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# Properties of Vertisols of middle and lower Narmada Valley in Central Peninsular India

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*Abstract*

Six typical Vertisol pedons, three each located in middle and lower Narmada valley were studied for their morphological, physical and chemical properties. The study showed that the pedons located in the middle Narmada valley which receives higher rainfall, had deeper slickensides, more wide cracks, higher bulk density and higher lime content as compared to those in lower Narmada valley. The middle Narmada valley pedons showed lower CEC, higher $Mg^{++}$, and lower $K^{+}$ ions than lower Narmada valley. The variations observed in some soil properties are due to parent material, climate and topography.

*Additional keywords:* Vertisol morphology.

## Introduction

Agriculture in Narmada valley of Madhya Pradesh is concentrated mainly on shrink-swell soils and most of the area is double cropped. Soil management is the single most important factor for sustainable agriculture and therefore, an attempt has been made to characterise the soils of Middle and Lower Narmada valley.

## Materials and methods

The pedons were studied at the villages Budhwara, Karanpur and Sohagpur in the middle Narmada valley (Tawa command project, Hoshangabad district) and Keshavi, Kadada and Kamata in lower Narmada valley (Man watershed, Sardar Sarovar catchment area, Dhar district). Horizonwise soil samples were collected and morphologically described in the field using USDA system (Soil Survey Staff, 1975, 1992, 1994). The soil samples were analysed for different physical and chemical properties according to the standard procedures (Richards 1954 and Jackson 1967). The site characteristics are given in table 1.

## Results and discussion

### *Morphological properties*

The soil colour ranges from black (10YR 2/1) in Keshavi soil to dark greyish brown (10 YR 4/2) in Budhwara soils (Table 2). In general, Lower Narmada valley soils are darker than Middle valley soils. The difference in colour of the soils in middle and lower Narmada valley might be due to variation in parent material, drainage, duration and severity of dry season and the type of pedogenic processes (Kaushal *et al.* 1986). The basaltic alluvium with admixture of calcareous sedimentary material resulted in the formation of soils of middle Narmada valley. The slickensides were found at deeper layers (54-168 cm) and tilted at 30 to 40° from the horizontal in Budhwara, Karanpur and Sohagpur pedons of middle Narmada valley. Vadivelu and Challa (1985) also observed deeper slickensides in the areas of high rainfall.

**Table 1. Site characteristics**

| Pedon | Location | Elevation MSL (m) | Parent material | Mean annual rainfall (mm) |
|---|---|---|---|---|
| | | *Middle Narmada valley* | | |
| Budhwara | 22° 43'15"N Lat. 78° 13'10"E Long. | 340 | Calcareous basaltic alluvium mixed with quartz, quartzite and agate | 1223 |
| Karanpur | 22° 44'25"N Lat. 78° 15'05"E Long. | 345 | Calcareous basalt | 1146 |
| Sohagpur | 22° 41'10"N Lat. 77° 12'18"E Long. | 352 | Calcareous basalt | 1200 |
| | | *Lower Narmada valley* | | |
| Kesavi | 22° 28'25"N Lat. 76° 07'10"E Long. | 405 | Pure basaltic alluvium | 685 |
| Kadada | 22° 22'42"N Lat. 75° 04'32"E Long. | 382 | Basalt | 710 |
| Kamata | 22° 20'24"N Lat. 75° 11'48"E Long. | 400 | Basalt | 750 |

**Table 2. Morphological characteristics of soils of middle and lower Narmada Valley**

| Horizon | Depth (cm) | Colour (moist) | Tex-ture | Structure | Slicken-sides angle(°) | Effer-vesc-ence | Width of crack (cm) |
|---|---|---|---|---|---|---|---|
| | | *Middle Narmada valley* | | | | | |
| *Budhwara pedon* | | | | | | | |
| Ap | 0-16 | 10YR 4/2 | c | 2 msbk | — | e | 4 |
| Bw1 | 16-39 | 10YR 4/2 | c | 2 msbk | — | e | 4 |
| Bw2 | 39-70 | 10YR 4/2 | c | 3 msbk | — | es | 3 |
| Bss1 | 70-105 | 10YR 4/2 | c | 3 msbk | 40 | es | 2 |
| Bss2 | 105-168 | 10YR 4/2 | c | 3 msbk | 35 | es | - |
| *Karanpur pedon* | | | | | | | |
| Ap | 0-19 | 10YR 3/1 | c | 2 msbk | — | e | 3 |
| Bw | 19-54 | 10YR 3/1 | c | 3 msbk | — | e | 2 |
| Bss1 | 54-93 | 10YR 3/1 | c | 3 msbk | 35 | e | 2 |
| Bss2 | 93-128 | 10YR 3/1 | c | 3 msbk | 35 | e | 2 |
| BC | 128-165 | 10YR 3/2 | c | 3 msbk | — | es | - |
| *Sohagpur pedon* | | | | | | | |
| Ap | 0-21 | 10YR 3/1 | c | 2 msbk | — | e | 4 |
| Bw | 21-56 | 10YR 3/1 | c | 2 mabk | — | e | 3 |
| Bss | 56-114 | 10YR 3/2 | c | 3 cabk | 40 | e | 2 |
| BC | 114-183 | 10YR 4/2 | c | 3 cabk | — | es | - |
| | | *Lower Narmada valley* | | | | | |
| *Keshavi pedon* | | | | | | | |
| Ap | 0-12 | 10YR 2/1 | c | 2 msbk | — | e | 2 |
| Bw | 12-24 | 10YR 2/1 | c | 3 csbk | — | e | 3 |
| Bss1 | 24-51 | 10YR 2/1 | c | 3 csbk | 45 | e | 2 |
| Bss2 | 51-105 | 10YR 2/1 | c | 3 csbk | 40 | e | - |
| Bss3 | 105-164 | 10YR 2/1 | c | 3 cabk | 35 | e | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Kadada pedon* | | | | | | | | | |
| Ap | 0-17 | 10YR | 3/1 | c | 2 | msbk | — | e | 2 |
| Bw | 17-39 | 10YR | 2/1 | c | 2 | msbk | — | e | 2 |
| Bss1 | 39-62 | 10YR | 2/1 | c | 3 | csbk | 45 | e | 2 |
| Bss2 | 62-75 | 10YR | 2/1 | c | 2 | msbk | 45 | e | 2 |
| Bss3 | 75-90 | 10YR | 2/2 | c | 1 | fsbk | 40 | e | - |
| C | 90-170 | 10YR | 4/3 | c | 1 | fsbk | — | e | - |
| *Kamata pedon* | | | | | | | | | |
| Ap | 0-15 | 10YR | 2/2 | c | 2 | msbk | — | e | 3 |
| Bw | 15-30 | 10YR | 2/2 | c | 2 | msbk | — | e | 2 |
| Bss1 | 30-65 | 10YR | 2/2 | c | 3 | msbk | 40 | e | 2 |
| Bss2 | 65-78 | 10YR | 3/2 | c | 3 | msbk | 35 | e | 2 |
| Bss3 | 78-114 | 10YR | 3/2 | c | 2 | msbk | 35 | e | 2 |
| BC | 114-138 | 10YR | 3/4 | c | 2 | msbk | — | e | - |

*Physical properties*

The data regarding the mechanical composition (Table 3) indicated that the soils are clayey and clay content was high in the pedons of both the middle and lower Narmada valley. Fine clay is dominating in the soils of middle Narmada valley. The bulk density was higher in the pedons of middle Narmada valley (Table 3) than the pedons of lower Narmada valley due to difference in parent material and organic carbon content.

**Table 3. Physical and chemical characteristics of the soils**

| Depth (cm) | Clay (%) | F.Clay (%) | B.D. ($Mg\ m^{-3}$) | pHe | pH (1:2) | ECe ($dS\ m^{-1}$) | O.C. <-($gkg^{-1}$)—> | $CaCO_3$ | CEC <———($cmol\ (p+)\ kg^{-1}$———> | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| | | | | | *Middle Narmada valley* | | | | | | | | |
| *Budhwara pedon* | | | | | | | | | | | | | |
| 0-16 | 59.3 | 53.1 | 1.36 | 7.2 | 7.3 | 0.31 | 5.5 | 20 | 48.7 | 38.0 | 7.3 | 0.1 | 0.8 |
| 16-39 | 60.6 | 54.7 | 1.36 | 7.2 | 7.4 | 0.25 | 4.0 | 30 | 50.0 | 39.6 | 6.0 | 0.1 | 1.1 |
| 39-70 | 60.6 | 55.9 | 1.38 | 7.2 | 7.3 | 0.24 | 4.0 | 35 | 48.7 | 38.9 | 6.9 | 0.1 | 1.1 |
| 70-105 | 62.7 | 54.3 | 1.39 | 7.3 | 7.3 | 0.22 | 3.4 | 40 | 53.8 | 42.7 | 3.9 | 0.1 | 0.6 |
| 105-168 | 63.5 | 56.1 | 1.41 | 7.2 | 7.4 | 0.21 | 3.1 | 45 | 52.5 | 40.1 | 9.5 | 0.1 | 0.8 |
| *Karanpur pedon* | | | | | | | | | | | | | |
| 0-19 | 46.0 | 39.7 | 1.32 | 7.4 | 7.6 | 0.46 | 4.5 | 25 | 42.3 | 34.2 | 8.9 | 0.1 | 1.1 |
| 19-54 | 40.6 | 34.6 | 1.40 | 7.4 | 7.7 | 0.55 | 3.4 | 25 | 40.5 | 32.0 | 6.2 | 0.1 | 1.2 |
| 54-93 | 48.3 | 40.2 | 1.38 | 7.3 | 7.5 | 0.55 | 3.4 | 40 | 44.2 | 33.0 | 8.9 | 0.1 | 1.2 |
| 93-128 | 42.2 | 34.2 | 1.30 | 7.4 | 7.5 | 0.64 | 4.1 | 25 | 40.3 | 34.5 | 5.6 | 0.1 | 1.3 |
| 128-165 | 42.6 | 34.0 | 1.36 | 7.3 | 7.7 | 0.73 | 2.9 | 40 | 40.1 | 30.3 | 6.1 | 0.3 | 1.3 |
| *Sohagpur pedon* | | | | | | | | | | | | | |
| 0-21 | 57.1 | 49.1 | 1.35 | 7.4 | 7.5 | 0.32 | 4.3 | 15 | 46.8 | 32.0 | 10.5 | 0.2 | 2.1 |
| 21-56 | 57.8 | 47.0 | 1.40 | 7.3 | 7.5 | 0.31 | 3.8 | 25 | 46.2 | 33.0 | 10.1 | 0.2 | 1.9 |
| 56-114 | 60.7 | 49.8 | 1.44 | 7.3 | 7.6 | 0.34 | 3.5 | 5 | 48.2 | 33.5 | 9.9 | 0.2 | 1.5 |
| 114-183 | 52.5 | 41.5 | 1.49 | 7.4 | 7.7 | 0.31 | 3.1 | 15 | 43.9 | 30.0 | 11.8 | 0.2 | 1.4 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Lower Narmada valley* | | | | | | | |
| *Keshavi pedon* | | | | | | | | | | | | | |
| 0-12 | 60.5 | 53.9 | 1.24 | 7.4 | 7.5 | 0.47 | 5.5 | 5 | 58.2 | 38.8 | 18.1 | 0.1 | 1.0 |
| 12-24 | 62.8 | 53.8 | 1.28 | 7.4 | 7.5 | 0.36 | 4.0 | 6 | 57.2 | 48.0 | 15.5 | 0.1 | 0.5 |
| 24-51 | 63.0 | 56.3 | 1.29 | 7.4 | 7.5 | 0.36 | 3.4 | 7 | 59.4 | 36.5 | 17.8 | 0.2 | 0.8 |
| 51-105 | 66.0 | 56.7 | 1.32 | 7.6 | 7.6 | 0.43 | 3.1 | 7 | 59.4 | 33.9 | 16.9 | 0.1 | 0.6 |
| 105-164 | 67.0 | 60.9 | 1.33 | 7.6 | 7.7 | 0.47 | 2.6 | 10 | 56.2 | 35.5 | 14.3 | 0.3 | 0.9 |
| *Kadada pedon* | | | | | | | | | | | | | |
| 0-17 | 40.3 | 25.1 | 1.29 | 7.0 | 7.5 | 0.50 | 5.8 | 15 | 40.0 | 32.5 | 6.1 | 0.5 | 0.9 |
| 17-39 | 48.0 | 35.8 | 1.32 | 7.0 | 7.5 | 0.50 | 4.9 | 20 | 47.2 | 41.4 | 3.6 | 0.5 | 0.9 |
| 39-62 | 51.0 | 35.1 | 1.30 | 7.0 | 7.5 | 0.35 | 4.8 | 15 | 50.6 | 41.9 | 2.5 | 0.4 | 0.9 |
| 62-75 | 55.8 | 39.4 | 1.30 | 7.0 | 7.6 | 0.34 | 3.7 | 25 | 51.4 | 43.6 | 6.4 | 0.4 | 0.9 |
| 75-90 | 57.7 | 34.0 | 1.39 | 7.0 | 7.7 | 0.40 | 3.2 | 25 | 53.8 | 50.0 | 3.2 | 0.3 | 0.8 |
| 90-170 | 53.8 | 32.2 | 1.42 | 7.0 | 7.7 | 0.25 | 2.8 | 20 | 48.1 | 40.0 | 6.2 | 0.3 | 0.7 |
| *Kamata pedon* | | | | | | | | | | | | | |
| 0-15 | 49.9 | 30.4 | 1.32 | 7.0 | 7.5 | 0.80 | 5.3 | 10 | 50.5 | 36.9 | 11.4 | 0.4 | 0.7 |
| 15-30 | 44.3 | 31.0 | 1.32 | 7.0 | 7.5 | 0.50 | 4.8 | 25 | 40.2 | 29.7 | 9.1 | 0.2 | 0.7 |
| 30-65 | 48.3 | 28.8 | 1.32 | 7.0 | 7.5 | 0.56 | 4.5 | 10 | 48.7 | 37.0 | 10.9 | 0.2 | 0.7 |
| 65-78 | 52.0 | 42.0 | 1.30 | 7.0 | 7.6 | 0.73 | 4.8 | 15 | 48.3 | 36.6 | 8.9 | 0.2 | 0.6 |
| 78-114 | 45.0 | 34.2 | 1.30 | 7.0 | 7.7 | 0.80 | 2.3 | 10 | 41.3 | 33.9 | 6.6 | 0.1 | 0.6 |
| 114-138 | 35.0 | 30.0 | 1.40 | 7.1 | 7.6 | 0.80 | 1.6 | 10 | 35.8 | 27.5 | 5.5 | 0.1 | 0.7 |

*Chemical properties*

The soil reaction was determined in both soil solution and saturated extract (pHe). The soils of both middle and lower Narmada valley are neutral to mildly alkaline (pH 7.0 to 7.7) (Table 3). In general, the pH (water) values were higher than the pHe values and it may be due to the presence of bicarbonate ions which are capable of alkaline hydrolysis thereby raising the pH values (Richards 1954). The electrical conductivity values were slightly higher (0.25 - 0.80 dS $m^{-1}$) in the soils of lower Narmada valley due to lower rainfall resulting in aridity conditions and addition of salts from upper reaches through runoff water. There was no considerable difference in the organic carbon content of the soils of middle and lower Narmada valley. However, decreasing trend of organic carbon with depth was seen in almost all the pedons. The presence of calcium carbonate differentiated further the two parts of the valley. The middle valley pedons were more enriched (5 to 75 g $kg^{-1}$) with $CaCO_3$. Higher cation exchange capacity was recorded in the pedons of lower Narmada valley (35.8 to 59.4 cmol (p+) $kg^{-1}$) as compared to middle valley (34.8 to 53.8 cmol (p+) $kg^{-1}$). The CEC of all the soils is, in general, high (34.8 - 59.4 cmol (p+) $kg^{-1}$) due to the presence of smectitic minerals as indicated by the ratio of CEC/clay (>0.8).

The cationic composition was dominated by $Ca^{++}$ followed by the $Mg^{++}$ in all the pedons of middle and lower Narmada valley. Similar results were reported by Kalbande *et al.* (1986). However, the ratio of Ca/Mg in these pedons did not indicate any definite trend with depth. The higher content of exchangeable $Na^{+}$ in lower Narmada valley (P4, P5 and P6) might be due to more aridity prevailing in the area.

It is concluded that the climatic differences coupled with differences in parent material influence the pedogenesis and also the physical and chemical characteristics of the soils.

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