Minerals (carbonate and palygorskite) induced natural soil degradation (sodicity and poor drainage) in Vertisols of semi-arid Central India

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INTRODUCTION

Anthropogenic land degradation is a global concern, however, increasing aridity and water scarcity in the semi-arid tropical (SAT) environments causes natural land degradation which needs attention in the climate change scenario (UNCCD, 2012). About 47 % of India's net sown area falls under the SAT climate (Bhattacharyya et al., 2013) with low productive shrink-swell (SS) soils (Vertisols and their intergrades) mostly under rain-fed agriculture (Pal et al., 2012; 2016).
Field observations during the land resource inventory indicated that both sodic and non-sodic Vertisols in Yavatmal district of SAT central India are less productive. Natural degradation of Vertisols due to subsoil sodicity is one of the major causes for such low productivity (Pal, 2017) but the reasons of low productive non-sodic Vertisols is yet to be explored. Therefore, this study aims to identify the cause-and-effect relation of such degradation through a systematic approach by analyzing the physical, chemical and mineralogical properties for developing innovative methods to make these soils resilient.

METHODOLOGY

Five spatially associated Vertisols in toposequence representing pediment and alluvial plain landform from Wani and Maregaon tehsil of Yavatmal district, Maharashtra were selected (Fig 1). Major land use are cotton, soybean and pigeon pea under rainfed conditions. The area receives annual rainfall of 1021 mm. The texture, pH, organic carbon, CaCO3 equivalent, exchangeable cations and cation exchange capacity (CEC) of collected soil samples were estimated by standard methods. The saturated hydraulic conductivity (K_s) was determined by the constant head method (Klute and Dirksen, 1986). The X-ray diffractograms (XRD) of water-dispersible clays (WDC) obtained by scanning at 2°2θ min^{-1} in X'Pert PRO, M/s PANalytical, were deconvoluted using the curve decomposition method (Paul et al., 2020) to detect trace amount of any mineral.

RESULTS

Among the selected Vertisols three were sodic (Sodic Haplusterts; P1, P3 and P5) and two were non-sodic (Typic Haplusterts; P2 and P4) (Fig 1). High pH (8.2-9.3) and base saturation (BS) (> 100 %) were observed in all soils (Fig 2). Organic carbon is generally low (<1%) and is decreased with depth. Soils have ECe <4 dS m^{-1}, indicating their non-saline character. The sodic soils have ESP >15.

RESULTS

The sodic soils contain $CaCO_3$ which decreases with depth (except P1), and non-sodic soils also contain $CaCO_3$, which however increases with depth. The K_s of these clayey soils are poor to very poor in the range of 0.01-8 mm hr^{-1}. The exchangeable Ca/Mg ratio decreases with depth of both the soil. Sodic soils show higher Ca/Mg ratio than non-sodic soils. Although the XRD diagrams indicated the presence of clay size smectite, mica and kaolinite (Fig 3-a), the deconvoluted X-ray diffractogram of both sodic and non-sodic soil clays showed multiple smaller peaks of palygorskite at 1.04, 1.01, and 0.99 nm in trace amount (2-2.5%) (Fig 3-b). Low Ca/Mg ratio (i.e. <1) in non-sodic soils suggests the enrichment of Mg in subsoils (Fig 2) due to the translocation of very fine clay palygorskite in preference to smectite (Paul et al., 2021).

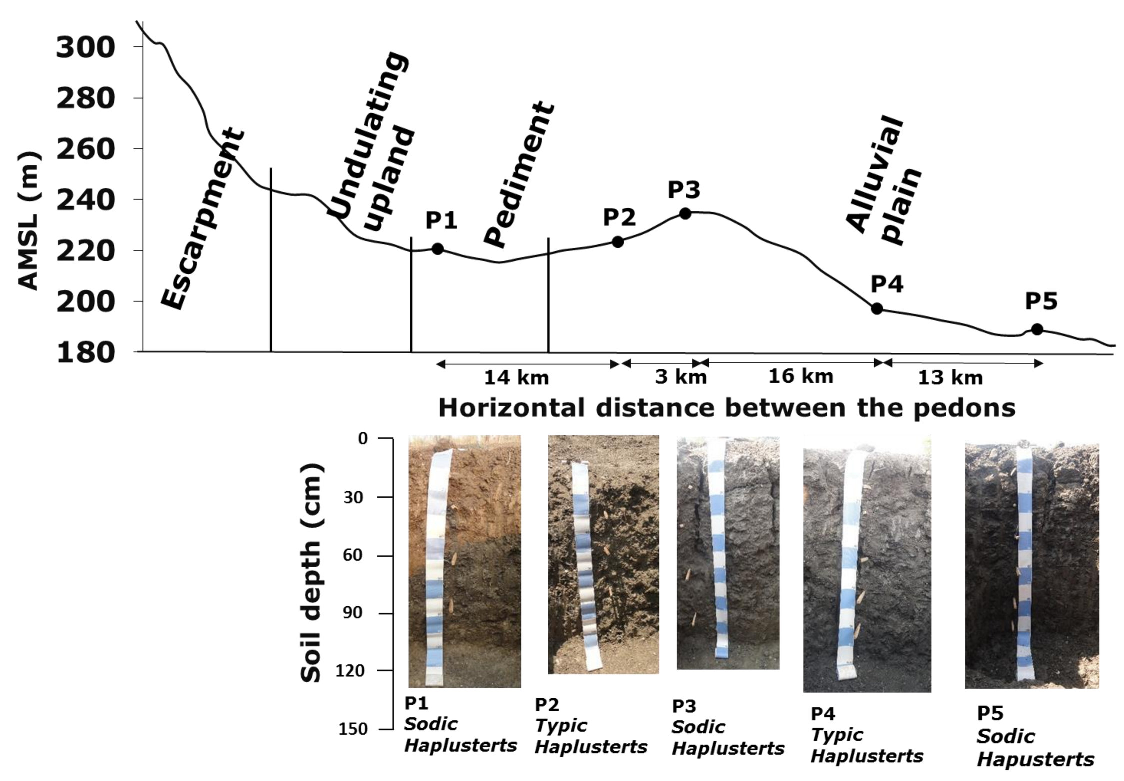

Fig 1. Selected pedons in different landforms

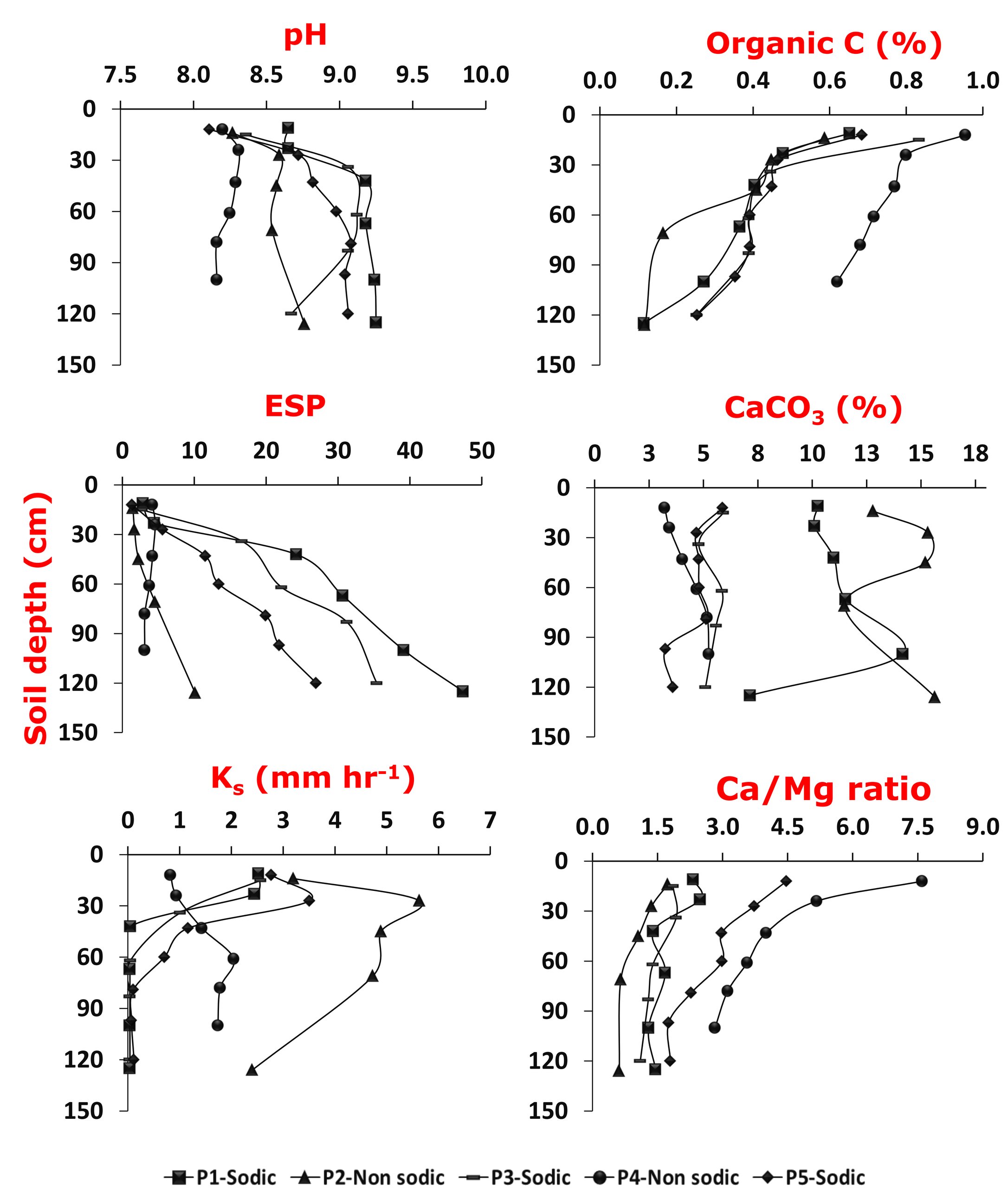

Fig 2. Depth-wise distribution of selected soil properties

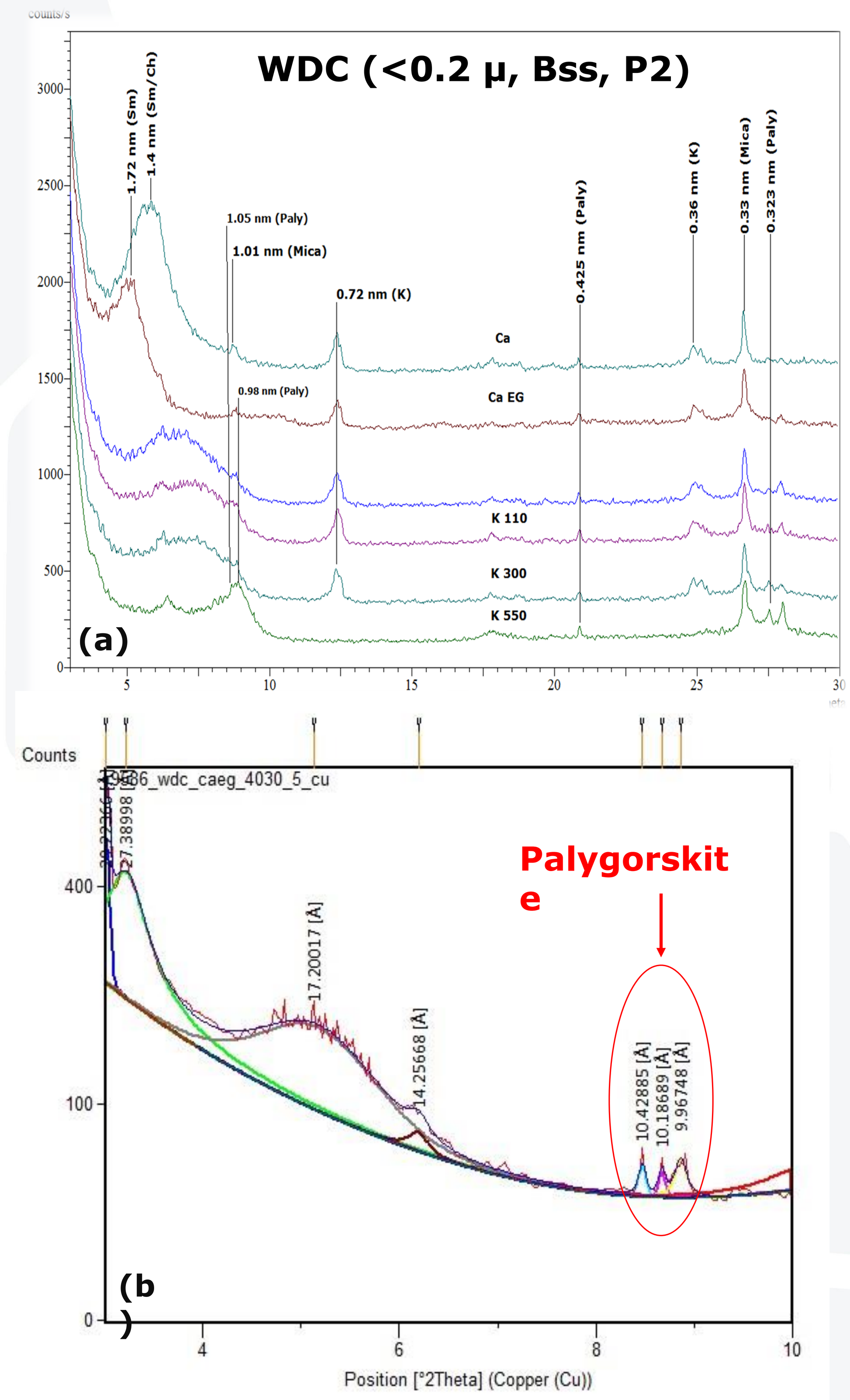

Fig 3. XRD diagram of WDC of Bss horizon of non-sodic Vertisol (P2) (a); Deconvoluted XRD diagram of the similar sample (b)

DISCUSSION

The sodic soils are naturally degraded due to the development of sub-soil sodicity because of the formation of pedogenic CaCO3 in SAT environment (Pal et al., 2016), which ultimately impaired the hydraulic properties of soils. As a result, considerable reduction in crop productivity is observed. In addition, the Mg bearing palygorskite clay mineral adversely affects the soil drainage (Ks < 10 mm hr^{-1}) due to the presence of more Mg^{2+} ions than Ca^{2+} on the soil exchange complex in non-sodic soils. Thus, the ratio of exchangeable Ca/Mg decreases with pedon depth, likewise the K_s, but with an increase in BS (> 100 %) (Zade et al., 2017).

CONCLUSIONS

The present study demonstrates a unique case on cause-effect relation of mineral induced natural soil degradation in terms of drainage impairment in sodic and non-sodic Vertisols of SAT central India. This novel information may help natural resource managers to innovate management protocols for enhancing their production potential.

ACKNOWLEDGEMENTS

The authors thankfully acknowledge the instrumental facilities provided by Director and the help received from all the staff of Division of Soil Resource studies, ICAR-NBSS & LUP, Nagpur.