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# Chemical characteristics and nutrients status of the soils of North-West Gir Madhuvanti Toposequence of South Saurashtra region of Gujarat

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**Abstract**
Six representative pedons were characterize of chemical, chemical composition of saturation extract and available nutrients properties of the soils of different land slope of north-west Gir Madhuvanti toposequence of south Saurashtra region of Gujarat. The six representative pedon soils have been classified as Lithic Ustorthents ($P_1$), Lithic Ustorthents ($P_2$), Vertic Haplusterts ($P_3$), Typic Haplusterts ($P_4$), Sodic Haplusterts ($P_5$) and Fluventic Calciustepts ($P_6$). Soils of the study area pH, EC, organic carbon and $CaCO_3$ were 7.89, 1.41 $dSm^{-1}$, 0.58 percent and 19.93 percent, respectively indicating the soils to be moderately alkaline, medium in O.C. and highly calcareous in nature. The CEC, BSP and ESP were 33.18 cmol (p+) $kg^{-1}$, 92.71 and 8.27, respectively. The exchangeable $Ca^{2+}$ was the dominant cation followed by $Mg^{2+}$, $Na^{+}$ and $K^{+}$. The saturation percentage was 42.49 in the soils of different land slopes. The pHs and ECe were 8.04 and 5.00 $dSm^{-1}$, respectively. The proportion of water soluble cations and anions were to be decreasing order of $Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ and $Cl^{-} > HCO_3^{-} > CO_3^{--}$. The SAR value observed 3.84. The soils were low in available N as well as $P_2O_5$, medium in available $K_2O$, Fe and Zn and high in Mn and Cu.

**Keywords:** chemical, saturation extract, available nutrients, land slopes, North-West Gir Madhuvanti Toposequence

## Introduction
Soil is vital natural resource on whose proper use depends the life supporting system of a country and the socio-economic development of its people. To meet the requirements of food, fiber, fuel and fruits for the increasing population, farm land development is often extended even to the areas unsuitable to agriculture and when the land for agriculture is shrinking; the existing cultivated area is subjected to greater burden in many cases. Success in agriculture depends on the land quality and soil characteristics. Poor performance of crops on salts affected soil may be due to excessive quantities of soluble salt and higher exchangeable sodium percentage, which consequently result in nutritional disorders in plants. Excess salt content in soil create high osmotic pressure of soil solution, which obstructs water and nutrient uptake by plant roots. High ESP level deteriorates the soil physical condition and there by limit adequate supply of air, water and nutrient to the crop. In present time, salinity and alkalinity of the soil are serious problem in India. These soils are usually supposed to be for need as a result of high water table, arid and semi-arid weather, and ingress of sea water, saline nature of barren materials, poor drainage and salt deposition through windblown particles. Better crop production in salt affected soils can be attained if the nature and extent of salinity problems are correctly diagnosed and appropriate reclamation and management practices are adopted. Soil survey provides useful information for planning proper soil management practices, which are play important role in augmenting crop production. For the sustainable use of the natural resources, a detailed charter of land resources giving its potential and constraints becomes pre-requisite for planning.

## Material and method
The study area (north-west Gir Madhuvanti toposequence) was located between $21^{0}13'$ to

$21^0$25' N latitudes and $69^0$57' to $70^0$32' E longitudes encompassing parts of the Mendarda, Vanthli, and Keshod tehsils of Junagadh district and Porbandar tehsil of Porbandar district of south Saurashtra at an elevation ranged from 5 to 190 above mean sea level. IRS IA LISS II FCC imagery on 1:50,000 scale in conjunction with Survey of India topographical (SOI) map referred above on 1:50,000 scale were used to select various land slopes of north-west Gir Madhuvanti toposequence of south Saurashtra region of Gujarat namely: hill slope (LS-1), upper piedmont (LS-2), lower piedmont (LS-3), plain area (LS-4), depression area (LS-5) and upper coast (LS-6) (Fig.-1). The mean annual rainfall is 1120 mm and the climate of the area is semi-arid characterized by extremes of temperature and low wind velocity. Two to three kilograms of soil samples were collected in cotton bags from each horizon of the pedons under study and labeled properly in month of May. In all soil samples (1 to 5 samples from each pedon depending upon the horizon differentiation) were collected from the different profiles. Soil samples collected were air dried. Some of the clods were use for bulk density determination and remaining soils were gently crushed (ground) with a wooden mortar with pestle and passed through the 2 mm sieve for chemical analysis. The analysed of chemical characteristics by different methods in which, Soil reaction (pH) and Electrical conductivity were determined in the 1: 2.5 soil-water suspension using glass electrodes as described by Richards (1954) [8]**.** Organic carbon by Walkley and Black rapid titration method was followed as outlined by Jackson (1958) [3]. Calcium carbonate by Acid neutralization method was followed as outlined by Allison and Moodi (1965) [1]. Cation exchange capacity was determining by using neutral normal ammonium acetate method as described by procedure given by Richards (1954) [8]. Exchangeable cations (Ca, Mg, Na, K) determined by normal ammonium acetate leachate (pH 7.0) as per the method described by Richards (1954) [8]. The BSP, ESP and CEC/ Clay were calculated based on the above parameters as suggested by Richards (1954) [8]. The saturation extract was obtained by preparing a saturated paste of soil, followed by vacuum filtering to obtain the saturated extract and saturation percentage and other parameters (ECe ($dSm^{-1}$), pHs, carbonate, bicarbonate, sodium, potassium, calcium, magnesium and chlorine in the saturation extract were estimated by the method outlined by Richards, (1954) [8]. The analysed of available nutrients by different methods in which, available nitrogen was estimated using alkaline potassium paramagnet method as suggested by Subbiah and Asija (1956) [13], available phosphorus in soil was extracted with 0.5 M $NaHCO_3$ (pH 8.5) as described by Olsen *et al*. (1954) [5], available potassium in soil was determined by using neutral normal ammonium acetate extraction method as described by Richards (1954) [8] and available Zn, Cu, Fe and Mn were determined by extraction with 0.005 M DTPA and 0.01 M CaCl2 estimated by atomic absorption spectrophotometer following the procedure give by Lindsay and Norwell (1978) [4].

## Result and discussion

### Chemical characteristics of soils

The soils of different pedons of north-west Gir Madhuvanti toposequence of south Saurashtra region are presented in Table -1 and 2.The results obtained that pH, EC, organic carbon and $CaCO_3$ ranged from 6.79 to 8.28, 0.28 to 3.08 $dSm^{-1}$, 0.37 to 0.84 per cent and 2.75 to 31.80 per cent with the overall mean value of 7.89, 1.41 $dSm^{-1}$, 0.58 per cent and 19.93 per cent, respectively, indicating the soils of different pedons of north-west Gir Madhuvanti toposequence were moderately alkaline in reaction, medium in organic carbon status and highly calcareous in nature. The pH of the soils of north-west Gir Madhuvanti toposequence was observed to follow an increasing sequence Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast. A thorough examination of the data revealed that an increase in soil pH gradually along the topography from hill slope to upper coast could be the result of continuous flow of bases from higher topography to lower topography of north-west Gir Madhuvanti toposequence**.** The higher values of pH in Plain area, Depression area and Upper coast might be due high accumulation of soluble salts**.** The electrical conductivity was recorded in increasing order of Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast. The electrical conductivity increases from higher elevation to the lower elevation indicating that appreciable amount of salts have moved down the slope along with flowing water from hill slope area to sea coast area. Sharma and Roychowdhury (1988) [12] reported that accumulation of soluble salts in soils occurring on flood plain and adjoining Piedmont and valley was comparatively higher and was mainly due to their relatively poor drainage, high water table conditions, high evaporative demand from the soil, which alternately regulate the salt regime (EC). The medium organic carbon content in the soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at faster rate with low vegetation cover, thereby leaving less organic carbon in the soils. The organic carbon content of the studied soils was found in the order of Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast, indicating decreased with decreasing in elevation. The $CaCO_3$ content was found in the increasing order of Hill slope < Lower piedmont < Plain area < Depression area < Upper coast < Upper piedmont. The content of $CaCO_3$ in general increased down the slope and it registered its maximum value in upper piedmont (31.80 per cent) because the upper piedmont area has a rich source of lime stone. A fact corroborated by the finding of Savalia (2005), Patel (2010), Gandhi (2013), Pulakeshi *et al*. (2014), Shirgire *et al.* (2015) and Singh and Rathore (2015) [9, 6, 2, 7, 10, 11].

The cation exchange capacity in the studied soils ranged from 20.60 and 43.96 cmol ($P^+$) $kg^{-1}$ with the mean value of 33.18 cmol (p+) $kg^{-1}$. The CEC recorded in the increasing order of Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast, indicating that CEC increased with decreasing topography. The exchangeable $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$ ranged from 12.99 to 24.96, 5.09 to 9.87, 0.11 to 7.43 and 0.04 to 0.33 cmol ($p^+$) $kg^{-1}$ with the overall mean value of 19.93, 7.63, 3.21 and 0.20 cmol ($p^+$) $kg^{-1}$, respectively. Thus, the exchangeable $Ca^{2+}$ was dominant cations followed by $Mg^{2+}$, $Na^+$ and $K^+$. The content of all exchangeable cations in the soils of north-west Gir Madhuvanti toposequence was found in the increasing order of Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast. Thus, there was proper systematic pattern observed in content of all exchangeable cations from hill slope to upper coast. The BSP and ESP ranged from 88.44 to 96.31 and 0.53 to 16.93 with the mean value of 92.71 and 8.27, respectively, indicating moderate sodicity. The content of BSP and ESP were found in increasing sequence of Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast,

indicating BSP and ESP increases with decreasing an elevation. The ESP of more than 10.00 in plain area to upper coast which may be due to its mobility and position of profile in transect, poor drainage, shallow underground water and high Na salts. The relatively higher ESP (16.93) of these coastal soils indicates the strong alkalinity hazard. Exchangeable sodium exerts severe effects which lower the production in lower elevated coastal soils of studied area Sodium ions, when coupled with high pH, have a toxic effect on roots under extreme conditions. Aeration is often problem in depression area as well as upper Coast. Strong alkalinity, high $Na^+$ and poor aeration (Sat. hydraulic conductivity of 0.00 cm $hr^{-1}$) affect in plant nutrition adversely. Reclamation measures like green manuring and growing salt tolerant crops should be adopted lower elevated coastal areas of north-west Gir Madhuvanti toposequence. A fact corroborated by the finding of Savalia (2005), Patel (2010), Gandhi (2013), Pulakeshi *et al*. (2014) and Shirgire *et al.* (2015) [9, 6, 2, 7, 10].

**Composition of Saturation Extracts of soils**

The composition of saturation extract from different pedons of north-west Gir Madhuvanti toposequence of south Saurashtra region are presented in Table 3 and 4. The results reveal that saturation percentage ranged from 40.38 to 44.90 with overall mean value of 42.49 in the studied soils. The saturation per cent was found in the decreasing order of Upper coast > Upper piedmont > Hill slope > Lower piedmont > Plain area > Depression area. The pHs and ECe ranged from 7.57 to 8.32 (weighted mean of 8.04) and 0.63 to 11.82 $dSm^{-1}$ (weighted mean of 5.00 $dSm^{-1}$) indicating that the soils of different pedons of north-west Gir Madhuvanti toposequence were in general moderately saline and non sodic in nature. The pHs and ECe, in different pedons were in the order of Hill slope < Upper piedmont < Lower piedmont < Plain area <Depression area < Upper coast, indicating the pHs and ECe increased with decreasing topography. The water soluble $Ca^{2+}$, $Mg^{2+}$, $Na^+$ and $K^+$ ranged from 2.06 to 17.20, 1.35 to 15.75, 1.99 to 34.06 and 0.02 to 0.36 me $l^{-1}$ with overall mean value of 10.07, 8.46, 16.47 and 0.15 $mel^{-1}$, respectively. The proportion of water soluble $Na^+$ was dominant followed by $Ca^{2+}$, $Mg^{2+}$ and $K^+$. The total water soluble cations ranged from 5.42 to 67.37 with overall mean value of 35.16 me $l^{-1}$. The distribution of total water soluble cations in different land slopes of north-west Gir Madhuvanti toposequence were in the order of Hill slope < Upper piedmont < Lower piedmont < Plain area <Depression area < Upper coast, Thus, the total water soluble cations increased from hill slope to upper coast of studied area (Savalia, 2005) [9]. This might be due to the effect of hydraulic distribution of soluble ions in the soils from higher to lower altitude and soil depth. Similar results were also observed by Gandhi (2013) and Shirgire *et al.* (2015) [2, 10].

Among the water soluble anions, $CO_3^{2-}$, $HCO_3^-$ *and* $Cl^-$ ranged from 0.00 to 0.23, 1.45 to 6.22 and 2.32 to 48.15 me $l^{-1}$ with overall mean value of 0.11, 3.32 and 22.64 me $l^{-1}$, respectively indicating the proportion of $Cl^-$ was dominant followed by $HCO_3^-$ and $CO_3^{--}$ in saturation extract of the soils of north-west Gir Madhuvanti toposequence. The distribution of $CO_3^{--}$ in different land slopes was observed in lower topography in order of Hill slope < Upper piedmont < Lower piedmont < Plain area < Depression area < Upper coast and $HCO_3^-$ in different pedon was observed in order of Hill slope < Upper piedmont < Lower piedmont < Plain area < Upper coast <Depression area. The $Cl^-$ gradually increased from hill slope to the upper coast. The SAR ranged from 1.20 to 6.78 with overall mean value of 3.84. The distribution of SAR observed in different land slop was in order of Hill Slope < Upper Piedmont < Lower Piedmont < Plain area <Depression area < Upper Coast. Thus, the SAR increased gradually from hill slope to upper coast of the different pedons of north-west Gir Madhuvanti toposequence in south Saurashtra region. Similar results were also observed by Savalia (2005), Patel (2010), Gandhi (2013) and Shirgire *et al.* (2015) [9, 6, 2, 10].

**Available Nutrients status of soils**

Available nutrients of pedons $P_1$ to $P_6$ of north-west Gir Madhuvanti toposequence are presented in Table -5 and 6. In general, the content of available N, $P_2O_5$ and $K_2O$ revealed between 164.61 to 304.19, 18.37 to 24.91 and 140.11 to 348.10 kg $ha^{-1}$ with the overall mean values of 222.55, 21.16 and 251.90 kg $ha^{-1}$, respectively. The results indicate that the soils could be categorized as low in available N as well as $P_2O_5$ and medium in available $K_2O$. The reason for low in available N and $P_2O_5$ could be attributed to high temperature, low moisture, low O.M., high $CaCO_3$, presence of smectite clay mistrals and fixation of $P_2O_5$. Based on weighted mean data, the available nitrogen was in the increasing order of Upper coast < Depression area < Plain area < Lower piedmont < Upper piedmont <Hill slope. The high level of available N in elevated topography as compared to lower topography is probably due to good vegetation cover which have in turn resulted in higher organic carbon content of the soil and thereby a higher status of available nitrogen Patel (2010) and Gandhi (2013) [6, 2] have also reported similar results. At the lower topography the soils were subjected to intensive cultivation, encouraging the oxidation of organic carbon. Low organic matter content in these areas due to low rainfall and low vegetation cover facilitate faster degradation and removal of organic matter leading to nitrogen deficiency. The data reveals that surface horizons of pedons $P_1$ to $P_6$ could have been enriched in available N due to periodic fertilizer applications, high organic matter and high microbial activity. The available N content of surface horizons of the pedons $P_3$ and $P_6$ reveals that generally these pedons come under low category. This stresses the need for adequate N fertilizer application to pedons $P_3$ and $P_6$ for sustaining productivity. As far as available $P_2O_5$ is concerned, it recorded to be in the increasing order of Upper piedmont < Plain area < Lower piedmont < Upper coast < Depression area < Hill slope. Based on weighted mean data, the available $K_2O$ content recorded to be in the order of Upper piedmont < Lower piedmont < Hill slope < Plain area < Depression area < Upper coast. The soils of north-west Gir Madhuvanti toposequence are categorized as medium in K status. Similar observations were made by Savalia (2005), Patel (2010), Gandhi (2013), Pulakeshi *et al*. (2014) and Singh and Rathore (2015) [9, 6, 2, 7, 11].

The availability of micro-nutrients *viz*., Fe, Mn, Zn and Cu contents ranged from 5.08 to 22.05, 5.41 to 30.18, 0.32 to 1.45 and 2.35 to 4.88 ppm with the overall mean value of 8.23, 10.65, 0.65 and 3.22 ppm, respectively indicating the soils of different pedons of north-west Gir Madhuvanti toposequence to be medium in Fe and Zn whereas high in Mn and Cu. Similar observations were made by Savalia (2005), Patel (2010) and Gandhi (2013) [9, 6, 2]. The distribution of available Fe, Mn, Zn and Cu in different pedons of north-west Gir Madhuvanti toposequence were observed in the decreasing sequence as per under.

Fe- Hill slope > Upper coast > Plain area > Upper piedmont > Depression area > Lower piedmont.

Mn- Hill slope > Upper piedmont > Lower piedmont > Upper coast > Plain area > Depression area.
Zn- Hill slope > Upper piedmont > Upper coast > Depression area > Plain area > Lower piedmont.
Cu- Hill slope > Upper coast > Plain area > Depression area > Upper piedmont > Lower piedmont.

## Conclusion

From ongoing discussion, it may be concluded that soils of different land slopes of north-west Gir Madhuvanti toposequence were loam to clay texture, calcareous in nature ($CaCO_3$ 2.75 to 31.80 per cent), moderately alkaline in reaction and moderately saline and medium in organic carbon status. The pH, pHs, EC, ECe, CEC, BSP, ESP, exchangeable and water soluble cations, SAR, which increased gradually with decreasing elevation from hill slope to upper coast. The soils were low in available N, and $P_2O_5$, medium in available $K_2O$, Fe and Zn, whereas high in Mn and Cu. The land management measures like conservation tillage, contour bunding, use of organic manures along with chemical fertilizers, application of weathered materials, *tanch* / sand in furrow, gypsum *etc.*, and provision of drainage and adoption of salt tolerant crops should be adopted for their better management.

**Table 1:** Chemical characteristics of representative pedons of north-west Gir Madhuvanti toposequence of south Saurashtra

| Horizon | Depth (cm) | pH (1:2.5) | EC ($dSm^{-1}$) | O.C. (%) | $CaCO_3$ (%) | CEC (cmol ($p^+$) $kg^{-1}$) | Exchangeable cation (cmol ($p^+$) $kg^{-1}$) | | | | BSP | ESP | CEC/Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ | | | |
| **Pedon-1 Hill slope (Karsangadh) slope:15-30%, drainage: somewhat excessive, erosion: severe, MSL : 190 m, 21$^0$13' N latitudes, 70$^0$32' E longitude, Lithic Ustorthents** | | | | | | | | | | | | | |
| A1 | 0-25 | 6.79 | 0.28 | 0.84 | 2.75 | 20.60 | 12.99 | 5.09 | 0.11 | 0.04 | 88.44 | 0.53 | 0.72 |
| R | 25+ | | | | | | | | | | | | |
| **Pedon-2 Upper piedmont (Malanka) slope:3-8 %, drainage: well, erosion: moderate, MSL : 155 m, 21$^0$16' N latitudes, 70$^0$29' E longitude, Lithic Ustorthents** | | | | | | | | | | | | | |
| Ap | 0-12 | 7.80 | 0.34 | 0.81 | 27.50 | 27.70 | 18.48 | 6.15 | 0.41 | 0.06 | 91.87 | 1.48 | 0.78 |
| BCk | 12-27 | 7.98 | 0.37 | 0.58 | 35.25 | 24.25 | 16.62 | 5.10 | 0.84 | 0.04 | 90.96 | 3.42 | 0.76 |
| R | 27+ | | | | | | | | | | | | |
| **Pedon-3 Lower piedmont (Mendarda) slope:1-3%, drainage: well, erosion: slight, MSL : 92 m, 21$^0$18' N latitudes, 70$^0$25' E longitude, Vertic Haplusterts** | | | | | | | | | | | | | |
| Ap | 0-28 | 7.98 | 0.87 | 0.72 | 17.62 | 32.51 | 20.81 | 7.79 | 1.65 | 0.35 | 94.13 | 5.06 | 0.56 |
| B1 | 28-44 | 8.05 | 0.91 | 0.61 | 20.12 | 34.75 | 22.28 | 8.06 | 1.92 | 0.22 | 93.47 | 5.54 | 0.59 |
| BC | 44-70 | 8.11 | 0.97 | 0.48 | 22.00 | 26.62 | 14.75 | 7.00 | 1.80 | 0.12 | 88.89 | 6.77 | 0.49 |
| R | 70+ | | | | | | | | | | | | |
| **Pedon-4 Plain area (Tinmus) slope:0-1%, drainage: well, erosion: slight, MSL : 27 m, 21$^0$25' N latitudes, 70$^0$15' E longitude, Typic Haplusterts** | | | | | | | | | | | | | |
| Ap | 0-19 | 8.12 | 0.90 | 0.69 | 16.50 | 33.90 | 21.77 | 7.39 | 2.72 | 0.38 | 95.16 | 8.02 | 0.81 |
| A2 | 19-45 | 8.05 | 1.08 | 0.51 | 17.50 | 33.30 | 20.20 | 7.68 | 3.04 | 0.28 | 93.69 | 9.12 | 0.80 |
| A3ss | 45-60 | 8.09 | 1.54 | 0.60 | 19.00 | 37.25 | 22.57 | 8.33 | 3.85 | 0.30 | 94.09 | 10.33 | 0.85 |
| AC1 | 60-74 | 8.18 | 2.34 | 0.42 | 22.50 | 36.30 | 21.08 | 8.21 | 4.59 | 0.21 | 93.91 | 12.64 | 0.97 |
| AC2 | 74-94 | 8.28 | 2.74 | 0.30 | 25.50 | 34.10 | 18.37 | 8.32 | 5.02 | 0.18 | 93.51 | 14.72 | 1.18 |
| **Pedon-5 Depression area (Akhodar) slope:0-1%, drainage: moderately well, erosion: slight, MSL : 13 m, 21$^0$19' N latitudes, 70$^0$08' E longitude, Sodic Haplusterts** | | | | | | | | | | | | | |
| Ap | 0-28 | 7.86 | 1.16 | 0.60 | 17.50 | 42.95 | 25.28 | 11.06 | 3.73 | 0.35 | 94.10 | 8.68 | 1.05 |
| A2 | 28-57 | 8.39 | 1.48 | 0.48 | 19.00 | 41.90 | 24.21 | 9.10 | 4.93 | 0.34 | 92.07 | 11.76 | 1.03 |
| A3 | 57-76 | 8.22 | 2.40 | 0.54 | 19.50 | 44.80 | 26.45 | 10.60 | 5.80 | 0.38 | 96.49 | 12.94 | 1.05 |
| AC1 | 76-87 | 8.30 | 3.08 | 0.42 | 23.00 | 42.10 | 23.96 | 8.60 | 6.82 | 0.29 | 94.22 | 16.19 | 1.12 |
| AC2 | 87-105 | 8.36 | 4.07 | 0.34 | 24.50 | 43.20 | 23.27 | 8.55 | 8.65 | 0.24 | 94.23 | 20.02 | 1.23 |
| **Pedon-6 Upper coast (Madhavpur) slope:0-1%, drainage: imperfect, erosion: slight, MSL : 5 m, 21$^0$16' N latitudes, 69$^0$57' E longitude, Fluventic Calciustepts** | | | | | | | | | | | | | |
| Ap | 0-20 | 8.00 | 2.06 | 0.54 | 20.35 | 42.45 | 25.77 | 10.04 | 4.82 | 0.34 | 96.41 | 11.35 | 1.19 |
| B1 | 20-48 | 8.11 | 2.15 | 0.42 | 18.50 | 42.05 | 25.98 | 8.74 | 5.85 | 0.31 | 97.17 | 13.91 | 1.14 |
| B2k | 48-65 | 8.21 | 3.24 | 0.48 | 26.00 | 46.25 | 27.02 | 10.68 | 6.94 | 0.38 | 97.21 | 15.00 | 1.18 |
| IC1k | 65-90 | 8.29 | 3.25 | 0.35 | 27.50 | 48.50 | 26.40 | 9.89 | 8.26 | 0.36 | 95.19 | 17.03 | 1.59 |
| IIC1k | 90-127 | 8.59 | 4.14 | 0.21 | 31.00 | 42.12 | 20.22 | 10.24 | 9.72 | 0.29 | 95.96 | 23.07 | 1.67 |

**Table 2:** Chemical characteristics of representative pedons of north-west Gir Madhuvanti toposequence of south Saurashtra (Weighted mean)

| Pedon & toposequence | pH (1:2.5) | EC ($dSm^{-1}$) | O.C. (%) | $CaCO_3$ (%) | CEC (cmol ($p^+$) $kg^{-1}$) | Exchangeable cation (cmol ($p^+$) $kg^{-1}$) | | | | BSP | ESP | CEC/Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
| **Pedon-1 Hill slope (Karsangadh), MSL : 190 m, 21$^0$13' N latitudes, 70$^0$32' E longitude, Lithic Ustorthents** | | | | | | | | | | | | |
| **$P_1$** | 6.79 | 0.28 | 0.84 | 2.75 | 20.60 | 12.99 | 5.09 | 0.11 | 0.04 | 88.44 | 0.53 | 0.72 |
| **Pedon-2 Upper piedmont (Malanka), MSL :155 m, 21$^0$16' N latitudes, 70$^0$29' E longitude, Lithic Ustorthents** | | | | | | | | | | | | |
| **$P_2$** | 7.90 | 0.35 | 0.68 | 31.80 | 25.78 | 17.44 | 5.56 | 0.65 | 0.05 | 91.36 | 2.56 | 0.78 |
| **Pedon-3 Lower piedmont (Mendarda), MSL : 92 m, 21$^0$18' N latitudes, 70$^0$25' E longitude, Vertic Haplusterts** | | | | | | | | | | | | |
| **$P_3$** | 8.04 | 0.91 | 0.60 | 19.81 | 30.83 | 18.89 | 7.56 | 1.76 | 0.23 | 92.03 | 5.80 | 0.54 |
| **Pedon-4 Plain area (Tinmus), MSL : 27 m, 21$^0$25' N latitudes, 70$^0$15' E longitude, Typic Haplusterts** | | | | | | | | | | | | |
| **$P_4$** | 8.13 | 1.66 | 0.50 | 19.98 | 34.66 | 20.64 | 7.94 | 3.75 | 0.27 | 94.04 | 10.80 | 0.91 |
| **Pedon-5 Depression area (Akhodar), MSL : 13 m, 21$^0$19' N latitudes, 70$^0$08' E longitude, Sodic Haplusterts** | | | | | | | | | | | | |
| **$P_5$** | 8.20 | 2.17 | 0.49 | 20.05 | 42.94 | 24.71 | 9.75 | 5.60 | 0.32 | 94.10 | 13.03 | 1.08 |
| **Pedon-6 Upper coast (Madhavpur), MSL : 5 m, 21$^0$16 N latitudes, 69$^0$57' E longitude, Fluventic Calciustepts** | | | | | | | | | | | | |
| **$P_6$** | 8.28 | 3.08 | 0.37 | 25.20 | 43.96 | 24.96 | 9.87 | 7.43 | 0.33 | 96.31 | 16.93 | 1.39 |
| Overall mean | 7.89 | 1.41 | 0.58 | 19.93 | 33.18 | 19.93 | 7.63 | 3.21 | 0.20 | 92.71 | 8.27 | 0.90 |

**Table 3:** Chemical composition of saturated extract of representative pedons of north-west Gir Madhuvanti toposequence of south Saurashtra

| Horizon | Depth (cm) | Saturated percent | pHs | ECe ($dSm^{-1}$) | Soluble cation (me $l^{-1}$) | | | | Soluble anions (me $l^{-1}$) | | | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | $CO_3^{2-}$ | $HCO_3^{-}$ | $Cl^{-}$ | |
| **Pedon-1 Hill slope (Karsangadh) slope:15-30%, drainage: somewhat excessive, erosion: severe, MSL : 190 m, $21^0$13' N latitudes, $70^0$32' E longitude, Lithic Ustorthents** | | | | | | | | | | | | |
| A1 | 0-25 | 41.98 | 7.57 | 0.63 | 2.06 | 1.35 | 1.99 | 0.02 | 0 | 1.45 | 2.32 | 1.20 |
| R | 25+ | | | | | | | | | | | |
| **Pedon-2 Upper piedmont (Malanka) slope:3-8 %, drainage: well, erosion: moderate, MSL : 155 m, $21^0$16' N latitudes, $70^0$29' E longitude, Lithic Ustorthents** | | | | | | | | | | | | |
| Ap | 0-12 | 42.00 | 7.90 | 0.83 | 3.92 | 2.60 | 2.78 | 0.03 | 0.0 | 2.10 | 3.80 | 1.21 |
| BCk | 12-27 | 39.96 | 7.95 | 0.92 | 4.03 | 2.05 | 2.93 | 0.04 | 0.0 | 1.55 | 2.51 | 1.30 |
| R | 27+ | | | | | | | | | | | |
| **Pedon-3 Lower piedmont (Mendarda) slope:1-3%, drainage: well, erosion: slight, MSL : 92 m, $21^0$18' N latitudes, $70^0$25' E longitude, Vertic Haplusterts** | | | | | | | | | | | | |
| Ap | 0-28 | 42.84 | 7.98 | 2.85 | 7.48 | 6.35 | 9.36 | 0.04 | 0.00 | 2.85 | 12.50 | 2.87 |
| B1 | 28-44 | 42.99 | 8.10 | 2.83 | 6.90 | 6.06 | 9.23 | 0.03 | 0.10 | 1.86 | 12.20 | 2.93 |
| BC | 44-70 | 41.38 | 8.15 | 2.91 | 6.69 | 5.76 | 9.56 | 0.04 | 0.20 | 1.57 | 12.70 | 3.09 |
| R | 70+ | | | | | | | | | | | |
| **Pedon-4 Plain area (Tinmus) slope:0-1%, drainage: well, erosion: slight, MSL : 27 m, $21^0$25' N latitudes, $70^0$15' E longitude, Typic Haplusterts** | | | | | | | | | | | | |
| Ap | 0-19 | 44.56 | 8.15 | 4.68 | 11.40 | 8.85 | 16.67 | 0.10 | 0.10 | 3.00 | 18.40 | 4.19 |
| A2 | 19-45 | 44.42 | 8.06 | 5.38 | 14.84 | 9.20 | 19.45 | 0.09 | 0.10 | 2.60 | 29.50 | 4.41 |
| A3ss | 45-60 | 44.25 | 8.09 | 5.88 | 10.65 | 10.20 | 20.30 | 0.20 | 0.20 | 3.50 | 28.30 | 5.11 |
| AC1 | 60-74 | 45.36 | 8.22 | 6.83 | 13.25 | 12.30 | 23.91 | 0.30 | 0.30 | 2.80 | 36.50 | 5.43 |
| AC2 | 74-94 | 44.06 | 8.30 | 7.35 | 17.80 | 14.65 | 25.11 | 0.30 | 0.10 | 3.60 | 40.30 | 5.00 |
| **Pedon-5 Depression area (Akhodar) slope:0-1%, drainage: moderately well, erosion: slight, MSL : 13 m, $21^0$19' N latitudes, $70^0$08' E longitude, Sodic Haplusterts** | | | | | | | | | | | | |
| Ap | 0-28 | 45.40 | 7.90 | 5.83 | 12.20 | 11.00 | 20.86 | 0.35 | 0.20 | 5.90 | 27.00 | 4.95 |
| A2 | 28-57 | 45.10 | 8.40 | 6.65 | 16.00 | 12.81 | 22.75 | 0.20 | 0.10 | 5.52 | 26.20 | 5.65 |
| A3 | 57-76 | 45.03 | 8.25 | 8.12 | 14.40 | 16.88 | 33.58 | 0.20 | 0.10 | 5.74 | 40.50 | 7.02 |
| AC1 | 76-87 | 44.63 | 8.35 | 10.30 | 20.65 | 17.20 | 35.26 | 0.40 | 0.10 | 7.92 | 58.30 | 6.51 |
| AC2 | 87-105 | 43.83 | 8.37 | 11.02 | 22.50 | 18.00 | 40.40 | 0.30 | 0.30 | 7.50 | 67.50 | 7.19 |
| **Pedon-6 Upper coast (Madhavpur) slope:0-1%, drainage: imperfect, erosion: slight, MSL : 5 m, $21^0$16' N latitudes, $69^0$57' E longitude, Fluventic Calciustepts** | | | | | | | | | | | | |
| Ap | 0-20 | 43.10 | 8.10 | 6.91 | 12.28 | 11.05 | 19.78 | 0.27 | 0.20 | 5.90 | 29.00 | 4.68 |
| B1 | 20-48 | 42.73 | 8.15 | 10.75 | 11.92 | 10.82 | 28.76 | 0.24 | 0.10 | 5.94 | 28.10 | 6.83 |
| B2k | 48-65 | 42.60 | 8.20 | 11.51 | 16.38 | 14.95 | 35.25 | 0.37 | 0.20 | 5.70 | 44.30 | 7.22 |
| IC1k | 65-90 | 39.56 | 8.30 | 12.52 | 19.40 | 18.05 | 38.35 | 0.35 | 0.20 | 4.52 | 59.20 | 7.19 |
| IIC1k | 90-127 | 36.66 | 8.64 | 14.95 | 22.75 | 20.85 | 42.60 | 0.52 | 0.40 | 4.60 | 68.00 | 7.39 |

**Table 4:** Chemical composition of saturated extract of representative pedons of north-west Gir Madhuvanti toposequence of south Saurashtra (Weighted mean)

| Pedon & toposequence | Saturated percent | pHs | ECe ($dSm^{-1}$) | Soluble cation (me $l^{-1}$) | | | | Total cation (me $l^{-1}$) | Soluble anions (me $l^{-1}$) | | | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | | $CO_3^{2-}$ | $HCO_3^{-}$ | $Cl^{-}$ | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
| **Pedon-1 Hill slope (Karsangadh), MSL : 190 m, $21^0$13' N latitudes, $70^0$32' E longitude, Lithic Ustorthents** | | | | | | | | | | | | |
| **$P_1$** | 41.98 | 7.57 | 0.63 | 2.06 | 1.35 | 1.99 | 0.02 | 5.42 | 0.00 | 1.45 | 2.32 | 1.20 |
| **Pedon-2 Upper piedmont (Malanka), MSL :155 m, $21^0$16' N latitudes, $70^0$29' E longitude, Lithic Ustorthents** | | | | | | | | | | | | |
| **$P_2$** | 40.86 | 7.93 | 0.88 | 3.98 | 2.29 | 2.86 | 0.03 | 9.16 | 0.00 | 1.79 | 3.08 | 1.26 |
| **Pedon-3 Lower piedmont (Mendarda), MSL : 92 m, $21^0$18' N latitudes, $70^0$25' E longitude, Vertic Haplusterts** | | | | | | | | | | | | |
| **$P_3$** | 42.33 | 8.07 | 2.86 | 7.05 | 6.06 | 9.40 | 0.04 | 22.55 | 0.12 | 2.15 | 12.50 | 2.96 |
| **Pedon-4 Plain area (Tinmus), MSL : 27 m, $21^0$25' N latitudes, $70^0$15' E longitude, Typic Haplusterts** | | | | | | | | | | | | |
| **$P_4$** | 44.48 | 8.16 | 5.95 | 13.87 | 10.91 | 20.89 | 0.18 | 45.85 | 0.14 | 3.07 | 30.40 | 4.76 |
| **Pedon-5 Depression area (Akhodar), MSL : 13 m, $21^0$19' N latitudes, $70^0$08' E longitude, Sodic Haplusterts** | | | | | | | | | | | | |
| **$P_5$** | 44.90 | 8.23 | 7.86 | 16.30 | 14.41 | 29.64 | 0.27 | 60.62 | 0.16 | 6.22 | 39.44 | 6.07 |
| **Pedon-6 Upper coast (Madhavpur), MSL : 5 m, $21^0$16 N latitudes, $69^0$57' E longitude, Fluventic Calciustepts** | | | | | | | | | | | | |
| **$P_6$** | 40.38 | 8.32 | 11.82 | 17.20 | 15.75 | 34.06 | 0.36 | 67.37 | 0.23 | 5.23 | 48.15 | 6.78 |
| Overall mean | 42.49 | 8.04 | 5.00 | 10.07 | 8.46 | 16.47 | 0.15 | 35.16 | 0.11 | 3.32 | 22.65 | 3.84 |

**Table 5:** Available nutrients status of representative pedons of north-west Gir Madhuvanti toposequence of south Saurashtra

| Horizon | Depth (cm) | Avail. N (kg ha$^{-1}$) | Avail. $P_2O_5$ (kg ha$^{-1}$) | Avail. $K_2O$ (kg ha$^{-1}$) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) |
|---|---|---|---|---|---|---|---|---|
| **Pedon-1 Hill slope (Karsangadh) slope:15-30%, drainage: somewhat excessive, erosion: severe, MSL : 190 m, 21$^0$13' N latitudes, 70$^0$32' E longitude, Lithic Ustorthents** | | | | | | | | |
| A1 | 0-15 | 304.19 | 24.91 | 217.21 | 22.05 | 30.18 | 1.45 | 4.88 |
| R | 25+ | | | | | | | |
| **Pedon-2 Upper piedmont (Malanka) slope:3-8 %, drainage: well, erosion: moderate, MSL : 155 m, 21$^0$16' N latitudes, 70$^0$29' E longitude, Lithic Ustorthents** | | | | | | | | |
| Ap | 0-12 | 332.41 | 20.42 | 187.68 | 6.75 | 12.15 | 1.36 | 2.68 |
| BCk | 12-27 | 251.06 | 16.73 | 102.06 | 4.15 | 6.98 | 0.44 | 2.39 |
| R | 27+ | | | | | | | |
| **Pedon-3 Lower piedmont (Mendarda) slope:1-3%, drainage: well, erosion: slight, MSL : 92 m, 21$^0$18' N latitudes, 70$^0$25' E longitude, Vertic Haplusterts** | | | | | | | | |
| Ap | 0-28 | 249.98 | 25.24 | 208.42 | 5.56 | 9.06 | 0.27 | 2.39 |
| B1 | 28-44 | 206.19 | 23.85 | 175.66 | 4.85 | 5.74 | 0.42 | 2.29 |
| BC | 44-70 | 156.79 | 11.79 | 158.26 | 4.72 | 5.46 | 0.31 | 2.35 |
| R | 70+ | | | | | | | |
| **Pedon-4 Plain area (Tinmus) slope:0-1%, drainage: well, erosion: slight, MSL : 27 m, 21$^0$25' N latitudes, 70$^0$15' E longitude, Typic Haplusterts** | | | | | | | | |
| Ap | 0-19 | 244.60 | 27.18 | 303.74 | 6.66 | 6.27 | 0.34 | 3.74 |
| A2 | 19-45 | 213.70 | 16.41 | 297.56 | 6.48 | 7.32 | 0.30 | 3.01 |
| A3ss | 45-60 | 200.24 | 29.75 | 260.25 | 3.81 | 5.03 | 0.50 | 2.57 |
| AC1 | 60-74 | 159.93 | 17.44 | 281.44 | 3.48 | 4.95 | 0.27 | 2.36 |
| AC2 | 74-94 | 145.82 | 11.79 | 258.52 | 6.43 | 5.47 | 0.39 | 3.15 |
| **Pedon-5 Depression area (Akhodar) slope:0-1%, drainage: moderately well, erosion: slight, MSL : 13 m, 21$^0$19' N latitudes, 70$^0$08' E longitude, Sodic Haplusterts** | | | | | | | | |
| Ap | 0-28 | 232.06 | 29.50 | 384.12 | 3.51 | 3.69 | 0.34 | 2.82 |
| A2 | 28-57 | 189.34 | 24.45 | 302.94 | 6.00 | 6.03 | 0.31 | 2.94 |
| A3 | 57-76 | 178.75 | 27.60 | 305.63 | 6.30 | 5.75 | 0.61 | 2.80 |
| AC1 | 76-87 | 150.52 | 19.95 | 316.38 | 5.45 | 6.64 | 0.39 | 2.96 |
| AC2 | 87-105 | 127.60 | 13.33 | 390.84 | 5.07 | 5.98 | 0.38 | 3.02 |
| **Pedon-6 Upper coast (Madhavpur) slope:0-1%, drainage: imperfect, erosion: slight, MSL : 5 m, 21$^0$16' N latitudes, 69$^0$57' E longitude, Fluventic Calciustepts** | | | | | | | | |
| Ap | 0-20 | 261.85 | 27.44 | 336.00 | 8.76 | 7.93 | 0.45 | 4.28 |
| B1 | 20-48 | 202.27 | 21.18 | 298.36 | 7.29 | 6.38 | 0.41 | 4.09 |
| B2k | 48-65 | 164.64 | 25.36 | 361.53 | 6.66 | 7.57 | 0.50 | 4.51 |
| IC1k | 65-90 | 126.71 | 17.95 | 381.69 | 5.87 | 6.07 | 0.41 | 3.93 |
| IIC1k | 90-127 | 109.16 | 14.36 | 363.42 | 3.89 | 4.20 | 0.74 | 2.47 |

**Table 6:** Available nutrients status of representative pedons of north-west Gir Madhuvanti toposequence of south Saurashtra (Weighted mean)

| Pedon & toposequence | Major available nutrients (kg ha$^{-1}$) | | | Available micronutrient (ppm) | | | |
|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | Fe | Mn | Zn | Cu |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Pedon-1 Hill slope (Karsangadh), MSL : 190 m, 21$^0$13' N latitudes, 70$^0$32' E longitude, Lithic Ustorthents** | | | | | | | |
| **$P_1$** | 304.19 | 24.91 | 217.21 | 22.05 | 30.18 | 1.45 | 4.88 |
| **Pedon-2 Upper piedmont (Malanka), MSL :155 m, 21$^0$16' N latitudes, 70$^0$29' E longitude, Lithic Ustorthents** | | | | | | | |
| **$P_2$** | 281.66 | 18.37 | 140.11 | 5.30 | 9.28 | 0.85 | 2.52 |
| **Pedon-3 Lower piedmont (Mendarda), MSL : 92 m, 21$^0$18' N latitudes, 70$^0$25' E longitude, Vertic Haplusterts** | | | | | | | |
| **$P_3$** | 205.35 | 19.92 | 182.30 | 5.08 | 6.96 | 0.32 | 2.35 |
| **Pedon-4 Plain area (Tinmus), MSL : 27 m, 21$^0$25' N latitudes, 70$^0$15' E longitude, Typic Haplusterts** | | | | | | | |
| **$P_4$** | 195.34 | 19.88 | 282.15 | 5.63 | 5.99 | 0.35 | 3.02 |
| **Pedon-5 Depression area (Akhodar), MSL : 13 m, 21$^0$19' N latitudes, 70$^0$08' E longitude, Sodic Haplusterts** | | | | | | | |
| **$P_5$** | 184.16 | 23.82 | 341.55 | 5.17 | 5.41 | 0.39 | 2.90 |
| **Pedon-6 Upper coast (Madhavpur), MSL : 5 m, 21$^0$16 N latitudes, 69$^0$57' E longitude, Fluventic Calciustepts** | | | | | | | |
| **$P_6$** | 164.61 | 20.10 | 348.10 | 6.16 | 6.08 | 0.52 | 3.67 |
| Overall mean | 222.55 | 21.16 | 251.90 | 8.23 | 10.65 | 0.65 | 3.22 |

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