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Monotonic Trend of Oral Health During the COVID-19 Pandemic Period in Caraga Region, Philippines

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A B S T R A C T

Oral diseases are among the prevalent non-communicable diseases worldwide, affecting billions of people. This research study analyzed oral health data from 2017 to 2021 to address the lack of published studies on dental cases in the Caraga Region. It focused on various aspects of oral health, including dental services, dental caries, gingivitis, and periodontitis. Data was collected by formally requesting information for various dental records collated from the Department of Health (DOH) Caraga database and collaborating with the Acebu Dental Clinic for images on dental diseases. In total, 547,405 individual dental cases from the Caraga region were collected from 2017-2021. The findings showed that noninvasive procedures often included oral hygiene counseling, while tooth extraction had the highest recorded data among invasive procedures. Data analysis by age group revealed that children aged nine and below had a higher susceptibility to dental caries, while those between 10 and 24 years old had higher instances of gingivitis. Individuals aged 25 and above were more prone to periodontal disease. The females exhibited a higher prevalence of dental caries, gingivitis, and periodontitis compared to males. Pregnant women also had a high incidence of untreated dental caries. This study reported a decline in the number of orally fit children, determined through oral examinations and complete rehabilitation, from 2017 to 2021. Trend analysis using the Mann-Kendall Test and Sen's Slope revealed a monotonic decrease with negative values. The disruptions caused by the COVID-19 pandemic, such as lockdowns, limited access to dental care, and decreased awareness of oral hygiene, likely contributed to the decline in reported cases during this period.

Keywords: *Dental Caries, Dental Services, Gingivitis, Periodontitis, Pregnancy*

1 Introduction

Oral diseases are among the prevalent noncommunicable diseases worldwide, affecting billions of people. The most common diseases include cavities and gum disease (Centers for Disease Control and Prevention 2022; World Health Organization 2023). While oral diseases are generally preventable, they persist with high prevalence, reflecting widespread social and economic disparities and insufficient funding for prevention and treatment. Thus, imposing serious health and economic burdens (Peres et al. 2019).

The COVID-19 pandemic led to a widespread decline in children's oral health and access to oral healthcare, with children in 2020 being less likely to have excellent dental health, more likely to have poor dental health, and experiencing reduced dental visits compared to previous years (Lyu & Wehby 2022). Most dental procedures generate significant amounts of droplets and aerosol, which could promote the spread of COVID-19 infection, thereby endangering dental care practitioners, staff, and patients (Meng et al. 2019). In May

2020, the Philippine Dental Association (PDA) published the "Interim Guidelines on Infection Prevention During the COVID-19 Pandemic" from existing COVID-19 literature and relevant international guidelines. This guideline was adopted and implemented for all dental clinics in the Philippines. The primary objective of such guidelines is to safeguard the well-being of dental healthcare practitioners, staff, and patients within dental facilities and mitigate the transmission of COVID-19 in the broader community (Philippine Dental Association 2020).

Oral disease remains a serious public health problem in the Philippines. The prevalence of dental caries on permanent teeth has consistently remained above 90% over the years. Approximately 92.4% of Filipinos have tooth decay (dental caries), and 78% have gum diseases (e.g., periodontal diseases; Ofilada 2018). The burden of gum diseases is carried by Filipinos from an early age, with children as young as twelve suffering from gingivitis. Failure to receive timely treatment could render these children vulnerable to irreversible periodontal disease as they progress into adolescence and adulthood. Fadare et al. (2021) conducted a study that assessed oral health knowledge and practices among elementary pupils attending Saint Louis College in the City of San Fernando, La Union, Philippines. The study revealed that most pupils demonstrated satisfactory knowledge about the causes (87.23%) and preventive measures (86.21%) of oral diseases. However, it also showed that oral hygiene practices among these pupils were only moderately practiced (55.80%).

The recorded number of dental cases in the Caraga Region has not been addressed in any published studies. Hence, this research was conducted with objectives including classifying dental services, comparing dental disease cases by demographics, and conducting a trend analysis for 2017-2021. By examining the trends in dental cases during this period, the study can contribute to a better understanding of the oral health situation in the region and inform future interventions and policies to address the prevailing oral health issues, including the impacts of the COVID-19 pandemic among individuals.

2 Materials and Methods

Data Collection and Documentation

Data collection involved two main approaches. Initially, a formal request letter was sent to the Department of Health (DOH) Caraga, seeking access to oral health data from 2017 to 2021 for all five provinces of the Caraga Region (Figure 1). It facilitated gathering comprehensive and reliable information on the region's trends, prevalence, and outcomes related to oral health. Subsequently, a separate request letter was submitted to Acebu Dental Clinic in Butuan City, requesting permission to obtain pictures of sample dental diseases. These visuals served valuable resources for the research, aiding in the analysis and documentation of various dental conditions and procedures with high regard to preserving the anonymity of photographed patients.

*Descriptive Statistic*s

Statistical tools are utilized to analyze oral health data collected over a specific period.

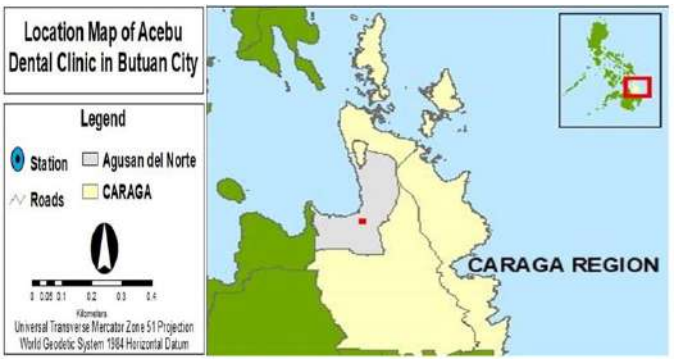

Figure 1. Map of The Caraga Region. Red Square is Acebu Dental Clinic located in Butuan City. Coordinates: 8.946035854274125°, 125.53659518550 285° or Latitude: 8° 56' 45.731' N Longitude: 125° 32' 11.744' E.

Various factors, such as dental services, age, sex, pregnancy, dental conditions, and children's oral health, were examined. Nonparametric statistical methods, specifically the Mann-Kendall test and Sen's slope, are applied to identify trends in dental disease prevalence. These robust statistical tools effectively detect monotonic upward or downward trends, taking into account the ordinal nature of the data and incorporating medians to handle extreme values (Helsel and Hirsch 1992, Zaiontz 2023).

Ethics Statement

Permission secured from DOH-Caraga, seeking access to oral health data from 2017 to 2021, was obtained following prescribed ethical protocols. Ethical guidelines were strictly observed by obtaining consent from patients, their legal guardians (for minors), and the dentist at the Acebu Dental Clinic. Only the oral region of the patients was shown in the images.

3 Results and Discussion

Services Rendered

The breakdown of dental services rendered by dentists in the Caraga region is divided into noninvasive and invasive procedures (Table 1). Noninvasive procedures encompass preventive, restorative, and diagnostic treatments, while invasive procedures involve more complex interventions such as surgical procedures.

Noninvasive Procedures

A concerning trend is observed in the use of noninvasive procedures to improve oral hygiene over the five years from 2017 to 2021, which includes the challenging COVID-19 years (Figure 2). Counseling education on oral hygiene steadily declined, starting in 2018 and worsening in 2020, likely due to limited healthcare access during the pandemic. By 2021, there was a significant decrease in the number of individuals receiving counseling education, highlighting ongoing challenges. Similarly, the number of individuals completing fluoride therapy showed a decreasing pattern. Following a slight decline in 2018, a significant drop in 2019 continued into 2020 and 2021.

The Mann-Kendall test revealed a significant downward trend in oral hygiene counseling. The calculated Z-value (-2.2045) and the corresponding p-value (0.02749) indicate evidence to reject the null hypothesis of no trend. Additionally, Sen's slope estimates (-34519.83) suggest a substantial negative slope, indicating a notable decline in the number of individuals receiving counseling education on oral hygiene over the study period. These statistical results highlight the significance of the decreasing trend and emphasize the importance of targeted interventions during the pandemic.

Over the five-year period, which included the COVID-19 pandemic, the utilization of sealants

Table 1. Number of Noninvasive and Invasive Dental Procedures in Caraga Region from 2017-2021.

Noninvasive Procedure						
Procedure	**2017**	**2018**	**2019**	**2020**	**2021**	**TOTAL**
Given Counseling Education on Oral hygiene	141,753	119,500	116524	37642	4409	**419,828**
Completed Fluoride Therapy	88,897	88,008	30,348	23,172	2,176	**232,601**
Given Sealant	3,035	2,830	11,666	7,528	28	**25,087**
Given OP/ Scaling	4,874	5,190	10,411	0	135	**20,610**
Given Permanent Fillings	6,564	6,444	2,785	0	27	**15,820**
Given Temporary Filling	3,164	3,224	4,585	0	14	**10,987**
Given Post-Operative Treatment	1,279	2,362	1448	1,006	715	**6,810**
Given gum treatment	1,001	1,832	1,871	0	252	**4,956**
Referred	146	207	306	692	148	**1,499**
Invasive Procedure						
Procedure	**2017**	**2018**	**2019**	**2020**	**2021**	**TOTAL**
Given Extraction	37,247	23,445	12053	8025	1295	82,065
Patients with Oral Abscesses drained	84	180	153	0	0	417

and temporary fillings displayed a fluctuating pattern (Figure 3). Sealants initially declined from 2017 to 2018, followed by a notable increase in 2019 and subsequent decreases in 2020 and 2021, reflecting the direct impact of the pandemic. Similarly, temporary fillings showed a similar trend, with a slight rise in 2018 and a gradual decline afterward. The number of individuals receiving permanent fillings gradually decreased throughout the years, likely due to the various challenges posed by the pandemic. Additionally, oral prophylaxis or scaling utilization fluctuated, with a significant increase in 2019 and a decrease in 2021.

Dentists use fluoride to strengthen teeth because it prevents tooth decay by strengthening enamel, promotes remineralization to repair weakened areas, inhibits harmful bacteria that cause decay, and enhances enamel development, especially in children. Fluoride application is a widely accepted preventive measure in dentistry to protect teeth, prevent cavities, and improve overall oral health (Medjedovic et al. 2015).

Restoring teeth, including both permanent and primary teeth, is extremely important for keeping a healthy mouth and ensuring proper chewing, speaking, and appearance. Composite fillings are valuable because they can make teeth look and function naturally. Saving primary teeth, also called baby teeth, is crucial for children's development as they help with eating, speaking, and guiding permanent teeth into the proper position. Losing

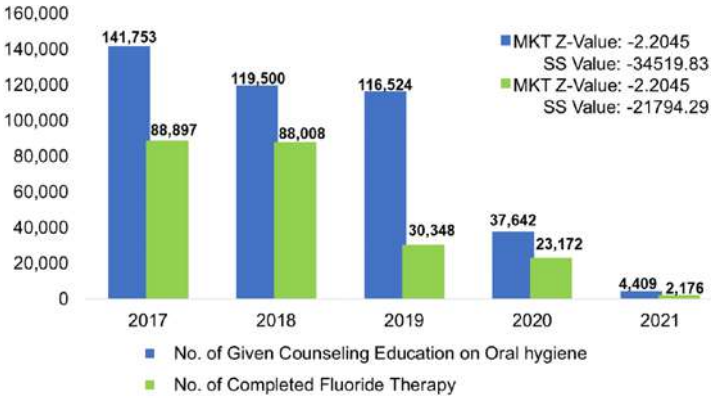

Figure 2. Noninvasive Counseling on Oral Hygiene and Fluoride Therapy in Caraga Region from 2017-2021. Mann-Kendall Test (MKT) Z-Value and Sen's Slope (SS) Value.

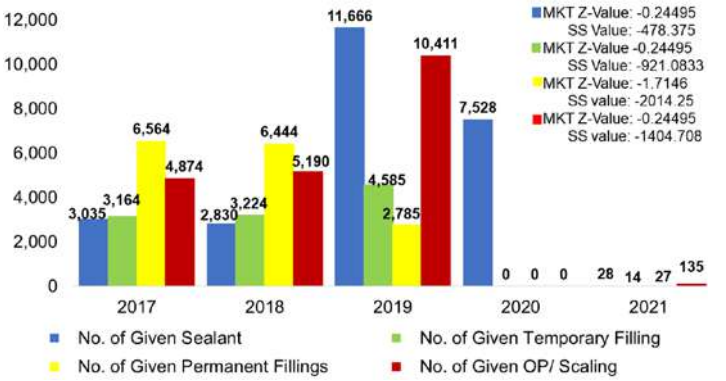

Figure 3. Cases of Sealant, Temporary Filling, Permanent Filling, and OP/ Scaling in the Caraga Region from 2017-2021. Mann-Kendall Test (MKT) Z-Value and Sen's Slope (SS) Value.

baby teeth too soon can cause problems like misaligned permanent teeth or overcrowding, which may require orthodontic treatment later (Yengopal et al. 2009).

Analysis of noninvasive data procedures from 2017-2021 (Figure 4) reveals distinct trends. The number of individuals receiving post-operative treatment fluctuated, indicating a need for ongoing evaluation and interventions for consistent access. Referrals for further treatment initially increased but showed fluctuations, highlighting the importance of minimizing referrals and optimizing patient management. The utilization of gum treatment has varied over the years. These findings underscore the importance of consistent post-operative care, reducing referrals, and addressing treatment availability gaps.

The statistical analysis of the data revealed declining trends in Post-Operative Treatment (-328.75) and Gum Treatment (-260.4583) based on Sen's slope values. However, the lack of statistical significance (p=0.2207 and 0.8065, respectively) prevents definitive conclusions. These trends may have been influenced by the global COVID-19 pandemic, which disrupted healthcare systems. Postponement or cancellation of non-urgent procedures and changes in referral patterns could have contributed to the observed declines. However, it is important to note that it is challenging to attribute these trends solely to the COVID-19 pandemic without additional context or data.

Invasive Procedures

The data from the DOH-Caraga sheds light on tooth extraction trends in the Caraga Region over five years (Figure 5). A significant decrease in tooth extractions is observed over time, with fluctuations indicating dynamic dental health patterns.

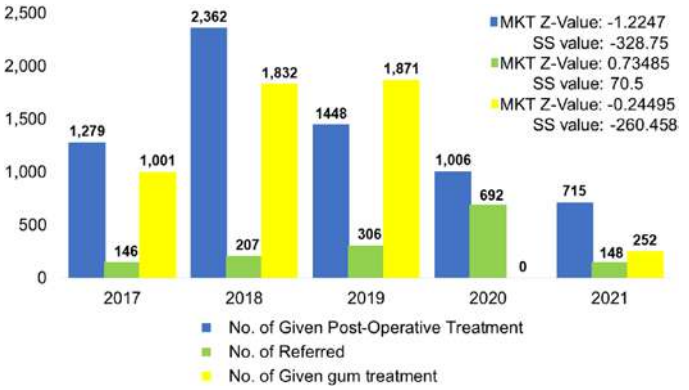

Figure 4. Post-operative treatment, Referred, and Gum Treatment in Caraga Region from 2017-2021. Mann-Kendall Test (MKT) Z-Value and Sen's Slope (SS) Value.

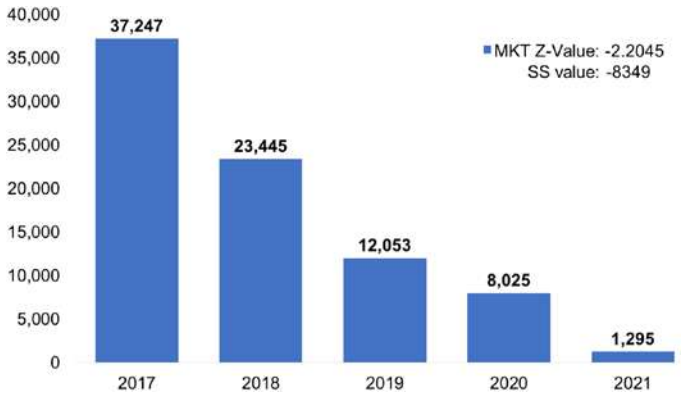

Figure 5. Cases of tooth extraction procedure in Caraga Region. Mann-Kendall Test (MKT) Z-Value and Sen's Slope (SS) value.

Statistical analysis using the Mann-Kendall test and Sen's slope values confirms a statistically significant association (Z-value: -2.2045; p-value: 0.02749; Sen's value: -8349) between the COVID-19 pandemic years and reduced tooth extractions. The data suggest that changes in oral health habits, limited dental care access, and pandemic-related factors contributed to this declining trend, highlighting the pandemic's impact on dental health outcomes in the region.

The DOH-Caraga recorded data on oral abscess drainage alongside tooth extraction (Figure 6). Patients with drained abscesses increased from 84 in 2017 to 180 in 2018 but slightly decreased to 153 in 2019. Surprisingly, no cases were recorded in 2020 and 2021. The Mann-Kendall test showed a negative trend (Z- Z-value: -1.0106; p-value: 0.3122), and Sen's slope (-27.5) indicated a consistent decline in abscess drainage. The absence of cases in 2020 and 2021 may be linked to the COVID-19 pandemic. Further investigation is needed to understand the factors influencing this downward trend.

Dental Diseases

The prevalence of dental diseases, including dental caries, gingivitis, and periodontitis (Figure 7), divided by age group, sex, and specifically for

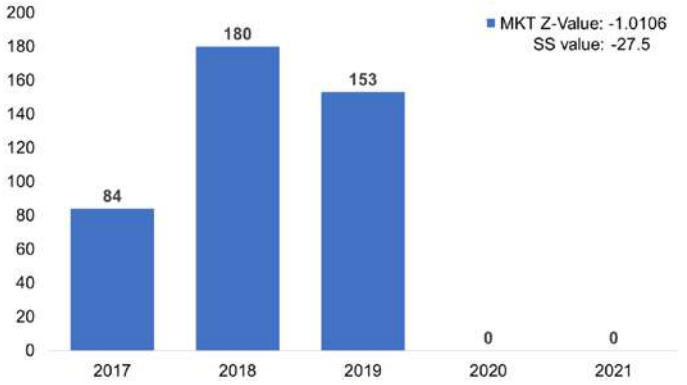

Figure 6. Cases of patients with oral abscesses drained in the Caraga Region from 2017-2021. Mann-Kendall Test (MKT) Z-Value and Sen's Slope (SS) Value.

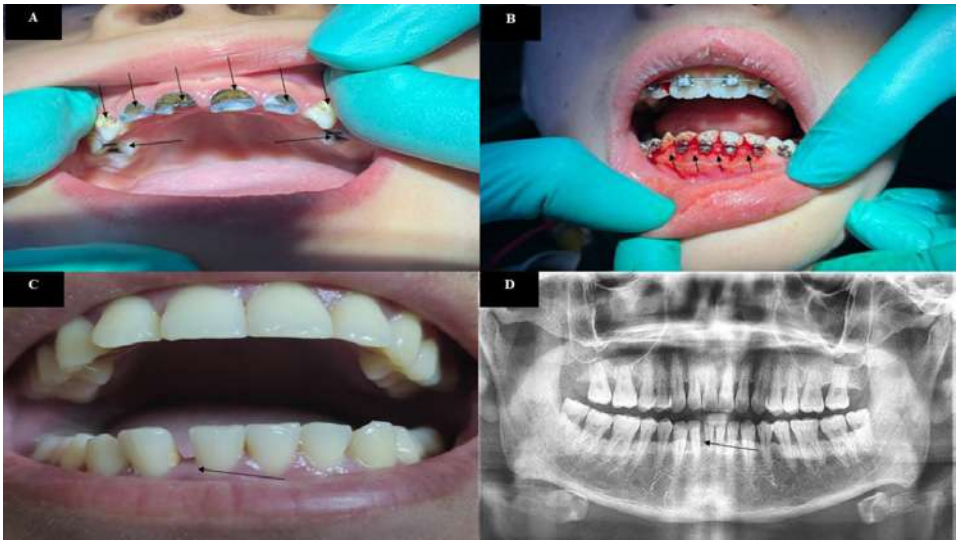

Figure 7. Some oral diseases are depicted. A. Dental Caries B. Gingivitis C. Periodontitis D. X-ray of periodontal case. Photo courtesy of JYatar and Acebu Dental Clinic.

pregnant women, are recorded over five years. By examining these graphs, valuable insights can be gained regarding the frequency and distribution of these dental ailments within different demographics, enabling a better understanding of the patterns and trends associated with these dental diseases.

Dental Caries

The data reveals a notable rise in dental caries in the Caraga Region from 2017 to 2018, followed by a sharp drop in 2019 and subsequent decreases in 2020 and 2021 (Figure 8). These findings depict a fluctuating trend in dental caries throughout the specified five-year span. The observed negative Mann-Kendall Z-value (-2.20454) provides evidence of a notable monotonic trend in the prevalence of dental caries, indicating a consistent and noteworthy decline in cases over the specified period. This downward trend in dental caries can be attributed to various influential factors, among which the COVID-19 pandemic is a significant contributor.

The dental caries cases differ across age groups from 2017 to 2021. Individuals aged nine years and below consistently had the highest number of cases, peaking in 2018 and gradually declining, reaching the lowest point in 2021 (Figure 9). This decrease may be partially linked to COVID-19 measures like lockdowns, school closures, and improved personal hygiene, potentially affecting dental care access, oral hygiene routines, and dietary habits. Comparatively, the 10-24-year-old age group had lower but significant numbers of dental caries cases, while individuals aged 25 and above consistently had the lowest numbers. These findings emphasize the vulnerability of those aged nine and below to dental caries, showing a decreasing trend during the five years, possibly influenced by the COVID-19 pandemic. Children aged nine and below are more prone to dental caries. A study by Othman et al. (2020) discovered that bottle feeding, particularly when combined with breastfeeding or extended beyond two years, increased the risk of early childhood caries (ECC).

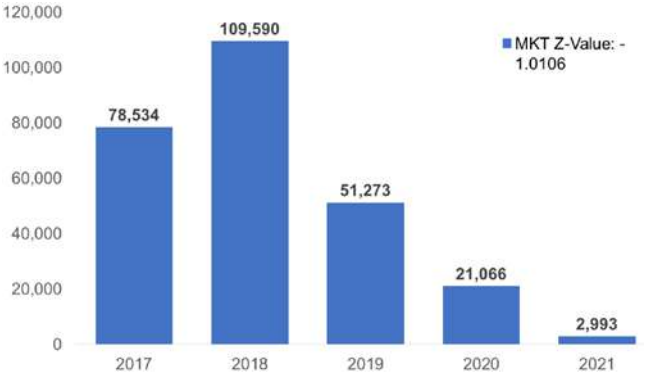

Figure 8. Cases of dental caries from 2017 to 2021 in the Caraga Region and Mann-Kendall Test (MKT) Z-Value.

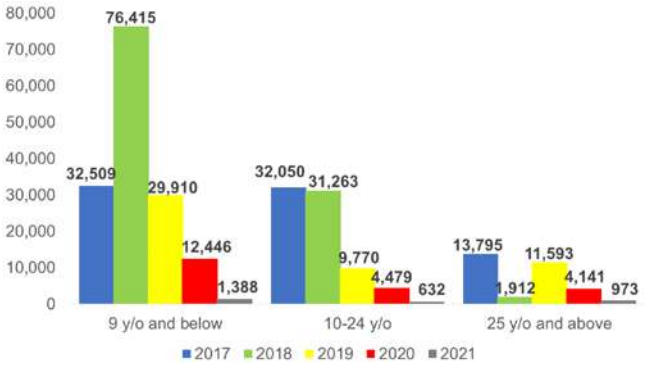

Figure 9. Cases of Dental Caries by Age Group in Caraga Region from 2017-2021.

Frequent feeding (more than six times per day) and nighttime feeding were also linked to more severe dental caries. The dental care of geriatric patients, however, is challenging and needs more attention than the dental care of younger people, as the elderly also encounter oral health problems and need serious attention (Ngwu and Fadare 2022). Coll et al. (2019) further highlight the increased vulnerability of geriatric individuals to oral infections and their associated complications. It emphasizes that chronic oral infections can lead to heart disease and malnutrition due to tooth loss. Moreover, the spread of infection to other body parts is a concern. Good oral hygiene, fluoride use, regular dental care, and appropriate antibiotic usage are underlined as preventive measures for geriatric individuals.

The number of cases fluctuates from year to year (Figure 10), and in 2018, the growth rate was significantly higher than in 2019, followed by a decline in 2020 and 2021. There is a higher prevalence of dental caries among females than among males. There was a widening gender gap in 2018 and a narrowing in subsequent years. Females consistently exhibit higher rates of dental caries than males, as Lukacs and Largaespada (2006) reported. This discrepancy can be attributed to early tooth eruption, food availability, snacking habits during food preparation, and hormonal influences during puberty, menstruation, and pregnancy.

Based on data from 2017-2021 (Figure 11), the number of dental caries cases among pregnant women fluctuated. The recorded cases in 2017 decreased in 2018 but increased in 2019. In 2020, the number decreased again, and in 2021, fewer cases were reported. The data highlights the changing trends in dental caries among pregnant women during this period. According to statistics, one in four women of childbearing age have untreated cavities, and children of mothers with untreated cavities are more than twice as likely to develop cavities. Untreated dental caries can lead to tooth decay and possible infections, negatively affecting the mother's oral health and overall quality of life (Yenen and Atacag 2019, CDC 2022).

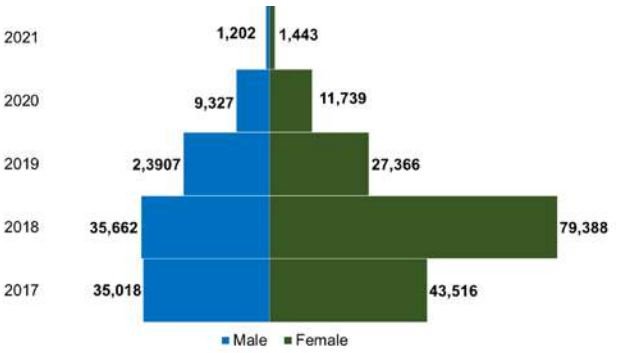

Figure 10. Comparison of Dental Caries in Males and Females in the Caraga Region from 2017-2021.

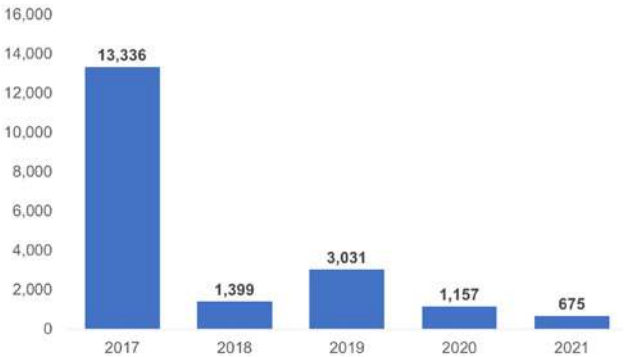

Figure 11. Dental caries cases in pregnant women in the Caraga Region from 2017-2021.

Gingivitis

Gingivitis cases decreased steadily over the five years, from 15,946 cases in 2017 to 405 cases in 2021 (Figure 12). Notably, there was a significant decline in gingivitis cases between 2019 and 2020. The Mann-Kendall Test confirms this trend, showing a negative Z-value (-2.6944), indicating a consistent decrease in gingivitis. The impact of the COVID-19 pandemic should be considered, as changes in oral hygiene practices, access to dental care, and health awareness may have contributed to the declining trend of gingivitis.

From 2017 to 2021, gingivitis cases declined across all age groups (Figure 13). However, there was an increase in gingivitis cases in 2019 among individuals aged nine and below and those aged 25 and older. Overall, the number of cases decreased in 2020 and 2021, with the most significant decline observed in the 10-24-year-old age group. Among the age groups, the 10-24-year-olds had the highest total number of gingivitis cases, followed by those aged 25 and above and those aged nine and below. Gingivitis accounted for approximately 62.9% in the 10-24-year-old group, 19.1% in the 25 and above group, and 18.0% in the nine and below group, respectively. Both males and females have experienced a general decline in cases over time. As with dental caries, gingivitis is more prevalent in females than males (Figure 14).

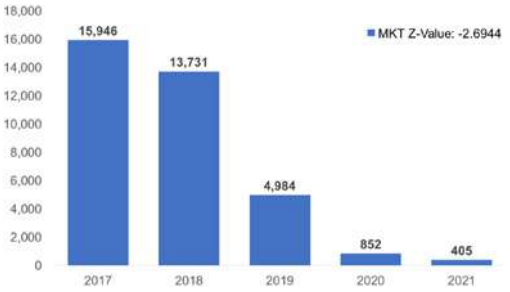

Figure 12. Gingivitis cases from 2017 to 2021 in the Caraga Region and Mann-Kendall Test (MKT) Z-Value.

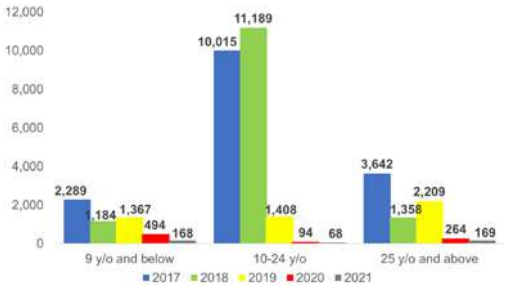

Figure 13. Cases of Gingivitis by Age Group in Caraga Region from 2017-2021.

In the study of Liu et al. (2022), insufficient adherence to proper oral hygiene routines, such as infrequent brushing and flossing, can lead to plaque buildup and bacteria proliferation, resulting in gum inflammation. Moreover, the accumulation of plaque and the formation of tartar can exacerbate gum irritation. It is crucial to promote the adoption of effective oral hygiene practices, maintain a well-balanced diet, and ensure regular dental examinations to mitigate the risk of gingivitis in children. It was also reported that a high prevalence of gingivitis (87.5%), with a higher incidence among girls (60.6%) than boys (39.5%). 58.2% of students had plaque-induced gingivitis, 67% had moderate gingival inflammation, and 64.7% had localized gingivitis among school students (Kane et al. 2018). The previous study's findings are consistent with the current results, demonstrating a higher incidence of gingivitis among females than males. This suggests that gender differences play a role in the prevalence of gingivitis cases.

The given data represents the incidence of gingivitis among pregnant women from 2017 to 2021 (Figure 15). There were 3,478 reported cases in 2017, which decreased to 715 cases in 2018. The number increased slightly to 1,035 cases in 2019 before dropping significantly to 502 cases in 2020. Finally, in 2021, there were 178 reported cases of gingivitis among pregnant women. These numbers reflect the prevalence of gingivitis as a common oral health condition experienced by pregnant women, with fluctuations observed over the years. Gingivitis, a common occurrence during pregnancy due to hormonal changes, can

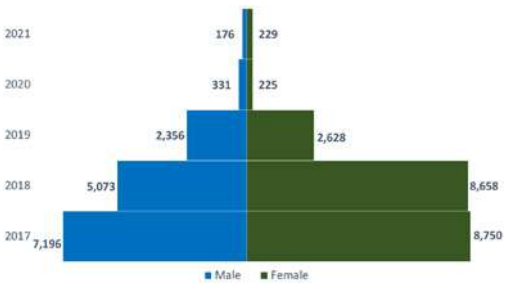

Figure 14. Comparison of Gingivitis Cases in Males and Females in the Caraga Region from 2017-2021.

progress to periodontitis if not properly managed (Rathee 2023). Proper management and prompt treatment of gingivitis are crucial to prevent its progression and minimize the risk of periodontitis.

Periodontitis

The reported cases of periodontitis exhibited a fluctuating pattern from 2017 to 2021. A total of 6,888 cases were recorded in 2017, and it significantly increased to 18,616 in 2018 (Figure 16). However, there was a sharp decline in 2019, with only 3,141 cases, followed by a minimal number of cases at 206 in 2020. In 2021, there were 366 reported cases. These figures indicate an initial rise in 2018, subsequent decreases, and a slight increase in 2021. This suggests varying levels of awareness, diagnosis, and treatment for periodontitis. It emphasizes the importance of continuous monitoring, targeted prevention, and considering public health implications to address the condition effectively.

Fluctuations across different age groups in periodontitis cases can be observed from 2017 to 2021 (Figure 17). The age groups analyzed were "9 years old and below," "10-24 years old," and "25 years old and above." In the "9 years old and below" group, there was an initial increase in cases from 2017 to 2018, followed by a decrease in 2019, a significant drop in 2020, and a slight rise in 2021. Similarly, the "10-24 years old" group experienced a gradual decrease in cases over the years, reaching a low point in 2020 and slightly increasing in 2021. Conversely, the "25 years old and above" group displayed a significant increase in cases from 2017 to 2018, a further rise in 2019, a decline in 2020, and a slight increase in 2021. The "25 years old and above" group reported the highest number of periodontitis cases, based on the provided data. In the study conducted in the Philippines by Punzalan et al. (2013), the prevalence of female smokers was found to be highest (23.2%) among those over the age of 70, followed by the 50-59 age group (15.3%). The lowest prevalence was observed among respondents in the 20-29 age group.

Periodontitis, a gum disease, affects people of all ages and is classified by gender (Figure 18). From 2017 to 2021, recorded cases increased significantly in 2017 and 2018, followed by a decrease in subsequent years. DOH Caraga

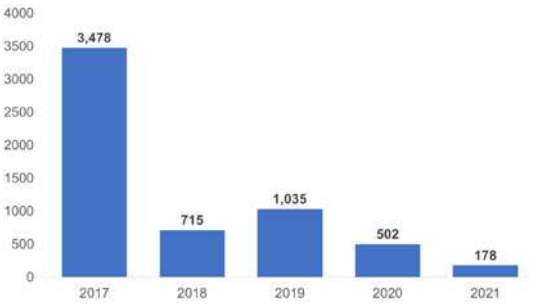

Figure 15. Gingivitis cases in pregnant women in the Caraga Region from 2017-2021.

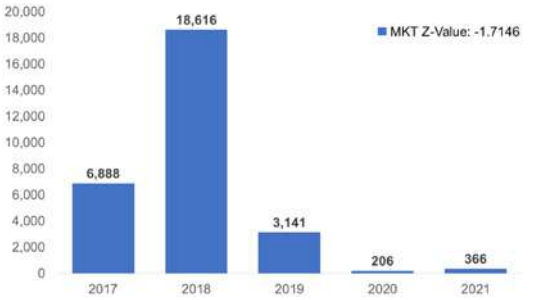

Figure 16. Periodontitis cases from 2017 to 2021 in the Caraga Region and Mann-Kendall Test (MKT) Z-Value.

reported a higher prevalence of periodontitis among females in all years. There were 18,616 cases reported in 2018, while only 206 cases in 2020. The periodontitis prevalence among pregnant women fluctuated from 2017 to 2021 (Figure 19). The numbers revealed a decline over time, with a notable decrease in recent years, indicating a changing pattern in the occurrence of periodontitis among pregnant women.

The DOH Caraga recorded a higher prevalence of periodontitis among females in all years, contradicting literature that suggests males have a higher prevalence and susceptibility to the disease. Ababneh et al. (2012) found that men have a higher prevalence of periodontitis, increasing with age. Grover et al. (2016) observed a variation in susceptibility, with males at a greater risk. Further investigation is needed to reconcile these findings. Smoking is considered the most significant risk factor for gum disease. Other factors include hormonal changes in females, certain medical conditions, medications, and genetic predisposition (Ababneh et al. 2012). Wen et al. (2023) suggest that hormonal changes during pregnancy contribute to the association between periodontal disease and adverse pregnancy outcomes, including preterm birth and low birth weight. The disruption of the fetal-placental unit caused by elevated systemic inflammation, increased periodontal pathogens, and a suppressed immune system are proposed mechanisms underlying these unfavorable outcomes.

Orally Fit Children

The data indicates a declining trend in the number of orally fit children aged nine years and below from 2017 to 2021 (Figure 20). The result shows a continuous decrease in the number of orally fit children aged nine years and below from 2017 to 2021, indicating a concerning

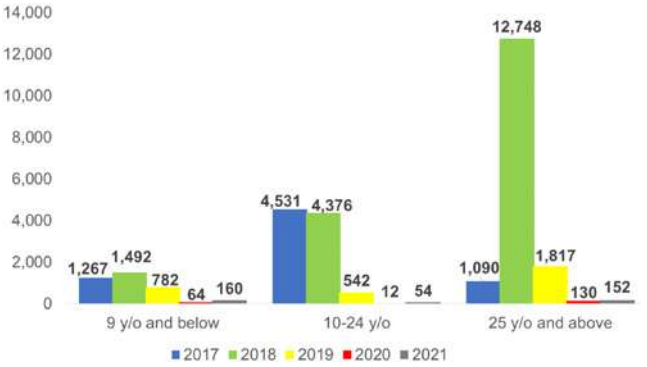

Figure 17. Cases of Periodontitis by Age Group in Caraga Region from 2017-2021.

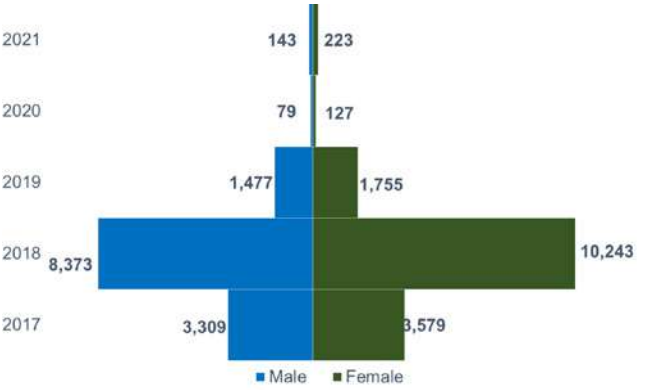

Figure 18. Comparison of periodontitis cases in males and females in the Caraga Region from 2017-2021.

decline in oral health among this age group. This highlights the need for interventions and awareness programs to improve oral health practices among young children.

Figure 21 shows the number of orally fit children aged nine years and below who underwent complete oral rehabilitation. In 2017 and 2018, 380 children received these services, indicating some access and focus on providing them, contributing to improved oral health and well-being. However, in 2019 and 2020, no children underwent complete oral rehabilitation, suggesting a lack of interventions and potential negative implications for their oral and overall health. In 2021, there was a partial resurgence, with 163 children receiving complete oral rehabilitation. Although a step in the right direction, this number is significantly lower than in previous years, underscoring the need to increase focus and access to these services for children. Policymakers

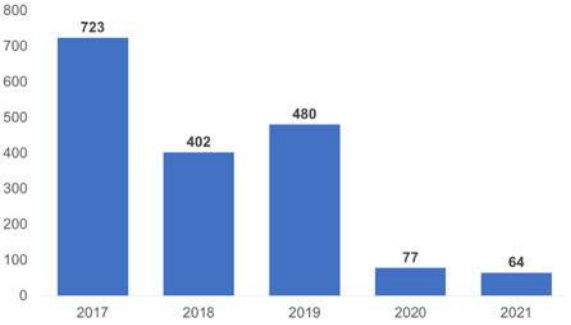

Figure 19. Periodontitis cases in pregnant women in the Caraga Region from 2017-2021.

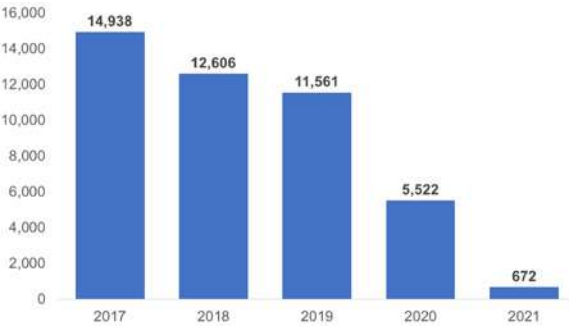

Figure 20. Report of orally fit children 9 years old and below upon oral examination in Caraga Region from 2017-2021.

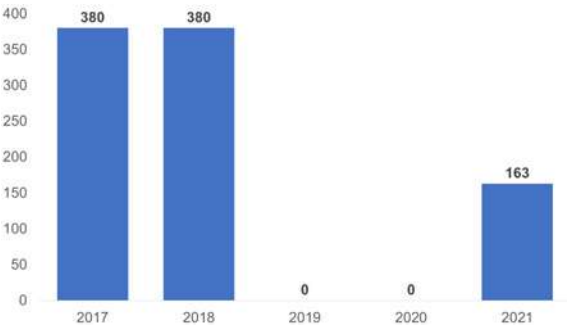

Figure 21. Orally fit children 9 years old and below upon complete oral rehabilitation in the Caraga Region from 2017-2021.

and healthcare providers must recognize the importance of such interventions and work towards ensuring their availability and affordability to all children in need to enhance their oral health and overall well-being.

In statistics, a monotonic trend refers to a consistent and structured pattern of change in a dataset over a specific period. It indicates a steady and predictable progression or regression of variable values (Raj 2014). The closure of dental clinics during the COVID-19 pandemic and the increased cost of traditional dentistry have led to declining access to dental care, particularly affecting individuals with limited financial means (Brillo et al. 2022). Consequently, many people have turned to home remedies for treating dental issues instead of seeking professional dental assistance during lockdowns (Pavithra & Anjali 2020). An analysis of Google Trends data from 2020 to 2022 reveals that Northern Mindanao, along with Western Visayas, Davao Region, Central Visayas, and Calabarzon, ranks among the top subregions with the highest searches for toothache home remedies (Brillo et al. 2022).

4 Conclusion and Recommendations

The five-year analysis of dental cases in the Caraga Region reveals noteworthy dental disease and service trends. It points to decreased gingivitis cases, fluctuating periodontitis cases, and varying outcomes in dental services. Additionally, there is a decline in oral health among children, while pregnant women exhibit a high incidence of untreated dental caries. These findings demonstrate a consistent decline in dental health, which can be attributed to the impact of the COVID-19 pandemic. The pandemic's influence on dental care and disease prevalence, whether during pandemic periods or not, necessitates reevaluating and enhancing dental care strategies. This study underscores the importance of organized and safe access to dental care services and the implementation of a robust oral health education and awareness campaign targeting vulnerable populations, specifically children and pregnant women. Furthermore, it advocates for regular dental check-ups and promoting proper oral hygiene practices. These initiatives should be tailored to address the unique needs of these groups and reduce disparities in oral health outcomes.

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution Statement

JC Yatar conducted the study, collected data, and did some analysis, and JH Jumawan conceptualized the study design, analysis, and editing. JC Jumawan and MEQ Won provided technical inputs in the writing of the article. JC Jumawan and JH Jumawan, as members of the JESEG Editorial Board, did not interfere with the review process. All authors approved the final version of the article.

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POLICY BRIEF

Satellite Remote Sensing and Geographic Information System Technologies for Industrial Tree Plantation Mapping and Monitoring: A Way Forward for the Sustainable Development of the Philippine ITP Industry

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KEY POINTS

- Industrial Tree Plantations (ITPs) are a vital contributor to the Philippines' log and timber production, but these ITPs requires better and more efficient way of characterization and monitoring.
- Current policies require ground validations surveys to monitor ITPs for regulation purposes. However, these approaches are often difficult to conduct, time consuming and expensive.
- Satellite remote sensing (SRS) and Geographic Information System (GIS) technologies offer an efficient alternative to traditional ground surveys for mapping and monitoring ITPs.
- SRS and GIS enable detailed mapping of ITPs, including species-level identification, and provides valuable data for forest resource management and environmental monitoring.
- SRS and GIS technologies should be integrated into existing policies by the Department of Environment and Natural Resources (DENR) to efficiently map, monitor, and manage ITPs in the country, ensuring informed decision-making and sustainable forestry practices.

Keywords: *satellite remote sensing, GIS, industrial tree plantation, mapping, monitoring*

1 Industrial Tree Plantations: How much do we know?

Industrial Tree Plantations (ITPs), often referred to as "tree farms," serve as primary contributors to the Philippines' log and timber production. This role has emerged in response to the increasing demand for logs from wood-based industries, and it underscores a well-established fact: natural forests alone are insufficient to meet this demand (Arguirre-Salado et al. 2015). The pressure on forestlands has escalated due to competing land uses, intensifying the need for plantation forest management (Codilan et al. 2015). Consequently, the significance of ITPs is expected to persist, especially in the Philippines, given the issuance of Executive Order No. 23 in 2011, which imposed a nationwide moratorium on timber cutting and harvesting in natural and residual forests (Philippine Star 2018).

Notably, among all regions in the country, Caraga (Figure 1) has emerged as the foremost producer

of significant forest products in the Philippines, earning its reputation as the 'Timber corridor of the country' (Balanay et al. 2022). In the year 2022, this region made an outstanding contribution, accounting for 70% (equivalent to 557,058 m^3) of the nation's total log production, which stood at 797,192 m^3 (FMB 2023). This significant achievement is attributed to the numerous industrial tree plantations in the Caraga region, and this trend has remained steady in recent years (Figure 2). Despite their significance in the country's log and timber production, ITPs have not been adequately characterized in terms of their types, locations, spatial arrangements, and total area. The spatial-temporal aspects of their growth and development, and management dynamics are also not well documented. The limited availability of these information makes it difficult to understand many relevant questions related to ITPs such as their location and extent, species composition, potential areas for expansion, location of processing plants, among others.

Periodic inventories through ground surveys have traditionally been employed to identify the types, locations, spatial arrangements, and total area of forest resources. In the context of ITPs, the current policies established by the country's Department of Environment and Natural Resources (DENR) (Table 1) necessitate ground validation surveys for various purposes, such as verifying tree plantation registrations, validating timber inventory reports for permit applications, and assessing expansion applications by Community-Based Forest Management Agreement (CBFMA) holders (Calub 2005, DENR 1997, 1999, 2000, 2020, 2021). However, conducting ground surveys can

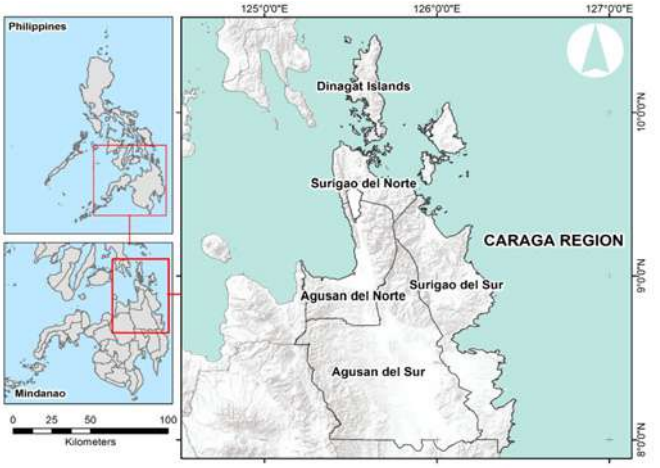

Figure 1. Caraga Region, Mindanao, Philippines. (Credit: Arnaldo C. Gagula, Caraga State University)

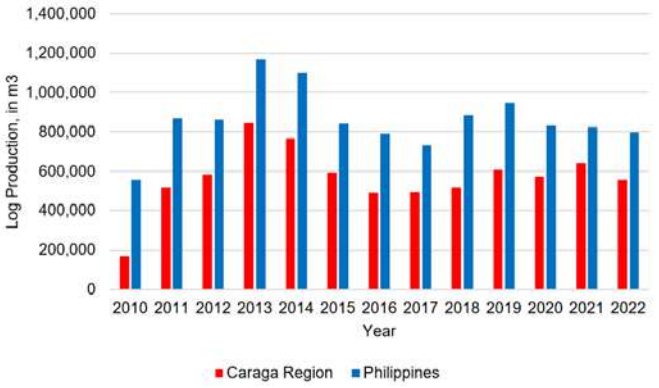

Figure 2. Log production statistics for 2010-2022. Source: Philippine Forestry Statistics, Forest Management Bureau.

Table 1. Some of the policy issuances of the DENR relevant to the ITP industry where SRS and GIS technologies can be incorporated.

Policy Name and Number	Subject	Short name (as used in the paper)
DENR Memorandum Circular No. 97-09	Documentation of Tree Plantations in Private Lands (DENR 1997)	DMC 97-09
DENR Memorandum Order No. 99-20	Supplemental Guidelines Governing the Registration, Harvesting, Transport and Marketing of Timber By-Products Coming from Private Plantations within Private Lands or Tax Declared Alienable or Disposable Lands (DENR 1999)	DMO 99-20
DENR Administrative Order No. 2000-21	Revised Guidelines in the Issuance of Private Land Timber Permit/ Special Private Land Timber Permit (PLTP/SPLTP) (DENR 2000)	DAO 2000-21
DENR Administrative Order No. 2020-18	Promoting Tree Plantation Development and Liberalizing Harvesting and Transport of Planted Trees and Tree Derivatives for Inclusive Growth and Sustainable Development (DENR 2020)	DAO 2020-18
DENR Administrative Order No. 2021 – 42	Guidelines on the Processing of Applications for Expansion of Areas Under Community-based Forest Management Agreement (CBFMA) to cover Adjacent Untenured Areas Within Forestlands (DENR 2021)	DAO 2021-42

be challenging, time-consuming, and expensive. These challenges are particularly pronounced when dealing with ITPs, which can span vast and often inaccessible areas, making it beneficial to explore more efficient and comprehensive approaches for mapping and monitoring.

2 Satellite Remote Sensing and GIS Technologies – A Boon for ITP Mapping and Monitoring

Satellite remote sensing (SRS) is commonly used nowadays as an efficient alternative to ground surveys. Generally, it enables the collection of information about the earth surface through analysis of data acquired by sensors installed in a satellite that is orbiting the Earth.

Essentially, the sensor functions similar to a camera, capturing visual "snapshots" of specific sections of the Earth's surface. Subsequently, these images, or in other words, the acquired data, are transmitted from the satellite and made accessible to potential users. Users then process and analyze the images using Geographic Information System (GIS) software and tools to extract various layers of information that may include vegetation, buildings, roads, rivers, and other land-cover types, among others. GIS, therefore, is crucial for converting raw SRS data into valuable information, enabling a comprehensive understanding of Earth's surface characteristics for various applications.

SRS in combination with GIS has emerged as an effective method for mapping and conducting inventories of forest resources over extensive areas (Chen et al. 2016, Fagan et al. 2018). This approach is especially valuable for regions that are challenging and costly to monitor through ground surveys. Consequently, SRS and GIS offer the capability to accurately pinpoint the location and scale of industrial tree plantations (ITPs), as depicted in Figure 4. It can also track the dynamic changes in ITPs, including detailed data down to the level of individual tree species (e.g., as demonstrated by Koukoulas and Blackburn in 2005).

The detailed layers of information about ITPs derived from satellite images can be further analyzed and integrated with other spatial and non-spatial datasets using GIS to derive new information. Some of the analyses that can be performed include determining the environmental characteristics of mapped tree locations, detecting and determining the rate of change of forest resources, and finding areas suitable for establishing tree plantations and processing plants (e.g., Arguirre-Salado et al. 2015, Williamson and Nieuwenhuis 1993).

This integrated information is also valuable for efficient management and monitoring of ITPs in the region. It can be employed for checking if the ITPs fall into alienable and disposable lands, restricted areas such as protected areas, and other land categories. Moreover, this data can be utilized for forecasting wood supply and market trends, developing economic models that consider climate change scenarios, and addressing various needs that demand information related to the wood industry (Balanay et al. 2022). On the other hand, monitoring the extent of ITPs through SRS and GIS is critical for understanding environmental and socioeconomic impacts (Torbick et al. 2016).

3 SRS and GIS for Mapping ITPs: The Case of Caraga Region

The ITP Mapping Project of the ITP Research and Innovation Center of Caraga State University utilized SRS and GIS to map the spatial distribution of ITPs in Caraga Region (Santillan et al. 2021). To exemplify the ease and advantages of SRS and GIS for mapping ITPs, the team used a combination of Sentinel-2 and high-resolution satellite images available on Google Earth. The images were analyzed and then used to map various ITP species throughout Caraga Region in not more than three months' time, a task that may take more than a year using ground surveys. The project focused on mapping ITP species which are used by the lumber, veneer, and plywood industry (DOST PCAARRD 2016), namely Falcata (*Paraserianthes falcataria* (L.) Nielsen), Yemane/Gmelina (*Gmelina arborea* Roxb), Mangium (*Acacia mangium* Wild), and Bagras (*Eucalyptus deglupta* Blume). Among these species, Falcata plantations (Figure 3, Figure 4) were found to be dominant in the region.

The project's mapping methodology can map

Figure 3. A Falcata tree farm in Butuan City, Philippines. (Source: Santillan et al. 2021)

Figure 4. A satellite remote sensing image showing Falcata plantations (in bright green) in Butuan City in Caraga region, Philippines. The image was captured on August 10, 2019. (Credits: Google Earth; Santillan et al. 2021)

tree farms with size of 10x10 m or larger using freely available Sentinel-2 images, with more than 90% accuracy (Santillan and Gesta 2021). Since 10 m x 10 m is relatively coarse, the extent of mapped tree farms was refined by using high resolution satellite images, increasing the detail to almost 1x1 meter, and greatly defining the boundaries of the plantations with other land-cover types (Figure 5).

With the aid of GIS software, relevant maps and statistics can be generated from the results which clearly show in which localities and what ITP species are most commonly planted, and by how much (Figure 6, Figure 7, Table 2). In the past, such maps and statistics were difficult to find. To illustrate the potential applications, mapped ITPs can be integrated with other data in GIS for monitoring and regulatory purposes, such as verifying the compliance of ITPs with restricted land use regulations (Figure 8). Overall, the SRS approach coupled with the integrative power of GIS is a significant way forward for detailed mapping and monitoring of ITPs in the country.

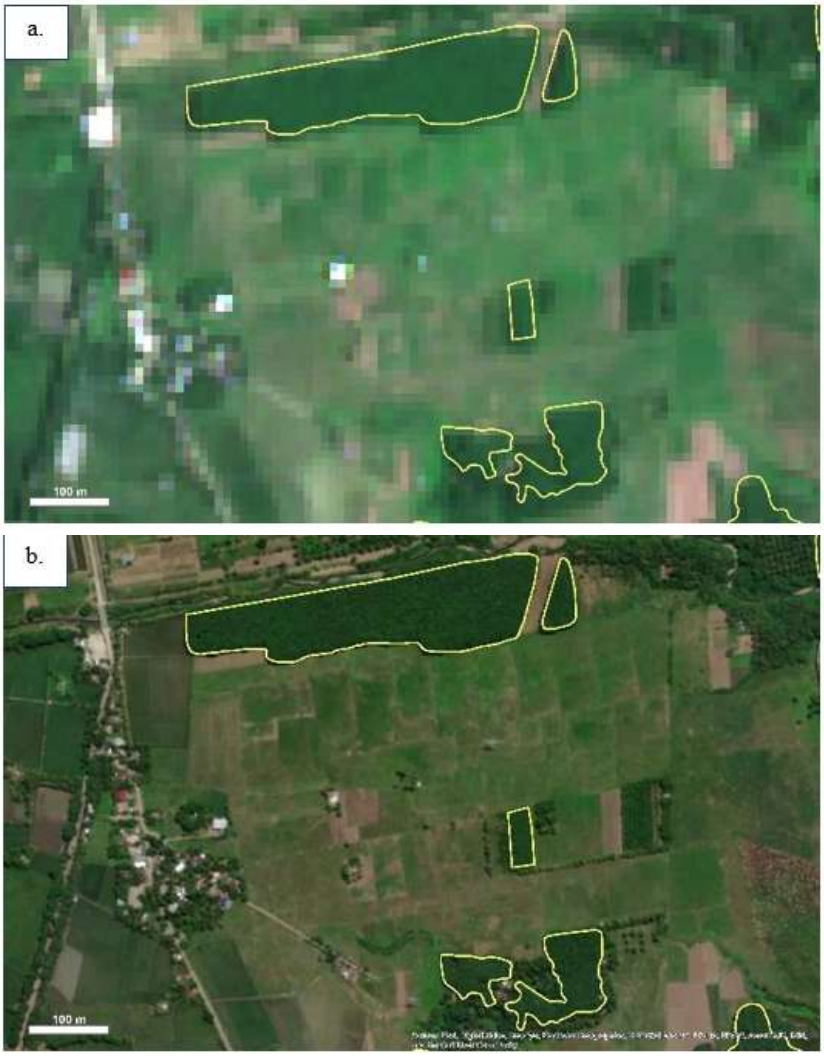

Figure 5. Falcata plantations as can be seen in a 10-m resolution Sentinel-2 image (a) and in a ~1-m resolution Google Earth image (b). (Credits: European Space Agency; Google Earth; Santillan et al. 2021)

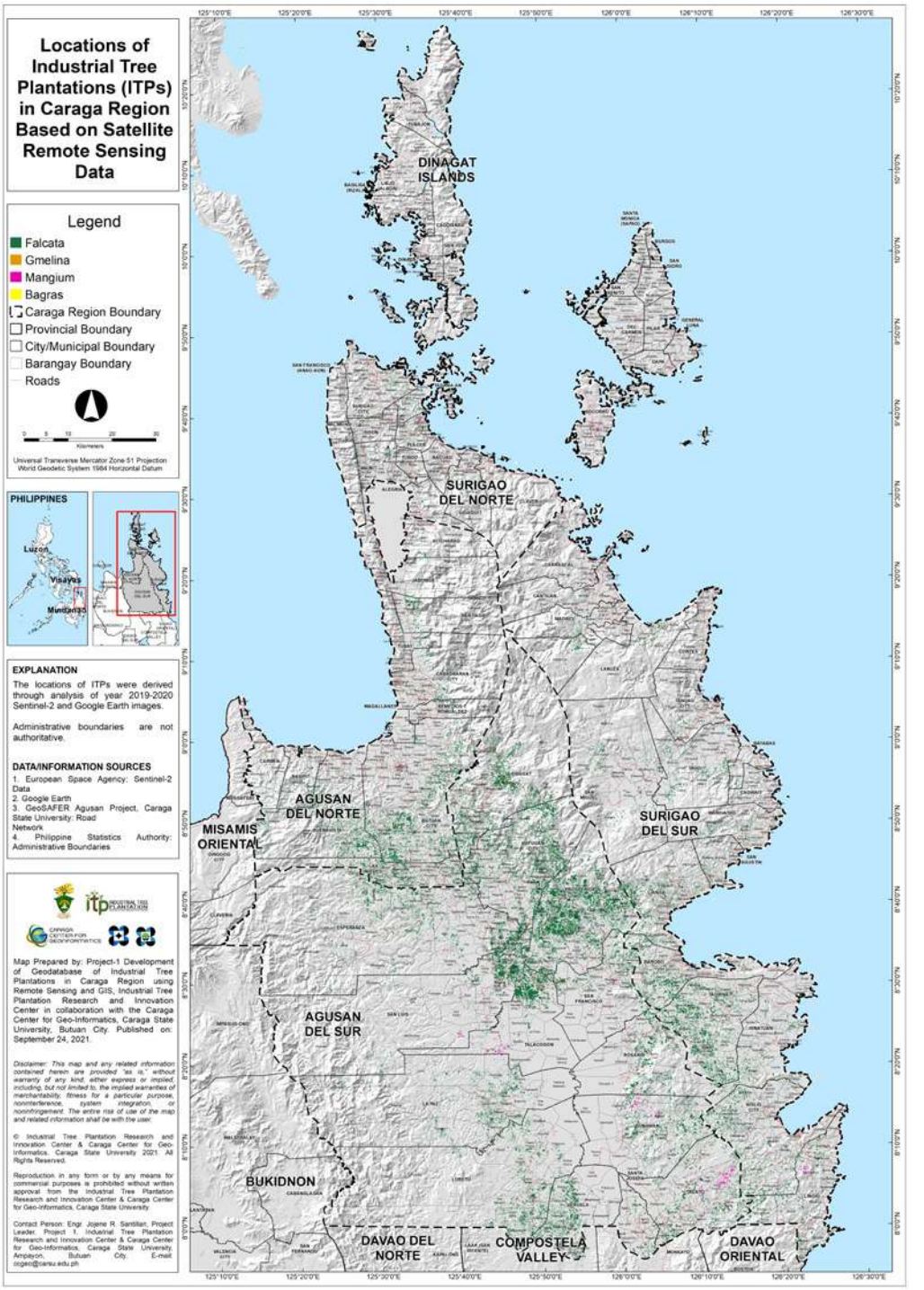

Figure 6. A map of ITPs in Caraga Region generated from year 2019-2020 satellite remote sensing images. Falcata plantations (in dark green) are dominant, especially in the provinces of Agusan del Norte, Agusan del Sur, and Surigao del Sur. A high-resolution version of this map is available at https://tinyurl.com/caraga-itp-map.

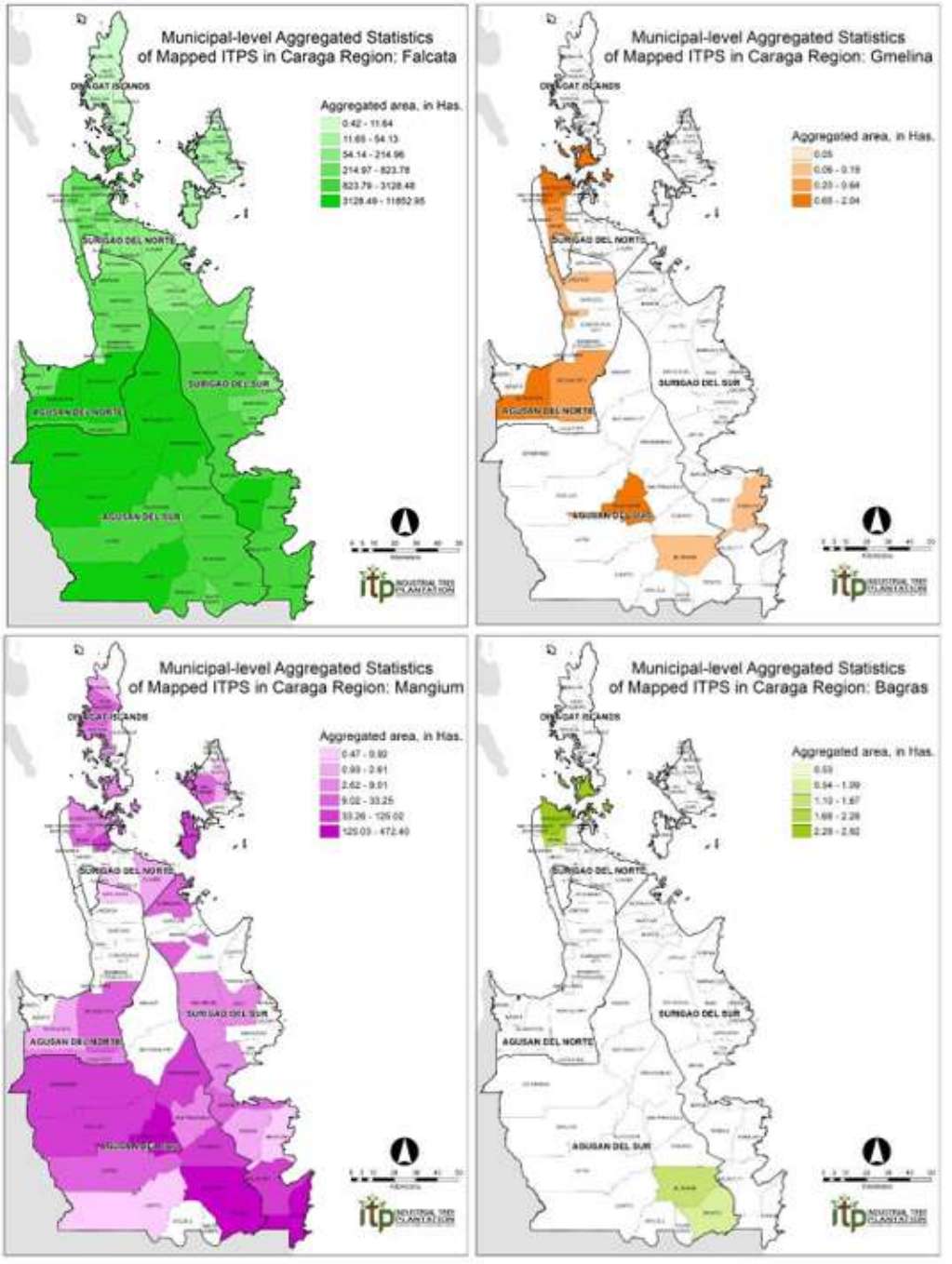

Figure 7. Maps illustrating the municipal-level aggregated areas of mapped ITPs from year 2019-2020 satellite remote sensing images. These maps highlight those cities and municipalities where the ITP species are planted, including where they are least/most abundant.

Table 2. Area of ITPs in the provinces of Caraga Region mapped using SRS and GIS. The areas, in hectares, are estimated for the years 2019-2020.

Province	Falcata	Bagras	Yemane ("Gmelina")	Mangium
Agusan del Norte	14,593.16	-	1.63	20.15
Agusan del Sur	55,337.99	2.40	1.07	1,102.43
Dinagat Islands	20.32	-	-	16.84
Surigao del Norte	2,376.39	4.67	2.82	197.37
Surigao del Sur	21,308.64	-	0.13	331.53
Total Area	93,636.50	7.07	5.65	1,668.32

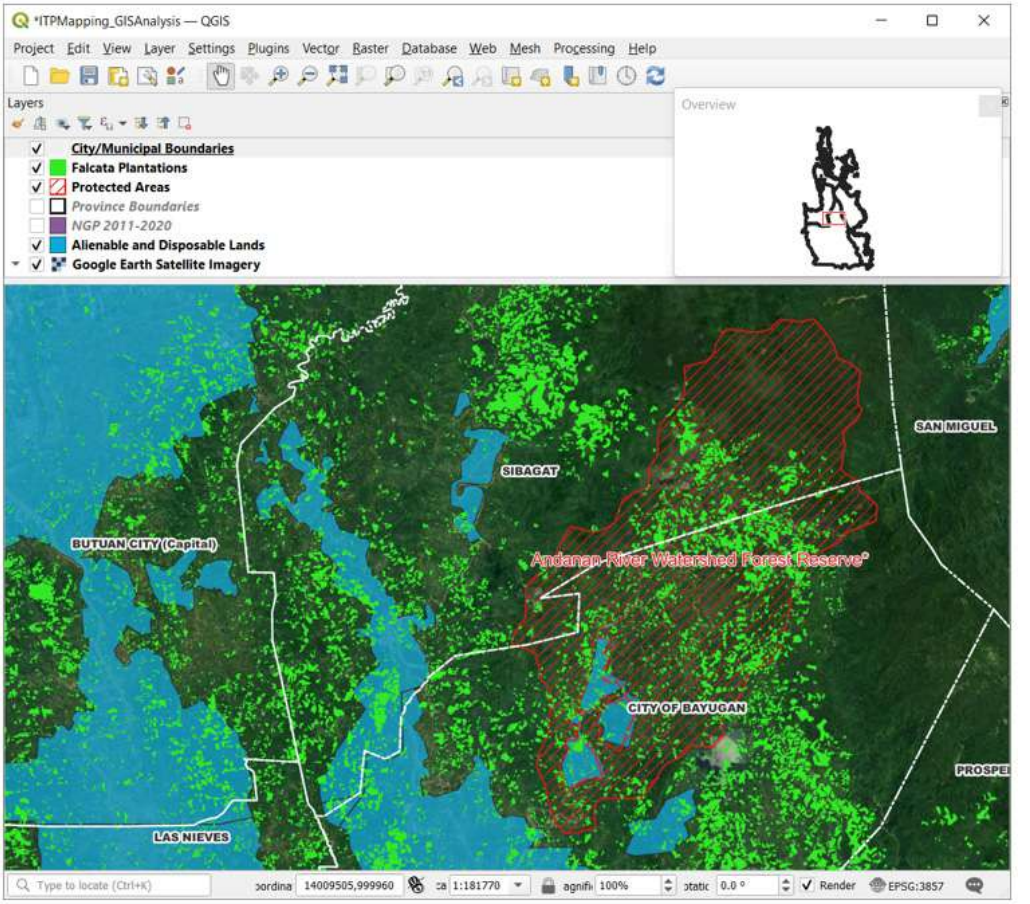

Figure 8. This example demonstrates the practical application of mapped ITPs by integrating it with other datasets in a GIS environment. It involves overlaying the mapped Falcata plantations with administrative boundaries and land classification data, including alienable and disposable (A&D) lands and protected areas. This illustration underscores the capacity of satellite remote sensing coupled with GIS in verifying compliance with land use regulations, revealing instances where plantations are situated both within and outside A&D lands, as well as within protected areas. (Sources of illustrated data: Santillan et al., 2021; DENR Region 13; Caraga Center for Geo-Informatics – Caraga State University).

4 Implications and Policy Recommendations

Mapping and monitoring ITPs in the country can be enhanced by taking advantage of SRS and GIS. These technologies are recommended for the use of the Community Environment and Natural Resources Office (CENROs) and Provincial Environment and Natural Resources Office (PENROs) of the DENR as a better alternative to the laborious and expensive ground surveys, and to complement their existing tree plantation-related registration and monitoring activities.

Specifically, the use of SRS and GIS will benefit the CENRO/PENROs in the following ways:

- Generate detailed maps and statistics on the location and area of ITPs at the regional, provincial, municipal and barangay levels.

- Permit yearly or even monthly monitoring of ITPs, including planting and logging/harvesting activities.

- Identify and limit potential areas for establishing ITPs.

- Verify the locations of areas being applied for certificates of tree plantation registration and ownership.

- Generate ITP-level timber harvest and wood supply projections.

To realize these benefits, existing DENR policies, rules, and regulations relevant to the ITPs industry (Table 1) should be amended for the integration of SRS and GIS technologies and derivative maps (e.g., ITP maps). Among the recommended amendments are as follows:

- DMC 97-09, DMO 99-20, and DAO 2020-18 should be amended to include sections/subsections on the SRS andGIS-based mapping of tree plantations to be undertaken by the CENROs/PENROs to complement their yearly private land tree plantation registration activities. The maps derived from this mapping activity should be utilized in several ways, such as (i.) to verify tree plantation registration applications prior to the issuance of Certificate of Registrations and Certificate of Tree Plantation Ownership; (ii.) to become part of the database on tree plantation records; and (iii.) as supporting documentation for the annual report submitted by the CENRO to the DENR Secretary, especially on the total area planted by species.

- Section 6 of DAO 2000-21 should be updated to incorporate the use of satellite remote sensing-derived ITP map to cross-check/validate the timber inventory report required for the timber permit application. The ITP map can aid in verifying the location and existence of trees/forest resources being applied for a timber permit.

- Section 5 of DAO 2021-42 should be updated to incorporate the most up-to-date ITP map derived from SRS, along with GIS-derived maps of relevant land classification and tenurial instruments. The inclusion of ITP maps is crucial as they transcend administrative boundaries, tenurial jurisdictions, and land classifications. These maps are valuable in providing the information needed to fulfill the requirements outlined in Section 5. For instance, they aid in verifying whether the CBFMA holder has fully developed their existing plantable area and whether adjacent, untendered areas host existing plantations.

- In consonance with the previous recommendation, Section 7 of DAO 2021-42 should be updated such that the most up-to-date ITP map derived from SRS is utilized when the CENRO or the implementing PENRO reviews and evaluates the application for expansion by a CBFMA holder in accordance with the provisions of Section 5. Likewise, the ITP map can complement, if not avoid, the need for ground validation surveys.

With these policy recommendations, there is a need to recognize SRS and GIS as more than mere mapping tools. These technologies, alongside the ITP maps and other data/information layers they generate, should be considered as integral and inseparable components of the proposed policy advocacy for the sustainable development of the ITP industry. The utilization of these technologies presents a comprehensive approach that surpasses traditional mapping practices. By recognizing SRS and GIS as integral parts of the advocacy, we underscore the paramount importance of these technological advancements in guiding amendments of ITP-related policies.

Furthermore, it is also crucial to acknowledge that the operational use of SRS and GIS in the Philippines for ITP assessment is long overdue.

There have been considerable evolution and significant improvements in the accuracy of these technologies over the last few decades. Integrating these technologies with advances and innovations in Information and Communication Technology (ICT), including data science, data analytics, and artificial intelligence can optimize the assessment process. It can also ensure that ITP mapping and monitoring processes leverage state-of-the-art technologies. By embracing these innovations, a holistic approach is established that aligns with the latest technological advancements, ultimately benefiting the DENR and its CENROs and PENROs, and the overall ITP industry.

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Statement of Conflict of Interest

The author declares no potential conflict of interest.

Data Availability

Data supporting the formulation of this policy brief, including all outputs of the project, are publicly available at https://tinyurl.com/csu-itp-project.

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Quality of Soils in Soybean Producing Areas in Caraga Region, Philippines

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A B S T R A C T

This study aims to determine the soil quality of selected soybean producing farms in the Caraga region using soil quality index (SQI) measurements. Five sites were selected in the municipalities of San Miguel, Surigao del Sur and Trento, Agusan del Sur. Three 10×10 m soil monitoring plots were established within soybean fields in each site. Within each monitoring plot, three composite samples were collected coming from 10 subsamples using a soil probe. SQI was calculated following three general steps, (1) selection of minimum data set (MDS) via Principal Components Analysis (PCA), (2) Scoring of MDS via linear method, and (3) Calculation of weighted overall SQI. Out of the 16-soil property indicator, a total of five soil properties (exchangeable Ca, % sand, electrical conductivity, available P, and soil respiration) were extracted and used as the MDS for the calculation of SQI in each site. The main indicator properties for determining the quality of the soils in the area were Exchangeable Ca and % Sand contents offering a 68% and 26% weights over other soil properties, respectively. High SQI classification was found on four out of five sites evaluated, these were the two sites in the Municipality of Trento (Cebolin.M (61%) & Cebolin.T (54%)) and two sites in the Municipality of San Miguel (Libas-gua (68%) & Upper Carromata (93%)). One site in San Miguel revealed a low SQI (Lower Carromata (41%)). These SQI values indicate that in these areas, soils with very high Exchangeable Ca and Sand content could have a low-quality condition, and sites with optimal Exchangeable Ca (400 - 600 ppm) contents and loamy to sandy loam texture could be classified as high quality soils. Proper drainage system could be best done to manage the very high exchangeable Ca content in these soil and thus, could improve its quality.

Keywords: *Soil Quality Index (SQI), Principal Component Analysis (PCA), Minimum Dataset (MDS)*

1 Introduction

In the Caraga region, soybean is one of the commercial high-value crops produced, and historically, the region was recognized as the soybean capital of the Philippines. However, upon recent assessments, there is a decline in the production quantity and quality of the produced beans (Balanay & Laureta 2021). Most of the study focuses on the economics of soybean but very little to no study regarding the quality of the soil in the area (Balanay & Laureta 2021, Dela Cruz & Neric 2016).

The quality of the soil is a direct determinant

of the quality and quantity of crop production. Soil quality is the ability of soils to function within the boundaries of a natural or handled ecosystem, to sustain the productivity of plants and animals, to maintain or improve the quality of air and water, and to sustain human health and habitat (Karlen et al. 2003). The soil quality cannot be measured directly, but soil properties that are sensitive to changes under environmental and/or anthropogenic influences could be used as indicators of its quality (Schloter et al. 2003).

Although knowledge of soil quality plays an essential role in the improvement of crop production and productivity, there is scarce scientific information available about the soil quality of soybean farms in the region. There is currently no agreement or established methodology for the selection of soil quality indicators. Many indicators of soil quality have been proposed, but few have been tested and validated (Ghaemi et al. 2014). For soybean plants, a good quality soybean should be high in crude protein (CP) and high yielding. These quality parameters are highly related to the capacity of the soil to function as a nutrient supplying and reservoir system. This capacity of the soil can be indicated by optimum levels of soil pH, soil nutrients, water holding capacity, etc. With a proper assessment of the quality status of the soil, specific measures can be made to alleviate any constraints that can be uncovered from the assessment process.

Hence, this study aims to determine the soil quality of selected soybean producing farms in the Caraga region. In this study, the quality of the soil was assessed following specific protocols and procedures as outlined for soil quality assessments. Moreover, these data could potentially provide recommendations to alleviate the constraints that will be uncovered and relevant information to improved soil quality in soybean producing farms.

2 Materials and Methods

Site Characterization

The sites were located in the municipalities of San Miguel, Surigao del Sur and Trento, Agusan del Sur. In San Miguel, three barangays were selected namely; Libas-gua, Upper Carromata (inside experimental station of SDSSU - Surigao del Sur State University, now NEMSU - North Eastern Mindanao State University) and, Lower Carromata. Manchuria variety was planted in Libas-gua and Lower Carromata while Tiwala variety was planted in Upper Carromata. One site in Trento was also planted with Manchuria and another site with Tudela Black variety. Both sites in Trento were located in Brgy. Cebolin. Both areas were closely situated along relatively huge river systems (Tago River – San Miguel and Sumilao River - Trento). Thus, seasonal flooding is expected to happen around October to July. The general parent material of the soil in these areas were alluvial deposits, primarily from the flooding events which is the common mechanism of formation for soils near flood plains or lowlands near river systems (Carating et al. 2014). These soils are considered economically important in the Philippines since most of the agricultural activities happen in this piece of land (Carating et al. 2014). The general soil type in San Miguel sites based on the soil series map in geoportal philippines (NAMRIA n.d.) belong to the San Manuel series while the sites in Trento belong to the Mambutay Series. A typical Silt Loam and Sandy Loam soil texture can be found in these areas respectively.

Soil Sampling Technique and Preparations

Three 10×10 m soil monitoring plots grown with soybeans were established in each site. Within each monitoring plot, three composite samples were collected coming from 10 subsamples at 20 cm depth using a soil probe. A total of nine composite samples were collected in each site. Each composite sample was air-dried, quartered and processed separately in relation to the laboratory analysis it would undergo.

Soil Laboratory Analysis

The physical analysis of the soil was conducted at the Soil and Plant Health Laboratory of the College of Agriculture and Agri-Industries – Caraga State University. For soil texture analysis, it was analyzed following the micro-pipette method (Miller & Miller 1987). Briefly, air-dried soil sample was pulverized and sieved to pass a 2 mm mesh. Around 4 g of this was placed in a falcon tube and was added with 40 ml dispersing solution (5% conc.) and then, was shaken for 20 mins in an end-to-end rotary shaker (60 rpm). After shaking, the samples were placed in a stable rack for 2 hours to allow settling process thereafter, around 2 ml aliquot was collected and oven dried to represent the

clay contents of the soil, the remaining suspensions were passed through a 0.053 mm sieve to collect for the sand component. Silt was then computed as a proportion of clay and sand percentages. For Bulk density, after collecting in the field via core samplers (5 cm dia. and 5 cm depth), it was brought to the laboratory for oven-drying. For Aggregate stability analysis, a quarter of the air-dried sample was pass through a 1 mm mesh. This size class was subjected to aggregates stability analysis in wet condition following the methods outlines by Patton et al. (2001).

The chemical analysis of the soil was done at the Regional Soils Laboratory at Brgy. Taguibo, Butuan City. Organic matter (OM) was analyzed following the Walkley-Black Method (Nelson and Sommers 1996), Total Nitrogen by Kjeldahl Method (Bremner 1996), Available Phosphorus by Olsen Method and Exchangeable K, Ca, Mg, Na via Ammonium Acetate Extraction Method (Van Reeuwijik 2002).

Soil Quality Index (SQI) Calculation

This is primarily done using the procedures outlined by Ramirez et al (2022). We created a spreadsheet to semi-automate the process but briefly, it starts with a selection of the minimum data set (MDS) using the results of principal components analysis (PCA) of all variables. Only PCs with at least 1 eigenvalue, 1 standard deviation or the total cumulative proportion of variance explained was at least 75% were retained. Then soil properties with at least 30% or 0.3 factor loading (absolute value) were considered to be selected as one of the MDS parameters (Andrews & Carroll 2001). When more than two soil properties were in a PC, correlation analysis was done among those parameters and only those with the highest absolute total correlation coefficient (Pearson's method) was retained to avoid redundancy. In cases when no correlation is found, then those parameters were retained.

After that, the selected MDS were scored using a linear method following these principles; "More is better", "Less is better", and "Optimum is better". To score the "more is better" indicator, observed values were divided by the highest value under that parameter such that the highest observed value among them received a score of 1 and the rest was scored <1. For the "less is better" indicator, observed values were divided by the lowest value under that parameter such that the lowest observed value among them received a score of 1 and the rest was scored <1. Then, in scoring the "optimum is better" indicator, thresholds of more is better and less is better scoring was observed, thus, when a parameter observed value was beyond its threshold level, it will be scored based on "less is better" method, and when a parameter observed value is below its threshold level, it will be scored based on "more is better" method (Ramirez et al. 2022 p. 1160).

And lastly, the scores will be used to compute for the soil quality index (SQI) following the formula below:

$$SQI = \sum_{1}^{n} W_i S_i \qquad (1)$$

where; W is the weight of a parameter as indicated in the PCA. The weight was based on the ratio between the proportion of variance in that PC and the cumulative variance for all PCs with standard deviation of >1 (Table 3), and S is the indicator score using the linear method.

Statistical Analysis

All data were subjected to the analysis of variance to determine mean differences across the six sites against selected soil parameters. Post hoc for significant differences were conducted using Fisher Least Significant Difference (F-LSD). A T-test was also conducted to compare the mean difference between the two municipalities. Correlation analysis and Principal Component Analysis was also done on selected soil parameters. All statistical analyses was conducted in R Studio ver. 023.06.0+421.

3 Results and Discussion

Properties of the soil and its implication on soil quality

Understanding the properties of the soil could pave the way to properly managing its quality. Table 1 shows the selected physical, chemical and biological properties of the soils under three varieties planted in five locations in two municipalities. Results revealed that there were significant differences (n = 54, *p-values* = <0.05) across the five locations for all parameters determined. We could speculate that the areas planted to soybeans in the Caraga region were

naturally different from one another. This entails that the management of these farms should be anchored to its salient soil properties and thus, the management of soil should be location and crop specific. Moreover, the analysis of variance also revealed that some of the parameter means were also statistically comparable (same letter subscript) thus, groupings or soil clustering would also be a good step before planning any intervention toward enhancing the quality of such soils.

A good clustering parameter would be soil textural class, as it is a static property thus, will not instantly change over time. As shown in Table 1, soil textural classes can be summarized into three clusters. First, the Loam Cluster, under which was the site in Libas-gua, San Miguel planted with Manchuria variety. Second is the Loamy Sand cluster, which was observed in Lower Carromata site in San Miguel grown with Manchuria variety as well. The third cluster is Sandy Loam, which was found to be under three sites, two in Trento Municipality – Cebolin.M planted with Manchuria and Cebolin.T planted with Tudela Black and one in San Miguel, Upper Carromata. In principle, those soils under the same textural cluster can be managed similarly however, with precaution as to the other set of dynamic parameters.

The dynamic physical parameters evaluated were bulk density (BD), aggregate stability (AS) and plant available water (PAW) content. These properties were known to indicate the degree of compaction, stability of the soil and capacity of the soil to retain moisture for plant use, respectively. Thus, it could indicate the effects of tillage, cultural management and water use efficiency of the soil. All of the BD means were within the optimal range for good root growth (Landon 1991). Moreover, the analysis of variance (*p-value* = 1.82e-11***) revealed that across sites, the lowest was observed in Upper Carromata. This could be due to the fact that this area was the experimental site of NEMSU thus, might receive intensive addition of soil amendments and cultivation to prepare the field for experimental purposes.

For soil AS in wet conditions, results revealed that all means in each location were below the optimal range (80-100%) (Weil & Brady 2017). This could indicate that the soil in all of the sites were poor in terms of stability against the action

Table 1. Mean values of soil properties under the different sites.

Parameters	Manchuria			Tiwala	Tudela Black	Statistics	
	San Miguel		Trento	San Miguel	Trento		
	Libas-gua	Lower Carromata	Cebolin.M	Upper Carromata	Cebolin.T	*p-value*	*CV(%)*
% Sand	33.6_{c}	86.3_{a}	62.1_{b}	64.3_{b}	60.1_{b}	2.75e-15***	14.1
% Silt	45.8_{a}	7.6_{c}	27.9_{b}	24.1_{b}	23.3_{b}	4.98e-11***	32.4
% Clay	20.7_{a}	6.2_{c}	10.0_{bc}	10.7_{b}	16.6_{a}	2.47e-07***	38.9
Textural Class-USDA	L	LS	SL	SL	SL	-	-
Bulk Density (g/cm3)	1.0_{b}	1.2_{a}	1.2_{a}	0.9_{c}	1.2_{a}	1.82e-11***	6.6
% Aggregate Stability	41.6_{b}	11.4_{c}	16.8_{c}	55.9_{a}	13.7_{c}	<2e-16***	20.7
Plant Available Water (%)	5.9_{b}	0.6_{c}	1.1_{c}	38.8_{a}	0.3_{c}	<2e-16***	23.6
pH in water (1:2.5)	6.8_{b}	7.5_{a}	6.1_{c}	4.65_{d}	6.2_{c}	<2e-16***	3.1
pH in CaCl2 (1:2.5)	6.2_{b}	7.2_{a}	5.8_{c}	4.3_{d}	6.1_{bc}	<2e-16***	6.0
EC (µS/cm)	55.2_{b}	230.2_{a}	24.9_{d}	41.8_{c}	36.7_{cd}	<2e-16***	20.3
Organic matter (%)	1.8_{b}	1.2_{d}	1.3_{cd}	2.4_{a}	1.4_{c}	<2e-16***	13.8
Total N (%)	0.1_{b}	0.0_{d}	0.1_{c}	0.2_{a}	0.1c	<2e-16***	9.6
Avail. P (ppm)	15.4_{a}	12.4_{b}	13.2_{ab}	7.6_{c}	11.7_{b}	1.39e-06***	28.0
Exch. K (ppm)	161.9_{a}	171.9_{a}	175.6_{a}	88.6_{b}	160.4_{a}	3.15e-05***	33.8
Exch. Ca (ppm)	5351.1_{d}	7649.1_{a}	6165.6_{c}	1789.2_{d}	6535.6_{b}	<2e-16***	5.3
Exch. Mg (ppm)	1776.7_{a}	522.0_{b}	551.1_{b}	229.7_{c}	550.0_{b}	<2e-16***	8.1
Exch. Na (ppm)	51.2_{a}	54.8_{a}	54.8_{a}	25.4_{b}	54.5_{a}	1.19e-15***	16.8
Soil Respiration (mg C/g)	1.2_{a}	1.0_{a}	0.7_{b}	1.2_{a}	0.9_{ab}	0.00233**	27.3

Note: Composite samples analyzed per parameter is n = 9, except for Bulk Density (n=5). Textural Class (L – Loam, LS – Loamy Sand, SL – Sandy Loam). Means followed with same letter subscript across sites is not significantly different at 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

of water (e.g. rainfall and irrigation) and could be prone to erosion and run-off. Moreover, based on the analysis of variance, the highest AS was observed in Upper Carromata and the lowest in Lower Carromata. These significant differences (<0.05) could be attributed primarily to the OM content of these soils since OM is one of the most important binding agents for soil aggregate formation and stability (Villasica et al. 2018). This can also be seen in the correlation analysis in Figure 1 wherein a positive and significant correlation was observed between AS and OM (r = 0.83). In terms of the PAW content of the soil, it also follows the same pattern for the highest content as to AS. The site in Upper Carromata revealed the highest PAW content and this could still be attributed to the OM content of the soil (see Figure 1) having a positive and significant correlation (r = 0.86). The OM content of the soil is very dynamic in nature and thus should be managed properly since it can affect several dynamic physical and chemical properties of the soil as well.

All chemical properties evaluated in this study were dynamic properties. The pH in water and pH in CaCl2 were considered to be very dynamic and could determine the availability of other nutrients in the soil. Results revealed that a near neutral pH in water and in CaCl2 was observed in Lower Carromata sites. This indicates that the soil could still have the basic cations in its soil solution. Moreover, the lowest pH in water and CaCl2 was observed in Upper Carromata site indicating that some of the bases might have leach over time. Correlation analysis between pH and the basic cations (Ca, Mg, Na) (Figure 1) shows a generally positive and significant (r = 0.91, 0.55, 0.77, respectively) correlation thus directly affecting each other. For EC or Electrical conductivity of the soil, this indicates the salinity or the relative contents of soluble salts in the soil solution. Results showed that the EC of the soils were all below the range of salinity or sodicity problems (Landon 1991). The highest across the sites is the one on Lower Carromata indicating that a source of soluble salt might be present in the area such as the seasonal flooding events of the proximate river systems. Similar to pH, EC is very dynamic and can also affect nutrient availability (Weil & Brady 2017).

For the nutrient status of the soil, OM plays a vital role as a nutrient supplying component in the soil. OM affects the contents of Nitrogen (N) and Phosphorus (P) in various degrees. Across all sites, the highest OM content was quantified under Upper Carromata site. This could be due to the management employed by the caretakers of this area. Based on the correlation analysis in Figure 1, OM and N contents were strongly

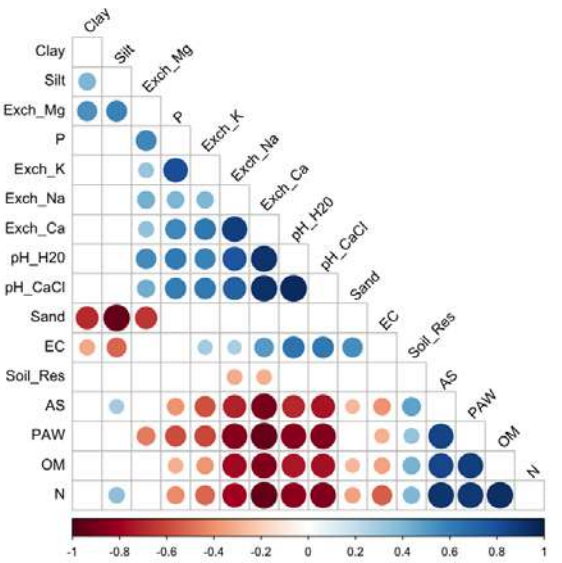

Figure 1. Correlation Matrix for pertinent data. *Note: Blue color – Positive significant correlation; Red Color – Negative significant correlation.*

related to one another (r = 0.93) indicating that N contents could be derived from the decomposition of OM in the soil. Moreover, N contents follows the same pattern as to the OM contents of the soil indicating a direct relationship, thus in terms of management, an active organic-based farming would be beneficial across all sites for the availability of N. Moreover, the available P across sites is within the range for optimal P contents (Landon 1991). Significant differences (*p value* = 1.39e-06***) were still observed across sites. For the Exchangeable cations determined in every site, exchangeable Ca shows the highest concentration among the cations, indicating that these soils experience loading of calcium-rich sediments and that leaching of this cation is not prominent. This could also imply that these soils are young and thus, should be managed more critically. The last property determined was basal soil respiration, which can indicate the biological property of the soil. Soil respiration is directly related to mineralization or decomposition of organic matter which in turn releases carbon from the soil in the form of CO2, thereby changing the chemical dynamics within the soil and the surrounding atmosphere. As shown in Figure 1, soil respiration was slightly correlated with PAW, OM, N showing its effect to the dynamics within the soil. In addition, the highest soil respiration was observed in the Upper Carromata area since it also has the highest OM contents (Table 1).

Soil Quality Evaluation and its Implications

Following the steps for SQI calculation using the 16-soil properties evaluated, 82% of the variance in the data was explained by the first three principal components (PCs). In Table 2 under PC1, seven soil properties show relevant factor loadings (>0.3) and thus, were pre-selected to be retained under PC1. Since the correlation analysis showed that all properties under PC1 are highly correlated to one another thus, the highest sum of the absolute value of its correlation coefficient was determined and the parameter with the highest absolute sum of correlation will be used as the minimum data set (MDS) for SQI calculation. Exchangeable Ca revealed the highest sum of absolute correlation coefficient compared with the other parameters (sum absolute r = 5.49) in PC1 hence, was selected to represent PC1. Following the

Table 2. Results from the PCA including the corresponding factor loading for each soil property

Soil Property	PC1	PC2	PC3
Clay	-0.007	**-0.407**	0.059
Silt	-0.075	**-0.453**	-0.188
Sand	0.062	**0.511**	0.125
AS	**-0.308**	-0.096	0.197
PAW	**-0.331**	0.087	0.106
pH_H20	**0.326**	-0.059	0.164
pH_CaCl	**0.328**	-0.019	0.163
EC	0.187	0.246	**0.415**
OM	**-0.305**	-0.092	0.241
N	**-0.334**	-0.113	0.096
P	0.211	-0.232	**0.335**
Exch_K	0.233	-0.123	0.195
Exch_Ca	**0.344**	-0.004	-0.024
Exch_Mg	0.129	**-0.434**	0.147
Exch_Na	0.292	-0.086	-0.194
Soil_Res	-0.119	-0.037	**0.626**
Standard Deviation	2.868	1.8613	1.20229
Proportion of Variance	0.514	0.2165	0.09034
Cumulative Proportion	0.514	0.7306	0.82092

Note: Values in bold and underline were considered to significantly contribute to the total explained variance under the PCs.

same approach employed under PC1, Percent Sand content was the only one retained under PC2 with significant factor loading while all three properties under PC3 with >0.3 factor loadings were retained since all of these properties were uncorrelated. A total of five soil properties were considered to contain significant amounts of variance (82%) that best represent the soil attributes of the sites (Table 2 & Table 3)

Table 3 shows the final minimum data set (MDS) of this study with its corresponding weights. The highest weight was assigned to Exchangeable Ca and the lowest weight was assigned to EC, Avail. P and Soil Respiration. The scoring principles were also indicated wherein Exchangeable Ca and Available P where scored based on "optimum" value, then % Sand, EC and Soil respiration where score as "less is better". Results revealed that among the sites planted to soybean cultivars, the area in Upper Carromata showed the highest SQI (93%) and the area in Lower Carromata revealed the lowest SQI (41%) (Table 4). The reason for a very high SQI in Upper Carromata could be attributed to its optimal Exchangeable Ca contents, which was considered the most powerful indicator of the SQI. Specifically, Exchangeable Ca contributed 63% to the SQI of Upper Carromata and an average of 17.82% for the rest of the sites. The optimal contents of Exchangeable Ca in the soil ranges from 1000-2000 ppm, below those value can cause Ca deficiency to the plants, and above those value can cause fixation or alter the availability of other nutrients and cations in the soil (Landon 1991). The possible reason for very high contents of Exchangeable Ca to the other site could be due to its seasonal flooding events wherein Ca-rich deposits might be enriching the soil during those events. Upper Carromata area is relatively elevated compared to the other sites thus, it is not essentially prone to seasonal flooding. Other sites were within 50 m away from its associated river system and seasonal flooding of this rivers brings loads of sediments across a wide floodplain wherein this plantation were situated.

Other indicators influenced the SQI of other sites. In Cebolin planted to Manchuria and Tudela Black and, in Libas-gua having high SQI with 61%, 54%, and 68%, respectively, was due to low Sand contents which contributed to around 14-28% to the SQI. The site with the lowest SQI (Lower Carromata (41%)) was due primarily to its very high Exchangeable Ca Contents (7649.11 ppm) and very high sand content (86.29% textural class is – Loamy Sand, see Table 1) which contributes 14% and 10% to its SQI respectively. These SQI values indicate that in these areas, soils with very high Exchangeable Ca and Sand content could have a low-quality condition, and sites with optimal Exchangeable Ca contents and loamy to sandy loam texture could be classified as high quality soils.

Table 3. Corresponding weights for each indicator and the scoring principle necessary for computing SQI.

Indicator (MDS)	Scoring Principle	Weight
Exchangeable Ca	Optimum	0.63
% Sand	Less is better	0.26
Electrical Conductivity	Less is better	0.1
Available P	Optimum	0.1
Soil Respiration	Less is better	0.1

Table 4. The SQI of each site using linear scoring method.

Location	SQI (%)	Classification
Cebolin.M	61	High
Cebolin.T	54	High
Libas-gua	68	High
Lower Carromata	41	Low
Upper Carromata	93	Very High

Management of soil planted with soybean based on SQI in Caraga Region

Based on the SQI results shown in Table 4, Cebolin sites planted to Manchuria and Tudela black variety and soils in Libas-gua and Upper Carromata soybean farms revealed a high to very high quality soil. The main focus of management within these sites should be in the maintenance of its quality. Maintenance management suggests that a regular soil sampling and analysis of the five indicator parameters should be conducted. Changes in the SQI value from these soils based on the five parameters can serve as a forecasting system on the specific management or cultural practices employed in this field. On the other hand, soils in Lower Carromata planted with Manchuria variety showed a low soil quality as indicated by its unusually high exchangeable Ca and sand contents. Management for high exchangeable Ca content in the soil could be done by adding stable organic materials in the soil and improvements of drainage systems particularly in managing the seasonal flood that is known to occur in the area.

4 Conclusion and Recommendations

The physical, chemical and biological properties of these soils vary significantly thus, could make direct interpretation from individual properties difficult. The soil quality index (SQI) provides a simple yet uncompromised way for evaluating soil condition based on measured soil properties. The soil quality of the sites were generated following protocols from several studies. Out of the 16-property indicator, a total of five soil properties were extracted and use as the minimum data set (MDS) for the calculation of SQI in each site. The main indicator properties for determining the quality of the soils in the area were Exchangeable Ca and % Sand contents offering a 68% and 26% weights over other soil properties, respectively. High SQI classification was found on four out of five sites evaluated, these were the two sites in the Municipality of Trento (Cebolin.M (61%) & Cebolin.T (54%)) and two sites in the Municipality of San Miguel (Libas-gua (68%) & Upper Carromata (93%)). One site in San Miguel revealed a low SQI (Lower Carromata (41%)). These SQI values indicate that in these areas, soils with very high Exchangeable Ca and Sand content could have a low-quality condition, and sites with optimal Exchangeable Ca contents and loamy to sandy loam texture could be classified as high quality soils.

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Statement of Conflict of Interest

The authors declare no conflict of interest associated with the submission and publication of this manuscript.

Author Contribution Statement

Sharyl Mae Daverao, Jason Gambuta, Avegael Sagaysay, Clyde Cabillo: Conduct of the study, soil sampling and parameter analysis. Reuben James Rollon, James Jade Lasquites: provided technical inputs in the writing of the article. Leo Jude Villasica: conceptualized the sampling design, did the statistical analysis, and spearheaded the editing of the paper. As a member of the JESEG Editorial Board, RJ Rollon and LJ Villasica did not interfere with the review process. All authors approved the final version of the article.

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Estimating the Total Annual Economic Loss Attributed to Climate Variations in Agusan Marsh Wildlife Sanctuary: The Case of Fishing and Farming Activities in Talacogon, Agusan del Sur, Philippines

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A B S T R A C T

The cost of alterations in the quantity or quality of ecosystem services (ES) that are traded on commercial markets can be approximated with the aid of a revealed preference approach, such as the market price method. This study used the market price method to estimate the total annual economic loss from the changes in the demand and supply of fish and crops due to climate variations in Agusan Marsh Wildlife Sanctuary (AMWS). Household interviews were done in the municipality of Talacogon using four sets of structured survey instruments to gather information such as the quantity supplied monthly by fisherfolks and farmers as well as the quantity demanded by residents at different market prices. The consumer surplus and producer surplus during peak and off-seasons were calculated to estimate the annual loss in economic benefits to consumers and producers. The most commonly consumed and produced products in terms of fishing and farming were *Channa striata* and *Oryza sativa* L., respectively. Climate variations have an impact on both fishing and farming commercial activities. During the dry season (March to August), fewer fish are caught due to low water levels in rivers and lakes, while crops cannot be planted during the wet season (September to February) because a lot of land areas are flooded. The total annual economic loss was calculated at PHP 99,974.50. This estimated monetary value can be a basis for decision-makers and concerned stakeholders to efficiently allocate funds for sustainable programs to capacitate the fisherfolks and farmers to increase adaptation mechanisms for climate variations.

Keywords: *Climate variations; market price; total annual economic loss; wetlands*

1 Introduction

Ecological systems provide benefits that contribute to the overall well-being of humans. These benefits are widely known as ecosystem services (ES) which are categorized into four broad categories: 1. provisioning services such as the production of food, water, fuel, and wood; 2. regulating services like regulation of water quality, flood, climate, and pest control; 3. cultural services which include education, spiritual, and recreation; and 4. supporting services that are necessary for the production of other ES which encompasses nutrient cycling and photosynthesis, among others

(Millennium Ecosystem Assessment 2005). While some ES already have market prices, others do not have hence cannot be traded directly in commercial markets (Carson and Bergstrom 2003). In the absence of a price tag, market failure often happens, and ecosystems are undeniably exploited. Additionally, property rights regime also plays a pivotal role. Since most of the ES are classified as public goods, non-paying users of a certain ES are difficult to exclude (low excludability), and the consumption of one person cannot prevent simultaneous consumption by another person (low rivalry in consumption) (Quah and Tan 2019) which eventually lead again to overexploitation.

Consequently, environmental degradation can be attributed to market failure or the absence of a market that accounts for externalities from a certain economic activity wherein a given ES is utilized. These externalities are forms of market distortion that cause unintended positive benefits or negative consequences to a third party. When these externalities and problematic property rights regimes are not taken into consideration, there will be a misallocation of scarce resources (Dasgupta 1996). Thus, the assignment of monetary values to ES through valuation is crucial and essential.

Ecosystem valuation focuses on the economic value of change in the quality or quantity of resource stock rather than the true value of ecosystems. In estimating direct consumptive use values like fish and crops, a revealed preference approach such as the market price method is more suitable (Hailu 2013). The market price method estimates the value of the changes in the quality or quantity of ES using the prices of goods that are traded in commercial markets (King and Mazzotta 2000).

Wetlands are among the most productive and valuable ecosystems in the Philippines, given that the average area of their largest type is 126,000 ha (Sespeñe et al. 2016). They serve as important habitats for different wildlife species, including migratory waterfowl. The RAMSAR Convention declared the Agusan Marsh Wildlife Sanctuary (AMWS) as a "Wetlands of International Importance" in 1999 (Sespeñe et al. 2016), and is one of the designated natural wetlands in the country. Aside from its biodiversity importance, AMWS provides food, such as fish and crops, to the dwellers within the protected area. It further acts as a natural flood control and water filtration system for the downstream communities (Mora-Garcia et al. 2020).

Despite these importance, threats and problems such as the conversion of forestland to agricultural production areas, illegal fishing, illegal logging, and wildlife hunting challenged the natural production of ES in the area. Climate variations also aggravate the impacts of these anthropogenic activities (DENR 2015). Thus, this study aimed to estimate the total annual economic loss due to climate variations in AMWS using the market price method, specifically in the case of fishing and farming activities in Talacogon, Agusan del Sur. This helps in designing sustainable programs to compensate for the loss of economic benefits to consumers and producers.

2 Materials and Methods

Study Area

The study was conducted from January to May of 2018 in the municipality of Talacogon. The area is part of the geopolitical boundary of Agusan Marsh Wildlife Sanctuary (AMWS), in the province of Agusan del Sur, Caraga Region, the Philippines. The AMWS covered six (6) municipalities, namely: Bunawan, La Paz, Loreto, Rosario, Talacogon, and San Francisco. Talacogon was documented to have the highest number of marsh inhabitants specifically the number of fisherfolks and farmers (DENR 2015). In this study, five (5) villages were chosen considering the route of the river, nearby lakes, creeks, and the number of fisherfolks and farmers. These are the villages of Desamparados, La Flora, Marbon, Sabang Gibong, and San Nicolas (Figure 1).

The common fishing gears used by fisherfolks in the said study areas are fish pots, push nets, cast nets, set gill nets, and set long lines. Electrofishing is common in Sabang Gibong, and La Flora. Push nets and cast nets, on the other hand, are only used in La Flora. The village of La Flora is considered a major landing center with direct fishers, and many of the fisherfolks live in floating houses. Fish ponds are also practiced specifically in Marbon, and fisherfolk associations are noted in Desamparados and San Nicolas. Agriculture is also one of the primary livelihood activities in the area. Rice and corn are the common crops planted in all of the study areas. Explicitly, the soil in Maharlika and La Flora is effective in the substantial production of corn. Irrigation canals

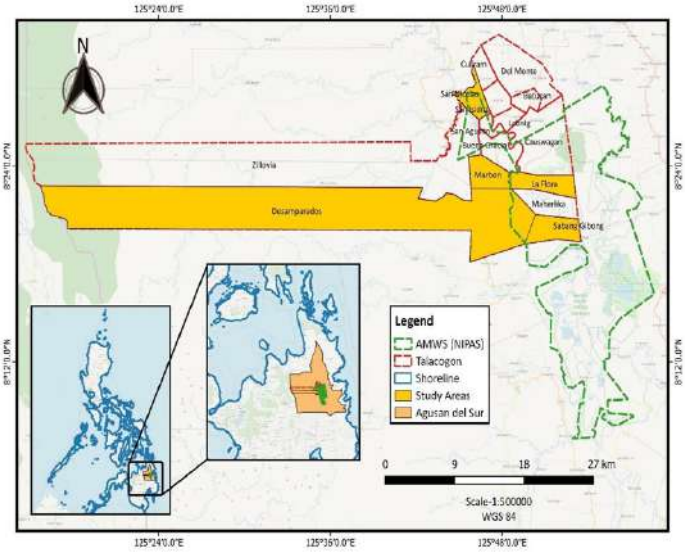

Figure 1. Location map of Agusan Marsh Wildlife Sanctuary with the five villages in Talacogon, Agusan del Sur, Philippines

are commonly used in the fields, and farmers' and irrigators' associations are established (Mindanao State University-Naawan 2013, and Baclayo et al. 2020).

Household Interviews

A stratified random sampling technique was used to gather representative samples from Talacogon's total population of 38,374 (Philippine Statistics Authority Census 2015). The population was divided into subgroups or strata (different villages for this case), and samples were randomly selected from the strata. The appropriate sample size was calculated using the formula of Cochran (1963):

$$n_0 = \frac{z^2 \rho q}{e^2} \qquad (1)$$

where n_0 is the sample size, z is 1.96 at 95% level of confidence, ρ is the sample proportion (0.50), q is $1-\rho$ and e is the margin of error (0.50);

$$n = \frac{n_0}{1+\frac{(n_0-1)}{N}} \qquad (2)$$

where n is the sample size and N is the population size.

Hence, a total of 603 respondents were interviewed in the five chosen villages of Talacogon consisting of 99 (16%) fisherfolks, 217 (36%) farmers, and 287 (48%) residents (Table 1). The target number of respondents was predetermined, however, there are changes in the actual number of respondents being interviewed. Therefore, the percentages per sector were identified after the conduct of the interview. One-on-one household interviews were done using four sets of structured survey instruments (for fisherfolks, farmers, and residents that consumed numerous species of fish and crops) to gather information such as the quantity of fish and crops supplied monthly by fisherfolks and farmers as well as the quantity demanded by residents at different market prices. Moreover, the survey instruments contain questions about the fishing and farming activities within AMWS, specifically the common fish and crops produced and consumed, types of fishing gear commonly used by the fisherfolks, factors that affect the said commercial activities, and marketing channels or buying schemes. The collected data were analyzed using descriptive statistics.

Revealed Preference Approach (Market Price Method)

The market price method by King and Mazzotta (2000) was used to estimate the total annual economic loss from the changes in the demand and supply of fishing and farming activities within Talacogon. Calculating the consumer and producer surplus is important in estimating the total annual economic loss. Consumer surplus

is the amount that individuals would have been willing to pay minus the amount that they actually paid, while producer surplus is the amount that a seller is paid for a good minus the seller's actual cost (Stanlake and Grant 1999). Furthermore, the market equilibrium is the point where the demand and supply intersect. It is important in determining the equilibrium price and quantity (Dean et al. 2016). Figure 2 shows the consumer and producer surplus in a graph. They were calculated using the formula in determining the area of a triangle as shown below (Frakt and Piper 2014):

Area of a triangle (consumer and producer surplus) = ½ (base x height) (3)

Two scenarios were compared in this study — the peak season and the off-season. The before and after closure scenarios are not applicable in the study area since the commercial fishing and farming activities in Talacogon are not limited or bounded to one area. Therefore, the actual values of the changes in the quantity of consumption and production due to climate variations were used. The total annual economic loss was estimated using the seven steps provided by King and Mazzotta (2000) which were also used by Adeyemi et al. (2012). The modified one was used accordingly:

Step 1 - Estimating the market demand function and consumer surplus during the peak season

Consumer Surplus

= (Initial Market Price - Maximum Willingness-to-Pay) × (Annual Demand ÷ 2)

Step 2 - Estimating the market demand function and consumer surplus during the off-season

New Consumer Surplus

= (Initial Market Price - Maximum Willingness-to-Pay) × (Annual Demand ÷ 2)

Step 3 - Estimating the annual loss in economic benefits to consumers

Consumer surplus during the peak season minus the consumer surplus during the off-season

Step 4 - Estimating the supply function and producer surplus during the peak season

Table 1. Number of respondents interviewed in Talacogon, Agusan del Sur

Villages	Fisherfolks (Producers)	Farmers (Producers)	Residents (Consumers)
Desamparados	17	35	61
La Flora	27	77	51
Marbon	14	41	59
Sabang Gibong	22	27	53
San Nicolas	19	37	63
Total	**99**	**217**	**287**
Grand Total		**603**	

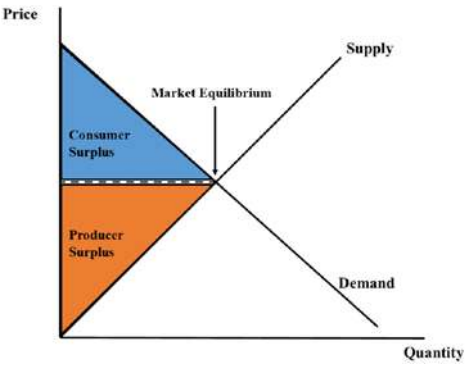

Figure 2. The demand and supply model showing the consumer and producer surplus (Source: Stanlake and Grant 1999)

Producer surplus
= Total revenues earned – Total variable costs of production

Step 5 - Estimating the supply function and producer surplus during the off-season
New Producer surplus
= Total revenues earned – Total variable costs of production

Step 6 - Estimating the annual loss in economic benefits to producers
Producer surplus during the peak season minus the producer surplus during the off-season

Step 7 - Estimating the total annual economic loss
Annual loss in economic benefits to consumers + annual loss in economic benefits to producers

Ethics statement

The study was conducted with clearance from the Protected Area Management Board-Department of Environment and Natural Resources (PAMB-DENR) Caraga Region through the approval of the Protected Area Superintendent's (PASu) Office-Agusan Marsh Wildlife Sanctuary (AMWS). Prior informed consent from the barangay captain was also secured and all respondents gave their informed consent before they participated in the study. Their participation was voluntary, which means that they have the liberty to participate or not. Furthermore, all collected data were kept confidential in accordance with the Philippine Data Privacy Act of 2012 (RA 10173). The research team only has access to the information gathered from the field, and the names or identities of the respondents are concealed in the results and discussions of this study.

3 Results and Discussion

Fishing Activities in Talacogon

The investigation revealed that the fish species commonly caught and sold in Talacogon Market were *Anabas testudineus* (Puyo), *Channa striata* (Halu-an), *Clarias gariepinus* (Taiwan, Hito) *Clarias macrocephalus* (Pantat), *Cyprinus carpio* (Karpa), *Oreochromis niloticus* (Tilapia), and *Osphronemus goramy* (Giant gourami). *Channa striata* is the most commonly consumed and produced in a month with an average volume of 11 kg and 185 kg, respectively (Figure 3). These findings are similar to the study of Baclayo et al. (2020) wherein the said species is the most dominant. Some of them are abundant in population status, like Halu-an, Tilapia and Karpa while some are scarce like the Puyo, Taiwan/Hito, Pantat, and Giant Gourami.

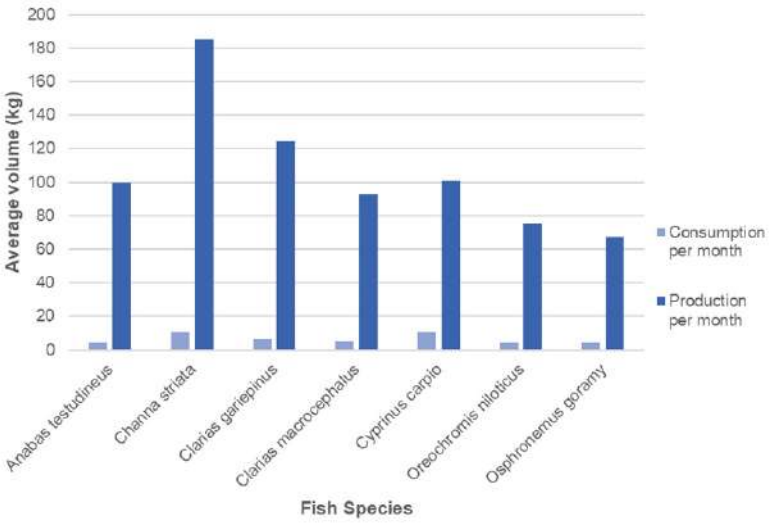

Figure 3. Monthly consumption and production of various fish species in Talacogon, Agusan del Sur

In terms of fishing gears, fisherfolks in the area commonly used the bottom set longline (taga), bottom set gill net (pukot), and fish pot (screen) (Figure 4). They are commonly used during the months of March to May. The taga is a long mono nylon with a large series of baited hooks that are attached at the bottom of the water to prevent it from moving with the current. It is baited naturally with shrimps, gourami, and dead frogs. The pukot is a 100 m long mono nylon with mesh sizes of 5-6 cm. It has a height of 2 m and is also attached to the bottom of the water to prevent it from moving with the current. Rubber floaters are attached to the float line at a distance of 1.5 m and the lead sinkers are tied to the sinker line at a distance of 0.35 m. The screen is a rectangular receptacle made from metal chicken wires with a non-return valve located at the top. This valve provides an easy entrance but difficult to exit. This pot is commonly placed in a grassy substrate for a year by fisherfolks through a non-motorized boat, which aims to catch fish species such as tilapia and karpa (Mindanao State University-Naawan 2013).

One factor that greatly affects fishing is the climate. The months of September to February are the peak season for fishing. However, during the dry season (March to August), fewer fish are caught due to low water levels in rivers and lakes. Illegal fishing, like electric fishing, was also identified and still exists despite the strong regulations prohibiting it. Water pollution and land degradation are also noted (Figure 5). Conversion of many parts of the marshland to rice land, illegal logging operations, contaminants from mining operations, domestic wastes, and agricultural wastes are the causes of these identified factors that affect fish catch (Mindanao State University-Naawan 2013).

With regard to marketing channels or buying schemes, house-to-house selling and commercial markets, including dealers, were observed. Most of the fisherfolks sell their fish through dealers, and every fisherfolk has an average of three dealers. Cash payments were commonly observed, and the usual location of markets is within the municipality or village.

Farming Activities in Talacogon

The common crops planted within the marsh are *Oryza sativa* L. (Rice) and *Zea mays* (Corn). Rice is the most commonly consumed and produced annually, with an average volume of 616 kg and 4,261 kg, respectively (Figure 6). Sweet potatoes, cassava, and peanuts are also planted within the area but are only consumed in households and not sold in commercial markets. The farmers have an average farming lot area of 1 ha and plant crops only once a year because of the rising water level during the months of December to February. Nonetheless, some tried to plant twice a year (Mindanao State University-Naawan 2013).

The months of March to August (dry season) are the peak season for farming, which is done in a large part of the marsh. Most of the local residents are farmers during the dry season and become fishers during the wet season (Mora-Garcia et al. 2020). Similar to fishing, climate variations are one of the factors that affect farming activities since land areas are flooded during the wet season (September to February). Land degradation and financial constraints are also recognized. However, the common problems of farmers are pests like rats, worms, black bugs, snails, weevils, and stem borers (Figure 7). They are the culprits of low yields because they feed on a growing number of

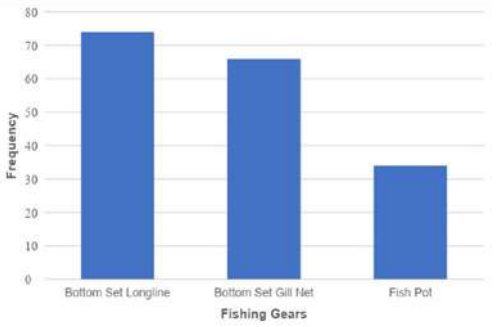

Figure 4. Common fishing gears used by fisherfolks in Talacogon, Agusan del Sur

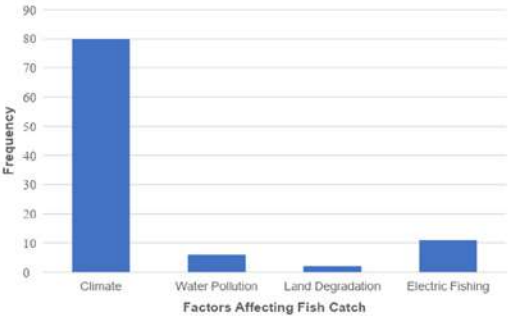

Figure 5. Perceptions of the respondents on the factors that affect fish catch

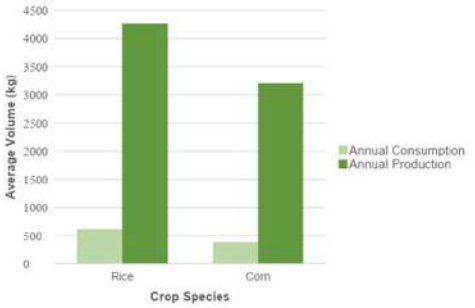

Figure 6. The annual consumption and production of crops in Talacogon, Agusan del Sur

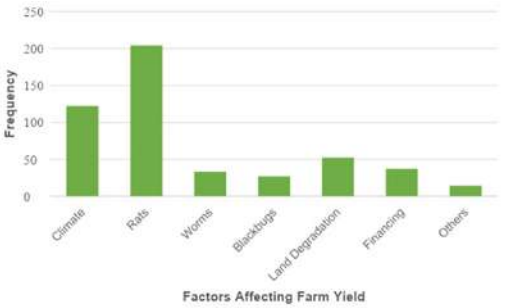

Figure 7. Perceptions of the respondents on the factors that affect farm yield

crops. Climate change increases the risk of pests spreading in agricultural and forestry ecosystems. A warmer climate exacerbates the establishment of invasive pests and helps to change their migratory patterns and geographical distribution (Food and Agriculture Organization 2021). In terms of marketing channels or buying schemes, dealers were highly noticed, and every farmer has an average of one dealer. Most are buyers in commercial markets. Cash payments and direct selling were commonly observed, and the usual location of markets is within the municipality or village.

Consumer Surplus and Annual Loss in Economic Benefits to Consumers

Fishing and farming are the main sources of livelihood in Agusan Marsh. These commercial activities produce ecosystem products such as fish and crops. The species of fish and crops shown in Table 2 are commonly consumed by residents and sold in the commercial markets of Talacogon, Agusan del Sur. Following the steps of the market price valuation method, consumer surplus and annual loss in economic benefits to consumers were estimated first. This was done through the identification of the initial market price and maximum willingness-to-pay (WTP) per species of fish and crops during peak and off-seasons. The unit of measurement is in Philippine pesos per kilogram (PHP/kg). The volume of catch per species purchased by consumers annually was also identified (kg). These are averages of the actual values collected in the area. It is evident that the initial market price increases during off-season and the consumers' demand decreases.

It is assumed that the quantity demanded during the off-season would fall to 60% as adapted from the studies of King and Mazzotta (2000) and Adeyemi et al. (2012). The data on the quantity demanded during the off-season was not captured because the respondents still bought the same quantity of fish and crops during the off-season despite the increase in market prices. This shows that the respondents' behavior is price-inelastic. It means that a change in price results in only a small change in quantity demanded (Hofstrand 2020). As pointed by Fibich et al. (2005), the price elasticity of demand is due to various factors which include the availability of substitute products, the importance or necessity of a good in reference to expenditure, time for adjustment, product durability, and range of uses. In this study, the results showed price-inelastic behavior because the said goods are of great necessity to the locals and are commonly consumed daily. The annual loss in economic benefits to consumers ranges from PHP 511 to PHP 1,037. This is crucial in estimating the total annual economic loss due to climate variations.

Producer Surplus and Annual Loss in Economic Benefits to Producers

The estimation of producer surplus and annual loss in economic benefits to producers was the next step. The total revenues vary per species since their initial market price and quantity demanded by the consumers also vary. Furthermore, the total variable costs vary per species because the volume sold per species also varies (Table 3). On the part of producers, an increase in price leads to an increase in quantity supplied, and a decrease in price also decrease the quantity supplied (Dean et al. 2016). The average variable costs per kg for fish species,

rice, and corn were calculated at PHP 2.30, PHP 7.43, and PHP 9.23, respectively. These costs were multiplied by the average volume sold per season for each ecosystem product. The resulting values are the total variable costs. The difference between the total revenues and the total variable costs is the producer surplus, while the difference between the producer surplus during peak season and off-season is the annual loss in economic benefits to producers (King and Mazzotta 2000).

Total Annual Economic Loss

The annual loss in economic benefits to consumers and producers as a result of climate variations was added to determine the total annual economic loss for each species of fish and crop. The amount computed was 99,974.50 PHP (Table 4). The approximate monetary worth of this asset can serve as a foundation for directing financial resources towards initiatives that empower farmers and fishermen to enhance their capacity

Table 2. Consumer surplus and annual loss in economic benefits to consumers per ecosystem products

Ecosystem Products	Initial Market Price during Peak Season (PHP/kg)	Maximum WTP (PHP/kg)	Quantity Demanded by Consumers during Peak Season (kg)	Consumer Surplus during Peak Season (PHP)	Initial Market Price during Off-Season (PHP/kg)	Quantity Demanded by Consumers during Off-Season (kg)	Consumer Surplus during Off-Season (PHP)	Annual Loss in Economic Benefits to Consumers (PHP)
Fishing Activities								
Anabas testudineus (Puyo)	45.00	61.00	235	1,880.00	47.00	141	987.00	**893.00**
Channa striata (Halu-an)	85.00	100.00	142	1,065.00	87.00	85	553.80	**511.20**
Clarias gariepinus (Taiwan, Hito)	79.00	96.00	244	2,074.00	81.00	146	1,098.00	**976.00**
Clarias macrocephalus (Pantat)	81.00	98.00	112	952.00	83.00	67	504.00	**448.00**
Cyprinus carpio (Karpa)	67.00	83.00	152	1,216.00	69.00	91	638.40	**577.60**
Oreochromis niloticus (Tilapia)	79.00	95.00	133	1,064.00	80.00	80	598.50	**465.50**
Osphronemus goramy (Giant gourami)	62.00	73.00	191	1,050.50	65.00	115	458.40	**592.10**
Farming Activities								
Oryza sativa L. (Rice)	46.00	53.00	610	2,135.00	47.00	366	1,098.00	**1,037.00**
Zea mays (Corn)	35.00	44.00	381	1,714.50	36.00	229	914.40	**800.10**

Table 3. Producer surplus and annual loss in economic benefits to producers per ecosystem products

Ecosystem Products	Total Revenues during Peak Season (PHP)	Total Variable Costs during Peak Season (PHP)	Producer Surplus during Peak Season (PHP)	Total Revenues during Off-Season (PHP)	Total Variable Costs during Off-Season (PHP)	Producer Surplus during Off-Season (PHP)	Annual Loss in Economic Benefits to Producers (PHP)
Fishing Activities							
Anabas testudineus (Puyo)	15,431.00	786.00	14,645.00	9,860.00	1,572.00	8,288.00	**6,357.00**
Channa striata (Halu-an)	48,579.00	1,788.00	46,791.00	42,545.00	1,910.00	40,635.00	**6,156.00**
Clarias gariepinus (Taiwan, Hito)	40,422.00	851.00	39,571.00	19,335.00	1,582.00	17,753.00	**21,818.00**
Clarias macrocephalus (Pantat)	15,320.00	413.00	14,907.00	14,400.00	640.00	13,760.00	**1,147.00**
Cyprinus carpio (Karpa)	28,749.00	988.00	27,761.00	18,399.00	1,405.00	16,994.00	**10,767.00**
Oreochromis niloticus (Tilapia)	24,482.00	832.00	23,650.00	17,250.00	1,126.00	16,124.00	**7,526.00**
Osphronemus goramy (Giant gourami)	22,875.00	779.00	22,096.00	11,100.00	1,363.00	9,737.00	**12,359.00**
Farming Activities							
Oryza sativa L. (Rice)	41,827.00	13,864.00	27,963.00	32,671.00	19,143.00	13,528.00	**14,435.00**
Zea mays (Corn)	27,333.00	12,034.00	15,299.00	19,947.00	17,757.00	2,190.00	**13,109.00**

Table 4. Total annual economic loss due to climate variations

Ecosystem Products	Annual Loss in Economic Benefits to Consumers (PHP)	Annual Loss in Economic Benefits to Producers (PHP)	Total Annual Economic Loss (PHP)
Fishing Activities			
Anabas testudineus (Puyo)	893.00	6,357.00	**7,250.00**
Channa striata (Halu-an)	511.20	6,156.00	**6,667.20**
Clarias gariepinus (Taiwan, Hito)	976.00	21,818.00	**22,794.00**
Clarias macrocephalus (Pantat)	448.00	1,147.00	**1,595.00**
Cyprinus carpio (Karpa)	577.60	10,767.00	**11,344.60**
Oreochromis niloticus (Tilapia)	465.50	7,526.00	**7,991.50**
Osphronemus goramy (Giant gourami)	592.10	12,359.00	**12,951.10**
Farming Activities			
Oryza sativa L. (Rice)	1,037.00	14,435.00	**15,472.00**
Zea mays (Corn)	800.10	13,109.00	**13,909.10**
	TOTAL		**99,974.50**

to withstand climate fluctuations. Moreover, their status as land managers qualifies them to advocate for the implementation of sustainable land use practices in AMWS. In addition to economic development investments such as road construction, school buildings, and river dikes, programs may provide non-monetary compensations and monetary compensations in the form of provisions of fishing gear and farming equipment, employment opportunities, and alternative means of subsistence. If a sustainable financing scheme for the ecosystem services management program will be implemented, the estimated amount will be the head start for decision-makers and concerned stakeholders when efficiently allocating scarce resources (Mora-Garcia et al. 2020).

4 Conclusion and Recommendations

Fishing and farming are the main sources of livelihood in Talacogon, situated within the geopolitical boundary of Agusan Marsh Wildlife Sanctuary (AMWS). The livelihoods of residents are affected by existing threats in AMWS such as land conversion, illegal fishing, illegal logging, and wildlife hunting. Climate variations aggravate these threats. Thus, estimating the total annual economic loss from the changes in the demand and supply of fish and crops due to climate variations in AMWS is crucial.

The most commonly consumed and produced products in terms of fishing and farming were *Channa striata* and *Oryza sativa* L., respectively. Climate variations have an impact on both commercial activities. During the dry season (March to August), fewer fish are caught due to low water levels in rivers and lakes, while crops cannot be planted during the wet season (September to February) because a lot of land areas are flooded. The total annual economic loss of these ecosystem goods due to climate variations was calculated at PHP 99,974.50. This estimated monetary value can be a basis for decision-makers and concerned stakeholders to efficiently allocate funds for sustainable programs to capacitate the fisherfolks and farmers to increase adaptation mechanisms for climate variations.

The conduct of valuation studies in other areas within the geopolitical boundary of AMWS is recommended because the estimated monetary value is only specific to the municipality of Talacogon. The demand and supply of products might be different in other municipalities. The findings of this study should be used cautiously since we are considering a lot of assumptions. Furthermore, more studies using the market price method should be carried out to improve and develop its usage.

5 Acknowledgement

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution Statement

Roberto G. Campos Jr.: Acquisition of primary and secondary data, data analysis, interpretation, and writing of the manuscript. Meycel C. Amarille: Conceptualization and design of the study, data analysis, interpretation, and revision of manuscript for publication. Romell A. Seronay: Conceptualization and design of the study, and revision of manuscript for publication. Dr. Seronay, as a member of the JESEG Editorial Board, did not participate with the review process. All authors approved the final version of the manuscript.

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Effects of land use and land cover on Soil-Water Infiltration: A Literature Review and Bibliometric Analysis

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A B S T R A C T

The impact of land use and land cover (LULC) on hydrology is gaining increased attention due to global concerns about water sustainability. Although various studies have been conducted related to the topic, there were only a few publications that specifically focused on the effects of LULC on soil-water infiltration. This study gathered and synthesized relevant research publications and performed co-occurrence and co-citation analyses to identify the existing themes and the research development trend on LULC-soil infiltration relation. Analysis of 103 Scopus-indexed articles from as early as 2000 revealed four major themes: soil characteristics, hydrology and watershed, hydrology and management, and groundwater and LULC. These findings highlight key areas of focus and can assist in identifying research gaps and topics requiring further exploration. The paper offers a concise overview of the current research trajectory in the realm of LULC and soul water infiltration.

Keywords: *Ecosystem services, Land use planning, VOSviewer*

1 Introduction

Soil-water infiltration is a crucial process in the hydrologic cycle (Pahlavan-Rad et al. 2020, Xiao et al. 2019, Ghorbani-Dastaki et al. 2016, Neris et al. 2012). It is the process wherein the water on the ground surface enters the soil (Liu et al. 2018, Tashayo et al. 2020). It is also vital in groundwater recharge and influences potential topsoil loss by erosion and runoff (Zomlot et al. 2017). Throughout the years, soil infiltration and other hydrologic processes have been affected by changes in the environmental conditions of watersheds. LULC, as well as climate change, especially in watersheds, are considered the foremost drivers of changes in the hydrologic processes (Anand et al. 2018, de Almeida et al. 2018, Nyutuame et al. 2020). The rapid changes in land use, along with climate change, can significantly influence hydrologic processes (Shawul et al. 2019), which include soil-water infiltration. Land use affects surface runoff as it alters interception, infiltration, and evapotranspiration (Han et al. 2011).

As emphasized by Daneshi et al. (2021), changes in LULC are mainly anthropogenic. They are characterized by the removal or alteration of vegetation along with changes in land use practices (Anand et al. 2018). Human decisions such as land allocation for urbanization, agriculture intensification, or deforestation influence LULC (Liu et al. 2018), and consequently on the infiltration process. Understanding the dynamics between LULC and the infiltration process is important in improving policy and public decision-making process. In particular, it involves having a better understanding of its spatial variabilities and accurate estimations that could support efforts toward water conservation and agricultural management (Pahlavan-Rad et al. 2020, Tashayo

et al. 2020). It also leads to optimizing natural resource management (Zomlot et al. 2017).

With the importance of understanding the effects of LULC, it is imperative to understand the current research landscape on this topic. Conducting a systematic and unbiased collection of existing publications establishes a benchmark as to how the research community has progressed in the context of the effects of LULC on soil-water infiltration. Thus, this paper aims to gather and synthesize relevant articles primarily dealing with the quantification of the effects of LULC change on soil-water infiltration. Using bibliometric analysis, the study also assesses the trends in scientific outputs that deal with the relationship between LULC and soil-water infiltration.

2 Materials and Methods

Selection of studies

To identify relevant research, a search was made in the Scopus database for open-access journal articles expressed in English and published not earlier than the year 2000. The Scopus database was used as it is the largest collection of peer-reviewed journals (Leong 2021). It provides uniform records and resources that can be used conveniently for citation analysis (Singh et al. 2021). This database has also been used in various bibliometric research as it is considered to be the largest repository of peer-reviewed research and literature citations (Piwowar-Sulej et al. 2021). The search includes keywords from titles, abstracts, and keywords.

The queries with keywords and Boolean operators used were as follows:

"land use" AND "infiltration"

"land use change" AND "infiltration"

"LUC" and "infiltration"

"LULC" and "infiltration"

After gathering all the results using the Scopus database search engine, they were manually screened based on duplicity, titles, and abstracts. Figure 1 shows the summary of the screening process, while Table 1 shows the detailed results of the search.

Bibliometric analysis

Bibliometric analysis is an analytical method that is designed to assess the status and map out the development trends of a particular research topic (Biswas et al. 2021, Mas-Tur et al. 2021). Among its uses include systematic identification, organization, and analysis of research topics (Zeng et al. 2021). This technique establishes a structure of a field without subjective biases. It is a cross-disciplinary procedure that allows effective mapping of directions and themes in the process of development of a particular research field (Tandon et al. 2021, Kim et al. 2021). Bibliometrics also classifies and provides a quick overview of bibliometric documents (Robertson et al. 2020). Since the trends are set, this gives decision-makers as well as researchers a better analysis for a comprehensive understanding of the development of the topics of concern.

In performing the bibliometric analysis, VOSviewer was used. This tool produces cluster-based maps that enable easy classification of the research outputs and is commonly used to visualize

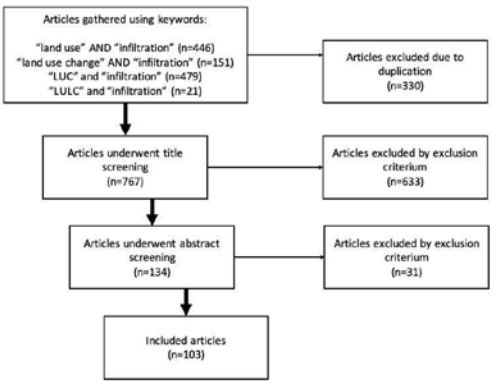

Figure 1. Summary of the selection process (modified and adapted from Piwowar-Sulej et al. 2021)

Table 1. Search criteria results.

Keywords used	Database	Document Type	Results
"land use" AND "infiltration"	Scopus	Article (open access)	446
"land use change" AND "infiltration"			151
"LUC" and "infiltration"			479
"LULC" and "infiltration"			21

and analyze bibliometric networks (Di Ciacco and Troisi 2021, Hamidah et al. 2021). Furthermore, it is an open-source software that provides features to map the literature networks (Singh et al. 2021). In this study, bibliometric analysis was used to measure the co-occurrence and co-citation.

Co-occurrence. This measures the frequency where keywords co-occur which enables the visualization of the main content of research publications (Tandon et al. 2021). It counts the number of appearances of a group of words in literature and becomes the measure of the affinity between two papers (Zhang et al. 2021). This also provides an overview of the trend or potential trends of the focused research area. The analysis was based on keywords used in the literature search.

Co-citation. This is the frequency of texts or words cited together. This occurs when at least two journal articles cite the same journal article (Chang et al. 2021). The higher number of co-citations translates to higher similarity and more positive correlation between and among different journal articles. (Zhang et al. 2021). The unit of analysis used is the cited references.

3 Results and Discussion

Descriptive statistics

The results show that the research published in Scopus-indexed journals focusing on the relationship between LULC and infiltration has increased over the years. Figure 2 shows the distribution of journal articles published from 2000 to 2021. It shows that only a few journal articles were published on the effects of LULC on soil-water infiltration. Although there were 18 journal articles published in 2018, the rest of the years had less than 10 journal articles (Figure 2). This further underscores the limited published work on the topic, particularly within the journals cataloged in the Scopus database.

Table 2 shows the top 10 countries with the most citations. Although China had more related publications than the USA (i.e., a difference of 3 publications), the USA had a greater number of citations than China (Table 2). The USA leads with 789 citations. It was followed by China with only 327 citations. This indicates that even with the higher number of China-based publications on the topic, more researchers cited the papers published in the USA.

Among the journals that published papers about the effects of LULC on infiltration from 2000 to 2021, the Journal of Hydrology has the most number that was found in the Scopus database, with a total of seven publications. It is followed by Water (Switzerland) and Land Degradation and Development. Figure 3 shows the rest of the top 3 journals with the most publications regarding LULC and infiltration.

Keyword co-occurrence and research thematic areas

Figure 4 provides an overview of the co-occurrence between and among the different papers about the keywords associated with the topics on the effects of LULC on soil-water infiltration. The blue line or connection between nodes denotes a more recent co-occurrence of the keywords used by authors (Figure 4). The smaller blue nodes indicate that the focus on this research domain is now branching out and is now developing new

Table 2. Top countries with the most citations on LULC and infiltration, 2000-2021

Keywords used	Number of Citations	Number of Publications
United States of America (USA)	789	20
China	327	23
Netherlands	260	3
Germany	208	7
Australia	157	7
Spain	145	4
Brazil	123	14
Iran	93	3
Switzerland	91	3
France	80	3

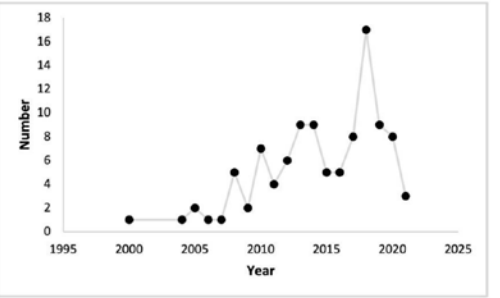

Figure 2. Number of yearly publications, 2000-2021

relevant subtopics. For instance, from research areas on LULC and infiltration, new research projects are shifting their focus to other research areas such as ecosystems and groundwater.

Although 'land use' and 'infiltration' are the two most used keywords among the publications gathered, the timeline shows that both terms were most commonly used for papers published around 2014. Figure 4 shows that the research related to land use and infiltration during the earlier years was more on physical sciences. Furthermore, the recent trend of the relevant studies is now incorporating ecosystems and their dynamics with infiltration (Figure 4). This demonstrates how the themes and specific topics have evolved from soil science to a more holistic approach that captures the role that the ecosystems and human system take in the process of soil-water infiltration and hydrology in general.

The different keywords were clustered together through the assistance of VOSviewer. These clusters form 4 research themes, which are (1) soil and its characteristics, (2) hydrology and watershed dynamics, (3) LULC and methods, and (4) groundwater and LULC. Each of these thematic

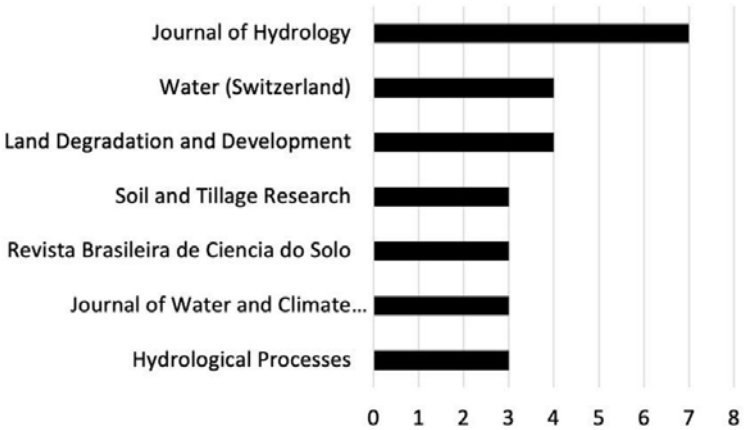

Figure 3. Top 3 journals with most published articles on LULC and infiltration, 2000-2021

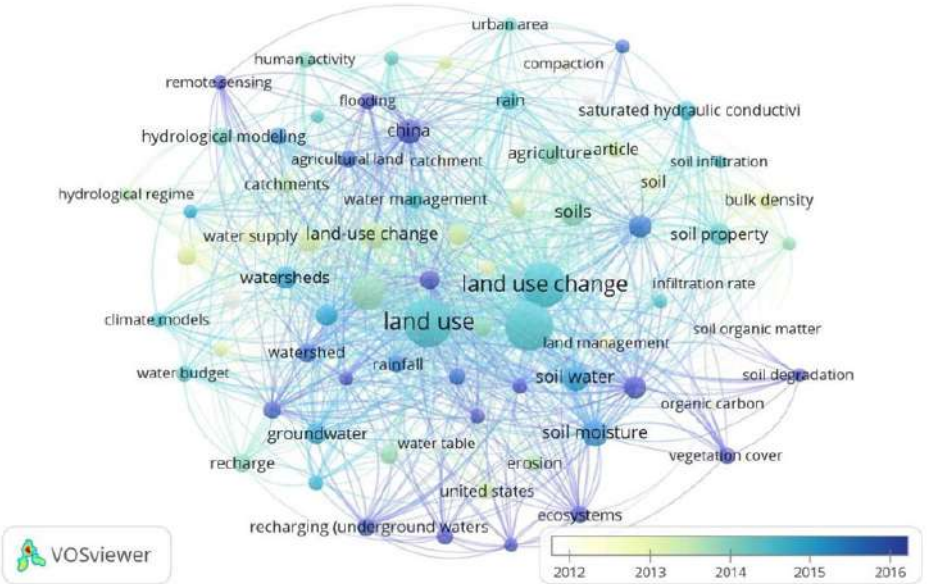

Figure 4. The most commonly occurring keywords on the effects of LULC on soil-water infiltration

areas covers a varying number of keywords. It is also important to note that these thematic areas are interconnected and interrelated. This further explains how different keywords may fall under different thematic areas.

Soil and its characteristics. This theme covers 39 keywords associated with the effects of LULC on soil-water infiltration. Soil-specific terms like bulk density, erosion, seepage, porosity, soil degradation, and soil property were among the keywords, which are under this theme. This theme illustrates the physical, chemical, and hydrological characteristics of soil. This highlights focused research in understanding, classifying, and managing soils, with potential applications in environmental science, agriculture, and resource management.

Hydrology and watershed dynamics. A total of 35 keywords fall under this theme. Their prominence in the co-occurrence analysis signifies a robust scholarly interest in understanding the relationships between hydrological processes and the dynamics of the watershed ecosystem. This may also imply a recognition of the crucial role that watershed plays in addressing water-related challenges and environmental conservation. This also suggests potential collaboration and knowledge exchange between experts on hydrology and watershed dynamics. This information is relevant for stakeholders to gain insights into the current trends, gaps, and collaborative networks within this area of interest.

LULC and methods. This emergence as a theme suggests a notable concentration of research initiatives in the interdisciplinary field that includes the study of land use, land cover, and their associated methodologies. This also means that there is a strong focus on understanding the developments in land use, including the methodologies used to analyze and assess these changes.

Groundwater and LULC. This thematic focus indicates research focus on the dynamic relationship between groundwater dynamics and the patterns of LULC. This suggests a keen interest in learning more about how LULC affects groundwater dynamics, especially as urbanization, agricultural practices, and other land-related activities influence groundwater resources. Furthermore, the theme implies a potential emphasis on water resource management, as groundwater is a crucial component of the hydrologic cycle.

Co-citation among related research papers

As earlier discussed, co-citation is a bibliometric method that highlights the connection between research articles based on their citations in other publications. In the context of understanding the effects of LULC on soil-water infiltration, the result shows that there is a strong conceptual relationship between two or more cited journal articles. This relationship and connections between and among these journal articles are illustrated in Figure 5. It highlights the greatest number of co-cited journal articles on the topic (i.e., effects of LULC on soil-water infiltration). The size of the individual nodes illustrates the weighted co-citation of each journal article. It provides a quantitative measure of the potential contribution of these journal articles to academic discourse.

Among the cited journal articles, the most notable was the study of Neris et al. (2012) titled 'Vegetation and land use effects on soil properties and water infiltration of andosols in Tenerife (Canary Islands, Spain)'. With a total of 7 citations, this journal article recorded the highest weight making it the central node in Figure 5. This could further indicate that this journal article was recognized by different scholars, who are researching the topic. By understanding these co-citation networks and relationships, scholars could have insights into the current research landscape through an identification of key studies and their relationship.

Understanding the current research landscape

The different studies covered in the bibliometric analysis offer insights into the scholarship on the effects of land use change on water infiltration. In particular, these insights focus on (1) methods in measuring the infiltration, and (2) effects of land use change or various uses on the soil-water infiltration. It is also interesting to note that these studies are grounded in different biophysical conditions such as temperature, soil type, vegetation type, and elevation.

Approaches. The collection of journal articles presents the different available approaches, which could be used to understand the effects of LULC on soil-water infiltration. These approaches include actual measurements of the water infiltration under different soil cover types (de Almeida 2018, Liu et al. 2018, Neris et al. 2012). Measurements were done either in situ (Liu et al. 2018, Neris et

al. 2012) or using controlled plots (de Almeida 2018). The in-site sampling procedure involves identifying sampling plots within the study site with varied land uses such as forest areas, agricultural areas, and built-up areas (Liu et al. 2018, Neris et al. 2012). On the other hand, de Almeida (2018) implemented an experimental design using plots with different "soil covers and management". Among the measurement techniques mentioned in these studies was the use of the double-ring method.

In some studies, the infiltration was indirectly measured through groundwater recharge. For instance, a study used a drought severity index to understand the effects of vegetation restoration (see Han et al. 2020). This drought severity index was based on anomalies in groundwater storage. The increase in groundwater in the area was attributed to the increase in afforested areas. The study corroborates other studies where afforestation has a positive effect on soil and water conservation. It includes an increase in the infiltration rate.

Findings. All of the studies covered in the bibliometric analysis led to one direction – LULC has an influence on soil-water infiltration. These studies offer explanations on how changes in LULC influence the infiltration process (Lie et al. 2018). Sun et al. (2018) highlights that changes in LULC alter properties of soil, which consequently affect the infiltration rate. For instance, a decrease in infiltration rate could be observed as agricultural and forested areas are converted into urbanized [or built-up areas] areas (Bawa and Dwivedi 2019). The decrease in infiltration rate was attributed to the increase in more resistant impervious surfaces. Wu et al. (2015) reported the same observation, and how the phenomenon affects both the quality and quantity of surface water. The increasing urban areas have also increased impervious areas significantly decreasing the volume of the water that could have infiltrated the soil (Anand et al. 2018). This affects the hydrologic processes that lead to various phenomena, like reduction of groundwater recharge and lowering of water level (Nath et al. 2021).

This further highlights that vegetation cover could result in the improvement of soil-water infiltration. Unfolding the interaction of vegetation and water balance at the surface level also leads to a better understanding of soil-water infiltration (Canora et al. 2008). To cite an example, areas covered with grass protect the soil from erosion and help in the infiltration process (Yenehun et al. 2017). Recent climate-soil-vegetation research showed that vegetated soils can keep more infiltrating rainfall compared to bare soils (Zhang and Schilling 2006). As indicated in various studies, vegetation and the physical properties of soil, which includes the presence of organic matter, are the main factors that dictate the infiltration capacity (Sun et al. 2018).

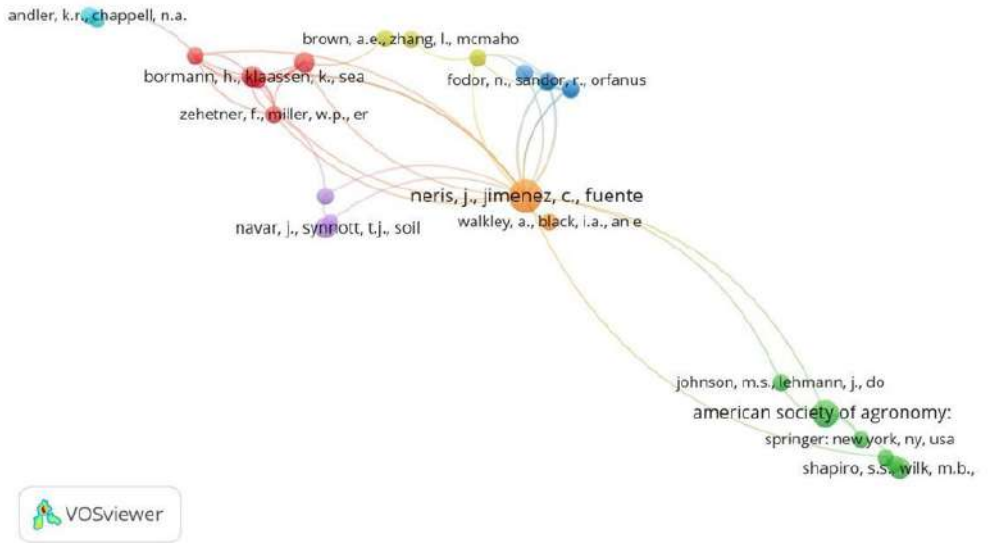

Figure 5. Co-citation of articles on the effects of LULC on soil-water infiltration

Considering the effects of vegetation, Neris et al. (2012) found that infiltration is higher in forested areas than in agricultural or crop areas. This could be attributed to the changes in the different soil characteristics such as structural stability (Neris et al. 2012). According to Ding et al. (2019), the structure and stability of soil aggregates highly dictate soil-water infiltrability. The soil-water infiltration rate strongly demonstrated Der jaguin-Landau-Verwy-Overbeek (DLVO) theories and depended on hydration forces between particles of soil (Ding et al. 2019). There were observed strong specific ion effects in soil-water infiltrability for Li+, Na+, K+, and Cs+, thus influencing both DLVO and hydration forces wherein Hofmeister energies of cations come into play at the soil and water interface.

Soil management methods were also found to affect the infiltration rate (de Almeida 2018, Liu, et al. 2018). Finally, in the case of seasonally frozen areas such as in the Qinghai-Tibet plateau, the deep soil-water infiltration is primarily dependent on volumetric soil moisture—which also explains the result of 80.05% in terms of seasonal variability (Dai et al. 2019). Rainfall was seen to have a weak impact, most of which already returns to the atmosphere through evapotranspiration even before the water starts to infiltrate.

4 Conclusion and Recommendations

The paper presented a critical issue that is proven to be relevant across different countries within various regions across the globe. It poses important questions related to environment and land use planning at different scales and levels (municipal, provincial, regional, and national). However, it is important to note that this paper has its limitations as bibliometric research. First, the paper was designed only to focus on the studies collated through Science Direct. The next limitation is regarding the use of the English language as a main filter. As explained by Gao et al. (2019), the use of this filter exhibits "language bias" in the selection of the journal articles. As with the first limitation, this may likewise result in missing other journal articles on the topic when they are not written in English.

This study attempts to provide a collection of papers that focus on the effect of LULC on soil-water infiltration. The results of this paper can establish a wider and consolidated picture of the research on LULC and soil-water infiltration. The findings using bibliometric analysis will enable researchers to understand further the multi-disciplinarity of this research interest and discover what other themes and topics have been studied alongside LULC and soil-water infiltration. The collection of the gist of other related research in this paper can also uncover gaps that can become the focus of future research.

The selection of papers has presented evidence that LULC could affect soil-water infiltration. It is worth noting though that the tillage done has more influence on soil-water infiltration compared to the vegetation type. It was revealed that the themes of the research papers revolving around LULC and soil-water infiltration are: (1) soil and water characteristics, (2) hydrology and watershed dynamics, (3) LULC and methods, and (4) groundwater and LULC. These results show that the trend of research relevant to the topic of interest is geared towards ecosystems and human systems, their dynamics, and how they affect soil-water infiltration.

Although this paper has limitations, it provides valuable insights into current research on how LULC affects soil-water infiltration. Understanding their research can contribute to improving both development theory and practice. The perspectives in the paper can influence decision-making in areas like land use planning, biodiversity conservation, and landscape ecology. By recognizing trends in this research area, policymakers can better understand the connection between ecological processes and human activities. This understanding helps design strategies for socio-economic development that prioritize environmental sustainability. Overall, the paper's findings lay the groundwork for informed decision-making, promoting a holistic approach to development that integrates ecological considerations into broader socio-economic plans.

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Statement of Conflict of Interest

There are no conflicts of interest to report since the research was not funded externally and there are no financial, personal, or professional relationships that could influence the study.

Author Contribution Statement

Gemmalyn M. Trespalacio: Data collection, bibliometric analysis, synthesis of literature, drafting of manuscript. Nico Jayson C. Anastacio: Data collection, synthesis of collected additional data, editing of manuscript.

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Herpetofauna of forest fragments within the Agata Mining Ventures Incorporated (AMVI), Agusan del Norte, Caraga Region, Philippines

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ABSTRACT

The Philippines holds an extraordinary record of amphibian and reptile diversity and endemism; however, factors like habitat loss and fragmentation that may result from activities related to resource extraction, such as mining, pose a significant threat to their conservation. This study examined the herpetofauna composition in select forest fragments within one of the important mining sites in Caraga, the Agata Mining Ventures Incorporated, between 2018 and 2021. Standardized time searches along the established two 2km transects in two sampling stations (Lawigan and Tinigabasan) were conducted to record reptiles and amphibians accounting for 880 man-hours. In both surveys, 513 individuals representing 12 species of amphibians and 17 species of reptiles were recorded in the area. Of these species, 62% (n = 18 spp.) are Philippine endemic, 35% (n = 10 spp.) native, and 3% (n = 1 spp.) are invasive alien species. Overall, the Shannon-Weiner diversity index is high (H'=2.52) and varied significantly across survey periods (Mann-Whitney U test = 248.5, p=0.007). The species-area relationship analysis showed a strong positive correlation for total herpetofauna ($R^2 = 0.98$), amphibians ($R^2 = 0.87$), and reptiles ($R^2 = 0.99$), and a significant correlation existed between reptiles and forest area ($p = 0.05$). The result suggests a strong reliance of herpetofauna richness in forested areas. Combined forest clearing and the effects of mining activities in the area might threaten these environment-sensitive taxa. Preserving these forest fragments within AMVI and allocating buffer zones is highly recommended. Periodic scientific field-based surveys and re-surveys, encompassing not only amphibians and reptiles but also various other species, are recommended to monitor species distributions, population trends, and impacts of ongoing activities. These efforts aim to update data-driven sources supporting the mining area's rehabilitation program, contributing to societal and environmental benefits. .

Keywords: *amphibians, monitoring, mining environment, reptiles, species-area relationship*

1 Introduction

The Philippines is recognized as an important center of herpetofauna diversity in Southeast Asia (Diesmos et al. 2002). Currently, the country supports 118 amphibian species (Sy 2022) and 361 reptile species (Uetz et al. 2018). Mindanao, in particular, is known to harbor high biodiversity, specifically herpetofaunal diversity (Brown et al. 2013, Diesmos et al. 2015, Abdullah et al. 2023).

Aside from being recognized as a megadiverse country, the Philippines also ranks 5th as the most mineral-rich country in the world for mining gold, copper, nickel, and other metallic minerals (MGB-DENR 2013). It has been recognized that surface mining can potentially displace topsoil and vegetation (Wickham et al. 2013), and pollution in surface waters brought about by the processing of mined materials is one of the major problems in mining areas (Fletcher et al. 2006). Unfortunately, mining concessions overlap with the Eastern Mindanao Biodiversity Corridor, which is recognized as one of the designated Key Biodiversity Areas (KBA) (Critical Ecosystem Partnership Fund 2001). This overlap poses a threat and pressure to biodiversity, particularly the environment-sensitive herpetofauna.

Studies on herpetofauna in the Philippines are progressively increasing. In Mindanao, several explorations are conducted in mountains, forested habitats, caves, and watersheds (Supsup et al. 2017, Nuñeza and Galorio 2015, Sanguila et al. 2016, Sanguila et al. 2020) but not sufficiently in mining areas. Mining activities are believed to pose a significant threat to herpetofauna, yet it has received limited research attention (Mayani-Paras et al. 2019). Research on herpetofauna in mining areas has been constrained, with surveys only conducted in Tumbagon, Cagayan de Oro City (Ascaño et al. 2015a b), Agusan del Sur, and Surigao del Norte (Galolo et al. 2021). Mindanao, the center for herpetofauna endemism (Sanguila et al 2016), needs more studies on herpetofauna, particularly in mining areas. Amphibians and reptiles are good biological indicators of environmental health because their presence provides baselines for assessing habitat conditions and restoration success (Mifsud 2013). Amphibians are sensitive to environmental changes such as climatic and land-use alterations (Hof et al. 2011), acidification (Gibbons et al. 2000), and metal contaminants (Christy and Dickman 2002). Reptiles are also good bio-indicators in mine sites due to their ease of sampling, defined activity areas and periods, long life spans, complex and diverse community structures, and different size ranges (Thompson and Thompson 2005).

Amphibians had a higher species threat index than birds and mammals, and reptiles remained the least studied group among terrestrial vertebrates (Abdullah et al. 2023). Hence, a study on amphibians and reptiles within barangay Lawigan and Tinigbasan of Agata Mining Ventures Inc. (AMVI) was conducted in 2018 and 2021. Repeated surveys are essential to determine species occurrences, thereby assessing their diversity and conservation status (Supsup et al. 2017). The two barangays were explored to document the herpetofauna species present, highlighting the endemic, threatened, and socio-economically important species. This study will give preliminary information on priority taxa in the forest fragments within AMVI for species conservation and the creation of mitigation programs to reduce the impact of mining activities.

2 Materials and Methods

Study Site

Agata Mining Ventures Incorporated is located in Agusan del Norte, Mindanao, Philippines, with geographical coordinates between 09°14'43 "N and 125°32'36 "E. The mine area is about 3.5 kilometers from its own seaport. Agusan del Norte falls under a Type II climate, characterized by the absence of a dry season and a distinct peak in rainfall from December to February. There is no month without rainfall, and the minimum monthly rainfall occurs from March to May (DA-BSWM 2017). Tubay receives an average annual precipitation of about 81.33mm (3.2in), a humidity of 82.61%, and an average temperature of 23.48ºC (74.26ºF) to 32.61ºC (90.7ºF) (Weather and Climate 2023)

Herpetological surveys were conducted between June 5-8, 2018, and November 3-12, 2021, in two sampling stations: Barangay Lawigan and Barangay Tinigbasan, Tubay, Agusan del Norte, within the Mineral Production Sharing Agreement (MPSA) of Agata Mining Ventures Incorporated (Figure 1). Within each station, two 2-km transect lines were laid. In each transect line, six 10 x 100-meter strip transects were established randomly (Supsup et al. 2016).

The habitat types in the area are dominated by early secondary growth (ESG) forest, brushland (BRL), and cultivated areas (CVT) with patches of advanced secondary growth (ASG) forest, agroforest (AF), and grassland with elevation ranging from 24masl to 455masl (Figure 2). Coconut (*Cocos nucifera*) and Falcata (*Falcataria falcata*) plantations are common in the area. Several tree species, such as Alagasi (*Leucosyke*

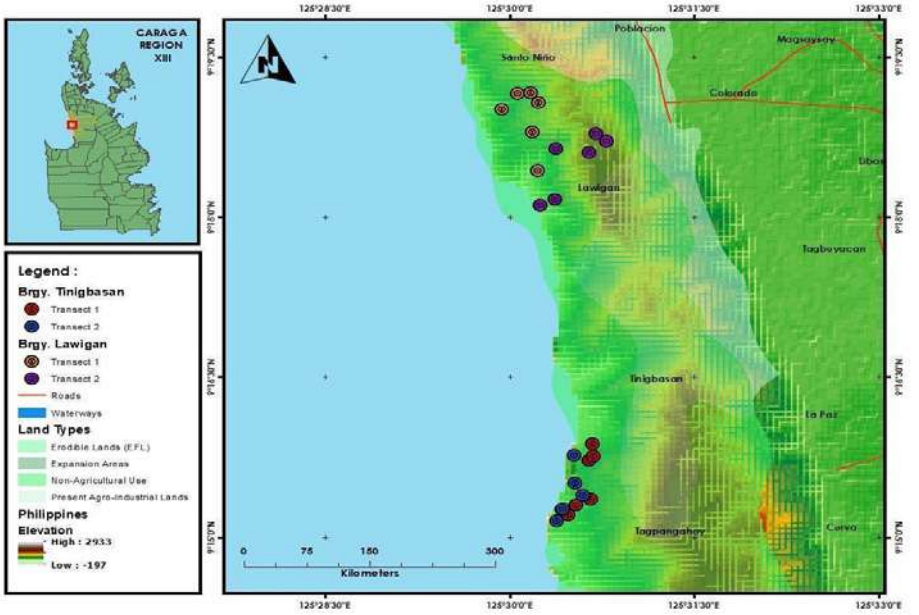

Figure 1. Amphibians and reptiles sampling sites within Agata Mining Ventures Incorporated (AMVI), Tubay, Agusan del Norte, Philippines.

Figure 2. Vegetation within Agata Mining Ventures Inc.: A. Early secondary growth forest within the lowland areas, B. Thick agsam (*Lygodium circinnatum*) vegetation along the forest ridge, and C. Panoramic view of the forest fragments within AMVI.

capitellata), Narra (*Pterocarpus indicus*), Molave (*Vitex parviflora*), and Antipulo (*Artocarpus blancoi*) were also recorded along streams of sampling stations.

Herpetofaunal Surveys and Identification of Samples

Extensive diurnal (1000 to 1500h) and nocturnal (1900 to 2200h) opportunistic surveys of amphibian and reptile populations were conducted, accounting for 880 man-hours in searching and traversing all the sampling stations. Morphometric measurements of each sample were measured on-site, such as snout-vent length (SVL), head length (HL), Head width (HW), Forelimb length (FL), and Leg length (LL) using a vernier caliper or ruler, and the weight through a digital weighing scale to aid in the identification. After measuring and processing, species were photographed, marked, and released back into the environment. The catch-and-release method was employed using water-based paint to avoid

duplication of counts. No voucher specimens were collected.

Species were identified using published photographic guides and identification keys, using the Philippine Checklists of Alcala et al. (2015), Diesmos et al. (2015), and Sanguila et al. (2016). The conservation status of the recorded species was determined using the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (version 2022-2) and the DENR Department Administrative Order (DAO) No. 2019-09. DAO conservation assessment is a National Red List that evaluates the status and extinction risks of local species limited to Philippine populations instead of IUCN considering global distribution. Both were used to determine the conservation status of recorded species.

Data Analysis

Cluster analysis using Jaccard's abundance-based similarity matrix was conducted to analyze species' resemblances between survey periods. Biodiversity indices were also computed to aid in the comparison of species composition across survey periods; these include species richness (S), abundance (N), Shannon-Weiner diversity (H'), and evenness (J). Species diversity was characterized using the following criteria: If H' <1, the species diversity is considered low. The species diversity is moderate if H' is between 1 and 1.5. If H' is between 1.6 and 3, the species diversity is high, while if H'>3, the species diversity is extremely high (Odum 1971 as cited by Jalil et al. 2020). Mann Whitney U-Test was also used to determine the significant differences between sampling years using Paleontological Statistics (PAST) software ver 4.11. The species–area curve depicts the relationship between species richness and the transects surveyed. To enhance the curve's interpretability, logarithmic transformations ($\log_{10}$ values) were applied to both species and land area values, and the resulting data were subjected to linear regression. R^2 and p-values were computed for each regression analysis, serving as metrics to quantify the deviation from the regression line and providing a measure of accuracy for the predictive models (Jessee et al. 2022). Linear regression and scatter plots were performed using JASP version 0.18.1 software.

3 Results and Discussion

Species Composition and Endemicity

In total, 513 individuals of herpetofauna belonging to 13 families, 25 genera, and 29 species were recorded within the forest fragments of Agata Mining Ventures Incorporated (Table 1 and Figure 5-6). Anurans accounted for 80.9% (N = 415 individuals, n = 12 spp) of the total population captured, and 19.1% (N = 98 individuals, n = 17 spp) were reptiles. The record represents 18.13% of the Mindanao records (Agduma et al., 2023) and 6.05% of the entire Philippine herpetofauna (Sy 2022, Uetz et al. 2018). Among anurans, the family Dicroglossidae, composed of semi-aquatic frogs, was the most species-rich (n = 4 spp., 34%). In contrast, the family Bufonidae, Megophryidae Microhylidae yielded the lowest number of species recorded (n = 1 spp., 8%). *Limnonectes magnus* had the most individuals (35.18%), followed by *Pulchrana grandocula* with 16.63%. (Figure 3A). For the reptiles, the family Scincidae had the highest number of species (n = 5 spp., 29%), while families Lamprophiidae and Geoemydidae, each represented by a single species (n = 1 spp., 6%). *Gekko gecko* from the family Gekkonidae gained the most individuals across sampling stations (7.49%, Figure 3B).

Regarding endemicity, 62% of the species recorded were Philippine endemic, 35% were non-endemic, and 3% were Invasive Alien Species (Figure 4A). Most of the herpetofauna recorded in the fragmented forests were categorized as least concern species (93%) as listed in the IUCN Red List of Threatened Species (Figure 4B). It is also notable for recording one endangered species, *Coura philippinensis* (3%) in the area. Five species (17.24%) were listed as Other Threatened Species, namely *L. magnus, Megophrys stejnegeri, Hydrosaurus pustulatus, Gekko gecko* and *C. philippinensis* based on Philippine Red List Status (DAO 2019-09). Most amphibians and reptiles have decreasing population trends (n = 11 spp., 38%). These species are not critically endangered, endangered, or vulnerable but are known to face anthropogenic threats and might be moved to a threatened category in the future. The socio-economically important anuran, *L. magnus*, was abundantly recorded in both surveys. This species is primarily known to be harvested and exploited for food by the local community. Gonzalez et

Table 1. The list of herpetofauna recorded in the two sampling stations in Tubay, Agusan del Norte during the field samplings with their corresponding Endemicity, IUCN's conservation status (CS), Population Trend, DAO 2019-09 status, and abundance (relative abundance).

Taxa	Common Name	Endemicity	CS, Pop'n trend	PRLS	Abundance (Relative Abundance)	
					2018	2021
Amphibians						
Bufonidae						
Rhinella marina (Linnaeus, 1758)	Cane Toad	IAS	LC, ↑	-	22 (10.68)	10 (3.26)
Ceratobatrachidae						
Platymantis guentheri (Boulenger, 1882)	Gunther's wrinkled ground frog	ME	LC, ↓	OWS	-	3 (0.98)
Platymantis dorsalis (Duméril, 1853)	Common forest frog	PE	LC, ↓	OWS	-	1 (0.33)
Dicroglossidae						
Fejervarya vittigera (Wiegmann, 1835)	Luzon Wart Frog	PE	LC, ↓	OWS	-	1 (0.33)
Limnonectes magnus (Stejneger, 1909)	Mindanao Fanged Frog	PE	NT, ↓	OTS	90 (43.69)	56 (18.24)
Limnonectes leytensis (Boettger, 1893)	Leyte Wart Frog	PE	LC, ↓	OWS	3 (1.46)	16 (5.21)
Occidozyga laevis (Günther, 1858)	Philippine Oriental Frog	NE	LC, ↓	OWS	3 (1.46)	22 (7.17)
Microhylidae						
Kalophrynus sinensis Tschudi, 1838	Black-spotted sticky frog	NE	LC, ↓	OWS	-	33 (10.75)
Megophyridae						
Megophrys stejnegeri (Taylor, 1920)	Mindanao Horned Frog	PE	LC, ?	OTS	6 (2.91)	18 (5.86)
Rhacophoridae						
Polypedates leucomystax (Gravenhorst, 1829)	Four-lined tree Frog	NE	LC, -	OWS	25 (12.14)	35 (11.40)
Kurixalus appendiculatus (Günther, 1858)	Philippine Flying Frog	PE	LC, ↓	OWS	-	2 (0.65)
Ranidae						
Pulchrana grandocula (Taylor, 1920)	Big-eyed Frog	PE	LC, -	OWS	35 (16.99)	34 (11.07)
Reptiles						
Lizards						
Agamidae						
Draco bimaculatus Günther, 1864	Two-spotted Flying Lizard	NE	LC, -	OWS	2 (0.97)	6 (1.85)
Draco cyanopterus Peters, 1867	Flying Dragon	ME	LC, -	OWS	2 (0.97)	-
Hydrosaurus pustulatus (Eschscholtz, 1829)	Phil. Sailfin lizard	PE	LC, ↓	OTS	7 (3.40)	9 (2.93)
Gekkonidae						
Cyrtodactylus agusanensis (Taylor, 1915)	Agusan Bent-toed Gecko	ME	LC, ?	OWS	1 (0.49)	3 (0.98)
Gehyra mutilata (Wiegmann, 1834)	Stump-toed Gecko	NE	LC, -	OWS	-	1 (0.33)
Gekko gecko (Linnaeus, 1758)	Tokay gecko	NE	LC, ?	OTS	-	23 (7.49)
Scincidae						
Brachymeles orientalis Brown & Rabor, 1967	Southern Burrowing Skink	PE	LC, ?	OWS	-	5 (1.63)
Eutropis multicarinata (Gray, 1845)	Two-striped Mabouya	ME	LC, -	OWS	-	3 (0.97)
Eutropis multifasciata (Kuhl, 1820)	Common Mabuya	NE	LC, -	OWS	-	1 (0.33)
Pinoyscincus coxi (Taylor, 1915)	Cox's Sphenomorphus	PE	LC, ?	OWS	1 (0.49)	2 (0.65)
Tropidophorus misaminius Stejneger, 1908	Misamis Waterside Skink	ME	LC, -	OWS	4 (1.94)	6 (1.95)

Legend: Conservation Status (CS) based on IUCN 2022 = EN-Endangered, NT- Near Threatened, LC-Least Concern, DD-Data Deficient; Population Trend: (↓) – decreasing, (↑) – increasing; (-) – stable, and (?) – unknown. Endemicity = IAS -Invasive Alien Species, PE- Philippine Endemic, NE-Non-Endemic, ME- Mindanao Endemic. Philippine Red List Status (PRLS) based on DAO 2019-09: VU – Vulnerable; OTS – Other Threatened Species; OWS – Other Wildlife Species

Table 1. Continuation. The list of herpetofauna recorded in the two sampling stations in Tubay, Agusan del Norte during the field samplings with their corresponding Endemicity, IUCN's conservation status (CS), Population Trend, DAO 2019-09 status, and abundance (relative abundance).

Taxa	Common Name	Endemicity	CS, Pop'n trend	PRLS	Abundance (Relative Abundance)	
					2018	2021
Snakes						
Colubridae						
Ahaetulla prasina preoccularis (Boie, 1827)	Gunther's whip snake	NE	LC, -	OWS	1 (0.49)	5 (1.63)
Chrysopelea paradisi H. Boie in F. Boie, 1827	Garden Flying Snake	NE	LC, -	OWS	1 (0.49)	-
Dendrelaphis philippinensis (Günther, 1879)	Mindanao Stripe-tailed Bronzeback	PE	LC, -	OWS	1 (0.49)	-
Lycodon capucinus H. Boie in F. Boie, 1827	Common Wolf Snake	NE	LC, -	OWS	1 (0.49)	2 (0.65)
Lamprophiidae						
Oxyrhabdium modestum (Duméril, 1853)	Phil. Shrub Snake	ME	LC, ↓	OWS	1 (0.49)	8 (2.60)
Turtle						
Geoemydidae						
Cuora philippinensis (Riche in Daudin, 1801)	Southeast Asian Box Turtle	PE	EN, ↓	OTS	-	2 (0.65)

Legend: Conservation Status (CS) based on IUCN 2022 = EN-Endangered, NT- Near Threatened, LC-Least Concern, DD-Data Deficient; Population Trend: (↓) – decreasing, (↑) – increasing; (-) – stable, and (?) – unknown. Endemicity = IAS -Invasive Alien Species, PE- Philippine Endemic, NE-Non-Endemic, ME- Mindanao Endemic. Philippine Red List Status (PRLS) based on DAO 2019-09: VU – Vulnerable; OTS – Other Threatened Species; OWS – Other Wildlife Species.

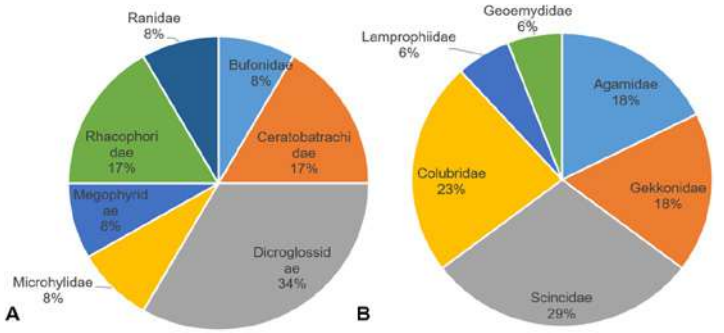

Figure 3. Family composition of (A) amphibians and (B) reptiles collected in the forest fragments of AMVI, Tubay, Agusan del Norte.

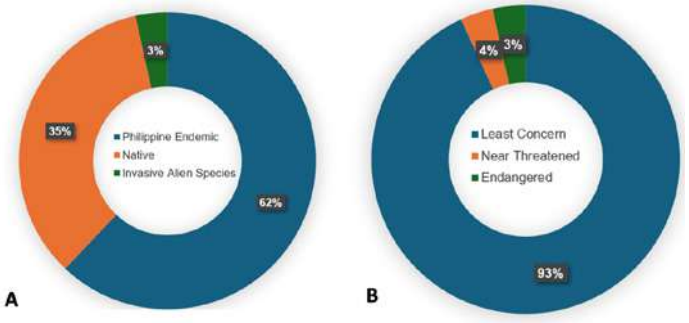

Figure 4. Status of the herpetofauna species (A) Endemicity and (B) IUCN Red List collected in the area.

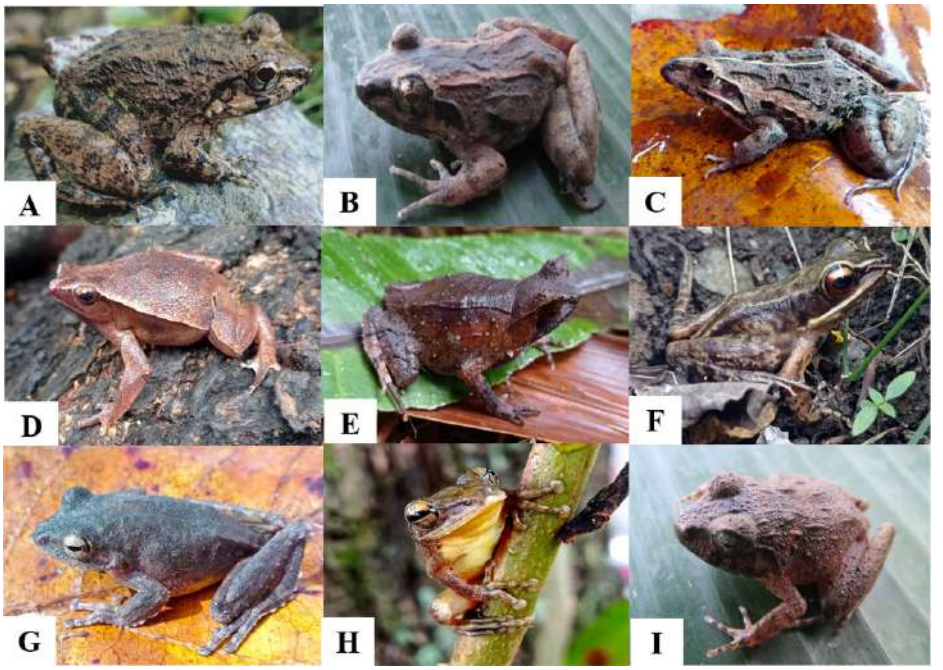

Figure 5. Some Amphibians of AMVI, Tubay, Agusan del Norte: (A) *Limnonectes magnus*, (B) *Limnonectes leytensis*, (C) *Fejervarya vittigera*, (D) *Kalophrynus sinensis*, (E) *Megophrys stejnegeri*, (F) *Pulchrana grandocula*, (G) *Kurixalus appendiculatus*, (H) *Platymantis guentheri*, and (I) *Platymantis dorsalis*.

Figure 6. Some Reptiles of AMVI, Tubay, Agusan del Norte: (A) *Hydrosaurus pustulatus*, (B) *Cyrtodactylus agusanensis*, (C) *Brachymeles orientalis*, (D) *Eutropis multicarinata*, (E) *Tropidophorus misaminius*, (G) *Oxyrhabdium modestum*, (H) *Ahaetulla prasina preoccularis*, and (I) *Cuora philippinensis.*

al. (2018) identified three threat criteria for herpetofauna in the Philippines: illegal wildlife trade, habitat loss, and hunting or overharvesting. Both habitat loss and hunting for subsistence or local commerce were observed in the survey area. This observation coincides with the study of Abdullah et al. (2023) that showed habitat loss driven by deforestation and the collection of wildlife for consumption, threatening a high proportion of herpetofauna in Mindanao.

Furthermore, an alarming presence of the invasive alien species, *Rhinella marina* was also recorded in the area. This species is known to have a high degree of spatial and dietary overlap with native frogs, leading to potentially intense competition (Diesmos 2008). The key threats and the documented presence of invasive species could potentially endanger native amphibian populations in the area.

Compared to studies in mining areas within Mindanao, a study conducted by Galolo et al. (2021) recorded 35 amphibians in select mining areas (1. Masabong, Rosario, Agusan del Sur; 2. Philsaga Mining Corporation, Agusan del Sur; 3. San Andres, Bunawan, Agusan del Sur; and 4. Adnama Mining Resources Incorporated (AMRI), Claver, Surigao del Norte) within the Caraga Region. Noteworthy is that all of the amphibians recorded in AMVI were also recorded in other regional mining areas. Another study conducted within and outside the Hydraulicking Mining area in Tumpagon, Cagayan de Oro City, recorded 13 species of anurans and 17 reptiles (Ascaño et al. 2015a,b). This record aligned with the current study that recorded the same number of amphibians and reptiles in a nickel mining environment. The presence of the recorded species in other mining sites in Mindanao indicates the tolerance of these species to disturbances brought about by mining activities. However, it might lead to local declines when not given enough attention for conservation.

Species Diversity Between Survey Periods

Comparing the surveys, the 2018 herpetofauna inventory recorded 18 species of herpetofauna (7 amphibians and 11 reptile species), while the 2021 survey recorded 26 species (12 amphibians and 14 reptile species). Eleven species namely; *Platymantis guentheri, Platymantis dorsalis, Fejervarya vittigera, Kalophrynus sinensis, Kurixalus appendiculatus, Gehyra mutilata, Gekko gecko, Brachymeles orientalis, Eutropis multicarinata, Eutropis multifasciata,* and *C. philippinensis* were new records for AMVI. Species abundance and diversity were significantly highest during the 2021 herpetofauna survey, N=307, and H'=2.73, respectively (Mann-Whitney U test = 248.5, p=0.007). Overall, species diversity within the remaining forest fragments of AMVI is high, H'=2.52. Jaccard's Abundance-based similarity index between the survey periods was 0.525 (Table 2).

Factors contributing to the observed variations in detected species between the sampling years of 2018 and 2021 could include influences from diverse environmental conditions. In 2018, the sampling period coincided with the rainy season, potentially affecting the presence and distribution of species due to weather-related factors. Additionally, mining operations could alter species' behavior and interspecies interactions, contributing to the observed differences in species composition. Conversely, in 2021, reduced human visitation to the sites, a consequence of pandemic-

Table 2. Diversity Indices and comparison between survey periods in forest fragments within Agata Mining Ventures Incorporated, Tubay, Agusan del Norte, Philippines.

Biodiversity Index	Survey Period		Overall
	2018	2021	
Species Richness (S)	18	26	29
Species Abundance (N)	206	307	513
Shannon-Weiner (H')	1.89	2.73	2.52
Evenness (J)	0.37	0.59	0.43
p-value	0.007*		
Jaccard Abundance-based similarity index	0.525		

Tested at α=0.05 using Mann Whitney U-Test

related restrictions, may contribute to an increased number of observed species due to reduced mining activity and less destruction of habitats.

Despite these variations, notable consistencies emerge in species composition. The surveyed areas within Agata's Mineral Production Sharing Agreement (MPSA) sampling stations (Brgy. Tinigbasan and Lawigan) both exhibited early secondary growth (ESG) forest, brushland (BRL), and cultivated areas (CVT) with patches of advanced secondary growth (ASG) forest, agroforest (AF), and grassland. This similarity in vegetation structure suggests that habitat types within the MPSA provide relatively diverse species of amphibians and reptiles.

Furthermore, habitat variability, food sources, and substantial microhabitats of the sampling stations influence species composition and diversity. For instance, barangay Lawigan is largely covered by ground vegetation and the creeks' damp areas, with huge trees forming scattered tree patches. The primary ground vegetation, however, was made up of new growth of several species of ferns and various plant species, which serve as suitable shelter for ground-dwelling amphibians and reptiles. Both sampling stations had secondary-growth forests (Along et al. 2020, Sarmiento 2020) and agroforest and grassland vegetation.

Species-Area Relationship

The relationship of species richness to area was positively correlated and accounted for a large portion of the variation for total herpetofauna (R^2 = 0.98), amphibians (R^2 = 0.87), and reptiles (R^2 = 0.99) (Figure 7) which means that for the fragmented forest studied, herpetofauna adheres more closely to the species-area relationship, proving the dependence of amphibians and reptiles on their habitats. This data coincides with the study of Jessee et al. (2022), wherein total herpetofauna and amphibians had a strong, positive correlation to land area.

Amphibian abundance and richness are known to be influenced by the size of the forest area. Due to their limited mobility, strong tendency to remain in their established habitats, and susceptibility to desiccation, amphibians could be especially at risk when faced with habitat fragmentation (Wind 1999). A significant correlation existed between reptiles and forest area (p = 0.05), also recorded in the study. Reptiles are highly sensitive to changes in landscape configuration and condition. Habitat modification is the primary driver of declines in the reptile population (Doherty et al. 2020). Snakes manifested to have the sharpest declines in the fragmented forests (Diesmos 2008). A study conducted by Mayani-Paras et al. (2019) showed that the combined negative impacts of mining and habitat loss resulted in decreased distribution and a potential increase in species extinction to endemic reptiles.

Furthermore, according to Loehle et al. (2005), reptile richness was most pronounced at sampling locations characterized by the lowest basal area (BA) stands, while amphibians exhibited the highest richness at points with the highest BA within the forest landscape. These differences in habitat requirements suggest protection for the area's remaining early and advanced secondary-growth forests. Although fragmentation led to a cascading decline in herpetofauna, with 15–94% of the overall species diversity disappearing in forest fragments, these fragments can play a crucial role as essential refuge sites for rare endemics and those facing threats (Diesmos 2008).

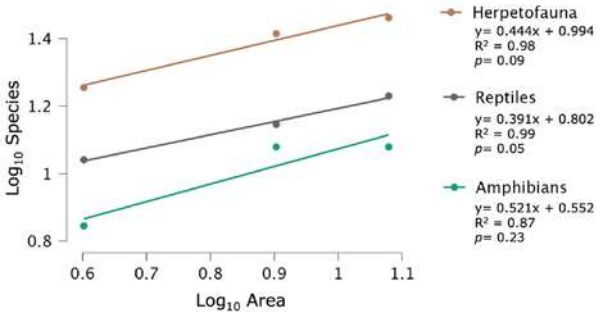

Figure 7. Species-Area relationship of herpetofaunal richness. Log_{10} of species richness and area with regression equation, R^2 and p-values.

The recorded herpetofauna in the sampling stations indicate that the remaining surviving blocks of forests in the study area still provide foraging sites and habitats for reproduction, especially for endemic species. However, if conservation efforts are not prioritized, habitat fragmentation and forest degradation can lead to species decline, losses, and extinction (Solania et al. 2020). Most of the endemic species are forest-dependent organisms and very vulnerable to changes in the ecosystems because they depend so much on the services provided by the forest, such as protection from predators, food, refuge, and shelter (Thompson et al. 2009).

Amphibians and reptiles are known as biological and environmental indicators. These organisms are susceptible to the impacts of mining and mining activities. However, the remaining forest fragments within AMVI still harbor different species of amphibians and reptiles, including threatened species, which suggests actions for conservation. Maintaining the remaining reserves of early and mature stands within the mining area and allocating buffer zones from the forest habitat is recommended. Identifying key habitat attributes for protection, such as aquatic habitats (rivers, streams, and ponds) and habitats that provide cover and moisture, is essential to conservation. Also, reducing reliance on non-native tree crop species for plantation, afforestation, or reforestation projects within the study area might be included in the biodiversity management plan of the mining company.

4 Conclusion and Recommendations

Even with fragmented forests, the area still harbors endemic, threatened, and socio-economically important herpetofauna. These environment-sensitive species indicate the good habitat quality of the remaining forest fragments. Regular monitoring, herpetofauna and habitat associations, and population dynamics studies are important to inform effective herpetofauna conservation in the area. The data from the study would be a baseline for policy reforms to balance socio-economic development and biodiversity conservation.

5 Acknowledgement

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Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contribution Statement

Apple Rosales and John Patrick B. Suhian contributed to the conceptualization, collection, analysis, and interpretation of data. Eve F. Gamalinda was involved in conceptualization, collection, analysis, interpretation, writing, and manuscript revision for publication. As a member of the JESEG Editorial Board, Gamalinda did not participate in the review process. Sherryl L. Paz was responsible for conceptualization and acquiring primary and secondary data. Chennie Solania-Naling played a role in conceptualization, collection, analysis, interpretation of data, writing, and manuscript revision. All authors approved the final manuscript version.

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