Soil Related Issues of South Gujarat, India

Abstract

The soil related issues have been ever since farming on soils initiated. But, it is critically intensified in recent decades because of growing population which posing serious threat to the sustained agricultural production and food security. South Gujarat faces formidable challenge with its lengthy coastal line, salt affected soils, high rainfall areas, hilly undulated territory, irrigated plains and highly industrialize. These challenges will be much severe in the next decades due to issues related to land resources and declining water availability. The South Gujarat has 21.01 lakh ha total geographical area (10.75 % of state TGA) which sustains 122.90 lakh populations *i.e.* 20.36 % of the Gujarat state. More than 25 per cent land of total geographical area of south Gujarat is affected with various soil issues which are comparatively much higher than the state (15.95%). The issues are related to soil degradation mainly by soil erosion through water, followed by exclusive salinity, decline in the above ground biomass resulted from deforestation/overgrazing and human interventions that include mining, industrial activities and urbanization. The present paper delivers a brief account of soil issues and causes with special reference to the South Gujarat.

Key Word: Soil erosion, salinity, nutrient imbalance, soil contamination.

1. Introduction

1.1 South Gujarat

The South Gujarat is one of the wettest regions of India. It comprises of seven districts *viz.* Bharuch, Narmada, Navsari, Surat, Tapi, The Dangs and Valsad. Geographically, it is located between longitude 72°54' East and latitude 20°57' North. The area of south Gujarat can be broadly categorized into two major agro-climatic zones *viz.*, South Gujarat heavy rainfall zone with annual rainfall of 1592 - 2534 mm in 65 to 95 rainy days and South Gujarat medium rainfall zone with 31-71 rainy days and annual rainfall of 798 - 1655 mm. The total geographical area of South Gujarat is 23.81 lakh hectares (12.14 % of state) covering 122.90 lakh population *i.e.* 20.36 % of the Gujarat state with occupying too much higher population density (513 persons/km) than the Gujarat state as whole (308.2 persons/km).

"At the national level, although key portion of the South Gujarat is grouped under coastal ecosystem with sub humid climate however, at block level remarkable deviations in climatic parameters are observed. Excluding, Nandod of Narmada and Nizar and Uchhal of Tapi district, entire eastern belt is sub-humid (moist/dry) and the South eastern part comprising Dharmpur and Kaparada blocks of Valsad as well as Gandevi block of Navsari district are categorized as humid. Almost all blocks of Bharuch are categorized into semiarid (dry/moist). This diversity is also apparent in rainfall pattern in South Gujarat as Dharampur and Kaparada blocks get 2384 mm and that of Jamusar block get only 773 mm of rainfall". (Naik *et al.*, 2012). "Paddy and sugarcane in addition to mango, sapota and banana are the major crops of South Gujarat due to constant irrigation facility and heavy rainfall zone. The cereal crops which involves mainly paddy are covers 35 per cent South Gujarat. It is followed by pulses and sugarcane. The 11 per cent area are under fruit crops primarily consist of mongo, sapota and banana. Cotton cultivated in Bharuch and Narmada districts only with 13 per cent area of South Gujarat", (Naik *et al.*, 2012)

1.2 Soils of South Gujarat- In general

The soils of south Gujarat extensively vary in their characteristics. The district wise distribution of the soils of South Gujarat is given in the table 1. “A deep black cotton soil occupies more than 50 per cent area in both the zones. Although, the soils as per crop based grouping under deep black cotton soils, but, these soils are not true Vertisols except some pockets in Bharuch district. However, in rest of the South Gujarat, the soils belong to Inceptisols having *Vertic* as characteristics horizon with predominance of montmorillonite silicate clay mineral. As a result of high clay content (> 40 %) that too with montmorillonitic silicate mineral, these soils exhibit cracking, gillgai formation etc. properties” (Anon., 2000)

Table 1: Agro-climatic zone distribution of the soils

Agro-climatic Zone	Types of soil	Approx Area ('000 ha)	% Total Area
South Gujarat Heavy Rainfall (The Dangs, Navsari, Valsad and Surat)	Deep Cotton Black Soil	483.7	55
	Laterite soils	159.5	18
	Hilly and forest soils	109.6	12
	Coastal alluvial soils	136.7	15
	Saline/alkaline soils	15.4	00
South Gujarat Medium Rainfall (Tapi, Narmada and Bharuch)	Deep Cotton Black Soil	542.0	53
	Coastal alluvial soils	290.6	28
	Saline/alkaline soils	79.2	08
	Hilly and forest soils	117.2	11

Source: The joint report by Navsari campus, GAU and NBSSLUP, Udaipur (2000)

Table 2: Degraded and wastelands statistics of Gujarat and South Gujarat

Class	Area ('000 ha)	
	Gujarat	**South Gujarat**
Exclusively water erosion (>10 t/ha/yr)	979	529
Water erosion under open forest	32	18
Exclusively saline soils	1495	55
Eroded saline soils	4	0
Saline soils under open forest	60	0
Exclusively sodic soils	545	0
Mining/Industrial waste	13	5
Waterlogged area (Permanent)	0	0
Total of degraded & wasteland	**3128**	**607**
Normal agricultural lands, water-bodies, rivers, lakes and habitats *etc*	16485	1806
Total Geographical Area	**19613**	**2414**

Source: NBSSLUP, Nagpur (1994) and author's own calculations based on data from the sources

2. Major soil related issues of South Gujarat:

2.1 Issues related to soil physical properties:

2.2.1 Soil Erosion:

"Soil erosion has both on-site and off-site negative impacts and badly disturbs both environment and economy. Erosivity, erodibility and land use management practices play important role in describing status of soil erosion. Topography controls soil movement in a watershed and the areas generally covered by large proportion vegetation are at a lower risk of soil erosion" (Prasannakumar *et al.*, 2011).

The western hilly undulated tract of south Gujarat covering 4.77 lakh hectare cultivated land are prone to soil erosion with the tune of 5 to 40 t ha^{-1} soil loss annually. It consist Kaprada and Dharmapur block of Valsad; Vansda block of Navsari; Dolvan, Songadh and Uchhal block of Tapi; Mandvi and Umarpada of Surat; Netrang and Jhagdia of Bharuch; Dediyapada, Sagbara and Tilakwada of Narmada and the entire Dang district. The joint report by Navsari Campus, GAU and NBSSLUP, Udaipur (table 3) categorized soil related issues of South Gujarat according to the physiographic locations. The piedmont slope soils of both the zone of south Gujarat have shallow depth, highly erosive, high permeability (Anon., 2000).

Table 3: Agro climatic zone wise soil related issues

Agro climatic Zone	Physiographic Locations	Pre- dominant sub order association	Issues
Heavy Rainfall Zone	Piedmont slope and plain	Ochrepts	➢ Shallow depth, ➢ Highly erosive, ➢ Low to moderate MHC, ➢ High permeable
	Mid alluvial plains	Ochrepts Usterts	➢ Severe cracking, ➢ Low to very low permeability, ➢ Poor internal drainage, ➢ Secondary salinization
	Coastal alluvial plains	Aquepts Ochrept	➢ Highly dispersive, ➢ Poor drainage ➢ Low permeability, mild cracking
Medium Rainfall Zone	Piedmont slope and valley plains	Ochrepts	➢ Highly erosive, ➢ Low to medium MCH ➢ Highly permeable ➢ Secondary salinization
	Alluvial plains	Usterts Ustochrepts	➢ Prone to erosive, ➢ Moderate to poor drainage ➢ Medium to low permeability
	Coastal alluvial plains	Aquepts Ochrepts	➢ Highly dispersive, ➢ Poor drainage ➢ Low permeability, mild cracking

The most of the area under study in the Dangs district falls in moderate to very severe erosion class. The soils having the erosion classes varying widely ranged from e1 (slight/ sheet erosion) to e4 (very severe/ big gully). The erosion classes can be attributed to steep slopes (> 5 %) and shallow to very shallow depth (< 22.5 cm) of soils in the region (Das and Shinde, 2014). These findings are also in agreement with Shinde *et al.* (2020) who reported "during quantitative assessment of soil loss in Ambika watershed of the Dangs district that nearly 80% of the watershed area is affected by moderately high to very high soil erosion (>15 tons ha^{-1} $year^{-1}$). The annual average soil loss for the entire watershed was estimated as 22.41 tonne ha^{-1} $year^{-1}$. A huge portion of the watershed was affected by sheet and rill erosion causing low agricultural productivity". Lakkad *et al.* (2016) carried out study to identify erosion susceptible area for the sub-watershed in Narmada district. The findings indicated that nearly 3500 ha *i.e.* 45% of total study area having annual soil loss from 10 to 80 t ha^{-1} $year^{-1}$. On average cumulative soil erosion was lowest for evergreen forest (*i.e.* 5.16 tons/ha/yr) followed by mixed forest (*i.e.* 21.87 tons/ha/yr), land under cultivation (*i.e.* 33.28 tons/ha/yr), deciduous forest (*i. e.* 45.75 tons/ha/yr), pasture (*i.e.* 51.42 tons/ha/yr) and maximum for wasteland without vegetation / low density inhabited area (*i.e.* 64.64 tons/ha/yr). Soil erodibility factor plays central role and principal factor for inter-rill and rill erosion. Soil erodibility is defined as the susceptibility of soil particles to be detached and become available for erosion by wind, water, or ice. In another study by Lakkad *et al.* (2016) estimated soil erodibility factor for soil erosion modeling of the study area in Narmada district. The average erodibility assessed for clay loam (53.36 % area) and clay soil (46.61 %) was 0.236 and 0.177 respectively. Tiwari *et al.* (2018) conducted detailed soil survey and described soil characteristics of Valia taluka of Bharuch district. He reported about 50 % area affected with moderate to severe soil erosion and imperfect drainage.

2.2.2 Inadequate soil moisture retention and compaction

It is apparent that more the gravels/coarse fragments compared to silt and/or clay in the soils, lower the moisture holding capacity of soil. The pedons in the Dangs district contained >35% of gravels/coarse fragments (>2 mm) and pedons mean moisture water holding capacity (MWHC) value varied from 39.45 to 42.28 % (Prasad *et al.,*2018). They also reported that soils at higher elevation or at upper pediment, showed higher values of bulk density contrary to those at lower most elevation or at slightly flat land. This might be due to clogging of pores by dispersed clays in sub-soil layers and leaching loss of clay particle attributed to illuviation of upper surface in The Dang district. High bulk density is an indicator of soil compaction and low soil porosity. Descriptive analysis of South Gujarat zone soil by Patel *et al.,* (2015) revealed the maximum values of bulk density were 1.76 gm /cm^3 (pre-monsoon), 1.07 gm /cm^3 (post-monsoon) and 1.48 gm /cm^3 (summer) indicating low organic matter content in majority of soils. The similar trend was revealed for porosity, water holding capacity and moisture content. The coastal salt affected soils in Valsad and Surat districts are medium to heavy in texture with permeability is low to very low however coastal soils in Bharuch district are heavier and clay in texture throughout the depth (Chinchmalatpure, 2018). Heavy soils comprise of few large pores and less total pore volume and, hence have a greater density and compacted.

2.2 Issues related to soil chemical properties:

2.2.1 Salinity and Sodicity

The increase in irrigation area has been one of the significant approaches in attaining self-reliance in the food production. In most of the expansion, the area is enhanced under canal irrigation that causing the soil deterioration through salt accumulation. These soils contain excess amount of either soluble salts or exchangeable sodium or both reducing crop yields. Such soils are classified into saline, sodic and saline-sodic subjected to the physiochemical properties and the nature of the salts. The major multipurpose project Ukai-Kakrapar is built on river Tapi with command area of 3.42 lakh ha area of South Gujarat. The command area of Sardar Sarovar covers 1.22 lakh ha in Bharuch and Narmada districts of South Gujarat. An experiment on pre and post monsoon changes in soil properties of five blocks of Navsari district of South Gujarat showed the salinity and ESP was higher in soils during pre-monsoon with 0.64 to 2.15 dSm^{-1} and 12.67 to 25.41, respectively. The overall ESP of Navsari district was reported high (fig. 1).
The slight declined in the sodicity of soils in post-monsoon period as a consequence of washing out of part of Na+ ion from the exchange complex due to precipitation (Das and Zambre, 2016)

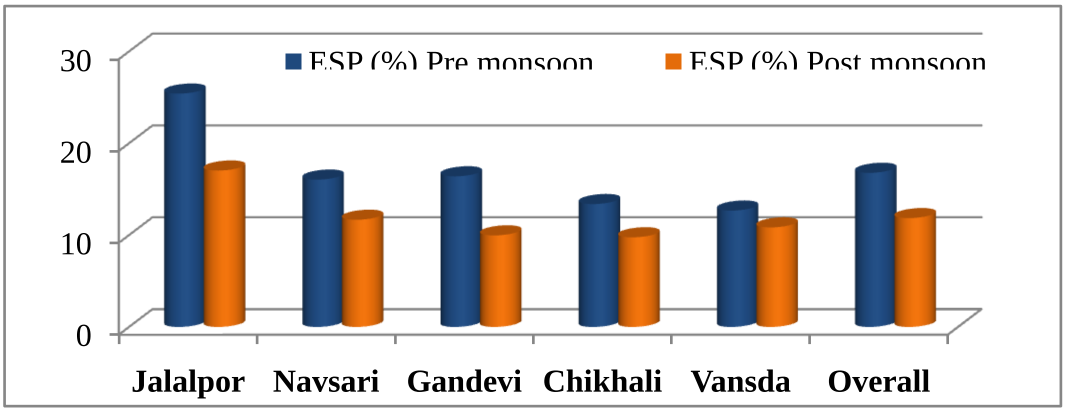

Fig. 1: Changes in pre and post monsoon Na concentration in five blocks of Navsari district

The chemical properties of irrigated and rainfed cotton growing soils of South Gujarat and their rating showed that about 42% of rainfed soils came under 'strongly alkaline' to 'very strongly alkaline' category, Nearly 90 % irrigated and 71 % rainfed soils belonged to 'medium' salinity class. The ESP of majority of irrigated and rainfed soils were in the range between 5 -15. The cause for higher percentage of rainfed soils with higher pH range was primarily due to higher surface evaporation under rainfed condition along with higher organic acids under irrigated condition arising from incorporation of larger quantity of organic matter by the farmers (Bambhaneeya *et al.*, 2017). Vasu *et al.* (2019) undertook characterization and classification of coastal region soils of Valsad district of South Gujarat and reported the soil reaction varied from slightly alkaline to strongly alkaline and electrical conductivity (EC) varied from 0.2 to 4.4 dSm^{-1} in surface horizons indicating saline soils, and it could be because of the tidal deposits of salts and further accumulation triggered by the high evapotranspiration in the summer period under semi-arid conditions. They also revealed The ESP of these soils varied from 1.1 to 47.8 indicating the high concentration of exchangeable Na.

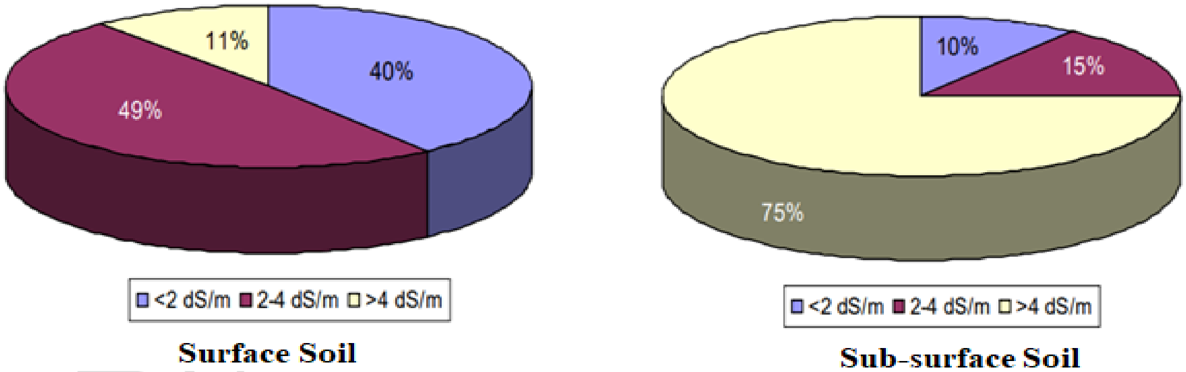

Fig. 2: Per cent area of surface soils of Bara tract of south Gujarat affected by soil salinity

In Bara tract, it was recorded that only 40 per cent of surface soils are free from salinity (<2 dS m^{-1}), 49 % soils are saline (2-4 dS m^{-1}) and only 11 % soils are having salinity > 4.0 dS m^{-1}. In the sub-surface 10 per cent have salinity < 2 dS m^{-1}, 15 per cent between 2-4 dS m^{-1} and 75 per cent greater than 4 dS m^{-1} (Chinchmalatpure *et al.*, 2010), the cause of such conditions as the sub-soil salts are very hard to leach down more because of very low saturated hydraulic conductivity and presence of high saline groundwater table conditions.

2.2.2 Nutrient Imbalance / Nutrient depletion

A balanced nutrient supply is essential for attaining high crop yields, but excess and/or imbalanced nutrient inputs may pose threat on the environment, human health and ecosystems. A GPS-referenced representative surface soil samples were collected randomly from farmers field covering nine talukas (Bharuch, Ankleshwar, Valia, Vagra, Jambusar, Amod, Hansot, Netrang and Jhagadia) of Bharuch district at 0-22.5 cm depth by Patel *et al*. (2018) and revealed out of 135 surface soil samples, 80.74 % samples were deficient in available N, 45.92 % samples were deficient in available P_2O_5 and 49.62 % samples were deficient in available S content. This wide variation in nutrients content is might be due to variation in soil properties viz., pH, texture and agronomic practices. On categorization of soils of South Gujarat in deficit and near to deficit class for available S, DTPA extractable Zn and Fe (table 4) Ramani *et al.*(2019) reported about 25, 32 and 7 % samples were deficit and 71, 23 and 2 % were near to deficit for available S, DTPA extractable Zn and Fe, respectively.

Table 4: Percentage area falls in deficit and near to deficit situation for available S, DTPA extractable Zn and Fe

District	Available S		DTPA Extractable Zn		DTPA Extractable Fe	
	Deficit	Near to Deficit	Deficit	Near to Deficit	Deficit	Near to Deficit
Bharuch	11.23	88.77	42.23	33.77	9.66	6.68
Dangs	36.63	62.67	27.93	38.50	0.00	0.00
Narmada	53.76	28.16	36.40	33.14	34.12	2.66
Navsari	19.50	80.32	15.78	7.15	4.42	0.82
Surat	35.07	64.9	34.81	17.97	0.00	0.43
Tapi	5.07	88.06	56.13	23.26	0.01	2.04
Valsad	11.28	80.58	8.36	6.78	0.00	0.00
Average	**24.65**	**70.49**	**31.66**	**22.94**	**6.89**	**1.80**

2.2.3 Toxic Accumulation in soil.

The main industrial belts in the South Gujarat are located at Vapi, Valsad, Navsari, Ankleshwar, Bharuch and Surat which are dominated by chemicals and pharmaceutical industries, glass industries, industrial equipment and electronics manufacturing industries, in addition to some industries of textile, paper, plywood, paper and food products and. The release of by-products or wastes by these industries into the rivers streams and rivulets is the leading cause for the higher concentration of heavy metals especially the toxic metals in the areas. The soils in the vicinity of Surat industrial area were significantly contaminated with metals especially Ba (471.7 mg/kg), Cu (137.5 mg/kg), Cr (305.2 mg/kg) Co (51.3 mg/kg) and V (380.6 mg/kg) at levels far beyond the background concentration in soil which result from very localized additions or accidental leakages of highly concentrated pollutant materials (Krishna and Govil 2007). A significant enrichment of heavy metals like As and Pb in Ankleshwar area reported by Shirke and Pawar (2018) which are influenced anthropologically including industrial and urban area. It is observed that heavy metals like Zn, Ni, Cu, and Mo show a positive correlation with the silt size fraction. In the same way, Pb, Cr, As and Mn show positive correlation with clay size fraction. High correlation with chemical properties like EC and CEC suggests that higher ionic conductivity soils have high heavy metal content. They also observed the highest concentration of Mo and Cu in the soil samples of the lower stretch as it is openly in contact with the highly toxic and polluted industrial effluent.

3. *Issues related to soil biological properties:*

Soil biological properties are one of the most crucial components to evaluate the functional stability of agro ecosystems in response to environmental degradation. The correlation of soil organic carbon and biological properties allows the biological properties to be successfully projected. The soil organic carbon (SOC) in Bharuch, Surat and Narmada districts of South Gujarat varied from 2.70-9.42 g kg^{-1}. The findings also revealed about 62 % soils under low category followed by medium (about 36 %) for SOC content in rainfed soils of South Gujarat. The dissimilarity in SOC content in both irrigated and rainfed soils might be attributed to application of varying quantity of various sources of organic matters by farmers, differences in tillage operation/ cultivation by the farmers and variation in rate of organic matter decomposition due to deviations in temperature and precipitations Bambhaneeya *et al.* (2017). A summarized report of the soil health card mission stated 91% soils of Valsad and about 25 % soils of Surat district have “low” soil organic carbon. However, soils of Dangs and Navsari have high content of organic carbon (fig. 3) (Annon., 2020)

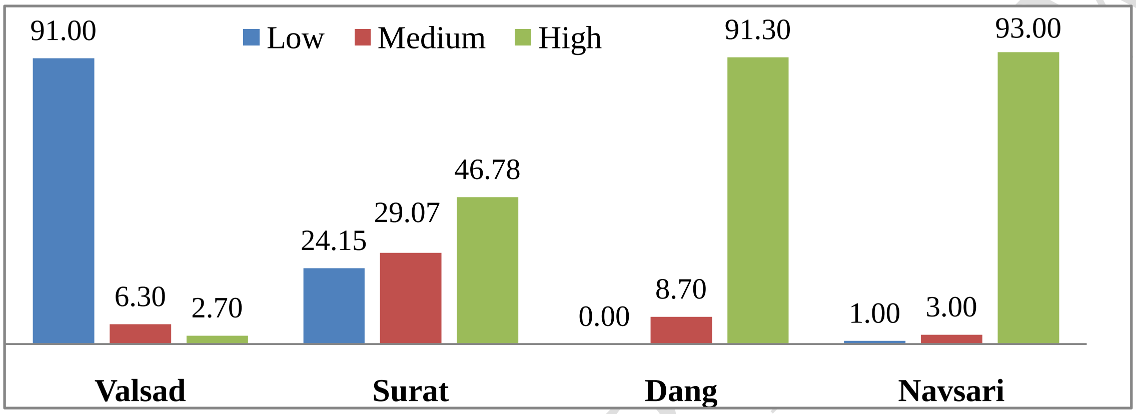

Fig. 3: Categorization of soil samples of Valsad, Surat, Dangs and Navsari district for organic carbon content (% of total)

Kikani (2021) observed comparatively higher microbial load present in Bardoli soils followed by soils of Vyara and Navsari from different locations. It might be attributed to varying physic-chemical properties of soils, existing cropping system, irrigation facilities and management practices followed by farmers in the area.

Conclusion:

The soils of South Gujarat extensively vary in their characteristic. In broad, the soil of eastern hilly belt of both the agro climatic zones of south Gujarat are shallow in depth and vulnerable to medium to high soil erosion however the soils of mid plain are heavy in texture, cracking and poor in drainage which accentuate the secondary salinization issues predominantly in canal command areas. The soils are poor in drainage, highly dispersive and salt affected in coastal belts of both the heavy and medium rainfall zones. The soils of south Gujarat are also facing a nutrient imbalance, nutrient depletion and toxic accumulation scenarios contribute to food insecurity and environmentally unsustainable growth.

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