Trend analysis of Zagros forest dynamics and its responses to climate change: time series analysis using Google Earth Engine

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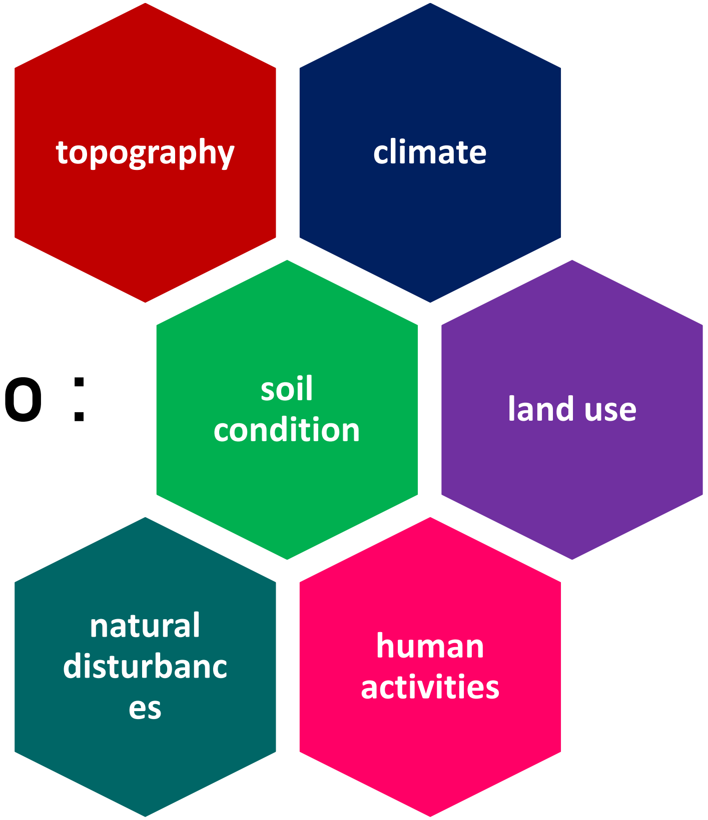
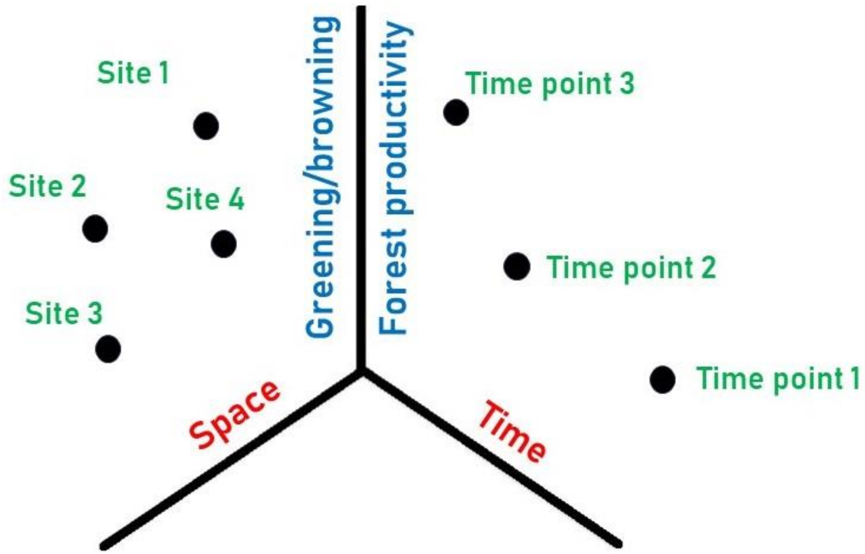
Content

Introduction : Forest dynamics

Changing patterns of vegetation growth and density **across different geographical** location and **time periods**.

Response to :





Introduction : spatiotemporal variation in forest dynamics

Abrupt

- significant changes
- occur rapidly
- often unpredictably.
- Wildfire, Storm, Landslides, …

Seasonal

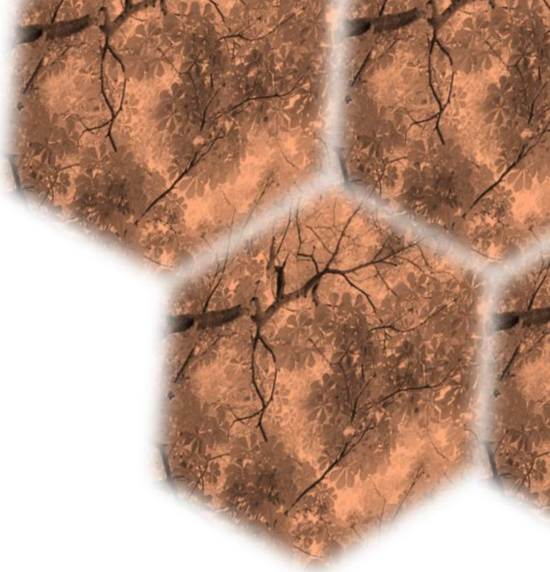
- surface phenological events

Next step: trends in phenological stages

Long-term

- gradual climate change such as temperature, precipitation, or changes due to some land management practices.

Introduction : greening and browning trends



Greening: a positive trend in vegetation health and productivity

Favorable environmental conditions:

Warmer temperatures, sufficient moisture, and increased atmospheric carbon dioxide levels.

Enhance:

Forest growth, expansion of forested areas, and improved ecosystem services.

Browning: negative trend in vegetation health and productivity

Unfavorable climatic condition + stressors and disturbances:

drought, heatwaves, nutrient deficiencies, pest outbreaks, diseases, and human disturbances

Weaken:

Forest growth, canopy density, foliage discoloration, dieback, or mortality, provision of ecosystem services

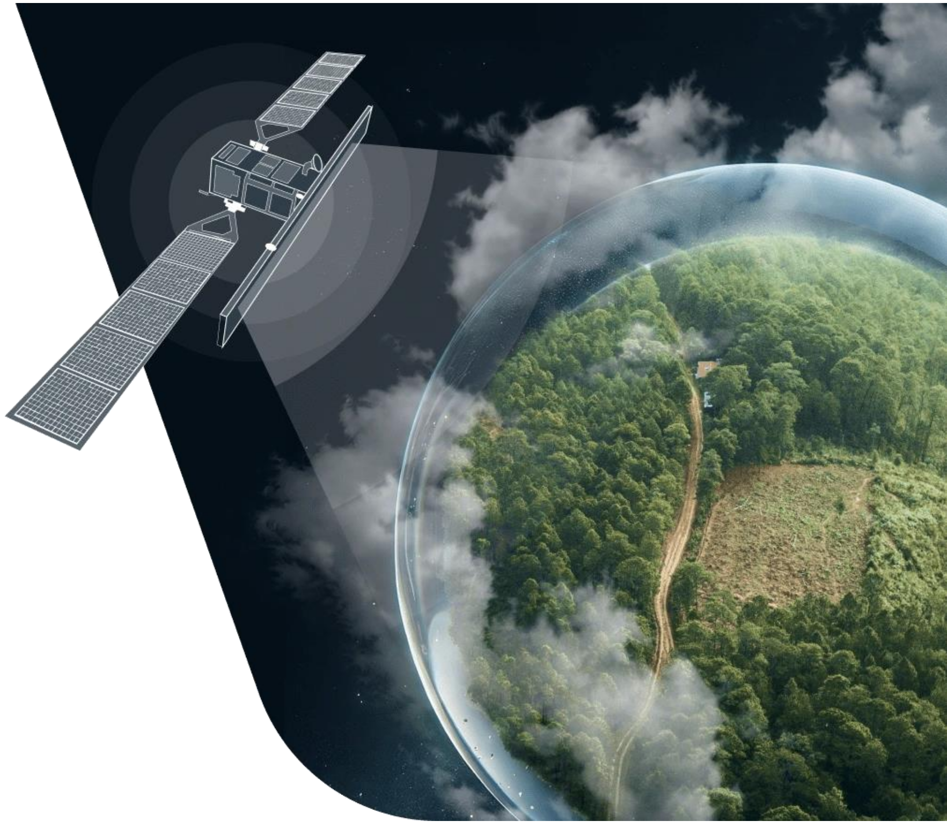
Introduction : large-scale monitoring and remote sensing

Greening and browning process:

- mostly visible at the landscape level
- necessitating a long-term and large-scale monitoring
- detecting changes in vegetation attributes as well as driving factors (Climate, disturbances, etc.)

⬇

- Satellite imagery
- Spatial statistical methods
- Computing platforms



Introduction : Objectives

- ✓ Assess greening and browning trends in the Zagros forest using time-series vegetation indices.
- ✓ Investigate of the spatial and temporal trends of climatic factors
- ✓ Determine how climatic and factors (LSTd, LSTn, ET, and Prec) are related to long-term trends in the greening and browning process

Materials and methods : Zagros forests

- **Elevation ranges between 650 and 2400 meters**
- **Annual precipitation varies between 600 and 800 mm**
- **Annual temperature fluctuates between 10 and 25 °C**
- **2 million of Iran's population live in this region**
- **Dominant tree species include *Persian oak (Quercus brantii), gall oak (Q. infectoria), wild pistachio (Pistacia atlantica),* and *Montpellier maple (Acer monspessulanum).***
- **Palynological studies by Van Zeist and Wright Jr (1963) and Safaeirad et al. (2014) have suggested that the pinnacle of development of these forests in their current form (i.e., oak forests) occurred 5500 to 6500 years ago.**








Materials and methods : Datasets (vegetation indices)

MOD13Q1.061 Terra Vegetation Indices 16-Day Global 250m

Dataset Availability

2000-02-18T00:00:00Z–2024-04-06T00:00:00Z

Dataset Provider

NASA LP DAAC at the USGS EROS Center

Earth Engine Snippet

`ee.ImageCollection("MODIS/061/MOD13Q1")`

Description | Bands | Terms of Use

Resolution
250 meters

Bands

Name	Units
NDVI	

MYD13Q1.061 Aqua Vegetation Indices 16-Day Global 250m

Dataset Availability

2002-07-04T00:00:00Z–2024-04-14T00:00:00Z

Dataset Provider

NASA LP DAAC at the USGS EROS Center

Earth Engine Snippet

`ee.ImageCollection("MODIS/061/MYD13Q1")`

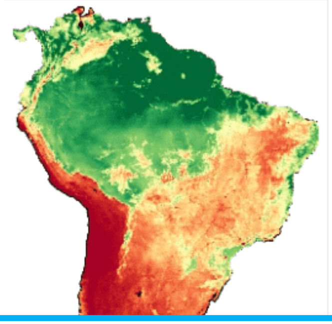
Description | Bands | Terms of Use

Resolution
250 meters

Bands

Name	Units
NDVI	

PML_V2 0.1.7: Coupled Evapotranspiration and Gross Primary Product (GPP)



Dataset Availability

2000-02-26T00:00:00Z–2020-12-26T00:00:00Z

Dataset Provider

PML_V2

Earth Engine Snippet

`ee.ImageCollection("CAS/IGSNRR/PML/V2_v017")`

Description | Bands | Terms of Use | Citations

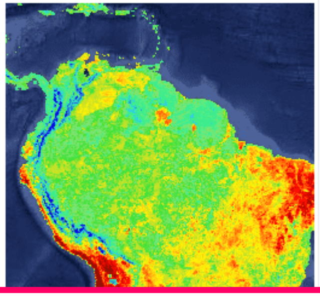
Resolution
500 meters

Bands

Name	Units	Min	Max
GPP	gC m-2 d-1	0*	39.01*

Materials and methods : Datasets (climatic factors)

MOD11A2.061 Terra Land Surface Temperature and Emissivity 8-Day Global 1km



Dataset Availability

2000-02-18T00:00:00Z–2024-04-22T00:00:00Z

Dataset Provider

NASA LP DAAC at the USGS EROS Center

Earth Engine Snippet

```
ee.ImageCollection("MODIS/061/MOD11A2")
```

Description | Bands | Terms of Use | Citations | DOIs

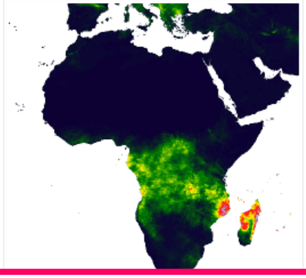
Resolution

1000 meters

Bands

Name	Units	Min	Max
LST_Day_1km	K	7500	65535
LST_Night_1km	K	7500	65635

CHIRPS Daily: Climate Hazards Group InfraRed Precipitation With Station Data (Version 2.0 Final)



Dataset Availability

1981-01-01T00:00:00Z–2024-03-31T00:00:00Z

Dataset Provider

UCSB/CHG

Earth Engine Snippet

```
ee.ImageCollection("UCSB-CHG/CHIRPS/DAILY")
```

Description | Bands | Terms of Use | Citations

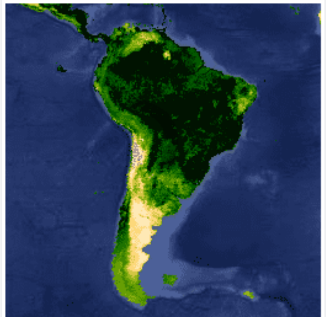
Resolution

5566 meters

Bands

Name	Units
precipitation	mm/d

MOD16A2.061: Terra Net Evapotranspiration 8-Day Global 500m



Dataset Availability

2001-01-01T00:00:00Z–2024-04-14T00:00:00Z

Dataset Provider

NASA LP DAAC at the USGS EROS Center

Earth Engine Snippet

```
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```

Description | Bands | Terms of Use | Citations | DOIs

Resolution

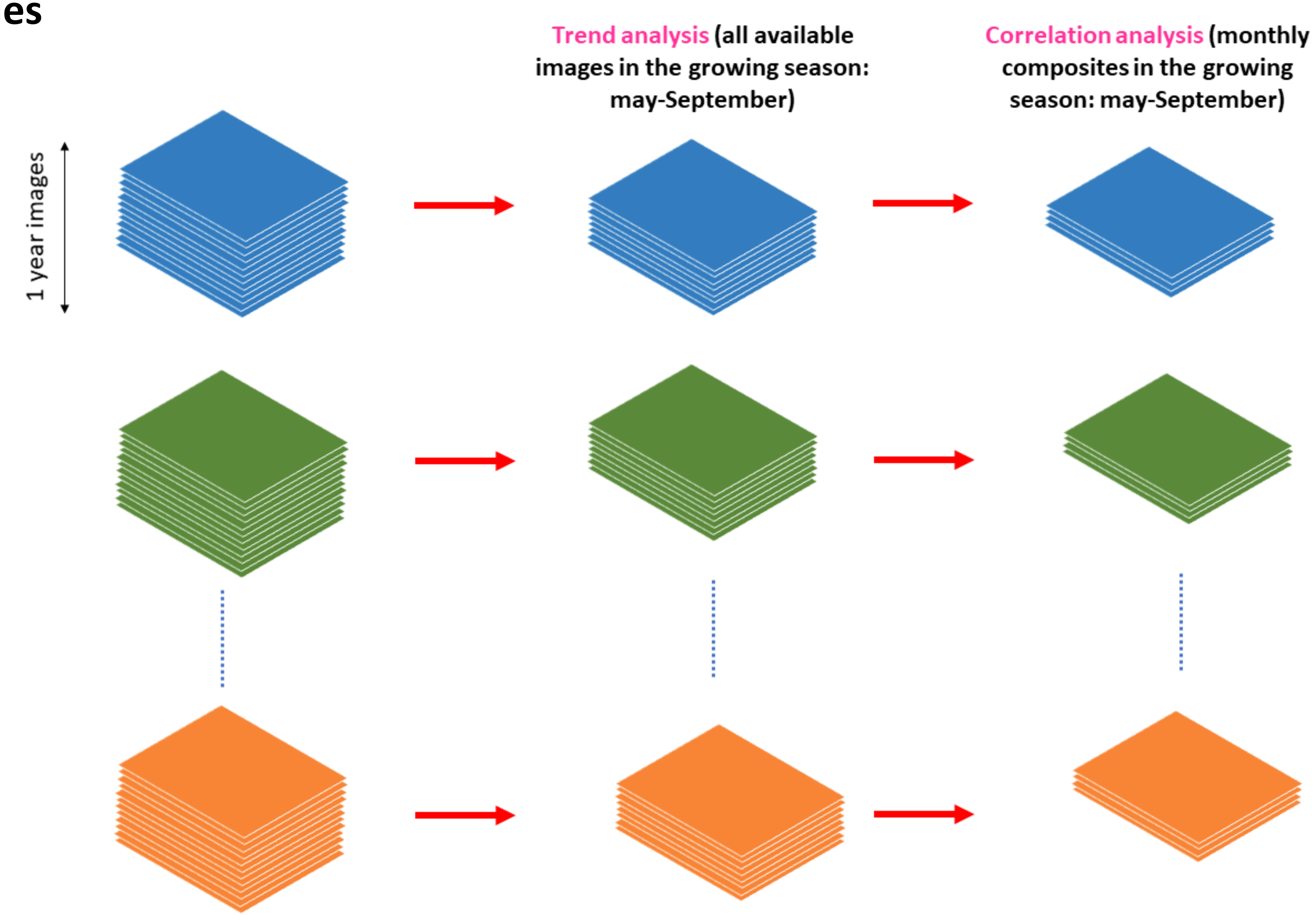
500 meters

Bands

Name	Units	Min	Max
ET	kg/m^2/8day	-32767	32700

Materials and methods : Datasets

Aggregation of time series



Materials and methods : Statistical methods (pixel level)

- Trend analysis: Mann-Kendall trend test

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_i - x_j)$$

$$sgn(x) = \begin{cases} +1 & if \quad (x_i - x_j) > 0 \\ 0 & if \quad (x_i - x_j) = 0 \\ -1 & if \quad (x_i - x_j) < 0 \end{cases}$$

$$\tau = \frac{2s}{n(n-1)}$$

$$Var(S) = \frac{x(x-1)(2x+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18}$$

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{var(S)}} & for \quad S > 0 \\ 0 & for \quad S = 0 \\ \frac{S+1}{\sqrt{var(S)}} & for \quad S < 0 \end{cases}$$

- The Pearson's correlation relationship between VIs (EVI and GPP) and climatic-hydrological factors (PRE, LSTd, LSTn, ET)

$$r_{VI,CF} = \frac{\sum_{i=1}^{n}(VI_i - \overline{VI})(CF_i - \overline{CF})}{\sqrt{\sum_{i=1}^{n}(VI_i - \overline{VI})^2 \sum_{i=1}^{n}(CF_i - CF)^2}}$$

The correlation was computed within the same month and with increasing backward time lags: one-month lag, two-month lag, and three-month lag.

x_i and x_j are the dataset amounts in time points *i* and *j* (*j*>*i*) respectively, *n* is the number of input data sets, *S* is the Kendall score, *τ* range is between -1 and +1, with -1 denoting a regularly declining trend or increasing trend, *Var(S)* represents the variance *S* and *Z_s* indicates the *Z* statistic.

$r_{VI,CF}$ is the correlation coefficient, *n* is the number of the observation in time series); *i* is the time ; VI_i and CF_i are the vegetation index and climatic factor respectively in time *i*; $\overline{VI}$ is the mean of the vegetation index and $\overline{CF}$ is the mean of the climatic factor.

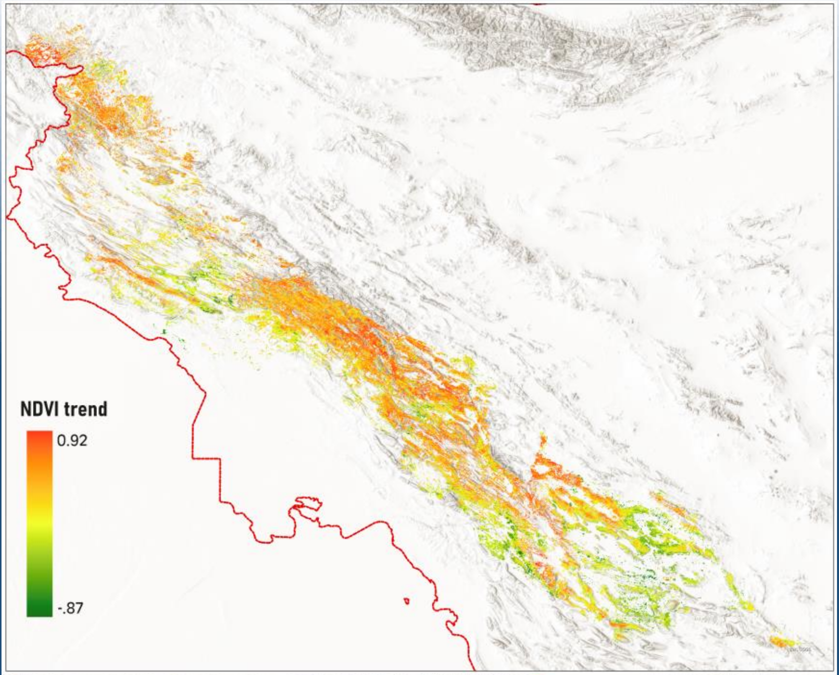
Results: Trend analysis

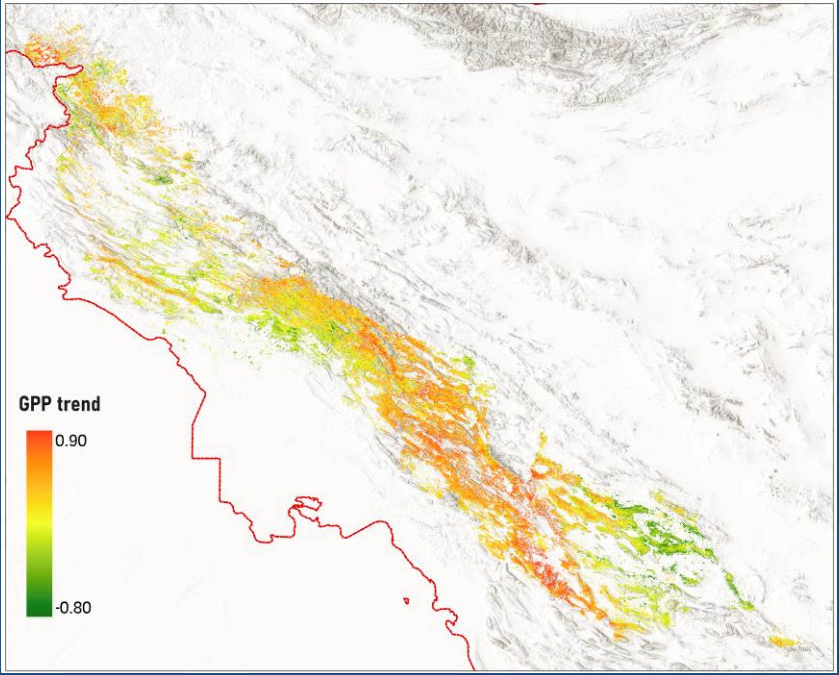
Trends in NDVI and GPP

		GPP (ha)	GPP %	NDVI (ha)	NDVI %
Significant Mann–Kendall (level of significance = 0.05)	Significant decreasing trend	77,031.25	1.28	44,475	0.74
	Insignificant decreasing trend	528,331.25	8.79	280,950	4.67
	stable	34,468.75	0.57	26,243.75	0.44
	Insignificant increasing trend	1,874,118.75	31.17	1,465,218.75	24.37
	Significant increasing trend	3,498,068.75	58.18	4,196,656.25	69.79

89.35 %

94.16 %



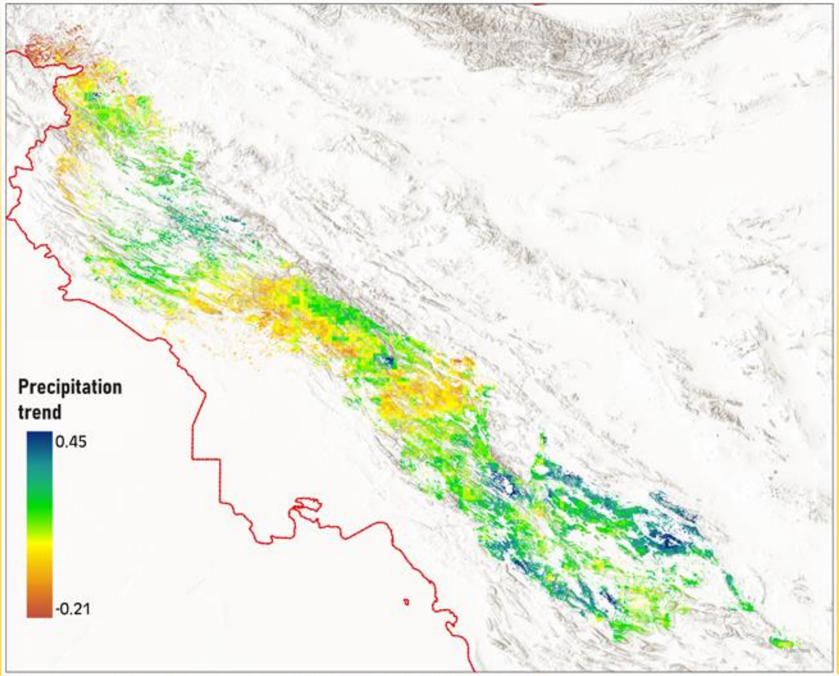


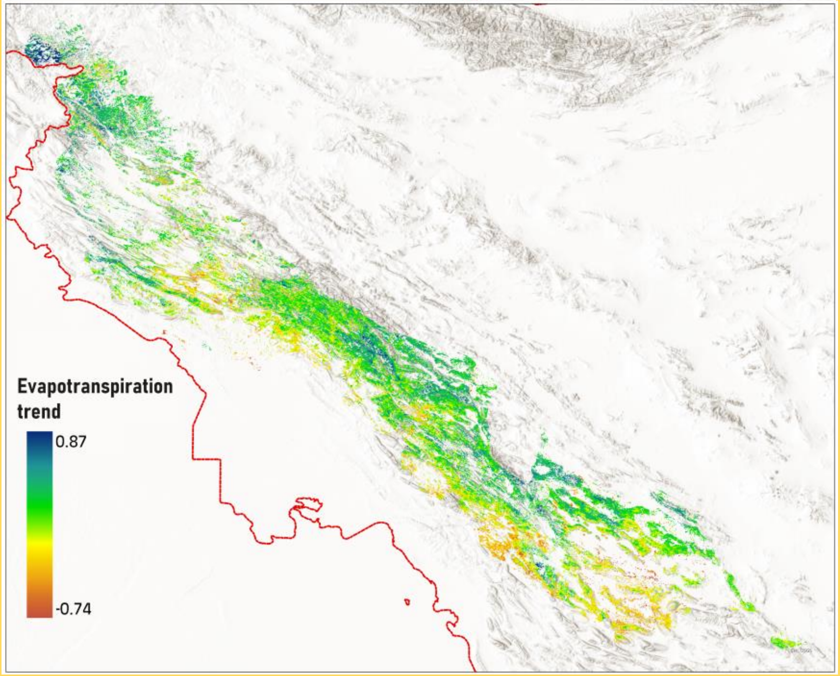
Results: Trend analysis

Trends in evapotranspiration (ET) and precipitation (prec)

		ET (ha)	ET %	P (ha)	P%
Mann–Kendall Significant Mann–Kendall (level of significance = 0.05)	Significant decreasing trend	17,400	0.29	0	0
	Insignificant decreasing trend	286,300	4.75	126,050	2.09
	stable	37,600	0.62	25,550	0.42
	Insignificant increasing trend	3,247,000	53.92	5,672,875	94.27
	Significant increasing trend	2,433,825	40.41	192,925	3.21

94.33 %   97.48 %





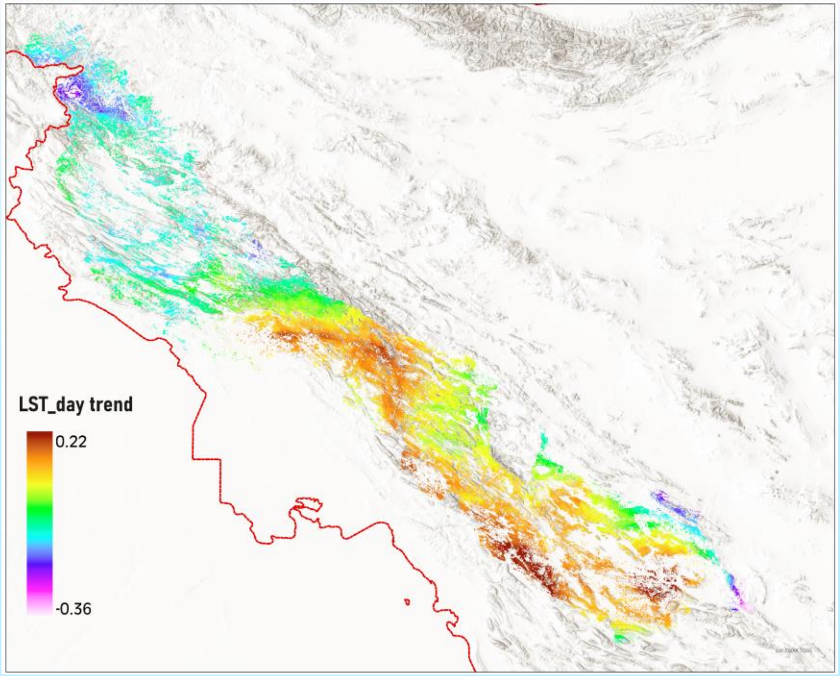
Results: Trend analysis

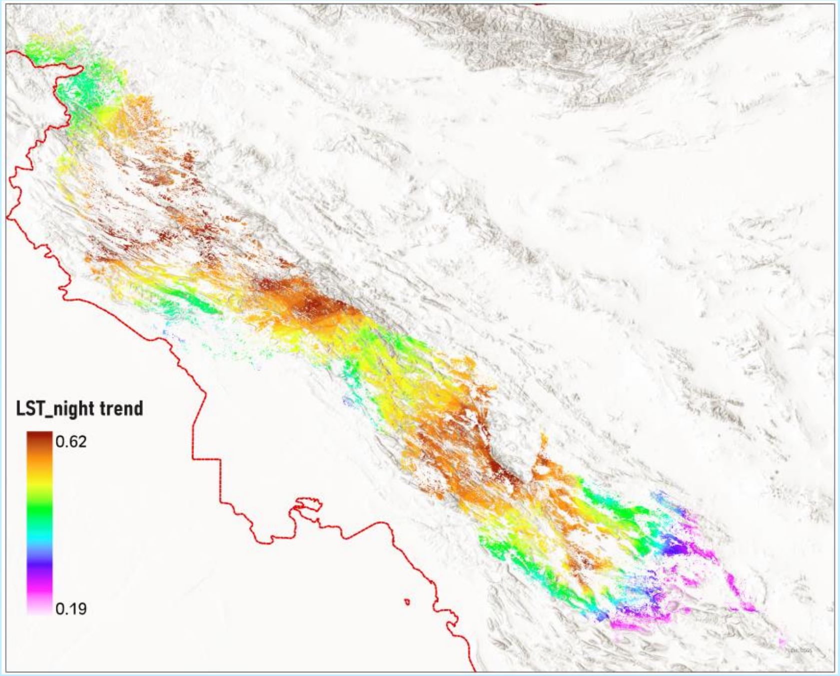
Trends during 2001-2024 in day time LST (LST-D) and night time LST (LST-N)

		LST_D (ha)	LST_D %	LST_N (ha)	LST_N %
Significant Mann–Kendall Significant Mann–Kendall (level of significance = 0.05)	Significant decreasing trend	0	0	0	0
	Insignificant decreasing trend	1,694,050	28.15	0	0
	stable	100,950	1.68	0	0
	Insignificant increasing trend	4,199,175	69.78	52,900	0.88
	Significant increasing trend	23,225	0.39	5,9645,00	99.12

70.17 %

100 %

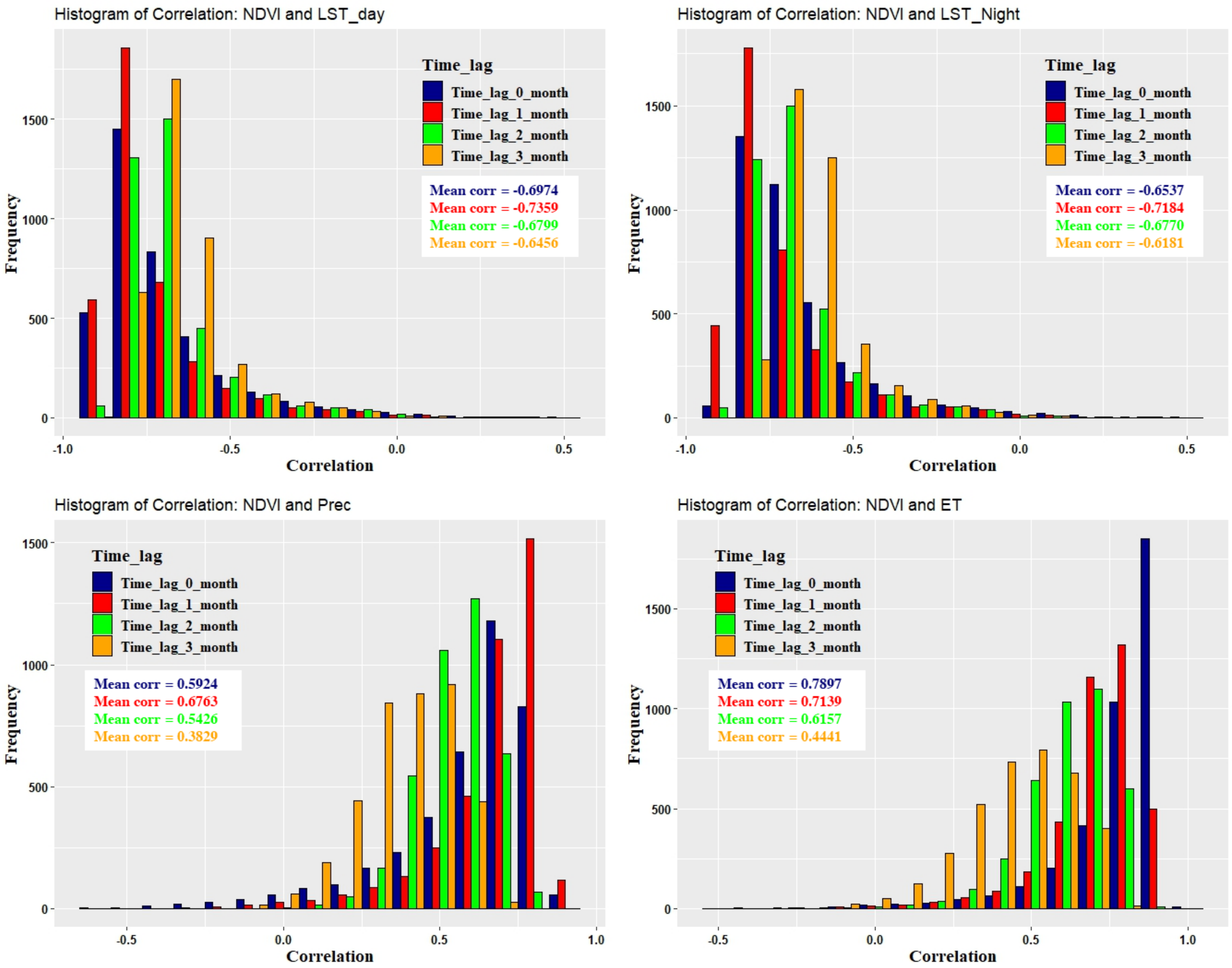




Results: Correlation and time lag analysis (NDVI)

NDVI and climatic factors:

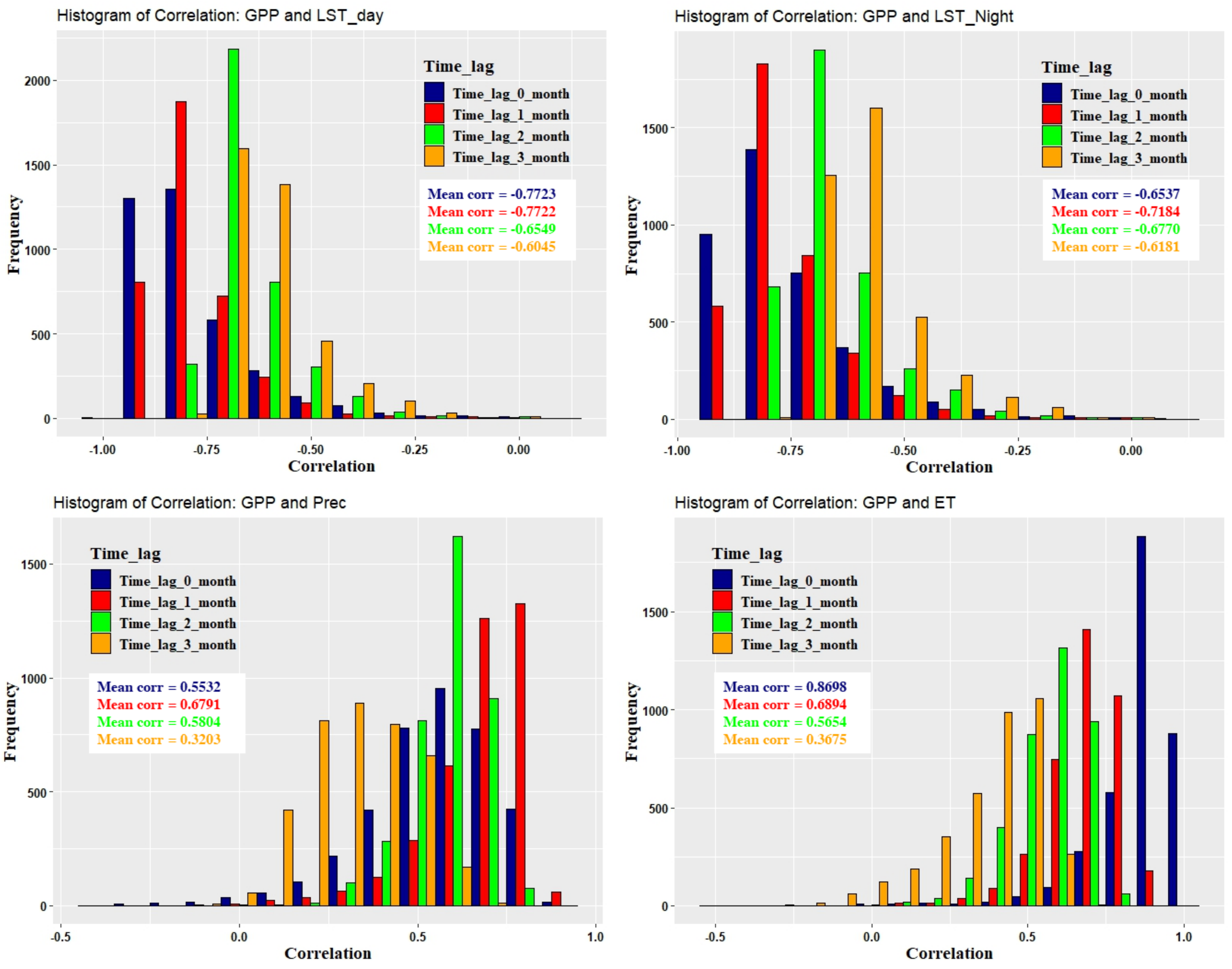
- Negative correlation between LST (day and night) and NDVI
- Positive correlation between precipitation and evapotranspiration with NDVI
- Highest correlation = NDVI & ET (0.7897)
- There is no time lag effect between NDVI and ET in most parts of the study area.
- The highest correlation between LST (day and night) and NDVI was observed with a one-month time lag.
- The highest correlation between precipitation and NDVI was observed with a one-month time lag.
- The impact of precipitation on vegetation growth diminishes more rapidly over time compared to the impact of land surface temperature.



Results: Correlation and time lag analysis (GPP)

GPP and climatic factors:

- Negative correlation between LST (day and night) and GPP
- Positive correlation between precipitation and evapotranspiration with GPP
- Highest correlation = GPP & ET (0.8698)
- There is no time lag effect between GPP and ET in most parts of the study area.
- The highest correlation between LST (day and night) and GPP was observed with a one-month time lag.
- The highest correlation between precipitation and GPP was observed with a one-month time lag.
- The impact of precipitation and evapotranspiration on GPP diminishes more rapidly over time compared to the impact of land surface temperature.



Discussion and Conclusion:

- **An increase trend was observed in the quantity and productivity of the Zagros forests.**

These findings are in connection with (Emmett et al. 2019; Tian et al. 2021; Zhu et al. 2023).

- **A greening trend is related to increased precipitation, warmer temperatures, and higher levels of CO_2 in the atmosphere, which stimulate photosynthesis and plant growth.**

An increasing trend in temperature, precipitation, and evapotranspiration has been detected.

- **In some parts of the study area, a decreasing trend or browning trend was observed (6-10% of the study area)**

- **A browning trend can be related to insect infestation, disease outbreaks, wildfires, and human activities.**

We don't have such dataset to identify the exact drivers, but based on our knowledge from the study area, there are such disturbances in Zagros forests.

Discussion and Conclusion:

- **Advantage of the datasets:** A dense time series, with a temporal resolution of 1-8 days, can help account for all of the small changes.

- **Limitation of the datasets:** The coarse spatial resolution of the dataset used may not capture fine-scale vegetation changes or variations in climatic conditions within heterogeneous landscapes.

- Based on the results, the GEE can be considered as a powerful data source and processing platform for long-term vegetation dynamics and climate change analysis.

Thank you

Contact :

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Trends during 2001-2024 in NDVI and GPP

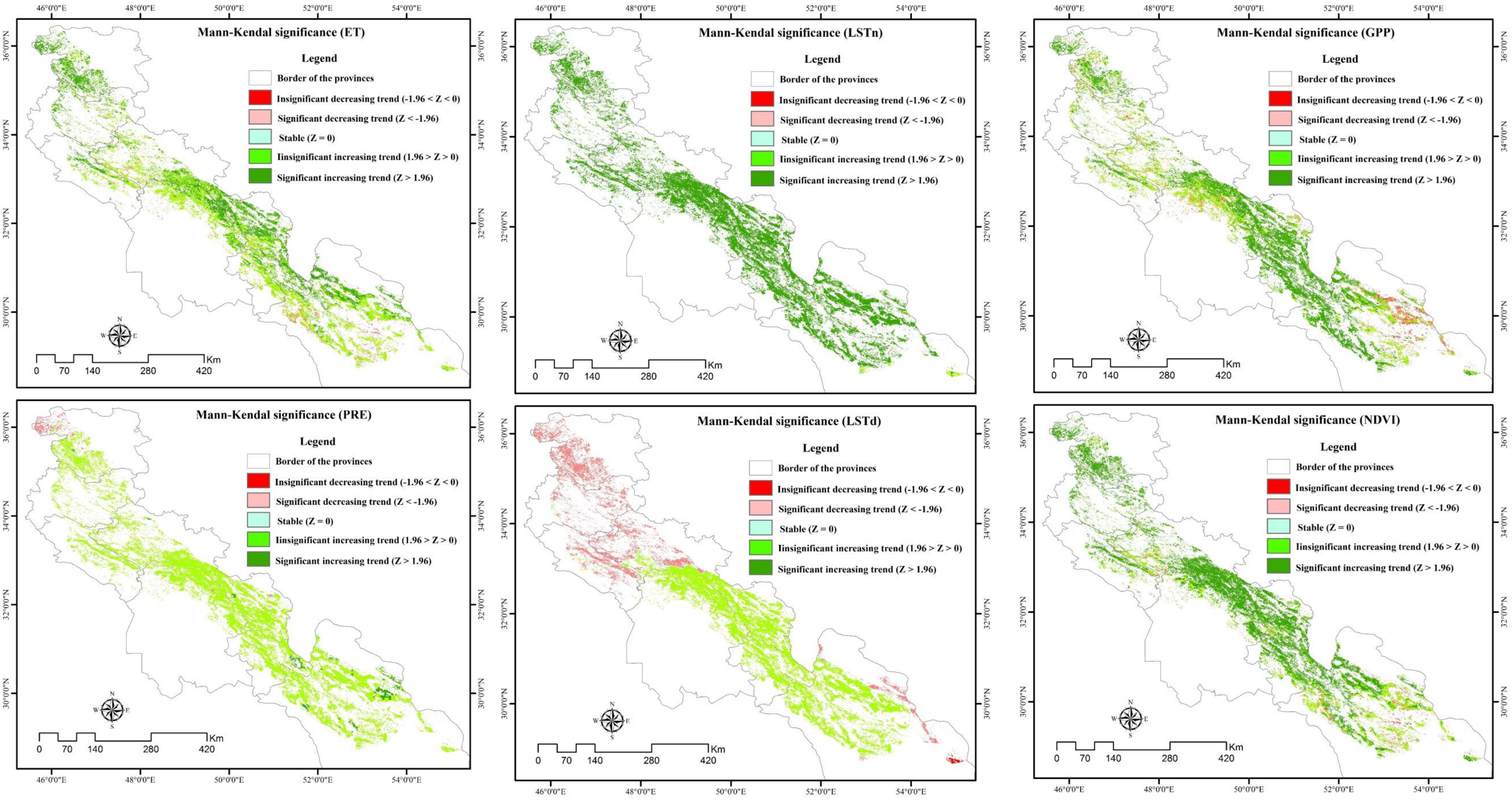
	Increasing trend (greening)		Decreasing trend (browning)	
	Area (ha)	% of ZF	Area (ha)	% of ZF
NDVI	4,827,026.57	94.33	289,868.02	5.66
GPP	4,552,754.152	88.97	564,140.44	11.03

Trends during 2001-2024 in evapotranspiration (ET) and precipitation (prec)

	Increasing trend (greening)		Decreasing trend (browning)	
	Area (ha)	% of ZF	Area (ha)	% of ZF
ET	4,828,609.59	98.53	288,285.00	1.43
prec	4,993,071.35	97.58	123.823.24	2.41

Trends during 2001-2024 in day time LST (LST-D) and night time LST (LST-N)

	Increasing trend (greening)		Decreasing trend (browning)	
	Area (ha)	% of ZF	Area (ha)	% of ZF
LST-D	3,577,607.19	69.92	1,539,287.41	30.08
LST-N	5,116,894.60	100	-	-


Mann-Kendal significance (ET)
Legend
Border of the provinces
Insignificant decreasing trend (-1.96 < Z < 0)
Significant decreasing trend (Z < -1.96)
Stable (Z = 0)
Iinsignificant increasing trend (1.96 > Z > 0)
Significant increasing trend (Z > 1.96)
0 70 140 280 420 Km
Mann-Kendal significance (LSTn)
Legend
Border of the provinces
Insignificant decreasing trend (-1.96 < Z < 0)
Significant decreasing trend (Z < -1.96)
Stable (Z = 0)
Iinsignificant increasing trend (1.96 > Z > 0)
Significant increasing trend (Z > 1.96)
0 70 140 280 420 Km
Mann-Kendal significance (GPP)
Legend
Border of the provinces
Insignificant decreasing trend (-1.96 < Z < 0)
Significant decreasing trend (Z < -1.96)
Stable (Z = 0)
Iinsignificant increasing trend (1.96 > Z > 0)
Significant increasing trend (Z > 1.96)
0 70 140 280 420 Km
Mann-Kendal significance (PRE)
Legend
Border of the provinces
Insignificant decreasing trend (-1.96 < Z < 0)
Significant decreasing trend (Z < -1.96)
Stable (Z = 0)
Iinsignificant increasing trend (1.96 > Z > 0)
Significant increasing trend (Z > 1.96)
0 70 140 280 420 Km
Mann-Kendal significance (LSTd)
Legend
Border of the provinces
Insignificant decreasing trend (-1.96 < Z < 0)
Significant decreasing trend (Z < -1.96)
Stable (Z = 0)
Iinsignificant increasing trend (1.96 > Z > 0)
Significant increasing trend (Z > 1.96)
0 70 140 280 420 Km
Mann-Kendal significance (NDVI)
Legend
Border of the provinces
Insignificant decreasing trend (-1.96 < Z < 0)
Significant decreasing trend (Z < -1.96)
Stable (Z = 0)
Iinsignificant increasing trend (1.96 > Z > 0)
Significant increasing trend (Z > 1.96)
0 70 140 280 420 Km