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Means and ways of engaging, communicating and preserving local soil knowledge of smallholder farmers in Central Vietnam

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Abstract

Increasing interest in farmers' local soil knowledge (LSK) and soil management practice as a way to promote sustainable agriculture and soil conservation needs a reliable means to connect to it. This study sought to examine if Visual Soil Assessment (VSA) and farmer workshops were suitable means to engage, communicate and preserve farmers' LSK in two mountainous communes of Central Vietnam. Twenty-four farmers with reasonable or comprehensive LSK from previously studied communes were selected for the efficacy of VSA and farmer workshops for integrating LSK into a well-accepted soil assessment tool (VSA). In field sites chosen by the farmers, VSA was independently executed by both farmers and scientists at the same time. Close congruence of VSA scores between the two groups highlighted that farmers could competently undertake VSA. Farmers' VSA score was compared with their perception of field's soil quality. For the majority of farmers' perception of soil quality was consistent to their VSA score (62.5%), while the remainder perceived their soil quality was lower than their VSA score. For most farmers their assessment of soil quality using VSA valued their LSK, and the two measures were well aligned. Soil colour and presence or vulnerability to erosion were common soil characteristics mentioned by farmers and affected the final VSA score. Farmers' participation in VSA and workshops strengthen farmers' confidence in their LSK and provided guidance on the impact of their soil management on soil improvement and conservation.

Keywords Smallholder farmers · Local soil knowledge (LSK) · Visual Soil Assessment (VSA) · Soil quality · Soil indicators · Acrisols

Abbreviations

LSK	Local soil knowledge
VSA	Visual Soil Assessment
BMNP	Bach Ma National Park

Introduction

Soil degradation and erosion on farms is a worldwide problem, there have been calls for more sustainable changes in soil management practices (Rust et al. 2020, 2021). Many studies have indicated that an increase in agricultural activities and the use of agrochemicals or intensive agricultural practices have caused ongoing soil erosion and degradation, specifically in mountainous areas (Doppler et al. 2006; Hagel et al. 2013; Nguyen et al. 2008; Wezel et al. 2002; Ziegler et al. 2011; Thomas et al. 2018). In Asia including Vietnam, the biggest threats to soil function are soil erosion and loss of soil organic carbon with the situation likely to worsen unless individuals, the private sector, governments, and international organisations take concerted actions (Montanarella et al. 2016). However, the development of more sustainable soil management practices has continued to slowly evolve (Alskaf et al. 2020; Lahmar 2010), but with little acknowledgement of farmers' local knowledge and practice (Rust et al. 2021).

Local soil knowledge (LSK) has been broadly recognised for its importance and contribution to the sustainability of soil management in farming practices (Ali 2003; Barrera-Bassols and Zinck 2000; Buthelezi-Dube et al. 2018; Nath et al. 2015; Niemeijer and Mazzucato 2003; Sillitoe 1998; WinklerPrins and Barrera-Bassols 2004). LSK was defined by WinklerPrins (1999) as "the knowledge of soil properties and management possessed by people living in a particular environment for some period of time". Research of Ali

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(2003) indicated that farmers over generations through their lived experiences have developed strategies to maintain their agricultural systems. Nath et al. (2015) provided a model for blending science, through a soil quality index, and farmer-derived soil identification to incorporate farmers' LSK and apply it to sustainable land management. WinklerPrins and Barrera-Bassols (2004) recommended if researchers, particularly those working at the local level on land-use issues can acknowledge and work with locally-derived knowledge concepts and constructs that adoption and implementation of sustainable land-use systems could be improved.

In developing countries such as Vietnam, there is a threat to the retention of LSK due to an aging farming population and the younger generation expressing less interest in farming, while other soil information either provided by research, extension or independent laboratories is lacking (Huynh et al. 2021). Despite reviews that have highlighted the value of LSK and the science of ethnopedology advocating that participation of local people and their LSK is essential in the formulation and implementation of natural resource or rural development projects, scientific methods tends to take precedence over gaining insights into LSK held by local people (Huynh et al. 2020). Given the farmer's critical role in implementing sustainable soil management, a deeper understanding of their decision-making environment and LSK is needed to improve engagement with local or traditional approaches and develop applicable solutions to soil issues (Lobry de Bruyn et al. 2017). The incorporation of LSK with sustainable soil management techniques is aligned to the Sustainable Development Goal 15 "Life on Land" that helps to create more sustainable futures.

The conventional approach used in many LSK studies involves farmers corroborating a scientific soil assessment rather than having the farmers involved in initiating the areas to be sampled and establishing what their assessment would be, based on their LSK, before soil assessment by other means (Huynh et al. 2020). Soil mapping has also been used as an approach to verify farmers' LSK, where their LSK was compared with available soil information (e.g. soil maps) undertaken with accepted international standards (FAO USDA) to suggest how accurate LSK may be (Buthelezi et al. 2013; Gosai et al. 2011; Nath et al. 2015). In terms of reviewing international projects, Huynh et al. (2020) indicated that most of these projects (e.g. field schools run by the FAO) focused on training farmers in soil fertility management, without any exchange of LSK or learning from LSK. Hence, these approaches have mainly maintained the status quo, where LSK is deemed inferior or subsidiary to scientific soil assessment. Overall, there needs to be a more critical comparison between LSK and scientific knowledge so that local communities can confirm their own soil knowledge, and it can be used to support their local farming practices.

Contrasting with the conventional top-down approach of information flow from scientists to extension agents, and then to farmers, there has been a long legacy of placing ''farmer-first'' in research, which continues to the present day (Chambers 1994, 2009; Chambers et al. 1989; WinklerPrins 1999; Ashby 2009; Aquino et al. 2018; Pal et al. 2021). For instance, the research of Aquino et al. (2018) in Philippines and Japan highlighted the importance of farmer-first approach in building farmers' confidence to carry out further training and to develop environmentally-friendly agricultural systems. In India, there was an implementation of the Farm First project to address problems relating to innovations and its management at farmers' field conditions by enhancing farmer-scientist interface (Das et al. 2020). Maintaining the "farmer-first" research philosophy, our study applied a blended model of social and soil science participatory research that includes a household survey (2018), key informant interviews (2019), Visual Soil Assessment (VSA) and farmer workshops to examine farmers' LSK and relevant issues (2019). In which, the VSA was chosen as the scientific method for soil assessment because this tool is based on observable soil properties, and it is also considered sympathetic to local practice and farmers' LSK investigated in the study area prior to current research (Huynh et al. 2021). Other advantages of VSA is for time poor and impoverished smallholder farmers it can be easily, and affordably executed to evaluate soil condition, plant performance and the suitability of the soil (usually for annual cropping) (Batey et al. 2015; Shepherd et al. 2008; Shepherd and Park 2003). These assessments were intended to help land managers to assess their soil condition and the suitability for growing crops, and also to help them to make informed decisions that will lead to sustainable land and environmental management (Shepherd et al. 2008).

Additionally, to preserve LSK, farmers need to be involved in integration with external scientific resources. Many studies stated that improved communication and appreciation of farmers' LSK is based on co-production of knowledge and social learning to promote practices for farmers' soil quality recognition and sustainable land management (Barrios et al. 2012; Bennett and Cattle 2013; Macharia and Ng'ang'a 2005; Schneider et al. 2009; Winowiecki et al. 2014). For example, Winowiecki et al. (2014) and Macharia and Ng'ang'a (2005) found that discussion groups or participatory community workshops after fieldwork activities became a forum for farmers to share their knowledge, constraints and opportunities in soil management with other community members and researchers. Barrios et al. (2012) organised consensus-building workshops with farmers to build a list of prioritised local soil indicators, and then the modifiable soil indicators were selected to identify agroecological management options that could address soil quality constraints.

Hence, the aim of this study was to examine if a combination and sequencing of activities, namely key informant interviews, VSA, and farmer workshops, could be used as strategies to engage, communicate and preserve smallholder farmers' LSK in two mountainous communes in Central Vietnam.

Materials and methods

Study area and research design

Two communes of the study area, Thuong Nhat and Huong Phu, are located in the buffer zones of the Bach Ma National Park (BMNP) in Nam Dong district, Thua Thien Hue province, Central Vietnam (Fig. 1). Acrisols are the common soil order across Nam Dong district (Hoang 2017) and the Thua Thien.

Hue province (Dong et al. 2014), however, there is little detail known of the soil type and its performance at the farm scale. Thuong Nhat and Huong Phu communes are dominated by the Katu (95%) and Kinh (90%), respectively, which are the two major ethnic groups in Nam Dong district. According to Nguyen (2015) and Huynh et al. (2021), who undertook research in the same communes the main agricultural activities were acacia plantation (92%), mixed garden (51%) and rubber plantation (38%).

Human Research Ethics approval (HE17-219) from the University of New England was obtained before the interviews were conducted. The household survey (2018) of 146 farmers from Thuong Nhat and Huong Phu communes provided evidence of farmers' LSK and its use to select suitable crops, identify soil problems and soil management techniques. The survey results also categorised farmers' LSK into three categories limited, reasonable, and comprehensive LSK. The dominant category was reasonable LSK with 70% of surveyed farmers, and 20% of farmers were categorized as having comprehensive LSK. Those farmers with comprehensive LSK were more familiar with their soils and the relationships between essential soil properties that reflect

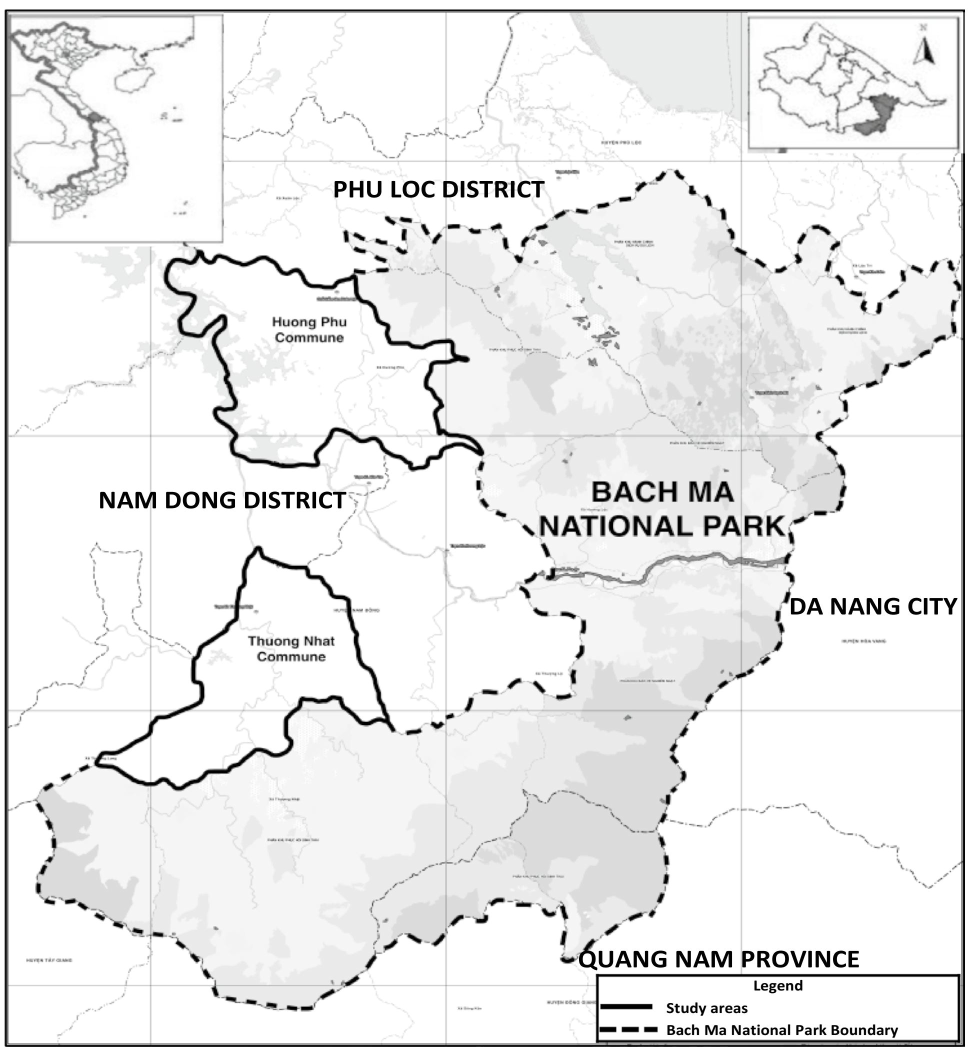


Fig. 1 Location of BMNP and the study areas in its buffer zone. Top left insert location within Vietnam. Insert top right is Thua Thien Hue province with the location of BMNP shaded (Adapted from Nguyen, 2015 and Forest status map of BMNP (Scale 1:25,000), 2018)

soil problems, and could express their LSK in greater detail (Huynh et al. 2021).

The household survey findings highlighted the predominance of farmers' reasonable to comprehensive LSK but also the need for practical approaches for cross-generational knowledge exchange, as there was evidence of loss of LSK in Kinh ethnic group due to lack of succession planning (Huynh et al. 2021). The methodology sequence is presented in Fig. 2. Based on earlier research findings on depth of LSK (Huynh et al. 2021), from March to April 2019 this study selected 24 farmers previously characterised as having reasonable and comprehensive LSK for key informant interviews as part of VSA and workshop participatory assessment (12 farmers were chosen from each commune). These farmers were selected because they are more familiar with their soils and the relationships between soil properties and soil issues. Other reasons for selecting the 24 farmers were based on major crops that they are growing (e.g. acacia, rubber, mixed garden) and their farm size (medium to large). Five additional key informant interviews were conducted with relevant stakeholders: local government representatives from Huong Phu, Thuong Nhat commune and BMNP, a soil scientist from a university, and a researcher from a Rural Development Centre in Central Vietnam. Each stakeholder had over a decade of experience in Nam Dong district. The interviews sought stakeholders' views of local soils and LSK in relation to agricultural and rural development and natural resource conservation.

After each interview with a farmer, he or she selected a field and decided on the level of soil quality (good, moderate, or poor) prior to VSA. Then VSA was applied, as advocated by the FAO for annual crops (Shepherd et al. 2008), on the field chosen by farmers. The farmer and scientists (the first and second authors of this paper) independently undertook VSA to derive a soil quality score that was determined as good (> 30), moderate (15–30) or poor (< 15). The VSA results were then compared and presented at two farmer workshops. Figure 3 shows the GPS location of the 24 field sites of the 24 farmers in which the VSAs were undertaken, with 12 field sites in each of the two communes.

Field soil tests and Visual Soil Assessment (VSA)

Before commencement of the VSA, soil chemical test strips were used to assess topsoil pH (soil reaction), Phosphate, Nitrite and Nitrate in the field selected by the farmer to characterise some elements of soil fertility and soil pH that affect nutrient availability. For the VSA, a 200 × 200 mm square by 300 mm deep hole was dug. In the process, the topsoil (and upper subsoil if present) was observed in terms of its uniformity and soil structure (Shepherd et al. 2008). The VSA procedure of Shepherd et al. (2008) indicated that a representative assessment of soil quality for over a 5-ha area

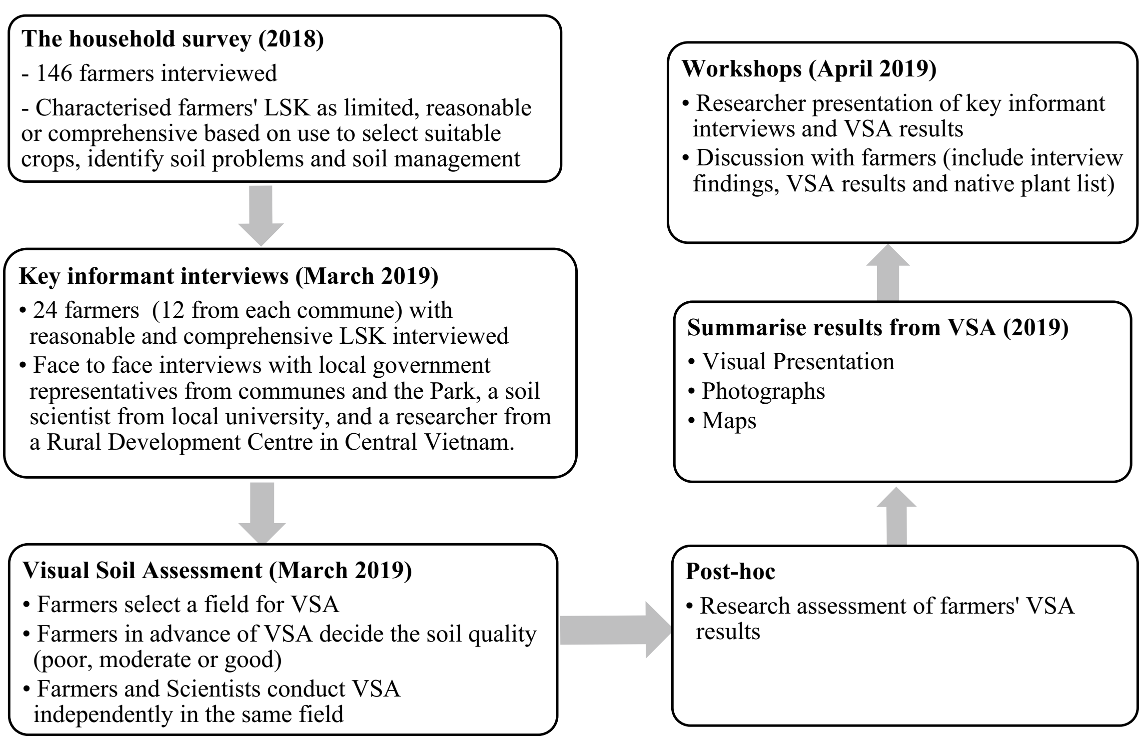


Fig. 2 Methodological sequence of the strategies and associated research activities undertaken during the research into VSA and LSK in two communes adjacent to BMNP

Fig. 3 Location of farmers' VSA (white sample dot with data identifier code) conducted in Huong Phu (HP) and Thuong Nhat (TN) communes (scale bar = 1 km)

(HP)

(TN)

needed 4 sample sites. However, most field sites selected by farmers were near their houses and either 1 ha or under 2 ha (Huynh et al. 2021), therefore this study needed only one sample location per field site.

A 200 × 200 mm square × 300 mm deep cube was dug out with the spade to undertake the drop shatter test. Each test sample in the study area was dropped up to three times from a height of 1 m, as described in the VSA manual (Shepherd et al. 2008), into a broad metal pot, which was thicker and more durable than a plastic basin. The farmer and the scientists worked systematically through the scorecard (see Appendix A, B), assigning a visual score (0—poor, 1—moderate or 2—good) to each indicator by comparing it with the photographs (or the table in the manual) and description reported in the field guide (Shepherd et al. 2008). The lead author is fluent in Vietnamese and could translate any written text as the VSA was performed. Each field took about 30 or 45 min to complete all VSA steps and finalise the score sheet. The final soil quality index comprises three levels with a score: greater than 30 (good), 15 to 30 (moderate) and less than 15 (poor) (see Appendix A). The annual crop manual was used for all crop types in the fields, and the orchard manual scorecard was applied to calculate the soil quality index for citrus, rubber and acacia. However, there was no significant difference in average VSA score between the orchard soils regardless of whether the orchard or annual manual scorecard was used. Subsequently, the VSA score was presented based on the annual crop manual throughout the results.

Data analysis

Microsoft Excel (version 16) was used to collate data from the key informant interviews and tabulate the VSA data collected from the fields. NVivo 12 Plus was used to explore the type and frequency of words that the 24 farmers used to describe their soil quality when they were asked how they recognise a poor soil and a good soil, to determine the type of characteristics they use. PRIMER software V.5.2.9 was used to undertake principal component analysis (PCA). The PCA identified characteristics that drove the distribution of the individual VSA scores (Townend 2013). Data visualisation using PCA on VSA scores for all participants (farmers and scientists) for the type of soil characteristics that separate out the soil quality categories, as well as overlayed with farmers' advanced assessment of soil quality pre-VSA was deemed appropriate to show: the more important soil properties for VSA out of the 10 measured and also how the farmers' advanced soil quality assessment varied from the VSA.

Participatory approach

The PCA outputs, the photographs from various farmers' fields and maps were used in two farmer workshops in each commune's meeting hall from 17 to 18 April 2019. In each commune, three village heads of each commune and the 12 farmers who participated in the key informant interviews and VSA were invited to attend. All 12 participating Huong Phu farmers attended, while only eight participating Thuong Nhat farmers attended the workshop. Participants were encouraged to define soil types based on the field site location and the land-use status of communes (Fig. 2, Figure 7 and Appendix B1). The objective of this first activity was to exchange soil knowledge about the location of soil types between farmers with locally derived names.

In the second and third workshop activities, a brief overview of the VSA results were presented using handouts and interactive activities. Those soil characteristics that were the prime determinants of the soil quality assessment were presented with three visual props: PCA visual data output, photographs of the main soil issues and management interventions farmers have used with their associated VSA scores. The fourth, the native plant list that was obtained through the initial household survey and discussed individually with those farmers undertaking the VSA, was also presented to the workshop group for further elaboration (see Appendix B2). These activities were designed for farmers to express their opinions about the similarities and differences between local and scientific soil knowledge. Finally, participants discussed the benefits of the workshops and suggested how LSK should be developed and maintained in the near future.

Results

Key informant interviews with farmers and other stakeholders

Farmers

An examination of the word frequencies in the NVivo word clouds indicated similarities and differences in soil properties between good and poor soils described by the 24 farmers (Fig. 4). Soil colour was a characteristic mentioned by most farmers, both for good and poor soils. Darker and blacker soils were stated to indicate good soils, and farmers explained these soil colours were strongly related to soil moisture and the number of earthworms or humus on the soil surface. Poor soils were also described based on their colour, using terms such as white, lighter and paler red or yellow soil colour, and the types of rocks or stones (small, round or sharp and more than 60% stones in soil), although good soil could also have some big rocks or decayed stones (Fig. 4).

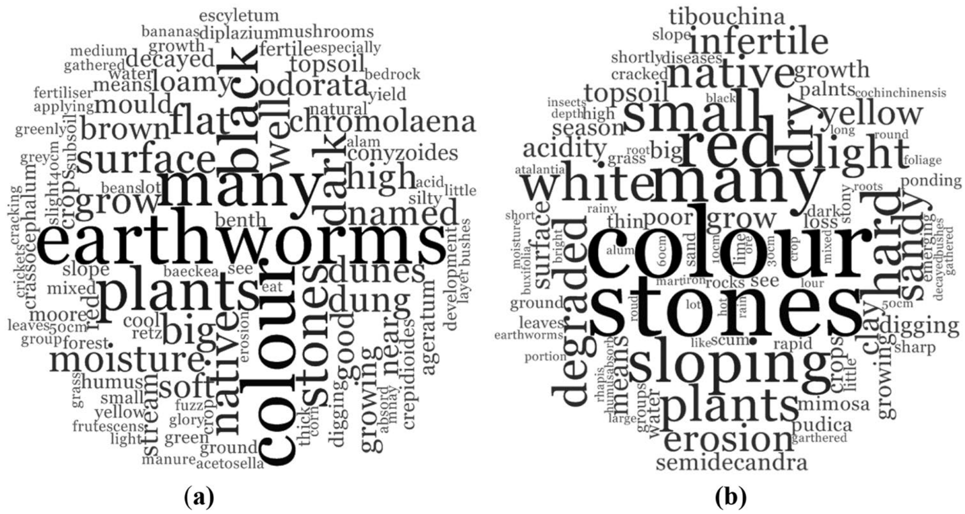


Fig. 4 Word cloud for **a** good soil and **b** poor soil with the larger font size representing more frequently used words, and vice versa to describe soil quality by KI farmers (n = 24). For Vietnamese translation refer to Appendix D

Critical differences in the two-word clouds between good and poor soils showed earthworms were only mentioned as a signal for good soil, whereas stones or sloping land was more strongly associated with poor soil (Fig. 4). Soft soil (mould) and hard soil (clay, dry) relating to soil porosity or soil structure were also used by most farmers to distinguish good soil and poor soil, respectively. Also, a high proportion of farmers mentioned native plants when asked how they distinguish between good or poor soils. Some common plants associated with good soil were located in the word cloud, such as *Crassocephalum crepidioides* (Benth.) S. Moore ("rau tàu bay"), *Ageratum conyzoides* ("cỏ hôi") and *Chromolaena odorata* ("cây bớp bớp"). These native plants often grow in low lying areas or near streams, while *Tibouchina semidecandra* ("cây mua") and *Mimosa pudica* ("cây xấu hổ"/ "cây trinh nữ") were identified as commonly growing on poor soils that farmers also associated with acidity, stony, and sloping land.

Local government managers and researchers engagement in soil conservation and LSK development

In the key informant interviews with local government managers and researchers, they agreed that soil plays a vital role in current and past agriculture or livelihood projects, but suitable crop types or plants, livestock management and financial issues are prioritised more than soil assessment or management. Our key informant interviews also showed that there is very little ongoing direct communication by these people with farmers once a project has finished. The researcher from a university who conducted many projects in Nam Dong district, including in our study area, had laboratory tested soil samples from several sites. However, the soil testing that they carried out did not involve the farmers directly. Most of the soil analysis results from the laboratory were reported to the agricultural staff in Nam Dong district or communes, but very few soil test results were communicated in person to local people. Researchers also commented that they related native plants to poor soil, such as *Ageratum conyzoides* "cỏ hôi" occurring in acid soil, but had not considered their role in identifying good soil.

Moreover, only two of the five government or researchers interviewed mentioned the impacts of intensive agriculture on soil loss, while this was a priority issue for most of the farmers interviewed. One of the local government managers raised a critical issue that they felt local people were more recently giving attention to soils. He said that local people have shown increased interest in soil quality improvement and sustainable methods since the late 1990s because farmers had shifted to perennial crops such as acacia and rubber. However, neither farmers or local government managers and researchers mentioned the management of erosion, nor did they make reference to plans, either past or present, to further investigate LSK.

VSA as a strategy for two-way communication with farmers

Background to sampled fields

This study conducted soil assessments in five different crops including mix garden (7 fields), rubber (6 fields), acacia (5 fields), banana and orange garden (4 fields) and cassava (2 fields). The soil analysis using chemical test strips found the soils were similar in soil pH, Nitrite and Nitrate levels between the field sites of Thuong Nhat and Huong Phu. In all field sites from both communes, soil pH was acidic with a range of 4.3 to 5.0, and with low levels of Nitrite and Nitrate (0–2 ppm). The Phosphate results were low, with an average of 18 ppm across the 24 soil samples taken from farmers' fields. The available Phosphate of the natural forest soil in Thuong Nhat (12 ppm) is slightly lower than the natural forest soil in Huong Phu (15 ppm) and the farmers' field sites. The average level of available Phosphate in the Thuong Nhat farmers' field sites (21 ppm) was higher than the Huong Phu farmers' field sites (15 ppm), but not significantly different. The three field sites with the highest level of Phosphate (35–50 ppm) were in the Thuong Nhat commune (TN-V2-24, TN-V3-12 and TN-V3-01) and also had the highest VSA scores (mean = 40.2). Hence, based on rapid field-based soil tests, most farmers' field sites were of low fertility (in terms of available N and P) and acidic.

Farmers' advanced assessment of soil quality and comparison to VSA results

Before conducting the VSA, nearly two-thirds of the farmers (63%) perceived their soil quality to be moderate, with 21% considering it poor and only 16% perceiving it to be good (Fig. 5a). However, when applying VSA, most soils were assessed as moderate (71%) and 29% scored a good VSA score, with no soil given a VSA score that would place it as poor (Fig. 5a).

In terms of communes, Huong Phu commune farmers were less critical in their soil assessment than farmers from

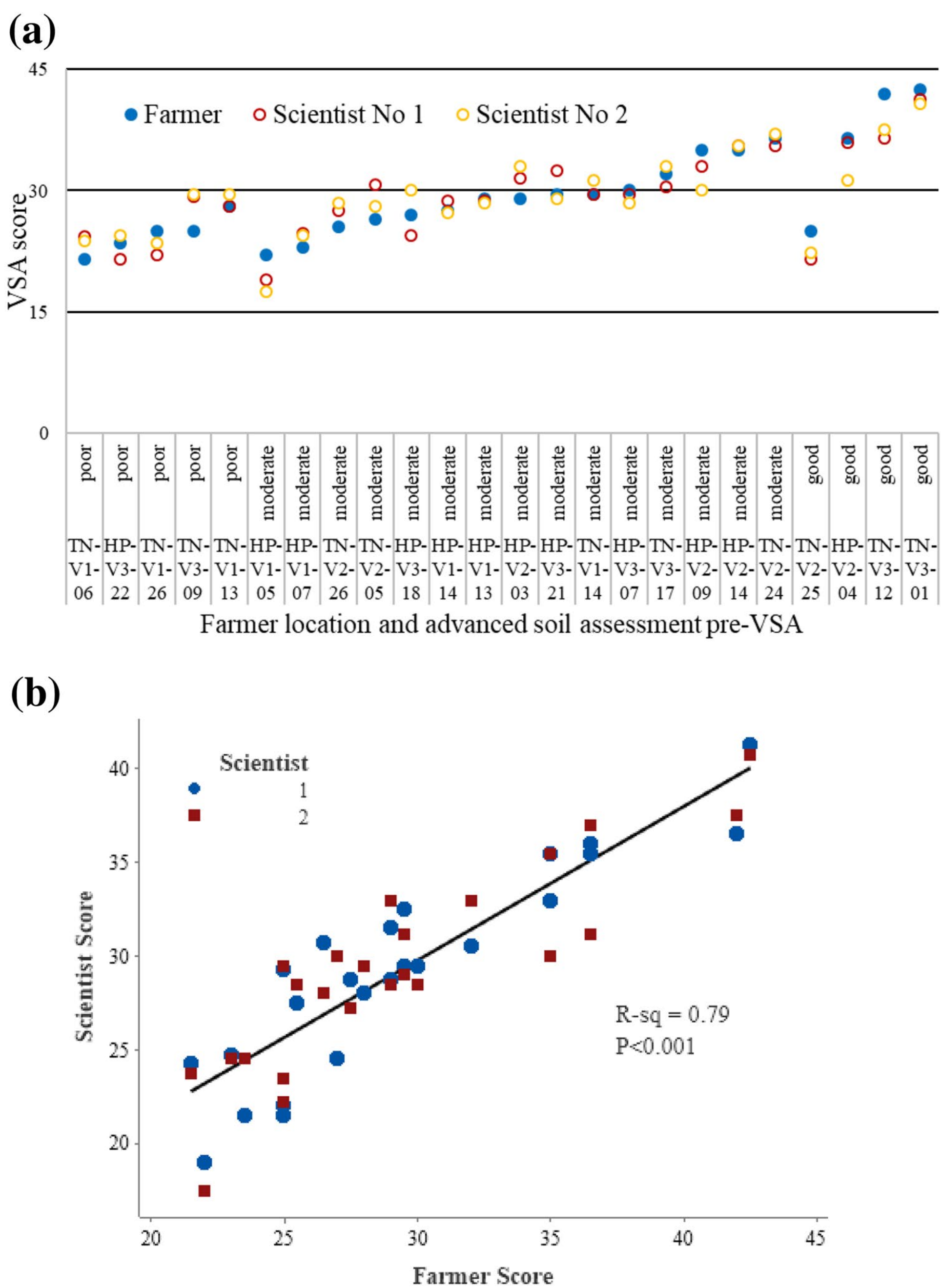


Fig. 5 **A** Distribution of VSA score of farmers and scientists (n = 72) with farmers' advanced assessment of soil quality pre-VSA, **B** The linear regression between famer ($r^2 = 0.79$, $P < 0.001$, n = 24) and scientists VSA scores undertaken in farmer's field (n = 24) in two communes with VSA score good (> 30), moderate (15 > 30), and poor (< 15)

the Thuong Nhat commune. Seventy-five per cent of Huong Phu farmers arrived at a VSA score that aligned with their pre-assessment, while a lower proportion of Thuong Nhat farmers' (41.7%) pre-assessment corresponded to their VSA score (Fig. 5a). Farmers' perception of their field site's soil quality was generally (62.5%) consistent with the score determined by the VSA. However, for those farmers who differed in their perception of soil quality compare to the VSA score, especially those located in Thuong Nhat commune, it tended to be of a lower quality (Fig. 5a). In addition, there was a strong correlation between the farmers' and scientists' VSA scores from the same field site of $r = 0.89$ ($P < 0.0001$) (Fig. 5b).

Soil properties driving VSA score distribution

The PC1 and PC2 was derived from the ten soil characteristics used to determine the VSA score and 50% of the distribution variation in the data points could be described by these 10 soil characteristics. Of these characteristics, the five variables that contributed most to the distribution of VSA scores were rooting depth, soil erosion, soil colour, number and colour soil mottles and surface ponding (Fig. 6). The VSA scores were largely determined by soil structural properties and the movement of water over or in the soil with two soil characteristics – surface ponding and soil erosion – reliant on the LSK of the farmers for their determination (Fig. 6).

Farmers' views of participation in VSA with soil scientists

All participating farmers were asked if they had been previously involvement in soil test training and/or soil analysis or a visual soil assessment (VSA) procedure. All farmers stated they had no previous experience in such types of soil assessment. After completing the VSA they were asked to rate their level of confidence in the VSA execution and results, on a scale from no confidence to 100% confident. Only one farmer from Thuong Nhat said that he was not confident in undertaking the VSA, while four farmers said that they were 50–60% confident and the remaining 19 farmers were 70–100% confident that their VSA results matched their own soil quality assessments.

Most of the smallholder farmers agreed that the VSA in their fields was useful and of interest to them. Notably, most of the farmers said that through their participation in the VSA, they were more attentive to their soils and their management. For example, HP-V3-07 said that he could compare the VSA result with his own assessment. HP-V2-14 said, *"the VSA helps me know more about soil characteristics, especially rooting depth and soil erosion and that I should pay more attention if I want to buy new land or assess the soil in the near future"*. HP-V1-13 and TN-V1-26 said that they could assess their soil more precisely after completing the VSA. HP-V1-07 stated, *"the combination of looking, feeling and touching the soil makes the soil evaluation more thorough"*. TN-V3-01 also indicated that the VSA was focused and practical, not too theoretical and not too complicated to apply.

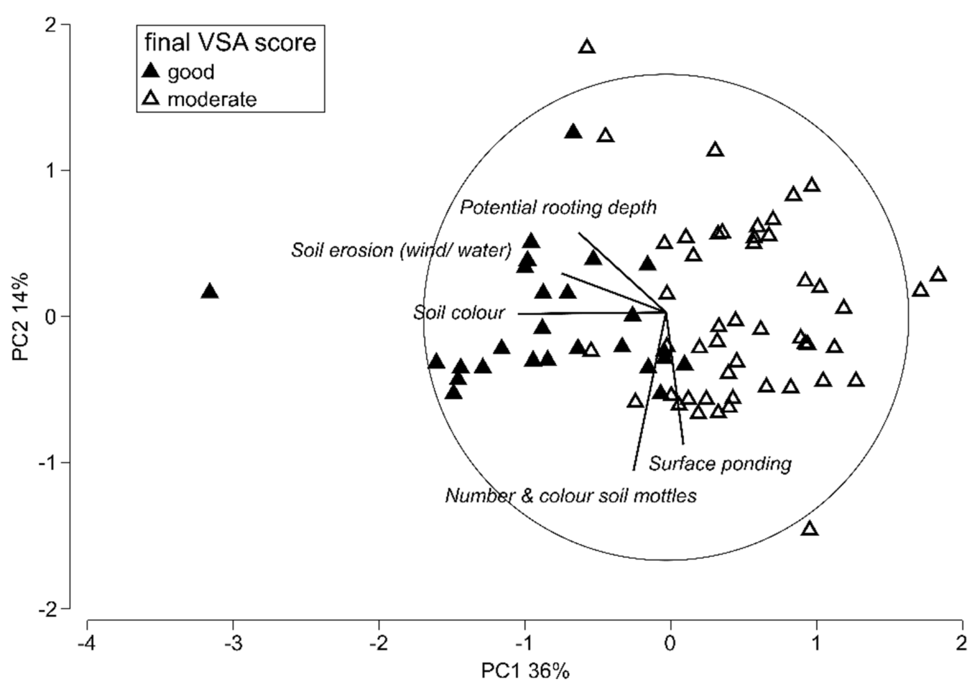


Fig. 6 Distribution of VSA score of farmers and scientists ($n = 72$) final VSA score. All 10 soil properties were used in PCA but the five that contributed to the distances (PC1, PC2) between samples were rooting depth, soil erosion, soil colour, number and colour soil mottles and surface ponding

Communication between local farmers and soil scientists via workshops

The primary outcome of the two workshops was to promote dialogue between researchers and local farmers in a group having only experienced the VSA in a one-on-one situation. The first activity focused on LSK exchange between local farmers by defining soil types on a location map of the local soil sample collection (Google Earth) and the communes' land-use status map (Fig. 7). Very few participants could locate the soil types via the 'official' land-use status map, while many others easily defined and described soil types according to houses or fields of villagers named on the location map of the VSA field sites. For example, the soil type around HP-V2-09 and HP-V2-04 was defined as sandy soil, which is suitable for croplands, while 1 km away (to the southeast of the site), the soil was described as too stony because of nearby rapids ("đá gềnh chết").

The second activity in the workshop was discussing the preliminary results of the VSA score and farmers' pre-assessment of their soil quality. There were some participants, less than half, whose VSA score was higher than their pre-assessment of soil quality, and they were not expecting this result. However, with a higher VSA score, they were more optimistic about their soil quality, which implied their soil was in better quality than they first believed. The VSA score also provided renewed farmers' enthusiasm to improve soil management, such as erosion control and more closely monitor soil erosion.

The third activity in the workshop was examining photographs taken from different fields to discuss soil issues and sustainable management (Fig. 8). Pictures of farms with high and low VSA scores that reflected good or poor soil quality, respectively were useful props to encourage discussion about soil problems and the role of soil management. For instance, the mixed garden field site of TN_V3_01 had a good VSA score (42) because the farmer had implemented soil improving practices, such as using rice husks and residue from the garden to cover the soil surface, applying manure and avoiding heavy use of chemical fertiliser and pesticides that resulted in improved soil structure, higher soil moisture retention and darker soil colour. In contrast, the field site of TN_V1_06, which had a low VSA score (21), was a mixed garden in the past that was planted to acacia. This field was harvested, residues burnt, lacked ground cover and exhibited evidence of erosion, and in the workshop the vulnerability of the field to erosion was discussed.

All farmer participants were interested in the third activity because of the visual nature of the photographs and the comparison with the VSA scores. They said that their soil management would be more focused in the future. Some of them discussed their soil problems and openly asked other farmers and the researchers how they could improve their soil quality. Through this activity, differences in soil management between the communes became apparent, with Thuong Nhat farmers burning or removing the ground cover as their conventional way of farming, while Huong Phu farmers spray herbicides and pesticides to protect their crops.

The fourth activity of the workshops was verifying the list of native plant indicators and their local names and interpretations from photographs collected during the household survey and key informant interviews (Table 1). During fieldwork in 2018, 12 different types of native plants with a diverse description of soil characteristics were communicated to the researcher by several Katu farmers within the Thuong Nhat commune. In the 2019 fieldwork, these native plants were revisited with the key informant interviews, where farmers provided seven more native plant names and their association with soil quality.

All the native plants were listed with their local names and scientific names. The farmers had nominated these native plants due to the association with certain types of soil quality (Table 1). Farmers associated nine of the native

Fig. 7 Participation of Huong Phu and Thuong Nhat farmers in defining soil types on Huong Phu's (left) and Thuong Nhat's (right) maps

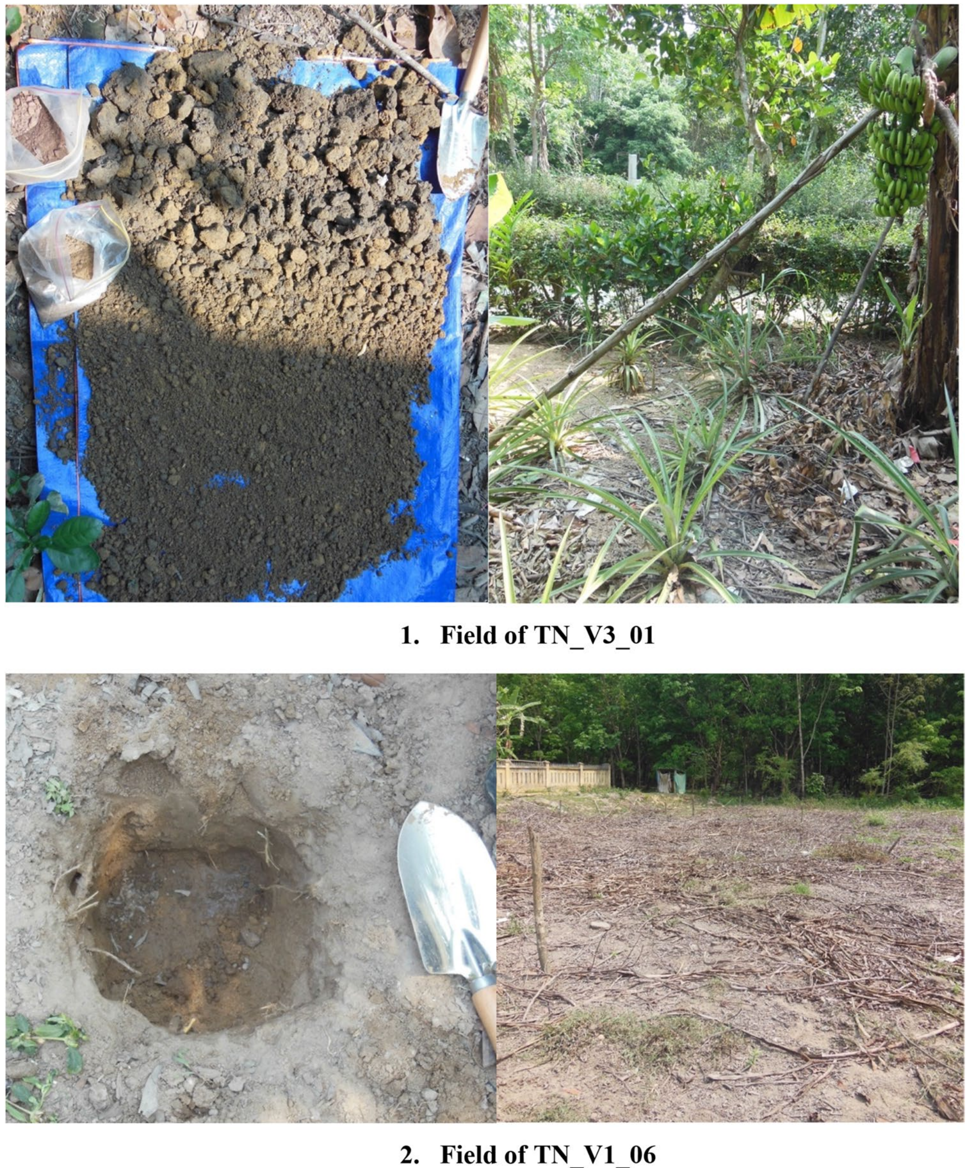


Fig. 8 Comparison of different farmers' fields and VSA score in relation to soil issues and sustainable management, a. Mixed garden with high litter cover, VSA score: 42; b. Harvested acacia with low ground cover, VSA score: 21

plants (numbered from 1 to 9 in Table 1) with good soils and other soil characteristics such as high soil moisture (near stream/creek or wet area), low topography, heavier soil texture or well-structured soils. Conversely, ten native plants (numbered from 10 to 19 in Table 1) were found growing on dry or hard soils (due to low soil moisture and sandy texture), steeply sloping land and containing many stones, which farmers associated with poor soils.

The final activity captured participants' suggestions and thoughts on how LSK should be developed and maintained. Most farmers responded that they would increase their focus on improving soil quality following the workshop. Many farmers acknowledged after the workshops they were more confident of their local knowledge about the soil, and if they were not then they were connected to other farmers in their commune from whom they could learn more about sustainable and effective soil management methods. Most farmers also expressed a desire for further VSA and farmer workshops. In the end, a third of the farmers indicated an interest in more detailed soil surveys and developing local soil maps based on LSK from their villages, with a view to planning suitable crops with improved soil sustainability.

Discussion and implications

Relevance of VSA as a means of engagement with LSK

Farmers reported they confidently participated in all steps of the VSA, and the results were immediately available to them in the field. In contrast, soil tested conventionally (i.e. field

Table 1 Native plant indicators for soil quality provided by farmers from Thuong Nhat and Huong Phu in the language of their ethnic group

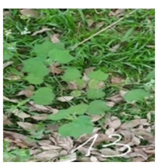
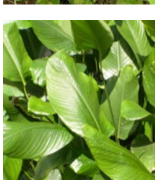
	Photos	Thuong Nhat name	Huong Phu name	Scientific name	Family name	Farmers' description
1		A Giuồng	Củ nóc	*Curculigo latifolia*	Hypoxidaceae (Tỏi voi lùn)	Grow on good soil, near the stream, wet area
2		Pây lu	Lá tầu bay	*Crassocephalum crepidioides* (Benth.) S. Moore	Asteraceae (Cúc)	Grow many on good soils, especially after burning field (Katu respondents)
3		Tịnh toăng	Tầm bóp	*Physalis angulata* L	Solanaceae (Cà)	Grow on good soil and flat areas, especially grow on the garden soil
4		A loòng	Rớn	*Diplazium escyletum* Retz	Athyriaceae (Họ Dớn)	Grow near the stream, high soil moisture
5		A lập	Ké Anh Đào	*Urena lobata* L	Malvaceae (Cẩm quỳ/ Dâm bụt)	Grow on moderate good soil, many in "rung non" (young forest) but very few in "rung gia" (forest of high trees)
6		A Nút	Cỏ hôi	*Ageratum conyzoides*	Asteraceace (Cúc)	Grow on good soil, wet area
7		A pếch/ P hười	Mâm xôi/ Ngấy trắng	Rubus	Rosaceae (Hoa hồng)	Grow on good soil
8		N/A	Cây bóp bóp	*Chromolaena odorata*	Asteraceace (Cúc)	Grow on good soil, forest edge
9		N/A	Lá dong rừng	*Phrynium placentarium*	Marantaceae	Grow on good soil, shady wet area, along streams

Table 1 (continued)

	Photos	Thuong Nhat name	Huong Phu name	Scientific name	Family name	Farmers' description
10		Ra sor	N/A	N/A	Polypodiaceae (Họ Dương xỉ)	Grow on poor soil, and stony; upland rice cannot grow on the soil where this plant develops densely
11		Avar	Bòng bong	*Lygodium* sp.	Schizaeaceae (Họ bồng bồng)	Grow sparsely on good soil, grow densely on poor soil
12		Ka pai	Lá hón	*Mallotus microcarpus* Pax. et Hoffm	Euphorbiaceae (Họ thầu dầu)	Not grow on good soil and flat areas. Mainly develop in "rung non" (young forest)
13		Ri lò	Lụi	*Rhapis cochinchinensis* (Lour.) Mart	Arecaeae (Cau)	Grow on poor quality soils, mainly develop in "rung gia" (forest of high trees), never see in "rung non", slope, stony
14		Tì bàng	Bướm bạc/ trắng	*Mussaenda pubescens* Ait. f	Rubiaceae (Cà phê)	Grow on poor quality soils, dry soil
15		À rạch	Bồng bồng lá liễu	*Lygodium flexuosum* (L.) Sw	Schizaeaceae (Họ bồng bồng)	Grow on poor quality soils, dry soil, a lot of stones; rated as the 3rd poorest soil
16		Pi- prờ	Đuôi chuột	*Stachytarpheta jamaicensis* (L.,) Vahl	Verbenaceae (Tếch)	Grow on poor quality soils, hard soil
17		Plẳng	Cỏ tranh	*Imperata cylindrica* (L.) Beauv.)	*Poaceae (Lúa)*	Grow on poor quality soils, very hard and dry soil; rated as the 2nd poorest soil
18		Chi chà	Mua bà	*Melastoma normale* D. Don	Melastomataceae (Mua)	Soil acidity, impoverished soil, very poor soil quality

Table 1 (continued)

	Photos	Thuong Nhat name	Huong Phu name	Scientific name	Family name	Farmers' description
19		A sor	Vọt	*Dicranopteris* spp.	Gleicheniaceae (Tế guột)	Very poor soil, many stones; rated as the 1st poorest soil

sampling and laboratory analysis) delivers results to farmers (assuming that level of testing was available to them in the first place) with far less immediacy. As stated by many participating farmers, the VSA was an excellent practical combination of looking, feeling and touching to evaluate soil more precisely, and frequently. There was a high congruence between farmers and scientists in their final VSA scores, suggesting that the technique could be performed by participants with or without LSK and limited scientific training, and arrive at similar conclusions.

Concerning the type of soil properties that farmers used for distinguishing good or poor soil quality, the most common soil characteristics chosen by them were visual and easily observed soil properties such as colour or geology. Often these soil properties are also associated with land degradation issues such as soil erosion and poor nutrient levels in the soil. In both the farmer interviews and the VSA results, soil colour was a dominant soil property used by farmers to distinguish good soil from poor soil because of its perceived relationship with other characteristics such as high or low organic matter content, soil fertility, presence of surface bedrock stones, position in the landscape (flat or steeply sloping land), level of soil moisture and soil texture. Many farmers stated that black soil is viewed as "good" soil because the soil is moist, and earthworms are active in this kind of soil. Similarly, even though soil erosion is one of the five most influential soil characteristics for the VSA, as scientists visiting the site, we relied on farmers' observations to score this property, since soil erosion can be episodic. While many farmers shared their experiences of soil erosion, they too rely on recollecting past experiences, for instance of emerging roots on the soil surface or other observable measures such as steeply sloping land or presence of stones in the soil.

Apart from soil erosion and soil colour, farmers determine a good soil based on relationships between the number and size of earthworms and other related factors such as soil porosity or soil structure, soil moisture and soil fertility. Due to VSA undertaken in the dry season few earthworms were recorded in the field site assessment, and preferably VSA should be completed in optimal soil moisture conditions when earthworms would be most active (Shepherd et al. 2008). The lack of earthworm activity during the VSA assessments was in contrast to the importance that farmers place on the presence of earthworms (Fig. 4), which highlights the disadvantage of single time point assessments like the VSA compared to LSK, which is developed from observations made over a number of seasons and years. Other characteristics of the soil used by farmers in their pre-assessment of soil quality were not part of VSA scorecard, for instance stone colour combined with quantity.

Furthermore, in just over a third of cases, local farmers were harsher in the pre-assessment of a field's soil quality compared with the assessment using VSA. In four field sites in which the final VSA score was good, farmers had pre-assessed these field sites as moderate. A harsher assessment was more noticeable in five field sites where pre-assessment by the farmers was poor, but these field sites were all assessed as moderate by the VSA. Farmers' perception of poor soil quality can be hypothesised as a result of their long history in the local area, with some farming for 40 years in the locality, and possibly experiencing a loss of soil condition over this time. In scientists' VSA, surface ponding, soil erosion and rooting depth were all informed by farmers because of their observations while farming the field where the VSA assessment took place. These differences between in how farmers perceived their soil quality before the VSA and the results of the VSA could be interpreted as farmers' LSK being less adept at identifying soil quality as examined through the VSA. However, the reverse could also be true, in that the VSA lacks the subtleties and historical learnings that are inherent in the farmers' LSK. The risk of not valuing LSK due to the contest of authority between soil science (VSA) and LSK was also raised by Huynh et al. (2020) in a review that showed over the past 15 years farmers' LSK has not commonly been used, especially in soil quality assessment.

Also, it was found that some properties used in VSA have very little influence on the distribution of the VSA scores. This included the drop shatter test, which was time-consuming, and included soil texture, which is linked to a number of other soil properties that are considered to affect the VSA score such as erosion, ponding and mottles. As stated by Giarola et al. (2013), the VSA index in the method of Graham Shepherd (Shepherd et al. 2008; Shepherd 2009) is strongly dependent on soil texture, while others suggest the relationship with soil texture is not significant in the visual evaluation of soil structure (VESS) method (Ball et al. 2007). Murphy et al. (2013) while indicating that VSA is a cost-effective way of quickly monitoring soil change but also suggested that this method needs further improvement.

The use of soil test strips was to rapidly gauge overall soil fertility and soil pH status. In alignment with the two scientific reports on Nam Dong district by Hoang et al. (2017) and Hoang (2017), our field results from soil test strips confirmed the acidic soil condition the study area. In general, the available phosphate tested in our study area was low, probably due to immobilisation with Fe and Al in the Acrisols of Nam Dong province (Le et al. 2015; Thua Thien Hue 2005). Field sites with the highest phosphate levels were mixed gardens, banana or croplands that were closest to farmers' houses. It is plausible that these field sites could receive more inputs (e.g. manure or N, P, K fertiliser) and more intense soil management as a result of their proximity to the dwellings. However, it was also apparent that test strips could provide immediate soil test results for communication with farmers, even if only for a limited number of soil properties.

From the issues discussed, useful complementary information from LSK should be incorporated to enhance the quality of VSA in either further research or for local adaptation to farmers' soil information needs. Through documenting farmers' LSK, we learned of farmers' experience and concerns with soil erosion or deteriorating soil quality on their farms. Such insights would provide locally derived ideas to promote local farmers' awareness of soil use and management, and increase confidence in their choices. Equally, it is crucial to raise awareness of how local people can preserve their soil knowledge and utilise their farming experience, while also fostering respect from scientists and other stakeholders for LSK.

Effectiveness of workshops to communicate with farmers and preserve their LSK

The outcomes of the first workshop activity indicated that most participants were more than willing to share their LSK with other participants such as the local soil names and their location using a farm scale topographical map. This observation may be useful in further studies in remote areas, like Nam Dong district, where farm-scale soil classification maps do not exist, but where maps generated with guidance from LSK could facilitate farmer-to-farmer knowledge exchange. In addition to the opportunity for farmers to share their LSK with each other, the second workshop activity enabled participants to review data analysed from the key informant interviews and VSA, which has not been a common occurrence in previous projects. The key informant interviews with farmers and relevant stakeholders confirmed that soil analysis results were reported to the Nam Dong district or commune government, but very few soil test results were communicated to local people. Thirty-seven per cent of farmers scored a higher soil quality outcome from the VSA compared with their pre-assessment of the soil quality. Their judgement of soil quality, pre-VSA, might well have been influenced by historical land categorisations. Some farmers mentioned how land taxation in the 1990s and joint discussion between local government officials and farmers had led to three main categories of land quality. The three categories were called best soil "đất loại 1" (thick topsoil, no soil erosion, high yields), moderate soil "đất loại 2,3" (sandy soil) and poor soil "đất loại 4" (hard, dry, sloping, stony).

Also, six farmers in Thuong Nhat underestimated their soil quality, and they said that their present soil quality assessment was based on the forest soils where they lived before 1975 and original areas where they first settled and started farming after 1975. The majority of Huong Phu farmers (75%) perceived their soil to have a similar soil quality to the VSA score, while Thuong Nhat farmers were harsher in their soil assessment. This could be explained by their historical settlement patterns and longer association with the natural forests that lie adjacent to their farmland. This finding is in keeping with WinklerPrins (1999) and Niemeijer and Mazzucato (2003), who indicated that researchers need to consider both past historical and socioeconomic situations to understand existing LSK.

The third activity also raised farmers' awareness of soil problems and management opportunities and implications through the use of photographs and emphasising certain aspects of the VSA and final scores. For example, farmers were shown photos of alternative practices to the traditional practices of burning or removing ground cover to demonstrate the benefits of alternative practices for reducing soil erosion risk. The second and third workshop activities also highlighted how soil knowledge exchange opportunities between farmers' and researchers' was provided through their participation in the VSA and subsequent workshops. By introducing the farmers to the VSA, we, as scientists, also learned about LSK from the farmers. The activities raised farmers' confidence in their LSK, and they took an active role in our research. For future studies, similar field experiences and workshops with farmers could provide a participatory model to gain farmers' involvement and feedback on the relevance of their research activities.

The fourth workshop activity involved farmers in the workshop examining the 19 native plant names and descriptors associated with certain levels of soil quality (Table 1) to verify their accuracy. Most of these plant species were identified and more widely utilised by farmers from the Thuong Nhat commune, which is a reflection of their more prolonged association with the forests where daily life is still based on harvesting forest resources (Poffenberger et al. 1998; Thang et al. 2010). Most farmers in Huong Phu had re-located from the lowlands of Vietnam where soil type and quality were different, so even though they had lived in Huong Phu commune for nearly 40 years, they had some contrasting associations with native plants and soil quality compared to farmers from Thuong Nhat (Huynh et al. 2021).

In several LSK studies else where, farmers used native plants because of their locally perceived association with soil quality or fertility (Huynh et al. 2020). However, there has been limited interest from scientists in researching the role of native plants to soil quality. A study by Gosai et al. (2011) suggested that there is a need to document the traditional knowledge base with both local and standard scientific terminology. However, local differences in native plant names and soil quality associations were apparent in our two workshops. Yodda and Rambo (2018), researching in Thailand, also showed the different ways that villagers acquire their soil knowledge and how this could lead to a lack of agreement about soil names and classifications among community members. Therefore, it seems native plants could have developed different meanings for soil assessment in different localities due to contextual differences, LSK can indeed be very local and not necessarily transportable to other communes, let alone being scaled up to districts or provinces. These observations highlight that there remains more to be done in this area with regard to using plants as an aspect of understanding LSK or in developing VSA techniques.

In communicating with landholders one-on-one and examining the soil of a farmed field with them using VSA, there was time to explore how they view the relationships between soil properties and soil quality, and how their actions can influence the trajectory of soil quality improvement. These discussions with local farmers in key informant interviews, VSA and workshops revealed a leaning towards underestimating soil quality. At the same time, VSA may need further modification to include more locally-derived knowledge and experiences. Furthermore, Guimarães et al. (2017) indicated that more detailed VSA methods could be applied successfully with more specific soil knowledge. Our observations support this premise, and we would suggest that VSA could be developed further by involving LSK in designing or modifying the scorecard and adding relevant local classifications (e.g. native plants; size, colour and presence of stones in soils; earthworms and other seasonal observations. This suggestion was also offered by two Huong Phu farmers (HP-V2-09 and HP-V3-21) after undertaking VSA in their fields as well as participants in the final activity of the two workshops. To adapt the VSA to be more inclusive of LSK, this study proposes a VSA scorecard using native plants as one of the main indicators for Nam Dong mountainous areas and similar areas (see Appendix C).

The implications for government and extension advisor engagement in soil conservation and LSK development with farmers

Continuing soil degradation in and around forested areas is a consequence of limited consideration of soil in forest policy and management (Montanarella and Alva 2015). A number of studies in Northern Vietnam have stated that farmers are well aware of soil erosion or land degradation risks, but they lack relevant information regarding locally relevant solutions and how to apply them (Hagel et al. 2013; Lua et al. 2016; Nguyen et al. 2009; Saint-Macary et al. 2010; Wezel et al. 2002). As stated by recent studies, although not in Vietnam, land managers often lack information about soils to bridge the attitude-behaviour gap (Juerges and Hansjürgens 2018; Lähtinen et al. 2017; Sousa-Silva et al. 2018). In our key informant interviews with government officials and researchers, it was found that they were not aware of the strategies to connect smallholder farmers to measures or means for soil conservation, improved land management and LSK, which would assist them in addressing soil degradation in mountainous areas like Nam Dong district. Our study in Central Vietnam suggested that VSA could serve as a useful means for soil scientists or other government officials to foster a connection with farmers, and their actions in addressing soil conservation.

Additionally, the key informant interviews with government or research organisations showed that despite a number of active rural development activities in the region, these activities were weakly connected to farmers and the issues they mentioned in the interviews with us. To be more inclusive of farmers' LSK and their relationship between soil, agricultural activities and livelihoods, government or research organisations need to use communication strategies that provide early interaction between local farmers and themselves. In support of this, there is mounting evidence that integration of LSK that is derived from local stakeholder engagement and participation in soil surveys, could help guide appropriate solutions to address soil issues in local contexts (Barrera-Bassols et al. 2009; Christie et al. 2016; Hagel et al. 2013; Huynh et al. 2020, Huynh et al. 2021; Ingram et al. 2016; Jacobi et al. 2017). We also recommend, as do other researchers, that for forest and soil policies to be effective, government officials need to accurately identify the issues that policy needs to address by using a participatory approach that includes all stakeholders' views and integrates farmers' LSK to obtain a more inclusive and adoptable policy platform (Adhikari and Baral 2018; Carnol et al. 2014; Mendoza and Prabhu 2006; Raymond et al. 2010; Šūmane et al. 2018). Hence, national programmes or projects need to be designed with a view to strengthening farmers' capacity to make informed management decisions, which can support sustainable land-use planning from the field to national policymaking level (Huynh et al. 2021). According to Prager and Curfs (2016), developing the common ground between farmers' LSK, scientific soil analysis and mapping, administrators' governance structures, advisors' extension approaches and policymakers requires improved communication channels between stakeholders and feedback loops. In our study areas, local extension workers or agricultural cadastral officials of communes and the BMNP staff are those closest to farmers and work in livelihood development for the buffer zone and are the best candidates for fieldwork and workshop activities with farmers. Workshop settings could be used for knowledge exchange and connecting the local government managers and Non-government organisations, who are responsible for further agricultural and rural development projects, to farmers' LSK.

Observations on the various strategies used to engage with local smallholder farmers have indicated that VSA creates opportunities for field topsoil assessment especially at field scale. However, even though introducing VSA is seen as a critical component in delivering effective uptake for farmers, it places additional resource and organisational requirements upon government organisations. At present, only a few soil scientists are trained in VSA; hence, we recommend that local extension workers or agricultural cadastral officials at commune and district levels be trained in VSA. By undertaking this, VSA could be applied more broadly at a local level to assess soil management by local farmers and examine areas of knowledge co-production whereby LSK and scientific assessment can be integrated.

Conclusion

The key informant interviews, VSA and farmer workshops offered scientists direct contact with farmers and enabled the scientists to learn from smallholder farmers with previously identified reasonable or comprehensive LSK (Huynh et al. 2021) about their farming and soil management, views on the relationships between soil properties and soil quality and the actions they take for soil quality improvement. Also, farmers' participation in VSA and workshops confirmed that these approaches could foster two-way communication, strengthen farmers' confidence in using their LSK and promote interaction with locally conducted research and other stakeholders, which conform to the conditions that optimise knowledge co-production (Norström et al. 2020).

The findings demonstrated that the use of both local and scientific soil knowledge enabled farmers to confirm their own LSK through the application of the VSA. Additionally, the discrepancy between farmers' soil quality assessments and those generated from the VSA could be used to improve the VSA, at least for soil assessment in Central Vietnam, and more particularly for this region. Including local soil quality characteristics such as native plants, size, colour and presence of stones and seasonal or annual observations (e.g. earthworms, yield) could improve the application of VSA and also preserve existing LSK. Using and modifying existing soil assessment tools such as the VSA with input from LSK could improve farmer engagement with government officers and research staff to inform future research and communication with them. Observations on the various strategies used to engage with local smallholder farmers have indicated that VSA creates opportunities for field topsoil assessment, especially in countries where soil testing is non-existant and soil assessment has been limited, especially at field scale (Montanarella et al. 2016). A direct outcome of such an undertaking could be to mitigate soil issues, especially soil erosion or land degradation, which are a threat to sustainable soil management in mountainous areas like Nam Dong district, Central Vietnam.

Appendix A

See Fig. 9.

Fig. 9 VSA soil scorecard (Shepherd et al., 2008) used in the 2019 fieldwork

FIGURE 1 **Soil scorecard – visual indicators for assessing soil quality in annual crops**

Landowner:

Land use:

Site location:

GPS ref:

Sample depth:

Date:

Soil type:

Soil classification:

Drainage class:

Textual group (upper 1 m): ☐ Sandy ☐ Loamy ☐ Silty ☐ Clayey ☐ Other

Moisture condition: ☐ Dry ☐ Slightly moist ☐ Moist ☐ Very moist ☐ Wet

Seasonal weather conditions: ☐ Dry ☐ Wet ☐ Cold ☐ Warm ☐ Average

Visual indicators of soil quality		Visual score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS ranking
Soil texture	pg. 2		x 3	
Soil structure	pg. 4		x 3	
Soil porosity	pg. 6		x 3	
Soil colour	pg. 8		x 2	
Number and colour of soil mottles	pg. 10		x 2	
Earthworms (Number =) (Av. size =)	pg. 12		x 3	
Potential rooting depth (m)	pg. 14		x 3	
Surface ponding	pg. 18		x 1	
Surface crusting and surface cover	pg. 20		x 2	
Soil erosion (wind/water)	pg. 22		x 2	
SOIL QUALITY INDEX (sum of VS rankings)				

Soil Quality Assessment	Soil Quality Index
Poor	< 15
Moderate	15–30
Good	> 30

Appendix B

See Fig. 10.

Fig. 10 Engagement of local people in field work and workshop activities of the LSK research

(1)

(2)

Appendix C

See Fig. 11.

Modified Soil scorecard (FAO, 2008) - visual indicators for assessing soil quality in Nam Dong district or in other areas having same environmental conditions								
Landowner:				Land use:				
Site location:				GPS ref:				
Sample depth:				Date:				
Soil type:				Soil classification:				
Drainage class:								
Textual group (upper 1m):	Sandy/ Loamy/ Silty/ Clayey/ Other							
Moisture condition:	Dry/ Slightly moist/ Moist/ Very moist/ Wet							
Seasonal weather conditions:	Dry/ Wet/ Cold/ Warm/ Average							
Visual indicators of soil quality	**Modified indicators**	**Visual score (VS) 0=poor, 1=moderate, 2=good**			**Weighting**	**VS Ranking**		
		Scientist	Farmer	Other stakeholder		Scientist	Farmer	Other stakeholder
Soil texture					x3			
Soil structure					x3			
Soil porosity					x3			
Soil colour					x2			
Number and colour soil mottles					x2			
Earthworms (Number= Av.size=)					x3			
Potential rooting depth (m)	Size and % stones in soil				x3			
Surface ponding					x1			
Surface crusting and surface cover	Native plants				x2			
Soil erosion (wind/water)	Seasonal observations				x2			
Soil quality assessment	**Soil quality index**	**E.g. Notes for Native plants**						
Poor	<15	0=poor (cỏ tranh/ (Imperata cylindrica (L.) Beauv.)), mua (Melastoma normale D. Don),...)						
Moderate	15-30	1=moderate (ké anh đào (Urena lobata L.),...)						
Good	>30	2=good (rớn (Diplazium escyletum Retz), Lá tầu bay (Crassocephalum crepidioides (Benth.) S. Moore),…)						

Fig. 11 Modified VSA scorecard

Appendix D

See Table 2.

Table 2 Figure 4 Vietnamese translations of Word cloud

Words described by farmers for good soil	Vietnamese translation	Words described by farmers for poor soil	Vietnamese translation
Soil colour -Dark/ Black -Brown -Red	Màu sắc đất -Tối sẫm/ đen -Nâu/ đà -Đỏ	Soil colour: -Yellow -White -Light	Màu sắc đất: -Vàng -Trắng -Nhạt/ sáng màu
Stones -Big -Decayed	Đá, sỏi -Đá To -Đá phong hoá dễ vỡ	Stones -Small -Stony -Round -Sharp	Đá, sỏi -Đá Nhỏ -Đầy đá sỏi -Đá tròn, nhẵn -Đá sắc nhọn
Earthworms -Many -Dunes/ dung	Giun đất -Nhiều trùn/giun -Phân trùn/ giun ụn đất lên bề mặt	Earthworms -Few	Giun đất -Ít
Geographic position -Less sloping -Flat	Địa hình -Ít dốc -Bằng phẳng/ đằm	Erosion -Sloping -Degraded -Soil loss	Xoái mòn -Dốc -Thoái hoá -Trôi/ mất đất
Native Plants - Ageratum conyzoides L - Chromolaena odorata - Mushrooms - *Crassocephalum crepidioides* (Benth.) S.Moore	Cây chỉ thị bản địa - Cây cứt lợn/ cỏ hôi - Cây bớp bớp/ phân xanh - Cây nấm - Cây/ lá tàu bay	Native Plants -Tibouchina Semidecandra -Mimosa Pudica -Rhapis cochinchinensis (Lour.) Mart	Cây chỉ thị bản địa -Cây mua -Cây xấu hổ/ Cây trinh nữ -Cây lụi
Soil Texture/ structure -Loamy -Soft -Humus -Mould	Kết cấu đất -Đất thịt -Mềm -Mùn -Tơi xốp	Soil Texture/ structure -Sandy -Clay -Hard -Dry	Kết cấu đất -Đất cát -Đất sét -Cứng -Khô cằn
Fertility -Good -Fertile	Dinh dưỡng đất -Tốt/ giàu dinh duỡng -Màu mỡ	Fertility -Poor -Infertile	Dinh dưỡng đất -Nghèo dinh duỡng -Không màu mỡ/ cằn cỗi
Top soil -Thick	Tầng đất mặt -Dày	Top soil -Thin	Tầng đất mặt -Mỏng
Yield/growth of crops -Good -Growing Bananas and Jack Fruits/ fruits well	Năng suất/ Sự phát triển cây trồng -Năng suất tốt -Trồng chuối, mít các loại cây ăn quả thấy lên nhanh/ phát triển tốt	Yield/growth of crops -Poor -Slow growing	Năng suất/ Sự phát triển cây trồng -Năng suất kém -Phát triển chậm/ kém

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