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EDITED BY
Godfrey Hampwaye,
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REVIEWED BY
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Mukhiddin Juliev,
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Uzbekistan

*CORRESPONDENCE
Armstrong Francis Tumawu
farmstrong03@gmail.com

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Combating land degradation for sustainable smallholder agriculture and food sovereignty in Ghana's Volta Region

Armstrong Francis Tumawu[1]*, George Yao Kafu[2], Anthony Kangah[3] and Mary Magdalene M. Tumawu[1]

[1]Department of Geography and Resource Development, University of Ghana, Accra, Ghana, [2]Department of Social Science, Peki College of Education, Peki, Ghana, [3]Faculty of Social Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

The severe and accelerating loss of land quality and productivity is widely acknowledged at all geographic scales, from the global scale down to the local level, across the world. Global food yield has decreased by 13% as a result of the 40% moderate degradation and 9% severe degradation of agricultural land. This study examines the dynamics of land degradation and its impacts on smallholder agriculture and food sovereignty in Ghana's Volta Region, focusing on the Ho Municipality. Employing a mixed-methods approach, the research combines remote sensing analysis, quantitative surveys of 200 smallholder farmers, and qualitative interviews with experts and farmers. Findings reveal a concerning trend of increasing land degradation, with areas experiencing degradation rising from 2% in 2013 to 5% in 2023. The study demonstrates significant impacts on crop yields and farm income, with 87% of surveyed farmers reporting negative effects on their crop production due to land degradation. Smallholder farmers have adopted various coping strategies, with compost application (62.5%) and chemical fertilizer use (60%) being the most prevalent practices. The research highlights a discrepancy between scientific measurements and farmers' perceptions of land degradation, emphasizing the importance of integrating local knowledge with technical assessments. The study contributes to the existing literature by providing a detailed, localized analysis of land degradation dynamics and their implications for smallholder agriculture and food sovereignty in the region. It offers valuable insights for policymakers and practitioners, underscoring the urgent need for targeted interventions to address land degradation while supporting sustainable agriculture and food security in Ghana and similar contexts.

KEYWORDS

land degradation, smallholder, agriculture, food sovereignty, Volta region, remote sensing, sustainable agriculture

1 Introduction

The severe and accelerating loss of land quality and productivity is widely acknowledged at all geographic scales, from the global scale down to the local level, across the world (Hossain et al., 2020). About 30% of the earth's total land surface is either currently degraded or in the process of becoming degraded (Prăvălie et al., 2021). Land degradation, as defined by Masson-Delmotte et al. (2019), refers to the deterioration of land conditions due to natural processes or human activities, either directly or indirectly, resulting in reduced biological productivity, ecological integrity, or value for human use. In this context, biological productivity is the rate

at which plants, microorganisms, and animals produce within an ecosystem at a given time (Coleman and Grys-Rubenstein, 2019). Ecological integrity means the ecosystem's ability to maintain ecological processes and support a diverse community of organisms (Assennato et al., 2020). "Human value" refers to all the benefits that people derive from the land (Fritz-Vietta, 2016).

Global food yield has decreased by 13% as a result of the 40% moderate degradation and 9% severe degradation of agricultural land (AbdelRahman, 2023). Soil deterioration and reduced land productivity an environmental challenge experienced by numerous nations across the African continent (Diop et al., 2022). The detrimental effects of land deterioration are more pronounced in Africa compared to other parts of the world, owing to factors such as limited access to technology, high poverty levels, and inadequate education (Tindwa and Singh, 2023). The challenges associated with land degradation are similarly prevalent in the sub-Saharan African region. It is estimated that approximately 40 to 60% of the workforce in sub-Saharan Africa is employed in the agricultural sector and related industries (Adenidji and Özçatalbaş, 2022; Kibii, 2022; Yeboah and Flynn, 2021).

Likewise, Ghana is also grappling with the issue of land degradation, akin to the broader trends observed across sub-Saharan Africa (Awoonor et al., 2024). In Ghana, a majority of the workforce is employed in the agricultural sector and other primary industries that are heavily reliant on land and its natural resources (Dzanku and Tsikata, 2022). In Ghana, the agricultural sector plays a pivotal role in the national economy, employing approximately 40% of the total workforce (Statista, 2024a). Notably, a substantial proportion, around 70%, of those engaged in agricultural activities are smallholder farmers (Alidu et al., 2022). The agricultural sector contributes a significant 20% to the country's Gross Domestic Product (GDP) (Statista, 2024b). However, the rapid rate of land degradation, driven by both natural processes and anthropogenic activities, has profound implications for the livelihoods and food security of smallholder farmers who rely on the land for their subsistence and income generation (Abdallah et al., 2023).

In the Volta Region of Ghana, agriculture and related activities form the backbone of the economy, employing approximately 60% of the total workforce, similar to most other regions in the country (Awuku Manteaw, 2022). A significant number of households, around 599,276 are engaged in the agricultural sector, with 116,507 residing in urban areas and 482,769 in rural areas [Ministry of Food and Agriculture (MoFA), 2024]. Agriculture is not merely a source of income for these households but also a source of food and a way of life (Awuku Manteaw, 2022; Sarku, 2023). Additionally, agriculture plays a crucial role in reducing rural poverty in the region (Amenuvor, 2019). Despite the vital contributions of the agricultural sector to the socio-economic development of the region, the crop production subsector faces numerous challenges that hinder the realization of its full potential and contribution (Kavi et al., 2023; Kolleh and Jones, 2018). Among these critical challenges are land degradation, disease and pest infestations, and climate change, which impede the fulfillment of the subsector's complete potential for the region's development (Amenuvor, 2019; Sackey et al., 2021).

Previous research has investigated the intricate relationships between land degradation, poverty, and environmental degradation on broader scales (Barbier and Hochard, 2018; Olanipekun et al., 2019). However, there remains a significant gap in understanding the specific local processes, responses, and implications of agricultural land degradation for smallholder farmers and food sovereignty in Ghana's Volta Region. Addressing this gap is essential for developing customized, integrated sustainable land management strategies that can concurrently combat land degradation, enhance resilience to climate change, and improve food security for these vulnerable rural communities (Smith et al., 2020). This proposed study seeks to address this need by conducting an in-depth examination of the dynamics and impacts of land degradation in the Volta Region and identifying promising practices that could help achieve the interconnected goals of environmental sustainability, climate adaptation, and food sovereignty for smallholder farmers.

2 Literature review

2.1 Type of land degradation

Land degradation encompasses various types, broadly categorized into physical, chemical, and biological degradation (Eswaran et al., 2019). Physical degradation involves the deterioration of soil's physical properties, impacting its ability to support plant growth and ecosystem services (Mohamed et al., 2019). It includes compaction, crusting, hardpan formation, and erosion (Eswaran et al., 2019). Erosion, the most prevalent form, can be caused by water or wind and leads to significant soil loss globally (Borrelli et al., 2014). Chemical degradation results from the accumulation of toxic substances and alterations in soil chemical properties, often due to pollution, deforestation, and poor farming practices (Tetteh, 2015). It manifests in forms such as salinization, acidification, and the effects of chemical fertilizers and pesticides (Tindwa and Singh, 2023).

Biological degradation refers to the eradication of soil microorganisms, which play crucial roles in maintaining ecosystem functions (Lehman et al., 2015). This type of degradation is primarily caused by agricultural intensification and the use of agrochemicals. The consequences of land degradation are far-reaching, affecting soil fertility, water retention, and overall ecosystem health (Borrelli et al., 2014). It can lead to reduced crop yields, increased water pollution, and the loss of arable land. The global scale of this issue is significant, with millions of hectares affected by various forms of degradation (Osman, 2014). Addressing land degradation requires understanding its complex types and implementing sustainable land management practices to mitigate its impacts on agriculture, the environment, and human well-being (Eswaran et al., 2019; Mohamed et al., 2019; Tindwa and Singh, 2023).

2.2 Impact of land degradation on smallholder agriculture in Ghana

Land degradation has significant negative impacts on smallholder agriculture in Ghana, affecting rural development and poverty reduction efforts (Fredua, 2014). The primary effects include reduced soil fertility, decreased crop quality and yield, and diminished farm income (Tindan, 2015). Soil fertility decline is the initial impact, resulting from reduced water infiltration and storage capacity (Andam et al., 2019) and altered organic matter content (Adimassu et al., 2014). Studies across various regions in Ghana, including the Upper East

Region, North Eastern Ghana, and the Volta region, have documented significant soil fertility losses due to land degradation (Kanton Osumanu et al., 2016; Sackey et al., 2021). The decline in soil fertility leads to reduced crop quality and yield, which in turn results in decreased farm income (Tesfahunegn et al., 2021). Research in various districts has shown consistent patterns of declining crop yields due to land degradation (Kanton Osumanu et al., 2016; Tindan, 2015). The economic impact on smallholder farmers is substantial, with estimated losses of GHS450 million in 2010 and GHS999 million in 2012 due to crop production losses (Fredua, 2014). Projections suggest further significant losses in farm income (Jayne et al., 2015). This decrease in farm income has contributed to increased poverty among smallholder farmers (Adanu et al., 2014). The severity of these impacts necessitates the implementation of coping strategies and adaptation measures by farmers to mitigate the effects of land degradation on their livelihoods (Diop et al., 2022; Smith et al., 2020).

2.3 The Management of Agricultural Land Degradation in Ghana

Smallholder farmers in Ghana employ various methods to manage and control land degradation, including crop rotation, mulching, application of manure, composting, stone bonding, chemical fertilizer application, zero-tillage, no bush burning, and cover cropping (Adamtey et al., 2014; Kansanga et al., 2020; Kanton Osumanu et al., 2016). Crop rotation, practiced by planting different crops on the same field in different seasons, improves soil nutrients and fertility (Tatenda et al., 2021). For instance, in Ghana, farmers often plant legumes after maize or cassava to enhance soil stability and nutrient balance (Fredua, 2014; Tindan, 2015). Mulching, another effective method, involves covering the soil surface with organic or inorganic materials to reduce moisture loss and regulate temperature (Kader et al., 2017; Ghouse et al., 2020). This technique helps maintain soil fertility, prevent erosion, retain moisture, and improve crop yield and quality, as observed in studies conducted in Wa East and West District and the Ashanti region (Ehiakpor et al., 2021).

The application of manure and compost as fertilizers is widely used to manage land degradation in Ghana, as evidenced by studies in Nabdam and Lawra Districts (Anafo et al., 2020). These organic fertilizers improve soil organic matter content, leading to enhanced soil quality, reduced erosion, and decreased nutrient leaching (Gay-des-Combes et al., 2017). Manure and compost application improves soil structure, water penetration, and water-holding capacity, while also building firmer soil aggregates that resist erosion (Tatenda et al., 2021). Studies by Kader et al. (2017) and Bedada et al. (2014) have shown that this practice results in improved crop yield and quality. Additionally, farmers use sustainable practices such as stone bonding, zero-tillage, and no bush burning to combat land degradation (Igwe et al., 2017).

Stone bonding is employed to control runoff, prevent erosion, and preserve soil moisture during dry seasons (Dimelu et al., 2013). This method is particularly popular in Northern Ghana and the Upper East Region (Abubakari and Abubakari, 2015; Malongza Bukari, 2013). Zero-tillage and no bush burning practices help reduce soil compaction and erosion while improving soil moisture retention and overall fertility. These techniques have been observed to increase crop yields in various districts across Ghana, including Nabdam and Lawra (Anafo et al., 2020; Kanton Osumanu et al., 2016).

3 Methodology

3.1 Study area

The study area for this research is the Ho Municipal area, situated in the Volta Region of Ghana. Geographically, the Ho Municipality spans a total land area of 574.22 square kilometers and lies between latitudes 6°20'N and 6°55'N, and longitudes 0°12′E and 0°53′E (Diema Konlan et al., 2019). It is delineated by the Agotime-Ziope and Adaklu districts to the south, the Ho West district to the north, and the international border with the Republic of Togo to the east (Axame et al., 2022). The climate of the study area is characterized as tropical, exhibiting average temperatures in the range of 22°C to 32°C (Agodzo et al., 2023). The area experiences a bimodal rainfall pattern, consisting of a major rainy season occurring from March to June, and a minor rainy season spanning July to November (Awuni et al., 2023). Annual precipitation amounts range between 1,900 mm and 2,100 mm, with September typically being the wettest month and January the driest (Agodzo et al., 2023). The average relative humidity is 72%. The Figure 1 displays the map of Ho municipality.

In terms of vegetation, the study area falls within the semi-deciduous forest zone, with remnant forest cover confined to the mountainous and hilly terrain (Atiah et al., 2019; Owusu et al., 2021). The southern lowland areas have been largely converted to grassland and herbaceous vegetation due to human activities such as agriculture and settlement (Adanu et al., 2014). Notable tree species present include *Milicia excelsa* (odum), Khaya ivorensis (mahogany), Triplochiton scleroxylon (wawa), and acacia. Edaphically, the area exhibits a dichotomy of forest soils (lethosols, ochrosols, and integrades) found in wetter areas, and sandy savannah soils concentrated around the Ho and Sokode communities. The economy of the Ho Municipal area is primarily agrarian, with the agricultural sector employing approximately half of the economically active population (Axame et al., 2022). Agriculture is dominated by smallholder farming systems, with an average farm holding size of 0.52 hectares (Diema Konlan et al., 2019). The major crops cultivated include yams, cassava, maize, oil palm, cocoa, and legumes (Adanu et al., 2014). However, the agricultural sector is beset by multifarious challenges such as low productivity, declining soil fertility, an overreliance on rainfall for crop production, and a paucity of irrigation infrastructure.

3.2 Research design and approach

This research employed a mixed-methods research design, incorporating both quantitative and qualitative data collection and analysis techniques. The rationale for adopting a mixed-methods approach was to gain a comprehensive understanding of the intricate issue of land degradation and its impacts on smallholder agriculture and food sovereignty in the Volta Region (Almeida, 2018). The mixed-methods paradigm facilitated the integration of quantitative data, which provided measurable and statistically significant trends, with qualitative data, which offered profound insights into the lived experiences, perspectives, and context-specific nuances of the phenomenon under investigation (Dawadi et al., 2021). Furthermore, the utilization of mixed methods enabled the triangulation of findings from multiple data sources and methodologies, thereby enhancing the

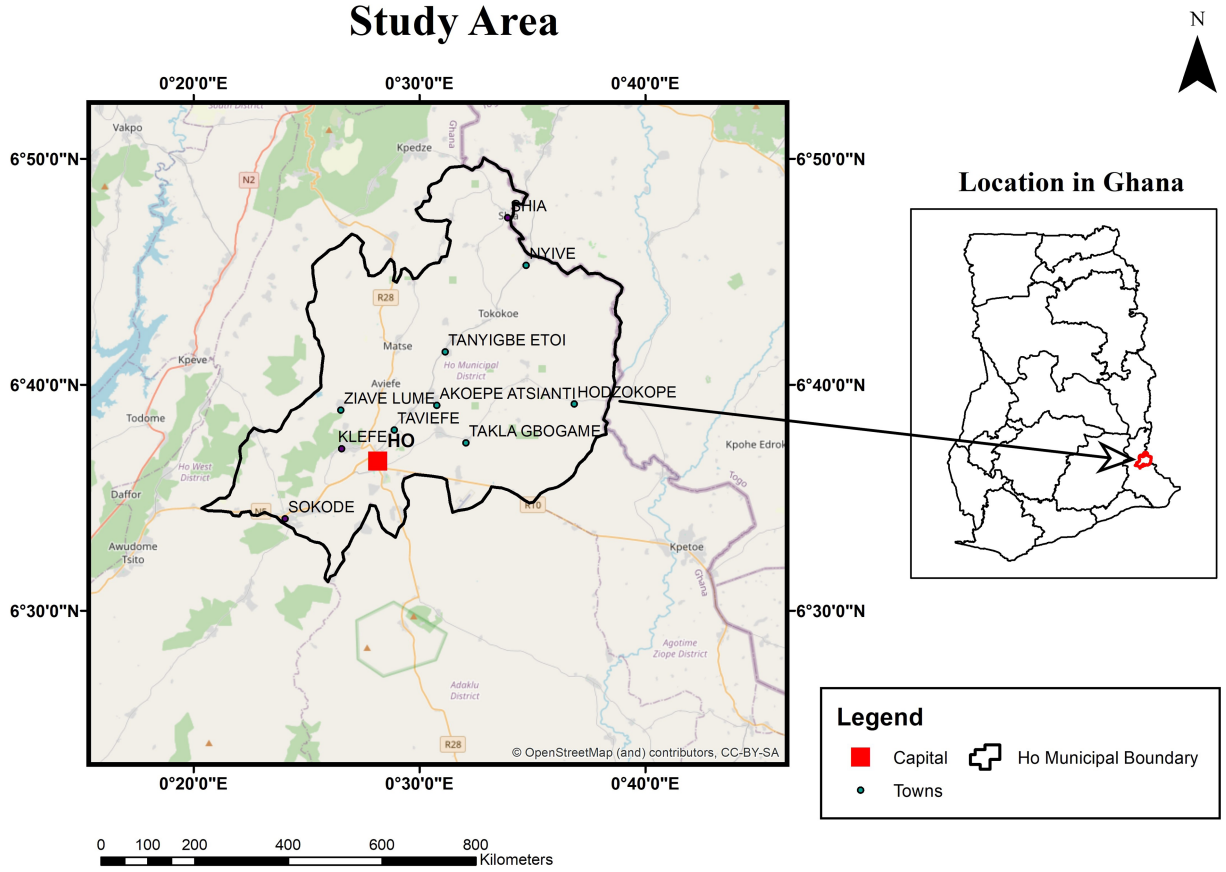

FIGURE 1
Geographical location and administrative boundaries of the Ho Municipality in Ghana, showing major towns and the municipal capital.

validity and credibility of the research findings (Strijker et al., 2020). A convergent parallel mixed methods design was employed, where qualitative and quantitative data were collected concurrently and given equal priority (Creswell and Plano Clark, 2017). This allowed for triangulation of findings to develop a comprehensive understanding of the problem.

The research methodology involved a comprehensive survey of smallholder farmers in the Ho municipal district. A list of 500 farming households was obtained from the Ministry of Food and Agriculture (MoFA) district office. Using Cochran's formula with a 95% confidence level and a 5% margin of error, the initial sample size was calculated as 218. This was subsequently adjusted to 200 households. The quantitative data collection employed simple random sampling, with 200 questionnaires administered to farmers selected from the provided list. For the qualitative component, a purposive sampling technique was utilized. Farmer group leaders and experienced farmers were identified and recommended by local extension and crop officers. To ensure diverse perspectives and achieve data saturation, the qualitative research included 10 expert interviews and 20 semi-structured interviews. This mixed-method approach allowed for a comprehensive exploration of the research objectives, combining breadth from the quantitative survey with depth from the qualitative interviews.

Both primary and secondary data were collected through the following methods: 10 semi-structured key informant interviews with agricultural experts and officials, 20 in-depth interviews with smallholder farmers in degradation hotspots, field observations documented through photos and notes, structured household survey of 200 smallholder farmer households using simple random sampling, remote sensing data from Landsat 8 OLI satellite imagery (2013–2023). Secondary data on agricultural statistics and soil data were obtained from government reports (Table 1). Several measures enhanced validity and reliability: random sampling, enumerator training, pre-testing tools, triangulation of multiple data sources, and member-checking of findings with participants (Jiang et al., 2019; Xiao et al., 2018). Satellite data processing used standard atmospheric and topographic corrections.

The land degradation analysis was conducted using Landsat 8 satellite imagery in ArcGIS Pro 3.1, following a systematic methodology. Since the images were Level 2 Collection 2, they were already preprocessed, eliminating the need for additional preprocessing steps. The workflow involved several key stages of image processing. The uploaded Landsat 8 images into ArcGIS Pro and then clipped the images to the Ho municipality district boundary. Vegetation index analysis was performed by applying the Soil Adjusted Vegetative Index (SAVI) and Normalized Difference Vegetative Index (NDVI). These indices were then combined to create a comprehensive land degradation map. The land degradation was categorized into five distinct classes based on vegetative index values, derived from expert knowledge, histogram analysis, field surveys, and land use/land cover

classification. The first class, ranging from 0.001 to 0.286, represents sparse vegetation, bare soil, or severely degraded land. The second class, from 0.287 to 0.384, indicates low to moderate vegetation cover and moderate land degradation. The third class, spanning 0.385 to 0.45, shows moderate vegetation cover with minimal degradation. The fourth class, between 0.451 and 0.513, represents moderate to relatively dense vegetation with a lower risk of degradation. The final class, from 0.514 to 1, encompasses dense vegetation cover like forests and healthy agricultural lands, indicating minimal degradation potential. To quantify the land degradation, the research converted the raster map to a vector polygon and used geometry calculation to determine the area in hectares. The percentages were calculated based on the total study area land surface, providing a detailed, spatially explicit assessment of land degradation across the Ho municipality.

Qualitative data from interviews were transcribed and analyzed using NVivo 14 software to identify key themes through coding. Quantitative survey data were analyzed using SPSS 27 to generate descriptive statistics, cross-tabulations, and statistical tests.

4 Results

The study provides a thorough analysis of three interconnected aspects. First, it presents empirical data detailing the current state of land degradation in the study area, highlighting its extent and severity. Second, it examines the effects of land degradation on smallholder agriculture, focusing on the diverse impacts on this important economic sector and the livelihoods it supports. Third, it investigates the responses and coping strategies of farmers facing land degradation, illuminating the adaptive measures taken by this key group of stakeholders.

4.1 The state of land degradation

Figure 2 provides a comprehensive spatial analysis of land degradation patterns in the Ho municipality from 2013 to 2023. The map uses a color-coded scheme to illustrate different levels of land degradation severity. Red areas indicate regions actively undergoing land degradation, while brown areas mark zones susceptible to potential degradation, necessitating monitoring and preventive measures. Yellow areas represent regions with a lower likelihood of degradation, and light green areas are deemed free from significant degradation risks. Dark green areas depict territories with robust and healthy land conditions. Table 2 presents data on land degradation across different categories for the years 2013, 2018, and 2023. In 2013, 2% (11.48 km^2) of the land was experiencing degradation, which rose to 3.6% (20.67 km^2) in 2018 and 5% (28.71 km^2) in 2023, showing a gradual increase over the years. The percentage of land prone to degradation also increased from 8% (45.94 km^2) in 2013 to 12%

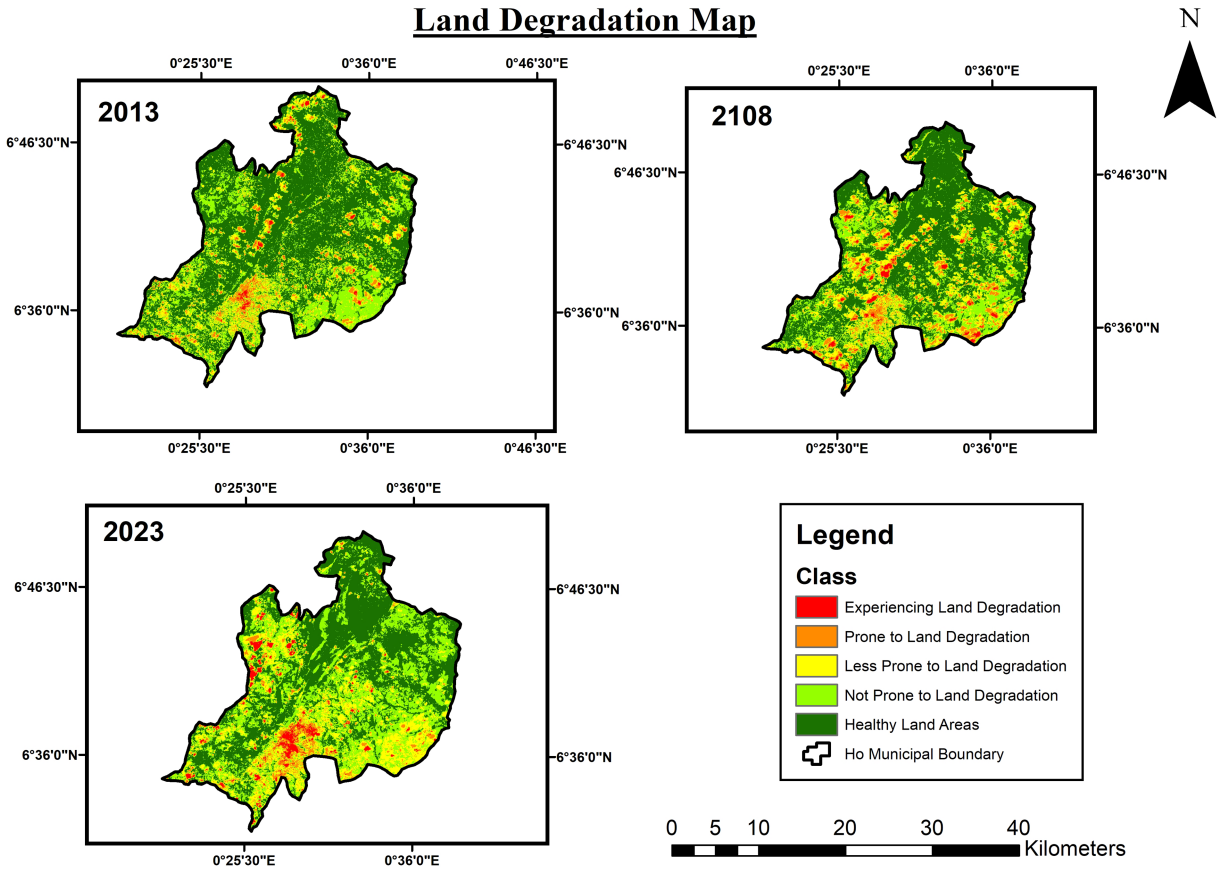

FIGURE 2
Spatiotemporal analysis of land degradation patterns and intensity across the study region during the 2013-2023 period.

TABLE 1 Characteristics of satellite images.

satellite	Date of acquisition	Spatial resolution	Paths	Rows
Landsat 8 OLI	October 13, 2013	30 m	193	055
Landsat 8 OLI	November 12, 2018	30 m	193	055
Landsat 8 OLI	November 18, 2023	30 m	193	055

Source: Authors Construct (2024).

(68.91 km^2) in 2018, and further to 15% in 2023, indicating an escalating risk.

The areas less prone to degradation remained relatively stable, with 10% (57.42 km^2) in 2013, 12% (68.91 km^2) in 2018, and 11% (63.16 km^2) in 2023. However, areas not prone to degradation decreased from 30% (172.27 km^2) in 2013 to 27% (155.04 km^2) in 2018 and 25% 143.57 km^2) in 2023. Similarly, healthy land areas declined from 50% (287.11 km^2) in 2013 to 45.4% (260.70 km^2) in 2018 and 44% (252.66 km^2) in 2023, reflecting a deterioration in overall land health. The data suggests an increasing trend in areas experiencing or at risk of land degradation, while areas considered healthy are diminishing, indicating worsening land conditions and potential environmental concerns.

Additionally, the study incorporated feedback from land users, particularly smallholder farmers. Figure 3, a pie chart, shows the distribution of their responses regarding land degradation on their farms. Responses are categorized into five levels: strongly disagree, disagree, neutral, agree, and strongly agree. The largest group, 35% (70 respondents), agreed they were experiencing land degradation, while 30% (60 respondents) strongly agreed. In contrast, 15% (30 respondents) disagreed, and 10% (20 respondents) strongly disagreed, indicating no significant degradation. The remaining 10% (20 respondents) were neutral. Overall, 65% (130 respondents) of respondents acknowledged land degradation on their farms, while 25% (50 respondents) did not perceive such processes.

To achieve a more comprehensive understanding of land degradation, qualitative data were utilized to describe the specific types of degradation observed by local farmers. A farmer in Ho reported a noticeable decline in soil moisture and fertility, along with a reduction in crop yields compared to the previous decade. Meanwhile, a farmer from Sokode emphasized the significant loss of large trees due to logging activities. Additionally, a farmer from Klefe identified several issues, including deteriorating soil fertility, heightened erosion, and decreased crop growth, all of which have culminated in poor agricultural yields.

4.2 The impact of land degradation on smallholder agriculture

Figure 4 illustrates the effects of varying levels of land degradation (LD) on crop yields. According to the graph, 18% (36) of respondents reported high levels of degradation, adversely affecting yields. Moderate degradation was experienced by 36% (72), also leading to reduced yields. Additionally, 33% (66) reported low levels of degradation, with some negative impact on crop production. Finally, 13% (26) reported neutral or no degradation, implying no significant effect on yields. The data suggests that higher degradation levels correspond to greater yield reductions, while lower levels or no degradation have fewer reported impacts on productivity.

Land degradation also significantly impacts smallholder farmers' income. The survey categorized the perceived impact into four levels: Neutral, Low, Medium, and High. According to Table 3, 16% (32) of respondents reported a neutral impact on income, 38% (76) perceived a low impact, 31% (62) experienced a medium impact, and 15% (30) reported a high impact. Overall, 46% (92) of respondents faced moderate to severe impacts on income, highlighting the diverse effects of degradation on agricultural productivity and economic well-being.

The primary cause of reduced farm revenue was decreased agricultural production and crop quality. Farmers noted that declining crop quality reduced product value, leading to lower revenue. Additionally, decreased crop output contributed to reduced income. One farmer emphasized that soil degradation had decreased both the quantity and quality of their crops, impacting revenue. Many farmers also reported increasing input use to compensate for revenue loss due to soil deterioration.

4.3 The local farm management coping strategies

The study found that smallholder farmers employed various strategies to mitigate land degradation impacts. These included mulching, cover cropping, crop rotation, manure application, compost application, and chemical fertilizer use. Table 4 details the percentages of respondents adopting these practices, with multiple responses allowed. Compost application 62.5% (125) and chemical fertilizer use 60% (120) were the most common practices. Mulching and crop rotation were adopted by 50% (100) of respondents each, while manure application was reported by 47.5%. Cover cropping had the lowest adoption rate at 37.5% (75). These practices are not mutually exclusive, and respondents often used multiple strategies to combat land degradation. The data indicates a mix of organic and inorganic approaches, with a slight preference for compost over chemical fertilizers. Survey results were consistent with information from key informant interviews. Extension officers cited mulching, crop rotation, cover cropping, manure application, chemical fertilizer use, and compost application as common practices among farmers to manage soil degradation.

4.4 The effectiveness of farm management strategies

The Figure 5 illustrates effectiveness of various farm management strategies employed by smallholder farmers to combat land degradation. These strategies include cover cropping, compost application, chemical fertilizer use, manure application, crop rotation, and mulching.

Compost application stands out as the most highly regarded strategy, with 82% (164) of respondents rating it as either "More Effective" or "Most Effective." This aligns with the study's finding that compost application was the most widely adopted practice. Chemical fertilizer and manure application are equally viewed as the second most effective strategies, both receiving "Most Effective" ratings from

TABLE 2 Land degradation statistics of Ho municipality.

Year	Experiencing land degradation	Prone to land degradation	Less prone to land degradation	Not prone to land degradation	Healthy land areas
2013	2%	8%	10%	30%	50%
2018	3.6%	12%	12%	27%	45.4%
2023	5%	15%	11%	25%	44%

Source: Authors Construct (2024).

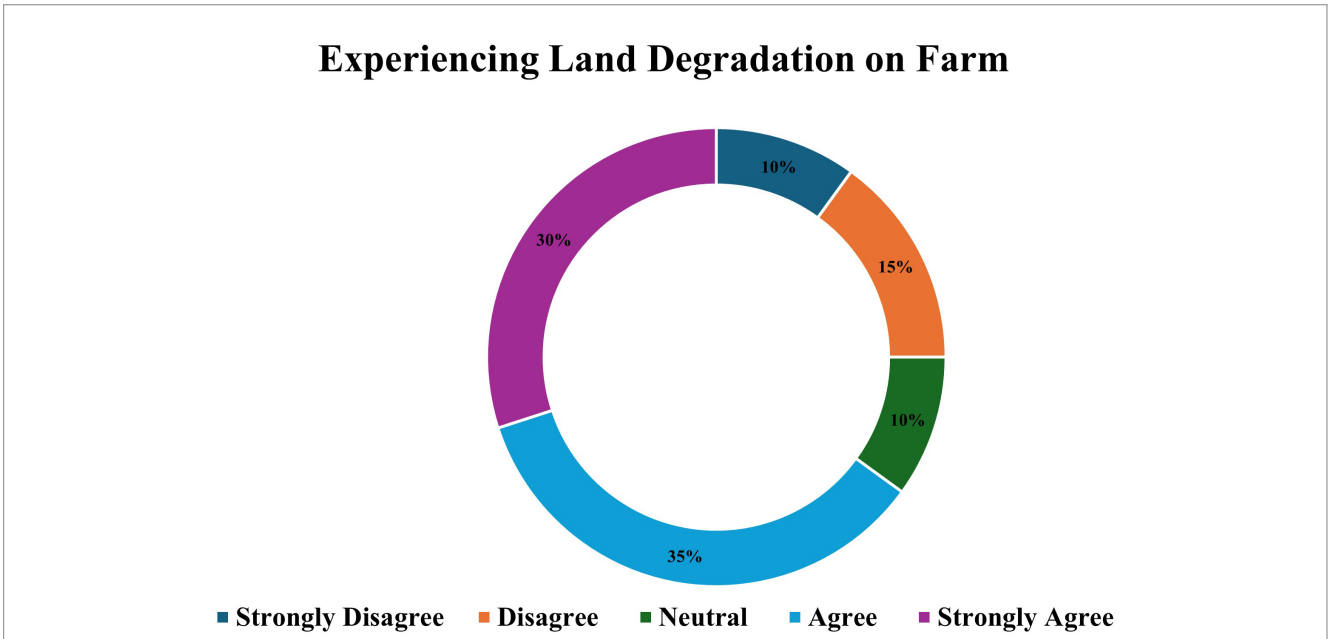

FIGURE 3
Distribution of farmers' perceptions regarding land degradation on their farms, measured on a five-point Likert scale from strongly disagree to strongly agree.

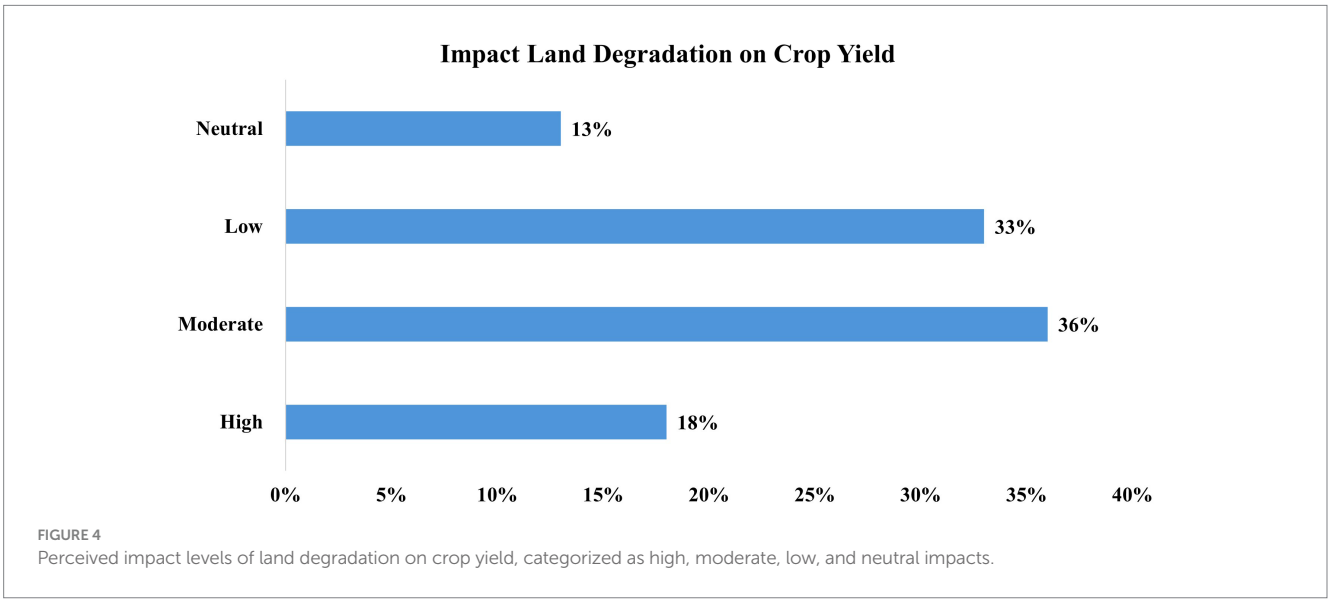

FIGURE 4
Perceived impact levels of land degradation on crop yield, categorized as high, moderate, low, and neutral impacts.

55% (110) of respondents. While crop rotation and mulching are also viewed favorably, they rank slightly lower than the top strategies. Cover cropping, although perceived as beneficial overall, is considered the least effective among the presented strategies. Nevertheless, 65% (130) of respondents still rate cover cropping as either "More Effective" or "Most Effective." The data suggests that farmers in the study area generally hold positive views towards these land management strategies, recognizing their value in mitigating the effects of land degradation on agricultural activities. The high perceived effectiveness of compost and fertilizer application particularly highlights the

TABLE 3 Impact of land degradation on farm income.

The impact of land degradation on farm income			
Neutral	Low	Medium	High
16% (32)	38% (76 respondents)	31% (62 respondents)	15% (30 respondents)

Source: Authors Construct (2024).

importance of soil fertility management in farmers' approaches to combating land degradation.

These survey results are corroborated by expert opinions gathered in the study. An experienced farmer with over 30 years in agriculture emphasized the effectiveness of mulching, cover cropping, animal waste utilization, and crop rotation, but stressed that their success depends on correct application. Similarly, a district crop officer identified cover cropping, crop rotation, manure application, and compost application as the simplest and most efficient techniques to reduce soil degradation. The officer also noted the particular usefulness of chemical fertilizer in enhancing crop output. The alignment between the survey results and expert opinions underscores the potential of these strategies to address both soil degradation and crop productivity concerns. It also highlights the importance of proper implementation to maximize the benefits of these farm management practices.

5 Discussion

This study provides valuable insights into the dynamics of land degradation and its impacts on smallholder agriculture in Ghana's Volta Region, specifically focusing on the Ho Municipality. The findings both align with and expand upon existing literature, offering a nuanced understanding of these issues in a specific African context.

5.1 Trends and impacts of land degradation

The observed increase in land degradation over time, with areas experiencing degradation rising from 2% in 2013 to 5% in 2023, corroborates broader global trends noted by researchers like Hossain et al. (2020) and Prăvălie et al. (2021). This study provides crucial localized data to complement these global assessments. The impacts on smallholder agriculture, particularly reduced crop yields and farm income, echo findings from previous research in Ghana and other African countries (Fredua, 2014; Tindan, 2015). The quantification of these impacts, with 54% of farmers reporting moderate to high levels of degradation affecting yields, offers more precise data on the scale of the problem in the Volta Region.

An interesting discrepancy emerged between remote sensing data and farmers' perceptions of land degradation. While satellite imagery analysis showed 5% of land experiencing degradation in 2023, 65% of surveyed farmers reported experiencing land degradation on their farms. This difference could be attributed to varying definitions of degradation, the scale of analysis, or farmers' heightened sensitivity to even minor changes in soil quality. This discrepancy highlights the importance of integrating both scientific measurements and local knowledge in assessing and addressing land degradation.

5.2 Coping strategies and their effectiveness

The coping strategies employed by smallholder farmers, including mulching, cover cropping, and application of compost and chemical fertilizers, reflect the range of soil conservation practices documented in previous studies (Adamtey et al., 2014; Kansanga et al., 2020). However, this study offers new insights into the relative adoption rates and perceived effectiveness of these strategies in the Ho municipality. The high adoption rates of compost application (62.5%) and chemical fertilizer use (60%) suggest that farmers are actively seeking solutions to combat land degradation.

The study's findings on the effectiveness of various farm management techniques contribute significant new knowledge. The high regard for compost application, with 82% of respondents rating it as either "More Effective" or "Most Effective," provides strong empirical support for promoting this practice in sustainable land management policies. This aligns with but also extends the findings of studies such as Bedada et al. (2014), offering more specific data on farmers' perceptions of effectiveness.

5.3 Implications for food sovereignty and climate change adaptation

The observed impacts on crop yields and farm income suggest that land degradation is not only an environmental issue but also a significant threat to food security and agricultural sustainability in the region. This aligns with broader concerns raised by researchers such as Bedada et al. (2014) and Olanipekun et al. (2019) about the links between land degradation and poverty in African contexts.

The adoption of various soil conservation practices by farmers can be seen as a form of autonomous adaptation to changing environmental conditions. This aligns with findings from researchers like Smith et al. (2020) on the co-benefits of certain agricultural practices for both climate adaptation and combating land degradation.

5.4 Methodological contributions and policy implications

From a methodological perspective, this study demonstrates the value of mixed-methods approaches in land degradation research. The combination of remote sensing analysis, quantitative surveys, and qualitative interviews provides a more comprehensive picture of the issue than any single method could offer.

The findings have important policy implications for addressing land degradation and supporting smallholder agriculture in Ghana and similar contexts. The clear trend of increasing land degradation over the past decade underscores the urgency of implementing more robust land management policies and practices. Policymakers should consider prioritizing support for the most effective and widely adopted strategies identified in this study, particularly compost application and judicious use of chemical fertilizers.

Furthermore, the study suggests a need for a multi-faceted approach to addressing land degradation. This could include strengthening land tenure systems, developing targeted financial incentives for soil conservation practices, enhancing agricultural extension services,

TABLE 4 Tabulation of farm practices used to mitigate the effect of land degradation.

Mulching	Cover cropping	Crop rotation	Manure application	Compost application	Chemical fertilizer application
50% (100 respondents)	37.5% (75 respondents)	50% (100 respondents)	47.5% (95 respondents)	62.5 (125 respondents)	60% (120 respondents)

*Multiple response table. Source: Authors Construct (2024).

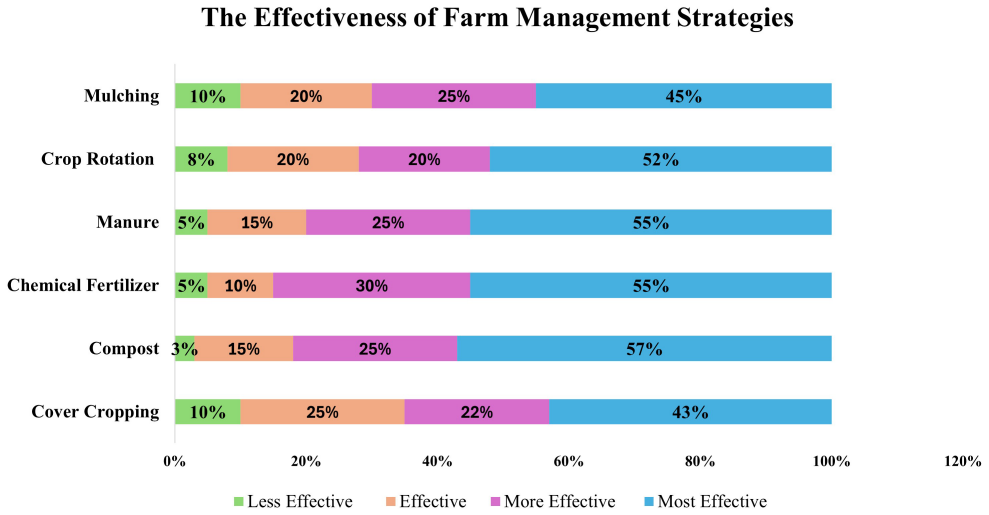

FIGURE 5
Comparative effectiveness of six farm management strategies (cover cropping, compost, chemical fertilizer, manure, crop rotation, and mulching) in addressing land degradation, rated from less effective to most effective.

investing in infrastructure and technology to support sustainable intensification, and promoting diversification of rural livelihoods.

5.5 Long-term sustainability and future research directions

The research raises important questions about the long-term sustainability of current farming practices in the face of increasing land degradation. While farmers are adopting various coping strategies, the continuing trend of degradation suggests that these measures may not be sufficient to fully address the problem. This points to the need for more transformative approaches to agriculture in the region, potentially including landscape-level interventions, changes in crop selection, or the adoption of agroforestry systems.

Future research could explore the potential of these more transformative approaches, as well as investigate the long-term effectiveness of current coping strategies. Additionally, comparative studies across different regions of Ghana or West Africa could help identify broader patterns and region-specific challenges in combating land degradation.

In summary, this study makes a significant contribution to our understanding of land degradation dynamics in Ghana's Volta Region and their implications for smallholder agriculture and food sovereignty. By providing a detailed, localized analysis of degradation trends, impacts, and farmer responses, it offers valuable insights for policymakers, researchers, and practitioners working to promote sustainable land management and agricultural development in Ghana and beyond. The findings underscore the urgent need for integrated, context-specific approaches to combating land degradation while supporting the livelihoods and food security of smallholder farmers.

6 Conclusion

This research has provided valuable insights into the complex dynamics of land degradation and its impacts on smallholder agriculture and food sovereignty in Ghana's Volta Region, specifically focusing on the Ho Municipality. The study employed a mixed-methods approach, combining remote sensing analysis, quantitative surveys, and qualitative interviews to offer a multifaceted perspective on the issue.

Key findings from the study include:

i A concerning trend of increasing land degradation in the study area, with the percentage of land experiencing degradation rising from 2% in 2013 to 5% in 2023, and areas prone to degradation increasing from 8 to 15% over the same period.
ii A significant impact of land degradation on crop yields and farm income, with 87% of surveyed farmers reporting some level of negative impact on their crop production.
iii The adoption of various coping strategies by smallholder farmers, with compost application (62.5%) and chemical fertilizer use (60%) being the most prevalent practices.
iv A discrepancy between scientific measurements and farmers' perceptions of land degradation, highlighting the importance of integrating local knowledge with technical assessments.
v The effectiveness of different farm management techniques, with compost application being perceived as the most effective strategy by farmers.

These findings underscore the urgent need for targeted interventions to address land degradation in the region. The study reveals that while farmers are adopting various coping strategies, the continuing trend of degradation suggests that current measures may not be sufficient to fully address the problem.

The research contributes significantly to the existing literature by providing a detailed, localized analysis of land degradation dynamics and their implications for smallholder agriculture and food sovereignty. It offers valuable insights for policymakers, researchers, and practitioners working to promote sustainable land management and agricultural development in Ghana and beyond.

Moving forward, the study suggests several key areas for action:

a. The development of integrated, context-specific approaches to combating land degradation while supporting the livelihoods and food security of smallholder farmers.
b. Strengthening agricultural extension services to provide more comprehensive support for sustainable land management practices.
c. Investing in infrastructure and technology to support sustainable intensification of agriculture and reduce pressure on marginal lands.
d. Promoting diversification of rural livelihoods to reduce overreliance on degraded agricultural lands.
e. Enhancing policies that encourage long-term investments in soil conservation and sustainable land management.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AT: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. GK: Conceptualization, Data curation, Formal analysis, Supervision, Writing – original draft, Writing – review & editing. AK: Writing – original draft, Writing – review & editing. MT: Conceptualization, Data curation, Formal analysis, Methodology, Investigation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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