Sandy soils in South Central Coastal Vietnam: Their origin, constraints and management

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Abstract
In Vietnam, sandy soils are distributed mainly in the coastal central provinces where they occupy 337,768 ha comprising 63 % of the nation's sandy soils, and they are also important to regional economic growth where more than 10 million people are living i.e.14 % of the Vietnamese population. The sandy materials in the central coastal Vietnam originate from mostly in situ weathering of granite although aeolian sediments are parent materials for sandy soils also. Sandy soils have a wide range of limiting factors for agricultural production, including nutrient deficiencies, acidity, low water holding capacity and wind erosion risk (on coastal dunal sands). Although there are soil fertility constraints to the use of sandy soils in Vietnam, 79,076 ha has been utilized in agriculture. Developing integrated nutrient management practices are needed to improve soil physical, chemical and biological fertilities of sandy soils. For example, systematic use of farmyard manures, crop residues, green manures, and alley cropping need to be considered. Developing integrated nutrient management practices also need to address environmental considerations by matching nutrient applications to crop needs and amending soils to minimise nutrient losses to water. Developing new soil management technologies (such as use of biochar, slow release fertilisers and minimum tillage) is also important for sustainable management of sandy soils in Vietnam.

Key Words
Nutrient deficiencies, soil acidity, soil fertility, integrated nutrient management

Introduction
Sandy soils occur in many parts of the tropics but low fertility and low water retention are major constraints to their agricultural productivity. Most of these soils are strongly acidic and have low organic matter content. In addition, as the clay fraction is also low in these soils, the cation exchange capacity (CEC) mostly depends on organic matter which also serves as the major component of the adsorbing complex for water (Le Thanh Bon, 1996; Le Sam and Nguyen Dinh Vuong, 2008; Hoang Thi Thai Hoa, 2008).
In Vietnam, sandy soils are distributed mainly in the coastal central provinces where they occupy 339,339 ha comprising 63 % of the nation's sandy soils (Table 1 and Figure 1). While the sandy soils occupy only 1.6 % of the territory and 4.6 % of agricultural land, they are important to regional economic growth where more than 10 million people are living i.e. 14 % of the Vietnamese population (Pham Quang Ha *et al*., 2005; Tran Van Y *et al*., 2006).
The purpose of this review paper is to review the current knowledge to identify the main constraints for the development of productive and sustainable farming systems on sandy soils in central coastal Vietnam and help developing integrated nutrient management practices.

Table 1. Area of coastal sandy soils in Vietnam.

Local name	All Vietnam (ha)	Coast central areas (ha)
Yellow & white sandy dune soil	222,043	134,113
Red sandy dune soil	76,886	75,000
Sandy marine soil	234,505	130,277
Total	533,434	339,339

Source: Vietnam Soil Association, 1996

Origin and classification of sandy soils
The sandy materials in central coastal Vietnam originate from mostly granitic geologies. Sandy soils formed from in situ weathering of granite occur in the coastal zone of south central Vietnam. However, the sandy sediments also form the soil parent materials after transport by fluvial, marine and aeolian processes (NIFS, 2001).

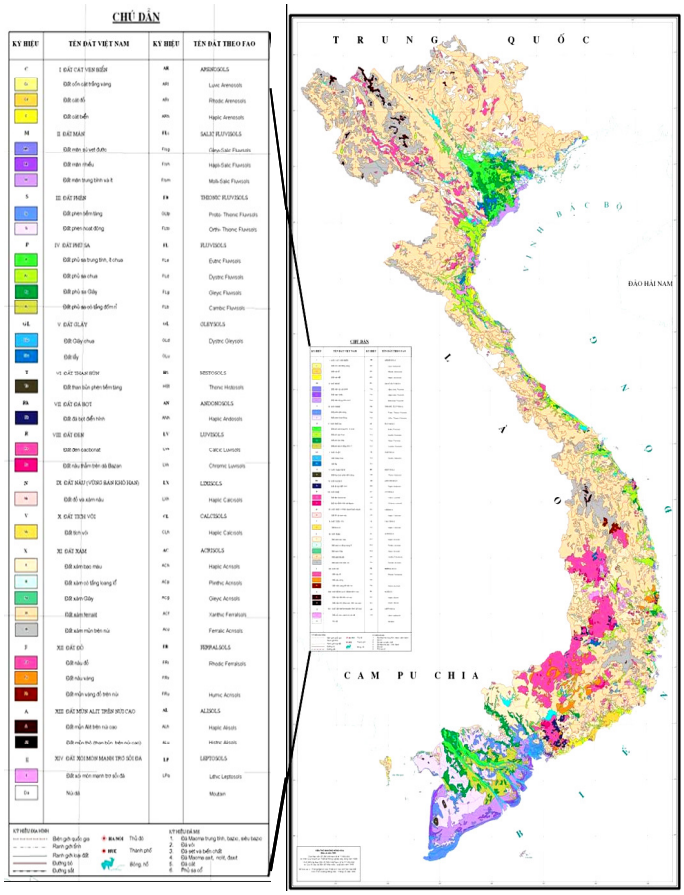

Figure 1. Soil map in Vietnam (NIFS, 2001).

Sandy soils as defined in the World Reference Base (FAO-ISRAC-ISSS, 1998) as containing <18 % clay and >65 % sand in the first metre of the solum, however, this still represents a broad range of soils with clay contents from 1-17 % and a wide range of chemical and mineralogical properties. The Vietnamese definition of sandy soils comprises all soils with sand content >80 % and encompasses degraded soils distinguishable by a relatively low clay and organic carbon content (Nguyen Van Toan, 2004). According to the Vietnam soil association (1996), the sandy soils may be classified mainly into 3 units: white and yellow sand dune soils; red sand dune soils and sandy marine soils representing 41, 15 and 43 %, respectively of the total (NIFS, 2001).

Constraints

Sandy soils have a wide range of limiting factors for agricultural production, which include nutrient deficiencies, acidity, low water holding capacity and on the dunal sands, susceptibility to wind erosion (Hoang Thi Thai Hoa, 2008). The soil physical and chemical properties of sandy soils are summarized in Table 2. Generally, sandy soils are strongly acidic with the mean pH_{KCl} below 4.7 but in particular cases of sandy marine soils that contain carbonate fragments, pH_{KCl} of Vietnam sandy soil may exceed 6.0. The coarse texture of sandy soils together with low organic matter often leads to a low water holding capacity and high infiltration rate which represent major challenges for agriculture production (Hoang Thi Thai Hoa, 2008). Three hundred cultivated sandy soils from Thua Thien Hue province showed a very large variation of organic content. The average was 1.08 % (standard deviation of 0.67) (Hoang Thi Thai Hoa, 2008). Both acidity and organic content of sandy soil may be influenced by agronomic activity, water logging condition, rate of organic material mineralization and sea water contamination (Nguyen Cong Vinh, 2005). Deficiencies of essential nutrients for crop production on sandy soils are often reported. For example, an omission experiment conducted in Binh Thuan province (Nguyen Cong Vinh, 2005) revealed that deficiencies of essential nutrients for crop growth were N>P>K and B>Mo>Zn for red sandy soils and P>N>K and B>Mo>Zn for white sand soils.

Table 2. Soil physical and chemical properties of sandy soils in Vietnam.

Indicators	Red sand dune soil (1)	Sandy marine soil (2)	White and yellow sand dune soil (3)
Bulk density (g/cm^3)	1.48	1.51	1.31
Particle density (g/cm^3)	2.63	2.65	2.62
Porosity (%)	44.0	43.0	50.0
Clay (%)	1.7	11.6	0
Silt (%)	1.7	11.6	0
Sand (%)	96.6	76.8	100
pH_{KCl}	4.20	6.30	5.40
OC (%)	1.43	0.52	0.08
N (%)	0.080	0.060	-
P_2O_5 (%)	0.030	0.10	-
K_2O (%)	0.15	0.22	0.02
CEC (cmolc/kg)	1.04	9.00	0.80

(1): Soil sample from Binh Thuan province
(2): Soil sample from Nghe An province
(3): Soil sample from Quang Binh province
Source: NISF, 2001.

Results on 211 sandy soils in Vietnam in 18 provinces showed that the average content of total Zn was 19 mg/kg soil which is lower in comparison with the Vietnamese recommendation (200 mg/kg soil) for agricultural soils. Zinc content in sandy soils of the south central coast of Vietnam was only 15 mg/kg soil. Average content of Zn in white and yellow sand dune soils was 2 times higher than in sandy marine soils and red sand dune soils (Le Thi Thuy and Pham Quang Ha, 2007).
At present wind erosion occurs more seriously in sandy soil areas in the dry season, especially in Ninh Thuan and Binh Thuan provinces. Due to lack of wind protection belts, sand spreads over cultivated and inhabited areas or creates new unstable sand dunes. Risk factors influencing occurrence of wind erosion include: (1) dry season from November to August with strong wind; (2) fine sand texture, unstable soil aggregates; (3) lack of mulching, deforestation and sparse vegetative cover (Le Sam and Nguyen Dinh Vuong, 2008).

Management

Although there are soil fertility constraints to the use of sandy soils in Vietnam, 79,076 ha has been utilized in agriculture. However, economic output per unit area is still low in comparison with the average for the rest of the country (Nguyen Van Toan, 2004). Choice of suitable crops and cropping sequences are often very delicate on sandy soils. Casuarinas (*Casuarinas equisetifolia*), Eucalyptus (*Eucalyptus sp*), Photina (*Phitinia prunifolia*), Kapok (*Alba pentandra*), Guava (*Psidium guajava*), Jack fruit (*Artocarpus heterophyllus*); and Vetiver grass (*Vetiveria sp*) are frequently used as pioneer species on sandy soils in Vietnam and used for wood, fuel, fruit or medicinal purposes. Cashew (*Anacardium occidentale L*); mango (*Mangifera indica L*), coconut (*Cocos nucifera L)*, dragon Fruit (*Hylocereus undatus),* citrus/lemon or orange (*Cistrus reticulata Blanto*) are also well adapted on sandy soils. Dryland sandy soils may be also used for cash crops such as peanut, maize and sesame. In the rainy season, seasonal or permanent flooded areas are well adapted for rice crops (Pham Quang Ha *et al*., 2005). The senior author's recent farm survey conducted in the coastal provinces of Central Vietnam suggested the potential to improve annual and tree crop yields through developing integrated nutrient management practices in sandy soils (Table 3).

Table 3. Crop yields achieved by farmers and their potential (unpublished data).

Crop	Yield range achieved by farmers (t/ha)	Potential yield (t/ha)
Rice	2.6 – 4.8	7.0 -8.0
Peanut	1.6 – 3.0	3.0 – 4.0
Cassava	6.0 – 11.9	15.0 – 16.0
Cashew	0.64 - 0.80	2.0

Source: Survey on socio-economic in Binh Dinh, Phu Yen and Ninh Thuan, 2009

Integrated nutrient management practices are needed to improve soil physical, chemical and biological fertilities of sandy soils. For example, systematic use of farmyard manures, crop residues, green manures, and alley cropping need to be considered. Recycling of manure and crop residues not only provide organic matter to improve soil physical properties but also supply nutrients for crop growth. Manure is widely used

in Vietnam for crop production and published literature in Vietnam (Nguyen Cong Vinh, 2005, Hoang Thi Thai Hoa, 2008) consistently suggested that highest and sustainable crop production were achieved from mixtures of chemical fertilisers and animal manure.

Developing integrated nutrient management practices also need to address environmental considerations by matching nutrient applications to crop needs and soil conditions to minimise nutrient losses to water. The nutrient balances conducted at field level by Hoang Thi Thai Hoa (2008) showed there were often positive balances for N and P which could lead to losses of nutrients into the environment. Many sandy soils are prone to significant losses of nutrients through leaching, so that any intensification of production needs to recognize this potentially adverse effect and develop management strategies that minimize off-site pollution. Furthermore, integrated nutrient management practices need to be assessed in pilot demonstration plots under local conditions prior to recommending their adoption by the wider agricultural community in coastal areas. Developing new soil management technologies (such as use of biochar, clay amendment, slow release fertilisers, minimum tillage), is also important for sustainable management of sandy soils in Vietnam.

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