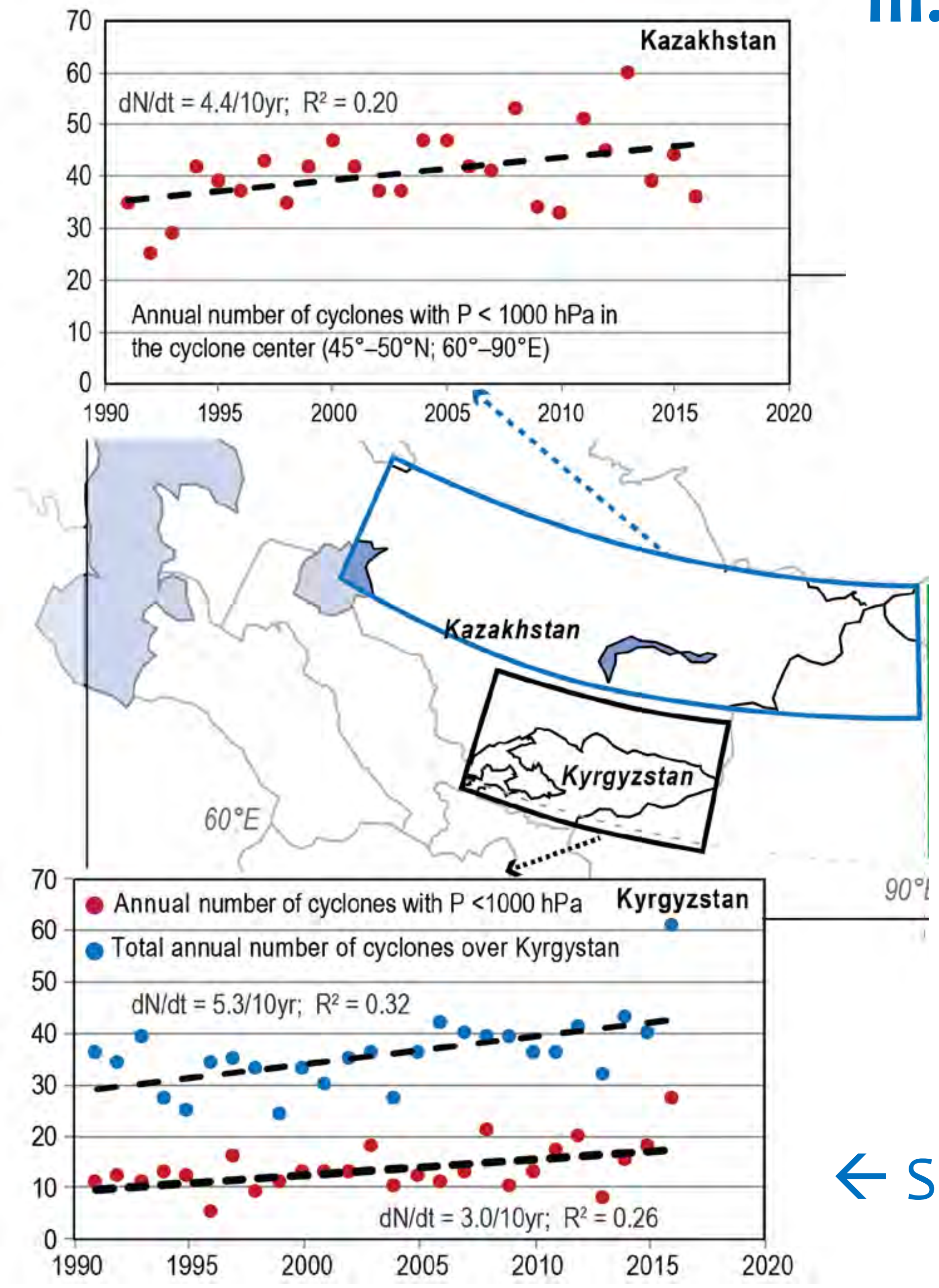


Table 1: Water vapor flux into Central Asia during 1990-2017

Period	Southward annual flux through 50°N [kg (m×s)$^{-1}$]	Eastward annual flux through 50°E [kg (m×s)$^{-1}$]
1990-1999	0.14	46.4
2000-2009	-0.48	43.4
2010-2017	1.11	39.6

Down 15%

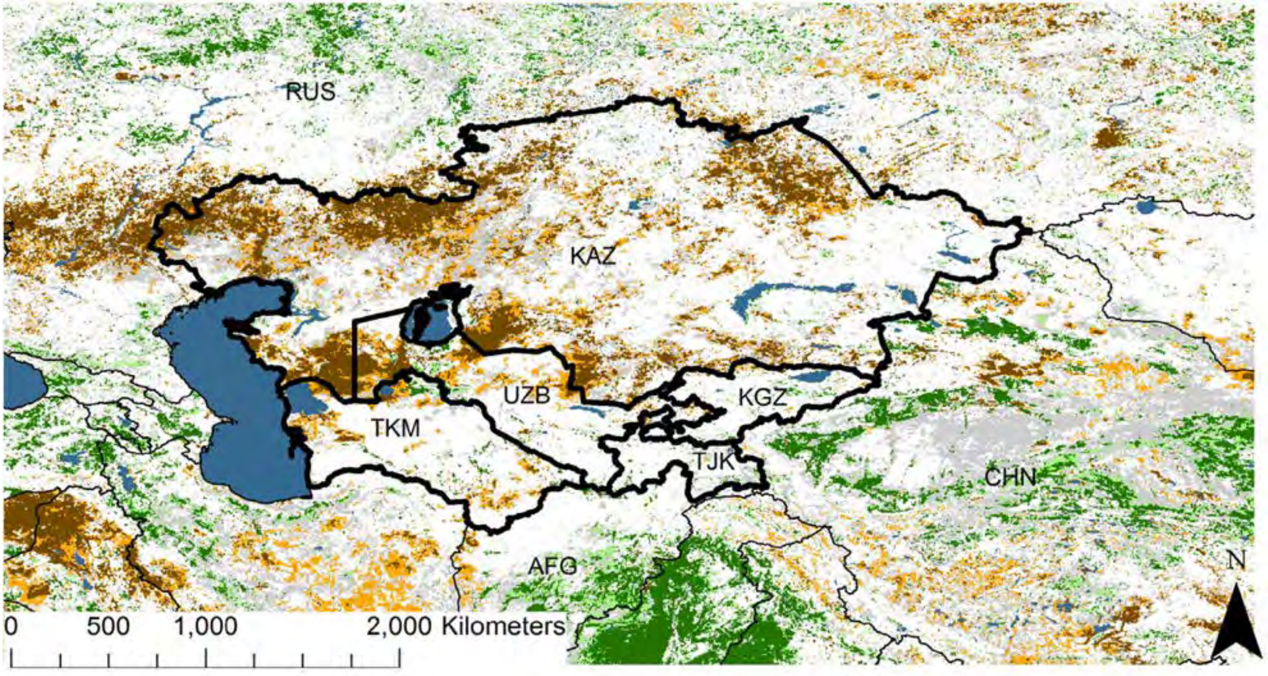
Extratropical cyclones bring water vapor into Central Asia during spring & summer.

Table 2: Mean number of cyclones with atmospheric pressure <1,000 hPa at its center during 1979-2016 by season

Region	JFM	AMJ	JAS	OND	Annual
Kazakhstan	3	17	18	2	40
Kyrgyzstan	1	6	7	0	14

← Some evidence of increasing trend of cyclones.

Groisman *et al.* 2018. Dry land belt of Northern Eurasia: Contemporary environmental changes and their consequences. ***Environmental Research Letters***, to appear.



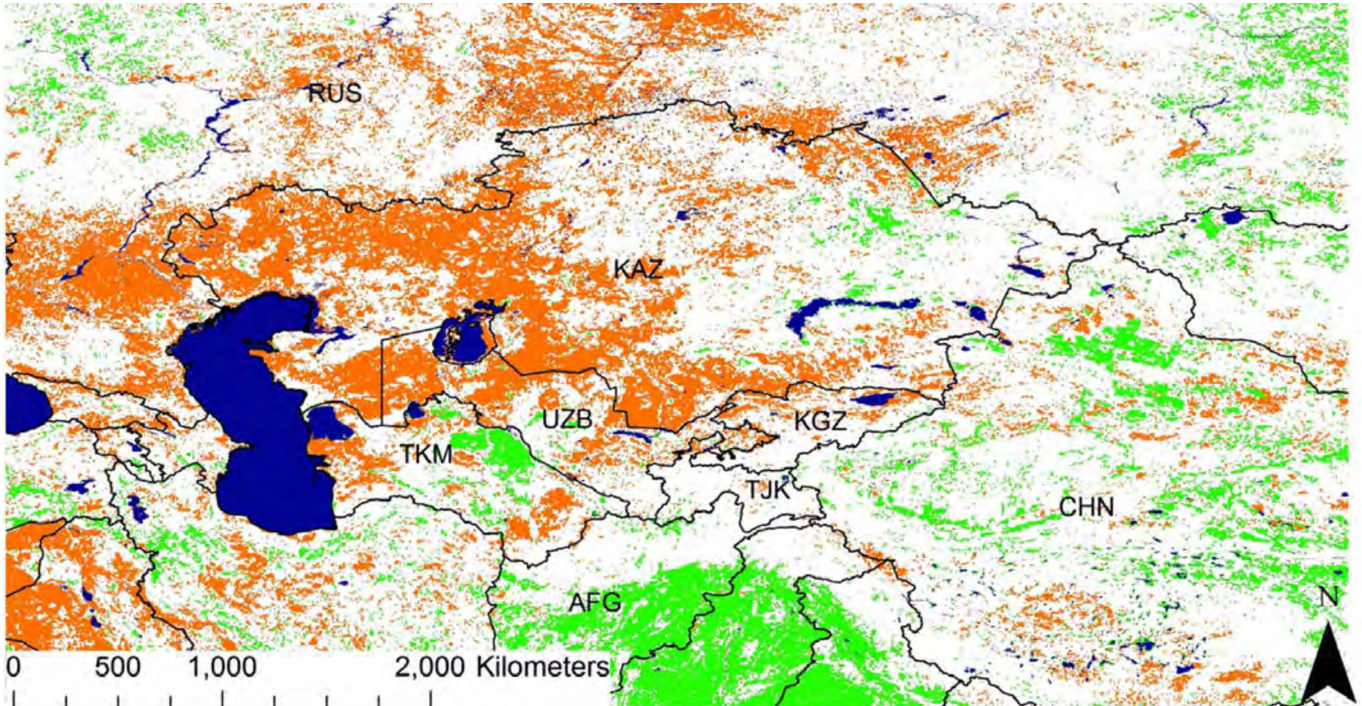
IV. Trends in the vegetated land surface

← Multiple vegetation indices show significant "browning" in Central Asia between 2001-2013

[Browns indicate significant negative trends in vegetation]
[Greens indicate significant positive trends in vegetation]

Remotely sensed wetness index shows → significant "drying" across Central Asia between 2001-2013

[Orange indicates significant negative trends in wetness]
[Green indicates significant positive trends in wetness]



de Beurs KM, GM Henebry, BC Owsley, I Sokolik. 2015. Using multiple remote sensing perspectives to identify and attribute land surface dynamics in Central Asia 2001-2013. ***Remote Sensing of Environment*** 170:48-61.

V. Trends in snow seasonality in Kyrgyzstan

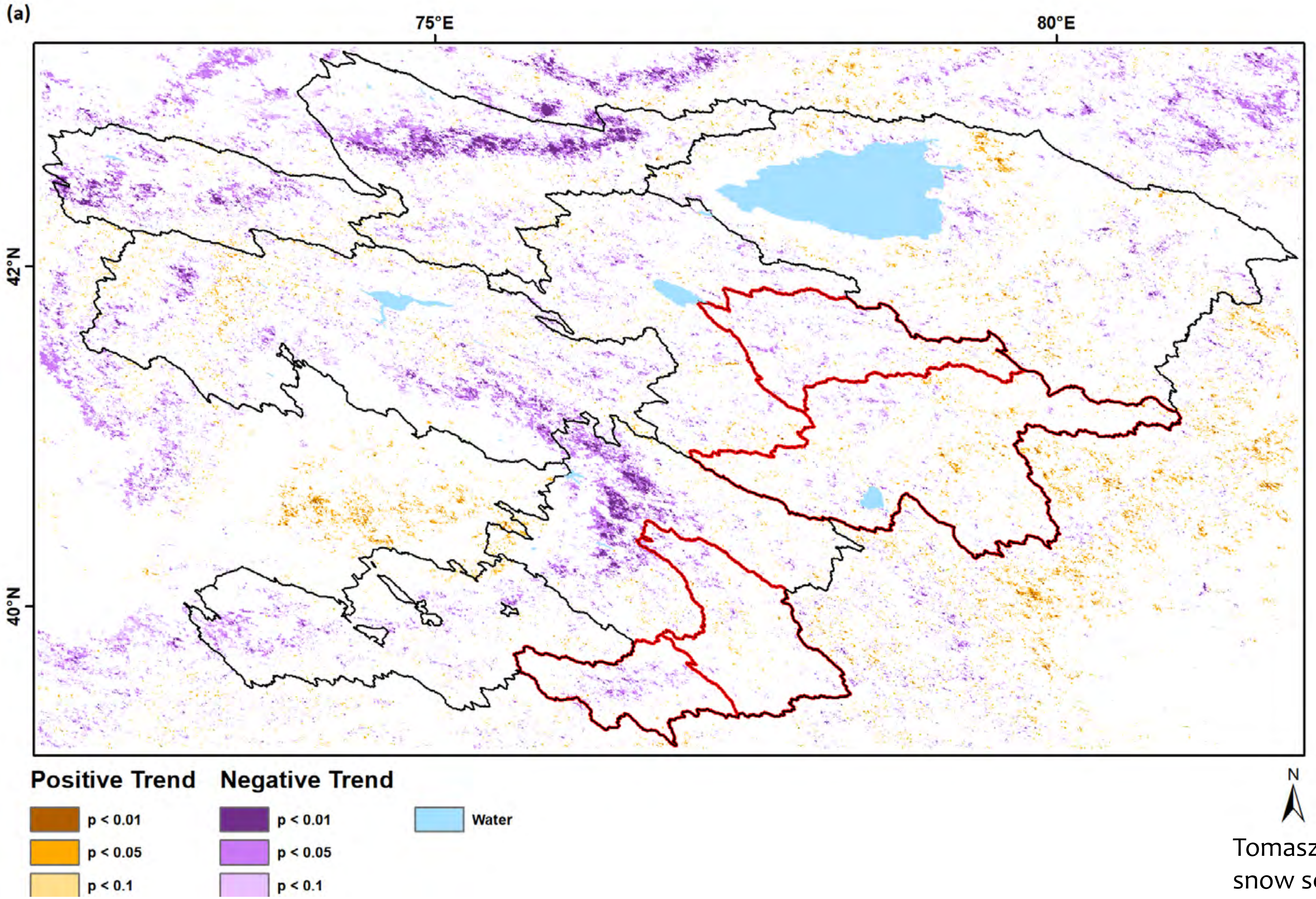
Most of the annual precipitation in the Kyrgyz highlands falls outside of the growing season.

Snow cover, snow amount, and timing of onset and melt all affect soil moisture availability that supports early growth in pastures.

We determined the snow season using remotely sensed snow cover products from MODIS (500 m, 8-day composites, 2002-2016, Terra only).

We evaluated trends in First Date of Snow, Last Date of Snow, Duration of the Snow Season using nonparametric methods.

Significant Trends in First Date of Snow across Kyrgyzstan

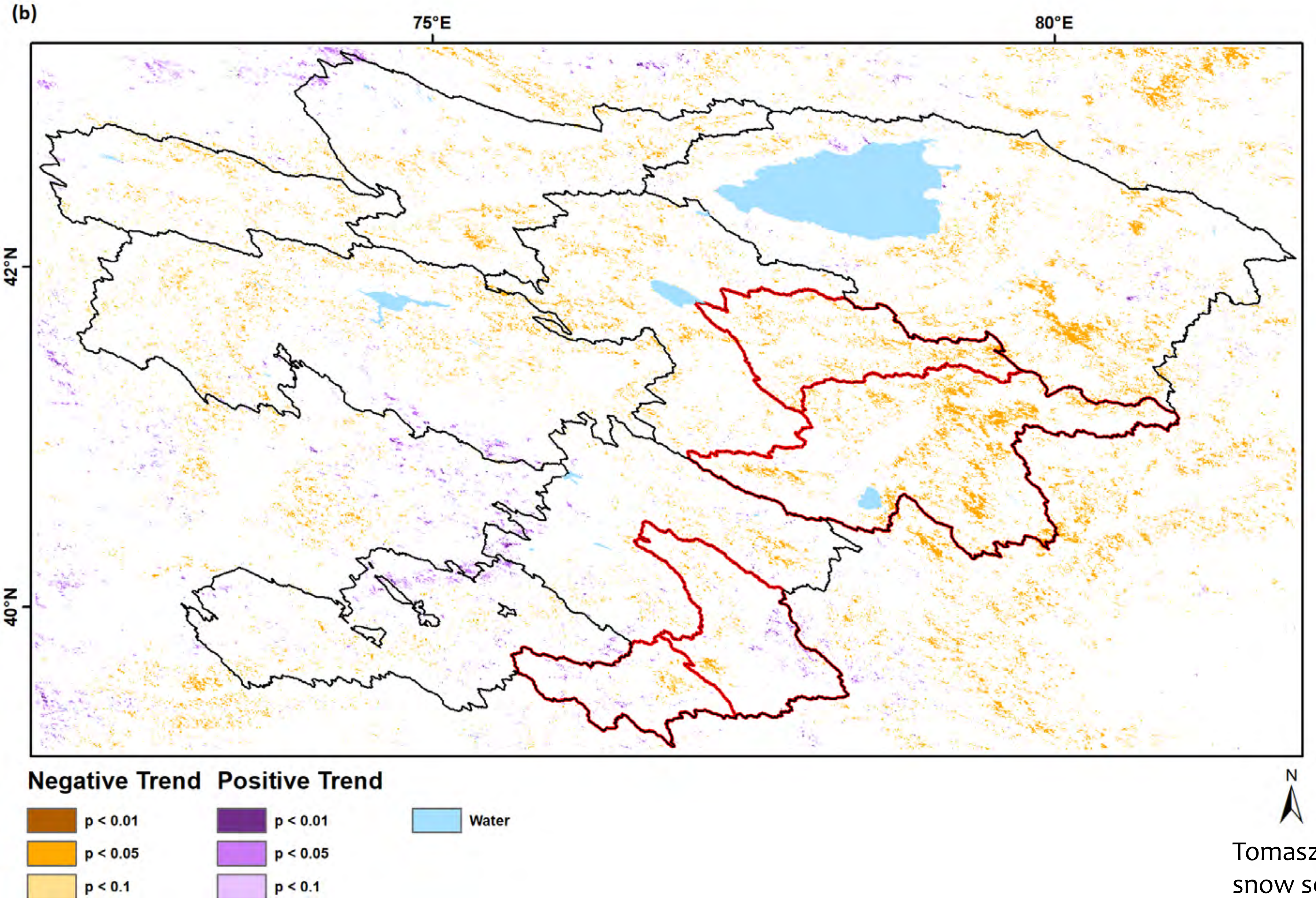


Significantly earlier snow onset—especially in Chuy and Osh oblasts

oblast	FDoS earlier (km²)
Batken	526
Chuy	2,079
Issyk-Kul	--
Jalal-Abad	1534
Naryn	839
Osh	2,021
Talas	972
total	7,971

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Significant Trends in Last Date of Snow across Kyrgyzstan

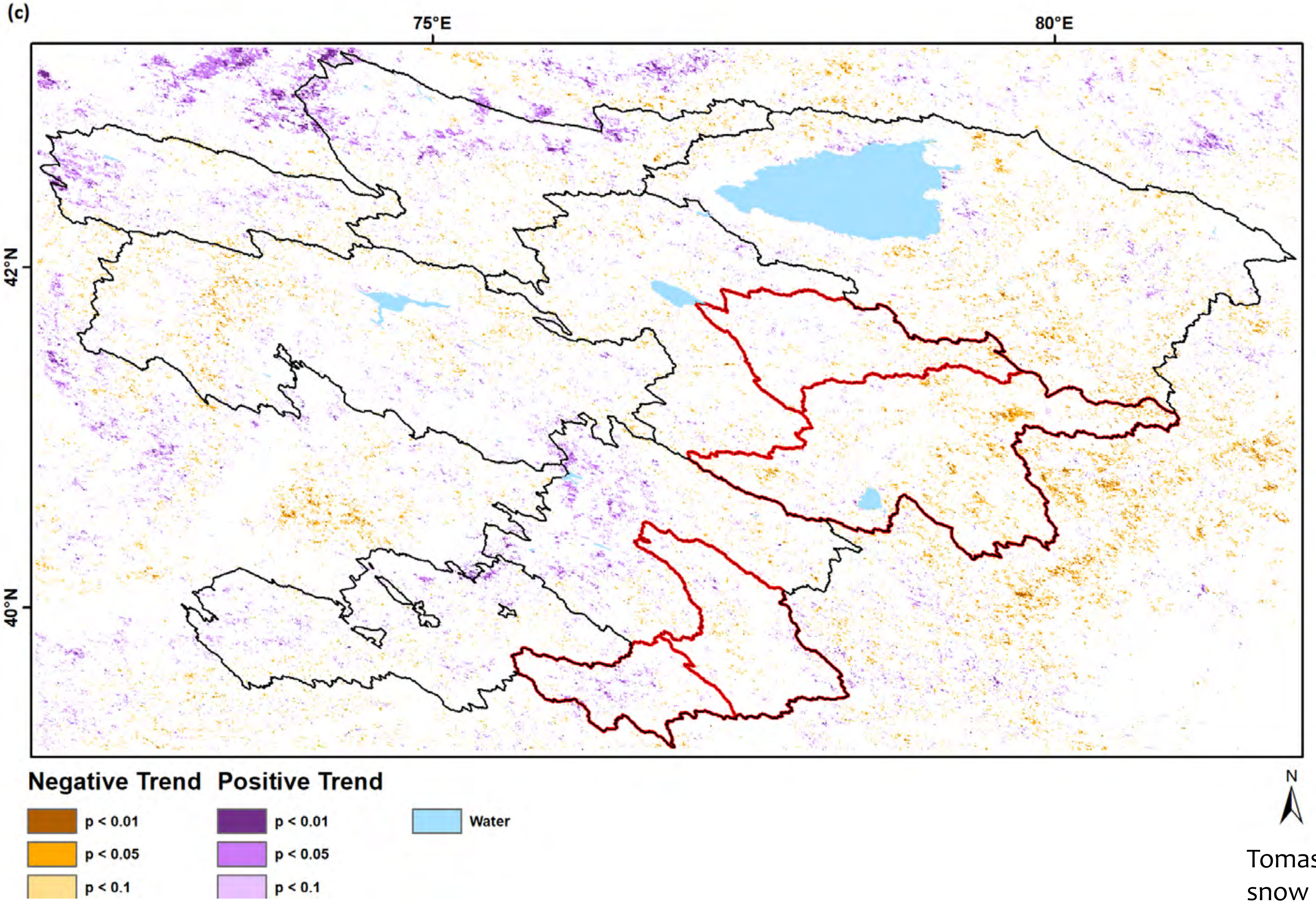


Significantly earlier snow melt— especially in Naryn and Issyk-Kul oblasts

oblast	LDoS earlier (km^2)
Batken	--
Chuy	401
Issyk-Kul	1,376
Jalal-Abad	759
Naryn	2,227
Osh	--
Talas	222
total	4,985

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Significant Trends in Duration of Snow Season across Kyrgyzstan



Shorter snow season to the east.

Longer snow season to the west.

oblast	DoSS shorter (km^2)	DoSS longer (km^2)
Batken	--	325
Chuy	--	701
Issyk-Kul	884	--
Jalal-Abad	--	--
Naryn	872	--
Osh	--	701
Talas	--	357
total	1,757	2,084

Tomaszewska MA, GM Henebry. 2018. Changing snow seasonality in the highlands of Kyrgyzstan. ***Environmental Research Letters*** 13:065006.

Potential impacts of changing snow seasonality include

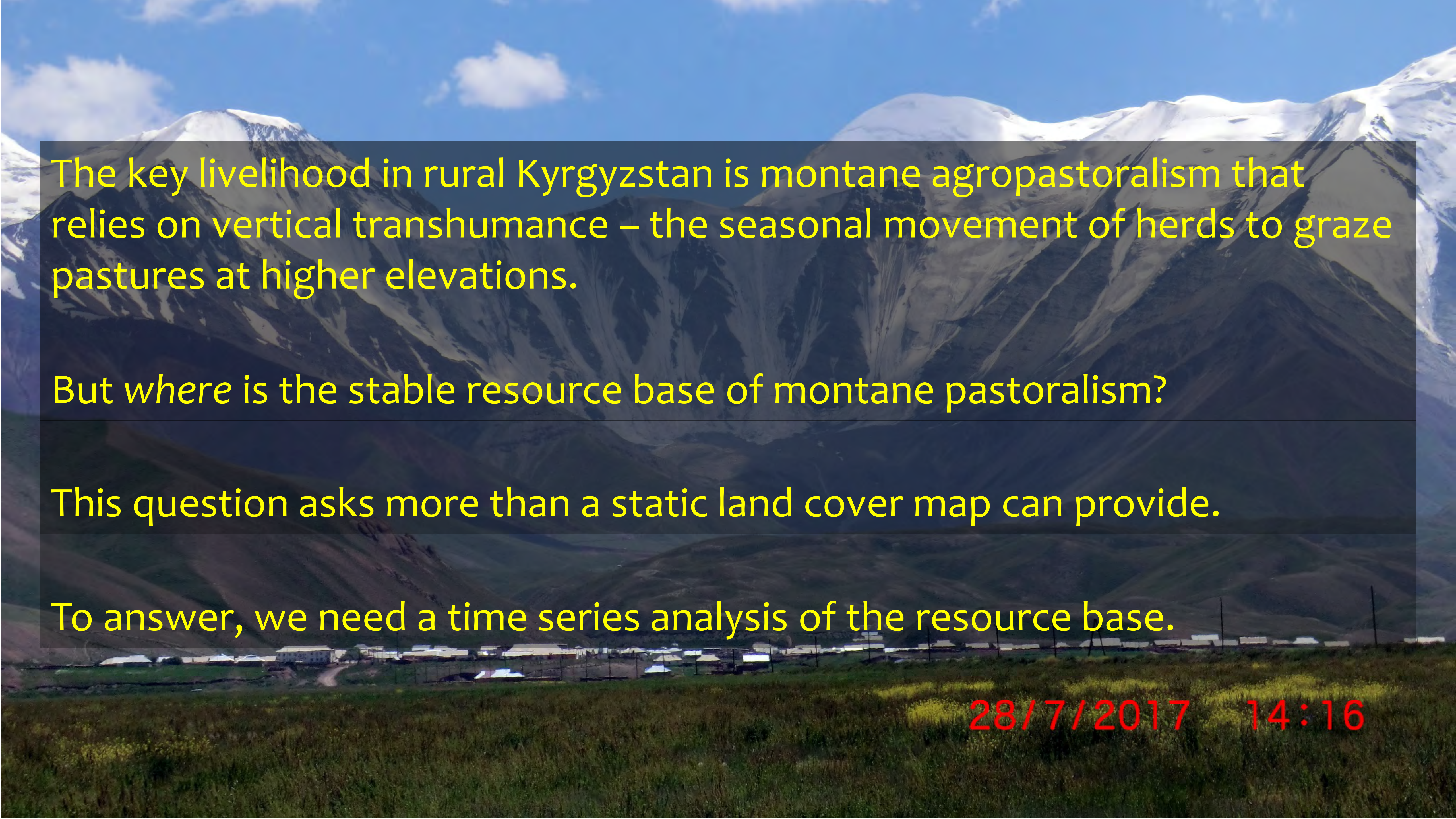
- Disruption of ecological calendars & transhumance timing
- Earlier end to growing season in summer and spring/fall pastures, if moisture not supplemented by rainfall
- Earlier end of access to fall and winter pastures
- Increasing the difference in productivity between northern and southern aspect pastures
- Increasing the invasibility of pastures by non-palatable species that are active earlier in the growing season

VI. Locating the stable natural resource base: highland pastures

Like many mountain nations, the land area of Kyrgyzstan is limited (<200K km^2), but it is highly mountainous (94%) with a population of ~6M that is mostly rural.

Lots of livestock grazing the land:

Horses, Cattle, Sheep, Goats, Yaks



The key livelihood in rural Kyrgyzstan is montane agropastoralism that relies on vertical transhumance – the seasonal movement of herds to graze pastures at higher elevations.

But *where* is the stable resource base of montane pastoralism?

This question asks more than a static land cover map can provide.

To answer, we need a time series analysis of the resource base.

The Convex Quadratic (CxQ) model of Land Surface Phenology (LSP) links a remotely sensed vegetation index (*e.g.*, NDVI) to the temporal progression of accumulated growing degree-days (AGDD).

The CxQ model has been successfully applied to a variety of settings and scales.

$$NDVI = \alpha + \beta \times AGDD + \gamma \times AGDD^2$$

$$PH = \alpha - (\beta^2 / 4 \times \gamma)$$

$$TTP = -\beta / 2 \times \gamma$$

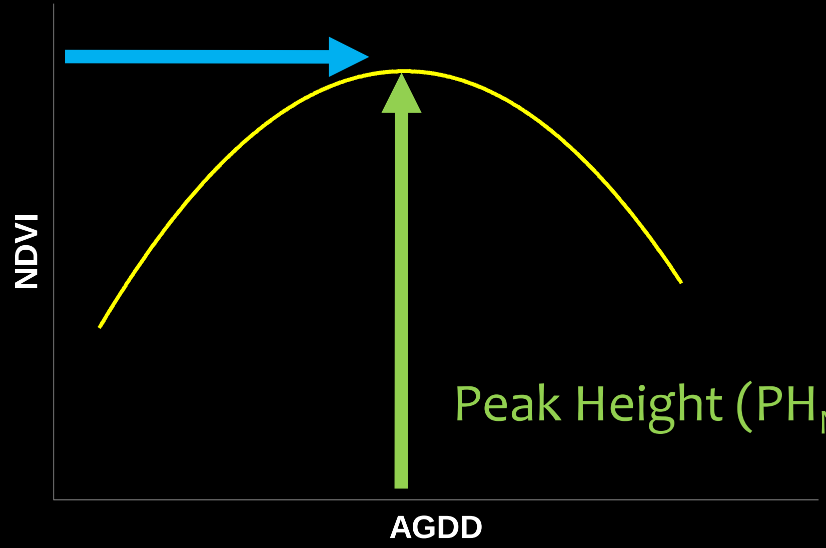
(1) Calculate the AGDD at 1 km resolution from MODIS land surface temperature products.

(2) Calculate the NDVI at 30 m resolution from Landsat time series.

(3) Fit CxQ model to each 30 m pixel time series year by year & across all years

(4) Map out the resulting phenometrics.

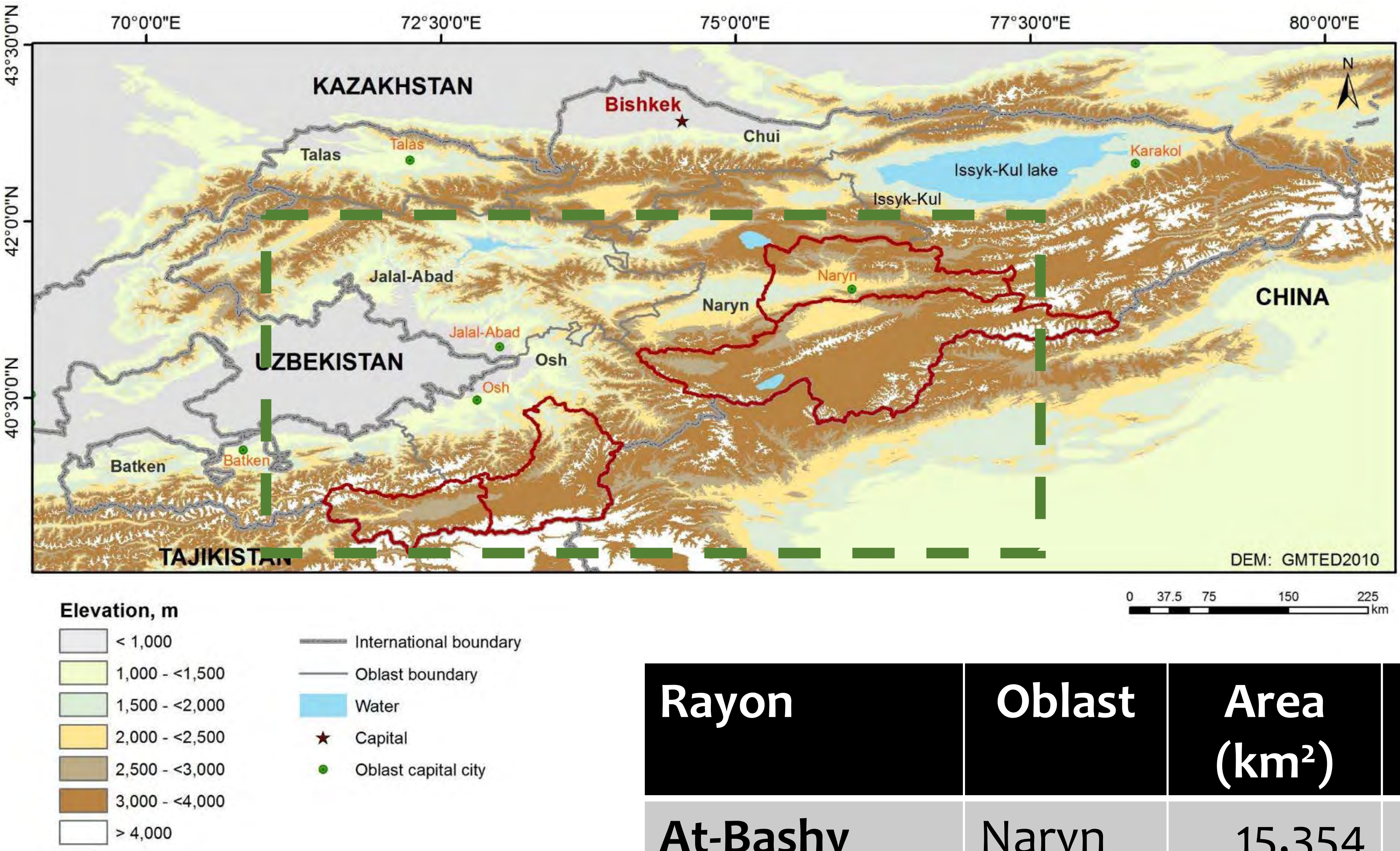
Thermal Time to Peak (TTP_{NDVI})



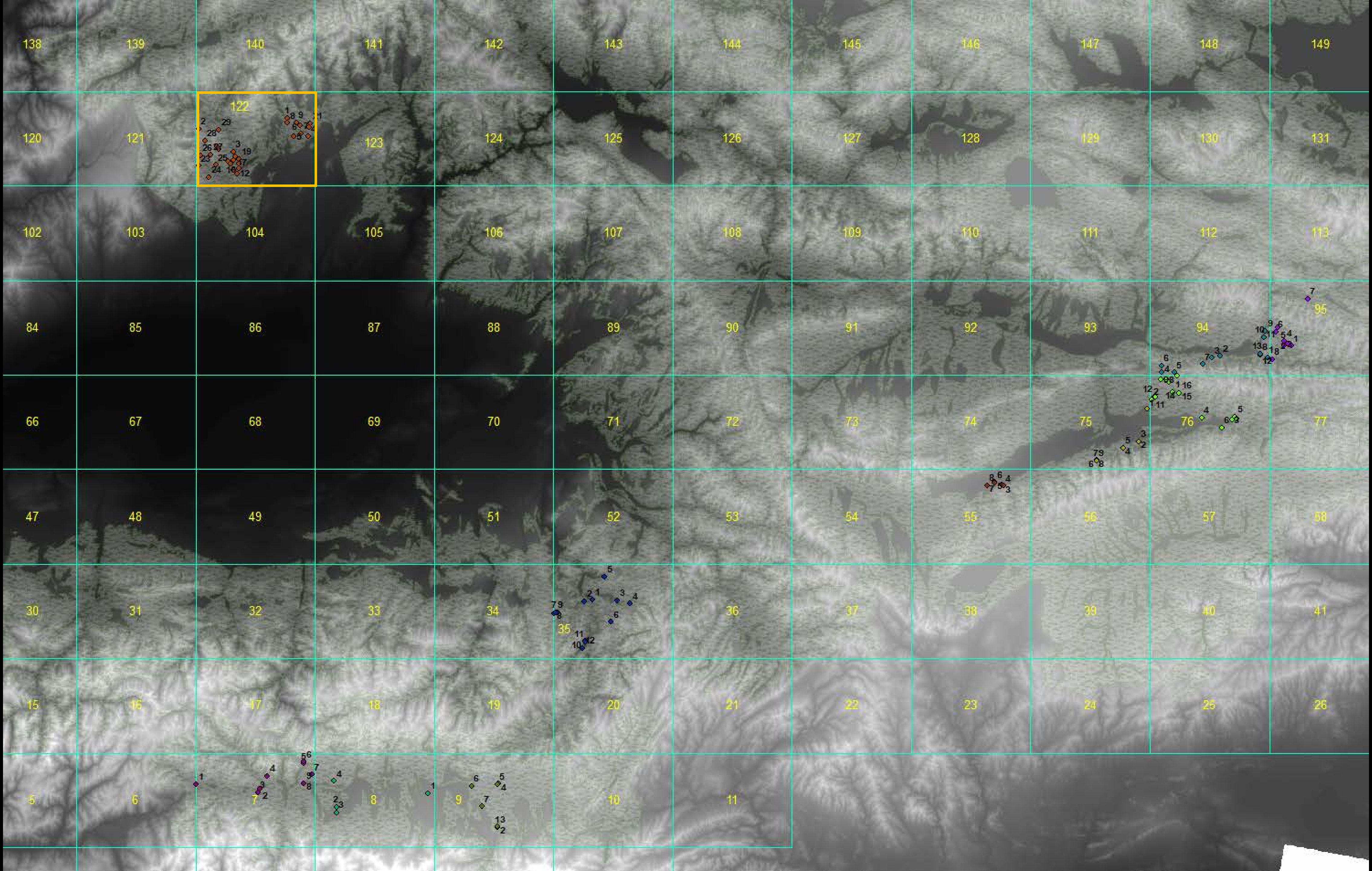
Peak Height (PH_{NDVI})

de Beurs KM, GM Henebry. 2004. Land surface phenology, climatic variation, and institutional change: Analyzing agricultural land cover change in Kazakhstan. ***Remote Sensing of Environment*** 89(4):497-509.

Finding Persistent Pastures in Four Focal Rayons



Rayon	Oblast	Area (km^2)	Population (n)	Density (n/km^2)
At-Bashy	Naryn	15,354	~49,000	~3
Naryn	Naryn	4,055	~44,000	~4
Alay	Osh	6,821	~72,000	~11
Chong-Alay	Osh	4,857	~25,000	~5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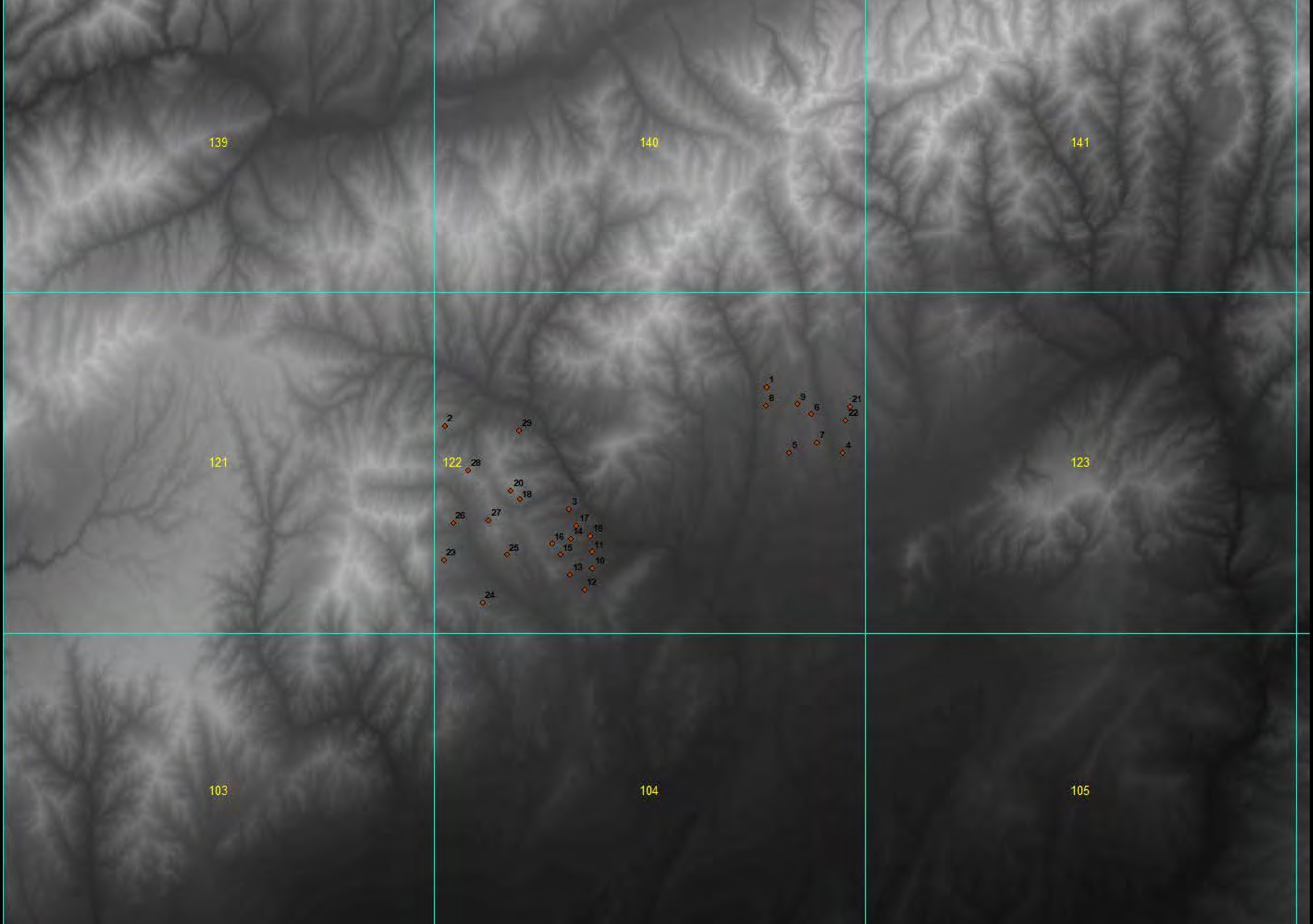
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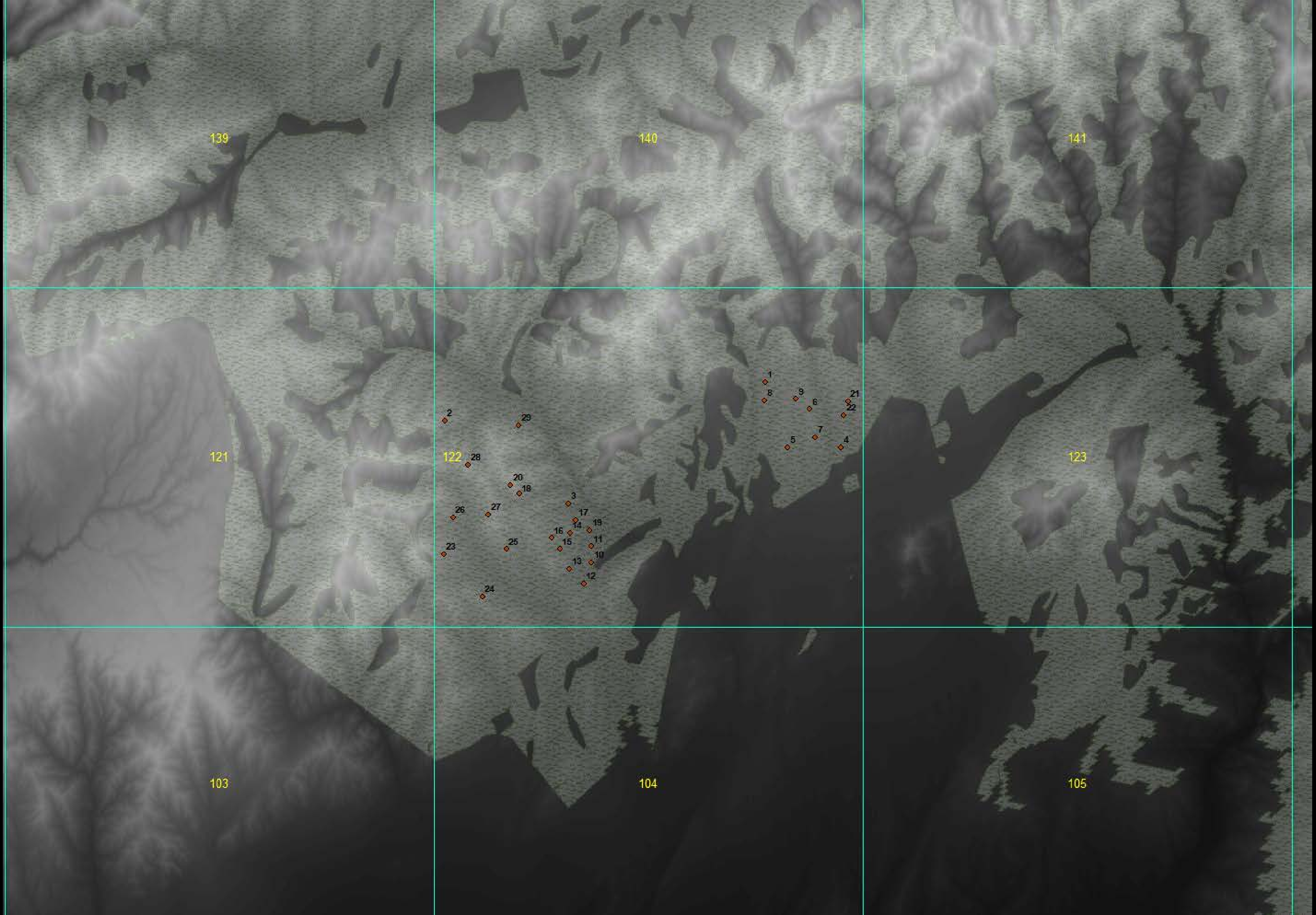
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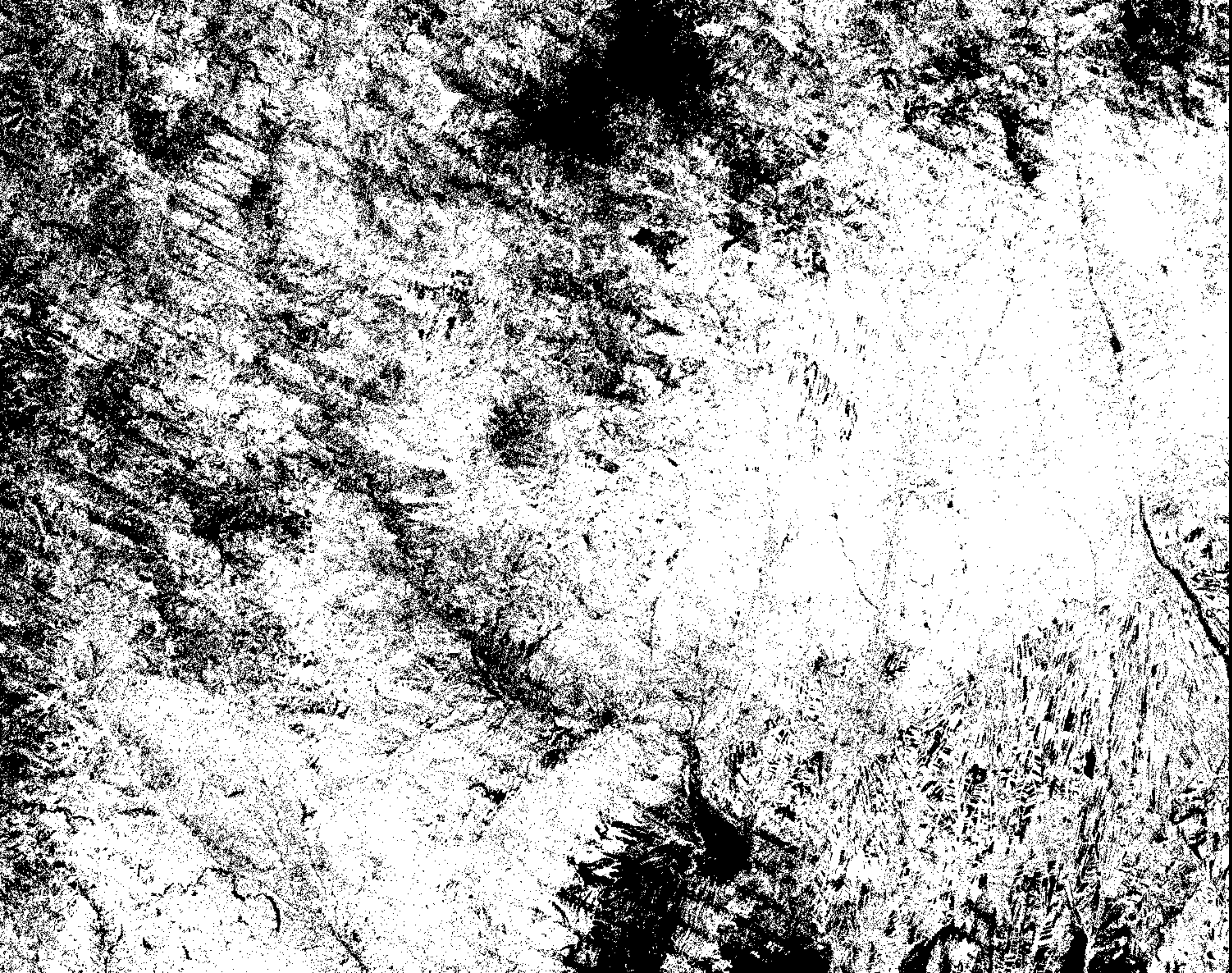

2014

Raw Landsat time series at 30 m

White displays pixel with some number of valid observations

Black displays no valid observations

2014

Grey scale displays the difference in number of obs between raw and filtered Landsat time series

69% pixels with good fits

No fit in 5% due to low obs after filtering

No fit in 8% due to wrong shape

No fit in 19% due to too few obs on either side of peak

2014

Fitted **Thermal Times to Peak**

Notice the gradient from ag fields in the lower right to the highlands in the upper center.

SLC-off effects still evident, but not so strong.

2014

Fitted **Peak Heights** of NDVI

Notice terrain effects

2014

Area Under the Curve

Integrating under the fitted CxQ model