Chapter 1 : Clays and Clay Minerals: Volume 2 Issue 1

This book on Applied Clay Mineralogy is comprehensive. It covers the structure, composition, and physical and chemical properties of kaolinite, halloysite, ball clays; bentonites including sodium montmorillonite, calcium montmorillonite, and hectorite; and palygorskite and sepiolite.

Introduction Ethiopia has a long history of intensive agriculture and human settlement particularly in the highlands [1]. Misuse of soils, arising from a desperate attempt by farmers to increase production for the growing population, has resulted in soil quality degradation. It is associated with soil nutrient depletion by repeated cultivation with low external inputs of nutrients and soil erosion caused by long-term deterioration of natural vegetation and intensive cultivation [2 â€” 4]. Phosphorus P deficiency is particularly widespread in rain-fed upland farming systems throughout the tropics and remains a major plant nutrient constraint. In this respect, the Ethiopian soils are similar to the other agricultural soils of the tropics being generally low in P [5 â€” 8] and hence P is one of the limiting elements in crop production in the highlands of Ethiopia. Accordingly, P supply is apparently essential in the management and sustainability of upland land use systems in the tropical environment [9 â€” 12]. Soil P deficiency can be attributable to the low P content of the parent material, high weathering intensity, long-term anthropogenic mismanagement through imbalance between nutrient inputs and exports, and P loss by soil erosion [11]. Limited availability of P in many tropical soils can be attributed to severe P fixation or retention, which is particularly strong in soils of low P status. In acidic soils, crystalline and noncrystalline oxides of Fe and Al sesquioxides are the main adsorbing agents of phosphate [13]. However, noncrystalline forms tend to control the soil adsorption reactions, due to their large specific surface area [14]. Chemical fractionation provides a method for identifying the predominant individual forms of inorganic P in soils, most commonly easily soluble P, active forms of inorganic P, including P adsorbed on the surface of Al and Fe oxides Al-P and Fe-P and associated with Ca Ca-P as secondary precipitation or native minerals such as apatite, and inactive forms of P, including P occluded in the interiors of Al and Fe oxides occl-Al-Fe-P and reductant soluble Fe-P reds-Fe-P [10]. Paulos [16] indicated that the concentrations of active P forms were related to the degree of chemical weathering. All the forms of P can exist in all soils but P bound by Al and Fe is abundant in highly weathered acidic soils, while Ca-P predominates in young calcareous soils of arid and semiarid areas which usually have high pH. These fractions have remarkable differences in mobility, bioavailability, and chemical behavior in soils and they can be transformed from one form to another under certain conditions. Information of the abundance of the various P forms and their interactions with each other and other factors that influence P availability in the soils of Ethiopia in general and in the study area in particular is crucial for sustainable management of soil P. Therefore, this study was conducted to assess the P status and the amounts and the distributions of the different inorganic P forms and their relationship with other properties and their implications for the future P management strategy of acidic soils of Farta District, Northwestern Highlands of Ethiopia. Materials and Methods 2. Location map of the study area. According to the Regional Office of Planning for Northwestern Ethiopia [17], geologically, the study area is covered with thick trap series volcanic rocks which were erupted from fissures during the early and middle Tertiary and from Choke Shield volcanic mountain center during the Miocene and the Pliocene. The trap volcanic series consists mainly of weathered and jointed basalt. The soils of the study area are developed from the parent materials of volcanic origin, predominantly Tertiary basalt. Luvisols are potentially suitable for a wide range of agricultural uses because of their favorable physical characteristics and moderate chemical fertility [19]. The soils of the study area have not been classified according to U. Soil Taxonomy, but tentatively many of them likely fall in the Alfisol order, more accurately Haplustalfs [20]. The natural vegetation in the study area consists of tree species that are remnants of a once dense evergreen forest occurring on slopes and sparse grass complex in various areas. The dominant tree species in the area include Juniperus procera, Olea africana, and Hagenia abyssinica. Currently, refilling or replantation strategy is being implemented in the study area [21]. The rural households are engaged primarily in crop-livestock mixed farming systems. Barley, wheat, teff, sorghum, maize, faba beans, peas, and potatoes are dominant crops while chickpeas and some oil crops are also grown. The average minimum, maximum, and mean temperatures are 9. The rainfall pattern is unimodal, stretching from May to September. The mean annual rainfall is mm [22]. Mean monthly rainfall and mean monthly maximum and minimum temperatures of the study area. Based on the field survey, the pH of the soils was measured using portable digital pH meter under field condition. Composite soil samples were prepared after thoroughly mixing the three subsamples. The soil samples were air-dried and ground to pass through a 2 mm sieve for the analyses of physicochemical properties of the soils following standard laboratory procedures. Sampling locations and site description. Particle size distribution was analyzed by the Bouyoucos hydrometer method as described by Day [24] after dispersion with hydrogen peroxide and sodium hexametaphosphate. Soil bulk density was measured from three undisturbed samples collected using a core sampler 2. Organic carbon OC and total nitrogen N contents of the soil samples were determined using the Vario MAX elemental analyzer by dry combustion method. It was assumed that in our acidic soils total C, which is determined by the analyzer, is all organic. Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution and titrated with 0. From the same extract, exchangeable Al in the soil samples was determined by application of 1 M NaF which forms a complex with Al and releases NaOH, which was back titrated with 0. The effective cation exchange capacity ECEC of the soil was calculated as the sum of exchangeable bases and exchangeable acidity. Cation exchange capacity attributable to the clay fraction was estimated as follows: An index of plant available P was determined according to Olsen et al. The modification here was that the NH4F had a pH of 8. Citrate dithionite bicarbonate-extractable Fe and Al Fed and Ald were determined by the method of Mehra and Jackson [35]. DPS was also calculated separately for Alox and Feox as Among the eight representative sampling sites, the soil samples collected from the Abalomeda and Kumbelie sites were analyzed for the mineralogical composition of the clay-sized fractions. Results and Discussion 3. Soil Physical Properties and Mineralogy of the Clay Fraction The textural class of all the soils was clay except Agawer I which was clay loam, indicating the similarity in parent material Table 2. The mineralogy analysis of the clay-sized fraction of the two sampling sites Abalomeda and Kumbelie showed that they had similar mineral composition and relative proportion, implying similar source of parent materials and similar pedogenesis. In general, the mineral compositions of both samples were dominated by kaolinite and quartz. Smectite-group clay minerals and illite were present as minor components, and the Kumbelie soil contained minor potassic feldspar microcline and trace amounts of chlorite. Selected physical properties of the studied soils. Organic carbon OC contents Table 2 were similar to those reported for thirteen clay soils in Ethiopia with a mean value of 2. According to the rating by Tekalign [39], the soil OC contents were in moderate to high range. However, the total N contents of all the soils were in the high range 0. N ratios of 8. N ratio in the A horizons of six soils of the Rift Valley range The result reflects the low inputs of organic material, such as straw, in these agricultural soils while N compounds are contained in the stable humus. Hence, the soils of the sampling sites are chemically degraded as to hinder production of acid sensitive crops unless the magnitude of acidity is reduced. This situation mainly occurs in tropical soils due to acidity and significant quantities of oxides, mainly those of Al and Fe [43]. Hence, our soils were rich in weatherable minerals as indicated by the presence of illite, smectite, and K-feldspar. For example, the soil sample collected from the Korekonch site required 8. Therefore, the soils of the study area need high amounts of lime to alleviate the acidity problem and increase the productivity of acid sensitive crops. Soil pH, buffer pH, and lime requirement LR. In a global soil material of about soil samples, the soil samples from Central and Western Ethiopia had nearly the highest CEC and clay content among the 30 countries that were sampled [45]. The present CEC values were lower than the mean of Exchangeable Ca was dominant in the exchange sites followed by Mg, K, and Na ions in that order. As per the ratings of FAO [46], the exchangeable Na in the soils of the sampling sites was medium, indicating that the soils were not sodic, the leaching being sufficient to remove excess salts; the exchangeable Ca and Mg were medium except at the Ayermarefiya and Abalomeda sites which had high values while the exchangeable K was low except at the Ayermarefiya, Agawer I, and Jura II sites which had high values. According to Barber [47], the critical level of exchangeable K for optimum crop production is 0. On this basis, only three of our sampling sites had optimum levels of exchangeable K. The result was in agreement with the findings of Alemayehu [48] who reported K deficiency in Nitosols in Wolega state farm. In terms of K, the results were in contrast to the common belief that Ethiopian soils are rich in K. There is obviously a large variation in K supply among the clay soils of Ethiopia. This conclusion is supported by many results from different parts of the tropics in which soil type and mineralogy, intensity of weathering, climatic factors, intensive cultivation, and use of acid forming inorganic fertilizers affect the distribution of K in soil and enhance its depletion [49 , 50]. Exchangeable cations and exchange properties. It was also shown in an earlier study [52] on the fertility status of some Ethiopian soils that Ca and Mg ions dominate the exchange sites of most soils. Exchangeable Al had a strong and negative correlation with pH , and strong positive correlation with LR ,. Therefore, both the pH and exchangeable Al determined the amount of liming material required for the proper management of acid soils of the sampling sites. Indeed, these results seem not to be low but as a matter of fact they are in the same range as in heavily fertilized soils of Europe. Total phosphorus content of the soils. Also, compared to some other African countries, the soils of our study area showed higher total P contents. Therefore, it can be concluded that the total P contents of Ethiopian soils are not as poor as in many other tropical soils studied. Inorganic Phosphorus Fractions The abundance of the various inorganic P fractions Table 6 was commonly as follows: Inorganic P fractions and percentage distribution of active P forms. In all studies, the abundance of different forms of Fe-bound P was high and Al-bound P was low, which agrees with our results. The very high contents of Fe-P among the active inorganic P fractions compared to the other fractions is due to the high content of Fe-oxides, low pH, and advanced stage of weathering Tables 2 , 3 , and 7. Rather low content of Al-P reflects the fact that Al-P fraction, which controls the plant available P in acidic soils in the first place, has been severely depleted in the study area. The degree of P associated with Al, Fe, and Ca was directly related to the intensity of weathering in that when Al and Fe fraction dominated in the soil system, the soil is highly weathered and vice versa [65]. The poorly crystalline oxides of Al Alox and Fe Feox are considered the active components in acidic soils to retain P. However, P in the oxide-bound pools was not related to the quantity of the corresponding poorly crystalline oxides; the correlation coefficient between Alox and Al-P was only 0. A similar low correlation has been reported by Hartikainen et al. Compared to Feox, 6. Even though the Feox was higher in our Ethiopian soils, the difference arises mainly from the fact that the Fed content in the Ethiopian soils was as much as fivefold compared to the European soils, reflecting the difference in soil age and degree of pedogenic development. Mamo and Haque [6] also reported that the Fed contents of 32 Ethiopian soils ranged from Our soils thus seem to represent nearly the average amounts of Fed in soils of Ethiopia. The linear correlation coefficients between the selected soil chemical properties.

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