Analysis of spatiotemporal patterns and driving forces for land degradation and restoration in Mongolia from 1990 to 2015

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Outline

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1. Background

1.1 Study background:

- The United Nations Sustainable Development Goals (SDGs) for 2030 aims to tackle this issue and achieve **Land Degradation Neutrality (LDN)** by 2030. However, this is a serious challenge in the fragile environment of Mongolia.
- Mongolia is located in the **transition zone** between the Arctic Ocean climate zone and the Pacific Ocean climate zone. The increasingly land degradation in Mongolia has had a direct impact on the ecology of the entire Mongolian plateau and adjacent regions.
- **Land degradation and restoration** in this region fluctuate spatially and temporally because of the impacts of global climate change and human activity.

1. Background

1.2 Study status:

The scientific question of whether Mongolia is degraded or restored has never reached a universally recognized consensus.

- Japanese scientist shows that **Mongolia's vegetation restored** between 1981 and 2014, and the country as a whole was "greener" (Tomoko et al., 2019).
- The scientists from the National University of Mongolia point out that the green of the ground does not necessarily mean that the land is being restored. The **restoration of land is reflected in productivity or biomass.**
- In collaboration with Mongolian scientists, Chinese scholars found **that land degradation is still the dominant trend in Mongolia.** However, land degradation and restoration processes coexist, and the rate of evolution is different (Wang et al., 2020).

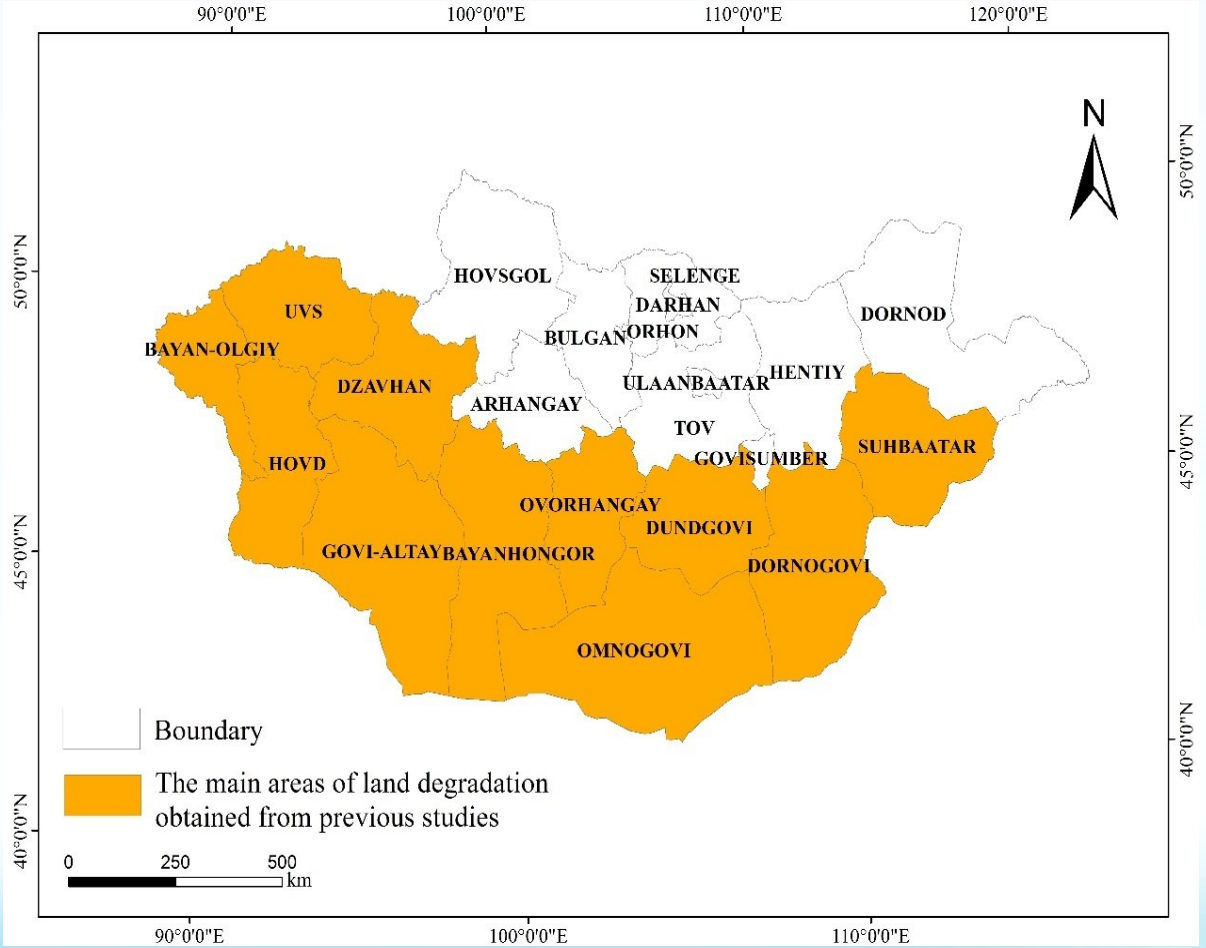
1. Background

- With the continuous enrichment of remote sensing data sources, **a lot of monitoring studies have emerged to reflect the large-scale land degradation and restoration of Mongolia**.
  - Based on the 1 km spatial resolution of **MODIS-NDVI data**, Wang et al. (2011) found that Mongolia's vegetation cover showed an overall stable trend with slight local improvement from 2001 to 2010.
  - Miu et al. (2014) analyzed vegetation cover and land degradation in the Mongolian plateau from 1998 to 2001, based on observations data of meteorological stations and **SPOT-NDVI data** in the Mongolian plateau.
  - Based on the long-term **MODIS-NDVI data**, Sandra et al. (2015) conducted land degradation and restoration surveys in Mongolia and obtained a significant trend map of land change from 2001 to 2011.
- **There are few studies on land cover and vegetation change with high resolution**. So it is difficult to reveal the detailed land degradation process.

2. Data sources

2.1 Study area:

- Mongolia is a typical landlocked country located in the interior of central Asia, at the north of the Mongolian plateau at a latitude of 42° - 52° and a longitude of 88° - 120° . It has an area of approximately 1.5665 million km^2, with 21 provinces.
- The overall topography of Mongolia is plateau which gradually decreases from west to east. The northwest of the country is characterized by high mountains, the south by the Gobi and desert, and the east by plains.

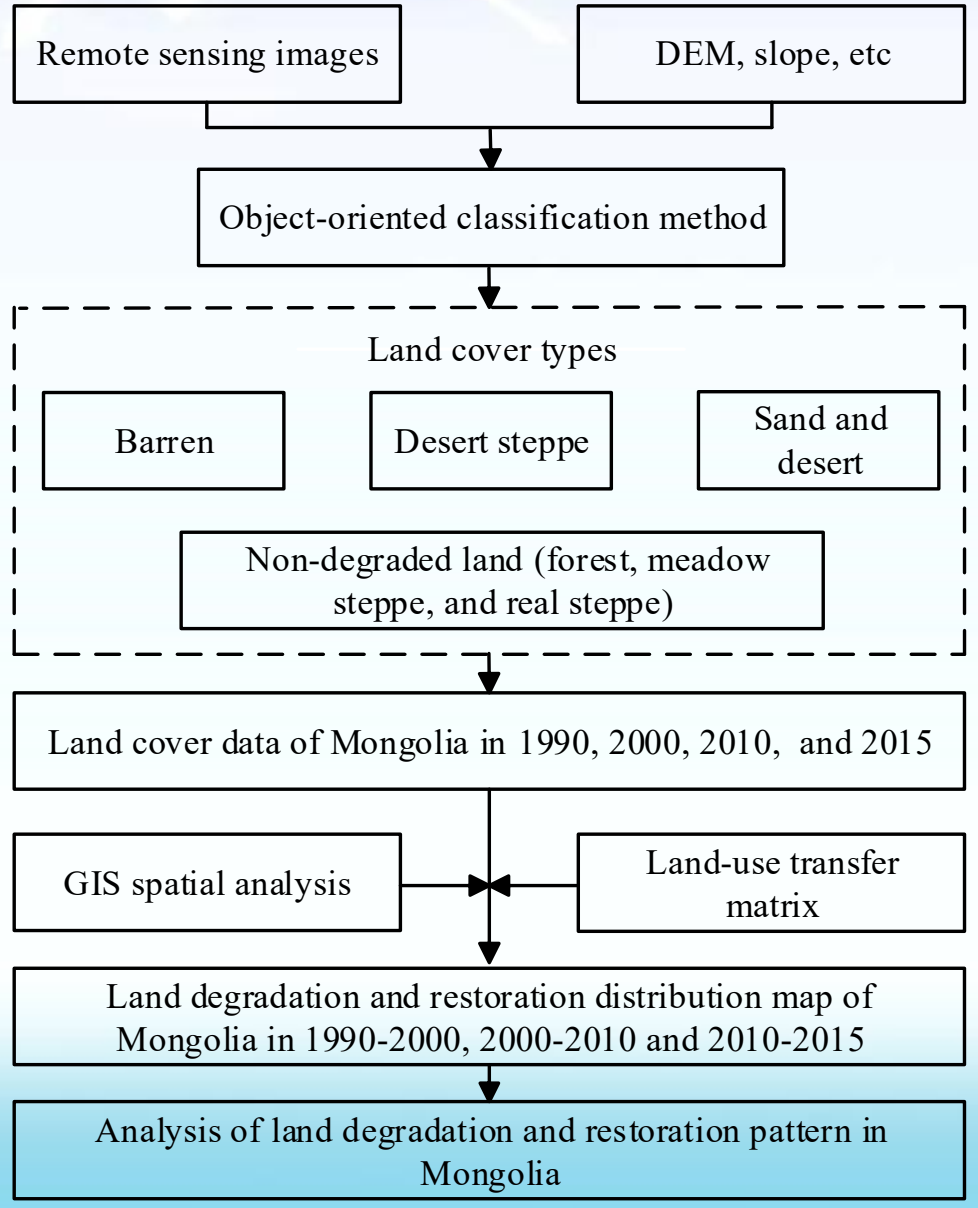


2. Data sources

2.2 Data sources:

- **Basic data:** remote sensing images of Landsat series
- **Spatial resolution:** 30 m
- **Time:** 1990, 2000, 2010, and 2015
- **Number of images:** about 520 images
- **Auxiliary data:** 1) digital elevation model (DEM) and slope data, with spatial resolutions of 30 m; 2) statistics on average annual temperature, average annual precipitation, population, and livestock; 3) field investigation data of land cover types in Mongolia in 2013, 2014, 2015, 2016, 2017, 2018, and 2019.

3. Methods



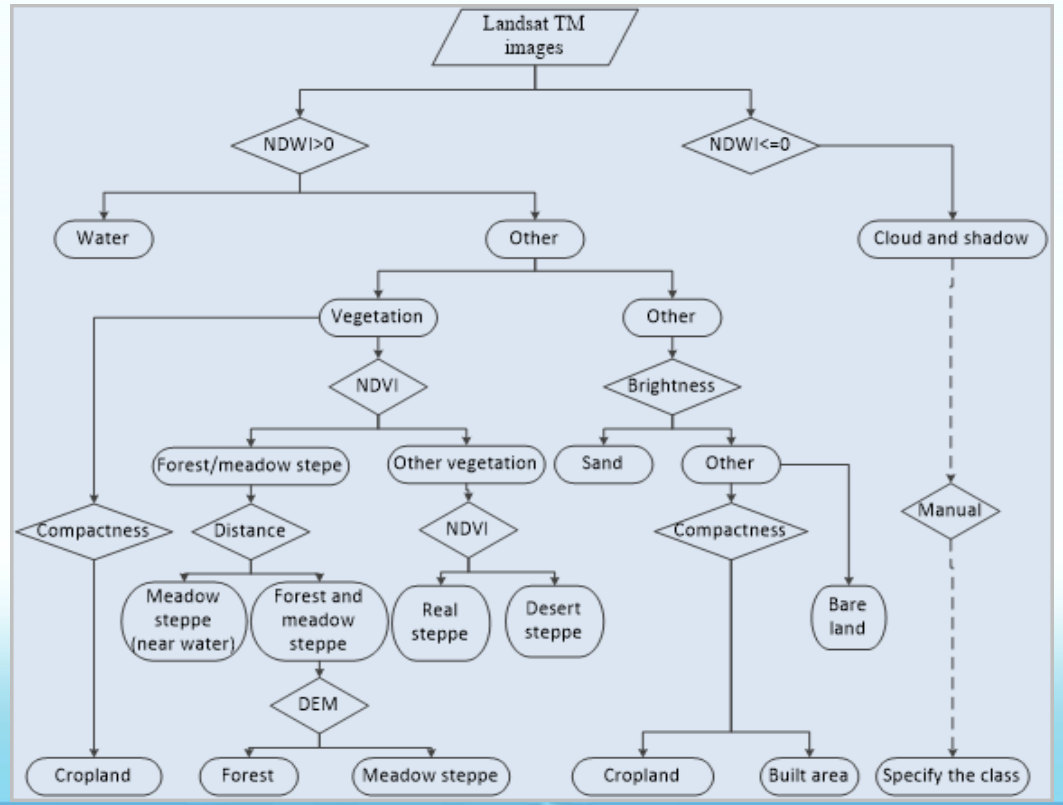
Technical flowchart:

- Based on the multi-source remote sensing images, the object oriented classification method is adopted to obtain the land cover data with 30-m spatial resolution.
- **We classify forest, meadow steppe and real steppe without land degradation characteristics as non-degraded lands.** Then, we separately extract the information of desert steppe, barren, sand, desert, and other land cover types.
- With the support of GIS, we constructed the land cover transfer matrix of Mongolia and **obtained the land degradation and restoration data of Mongolia in 1990-2000, 2000-2010 and 2010-2015 with a spatial resolution of 30-m.**
- Finally, we identified key areas in the process of land degradation and restoration, analyzed the driving forces, and proposed the prevention and control countermeasures of land degradation.

3. Methods

Remote-sensing interpretation of land cover data:

- The eCognition software was used for multiresolution segmentation and spectral difference segmentation of each image in different years. Then, objects were classified according to specified rules, taking full advantage of the textural, spatial, and spectral characteristics of ground objects.



Land cover types	Rules and reference threshold
forest	NDVI > 0.5; DEM > 1800 m
meadow steppe	0.4 <= NDVI < 0.5; Distance to water < 40 pixels; DEM< = 1800 m
real steppe	0.2 <= NDVI< 0.4
desert steppe	0.1 < NDVI < 0.2
barren lands	NDSI > 0.03
desert	visual interpretation
sand	Brightness >= 600
cropland	Compactness <= 1.4
built area	visual interpretation
water	NDWI > 0.036

4. Results and discussion

(1) Land cover spatial distribution pattern of Mongolia in 1990, 2000, 2010 and 2015

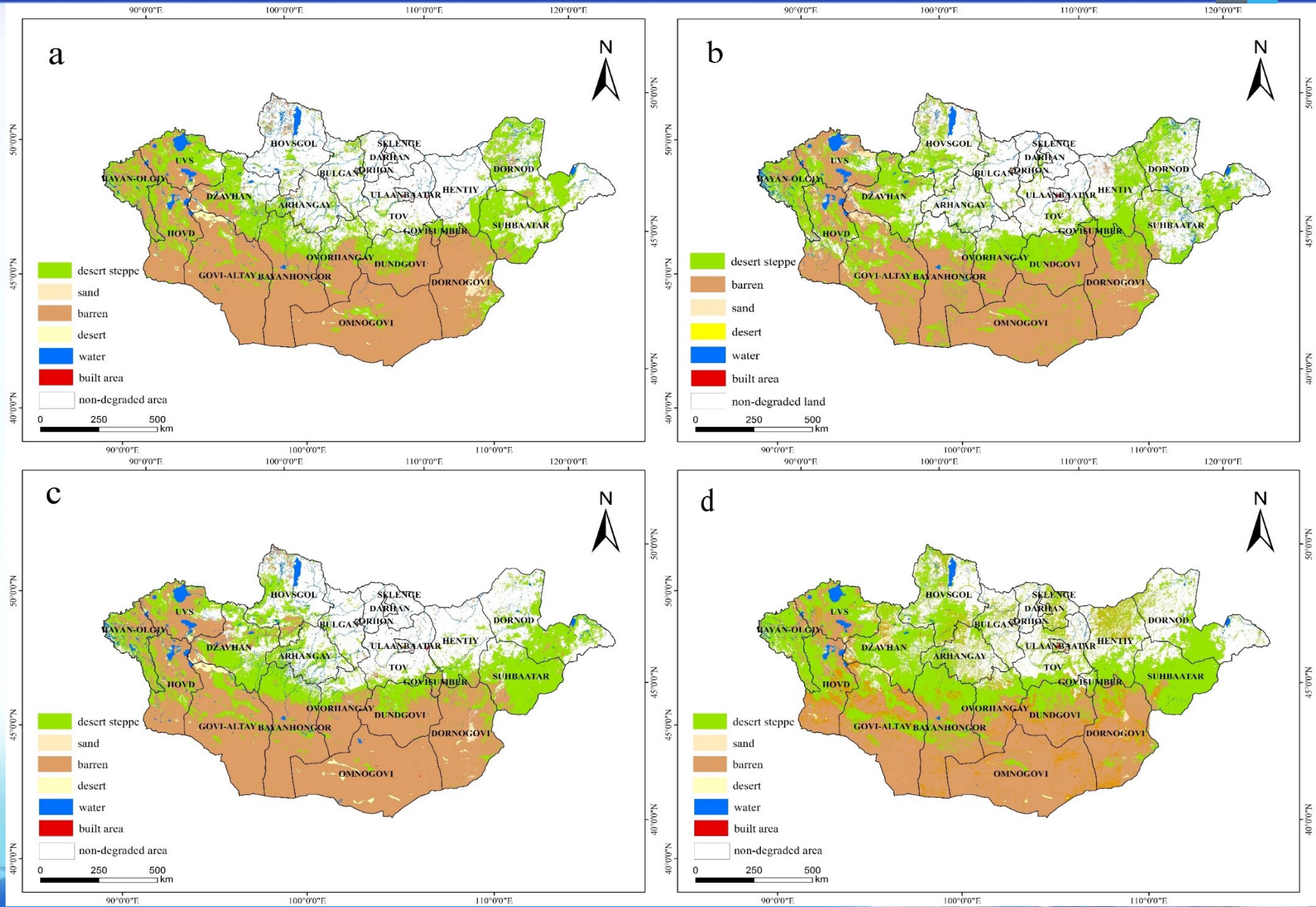
- The total area of desert steppe, and barren lands, sand and desert in 1990, 2000, 2010 and 2015 accounts for **61.81%, 62.59%, 65.25% and 66.33% of Mongolia's total area** respectively. **It presents a gradually increasing trend.**

- The distribution of non-degraded lands, desert steppe, and barren lands in Mongolia show evident transition characteristics. From north to south and northeast to southwest, the successive land cover types were originally non-degraded lands, desert steppe, and barren lands.

Time	Land cover types	Area (km^2)	Proportion (%)
1990	desert steppe	231,266.83	14.78
	barren lands	720,467.43	46.06
	sand	5798.06	0.37
	desert	9403.75	0.60
	non-degraded lands	**597,432.27**	**38.19**
	total	1,564,368.34	100
2000	desert steppe	302,194.92	19.32
	barren lands	658,128.90	42.07
	sand	18,756.83	1.20
	desert	10.43	0.0007
	non-degraded lands	**585,277.26**	**37.41**
	total	1,564,368.34	100
2010	desert steppe	259,083.51	16.56
	barren lands	748,187.64	47.83
	sand	1929.98	0.12
	desert	11,514.17	0.74
	non-degraded lands	**543,617.98**	**34.75**
	total	1,564,368.34	100
2015	desert steppe	346,761.95	22.17
	barren lands	669,109.76	42.77
	sand	20,074.40	1.28
	desert	1724.90	0.11
	non-degraded lands	**526,722.82**	**33.67**
	total	1,564,368.34	100

4. Results and discussion

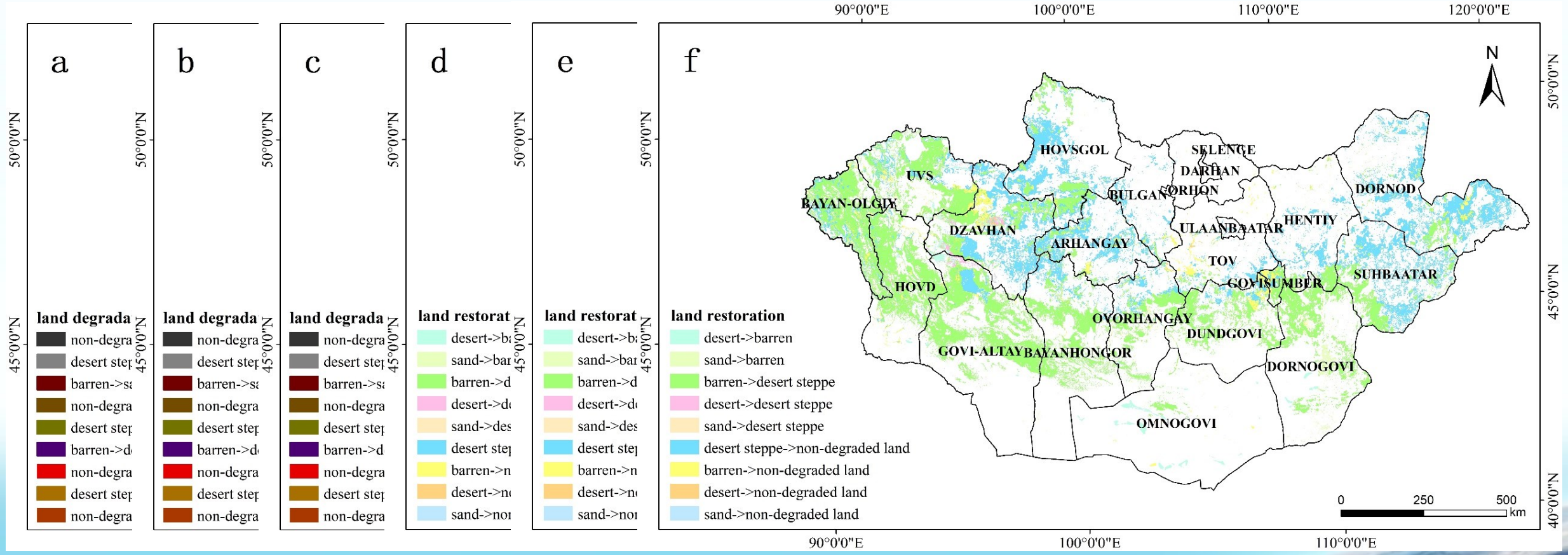
- The distribution map showing different types of land cover in Mongolia (**a:1990; b: 2000; c: 2010; d: 2015**).



4. Results and discussion

(2) The spatial distribution pattern of land degradation and restoration in Mongolia

a: land degradation (1990-2000); b: land degradation (2000-2010); c: land degradation (2010-2015); d: land restoration (1990-2000); e: land restoration (2000-2010); f: land restoration (2010-2015)



4. Results and discussion

Time	Degradation	Area (km^2)	%	Restoration	Area (km^2)	%
1990-2000	NDL→sand	6182.16	0.39	desert→barren lands	54.70	0.003
	desert steppe→sand	2189.36	0.14	sand→barren lands	5021.39	0.32
	barren lands→sand	9571.60	0.61	barren lands→desert steppe	103,123.41	6.59
	NDL→desert	0	0	desert→desert steppe	65.72	0.004
	desert steppe→desert	5.57	0.0004	sand→desert steppe	105.94	0.006
	barren lands→desert	4.85	0.0003	desert steppe→NDL	88,954.27	5.69
	NDL→barren lands	18,890.60	1.21	barren lands→NDL	28,372.64	1.81
	desert steppe→barren lands	43,436.46	2.78	desert→NDL	352.39	0.02
	NDL→desert steppe	95,021.37	6.07	sand→NDL	7.44	0.0005
	total	**175,301.97**	**11.21**	**total**	**226,057.90**	**14.45**
2000-2010	NDL→sand	0.52	0.00003	desert→barren lands	0	0
	desert steppe→sand	8.06	0.0005	sand→barren lands	10,600.17	0.68
	barren lands→sand	1515.13	0.10	barren lands→desert steppe	33,426.65	2.14
	NDL→desert	248.27	0.02	desert→desert steppe	10.25	0.0007
	desert steppe→desert	846.33	0.05	sand→desert steppe	1684.38	0.11
	barren lands→desert	5279.19	0.38	desert steppe→NDL	78,686.50	5.03
	NDL→barren lands	26,911.44	1.72	barren lands→NDL	12,871.86	0.82
	desert steppe→barren lands	118,262.36	7.56	desert→NDL	0.17	0.00001
	NDL→desert steppe	127,874.43	8.17	sand→NDL	761.53	0.05
	total	**280,945.73**	**17.96**	**total**	**138,041.51**	**8.82**
2010-2015	NDL→sand	161.32	0.01	desert→barren lands	3259.61	0.21
	desert steppe→sand	1183.87	0.08	sand→barren lands	963.04	0.06
	barren lands→sand	11,470.10	0.73	barren lands→desert steppe	111,765.26	7.14
	NDL→desert	16.36	0.0010	desert→desert steppe	854.68	0.05
	desert steppe→desert	21.27	0.0013	sand→desert steppe	53.05	0.003
	barren lands→desert	913.36	0.06	desert steppe→NDL	68,099.91	4.35
	NDL→barren lands	12,326.79	0.79	barren lands→NDL	16,221.74	1.04
	desert steppe→barren lands	31,916.81	2.04	desert→NDL	880.37	0.06
	NDL→desert steppe	70,134.95	4.48	sand→NDL	0.29	0.00002
	total	**128,144.83**	**8.19**	**total**	**202,097.95**	**12.92**

4. Results and discussion

- **The land degradation areas are mainly distributed in the northwest of Mongolia in belts and in the north and central of Mongolia in blocks.** The main forms of land degradation are non-degrading land degrading to desert steppe, and desert steppe degraded to barren lands.
- From 1990 to 2015, the land degradation areas show the change characteristics of increasing first, then decreasing slightly and leveling off. **The land degradation areas show the change characteristics** of spreading to the southwest, south and southeast with a half ring, and then concentrating to the central and northern part of Mongolia with a half ring.
- Areas where **land degradation and restoration in Mongolia have strong transitional nature**. The degree of land degradation gradually increased from northeast to southwest Mongolia. The degree of land restoration gradually increased from southwest to northeast Mongolia.

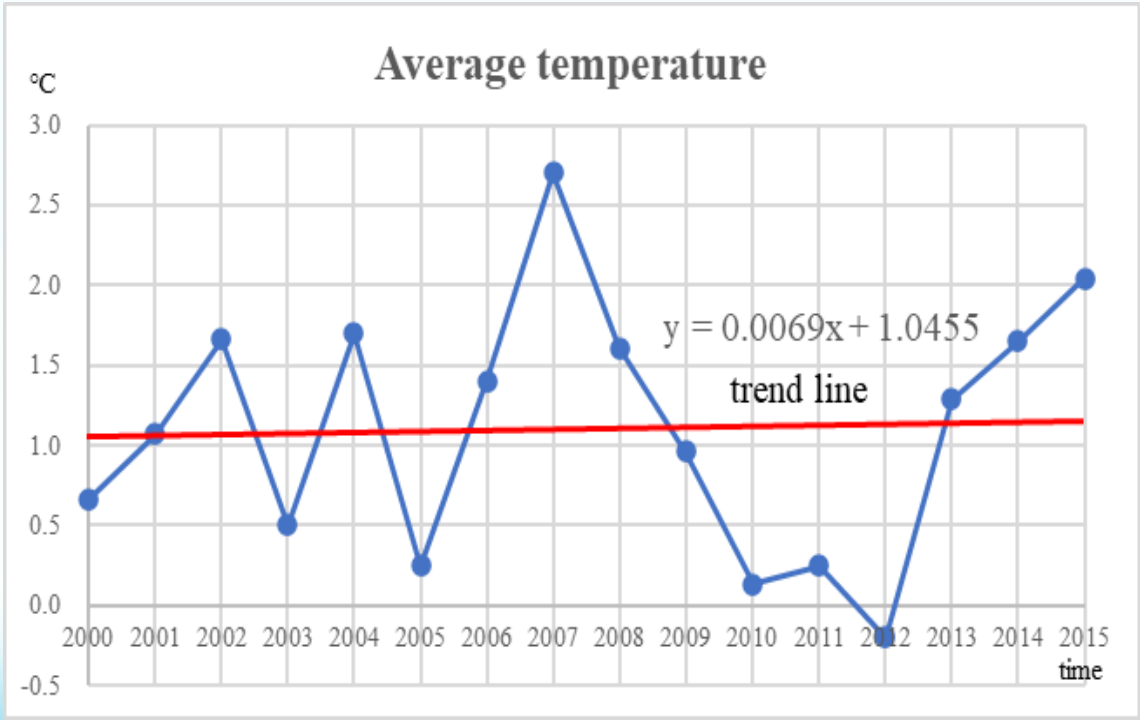
4. Results and discussion

(3) An analysis of the driving forces behind land degradation and restoration in Mongolia

1) An analysis of the driving forces behind land degradation

➢ **Natural factors**

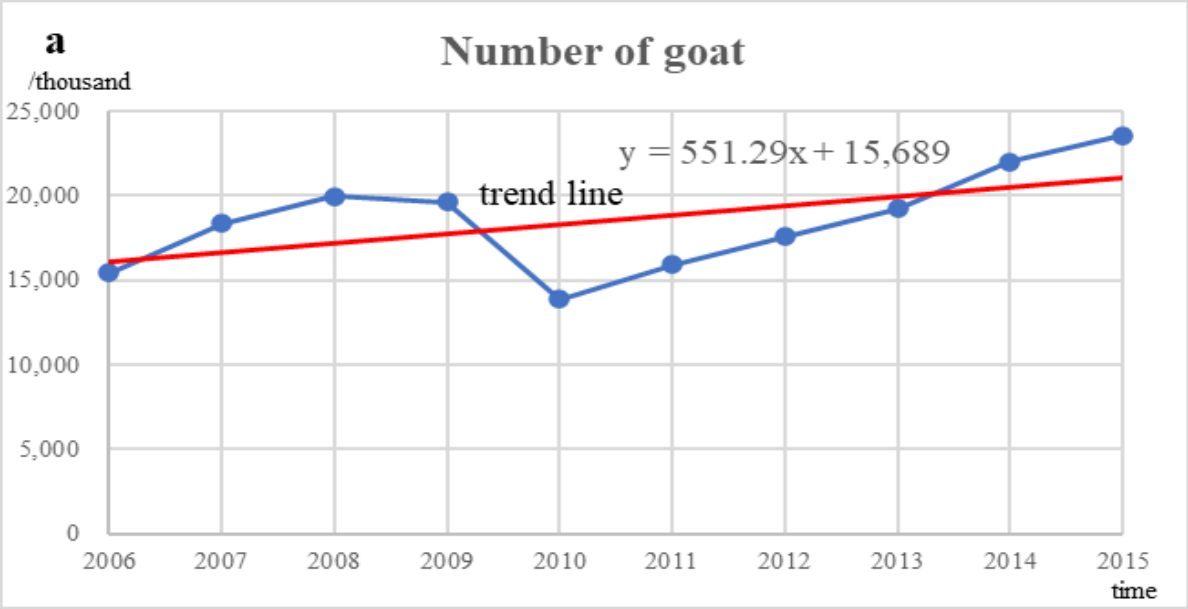
- The temperature in Mongolia showed a slow upward trend (increased by 1.5 to 2.5 ℃) and significantly fluctuation during 2000-2015. **Because of the fluctuation and rising of temperature, the growth and succession of vegetation is interfered**.
- The average annual precipitation from 2008 to 2011 was 4669.00 mm, and the average annual precipitation from 2012 to 2015 was 4520.50 mm. **Decreased precipitation restrains the vegetation growth**.

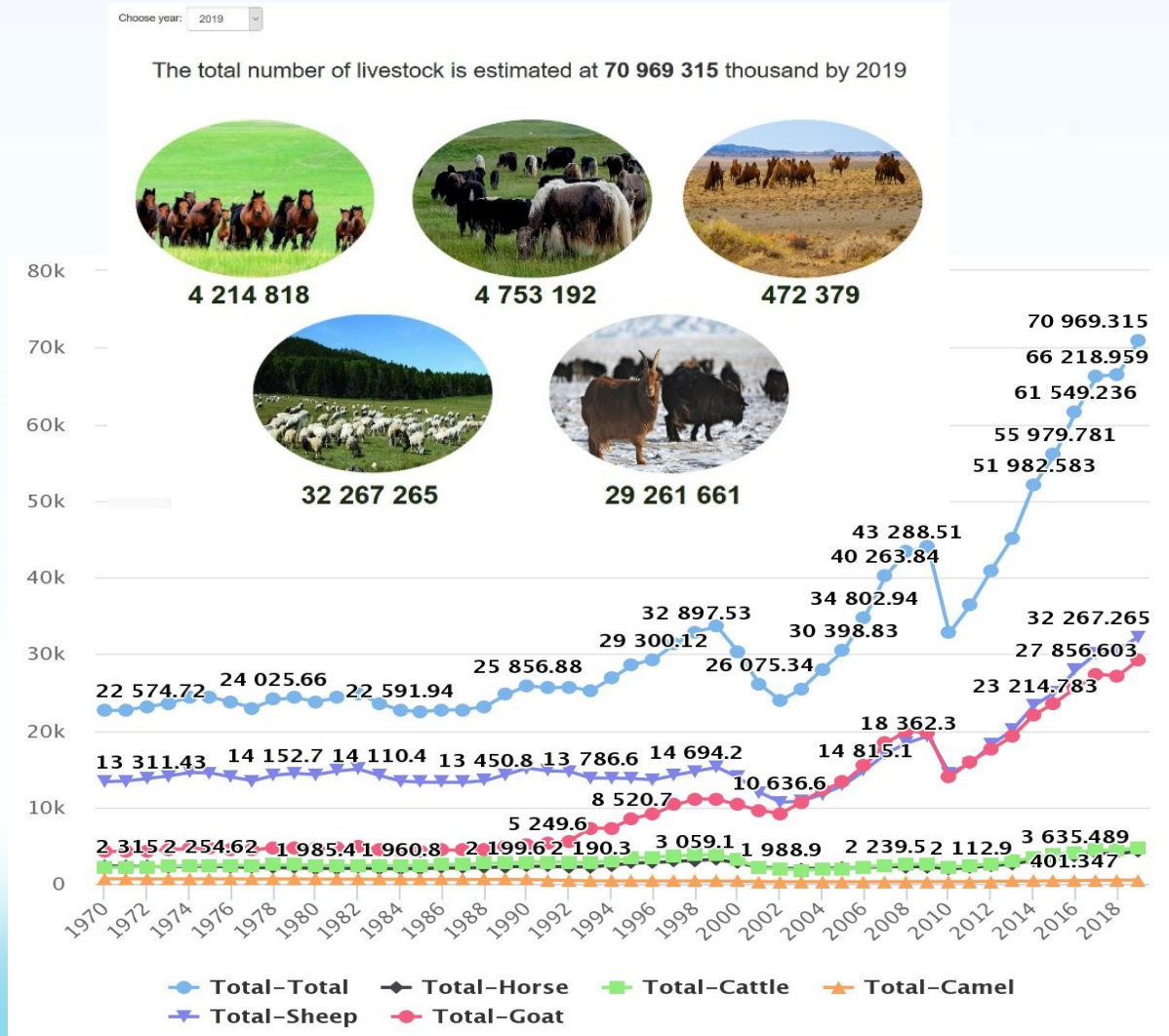


4. Results and discussion

➢ Socioeconomic factors

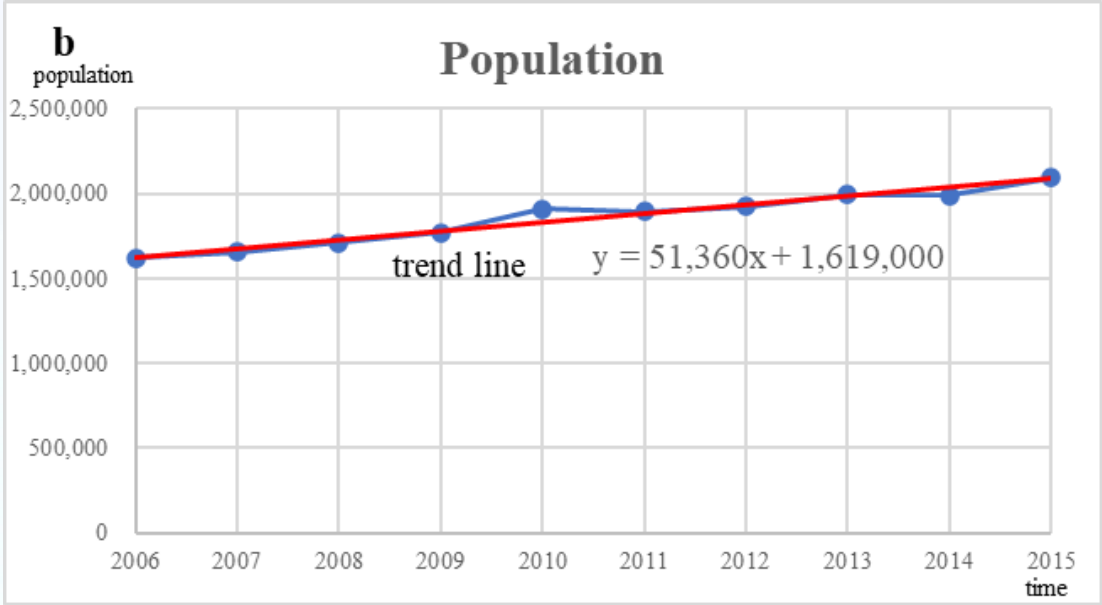
- **Overgrazing accelerated land degradation in Mongolia**. With the increase in both the international and domestic consumption of cashmere, the number of breeding Mongolian goats has increased by an estimated 3.3857 million over ten years between 2006 and 2015, with a growth rate of approximately 75.70%. This has resulted in serious overloading of pasture land.





4. Results and discussion

- The urban population of Mongolia increased by about 474,500 from 2006 to 2015, an increase of about 29.26%. Herdsmen have occupied significant amounts of land, and have built many family courtyard houses where people and their livestock (e.g. cattle, lambs, etc.) are living together. **This situation has caused inefficient land utilization, wasted significant land resources, and reduced the vegetation coverage of local areas, thereby increasing the risk of land degradation**.



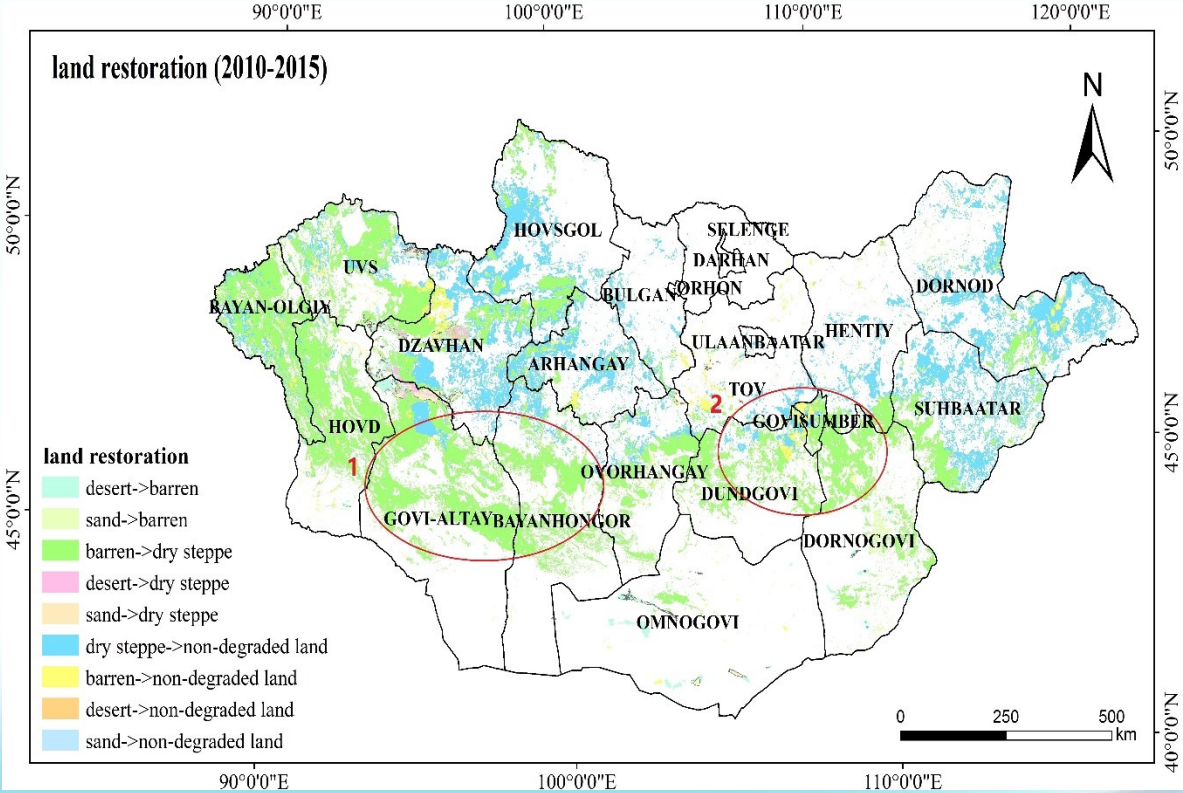
- **Excessive and unscientific mining activities by mining enterprises could also exacerbate land degradation**. Mongolia is an important exporter of mineral resources in Asia. Many mining enterprises are concentrated in a relatively small area, using relatively old mining technology, and the scale of mining has not been limited. Therefore, local surface vegetation has been destroyed, and the land surface structure has been modified, causing declining land quality and a serious land degradation problem.

4. Results and discussion

2) An analysis of the driving forces behind land restoration

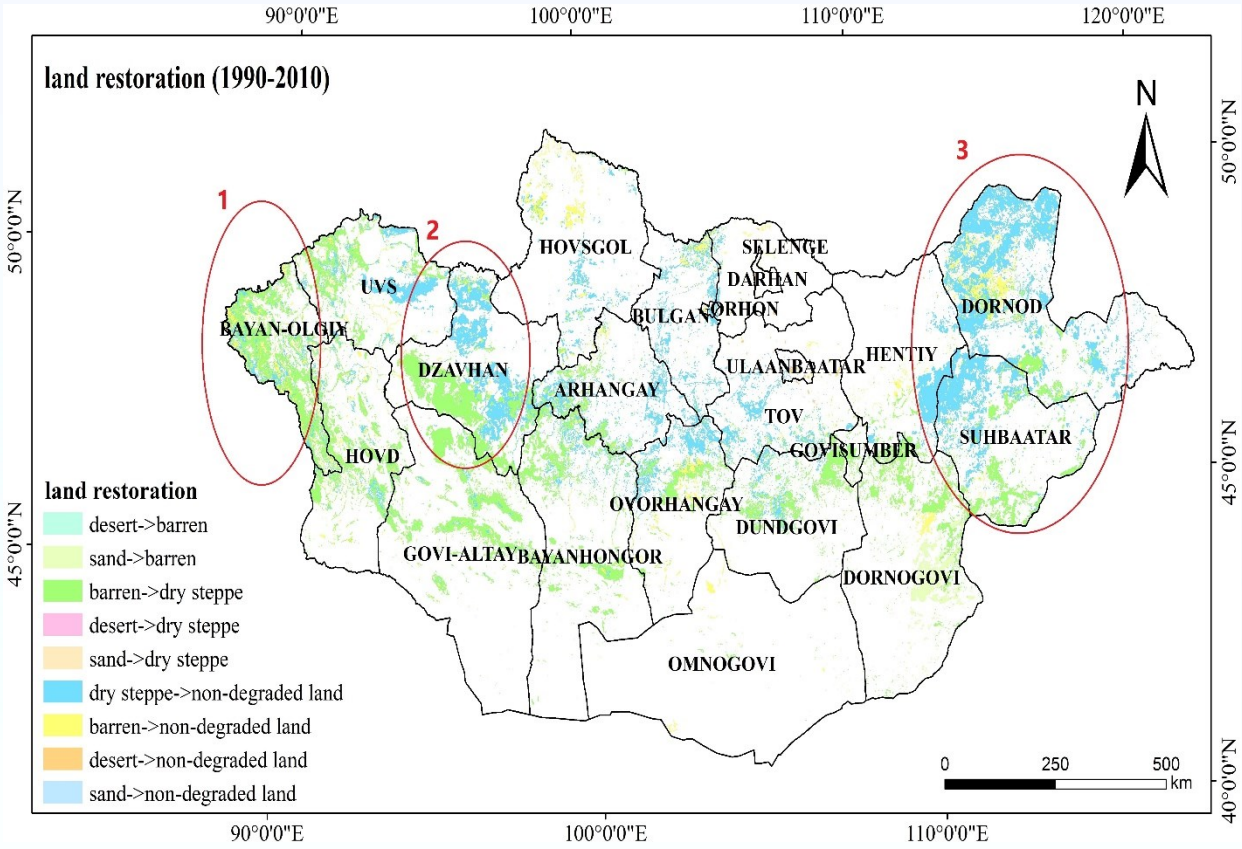
We found that land change in Mongolia presents a pattern of land degradation in overall and land restoration in local regions. In view of this characteristic, we took typical regions of land restoration as the entry point to complete the driving force analysis combined natural and socioeconomic factors.

- **Typical region 1：** The northeastern part of Govi-Altay is the source of many small rivers with abundant water resources. Since 2010, the annual average temperature in Govi-Altay and Bayanhongor has gradually risen above 0 ℃. Snow melt, in this region has begun to provide additional water for vegetation growth.
- **Typical region 2：** This region hosts the factories and mines of many international mining enterprises. However, the export of mineral products showed a declining trend in Mongolia between 2010 and 2015. This may reduce the degree of damage to land and providing an opportunity for land restoration in the region.



4. Results and discussion

- **Typical region 1：This snow melt also supplies relatively sufficient water to promote vegetation growth in some areas**. In addition, the number of livestock in this region has declined sharply between 1990 and 1993, with a proportional reduction of more than 80%. By 2015, the number of livestock only recovered to approximately 64 % of its number in 1990..
- **Typical region 2：** From 1990 to 2010, the population declined by 30% in Dzavhan. There was a relatively small population increase between 2010 and 2015. **As the population decreased, so did the impact of human activities, and the disturbance to the environment was not relatively marginal.**



- **Typical region 3：** As Mongolia is located inland, the **east Asian monsoon** only reaches the eastern edge of Mongolia. **It brings relatively sufficient precipitation to the east of Mongolia, which is conducive to vegetation growth and creates conditions for land restoration in this region.** In addition, the typical region 3 has flat terrain, numerous rivers and lakes, and abundant water resources.

5. Conclusions

- **For the past 25 years, land change in Mongolia has been dominated by land degradation.** However, land degradation was accompanied by ongoing restoration of some land areas, and the capacity for land restoration has gradually improved.

- **The results of land degradation and restoration monitoring indicate that the combined effect of natural and socioeconomic factors has resulted in land degradation in Mongolia**.
  - Significant fluctuations in temperature and reductions in precipitation are crucial factors. Overgrazing, excessive and irrational mining, rapid urbanization, and unplanned development of infrastructure all **contribute to land degradation**.
  - This study also infers that **global warming creates conditions** appropriate for land restoration in alpine snow regions, springs, river valleys, and other areas abundant in water resources. The east Asian monsoon provides the possibility of land restoration in the eastern border areas of Mongolia.
  - The decline of population and livestock **in the less developed areas** of the northeastern border regions have also contributed to land restoration in the region.

Thank you for your attention !

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