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Integrating land quality in peri-urban agriculture for sustainability and green revolution in Vietnam

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Abstract: Agricultural Land Use Systems (LUS) contributes to Green Revolution (GR) and sustainable development in Vietnam, however, the GR exerts a dual impact-both positive and negative-on agricultural LUS in suburban regions. Land Quality Indicators (LQI) is integrated into the Pressure-State-Response (PSR) model to assess agricultural LUS across four landscapes in a peri-urban area of Hanoi capital city (Vietnam). The selected 75 indicators are subject to elimination based on the distinct natural and social contexts prevalent in each landscape. The findings indicate that primary pressures impinging upon agricultural LUS are dwindling irrigation water, escalating erosion resulting from cultivation, inadequate agricultural infrastructure, price imbalances, and pollution from industrial parks and craft villages. An amalgamation of traditional and high-tech solutions is recommended to enhance the quality of organic produce and foster stronger connections between suburban and urban. Integrating LQI into the PSR framework supplants conventional assessment methods, paving the way for more effective sustainable land use planning in peri-urban areas in the foreseeable future.

Keywords: agricultural land use systems (LUS), land quality indicator (LQI), sustainable land use, peri-urban, Hanoi, Vietnam

1. Introduction

The Green Revolution (GR) brought about significant transformations in agricultural land use systems (LUSs), which serve as essential livelihoods for a considerable population (Madalla and Majule, 2016) and are fundamental to ensuring food security in peri-urban areas (Ayambire et al., 2019; Viana et al., 2022). However, LUS constantly face pressures stemming from urban migration, urbanization, tourism, and industrialization in peri-urban regions (Ayambire et al., 2019; Prasada and Masyhuri, 2020; Zhao and Jiang, 2022; Nam and Yen, 2022). Zhang et al. (2015) and Sagar et al. (2022) highlighted the adverse effects of peri-urban agricultural activities on soil, water, air quality, and microclimate changes in urban areas. For instance, the expansion of terrace farming in tropical terrains with steep slopes and heavy rainfall worsens soil erosion processes (Ziadat and Taimeh, 2013). The adoption of intensive farming increases agricultural production rates from 30-50% to over 70% in countries such as Thailand and Germany (Schiefer et al., 2015). This leads to increased levels of permanganate oxidizable carbon (Pox-C) in soil, resulting in reduced maize yields in Thailand (Bruun et al. 2017). Abate et al. (2017) and Prasada and Masyhuri (2020) emphasized that the sustainability of agricultural land hinges on farmers' perceptions and practices. Agricultural LUS in peri-urban areas often exhibit inconsistencies and limited scientific scopes, and the interconnectedness among various system components is often overlooked (FAO, 1984; Bogoviz, 2021; Song et al.,, 2022). There is a pressing need to establish a set of indicators for comprehensive assessments of agricultural LUS (Pham et al. 2022).

Land quality indicators (LQIs) provide essential instruments for evaluating the impact of agricultural LUS, particularly within the context of the Green Revolution (GR). With the widespread adoption of agrochemicals, irrigation, and high-yielding crop varieties in contemporary farming landscapes, understanding the environmental, social, and economic implications of these intensive farming methods is crucial (Danilo et al., 2022; Liu et al., 2020). Indicators of land health, such as nutrient levels and organic matter content, offer valuable insights into the long-term sustainability of land use under intensive agricultural practices (Nguyen and Hens 2020). Assessing water quality indicators, especially in regions reliant on irrigation, is critical for understanding the impacts on soil salinity and water tables (Gad et al., 2023). Biodiversity indicators help evaluate the ecological resilience of agricultural landscapes to the risks associated with monoculture (Bockstaller et al.,

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2011; Ríos-Touma et al., 2023). The examination of land conservation indicators and erosion rates contributes to a comprehensive understanding of the enduring effects of intensive cultivation on land characteristics (Pham et al. 2018; Tsymbarovich et al., 2020). Satellite imagery enables longitudinal monitoring of changes in land cover and patterns, while socioeconomic and policy indicators shed light on how alterations in agricultural land use affect human aspects (Brinkley and Visser, 2022). Ecological footprint analysis provides comprehensive insights into the environmental consequences of intensive agricultural practices, while remote sensing and GIS enhance the mapping of land use patterns, facilitating informed decision-making for sustainable land management (Goyal et al., 2020). The LQI offers a comprehensive methodology for assessing the intricate interplay among human activities, land quality, and the environment (Nguyen and Hens, 2020) and facilitating the establishment of sustainable and resilient agricultural land use systems after the GR.

The LQI provides comprehensive insights into farming practices, analyses shifts in local land-use policies, and evaluates progress toward sustainable development goals (Teshome et al., 2014; Tesfahunegn et al., 2014; Pham et al., 2022). The LQI encompasses indicators of land use efficiency, management quality, and environmental policy (Adriaanse, 1993; Zhang and Schwärzel, 2017; Liu, 2022). Dumanski and Pieri (2000) and Smith et al (2002) employed the LQI for land suitability classification. Kamaldeen (2015), Nguyen and Hens (2020), Dera et al (2022) and Wang et al (2023) proposed the LQI to guide land-use planning and foster sustainable agricultural development, reconciling economic development with environmental conservation imperatives. Despite the widespread application of LQI across various locales, efforts to compile a comprehensive LQI for informed decision-making and sustainable development generally and within the peri-urban agricultural sector in particular remain nascent.

GR has led to profound transformations in Vietnam's rice industry and agricultural land use systems. Within GR-affiliated domains, agricultural LUS in Vietnam contributes to local farmer livelihoods, positioning Vietnam as a global leader in rice exports (Nam, 2023). The GR enables Vietnam to achieve rice self-sufficiency, making it a top rice exporter globally and ensuring relatively stable and affordable rice prices in the consumption market. However, GR has adverse biological, environmental, and socioeconomic consequences for agricultural land use systems (Nam, 2023). The Hanoi capital city in Vietnam boasts approximately 200 thousand hectares of agricultural land, constituting 59% of the total area and supporting more than 2.2 million rural laborers, accounting for more than 56% of the city's workforce. The peri-urban area is hailed as an agricultural green corridor, supplying a variety of food commodities, such as rice, corn, meat, fish, and green vegetables, and fresh produce to urban residents. However, escalating urbanization and population growth have led to deforestation, while volatile input and output prices of agricultural production pose challenges. Notably, agricultural land in Hanoi has undergone a significant reduction since the 2010s, resulting in fallow and fragmented agricultural landscapes encompassing nearly 5,000 hectares or, conversely, conversion to industrial purposes. These developments adversely impact the livelihoods of more than 150,000 peri-urban farmers (Labbé, 2021). Consequently, examining agricultural land use systems within peri-urban areas holds promise for elucidating GR constraints and understanding the internal dynamics within the region, alongside supply-demand dynamics in agricultural development vis-à-vis urban centers. An interdisciplinary approach is imperative to ensure the sustainability of local land use systems, thereby enabling timely responses to multilevel authorities (Saint-Macary et al., 2010; Tombolini et al., 2022a). The assessment of agricultural LUS in GR-affiliated zones in Vietnam primarily adheres to the process outlined by the Food and Agriculture Organization (FAO) in 1976, necessitating the development of land unit maps (Dan et al., 2018). Integrating a multitude of land quality aspects within the agricultural land use context, which are increasingly influenced by multifarious factors, poses significant challenges.

The objectives of this study are to propose a comprehensive set of LQIs tailored to diverse agricultural land use system types for assessing sustainability constraints within peri-urban domains and evaluating agricultural land use systems within the peri-urban ambit of Hanoi, Vietnam, with consideration of the pressure-state-response (PSR) model. We consult and synthesize disparate LQIs from global contexts, culminating in the formulation of a comprehensive indicator set subsequently applied within the research domain.

2. Materials and Methods

2.1. Study area

The selected peri-urban area is located in Quoc Oai district, Hanoi capital city of Vietnam (Figure 1). Nestled within the greenery corridor enveloping the western edge of Hanoi, this area sits approximately 20 km from the city center, facilitating convenient economic trade relations with inner districts. With a population of approximately 190,000 people and an average population density of 1,280 people/km², the district heavily relies on agriculture for employment, accounting for 42% of the total population. The Quoc Oai district boasts a diverse demographic composition, with 14 ethnic groups cohabiting harmoniously and ethnic minorities comprising 3.6% of the population. From 2005 to 2020, the proportion of agricultural land area to nonagricultural land in the district's land use structure decreased from 1.86 to 1.19 (Quoc Oai DPC, 2020). The selected area is delineated into four distinct landscapes: highland, lowland, delta-flood, and alluvial.

Figure 1 shows that the highland landscape (SZ1) represents a low mountain forest LUS, which is predominantly characterized by production and protection forests. The lowland landscape (SZ2) encompasses an agroforestry LUS nestled amidst undulating terrain, hosting a diverse array of land use systems, including afforested land, rice paddies, and perennial crops, comprising perennial fruit trees and industrial plants. Rice cultivation and perennial crop cultivation, which constitute 87.2% of the subregion's agricultural land area, prevail over forested areas within this zone. The delta-flooded landscape (SZ3) is designated for agricultural production on alluvial banks enclosed by dikes, with specialized rice cultivation occupying 82% of this subregion and serving as a primary food source for Hanoi residents. The alluvial landscape (SZ4) is dedicated to agricultural production on alluvial plains lying beyond the dikes and along the Day River in Hanoi city. Vegetable cultivation constitutes nearly 55% of the agricultural land within this subregion, serving as a primary food source for urban inhabitants.

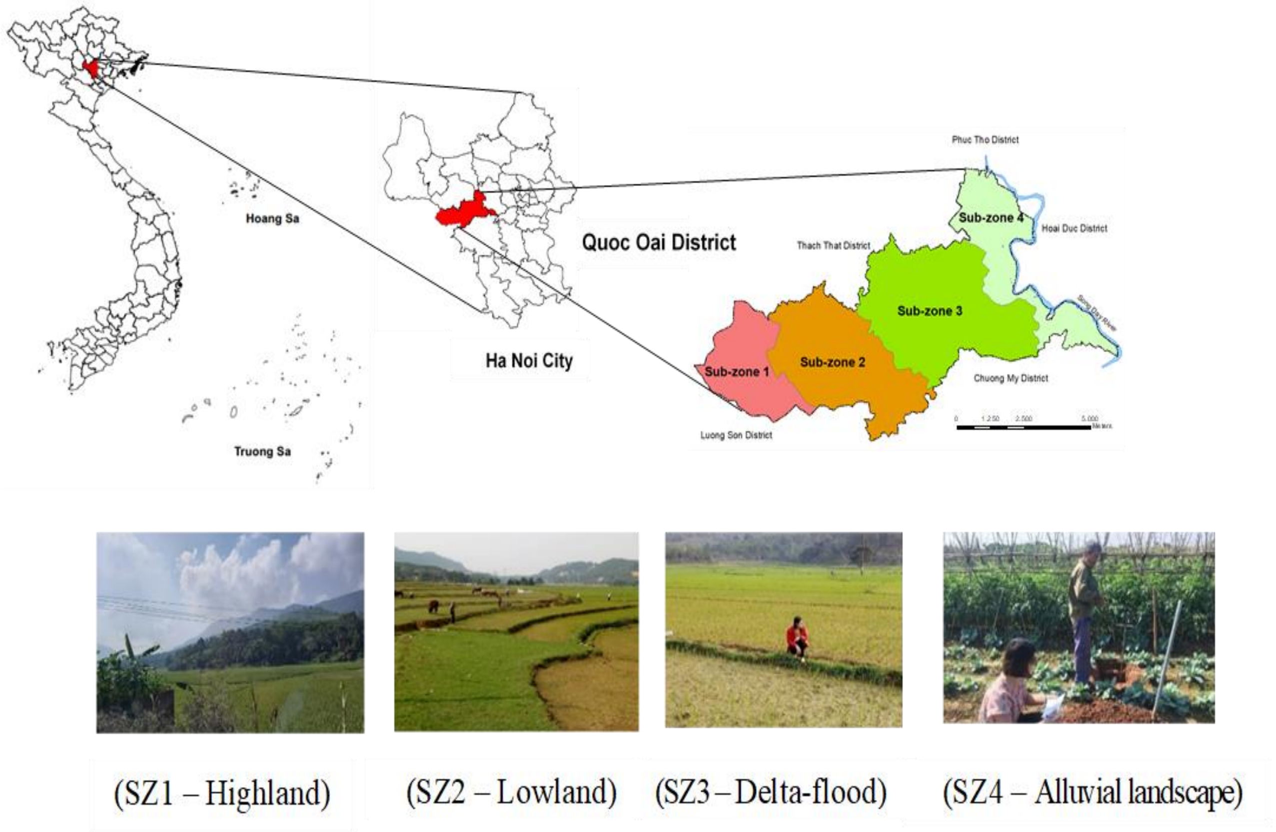

Figure 1 Study area location in Hanoi (Vietnam).

2.2. Land quality indicators for PSR assessment

The pressure-state-response (PSR) framework is widely applied in ecological studies (Lai et al., 2022; Zhang et al., 2023; Wang et al. 2021) and land-use assessments (Hao and Chunjing, 2013; Zhang et al., 2019; Dera et al., 2022; Kapur et al., 2019). This framework provides tools for establishing causal relationships between land use components and land management research (Nguyen and Hens, 2020). By integrating the PSR framework into the LQI, we restructured the indicator system, reduced redundancies, and ensured a balanced representation of the indicators. However, the distinction between pressure, state, and response can sometimes be blurred due to the complex interdependencies between land and human activities (Kamaldeen, 2015; Nguyen and Hens, 2020).

Figure 2 shows the three dimensions of land quality in the PSR framework:

- Pressure (P) represents the natural or socioeconomic pressures arising from existing agricultural LUS and land management policies;
- State (S) refers to the original and altered land quality states, encompassing aspects such as land use intensity, soil and water quality, and agricultural practices; and
- Response (R) indicates the responses or efforts of stakeholders, including land users, managers, and policymakers, aimed at mitigating pressure impacts, altering LUS status, and enhancing land quality.

In the land use analysis, pressure (P) indicators are utilized, while state (S) indicators are employed for the land assessment. The response (R) indicators are utilized in the development of land use guidelines and planning. To comprehensively evaluate agriculture in peri-urban areas according to the PSR framework, a set of LQIs is proposed (Table 1). These indicators can be used to quantitatively and qualitatively measure the "conditions" or "health" of the land (FAO, 1976). Establishing a set of LQIs is necessary for land use analysis, assessment, guidance, and planning (Teshome et al., 2014; Tesfahunegn et al., 2014; Pham et al., 2022). The LQI facilitates the monitoring of agricultural and forestry productivity performance and the prediction of project impacts on the environment (FAO, UNDP, UNEP and WB, 1997) at various scales, including the regional, provincial, district, and community levels (Adriaanse, 1993), encompassing both qualitative and quantitative dimensions (Dumanski and Pieri, 2000; Wang et al., 2023).

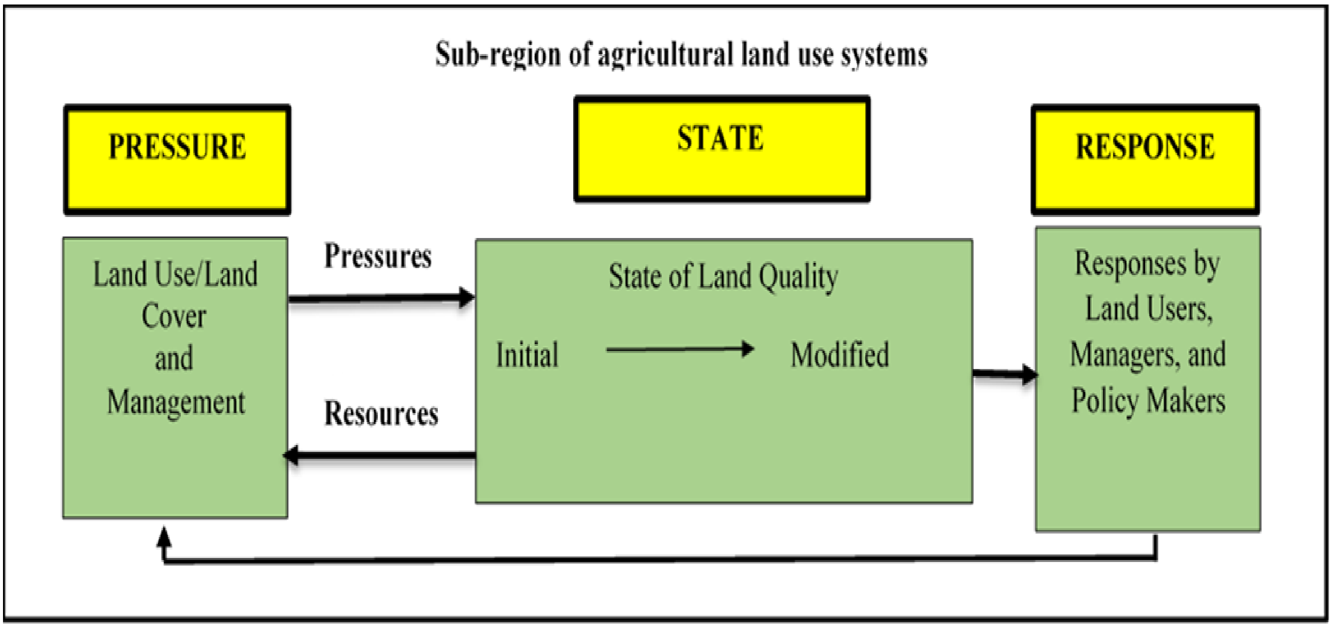

Figure 2 Integrated model of the LQI and PSR (adapted from Dumanski, Pieri 1995-2000).

Figure 3, Table 1 and Appendix 1, 2, 3 and 4 shows that a PSR framework designed for the examination of agricultural LUS is illustrated. Biophysical drivers (P1), which fall under the "Pressure" category, encompass a variety of stressors for agricultural practices, such as limited agricultural land, landslides, extreme cold, and insufficient irrigated water (Quang et al., 2014; MONRE 2015; Nguyen and Hens, 2020). The socioeconomic variables (P2) encompass various socioeconomic factors, such as urbanization, poverty, and population growth. Extensive research conducted by (Saint-Macary et al., 2010; Zhang and Schwärzel, 2017; Tuan and Hegedűs, 2022a) offers valuable insights in this area. Macropolicy (P3) comprises indicators of governmental interventions, including afforestation and crop restructuring. Research conducted by (Ravetz et al., 2013; Nguyen and Hens, 2020) has enhanced our understanding of the pressures on LUS influenced by policy.

Regarding the "State" component, indicators of soil erosion and land degradation (S1) encompass concerns such as topsoil loss, soil fertility decline, and soil pollution. Furthermore, land use system change (S2) includes indicators such as the expansion of cultivated land and alterations in local cultivation practices (S3). Kyeyune and Turner (2016), Nguyen and Hens (2020), Tombolini et al (2022b) and Wang et al (2023) provided empirical substantiation for the current condition of LUS and the dynamics that underlie it.

The "Response" delineates a range of approaches and actions intended to alleviate identified pressures and enhance the condition of agricultural land. The effectiveness of traditional conservation practices (R1), which include crop rotation and terraced fields, has been validated by different studies (Saint-Macary et al., 2010; Nguyen and Hens, 2020). The benefits of cultivation options (R2), such as changing crop patterns and accelerating agroforestry, have been validated by Nguyen and Hens (2020) and Tuan and Hegedűs (2022b). Saint-Macary et al (2010) and Ravetz et al (2013) supported the notion that land use policies (R3) should incorporate social and environmental concerns and involve the public in land use planning. The enhancement of indigenous methods (R4) encompasses the implementation of sustainable practices such as intercropping and the use of on-farm biological nutrients. Quang et al (2014), Prasada and Masyhuri (2020) and Fei (2022) have contributed significant insights in this regard.

The selection of indicators and parameters for their quantification is aligned with the local context and agricultural LUS characteristics of peri-urban farmers (Bouma, 2002; Kamaldeen, 2015; Nguyen and Hens, 2020; Tombolini et al., 2022a). The chosen parameters are determined by important factors such as natural, economic, social, cultural, environmental, and governance aspects of the study region (Kamaldeen, 2015; Nguyen and Hens, 2020; Wang et al., 2023). The process of selecting indicators involves consultation with experts through direct interviews and a literature review to produce the proposed comprehensive set of indicators. Experts in specialized fields such as sustainable agriculture, land management, green revolution, and land use planning were consulted. Based on these indicators, quantifications are verified based on the perceptions of farmers and local officials who were interviewed to assess the sustainability of detailed agricultural LUS, particularly in the peri-urban area of Hanoi. Additionally, land use statistics, land use status maps, and soil sample analysis results assist in determining the final set of LQIs for the study area (Figure 3).

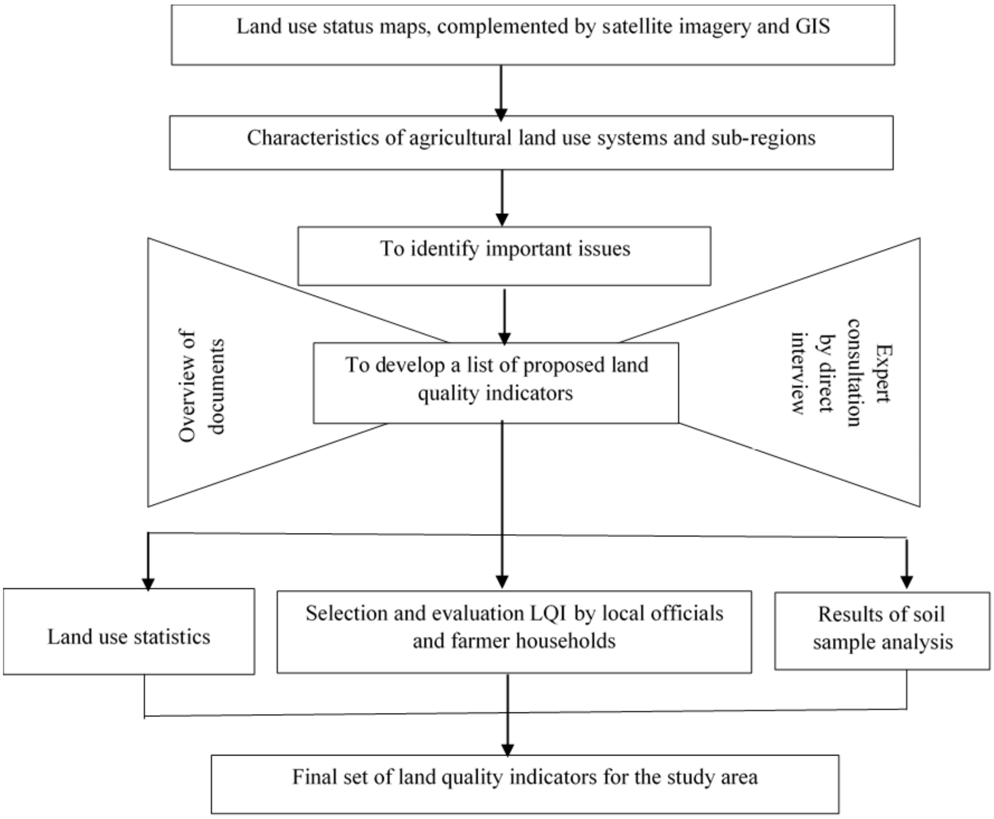

Figure 3 A logical process for building land quality indicators.

2.3. Data collection

To identify agricultural LUS, we obtained land-use maps for 2015 and 2020 from the Ministry of Natural Resources and Environment of Vietnam. These maps, combined with satellite imagery and geographic information systems (GIS), provided a comprehensive depiction of changes in agricultural land use systems from 2015 to the present. Additionally, we gathered agricultural statistics from officials to quantify the selected indicators. Seventeen soil samples were collected and analyzed at the Faculty of Environment, VNU University of Science, Hanoi, Vietnam. Furthermore, updates and information on local-specific issues were gathered through interviews with agricultural households and local officials. This information determines the suitability for applying the LQI in peri-urban areas.

The selection of interview candidates was based on random sampling to ensure uniform representation across the population throughout the region (Henry et al. 2009). Lists of households and local officials in each landscape are compiled from local authorities and departments, and individuals from these lists are randomly chosen for interviews. A standardized set of questions is administered to all participants to gather diverse perspectives from the community and management, thereby elucidating the specific characteristics of LUS in each locality. The survey was conducted in Vietnamese by a research team of the Faculty of Geography, VNU University of Science, Hanoi.

The survey uses a three-dimensional PSR-structured questionnaire with 10 parameters (including P1, P2, P3, S1, S2, S3, R1, R2, R3, and R4) and 75 closed questions, corresponding to 75 LQIs (see Table 1 and the Appendix). The interviews were conducted over four landscapes with different natural, socioeconomic, and cultural characteristics. Each question provides information about different aspects of land quality, with respondents expressing their perceptions of LQIs using a 5-point Likert scale, where 1 indicates strongly disagree and 5 indicates strongly agree.

Four surveys were conducted in 2018 and 2022 in the Quoc Oai district, resulting in a total of 690 questionnaires collected from the four landscapes: at the end of 2018, 190 questionnaires were collected; from 2019 to 2020, due to the COVID-19 epidemic, 500 questionnaires were collected in 2022. Each landscape contributed to the survey as follows: 170 questionnaires in the highland landscape (SZ1) and delta-flooded landscape (SZ3) and 175 questionnaires in the lowland landscape (SZ2) and alluvial landscape (SZ4).

Experienced farmers and local officials answered questions regarding the meaning and scale of the LQI. Additionally, we formulated open-ended questions that allowed participants to elaborate on their criteria and provide concrete examples. For instance, the head of the agricultural cooperatives in the Dai Thanh commune noted that the lack of facilities to preserve and process agricultural products significantly hindered the export of local longans to the international market, as longans cannot be adequately preserved after harvest to ensure freshness.

Before further analysis, Cronbach’s alpha was used to verify the reliability of the scale following previous studies (Cronbach 1951). The data were considered reliable when the Cronbach’s alpha coefficients fell within the range of 0.6 to 0.95. Additionally, Cronbach’s alpha serves as a probability test for assessing the connections between individual indicators, which is crucial for exploring the relative importance of indicators. Specifically, Cronbach’s alpha (α) is calculated as follows (Eq 1):

$$\alpha = \frac{k \times c}{v + c(k-1)} \qquad (1)$$

where c = the average interitem covariance among the questions, k = the number of questions, and v = the average variance.

Table 1 Selected land quality parameters and indicators of PSR dimensions.

	Parameters	Indicators (Symbols)	References
Pressure (P)	Biophysical drivers (P1)	Scarce irrigated water (TN01), Drought (TN02), Flooding (TN03), Flash flood (TN04), Extreme cold (TN05), Landslides (TN06), Scarce agricultural land (TN07), Sloping land (TN08)	Nguyen and Hens (2020), Quang et al. (2014), MONRE (2015), Prasada and Masyhuri (2020), Dera et al (2022)
	Socioeconomic drivers (P2)	Population growth (XH01), Lack of output market (XH02), Poverty (XH03), Extensive livestock (XH04), Unbalanced price (XH05), Planted forests (XH06), Urbanization from agriculture (XH07), Land use conversion (XH08), Deforestation (XH09), Tourism (XH10), Industrial zones - craft villages (XH11), Lack of facilities for processing - preserving (XH12)	Saint-Macary et al. (2010), Kamaldeen (2015), Zhang et al. (2017), Kyeyune and Turner (2016), Tombolini et al. (2022b), Tuan and Hegedűs (2022)
	Macro policy (P3)	Crop restructuring (VM01), Irrigation protection services (VM02), Agricultural support (VM03), Local land use planning (VM04), Land consolidation (VM05), Aforestation and land allocation (VM06)	Nguyen and Hens (2020), Ravetz et al. (2013), Fei (2022)
State (S)	Soil erosion and land degradation (S1)	Loss of topsoil (MT01), Water shortage in dry season (MT02), Soil fertility decline (MT03), Reduced vegetation cover (MT04), Soil pollution (MT05), Flooding in the rainy season (MT06), Land fragmentation (MT07)	Saint-Macary et al. (2010), Nguyen and Hens (2020)
	Land use systems change (S2)	Cultivated land increase (SD01), More terraced paddy fields (SD02), More commodity crops (SD03), Less local plant (SD04), Crop systems diversification (SD05), More crop yields (SD06), More bare land and hills (SD07), More food crop (SD08), More reforestation (SD09), More agroforestry (SD10), Loss of arable land (SD11), Provide organic food (SD12)	Tombolini et al. (2022b), Zhang et al. (2017), Prasada and Masyhuri (2020), Wang et al. (2023)
	Local cultivation practices (S3)	Easy access to land resources (KT01), Intensive farming (KT02), Accelerating traditional cultivation methods (KT03), New technologies (KT04), Indigenous knowledge (KT05), More female farmers (KT06), Easy access to consumption area (KT07), Higher income from agriculture (KT08)	Zhang et al. (2017), Kyeyune and Turner (2016), Wang et al. (2023)
Response (R)	Traditional conservation practices (R1)	Terraced fields (GTT1), Rotation of crops (GTT2), Contour cultivation (GTT3), Local seeds use (GTT4)	Saint-Macary et al. (2010), Prasada and Masyhuri (2020)
	Cultivation options (R2)	Changing crop pattern (GSD1), Diversification of organic farming systems (GSD2), Accelerating agro-tourism (GSD3), Accelerating agroforestry (GSD4), Diversifcation of species and varieties (GSD5)	Nguyen and Hens (2020), Tuan and Hegedűs (2022), Tombolini et al. (2022b)
	Land use policies (R3)	Participatory land use planning (GCS1), More attention to social issues in LUP (GCS2), Craft village industrial clusters planning (GCS3), Branding commodities and market expansion (GCS4), Protection forests (GCS5), More attention to environmental issues in LUP (GCS6), Training organic agriculture and high-tech agriculture (GCS7)	Saint-Macary et al. (2010), Kyeyune and Turner (2016), Ravetz et al. (2013)
	Improving indigenous techniques (R4)	Use of on-farm biological nutrients (GKT1), Growing shadow plants under fruit trees (GKT2), Land cover by vegetables (GKT3), Dike protection - prevent flooding (GKT4), Intercropping and crop rotation (GKT5), Digging wells for irrigation (GKT6)	Quang et al. (2014), Nguyen and Hens (2020), Prasada and Masyhuri (2020)

Subsequently, we select indicators for integration into the PSR model. The chosen criteria include the weighted mean (wM) and the weighted standard deviation mean (wstD), both of which are recognized as reliable measures commonly utilized for indicator selection (Kamaldeen 2015; Nguyen and Hens 2020). Through calculations of wM and wstD, we categorized the indicators into five levels: from 1.0 to 1.8 as "very low"; from over 1.8 to 2.6 as "low"; from over 2.6 to 3.4 as "moderate"; from over 3.4 to 4.2 as "high"; and from over 4.2 to 5 as "very high".

Data analyses are conducted for each landscape, leading to the establishment of connections between individual PSR elements. Each distinct PSR elucidates the concept of sustainable LUS within its respective region (Bing-zhong 2002).

Consequently, the significance and role of each subregion are leveraged to establish regional linkages among the studied landscapes. The calculations for wM and wstD are performed as follows:

$$wM = \frac{\sum_{i=1}^{n} X_i f(X_i)}{N} \qquad (2)$$

$$wstD = \sqrt{\frac{\sum [X_i - wM]^2}{N}} \qquad (3)$$

where $\sum f$ is the total frequency of the research indicator; $f(X_n)$ is the frequency or number of responses to level n (n=1,2,...,5); X_i represents each value on the 5-point Likert scale; and N is the total number of answers.

3. Results

3.1. LQI pressure-state-response analysis for highland landscapes

In the highland landscape (SZ1), 72 out of 75 selected LQIs were included for analysis. However, indicators related to industrial craft villages (XH11), flooding during the rainy season (MT06), and the planning of craft village industrial clusters (GCS3) were excluded by local households and authorities (Figure 4, Appendix 1). Given the mountainous terrain of this landscape, it experiences minimal flooding during the rainy season, and no industrial clusters are present. Consequently, the local LUS is predominantly influenced by natural factors rather than socioeconomic and macropolicy factors. Specifically, drought (TN02 = 3.57) and sloping land (TN08 = 4.14) were the primary factors contributing to water scarcity during the dry season (MT02 = 4.12).

The advent of the Green Revolution (GR) in agriculture marked a significant milestone in this sector, yielding numerous societal and economic benefits. It has gradually transformed agricultural LUS and local cultivation practices (S3 = 2.94; S2 = 2.64). However, GR can also cause environmental depletion, soil erosion, and land degradation due to resource overutilization and adverse effects on biodiversity (S1 = 3.44). Soil erosion became particularly pronounced during the rainy season (MT01 = 3.66) in this context. To mitigate pressure on agricultural production, the community optes for solutions rooted in traditional conservation practices, e.g., terraced farming (GTT1= 3.54), contour line cultivation (GTT3 = 3.50), and indigenous techniques, e.g., self-constructed irrigation and drainage wells (GKT6 = 3.31). These solutions, endorsed by local authorities, are instrumental in fortifying canals and irrigation projects, thereby establishing a verdant corridor for Hanoi city, curtailing erosion, and minimizing irrigation water usage.

3.2. LQI pressure-state-response analysis for lowland landscapes

All 75 LQIs are endorsed by both locals and authorities in the lowland landscape (SZ2) (Figure 5, Appendix 2). Agroforestry LUS is influenced by a combination of natural and socioeconomic factors. Notably, urbanization (XH07 = 3.36), population growth (XH01 = 3.34), and market price imbalances (XH05 = 3.03) emerge as the most frequently cited socioeconomic influences. While positive changes are evident in the State group, opportunities for exporting products such as Long Phu tea (SD03 = 3.81) to consumer areas (KT07 = 3.60) are recognized. However, challenges such as water scarcity during the dry season (MT02 = 3.72) and soil pollution (MT05 = 3.41) are escalating concerns. Soil contamination, attributed to various production activities, including the use of toxic chemicals in agriculture (e.g., chemical fertilizers) and industrial processes, poses a significant threat. The introduction of chemical fertilizers and pesticides associated with the GR disrupts farmers' longstanding indigenous knowledge systems, which have accumulated over generations, concerning environmental factors, climate, and land cultivation practices. Local farming practices underwent substantial transformation during this period (S3 = 3.16), with haphazard and irresponsible techniques contributing to soil degradation and pollution (S1 = 3.30).

Peri-urban farmers experience land loss (SD11 = 2.80) due to the conversion of agricultural land for urban and industrial purposes, resulting in only average income levels from agricultural production (KT08 = 3.06). Among the chosen indigenous techniques, self-dug wells for irrigation and drainage (GKT6 = 3.26) and contour line crop cultivation (GTT3 = 3.23) are deemed the most effective. Embracing diversified organic and ecological agricultural systems (GSD2 = 3.18) represents the primary farming approach, facilitating income enhancement while curbing environmental degradation. The principal land use recommendations underscore the prioritization of environmental considerations (GCS6 = 2.69) and the strategic planning of craft villages and complex industrial clusters (GCS3 = 2.40).

3.3. LQI Pressure-State-Response analysis for delta-flood landscapes

For local households in the delta-flood landscape (SZ3), 61 out of 75 LQIs were selected, omitting TN04, TN08, XH06, XH09, VM06, SD02, SD07, SD09, SD10, KT05, GTT1, GTT3, GSD4, and GCS5. Socioeconomic factors had greater effects on agricultural activities in this landscape than in other peri-urban areas in Hanoi: population growth (XH01 = 3.96), price imbalances (XH05 = 3.71), urbanization (XH07 = 3.62), and waste from industries and handicraft villages (XH11 = 3.55) exerted significant influences on natural factors (Figure 6, Appendix 3). Rice cultivation, which is prevalent in peri-urban areas, is particularly impacted by macropolicy factors such as land consolidation (VM05 = 3.68). Although soil erosion is negligible due to the topographical elevation, signs of land degradation, pollution, and landslides along the riverbanks are apparent in this area (S1 = 3.04). The adoption of local farming practices shifted gradually (S3 = 3.03).

Notably, SZ3 exhibited the most significant results among the subregions based on the analysis of 17 soil samples. The decrease in organic matter content in SZ3 impacted soil productivity (MT04 = 3.24). Floods, which are particularly prevalent during the rainy season along the Tich River, adversely affect livelihoods (MT06 = 3.75). Hence, strategies to fortify dikes and mitigate flood risks garner considerable attention from both local farmers and officials (GKT4 = 3.06). Concurrently, stakeholders in this area prioritize land use policies such as enhancing community engagement in land use planning (GCS1 = 3.04), addressing social issues and environmental pollution (GCS2 = 3.12; GCS6 = 3.01), and promoting local agricultural product branding and expanding consumer markets to cater to urban demand (GCS4 = 3.02).

3.4. LQI Pressure-State-Response analysis for alluvial landscapes

Sixty-one out of 75 LQIs, excluding TN04, TN08, XH06, XH09, VM06, SD02, SD07, SD09, SD10, KT05, GTT1, GTT3, GSD4, and GCS5, responded. Indicators deemed atypical of agricultural land use in such areas are omitted from the comprehensive set of indicators for peri-urban Hanoi. Socioeconomic factors have emerged as predominant concerns compared to other categories (Figure 7, Appendix 4). Price imbalances (XH05 = 4.23), inadequate storage and processing facilities for agricultural products (XH12 = 4.02), and inadequate waste management in industrial parks and handicraft villages (XH11 = 4.02) exert the most significant influence on the LUS of vegetables and fruit trees. Local farmers undergo significant changes in cultivation practices (S3 = 3.43), prompting alterations in agricultural LUS (S2 = 2.99). The integration of modern science and technology into farming practices (KT04 = 3.76) bolsters the quality and quantity of cash crops (SD03 = 4.06). The diversification of organic LUS represents the most promising response in terms of soil conservation and income enhancement for farmers (SD12 = 3.90), facilitating progress toward sustainable and eco-friendly agriculture (S1 = 2.43). However, irrigation water remains insufficient for agricultural lands (TN01 = 4.01), exacerbated by pollution from industrial parks and handicraft village waste (XH11 = 4.02).

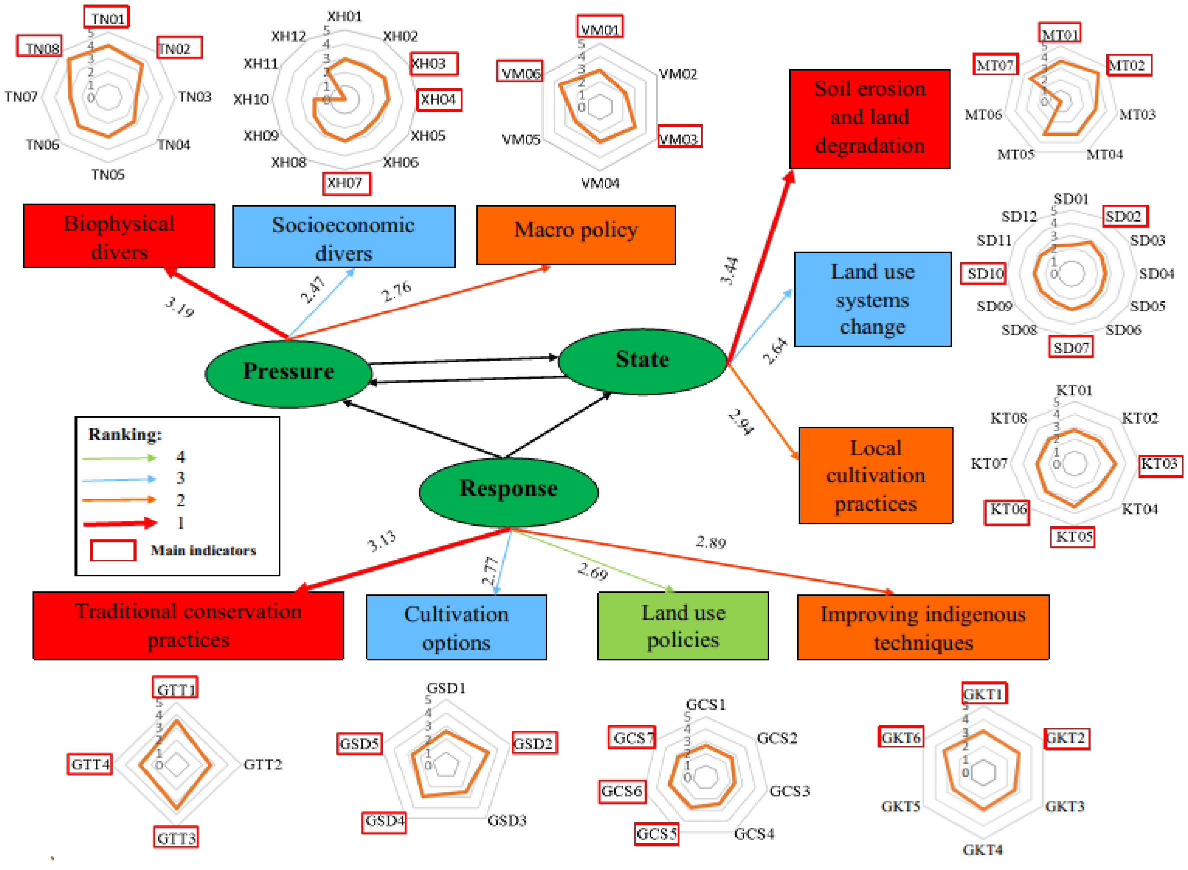

Figure 4 LQI pressure-state response analysis for the highland landscape.

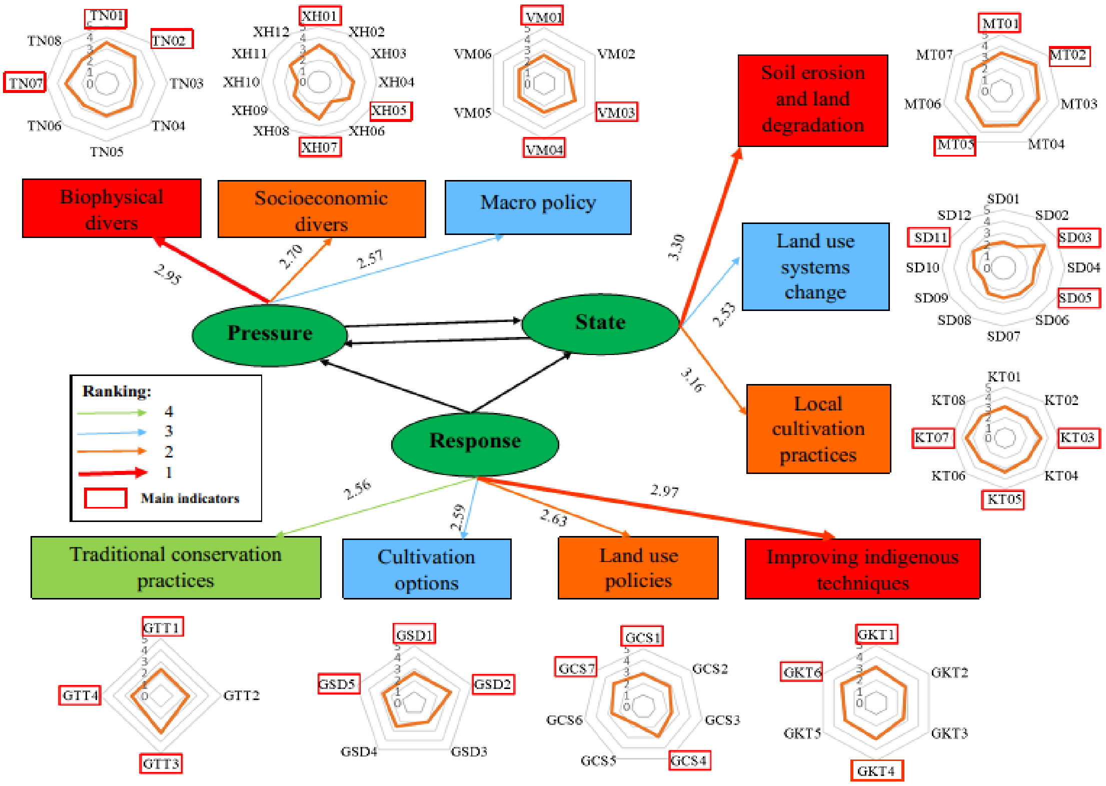

Figure 5 LQI pressure-state response analysis for the lowland landscape.

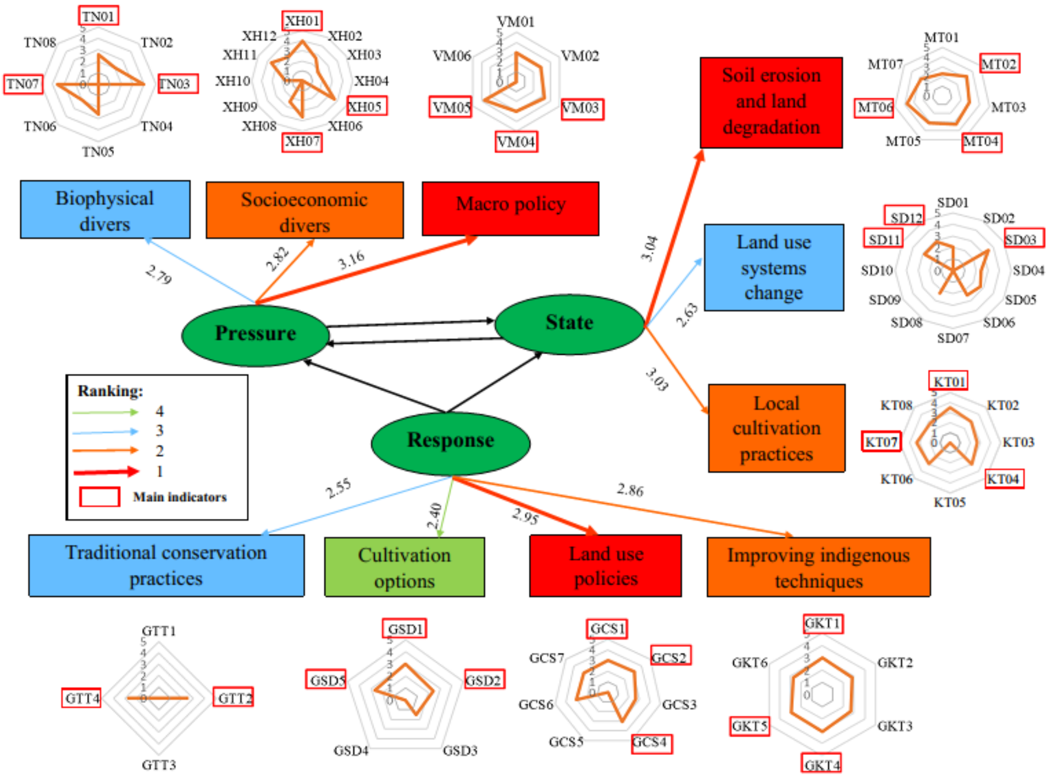

Figure 6 LQI pressure-state response analysis for delta-flood landscapes.

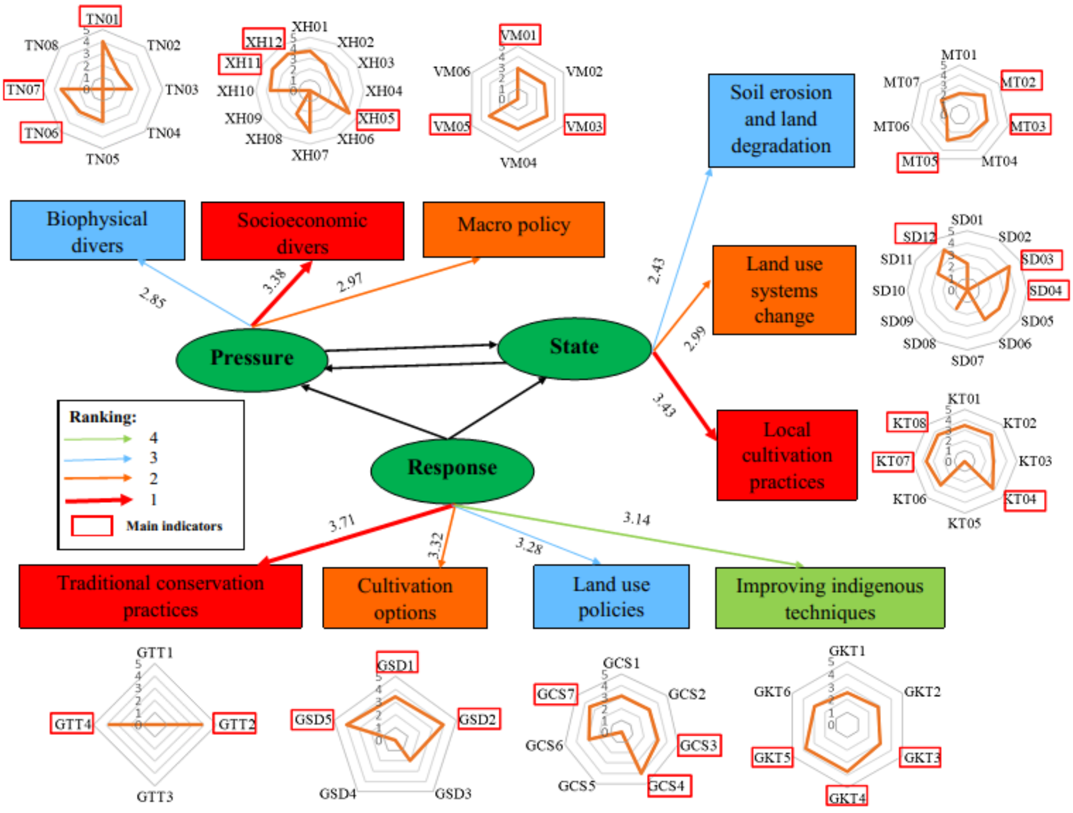

Figure 7 LQI pressure-state response analysis for the alluvial landscape.

4. Discussion

The evaluation and monitoring of LQI pose complex and challenging tasks, particularly within the recent dynamic context of GR and urbanization in Vietnam. Previous methodologies, such as those suggested by the FAO (1976), provide valuable insights but face limitations in integrating the increasing number of LQIs within evolving agricultural landscapes. For instance, Dan et al. (2018) employed eight indicators for agricultural land assessment, necessitating intricate map integration using GIS. However, as the number of indicators grows, constructing comprehensive land unit maps becomes increasingly complex. Similarly, Zhang et al. (2022) and Song et al. (2022) explored various aspects of LQI, highlighting challenges in connotation structure and evaluation methodologies.

Challenges in studying LQI revolve around understanding leading regional factors, employing effective observation and simulation techniques, and utilizing comprehensive evaluation theories and methods. Existing spatial estimation practices often struggle to capture the dynamic interactions of main factors and change processes. Statistical analysis methods, while useful, may fall short in addressing crucial questions regarding regional leading factors and their impact on arable land quality. Long-term surveys and observations at various scales are imperative for understanding the internal logic of leading factors within the human-environment system.

In this study, the integration of the LQI into PSR frameworks enables the evaluation of agricultural LUS across distinct landscapes in the peri-urban Hanoi capital city of Vietnam. Although the suitability of the PSR model is acknowledged, its application to peri-urban areas requires further validation and detailed analysis. This integration offers a holistic perspective on agricultural land use, providing diverse responses to sustainably manage LUS in peri-urban areas with varying socioecological settings. As urbanization and socioeconomic development exert pressure, assessing peri-urban agricultural LUS demands a comprehensive set of LQIs, as demonstrated in this study.

The PSR framework serves as a valuable analytical tool for evaluating LUS with consideration of GR, offering a systematic approach to understanding and facilitating decision-making. Its arrangement of data into pressure, state, and response elements aids in comprehending the dynamics influencing agricultural land use. By identifying systemic pressures, the framework establishes a foundation for assessing the ecological ramifications of these pressures on land conditions. The state component facilitates a comprehensive evaluation of environmental repercussions, while the response component evaluates policies and interventions aimed at resolving identified challenges. For example, crop restructuring (VM01) and land consolidation (VM05) help develop large specialized production areas such as organic vegetable production areas towards a sustainable Green Revolution in peri-urban area in Hanoi.

The landscapes examined in this study are intricately linked, each playing a unique role in enhancing the economic development of the urban center (Quoc Oai DPC, 2020). First, highland landscapes, characterized by LUSs comprising protective and productive forests, serve a crucial function in mitigating natural disasters, such as landslides and floods, from upstream to downstream areas, also contributing to environmental sustainability. Second, the lowland landscapes serve as seed and crop providers, supporting rural development within the green corridor and encompassing ecological regions accessible to inner-city dwellers. Third, delta flood landscapes provide readily available food, such as rice, corn, and potatoes, to both peri-urban and inner-city populations. Last, the alluvial landscapes yield organic vegetable products, fresh vegetables, and specialty fruit trees, serving as a vital subregion that helps Hanoi avoid floods during the rainy season, functioning as the outlet for draining floodwater.

The study findings indicate that the LUS in highland landscapes is significantly influenced by natural and disaster-related factors, such as sloping land, scarce irrigated water, and drought (biophysical drivers). This aligns with the observations of (Nguyen and Hens, 2020), who highlighted heightened disaster perceptions in mountainous areas. Populations in these areas are particularly vigilant due to extensive sloping land, frequent landslides, insufficient irrigated water resources, and recurring droughts. Furthermore, deforestation in the highland subregion leads to diminished vegetation cover, exacerbating agricultural LUS fragmentation due to topographical factors.

We observe differences in the perceptions of landscapes, with participants in lowlands assigning higher evaluations to both natural and socioeconomic factors. This perception is consistent with studies by Ravetz et al. (2013) and Prasada and Masyhuri (2020), indicating that biophysical impacts on agricultural land use are perceived as less significant in areas with lower slopes. The divergence is attributed to substantial pressure from urbanization and population growth in lowland regions, resulting in reduced agricultural LUS areas and directly impacting farmers' livelihoods (Ravetz et al., 2013; Prasada and Masyhuri, 2020). For example, according to the plan of the Hanoi People's Committee, the urbanization rate of Hanoi by 2025 will reach about 60 - 62%. By 2030, it will reach about 65 - 75%. On average each year, Hanoi's population increases by more than 200,000 people, of which more than 1/3 are people from outside the province immigrating to the capital. One of the reasons is that tourism and industry are strongly developing, attracting workers. In 2024, Hanoi aims to welcome 26.5 million visitors (an increase of 10.4% compared to 2023). The land fund for the above activities is largely taken from peri-urban agricultural land. Socioeconomic factors and macroeconomic policies emerge as principal determinants influencing agricultural LUS in delta flood landscapes, affecting local cultivation practices, as well as the quality of soil and water environments. This finding resonates with previous studies (Kamaldeen 2015; Madalla and Majule 2016), highlighting the challenges faced by agricultural LUSs due to socioeconomic and policy factors. The encouragement of new technologies to replace traditional techniques is evident.

In the alluvial landscape, the study findings reveal a transition toward organic and ecological practices, particularly in vegetable production areas, aligning with the principles of sustainable land-use planning and aiming for a new sustainable Green Revolution. A sustainable agricultural LUS is pivotal for achieving a sustainable GR and mitigating the negative biological, environmental, and socioeconomic impacts of land use. Organic farming has emerged as a crucial tool for attaining green yields and reducing the adverse effects of conventional farming by eliminating synthetic chemical inputs during production. This finding is corroborated by Nguyen et al. (2020), underscoring the importance of organic farming. Hence, a sustainable Green Revolution must prioritize environmental friendliness, eschewing environmental degradation for high crop productivity, emphasizing biodiversity, and leveraging the diversity of traditional ecosystems based on organic ecological agricultural LUS, integrating indigenous and scientific knowledge. This awareness has also been endorsed in local land-use planning up to 2030, with a visionary outlook to 2050 (Quoc Oai DPC, 2020). For example, currently the peri-urban areas in Hanoi have strongly transformed into organic vegetable growing areas, towards a sustainable Green Revolution such as Hoa Vien organic vegetables (Thach That district), Quang Yen organic vegetables (Quoc Oai district), Hiep Thuan organic vegetables (Phuc Tho district),... This helps increase income for farmers living in the suburbs. In the same agricultural cooperative, the average income of organic vegetable farming households is 400 - 450 million VND/ha/year higher than that of conventional farming households.

5. Conclusions

In this study, a comprehensive set of 75 LQIs is proposed for monitoring various types of peri-urban agricultural LUSs in peri-urban Hanoi. These indicators hold significant importance in informing urban planning initiatives, particularly amidst the ongoing processes of industrialization and modernization in developing countries. Employing the PSR framework, the built LQI facilitates the assessment of the agricultural development trajectory across four distinct landscapes. Given the unique pressures faced by each landscape, it is imperative to adapt land use planning orientations and solutions accordingly. Detailed quantitative analysis of these indicators can significantly aid decision-makers in formulating sustainable land management strategies, thus contributing to a sustainable Green Revolution.

Currently, land assessments in many localities, including Vietnam, predominantly rely on the process outlined by the FAO (1976). However, in light of the contemporary challenges posed by urbanization in peri-urban areas, we advocate the integration of a set of LQIs within the PSR framework as a more suitable alternative to the traditional FAO approach. The traditional process, which selects the LQI to construct land unit maps, faces considerable difficulty in peri-urban areas, where agricultural land use is increasingly influenced by multifaceted economic, social, and environmental factors. As demonstrated in this study, the integration of LQI within the PSR framework has emerged as an effective tool for assessing the limitations of the GR, conducting land use analysis, guiding land assessment, and informing land use planning initiatives.

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Ethical considerations

The study correctly followed the ethical policies for a study that included human subjects, in addition to confirming the consent of all the respondents involved.

Conflict of interest

The authors declare no conflicts of interest.

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References

Abate, E., Shimelis, H., Mark, L., & Fentahun, M. (2017). Soil Acidity under Multiple Land-Uses: Assessment of Perceived Causes and Indicators, and Nutrient Dynamics in Small-Holders’ Mixed-Farming System of Northwest Ethiopia. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 67*(2), 134–47. https://doi.org/10.1080/09064710.2016.1230227.

Adriaanse, A. (1993). Environmental Policy Performance Indicators. A Study on the Development of Indicators for Environmental Policy in The Netherlands. Uitgeverij, The Hague: 1- 183

Ayambire, R., Amponsah, O., Charles, P., & Stephen, A. T. (2019). A Review of Practices for Sustaining Urban and Peri-Urban Agriculture: Implications for Land Use Planning in Rapidly Urbanising Ghanaian Cities. *Land Use Policy 84*(May), 260–77. https://doi.org/10.1016/j.landusepol.2019.03.004.

Bockstaller, C., Françoise, L., Sophie, S. D., Séverine, P., Jean, V., Bernard, A., and Sylvain, P. (2011). Assessing Biodiversity in Arable Farmland by Means of Indicators: An Overview. *OCL - Oleagineux Corps Gras Lipides 18*(May), 137–44. https://doi.org/10.1684/ocl.2011.0381.

Bogoviz, A. V. (2021). The Challenge of Sustainability in Agricultural Systems: Volume 1. Vol. 205. Lecture Notes in Networks and Systems. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-73097-0.

Bouma, J. (2002). Land Quality Indicators of Sustainable Land Management across Scales. *Agriculture, Ecosystems & Environment, Soil Health as an Indicator of Sustainable Management, 88*(2), 129–36. https://doi.org/10.1016/S0167-8809(01)00248-1.

Brinkley, C., and Marjory, A. V. (2022). Socioeconomic and Environmental Indicators for Rural Communities: Bridging the Scholarly and Practice Gap. *Economic Development Quarterly 36*(2), 75–91. https://doi.org/10.1177/08912424221083023.

Cronbach, L. J. (1951). Coefficient Alpha and the Internal Structure of Tests. *Psychometrika 16*(3), 297–334. https://doi.org/10.1007/BF02310555.

Dan, N. N., Lei, G. P., and Le P. C. L. (2018). Land Unit Mapping and Evaluation of Land Suitability for Agro – Forestrye in Thua Thien Hue Province – VietNam as an Example. *IOP Conference Series: Earth and Environmental Science 159*(1), 012012. https://doi.org/10.1088/1755-1315/159/1/012012.

Danielle, L. (2021). Urban Transition in Hanoi: Huge Challenges Ahead | ISEAS Publishing. https://bookshop.iseas.edu.sg/publication/2471.

Danilo, Đ., Bojan, M., Marija, J., & Ivan, Đ. (2022). Land Productivity and Agri-Environmental Indicators: A Case Study of Western Balkans. Land 2022, 11, 2216. https://doi.org/10.3390/land11122216.

Dera, J., Canisio, M., & Neil, M. Z. (2022). Land Use Systems and Soil Quality Indicators in a Fersiallitic (5e) Soil at Matopos Research Farm in Zimbabwe. In Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas, edited by Xavier Poshiwa and G. Ravindra Chary, 251–59. Singapore: Springer Nature. https://doi.org/10.1007/978-981-16-7861-5_17.

Dumanski, J., & Pieri, C. (2000). Land Quality Indicators: Research Plan. Elsevier 81 (2): 93–102.

FAO. (1976). A Framework for Land Evaluation. Romeo, Italy, FAO.

FAO. (1984). Land Evaluation for Forestry. Romeo, Italy, FAO.

FAO, UNDP, UNEP and World Bank. (1997). Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development, FAO.

Fei, Z. (2022). Research on Rural Land Planning Based on Traditional Farming Culture. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 72*(1), 248–59. https://doi.org/10.1080/09064710.2021.2001041.

Gad, M., Ali H. S., Hend, H., Salah, E., & Mohamed, F. (2023). Water Quality Evaluation and Prediction Using Irrigation Indices, Artificial Neural Networks, and Partial Least Square Regression Models for the Nile River, Egypt. *Water 15*(12), 2244. https://doi.org/10.3390/w15122244.

Goyal, M., Ashutosh, S., & Rao, S. (2020). Remote Sensing and GIS Applications in Sustainability. *Sustainability*, 605–26. https://doi.org/10.1002/9781119434016.ch28.

Hao, S., & Lai, C. (2013). Analysis of LUCC in Loess Plateau Based on PSR Model-A Case Study in Shanghuang Study Area in Guyuan City. *BioTechnology: An Indian Journal 8*(January), 1009–14.

Henry, K., & Richard, V. (2009). Comparing Sampling and Estimation Strategies in Establishment Populations. *Survey Research Methods 3*(March), 27–44. https://doi.org/10.18148/srm/2009.v3i1.72.

Kamaldeen, Y. (2015). Constraints to Farmers Willingness to Pay for Private Irrigation Delivery in Nandom, Ghana. https://www.researchgate.net/publication/322057055_Constraints_to_Farmers_Willingness_to_Pay_for_Private_Irrigation_Delivery_in_Nandom_Ghana. 2015: 5(2):119-124.

Kapur, S., Erhan, A., Claudio, Z., Suha, B., & Somayyeh, R. M. (2019). Anthroscapes: A Robust Basis for Mapping Land Quality and Sustainable Land Use Patterns. In Eastern Mediterranean Port Cities: A Study of Mersin, Turkey—From Antiquity to Modernity, edited by Filiz Yenişehirlioğlu, Eyüp Özveren, and Tülin Selvi Ünlü, 63–77. The Urban Book Series. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-93662-8_5.

Kyeyune, V., & Sarah, T. (2016). Yielding to High Yields? Critiquing Food Security Definitions and Policy Implications for Ethnic Minority Livelihoods in Upland Vietnam. *Geoforum 71*(May), 33–43. https://doi.org/10.1016/j.geoforum.2016.03.001.

Lai, S., Jinming, S., Ahmed, E., Xiaomei, L., Jinliang, W., Eldar, K., Zejing, L., Longbin, W., Run, H., & Yung-Chih, S. (2022). Evaluation of Ecological Security and Ecological Maintenance Based on Pressure-State-Response (PSR) Model, Case Study: Fuzhou City, China. Human and Ecological Risk Assessment: *An International Journal 28*(July), 1–28. https://doi.org/10.1080/10807039.2022.2081835.

Liu, Y., Dongsheng, S., Huijuan, W., Xiaojuan, W., Guiqin, Y., & Xiujuan, Z. (2020). An Evaluation of China's Agricultural Green Production: 1978–2017. *Journal of Cleaner Production 243*(January), 118483. https://doi.org/10.1016/j.jclepro.2019.118483.

Liu, Y. (2022). Simulation of Land Use System Performance Dynamics Based on System Dynamics. In International Conference on Cognitive Based Information Processing and Applications (CIPA 2021), edited by Bernard J. Jansen, Haibo Liang, and Jun Ye, 195–207. Lecture Notes on Data Engineering and Communications Technologies. Singapore: Springer. https://doi.org/10.1007/978-981-16-5857-0_24.

Madalla, N., & Majule, A. (2016). Economic Value of Agricultural Land for Community Livelihoods within the Context of REDD+. *Journal of Agriculture and Ecology Research International 2*(June), 180–95. https://doi.org/10.9734/JAERI/2015/14132.

MONRE (2015). Regulations on Land Investigation and Assessment Techniques. The Ministry of Natural Resources and Environment, Vietnam.

Nam (2023). The Green Revolution in Vietnam. September 6, 2023. https://vietnamagriculture.nongnghiep.vn/the-green-revolution-in-vietnam-d361285.html.

Nam, P. P., & Yen, T.T. (2022). Determinants of the Lives of Households after Land Loss for Urbanization: Experiences from Vinh City, Nghe An Province. *Land Use Policy 119*(August), 106216. https://doi.org/10.1016/j.landusepol.2022.106216.

Nguyen, A. T., & Luc, H. (2020). Diversified Responses to Contemporary Pressures on Sloping Agricultural Land: Thai Farmer's Perception of Mountainous Landscapes in Northern Vietnam. *Environment, Development and Sustainability 23*(4), 5411–29. https://doi.org/10.1007/s10668-020-00822-x.

Nguyen, T.P.L, Nguyen, T.T., Doan, X.H., Tran, M.L., Tran, N.M., & Nguyen, T.D. (2020). A Dataset of Factors Influencing Intentions for Organic Farming in Vietnam. Data in Brief 33 (December): 106605. https://doi.org/10.1016/j.dib.2020.106605.

Pham, T. M., Dang, G.T.H., Bora, J., & Nguyen, T.T. (2022). Land Quality Evaluation for Sustainable Development Goals: A Structured Review Using Bibliometric and Social Network Analysis. *Environmental Monitoring and Assessment 194*(9), 603. https://doi.org/10.1007/s10661-022-10226-1.

Pham, T. G, Nguyen, T.H., & Martin, K. (2018). Assessment of Soil Quality Indicators under Different Agricultural Land Uses and Topographic Aspects in Central Vietnam. *International Soil and Water Conservation Research 6*(4), 280–88. https://doi.org/10.1016/j.iswcr.2018.08.001.

Prasada, I. Y., & Masyhuri, M. (2020). Factors Affecting Farmers' Perception toward Agricultural Land Sustainability in Peri-Urban Areas of Pekalongan City. *Caraka Tani: Journal of Sustainable Agriculture 35*(2), 203–12. https://doi.org/10.20961/carakatani.v35i2.31918.

Quang, D., Pepijn, S., and Thomas, B. (2014). Ex-Ante Assessment of Soil Conservation Methods in the Uplands of Vietnam: An Agent-Based Modeling Approach. *Agricultural Systems 123*(January), 108–19. https://doi.org/10.1016/j.agsy.2013.10.002.

Quoc Oai DPC (District People's Committee) (2020). Report on Land Use Planning in 2030 with a Vision to 2050. Quoc Oai District People's Committee.

Ravetz, J., Christian, F., & Thomas, S. N. (2013). The Dynamics of Peri-Urbanization. In Peri-Urban Futures: Scenarios and Models for Land Use Change in Europe, edited by Kjell Nilsson, Stephan Pauleit, Simon Bell, Carmen Aalbers, and Thomas A. Sick Nielsen, 13–44. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-30529-0_2.

Ríos-Touma, B., Paulina, R., Andrés, M., Juan, M. G., Chelsea, C., Santiago, V-C., Alejandro, S-U., Ibon, T., & Francisco, C. (2023). Biodiversity Responses to Land-Use Change in the Equatorial Andes. *Ecological Indicators 156*(December), 111100. https://doi.org/10.1016/j.ecolind.2023.111100.

Sagar, U. S., Yatharth, S., Ashwin, M., & Teja, M. (2022). Future Impacts of Urban and Peri-Urban Agriculture on Carbon Stock and Land Surface Temperatures in India. *Urban Climate 45*(September), 101267. https://doi.org/10.1016/j.uclim.2022.101267.

Saint-Macary, C., Alwin K., Manfred, Z., Franz, H., & Pham, T. M. D. (2010). Land Titling Policy and Soil Conservation in the Northern Uplands of Vietnam. *Land Use Policy, Forest transitions, 27*(2), 617–27. https://doi.org/10.1016/j.landusepol.2009.08.004.

Schiefer, J., Georg J. L., & Winfried, E. H. B. (2015). Indicators for the Definition of Land Quality as a Basis for the Sustainable Intensification of Agricultural Production. *International Soil and Water Conservation Research 3*(1), 42–49. https://doi.org/10.1016/j.iswcr.2015.03.003.

Smith, B., Rawlins, B. G., Ferguson, A. J., Fordyce, F., Hutchins, M. G. F., & Barr, D. M. (2002). Information on Land Quality in Scotland: Sources of Information: Including Background Contaminants. British Geological Survey & LGC.

Song, W., Huizhong, Z., Rui, Z., Kening, W., Xinju, L., Beibei, N., & Junying, L. (2022). Study on Cultivated Land Quality Evaluation from the Perspective of Farmland Ecosystems. *Ecological Indicators 139*(June), 108959. https://doi.org/10.1016/j.ecolind.2022.108959.

Tesfahunegn, G., Lulseged, T., Paul, V., & Kirubel, M. (2014). Assessing Farmers' Knowledge of Weed Species, Crop Type and Soil Management Practices in Relation to Soil Quality Status in Mai-Negus Catchment, Northern Ethiopia. *Land Degradation & Development 27*,(March). https://doi.org/10.1002/ldr.2233.

Teshome, A., Jan, G., Coen, R., & Menale, B. (2014). Farmers' Perceptions about the Influence of Land Quality, Land Fragmentation and Tenure Systems on Sustainable Land Management in the North Western Ethiopian Highlands. *Land Degradation & Development 27*(August). https://doi.org/10.1002/ldr.2298.

Thilde, B. B., Andreas de N., Maria, L. B., & Catherine, M. H. (2017). Intensification of Upland Agriculture in Thailand: Development or Degradation?: Intensification of Upland Agriculture in Thailand.

https://www.researchgate.net/publication/306009128_Intensification_of_Upland_Agriculture_in_Thailand_Development_or_Degradation_Intensification_of_Upland_Agriculture_in_Thailand.

Tombolini, I., Jesús, R-C, & Luca, S. (2022a). Land Quality and Sustainable Urban Forms: Changing Landscapes and Socioeconomic Structures of European Cities. Springer Geography. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-94732-3.

Tombolini, I., Jesús, R-C., & Luca, S. (2022b). What Type of Soil Was Consumed in the Metropolis of the Mediterranean Area? Land Quality and the Forms of Urbanization. In Land Quality and Sustainable Urban Forms: Changing Landscapes and Socioeconomic Structures of European Cities, edited by Ilaria Tombolini, Jesús Rodrigo-Comino, and Luca Salvati, 105–30. Springer Geography. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-94732-3_4.

Tsymbarovich, P., German, K., Mikhail, K., Valentin, G., & Olga, A. (2020). Soil Erosion: An Important Indicator for the Assessment of Land Degradation Neutrality in Russia. International Soil and Water Conservation Research, Soil erosion assessment tools and data; creation, consolidation, and harmonization – A special issue from the Global Symposium on Soil Erosion 2019 (Rome, FAO HQ)., 8 (4): 418–29. https://doi.org/10.1016/j.iswcr.2020.06.002.

Tuan, N. T., & Gábor, H. (2022a). Urbanization and Post-Acquisition Livelihood in a Peri-Urban Context in Vietnam: A Geographical Comparison between Hanoi, Danang, and Vinh City. *Land 11*(10), 1787. https://doi.org/10.3390/land11101787.

Tuan, N.T., & Gábor, H. (2022b). Urbanization and Post-Acquisition Livelihood in a Peri-Urban Context in Vietnam: A Geographical Comparison between Hanoi, Danang, and Vinh City. *Land 11*(10), 1787. https://doi.org/10.3390/land11101787.

Viana, C. M., Dulce, F., Patrícia, A., Jorge, R., & Paulo, P. (2022). Agricultural Land Systems Importance for Supporting Food Security and Sustainable Development Goals: A Systematic Review. *Science of The Total Environment 806*(February), 150718. https://doi.org/10.1016/j.scitotenv.2021.150718.

Wang, F., Yao, L., Jin, L., & Juan, N. (2021). Evaluating Environmentally Sustainable Development Based on the PSR Framework and Variable Weigh Analytic Hierarchy Process. *International Journal of Environmental Research and Public Health 18*(6), 2836. https://doi.org/10.3390/ijerph18062836.

Wang, M., Xingnan, L., Ziwei, L., Fengyan, W., Xiaoyan, L., Guanglei, H., & Shijun, Z. (2023). Evaluation and Driving Force Analysis of Cultivated Land Quality in Black Soil Region of Northeast China. *Chinese Geographical Science 33*(4), 601–15. https://doi.org/10.1007/s11769-023-1361-1.

Zhang, G., Chunyan, Z., Yi, W., Yufei, L., & Ying, X. (2015). Soil Organic Carbon and Microbial Community Structure Exhibit Different Responses to Three Land Use Types in the North China Plain. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science 65*(4), 341–49. https://doi.org/10.1080/09064710.2015.1011223.

Zhang, H., Chunyang, L., Kaidong, Y, & Linyun, D. (2019). Evaluation on Intensive Use of Urban Land Based on PSR Model Taking Henan Province as an Example. Journal of Physics: Conference Series 1419 (December): 012016. https://doi.org/10.1088/1742-6596/1419/1/012016.

Zhang, L., and Kai, S. (2017). Multifunctional Land-Use Systems for Managing the Nexus of Environmental Resources. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-54957-6.

Zhang, M., Junru, Y., & Xinke, D. (2022). Integrated Quantity, Quality and Ecology of County-Level Arable Land Improvement Potential Comprehensive Zoning: The Example of Tongxu County, China. *Journal of Geoscience and Environment Protection 10*(4), 287–302. https://doi.org/10.4236/gep.2022.104018.

Zhang, R., Chengli W., & Yachao, X. (2023). Ecological Security Assessment of China Based on the Pressure-State-Response Framework. *Ecological Indicators 154*(October), 110647. https://doi.org/10.1016/j.ecolind.2023.110647.

Zhao, S., & Yongmu, J. (2022). Heterogeneous Effects of Rural–urban Migration and Migrant Earnings on Land Efficiency: Empirical Evidence from China. *Land Use Policy 115*(April), 106003. https://doi.org/10.1016/j.landusepol.2022.106003.

Zhou, B., & Yang, H. (2002). PSR model and its application in the evaluation of sustainable land-use in the region. *Journal of Natural Resources 17*(5), 541–48. https://doi.org/10.11849/zrzyxb.2002.05.003.

Ziadat, F., & Awni, T. (2013). Effect of Rainfall Intensity, Slope, Land Use and Antecedent Soil Moisture on Soil Erosion in an Arid Environment. *Land Degradation & Development 24*(November). https://doi.org/10.1002/ldr.2239.