Understanding the Drivers of Desertification and Land Degradation (DLD) over the Central Highlands of India

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Supplementary Document

1. Data and Methodology

Table 1. List of Parameters used for estimating desertification and land degradation.

SL.no.	Indices	Full Form	Equation
1	AET	Actual Evapotranspiration	TerraClimate (climatologylab.org)
2	Albedo	Albedo	((0.16*Red)+(0.291*Nir)+(0.243*Blue)+(0.116*Green)+(0.112*Nir1)+(0.081*Swir2)-0.0015)
3	BI	Brightness Index	sqrt(Red^2 + Nir^2)
4	BSI	Bare Soil Index	(((Swir2 + Red) - (Nir + Blue)) / ((Swir2 + Red) + (Nir + Blue)))
5	DDI	Difference Drought Index	DVI <- (Nir - Red), DWI <- (Nir - Swir2), DDI <- (DVI - DWI)
6	EVI	Enhanced Vegetation Index	2.5 * ((NIR - R) / (NIR + 6 * R – 7.5 * B + 1))
7	GARI	Green Atmospherically Resistant Vegetation Index	(Nir-(Green-(Blue-Red)))/(Nir-(Green+(Blue-Red)))
8	GBNDVI	Green-Blue NDVI	Nir-(Green+Blue)/Nir+(Green+Blue)
9	GDVI	Difference NIR/Green Difference Vegetation Index	(Nir-Green)
10	GNDVI	Green Normalized Difference Vegetation Index	((Nir-Green)/(Nir+Green))
11	Kndvi	Kernal Normalized Difference Vegetation Index	tanh(((Nir - Red)/(Nir + Red)))^2
12	LAI	Leaf Area Index	0.57*exp(2.33*NDVI), 6.753*((NIR-RED)/(NIR+RED))
13	LST	Land Surface Temperature	Terra Modis
14	MSAVI	Modified Soil Adjusted Vegetation Index	Nir + 0.5 - (0.5 * sqrt((2 * Nir + 1)^2 - 8 * (Nir - (2 * Red))))
15	NBR	Normalized Burn Ratio	(Nir - Swir1) / (Nir + Swir1)

16	NDBI	Normalized Difference Built-Up Index	((Swir1 - Nir) / (Swir1 + Nir))
17	NDSI	Normalized Difference Salinity Index	((Red - Nir)/(Red + Nir))
18	NDVI	Normalized Difference Vegetation Index	((Nir - Red)/(Nir + Red))
19	NDWI	Normalized Difference Water Index	((Green - Nir) / (Green + Nir))
20	NMDI	Normalized Multi-Band Drought Index	(Nir - (Swir1 - Swir2)) / (Nir + (Swir1 - Swir2))
21	PCI	Precipitation Condition Index	(Prec - PrecMin/PrecMax - PrecMin)
22	PDSI	Palmer Drought Severity Index	TerraClimate (climatologylab.org)
23	PET	Potential Evapotranspiration	TerraClimate (climatologylab.org)
24	Precipitation	Precipitation	TerraClimate (climatologylab.org)
25	SATVI	Soil-Adjusted Total Vegetation Index	((Swir1 - Red)/(Swir1 + Red + 0.5) * (1 + 0.5) - (Swir2/2))
26	SAVI	Soil Adjusted Vegetation Index	1.5 * ((Nir - Red)/(Nir + Red+0.5))
27	SI	Salinity Index	sqrt(Red * Nir)
28	SMCI	Soil Moisture Condition Index	(SoilMoisture - SoilMoistureMin/SoilMoistureMax - SoilMoistureMin)
29	SMI	Soil Moisture Index	(LSTmax - LST)/(LSTmax - LSTmin)
30	Soil Moisture	Soil Moisture	TerraClimate (climatologylab.org)
31	Tmax	Maximum Temperature	TerraClimate (climatologylab.org)
32	Tmin	Minimum Temperature	TerraClimate (climatologylab.org)
33	TCI	Temperature Condition Index	(LSTmax - LST)/(LSTmax - LSTmin)*100
34	TGSI	Top Grain Soil Index	(Red-Blue)/(Red+Blue+Green)
35	TSAVI	Transformed Soil Adjusted Vegetation Index	(0.33 *(Nir - 0.33 * Red - 0.5)) / (0.5 * Nir + Red - 0.5 * 0.33 + 1.5 * (1 + 0.33^2))
36	VCI	Vegetation Condition Index	(NDVI - NDVImin)/(NDVImax - NDVImin)*100
37	VHI	Vegetation Health Index	0.5*VCI+(1-0.5)*TCI

38	VPD	Vapor Pressure Deficit	TerraClimate (climatologylab.org)
39	VSSI	Vegetation Soil Salinity Index	((2 * Green) - (5 * (Red + Nir)))
40	Water Deficit	Water Deficit	TerraClimate (climatologylab.org)
41	Soil Loss	Soil Erosion	RUSLE Soil Loss Model
42	Ghm	Global Human Modification	

1.1. Datasets

Table 2. List of satellited data used for estimating desertification and land degradation parameters.

Data used		**Wavelength used (nm)**	**Acquisition dates**	**Purpose**
Landsat 05 TM	30 m	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90 1.55-1.75	2001 - 2020	
Sentinel 2A MSI	10 m 20 m	0.45–0.52 0.54–0.57 0.65–0.68 0.69–0.71 0.78–0.90	2001 - 2020	
Modis Terra Surface Reflectance 8-Day Global 500 m (MOD09A1 V6.1)	500 m	459–479 545–565 620–670 841–876 1628–1652 2105–2155 1230–1250	2001 – 2020	Remote Sensing Indices
TerraClimate	4638.3 m (approx. 4km)	1. Actual Evapotranspiration (AET) 2. Palmer Drought Severity Index (PDSI) 3. Potential Evapotranspiration (PET) 4. Precipitation 5. Soil Moisture 6. Maximum Temperature 7. Minimum Temperature 8. Vapor Pressure Deficit (VPD)	1990 – 2020	Understanding long term climatic condition in the state For factors influencing DLD conditions
Modis Terra LST	1000 m	LST	2001 – 2020	For Understandin

				g long-term LST condition
Ghm	300 m	Global human modification v1.5 (Theobald, David M., Christina Kennedy, Bin Chen, James Oakleaf, Sharon Baruch-Mordo, and Joe Kiesecker. "Earth transformed: detailed mapping of global human modification from 1990 to 2017." Earth System Science Data 12, no. 3 (2020): 1953-1972.)	2000 and 2017	

2.2. RUSLE (Revised Universal Soil Loss Estimation) Model

The RUSLE model has been utilized to identify soil erosion in this study, which is based on GIS. The RUSLE model (equation - 1) is used to estimate the average annual soil loss.

$$A = R \times K \times LS \times C \times P \qquad \text{equation} - 1$$

where, A = yearly mean soil loss, R = precipitation erosivity factor, K = soil erodibility factor, C = cover management factor (dimensionless), LS = slope length and slope steepness factor (dimensionless), and P = support practices factor (dimensionless). The calculation of the RUSLE (soil loss) estimated using the cloud-based GIS platform Google Earth Engine (GEE).

2.2.1. Rainfall erosivity (R) factor

Rainfall erosivity is the major factor of RUSLE which is responsible for soil erosion over an area. It indicates the potential ability of a storm event to erode soil at a particular location. The R factor is estimated by total annual or seasonal rainfall erosivity (Ganasri & Ramesh, 2016).

2.2.2. Soil erodibility (K) factor

Soil erodibility or K factor indicates the susceptibility of soil to detachment of its particles and transport by rainfall. As the ability of soil to resist erosion depends upon the physicochemical properties of soil, the value of the K factor varies with different types of soil.

2.2.3. Cover and management (C) factor

The cover and management factor represents the ratio of soil loss under a given crop to that of the base soil (Soil Erosion and Conservation, 2016). Vegetation cover prevents soil erosion by reducing the raindrop energy during rainfall.

2.2.4. Slope length (LS) factor

The slope length factor also known as the gradient factor indicates the combined effect of slope steepness and slope length on the rate of soil loss. The steeper and longer slopes have a higher potentiality for soil loss as they produce higher overland flow velocities and correspondingly higher runoff (De Haan et al, 1994).

2.2.5. Conservation practice (P) factor

The support practice or P factor represents the ratio between soil loss from a field with the given conservation practice to that where no conservation is practiced.

Table 2: Desertification and Land Degradation change analysis from 2001 and 2020.

Desertification and Land Degradation Change Analysis					
	2020				
2001	**Intense (km²)**	**Severe (km²)**	**Moderate (km²)**	**Light (km²)**	**No Desertification (km²)**
Intense	24783.21	3819.68	1096.54	38.81	735.47
Severe	5879.55	13451.30	53.40	2.87	237.14
Moderate	4443.79	140.89	8578.92	1242.13	103.83
Light	149.51	2.28	3604.61	9590.72	53.87
No Desertification	566.43	62.37	29.90	5.03	1332.90

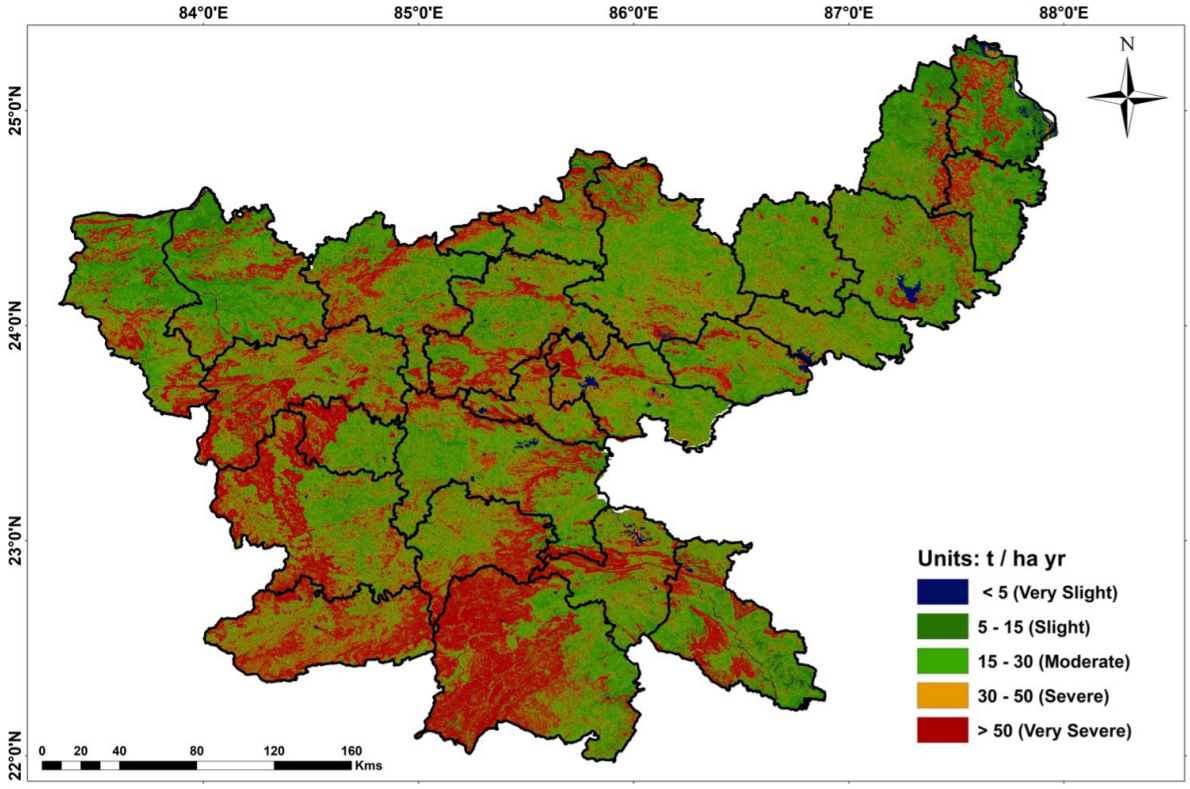

Figure 1: RUSLE (Soil Loss Jharkhand 2020)

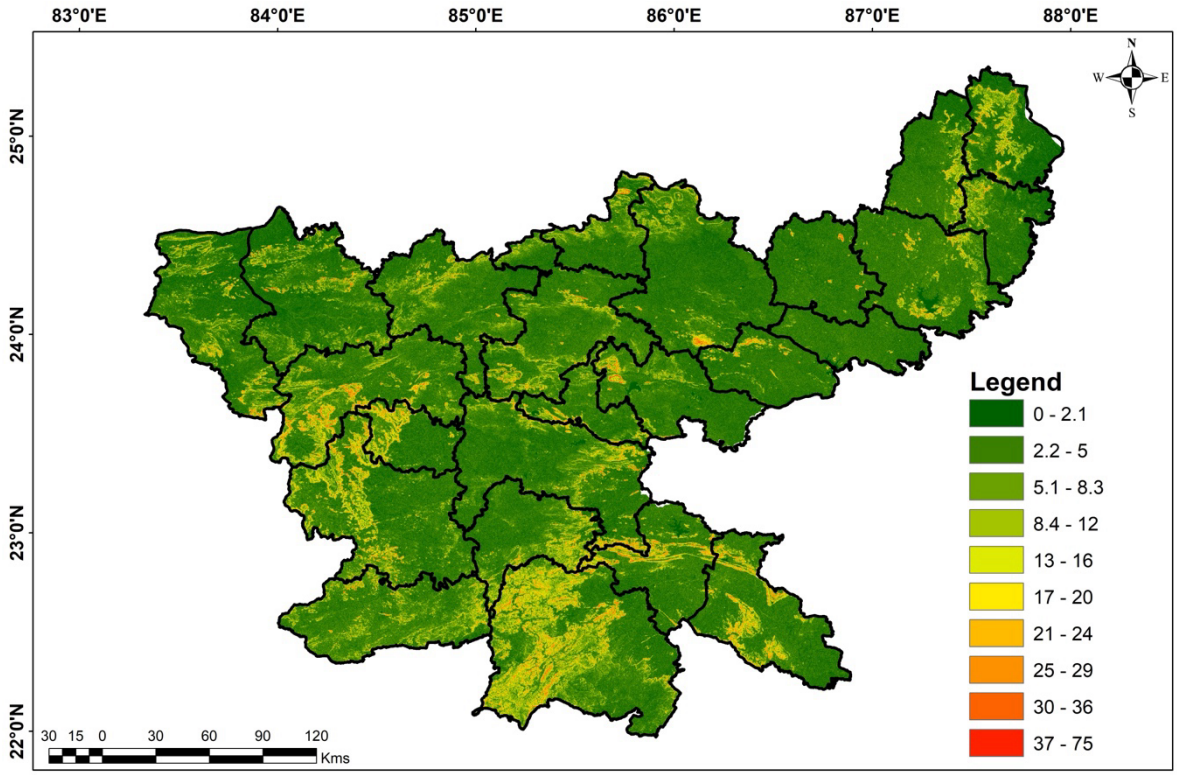

Figure 2: Surface Topography Slope (Degrees)

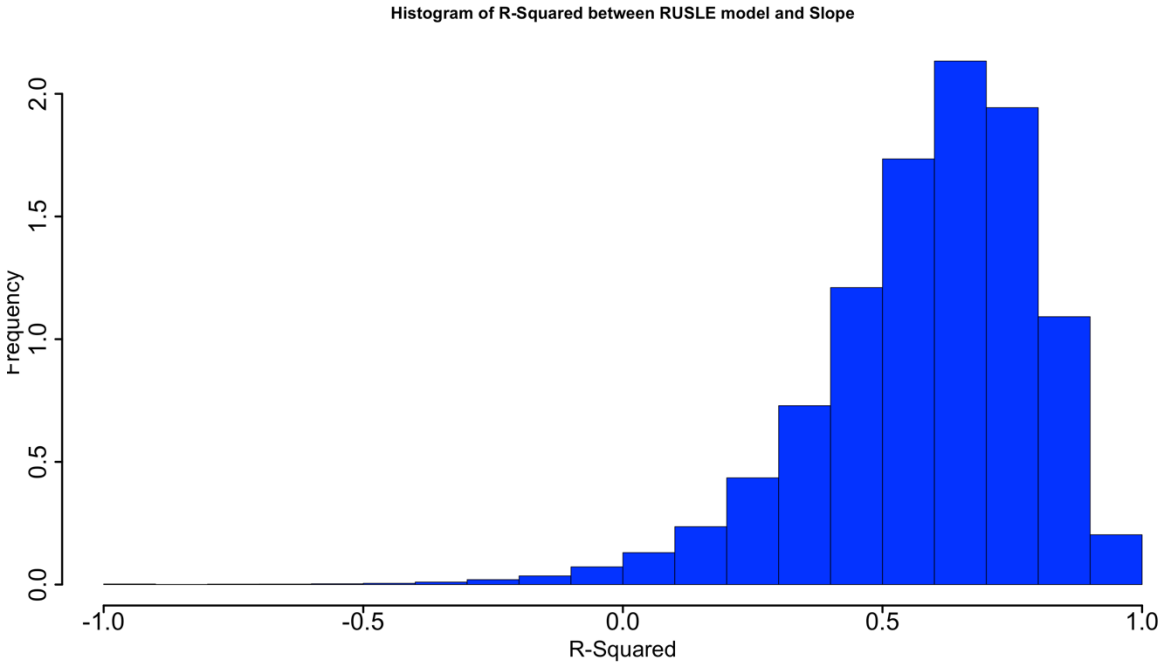

Figure 3: Correlation Analysis between RUSLE Model and Surface Topographical Slope