Grass Curing-Driven Fire Danger Mapping in Mountainous Grasslands Using Fused Satellite Data

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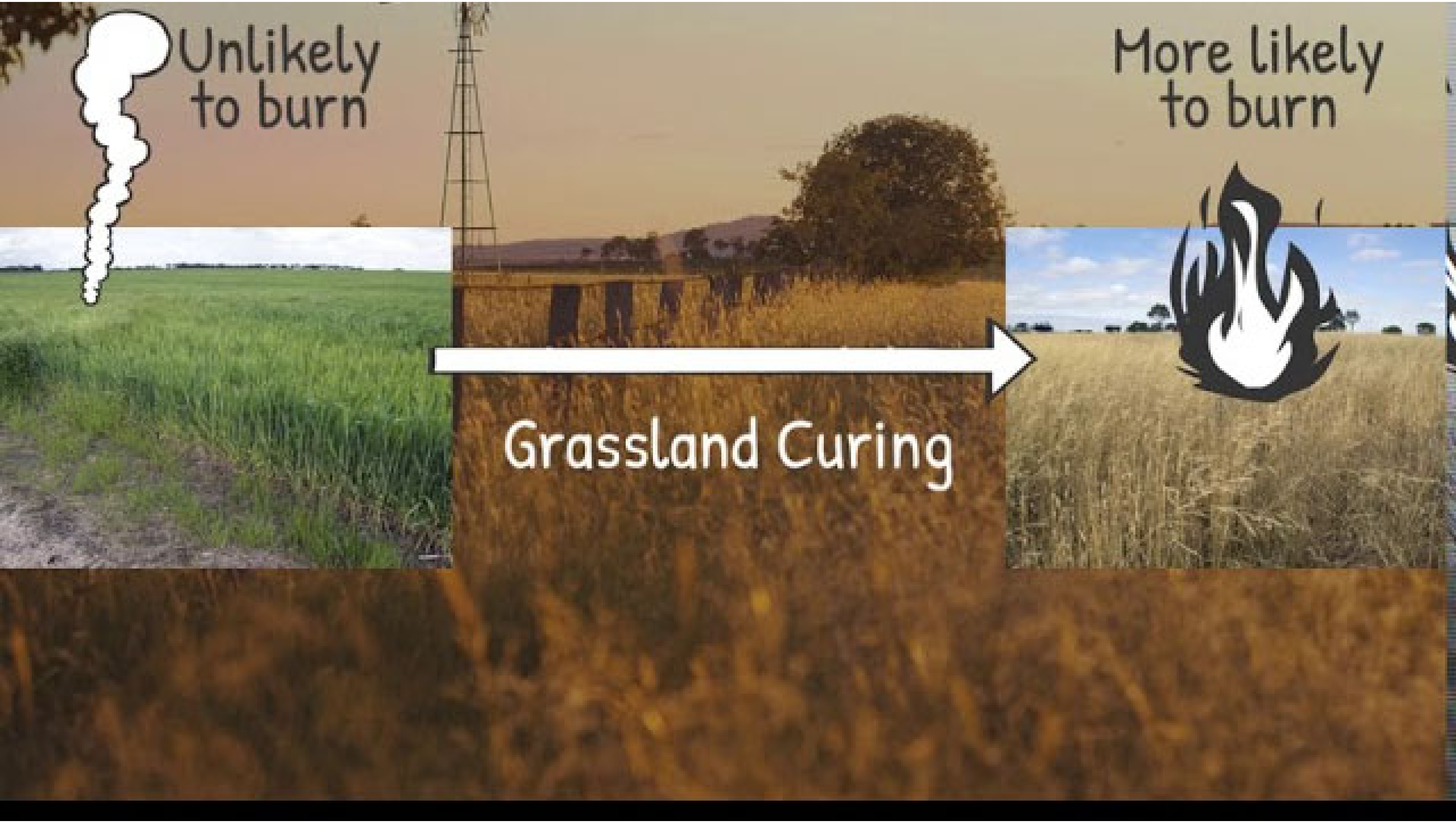

Unlikely to burn
More likely to burn
Grassland Curing

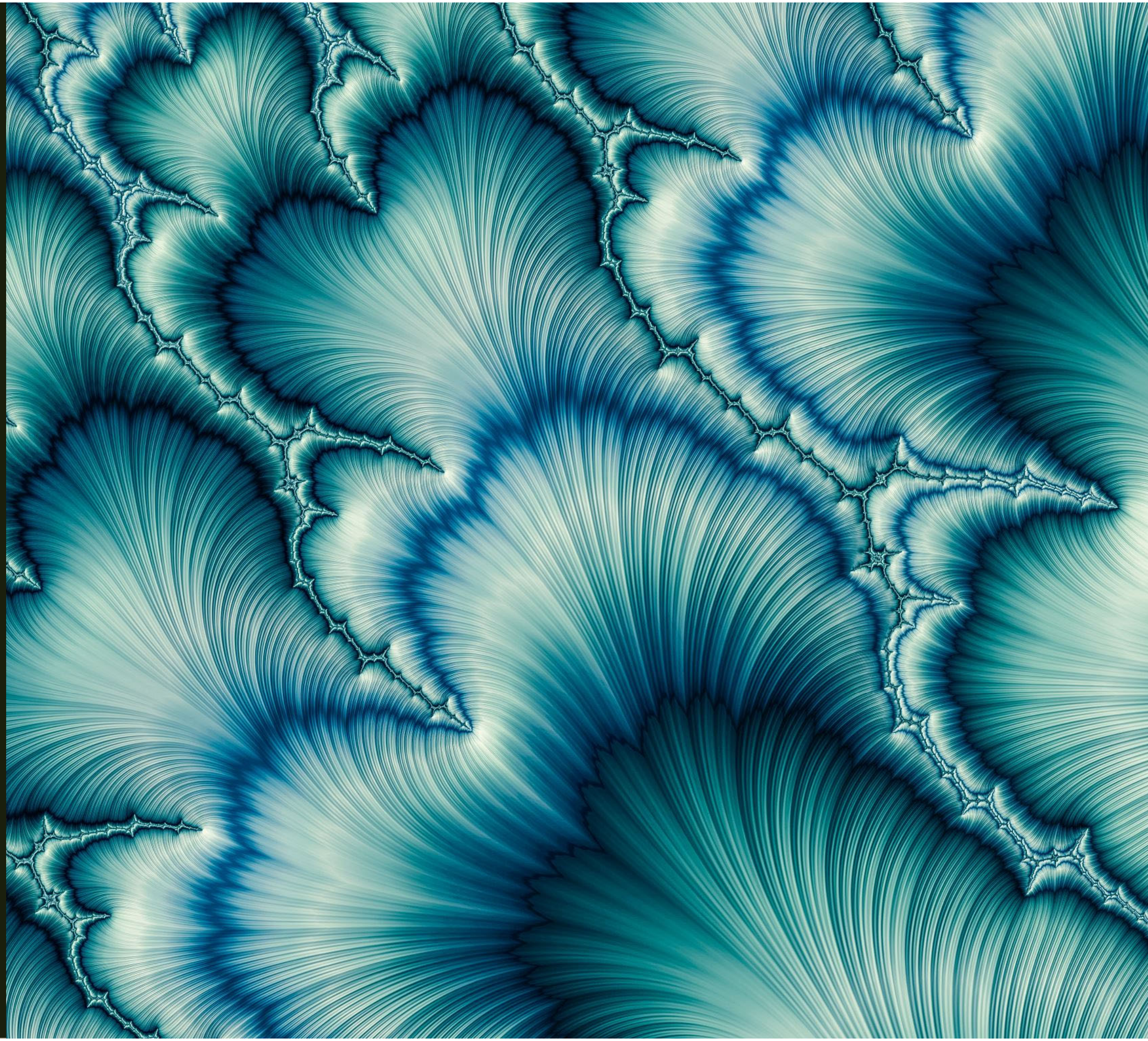
Introduction

- Hence, grass curing signifies the process of grass senescence, signifying the natural decay and marking the shift of live fuels into the dead component within the fuel bed

- Before the advent of remote sensing techniques, two direct field methods, destructive sampling and visual observation, were solutions to measure the degree of curing (DoC).

Introduction

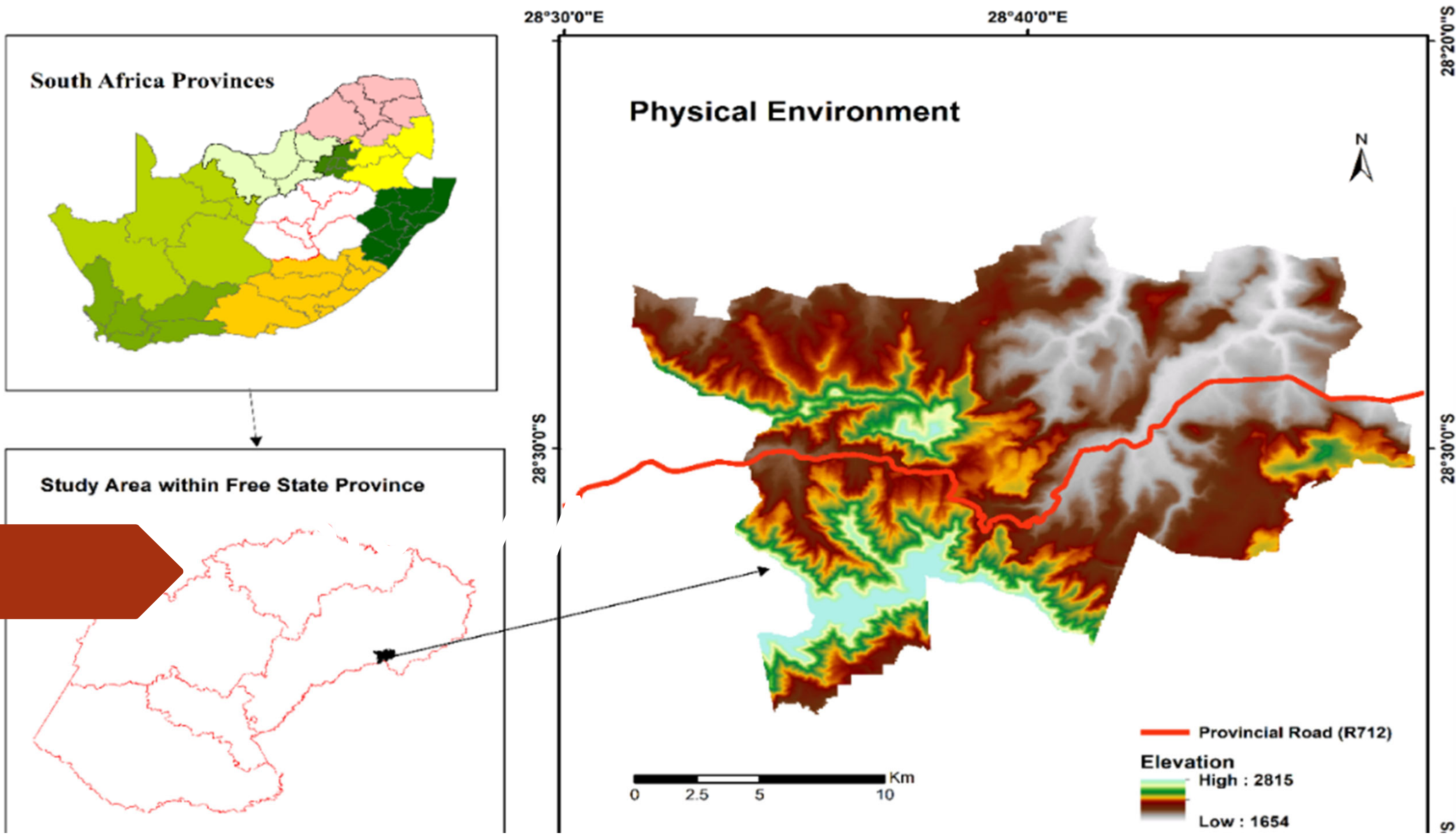
- AVHRR and MODIS
- NDVI
- GVMI
- NDWI



Introduction

- Fusion techniques
- STDFA (Wu et al. 2012),
- ESTARFM
- ISTDFA (Wu et al. 2015, 2018)
- FSDAF (Meng et al. 2019).

- Jarihani et al. (2014) and Wu et al. (2015) found that index fusion strategies outperform reflectance fusion strategies, particularly when applied to NDVI data.


South Africa Provinces
Study Area within Free State Province
Physical Environment
28°30'0"E
28°40'0"E
28°20'0"S
28°30'0"S
N
Provincial Road (R712)
Elevation
High : 2815
Low : 1654
0
2.5
5
10
Km

Methodology

- The study utilizes **remote sensing data from MODIS Terra MOD09A1 Version 6 product** and **Sentinel −2 multispectral imager (MSI) level-1C from 2016 to 2020** to assess grass curing and fire danger in the GGHNP.
- **Specifically, the study employs the Index-then-Blend (IB) data fusion method on the Google Earth Engine (GEE) platform to combine the strengths of both satellite datasets.**
- **This process involves calculating various vegetation and soil moisture indices, such as the NDVI, GVMI, NDMI, SIWSI, and SWCI, from the spectral bands of the satellite imagery.**

Table 1. Selected Optical Vegetation and Soil Moisture Indices

Index	Equation		References
	Sentinel-2	MODIS	
Normalized Difference Vegetation Index (NDVI)	$NDMI = \frac{B8-B4}{B8+B4}$	$NDMI = \frac{B2-B1}{B2+B1}$	Rouse Jr et al. (1974)
Global Vegetation Moisture Index (GVMI)	$GVMI = \frac{(B8+0.1)-(B11+0.02)}{(B8+0.1)+(B11+0.02)}$	$GVMI = \frac{(B2+0.1)-(B6+0.02)}{(B2+0.1)+(B6+0.02)}$	Ceccato et al. (2002)
Normalized Difference Moisture Index (NDMI)	$NDMI = \frac{B8-B11}{B8+B11}$	$NDMI = \frac{B2-B6}{B2+B6}$	Gao (1996); Wilson and Sader (2002)
Shortwave Infrared Water Stress Index (SIWSI)	$SIWSI = \frac{B11-B8}{B11+B8}$	$SIWSI = \frac{B6-B2}{B6+B2}$	Fensholt and Sandholt (2003)
Surface Water Capacity Index (SWCI)	$SWCI = \frac{B11-B12}{B11+B12}$	$SWCI = \frac{B6-B7}{B6+B7}$	Chen et al. (2009); Du et al. (2007)

Methodology

- Using these indices, the study computes the Grassland Curing Index (GCI) and generates Grassland Curing Maps (GCMs).
- ***GCI estimation using GVMI (GCI_GVMI):*** ***(Martin et al., 2015)***

$$Curing = (NDVI * -88.41) + (GVMI * -67.71) + 113.80 \dots\dots\dots\dots(1)$$

- ***GCI estimation using NDMI (GCI_NDMI):*** ***(Xiao et al., 2002; Chandrasekar et al., 2022)***

$$Curing = (NDVI * -88.41) + (NDMI * -67.71) + 113.80 \dots\dots\dots\dots(2)$$

- ***GCI estimation using SIWSI (GCI_SIWSI):*** ***(Fensholt and Sandholt., 2003)***

$$Curing = (NDVI * -88.41) + (SIWSI * -67.71) + 113.80 \dots\dots\dots\dots(3)$$

- ***GCI estimation using SWCI (GCI_SWCI):*** ***(Du et al. 2007)***

$$Curing = (NDVI * -88.41) + (SWCI * -67.71) + 113.80 \dots\dots\dots\dots(4)$$

- Generation of Fire Danger Maps
- Active fire points were used for accuracy assessment of the developed fire danger GCMs.

Methodology

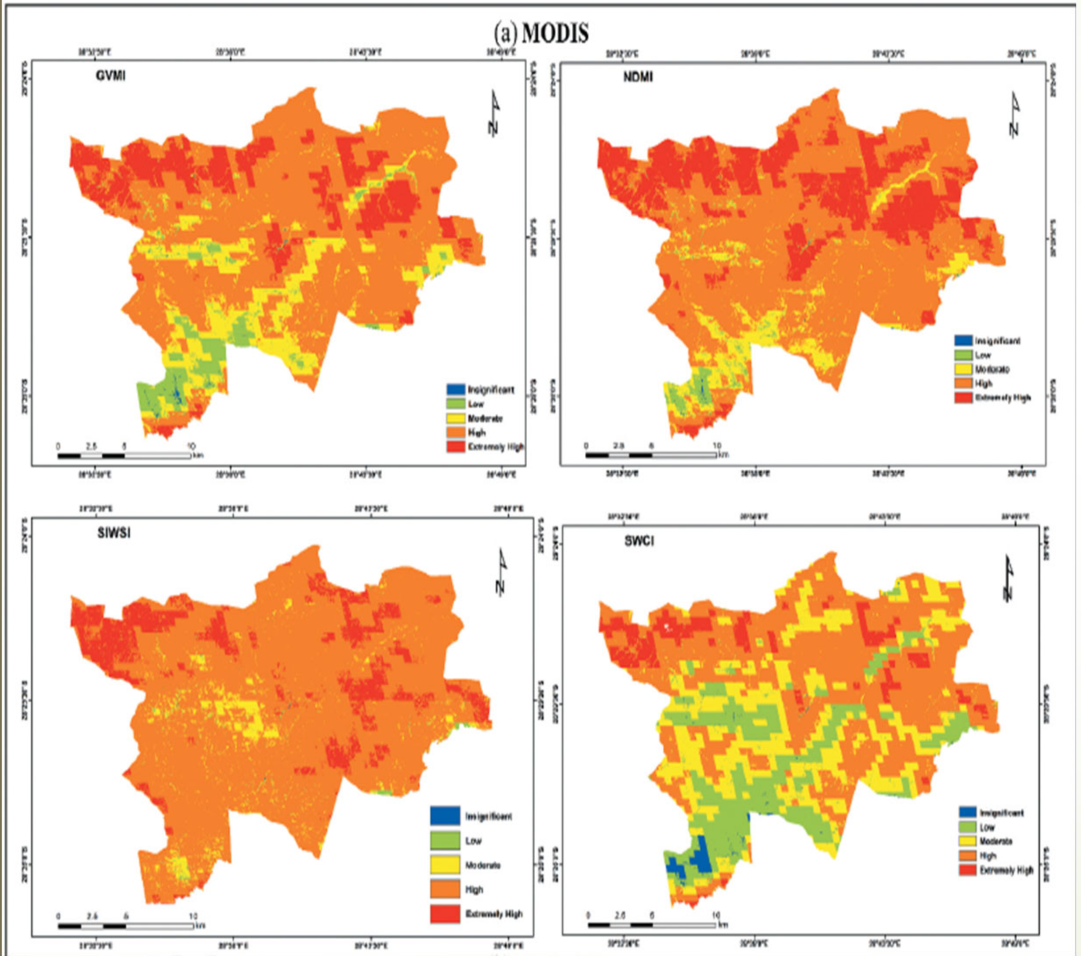
- The active fire points were overlaid to fire danger GCMs to evaluate the accuracy of danger maps using Zonal Statistics spatial analyst tool of ArcMap 10.7.

- Fire point data were then joined using Spatial Join Analysis tool of ArcMap with delineated study area polygons to create a binary layer (10m) indicating the presence and absence of fire polygons.

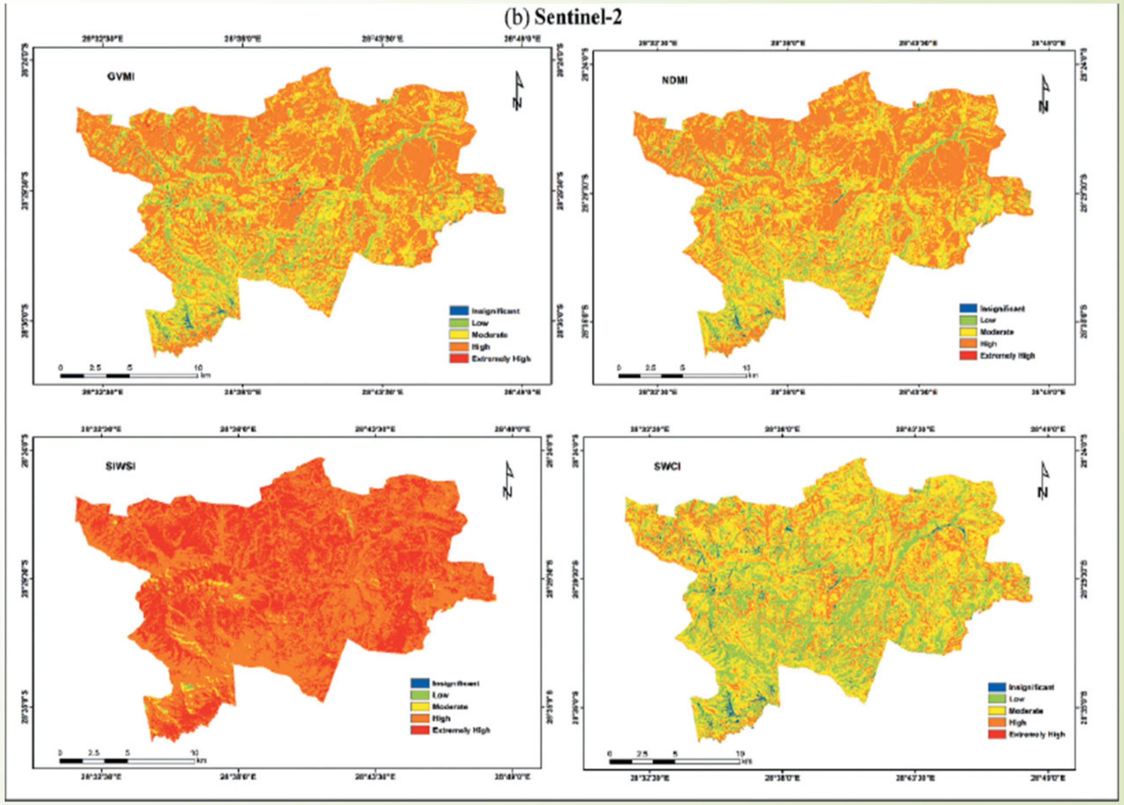
- Several measurements were employed to measure the performance of selected GCIs in fitting with fire points, which include the coefficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and F-value test (Sun et al., 2021).

Results

Grassland Curing Maps (GCMs) were developed to assess fire danger based on the degree of curing prone to fire spread.

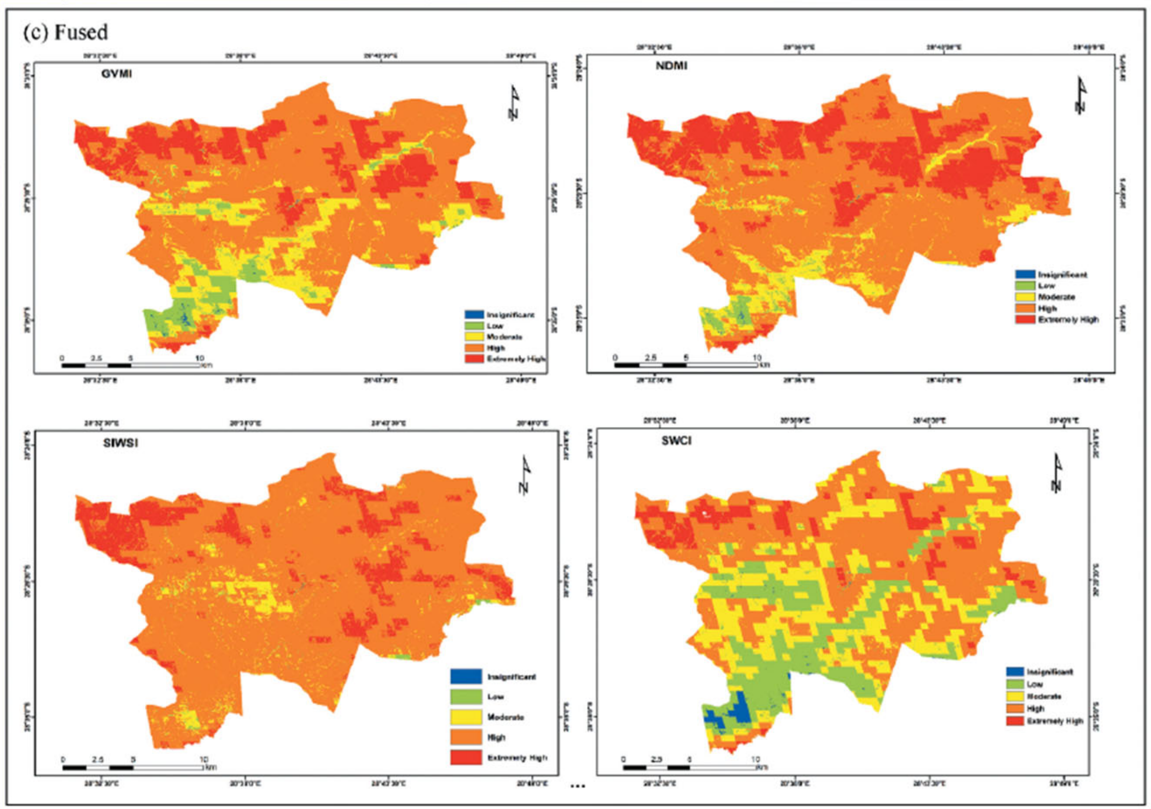


Sentinel-2 derived GCI_SIWSI identified the **highest area of extreme fire danger**, with over 95% of the study area falling within high to extremely high danger zones.



Results

- The analysis suggests that the **entire landmass is highly susceptible to fire**, with **very few regions** classified as **danger-free**, **mostly near rivers, fallows, and south-facing mountain ridges.**

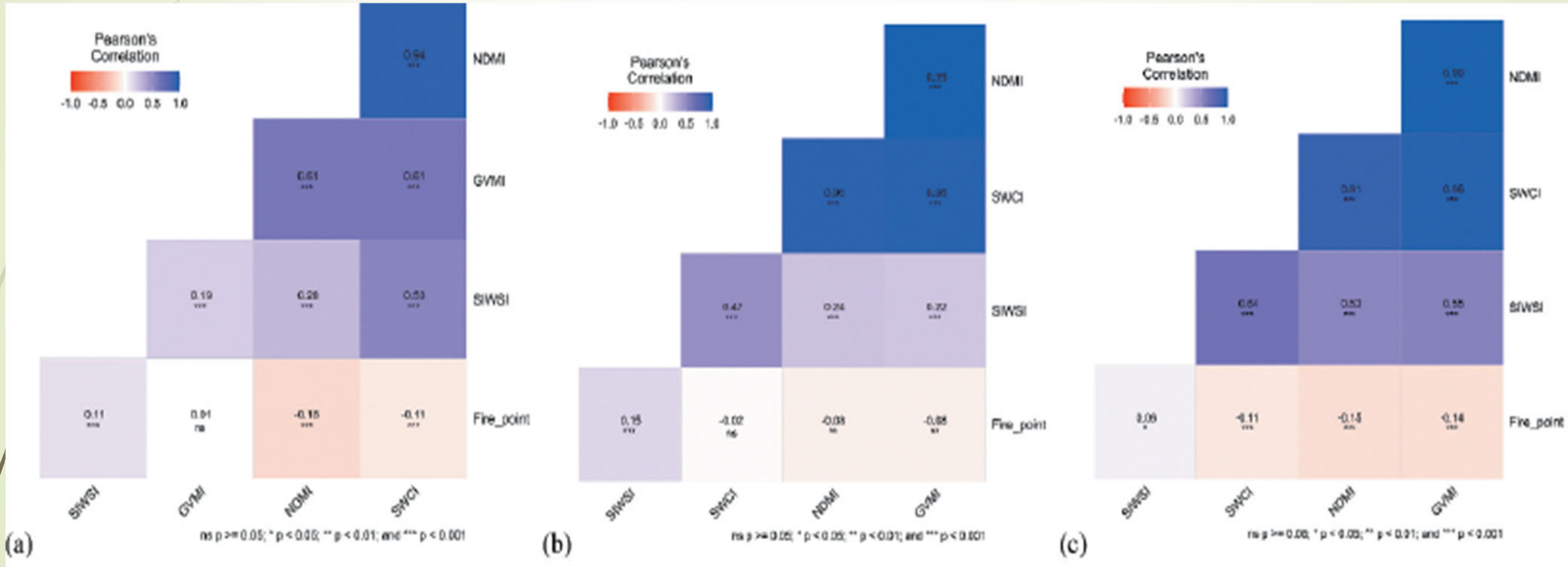


Percentage Area coverage of Fire Danger GCMs for the cumulative period from 2016 -2020

Data sources	Index	Fire danger classes				
		Insignificant	Low	Moderate	High	Extremely high
MODIS	GVMI	4.24	24.47	26.69	38.89	5.71
	NDMI	5.19	25.49	26.45	38.61	4.26
	SIWSI	1.10	14.00	20.17	48.67	16.06
	SWCI	5.57	31.43	26.39	32.44	4.17
Sentinel-2	GVMI	0.39	11.80	31.86	55.33	0.62
	NDMI	0.33	11.21	36.59	51.81	0.06
	SIWSI	0.001	0.19	1.35	54.94	43.52
	SWCI	0.92	28.51	49.07	21.47	0.03
Fused	GVMI	0.13	6.20	15.91	62.07	15.69
	NDMI	0.06	2.13	9.37	63.78	24.65
	SIWSI	0.02	0.59	5.01	81.13	13.25
	SWCI	1.07	18.54	25.69	47.73	6.97

Results Cont'd

- **Pearson correlation analysis** revealed that most indices were negatively correlated with fire points, except for SIWSI, with **the highest R-value of 0.17 found in NDMI derived from MODIS data.**



. Pearson correlation analysis between each of four indices and fire points (a) MODIS,(b) Sentinel-2 and (c) fused data.

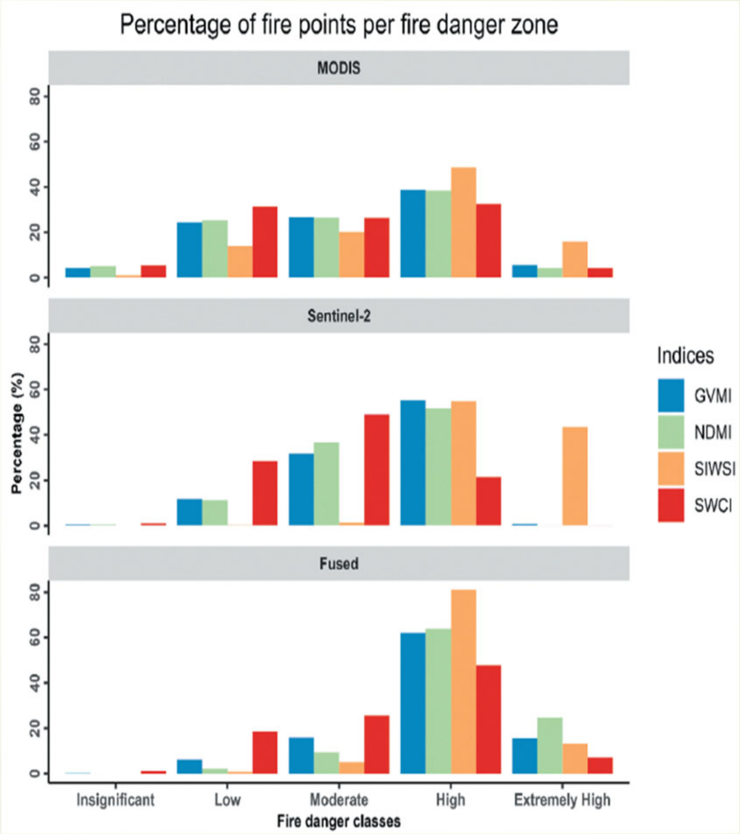
Results

❑ *Accuracy Assessment*

- None of the active fire points fell under the insignificant fire danger zones in Sentinel-2 and fused data-derived GCMs.

❖ However, some fire points were observed in the danger-free zones of MODIS-derived GCMs, with GVMI having the highest percentage at 6%, followed by SIWSI (5%), SWCI (4%) and NDMI (2%).

❖ Over 90% of fire points were within high to extremely high fire danger zones for fused data-derived GCMs, with NDMI showing the highest percentage at 99%.



Percentage of fire points in each fire danger zone of estimated GCMs

Results

- Grassland Curing Maps (GCMs) derived from fused data had the best performance, with the highest R^2 (0.65) and F-test (380) values.

- In contrast, Sentinel-2-derived GCMs have the lowest performance the worst with R^2 of 0.32 and F-test value of 73,

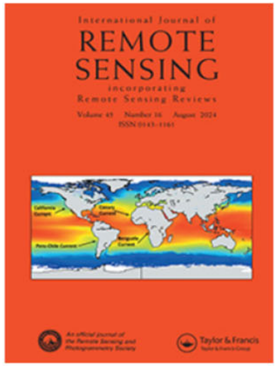
- while MODIS data showed moderate performance,

Regression analysis between fire points and selected indices derived from MODIS, Sentinel-2 and fused data.

Data source	R^2	RMSE	MAE	F
MODIS	0.51	0.03	0.04	161
Sentinel-2	0.32	0.34	31.74	73
Fused	0.65	0.36	32	380

Conclusion

- This study attempted the spatio-temporal pattern of grassland curing for fire danger in GGHNP using fused remotely sensed data from MODIS and Sentinel.
- The findings revealed that the highest Degree of Curing (DoC) occurred in September, with Sentinel-2-derived GCI_SIWSI identifying the largest area as extremely high fire danger.
- Moreover, the study revealed that GCMs derived from fused data outperformed MODIS and Sentinel-2, achieving the highest R2 and F values of 0.65 and 380, respectively.
- The study concludes that the fused remotely sensed data is a promising tool for accurately assessing DoC in mountainous grassland environments.
- The study provides valuable insights for fire management planning in mountainous grassland environments.



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Grass curing-driven fire danger index in a protected mountainous grassland using fused MODIS and Sentinel-2

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THANK YOU FOR LISTENING!