

Investigating wildlife crop pests and farmers' willingness to pay for pest management in the Batang Toru Forest, Indonesia

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1. Introduction
 2. Materials and Methods
 - 2.1. Study area
 - 2.2. Data analysis
 3. Results
 - 3.1. Farmers' Profile
 - 3.2. Pest regulation and farmers' strategy
 - 3.3. Farmers' willingness to pay for pest management
 4. Discussion
 5. Conclusions
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Keywords: farmers' strategies; farmers' willingness to pay; pest regulation; sustainable agriculture; wildlife pests.

Abstract. *Effective pest regulation is crucial for sustainable agriculture and livelihoods in agricultural landscapes. This study aims to understand the challenges faced by farmers, the strategies they employ, and their willingness to contribute to managing pest-related issues in the Batang Toru region. A*

quantitative research design was employed, and data were collected through face-to-face interviews with 125 randomly selected respondents from five villages between 2020 and 2022. Descriptive statistical analysis was used to analyze the survey data, and farmers' willingness to pay (WTP) was assessed using a choice experiment method. The findings reveal the diverse range of challenges and strategies associated with pest regulation in various crops, including peanut, paddy, durian, banana, and bitter bean farming. Wildlife pests such as wild boars, non-human primates, and birds were identified as significant contributors to crop damages and losses. Farmers employed physical barriers, scare tactics, repellents and deterrents, traps, and lethal means to mitigate these challenges. Most farmers expressed their readiness to contribute financially, with a preference for in-kind rewards such as paddy and benzoin over cash payments. The findings highlight the complex and context-specific nature of pest management strategies, emphasizing the importance of understanding local ecological dynamics and cultural factors when designing interventions.

1. Introduction

The sustainable livelihood of farmers and rural communities is greatly influenced by the sustainability of forests due to the valuable ecosystem services they offer. These services encompass a wide range of benefits, from the provision of resources to cultural services (Lele et al., 2013; Sandifer et al., 2015; Velasco-Muñoz et al., 2022), all of which contribute to the overall well-being of these communities and farmers. While there is a growing recognition of the significance of ecosystem services, previous studies have frequently overlooked the assessment and perspective of rural communities regarding the entire spectrum of these services. Instead, emphasis has been placed on regulatory services, with carbon sequestration emerging as the most highly valued among them (Acharya et al., 2019). For instance, the significance of ecosystem services in facilitating agricultural activities has been recognized among farmers in the Batang Toru ecosystem, as highlighted by Harahap et al., (2022) and Harahap & Yonariza (2022). However, certain economically valuable ecosystem services, such as pest control services, have not received sufficient attention and

investigation. Consequently, the assessment of ecosystem services for rural and agricultural economies, particularly with regard to pest control, remains significantly limited. Numerous studies have delved into different aspects of pest regulation and its impact on farmers. In this illustration, Brévault & Clouvel (2019) explores and examines a burgeoning methodology aimed at fostering agroecological pest management. The author emphasizes the essential interconnections among agronomy, ecology, and social sciences, highlighting the need for bridges to facilitate the development of this approach.

In a recent study by Wyckhuys et al. (2023), the complexities of pest management science within farming systems are explored and the need for a nuanced understanding of the multifaceted factors involved. The study emphasizes the importance approaches that consider the intricate interactions between pests, crops, and the farming environment, aiming to enhance pest management effectiveness and promote sustainable farming practices. Furthermore, Lazaridou and Michailidis (2023) conducted a recent study explored the intricate relationship between farmers' perceptions, attitudes, and practices regarding the use of avian species for pest management and the study enhances our understanding of birds' potential role in pest control strategies and emphasizes the significance of incorporating farmers' perspectives into the design of sustainable pest management interventions. However, there is a notable research gap in the field of pest regulation specifically concerning smallholder farmers in agroforestry systems. These farmers face unique challenges as their forests are connected to protected areas for conservation, and they cultivate a diverse range of crops and forest products that are often targeted by wildlife. This includes both protected species like orangutans (*Pongo* sp.) and non-protected species like wild boars and long-tailed macaques, all of which may be considered as pests by the farmers. Given the scarcity of research in this area, our study aims to delve into the farmers' experiences with pest regulation. We acknowledge that pests can exert a substantial influence on agricultural productivity and sustainability, making effective pest control measures indispensable for farmers in the Batang Toru region. By exploring the firsthand experiences of farmers, we seek to gain insights into the challenges they encounter, the strategies they employ, and their willingness to involve in managing pest-related issues. Building upon the insights garnered from these studies, our research aims to provide a comprehensive understanding of the farmers' experiences with pest regulation in the Batang Toru region. Additionally, our study will explore the willingness to pay of pest regulation and the potential benefits of harnessing ecosystem services for sustainable pest management.

2. Materials and methods

2.1. Study area

Our study focuses on smallholder farmers in the Batang Toru Ecosystem (BTE), encompassing South Tapanuli, Central Tapanuli, and North Tapanuli Regencies (see figure 1). This region's forest serves as a vital resource for the farmers, and it supports a diverse range of wildlife species, including orangutans, tigers, wild boars, and long-tailed macaques.

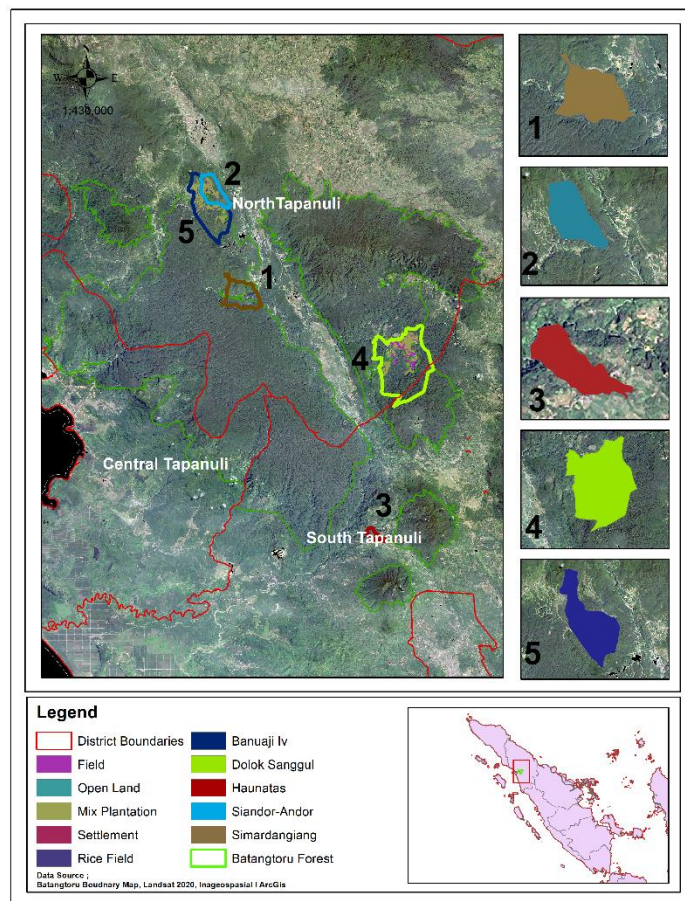


Figure 1. Study Area

The farmers cultivate various crops and forest products such as corn, rice fields, Durian, Petai or bitter bean, and bananas. A purposive sampling technique was utilized to select a representative sample of smallholder farmers for the survey. The study focused on all research village communities benefiting from ecosystem services, totaling approximately 675 household heads across four villages. For the sample selection, we used a formula considering the population of households benefiting from ecosystem services in the Batang Toru forest (675 heads of households). The Slovin Method, with a 95% confidence level and an 8% margin of error, yielded a sample size of 123 respondents, rounded up to 125 agroforestry farmers from 5 villages. The sample size was determined using the Slovin method, selecting farmers based on their agroforestry livelihoods and frequent interactions with wildlife pests in the Batang Toru forest. Interviews were conducted between 2020 and 2022 after obtaining permission from the respondents. Table 1 provides an overview of the sample distribution across districts, villages, and forest blocks.

No	Village	District	Total Household	Total Population
1	Simardangiang	North Tapanuli	188	680
2	Dolok Sanggul	North Tapanuli	140	657
3	Haunatas	South Tapanuli	110	550
4	Siandor-andor	North Tapanuli	130	603
5	Banuaji	North Tapanuli	250	988
Total			675	3478

Table 1. Distribution of samples by district, villages and forest block

Data analysis

A quantitative research design was employed to investigate smallholder farmers' perspectives and experiences regarding pest regulation services, with a focus on the role of wildlife within the Batang Toru forest. A household survey was conducted through face-to-face interviews using a structured questionnaire containing closed-ended questions with multiple-choice options. The interviews were conducted in a respectful and engaging manner, allowing the farmers to express their experiences, perspectives, and strategies in managing pests. The survey data were analyzed using descriptive statistical analysis, including frequencies and percentages. Additionally, farmers' willingness to pay (WTP) was assessed through a choice experiment method, and economic analysis was employed to determine their WTP. Data Analysis Descriptive statistical analysis was employed for the quantitative survey data collected. Frequencies and

percentages were calculated to summarize and analyze the data. Statistical software, such as SPSS and Microsoft Excel, was utilized for data analysis.

3. Results

3.1. Farmers' Profile

In our analysis of the demographic composition of the surveyed group of 125 farmers (refer to table 2), the distribution of age stands out as a significant factor. Notably, 9.6% of these individuals involved in agriculture belong to the 18-30 age group. Conversely, the majority, accounting for 68.8%, falls within the 31-60 age range, indicating a prevalence of middle-aged farmers. Additionally, 21.6% of respondents are aged over 60, emphasizing the presence of experienced and senior members within the farming community. Regarding gender, the agricultural landscape is predominantly male, with 85.6% of respondents identifying as male farmers. In contrast, female farmers constitute a smaller but noteworthy 14.4%, highlighting a distinct gender-based divide in agricultural participation.

Summary of farmer's demographic information		Total (n=125)
Age (%)	18-30	9.6
	31-60	68.8
	>60	21.6
Gender (%)	Male	85.6
	Female	14.4
Marriage status (%)	Single	6.4
	Married	85.6
	Widow/ed	8
Religion (%)	Christian	78.4
	Islam	21.6
Education level (%)	No Education	5.6
	Elementary school	33.6
	Junior high school	30.4
	Senior high school	30.4
	University	0
Agriculture training program (%)	Trained	28
	Untrained	72

Table 2. Farmers' demographic information

A thorough examination of marital status reveals a nuanced distribution among these farmers. A minority, constituting 6.4%, are categorized as single, while a significant majority of 85.6% declare themselves as married. Interestingly, 8% are widowed or widowers. In terms of religious affiliations, Christian farmers make up a predominant majority at 78.4%, underscoring the prevalence of Christianity within the surveyed farming community. Simultaneously, Islam represents the religious adherence of 21.6% of the respondents. It is noteworthy that 5.6% have not received any formal education. Furthermore, 33.6% have completed elementary school, indicating a foundational level of education, while 30.4% hold junior high school qualifications, denoting an intermediate level of educational attainment. Another 30.4% have achieved senior high school education, and no farmers reported possessing a university degree. Regarding participation in agricultural training programs, 28% of these farmers have undergone formal training, potentially equipping them with enhanced skills and knowledge. Conversely, 72% have not received such training, suggesting opportunities for capacity-building and skill enhancement in the sector.

3.2. Pest regulation and farmers' strategy

The results of our study reveal nuanced insights into the effects of pest regulation on different crops, focusing on peanuts, paddy, durian, banana, and bitter bean farming (see figure 2). Peanut (*Arachis hypogaea*) farmers in Banuaji reported a decrease in pest regulation, with 32% of farmers experiencing this issue. Similarly, in Siandor-andor, 20% of peanut farmers reported a diminishing of pest regulation. In Simardangiang, 16% of surveyed farmers also experienced a decrease in pest regulation. Notably, the pests most commonly reported by peanut farmers were wild boars (*Sus scrofa domesticus*), non-human primates like long-tailed macaques (*Macaca fascicularis*), and rats (*Rattus argentiventer*). Paddy (*Oryza sativa*) farmers, complaints about diminishing pest regulation were prominent. In Banuaji and Siandor-andor, 68% and 52% of farmers respectively claimed an increase in pests affecting their paddy fields. In Doloksanggul and Simardangiang, the situation was even more severe, with 92% of farmers reporting pest-related problems. Surprisingly, in Haunatas, a staggering 96% of paddy farmers faced challenges related to pest regulation. The pests commonly cited by these farmers included rats, wild boars (*Sus scrofa domesticus*), birds (*Aves sp.*), and rice ear bug (*Leptocorisa oratorius*). Durian (*Durio zibethinus*) farmers in Banuaji and Siandor-andor reported 20% and 28% respectively experiencing an increase in pests targeting their durian crops. In Doloksanggul, this figure rose to 64% of durian farmers, while in Haunatas, 76% faced similar issues. Notably, Simardangiang exhibited the highest percentage, with 84% of durian farmers

complaining about pests, including non-human primates and treeshrew (*Tupaiaidae*). Banana (*Musa sp.*) farmers in Doloksanggul faced significant challenges, with 92% of them reporting a decrease in pest regulation. The pests affecting banana crops in this region included fruit flies (*Nacoleia octasema*), leaf rollers (*Erionota thrax*), and beetles (*Cosmopolites sordidus*), as well as long-tailed macaques. Bitter bean (*Parkia speciosa*) farmers also experienced pest regulation issues although to a lesser extent. In Doloksanggul, approximately 8% of farmers reported this problem, while in Haunatas and Siandor-andor, the figures were around 4%. In Simardangiang, approximately 16% of bitter bean farmers faced challenges related to pests. The pests affecting bitter bean crops include non-human primates, caterpillars, insects, sap-sucking bugs, and ants. These findings highlight the diverse and nuanced nature of pest regulation challenges across different crops around the Batang Toru forest, providing valuable insights for developing targeted pest management strategies and interventions.

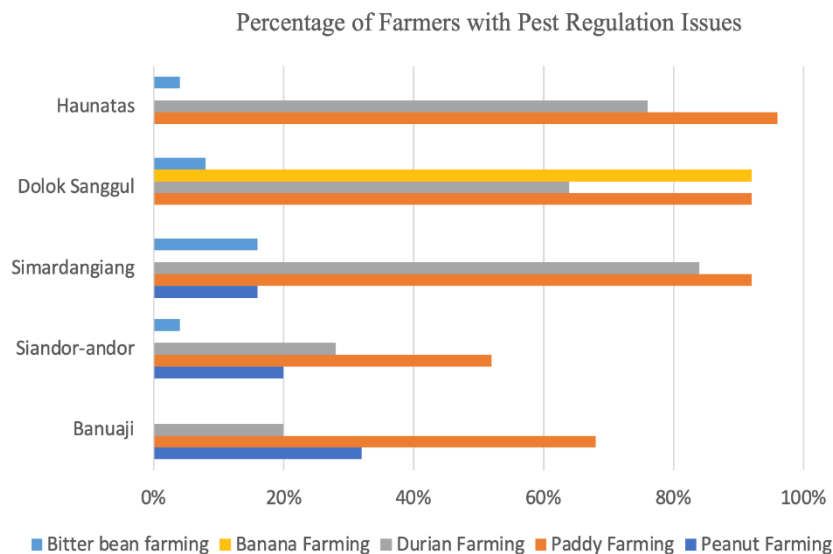


Figure 2. Pest regulation services diminishing for agricultural commodities in study area.

Our study aimed to gain insights into the strategies employed by farmers in addressing specific wildlife pests, namely wild boars, non-human primates, and birds, which were consistently reported as problematic across various agricultural

commodities including paddy, peanut, durian, bitterbean, and banana. We specifically excluded species such as squirrels and caterpillars from our analysis. Our investigation focused on farmers residing in the Batang Toru area and their approaches to managing these wildlife pests. Through our research, we identified several strategies commonly utilized by farmers to tackle wildlife pests (see figure 3). The strategies encompass physical barriers, scare tactics, repellents, and deterrents, as well as traps and scare guns. Farmers in the study area have adopted these diverse methods as part of their pest management practices to mitigate the damage caused by wild boars, non-human primates, and birds.

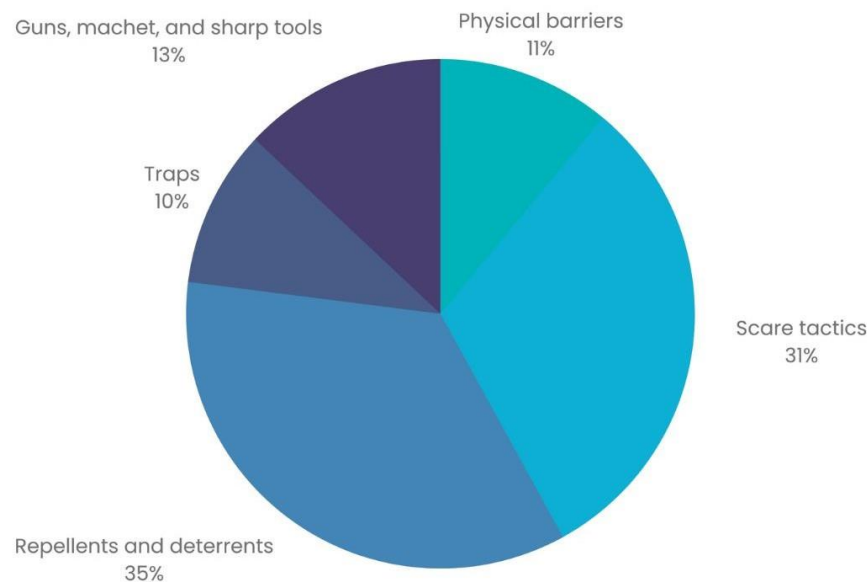


Figure 3. Farmers' strategy to tackle the wildlife pest.

Our study reveals a range of strategies employed by smallholder farmers in addressing wildlife pests within their agricultural practices. Among these strategies, physical barriers, such as the erection of fences around paddy, banana, and peanut fields to prevent access by wild boars, monkeys, and birds, were

commonly observed. However, only a small percentage (11%) of the interviewed farmers reported utilizing physical barriers, suggesting that this approach alone may be insufficient when dealing with wildlife pests. On the other hand, approximately 31% of farmers applied scare tactics as a means to frighten away wildlife pests. These tactics encompassed the creation of loud noises, the use of scarecrows or effigies, and the deployment of reflective materials that produce flashes of light, all intended to deter animals from entering their fields. This approach emerged as a prevalent practice across all studied villages, indicating its widespread use among farmers attempting to expel wildlife pests. A significant portion of farmers (35%) claimed to invest substantial time and effort in repelling and deterring wildlife pests on their own. They described activities such as "mamuro," a local term used to denote the vigilant protection of their crops, particularly paddy fields, from wildlife. This entailed farmers dedicating their time to actively monitor and safeguard their crops, employing their own vocalizations as a means of repelling wildlife. The involvement of children in assisting their parents in the field was also commonly reported across different agricultural commodities in all villages. Among the surveyed farmers, a small percentage (11%) still employed traps to expel wildlife pests, primarily targeting wild boars. This practice was observed in all villages except Dolok Sanggul, where the majority of farmers identified as Muslim. The absence of trap usage among Muslim farmers in Dolok Sanggul suggests that their cultural and dietary preferences may influence their decision not to trap wild boars. Furthermore, approximately 13% of the interviewed farmers claimed to utilize firearms, machetes, and sharp tools such as sticks and stones to repel pest wildlife. They asserted that this strategy was essential for ensuring the safety of their agricultural commodities. These farmers further emphasized that they employed lethal means intentionally, perceiving the wildlife species as a threat to their livelihoods. These findings underscore the diversity of strategies employed by smallholder farmers in addressing the challenges posed by wildlife pests within their agricultural operations.

3.3. Farmers' willingness to pay for pest management

Having gained a comprehensive understanding of the pest issues faced by farmers and their management strategies, our investigation delved into assessing their willingness to pay (WTP) for a pest management program aimed at safeguarding their agricultural commodities from wildlife such as wild boars and non-human primates. The primary objective of our study was to determine the extent to which farmers were willing to financially contribute to the enhancement of pest regulation services (see table 3). To collect data on farmers' WTP, we

conducted personal interviews through household surveys. The results revealed that a substantial proportion of farmers, specifically 82 percent, expressed readiness to pay for an improvement in pest regulation.

Type of payment	Freq.	Biannual WTP	Annual WTP	Transferred to monetary value
Pest regulation (Individual settings).				
Paddy (kg)	32	12	768	IDR 3,840,000
Benzoin (kg)	54	2	216	IDR 25,920,000
Cash (IDR)	16	60,000	IDR 1,920,000	IDR 1,920,000
WTP Median				IDR 148,922
WTP Annually				IDR 297,843
Total WTP Annually				IDR 1,035,898,431

Table 3. Farmers' WTP for pest management

Interestingly, most farmers preferred in-kind rewards, specifically paddy and benzoin, rather than cash payments. These rewards were provided after each harvest, which occurred once every six months. Among the available payment methods, benzoin emerged as the most popular choice among farmers, with 47 percent opting for this in-kind reward. On average, each farmer received a total of 2 kg of benzoin every six months. Paddy was the second most favoured option, chosen by 25 percent of farmers, who received an average of 12 kg of paddy per six-month period. Cash payment was selected by only about 18 percent of farmers, with an average amount of IDR 60,000 disbursed every six months. However, it is noteworthy that 18 percent of respondents cited the belief that pests like the long-tail macaque and wild boar were beyond control as their main reason for being unwilling to pay for pest regulation. Furthermore, farmers had been hearing rumours that the government had relocated these macaques from the forests near Lake Toba to their woodlands, where the species had become more prevalent. To provide an overall estimate of the farmers' WTP for ecosystem regulatory services, we calculated the aggregate value through an individual setting, which amounted to IDR 1,035,898,431 when converting the in-kind rewards to monetary value. This assessment accounts for the preferences expressed by the farmers and underscores their substantial contribution to pest management efforts.

4. Discussion

Our study provides valuable insights into the challenges and strategies associated with pest regulation in different crops, including peanuts, paddy, durian, banana, and bitter bean farming. These findings highlight the diverse and nuanced nature of pest regulation challenges across different crops in the Batang Toru forest region, offering valuable insights for developing targeted pest management strategies and interventions. These results align with previous research that emphasizes the significance of effective pest management practices in ensuring crop productivity and minimizing losses (Wyckhuys et al., 2023). In our study, we focused on addressing specific wildlife pests, namely wild boars, non-human primates, and birds, which were consistently reported as problematic across various agricultural commodities (Linden et al., 2019). This aligns with previous studies that have identified these species as major contributors to crop damages and losses (Harahap et al., 2022; Khattak et al., 2022a; Regmi et al., 2013a, 2013b). The strategies employed by farmers to tackle these wildlife pests included physical barriers, scare tactics, repellents and deterrents, traps, and scare guns. Farmers in the study area have adopted these diverse methods as part of their pest management practices mitigating the damage caused by these pests. While physical barriers, such as fences, were commonly observed among farmers, the low percentage of farmers utilizing this strategy suggests that it may not be sufficient on its own to effectively manage wildlife pests. Scare tactics emerged as a prevalent strategy, with farmers investing significant time and effort in repelling and deterring pests on their own. Our discovery uncovers the intricate practice of "*mamuro*" showcasing the meticulous safeguarding of crops, primarily paddy fields, against wildlife. It underscores the proactive stance adopted by farmers, who diligently employ this traditional method to deter pests. Although time-consuming, this widely practiced technique in the region aligns with our findings, reinforcing the prevalence of traditional practices within agricultural communities (Hussain et al., 2022). Traps were employed by a small percentage of farmers, primarily targeting wild boars, but were absent among Muslim farmers in Dolok Sanggul, likely influenced by cultural and dietary preferences. Additionally, some farmers resorted to using lethal means, such as firearms, machetes, and sharp tools, to repel pest wildlife, perceiving these species as threats to their livelihoods. These findings emphasize the diversity of strategies employed by smallholder farmers in addressing the challenges posed by wildlife pests within their agricultural operations. The strategies identified in our study align with previous research that has highlighted the range of methods used by farmers to mitigate wildlife-related crop damage (Khattak et al., 2022b; Kross et al., 2018; Micaelo et al., 2023). They underscore the complexity and context-

specific nature of pest management strategies, highlighting the importance of understanding local ecological dynamics and cultural factors when designing effective interventions (Hussain et al., 2022).

Understanding farmers' willingness to pay (WTP) for pest management programs is crucial for the development and implementation of sustainable pest regulation services. In our investigation, we assessed farmers' WTP for a pest management program aimed at safeguarding their agricultural commodities from wildlife such as wild boars and non-human primates. Our study found that a substantial proportion of farmers (82 percent) expressed readiness to financially contribute to an improvement in pest regulation. This aligns with previous research that has shown farmers' willingness to invest in pest management to protect their crops (Gitahi et al., 2019). Interestingly, most farmers preferred in-kind rewards, specifically paddy and benzoin, over cash payments. These rewards were provided after each harvest, which occurred once every six months. Benzoin emerged as the most popular choice among farmers for this in-kind reward, followed by paddy. Cash payment was selected by only a small number of farmers. The preference for in-kind rewards can be attributed to several factors. Firstly, it may be influenced by cultural and traditional practices, where agricultural commodities hold intrinsic value beyond monetary compensation. Secondly, in-kind rewards like paddy and benzoin provide tangible benefits directly related to farming activities, serving as inputs for future agricultural production or as valuable products that can be used or traded within local communities. This preference for in-kind rewards aligns with studies that have highlighted the importance of considering non-monetary incentives and local contexts when designing payment schemes for ecosystem services (Bottazzi et al., 2018; Grillos, 2017). It is noteworthy that a small percentage of respondents cited the belief that pests like the long-tailed macaque and wild boar were beyond control as their main reason for being unwilling to pay for pest regulation. This perception could stem from previous experiences or information circulating among farmers, such as rumours about the relocation of macaques from nearby forests to their woodlands, leading to an increase in their prevalence. This highlights the need for effective communication and outreach programs to address farmers' concerns and provide accurate information about pest management strategies and the potential benefits of collective efforts. Our findings on farmers' willingness to pay for pest management indicate that farmers recognize the value of effective pest regulation in safeguarding their agricultural commodities and livelihoods. This aligns with previous studies emphasizing the economic significance of pest management investments in enhancing crop productivity and reducing losses (Kpadé et al., 2017; Lazaridou & Michailidis,

2023; Parry, 2022; Tapsuwan et al., 2020; Wanger et al., 2014). Moreover, it highlights the potential for establishing financial mechanisms, such as payment for ecosystem services or community-based funding schemes, to support and sustain pest management initiatives in the study area. In conclusion, our study provides nuanced insights into the effects of pest regulation on different crops and the strategies employed by farmers to address wildlife pests. The diverse range of strategies, including physical barriers, scare tactics, repellents and deterrents, traps, and lethal means, underscores the complexity of pest management in agricultural landscapes. Furthermore, farmers' readiness to financially contribute to pest management programs, with a preference for in-kind rewards, highlights their active engagement and potential for collaboration in sustaining effective pest regulation services. These findings contribute to the development of targeted pest management strategies and interventions that consider local ecological dynamics, cultural factors, and farmers' perspectives, ultimately fostering sustainable agriculture and biodiversity conservation in the Batang Toru region.

5. Conclusions

Our study examines the intricate challenges and strategies involved in pest regulation across Batang Toru's diverse crops. The nuanced findings form the basis for targeted pest management, emphasizing specific wildlife pests such as wild boars, non-human primates, and birds, recognized contributors to crop damages. Farmers utilize diverse strategies, ranging from physical barriers to lethal means, exposing the complex and context-specific nature of pest management.

We propose practical initiatives, including the initiation of a comprehensive Integrated Pest Management (IPM) training program for farmers. This program emphasizes a holistic approach tailored to address wildlife challenges. Additionally, we recommend community-based outreach to address concerns, dispel misconceptions, and enhance effective pest control. Recognizing cultural influences, we suggest customizing incentive schemes to align with farmers' preferences for in-kind rewards.

Further research should investigate the long-term effectiveness of pest management strategies, considering ecological dynamics and evolving agricultural practices. Crucial research directions include exploring socio-economic impacts on local communities and assessing scalability for neighbouring regions.

Our findings underscore farmers' recognition of the value of effective pest regulation, proposing financial mechanisms like payment for ecosystem services to support sustainable pest management. This study offers insights for developing tailored strategies aligned with local dynamics, culture, and farmers' perspectives, fostering sustainable agriculture and biodiversity conservation in Batang Toru.

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