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Nepalese farmers’ perceptions of nitrogen inputs and attitudes to soil management: Implications for soil health and environmentally sustainable farming

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A R T I C L E   I N F O

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A B S T R A C T

Across Nepal, there is a decline in soil health. Thus, soils in Nepal require effective management to ensure its sustainability. The success of these strategies is contingent upon understanding farmers’ perceptions, opinions, and attitudes towards maintaining soil health. This paper investigates the current soil management practices, farmers’ perceptions of soil nutrient use in relation to soil fertility, yield, and environmental impact, attitudes to soil management, and how these differ by personal and economic characteristics. The result is based on a survey of 300 Nepalese farmers. The findings are that there is a prevalence of practices such as puddling, deep tillage, and broadcasting without incorporation. Over 60% of farmers do not consciously consider the weather or environmental impact in soil management decisions. Financial returns are a significant motivating factor for changing current soil and crop management practices for many farmers. Further, the results highlight a perception amongst a larger proportion of farmers that compared to synthetic fertiliser; manure enhances soil fertility, increases crop yield, and does less harm to biodiversity. The potential for overuse and environmental pollution from misperception around manure are supported by the findings in this paper. The regression results indicate that farmers who perceive different nitrogen inputs as increasing yield, the quality of the harvest, or harming the soil, and those who manage their soil depending on the weather with considerations for the environment tend to use less nitrogen inputs. The paper highlights aspects of farming practices, opinions, and attitudes that can be improved to maintain healthy soils.

Introduction

Soil serves as a fundamental component of ecosystems, supporting plant growth, nutrient cycling, and water filtration (Briones, 2014; Jónsson and Davíðsdóttir, 2016; Rabot et al., 2018). Despite its importance, approximately one-fifth of soil resources (around 2 billion hectares) of the total cropland, pasture, forest, and woodland worldwide is degraded (Jie et al., 2002). Various practices linked to intensive agriculture, cropping system with low ecological or environmental considerations, poor land-use management, and unbalanced nutrient management are recurring factors that exacerbate the decline in soil health (Yang et al., 2020; Waqas et al., 2020; Crow et al., 2023).

Unsustainable cropping systems, e.g., cultivation practices such as conventional tillage, deforestation, continuous monocropping, insufficient crop rotation, inadequate organic matter management, excessive pesticide use, overgrazing and poor water management, have contributed to soil degradation, erosion, loss of soil fertility, and the degradation of soils worldwide (Karlen and Rice, 2015; Shrestha et al., 2018). The decline in soil quality poses a significant threat to biodiversity, ecosystem functioning, food production and food security in many regions globally (Vista and Adhikari, 2015; Cook et al., 2016; Tripathi et al., 2022).

Further, over the last five decades, there has been an increased reliance on nitrogen-containing organic and inorganic fertilisers to provide nitrogen to the soil for crop growth (Almaz et al., 2017; Aryal et al., 2021). However, nitrogen pollution from agricultural activities has emerged as a significant environmental concern. This is because the unbalanced use of nitrogen poses a threat to soil quality. For example,
under certain conditions, excess nitrogen alters populations of soil organisms (Veithof et al., 2011). Also, the extended use of fertilisers containing ammonium is reported to cause soil acidification (Goulding, 2016; Gu et al., 2021). Further, there is the contention that overuse of synthetic nitrogen fertiliser results in a decline in soil carbon and negatively impacts soil organic matter content (Mulvaney et al., 2009). This is aside the evidence that nitrogen losses have significant negative effects such as eutrophication of water bodies, harmful algal blooms and disruptions in nutrient cycles (Wurtsbaugh et al., 2019; Morseletto, 2019).

In order to improve soil health, there is a need for urgent sustainable soil management. Sustainable soil management refers to the practice of using techniques and strategies that maintain or improve soil health while minimising negative environmental impacts. It involves adopting approaches that support long-term soil productivity, fertility, and overall ecosystem functioning. The goal is to ensure the long-term sustainability of soil resources for agricultural production, ecosystem health, and food security while preserving the environment. Examples of sustainable soil management practices include minimising soil erosion, promoting organic matter content, enhancing soil nutrient cycling, conserving water resources and using appropriate soil conservation measures. However, implementing sustainable soil management requires improving farmers’ knowledge of soil characteristics, crop requirements, and appropriate organic and inorganic fertiliser application methods. Further, modifying agricultural practices to minimize nitrogen loss, such as improving manure management, balanced fertiliser application, organic matter incorporation or site-specific nutrient management, all presents challenges to many existing farming practices. Notably, changing negative opinions, perceptions, and attitudes have been shown in a different context to shape farmers’ behaviour and decision-making processes. We expand on this aspect further in the paper. It is worthy to note that perception in this context refers to individuals’ cognitive interpretation and understanding of soil-related information, while attitude refers to the predisposition or evaluation individuals hold towards soil management practices. Further, attitude reflects individuals’ evaluations, beliefs, and values related to soil management practices. It encompasses preferences and intentions that shape behaviour and decision-making. There is still a lack of research on how farmers’ opinions, perceptions and attitudes are associated with current and future soil management actions. Besides, the precision in identifying barriers and motivations for adopting sustainable soil management practices is limited.

This paper contends that soil requires effective management strategies to ensure its long-term productivity and sustainability, and the success of these strategies is primarily contingent upon the farmers’ motivations and attitudes. Thus, addressing the concerns of agricultural soil fertility in Nepal requires examining and understanding farmers’ perceptions, opinions, attitudes and behaviours regarding fertiliser and manure balanced use, handling, and management to improve the status quo. Further, the findings of this paper will be relevant and interesting to other developing countries which are geographically and economically similar to Nepal. A better understanding of farmers’ perspectives on soil health which the paper contributes to, is essential for designing, implementing and optimising strategies aimed at soil security.

Thus, the objectives of this paper are to investigate the current soil current soil management practices, farmers’ perceptions of soil nutrient use in relation to soil fertility, yield, and environmental impact, attitudes to soil management, and how these differ by personal and economic characteristics.

**Background**

**Nepal: the case for an urgent need to shift to sustainable use of soils**

In nearly every region of Nepal, land degradation stands as a significant environmental concern (Chalise et al., 2019). Specifically, there is a notable decline in the quality and productivity of land in terms of soil fertility (Rawal et al., 2018; Tripathi et al., 2022). The decrease in soil fertility across Nepal is partly attributed to a combination of natural and human-induced factors. However, soil fertility status differs across various agroecological zones in Nepal, with soils in the Terai (plains) being relatively worst off in terms of fertility levels compared to the hills and mountains (Tripathi et al., 2022). According to MOAD (2017), the quantity of soil nutrients lost each year in Nepal is about 310 kg ha$^{-1}$ in contrast to 67 kg ha$^{-1}$ of fertiliser that is added to the soil. Approximately 1.8 million tons of plant nutrients are depleted from farmland, with crop harvesting accounting for 0.5 million tons, while soil erosion contributes to a loss of 1.3 million tons (Ministry of Population and Environment, 2004; Karma and Bauer, 2020). In addition, in numerous areas in Nepal, the organic matter content of the soils has declined substantially, from the ideal range of 4–5 percent to below 2 percent (Cook et al., 2016).

Cereal-based farming systems mostly drive human-induced losses. For example, Kharal et al. (2018) found that the soil health of the land used for traditional mixed cereal-based farming was comparatively poorer when contrasted to that of the nearby soils where vegetable was grown or grazing and forest land. In rice cultivation (one of the most important cereal crops in Nepal), the nutrients that were most constrained in Nepal are nitrogen and potassium (Regmi et al., 2002; Shrestha et al., 2017; Mandal et al., 2021). While there are concerns on the one hand that only 0.3 million tons of plant nutrients are restored through the application of organic and mineral fertilisers, on the other hand, there is also evidence that the heavy reliance and poor management of chemical and organic fertilisers, particularly amongst larger farms in Nepal, results in the deterioration of soil health (Khaddka et al., 2008).

Similar to most countries in Asia, Nepal’s rice cultivation relies on irrigation which is mostly farmer-managed irrigation systems (Pradan, 2000). However, the lack of appropriate soil and water conservation measures in cohesion with unsuitable agricultural practices results in soil erosion in cultivated lands (Minelli, 2016).

Based on these concerns, various initiatives have recently been launched in Nepal aimed at reversing the decline in soil fertility. For example, the Nepalese government has set a goal of raising the soil organic matter level from its present state (1.9 percent) to 4 percent by 2035 (MoAD, 2014; Gairhe et al., 2021). In addition, the government of Nepal has also enabled the policy environment to promote the utilisation of organic fertilisers (Cook et al., 2016). However, a top-down approach to addressing such problems has its limitations. Combining solutions from a bottom-up approach would contribute to better meeting these goals, hence the relevance of this study.

**The role of perceptions and attitudes in the adoption of best soil management practices**

Ajzen (1991) introduced a psychological framework that helps understand and predict human behaviour, particularly in relation to goal-directed actions, known as the theory of planned behaviour (TPB). According to TPB, an individual’s intention to engage in a specific behaviour is influenced by three primary factors, i.e., attitudes, subjective norms, and perceived behavioural control. Specifically, a favourable attitude fosters the motivation to engage in the behaviour (Ajzen, 2020). The TPB has successfully explained and predicted farmers’ behaviour in different contexts.

Drawing from the TPB and other theories, there is evidence from global studies suggesting that the decision to adopt a new technology or practice is influenced by intrinsic factors, including perceptions and attitudes towards innovation. For example, the adoption of agroforestry (Meijer et al., 2015), adoption of climate risk management practices (Mase et al., 2017), farmers’ intention to adopt nutrient management planning (Daxini et al., 2018) or various other sustainable agricultural practices (Zeweld et al., 2017). Previous studies have also shown that...
perception and attitude significantly influence various farm decision-making processes (e.g., Assefa et al., 2016; Zewelde et al., 2017; Ntshangase et al., 2018; Bolfe et al., 2020). Thus, a positive attitude to soil conservation and minimising the impact of human activities on the soil and positive perceptions of soil management are likely to motivate farmers to prioritise soil health in their decision-making. Conversely, negative or uninformed perceptions may hinder the adoption of sustainable practices and exacerbate a decline in soil health. Notably, perceptions are influenced by factors such as cognitive biases such as confirmation bias favouring information that confirms existing beliefs or availability bias (relying on easily accessible information), personal experiences, social and cultural factors, and the availability of information, some of which we do not account for in this paper.

Besides perceptions and attitudes, several studies have found that farmers with limited access to education and information have a narrower understanding of soil management practices. Similarly, the perceived risks and benefits of implementing new technologies practices have been shown to influence adoption decisions (Vignola et al., 2010; Habtemariam et al., 2016; Li et al., 2020; Mwaura et al., 2021). For instance, if farmers believe adopting sustainable practices will increase yields or reduce input costs in the long run, they may develop more positive attitudes towards such practices.

Methods

Sampling and data collection

Prior to data collection, an exclusion/inclusion criterion was used to sample only farmers that had land that was either owned or rented for farming in the last season, grew at least one of cereal crops, i.e., rice or wheat, were 18 years or older, and were directly involved in any decisions in relation to farming activities ranging from land preparation to harvesting in the last season. Only respondents that met these criteria in the sample frame were placed in a “new frame” from which the final sample participants for the study was drawn. The survey study was conducted in the Terai region of Nepal, which, although densely populated, accounts for the major agricultural activities within the country. Compared to the farming system in the hill and mountains, which are mainly integrated crop-livestock-tree based agroforestry systems with limited N inputs, in Terai, rice is grown predominantly with wheat, maize and pulses in rotation thus exposing the soil to a greater risk of soil nutrient loss and soil degradation from crop intensification. Data were obtained via multistage sampling from three provinces (Koshi Province (Morang district), Madhesh Province (Mahottari district) and Far Western Province (Kailali district)). Four villages were randomly selected from each district, and 25 farming households were randomly chosen within each village. In total, 100 farmers were included from each district, resulting in a total of 300 farmers. A structured questionnaire was used to collect data on household characteristics, farm characteristics, synthetic and organic fertilizer use, as well as attitudes, behaviours, perceptions, and opinions. Several questions related to the attitudes, behaviours, perceptions, and opinions were Likert-type. Thus, individual questions were considered as measurement tools.

Data analysis

Data analysis techniques, including descriptive statistics, were applied to derive meaningful insights from the collected data. Kendall’s tau-b and a rank-biserial correlation were used to measure the strength and direction of association between attitudes to soil and crop management and selected personal and economic characteristics. Multiple regression was estimated to examine the relationship between the continuous dependent variables and multiple predictors. The dependent variables were the quantity of urea, DAP and manure used. The predictors included perceptions of nitrogen input, attitudes to soil and environment, and farm or farmer-related factors. However, since there is reason to postulate that the error terms for the urea, DAP, and manure equations could be correlated due to these inputs being related, a seemingly unrelated regression (SUR) model was estimated.

Results

Farmer and farm characteristics

The average age of farmers in the sample is 49 years (SD= 12.9). 86% are male, while 14% are female. 92% reported being the heads of the household. On average, the respondents completed 5.2 years (SD= 4.7) of formal schooling. The average years of farming experience is 29.1 years (SD=14.9). The farm sizes are relatively small, averaging 0.9 hectares per household. 81.5% reported crop farming as the household’s main income source. 84.3% owned at least one of the plots on which they grew crops. Widely used fertilisers are the nitrogen fertilisers such as urea and di-ammonium phosphate (DAP) (Fig. 1). Livestock grazing plot before cultivation is the major source of manure for crops. Only 14.8% completed within the last five years vocational/professional agricultural training. Besides this tailored training, most (98.8%) farmers had not attended any crop demonstrations or training on fertiliser and manure use in the last two years.

Soil management practices of Nepalese cereal farmers

Regarding soil cultivation methods, a significant majority (98.5%) of farmers reported employing deep tillage to facilitate soil aeration, weed control, and incorporation of organic matter. The findings also indicated that broadcasting fertiliser was the most common application method, with 92.3% of farmers employing this technique. In contrast, a smaller percentage of farmers (35.8%) broadcasted manure, with more than half (59.9%) incorporating manure into the soil immediately after broadcasting. Of the 300 respondents, 90.9% indicated that they did not consider the amount of synthetic fertiliser applied before using manure. Except for two farmers, others puddle the field before direct seeding or transplanting rice. Regarding what farmers did with their crop residues after harvest, 40.7% were left on the field to be used as mulch, while 31.3% incorporated residue into the soil. 63.4% reported that when they use agricultural guidance or tools for fertilisation (e.g., amount to be used, timing), they do not follow the advice exactly but modify it.

Attitudes to soil management

As shown in Fig. 2, about one-third of farmers strongly agree or agree that how they manage their soil depends on the weather. A similar proportion expressed uncertainty, indicating that they may or may not consciously consider the weather in their decision-making processes. In contrast, 10% strongly agree, and 21% agree that they consider the environment when dealing with their soil. About 66% strongly agree or agree that the nutrition requirement of crops drives the decision they make with respect to the soil. 42% strongly agree, and 14% agree reported financial returns as the only condition that would motivate them to change their soil and crop management practices. 59.8% strongly agree or agree that they frequently try new things to improve their crops and soil, with a similar proportion avoiding change that involves any risk in the process.

Relationship between attitudes to soil and crop management and selected personal and economic characteristics

As presented in Table 1, a rank-biserial correlation (rrb) was estimated to determine the relationship between agricultural training and attitudes towards soil management. There was a statistically significant albeit very weak positive correlation between agricultural training and managing soil depending on the weather (rrb = 0.135, p = .029) and agricultural training and consideration for the environment in managing
In contrast, there was a statistically significant moderate negative correlation between agricultural training and the tendency to avoid taking risks associated with trying new soil and crop management practices ($r_{rb} = 0.436, p < 0.001$), i.e., having agricultural training and changes in the levels of agreement (e.g., from strongly agree to strongly disagree) of avoiding risks associated with trying new soil and crop management practices move in opposite directions.

In addition, the rank-biserial correlation estimated to determine the association between crop farming as the main income source and attitudes towards soil management showed a statistically significant positive but weak correlation between crop farming as the main income and managing soil depending on the weather ($r_{rb} = 0.332, p < 0.001$). Further, the direction of the association indicates that relying on crop farming as the main income source and changes in the levels of agreement (e.g., from strongly agree to strongly disagree) to managing soil depending on the weather moves in the same direction. While this finding appears counterintuitive, it is important to note that these relationships are correlational. Thus, further research is needed to establish any causal relationship. Also, a very weak positive correlation is observed between farming as the main income and consideration for the environment in managing soil ($r_{rb} = 0.176, p = 0.034$) and crop farming as the main income and potential for change in soil management solely to improve their financial situation ($r_{rb} = 0.115, p = 0.013$) on the other hand.

Farmers’ perceptions of manure and fertiliser use in relation to soil fertility, yield, and environmental impact

The results of farmers’ perceptions of fertiliser and manure are presented in Fig. 3. Compared to fertiliser, a greater proportion perceives manure to enhance soil fertility and increase yield and quality of harvest. However, there is the perception that the more manure applied, the better, and that runoff with manure is less polluting to water bodies. On the other hand, farmers perceived that different types of fertiliser produce the same benefit; fertiliser is more harmful to biodiversity compared to manure and has a higher risk of resulting in illness if it contaminates food (Fig. 3).

Multiple regression analysis was used to test if perceptions of nitrogen input, attitudes to soil and environment and farm or farmer-related factors significantly predicted the quantity of inorganic (synthetic fertiliser i.e., urea and DAP) and organic (manure) inputs used by farmers (Table 2). The results of the regression indicated that there was a collective significant effect between the predictors for all three models ($F(18, 214) = 2.58, p < .001$), ($F(18, 214) = 1.54, 0.078$), ($F(18, 240) = 2.88, p < .001$). An examination of the individual predictors indicated that, on average, farmers who perceive fertiliser increases yield, the quality of harvest or harms the soil, and those farmers who manage their soil depending on the weather tend to use less urea (kgN/ha). Similarly, farmers who manage their soil depending on the weather and those who perceive risks associated with trying new soil and crop management practices tend to use less DAP (kgN/ha). As for manure use, farmers whose perceptions are that fertiliser increases yield and manages their
Soil while paying attention to the environment tend to use less manure (kg/ha). There is also evidence that fertiliser subsidies decrease the quantity of DAP (kgN/ha) and manure (kg/ha) used by farmers. Following the assumption that the quantity of N input from inorganic and organic fertilisers are related and that their error terms might correlate, a Seemingly Unrelated Regression (SUR) was estimated. The result of the SUR regression presented in Table A1 in the appendix shows that the correlation of the residuals in the urea (kgN/ha) and DAP (kgN/ha) equations is 0.312, and that of the urea (kgN/ha) and manure (kgN/ha) equations is 0.939. Thus, the hypothesis that the correlation is zero is rejected. The results for the determinants of the quantity of DAP (kgN/ha) from the regression analyses in Tables 2 and A1 are similar. As for the determinants of the quantity of urea (kgN/ha), the results in Table A1 indicate that farmers who manage their soil depending on the weather and consider the nutrition requirement of crops when dealing with the soil tend to use less urea (kgN/ha). Similarly, for manure use, farmers that manage their soil depending on the weather and consider the nutrition requirement of crops and those who perceive risks associated with trying new soil and crop management practices tend to use less manure (kg/ha).

**Discussion**

The prevalence of puddling, deep tillage and broadcasting without incorporation have implications for soil health and the environment. Previous studies (e.g., Bartaula et al., 2020; Kalita et al., 2020) have shown that such practices can have a negative impact on soil physical conditions and yield and lead to increased soil erosion and nutrient loss.

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**Table 1**

<table>
<thead>
<tr>
<th>Attitudes proxies</th>
<th>Median&lt;sup&gt;5&lt;/sup&gt;</th>
<th>Agricultural training</th>
<th>Main income from crops</th>
<th>Formal education</th>
<th>Farming experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>How I manage my soil is dependent on the weather</td>
<td>Unsure</td>
<td>0.135&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.332&lt;sup&gt;3&lt;/sup&gt;</td>
<td>–0.044</td>
<td>0.014</td>
</tr>
<tr>
<td>When dealing with my soil I think about the environment</td>
<td>Unsure</td>
<td>0.091&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.176&lt;sup&gt;3&lt;/sup&gt;</td>
<td>–0.042</td>
<td>0.035</td>
</tr>
<tr>
<td>When dealing with my soil I think about the nutrition requirement of crops</td>
<td>Agree</td>
<td>0.139</td>
<td>0.103</td>
<td>0.061</td>
<td>0.090</td>
</tr>
</tbody>
</table>

**Openness to changes beneficial to the soil**

| I frequently try new things to improve my crops and soil | Agree               | –0.049               | –0.034              | 0.075           | 0.115<sup>3</sup> |
| I try to avoid taking risks that is associated with trying new soil and crop management practices | Agree               | –0.436<sup>3</sup>   | –0.171              | –0.076          | –0.072             |
| I would only change my soil and crop management practices if I was sure that my financial situation improves because of the change | Agree               | –0.270               | 0.210<sup>3</sup>    | 0.075           | 0.131<sup>3</sup>  |

<sup>3</sup> Median values on Five-point Likert type scale (1 = Strongly agree to 5 = Strongly disagree).

<sup>4</sup> significant at 5%.
if not managed properly. Similarly, although a simple and cost-effective method, broadcasting may result in uneven nutrient distribution and potential nutrient runoff. Notably, alternative methods such as incorporation may be more beneficial for minimising nutrient losses, and it normally requires additional labour and equipment. These findings highlight practices that should be targeted for improvement or change to sustainably improve soil fertility nutrients and lower environmental impacts from poor soil management.

The findings revealed that most respondents do not consider the amount of synthetic fertiliser they have already applied, which suggests a potential for nutrient overuse with implications for the soil, crop and environment. This aligns with the findings of Aryal et al. (2021), which highlight the imbalanced application of organic and inorganic fertilisers in the region. The findings highlight the need to explore the underlying
reasons and implications of such practices and avenues to ensure farmers balance synthetic and organic inputs and maintain soil health while minimising environmental impacts. Further, the majority of farmers reported that when they use agricultural guidance or tools for fertilisation, they do not follow the advice exactly, i.e., they modify it. On the one hand, this could be beneficial where a blanket recommendation is given, and farmers modify this for site-specific applications. This has benefits for crop nitrogen use efficiency as highlighted in Pandit et al. (2022). However, on the other hand, it could result in overapplication or soil nutrient mining when such modification is arbitrary.

There are advantages to the prevalence of manure deposition from grazing on the field, as solid waste and urine are deposited in the soil. The latter is important as it has been identified as one of the ways in which nitrogen from manure is often lost to the environment. However, the quantity applied to the soil through direct grazing would be more difficult to regulate. Thus, it is more likely to be prone to under or over-application compared to manure that is purposefully applied by the farmer. This finding also provides evidence that could support Challise et al. (2019) that grazing is widespread and contributes to soil degradation in Nepal. Also, the finding that a higher proportion of farmers perceived manure to have positive effects on soil fertility, as well as increased yield and quality of the harvest, compared to fertilisers suggests that manure is generally regarded as a beneficial input for agriculture. Interestingly, there was a prevailing perception amongst farmers that increasing the application of manure would increasingly lead to better outcomes. These perceptions have important implications, as they indicate a potential for overuse of manure and the associated risk of environmental pollution from farms relying heavily on manure.

The relatively lower prioritisation of environmental considerations implies that for small farmers, public goods such as environmental quality may not evoke strong motivation to use soil more sustainably. In addition, the results also highlight that weather considerations may not be consciously factored in by many farmers when managing their soil, given the substantial proportion that expressed uncertainty about depending on the weather when managing their soil. These findings indicate that there is the need to nudge positive inclination towards environmentally conscious practices as accounting for and recognising the impact of better attitudes towards the environment is a crucial step towards sustainable soil management and ecosystem preservation.

The finding that financial return was the single most important motivating factor that would drive farmers to change their soil and crop management practices underscores the strong influence of economic factors on farmers’ decision-making processes. While it is important to acknowledge the economic aspect of farming, this finding raises concerns about the potential trade-offs between financial gains and sustainable soil management practices. In line with Tiwari et al. (2008), we suggest further promoting a balanced approach that encompasses financial viability and environmental sustainability.

Exploring the relationships between agricultural training, crop farming as the main income source, farming experiences, and attitudes towards soil management indicates several statistically significant, albeit mostly weak correlations between these variables. For the moderately correlated relationships, there is an inverse relationship between agricultural training and avoiding the risk associated with trying new soil and crop management practices. In other words, training will likely increase trying new soil and crop management practices. If a causal relationship exists (as reported in Paudel & Thapa (2004); Tiwari et al. (2008); Rai et al. (2020)), then training may be used to break down the barrier in the perceived risk associated with adopting sustainable soil management practices. By providing farmers with training opportunities, policymakers can empower them to make informed decisions towards managing and improving soil health.

The finding that crop farming as the main income source is correlated with lower levels of agreement in prioritising weather soil management could be explained from several perspectives. First, it could be contended that small-scale farmers without alternative income, particularly from off-farm sources, may lack access to technologies, resources, and information, making it challenging to incorporate weather considerations into their decision-making process. This postulation aligns with the findings of Dhakal & Rai (2020). There may also be a lack of awareness or information regarding the connection between weather and soil management amongst individuals relying on crop farming. Thus, such farmers may not fully understand the potential consequences of disregarding weather conditions on their soil health or the long-term sustainability of their farming practices. Crucially, the results show the effect of farmers’ perceptions, opinions and attitudes regarding fertiliser and manure on the use of nitrogen inputs. This again underscores the importance of information and training so that farmers can have a balanced perception of the benefits and risks associated with nitrogen inputs would increase the likelihood of adopting sustainable soil management practices.

It is important to acknowledge the limitations of this paper. The findings are based on self-reported data, which may be subject to response biases. Future research could consider incorporating observational and objective measures to validate self-reported attitudes towards soil management. Additionally, this paper focused on farmers’ perceptions, opinions and attitudes towards soil management. Future research could explore other factors, such as access to resources, technological advancements, and social networks, to provide a more comprehensive understanding of the factors influencing soil management practices.

Implications for soil health and the environment

Farmers’ perceptions and attitudes influence their soil management practices and directly impact soil health. The results in this study bring to the fore a heterogenous level of perception of nitrogen inputs and attitudes to the soil and the environment by Nepalese farmers. Thus, while some farmers translate this into preserving soil health, others do not. Negative attitudes towards soil sustainability, or the perception that soil is a limitless resource and health is less important, can contribute to practices that degrade soil health. The findings in this paper also show that there is misinformation amongst some farmers about soil management techniques, which could result in unsustainable practices.

Amongst Nepalese farmers, the prevalence of practices such as deep tillage may be a contributory factor to human-induced soil degradation. There is evidence that compared to reduced or zero tillage, it is more likely that soils that are deep-tilled have less capacity to preserve soil structure, promote water infiltration, and reduce erosion risks. Therefore, changing such practices makes it possible to enhance soil health, improve crop yield, and avoid the environmental impact of the current farming practices.

Poor management of soils has a significant economic and social impact. For example, studies suggest it reduces crop yields and lower farm profitability. This may drive farmers to increase their reliance on inorganic and organic fertilisers, thus, resulting in increased production costs and the potential for a further decline in soil health from nutrient imbalance and environmental pollution from nitrogen compounds such as ammonia and nitrous oxide. In the broader context, soil resilience to environmental stresses is reduced, and the production of healthy food and long-term food security is threatened as achieving these relies fundamentally on healthy soil.

Conclusion

Effective soil and crop management practices are crucial for sustainable agriculture. Understanding the factors influencing farmers’ decision-making can provide valuable insights for designing targeted interventions and promoting sustainable agricultural practices. The prevalence of a lack of consideration for previous synthetic fertiliser applications before using manure calls attention to the need for awareness. Similarly, the prevalence of deep tillage and broadcasting as
common practices also need careful management to mitigate potential soil and environmental impacts. This study also provides valuable insights into the perspectives of farmers regarding the management of nitrogen inputs and their attitudes to soil management. The results highlight the importance of financial returns in shaping farmers’ decisions while also indicating potential areas for improvement in terms of considerations for weather conditions and environmental factors. Further, the views regarding the perceived benefits and risks of fertilisers and manure highlight the need for awareness to promote sustainable use.

Policymakers, agricultural extension services, and researchers can utilise these findings to develop targeted interventions to prevent potential negative consequences on soil health. One way of achieving this change could be through awareness campaigns and economic incentives. Specifically, promoting the benefits of sustainable soil management, publicising examples of successful outcomes, and providing farmers with technical support can help shift attitudes towards more environmentally friendly practices. Also, ensuring farmers have access to participate in research and demonstration farms and knowledge-sharing networks can also contribute to changing perceptions and fostering sustainable soil management practices.

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**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Data availability**

Data will be made available on request.

## Appendix

### Table A1

Seemingly Unrelated Regression estimates of the determinants of the quantity of nitrogen input (inorganic and organic fertilisers).

<table>
<thead>
<tr>
<th>Perception of nitrogen input</th>
<th>Urea (kgN/ha)</th>
<th>DAP (kgN/ha)</th>
<th>(Livestock manure kg/ha)&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhances soil fertility</td>
<td>0.002</td>
<td>0.022</td>
<td>0.082</td>
</tr>
<tr>
<td>Increase quality of harvest</td>
<td>−0.011</td>
<td>0.013</td>
<td>−0.005</td>
</tr>
<tr>
<td>Increases yield</td>
<td>−0.014</td>
<td>0.016</td>
<td>0.005</td>
</tr>
<tr>
<td>Runoff does not pollute water bodies</td>
<td>−0.007</td>
<td>0.024</td>
<td>0.039</td>
</tr>
<tr>
<td>Harms soil organisms/other living organisms on and around my farm</td>
<td>−0.007</td>
<td>0.009</td>
<td>−0.007</td>
</tr>
<tr>
<td>Different types provide the same benefits to the crops</td>
<td>0.004</td>
<td>0.011</td>
<td>0.002</td>
</tr>
<tr>
<td>Increasing the amount is always advantageous to my crop</td>
<td>0.008</td>
<td>0.013</td>
<td>0.017</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitudes to soil and environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>How I manage my soil is dependent on the weather</td>
</tr>
<tr>
<td>When dealing with my soil I think about the environment</td>
</tr>
<tr>
<td>When dealing with my soil I think about the nutrition requirement of crops</td>
</tr>
<tr>
<td>I frequently try new things to improve my crops and soil</td>
</tr>
<tr>
<td>I try to avoid taking risks that is associated with trying new soil and crop management practices</td>
</tr>
<tr>
<td>I would only change my soil and crop management practices if I was sure that my financial situation improves because of the change</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other farm/farmer related factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Synthetic fertiliser subsidy</td>
</tr>
<tr>
<td>Keep livestock</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
</tbody>
</table>

Breusch-Pagan test of independence: $\chi^2(3) = 225.777$, Pr = 0.001.

**p < .01, **p < .05, *p < .1.

**References**


