SOIL PROPERTIES ESTIMATION USING Vis-NIR SPECTROSCOPY DATA

Guide:

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Introduction

- Soil properties such as pH, electrical conductivity (EC), organic carbon (OC), and nutrient levels (e.g., Cu, Mn, Zn, Fe, K, P2O5, S) are crucial for agricultural productivity and environmental sustainability.
- The use of hyperspectral imaging technology allows for the detailed analysis of soil properties over large areas, providing a non-destructive method to gather data that can enhance soil management practices.
- This research focuses on estimating various soil properties using hyperspectral reflectance data, aiming to create accurate maps for better agricultural decision-making in the Anand district.

Objectives

- **Estimate Soil Properties:** To utilize hyperspectral imaging to estimate key soil properties, including pH, EC, OC, and essential nutrients, which are vital for crop growth and soil health.
- **Develop Predictive Models:** To apply machine learning techniques, specifically Random Forest and Multilayer Perceptron (MLP) regressors, to develop predictive models that can accurately assess soil characteristics from hyperspectral data.
- **Enhance Agricultural Practices:** To provide actionable insights and maps based on the estimated soil properties, facilitating improved agricultural practices and resource management in the studied region.

ABOUT DATA

2441	2442	2443	2444	2445	2446	2447	2448	pH	OC %	Cu mg/kg	Fe mg/kg	Mn mg/kg	Zn mg/kg	K kg/ha	P2O5	S(ppm)	EC dS/m
41.49816	41.44566	41.395	41.34558	41.30432	41.2761	41.25008	41.2194	6.756	0.431	4.822	26.087	29.292	1.417	324.537	279.7171	38.148	2.3667
37.1875	37.13437	37.08977	37.05347	37.01933	36.98427	36.95477	36.94	7.38	0.437	2.917	13.073	16.335	0.568	204.585	250.3809	71.04	2.8077
32.88723	32.83448	32.78378	32.7345	32.69183	32.6608	32.62925	32.58735	7.95	0.453	2.419	3.685	6.155	0.356	249.9	76.41052	14.06	1.5962
36.02113	35.99033	35.95847	35.92613	35.89513	35.8671	35.83813	35.80673	8.095	0.472	3.571	7.878	9.647	0.781	427.162	192.3908	13.32	1.5539
36.11627	36.10127	36.08403	36.06653	36.03963	35.99457	35.95227	35.93237	6.325	0.498	3.817	45.243	43.224	1.114	329.868	195.1197	18.5	2
30.52733	30.48757	30.44353	30.3953	30.35233	30.31787	30.28683	30.25603	6.805	0.457	3.869	3.356	40.597	1.597	456.484	94.83092	8.88	2.0576
31.6389	31.6001	31.56087	31.5203	31.49143	31.48193	31.4755	31.4627	7.93	0.435	2.439	2.063	15.673	0.553	379.182	78.45723	7.03	2.1869
38.6399	38.57337	38.521	38.4829	38.44733	38.41613	38.3776	38.31473	7.72	0.433	1.943	3.718	8.539	0.665	297.881	145.9987	141.34	1.2787
21.0611	21.04523	21.02973	21.0159	20.99613	20.96605	20.9346	20.90833	7.87	0.445	3.383	11.51	15.93	0.81	651.073	161.0079	140.97	5.335
19.1163	19.0929	19.0668	19.03713	19.00923	18.98643	18.9617	18.9275	8.76	0.447	2.634	7.311	7.162	0.32	239.238	112.5691	15.54	0.9747
32.6924	32.65123	32.62007	32.5987	32.58187	32.57267	32.55917	32.5272	7.71	0.471	2.288	3.384	17.697	0.74	547.114	124.1671	50.32	1.8336
42.06227	42.02057	41.98623	41.95977	41.93683	41.92043	41.89917	41.86127	7.89	0.434	1.888	1.633	6.802	0.74	324.537	86.64407	8.51	1.4605
42.94663	42.87617	42.81453	42.761	42.71737	42.6883	42.6608	42.62623	8.01	0.447	0.962	0.879	10.383	0.91	345.862	88.69078	6.66	1.303
38.9885	38.94123	38.8925	38.84297	38.7952	38.74863	38.7057	38.6713	8.802	0.518	0.716	0.733	6.533	0.201	269.892	56.62565	15.54	1.145
35.91355	35.87145	35.82603	35.7774	35.73233	35.6926	35.6564	35.6253	8.04	0.517	1.293	3.836	17.408	0.569	252.566	109.1579	14.06	1.5802
31.9293	31.8854	31.84803	31.81837	31.78353	31.74047	31.69163	31.63433	7.68	0.495	0.872	1.241	11.942	0.287	356.524	100.2888	29.23	2.4038
21.07273	21.04397	21.01003	20.97083	20.93447	20.90393	20.87443	20.8427	7.36	0.458	2.036	3.479	6.434	0.161	324.537	33.4296	16.28	1.0042
33.93527	33.92073	33.8991	33.87137	33.8398	33.8021	33.76607	33.74227	6.85	0.464	1.397	1.963	18.261	1.075	591.097	167.8303	5.18	1.0285
30.22687	30.1767	30.13713	30.10827	30.08067	30.0525	30.02423	29.99373	7.25	0.484	2.101	4.383	42.867	1.206	443.156	73.68157	6.66	2.3098
44.1	44.1	44	44	43.9	43.9	43.8	43.8	7.332	0.444	0.897	2.085	30.388	0.519	388.511	62.08355	9.62	1.552
45.26667	45.212	45.15277	45.08887	45.03237	44.98773	44.9476	44.91027	8.01	0.451	1.157	0.662	7.93	0.328	243.236	50.48552	2.96	0.8781
41.9821	41.9473	41.90707	41.86183	41.8205	41.7856	41.7536	41.7242	7.8	0.44	1.742	1.838	14.876	1.335	360.522	77.09276	24.42	0.7661
39.3814	39.3254	39.2757	39.23263	39.19345	39.15778	39.12518	39.0965	7.65	0.538	1.123	0.676	8.478	0.543	247.234	75.72828	4.07	1.2365
38.07358	38.03928	37.99215	37.93215	37.87223	37.81515	37.75935	37.7077	7.4	0.43	1.064	1.222	6.373	0.256	308.543	74.36381	2.479	5.072
42.64883	42.6028	42.55617	42.5092	42.46437	42.42327	42.38217	42.33853	7.27	0.465	2.953	10.307	30.937	1.254	363.188	211.4934	7.4	1.6013
40.58123	40.536	40.48907	40.4399	40.4012	40.3834	40.36133	40.3132	7.485	0.453	2.846	14.401	18.67	0.731	308.543	163.0546	13.32	1.5392
46.33627	46.27377	46.20443	46.12783	46.06553	46.02713	45.99483	45.96	8.02	0.412	1.108	2.043	13.495	0.745	272.558	163.7368	5.18	0.9549
29.40533	29.37873	29.35143	29.32443	29.29288	29.25505	29.21298	29.16533	8.04	0.471	1.014	2.109	12.415	0.773	241.903	128.2605	2.96	0.9037

VARIABLES

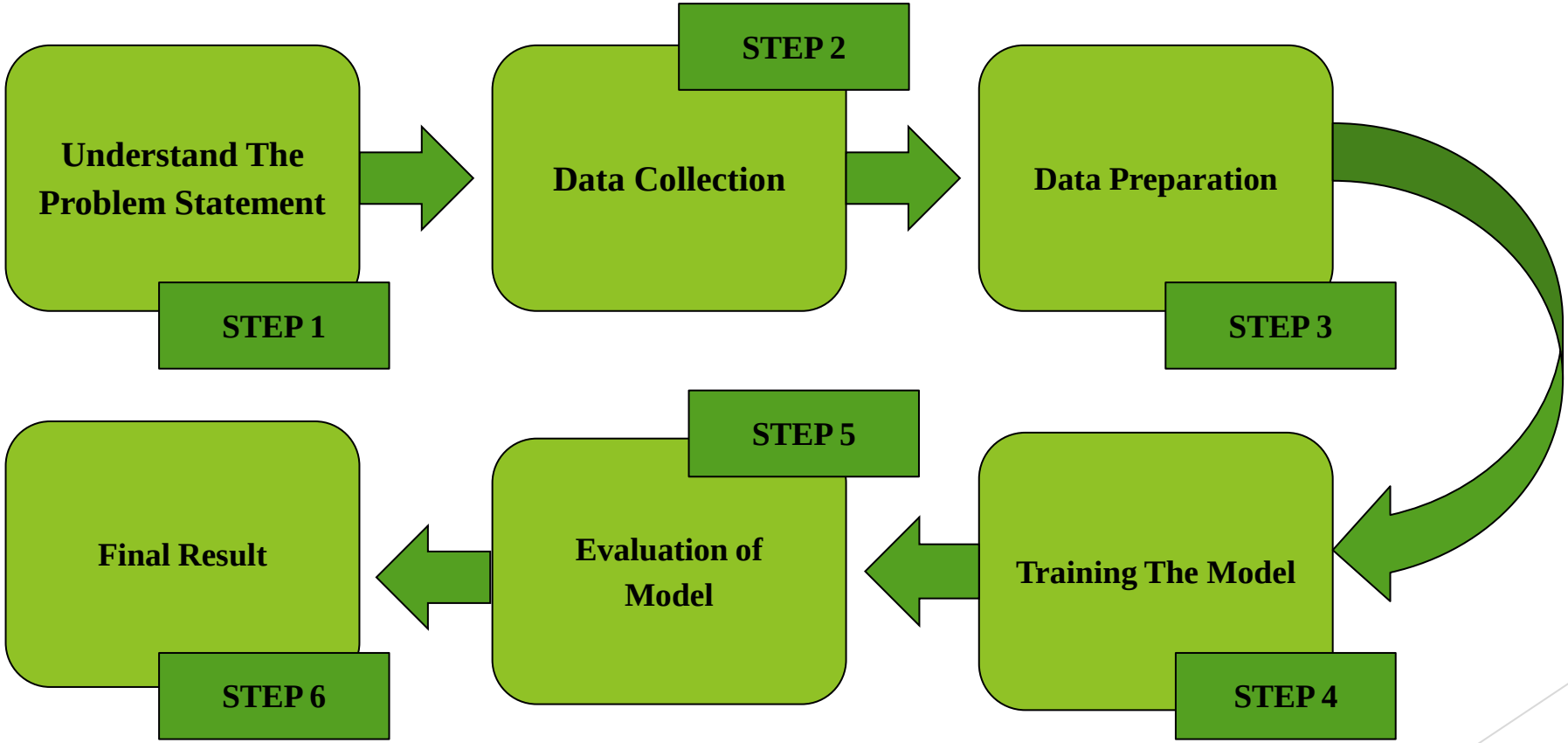
❖Independent Variables / Features:

➢HYPERSPECTRAL IMAGE WITH 2098 BANDS AND 499 GROUND TRUTH POINTS

❖Dependent Variable / Target:

➢ pH, EC, OC, Cu, Mn, Zn, Fe, K, P2O5, S

METHODOLOGY



Data Collection & Preparation

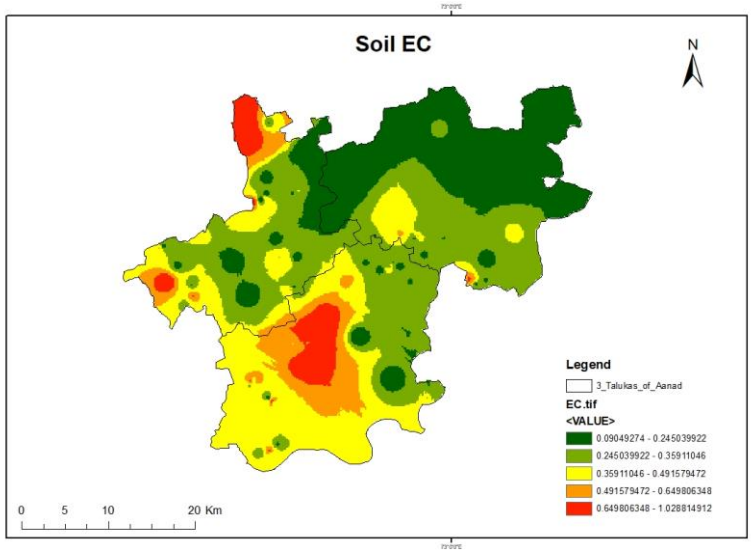
- Here, we have hyperspectral reflectance data from **350 - 2448 nm** along with soil chemistry data; collected from Pesticide residue laboratory, AAU.
- Firstly, we tried correlation analysis for any one soil chemistry with those hyperspectral data; but we got maximum of **31%** correlation among whole dataset for any of soil chemistry data.
- So, we used Standard Normal Variate(SNV) as preprocessing method.

How Standard Normal Variate (SNV) preprocessing works?

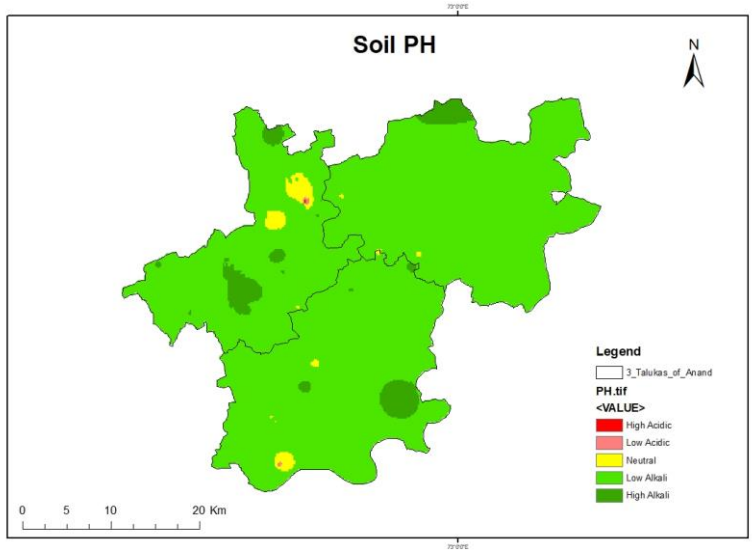
- Mean Centering: Each spectrum is adjusted by subtracting the mean of the spectrum from each data point. This centers the data around zero, removing any offset.
- Scaling by Standard Deviation: After mean centering, each data point is divided by the standard deviation of the spectrum. This step normalizes the data, ensuring that the variance is consistent across all spectra.
- Result: The processed spectra have a mean of zero and a standard deviation of one, which helps in reducing the effects of scatter and other physical variations, making the data more suitable for further analysis and modeling.

DATA ANALYSIS

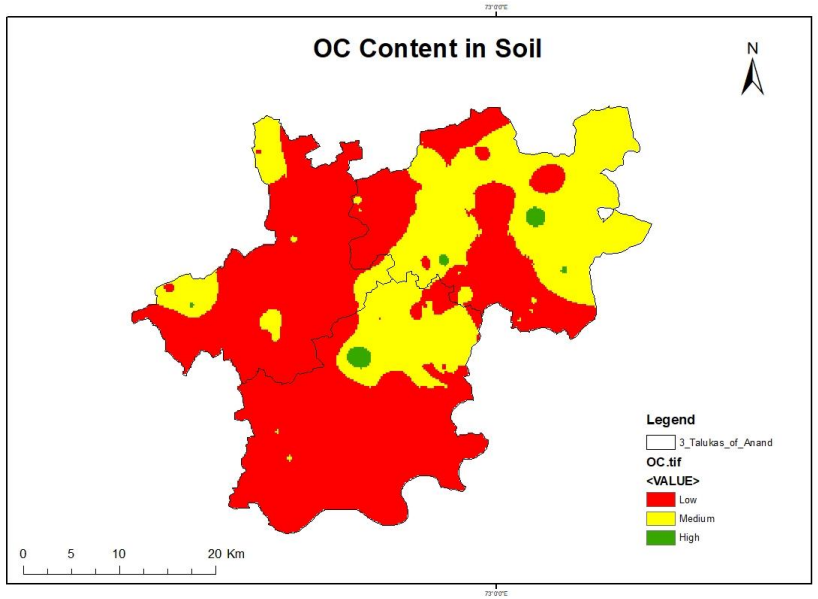
Here, we provided maps of the soil chemistry parameters and nutrients for three Talukas of Anand district (Anand, Borsad and Petlad).



Very Low: 0.09049274 - 0.245039922
Low: 0.245039922 0.35911046
Medium: 0.35911046-0.491579472
High: 0.491579472 - 0.649806348
Very High: 0.649806348 - 1.028814912



High Acidic: 0.09049274 - 0.245039922
Low acidic: 0.245039922 0.35911046
Neutral: 0.35911046-0.491579472
Low alkali: 0.491579472 - 0.649806348
High alkali: 0.649806348 - 1.028814912

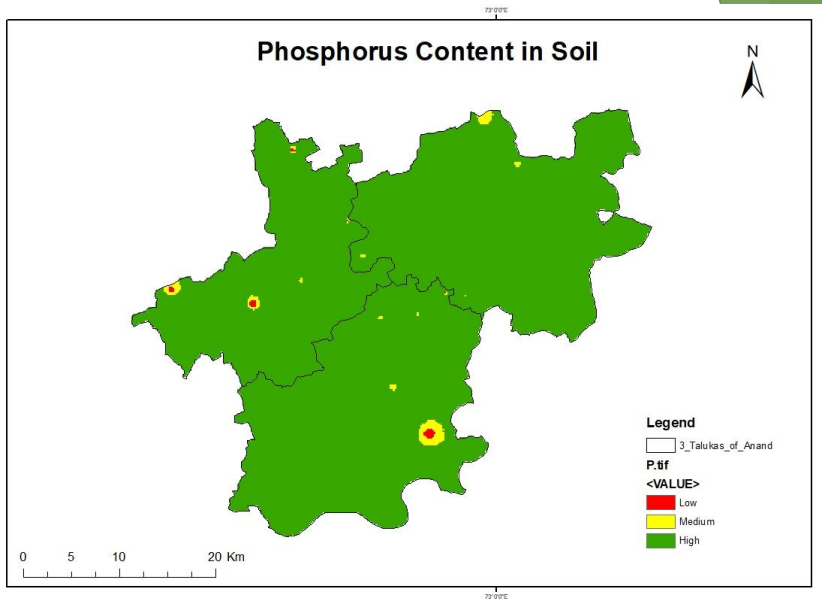


OC %

High: > 0.75%

Medium: 0.5 – 0.75 %

Low: <0.5%

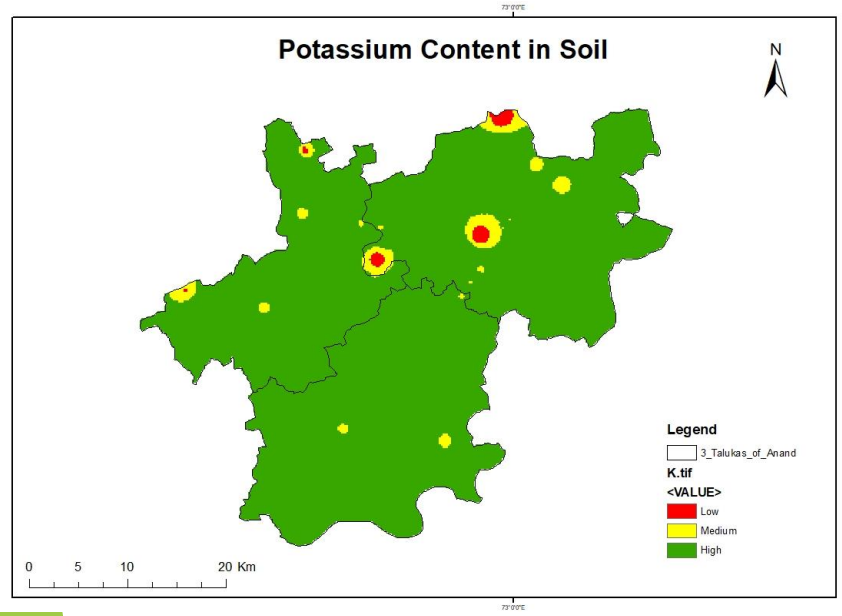


P2O5

High: > 22 kg/ha

Medium: 11 – 22 kg/ha

Low: <11 kg/ha

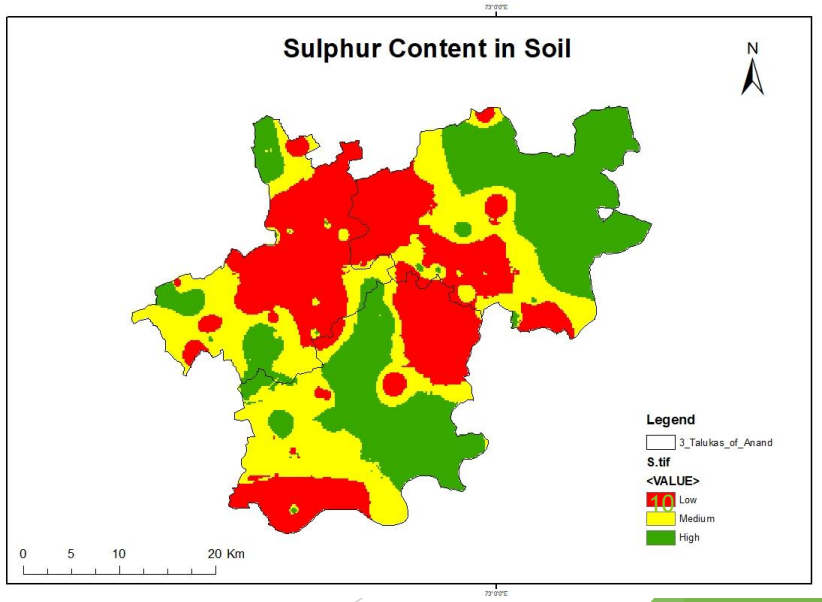


K

High: > 280 kg/ha

Medium: 180 – 280 kg/ha

Low: <180 kg/ha

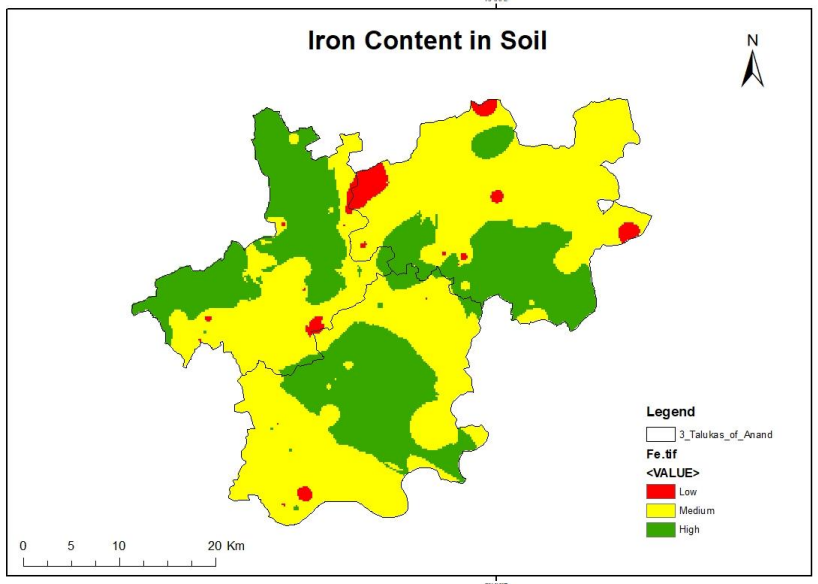


S

High: > 15 ppm

Medium: 10 – 15 ppm

Low: <10 ppm

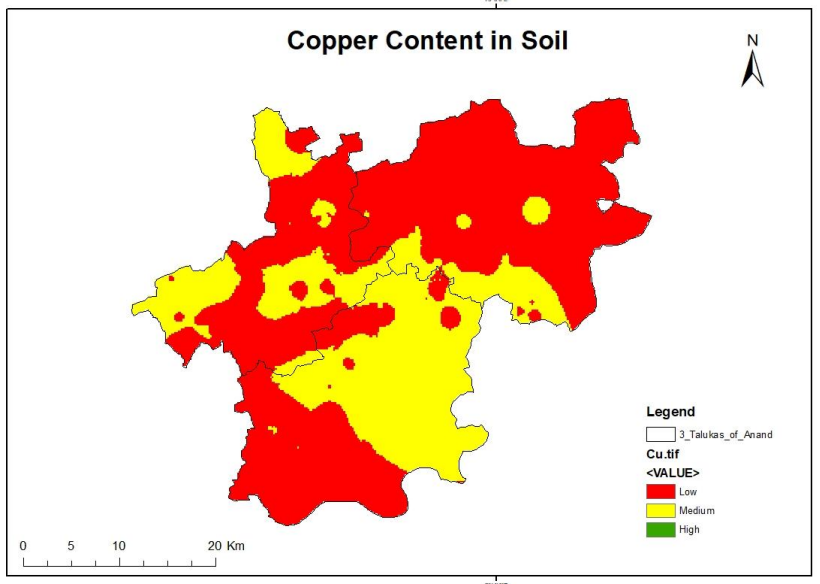


Fe

High: > 10 mg/kg

Medium: 5 – 10 mg/kg

Low: < 05 mg/kg

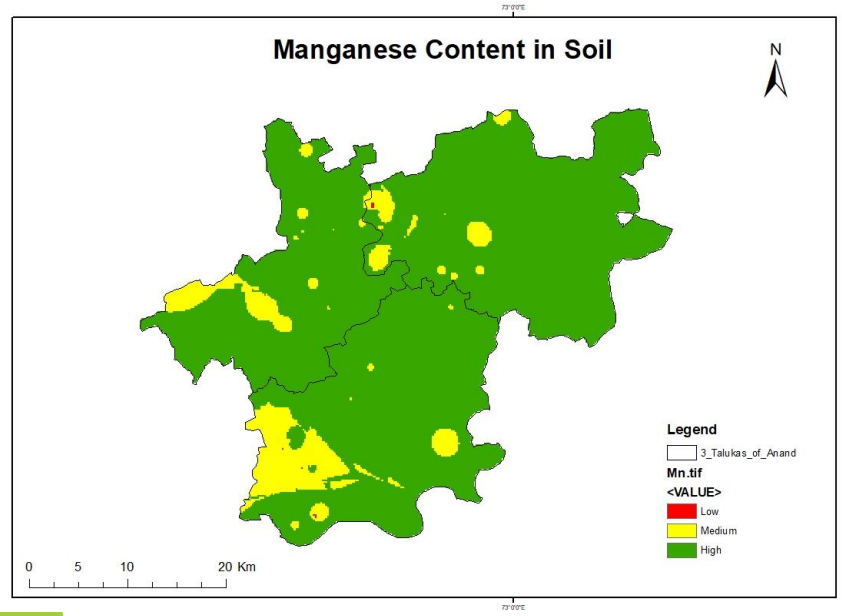


Cu

High: > 5 mg/kg

Medium: 2.5 – 5.0 mg/kg

Low: < 2.5 mg/kg

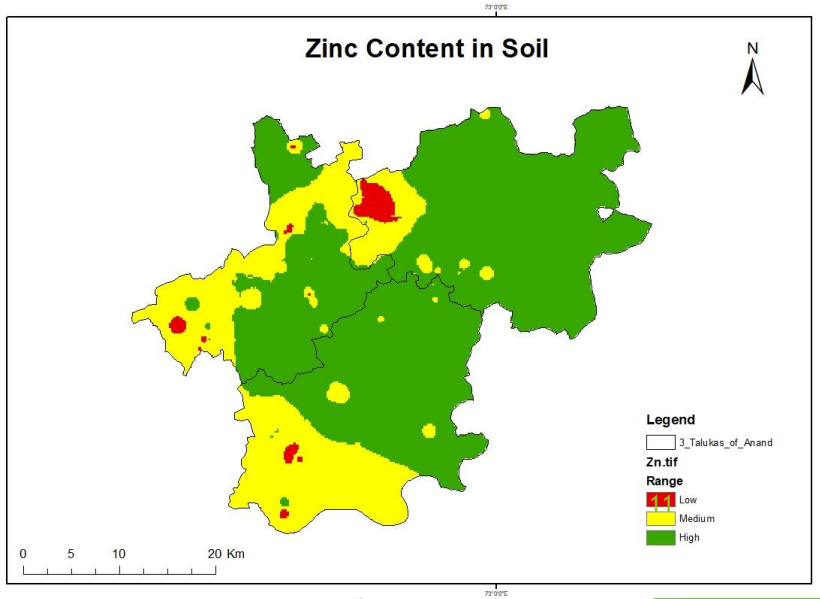


Mn

High: > 10 mg/kg

Medium: 5 – 10 mg/kg

Low: < 05 mg/kg

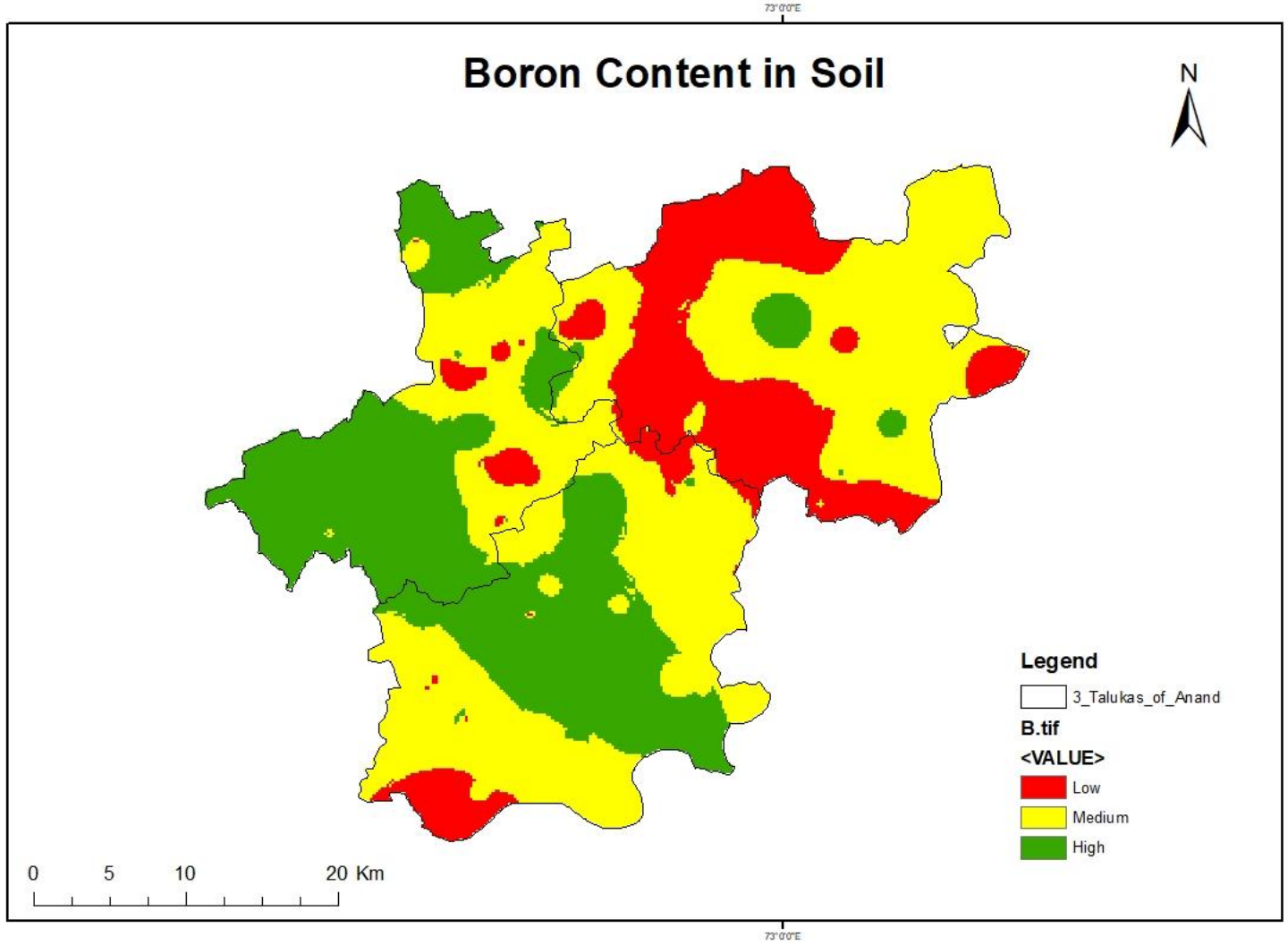


Zn

High: > 1 mg/kg

Medium: 0.5 – 1 mg/kg

Low: <0.5 mg/kg



B

High: > 1 mg/kg

Medium: 0.5 – 1 mg/kg

Low: <0.5 mg/kg

OBSERVATION

	RANDOM FOREST		MLP REGRESSOR	
SOIL PROPERTIES	TRAINING ACCURACY	TESTING ACCURACY	TRAINING ACCURACY	TESTING ACCURACY
pH	0.93	0.57	0.61	0.41
EC	0.89	0.17	0.55	0.01
OC	0.91	0.39	0.32	0.08
Cu	0.93	0.46	0.66	0.49
Mn	0.91	0.45	0.47	0.20
Zn	0.85	0.46	0.64	0.16
Fe	0.93	0.47	0.66	0.49
K	0.92	0.33	0.65	-0.26
P2O5	0.92	0.52	0.65	0.51
S	0.92	-0.12	0.72	-0.38

CONCLUSION

Random Forest

Training Accuracy: Generally high across all properties, ranging from 0.85 to 0.93.

Testing Accuracy: Significantly lower than training accuracy, indicating potential overfitting. The highest testing accuracy is for pH (0.57) and P2O5 (0.52), while the lowest is for S (-0.12).

Multilayer Perceptron(MLP) Regressor

Training Accuracy: Lower than Random Forest, ranging from 0.32 to 0.72.

Testing Accuracy: Also lower than Random Forest, with some negative values indicating poor generalization. The highest testing accuracy is for Cu and Fe (0.49), while the lowest is for S (-0.38).

Overall Conclusion

Random Forest: Performs better in terms of training accuracy but suffers from overfitting, as indicated by the drop in testing accuracy.

MLP Regressor: Shows lower training and testing accuracy overall, with some properties having very poor testing performance.

Thank You