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Impact of Soil Salinity on Soil Health and Crop Productivity in Coastal Areas of South Gujrat, India

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ABSTRACT

Soil salinization has become a significant environmental challenge in coastal agricultural regions, primarily driven by sea water intrusion, rising sea levels, and excessive groundwater extraction. These adverse changes result in declining soil fertility, severely affecting crop productivity. This research evaluates the salinity of coastal region of south Gujarat. The selected sites were Ubharat, Dandi, Tithal, Suvali and Dabhari. The prime method used was Salinity titrimetric method. The key parameters examined Conductivity, pH, Total Dissolved Solids (TDS), and Nutrients including Nitrogen, Phosphorous and organic carbon. The impact of salinization on economic and social perspectives of individual farmers for regional food security has been studied. Various methods could be employed for improving crop productivity of coastal areas like agroforestry, addition of gypsum and organic matter, bio-saline agriculture.

Figures : 08 References : 10 Tables : 07
KEY WORDS : Bio-saline agriculture, Sea water intrusion, Soil health, Soil salinization.

Introduction

Soil salinization affects the agricultural productivity and soil metabolism. South Gujarat faces significant challenges due to its extensive coastline, salt-affected soils, high rainfall areas, hilly terrain, irrigated plains, and heavy industrialization[7]. These challenges are expected to worsen in the coming decades due to land resource issues and declining water availability. There are various

TABLE-1 : Sampling Pattern

Collection sites (Beaches)	Abbreviation for Coastal soil distance(Distance between sampling sites(100m)	Abbreviation for Agricultural soil distance (Distance between sampling sites (500m)
Ubhrat	100 meter (cu-1,cu-2,cu- 3,cu-4)	500 meter (au-1,au-2,au- 3,au-4)
Dabhari	100 meter (cd-1,cd-2,cd- 3,cd-4)	500 meter (ad-1,ad-2,ad- 3,ad-4)
Suvali	100 meter (cs-1,cs-2,cs-3,cs-4)	500 meter (as-1,as-2,as-3,as-4)
Dandi	100 meter (cn-1,cn-2,cn- 3,cn-4)	500 meter (an-1,an-2,an- 3,an-4)
Tithal	100 meter(ct-1,ct-2,ct- 3,ct-4)	500 meter (at-1,at-2,at- 3,at-4)

TABLE-2 : Parameters studied and its method

S. No.	Name of parameter	Method	Reference
1.	pH	pH Paper measurement	APHA
2.	Electrical Conductivity	EC meter	APHA
3.	TDS	Gravimetric Method	Maiti, 2003
4.	Salinity Titration Method	Mohr's Method	Maiti, 2003
5.	Organic Carbon	Spectrophotometer	Modified Walkley-Black method
6.	Nitrogen	Spectrophotometer	Alef & Nannipieri
7.	Phosphorus	Spectrophotometer	(FAO, 2021), Olsen's method

Fig. 1 : Site 1 : Ubhrat

Fig. 2 : Site 2 : Dabhari

causes of soil salinization like dry climates, low precipitation, high evaporation rate, poor drainage or water logging conditions, irrigation with salt-rich water, removal of deep-rooted vegetation, seepage from salty geological deposits, seawater intrusion, salty breezes etc.

This process is a major threat in arid and semi-arid regions. It affects soil health in many ways. It creates

Fig. 3 : Site 3 : Suvali

TABLE-3 : Coastal soil Parameters

Sampling Site Name	Soil samples	Soil pH	Salinity titration (ppt)	Organic Carbon (%)	Phosph-orous (%)	TDS (ppm)	Conductivity (us/c m)	Nitrogen (%)
Umbhrat	cu-1	8.04	2.627	9.33	0.002	895	994	0.933
						1023	979	0.722
	cu-2	7.69	2.514	7.22	0.002			
	cu-3	7.61	2.485	6.02	0.000	999	799	0.602
	cu-4	7.60	2.327	3.91	0.000	875	762	0.391
Dabhari	cd-1	8.10	2.4	0.126	0.001	350	2700	126
	cd-2	8.00	2.327	0.15	0.001	331	2620	150
	cd-3	7.91	2.263	0.15	0.001	275	2320	150
	cd-4	7.62	2.249	0.156	0.001	206	2240	156
Suvali	cs-1	7.25	1.915	16.5	0.001	1736	3110	16500
	cs-2	7.10	1.882	18	0.001	1171	2190	18000
	cs-3	6.28	1.884	17.7	0.001	1180	2090	17700
	cs-4	6.90	1.872	20.1	0.001	1028	1490	20100
Dandi	cn-1	6.74	2.046	18	0.001	1857	3910	18000
	cn-2	6.70	2.018	18.3	0.001	1561	3540	18300
	cn-3	6.01	1.984	19.5	0.001	1732	3130	19500
	cn-4	6.10	1.97	23.1	0.001	1053	2520	23100
Titthal	ct-1	8.47	2.301	0.092	0.001	750	1543	92
	ct-2	8.30	2.245	0.089	0.001	741	1358	89
	ct-3	8.17	2.236	0.089	0.001	685	1354	89
	ct-4	7.00	2.2	0.085	0.001	632	1260	85

TABLE-4 : Agricultural soil Parameters

Sampling Site Name	Soil samples	Soil pH	Salinity titration (ppt)	Organic Carbon (%)	Phosph-orous (%)	TDS (ppm)	Conductivity (us/c m)	Nitrogen (%)
Umbhrat	au-1	7.55	1.945	0.34	0.002	854	1588	1800
	au-2	7.20	1.			899	1534	2200
	au-2	7.20	1.922	0.22	0.000			
	au-3	6.98	1.892	0.28	0.000	994	1412	2900
	au-4	7.00	1.800	0.4	0.000	873	1237	3840
Dabhari	ad-1	7.95	1.965	0.23	0.001	9389	1974	1200
	ad-2	7.45	1.950	0.22	0.001	8221	1690	1000
	ad-3	7.25	1.930	0.44	0.001	6190	1545	800
	ad-4	6.85	1.920	0.4	0.001	5483	1251	600
Suvali	as-1	7.28	1.975	0.43	0.001	9754	1974	1900
	as-2	7.38	1.952	0.4	0.001	9754	1999	300
	as-3	7.20	1.900	0.36	0.001	9766	1985	500
	as-4	6.90	1.945	0.45	0.001	9757	1970	900
Dandi	an-1	6.95	1.975	1.9	0.001	383	3960	1900
	an-2	7.25	1.952	0.3	0.001	582	3940	300
	an-3	8.65	1.9	0.5	0.001	613	3929	500
	an-4	9.20	1.945	0.9	0.001	699	2990	900
Titthal	at-1	7.25	2.032	0.02	0.001	746	3860	3960
	at-2	7.65	2.004	0.27	0.001	800	4000	3940
	at-3	8.55	1.99	0.39	0.001	800	3990	3929
	at-4	9.67	1.972	0.55	0.001	780	3866	2990

TABLE-5: Spearman Correlation between variables and correlation

Variables	Correlation (p)
Salinity – Organic Carbon	-0.26 (weak negative)
Salinity – Nitrogen	-0.58 (moderate negative)
Organic Carbon – Nitrogen	+0.47 (moderate positive)

osmotic stress on plants making it harder to take up water. It leads to drought-like conditions and poor crop health. Furthermore, it disrupts the structure of soil reducing its permeability and aeration. Compacted, poorly aerated soil increases the risk of waterlogging, which further hampers plant growth.

High salt concentrations disrupt the microbial community of soil and lead to reduced soil fertility. It also diminishes the soil's ability to regenerate and support plant life.

As the soil structure deteriorates due to salinization, it becomes more prone to erosion by wind and water. Erosion leads to loss of the fertile top soil and thus, lowering agricultural value. In severely salinized soils, even salt-tolerant crops may struggle to grow, making it difficult to sustain farming operations in affected areas[1].

The process of soil salinization occurs in two ways: natural and anthropogenic. The natural causes for soil salinity in coastal areas can be its geographical location and environmental conditions. One of the such process is seawater intrusion which happens when ocean saltwater flows towards the coastal lowland and seeps into groundwater aquifers. This intrusion is caused by hydraulic linkage between freshwater aquifers and seawater resulted due to over-extraction of groundwater[4]. Another cause is the repeated tidal inundation and storm surges in coastal regions which discharge salt directly on agricultural fields. Salt spray from the sea may travel long distances inland, leaving salt particles on soil and plant surfaces[2]. This process affects more when there are regular onshore winds. In some coastal areas, parent materials with high natural salt levels causes soil development causing this process.

Anthropogenic activities contributing to salinization process includes irrigation process where farmers use brackish groundwater due to scarcity of freshwater. Another one is the over-extraction of groundwater in coastal areas facilitating seawater intrusion[2]. Adding to this list, land use change and deforestation of wetlands eliminate plants that act as a seawater intrusion buffer[7]. In flat plains, poor drainage contributes to leaching of salts from root zone and this leads to salinization.

TABLE-6 : Soil Health Index (Agricultural Soil Suitability)

Site	SHI	Site	SHI	Site	SHI
au-1	0.49	as-1	0.29	at-1	0.32
au-2	0.40	as-2	0.26	at-2	0.41
au-3	0.45	as-3	0.28	at-3	0.53
au-4	0.59	as-4	0.26	at-4	0.65
ad-1	0.38	an-1	0.55		
ad-2	0.35	an-2	0.38		
ad-3	0.36	an-3	0.52		
ad-4	0.33	an-4	0.63		

TABLE-7 : Soil Health Index (Coastal Soil Suitability)

Site	SHI	Site	SHI
cu-1	0.46	cn-1	0.53
cu-2	0.45	cn-2	0.54
cu-3	0.34	cn-3	0.54
cu-4	0.37	cn-4	0.59
cd-1	0.39	ct-1	0.43
cd-2	0.40	ct-2	0.42
cd-3	0.41	ct-3	0.42
cd-4	0.41	ct-4	0.40
cs-1	0.59		
cs-2	0.63		
cs-3	0.58		
cs-4	0.64		

There are various effects of soil salinity on plant growth and productivity. It causes osmotic stress in plants due to salt solution in soil. It leads to hindrance in water absorption and finally lower growth rates. Since salts build up in plant tissues over time, particular ion toxicity emerges as a critical factor in constraining plant growth[5]. Sodium (Na+) and chloride (Cl-) ions, the most common in most saline soils, become toxic to plant cells at high concentrations, interfering with enzymatic functions and protein synthesis lowering the photosynthetic potential of the plant[5]. Calcium deficiency is especially undesirable under saline conditions because it compromises membrane integrity and selectivity and could increase sodium influx into cells[9]. Salt stress causes oxidative damage in plants by the generation of reactive oxygen species (ROS) such as superoxide radicals, hydrogen peroxide, and hydroxyl radicals. They damage the cellular components suppressing growth and yield loss.

Methodology

Surat is located on the Tapi River, near its confluence with the Arabian Sea.The city has a tropical savanna climate, with hot summers and abundant monsoon rainfall. Surat is a port city, and its western side is bordered by the **Gulf of Cambay** (Khambhat) and the Arabian Sea. The sea is about 16-22 kilometers away by road. There are many beaches found near the coastal periphery of Surat. These are considered as sampling sites.

Results

It comprises two types of parameters collected from all 5 beach sites with respective 4 sub-sites. Firstly, coastal soil parameters have been depicted while later on agricultural soil parameters have been shown in Tables.

To compare the results obtained from coastal and agricultural soils of these five beaches only pH follows normality curve with p-value 0.299 ($p>0.05$) while other parameters like salinity, organic carbon and Nitrogen do not. Thus, on applying independent samples t-test to compare soil pH between coastal soils and agricultural soils; the t-statistic value obtained is -0.936 with p-value 0.355. It can be easily interpreted that there exist no

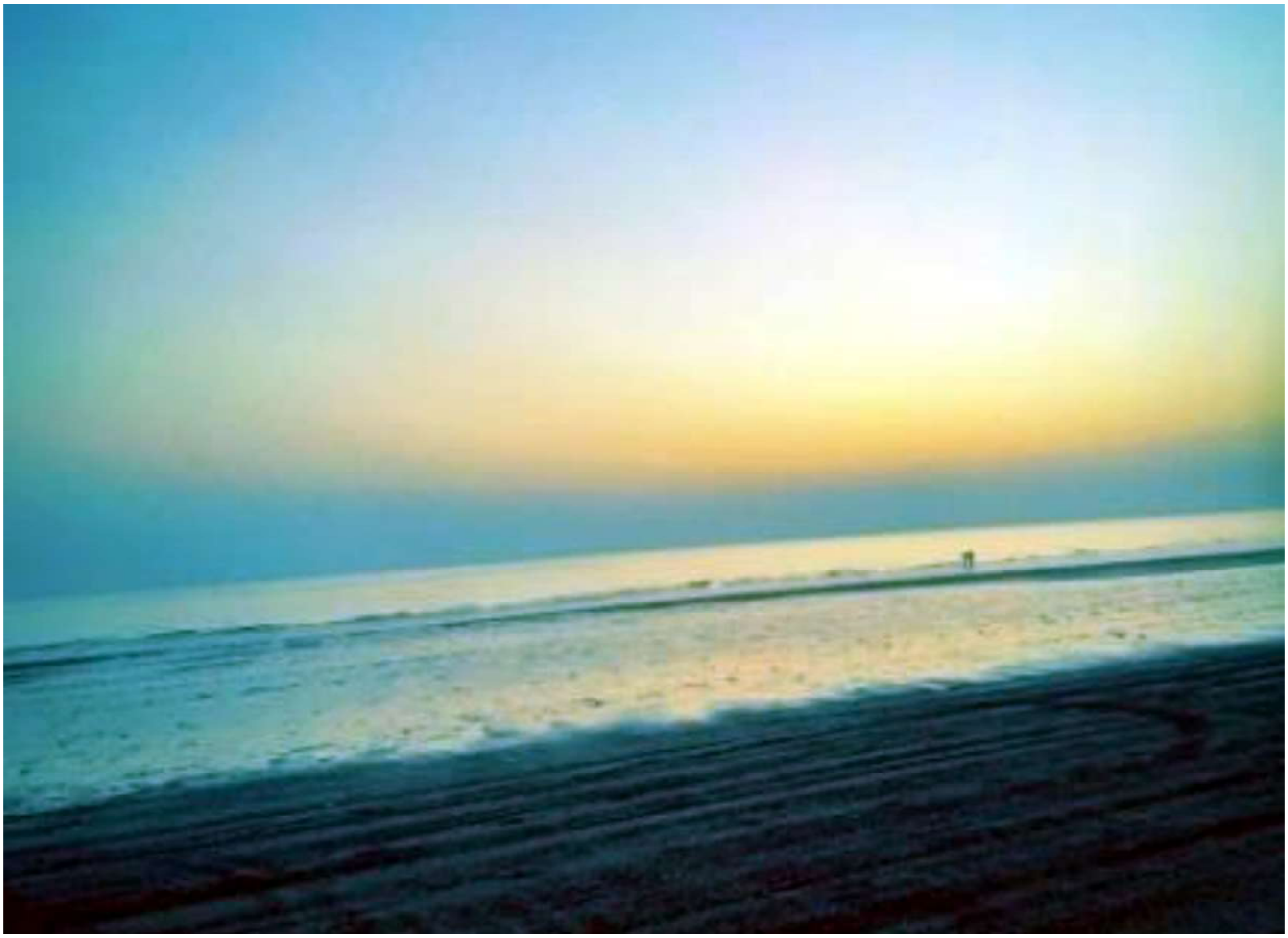

Fig. 4 - Site 4 : Dandi

Fig.5 : Site 5 : Tithal

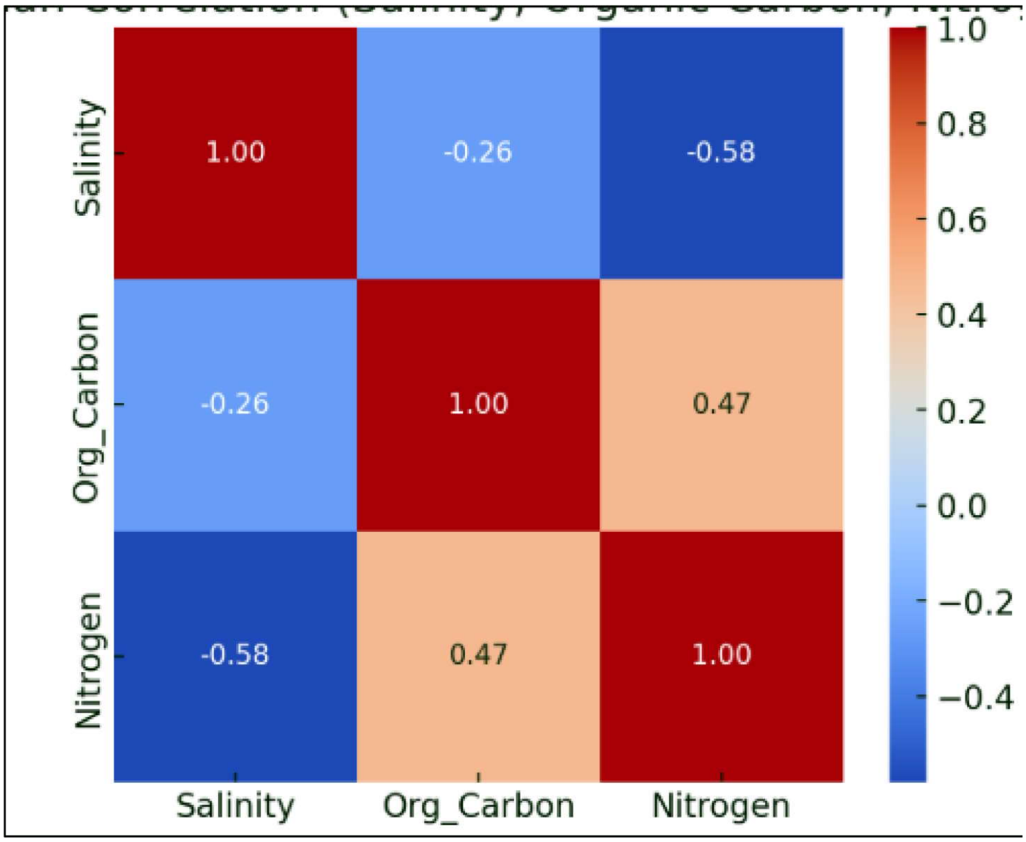

Fig. 6 : Spearman Correlation matrix heatmap graph between (Salinity, Organic Carbon, Nitrogen) and soil type

statistically significance different in soil pH between coastal and agricultural soils. Since p.0.05, this means pH levels have been relatively similar across the two soil types and other factors could be driving ones.

Another test accounts for salinity, organic carbon and nitrogen with soil type is Spearmen correlation test.

From above Table it can be easily interpreted that lower nitrogen and slightly lower organic carbon contribute to higher salinity. There exists a positive correlation between organic carbon and nitrogen. This suggests that salinity stress negatively impacts soil fertility parameters which are important for crop productivity. Soil Health Index (SHI) is the composite index that combines multiple parameters into single numerical value to evaluate the overall health and agricultural suitability of soil. Now soil health Index has been calculated by using normalized values of pH, salinity and all parameters which suggest agricultural suitability of the site.

From Table-6, it can be easily interpreted that best sites for agricultural suitability with higher SHI are at-4 (0.65), an-4 (0.63), au-4 (0.59), an-1 (0.55). They possess moderate to good suitability. On the basis of SHI score (0-1), the interpretation is carried on the base-

>0.7 = Good suitability; 0.4–0.7 = Moderate suitability; <0.4 = Poor suitability

It depicts that sites with higher coastal SHI are cs-2 (0.63), cs-4 (0.64), cn-1 to cn-4 (~0.53–0.59) and they possess moderate suitability for agricultural practices.

Conclusion

On the basis of graph, it can be easily noticed that land use type influences SHI. Agricultural soil shows wider variation with SHI ranging between lesser than 0.3 to more than 0.65. While coastal soils show consistent SHI values between 0.34-0.64 limited by salinity stress.

On comparing, the soils with regions another the graph entails that Dandi and Suvali coastal soils have best SHI values as per agricultural counterparts. Amongst agricultural soils, titthal account significant better value of 0.61 SHI. Umbhrat coastal soil holds better SHI as compared to agricultural soil and Dabhari is the site with lowest values in both categories.

Overall, coastal soils are healthier in Dandi, Suvali, and Umbhrat, while agricultural soils are healthier in Titthal. Dabhari remains the least healthy in both categories.

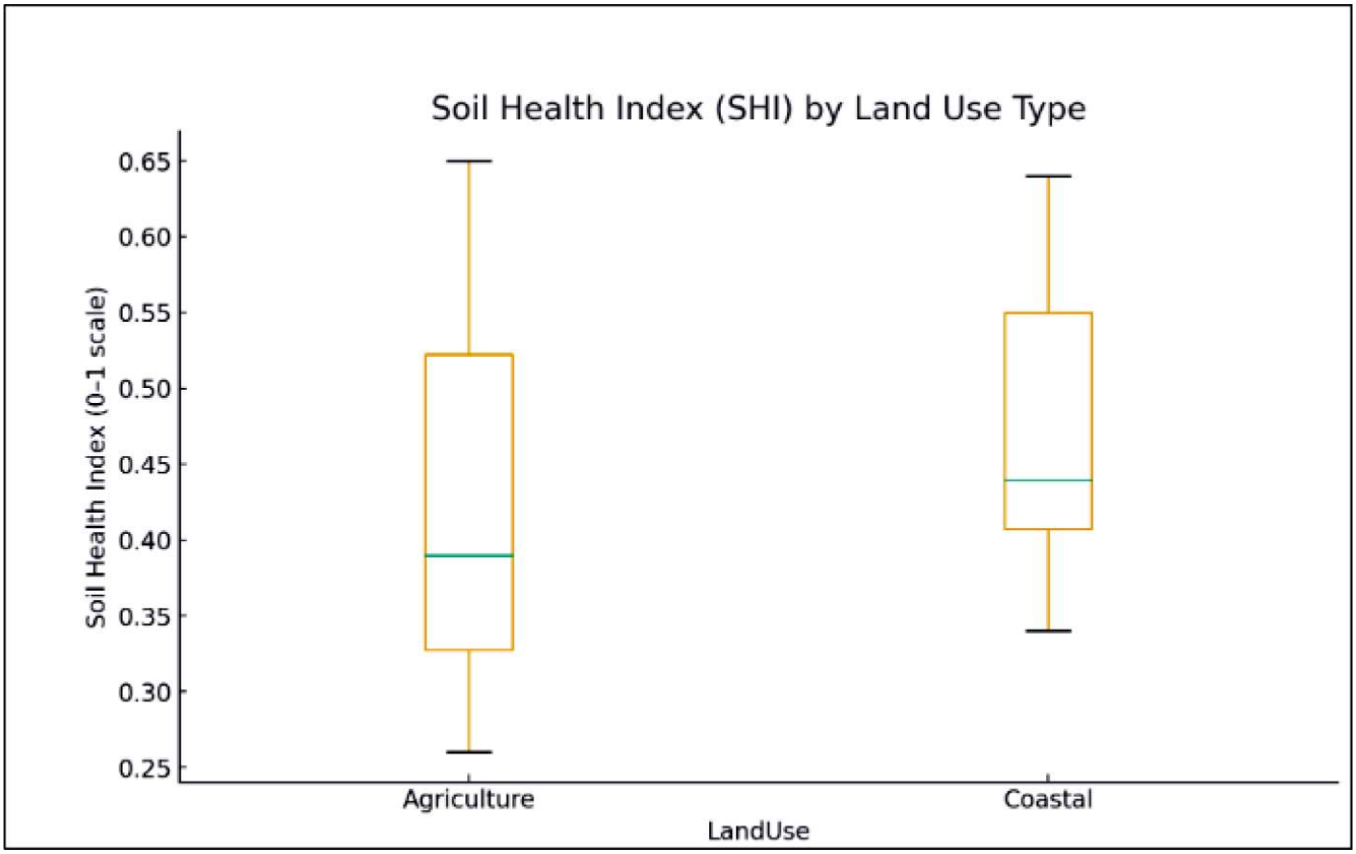

Fig. 7 : Comparisison of SHI between Agricultural and Coastal soils

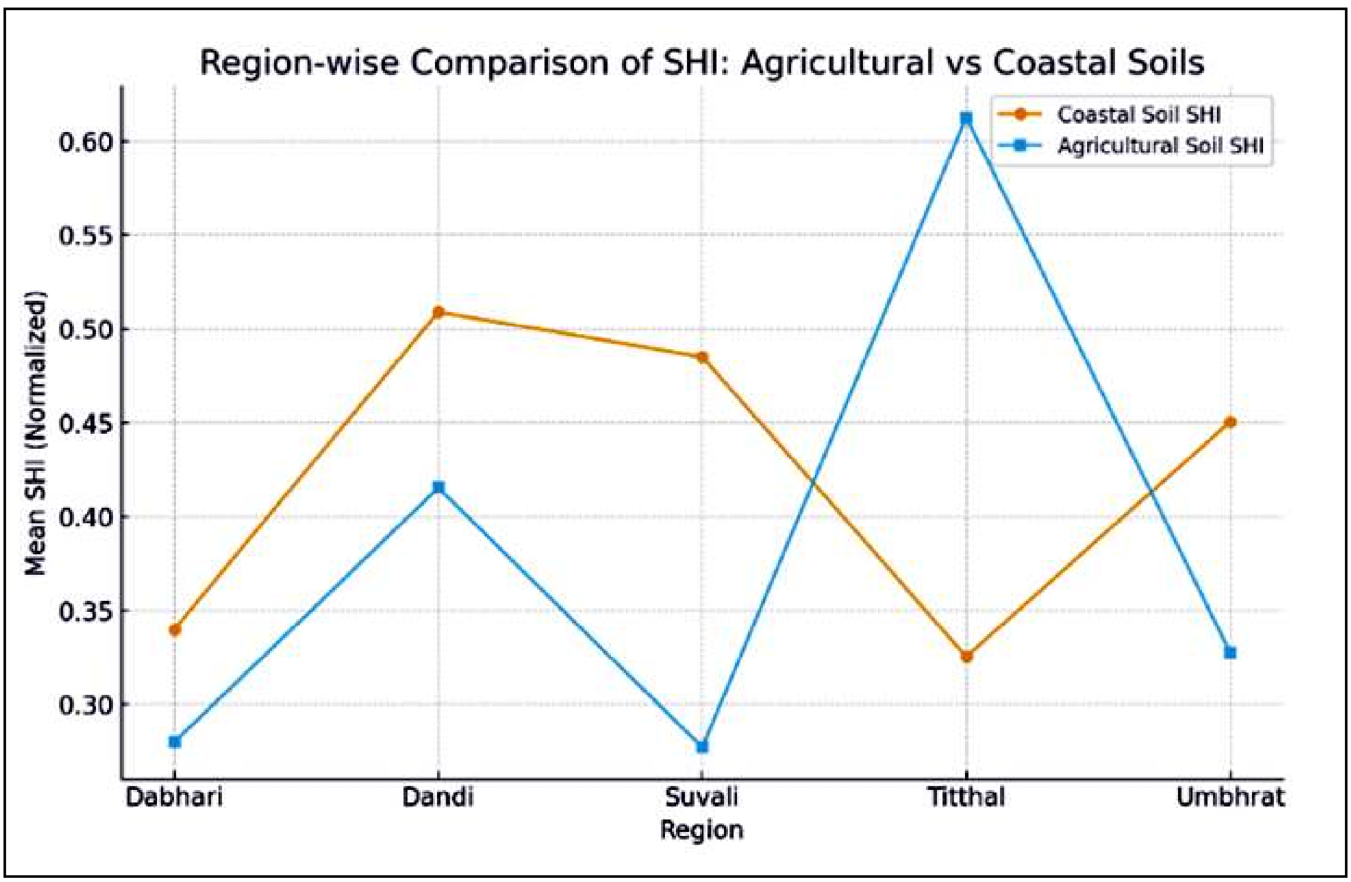

Fig. 8 : Region-wise comparison of SHI for agricultural *vs* Coastal soils

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