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Assessment of soil quality indicators under different agricultural land uses and topographic aspects in Central Vietnam

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ABSTRACT

Soil quality assessment is valuable for agricultural production. In this research, 155 soil samples at two soil depths were collected from four land use types in an agricultural area of the A Luoi district in the Central Vietnam. Differences of soil organic carbon, total nitrogen in soil and soil pH under different land use types and topographic aspects were compared. Soil organic carbon contents in arable land and plantation forest are higher than those in natural forest and grassland ($p < 0.05$). Conversely, the total nitrogen in natural forest was significantly lesser in comparison to other land use types. Meanwhile there were no significant differences of the total nitrogen content ($p < 0.05$) among arable land, plantation forest, and grassland. The soil of grassland, natural and plantation forests land use types were more significantly acidic than those of the soils of the arable land use type. Soil organic carbon and total nitrogen showed a decreasing trend while soil depth increased in all land use types. The soil pH in plantation forest and arable land use types showed no significant change in relation to soil depth. Significant differences were not found in topographic aspects and soil organic carbon content; however, the different changing trends of soil organic carbon content between land use types and aspects were found. The impact of slope, elevation, farming system or soil texture accounted for the differences in these soil indicators under different land use types in the A Luoi district.

1. Introduction

According to the first Revised World Soil Charter, endorsed by The Food and Agriculture Organization (FAO) of the United Nations,"soils are a key enabling resource, central to the creation of a host of goods and services integral to ecosystems and human well-being" (FAO, 2015a). In general, soil quality is the ability of soil to provide nutrients to plants, maintain and improve water and air within the soil, and support human needs (Doran, Coleman, Bezdicek, & Stewart, 1994). Unfortunately, soil quality is rapidly decreasing in many regions around the world (Vitousek, Mooney, Lubchenco, & Melillo, 1997). There are many reasons leading to soil quality deterioration, including changes in land use types from forest to arable land (Oguike & Mbagwu, 2009) and the consequences from intensive land use (Jamala & Oke, 2013). Improvement of soil quality because of different land use types or crop rotation can be measured by changes in soil indicators and other parameters (Müller & Zeller, 2002; Reynolds et al., 2007).

Various studies have been conducted to evaluate the soil quality indicators under different land use types (Abbasi, Zafar, & Khan, 2007; Ishaq et al., 2015; Kalu, Koirala, Khadka, & Anup, 2015). The most popular indicators used to assess soil quality are soil organic carbon (SOC), total nitrogen (TN) and soil acidity (pH). SOC is fundamental to soil fertility and is a strong indicator of a soil's biological health (Chan et al., 2010) as well as its chemical, biological, and physical processes. TN is the main nutrient used for vegetation growth and is also used as a key soil quality assessment (Ren, Wang, Chen, Zhang, & Lu, 2014). Soil pH is one of the most important soil parameters and essential for agricultural production. Most agricultural crops develop best in soil with a pH from 5.5 to 6.5 (Havlin, Beaton, Tisdale, & Nelson, 1999). In the warm and humid environments of Central Vietnam, soil acidification occurs over time as the products of weathering are leached by water moving laterally or downwards through the soil.

Although the effects of different land use types on SOC, TN, and pH have been widely studied, the results remain inconclusive. Abbasi et al. (2007), Dengiz, Sağlam, and Türkmen (2015), and Kalu

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et al. (2015) found that SOC content in forested land is higher compared to other land use types. Conversely, Jonczak (2013) argued that fallow land has a highest SOC content, whereas Shi, Zheng, Mei, Yu, and Jia (2010) stated that paddy rice has the highest SOC content. Similar to SOC, Chen, Juang, Cheng, and Pai (2016) reported that TN in croplands was significantly lower than in forested land; however, Moges, Dagnachew, and Yimer (2013) argued that TN did not show any significant variation across all land use types. Soil pH also is affected by different land use types (Fayissa, Ababaew, & Chimdi, 2015; Khormali & Shamsiv, 2014).

In general, the total organic carbon (OC) is the amount of carbon in the soil related to living organisms or derived from them. In Vietnamese soils, total OC usually differs remarkably depending on soil type and topography, typically ranging from 1.0% to 1.5% of total soil weight. Under rainfed farming systems, it is typically 1% (Nguyen & Klinnert, 2001). Increasing the quantity of OC stored in soil may be one option for decreasing the atmospheric concentration of carbon dioxide (CO_2), a major greenhouse gas. This function of OC is also considered in the Vietnamese National Adaptation strategy to Climate Change.

Increasing the amount of OC stored in soil may also improve soil quality as OC contributes to many beneficial physical, chemical, and biological processes in the soil ecosystem (Fig. 1). When OC in soil is below 1%, soil health is low and yield potential (based on rainfall) may be constrained (Kay & Angers, 1999).

The quantity of OC stored in soil is the difference between all OC inputs and losses from a soil. The main inputs of OC in rainfed farming systems are from crop residues, plant roots and animal manure. Inputs of plant material are generally higher when plant growth is denser.

Losses of OC from soil occur through decomposition by microorganisms, erosion of the surface soil, and withdrawal in plant and animal production. During decomposition, microorganisms convert about half of the OC to CO_2. This process is continual, thus without a steady supply of OC, the quantity stored in the soil will decrease over time.

Losses by erosion may heavily impact the quantity of OC storage due to the heavy concentration of OC as small particles in the surface soil layer that are easily eroded. In Vietnamese agriculture, erosion can cause the annual loss of less than 5 t/ha of soil under crop production (Andersson, 2002; Maglinao, Agus, Ilao, Toan, & Penning, 2002; Pham, Degener, & Kappas, 2018) and up to 150–200 t/ha from soil under bare fallow (Douglas, 2008). Withdrawal of OC in plant and animal production is also an important loss of OC from soil. Harvested materials such as grain, hay, feed, and forage, all represent loss of OC for plant and animal production.

Soil quality is simply defined as "the capacity of a specific kind of soil to function" (Karlen et al., 1997), i.e., mainly to provide nutrition to plants and absorb and drain water. The different properties of soil are – texture, moisture, fertility (level of nitrogen, phosphorus, and potassium) and pH level, where the pH is the measure of a soil's acidity or alkalinity.

Hydrology, in terms of surface runoff and soil erosion has a high impact on current and future OC contents in topsoil in Central Vietnam. The specific hydrological situation of the A Luoi study area was investigated by Rafiei Emam, Kappas, Linh, and Renchin (2017); Rafiei Emam, Kappas, Fassnacht, and Linh (2018) and Nguyen, Hang, Anh, and Kappas (2016).

Soil properties are significantly influenced by spatial factors such as topographic aspect, positions, and climatic conditions. The variations in soil properties and topographic positions are strongly related (Ovalles & Collins, 1986). According to Pausas et al. (2007), climatic and topographic conditions result in changes of SOC, and changes in OC depend on related topographic position (aspects and slope). In this study, the concept of paired correlation of SOC of land use types and aspects was analyzed.

Among the three macro regions of Vietnam, the Central region is the least developed (Bautista, 1999). The agricultural and forested land areas of the Central region account for 78% total area (Vietnam General Statistics Office, 2014). Concerning the impact of different land use types on the ecological systems in Vietnam, the researchers focused on soil erosion, carbon emissions, and climate changes (Avitabile et al., 2016; Laux, Nguyen, Cullmann, & Kunstmann, 2017; Tran, Doyle, Beadle, Corkrey, & Nguyen, 2014). In this area, no soil quality studies have been carried out to date for different types of land use and topographic aspects.

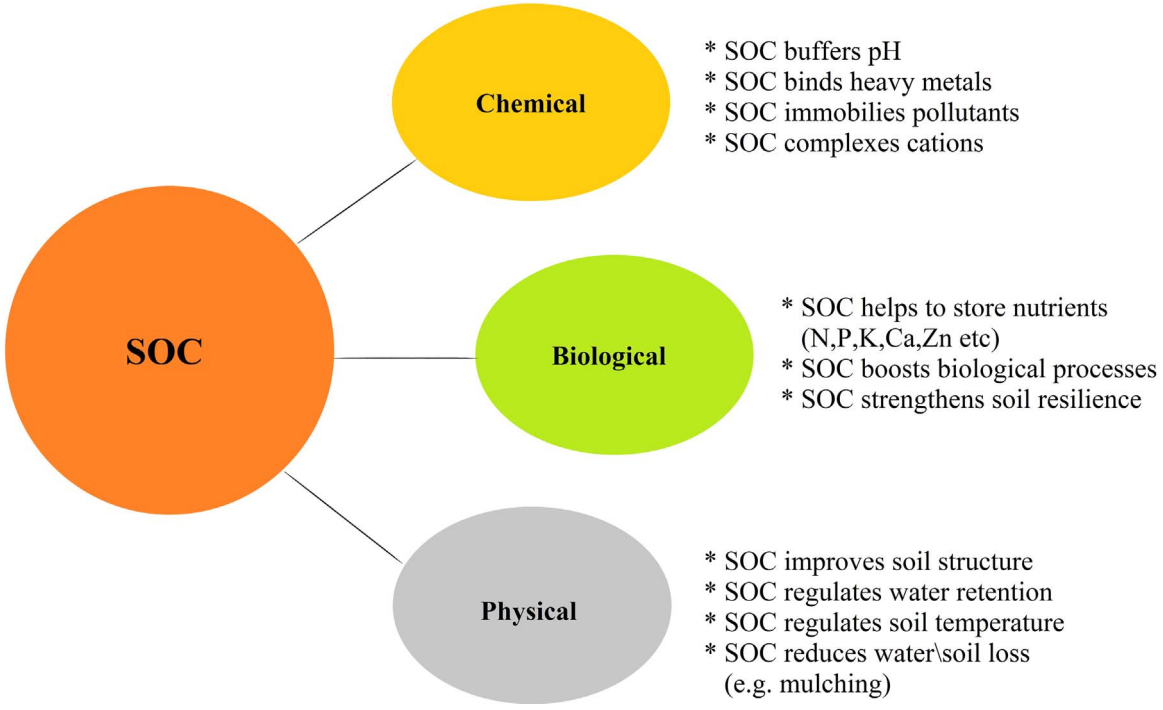

Fig. 1. Chemical, biological, and physical benefits in soil to which soil organic carbon (SOC) contributes (Carson, 2013).

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