University of the Philippines LOS BAÑOS

UPLBFI

WWF

SIPA
Sustainable Infrastructure Programme in Asia

TECHNICAL REPORT

Incorporating Green Strategies towards Sustainable Infrastructure Planning and Development: Mainstreaming Nature-based Solutions (NbS) for a Resilient Butuan City

Supported by:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

based on a decision of the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

SUSTAINABLE INFRASTRUCTURE PROGRAMME IN ASIA (SIPA): PHILIPPINES

TECHNICAL REPORT FROM THE TECHNICAL CONSULTANTS

Incorporating Green Strategies Towards Sustainable Infrastructure Planning and Development: Mainstreaming Nature-based Solutions and Spatial Planning for a Resilient Butuan City

Samantha Geraldine G. De los Santos, Nico Jayson C. Anastacio, Danesto B. Anacio,

Gemmalyn M. Trespalacio, Jan Joseph V. Dida, Malvin G. Biguerras

UPLB Foundation, Inc.

Funding Agency: WWF Philippines

September 1, 2023 – August 31, 2024

Executive Summary

This technical report is among the outputs for WWF's Sustainable Infrastructure in Asia Program (SIPA). This report focused on the objective of integrating Nature-based Solutions (NbS) into infrastructure planning in the Philippines, specifically in Butuan City, Agusan del Norte. To achieve this, a comprehensive methodology was employed, that included document analysis, key informant interviews, and focus group discussions.

The results and discussion part of this technical report provides a socio-economic profile of the local population, a physical characterization of the area, an assessment of climate and natural hazards, and a description of the ecological systems and biodiversity in Butuan City. Additionally, it synthesizes local plans, policies, institutions, and stakeholders to contextualize the local policy environment and identify factors that may support or hinder NbS project implementation.

The climate risk assessment section evaluates two primary hazards affecting Butuan City: flooding and rainfall-induced landslides. This assessment considers both existing linear infrastructures and proposed infrastructure projects. It concludes with an impact chain analysis to illustrate the effects of complex climate risks on the city.

The section on ecosystem services quantifies priority ecosystem services identified by local stakeholders as critically important and in urgent need of intervention. This quantification will assist infrastructure planners in selecting interventions that enhance or restore ecosystem services, while ensuring that infrastructures are more resilient to climate change. It also aims to support biodiversity conservation efforts.

Furthermore, the report outlines the preconditions and recommendations for implementing NbS in Butuan City. Finally, it identifies gaps, challenges, and opportunities to guide NbS implementers in overcoming potential roadblocks and leveraging prospects for mainstreaming NbS in linear infrastructure planning.

Table of Contents

List of Tables

List of Figures

Rationale

Infrastructures are essential inputs to economic development. Transportation networks, communications, and energy infrastructure directly affect the flow of goods and services in an economy, significantly reducing logistical costs and facilitating the mobility of human capital (Vagliasindi, 2022); which eventually lead to large positive effects on the return to private investments (Aschauer, 1989, as cited in the Penn Wharton Budget Model, 2018). Infrastructures are catalysts for expansion of both local business and foreign direct investments since they can improve the overall economic efficiency in producing goods and providing services. With the promise of a good, or even exceptional, return on investment, infrastructure development has become a top policy choice for economic development in many countries (Adler, et al., 2020). This is also the reason why infrastructure has been an integral component in the Philippine Development Plans since the post war period. Up until recently, the Philippine government has invested in infrastructure development through its Build-Build-Build and Build-Better-More programs to spur economic development.

However, the Philippines has a history of incurring billions of pesos in damages due to the impacts of natural and man-made hazards. From 2010 to 2019, it suffered PhP 463 billion worth of damages from disaster events, with damages to infrastructure amounting to a PhP 106 billion or a significant 23% of the total amount (Philippine Statistics Authority [PSA], 2020). The Philippine Government pursued to reduce disaster risk and enhance resiliency through various institutional measures as well as soft (related to service delivery and maintenance) and hard (or physical) infrastructures to increase adaptive capacity and reduce population exposure and vulnerability. Institutional arrangements have progressed since the enactment of the Climate Change Act of 2009 and Disaster Risk Reduction Management (DRRM) Act of 2010. These same policies mandated the crafting of national and local DRRM plans and also led to the inclusion of disaster preparedness as one of the criteria for good local governance (DILG, 2014 and 2022). Likewise, infrastructure development in the Philippines mainstreamed climate change adaptation and disaster risk reduction, in accordance with these policies. By the end of 2022, resilience roadmaps and investment portfolios for risk resilience for selected vulnerable areas in the Philippines have been completed[1].

Despite the efforts to mainstream climate change and DRRM, the Philippines remains to be highly at risk. It was reported to be number one in both 2022 and 2023 World Risk Index (WRI) Report due to its high exposure to natural hazards and impacts of climate change as it was found to be very highly susceptible and vulnerable to various hazards and lacks the adaptive capacity to address the risks. The difficulty of minimizing risks in the Philippines is also compounded by development challenges (e.g., poverty, inequality), its archipelagic characteristics, the slow integration of crisis mapping in planning, and digitalization challenges in disaster response systems (WRI, 2022). Diversity, inequality, and discrimination

[1] https://www.denr.gov.ph/index.php/news-events/press-releases/4728-denr-receives-resilience-roadmaps-for-16-climate-vulnerable-areas-in-ph

were also factors in exposure and vulnerability to risk as impacts of disasters tend to be more severe in marginalized groups (WRI, 2023).

Solutions to reduce disaster risks and improve resilience can be engineered. However, construction of infrastructures poses additional environmental costs. Over the years, infrastructure has contributed to the worsening conditions of the climate as it released 79% of greenhouse gas emissions (Thacker, et al., 2021). There is also a misconstrued idea that the presence of nature is an obstacle to infrastructure development. Road-widening and sewage system projects have often resulted in the felling of decades old trees, as this is considered more cost-effective than earth-balling, changing transportation modes, or using alternative technologies. This alters, or at worst, removes natural habitats and socio-ecological production landscapes and seascapes. When infrastructure development does not consider sustainability and inclusivity, it can lead to habitat fragmentation, biodiversity loss, and on the economic side, income, and productivity loss (Bliss-Ketchum, 2019; Tian et al., 2020; Satoyama Initiative, 2010). Finally, infrastructures are not capable of mitigating climate change and enabling nature to recuperate from fragmentation and biodiversity loss. Given the long lifespan of infrastructure assets, the investment decisions made today could lock countries into carbon-intensive development pathways for years to come and continue to worsen the climate conditions.

To make infrastructure planning sustainable in the long run, it is necessary to incorporate natural processes and resources, and social experiences and expectation in planning for sustainable development is necessary. Well-planned infrastructure can lead to improved resiliency from natural hazards, create conditions for a resource-efficient, sustainable economy, and promote inclusivity, leading to prosperity for all (Global Infrastructure Hub, 2021). This project proposes mainstreaming Nature-based Solutions (NbS) in infrastructure planning to ensure that the challenges of achieving sustainable development are addressed, including measures to balance development priorities and social equity concerns. At its core, NbS focuses on actions taken to protect, conserve, restore, sustainably use, and manage natural or modified ecosystems to cope with the pressing issues on social, economic, and ecological aspects (Cohen-Shacham et al. 2016; Maes & Jacobs, 2017; Ommer *et al*., 2022). NbS has the capacity to address food security (SDG 2), good health and well-being (SDG 3), availability of water (SDG 6), climate action (SDG 13), and life on land and water (SDG 14 & 15). Compounding all of its benefits, NbS can lead to sustainable cities and communities in the near future (SDG 11). Including NbS in infrastructure planning is particularly important in the Philippine context as the country has been at the forefront of the impacts of biodiversity loss and climate change.

Mainstreaming NbS in infrastructure planning can help communities mitigate and adapt to climate change and reduce disaster risks at relatively low costs while benefiting from the ecosystem services it can subsequently provide. NbS can also help in the recuperation of natural habitats impeded by biodiversity loss. Reforestation efforts upstream can help protect communities downstream from flooding and it can also help sequester carbon and protect

biodiversity. By mainstreaming NbS, there is an opportunity to increase green spaces and support urban cooling and pollution mitigation, while providing recreation and health benefits (Seddon, et al. 2020). Hence, this proposal aims to determine strategies to mainstream NbS in infrastructure planning, particularly on linear infrastructures, to ensure that habitat, biodiversity, and ecosystem services are minimally altered, and their benefits maximized in achieving sustainable development. This project will also carefully consider the existing natural resources and different land uses in the area (i.e., agricultural, residential, commercial). In this aspect, this project will utilize Geographic Information System (GIS) mapping in creating a decision-support tool that shall help identify how to carefully build infrastructures toward low carbon economy and sustainability.

I. Objectives

This project aims to mainstream Nature-Based solutions in infrastructure planning in the Philippines, particularly, Butuan City, Agusan Del Norte. Specifically, this project aims to:

1. Identify provisions in Philippine policy frameworks, from local to national legislation, that enable and/or mandate infrastructure planning, disaster risk reduction management, and environmental projects;
2. Assess the condition of important social and ecological landscapes and seascapes in the context of local and national development plans;
3. Examine the interaction of climate-related hazards with socio-ecological factors in existing and planned infrastructure areas;
4. Analyze the impacts of climate change as key drivers for risks;
5. Facilitate Butuan City decision makers in determining appropriate nature-based solutions for linear infrastructure planning that can maintain or even enhance biodiversity and ecosystem services;
6. Develop an algorithm/model to mainstream NbS for sustainable and strategic linear infrastructure in Butuan City; and
7. Recommend guidelines on mainstreaming Nature-based solutions in infrastructure planning in the Philippines.

II. Methodology

The Project Site

The Caraga region (R13) is one of the administrative regions of the Philippines located in the northeastern section of the Mindanao Island. This region is comprised of five provinces: the Agusan del Norte, Agusan del Sur, Dinagat Islands, Surigao del Norte and Surigao del Sur. According to 2020 census of population (PSA, 2020), the Caraga region has a total

population of 2,804,788 inhabitants, and a total area of 18,846.97 km^2 representing 6.3% of the total land area of the country. Topographically, the region is characterized by flat, rolling hills, and mountainous terrain. This project will specifically focus on Butuan City and the Agusan River Basin which has a direct effect to the ecology of Butuan City.

Butuan City. The city of Butuan is a highly urbanized city located in Agusan Del Norte, Caraga Region. It has a total land area of 81,728 hectares with approximately 70% of it classified as urban area, and the rest (30%) as rural area. Butuan is strategically positioned at the center of the province of Agusan del Norte and situated in the downstream portion of the Agusan River Basin. It is bounded on the north by Municipality of Magallanes, and Municipality of Remedios T. Romualdez, on the south by the Municipality of Las Nieves, on the East by the Municipality of Sibagat and on the West by the Municipality of Buenavista **(Figure 1).**

Based on the 2020 Census of Population, the city has a total population of 372,910 inhabitants with a population density of 457 persons per km^2 and an annual population growth rate of 2.15% (Census of Population, 2020; PhilAtlas, 2024). At this rate, Butuan City is expected to undergo further urbanization. Despite the urbanization that Butuan City underwent, its population is still low compared to Manila, the most densely populated City in the Philippines, which has a population density of 73,920 persons per km^2. Cagayan de Oro City, which is around 170 km away from Butuan City, has a population density of 1,765 persons per km^2.

For the next few years, rapid infrastructure development and expansion of urban areas within Butuan City are expected to happen. The execution of the infrastructure master plan for the city prioritizes 24 infrastructure programs and projects that the city Government of Butuan has started to implement (NEDA Region XIII, 2021). Part of the plan is to improve the city's competitiveness, disaster resiliency, and urban conditions by formulating a long-term development framework.

Butuan City is composed of a total of 86 barangays, 27 of which are classified as urban barangays, and the rest (59) are rural barangays. The level of urbanization in the Philippines is based on population of 5,000 or more, or existence of at least one establishment with 100 employees, or existence of five or more establishments with 10 to 99 employees, and five or more facilities within the 2-km radios from the barangay hall (PSA, 2020). It can be expected that the urban barangays of Butuan have a high population density with various businesses operating within the area.

Agusan River Basin. The Agusan River Basin is the third largest river system in the Philippines, covering an area of 10,921 km^2. It is located in the eastern portion of Mindanao Island, comprising the province of Bukidnon; Misamis Oriental, Davao del Norte, Davao Oriental, Davao de Oro (formerly Compostela Valley), Agusan del Norte, Agusan del Sur, and Surigao del Sur. The headwater of the basin comes from the mountainous area of Davao de Oro, draining to the northern part of Mindanao Island through Butuan City in Agusan del Norte.

The basin is also known for the Agusan Marsh Wildlife Sanctuary, a declared protected area under Proclamation No. 913, s. 1996, and considered one of the most ecologically significant wetlands in the country, which serves as home for various organisms. This marshland acts as a sponge and serves as a flood retention function for the Agusan River, reducing risks to lowland communities of the basin for flash floods. Any change in the capacity to function of the marsh is expected to have an impact on lowland areas such as Butuan City.

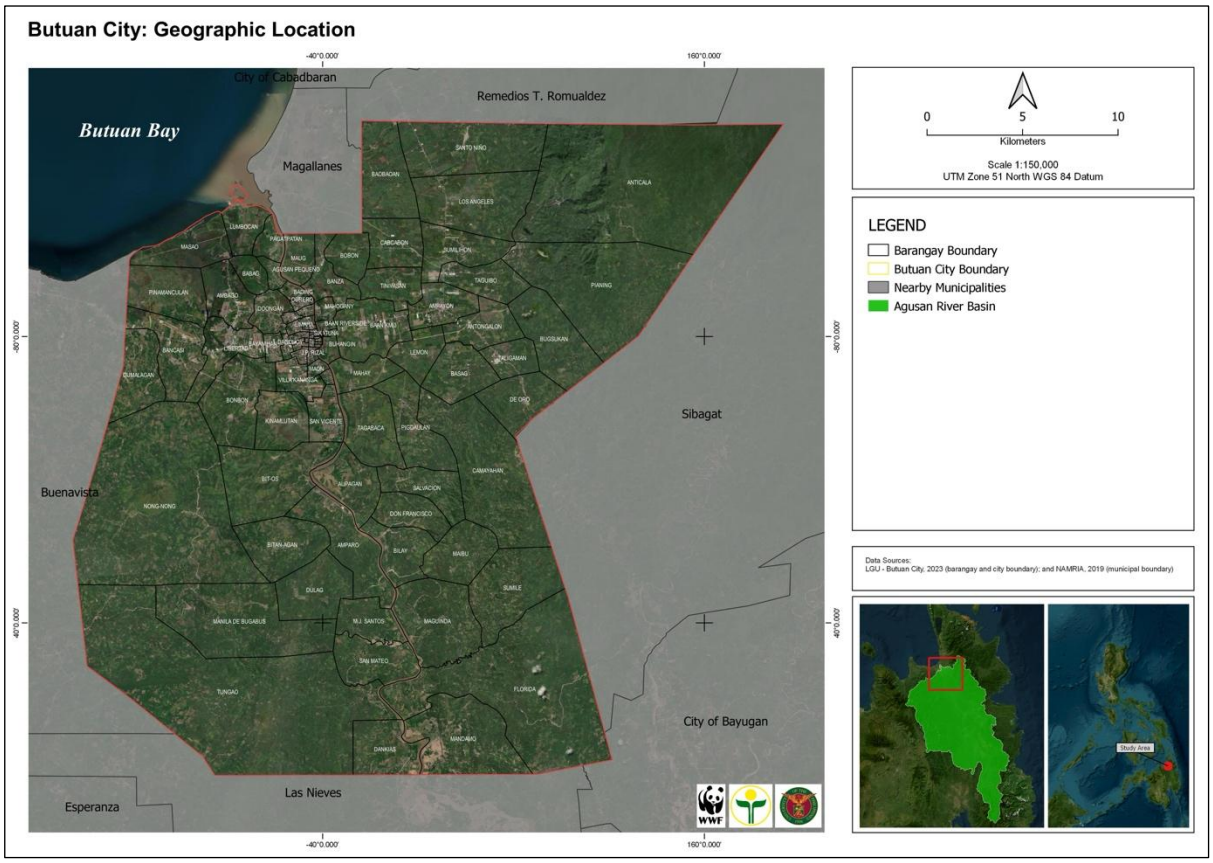


Figure 1. The geographic location of Butuan City in relation to Agusan River Basin.

Conceptual Framework

The conceptual understanding of how NbS sits within the interplay of the social and ecosystems is shown in **Figure 2**. The way the communities support and address the establishment of NbS approaches has an effect on the sustainability of both the green and gray infrastructures employed. In effect, the NbS can help alleviate the impact of climate change on the social system depending on the success of the NbS. The same goes for the relationship between the natural systems or ecosystems and NbS. The quality of the ecosystem affects the speed of the effects of the NbS to manifest. The sooner this happens, the faster the ecosystems can become more resilient to the impacts of climate change. The policies and other plans are crucial as these direct the intensity and magnitude of the application of NbS. The success and

sustainability of these NbS are greatly influenced not just by the policies alone, but also are also heavily reliant on the availability of funding social support, and acceptability. Both NbS and policies also affect the linear infrastructure. The design and construction of these infrastructures are aligned with the existing plans that take into consideration the existing policies. On the other hand, appropriate NbS approaches affect the linear infrastructure as they serve as protection from the effects of climate change and other natural hazards.

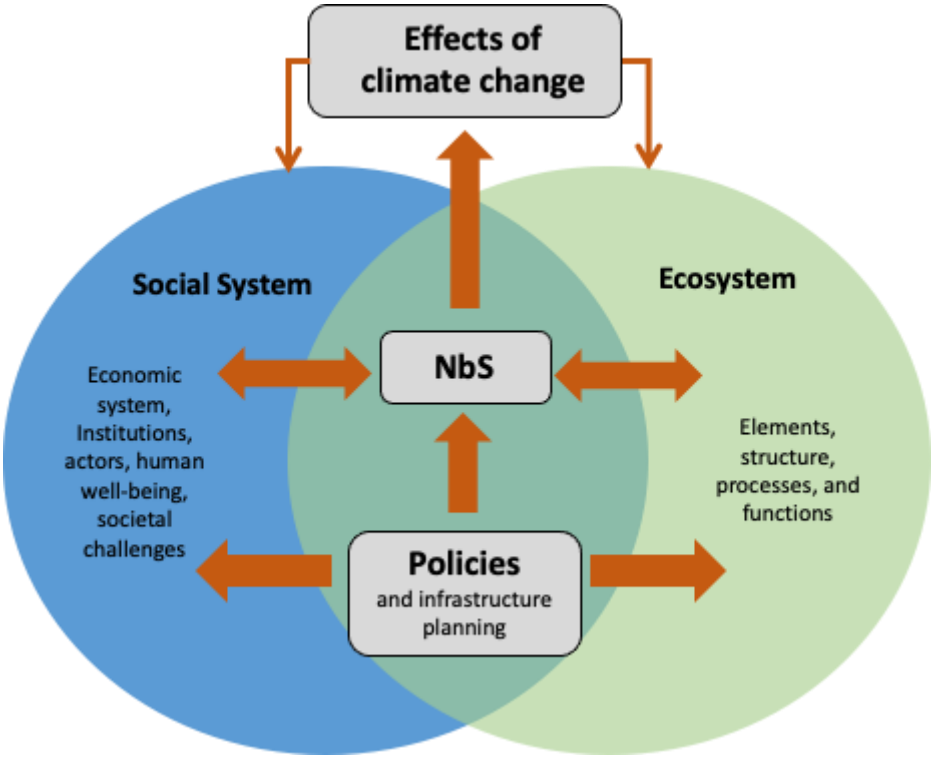


Figure 2. The conceptual framework of the study

To deconstruct the framework, it involves engaging multiple stakeholders and undertaking various actions. One notable approach gaining popularity is the use of GIS and remote sensing for assessing the ecosystem conditions, as well as identifying the areas that are prone to risks and hazards. This application facilitates essential spatial analysis, which plays a vital role in planning for linear infrastructure. Another important micro-component within the framework is the active involvement and engagement of stakeholders, which holds significant influence in the social system. It is essential to identify, characterize, and even profile these stakeholders, particularly when determining the ecosystem services, their respective users, and beneficiaries. Moreover, the stakeholders themselves are the primary users of the infrastructure.

Ultimately, the effects of climate change are causing pressure to both the social and natural systems and the areas they overlap, such the linear infrastructure. Thus, the more effective NbS there is, the higher the chance, not only of infrastructures, but most importantly of the social and ecosystems to be more resilient to the effects of climate change.

Primary Data Collection

A. Focus Group Discussion

Focus groups (FG) or a focus group discussion (FGD), as popularly used in Philippine technical parlance, is a qualitative technique for exploring hypotheses about a specific concern, for documenting insights about the motivations of target participants regarding an issue, and for describing common conceptions and thought processes of a select group of people about a particular topic (Calder 1977; Morgan & Spanish 1984). For this project, FGs involved relevant stakeholders in Butuan City such as barangay officials and representatives of the youth sector, senior citizens, women's groups, farmers' association, and fisherfolk association. The stakeholders were invited through a formal letter addressed to the mayor of Butuan City, as well as the barangay chairpersons of the selected barangays.

As a rule of thumb, participants of a focus group should not exceed ten (10) individuals (Fern, 1982). A moderator would then provide a background of the project, introduce participants to one another, and then proceed with asking questions for discussion by the group. The FGDs held for this project had a minimum of six to a maximum ten participants per FGD and each FGD lasted for 1.5 hour to 2 hours. The technical consultants moderated the discussion and the activities during the FGD.

Prior to each FGD, the consent of the participants was taken before the conversations were audio recorded. The recordings as well as notes taken were summarized for relevant themes and narratives needed to achieve the project objectives. The FGD guide used for the discussions can be found in Annex 1. Meanwhile, Table 1 lists the FGDs held for the project.

Table 1. Participants in the focus group discussions

Organizations/Group	Mode	Date of Interview
Local Government Representatives	Zoom	September 22, 2023
San Vicente	In-person	October 4, 2023
Villa Kananga	In-person	October 5, 2023
Bancasi	In-person	October 5, 2023
Pagatpatan	In-Person	January 23, 2024
Ampayon	In-Person	January 24, 2024
Taguibo	In-Person	January 24, 2024
Anticala	In-Person	January 25, 2024

Two sets of FGDs were held for this project. The first set of FGD was conducted from September 22 to October 5, 2023, and the second set from January 23 to 25, 2024. One of the FGDs held was with the local government representatives and was done via Zoom. This FGD session with the local government representatives aimed to gather reconnaissance information about infrastructure planning in Butuan City and firm up the guide questions that will be used for the in-person FGDs. On the other hand, the FGDs with the barangays of were conducted in person and used FGD guide to facilitate discussion. The in-person FGDs were held in the barangay hall of each of the barangays.

An important approach that was incorporated in the FGD is the prioritization of ES of each barangay. This guarantees that the priority ES that will be mapped, analyzed, and integrated in the training module aligns with community demands. ES prioritization was conducted through a participatory process wherein key officials and community representatives in the barangays discussed among themselves which ES is important for them. A comprehensive list of ecosystem services was introduced to the participants, with each service thoroughly explained and accompanied by proxies for a better understanding of what these services are about. The list is based on InVeST developed by the Natural Capital Project of Stanford University. Participants were then tasked with ranking these services based on perceived needs and importance for their constituents. Throughout the ranking process, officials openly deliberated on the rationale behind their collective choices.

B. Selection of Participating Barangays for FGD

Initially, the project planned to conduct only one set of FGD in Butuan City. The three barangays during the team's field visit in October 2023 were selected based on risk (i.e., flooding incidence), population density, and urban development. However, data collection activities, such as the FGD, revealed the diminished appreciation for the direct benefits of regulating services due to a shift in livelihood activities from natural-resource-reliant ones (i.e., agriculture and fisheries) into predominantly employment in retail and service sectors.

As a result, the second set of FGD was conducted in which less urbanized barangays with significant ecosystems that provide ecosystem services such as crop production, water yield, flood risk mitigation, and coastal vulnerability protection were selected. The aim was to provide a more comprehensive understanding of ecosystem service dynamics in the broader context. The project team used Butuan City's Comprehensive Land Use Plan in identifying four barangays according to land use classification: coastal/riparian, agricultural, combination of agriculture and forest, and forest.

Key Informant Interviews (KII)

Key informants (KI) were identified according to their roles and activities in Butuan City in relation to the project's objectives. As sources of important and local knowledge, these informants include local government officials, community leaders, private sector representatives operating in the project site, and civil society organizations, among other individuals whose experiences and perspectives are crucial for the project. Provincial and regional officers were also included among the key informants since they offer insights on infrastructure planning and ecosystem services present in the project site. **Table 2** lists down the key informant interviews conducted for the project. Similar to the FGD, a guide questionnaire was used in the conduct of KIIs. Consent was also taken from the KIs with regards to recording the conversations prior continuing with the interview.

Table 2. Participants of the key informant interviews

Key Informant	Affiliation	Mode	Date of Interview
Faculty members with expertise in environmental science	Caraga State University – College of Forestry and Environmental Science	Zoom	August 22, 2023
City Mayor's Office Representatives	Butuan City Local Government Unit (LGU)	In-person	October 4, 2023
Office of the Regional Executive Director	Department of Environment and Natural Resources (DENR) Region XIII	In-person	October 4, 2023
Engineers from the Planning and Design Division	Department of Public Works and Highways Region (DPWH) XIII	In-person	October 5, 2023
Faculty members with expertise in engineering science	Caraga State University – College of Engineering and Geo-Sciences	In-person	October 6, 2023
Mr. Ronald M. Lisayan (President and CEO)	Friendship Goals Society Caraga-Butuan Inc. (FGSCBI), a civil society organization	Zoom	November 14, 2023
Economic Development Specialists	National Economic Development Authority Region XIII	Zoom	December 20, 2023
Staff assigned to Infrastructure, Monitoring, and Evaluation	National Economic Development Authority Central Office	Zoom	December 21, 2023
Regional Agricultural Engineering Division	Department of Agriculture (DA) Region XIII (Caraga)	Zoom	January 22, 2024

Key Informant	Affiliation	Mode	Date of Interview
Engr. Iris Joy M. Canete-Galaura	City Planning and Development Department	In-person	January 24, 2024
Engr. Pierre Anthony D. Joven	City Agriculture and Veterinary Department	In-person	January 25, 2024

Secondary Data Collection

The study likewise utilized secondary data including socio-economic data (e.g., population, income), spatial data (e.g. vector, raster), and local plans. Socio-economic data is useful in profiling communities. It is also important in identifying and prioritizing recommendations for NbS. On the other hand, spatial data from various agencies was used for risk assessment and mapping of ecosystem services. The list of secondary data utilized in this study is listed in Table 3.

Table 3. List of secondary data collected for this study.

DATA	DATA TYPE	SOURCE
Flooding	Spatial Data (Vector)	Department of Environment and Natural Resources – Mines and Geosciences Bureau (DENR-MGB)
Rainfall-Induced Landslide	Spatial Data (Vector)	DENR-MGB
Rainfall intensity	Spatial Data (Raster)	PAGASA
Political Boundary (Municipal, Provincial, Regional, and National)	Spatial Data (Vector)	National Mapping and Resource Information Authority (NAMRIA)
Population Density, Population Distribution	Spatial Data (Raster)	Worldpop.org
2010, 2015 and 2020 Land Cover	Spatial Data (Vector)	NAMRIA
Soil Type	Spatial Data (Vector)	Department of Agriculture – Bureau of Soil and Water Management (DA-BSWM)
Key Biodiversity Area	Spatial Data (Vector)	DENR
Protected Areas (including forest and vegetation cover)	Spatial Data (Vector)	DENR
IfSAR Digital Elevation Model	Spatial Data (Raster)	NAMRIA
Proposed linear infrastructures (roads and bridges, drainage system, street lights and railway project) within Butuan City	Spatial Data (Vector)	DPWH
Existing linear infrastructures (roads and bridges) within Butuan City	Spatial Data (Vector)	DPWH

DATA	DATA TYPE	SOURCE
Population by age, gender by municipality	Numerical Data	PSA
Poverty Incidence by municipality	Numerical Data	PSA
Human Development Index by municipality	Numerical Data	LGUs
Income Classification by municipality	Document	PSA
Agusan River Basin Master Plan	Document	DENR-River Basin Control Office
Butuan City Comprehensive Land Use Plan	Document	Butuan City LGU
Butuan City Master Plan for Sustainable Urban Infrastructure Development	Document	NEDA
Butuan City Climate and Disaster Risk Assessment	Document	Butuan City LGU
Butuan City Local Climate Change Action Plan	Document	Butuan City LGU
Butuan City Local Disaster Risk Reduction and Management Plan	Document	Butuan City LGU
Barangay Development Plans	Document	Barangay Officials

Methods of Data Analysis

A. Policy and Institutional Analytic Process

The successful implementation of NbS projects requires an understanding of the political environment and institutional landscape. This understanding should be done both at the national and local levels as they have interlocking dynamics and influence on the implementation of different interventions. In this project, a policy analytic process was done to (1) understand the current support mechanisms in relation to NbS implementation, (2) identify potential policy gaps, and (3) design possible policy interventions to further support NbS implementation.

The initial process involved a review of different national policies, which are deemed relevant in the implementation of NbS projects. The team also reviewed relevant local ordinances that were being implemented. These ordinances include localized versions of national policies and various context-specific environmental policies. A series of in-depth interviews with key informants was conducted to further assess the current policies, particularly on their outcomes in the local context. Aside from the different policies, the in-

depth interviews also focused on highlighting the different programs and projects, which are designed to support environmental conservation and climate resilience.

Another important part of the process is the understanding of the prevailing institutional arrangements at the local level. This involves the identification of the relevant national government agencies, local government offices, and members of the private sector along with their respective roles, responsibilities, and implemented programs and projects. Once the review and interviews are completed and all data are processed, the different policy options or alternatives will be identified. These policy alternatives will be weighed as part of the NbS interventions. The last part is communication with different stakeholders mainly through stakeholder meetings and policy briefs.

B. Stakeholder analysis

Identified institutional agents identified as stakeholders were assessed according to their potential and actual roles and responsibilities related to infrastructure planning and managing natural resources. Focusing on the project site, social dynamics were analyzed by mapping stakeholder characteristics. This was achieved by creating a Stakeholder Matrix (Figure 3), a four-quadrant tool for plotting the levels of interest and power of influence per stakeholder, grouped according to common institutional affiliations. Levels of interest, whether interest against or in favor of a policy issue, ranging from no interest to high interest, were plotted on the x-axis. The y-axis, on the other hand, plotted the level of power or influence a particular stakeholder group has, whether in terms of approving or declining policy recommendations.

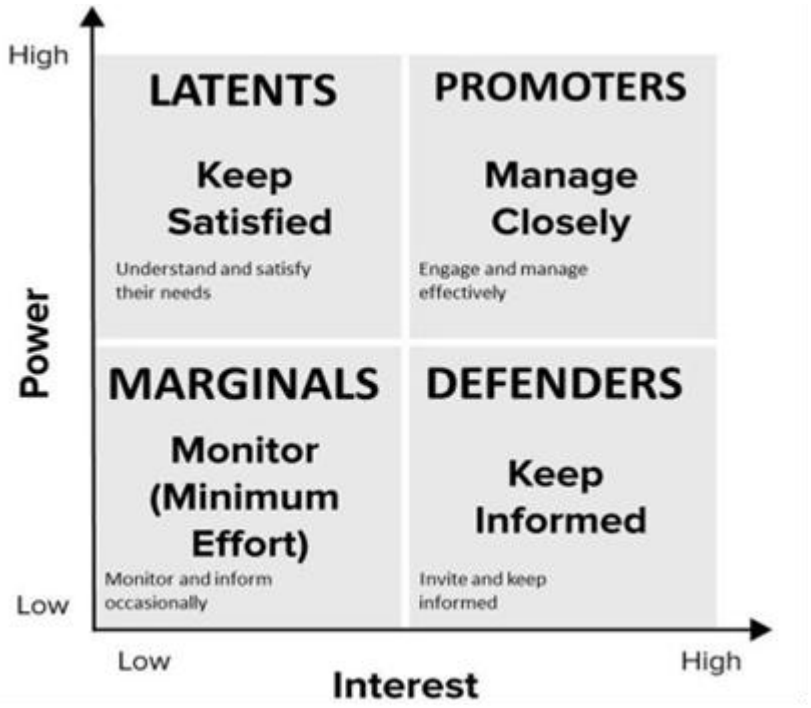


Figure 3. Classification of Stakeholders using a Stakeholder Matrix (Adapted from Mendelow, A.L. (1981).

C. Socio-Ecological Assessment

The socio-ecological assessment that was employed in this project involves the evaluation of ecosystem services, and in general, ecological systems structures and dynamics present in the project site. Using readily available data from academic publications, local government reports, geographical maps, and site visits, the socio-ecological assessment first establishes baseline information about key ecosystem characteristics in the area. Additionally, information regarding biophysical features was supplemented by socio-demographic and socio-cultural characteristics of human settlements and activities in the area.

This baseline information will serve as points for comparison regarding planned NbS projects to be implemented in the area. Relevant parameters will be obtained from baseline data to identify appropriate indicators of status, threats, and drivers of change. Using data from key informant interviews, focus group discussions, and in-depth interviews, additional assessments of socio-ecological systems will be conducted using additional analytical methods. This involves evaluating ecosystem services and options for the use of nature-based approaches in infrastructure for decision-making among selected government entities. Specifically, a risk assessment, impact change analysis, mapping, and a cultural consensus analysis will be done to assess socio-ecological systems.

a. Physical Characterization using Spatial and Attribute Analysis

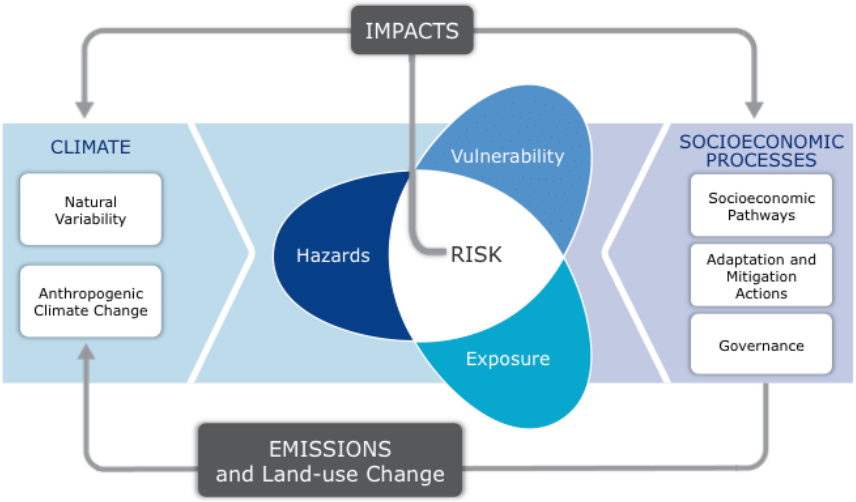
The study utilized QGIS, an open-source Geographic Information System (GIS) software to process spatial data from various sources. All thematic layers were projected into WGS 1984 Universal Transverse Mercator (UTM) Zone 51N. Geoprocessing techniques like clipping tool (vector) and extract by mask (raster) were used to create new feature classes for the study area based on larger feature classes or datasets. On the other hand, the utilization of a base map for the study site is a representation of the area's geographic reference information to orient the users on the landscape features. The following are the other geospatial processing that were employed in this study.

Digitization. This process was carried out in the absence of available linear infrastructure data. It is the linear process of converting geographic data into a digital format, which can be traced as polygon, polyline, and point. The generated data in digitization can be displayed in GIS and generate thematic map layers.

Attribute databasing – After digitization, the process of generating attribute data provided characteristics about the spatial data. The attribute data are non-spatial information about the geographic feature linked to the geographic features (spatial data) that describe the features.

b. Climate Risk Assessment

The study used the IPCC Risk framework published in the fifth assessment report (IPCC AR5) in assessing risk to various climate hazards in Butuan City, which is defined as a function of hazard, exposure, and vulnerability (Figure 4).



R= f (H x E x V)

Figure 4. The risk framework (Source: IPCC Fifth Assessment Report).

Hazard Mapping. Hazard is defined as a phenomenon, human activity or process that may cause harm, injury, property damage, socioeconomic disruption, loss of lives, and environmental degradation (UNDRR, 2017). Susceptibility maps provide information about the naturally occurring hazards in order to illustrate the affected areas. The study included climate-related hazards, such as floods, and rainfall-induced landslides

The study considered secondary and primary information to identify climate-related hazards associated with Butuan City. The Climate and Disaster Risk Assessment (CDRA) report from the City Planning and Development Office (CPDO) of Butuan City was reviewed and the identified climate-related hazards in CDRA were validated by the local stakeholders through Focus Group Discussions (FGD). The criteria for hazard identification were based on the significant impacts of hazards on linear infrastructure that can disrupt its functionality. The identified hazards were summarized in Table 2.

Table 2. List of major hazards within Butuan City for risk assessment

Hazards	Source
Flooding	DENR-MGB (2016)
Rainfall-Induced Landslide	DENR-MGB (2016)

Exposure Mapping. As defined by the UNISDR (2009), exposure are variables such as situation of people, infrastructure, housing, production capacities, and other tangible human assets located in the hazard-prone areas. In this study, the infrastructure utilities within Butuan City were treated as exposure variables, which can be used by planners and policymakers in developing strategies to protect these critical systems, enhance resilience, and ensure the continued functioning of essential services during and after adverse events. The list of exposure variables is summarized in Table 3.

Table 3. List of exposure variables for risk assessment

Exposure	Sources
Existing Road Network	City Government of Butuan (2023)
Proposed Road Network	City Government of Butuan (2023)
Proposed Mindanao Railway	City Government of Butuan (2023)
Proposed Drainage Line	City Government of Butuan (2023)
Proposed Streetlights	City Government of Butuan (2023)

Vulnerability Mapping. Vulnerability refers to the conditions determined by the physical, social, economic, and environmental factors or processes which increase the susceptibility level of the exposure variables (UNISDR, 2009). Vulnerability mapping was based on the hazard and exposure variables.

The vulnerability variables of the exposed elements were assessed by examining various factors that influence their susceptibility to damage. The identified vulnerability variable was categorized under environmental vulnerability due to their nature. These variables pertain to the condition of the natural environment and its capacity to absorb or mitigate the impacts of hazards. The list of vulnerability variables is summarized in Table 4.

Table 4. List of exposure variable/s for risk assessment

Exposure	Sources
Land Cover	NAMRIA (2020)

HEV Matching. Part of the risk mapping is the Hazard-Exposure-Vulnerability (HEV) matching. HEV component matching is a comprehensive method that integrates hazard, exposure, and vulnerability data to identify risk-sensitive areas. This approach helps people to understand and manage risks, ultimately enhancing the resilience of communities and systems. Table 5 shows the combined HEV variables used to generate risk maps.

Table 5. List of vulnerability variable/s for risk assessment

Hazard	Exposure	Vulnerability	Risk
Flooding	Existing Road Network	Land Cover	Risk to Existing Road Network due to Flooding
Flooding	Proposed Road Network	Land Cover	Risk to Proposed Road Network due to Flooding
Flooding	Proposed Mindanao Railway	Land Cover	Risk to Proposed Mindanao Railway due to Flooding
Flooding	Proposed Drainage Line	Land Cover	Risk to Proposed Drainage Line due to Flooding
Flooding	Proposed Streetlights	Land Cover	Risk to Proposed Streetlights due to Flooding
Rainfall-Induced Landslide	Existing Road Network	Land Cover	Risk to Existing Road Network due to Rainfall-Induced Landslide
Rainfall-Induced Landslide	Proposed Road Network	Land Cover	Risk to Proposed Road Network due to Rainfall-Induced Landslide
Rainfall-Induced Landslide	Proposed Mindanao Railway	Land Cover	Risk to Proposed Mindanao Railway due to Rainfall-Induced Landslide

Climate Risk Mapping. This study employed a criteria-based method in generating risk maps. Then, both hazard and vulnerability variables were classified into 3 major classes using the defined interval classification process in QGIS. After the reclassification process, both variables were combined using merge raster layers tool in QGIS. Essentially, it aims to present areas with "very low", "low", "moderate", "high", and "very high" risk areas (Figure 5). A color-coded map showing these risk categories was made for Butuan.

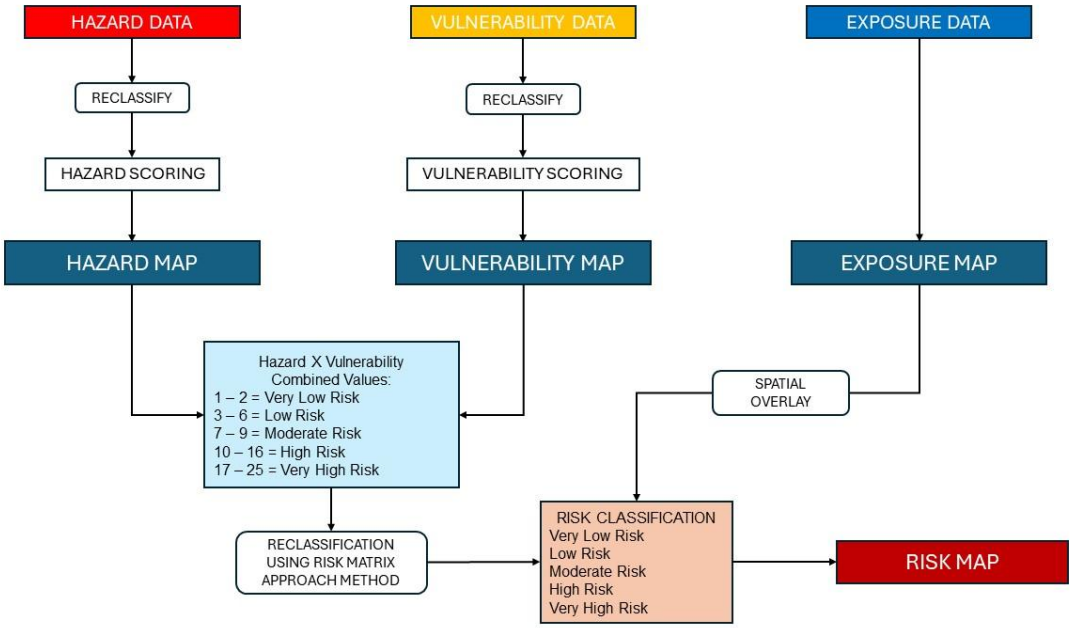


Figure 5. Flow diagram showing the methodological process of climate risk mapping

c. Impact Chain Analysis

After the risk assessment, the impact chain analysis was used as a guide to identify the direct and indirect impacts of risks and determine the stakeholders or sectors that are direct receptors of the identified climate-related hazards. Impact chain analysis is a conceptual systemic model that adheres to the comprehensive risk framework for specific climate risks in a given context. It is co-developed through an inclusive and participatory approach with experts and stakeholders, serving as the backbone for a risk assessment. These experts are organized around the core elements of risks—hazard, exposure, and vulnerability—and include representations of multiple hazards and cascading impacts across various exposed subsystems. Impact chains also facilitate early discussions on potential risk reduction measures by highlighting vulnerabilities, adaptation gaps, and risk mechanisms (UNDRR, 2022). The process of impact chain analysis is helpful for stakeholders and sectors to understand the impacts of climate change and to develop relevant strategies like nature-based solutions (Figure 6).

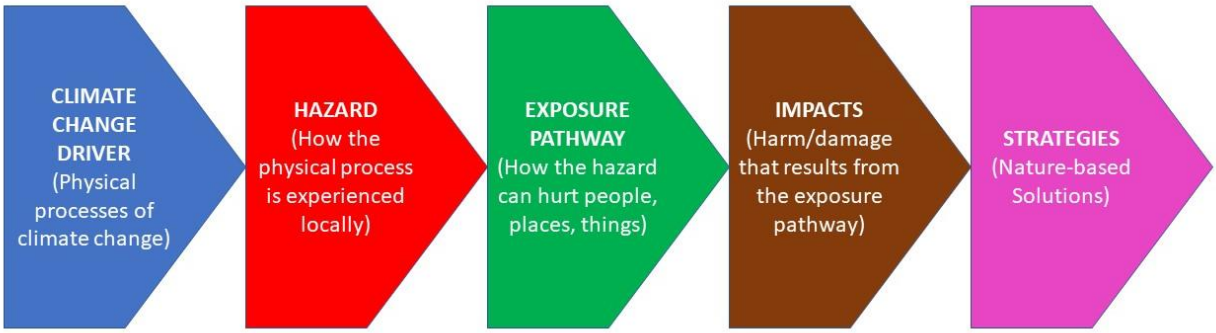


Figure 6. Steps in the impact chain analysis

d. Quantification of Ecosystem Services (ES)

Quantifying ecosystem services with spatial data is important for effective landscape management and policymaking. This process helps identify ecosystem services that might be at risk, which is crucial for choosing the right Nature-based Solutions (NbS). The ecosystem services were estimated based on the findings from the NbS technical consultants' focus group discussions.

The priority ecosystem services based on the priority of the stakeholders were estimated using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) by the Natural Capital Project of Stanford University. This model produces spatially explicit outputs, enabling the opportunity to support location-based approaches and decision-making.

Mapping of ES. The results of the quantification of ecosystem services revealed areas that are effective in delivering ecosystem services, and at the same time, showed the areas that need intervention. The generated maps are useful guides where it is best to implement NbS and may ultimately be one used in consideration of planning for linear infrastructures that are more resilient and climate-proof.

e. Mapping the ES hotspots and coldspots

After combining the multiple quantified ES maps into a new raster, the normalized field values were classified into five classes using symbology to visually represent the map. It is vital for users to easily interpret what the map shows. Identifying areas with ES concentrations is easier using symbology. This geospatial approach enables the identification of spatial clusters of ES, which will be valuable for the decision-makers (Lyu et al., 2021).

The spatial analysis was utilized to identify hotspots and cold spots in terms of ecosystem services distribution, highlighting areas of abundance and scarcity. It also

illustrated where future linear infrastructure projects are planned to be developed. Additionally, the process will identify areas where NbS should be implemented to enhance sustainability and resilience.

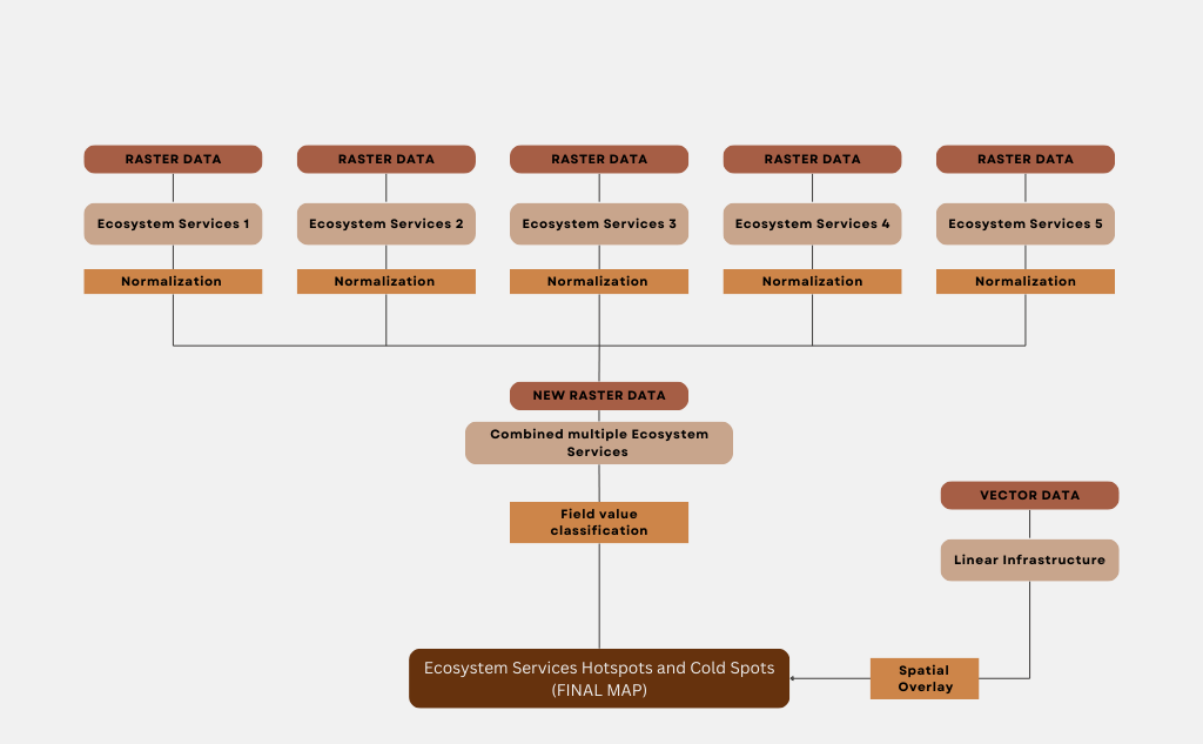


Figure 7. Flow diagram on the methodological process of generating geospatial layer that shows the ES hotspots and cold spots.

By conducting this, stakeholders are expected to better understand the spatial dynamics between ES and planned linear infrastructure projects. This information is necessary for informed decision-making in infrastructure planning and management. This will also allow decision-makers to identify priority areas for infrastructure development, anticipate potential impacts on ES, and integrate NbS where necessary to mitigate risks and enhance sustainability. The overall methodological process is shown in Figure 7.

Multi-Stakeholder Consultation

Validation of key informant interviews, focus groups, geospatial data, and generated maps was done through a validation workshop held on March 22, 2024 where the project team presented the conceptual framework, the mapping methodologies, the interim quantification of ES results, stakeholder analysis results, and among other relevant results. The consultation sessions gathered feedback regarding the relevance, validity, and usability of using NbS in linear infrastructure, including the use of a spatial-based decision support tool for the SIPA project. The participants during the validation include the technical personnel from DPWH Engineering District Offices, the local planning and development offices, barangay officials, and other offices and stakeholders involved in infrastructural planning, implementation and

construction, and maintenance. Annex 2 shows the list of offices, organizations, and agencies who attended the validation workshop.

Process Documentation

A training manual was prepared to serve as reference material for use by professionals and non-professionals in the rapid assessment of ecosystem services and identification of nature-based solutions. The material intends to provide an understanding of the basic principles of nature-based solutions and ecosystem services including tools and techniques. Pictures, best practices, and lessons-learned in the conduct of the assessment were incorporated in the manual. The manual aims to enable users to conduct similar activities in their respective areas.

III. Results and Discussion

Incorporation of Nature-based Solutions and Spatial Planning to achieve a resilient Butuan City, and eventually the whole Caraga Region, meant achieving the various objectives of this study. This section comprehensively details the results of the various activities conducted to achieve several specific objectives of this study, with a primary goal of putting forward recommendations on how NbS can be mainstreamed in the planning processes to achieve sustainable infrastructure planning and development.

This section will cover the discussion of the following:

- Socio-Economic Profile of Butuan City as the Case Study Site
- Physical Characterization of Butuan City
- Climate Profile and Natural Hazards
- Ecological System and Biodiversity
- Infrastructure Planning and Development in Butuan City
- Policy, Institutional, and Stakeholder Landscape
- Societal Challenges Observed
- Climate Risk Assessment
- Ecosystem Services

Socio-Economic Profile of Butuan City

Butuan City has a total population of 372,910 inhabitants and an annual population growth rate of 2.15% (Table 6). The population of Butuan represents 13.30% of the total population of the Caraga region which is 2,804,788 (PSA, 2021). The population growth in the past three decades was mainly due to the natural increase – where birth rates are higher than death rates or mortality rate (Butuan City LCCAP 2022-2026).

With a land area of 826.87 sq. km.[2], the city has a population density of 457 inhabitants per sq. km. There are a total of 89,408 households in Butuan City with an average household size of 4.1, and dependency ratio of 56.6%. This means that in a household of four, two of them are dependent on the income-earning household members.

Table 6. Population Statistics of Selected Barangays in Butuan City, in relation to Butuan City and Caraga Region.

Location	Land Area (sq. Km.)[a]	Population (Census 2020)[b]	Population Growth Rate[b] (%)	Population Density (per sq. Km.)
Caraga	**19,138.42**	**2,804,788**	**1.63**	**146**
Butuan City	**826.87**	**372,910**	**2.15**	**451**
Ampayon	6.43	13,820	1.76	2,148
Anticala	68.93	4,913	5.19	71
Bancasi	10.54	5,388	1.91	511
Pagatpatan	2.62	6,379	1.54	2,435
San Vicente	4.55	19,500	4.00	4,285
Taguibo	6.84	5,856	7.04	856
Villa Kananga	3.72	12,407	2.23	3,333

Source: [a]National Economic Development Authority for Caraga Region land area, and Butuan City Planning and Development Department for Butuan City and selected barangays.
[b]Philippine Statistics Authority for Caraga Region and Butuan City, and PhilAtlas for Barangay Population

Poverty incidence in Butuan is at 12.2% in 2023, a huge reduction from 22.6 % in 2021 (PSA, 2024). Meanwhile, the poverty threshold is at PhP 29,503 (US$ 530.34) and the food poverty threshold is at PhP 20,463 (US$ 367.84)[3]. The poverty incidence in Butuan is higher than the national poverty incidence of 10.9%. Also, the poverty threshold and the food poverty threshold statistics are lower than the national figure of PhP 33,296 (US$ 598.52) and PhP 22,994 (US$ 413.34), respectively. The higher incidence could be related to the less diverse sources of livelihood such as those related to the service sector (e.g., call centers, tourism),

[2] Data from the based from the City Planning and Development Department
[3] US$ 1.00 = PhP 55.6304. Source: https://www.bsp.gov.ph/statistics/external/tab12_pus_data.aspx

manufacturing, and local industries. Meanwhile, lower threshold is related to the lower cost of living in Butuan City, compared to metro cities.

Economic Development in Butuan

The logging industry of Butuan City is the foremost factor that catalyzed its cityhood, As a result of the income and employment the logging industry, generates, Butuan became a a charter city on August 2, 1950 through the Philippine Republic Act No. 523, and also became known as the "Timber City of the South" (Butuan City Website, 2023). Various businesses related to logging existed in Butuan City such as ports and shipping for logging logistics, sawmills, wood trading businesses, plantation forests, and wood processing. It was reclassified into a Highly Urbanized City on February 7, 1985 based on its income and population. By 1990s, the logging business in Butuan City waned as a result of anti-logging movements as well as policies restricting logging activities in the country (Environmental Science for Social Change [ESSC], 2015). Despite restrictions, sawmills, wood processors and wood traders or middlemen are still doing business in the City. They source their wood from plantation forests, and through log importation and procurement from other regions (Balanay, et al., 2022).

Prior to the logging industry boom, Butuan City is already a historically significant trading port (ESSC, 2015; Sia, 2009). At present, Butuan City's potential for further industrialization and urbanization remains high, being strategically connected through an airport, a docking port within the Agusan River, and road networks that connects it to other major cities in Mindanao, such as Davao, Cagayan de Oro, Mabaybalay, Surigao, and Tandag. It continues to be Caraga region's center for commerce, industry, and administration in the region where several national government agencies' regional offices are located.

The Butuan LCCAP notes that development is moving towards the rural barangays, resulting in the establishment of various housing projects and business establishments, transforming the agricultural landscape into commercial and residential areas. This expansion has been observed in the project's study barangays except for Anticala. For example, it has been noted in the FGDs that housing resettlement projects and commercial and industrial establishments can now be found in Bancasi, Pagatpatan, Taguibo, and Villa Kananga. Despite these changes, the economy of Butuan City still primarily relied on agriculture, fishery, and forestry. This can also be noted in the next section on profile of barangay study sites. According the LCCAP, agriculture covers 489.523 sq. km., with 62% used for growing rice, corn, coconut, banana, and other crops. Meanwhile, 10.5 sq. km., for is dedicated for the fishery sector, including freshwater and brackish water areas, and 16,640 square meters for fish cages, of which 10,400 square meters are developed. The forest area spans 268 sq. km., with 15.31 sq. km. dedicated to falcata farming. Falcata (*Paraserianthes falcataria*) is a Southeast Asian tree being cultivated for timber in Caraga region for processing into matchsticks and particle board. It takes 10–15-year cycles before it can be harvested (Brewbaker, 2004). While the logging industry of Butuan waned due to the anti-logging movements and the total log

ban[4] in the Philippines, lumber production continued, with 14 registered processors continuously in operation who source lumber from registered plantation forests and through importation.

Figure 8. Falcata Tree planted near the highway in Lemon, Butuan City

Quarrying, manufacturing, and retail also generate income for Butuan City. Quarrying of sand and gravel cover 85.63 sq. km., with 0.47 sq. km. actively used by 16 permitted operators. Manufacturing includes food and beverages, garments, wood-based products, and metal fabricators. Wholesale and retail trading are consistently growing contributing significantly to the city's economic growth. The existence of malls is also proof of the growing trade sector.

Other sectors present in Butuan City that also contribute to its local economy include finance and insurance sector, services sector (e.g. restaurants, construction, electricity, water, gas, and utilities), tourism, transportation, and communication. A number of accommodation establishments like resorts, hotels, inns, motels, lodges and pension houses are present in the city. Meanwhile, the number of fast-food establishments, restaurants, coffee shops, bars are continuously growing. These developments are testament to the economic potential and continuous urbanization of Butuan City.

[4] Executive Order No. 23, s. 2011 - Moratorium on the cutting and harvesting of timber in the natural and residual forests and creating the anti-illegal logging task force

Profile of Barangays Chosen as Study Sites

To achieve the objectives of the study, seven barangays were chosen to gather data on the socio-ecological conditions in Butuan City. These barangays are: Ampayon, Anticala, Bancasi, Pagatpatan, San Vicente, Taguibo, and Villa Kananga.

Table 7. Land area and population statistics in of selected barangays in Butuan City, Caraga Region

Location	Land Area (sq. Km.)[a]	Population (Census 2020)[b]	Population Growth Rate[b] (%)	Population Density (per sq. Km.)
Caraga	**19,138.42**	**2,804,788**	**1.63**	**146**
Butuan City	**826.87**	**372,910**	**2.15**	**451**
Ampayon	6.43	13,820	1.76	2,148
Anticala	68.93	4,913	5.19	71
Bancasi	10.54	5,388	1.91	511
Pagatpatan	2.62	6,379	1.54	2,435
San Vicente	4.55	19,500	4.00	4,285
Taguibo	6.84	5,856	7.04	856
Villa Kananga	3.72	12,407	2.23	3,333

Source: [a]National Economic Development Authority for Caraga Region land area, and Butuan City Planning and Development Department for Butuan City and selected barangays.

The barangays were all classified in the Butuan City DRRM Plan as rural barangays. However, in terms of the population, they are already urbanizing (See Figure 9). PSA (2022) considers a barangay as urban if it has any of the following characteristics:

a) a population size of 5,000 or more; or
b) presence of at least one establishment with a minimum of 100 employees; or
c) presence of five or more establishments with 10 to 99 employees, and five or more facilities such as the city hall, hospital, barangay health center, and a church or mosque, etc., within the two-kilometer radius from the barangay hall.

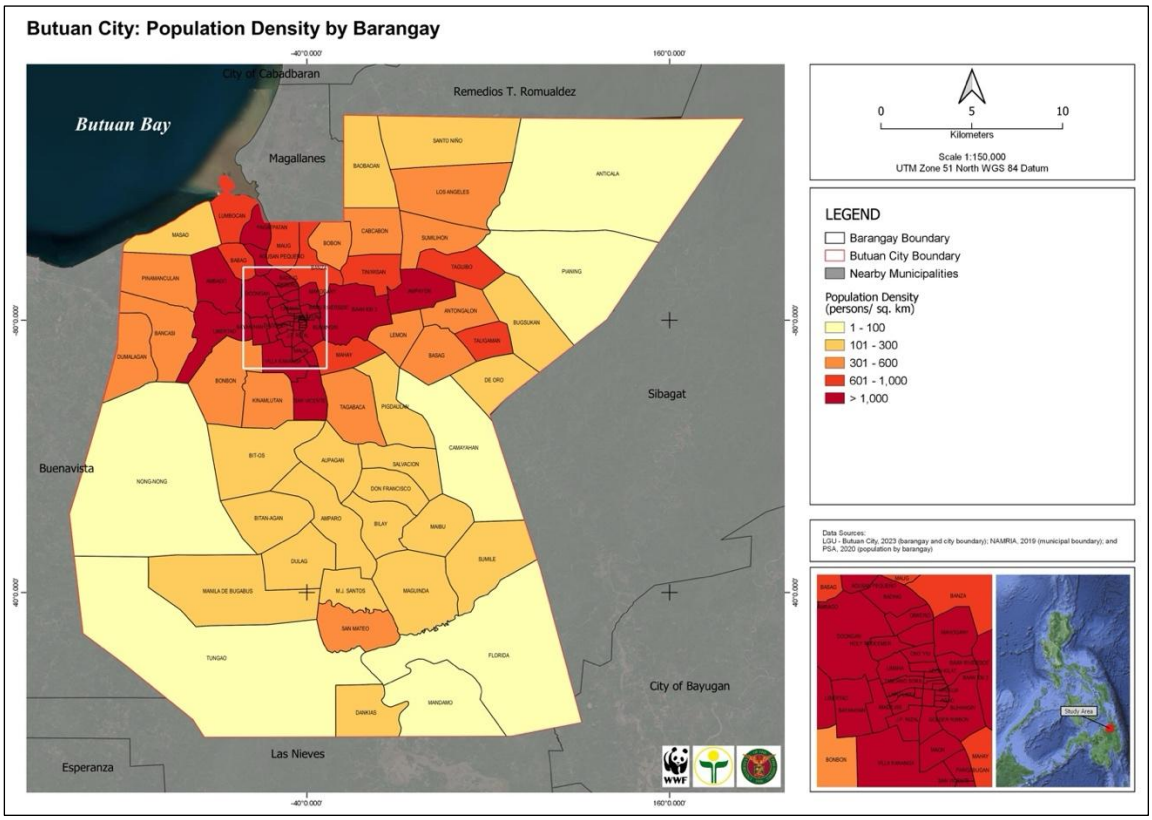


Figure 9. Population density by barangay in Butuan City

Except for Anticala, the rest of the barangays are recorded as urban in the 2020 Census of Population Report on Urban Population based on the category of having a population greater than 5,000 (PSA, 2022). To be specific, Ampayon, Bancasi, San Vicente, and Villa Kananga are already urbanized in its characteristics, not only on the basis of population but also on the presence of business establishments and housing projects. Meanwhile, Pagatpatan and Taguibo are experiencing increasing population as people relocate to these barangays where opportunities for government-supported relocation (Pagatpatan) and lowcost housing (Taguibo) are present.

Meanwhile, the following subsections present a more specific characterization of each study barangay.

A. Ampayon

Barangay Ampayon is among the barangays that can be found on the low-lying alluvial plain of Butuan City. Ampayon is a combination of a commercialized, residential, and agricultural area. It has a total population of 13,820, with a population growth rate of 1.76% and a population density of 2,148 per sq. km. This population statistic is affected by the number of students enrolled in schools and universities present in the barangay. The reason for this is that Ampayon is designated as the city's education zone in its Comprehensive Land Use Plan 2019-2028 where educational institutions are currently located. It is also where new educational institutions who will choose to open in Butuan are expected to build their facility.

As a result of the city's zoning plans, Ampayon benefited from it since the presence of educational institutions such as the Caraga State University has led to an establishment of an ecopark which provides a green livable space for the population, and the Philippine Carabao Center, a research center for carabaos.

While there is limited secondary data available on the various types of livelihoods in the barangay, the FGD participants related that farmers cultivate rice, corn, and a diverse number of lowland vegetables (e.g., eggplant, squash, Chinese chard or pechay, beans, turmeric). Some farms are practicing organic farming. One of these farms even opened a restaurant that offers a farm to table menu. A few farmers also have fishponds raising tilapia, catfish (*pantat*), and mudfish (*haw-an*). There is also an existing rice mill in the barangay.

Aside from the vibrant agricultural sector in Ampayon, the FGD participants agreed that businesses and enterprises (e.g., groceries, pharmacies, meatshops) are turning into the major sources of income for the people in Ampayon. At the time of the study, one of the largest Filipino Food chains even opened a branch in Ampayon, a proof the continuing urbanization of the barangay.

B. Anticala

Barangay Anticala has a total population of 4,913 with a relatively high population growth rate of 5.19%. It has the lowest population density among the barangay study sites at 71 persons per sq. Km., owing to its wide land area of 68.93 sq. Km. Barangay Anticala is located 23 km away from the población, on a mountain range that is forested, hence its topography is mountainous and hilly. Anticala has various sources of water such as springs, falls, and the Taguibo River, which is the primary source of water in Butuan City, that traverses the whole barangay from north to southwest. A large portion of the Taguibo Watershed and the Taguibo Dam can also be accessed via Anticala. The present water resources help sustain livelihoods, particularly farming.

Anticala is unique in that there is a recognized Manobo indigenous cultural community (ICC) in the barangay. The Manobo tribe is well represented in the barangay council of Anticala, where one of the members of the barangay council stands as the Indigenous Peoples Mandatory Representative (IPMR). Some members of the barangay police (*tanod*) are also members of the ICC. However, while the Manobo tribe resides in Anticala, the origin of the barangay's name is not related to the Manobo dialect, but rather from another indigenous people group who previously occupied the barangay. When the Manobo tribe came and settled in Anticala, they did not change the name of the barangay even as the previous indigenous people group moved to a different settlement.

Given the natural resources that abound and the ancestral domain accessible to the indigenous peoples, approximately 11% of the barangay population is engaged in farming, based on the Barangay DRRM Plan. There are also laborers, carpenters, and licensed professional drivers in the barangay. A few are into vending of various merchandise. In addition to these, the rest of the income-earning population in Barangay Anticala earns from

various types of livelihoods available in the area, such as employment, house help, and professional work.

C. Bancasi

Barangay Bancasi is among the urban barangays in the city. It is crossed by the Bancasi Creek, which connects to the Masao River and drains into Butuan Bay. Historically, Bancasi is a sitio of Barangay Libertad, where the Balanghai Boat, an evidential artifact of the pre-colonial civilization in the Caraga Region, was discovered. The name "Bancasi" is derived from Datu Balangkasi, who originally came from Jolo and migrated to Butuan. It is believed that Datu Balangkasi reached Bancasi via the Masao River. In recognition of his strong leadership among the lumads (indigenous people) in the area and Muslim migrants, the place was named in his honor.

Bancasi has a total population of 5,388, with a population growth rate of 1.91% and population density of 511 persons per sq. Km. Bancasi was recognized into a barangay as a result of population growth, both through natural growth and migration. The presence of the military camp enabled migration in Bancasi as the assigned soldiers in the camp chose to settle in the barangay. While Bancasi has started to urbanize because of population growth and the existence of business establishments in the area, a large portion of the barangay is still considered an agricultural area. From a total land area of 10.54 sq. km., 75% of it remains agricultural, and the rest is divided into forest, wetlands (swampy areas), residential areas, and idle lands.

It was reported in Bancasi's Barangay Development Plan that while many are still dependent on agriculture as farmers and farmworkers, about 8% of Bancasi's population are now reliant on commercial activities or businesses for livelihood. The existence of the Butuan Airport and various businesses (e.g. construction supplies, pharmaceuticals, canning corporation, logistics) make Bancasi an urban area. There are also skilled workers such as those in carpentry and professional driving. The Military Camp also employs several inhabitants from Bancasi. In summary, the source of livelihood in Bancasi is very diverse and has shifted away from natural resource dependent livelihoods such as agriculture. It is expected that Bancasi will continue to urbanize.

D. Pagatpatan

Barangay Pagatpatan is a low-lying barangay located north of Butuan City and is bounded by the Agusan river and Mantange Creek which lends to the existence of wetlands in the area. Accordingly, its name came from the *Pagatpat* tree, a mangrove abundant in the barangay. During the FGD, the participants mentioned the value of the *pagatpat* in their barangay as it serves to protect the households from flooding and provides them various ecosystem services such as food and livelihood from ecotourism activities. In the Barangay Development Plan (BDP) of Pagatpatan, it was mentioned that there is an existence of various ecoparks in the barangay such as the *Dungon* Tree Board Walk, *Kayam* Tree Park, and the

Mantange Creek Eco Park, which are set to be further developed for ecotourism. Barangay Pagatpatan also hosts a Wetland Learning Center funded by the Caraga State University as well as other funding partners (Wetland Link International, 2024).

Pagatpatan is approximately 6.4 km from the población. It has the smallest land area among the barangays study sites. With an area of 2.62 sq. km., it has a population of 6,379, a population growth rate of 1.54%, and population density of 2,435 persons/sq. km. Pagatpatan has a small land area as it used to be part (*purok* or small community) of Barangay Agusan Pequeno. It became a barangay in 1985 after a plebiscite to separate the area was approved.

The increase in the population in Pagatpatan started in the early 2000s as a result of the "Balangayan Butuan" program of the Butuan Local Government in partnership with non-government organizations (e.g., Gawad Kalinga, Habitat for Humanity). The Balangayan Butuan is a resettlement project conducted to relocate households living on the riverbanks of Agusan River. During this time, the Cotabato-Agusan River Basin Program-Lower Agusan Development Project (CARBDP-LADP) was implemented to prevent floodwater from the Agusan River to inundate Butuan City and to install flood control structures along the Agusan River. The households that were resettled were identified to be living on the "danger zone" which easily gets flooded and were considered as Informal Settlers. Seventeen out of 20 purok in Pagatpatan were all identified as a resettlement area.

Livelihood in Barangay Pagatpatan is heavily dependent on its natural resources. The BDP cites that a total of eight hectares are dedicated for aquaculture, four hectares are covered with mangrove, and two hectares are occupied by the Gawad Kalinga Enchanted Farm, a community development project of resettled families. Farmers produce various vegetables, root crops, and coconut. Households ferment the Nipa sap to produce Nipa Vinegar and wine as the Nipa palm, a mangrove associate, is abundant in the area. They also raise livestock and poultry for household consumption. It is also worthy to mention that there are 10 identified fishermen living in the barangay (Pagatpatan BDP 2023-2028).

Aside from livelihoods dependent on natural resources, micro- and small enterprises are also existent in Pagatpatan, particularly general merchandise stores (sari-sari stores), Block Tiendas (mini-wet market project in Barangays) and a lone Water Refilling Station. Aside from what has been mentioned, the residents earn income through various other work such as carpentry or skilled labor, employment (e.g., government, private), vending and peddling, and driving, among others (Pagatpatan BDP 2023-2028).

E. San Vicente

Barangay San Vicente is a lowland barangay located along the riverbank of Agusan River, 4.5 kilometers away from the población or city center. Among the barangays included for this study, San Vicente has the highest population statistic: a population of 19,500, population growth rate of 4%, and a population density of 4,285 per sq. km.

Aside from the population, the presence of the sawmill industry and various small-scale businesses make San Vicente an urban area. Sawmills and wood processors are among the sources of income in San Vicente, and is among the earlier business in Butuan in relation to the logging industry boom. Sawmills in San Vicente mainly process Falcata timber which are made into plywood and veneers by wood processors.

The residents of San Vicente earn their income from various types of livelihoods but most of the residents depend on carpentry, professional driving, farming, masonry, and online selling/marketing. Despite the diversity of livelihood opportunities, the residents in the barangay are still dependent on farming rice, corn farming, vegetables, and root crops. Some are also into horticulture, selling ornamentals such as bougainvillea and euphorbia to schools and establishments. Backyard poultry and livestock raising is also present in some parts of the barangay but this is for home consumption only. Large-scale poultry and livestock raising are not allowed in the barangay to prevent sanitation issues.

The Agusan River is an important natural resource in San Vicente. Eighty percent of the rice farms get their irrigation from the river. Subsistence fishing is also being done by the residents in the Agusan River.

Formerly an agricultural area, San Vicente faced the effects of population pressure in the city, leading to conversion of agricultural areas into residential areas in the early 2000s. People who chose to resettle in Butuan had chosen to reside in San Vicente given its proximity to the población. As a result, several real estate agencies developed housing projects within San Vicente. The are also problems where agrarian reform areas – farming areas that were distributed by the government to farmers under the Comprehensive Agrarian Reform Program – were converted by real estate agencies into residential subdivisions. FGD participants mentioned that land use change has resulted in reduced biodiversity in the area.

F. Taguibo

Barangay Taguibo has a total population of 5,856 and a population density of 856 inhabitants per sq. Km. It is an agroeconomic zone that sits on the foot of the mountain. A part of the land area of Taguibo is forested, particularly the mountainous area that is also part of the Taguibo watershed.

The Taguibo Barangay profile mentions that its name was derived from the words "*Taga Ibo*" meaning "From Ibo", as the residents were migrants of the Ibo Tribe from Mount Hilong-Hilong. While the name of the tribe was not mentioned during the FGD in Taguibo, the participants indeed mention that there are indigenous peoples living in Taguibo.

The residents of Taguibo are involved in various types of livelihoods. Taguibo residents rely on various types of livelihood, such as skilled labor, employment (e.g. private, government), and as practicing professionals (e.g., doctors, lawyers) (Taguibo Barangay DRRM Plan 2021-2025). However, agriculture-based livelihoods remain to be the primary source of income for its residents. Rice and coconut farms occupy large portions of the agricultural area in the barangay. Rice farms can be found near Taguibo river, the main source of irrigation, which allows the rice farmers to plant twice a year. Other crops planted in the

area include corn, banana, cacao, coconuts, vegetable crops, and other fruit bearing trees. Many farmers in Taguibo are dependent on banana harvest which is being brought to a local manufacturer that exports banana chips to the US, Europe, and Middle East. In the meantime, agri-businesses operated by private companies can also be found such as poultry farms and cattle ranch.

As the barangay is developing, other business establishments are beginning to open in the barangay (Taguibo Barangay DRRM Plan 2021-2025). The Taguibo River which passes through the barangay also provides livelihood through sand and gravel mining for construction and road materials.

G. Villa Kananga

Villa Kananga is located 3 kilometers southeast of Butuan City proper. The name Villa Kananga originates from the Manobo word "Kananga" for *ilang-ilang* (*Cananga odorata*), a tropical tree native to the Philippines whose flowers are being used to extract essential oils for use in perfumes and aromatherapy oils. These trees used to be prominent when the barangay had more idle land. It has a land formation categorized as a minor alluvial plain, characterized by a flat terrain with an elevation that varies from one to two meters on the southeast portion of the barangay and the rest of the higher ground with an elevation of 3 to 5 meters above sea level.

Prior to urbanization, 80% of Villa Kananga's land area is planted with rain-fed rice, with pockets of land planted with coconuts, bananas, and other local fruit trees (Villa Kananga Barangay Profile, 2021). As of the 2020 Census of Population, Villa Kananga has a population of 12,407 and population density of 3,333 per sq. km. Livelihood has also changed from agriculture-based to non-agricultural ones as most of the land in Villa Kananga has been converted into residential areas. Hotels, conference venues, pension houses, and apartments for rent are among the businesses present in Villa Kananga.

Physical Characterization of Butuan City

Butuan City has a total land area of 817.73 sq. km. Approximately 67% of it is composed of alienable and disposable lands and the rest is classified as forestlands[5]. It is part of the Agusan River Basin, wherein 70% of its land area is part of the basin itself (Table 8). Butuan City is situated at the lowest portion of the basin and flood plains exist at the downstream part of Agusan River, with marshlands at the river delta.

Table 8. Area in square kilometers of Butuan City in reference to the Agusan River Basin.

AREA OF INTEREST	TOTAL AREA (sq.km)	%
Agusan River Basin	11,701.90	
Butuan City	826.87	
Agusan River Basin within Butuan City	**579.45**	**70.08**

Agusan River is the third longest river in the Philippines and one of the seven major rivers in the country. It flows northward across the city into the Butuan Bay. It is also moderately deep to enable ferry boats to fetch passengers at the Butuan Port located on the city proper (or Población). During the logging industry boom, Agusan River was used as a means to transport logs from the upland areas. At present, it remains to be a significant natural resource in Butuan city as it still provides irrigation for farmlands near the river.

Geologic Features of Butuan City

There are eight different land formations that can be found in Butuan City (BSWM). These are: coastal lowlands, broad alluvial plains, minor alluvial plains, terraces, plateau landscape, hilly landscape, mountain landscapes, and miscellaneous landforms. The following geologic features were cited from Butuan City's LCCAP 2022-2026.

Coastal lowlands are those near the Butuan Bay, at the northern part of the city, and are composed of fishponds, mangrove, and mangrove associate species. Barangays composing the coastal lowlands are the coastal barangays of Lumbocan and Masao. The flat areas of Barangays Maug, Babag, Agusan Pequeno and Banza are also part of the coastal lowlands. Pagatpatan, the one of the barangay study sites, is part of the coastal lowland.

[5] From Butuan City's Local Climate Change Action Plan 2022-2026

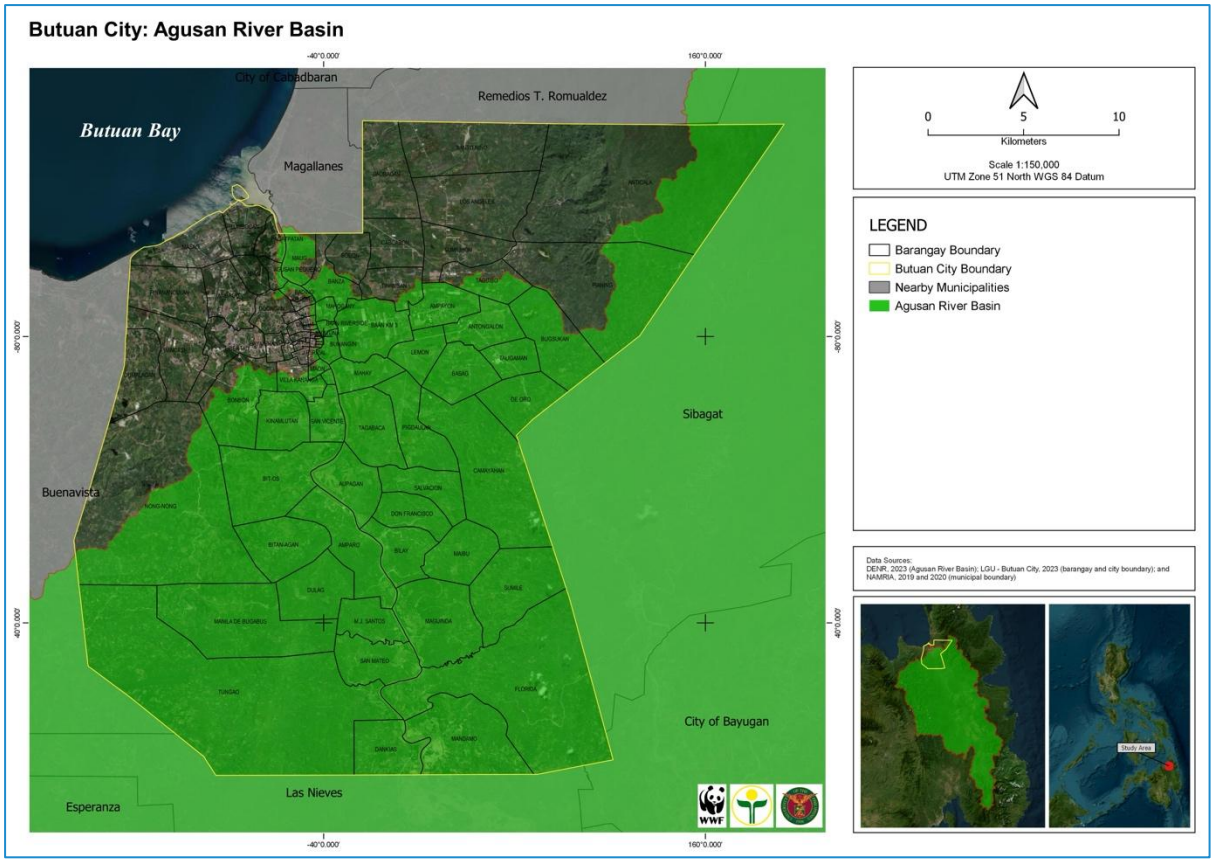


Figure 10. Butuan City Map in relation to the Agusan River Basin

Broad Alluvial Plains and **minor alluvial plains** form a large portion of Butuan City. Alluvial plains are formed as a result the accumulation of unsorted and unconsolidated clay, silt, sand, pebble and gravel size fragments of mixed volcanic and sedimentary origins eroded and transported through surface run-off and flows the surrounding hills and mountains. They are characterized by river levees, river terraces, broad plains, swamps, and marshes, which are characteristic of the barangays where Agusan River and other streams flow. A vast number of barangays are part of the alluvial plains of Butuan City. Twelve barangays compose the broad alluvial plains, of which Barangay Ampayon is one. (The rest are Amparo, Mandamo, Bilay, Maguinda, San Mateo, Abilan, Mahay, Los Angeles, Aupagan, Libertad, and Dankias). Meanwhile, the minor alluvial plains are composed of Barangay Bitan-agan and some areas at the base of the hill at the northeastern portion of Butuan City.

Terraces or Residual Slopes can also be found in Butuan, specifically in, Pinamanculan, Dumalagan, and Bancasi, one the study site for this project. Meanwhile, Barangays Bonbon and Nongnong, as well as Mount Mayapay are part of the city's **Plateau Landscape.** The upper portion of Barangay Los Angeles is identified as a **Hilly Landscape,** and the mountainous terrain going towards Mount Mayapay in the adjacent Municipality of Remedios T. Romualdez is considered a **Mountain Landscape** as they have an elevation of more than 500 meters above sea level with steep to very steep slopes. Anticala is part of the mountain landscape.

There are also areas identified as **Miscellaneous Landforms,** such as the sand bars at the shoreline of Barangay Masao, the waterlogged areas in of which Villa Kananga included along with Barangays Doongan, Kinamlutan, Aupagan, Tagabaca, Mahay, and areas between Libertad and Ambago. A river wash can also be found at Taguibo River of Barangay Taguibo where quarrying of sand and gravel is being undertaken

Topography, Slope, and Elevation

The city of Butuan is primarily composed of level to undulating lands, covering 37.83% of the area, making it highly suitable for agriculture, residential, and commercial development. The flat or level areas with a slope ranging from 0-8% are situated at the city proper and areas along the coastal barangays of Masao, Lumbocan, Pagatoatan and Pinamanculan. The remaining terrain is more varied, with 15.57% classified as undulating to rolling, and 17.83% as rolling to hilly, both of which present moderate challenges for development and may require slope stabilization. The hilly to mountainous areas, which account for 18.42%, and the mountainous regions, at 10.34%, are less suitable for development and are better suited for conservation and forest cover due to their steep slopes and higher erosion risk. The hilly to mountainous areas are located on the eastern, western, and southern portion of Butuan City with the highest elevations extended to about 700-meters or 2296.59 ft (Butuan City CLUP, 2023).

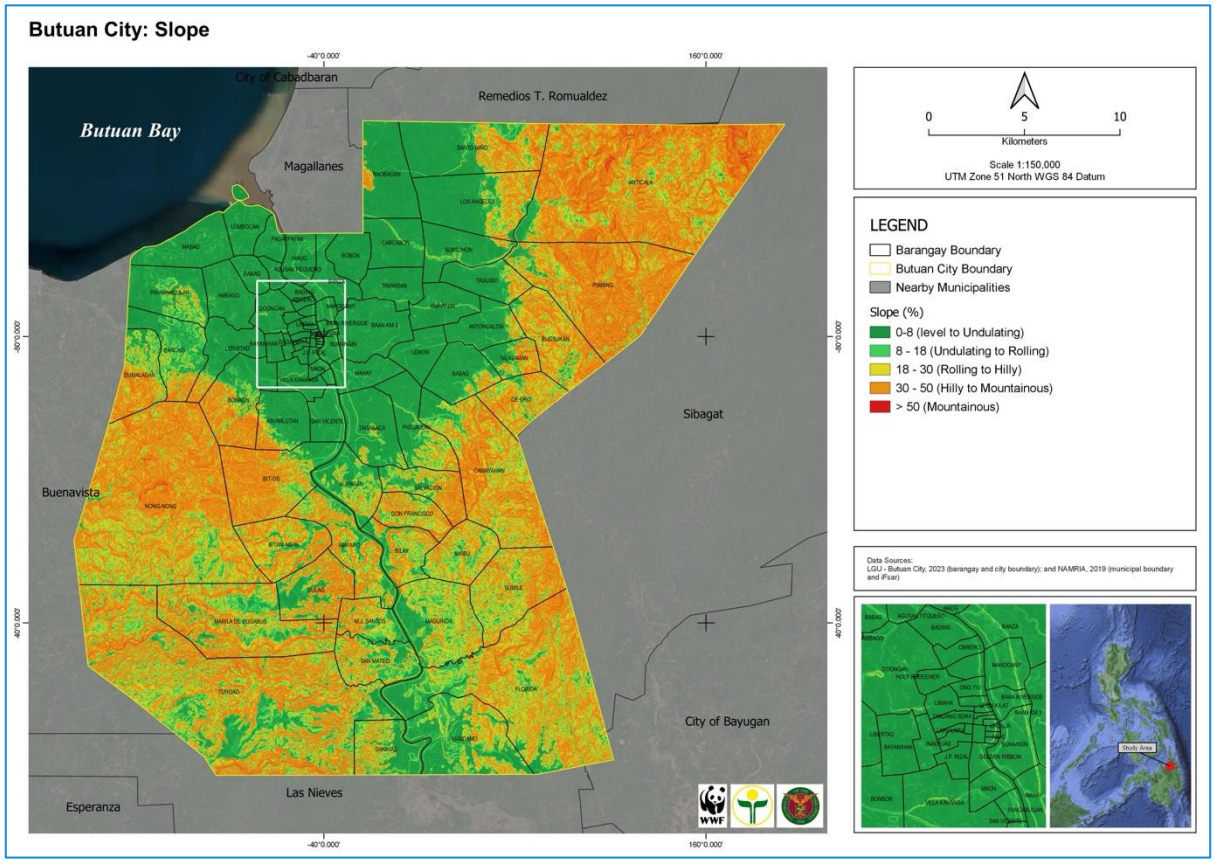


Figure 11. Slope map of Butuan City

Table 9 shows the percentage distribution of slope categories and its area (sq.km). The slope distribution highlights the need for balanced land-use planning that supports development in the flatter regions while preserving the more challenging and environmentally sensitive areas. Having a proper understanding of the effects of slopes in future NbS projects is essential. If the project should address food security for the people, such as urban or community gardens, it is recommended to be located in areas with slopes of 18% or lower. However, NbS meant to address soil erosion or landslides will be appropriate for areas with 19% slope or higher.

Table 9. Percentage distribution of slope categories within Butuan City

SLOPE DESCRIPTION	Area (sq. km)	%
0-8% [Level to Undulating]	312.84	37.83
9-18% [Undulating to Rolling]	128.78	15.57
19-30% [Rolling to Hilly]	147.41	17.83
31-50% [Hilly to Mountainous]	152.32	18.42
>50% [Mountainous]	85.52	10.34
TOTAL	**826.87**	**100.00**

Soil Type

Based on the soil data from BSWM (2013), Butuan City's soil profile is composed predominantly with Camansa clay, covering 56.52% (467.36 sq.km) of the area, followed by Butuan loam at 22.38% (185.03 sq.km) and Malalag silt loam at 8.57% (70.87 sq.km). These soil types are generally fertile and suitable for a wide range of agricultural activities, particularly for crops that thrive in well-drained, clay-rich soils.

In the meantime, the presence of Mountain soil (30.91 sq.km or 3.74%) and Rubble land (7.12 sq. km or 0.86%) indicates areas with more challenging conditions for agriculture and development, likely requiring significant soil management or being better suited for conservation. Finally, there is a limited extent of Hydrosol (0.35%) and unclassified areas, suggesting minimal waterlogged or undeveloped land. Indeed, in the discussion on the geologic features of Butuan City, Villa Kananga is among the barangays that are included in the identified waterlogged areas and there are still areas identified in the Butuan LCCAP as miscellaneous land formation.

The prevalence of Camansa clay and Butuan loam supports robust agricultural productivity, but the clayey nature could pose challenges for linear infrastructure and urban expansion due to poor drainage and potential soil shrink-swell issues. Careful soil management, including proper drainage systems, will be essential to ensure the stability of buildings and roads. On the other hand, the clay-loam soil profile may be suitable for NbS projects that may complement the planned infrastructure development in such areas.

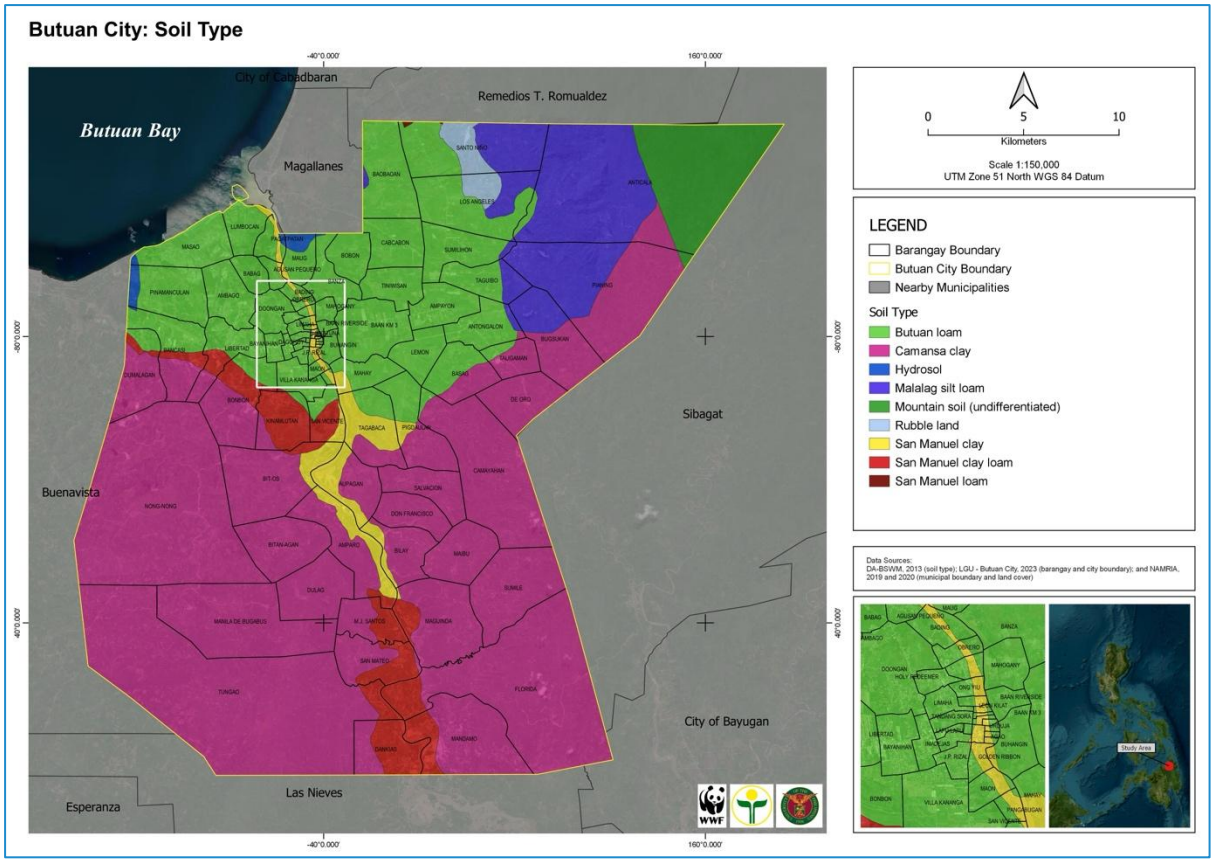


Figure 12. Soil type map of Butuan City

In the meantime, areas with mountain soil and rubble land may require significant investment in soil stabilization and erosion control if considered for development, potentially increasing the cost and complexity of expanding urban infrastructure into these regions. Such areas may likewise be challenging for NbS to flourish. Identifying appropriate plant species to stabilize the soil will mean consultation with soil science and botany experts. The diversity of soil types across Butuan City underscores the need for tailored land-use strategies that maximize agricultural output and incorporation of green spaces while mitigating risks in infrastructure and urban development.

Table 10. Percentage distribution of soil classification in Butuan City

SOIL TYPE	AREA (sq.km)	%
Mountain soil (undifferentiated)	30.91	3.74
Malalag silt loam	70.87	8.57
San Manuel loam	0.13	0.02
Hydrosol	2.88	0.35
Rubble land	7.12	0.86
Butuan loam	185.03	22.38
San Manuel clay	22.04	2.67
Camansa clay	467.36	56.52
San Manuel clay loam	40.13	4.85
Unclassified	0.40	0.05
TOTAL	**826.86**	**100.00**

Land Use/Land Cover

Based on the 2020 land cover data from National Mapping and Resource Information Authority (NAMRIA, 2020) (Table 11), Butuan City is predominantly characterized by perennial crops (e.g., coconut, fruit trees), which occupy 52.38% (433.12 sq.km) of the total area, reflecting that the city continues to have strong agricultural orientation. Aside from that, the annual crops account for 17.19% (142.12 sq.km), indicating a significant portion of land devoted to seasonal farming activities. The brush and shrubs cover 14.23% (117.68 sq.km), while built-up areas comprise 5.78% (47.76 sq.km), highlighting ongoing urbanization. Grasslands, inland water bodies, and fishponds make up smaller portions, at 2.39% (19.74 sq.km), 1.61% (13.34 sq.km), and 1.84% (15.24 sq.km) respectively, with open forests and mangrove forests contributing 3.69% (30.53 sq.km) and 0.69% (5.71 sq.km). The minimal 0.20% (1.62 sq.km) of open or barren land suggests limited unused land resources (Figure 13).

Table 11. Percentage distribution of the land cover classes within Butuan City

LAND COVER CLASSES	AREA (sq. km)	%
Grassland	19.74	2.39
Annual Crop	142.12	17.19
Perennial Crop	433.12	52.38
Built-up	47.76	5.78
Inland Water	13.34	1.61
Fishpond	15.24	1.84
Open Forest	30.53	3.69
Mangrove Forest	5.71	0.69
Brush/Shrubs	117.68	14.23
Open/Barren	1.62	0.20
TOTAL	**826.87**	**100.00**

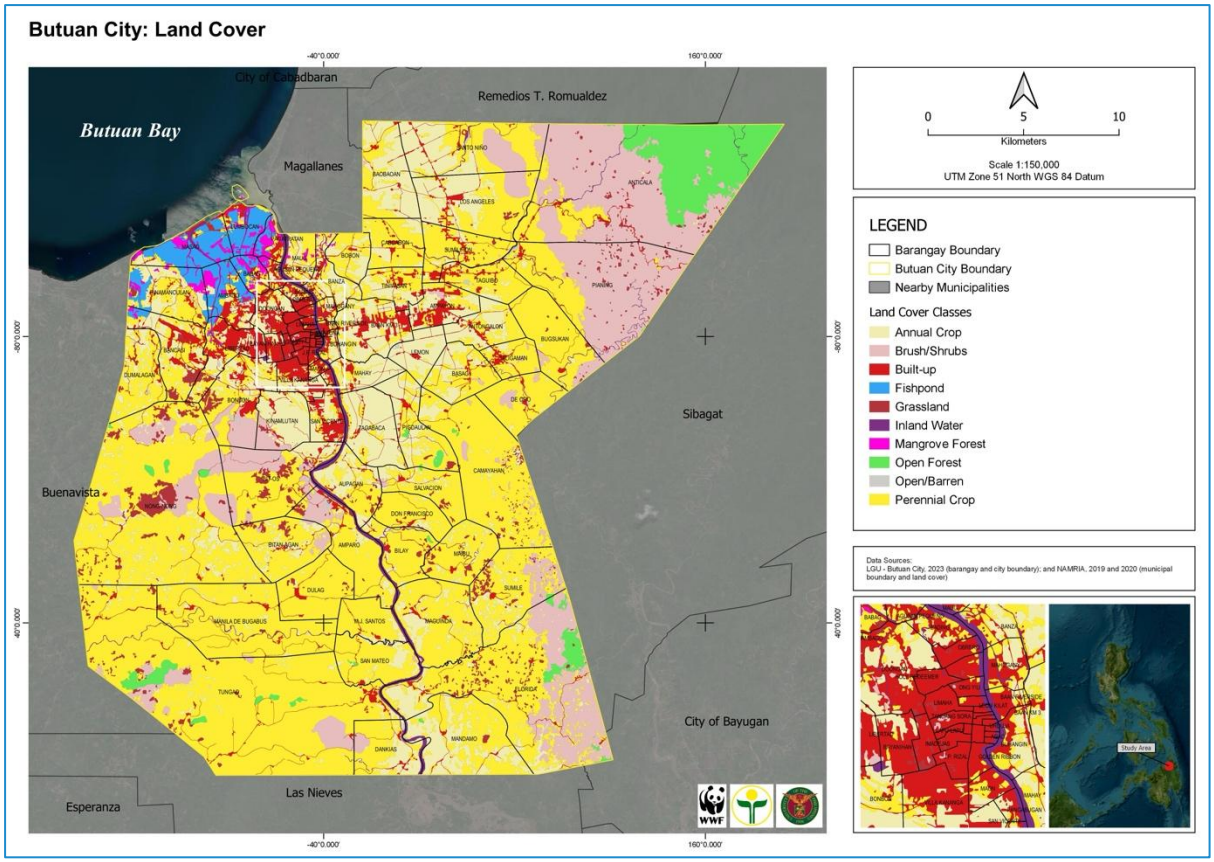


Figure 13. Land cover map of Butuan City

Based on the land cover dynamics of the city, the dominance of agricultural land use underscores the importance of farming to Butuan's economy, but also signals the potential for land degradation if not managed sustainably. The relatively small percentage of forested areas suggests limited natural habitat coverage, which could impact biodiversity and ecosystem services. Urbanization, though currently modest, may exert pressure on agricultural and natural lands as the population grows, necessitating careful land-use planning to balance development with conservation efforts. The distribution also emphasizes the need to protect water resources and manage the expansion of built-up areas to avoid environmental degradation. In the event that linear infrastructures in Butuan City will expand its breadth, the present land cover will be affected and may facilitate change land use afterwards. Abrupt and unplanned change in land use can be prevented through the implementation the CLUP, of which the current administrator (Mayor) of the local government unit of Butuan City aims to adhere to.

Climate and Natural Hazards Profile

Butuan City has a Type II climate where maximum rainfall is experienced from December to February (Figure 14). It had an observed baseline temperature of 26.2°C for the months of December to February, and 27.6 °C for the months of March to November based on the average of temperature in Butuan City from 1971 to 2000. Hazards that are present in Butuan City, as identified in their Climate and Disaster Risk Assessment (2023), include drought, flooding, rain-induced landslide, sea-level rise, and storm surge. It is imperative that these hazards are known as they will have an impact to the effectiveness and durability of infrastructures that will be built within Butuan City and adjacent municipalities. Likewise, they may affect the effectiveness of the proposed NbS.

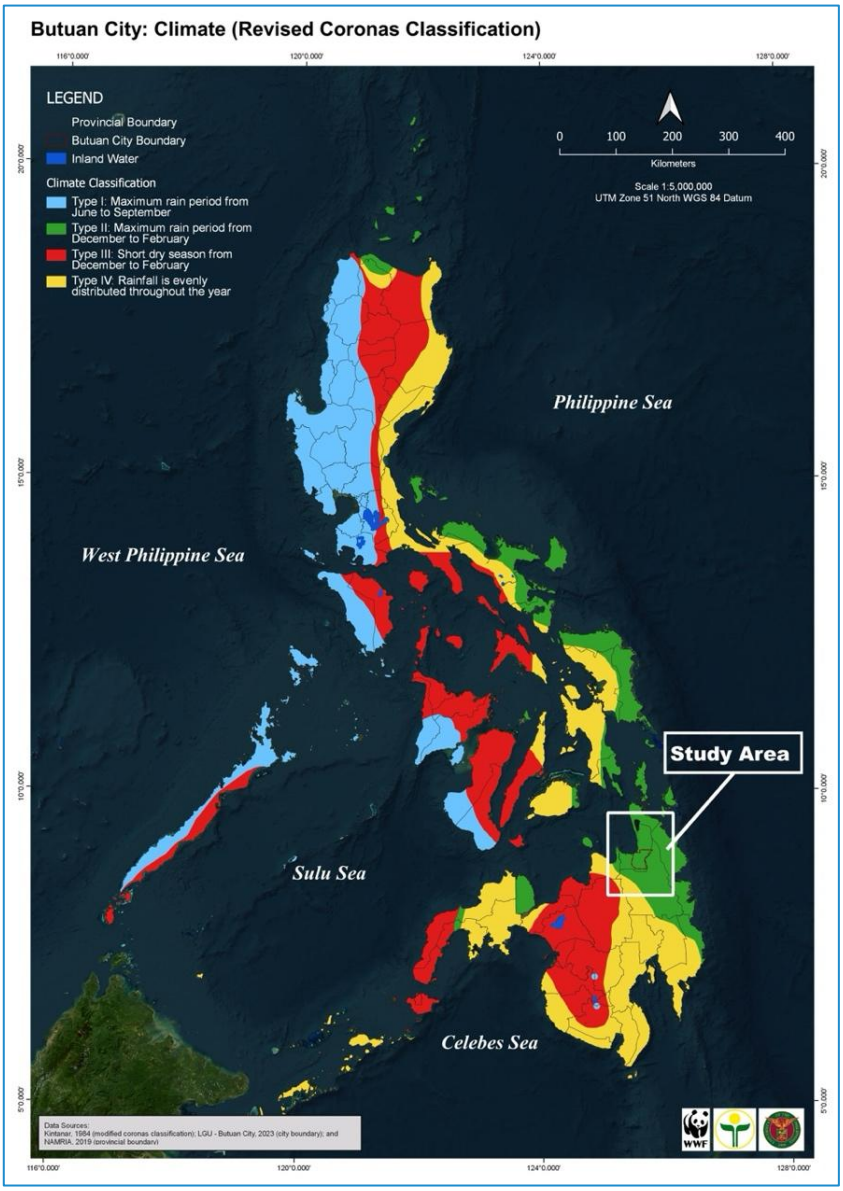


Figure 14. Climate map of the Philippines, with an emphasis on Butuan City. The climate map is based on the revised Coronas Classification.

Temperature and Drought

Having a tropical climate, Butuan City's baseline temperatures were already warm and yet were projected to increase by at least 1°C in 2020 and another 1°C by 2050 (Climate and Disaster Risk Assessment of Butuan, 2023). Therefore, by 2020, it is expected that the temperatures would increase to 27.2°C and 28.6°C. However, data from PSA (2024) reports that the mean temperature for the months of March to November have already risen to 28.7°C by 2023, which is already 0.1°C hotter than the projection. Published temperatures by PAGASA Butuan City during the month of May 2024 was even higher at 34°C (Annex 3), surpassing the climate projection. Meanwhile, the heat index[6,7] during these months were also recorded to increase to up to 45°C. The higher temperature implies hotter and drier climate and can be deduced to be a meteorological evidence of climate change. Higher temperatures, as well as heat index, are expected to negatively affect water yield, crop production, and health and well-being of the population.

Drought is also a hazard in Butuan City which may occur during the dry season, particularly during the months of March until May. Drought occurs when there is a prolonged below average precipitation (or rainfall) that results in water shortages. Drought impacts agriculture and households when irrigations systems and domestic water supply sources experience low water supply.

Recently, Butuan City experienced water scarcity in the months of April to May 2024 as the water level in the Taguibo dam, the city's primary source of domestic water, dipped to extremely low levels with flow rates of an average of 48.49 megaliters per day from an average of 56.6 megaliters per day. Water shortage affected 15% of the residents and 30% of the agricultural areas (Lopez, 2024). It was reported that during these months, Butuan City and the rest of Agusan Del Norte experienced dry spell, having three consecutive months of below normal rainfall condition, according to PAGASA Butuan City (See Annex 4).

Flooding

Flooding is a natural phenomenon that happens when the water level of a body of water rises beyond its natural banks or artificial levees, causing normally dry areas to be submerged (Luino, 2016). The hazard that is most common in Butuan City is flooding as its topographical characteristics make it highly vulnerable to flooding. It is a coastal city and is described to have a very flat terrain with low ground elevation with respect to the sea level. The Agusan River is also a factor to flooding, as the barangays adjacent to the river are prone to flooding when it overflows. During monsoon seasons, flooding naturally occurs near the

[6] Heat index is a measure of the contribution that high humidity makes with abnormally high temperatures in reducing the body's ability to cool itself. Source: DOST-PAGASA Meteorological Terms. https://www.pagasa.dost.gov.ph/learning-tools/meteorological-terms

[7] Information about heat index is being used in the Philippines to announce to the public how the temperature would actually feel on the human body when humidity is factored in so the people could take safety precaution

Agusan river delta and the riverbanks. Flooding is also observed whenever continuous heavy rain occurs at the location of the headwater (Davao de Oro), even though it is not raining in Butuan City. For areas in the mountainous areas such as Anticala and Taguibo, they experience flashfloods, albeit less frequently, and only occurs during a typhoon event.

In recent years, Butuan City also experience flooding during the months of December to February. It is during these months that the northeast monsoon pushes the trajectory of the wind southward, affecting the pathway of the storms during these months. As a result, low pressure areas (LPA) and typhoons formed during these months would affect the northern parts of Mindanao. As an example, in February 2024, Butuan City Local Government declared a state of calamity over several barangays as a result of heavy rain and flooding (Crismundo 2024; Lopez 2024). Flooding also occurred in January 2023, as a result of a LPA affecting Northern Mindanao (Mascarinas, 2023). Typhoon Rai (Local Name: Odette) in December 2021 also cause flooding in the city (Lopez, 2021). The typhoon even affected the waterline of the city as landslides and flashfloods occurred in Barangay Anticala during its onslaught. As a result, the FGD participants from San Vicente mentioned that they have receive less water supply since December 2021. A further emphasis was also noted during the FGDs as the participants revealed that flooding used to occur in the city only every 10 years, but in the last decade, they have observed that flooding is now an annual occurrence despite improvements in floodways. In the meantime, the city government still awaits whether the flood master plan for Butuan will be effective since its construction is still ongoing.

Storm Surge and Sea Level Rise

Storm surge and sea level rise are hazards that are also present and being experienced in Butuan City, particularly in the coastal barangays near Butuan Bay. Storm surge are big waves generated whenever a strong typhoon enters the Philippine waters. Storm surges which can reach a height of three meters can damage properties along coastal areas and may cause flooding as well (Figure 15).

Figure 15. Beams of a damaged shelter near Masao Port, which according to the locals, was washed away by a storm surge.

With climate change, the effects of flooding and storm surge can easily be compounded by sea level rise (SLR). SLR is a climate change associated phenomenon that results from the melting of glaciers and ice sheets and thermal expansion of seawater. A sea level rise of two meters may submerge the coastal barangays in the northern part of the city as well as the riverside barangays.

Rainfall-induced Landslides

In the Philippines, most landslides are triggered by rainfall, posing a significant threat when the southwest monsoon rain coincides with typhoons (Beroya-Eitner, 2016). For barangays in Butuan City with steep slopes and high elevation, rainfall-induced landslides (RIL) are hazards that may occur whenever there is heavy rainfall or typhoons. Households and agricultural areas in sloping areas can be vulnerable to RIL.

Ecological System and Biodiversity

Most of the land cover in Butuan City based on the NAMRIA land dataset is agroecosystems followed by brushlands/shrublands (Figure 16). Urban ecosystem is clustered in the northwest portion of the city adjacent to Butuan Bay.

Types of Ecosystems

Butuan City is home to highly urbanized settlements and a diverse array of ecosystems. Facing north, the coast of Butuan City overlooks the Butuan Bay of the Bohol Sea. Butuan Bay hosts several mangrove ecosystems, while the Bohol Sea is renowned for its diverse marine ecosystems (Goloran et al., 2020).

About a hundred kilometers to the south of the coastlines, the very rich inland wetland ecosystem of the Agusan Marsh Wildlife Sanctuary (AMWS) can be found. The coasts of Butuan Bay and the AWMS is connected by the Agusan River and is part of the Agusan River Basin – the third longest river basin in the country (UNESCO, 2024). The AMWS, and its Caimpugan Peat Swamp Forest, contains an extensive tall pole forest ecosystem and a pygmy forest in the center (Aribal & Fernando, 2018). The Taguibo Watershed, on the other hand, serves as a habitat to diverse riparian and terrestrial (dipterocarp and secondary-growth forests) ecosystems (Leaf Foundation Incorporated, 2007; Sanguila et al., 2020).

Traversing Butuan City is the Agusan River alongside its many other tributaries, most notable of which include the Masao River, Taguibo River, and Lumbocan River. All these tributaries harbor significant riparian ecosystems that provide economic and ecological services to the nearby communities (Berame, 2017; Eviota et al., 2016; Saro et al., 2022).

Butuan City also has several urban parks that provide refuge to urban biodiversity. Among these unique urban ecosystems are the **Kayam Forest**, **Bood Promontory and Eco-Park**, and **Sumile Botanical and Zoological Park**. Studies revealed that the Kayam Forest (Polynesian Chestnut) is home to two Philippine endemic bats (*Macroglossus minimus* and *Ptenochirus minor*) despite having a low floral biodiversity index (Betco et al., 2021; Susi & Ladesma, 2023). Both Bood Promontory Eco-Park and the Sumile Botanical and Zoological Park are home to endangered species in Butuan City. Limited assessments of Berame et al. (2021) and Tiempo et al. (2023) respectively reported that the former is home to endangered flora like Yakal (*Shorea astylosa*) and Philippine Teak (*Tectona philippinensis*) while the latter is refuge for endangered Long-tailed Macaques (*Macaca fascicularis*).

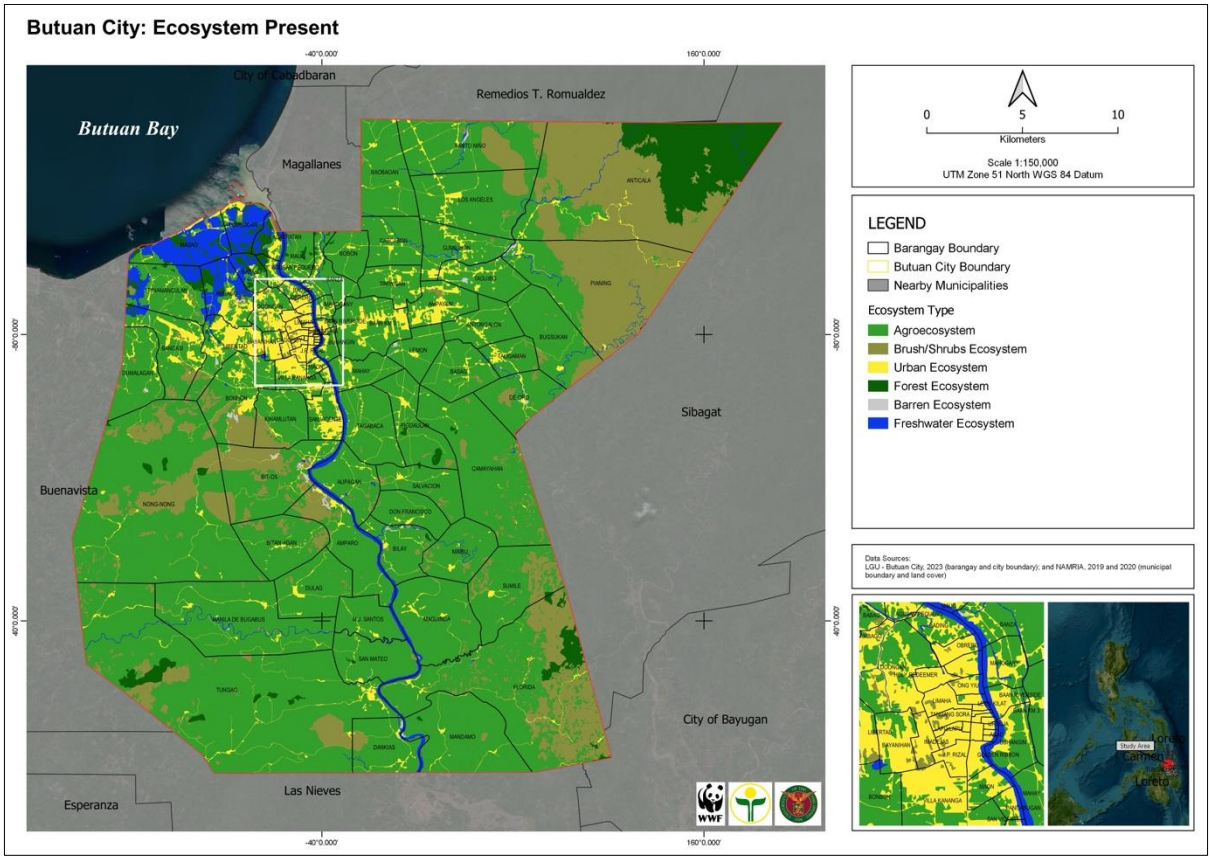


Figure 16. Land cover (2020) in Butuan City according to Ecosystem types.

Key Biodiversity Areas and Protected Areas

One of the key biodiversity areas (KBA) within the jurisdiction of Butuan City is Mount Hilong-Hilong (Figure 17). Among the barangay study sites, Anticala is located on the mountainous terrain of Mount Hilong-Hilong. While it is not declared as a protected area under the National Integrated Protected Areas System (NIPAS) Act of 1992 and the E-NIPAS Act of 2018, the LGU of Butuan City has mentioned the presence of its KBA in its Masterplan for Sustainable Urban Infrastructure Plan (MPSUID).

Protected Areas (PA), on the other hand, are also locally delineated through the Comprehensive Land Use Plan (CLUP) of Butuan City. Included among the locally declared PAs are Mount Mayapay, forestlands, and mangrove areas within the City's jurisdiction. House Bill No. 2267 was also filed in the 18th Congress to support the declaration of Mount Mayapay as protected landscape. This is still waiting for ratification in the House of Congress of the Philippines. In the meantime, the following are among the important natural resources within the Agusan River Basin and Butuan City that need to be protected and conserved: *the Agusan Marsh Wildlife Sanctuary, Agusan River Estuary, and the Taguibo Watershed Forest Reserve.*

Agusan Marsh Wildlife Sanctuary (AMWS)

The AMWS is a protected area and a recognized ASEAN Heritage Park (AHP). It is in the expansive Agusan River Basin of Agusan del Sur, a crucial inland wetland ecosystem

renowned for its diverse ecosystems, including freshwater swamp forests, marshes, and peatlands. Key species in the AMWS include wetland-dependent species like the endangered Philippine Duck (*Anas luzonica*) and the Philippine Sailfin Lizard (*Hydrosaurus pustulatus*). The Caimpugan Peat Swamp Forest is a notable feature of the AMWS and provides habitat for endangered species like the endangered Golden-crowned Flying Fox (*Acerodon jubatus*). Designated as a Ramsar Wetland of International Importance, it is noted for its rich biodiversity and vital ecosystem services, including flood regulation and carbon storage.

Agusan River Estuary

The Agusan River Estuary is a key ecological zone where freshwater from the Agusan River meets the saltwater of Butuan Bay. The estuary's unique environment fosters rich biodiversity and serves as an important habitat for various flora, especially mangrove, and fauna species (Goloran et al., 2020). It is renowned for the abundance of *Johnius borneensis*, locally known as "guama," a key food fish in the region (Solania & Seronay, 2017).

Taguibo Watershed Forest Reserve (TRWFR)

The TRWFR, with a drainage area of approximately 75.5 square kilometers, is a protected area established to safeguard the primary source of potable water and water supply irrigation in Butuan City (Serviano et al., 2017). Proclaimed as a watershed under the presidency of Fidel V. Ramos in 1997, through Proclamation No. 1076, it covers Barangay Anticala in Butuan City, Barangay San Antonio in Remedios Trinidad Romualdez, Barangay Mahaba in Cabadbaran, and part of Sibagat, Agusan Del Sur (Butuan City Water District, n.d.). TRWFR harbors historically documented species and features distinct riparian and terrestrial habitats such as dipterocarp and secondary-growth forests (Leaf Foundation Incorporated, 2007). Reptiles and amphibians have specialized microhabitat preferences, with many newly recorded species occupying specific or overlapping microhabitats (Sanguila et al., 2020).

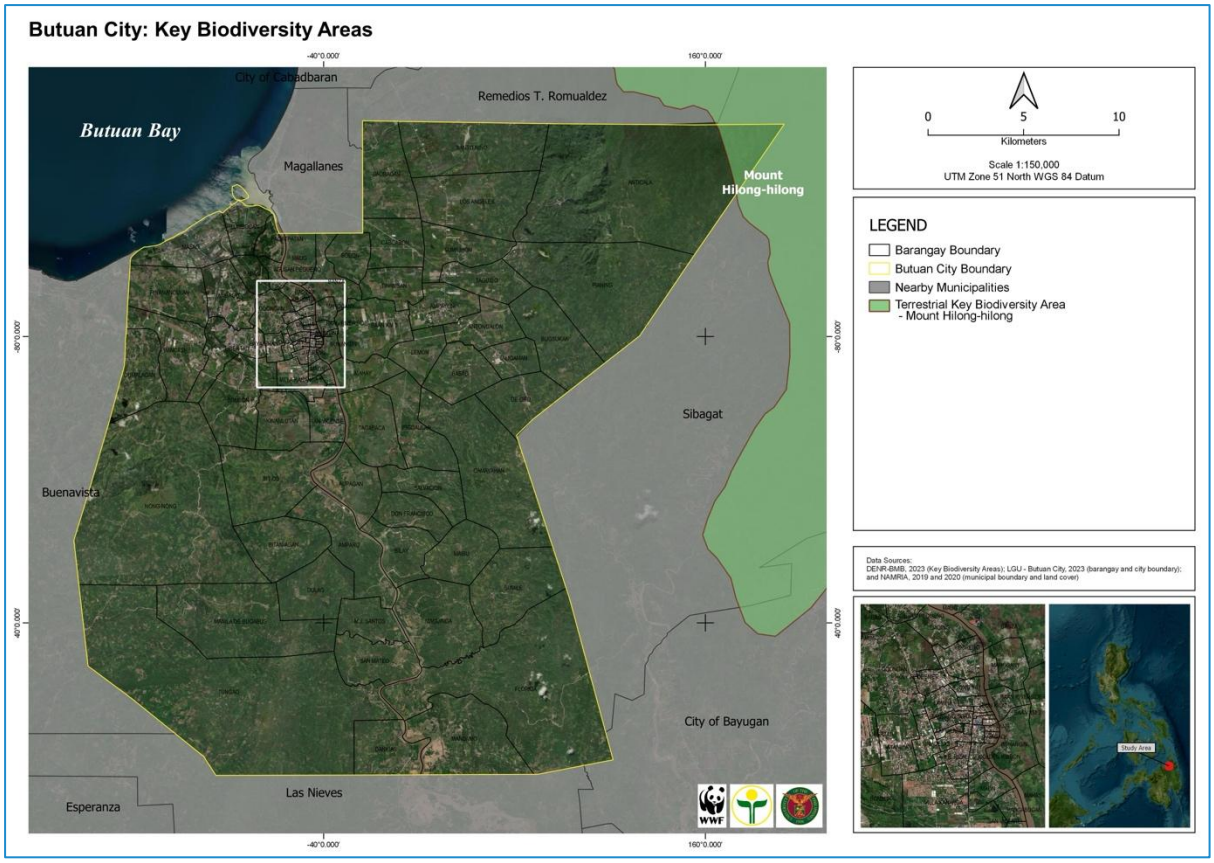


Figure 17. Map identifying the Key Biodiversity Area (Mount Hilong-Hilong) in Butuan City.

Butuan city is also home to notable flora and fauna species (Table 12). Five different flora species were identified to be present, two of which are native, and the rest are endemic. Among these, the *Palaquium pinnatinervium* is considered to be endangered in the IUCN 2024-1 Red list. In the meantime, seven fauna species were found to be native (3) and endemic (4) in Butuan City. Three of the species found in Butuan, the golden-crowned flying fox, the large flying fox, and the Philippine long-tailed macaque, bear the endangered status in the IUCN Red list.

Those with endangered status will need the urgent of the local government and the communities to protect and avoid heightening their status into critically endangered as their absence may impact the biodiversity not only in Butuan but in the areas of Agusan Del Norte and the rest of Caraga region where these species may be found. While the other species are not yet on the endangered status, understanding their conservation status will be an important consideration in identifying NbS projects to support and enhance the status of these species in the region.

Table 12. Notable species in Butuan City.

Scientific Name	**Family**	**Conservation Status (IUCN 2024-1)** LC – Least Concern NT – Near Threatened VU – Vulnerable EN – Endangered	**Distribution Range**	**Description (Source for Butuan City)**
Flora				
Terminalia copelandii	Combretaceae	LC	Native	Dominates the rare and diminishing *Terminalia* swamp forests within the AMWS (UNESCO, 2024)
Metroxylon sagu	Arecaceae	LC	Native	Dominates the rare and diminishing Sago swamp forests within the AMWS (UNESCO, 2024)
Tristaniopsis micrantha	Myrtaceae	VU	Endemic	Inhabits the AMWS (UNESCO, 2024)
Palaquium pinnatinervium	Sapotaceae	EN	Endemic	Inhabits the AMWS (UNESCO, 2024)
Pandanus radicans	Pandanaceae	VU	Endemic	Inhabits the AMWS (UNESCO, 2024)
Fauna				
Anas luzonica	Anatidae	VU	Endemic	Also known as the Philippine Duck, a wetland-dependent species that inhabits the AMWS (UNESCO, 2024)
Hydrosaurus pustulatus	Agamidae	LC	Endemic	Also known as the Philippine Sailfin Lizard, a wetland-dependent species that inhabits the AMWS (UNESCO, 2024)
Ceyx argentatus	Alcedinidae	NT	Endemic	Also known as the Southern Silvery Kingfisher, a wetland-dependent species that inhabits the AMWS (UNESCO, 2024)
Acerodon jubatus	Pteropodidae	EN	Endemic	Also known as the Golden-crowned Flying Fox, inhabits the AMWS (UNESCO, 2024)
Pteropus vampyrus	Pteropodidae	EN	Native	Also known as the Large Flying Fox,

Scientific Name	Family	Conservation Status (IUCN 2024-1) LC – Least Concern NT – Near Threatened VU – Vulnerable EN – Endangered	Distribution Range	Description (Source for Butuan City)
				inhabits the AMWS (UNESCO, 2024)
Johnius borneensis	Sciaenidae	LC	Native	A marine-estuarine dependent fish locally known as *guama;* the most abundant and important food fish in the Agusan River Estuary (Solania & Seronay, 2017)
Macaca fascicularis	Cercopithecidae	EN	Native	Philippine Long-tailed Macaque; present in Butuan City (Tiempo et al., 2023)

Infrastructure Planning and Development in Butuan City

For the next few years, rapid infrastructure development and expansion of urban areas within Butuan City and the rest of the Caraga region are expected to happen. Foremost reason is the execution of the Master Plan for Sustainable Urban Infrastructure Development (MPSUID) of Butuan City prioritizes 24 infrastructure programs and projects that the city Government of Butuan has started to implement (NEDA Region XIII, 2021). Part of the plan is to improve the city's competitiveness, disaster resiliency, and urban conditions by formulating a long-term development framework that has a goal to promote environmental sustainability, including strategies to preserve and conserve Butuan City's environment and natural resources. The MPSUID aligns with the Philippine Development Plan 2017-2022, National Spatial Strategy 2015-2045, Mindanao Spatial Strategy/Development Framework Plan (MSSDF 2015-2045), Caraga Regional Development Plan for 2017-2022, Butuan City's Comprehensive Land Use Plan 2019-2048, and Butuan City's Comprehensive Development Plan. With the developments that is occurring in Butuan City, Agusan Del Norte and the rest of Caraga region are expected to benefit from the various infrastructures that will be developed – from logistical highways, circumferential roads, seaports, and airport.

The MPSUID supports Butuan City's goals toward sustainable growth, development and resilience by preserving the natural environment (i.e. forest lands, agricultural lands, wetlands, mangroves), managing urbanization efficiently and preventing further urban sprawl. While it focuses on infrastructure development, it also mentioned the need for the integrity of the natural environment to remain intact, and that greens spaces be developed as recreation areas or buffers be maintained for natural hazard mitigation. The plan includes measures and programs that address mobility, social services, and economic development, and at the same time necessitates improved climate resilience, and conservation and sustainable use of natural resources. It also responds to the idea of Sustainable Development by anchoring its planning concepts and principles to the achievement of the 2030 Sustainable Development Goals. Accordingly, it abides by the definition forwarded by the IMF Global Commission on the Economy and Climate wherein "Sustainable Infrastructure are structures and facilities that are manmade as well as natural that a society needs to survive and to continue to function" (MPSUID, page IV-1).

Through the MPSUID, Butuan City is expected to implement sustainable infrastructure projects that include ecosystems-based green infrastructure in combination with conventional infrastructure to reduce negative impacts on the environment (e.g., filtering emissions and pollutants by increasing vegetation, absorbing storm surges with reforested mangroves). Infrastructures to be built should be sustainable environmentally, economically, and socially. The plan also elaborates that an environmentally sustainable infrastructure helps reduce pollution and conserve natural resources from construction to operation; is resource efficient (e.g., reduced energy and water consumption); and/or is resilient to climate change and disaster risks. Economically and socially sustainable infrastructure allows for generation of employment and livelihood opportunities and better social inclusion (e.g., gender, age group) and condition (i.e., better basic services, poverty reduction, and climate resiliency).

Along this conceptual foundation, it is the goal of the plan to promote environmental sustainability in Butuan City with developed and sustained agroforestry resources.

The masterplan identified five development strategies, two of which emphasized the importance of natural resources and nature-based structures, while one focused on capacitation of personnel. Specifically, these strategies are:

1. Preservation and conservation of the environment and natural resources
2. Adoption of sustainable infrastructure such as nature-based structures to preserve the ecological integrity of the environment.
3. Capacitation of the City Environment and Natural Resources Office's personnel.

The MPSUID of Butuan City identifies a list of Non-Infrastructure and Infrastructure Programs, Projects and Activities Environment, Disaster Risk and Reduction Management. It includes the following:

1. Non-Infrastructure
    a. Reforestation Project through the National Greening Program
    b. Coastal Resource Management Program including DRR-CCA for Coastal Environment (for coastal protection)
    c. Taguibo Watershed Rehabilitation Project
2. Infrastructure
    a. Inner City Park Development
    b. Establishment of Forest or Garden Cemeteries

In terms of prioritization, the stakeholders who were consulted for the plan prioritized 29 infrastructure projects. It was noticeable that the top priority infrastructures were engineering solutions which are necessary to immediately address environmental concerns and mobility. Top three of the priorities were: (1) Upgrade of Butuan City Solid Waste Management System; (2) Construction of New Bridges Crossing Agusan River; and (3) Septage Management and Treatment. There are also three listed river improvement projects, with different priority levels, to complement the Butuan City Urban Drainage Plan Projects and mitigate flashfloods.

Three projects that were included in the list that are related to greening of Butuan City are: (1) Inner City Park Development (Priority #9); (2) River Park Development (Priority #15); and (3) Bood Promontory Heritage Park (Priority #29). In the brief description of these projects, these will help solve the lack of green recreational spaces in the city and will have an open space with permeable surface to help reduce surface runoff, flooding and pollution. In particular, the river park development is slated to be developed that looks as natural as possible with an allowance for the overflow of the river. The trees and vegetation are meant to help prevent erosion of the riverbanks. Meanwhile, the Bood Promontory Heritage Park is one of the few existing green spaces in Butuan City. It can be noted that in the previous section on the Types of Ecosystems present in Butuan City, the Bood Promontory Heritage Park is among the refuge to urban biodiversity and serves as a home to identified endangered species that need to be protected. Hence, its further development will create a setting for protecting,

as well as viewing wildlife, plants and unique ecosystems for educational and recreational purposes for the residents of Butuan City. The ecological park will also reduce the heat island effect in the summer and mitigate flooding during the rainy season.

It is worthy to mention that the MPSUID includes a plan to build a business Information Technology (IT) Park which will have some environmentally sustainable features of the project such as tropical green spaces with trees between buildings for absorption of run-off and pollutants, and rain harvesting systems.

The MPSUID is an integration of green strategies in sustainable infrastructure planning. However, there is still an absence of the mention of combination NbS with infrastructure plan. While the plan inserts sustainability through allotting green spaces, the use of green solutions to complement construction of engineering-based solutions is lacking…where in its updating and revision, nature-based solutions may explicitly be identified as part of the sustainable infrastructure plan.

Other Plans involving Infrastructures in Butuan City

Prior to the present plans that prioritize infrastructure development in Butuan City, a prominent plan that incorporated the use of infrastructures in mitigating flood hazards in Butuan City is the Cotabato-Agusan River Basin Development Project (CARBDP). Established in 1987, CARBDP was meant to manage and develop the river basins of the Cotabato and Agusan rivers to address issues related to flooding, water resources management, and land development, by improving infrastructure (e.g., mega dikes) and supporting sustainable development in the river basins. CARBDP has resulted in the relocation of informal settlers along the Agusan River to Pagatpatan. The infrastructures built under the CARBDP is still being maintained through local government initiatives.

Aside from the previous CARBDP and the recent MPSUID which was discussed in the previous section, the local government of Butuan City also has various other development plans that include proposals for construction of various infrastructure. For example, the City Agriculture and Veterinary Department (CAVD) has its own Farm-to-Market Road (FMR) Development Plan and Irrigation Development Plan, which identify priority areas where FMRs are needed to be built in order to connect farms and facilitate transportation of crops and livestock to major markets and projects to maintain and improve the national irrigation system present in the city. The FMR Development Plan and Irrigation Development Plan is being used by the CAVD in submitting proposal for funding from the Department of Agriculture and the National Irrigation Administration. The LCCAP and the City DRRM Plan also has proposals for funding of infrastructure projects that will help mitigate and adapt to various risks and impacts of climate change.

FGDs conducted also revealed how barangay councils incorporate infrastructure project proposals in the Barangay Development Plan. While their budget may be limited,

based on their internal revenue allocation, they can still provide budget from their development funds for maintenance of barangay canals, gravelling of inner barangay roads, installation of streetlights, and minor road repairs. However, for projects that will need a higher amount of budget, they submit their proposals to the city-level, congressional-level or national-level. One of the study barangays also has plans to increase areas with electricity. For example, Barangay Bancasi has a plan for electrification of 200 houses in a resettlement area and a plan to install solar-powered water system for 2 areas (*purok)* that encounters problem with water supply.

Infrastructure Planning at the Caraga Region-Level

At the regional level, The Caraga Regional Development Plan (RDP) 2023-2028 serves as the guiding document that identifies the development priorities at the regional-level. The priorities for infrastructure development mainly involves improvements to ensure that infrastructures for various sectors (e.g., transportation, communication, water) are climate and disaster resilient, highlighting the vulnerabilities of the region to various climate hazards, picking up from the lessons of the impacts of Typhoons Auring (Dujuan) and Odette (Rai), which both affected the region in 2021. Caraga's RDP is aligned with the Philippine Development Plan 2023-2028, which prioritizes addressing various challenges in the Philippine society and prioritizes providing the necessary enabling environment, including disaster-resilient infrastructure. In terms of climate action and disaster resilience, the RDP mentioned balancing regional growth and resource protection through developing green and blue economies and integrating ecosystem-based approaches into development planning. This was however mentioned separately from the plans for infrastructure development. NbS or any green infrastructure plan was also absent from the latest RDP.

Linear Infrastructures of Butuan

Roads, railways, canals, power transmission and distribution lines, and pipelines are subsumed under the terminology linear infrastructure. Butuan City has these types of infrastructures present except for railway tracks. In the Philippines, a railway system is only present in the island of Luzon.

A. Existing Road Network

The overall existing road network in Butuan City is shown in Figure 18. A total of 1,596.39 km of road network of various classes are in place all over the city. The longest existing road network within the administrative bounds of the Butuan is the residential road, with 594.508 km in total length. Primary roads, which include important provincial and city roads that may consequently be included in the national system of highways (DPWH, 2022), have the shortest distance among existing road classes in Butuan City, with a total length of

only 47.0247 km. (Table 13). It can be observed that the concentration of these existing road networks are withing the barangays in the city-center, particularly those inside the square in Figure 18.

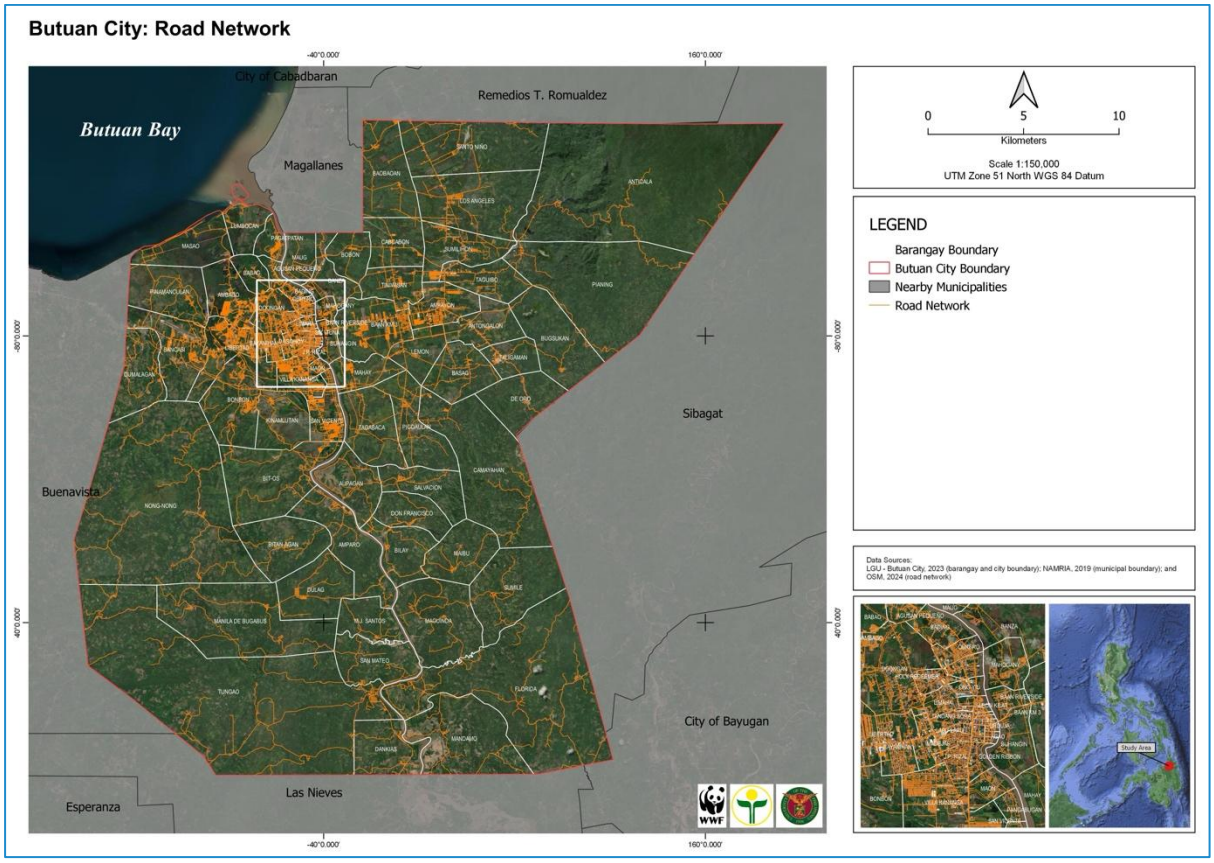


Figure 18. Map of the existing road network within Butuan City

Table 13. Existing road classes in Butuan City and its length in kilometers

ROAD CLASSIFICATION	Length (KM)
Primary	47.025
Residential	594.508
Secondary	143.302
Service	129.056
Tertiary	257.991
Trunk	42.494
Unclassified	309.222
Other Roads	72.792
TOTAL	**1,596.39**

B. Proposed Road Network

Apart from the existing road network, the city of Butuan has plenty of proposed road networks to connect areas that are isolated. Based on the Master Plan for the Sustainable Urban Infrastructure Development for Butuan City prepared by the City Planning and

Development Office, a total 168.52 km of proposed roads and bridges to be constructed within the city funded by DPWH-Caraga (Figure 19).

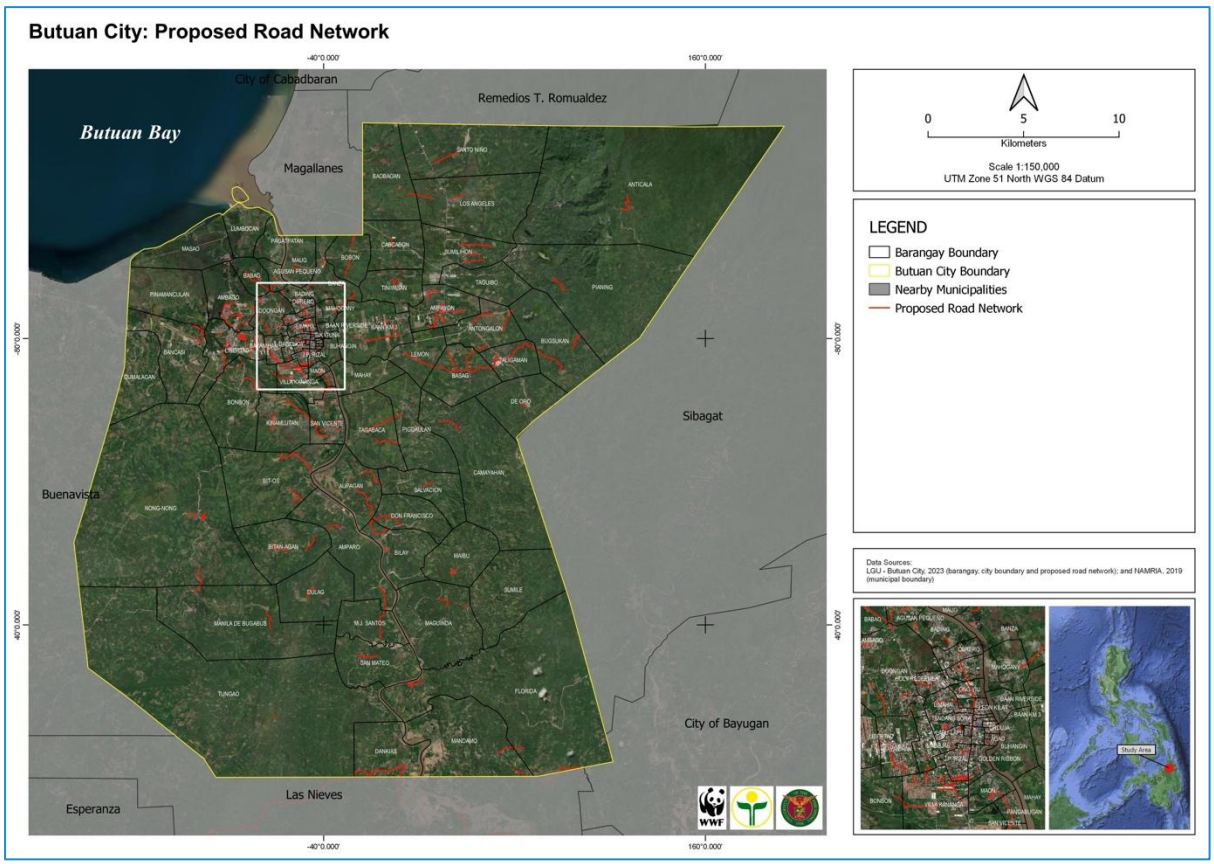


Figure 19. Map of the proposed road network within Butuan City

Based on the Butuan City MPSUID, the development strategies for road network are summarized below:

1. Construction of the Butuan City Urban Roads Network Improvement Project to divert traffic along the Butuan City-Cagayan de Oro-Iligan Road (BCIR) and to serve as alternate route in times of emergency situations or calamities, giving unhindered access from all directions. Among the urban road network improvement projects are:
    a. Butuan City West Diversion Road
    b. Butuan City Radial Road
    c. Bonbon-Libertad Bypass Road
    d. Butuan City Radial Road
    e. Libertad-Ambago to Employee's Village to Butuan City-Masao Port Road Section
    f. NRJ Butuan City-Masao Port Road-Logistical Highway Road Section
    g. NRJ Butuan City-Logistical Highway (JA Aquino Ave.-Montilla Blvd.-Salvador Calo) Road Section

2. Construction of the Logistical Highway to connect major traffic generators such as the planned Masao (and Nasipit) Special Economic Zones, and existing business districts. This is envisioned to be a high-standard highway (possibly 8-lanes) that will cater to commercial vehicles and trucks as well as private and public utility vehicles. This includes the construction of the "iconic" bridge crossing the Agusan River and minor bridges crossing the small rivers.

3. Construction of the Butuan City Hinterland Roads Network Improvement Project to address total regional connectivity between the regions in Northeastern Mindanao. Among the projects are:
    a. NRJ Mayor D. Plaza II Ave.-Delta Discovery Park leading to Mt. Mayapay to Jct Butuan City-East-West Lateral Road connecting Agusan del Sur/Agusan del Norte to Bukidnon, Dulag-Simbalan (Delta-Nongnong-Emelda Mar Section)
    b. NRJ Butuan City-Malaybalay Road leading to NRJ Buenavista-Bunaguit Road (Bitan-agan-Nongnong-Mt. Mayapay-Bunaguit, Buenavista Section)
    c. East-West Lateral Road (Mahayahay-Bilay Section)
    d. East-West Lateral Road (Bilay-Dulag Section)
    e. East-West Lateral Road (Dulag-Simbalan Section)
    f. NRJ BCIR-NRJ Butuan City-Malaybalay Road (via Dumalagan-Nongnong-Bit-os)
    g. NRJ BCIR-NRJ Buenavista Bunaguit Road
    h. NRJ Butuan City-Mayor D. Plaza II Ave. leading to Mt. Mayapay (Delta Discovery Park) Butuan City, Agusan del Norte

4. Construction of Daang Maharlika Alternate Roads to divert traffic away from Daang Maharlika and serve as alternative routes along the north-south direction. Among the road projects are:
    a. Jct. BCIR-Baan-Tiniwisan-NRJ Daang Maharlika, RTR Section
    b. Lemon-NRJ Antongalon-Pianing Section
    c. NRJ Daang Maharlika-Los Angeles-NRJ Pianing Tandang Road

C. Proposed Drainage Line

In many urban areas, a drainage line plays a vital role in flood control and prevention. Ideally, this linear infrastructure should efficiently collect, channel, and dispose the excess surface water during heavy rains and storm events. When systematically designed, drainage lines can direct runoff away from streets, buildings and other critical infrastructure to reduce the risk of water accumulation that can lead to localized flooding. By incorporating components such as storm drains, culverts, and underground pipes, urban drainage lines ensure that water is quickly and safely transported to larger drainage systems, rivers, or designated catchment areas. Additionally, these infrastructures help protect the urban environment from erosion and water damage, maintain public safety, and support the resilience of city infrastructure against the increasing frequency and intensity of storm events.

Based on the data from CPDO - Butuan, there are about 57.32 km of proposed drainage line to be constructed in the low-lying urban barangays of the city, specifically in the barangays of Libertad, Bayanihan, Imadejas, J.P. Rizal, Villa Kananga, Dagohoy, Lapu-lapu, Tandang Sora, Limaha, Fort Poyohon, Ongyiu, San Ignacio, Leon Kilat, Urduja, Humabon, Silongan, Diego Silang, Ago, and Golden Ribbon (Figure 20). The drainage line project is currently ongoing in Butuan City, with some parts already completed (Figure 21).

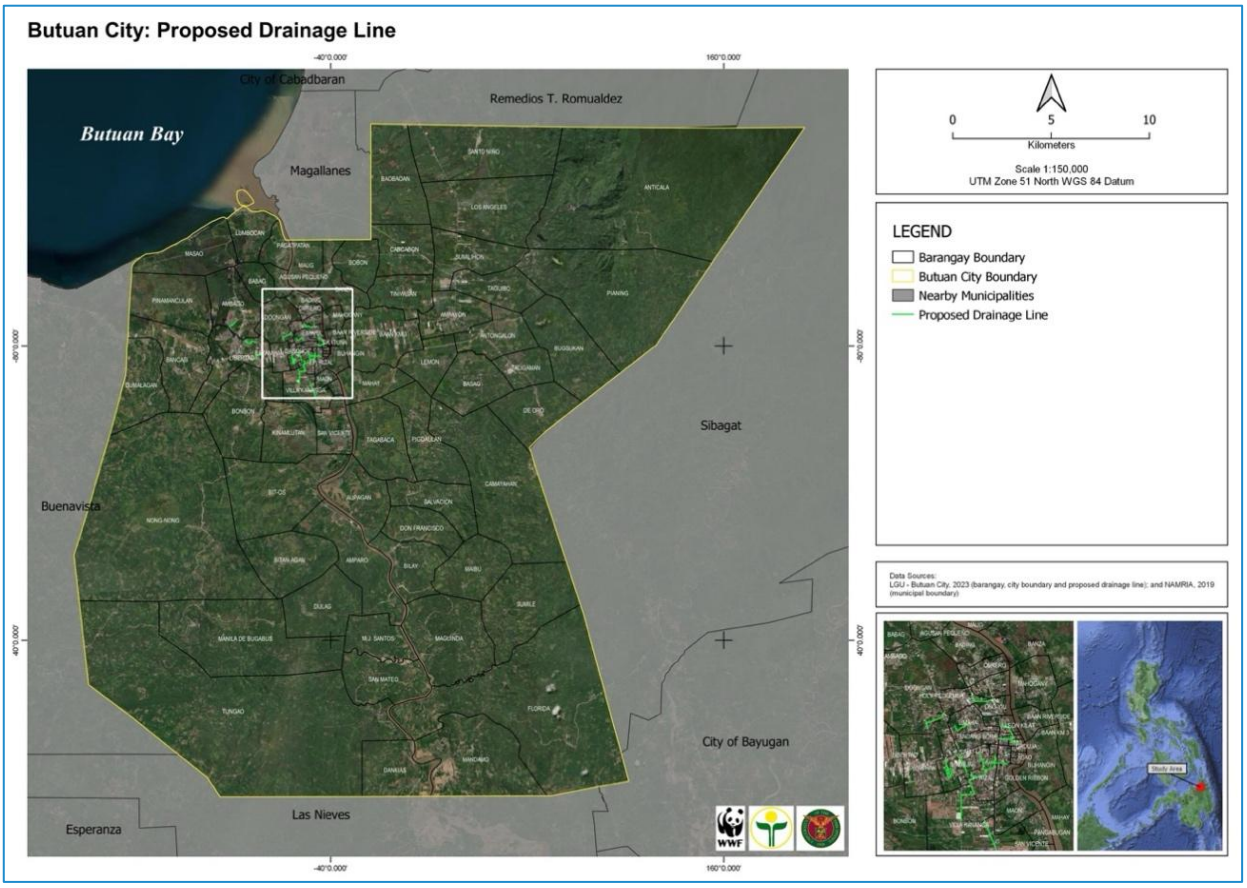


Figure 20. Location of the proposed drainage line within Butuan City

Figure 21. Portion of the drainage line project in Butuan City being constructed in June 2024 and completed in August 2024. Source: Butuan City PIO Facebook Page

D. Proposed Streetlights

The presence of this infrastructure within Butuan city serves multiple essential purposes that enhances both functionality and safety of the city. Streetlights are primarily for improving visibility during night until dawn, reducing risk of accidents and promoting safer travel when dark. This infrastructure also contributes to public safety by deterring criminal activities in well-lit areas, making neighborhoods and public spaces feel more secure.

According to CPDO – Butuan, there are about 12.95 km (about 8.05 mi) of proposed streetlights to be constructed within the city proper of Butuan. The streetlights aimed to support more economic activities in the urban barangays by extending the hours during which businesses can operate and encourage nighttime commerce. Overall, this infrastructure is a crucial component of urban planning, contributing to the quality of life in the city (Figure 21).

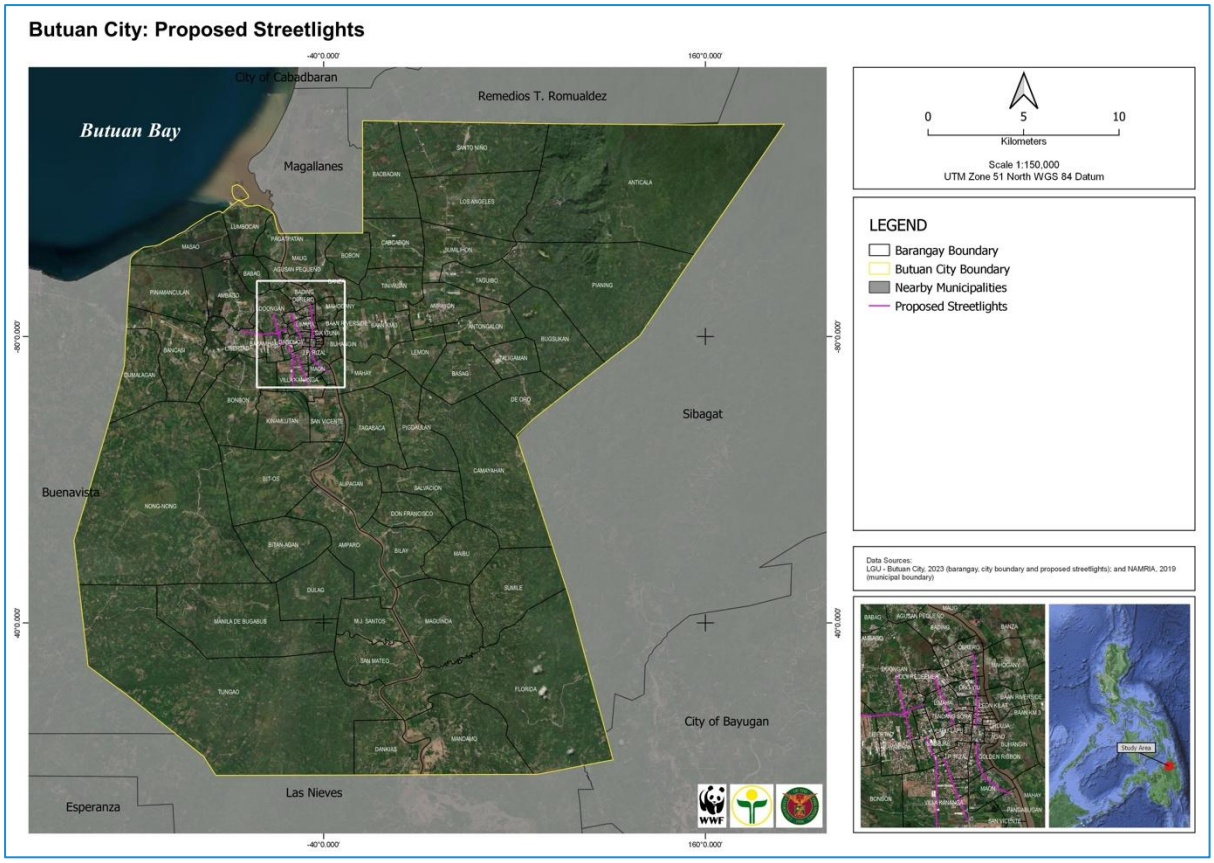


Figure 21. Location of the proposed streetlights within Butuan City

E. Proposed Mindanao Railway Project

The Mindanao Railway Project (MRP) is a flagship initiative of the Department of Transportation (DOTr). This project consists of a 1,544-kilometer railway system that will span Mindanao, linking major cities in Mindanao, such as Davao, General Santos, Cagayan de Oro, Iligan, Cotabato, Zamboanga, Butuan, Surigao, and Malaybalay (DOTr, 2020).

The MRP will traverse Butuan City with a total length of 168.54 km (Figure 22). Once the railway is constructed, it will play a critical role in enhancing urban mobility and economic development within Caraga and the rest of Mindanao. It will provide a reliable and efficient mode of transportation for commuters within and outside Butuan, reducing travel time and easing traffic congestion on city roads. This infrastructure will support the movement of goods, facilitate commerce, and contribute to the local economy.

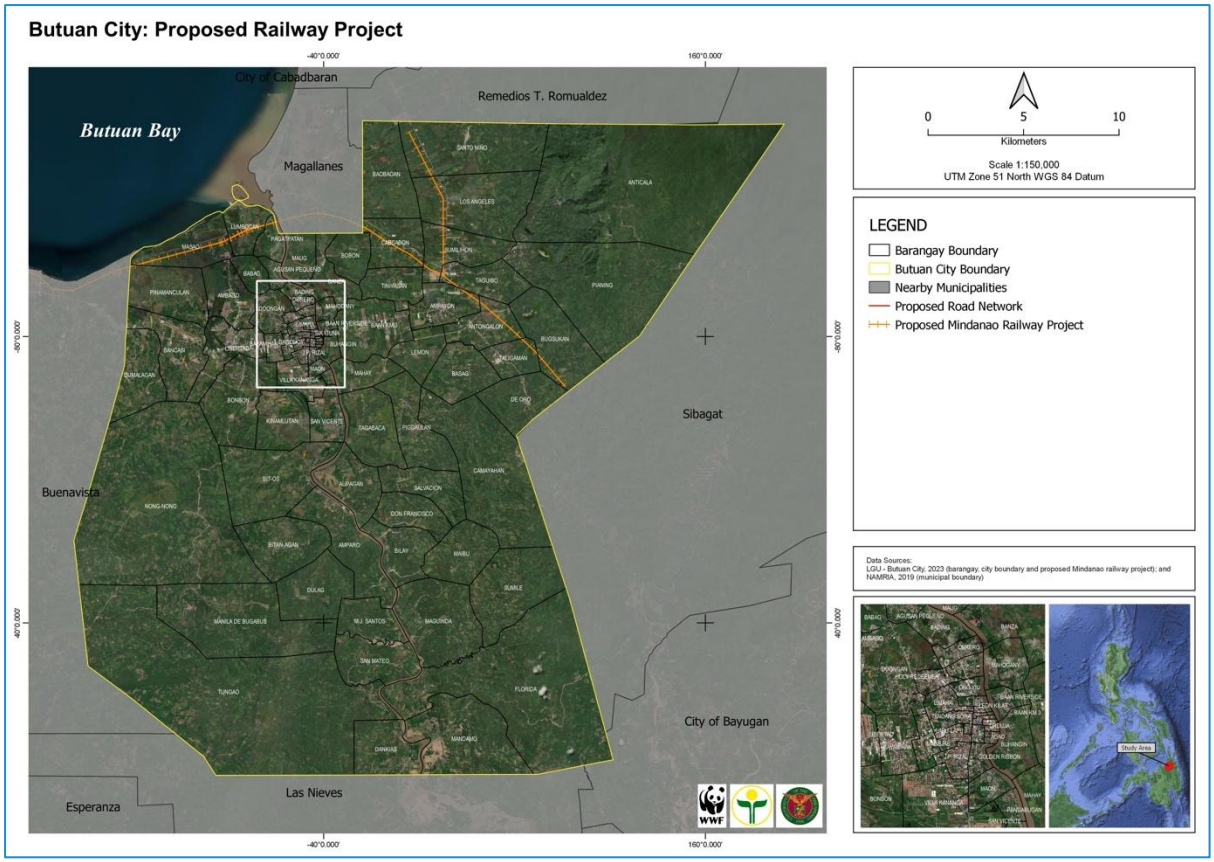


Figure 22. The proposed MRP within Butuan City

Additionally, the MRP offers an environmentally friendly alternative to car travel, reducing greenhouse gas emissions and lowering the city's carbon footprint. By connecting various parts of Mindanao and its suburbs, the railway system will promote regional integration and accessibility, making it easier for residents to access employment, education, and services. Overall, railway infrastructure is vital for sustainable urban growth, improving the quality of life for city dwellers and supporting the city's long-term development goals.

Policies Relevant to Establishment of NbS Projects

The successful integration of NbS in infrastructure planning and development in Butuan City, as well as for the other cities and municipalities in Caraga Region, is anchored in a comprehensive and multifaceted framework of national policies. While some of these policies are not designed directly for infrastructure development, they provide the necessary guidelines and support for the mainstreaming of NbS into infrastructure planning and development. Thus, adhering and utilizing the provisions of these policies could support the efforts of the LGU and other relevant stakeholder groups in ensuring a resilient and sustainable urban environment. These national policies are enumerated in Table 14, with discussions on their relevant provisions.

The provisions outlined in these policies address various issues that, when considered together with infrastructure planning, can contribute to a more sustainable and inclusive local development. For instance, national policies related to environmental conservation, climate change adaptation, and disaster risk reduction and management can inform the design and implementation of infrastructure projects that can enhance climate resilience.

Table 14. National policies in the Philippines that could influence infrastructure planning and development.

NATIONAL POLICY	RELEVANT PROVISIONS
National Building Code of the Philippines (PD 1096)	The provisions of PD 1096, particularly in Section 102, emphasize the commitment of the government in safeguarding or protecting "life, health, property, and public welfare". It highlights the need to comply with environmental management principles that align with the core principles of NbS. By regulating building and infrastructure development, this national policy creates an institutional environment that allows the better implementation of NbS initiatives.
Philippine Green Building Code	While not directly focused on linear infrastructure like roads, the green building concept likewise offers opportunities in promoting sustainable development by minimizing the negative impacts of buildings on human health and the environment. This could further support NbS initiatives, especially in urban areas.
The Right-of-Way Act (RA 10752)	This national policy emphasizes that negotiations with property owners and just compensations are needed in ensuring the acquisition of land for various government infrastructure projects such as roads. Thus, project implementors should include land ownership when designing and planning for linear infrastructure projects. Section 8 of RA 10752 also emphasizes the need to also consider the different possible ecological impacts of these infrastructure projects to the local communities.
National Electrification Administration Reform Act of 2013 (RA 10531)	RA 10531 stipulates the governance procedures for the electric cooperatives in the Philippines. This means that in planning for linear infrastructure developments that would involve or affect

NATIONAL POLICY	RELEVANT PROVISIONS
	electrical lines, local electric cooperatives should be involved. This ensures that their perspectives and potential concerns would be incorporated in the development plan. The electric cooperative likewise could implement the actual integration of NbS concept in establishing electric lines within the communities where they are operating.
Anti-obstruction of Power Lines Act (RA 11361)	An important provision of RA 11361 is the establishment of power line corridors. According to Section 5 of RA 11361, power line corridors are "The land beneath, the air spaces surrounding, and the areas traversed by power lines including its horizontal, vertical, and similar clearance requirements shall constitute the power line corridor, which shall at all times be kept clear and free from any power line obstructions, dangerous structures, hazardous activities and improvements, and other similar circumstances in accordance with the provisions of this Act". This means that in planning for linear infrastructures, implementing agencies should consider the existing power line corridors or their creation especially when constructing power lines. Government agencies and other development organizations should also consider the power line corridors when implementing NbS projects such as in the case of roadside greening initiatives.
Local Government Code of 1991 (RA 7610)	Section 17 of RA 7610 is the Philippine policy that mandates the decentralization and devolution of powers from the national government to the provincial and city or municipal LGU. It also states the different basic services being provided by the LGUs at different levels. Among these basic services are the maintenance and construction of linear infrastructure (roads). Given the potential resource restrictions, the barangays are only mandated to maintain their respective roads, bridges, canals, and water supply infrastructure. On the other hand, municipalities, cities, and provinces are expected to include proposals for infrastructure projects in their local development plans and finance the construction of municipal and barangay roads, as well as bridges.
Indigenous Peoples Rights Act of 1997 (RA 8371)	This policy emphasizes the inherent rights of the members of the indigenous cultural communities over their respective ancestral domains. Recognizing these rights, RA 8371 reiterates that all development initiatives within the ancestral domain are required to seek permission from the ICC members. This holds true as well in the case of infrastructure development and the implementation of different conservation projects, which are needed as part of NbS strategies. This policy is important to consider since portions of Butuan City is home to the Manobos in Anticala and Higaonon in Mount Mayapay.

NATIONAL POLICY	RELEVANT PROVISIONS
Environmental Impact Assessment Law (PD 1586)	PD 1586 reiterates the need for infrastructure projects to undergo an environmental screening at the minimum to understand its potential environmental and social impacts on the local communities. This will ensure that all infrastructure projects will have the necessary mitigating measures against their potential negative impacts before they are allowed to proceed.
Environmental Awareness and Education Act Of 2009 (RA 9512)	This policy can serve as the basis of the government in funding efforts to educate the public about the concept of NbS (i.e., including other NbS relevant terminologies and concepts) and its importance in linear infrastructure development.
Climate Change Act of 2009 (Republic Act No. 9729)	RA 9729 provides an important basis for climate-resilient infrastructure planning in the Philippines. By mandating the development of Local Climate Change Action Plans (LCCAPs) (Section 14), this national policy mandates LGUs to lead in addressing climate change challenges within their political jurisdictions. This decentralized approach ensures that infrastructure planning considers local vulnerabilities and priorities, promoting climate-resilient solutions that are based on context-specific needs. Furthermore, RA 9729 has provisions for funding allocation to ensure that adequate resources are available for the design and implementation of programs and plans to address the complex challenges related to climate change. This financial support is crucial for developing and implementing climate-resilient infrastructure projects that can withstand the impacts of climate change, such as extreme weather events and rising sea levels.
Philippine Disaster Risk Reduction and Management Act of 2010 (RA 10121)	RA 10121 highlights the importance of mainstreaming disaster risk reduction and climate change into various development initiatives, including infrastructure planning and development. By emphasizing the integration of climate change considerations into policy formulation, socioeconomic development planning, budgeting, and governance, the Act ensures that infrastructure projects are designed and implemented based on fundamental climate resilience principles. This approach helps to mitigate the potential impacts of climate change on infrastructure and could support their sustainability. RA 10121 also mandates the allotment of five percent (5%) of the estimated revenue from regular sources to support disaster risk management activities and the generation of the local DRRM Plan (Section 21).
The Agriculture and Fisheries Modernization Act of 1997 (RA 8435)	An important provision of RA 8435 is the emphasis on the need for farm-to-market roads, which are needed to support the livelihood of local farmers. In various rural areas including farming communities in Butuan City, this policy plays a significant basis for the construction of roads. Section 19 of this policy likewise emphasizes the roles of DA and DPWH in the

NATIONAL POLICY	RELEVANT PROVISIONS
	planning process for the infrastructure development relevant to the agriculture sector.
The Agriculture, Fisheries and Rural Development Financing Enhancement Act of 2022 (RA 11901)	Section 4 mandates an agriculture, fisheries, and rural development financing system to improve the productivity, income, competitiveness and welfare of the rural community beneficiaries. This includes financing systems for constructing and upgrading public rural infrastructure, such as farm-to-market roads and other infrastructure for transporting agricultural produce.
Whole-of-Nation approach as a government policy for the attainment of inclusive and sustainable peace (EO 70, s. 2018)	EO 70 created the National Task Force to End Local Communist Armed Conflict (NTF-ELCAC). NTF ELCAC is tasked to implement various programs to assist the members of the former conflict inflicted communities in the country. Among these programs include linear infrastructure development, which is crucial to better facilitate the entry of support services to the community. The construction of roads was also designed to support the livelihood of the local community like the construction of farm to market road.
National Cultural Heritage Act of 2009 (RA 10066)	Section 30c requires any government or nongovernment infrastructure project or architectural site development to include anthropological, archaeological and historical and heritage site conservation concerns in their Environmental Impact Assessment System. Additionally, Section 32e requires the DPWH to coordinate with national cultural agencies in the planning, design, construction, and maintenance of national roads and bridges as they impact on heritage structures or aspects of heritage conservation.

A close examination in these various Philippine policies reveal where mainstreaming NbS can be initiated and from where funds can come from. Specifically, mainstreaming at the local level can start in the local development plans (RA 7160), LCCAP (RA 9729), and the local DRRM Plan (RA 10121). Policies related to the various infrastructures in the Philippines (e.g., Green Building Code, RA 10752, RA 10531, RA 11361) provides a picture of how infrastructures are planned, financed, and evaluated prior to their construction. In the meantime, policies such as the RA 9512 and the IPRA law are particularly essential in the acceptance and sustainability of NbS Projects. Knowledge, awareness and community ownership will potentially result in the sustainability of the project and the participation of the local community in its management. This will also enable the community to create a sensibility to protect the NbS if there is high awareness of the benefits.

Institutional landscape in infrastructure planning and development

The successful integration of the NbS in infrastructure planning and development requires navigating the local institutional landscape. The institutional landscape is characterized by a complex dynamic of various institutional actors with various roles and responsibilities that could influence the design and implementation of NbS strategies. Specifically, the local institutional landscape identifies the different institutional actors in Butuan City. These institutional actors have varying roles and responsibilities in relation to infrastructure planning and development and in natural resources conservation and management. Within the context of this research, these roles are divided into **seven (7) categories** (also see Table 15). Each institutional actor falls into more than one category, which is based on the different programs, projects, and activities that they are implementing.

1. Funding source

Financial resources are crucial to the implementation of any development projects, which include linear infrastructure and environmental conservation. This category highlights the different institutional actors that provide financial resources for the implementation of linear infrastructure projects. Although recognizing that these financial resources can originate from both public and private entities, this institutional landscape only covers those coming from the Philippine government. Various institutional actors have the role of financing or allocating funds for linear infrastructure development. These roles are grounded in their primary mandate as an NGA or part of their programs in support of their development programs.

The construction and maintenance of the national roads are financed by DPWH based on their mandate, which is stipulated in EO 124, s. 1987. On the other hand, the provincial LGU and the city LGU are assigned to finance the construction of the provincial and city/municipal roads, respectively. However, since Barangay LGUs are often limited in terms of financial resources, their basic services are primarily in financing the maintenance of barangay roads and gravelling of dirt or paved roads. Other barangay roads in Butuan City were also financed through the funds allocated for the National Task Force to End Local Communist Armed Conflict (NTF ELCAC). This task force was created through EO 70 in 2018. The main objective of the funds allocated in NTF ELCAC is to end the insurgency in the different regions in the country by financing development projects and attain inclusive and sustainable peace. In Butuan City, barangays roads in Barangay Anticala were funded by NTF ELCAC. Another important source of funds for linear infrastructure development is DA for farm-to-market roads and irrigation systems.

2. *Planning and Design*

This role category is assigned to public organizations that are responsible for developing strategies and action plans for the development of the city and the region. This includes strategies that would strengthen the integration of NbS into infrastructure planning and development. The institutional actors that plan and design infrastructure projects include DPWH regional office. This government agency is mandated to plan and design infrastructure projects aligned with the local community's needs. DPWH creates short to long-term infrastructure development for the CARAGA region. This is crucial since it allows other government offices at different levels to plan their development Programs, Projects, and Activities (PPA) based on the infrastructure plans of DPWH. At the implementation of infrastructure projects, DPWH is also tasked to release a plan of work prior to the start of project implementation that identifies the various activities and timeline of each activity from the preparation, implementation, and post-implementation. In the context of the NbS strategies, DPWH, together with DENR and other relevant agencies could harmonize their respective plans that would allow the continued infrastructure development in the region while embedding the fundamental ecological principles. For instance, the roadside greening programs of the DENR could be harmonized with the infrastructure projects of DPWH.

At the regional level, the Regional Development Council (RDC), which is being coordinated by NEDA Regional Offices, plays a significant role in the planning process for regional development. EO 325 Section 4 has the function of coordinating regional development plans and investment programs at different planning horizons (short to long term). An important role of the RDC is integrating the development plans from the different institutional actors operating within the region into the regional development plan. Aside from the plans from the different national government agencies such as DPWH and DENR, these development plans likewise include the development plans of the provincial and city planning offices, the main planning units at the local level. In particular to the case of Butuan City, the city agriculture office likewise crafted a sectoral development plan that outlines the linear infrastructure needs of the local agriculture (e.g., farm to market roads, irrigation). It is also important to add that if there is an existing protected area and ancestral domain, these also have a respective protected area management plan and ancestral domain sustainable development and protection plan that the RDC needs to acknowledge and integrate.

3. *Monitoring and Evaluation*

This is integral to the successful implementation of linear infrastructure projects, particularly in ensuring that the NbS strategies are effective. It serves as an important feedback mechanism that offers insights into the timeliness of delivery and performance of the different projects and strategies being implemented by the different national government agencies and LGU offices. Through the conduct of monitoring and evaluation, the implementing agencies will be able to identify different issues and challenges that would

affect the effectiveness of their respective strategies. Thus, this could result in informed decisions about necessary improvements in the implementation process.

In relation to infrastructure development, the data collected from monitoring and evaluation is considered critical in assessing the immediate outcomes and, later, impacts of various government projects. This case will also apply with future NbS interventions. By monitoring the changes in relevant ecosystem services along with various socioeconomic indicators, relevant institutional actors could understand the dynamics between linear infrastructure development, NbS interventions, and the well-being of the communities. The institutional actors primarily performing monitoring and evaluation include those that also primarily facilitate the planning process at different levels. These include the DPWH, DENR, DA, RDC, and the different offices of the LGU.

4. Implementation

The implementation of actual infrastructure projects is primarily assigned to DPWH. This NGA has the mandate to construct and maintain a wide range of linear infrastructure in the Philippines. As specified in the EO 124, these linear infrastructures include "roads and bridges, flood control systems, water resource development projects, and other public works in accordance with national objectives". In terms of different PPAs that are aligned with the concept of NbS, DENR is considered the key national government agency. Among the notable initiatives of DENR are various reforestation projects and the protection of key biodiversity areas.

While DPWH are primarily mandated in implementing national linear infrastructure projects, in terms of the provincial and municipal roads, the Provincial and City LGUs are assigned to provide these basic services to their constituents, as per the provision in RA 7160.

5. Regulation

Institutional actors performing regulatory functions are mandated to regulate the implementation of various development initiatives. They are primarily responsible for issuing permits and ensuring the compliance of project implementors with the existing national and local policies. There are several regulatory agencies that are relevant to the implementation of infrastructure projects in the Philippines. Regulation could either compliance with different business-related permits or ensuring that infrastructure development would not result in environmental degradation. These regulations were also designed to ensure that any development initiatives would respect the way of life of the members of the host communities.

Among these regulatory agencies is the DENR. It has several regulatory functions in relation to development projects. The agency requires that infrastructure development projects, including those being implemented by DPWH, undergo environmental impact assessment. This ensures that infrastructure development would have the most minimal

impact on the environment. The NCIP is another relevant regulatory agency for infrastructure development projects. The agency requires that developers should undergo free and prior informed consent (FPIC) when implementing projects within ancestral domains. This reiterates the importance of seeking the permission of the indigenous cultural communities prior to the conduct or implementation of any development initiatives in any ancestral domain.

6. Data Generation and Storage

To effectively and efficiently plan and implement NbS strategies within the context of infrastructure development, national government agencies, and other relevant organizations should rely on empirical data. This will ensure that the design of the NbS strategies is based on the context of the local community, particularly their needs and challenges. The availability of local data is also crucial to understanding the potential impacts of the proposed NbS strategies at different levels and in different sectors. In terms of this category, several institutional actors are assigned to perform this role. Each of these institutional actors gather different sets of data, which are all crucial in the overall development planning process for the effective integration of NbS in infrastructure planning and development. At the local level, various offices of the LGU are tasked with gathering sectoral information from all the barangays within the city.

This sectoral information includes sociodemographic profile of the population, which covers age, sex, household size, and profession. Livelihood data were likewise part of the information being gathered by the different offices of the LGU. These data are crucial to understanding the varying needs of the entire population. Aside from sociodemographic information, biophysical information is also collected by different offices of the LGU. Ecological conditions and hazard susceptibility are among the biophysical information, which are being collected by the LGU. The socio-economic and biophysical information are available in different LGU offices including the city planning and development office, city agriculture office, city environment and natural resources office, city social welfare and development office, and city engineering office.

Several NGAs also have a role as data generators. These include DPWH, DENR, DA, and DOST. Each of these NGAs have offices, whose data are highly relevant to the integration of NbS to infrastructure planning and development. For instance, DOST PAGASA collects meteorological and climate data. These data are often used by various public, private, and development organizations in assessing the climate vulnerability of the population to better inform future NbS projects, there are environmental data that are being collected by different bureaus and attached agencies of DENR. These data include water quality, air quality, and biodiversity.

7. Other important roles

This category includes roles that are not directly related to infrastructure planning and development but are considered important in the successful implementation of relevant development initiatives. Within the context of Butuan City, among these roles include the maintenance of peace and order within the local communities. Insurgency in some areas in the city remains a critical concern. This can have detrimental effects on local development initiatives including the establishment of linear infrastructure in the city (transportation and communication). The Armed Forces of the Philippines (AFP) is primarily mandated to perform this role. AFP personnels were stationed and visible in Brgy Anticala to address insurgency.

Aside from ensuring peace and order in the context of the protection of linear infrastructure, other roles include community engagement and capacity building of the members of the local community, especially the representatives of the civil society organizations. Capacity-building initiatives are often needed to ensure that local stakeholders can better participate in the planning process. These capacity-building activities include the conduct of various training courses and workshops. Among the institutional actors, which are mainly performing these roles include the local government units and different universities and colleges in the area (Father Saturnino Urios University and Caraga State University).

Table 15. Institutional actors and their respective roles, Butuan City, CARAGA, Philippines

INSTITUTIONAL ACTORS	ROLES						
	Fund Source	Implementa-tion	Regulation	Planning & Design	Monitoring & Evaluation	Data Generation and Storage	Others
National Government Agencies							
DPWH	■	■		■	■	■	
DENR		■	■	■	■	■	
NEDA				■	■		
DA	■	■		■	■		
DHSUD				■			
DOST						■	
NCIP			■				
DILG		■	■				
AFP							■
Office of the Civil Defense							■
LGU	■	■	■	■	■	■	
CARSU				■		■	
Father Saturnino Urios University				■		■	
Private and Business Sector							
BCWD	■	■	■	■	■	■	
- Taguibo Aquatic Solutions Corporation (TASC)	■	■		■	■	■	

INSTITUTIONAL ACTORS	ROLES						
	Fund Source	**Implementa-tion**	**Regulation**	**Planning & Design**	**Monitoring & Evaluation**	**Data Generation and Storage**	**Others**
- Agusan Norte Electric Cooperative							
Telecommunicatio n Companies							
National Transmission Corporation							

Relevant Stakeholder Perceptions for Mainstreaming NbS

Based on the identified offices, agencies, and various organizations with explicit roles in linear infrastructure planning and natural resources management across national and local administrative levels (Table 16), representatives were consulted regarding perceived levels of power and interest relative to integrating NbS in linear infrastructure planning. These ***perceptions of power***, or the ability to significantly influence decisions and outcomes related to NbS and infrastructure planning, as well as ***perceived levels of interest***, or willingness to be involved in matters related to NbS in infrastructure planning, were both given weights by institutional representatives. Using a range of 1-5, a score of 1 means that a certain stakeholder group has an extremely low influence or interest, while a score of 5 means an extremely high influence or interest.

Table 16. Stakeholder Groupings for Weighting Perceived Levels of Interest and Power in NbS and in Infrastructure Planning for Butuan City and Caraga Region

STAKEHOLDER GROUPS	LIST OF IDENTIFIED STAKEHOLDERS

National Government Agencies	• DPWH (Department of Public Works and Highways)
	  ○ DPWH Regional Planning & Design Division
	  ○ DPWH Highway Section
	• DENR (Department of Environment and Natural Resources)
	  ○ Office of the Assistant Secretary for Policy, Planning, and Foreign Assisted and Special Projects
	  ○ DENR-EMB (Environmental Management Bureau)
	  ○ DENR Planning & Management Division
	  ○ PENRO (Provincial Environment and Natural Resources Office)
	  ○ CENRO (Community Environment and Natural Resources Office)
	• NEDA (National Economic and Development Authority)
	  ○ NEDA IS (Infrastructure Staff)
	  ○ NEDA RDC (Regional Development Council)
	• DA (Department of Agriculture)
	  ○ DA RAED (Regional Agricultural Engineering Division)
	  ○ DA RPCOs (Regional Project Coordination Offices)
	• DHSUD (Department of Human Settlements and Urban Development)
	• DOST (Department of Science and Technology)
	  ○ DOST PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration)
	• NCIP (National Commission on Indigenous Peoples)
	• DILG (Department of Interior and Local Government)
	• AFP (Armed Forces of the Philippines)
	• DND-OCD (Department of National Defense – Office of the Civil Defense)

STAKEHOLDER GROUPS	LIST OF IDENTIFIED STAKEHOLDERS
Local Government Unit	Provincial Level (Agusan del Norte): • PG (Provincial Government) • PGSP (Provincial Government Sangguniang Panlalawigan) • PPDO (Provincial Planning and Development Office) • PG ENRO (Provincial Environment and Natural Resources Office) • PDRRMO (Provincial Disaster Risk Reduction and Managment Office) • PEO (Provincial Engineering Office) • PAO (Provincial Agriculture Office)
	City Level (City Government of Butuan): • OCM (Office of the City Mayor) • CENRD (City Environment and Natural Resources Division) • CDRRMD (City Disaster Risk Reduction and Management Division) • CED (City Engineering Division) • CAVD (City Agriculture and Veterinary Division) • IPMR (Indigenous People's Mandatory Representative) • Barangays
Educational Institutions	• CarSU (Caraga State University) • FSUU (Father Saturnino Urios University) • UPLBFI (University of the Philippines Los Baños Foundation Incorporated)
Non-Government Organizations (NGOs)	• WWF Philippines (World Wildlife Fund) • PRC (Philippine Red Cross)
Civil Society Organizations (CSOs)	• FGSCBI (Friendship Goals Society Caraga-Butuan Inc.) • Farmers • Fisherfolks • Youth • Women • Senior Citizens
Utilities Provider, Private and Business Sectors	• BCWD (Butuan City Water District) • TASC (Taguibo Aquatech Solutions Corporation) • ANECO (Agusan del Norte Electric Cooperative) • Various telecommunication companies • Construction Companies and Contractors

To visualize the interplay of stakeholder power and interest, a stakeholder map is generated (Figure 23). This stakeholder map was based on 30 responses from participants during a validation workshop in Butuan City on March 22, 2024. Scores were averaged for the different stakeholder groups. Results reveal high levels of power and interest for mainstreaming NbS in linear infrastructure planning. These sentiments essentially show that

stakeholders are very supportive towards integrating NbS in planning and constructing linear infrastructure in Butuan City. While all of the stakeholders are in the upper right quadrant of the stakeholder matrix, National Government Agencies (NGAs), the Provincial Government (PG), City Government of Butuan, Non-government Organizations (NGOs), Higher Education Institutions (HEIs) and Business Sectors are perceived as having slightly higher levels of influence/power than (CSOs), as shown in Figure 24.

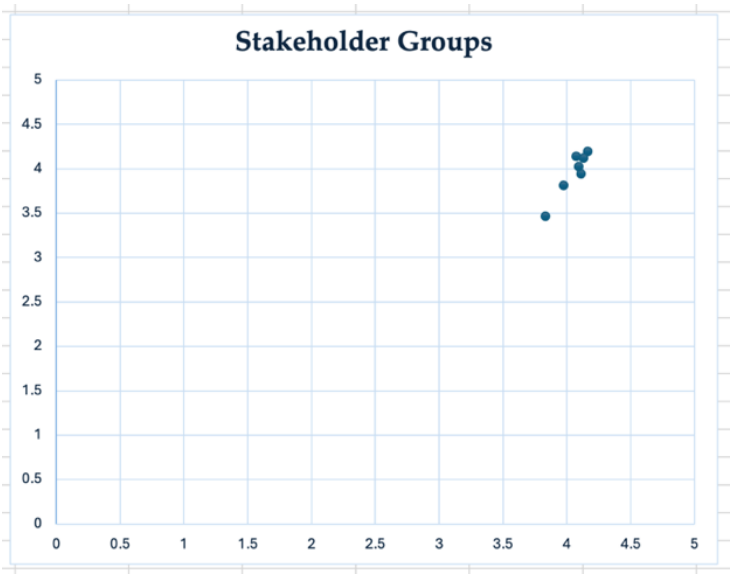


Figure 23. Stakeholder mapping for NbS in Infrastructure Planning in Butuan City

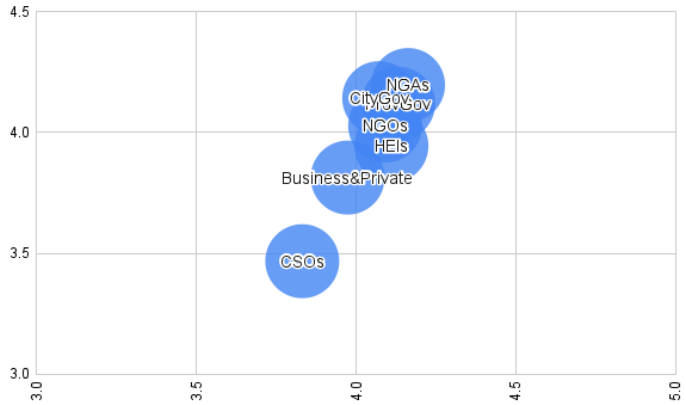


Figure 24. Upper Right Quadrant of Stakeholder Sentiments for Integrating NbS in Infrastructure Planning in Butuan City in relation to Agusan del Norte and Caraga Region

While not all of the identified stakeholder groups were able to send representatives during the workshop, these perceptions, nonetheless, show a high regard for the roles and participation of various groups for better infrastructures in the city. These sentiments signify the importance of involving this supportive stakeholder base to further increase discussions and support for NbS in infrastructures of Butuan City. In further analyzing the details of perceived influence and interest of different stakeholder representatives on affairs related to

infrastructure planning and NbS, the average scores of each stakeholder are shown in Table 17.

Table 17. Detailed Scores for Perceived Influence and Interest of Various Stakeholder Groups

STAKEHOLDER GROUP	INFLUENCE	INTEREST
DPWH	4.40	4.20
DPWH Regional Planning & Design Division	4.20	4.13
DPWH Highway Section	4.27	4.10
DENR	4.45	4.34
DENR Office of the Assistant Secretary for Policy, Planning, and Foreign Assisted and Special Projects	4.30	4.19
DENR EMB	4.29	4.25
DENR Planning Management Division	4.04	4.21
DENR PENRO	4.00	4.00
DENR CENRO	4.22	4.33
NEDA	4.32	4.39
NEDA Infrastructure Staff	4.26	4.22
NEDA Regional Development Council	4.42	4.30
DA	4.18	4.25
DA Regional Agricultural Engineering Division	4.35	4.35
DA Regional Project Coordinating Office	4.04	4.15
DHSUD	4.41	4.26
DOST	4.35	4.21
DOST PAGASA	3.93	3.97
NCIP	3.70	3.65
DILG	4.19	4.08
AFP	4.14	4.14
DND-OCD (NDRRMC)	3.88	3.85
Provincial Government of Agusan del Norte	4.39	4.48
Sangguniang Panlalawigan	4.09	4.09
Provincial Planning and Development Office (PPDO)	4.24	4.19
PG ENRO	4.13	4.06
PDRRMO	3.94	3.94
PEO	3.94	4.00
Provincial Agriculture Office	4.10	4.16
Office of the City Mayor	4.61	4.44

STAKEHOLDER GROUP	INFLUENCE	INTEREST
Sangguniang Panlungsod	4.36	4.12
Sangguniang Panlungsod (Indigenous Peoples Mandatory Representative)	3.90	3.81
City Planning and Development Department	4.25	4.22
City Environment and Natural Resources Department	3.79	3.80
City Agriculture and Veterinary Department	3.96	3.96
Barangays of Butuan City	4.12	4.15
Caraga State University	4.07	4.26
Father Saturnino Urios University	3.81	3.96
World Wildlife Fund (WWF)	4.41	4.48
Philippine Red Cross (PRC)	3.65	3.70
Farmers Associations	3.70	4.22
Fisherfolk Associations	3.52	3.91
Youth Associations	3.26	3.59
Women Associations	3.52	3.91
Senior Citizen Associations	3.45	3.59
Friendship Goals Society Caraga-Butuan Incorporated (FGSCBI)	3.35	3.76
Butuan City Water District (BCWD)	4.08	4.20
Taguibo Aquatic Solutions Corporation (TASC)	3.83	3.96
Agusan del Norte Electric Cooperative, Inc. (ANECO)	3.81	4.04
Telecommunication Companies	3.68	3.80
Contractors	3.67	3.88

Apart from these perceptions, which show high levels of influence and interest for including NbS in linear infrastructure planning, a crucial entry point for mainstreaming NbS would also rely on stakeholder consensus about what NbS is all about. "NbS" as a concept may be easily understood by key government offices and other formally trained personnel from various stakeholder groups (e.g. academe, research groups). However, to maximize grassroots discussions and further improve support, interest and sustainability for NbS in infrastructure planning, stakeholders were asked for local terminologies that may be used in understanding NbS. Two (2) distinct translations for NbS were agreed upon by the participants of the training-workshop held on 25-27 June 2024 at the Butuan Southville Hotel & Convention Center, namely:

1. ***Kinaiyanhong pagsulbad***, and
2. ***Mga kasulbaran pinasubay sa kinaiyanhan***

It should be noted that the abovementioned phrases are specific and distinct to Butuan City, however, their use and application to mainstream NbS in infrastructure planning may be considered for stakeholders located in adjacent areas of Butuan City. These local terms may be especially useful when introducing the concept to barangay officials, civil society organizations, and the general public. New and more appropriate translations of NbS may be further determined to capture the essence of NbS in infrastructure planning and development in local contexts and ignite stakeholder passion and interest to maintain implemented infrastructures with NbS as a core component.

Societal Challenges in Butuan City and Caraga Region

By definition of the International Union for the Conservation of Nature, NbS are not just actions to protect, sustainably manage, and restore natural or modified ecosystems. They also help solve seven societal challenges (IUCN, 2016) (Figure 25). In the context of Butuan City, this section identifies the societal challenges observed which will be important in identifying potential NbS for sustainable infrastructure planning.

Figure 25.The IUCN NbS Framework visualizing how ecosystem-based approaches can solve the seven societal challenges and improve human well-being and biodiversity

1. Climate Change Mitigation and Adaptation

The climate and natural hazards profile of Butuan City reveals its exposure to impacts of drought, flooding, storm surge, sea level rise, and rain-induced landslides. Proper planning for climate change mitigation and adaptation is necessary to address such, especially that climate projections, at business-as-usual scenario, predict that these hazards will intensify in the coming years. One piece of evidence is the annual flooding, which from accounts of the research participants, occurs less frequently than a decade before. Another is the worst drought occurrence experienced from April to May 2024 that almost dried up the Taguibo Dam, a structure whose primary purpose is to address water security in the city.

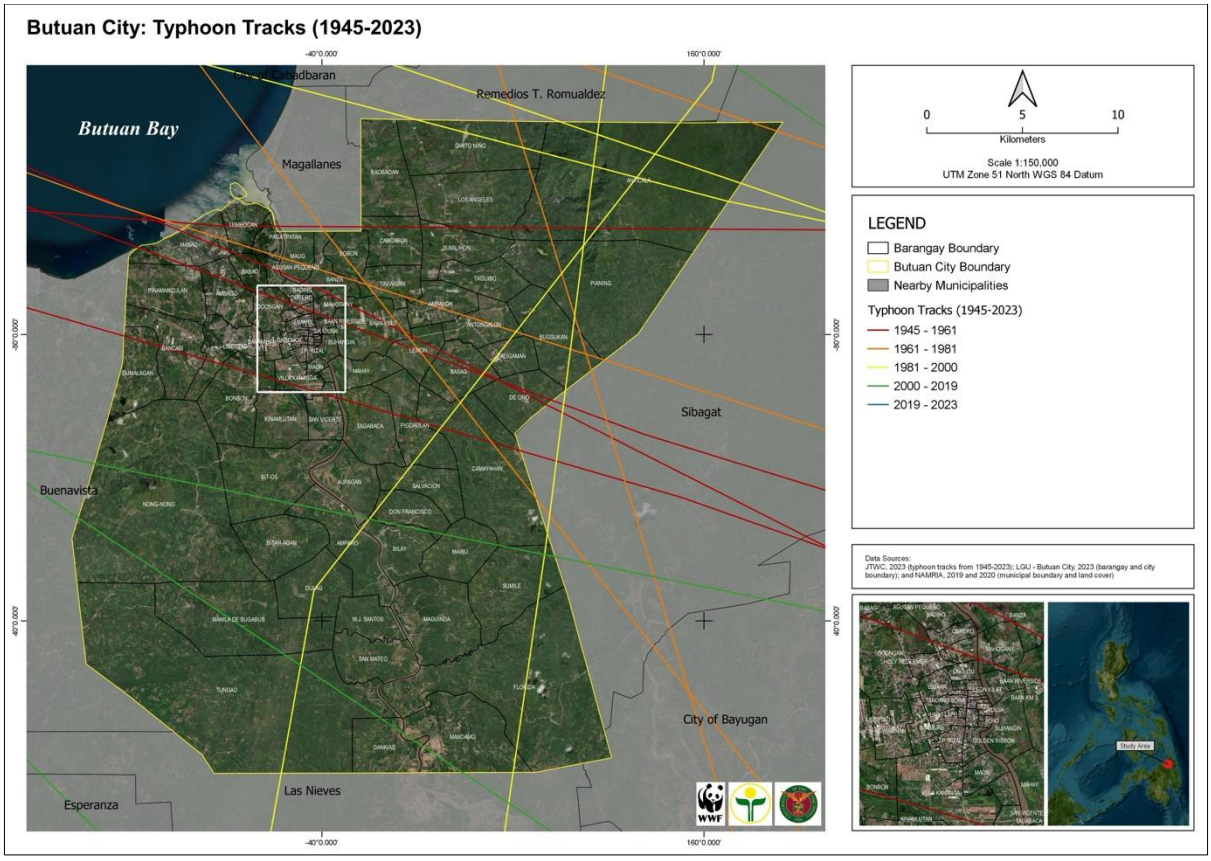


Figure 26. Pathways of typhoon that crossed Butuan City from 1945 to 2023

The Philippines is also vulnerable to typhoons formed in the Pacific Ocean, which are observed to intensify due to climate change due to higher sea surface temperatures (Holden & Marshall, 2018). Although the island of Mindanao, where the Caraga region is, is not typically along the typhoon pathway during the southwest monsoon season (when more typhoons are formed), once the northeast monsoon starts, the trajectory of typhoons changes. As a result, the typhoon pathways during the months of November until February move towards the Southern Philippines. Butuan and the rest of Caraga region, particularly the provinces on the eastern border receive the impacts of typhoons (Figure 26). More intense typhoons may affect the region in the future.

In 2021, Caraga region experienced the brunt of Typhoon Odette (Rai). While Butuan City was saved from the strong winds, flooding due to heavy rainfall resulted in the evacuation of thousands of residents (Lopez, 2021). For Agusan Del Norte province, 18,910 families were displaced, and 19 barangays were submerged in flood (Lopez, 2021). If climate change is not addressed, flooding may intensify. Combine this with the effects of sea level rise as a result of climate change, parts of Butuan City may become submerged, particularly the coastal and low-lying areas in Butuan City. The primary solution for the city to address flooding is to construct drainage canals and dikes.

The combination of drought from dry spells followed by sudden heavy rainfall (precipitation) and intense typhoon increases soil susceptibility to RIL. Intense heat is a factor for the increase in tension cracks in the soil, weakening the soil anchorage leading to landslides once heavy rain occurs (Tichavsky, et al., 2019). Hence, more RIL may occur as a result of high temperature, drought, followed by heavy rainfall.

If climate change mitigation and adaptation measures are not in effect, the impacts of the observed climate hazards in Butuan City may intensify. It is essential that planners of infrastructure development in Butuan and in Caraga Region are mindful in mainstreaming climate change into their Programs, Projects, and Activities (PPA) to ensure infrastructure development contributes to climate change adaptation and mitigation.

2. Disaster Risks

Both hydrometeorological and human-induced hazards pose risks in Caraga region. Hydrometeorological hazards result in climate risks which have already been discussed in the previous section. They also result in disasters that often involve loss of lives, destruction of properties, livelihood, and infrastructures. Typhoon Odette caused a rain-induced landslide that resulted in road closures in various parts of Butuan City in December 2021 (DPWH, 2021). It also damaged a road in Barangay Anticala when a flashflood carried various debris (e.g. logs, boulders) that blocked the water passages along the road that crosses the Taguibo river, destroying it (Figure 27). FGD participants also related that this flashflood destroyed a water pipeline in Anticala, reducing water supply in some parts of Butuan City. This was noted in the FGD in San Vicente as they were affected by the destroyed pipeline. Meanwhile, the agriculture sector of the province of Agusan Del Norte sustained damage amounting to PHP12,707,052.50 (US$ 228,419.22) (Lopez, 2021).

Figure 27. Bridge in Barangay Anticala that was destroyed by logs, boulders, and various debris carried by a flashflood when Typhoon Odette rampaged in December 2021.

Human-induced hazards, such as insurgency, are also present and may also result in loss of lives and various damages whenever there is violence involved. It may affect peace and order and risk human security if factors such as poverty and the provision of social services are not resolved in the area. The NTF-ELCAC was meant to address insurgency and mitigate disasters that may arise from insurgency.

Introducing NbS that addresses landslides and protects human settlements is needed in Butuan City. In terms of insurgency-related risks, an NbS project that improves the level of livelihood and quality of life of the local people may promote peace and order not just in Butuan but in the Caraga Region.

3. Economic and Social Development

Among the challenges that need to be addressed in Butuan City is poverty. Approximately 12.2% are living in poverty in 2023. People are still highly reliant on agriculture, which is highly vulnerable to climate change, and the industries present in Butuan City are not very diverse. Lack of financial resources and livelihood opportunities is also a factor in the incidence of informal settlers living in hazardous and risky locations. To prevent loss of lives and property damages, Butuan LGU and NGOs implemented a resettlement program in the early 2000s during the CARBDP implementation. Those who benefited are the households who relocated from the buffer zones of Agusan River to Pagatpatan. A more recent occurrence of relocation is in Bancasi where families affected by the extension of the extension ng airport and road widening projects were relocated to Purok 9A.

One challenge, however, is that relocation must not only address disaster risks and provide households with their own property, but it must also address poverty incidence, livelihood, and availability of utilities at the relocation site. Achieving economic and social development needs a multi-pronged strategy. During the FGD in Bancasi, they have a proposed project for the electrification of 200 houses in the relocation area, where they are considering utilizing solar power. For water supply, the local government installed solar-powered water pumps where households can access clean water.

The case of Pagatpatan, in terms of benefiting from NbS can be highlighted here. Since Pagtapatan is reclaimed area of a marshland, they were exposed to flooding and coastal inundation. According to the FGD participants, to solve such problems, various mangrove reforestation projects were conducted in their barangay.

While mangroves primarily provide protection from flooding and coastal inundation, the people in Pagatpatan also received direct economic and social benefits from mangrove reforestation. As the mangroves helped increase biodiversity in their area, they became a source of food and livelihood for the households living in Pagatpatan. The FGD participants are also looking forward to the proposed tourism development of their mangrove areas (e.g, mangrove ecoparks), which will provide more livelihood opportunities for those living in

their barangay. A building for a wetlands center had already been constructed in Pagatpatan where faculty members and researchers from Caraga State University, in partnership with Wetland Link International. The wetlands center is expected to be operational soon.

4. Public Health

Based on historical records, Typhoon Nitang in 1984 was one of the most devastating typhoons to hit Butuan City and the entire Caraga Region. It caused around 1,300 casualties and led to a severe disease outbreak due to water contamination (LCCAP-Butuan City). This highlights the public health challenges the city faces, especially during natural disasters.

Butuan City frequently experiences typhoons and flooding, which disrupt essential services like access to clean water and sanitation. These disruptions create favorable conditions for the spread of waterborne diseases such as diarrhea and leptospirosis, a bacterial infection transmitted through contaminated water. Vulnerable populations, including the elderly and low-income families, are at higher risk due to limited access to recovery resources. This problem was highlighted in Barangay Pagatpatan where one of their concerns during flooding is access to clean water, sanitation, and hygiene. Barangay San Vicente also experienced unstable water supply after typhoon Odette in 2021 when one of the pipelines were damage. Access to clean water is necessary for health and well-being.

In response, the city government has implemented flood management programs, including flood control projects aimed at reducing the risks to lives, properties, and production assets. These measures are expected to significantly improve public health by preventing flooding, eliminating breeding grounds for disease-carrying pests, and reducing the chances of water contamination, thus protecting the city's water supply and overall health conditions (Asian Development Bank, 2008). However, the flood management programs have been observed to be primarily reliant on grey infrastructures.

5. Food Security

Among the challenges of industrialization and urbanization is food security as land use changes from agricultural to commercial, industrial, and residential use. Another challenge is the migration of labor from rural areas to urban areas due to the promise of higher and more stable income. This is in contrast with agricultural production and income which is always at risk for climate hazards, soil infertility, and pests and diseases, that can cause a decline in the volume of agricultural production and income. Migration causes less available labor in agricultural areas that affect planting and harvesting of crops as people change their sources of income. The profile of the barangays has shown that while agriculture remain to be the top source of income for the population, the sources of income have diversified and many of the local people are now employed in the public and private sectors, providing skilled labor (e.g., driving, carpentry), or engaged in commerce. In some areas in the Philippines, the

exodus of agricultural labor is already a problem and factors such as wage differentials, road expansions leading to mobility, labor market efficiency, and better education contribute to labor migration (Cerutti & Li, 2021).

Figure 28. Bypass road under construction in Barangay Masao, Butuan City, cuts through agricultural lands and fishpond in the area. Photo taken on 6 October 2023.

Land fragmentation in the Philippines is also an issue as it can have an effect in farm efficiency and productivity. There have been proposals to push for farm consolidation as small parcels of land do not produce enough to remain profitable (Chikiamco, 2022). The primary cause of land fragmentation in the Philippines is the implementation of the Comprehensive Agrarian Reform Program which distributed a maximum of 3.0 hectares of land to tenants and farmworkers since 1988. Another cause of land fragmentation is change in land use. Infrastructure development may also cause fragmentation of agricultural areas if logistical highways will be built in these areas, such as what can be seen in Figures 28 and 29. Proper planning is needed to ensure that while infrastructure developments are ongoing, this will have minimal impacts to agriculture and food security.

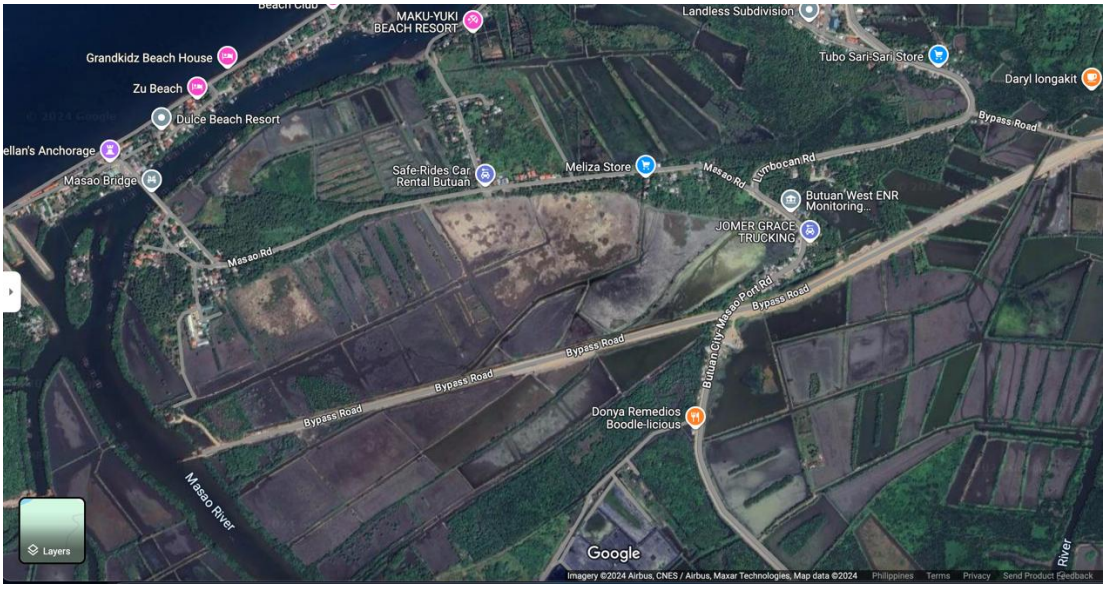


Figure 29. Screen capture of a satellite map from Google Maps (12 September 2024), showing the Bypass road traversing through fishponds and agricultural areas in Barangay Masao.

6. *Water Security*

Water security and climate change are interconnected societal challenges that significantly impact food security, the economy, and local communities. As climate change leads to more frequent and severe droughts, floods, and changes in rainfall patterns, it can diminish water resources and disrupt traditional water management practices, making it increasingly difficult for people to access clean water. As example, after Typhoon Odette, damage to pipelines necessitated costly repairs, highlighting the vulnerability of water infrastructure to extreme weather events.

For Butuan City, being located downstream of the Agusan River Basin, water insecurity has become a pressing issue due to recent experiences with droughts, typhoons, and flooding. Although water from the Agusan River is available, it is often turbid or appears brown and silted, particularly during the rainy season, making it unsuitable for domestic consumption. The turbidity of the Agusan River (Figure 30) is exacerbated by unsustainable practices such as deforestation and upland encroachment, as well as mining activities in the upland province of Davao de Oro. These mining operations can introduce sediments and chemicals into the river, further degrading water quality and affecting irrigation sources. For instance, the Barangay San Vicente area relies on irrigation from the Agusan River, which is managed by the National Irrigation Administration. While there were no seen effects to the residents, the FGD participants relayed concern on the possible contamination of the river.

Figure 30. Turbid waters of Agusan River, taken in January 2024

Additionally, flooding can impact deep wells and other water sources, complicating the situation further. In Taguibo River, which serves as a major water source for the city and nearby barangays, ongoing sand and gravel mining operations threaten the sustainability of this vital resource. While there are deep wells in areas like Brgy. Pagatpatan that provide potable water for emergencies and for those not connected to the Butuan City Water District, the overall water supply remains precarious. Moreover, the seasonal yield of water is often insufficient, particularly during dry spells, leading to increased competition for this essential resource. For instance, in 2024, the city faced a prolonged dry spell that resulted in significant water shortages. During the dry season, some areas of the city experienced a lack of available domestic water, forcing residents to conserve what little they had.

Although there are some issues with water pressure and infrastructure—such as small pipelines that have not been upgraded—overall, the quality of water remains acceptable.

Still, the combination of climate change and unsustainable human activities continues to exacerbate the challenges of securing a reliable water supply for Butuan City and its surrounding areas. Addressing these issues requires a comprehensive approach that prioritizes sustainable water management and the protection of natural ecosystems to ensure water security in the face of ongoing climate challenges.

7. Environmental Degradation, and Biodiversity Loss

These pressing societal challenges have significant implications for the human well-being, economic stability, and the overall ecosystem's condition of Butuan City. There are two major key drivers of environmental degradation within Butuan City, as identified by local stakeholders during FGD, which are: (a) the presence of quarrying in the river banks of Taguibo river in Brgy. Anticala, and (b) the rampant land cover change in the area.

a. Existing Quarrying

Based on the existing land use plan of Butuan City, there are three major sites utilized for quarrying, covering a total land area of 18.56 hectares (Table 18). The quarrying site in Taguibo river has various operations, including drilling, cutting, and transporting materials to be processed or used in construction and manufacturing (Figure 31).

Table 18. Locations of the existing quarrying sites within Butuan City

Quarrying Activities	Barangays
Site 1	Taguibo River – Bounded by barangays of Sumlihon, Taguibo, and Pianing
Site 2	Barangay De Oro
Site 3	Barangay Bonbon

Figure 31. Aerial photos of Taguibo River where a quarrying company is operating

Quarrying can have potential environmental and socio-economic impacts, including habitat destruction, pollution, community displacement, and property value reduction. Although these create environmental challenges, the negative impacts can be mitigated through sustainable practices, rehabilitation, and community engagement. This can be done through strict regulation. At present, the local government of Butuan City regulates the operations to safeguard the environment, and the local communities located along the

quarrying sites. However, concerns are still raised by residents in Barangay Anticala as they are wary that this may destroy their natural habitat.

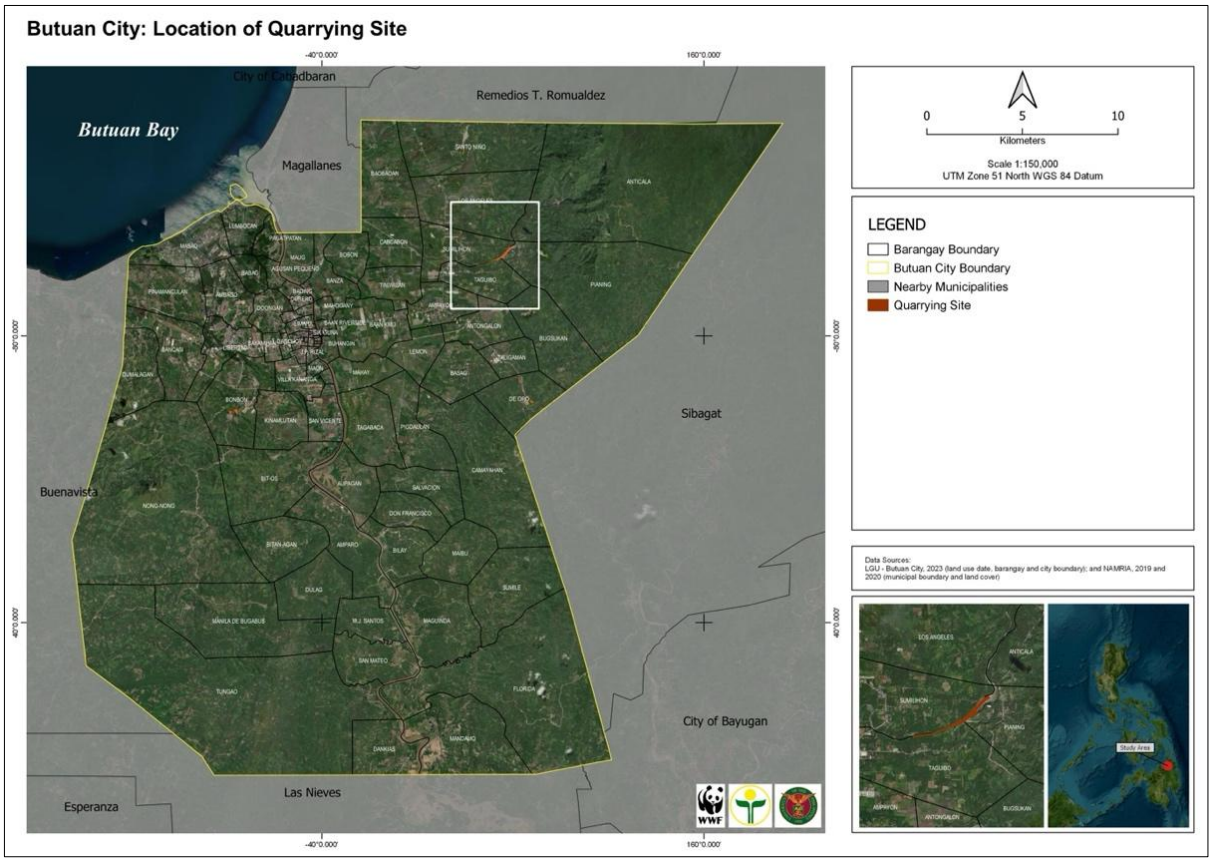


Figure 32. Location of quarrying sites in Butuan City.

b. Land Use/Land Cover Change

This process of landscape alteration involves the changes in the overall physical characteristics of the land surface, such as the conversion of forestland to agricultural purposes, grasslands to human settlements, or inland water to agro-industrial use (fishponds). This change is a significant component of environmental change and has profound implications for ecosystems, the ecosystem services, climate, and socio-economic condition of the locality.

Based on the land cover data from NAMRIA, Butuan City underwent significant landscape changes from 2010 to 2020 (Figure 33), reflecting the complex interaction between urban expansion, environmental pressures, and land-use management. These changes were further supported by the results of focus group discussions (FGD) with local stakeholders, particularly in Villa Kananga, San Vicente, and Bancasi, where commercialization and development of residential areas are observed.

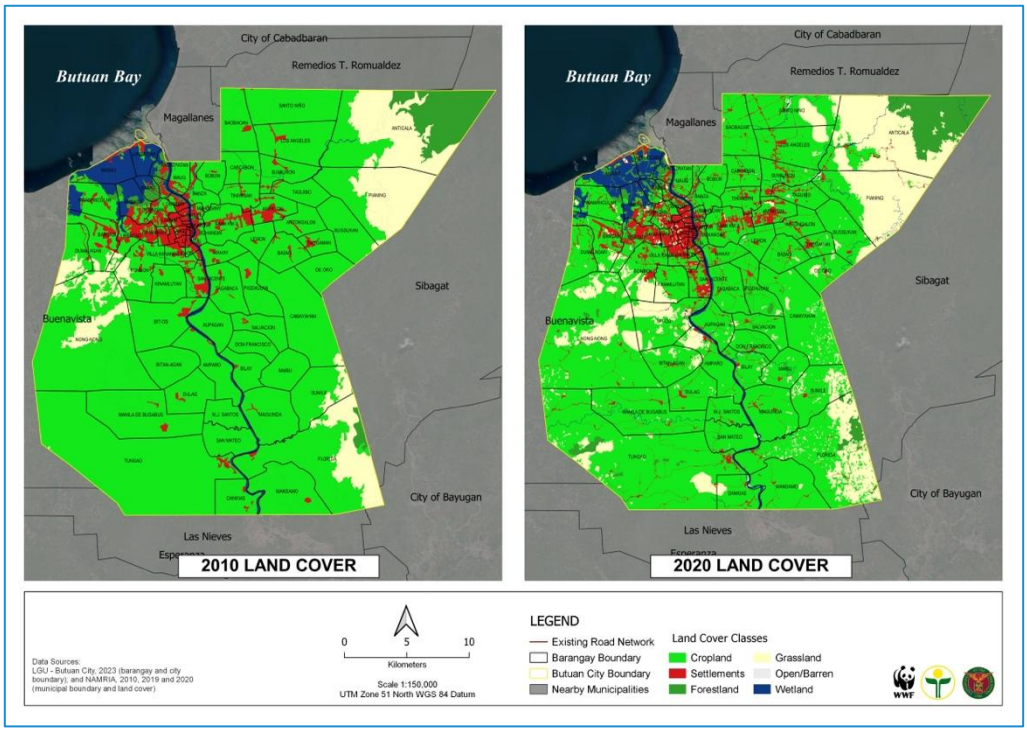


Figure 33. Land cover maps of Butuan City in 2010 and 2020

In contrast to the commercialization and urban development, Pagatpatan and Anticala experienced an increase in forest cover in the past years. As a result, the forestland in Butuan increased by 4.39 sq. km (0.53%) over the ten-year period. This can be attributed to the reforestation efforts led by the National Greening Program (NGP) under the Department of Environment and Natural Resources (DENR), along with initiatives from academic institutions, private sectors, and NGOs. However, despite this positive trend, issues persist, especially in the Taguibo Watershed, where the encroachment of agricultural lands poses a significant threat. The potential for illegal logging, poaching, and kaingin (slash-and-burn farming) in these areas continues to weaken ecosystems and disrupt the biodiversity of flora and fauna.

Additionally, the encroachment of ancestral domains into forested areas, particularly in Barangays Anticala, Los Angeles, and Pianing, has led to a delicate balance between resource conservation and indigenous rights. While forestland has increased, the ancestral domain encroachment puts both natural resources and the rights of indigenous people at risk, calling for a more integrated land management approach.

Grassland areas in Butuan City also showed a more substantial increase, growing by 42.24 sq. km (5.11%). This change can largely be attributed to the conversion of agricultural land into grazing areas. However, this trend contributes to the fragmentation of forest ecosystems, further weakening the resilience of local biodiversity and disrupting critical ecological functions. Forest fragmentation, coupled with the expansion of grasslands, has led to the degradation of key ecosystems, affecting the sustainability of both flora and fauna.

Table 19. Land cover change of Butuan City from 2010 to 2020

LAND COVER CLASSES	2010 LAND COVER (SQ.KM)	2010 LAND COVER (by %)	2020 LAND COVER (SQ.KM)	2020 LAND COVER (by %)	DIFFERENCE (SQ.KM)	PERCENTAGE CHANGE	RESULT
Forestland	31.85	3.85	36.24	4.38	4.39	0.53	INCREASED
Grassland	95.18	11.51	137.43	16.62	42.24	5.11	INCREASED
Cropland	637.29	77.07	576.22	69.69	-61.07	-7.39	DECREASED
Wetland	29.16	3.53	27.60	3.34	-1.56	-0.19	DECREASED
Settlements	33.38	4.04	47.76	5.78	14.38	1.74	INCREASED
Open/Barren	0.00	0.00	1.62	0.20	1.62	0.20	INCREASED
TOTAL	**826.87**	**100.00**	**826.87**	**100.00**	**0.00**	-	

Source: 2010 and 2020 land cover data from NAMRIA

In the meantime, urban expansion and economic development resulted in the increase in settlement areas (14.38 sq. km or 1.74%) and open/barren land (1.62 sq. km or 0.2%), particularly in rural barangays such as Bancasi, San Vicente, Villa Kananga, and Ampayon. Urban expansion has led to the reclassification of agricultural lands to residential and commercial purposes, contributing to a 61.07 sq. km (7.39%) decrease in cropland. The reduction in cropland raises concerns about food security, which has been discussed previously under the food security section, as agricultural land is lost to development. The overlap between Alienable and Disposable (A&D) lands and critical zones like the Taguibo Watershed exacerbates the risks of environmental degradation, especially in terms of water resource management and forest conservation.

In Barangay San Vicente, FGD participants reported that land conversion has led to the loss of their forests *(lasang)* and the covering of streams with soil. This has significantly reduced animal biodiversity in the area. For example, participants mentioned that they can now only catch carp in the Agusan River, a sign of declining water quality. Other fish species that once thrived in the river have disappeared, and the presence of wild animals in the vicinity has diminished, although specific types were not mentioned. These changes highlight the direct environmental impacts of land conversion on local ecosystems and biodiversity.

Lastly, it was observed that there is a decline of wetlands in Butuan, shrinking by 1.56 sq. km (0.19%). Wetlands in Butuan City can be found in the coastal barangays of Masao, Pagatpatan, and Lumbocan. This decline in wetlands is alarming given their importance for biodiversity, water filtration, and flood control. The decrease signals potential risks to agricultural productivity, as wetlands often serve as crucial components of irrigation systems

and biodiversity hotspots. The conversion of these areas for fishponds, settlements, and other economic activities poses further threats to the integrity of these ecosystems, particularly around the city's coastal and riverine zones. From accounts of barangay officials in Pagatpatan, the resettlement area in the barangay is actually part of the wetlands (*humok*) of Butuan City.

Climate Risk Assessment

The climate risk assessment conducted for Butuan City determines the nature and extent of risk of associated climate-related hazards within the city, evaluating the existing conditions of linear infrastructure and its vulnerability, which could potentially damage the infrastructure and disrupt its functionality, leading to economic losses and hindering essential services, like transportation, and mobility of people. Moreover, climate risk assessment was utilized since it is a critical approach to ensure the resilience, functionality, and sustainability of both the existing and proposed linear infrastructure within Butuan City. In the previous section on infrastructure planning and development, the linear infrastructures within Butuan City were discussed. These linear infrastructures were considered as exposure variables for risk assessment.

This section provides insights into the risks to infrastructures of present hazards, which are important in the identification of future NbS Projects. The results of the HEV matching process and the risk maps generated are discussed below:

Risk to Butuan City due to Flooding

Based on the Climate Disaster Risk Assessment (CDRA) report of Butuan City, flash floods and rainfall-induced landslides typically occur from November to February when the Agusan River and its tributaries overflow due to heavy rains or the monsoon season, especially in high-elevation areas of the city.

The result of the flood risk assessment for Butuan City indicates that while most areas of the city are at low risk, a considerable portion of about 34.78% falls under the moderate to very high-risk classification. This suggests that almost one-third of the city's land area requires attention and potentially enhanced risk management practices. Moderate risk areas also need significant attention to prevent escalation to higher risk levels. Table 20 summarizes the areas of Butuan City in relation to their risk classification.

Table 20. Flood risk classification distribution (by percentage) within Butuan City

RISK CLASSIFICATION	AREA (SQ. KM)	Percentage
Very Low Risk	31.36	3.79
Low Risk	516.22	62.43
Moderate Risk	148.65	17.98
High Risk	59.77	7.23
Very High Risk	70.88	8.57
TOTAL	**826.87**	**100.00**

Based on flood risk map (Figure 34), the barangays categorized as high to very high risk are located at the low-lying portion of the city, adjacent to the coastal area and near the Agusan River. These include 41 barangays out of 86: Masao, Lumbocan, Pagatpatan, Maug,

Banza, Bobon, Mahogany, Baan Riverside, Buhangin, Baan km3, Bading, Obrero, Holy Redemeer, Fort Poyohon, Ong Yiu, San Ignacio, Limaha, Leon Kilat, Humabon, Sikatuna, Urduja, Silongan, Rajah Soliman, Agao, Golden Ribbon, Diego Silang, New Village Society, Tandang Sora, Lapu-lapu, Dagohoy, J.P Rizal, Villa Kananga, Imadejas, Bayanihan, Doongan, Libertad, Ambago, Pinamanculan, Bancasi, Babag, and Agusan Pequeno.

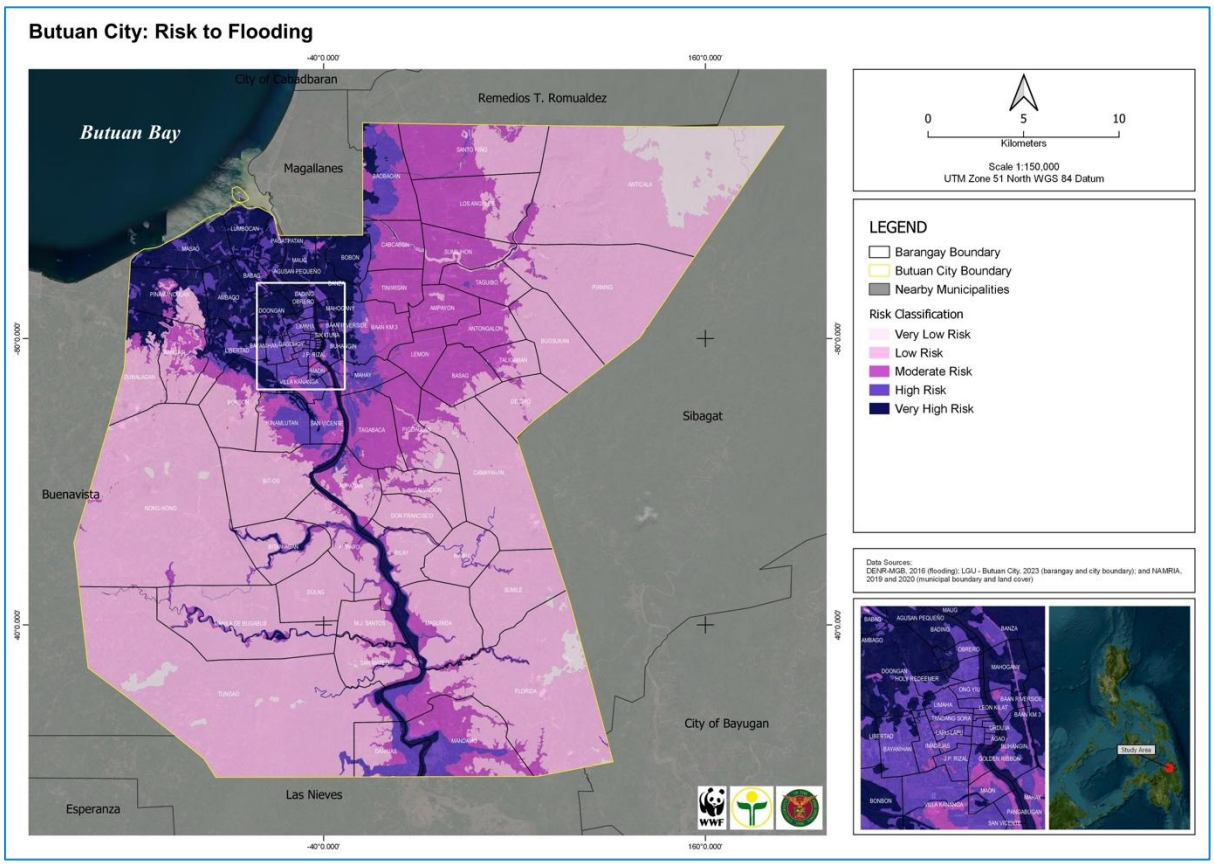


Figure 34. Flood risk map of Butuan City

A. Risk to Existing Road Network Due to Flooding

A substantial portion of the city's road network falls under low to moderate risk categories, with 481.54 km or 30.18% (low risk) and 525.96 km or 32.96% (moderate risk), respectively (Figure 35). However, a significant portion of the road network, totaling 331.36 km (20.77%), is classified as high risk, and 254.33 km (15.94%) is classified as very high risk. These roads are essential for connectivity and mobility but face substantial risks that could disrupt transportation during flood events.

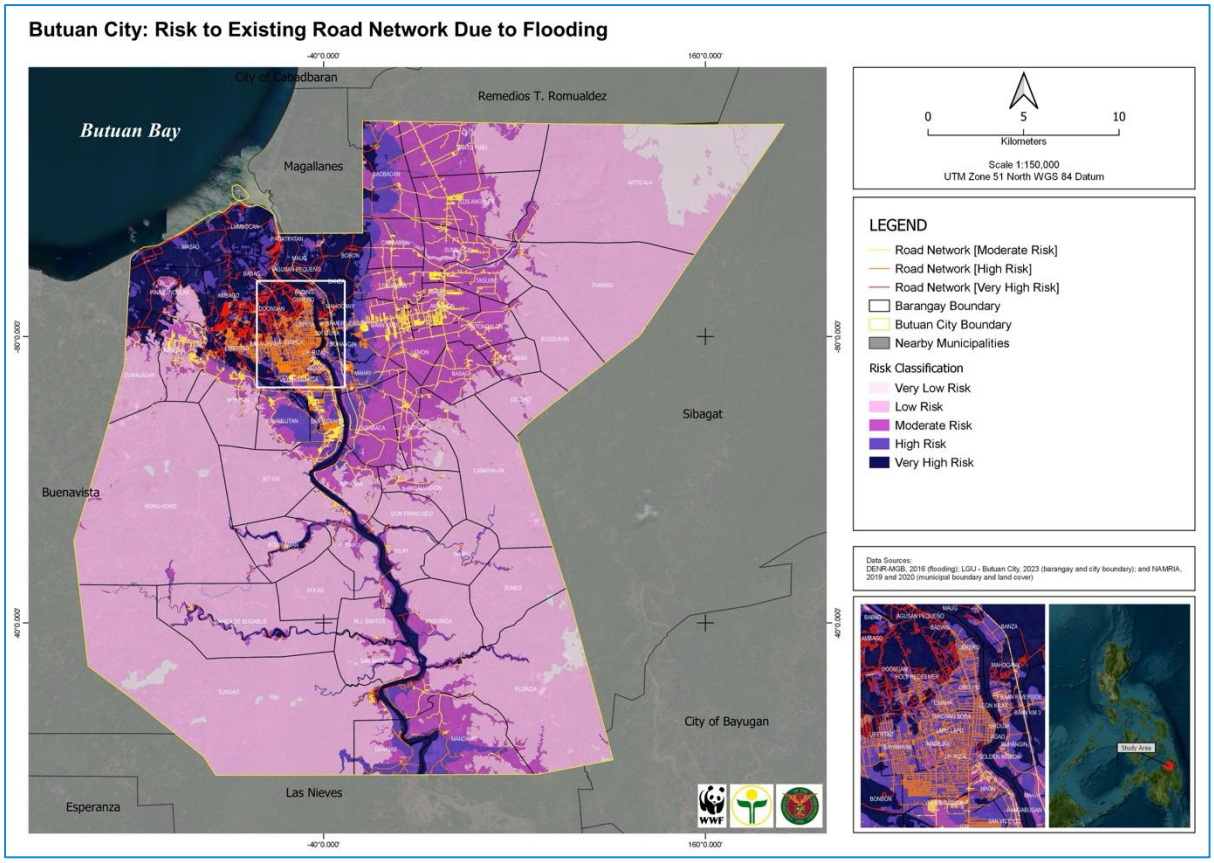


Figure 35. Flood risk map of the existing road network within Butuan City

On the other hand, only a small fraction of the road network, 2.57 km (0.16%), is classified as very-low risk. This indicates that most roads are exposed to flood risk. Table 21 summarizes the exposed road network of Butuan City in flooding based on risk classification.

Table 21. Flood risk classification distribution (by percentage) within Butuan City

RISK CLASSIFICATION	EXISTING ROAD (km)	%
Very Low Risk	2.57	0.16
Low Risk	481.54	30.18
Moderate Risk	525.96	32.96
High Risk	331.36	20.77
Very High Risk	254.33	15.94
TOTAL	**1,595.76**	**100.00**

B. Risk to Proposed Road Network Due to Flooding.

A huge portion of the proposed road network by DPWH from 2021 to 2023 within Butuan City falls under low to moderate risk categories, with 54.67 km (32.44%) and 55.27 km (32.80%), respectively (Figure #). On the other hand, a total of 27.9 km (16.56%) is classified as

high risk, while 30.68 km (18.21%) is classified as very high risk. These proposed road networks are expected to be completed by the end of the fourth quarter of 2024. Once completed, they will connect major roads, including rural barangays that were previously isolated.

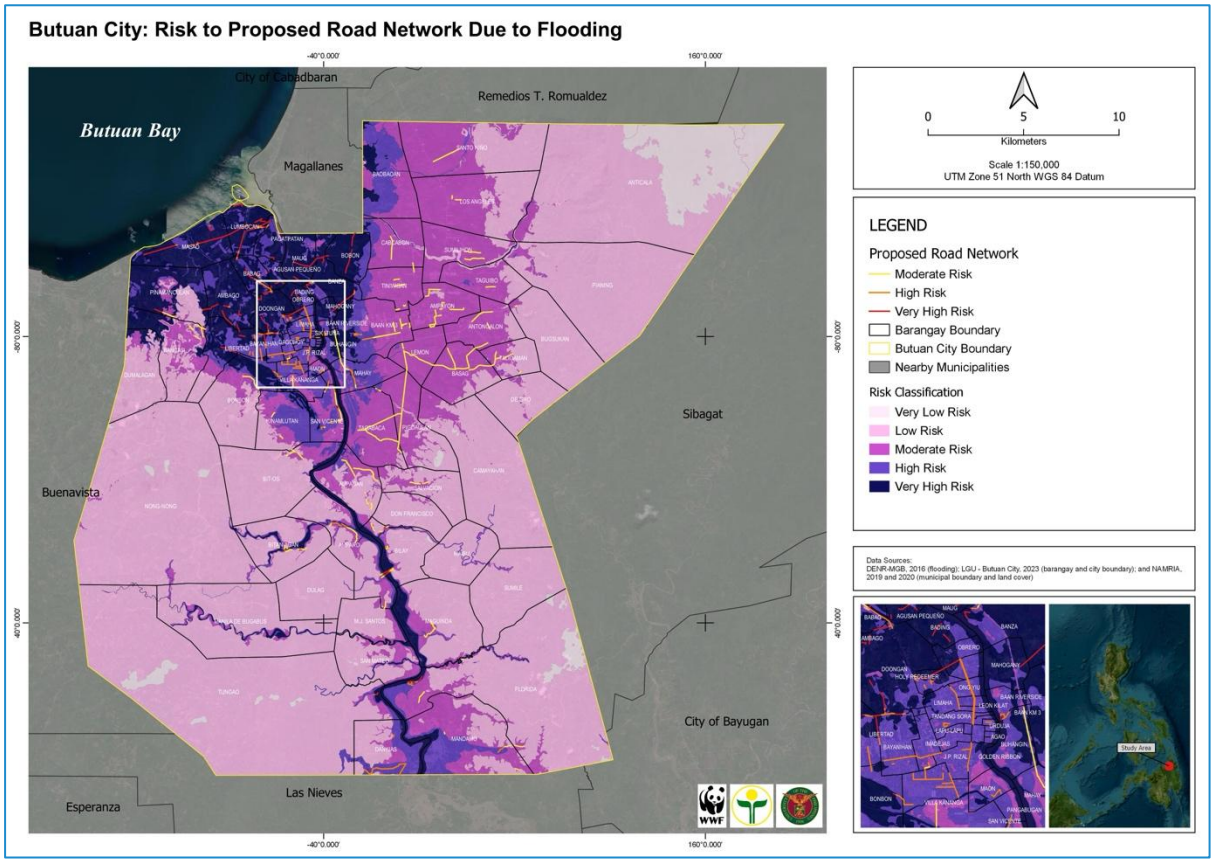


Figure 36. Flood risk map of the proposed road network within Butuan City

On the other hand, no portion of the proposed road network is classified as very low risk (0.00%). This indicates that most of the proposed roads are located within areas sensitive to flooding. Table 22 summarizes the exposed road network of Butuan City to flooding based on risk classification.

Table 22. Flood risk classification distribution (by percentage) for proposed road network within Butuan City

RISK CLASSIFICATION	PROPOSED ROAD NETWORK (km)	%
Very Low Risk	0	0.00
Low Risk	54.67	32.44
Moderate Risk	55.27	32.80
High Risk	27.9	16.56
Very High Risk	30.68	18.21
TOTAL	**168.52**	**100.00**

C. Risk to Proposed Drainage Line Due to Flooding

Given the role of drainage lines in flood prevention, their locations are expected to be exposed to flooding (Figure 37). The proposed drainage line will be constructed within the city proper of Butuan, specifically in low-lying urban barangays such as Libertad, Bayanihan, Imadejas, J.P. Rizal, Villa Kananga, Dagohoy, Lapu-lapu, Tandang Sora, Limaha, Fort Poyohon, Ong Yiu, San Ignacio, Leon Kilat, Urduja, Humabon, Silongan, Diego Silang, Ambago, and Golden Ribbon.

Meanwhile, the study included an assessment of this infrastructure for flooding to determine the level of risk associated with its area. The results show that a significant portion of the proposed drainage line is classified as high risk, with 42.93 km (74.94%), while the remaining 13.81 km (24.11%) falls within a very high-risk area.

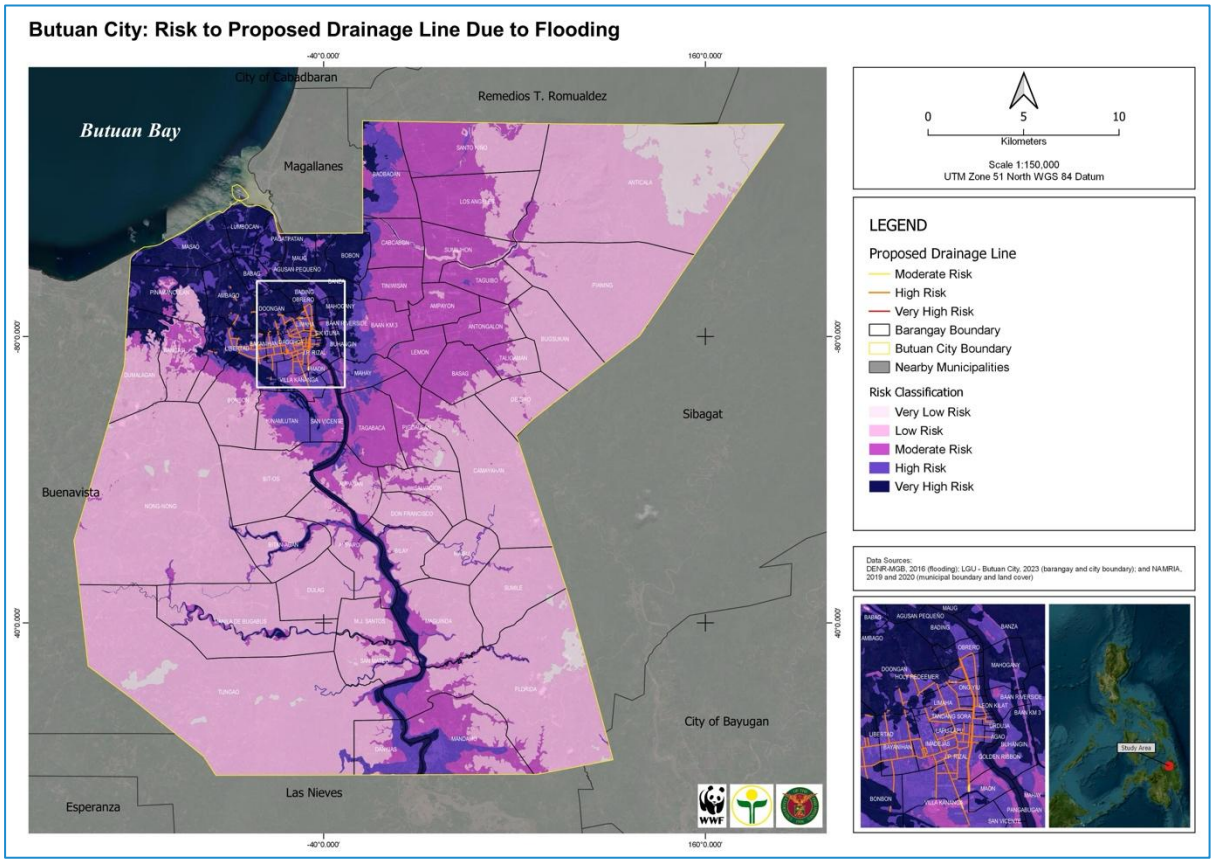


Figure 37. Flood risk map of the proposed drainage line within Butuan City

In contrast, no portion of the proposed drainage line is classified as very low risk (0.00%). This indicates that most of the proposed drainage lines are located in areas sensitive to flooding. Table 23 summarizes the proposed drainage lines of Butuan City in relation to flooding based on risk classification.

Table 23. Flood risk classification distribution (by percentage) for proposed drainage within Butuan City

RISK CLASSIFICATION	PROPOSED DRAINAGE (km)	%
Very Low Risk	0.00	0.00
Low Risk	0.00	0.00
Moderate Risk	0.55	0.96
High Risk	42.93	74.93
Very High Risk	13.81	24.11
TOTAL	**57.29**	**100.00**

D. Risk to Proposed Streetlights Due to Flooding

The inclusion of the proposed streetlights within Butuan City for flood risk assessment is essential to ensure the safety, reliability, and longevity of the infrastructure. This assessment aims to assist the City Planning Office of Butuan in determining the ideal design and placement of streetlights to minimize damage, maintain visibility during emergencies, and reduce repair costs. Overall, flood risk assessment is crucial for maintaining functional and safe streetlight systems, contributing to the city's overall resilience and sustainability.

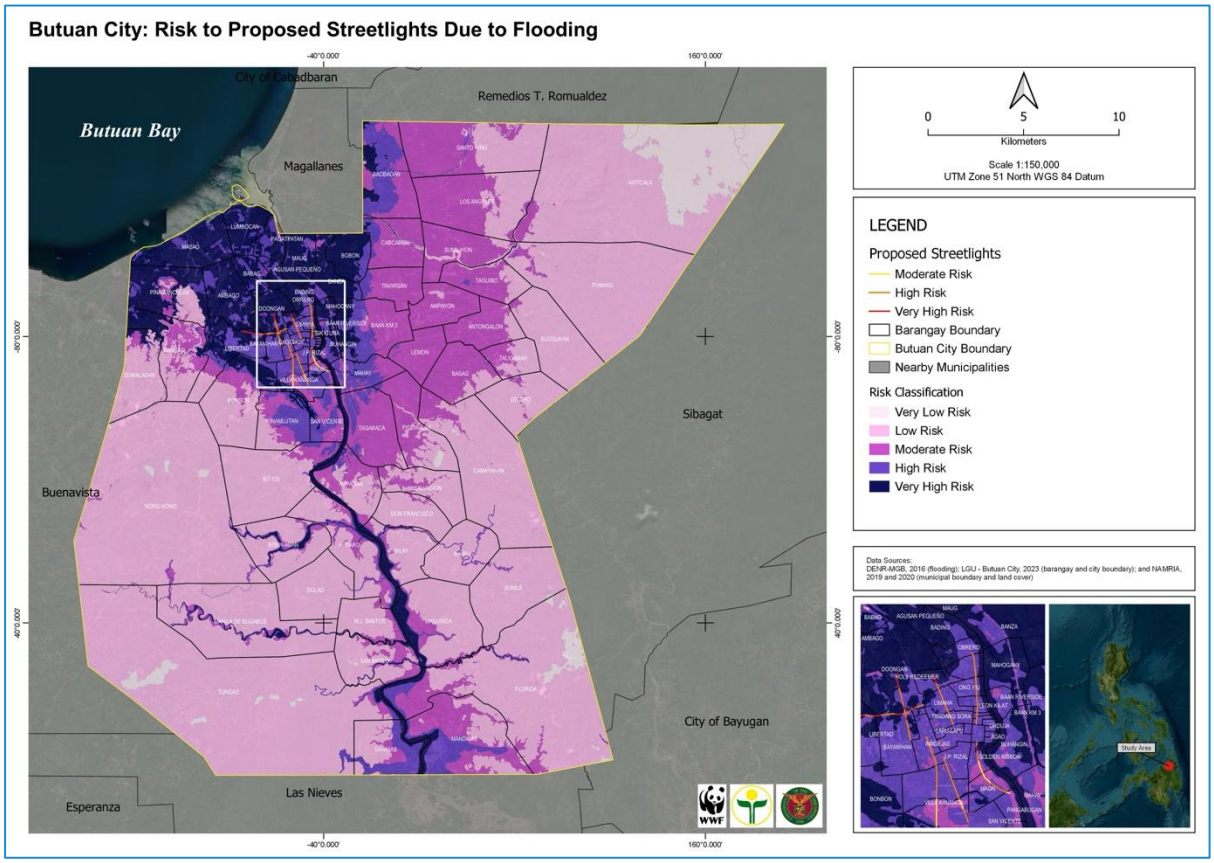


Figure 38. Flood risk map of the proposed streetlights within Butuan City

Based on the flood risk assessment result for the proposed streetlights within Butuan City (Figure 38), a huge portion of the streetlights within the city, totaling 11.4 km, is classified as high risk (8.7 km or 67.18%), and very high risk (2.7 km or 20.85%).

Areas where streetlights fall under moderate risk require some precautionary measures, while high-risk zones necessitate robust flood-resistant designs. Table 24 summarizes the streetlights exposed to flooding in Butuan City based on risk classification.

Table 24. Flood risk classification distribution (by percentage) for proposed streetlights within Butuan City

RISK CLASSIFICATION	PROPOSED STREETLIGHTS (km)	%
Very Low Risk	0.00	0.00
Low Risk	0.00	0.00
Moderate Risk	1.55	11.97
High Risk	8.70	67.18
Very High Risk	2.70	20.85
TOTAL	**12.95**	**100.00**

E. Risk to Proposed Mindanao Railway Due to Flooding

The inclusion of the flood risk assessment for the proposed Mindanao railway project within Butuan City is essential to ensure safety, operational continuity, and infrastructure resilience. As a city that is exposed to flood risk, this assessment helps in designing flood-resistant railway structures, managing costs by identifying potential issues early, and protecting local ecosystems.

Based on the flood risk assessment result for the existing road network within Butuan City (Figure 39), a substantial portion of the Mindanao railway within Butuan City falls under moderate risk (16.14 km or 48.78%). Additionally, 2.55 km (7.71%) are classified as high risk, and 9.71 km (29.34%) are in very high-risk zones. This distribution highlights the need for targeted flood mitigation measures, particularly in the high and very high-risk areas, to ensure the project's resilience and operational reliability.

Meanwhile, the proposed Mindanao Railway project has no sections classified as very low risk, with only a small portion (4.69 km or 14.17%) in low-risk areas. Table 25 provides a summary of Butuan City's railway network exposed to flooding, categorized by risk classification.

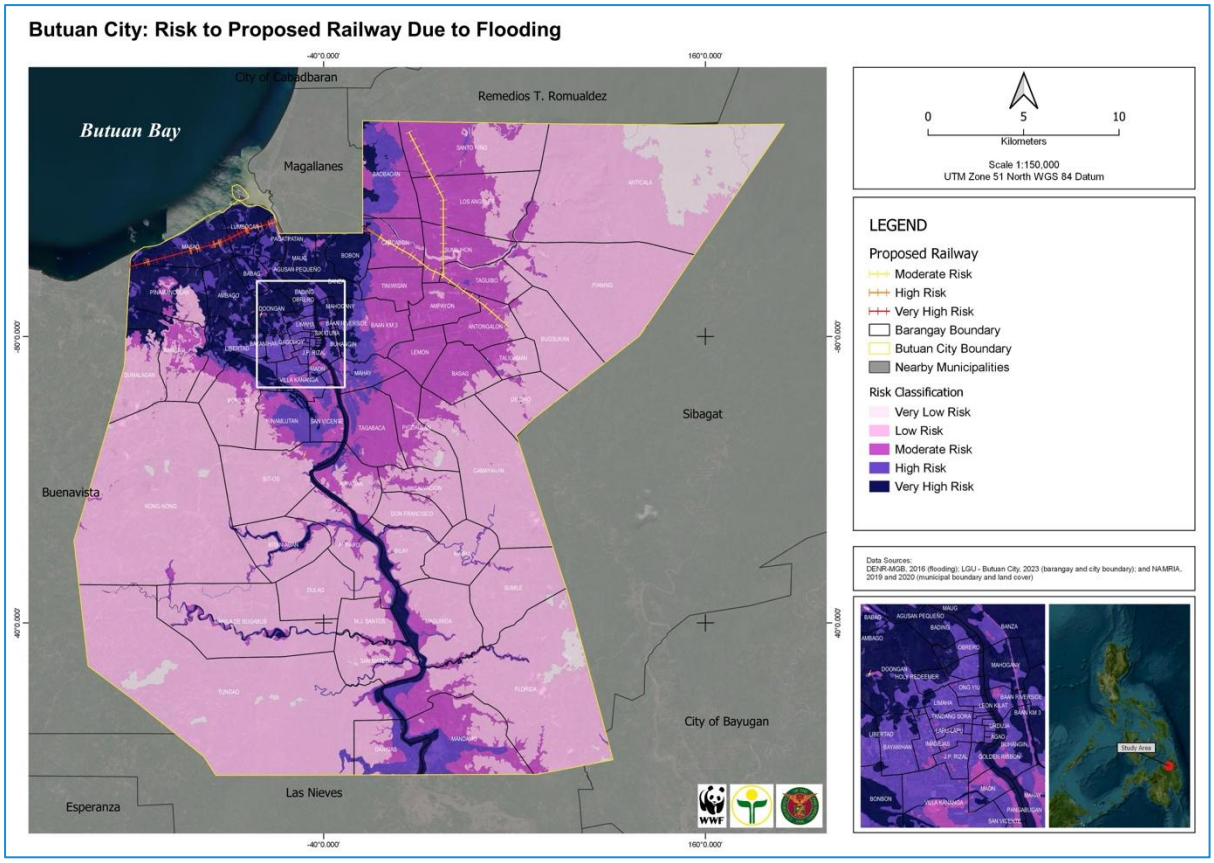


Figure 39. Flood risk map of the proposed Mindanao railway within Butuan City

Table 25. Flood risk classification distribution (by percentage) for proposed Mindanao Railway Project within Butuan City

RISK CLASSIFICATION	PROPOSED MINDANAO RAILWAY (km)	%
Very Low Risk	0.00	0.00
Low Risk	4.69	14.17
Moderate Risk	16.14	48.78
High Risk	2.55	7.71
Very High Risk	9.71	29.34
TOTAL	**33.09**	**100.00**

Risk to Butuan City due to Rainfall-Induced Landslide (RIL)

Every year, an average of 20 typhoons enters the Philippine Area of Responsibility (PAR), with approximately eight or nine making landfall (ESCAP/WMO, 2009; Bankoff, 2003), contributing to severe damage to infrastructure, agriculture, and property.

In reference to the Climate and Natural Hazards Profile of Butuan City, RIL is among the hazards that the city is exposed to. This hazard is a natural phenomenon involving the downhill movement of soil and rock materials due to the force of gravity (Kehew, 1988). Given Butuan's climatic conditions and geographical features, the risk of landslides poses a significant threat to the local population, infrastructure, and agricultural activities. RIL occurrences highlights the importance of implementing effective disaster risk reduction measures and raising awareness among residents about the potential dangers of landslides.

The risk assessment of rainfall-induced landslide for Butuan City indicates that a significant portion of the city (approximately 66.20%) is at very low to low risk for rainfall-induced landslides. On the other hand, the remaining considerable area of about 33.8% is ranging from moderate to very high risk (Table 26). This result emphasizes the need for differentiated yet tailored risk management strategies for each risk level, focusing particularly on the High and Very High-Risk areas to minimize potential landslide impacts. Effective disaster risk reduction efforts, community education, and infrastructure resilience planning are fundamental for enhancing Butuan city's preparedness and response to landslide hazards.

Table 26. Rainfall-induced landslide risk classification distribution (by percentage) within Butuan City

RISK CLASSIFICATION	AREA (SQ. KM)	%
Very Low Risk	274.61	33.21
Low Risk	272.80	32.99
Moderate Risk	99.45	12.03
High Risk	163.39	19.76
Very High Risk	16.61	2.01
TOTAL	**826.87**	**100.00**

The rainfall-induced landslide risk map shows the the barangays categorized as high to very high risk (Figure 40). These are the barangays located in the upland portion of the city: barangays of Anticala, Pianing, Bugsukan, De Oro, Camayahan, Dumalagan, Bonbon, Nong-Nong, Bit-Os, Tungao, Manila de Bugabus, Dulag, M.J Santos, and San Mateo.

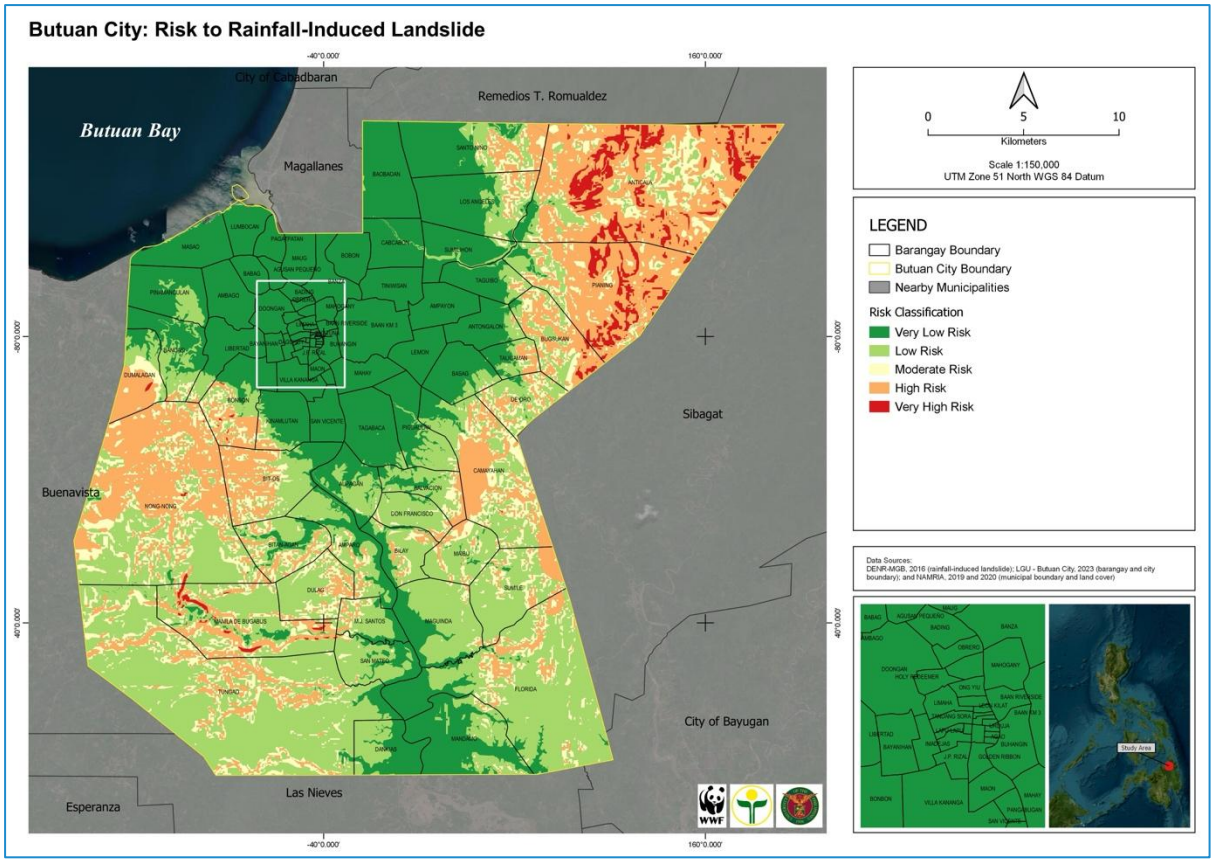


Figure 40. Rainfall-induced landslide risk map of Butuan City

Figure 41. Rainfall-induced landslide caused by Typhoon Odette (International Name: Rai) in December 2021. Landslides often occur in barangays that are on mountainous terrain such as in San Mateo (left) and De Oro (right). Photos courtesy of Butuan City Public Information Office Facebook Page (Left) and Butuan City Disaster Risk Reduction Management Office Facebook Page (Right).

A. Risk to Existing Road Network Due to Rainfall-Induced Landslide

The majority of Butuan City's roads are relatively in good condition, with 69.92% classified as Very-Low Risk and Low-Risk to rainfall-induced landslide. However, about 61.98 km or 32.96% of the proposed road network is categorized as Moderate-Risk, indicating areas that require attention but are not immediately critical. Notably, a total of 36.51% of the proposed road network falls under High Risk (68.62 km or 20.77%) and Very High-Risk (3.48 km or 15.94%) categories, highlighting a substantial portion that needs urgent maintenance, upgrades, or nature-based solutions for erosion control to prevent road closures and immediate deterioration.

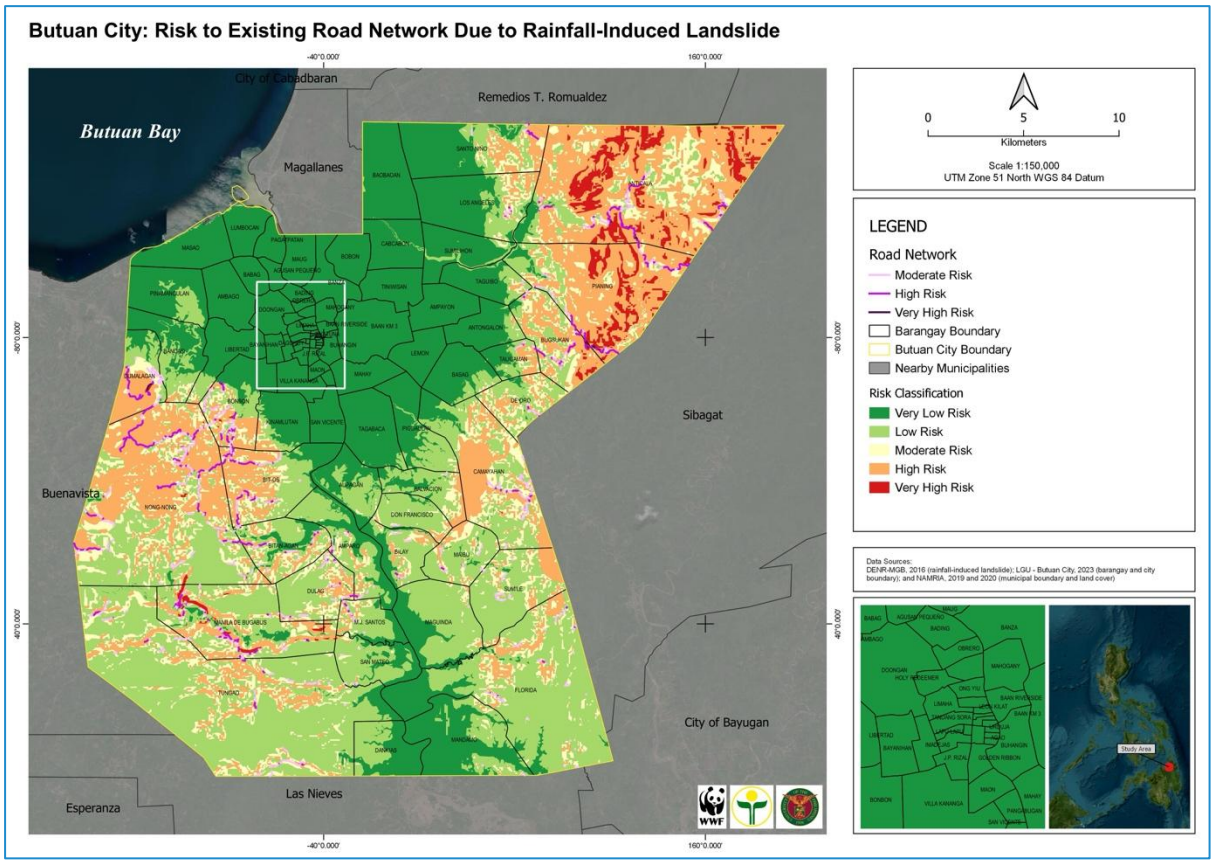


Figure 42. Rainfall-induced landslide risk map of the existing road network within Butuan City

To ensure the safety and functionality of the road network in upland areas, immediate focus should be directed towards the high-risk and Very High-Risk roads, with Moderate-risk roads monitored and addressed through future planning. Table 27 summarizes the exposed road network of Butuan City in rainfall-induced landslide based on risk classification.

Table 27. Rainfall-induced landslide risk classification distribution (by percentage) for existing road within Butuan City

RISK CLASSIFICATION	EXISTING ROAD (km)	%
Very Low Risk	1098.79	0.16
Low Risk	362.85	30.18
Moderate Risk	61.98	32.96
High Risk	68.62	20.77
Very High Risk	3.48	15.94
TOTAL	**1,595.76**	**100.00**

B. Risk to Proposed Road Network Due to Rainfall-Induced Landslide

The risk assessment of rainfall-induced landslides for Butuan City's proposed road network shows that a significant portion, 113.28 km or 67.26% is categorized as Very Low Risk (Table 28). This indicates that the majority of the proposed infrastructure is expected to be relatively stable under rainfall conditions. A smaller portion, 30.94 km or 18.37%, is classified as Low Risk, suggesting a generally low likelihood of landslides but with some potential for concern. Moderate Risk comprises 10.28 km or 6.10% of the network, which represents areas that could experience issues but are not highly prone to landslides. High-Risk accounts for 7.90% (13.31 km), and Very High Risk is minimal at 0.36% (0.6 km), pointing to only a small fraction of the network facing substantial landslide risk.

Overall, while most of the proposed road network appears to be well-suited to manage landslide risks, attention should be focused on the High-Risk areas to mitigate potential hazards and ensure the stability of the infrastructure. Figure 43 visualizes the various risk classifications in a map.

Table 28. Rainfall-induced landslide risk classification distribution (by percentage) for proposed road within Butuan City

RISK CLASSIFICATION	PROPOSED DRAINAGE (km)	%
Very Low Risk	113.28	67.26
Low Risk	30.94	18.37
Moderate Risk	10.28	6.10
High Risk	13.31	7.90
Very High Risk	0.6	0.36
TOTAL	**168.41**	100.00

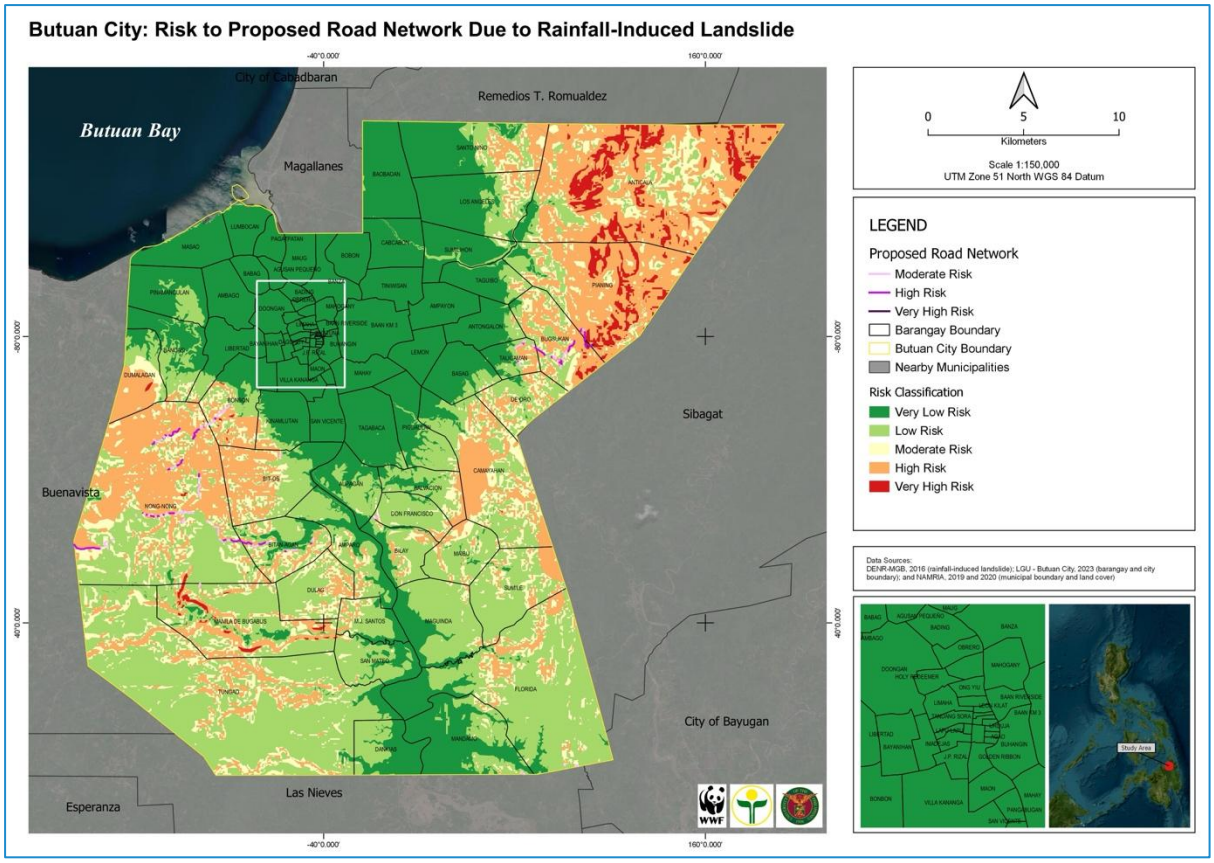


Figure 43. Rainfall-induced landslide risk map of the proposed road network within Butuan City

C. Risk to Proposed Mindanao Railway Due to Rainfall-Induced Landslide

Risk assessment of rainfall-induced landslides for Butuan City's proposed Mindanao Railway project, covering 33.08 km, reveals that 28.23 km or 85.34% of the railway alignment is classified as Very Low Risk, indicating a high level of stability under rainfall conditions (Figure #). A smaller proportion, 2.58 km or 7.80%, falls into the Low-Risk category, suggesting minimal but present risk. Only 1.1 km or 3.33% of the railway is considered Moderate Risk, and 3.54% (1.17 km) is High Risk. It should be emphasized that no sections of the proposed railways is classified as Very High Risk. This distribution suggests that the majority of the railway project is well-protected against landslides, though the High-Risk areas should be carefully managed to prevent potential issues. Overall, the assessment indicates that the proposed railway alignment is largely resilient to rainfall-induced landslides, with only a small fraction requiring targeted risk mitigation (Table 29).

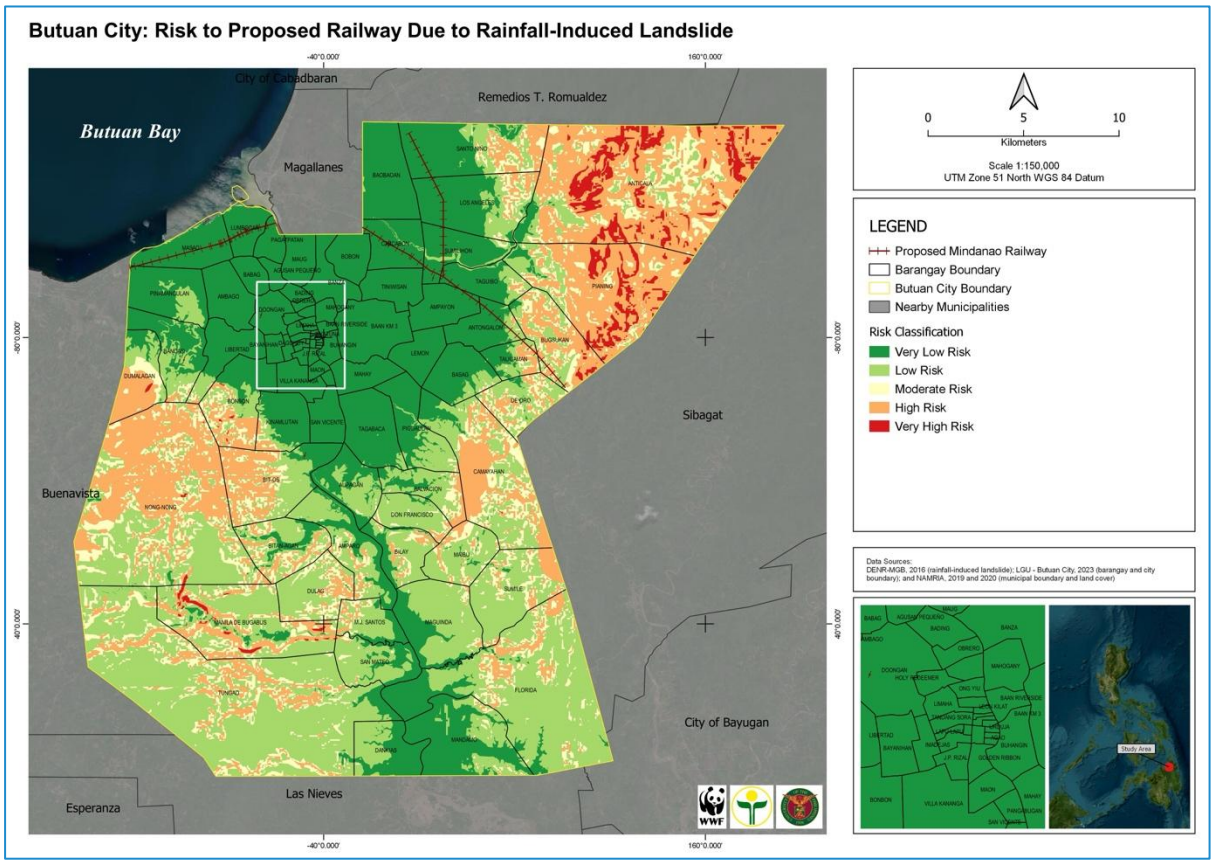


Figure 44. Rainfall-induced landslide risk map of the proposed Mindanao railway within Butuan City

Table 29. Rainfall-induced landslide risk classification distribution (by percentage) for proposed Mindanao Railway project within Butuan City

RISK CLASSIFICATION	PROPOSED MINDANAO RAILWAY (km)	%
Very Low Risk	28.23	85.34
Low Risk	2.58	7.80
Moderate Risk	1.1	3.33
High Risk	1.17	3.54
Very High Risk	0	0.00
TOTAL	**33.08**	100.00

Impact Chain Analysis

The 2023 World Risk Report ranks the Philippines as the 1st among 193 countries globally with the highest disaster risk (Bündnis Entwicklung Hilft and IFHV, 2023). The ranking was based on the World Risk Index, which considers various factors contributing to a country's overall risk of experiencing disasters. These factors include exposure to natural hazards, vulnerability, susceptibility, coping capacities, and adaptive capacities.

The high disaster risk ranking has various implications, including the humanitarian needs as a result of significant loss of life, injury, and displacement of people. Disasters also exacerbate existing social and economic inequalities, leading to substantial economic losses, affecting various sectors such as agriculture, industry, and tourism. The cost of disaster recovery and rebuilding further strains the national budget. In the context of policy, the ranking underscores the urgent need for comprehensive disaster risk reduction (DRR) strategies.

As part of the Comprehensive Climate Risk Assessment for Butuan City and its linear infrastructures, the "impact chain analysis" was utilized to analyze the complex climate risks associated in the city. The impact chain analysis applied the comprehensive risk framework for specific climate risks in a given context (UNDRR, 2022).

Step 1. Climate Change Driver

For many years, the Earth's climate system have been altered due to natural and anthropogenic factors. Although climate changes have been natural, human activities that emit greenhouse gases is indisputably the cause of global warming, leading to the increase in global surface temperature by 1.1°C above 1850-1900 in 2011-2020 (IPCC, 2023).

During the industrialization era, these activities have been the dominant cause of global warming, surpassing the small net increase from natural factors like solar energy changes and volcanic eruptions. Emissions from anthropogenic activities also generate aerosols (Zhang, 2020). These human-caused aerosols have complex effects, leading to cooling by interacting with radiation and clouds, though this offset has declined despite rising emissions. The Earth-atmosphere-ocean system features feedback processes that amplify or weaken responses to influences, with a net positive effect over the industrial era, further amplifying global warming and expected to continue in the future (Fahey, S.J. Doherty, Hibbard, and Taylor, 2017).

According to the observed climate data for the Philippines, prepared by DOST-PAGASA (2024), the country has experienced notable shifts in both rainfall and temperature patterns. Over the past 30 years, there has been a significant increase in the annual mean temperature, with certain regions observing slight decreases, while others have seen considerable rises. Additionally, the country has exhibited a consistent nationwide increase in monthly temperature trends, with the highest rates observed in central and northern Luzon

and Mindanao. In contrast, rainfall patterns in the Philippines display spatial and seasonal variability. Over recent decades, certain areas in Luzon and the Visayas have experienced significant increases in rainfall, while Mindanao generally shows a trend toward decreasing precipitation.

Climate projections for the Philippines (DOST-PAGASA, 2024) indicate a warming trend that is expected to persist through the end of the 21st century. Under the SSP 3-7.0 scenario, temperatures could rise by up to 3.5°C, while the SSP 5-8.5 scenario projects an increase of up to 4.4°C. By 2050 (mid-21st century), most regions are anticipated to experience temperature increases of approximately 0.8°C above the historical average, with mountainous areas potentially seeing increases of around 1°C during specific months. Projected changes in rainfall patterns also vary widely across the country. Some areas are expected to become wetter, while others may experience drier conditions. The median estimate suggests a slightly wetter climate between 2021 and 2050, underscoring the need for adaptive measures. Monthly projections reveal diverse trends, with potential decreases in rainfall over parts of Luzon and increases in other regions, reflecting the complexity of future rainfall dynamics in the Philippines.

Step 2. Climate Hazard Identification

Changes in climate have led to an increase in extreme weather events, including heavy rainfall and more frequent typhoons (Seneviratne, S.I, et al., 2012). Butuan City faces several climate hazards such as drought, flooding, sea level rise and storm surge, and RIL. The most damaging of all these, in the case of Butuan City, is flooding and second is landslide. This has been discussed previously on section on Climate and Natural Hazards Profile and the Societal Challenges faced by Butuan City. The intense rain brought by typhoons or even prolonged rainfall can saturate the soil (Rosso, Rulli, and Vannucchi, 2006), increasing the risk of flooding in low-lying areas and subsequently triggering landslides in mountainous areas.

Flooding occurs when water inundates land that is typically dry, primarily due to excessive rainfall, storm surges, or the failure of dams and levees (International Federation of Red Cross and Red Crescent Societies, 2021). Sea level rise also results to coastal flooding that can damage infrastructure, agricultural areas, and properties leading to displacement of communities (Climate Central, 2019). Meanwhile, the rainfall-induced landslides, occur when the saturated soil becomes unstable and flows downhill caused by severe and prolonged rains. Thus, the alterations in the climate system due to human activities not only contribute to global warming but also increase the frequency and severity of flooding and rainfall-induced landslides.

Step 3. Identifying Exposure Pathways

This section of the impact chain analysis focused on detailing the exposure pathways through which flooding and rainfall-induced landslides can inflict harm. The Butuan City

CDRA report mentions that a significant portion of the city is highly exposed to flooding because of its geographic location. The result of the spatial and attributed analysis showed that about 70.08% of the city's land area is part of the downstream portion of the Agusan River Basin, into which waters from the upland barangays of the city and provinces drain. the flooding in Butuan City is primarily caused by the overflow of the Agusan River and its tributaries due to heavy local rains and runoff from neighboring upland areas. Contributing factors include heavy rainfall in inland areas with poor drainage, precipitation from typhoons, monsoons, or low-pressure systems, and flash floods near Bonbon Creek at Sitio Matin-ao, Masao during prolonged and intense rainfall. On the other hand, rainfall-induced landslides also occur in the city during rainy and typhoon seasons, which usually happens from the months of November to February. The upland and mountainous barangays of the city are the most exposed area to landslides. Factors that contribute to landslides are the low vegetation cover and the presence of the small-scale mining activities in the areas (Butuan City CDRA 2023).

Given the geographic characteristics of the city, this section of the impact chain analysis specifically examines the linear infrastructures in Butuan City, including the current road network and proposed development projects. These projects encompass roads, streetlights, drainage systems, and railway networks. By identifying these infrastructure elements, the potential impacts of natural hazards can be understood. This also gives room for assessing the potential risks to urban resilience and safety.

Step 4. Impact Identification

Impacts of Flooding

Flooding can have a significant and multifaceted impact on the city proper of Butuan city, particularly on the linear infrastructure. Table 30 shows the impact chain results of linear infrastructure caused by flooding.

Impact on Road Network: The water inundation brought by heavy rains can damage roads in several ways. Water can erode the surface of the road, undermine the roadbed, and cause structural failures. Persistent flooding can create potholes, cracks, and even wash away parts of the road. Standing water can also lead to unsafe driving conditions and road closures.

Impact on Streetlights: Streetlights are vulnerable to flooding and can cause electrical malfunctions and damage to the fixtures. Water exposure can lead to short circuits, rendering streetlights inoperative and reducing visibility at night. This can increase the risk of accidents and security issues in affected areas.

Impact on Proposed Drainage Systems: Flooding often overwhelms drainage systems, leading to blocked or inadequate drainage. This can result in water pooling on streets and in low-lying areas, contributing to further flooding and damage. In severe cases, the excess water can erode drainage infrastructure and lead to long-term system failures.

Impact on Proposed Railway Project: Flooding can disrupt railway systems by causing track misalignment, damaging embankments, and affecting signaling and communication equipment. Waterlogged tracks can lead to delays and derailments. Floodwater can also damage railway stations and other infrastructure, impacting overall service and safety.

Table 30. Impact Chain Results on the Linear Infrastructure (Flood)

Linear Infrastructure	**Hazard: FLOODING**		
System of Interest	**Primary Impact**	**Secondary Impact**	**Tertiary Impact**
Road Network	**Damage to road infrastructure** - Floodwaters can cause immediate physical damage to roads, including erosion, pavement washout, and undermining of the roadbed. This damage can make roads impassable and pose safety risks to motorists.	**Disruption of Transportation and Mobility** - The damaged roads lead to disruptions in transportation, causing delays, detours, and increased travel times. Emergency services, public transport, and everyday commuting are all affected, which can result in economic losses and hinder access to essential services.	**Long-term Economic and Social Consequences** - Prolonged or repeated road damage can lead to long-term economic impacts, such as reduced business activity, decreased property values, and increased costs for road repairs and maintenance.
Proposed Drainage line	**Overwhelming of Drainage Capacity** - Floodwaters can exceed the design capacity of the proposed drainage line, leading to immediate flooding of surrounding areas.	**Erosion and Structural Damage** - The excess water from flooding can cause erosion around the drainage line, weakening its structural integrity. This can lead to blockages, collapse of sections of the drainage system, and further inefficiencies in water management.	**Increased Maintenance Costs and Long-Term Flood Risks** - Over time, the damage and inefficiencies caused by flooding can lead to higher maintenance and repair costs for the drainage system.
Proposed Streetlights	**Electrical and Structural Damage** - Flooding can cause immediate electrical short circuits, corrosion, or damage	**Loss of Illumination and Public Safety Risks** - Damaged or non-functional streetlights lead to a lack of proper	**Increased Maintenance Costs and Long-Term Infrastructure Degradation** - Repeated flooding

Linear Infrastructure	Hazard: FLOODING		
System of Interest	**Primary Impact**	**Secondary Impact**	**Tertiary Impact**
	to the foundation of streetlights.	illumination at nighttime, increasing the risk of accidents, reducing visibility for drivers and pedestrians, and potentially leading to a rise in crime due to poorly lit areas.	can lead to higher maintenance and replacement costs for the streetlights.
Proposed Railway	**Damage to Rail Infrastructure** - Flooding can cause immediate physical harm to railway tracks, embankments, and foundations.	**Disruption of Rail Services and Economic Losses** - Damage to the railway infrastructure can result in service disruptions, including delays, cancellations, and rerouting of trains.	**Long-Term Financial and Operational Challenges** - Repeated or severe flooding can lead to long-term financial strain due to the costs of repairs, maintenance, and implementing flood mitigation measures

Impacts of Rainfall-Induced Landslide

Similar to flooding, the rainfall-induced landslide can have a significant and multifaceted impact on the upland and mountainous barangays of Butuan city and its linear infrastructure. Table 31 shows the impact chain results of linear infrastructure caused by rainfall-induced landslide

Impact on Road Network: The rainfall-induced landslides can have severe impacts on road network by blocking access with debris, mud, rocks, and vegetation, and causing physical damage such as cracking and displacement of the road surface. The force of the landslide can also erode supporting structures and undermine the roadbed, leading to collapses or sinkholes. Moreover, the affected roads often face prolonged closures due to the extensive clean-up, repairs, and possible reconstruction required, significantly disrupting transportation and access.

Impact on Proposed Railway Project: This hazard can severely impact the railway systems by blocking tracks with debris and causing misalignment due to the shifting of tracks. The underlying support structures, including embankments and foundations, can also suffer significant damage or destruction, leading to potential track collapse. As a result, the railway will have a substantial service disruption, with train delays or cancellations, and require extensive repair efforts. The resulting downtime can lead to long-term operational challenges and significant economic losses for both freight and passenger services.

Table 31. Impact Chain Results on the Linear Infrastructure (Rainfall-Induced Landslide)

Linear Infrastructure	**Hazard: RAINFALL-INDUCED LANDSLIDE**		
System of Interest	**Primary Impact**	**Secondary Impact**	**Tertiary Impact**
Road Network	**Immediate Road Blockage and Surface Damage** - In mountainous areas, landslides can deposit debris, mud, and rocks onto roads, blocking access and making them impassable.	**Erosion and Structural Damage** - The landslide can erode the supporting structures of the road, undermining the roadbed and leading to further damage or collapse.	**Prolonged Closures and Economic Disruptions** - Roads affected by landslides often face prolonged closures due to the extensive clean-up, repair, and potential reconstruction required.
Proposed Railway	**Immediate Track Blockage and Misalignment -** The landslide can cover railway tracks with debris and mud, rendering them unusable.	**Damage to Support Structures** - The landslide can severely damage or undermine the supporting structures of the railway, such as embankments, bridges, and foundations	**Long-Term Service Disruptions and Financial Losses** - The damage and subsequent repairs can cause prolonged disruptions in railway service, affecting transportation schedules and operational efficiency.

Ecosystem Services

Ecosystem services, as defined by the Millenium Ecosystem Assessment (2005), are the benefits obtained from ecosystems. They are categorized into provisioning services (i.e., food, water, timber), regulating services (i.e., climate regulation, water purification), cultural services (i.e., recreation, spiritual benefits), and supporting services (i.e., nutrient cycling, soil formation).

As these services are essential for human well-being, it is imperative to also consider these for sustainable ecosystem management. Thus, these must be considered in linear infrastructure planning since they essentially play a crucial role in the sustainability and resilience of infrastructure projects. Moreover, quantifying these ecosystem services helps identify areas where ecosystem functions are strong or weak, guiding the placement and design of infrastructure to minimize environmental impact. This quantification is also necessary in determining the most effective NbS as it allows planners to select interventions that enhance or restore ecosystem services, thereby not only ensuring the infrastructure is more resilient to climate change and supports biodiversity, but also making sure that the construction of linear infrastructure does not exacerbate worsening ecosystem service condition.

In line with the methodology on ES prioritization, the study will not cover all ecosystem services present in Butuan City. Instead, it will concentrate on those services that local stakeholders have identified as the most important and in urgent need of intervention. These services were selected based on their perceived value to the community and the immediate benefits they provide in addressing local environmental challenges. The identified ecosystem services are baseflow, carbon storage, forest carbon edge effect, recharge contribution, urban cooling, and urban flood risk mitigation. These ecosystem services were estimated using InVEST.

A. Baseflow

Baseflow is the contribution of groundwater and delayed subsurface flow (Guisiano et al., 2024). It sustains river flow during droughts and dry periods, playing a crucial role in regulating streamflow during dry seasons and ensuring ecosystems continue to function effectively (Cao et al., 2024). Using the Seasonal Water Yield Model of InVEST, the baseflow in Butuan City was estimated. The SWYM calculates spatial indices that measure how much a specific area of land use/land cover contributes to the generation of both baseflow and quickflow (Bagstad et al., 2018). This model is useful due to its low data requirements and its outputs can be directly interpreted as water ecosystem services (i.e., water supply), making it readily applicable to managers and decision-makers (Benra et al., 2021).

Table 32 highlights the relationship between different land use/land cover types and their corresponding baseflow values, showing key insights into how land use/land cover

affect water infiltration and groundwater recharge. Upland areas, characterized by forests and grasslands as shown in Figure 45, demonstrate significantly higher baseflow values compared to lowland areas. This suggests that natural ecosystems in upland areas are particularly effective at allowing water to infiltrate into the ground, contributing to sustained groundwater levels and streamflow during dry periods

Table 32. Baseflow variation per land use/cover type.

Land Use/Land Cover Type	Baseflow (mm/m²/yr)
Agriculture	33851.92
Built-up Area	25660.90
Forest	35554.18
Grassland	36401.67
Open/Barren	37605.99

Similar to the results of the study by Owuor et al. (2016), bare land demonstrates a higher infiltration rate compared to forest areas. In their study, when bare land was restored, groundwater recharge decreased significantly, especially when the land was converted to forests. While open/barren lands may display the highest baseflow that may be attributed to the reduced evapotranspiration and fewer obstacles to water infiltration, it's important to note that this doesn't necessarily make them the most desirable or sustainable land use. These areas can be prone to erosion, and they often have limited ecological value.

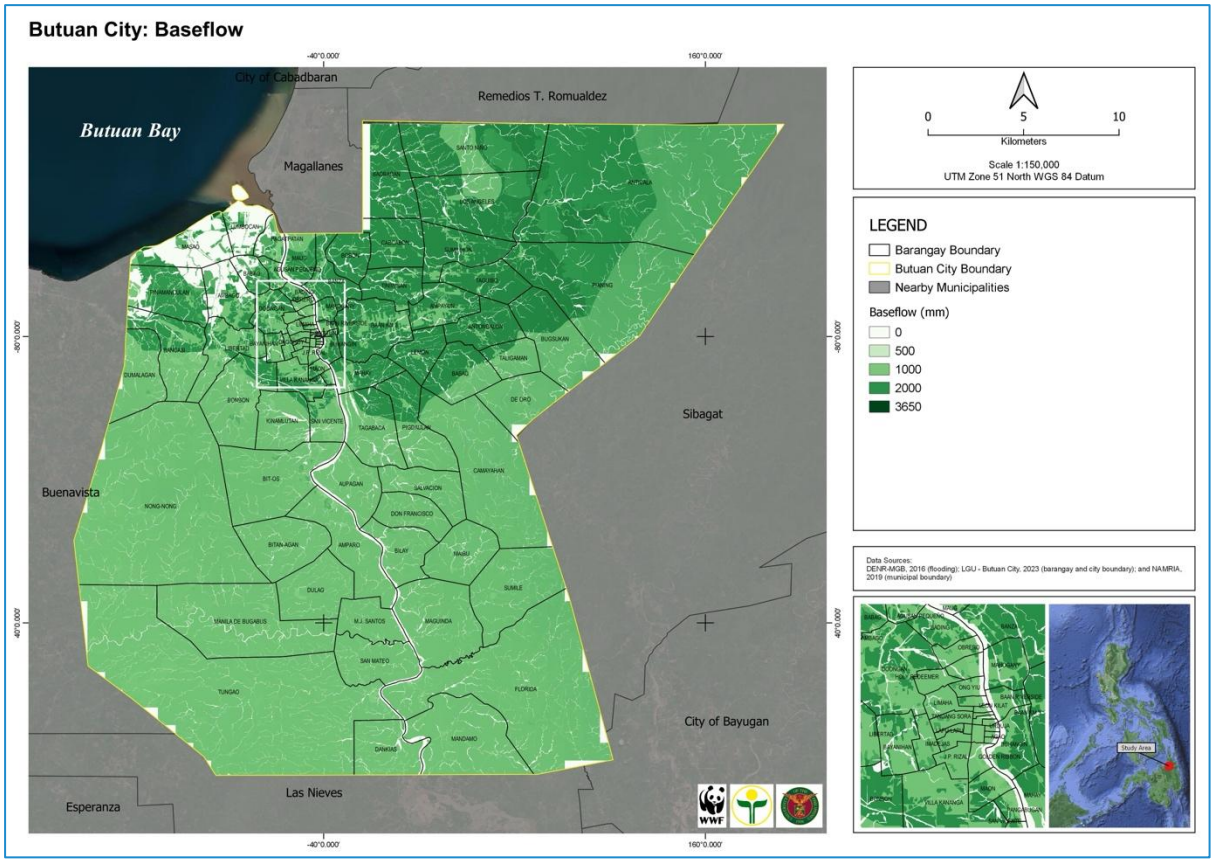


Figure 45. Baseflow in Butuan City.

In contrast, built-up areas have significantly lower baseflow, likely due to the prevalence of impermeable surfaces that prevent water from seeping into the soil. Agricultural lands also show moderate baseflow, which might also indicate that certain practices may hinder water retention.

The results underscore the importance of maintaining natural land cover, particularly in upland areas, for effective water management.

B. Carbon Storage

Carbon storage refers to the ability of ecosystems, such as forests and wetlands, to capture and store carbon dioxide from the atmosphere. This process is crucial in mitigating climate change, as it helps reduce carbon dioxide and supports efforts to achieve carbon neutrality (Wang et al., 2021). The InVEST model is used to evaluate the carbon storage of ecosystems, offering several advantages, such as ease of use, minimal data requirements, relatively accurate results, and the ability to visually represent these results spatially. Because of these benefits, it is widely used to assess the impact of land use on carbon storage (Wu et al., 2024).

Figure 46 shows the carbon distribution within the city. The majority of carbon is stored in the upper reaches of the city, coinciding with the location of the Taguibo watershed forest. These areas are predominantly forested.

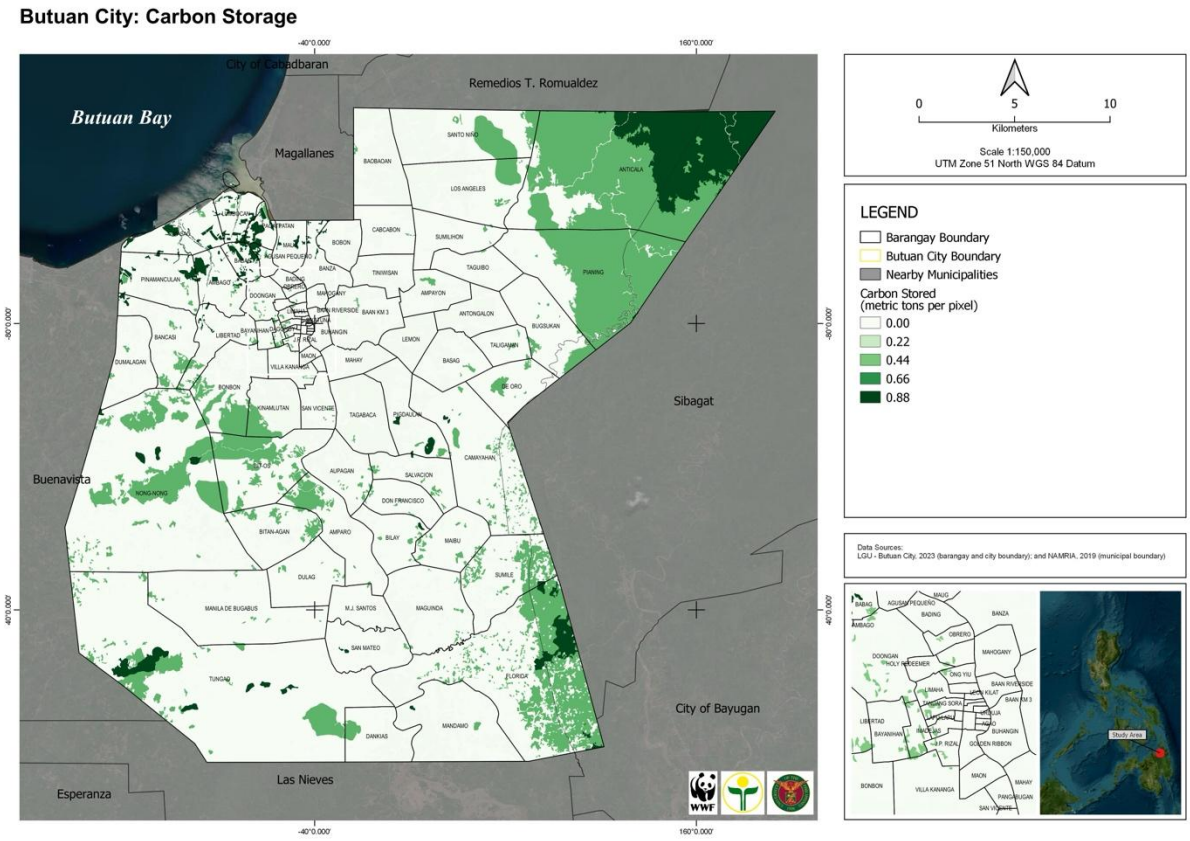


Figure 46. Carbon storage map for Butuan City

Table 33 shows the carbon stock values across different land use and land cover types, revealing significant variations in their carbon storage capacity. Forested areas hold the highest carbon stock per unit area, emphasizing their critical role in carbon sequestration and climate change mitigation. Grasslands follow with moderate carbon storage, while agricultural areas exhibit minimal carbon storage, largely due to land disturbances from farming practices. Built-up and open/barren areas have no carbon stock, reflecting their lack of vegetation and contribution to carbon sequestration. These results underscore the importance of protecting forests and sustainably managing grasslands to maximize carbon storage. In contrast, agricultural practices and urban development should incorporate climate-smart strategies like agroforestry and urban greening to mitigate the loss of carbon sequestration potential. The data highlights the need for land use planning to prioritize ecosystems with high carbon storage to support climate change mitigation and ecosystem resilience.

Table 33. Mean carbon storage by land use/land cover type (2020)

Land Use/Land Cover Type	Carbon stock (Metric tons per m^2)
Agriculture	0.023
Built-up Area	0.00
Forest	1.251
Grassland	0.527
Open/Barren	0.00

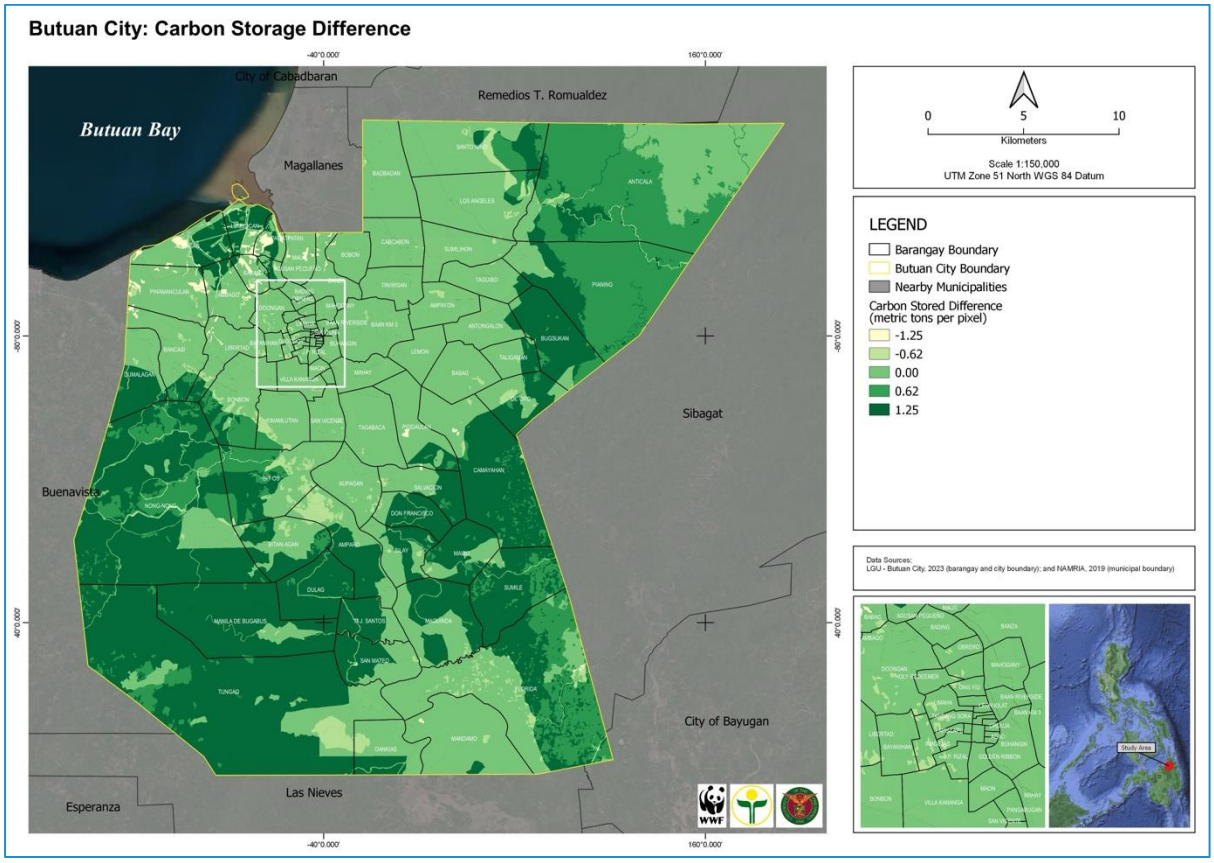


Figure 47. Carbon storage difference

C. Forest Carbon Edge Effect

The forest carbon edge effect refers to the reduction in carbon storage that occurs at forest edges compared to forest interiors, primarily due to forest fragmentation and degradation. This phenomenon is significant because forest edges can hold up to 25% less carbon than their interiors, leading to additional emissions, which contribute significantly to global carbon levels (Brinck et al., 2017). Forest fragmentation not only lowers the carbon sequestration potential of affected areas but also influences broader ecosystem functions and climate regulation. Properly accounting for these edge effects is essential for creating accurate carbon stock estimates, which are critical for climate change assessments and guiding landscape and forest management strategies (Chaplin-Kramer et al., 2015).

Ignoring these edge effects can lead to substantial overestimations of carbon storage in fragmented forests, resulting in misinformed policies and management plans (Chaplin-Kramer et al., 2015). By addressing the degradation of forest edges and the variability of carbon storage, carbon assessments become more reliable and valuable for policy development. Additionally, considering edge regeneration along with reforestation can significantly improve projections of potential carbon gains by over 20% (Chaplin-Kramer et al., 2021).

In this study, the InVEST Forest Carbon Edge Effect Model was utilized to assess the degradation of forest carbon stocks due to the creation of forest edges. This model applies established relationships between carbon storage and proximity to forest edges to estimate the edge effects on carbon storage. It integrates these estimates with carbon inventory data to create a comprehensive carbon map, focusing solely on above-ground carbon. Through this approach, the model provides a spatially explicit assessment that captures the impact of forest edges on carbon storage, allowing for more accurate climate assessments and better-informed forest management practices (Lam et al., 2021).

Table 34 shows the disparity in carbon stock among different land use/land cover. The mean values indicate the average carbon storage per (unit area) for each land use/land cover type.

Table 34. Variation in carbon stock across forest edges

Land Use/Land Cover Type	Carbon stock (Mg) per m^2
Agriculture	0.063
Built-up Area	0.000
Forest	22.216
Grassland	10.785
Open/Barren	0.000

Forests exhibit the highest carbon stock, followed by grasslands, while agriculture, built-up areas, and open/barren land have negligible or low carbon storage capacity.

The carbon storage capacity of forests is not solely determined by the type of forest but also by its proximity to other land cover types. The forest edge effect refers to the phenomenon where the carbon stock at the edge of a forest differs from that within the interior due to changes in microclimate, soil conditions, and disturbance regimes.

To maximize carbon storage, it is crucial to protect and restore intact forest ecosystems while also considering the impacts of forest edges. Strategies to mitigate the negative effects of forest edges include maintaining buffer zones, restoring degraded edges, and implementing sustainable land management practices in adjacent areas. By addressing these factors, policymakers and land managers can help to ensure the long-term sustainability of forests and their contribution to carbon sequestration.

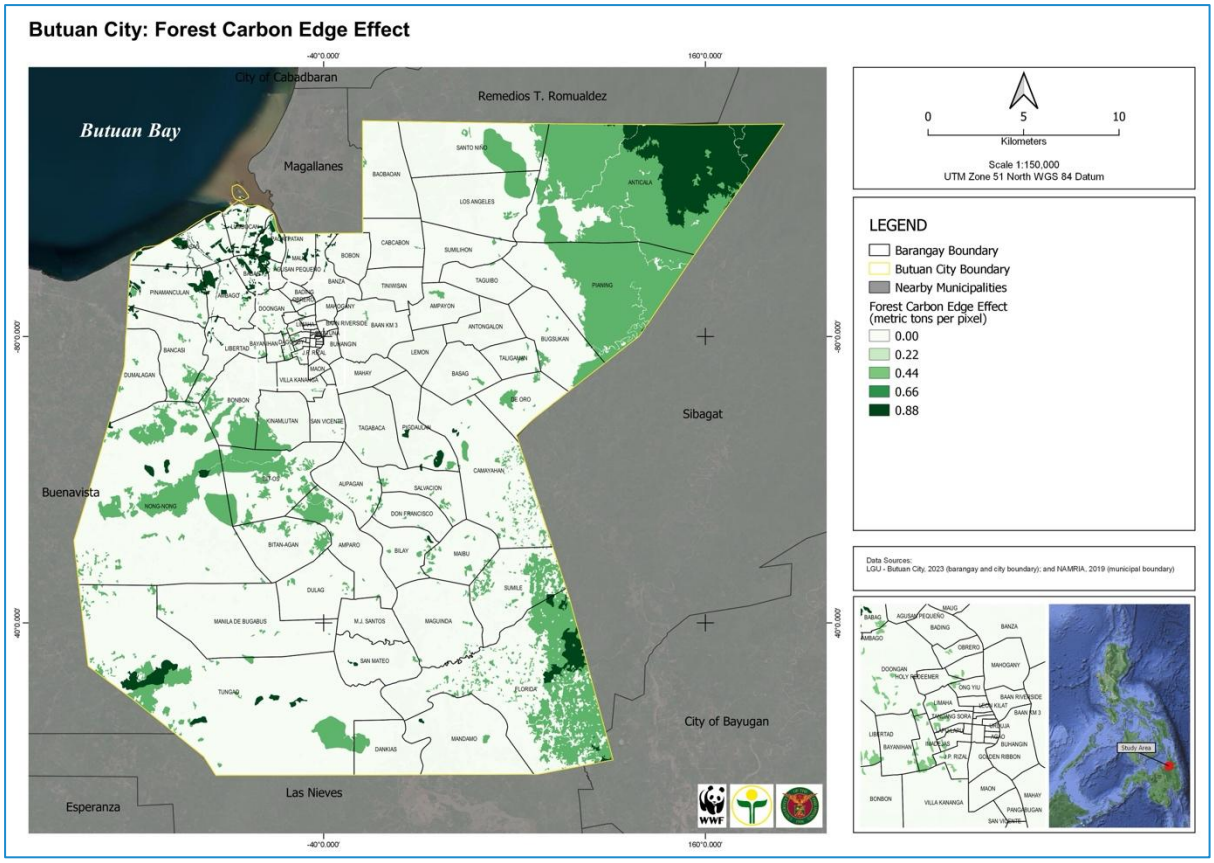


Figure 48. Forest Carbon Edge Effect for Butuan City

D. Local Recharge

Local recharge refers to the process in which water infiltrates from the surface into deeper soil layers, replenishing underground water sources (Dass et al., 2023). This process is crucial because it contributes to baseflow, the portion of streamflow sustained during dry periods. In regions where water availability is scarce, particularly during dry seasons, ensuring local recharge is essential for maintaining a stable water supply. Watershed management programs often aim to secure water resources, and understanding the factors that influence local recharge is critical to achieving this goal (Hamel et al., 2020).

Local recharge is computed through the local water balance, where precipitation that is not lost as quick flow or evapotranspiration can infiltrate the soil and recharge groundwater. This calculation highlights the importance of landscape management and how changes to the land surface can impact water balance, affecting both water security and the broader ecosystem services derived from freshwater, such as food and energy security (Mishra et al., 2021; Vári et al., 2021).

The InVEST SWYM model was used to quantify local recharge. The model estimates local recharge by subtracting quick flow and actual evapotranspiration from total precipitation, providing a spatial understanding of how water infiltrates the land and

contributes to underground water reserves (Bagstad et al., 2018). This tool is particularly useful in data-scarce environments, helping managers assess the impact of landscape changes on seasonal water balance and develop strategies for sustaining essential water-related ecosystem services (Sahle et al., 2019).

Results of the model revealodel revealodel reveal that grasslands and forests are particularly effective in promoting groundwater recharge due to their ability to absorb rainwater, reduce runoff, and improve soil infiltration. While agriculture can also contribute to recharge, its effectiveness can vary depending on specific practices. Built-up areas, on the other hand, often hinder groundwater recharge due to the prevalence of impermeable surfaces. Open/barren land can also be effective in promoting recharge, especially if undisturbed.

Table 35. Mean local recharge by land use/land cover type (2020)

Land Use/Land Cover Type	Mean Local Recharge (mm/m^2)
Agriculture	0.0000008129
Built-up Area	0.0000006200
Forest	0.0000008523
Grassland	0.0000008760
Open/Barren	0.0000008991

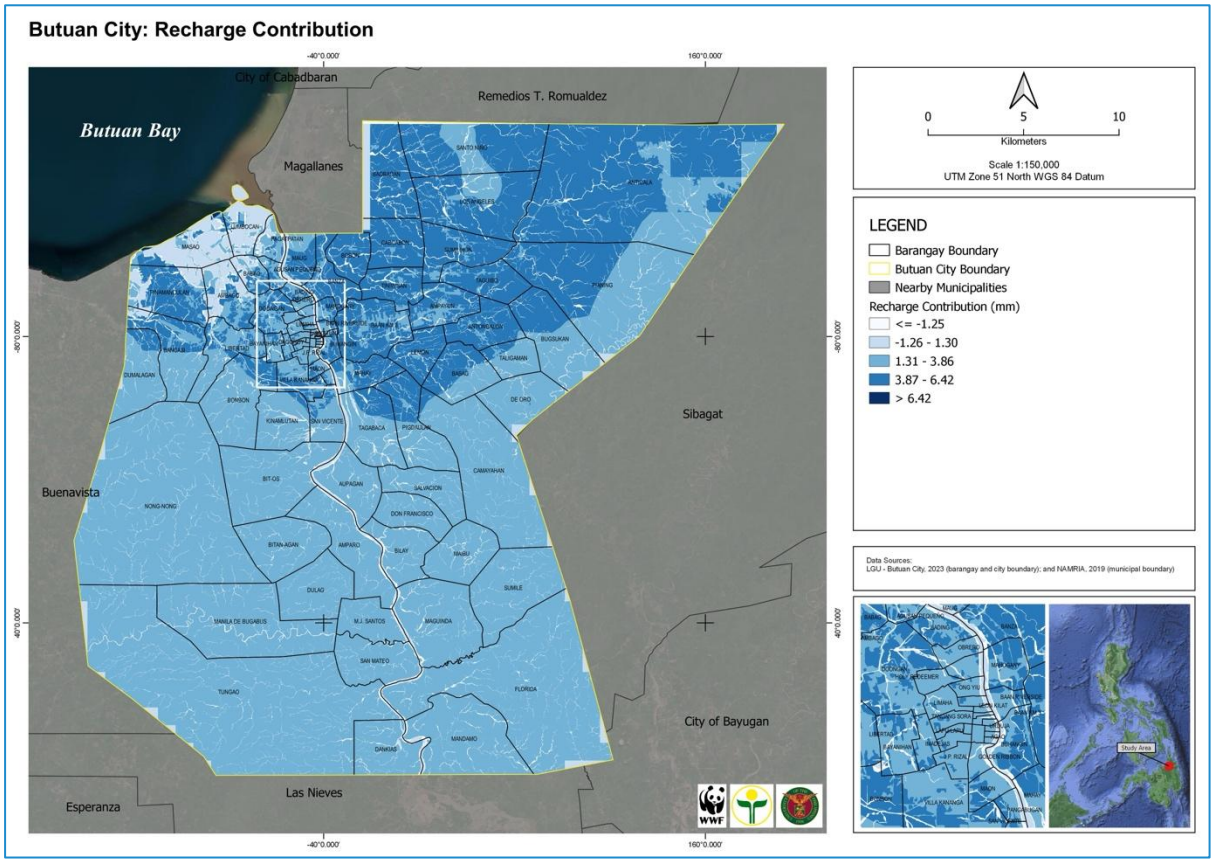


Figure 49. Recharge contribution for Butuan City

E. Urban Cooling

Urban areas are particularly vulnerable to the urban heat island (UHI) effect, where cities experience higher ambient temperatures compared to surrounding rural regions (Zawadzka et al., 2021). This phenomenon has become a significant threat, especially in densely populated cities already facing the consequences of climate change, and it poses serious risks to public health and well-being (Ronchi et al., 2020). The UHI effect not only intensifies the prevalence of vector-borne diseases, such as dengue, but also reduces thermal comfort, increases energy consumption and disproportionately exposes vulnerable populations to extreme heat (Silveira et al., 2024). To address these challenges, various interventions have been explored, including reflective surfaces to cool the built environment and the incorporation of urban green spaces to regulate temperatures (Anand & Sailor, 2023).

The InVEST Urban Cooling Model (UCM) was used to evaluate the ecosystem service that reduces UHI in Butuan City. The model plays a critical role in mitigating the UHI effect by leveraging data on land use, weather patterns, and biophysical factors (Chung et al., 2024). It simulates the spatial distribution of UHI by modeling key biophysical processes, such as evapotranspiration and albedo, and provides a spatially explicit framework to evaluate how different urbanization scenarios might influence heat distribution. This makes the UCM a valuable tool for urban planners and decision-makers, offering practical solutions for designing urban landscapes that mitigate heat impacts while balancing ecosystem tradeoffs (Hu et al., 2023).

Table 36 illustrates the urban heat mitigation (HM) index for different land use and land cover types. The HM index reflects the cooling effect of various land covers, with the value influenced by the proximity to large green spaces (>2 ha).

Table 36. Urban Heat Mitigation Index by Land Use/Land Cover Type

Land Use/Land Cover Type	Urban Heat Mitigation Index
Agriculture	23.864
Built-up Area	17.680
Forest	24.654
Grassland	24.579
Open/Barren	21.771

Forests and grasslands have the highest HM values, which indicates their strong ability to cool surrounding areas. This is due to their dense vegetation, which promotes shading and evapotranspiration, both of which are key factors in heat reduction (Gunawardena et al., 2017). Agricultural areas and open/barren lands show moderate HM values. Although they provide some cooling effects, they are less effective compared to forests and grasslands. Built-up areas have the lowest HM value, indicating that they contribute the least to urban cooling. This is typical in urban environments where impervious surfaces (concrete, asphalt) dominate, limiting vegetation's role in heat mitigation.

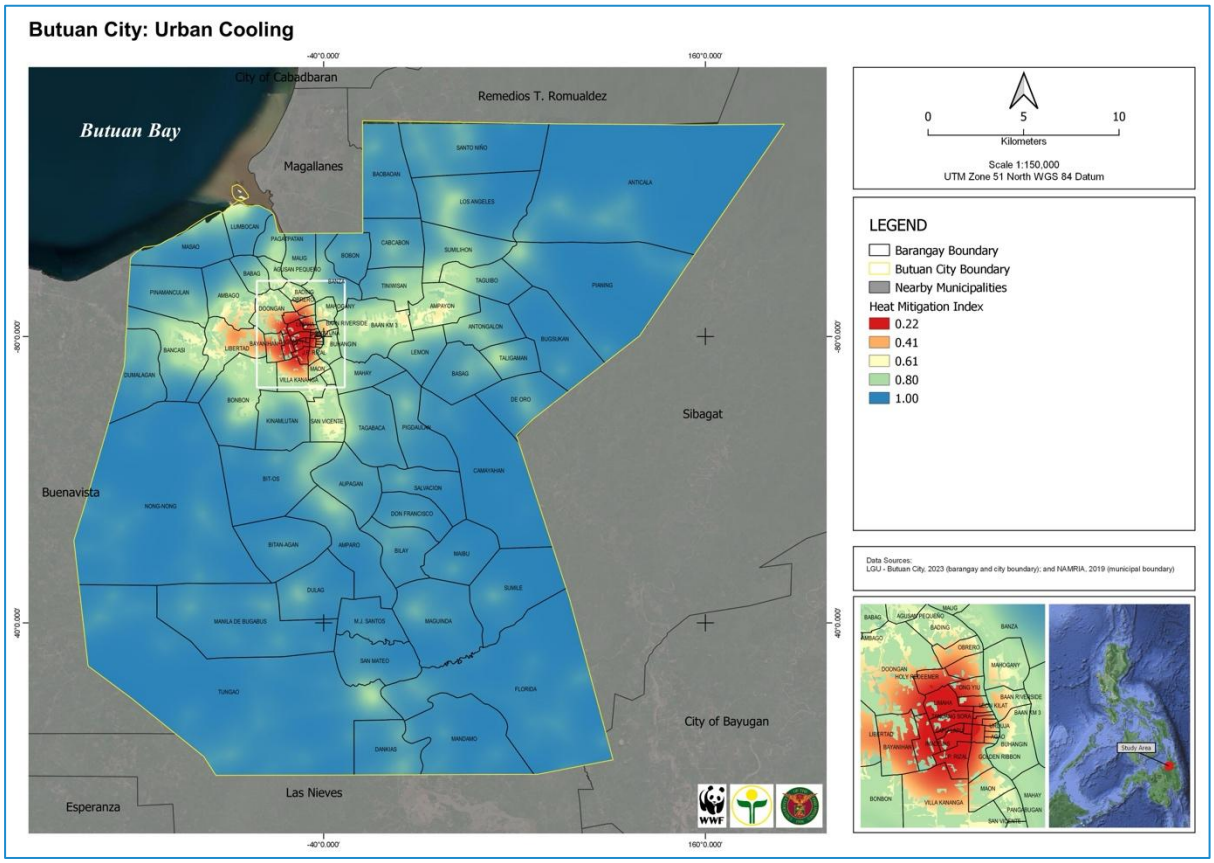


Figure 50. Map showing urban cooling through heat mitigation index for Butuan City

F. Urban Flood Risk Mitigation

Urban flooding has become a prevalent issue in cities, largely due to the increased impermeability of surfaces resulting from rapid urbanization. Climate change exacerbates this problem by intensifying the frequency and severity of extreme weather events, disrupting urban hydrology, and leading to more frequent flooding (Manandhar et al., 2023). Urban flood risk mitigation (UFRM) refers to the capacity of urban land surfaces to absorb and manage runoff (Dai et al., 2023). This ability highlights the benefits of urban ecosystems and green infrastructure, such as vegetation and soil, in mitigating flood risks by retaining and absorbing water during rainfall (Dong et al., 2023).

To estimate UFRM, the InVEST UFRM model was utilized to evaluate how effectively a city can reduce runoff during rain events. Although accurately estimating runoff in urban areas is challenging due to complex sewer systems and varying soil infiltration rates, the model simplifies these processes using empirical methods (Quagliolo et al., 2023). Its ease of use and adaptability make it a practical tool for urban flood mitigation across diverse urban settings (Xu et al., 2024; Bose & Mazumdar, 2023).

Table 37. Comparison of flood risk mitigation potential across different land use/land cover types

Land Use/Land Cover Type	Runoff Retention (m^3/m^2)
Agriculture	36.904
Built-up Area	15.447
Forest	41.663
Grassland	90.711
Open/Barren	34.515

Table 37 demonstrates the varying capacity of different land use/land cover types to mitigate urban flood risk. Grassland and forest, characterized by their complex ecological structures and high vegetation cover, are particularly effective in absorbing and retaining rainwater, reducing the likelihood of flooding. Agriculture and open/barren areas, while less effective than grassland and forest, still contribute to flood risk mitigation. Conversely, built-up areas, dominated by impervious surfaces like roads and buildings, have limited capacity to absorb rainwater, increasing the risk of flooding.

Based on Figure 51, it is notable that the coastal areas are one of those that have the least urban flood risk mitigation potential.

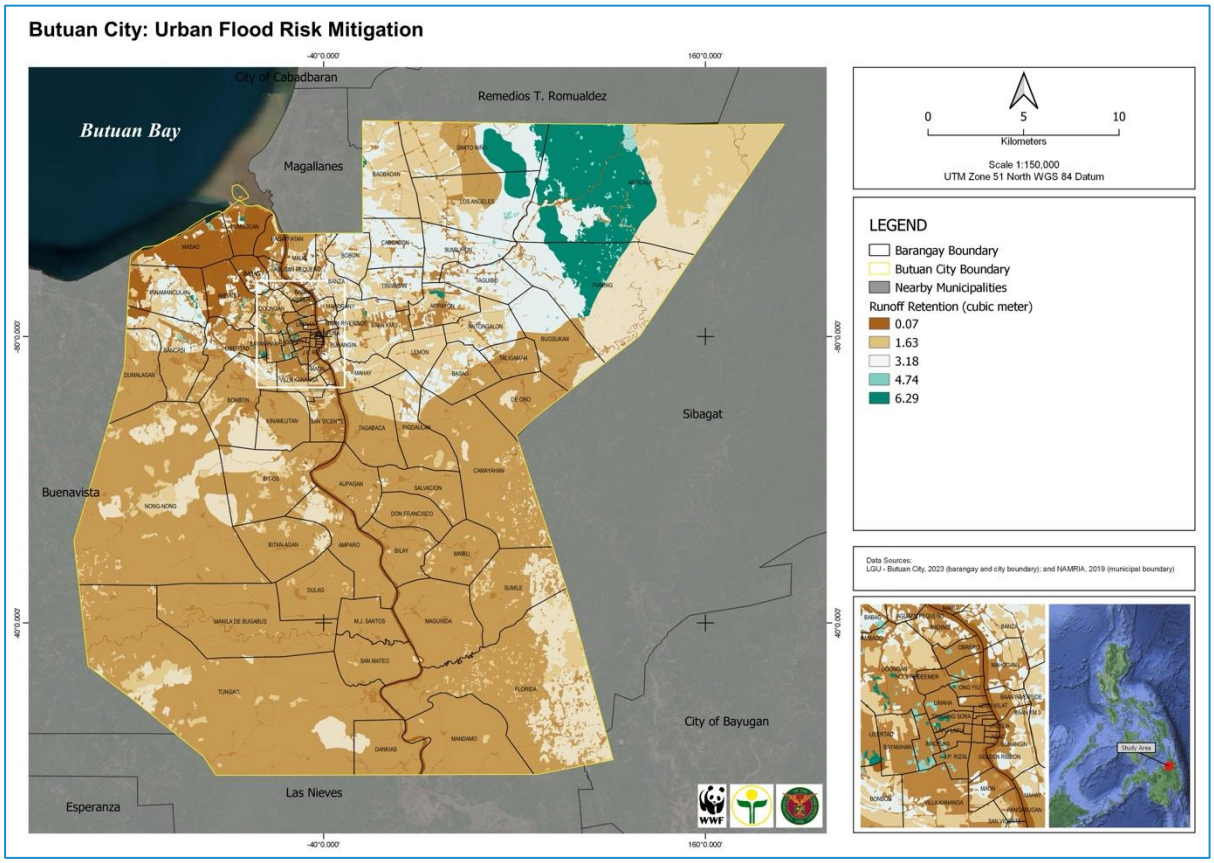


Figure 51. Urban flood risk mitigation showing runoff retention rate for Butuan City

G. Hotspots and Cold Spots of Ecosystem Services

Ecosystem service (ES) hotspot mapping is a valuable tool for identifying areas where the provision of ecosystem services is either at its highest or lowest. Hotspots refer to regions that deliver critical services such as water regulation, carbon storage, and biodiversity at high levels, while cold spots are areas where these services are minimal (Spanó et al., 2017). By mapping these areas, conservation planners can prioritize key locations for protection or restoration, directing resources to where they will have the greatest impact (Huo et al., 2018). This is especially crucial for integrating nature-based solutions (NbS) into linear infrastructure development and promoting sustainable development. By identifying ecological hotspots, planners can design infrastructure projects that minimize environmental impacts and enhance ecosystem resilience.

The increasing attention to ES hotspot mapping is driven by its ability to provide insights into conservation planning, assess the effectiveness of conservation efforts, and guide the management of synergies and conflicts within ecosystem services (Blumstein & Thompson, 2015). However, many decision-makers remain unaware of the potential for spatial prioritization to inform sustainable ecosystem service provision and management strategies (Schröter & Remme, 2016). By identifying both ecological hotspots and coldspots, this method offers critical scientific guidance for setting ecological protection boundaries and prioritizing areas for restoration (Dong et al., 2024). In the context of linear infrastructure and broader sustainable development, this information is invaluable for recommending NbS that can enhance ecosystem services while reducing environmental degradation, ensuring that development projects contribute positively to the surrounding ecosystems.

Figure 52 illustrates the spatial distribution of ecosystem service concentrations across various barangays. The areas with the highest ecosystem service (ES) hotspots are concentrated in Antongalon, Taguibo, Sumilihon, Lemon, Cabcabon, Los Angeles, Bonbon, and Tininwisan. Other barangays, including Sto. Niño, Anticala, Baan Km 3, Ampayon, Banza, Pianig, Mahay, Basag, Baobaoan, Bugsukan, Buhangin, and Doongan, exhibit moderate ES concentrations but still play a significant role in providing the ecosystem services that are deemed necessary by the local communities.

It is crucial to assess the tradeoffs between infrastructure development and the preservation of ecosystem services. By integrating nature-based solutions (NbS) into the planning process, decision-makers can strike a balance between the necessary expansion of infrastructure and the protection of ecosystems that provide long-term benefits to both the environment and local communities. This approach helps ensure that economic progress does not come at the expense of ecosystem degradation, safeguarding the services that are essential for sustainable development.

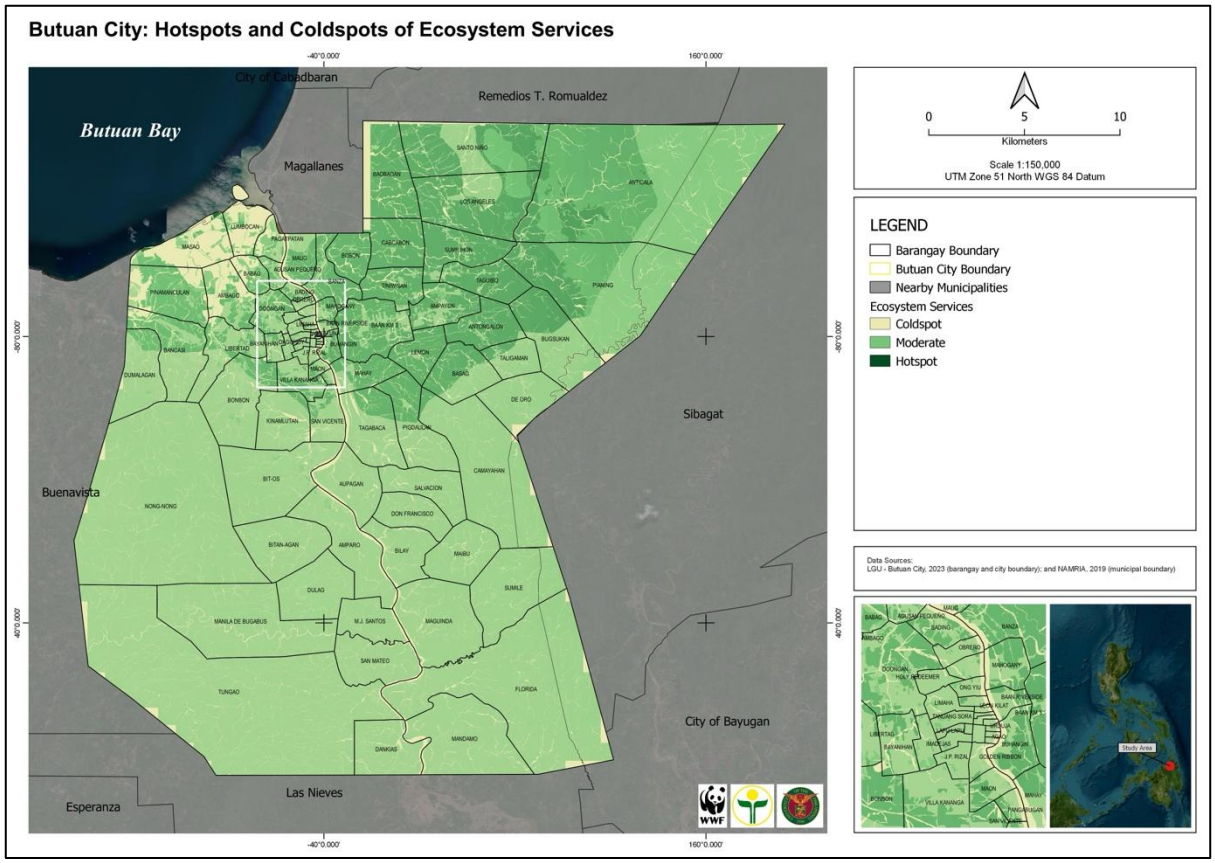


Figure 52. Hotspots and cold spots of ecosystem services for Butuan City

Table 38 demonstrates the varying concentrations of ecosystem service bundles across different land use/land cover types. Agriculture offers the highest concentration of these services. Forests also provide a wide array of benefits. Grasslands and open/barren areas, while less structurally complex, still contribute significantly to ecosystem services. Conversely, built-up areas, often dominated by human-made structures and limited vegetation, exhibit the lowest concentration of ecosystem service bundles.

It's important to note that this research's ecosystem service assessment was not exhaustive, focusing only on those perceived as critical by local stakeholders. Numerous regulating ecosystem services, often invisible to the general public, may not have been considered. Despite this, forests, both theoretically and empirically, remain the most effective land use/cover for providing a wide range of ecosystem services. Their complex ecological structures, high biodiversity, and crucial roles in regulating climate, water, and soil make them invaluable to human well-being.

Table 38. Distribution of Ecosystem Service Bundles Across Land Use/Land Cover Types

Land Use/Land Cover Type	Concentration of ES Bundles
Agriculture	Moderate
Built-up Area	Low
Forest	High
Grassland	High
Open/Barren	Moderate

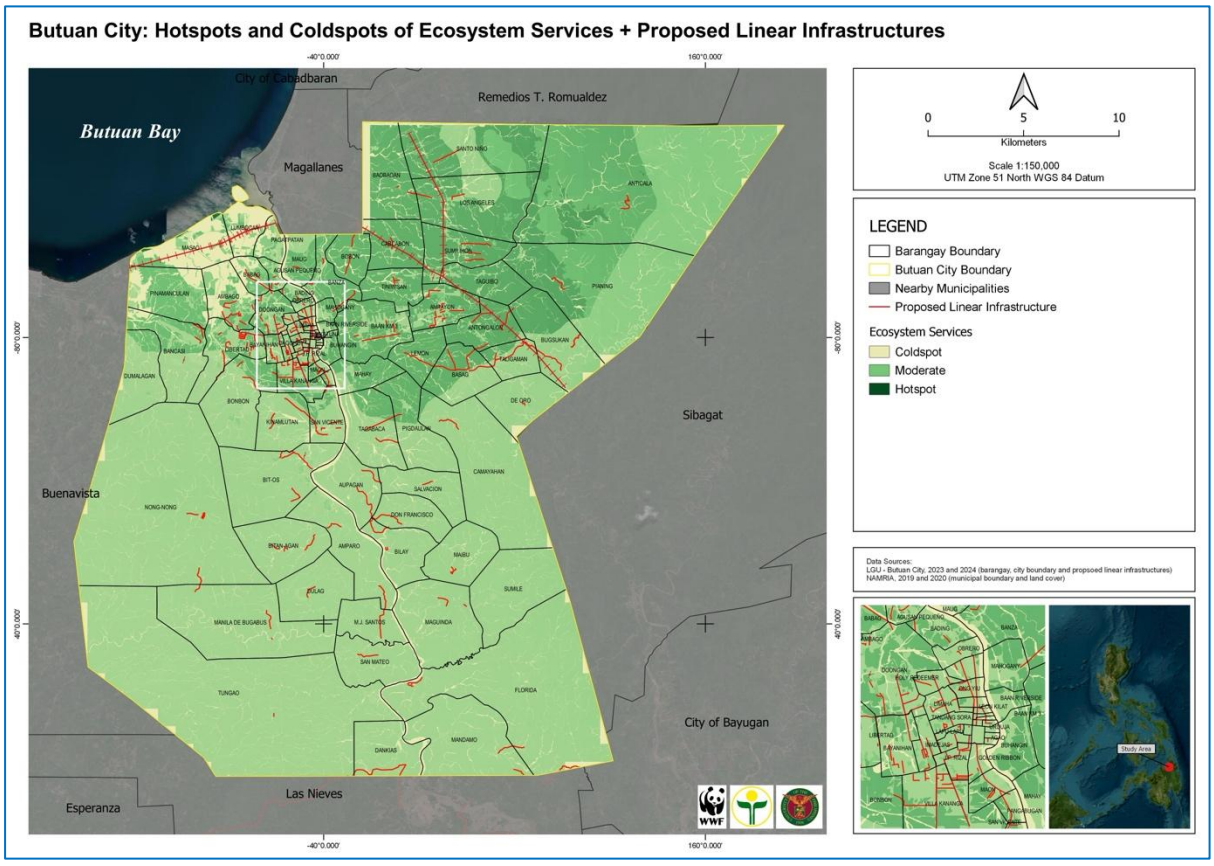


Figure 53. Ecosystem Service Hotspots and Cold Spots Overlaid with Future Linear Infrastructure Plans (2020).

Figure 54 illustrates the future linear infrastructure plans and how they fall within areas with a high concentration of ecosystem services (ES). A significant portion of the planned infrastructure, including roads and other linear developments, overlaps with agricultural regions that are classified as ES hotspots. These areas exhibit a high provision of ecosystem services with great importance to the local communities.

The concentration of planned infrastructure in these ES-rich zones presents both opportunities and challenges. On the one hand, such development can enhance access to these areas, potentially supporting agricultural productivity and rural development. However, it also poses a risk of ecosystem degradation, as linear infrastructure can lead to habitat fragmentation, increased runoff, and loss of soil fertility. Agricultural regions, being critical

for both food security and environmental sustainability, play a vital role in maintaining the balance between human needs and ecological health.

The findings from this map underscore the importance of integrating nature-based solutions (NbS) into infrastructure planning. Careful consideration of ecosystem services in these regions can inform strategies that mitigate negative impacts, such as designing green corridors alongside infrastructure to preserve ecological connectivity or using sustainable construction methods that minimize soil and habitat disturbance. Ensuring that infrastructure projects in ES hotspots are planned with environmental sustainability in mind is key to balancing development and long-term ecosystem health, ultimately contributing to the goals of sustainable development.

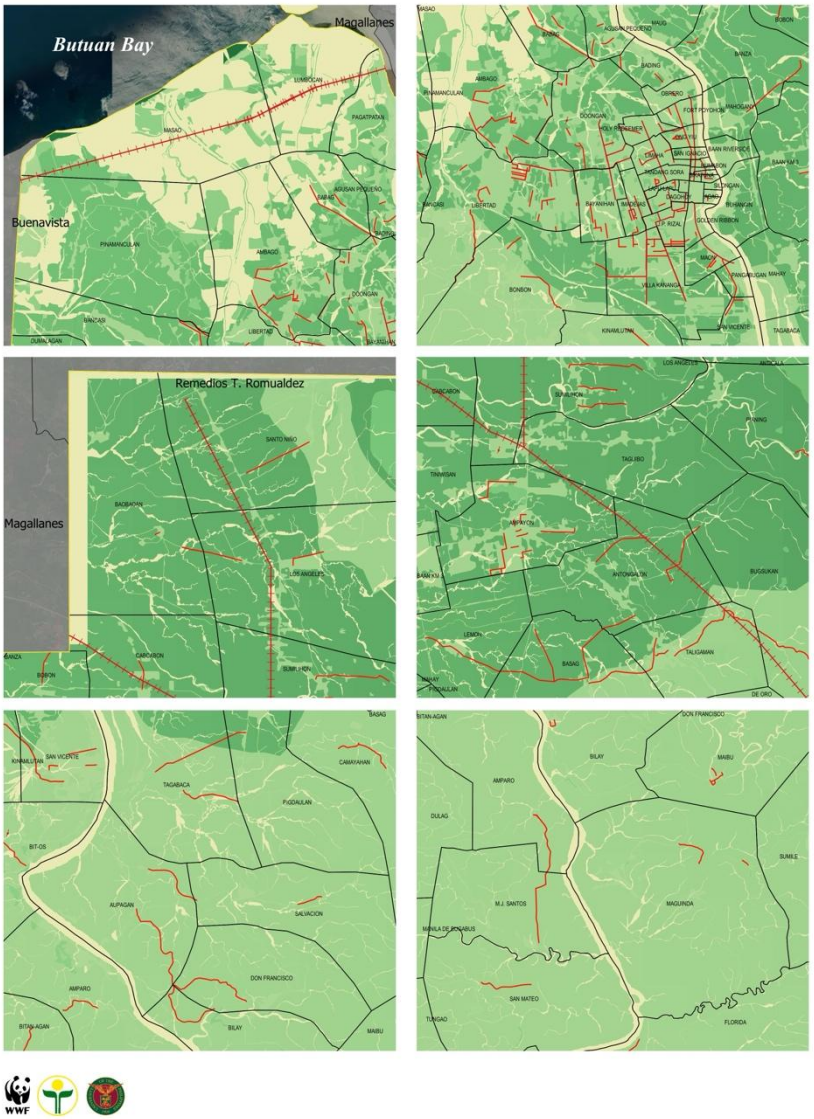


Figure 54. Proposed linear infrastructure within ES hotspots in Butuan City.

IV. Potential NbS Recommendation

Pre-conditions of NbS Recommendations

Prior to the implementation of an NbS-infused linear infrastructure project, several preconditions are suggested which are crucial to the realization of the project in the first place. These involve: **(A)** Enabling Policy and Regulatory Framework, **(B)** Engaged and Informed Stakeholders, including NbS-aware Implementing Agencies **(C)** Available Socio-ecological, Environmental, and Climatic Data, and **(D)** Established Ad-hoc Committees. The latter precondition, the needed Ad-hoc Committees are further categorized into **(d1**) Planning and Conceptualization, **(D2**) Capacity- and Scenario-building, and **(D3**) Evaluation and Monitoring.

A. Enabling Policy and Regulatory Frameworks

Implementing interventions to address a particular social issue will ultimately depend on whether these interventions are legally allowed by an administrative entity or not. At a nation-state's formal institutions of government, policies that promote and prioritize NbS in linear infrastructure planning will promote foundational imperatives for constructing linear infrastructures with NbS as key components. The nature of enabling policies may be explicit in providing specific details for infusing linear infrastructures with NbS, or implicitly embedded in currently existing policies which could aid in promoting systems that recognize and prioritize NbS in linear infrastructure planning.

Regulations which may implicitly enable NbS in infrastructure planning include policy frameworks that promote collaboration between different government agencies towards sustainable infrastructure; environmental impact assessment systems that promote alternative infrastructures which consider social, ecological, cultural, and spiritual concerns; science and technology roadmaps which induce research projects tackling NbS, green infrastructure, risk mapping, and other related concepts; and other existing laws which eventually could be leveraged for recognizing the importance of NbS. Most often, governments have some form of policy which tackles sustainability which could be further be emphasized together with other related laws to clearly enable the inclusion of NbS in infrastructure planning. The important task is to determine what these specific enabling policy and regulatory frameworks are in terms of scope and bureaucratic agents.

In cases when enabling policy frameworks are present along with regulatory barriers that would disable NbS in linear infrastructure planning, thorough legal research is required to determine how existing barriers can be addressed (see al Albert et al. 2019). This may also require the creation of new frameworks to explicitly integrate NbS in planning systems and national development strategies (Geneletti et al. 2020). Lobbying and policy-advocacy

activities may also be important to create the necessary legal frameworks for NbS and linear infrastructure planning. Apart from explicit policy frameworks, indirect policies for NbS may include economic and financial mechanisms for quantifying ecosystem services to eventually support NbS in infrastructure planning (Droste et al. 2017). Barriers for scaling-up local knowledge and application of NbS can also be addressed by developing financing strategies and cost-benefit analysis to support large-scale implementation of NbS in infrastructure planning (Nesshöver et al. 2017). What matters in the presence of legal barriers is that these same frameworks can evolve to support NbS not just in the context of infrastructure projects but as a general alternative for any applicable development project, whether these are implemented by the government or a non-government enterprise (Eggermont et al. 2015; McQuaid, Rhodes & Ortega 2021)

B. Engaged and Informed Stakeholders, including NbS-aware Implementing Agencies

The successful integration of identified alternatives to improve linear infrastructure, including the recognition of NbS, requires the engagement of a wide range of informed stakeholders throughout the planning process. These stakeholder groups include local communities in the actual project site, as well as communities adjacent to the project site; government agencies, especially agencies directly involved in project implementation; environmental NGOs which could further provide technical support, and even access to global funds not accessible by government agencies; the private sector which could contribute to necessary resources, but also for changing business practices into more sustainable systems, and; other stakeholder groups who need to be made aware of NbS as a concept, stakeholders that need to be engaged and involved, and stakeholders who should be informed about what is best for their affairs and practices. Stakeholder engagement across sectors and administrative scales is important for mainstreaming NbS in infrastructure planning, especially complex infrastructure systems (Frantzeskaki 2019).

C. Available Socio-ecological, Environmental, and Climatic Data

Socio-ecological data is important to know who the original communities are in the project site, and potentially avoid issues of migration and displacement arising from implemented NbS projects. Their relationships with the land, including the specific natural resources they rely on for their livelihoods, should be available to minimize disruptions. In connection with this, biodiversity data, land use and landcover, watershed parameters, among other related environmental data are important to determine the proper species that (1) need to be incorporated in the planned NbS and infrastructure, (2) critical landscapes that need to be enhanced or maintained, (3) the scope of areas that may be affected by the planned infrastructure, and (4) other necessary climatic data to assess the baseline conditions prior to planned interventions.

Apart from the presence of robust data, especially environmental and climate data to ensure the resilience of NbS, information related to stakeholders involved should also be present to determine their level of support and eventual dedication to ensure that projects consider NbS, and that implemented NbS projects are maintained (see also Seddon et al. 2020). Data is also important for anticipating future scenarios, including landscape change patterns, climatic scenarios, sea-level conditions, among other data related to the prediction of impacts to constructed infrastructures. As also shown in this report, the importance of available data can be seen in determining the potential areas for NbS-related infrastructure projects, as well as the overall social conditions that may sustain such projects when implemented. In case data gaps are present, it is important to secure and generate these data sets to enhance the resilience of NbS-infused infrastructure (Chausson et al. 2020). Additionally, the importance of basic research and the systems which promote basic research and data generation across various government institutions is highlighted as a critical precondition for mainstreaming NbS in infrastructure planning.

D. Established Ad-hoc Committees

Ad-hoc committees are influential in steering various stakeholders towards the use of NbS in infrastructure projects. Three specific committees are identified in this report as crucial to guide the different processes of infrastructure construction. These include a committee for Planning and Conceptualization, Scenario- and Capacity-building, and Evaluation and Monitoring, as further described as follows:

1. Planning and Conceptualization

Engineers, environmental and urban planners, policymakers, community members, among other stakeholders should establish the overall characteristics of the project site, identify the actual problem and its root causes, and the best approach if NbS are included in the potential infrastructure project. The multidisciplinary nature of this Planning and Conceptualization Committee will also be crucial for demonstration projects, case studies, feasibility indicators, and other related technical parameters to boost the acceptability of conceptualized projects and related plans for its construction. This Committee may also help in establishing other necessary committees to support the implementation of the NbS-infrastructure project.

2. Capacity- and Scenario-building

As a relatively novel concept, capacity-building is important to increase awareness and adoption of NbS, and enable the proper integration of NbS in linear infrastructure projects (Kabisch et al. 2016, Raymond et al. 2017)). In future scenarios in which NbS in infrastructures is already a standard practice, capacity-building is still deemed important to minimize risks of impacts brought by environmental uncertainties and social interactions. Scenario-building is therefore important to anticipate these future, "what if…" scenarios and ensure that planned infrastructures with NbS will withstand future shocks.

3. Evaluation and Monitoring

Even before the actual project is implemented, the establishment of an evaluation and monitoring committee together with the abovementioned committees is a precondition for a successful NbS-infrastructure project due to two reasons. Firstly, relevant indicators will already be determined together with accepted NbS project as identified by the Planning and Conceptualization Committee. This will guide future and actual monitoring, evaluation, accountability, and learning (MEAL) teams to have a working document for their roles and responsibilities. Secondly, identified indicators will create a focused research agenda to modify and improve set indicators. This Committee would thus be important for aligning indicators with concurrent ecological and community needs.

Potential NbS for Butuan City and upstream municipalities

In identifying the NbS strategies for Butuan City and upstream municipalities along the Agusan River Basin, different criteria need to be considered. For this initiative, we followed the criteria as enumerated by IUCN Global Standard for Nbs (Figure 55). These criteria were established to guide various stakeholder groups in the design, selection, and implementation of various NbS strategies. These stakeholder groups include civil society organizations, government (national and local), planners, and representatives from other development organizations (IUCN, 2020). The use of these criteria offers opportunities in assessing both the suitability and sustainability of the different NbS strategies within a specific geographical scale and context.

The IUCN criteria highlight the different areas of design and implementation of NbS strategies. It highlights the need for stakeholders to consider the social, economic, institutional and environmental dimensions of NbS strategies. By ensuring that the NbS strategies are based on the local context where these will be implemented, planners and policymakers will be able to design strategies based on the actual needs of the local people and environmental conditions of the watershed or specific locality. It could result in a more effective set of NbS strategies.

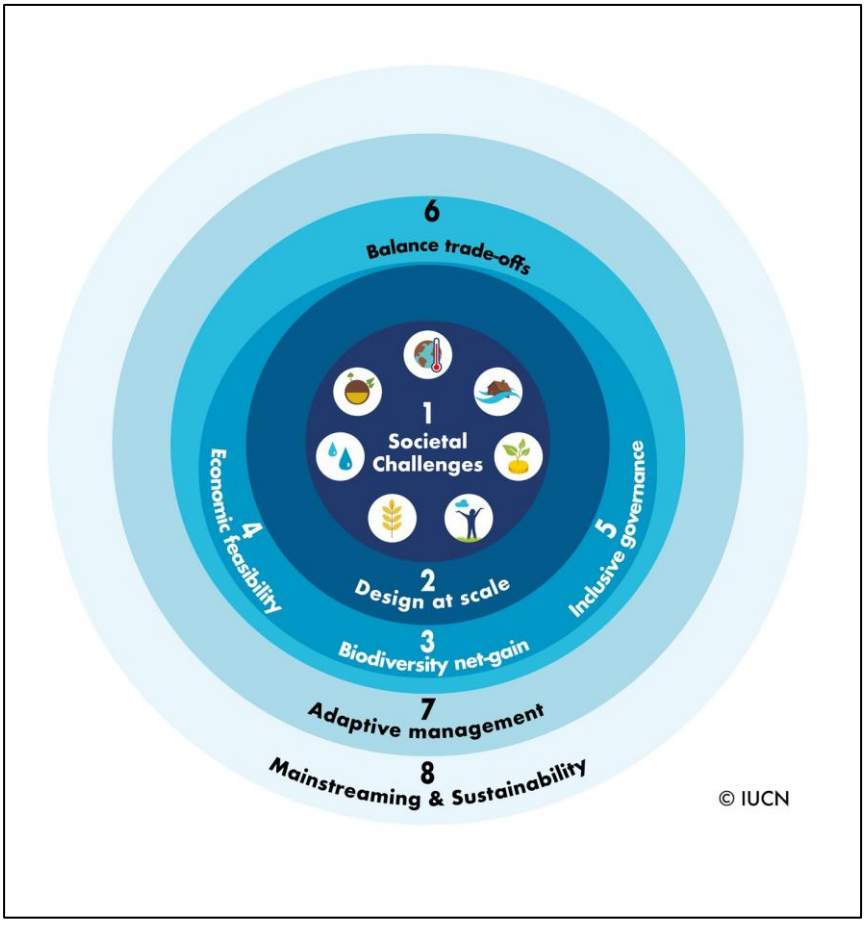


Figure 55. The IUCN Global Standard for Nature-based Solutions

The following are the criteria for the selection of NbS recommendations for Butuan City (IUCN, 2020):

Criterion 1: NbS effectively address societal challenges
Criterion 2: Design of NbS is informed by scale
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity
Criterion 4: NbS are economically viable
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits
Criterion 7: NbS are managed adaptively, based on evidence
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context

Based on these criteria, the following are the recommended NbS in Butuan City and upstream municipalities along Agusan River:

1. Reforestation and Afforestation

To reduce the effects of urban heat island surrounding the urban, it is necessary to maintain tree lines, urban green spaces, and vertical and edible gardens. In the upstream areas, trees can help in the regulation of surface runoff and reduces the speed and volume of water heading downstream. Based on the Butuan City MPSUID, they have proposed projects to maintain and enhance urban green spaces in line with the planned infrastructure developments such as the: (1) Inner City; and (2) the Bood Promontory Heritage Park. These projects can be further enhanced to ensure it does not only comply with NbS Global Standard Criterion 1 but also are guided by the other criteria. Other municipalities may follow the reforestation and afforestation projects with consciousness of incorporating pockets of green spaces along linear infrastructures.

2. River Buffer Maintenance

Maintaining good vegetation (trees and mangroves) along the Agusan River will reduce floodwater overflow and provide aesthetic benefits to the local community. The Butuan City MPSUID includes a proposal to implement a River Park Development. What needs to be checked is if it follows the prescribed easement distance based on the Philippine water code should be observed. For upstream barangays and municipalities, they may explore planting endemic or enhancing existing vegetation (e.g. bamboo) to assist in river buffer maintenance.

Another river buffer maintenance that may be recommended is the *kasumi-tei*, a Japanese traditional green infrastructure composed of discontinuous embankments that has been existing since the 16th century (Sustainable Infrastructure Partnership, 2022). In contrast to the straight and commonly smooth ripraps and dikes, the *kasumi-tei* have portions where floodwater can overflow to rice paddies and riverbank forests where floodwater can be stored. It also helps slow down the energy of the water as it passes through the discontinuous embankments. Once the water level in the river recedes, the rice paddies and forests will be drained. For centuries, *kasumi-tei* helped Japanese communities to be less exposed to natural hazards and benefit from the stored floodwater.

At the downstream, another recommendation is to protect and enhance the mangroves that can be found in coastal communities such as in Barangay Pagatpatan. The Barangay Council oversees the *Dungon* Tree Board Walk and the Mantange Creek Eco Park which needs funding to develop it further into a tourism spot. When properly governed and managed, these mangroves can provide various ecosystem benefits, including livelihood.

3. Establish Agroforestry Systems

Integrating trees into agricultural landscapes can help reduce soil erosion and surface runoff in sloping areas. In addition to providing diversified income, trees can also help retention of soil nutrients.

4. Restoration of Wetlands

As part of the downstream areas and watershed outlet, floodable parks and wetlands near the outlet of Agusan River should be established to ease the peak flood flows during heavy rains. The Butuan City MPSUID made mention of vulnerable areas – or areas that will be zoned or retained as non-residential or commercial areas for the purposes of allowing flood to flow towards these areas. However, this was not mentioned in the CLUP. It is recommended that the city allocates or identifies this in the CLUP to avoid building residential or commercial spaces in the identified vulnerable areas. Other municipalities with wetlands and marshes may follow suit.

V. Gaps, Challenges, and Opportunities

Sustainable infrastructure planning and development enables socio-political systems and natural systems to work together in a manner that addresses the need for social and economic development while at the same time assures that nature remains to be protected, or better yet restored and enhanced. Mainstreaming NbS in infrastructure planning has merits, not just in making infrastructures greener but it enhances its capacity to mitigate greenhouse gas emissions. Moreso, when planned properly and with community ownership, NbS have the capability to provide better scenic and habitat quality as well as livelihood opportunities.

Butuan City and the rest of Caraga Region is in the best position to start integrating the concept of nature in planning. With the almost pristine environment in the mountain tops and still urbanizing city and town centers, Caraga region need to move forward in planning for Sustainable Infrastructures to address infrastructure needs while protecting, restoring, and enhancing the functionality of natural ecosystems. Through sustainable infrastructures, it is expected that Butuan City and the rest of the Caraga region will avoid further biodiversity loss, while maximizing the benefits coming from nature.

From the lessons on the assessments conducted in Butuan City, this section presents the gaps, challenges, and opportunities in mainstreaming NbS in infrastructure planning in Butuan City, and the rest of Caraga region.

Gaps

In collecting data for the analysis and assessments conducted, the following gaps were identified:

- The availability of updated and context-based local plans (e.g. CLUP, LCCAP, LDRRMP, MPSUID, BDP) is highly important. The case study site, Butuan City, has been on top of updating their plans but this may not be the case for other cities' and municipalities' planning documents. As planning entails resources to tap experts, stakeholders, and dedicated personnel to complete a plan, cities and municipalities with lower budgets and scarce resources might come up a plan for compliance but this might not be as elaborate and contextualized as the plans that Butuan City has.
- Not all cities in Caraga region has a MPSUID, which, in the case of Butuan City is a good reference point for mainstreaming NbS for Infrastructure Planning.
- Not all barangays visited had an updated and comprehensive BDP, BDRRM Plan or barangay profile, which is needed to assess the socio-economic status of communities and risks. The barangay profile and other barangay plans are useful reference material in community characterization.

- Spatial data, such as vector and raster are necessary for mapping climate risks and ecosystem services. For Butuan City, the project was able to request data on necessary for the project, including existing and proposed road networks, railways, and streetlights. Other cities and municipalities may or may not have such data readily available. In lieu of this, infrastructure planning consultants and experts will need to conduct thorough ground data collection.
- It was evident in the focus group discussions that local people are not yet familiar with the term "Nature-based Solutions". Such knowledge gap must be taken into consideration in proposing for NbS Projects where communities need to take part.
- Additional data regarding ecological characteristics and biodiversity in the area are still needed to fine-tune specific NbS projects to be implemented.
- Primary data related to participation and equity among stakeholders, governance, valuation, infrastructure integration, and scale and feedback are needed for the successful implementation of NbS projects.

Challenges

Since the NbS concept is still relatively new, albeit familiar among representatives of regional and city level offices, not all stakeholders and communities are familiar with it. The following presents the obstacles that may affect mainstreaming of NbS in infrastructure planning:

- Data on typhoons is accessible only at the DOST-PAGASA National Office and not at the PAGASA Butuan Synoptic Station. Extra effort is needed to reach out to the national office to receive data on regarding typhoons.
- The absence of a more updated river basin and watershed assessment reports may cause redundant or inefficient NbS approaches. In line with the need for a local technical working committee, assessments are important inputs to better understand biophysical and socio-economic profiles that are crucial basis for a more holistic infrastructure planning.
- Economic valuation of the potential costs and benefits of the recommended NbS is needed to avoid proposing projects simply as planting or reforestation activity, slope stabilization, or erosion control project. With valuation, policy makers and planners will have a basis on how important a proposed NbS is in combatting climate change and natural hazards in Butuan and the rest of Caraga region.
- Getting people to understand what NbS is means there should be a well-thought of Information, Education, and Communication plan. It is encouraged that technical people and stakeholders in Caraga Region agree on a local terminology that will make

it easy for most, if not all, local people to understand that nature can be a solution to the different natural hazards they are experiencing.

- While recommended NbS projects could eventually protect coastal and river basin communities from flooding, sea-level rise may result in the submergences of low lying plains of Butuan City. Identifying other sites with higher elevation for relocation might be a more efficient solution rather than relying purely on NbS. Some areas may also be better left as flood plains and marshlands instead of allowing people to reside in these areas.

- Sustainability of NbS Projects necessitates a whole-of-society approach, a guiding principle in the Sendai Framework for Disaster Risk Reduction 2015 – 2030. While NbS may be a good strategy to reduce carbon emissions, particularly those from infrastructure construction, it may not be effective if stakeholders will not participate in its implementation.

  From the experience of Barangay Pagatpatan in mangrove reforestation, the community's ownership in the management of mangroves enabled them to understand its value in providing protection, food, and livelihood to the community. The continuous extension work of Caraga State University in Pagatpatan also became an opportunity for a Wetlands Center to be established in their area. With such consciousness and partnership, the local people values the existence of mangrove forests as it provides various opportunities that exemplifies what a sustainable NbS should be.

- The absence of a policy framework to enjoin all stakeholders will be among the challenges. If a policy framework is present, then it is seen that the next challenge would be social mobilization and community organizing at the barangay level. At the city level, the challenge foreseen is in the creation of a watershed management council. At the river basin level, the council that composed the CARBDP may need to be tapped once again.

- The people are highly aware that grey infrastructures such as the drainage and dikes are among the solutions to combat flooding. While such infrastructures are deemed necessary and provides immediate relief, the high affinity of the local people to grey infrastructures may become a challenge in getting their partnership to implement green solutions that needs time to grow (time lag) until it can provide protection and various ecosystem services to the community.

Opportunities

Unlike metro cities, Butuan City still has a huge area with greenery. It has a watershed and is traversed by major tributaries, one of which is Agusan River. Most importantly, through a review of the available plans in the city, there are several projects that may be

tagged as NbS. This could be a starting point for the city and a model for the rest of Caraga region to integrate of NbS in infrastructure planning. There are other opportunities that were identified as well on how NbS can be mainstreamed towards sustainable infrastructure planning.

The list below presents opportunities on how NbS can be integrated towards sustainable infrastructure planning and development:

- The presence of PAGASA Butuan City is an opportunity for the cities and municipalities in Caraga region to access data on rainfall and temperature, which will provide planners and policymakers with insights on which months received the highest rainfall, leading to flooding, as well as highest temperatures that may lead to drought.
- Local governments should have their own Sustainable Infrastructure Development Plan. where infrastructure projects can also include green infrastructures. The assessments conducted for Butuan City revealed that it is in fact ahead in Sustainable Infrastructure Planning through its MPSUID and they already have green infrastructure projects identified that aims to enhance urban cooling effect of ecosystems, increase vegetation and prevent erosion through riverbank development projects, include permeable surfaces to reduce surface runoff, flooding, and pollution of Agusan river and set a river buffer zones. These projects, when planned properly, can already be tagged as NbS.
- NbS may be a complete replacement or done in combination with DRRM Projects that involves infrastructures**.** RA 10121 and the National Disaster Risk Reduction and Management Plan 2011-2028 stress the importance of increasing the resilience of local communities to various disasters, including those induced by climate change. The Butuan City DRRM Plan mentions projects that involves construction, dredging, setting up of equipment, and provision of livelihood to farmers and fisherfolks as socio-economic intervention. To mainstream NbS, DRRM Projects may incorporate NbS with infrastructure projects to improve disaster resilience. This will result in projects that are not only adaptive but also mitigative. Provincial, City, and Municipal Planners may determine in their respective DRRM Plans which of these can be replaced by NbS or implemented in conjunction with NbS.
- The Butuan City LCCAP identifies several projects that supports the greening of Butuan City. This involves implementing the green building code, festivals to promote the preservation and conservation of nature, establishment of naturally grown areas, establishment of key biodiversity areas, green tourism, use of solar energy, securing Indigenous People's Community in the watersheds, among others. Butuan's LCCAP may be used as a model of guide for other local governments to pattern their LCCAP, incorporate green strategies and ensure funding of NbS
- Most of the communities recognize the impacts of climate change, but may not be aware of the dynamics of watersheds, river basins, and ecosystem services. CCA-

DRRM IEC campaigns be a starting point for communities to become knowledgeable about watershed, river basins, ecosystem services, and NbS. If there are plans for IECs in any of the plans, the local government units can use this opportunity to educate communities on the benefits of NbS. Awareness facilitates further education and encourages them to take stewardship of local NbS.

- Presence of Key Biodiversity Areas (KBA) and Legislative Proposals for Protected Areas (PA) are opportunities to push forward for funding of NbS. Proposed NbS that utilizes species found in KBAs and PAs can be better appreciated by top-level management if these are implemented in relation to nationally recognized national resource management systems (e.g. NIPAS). For example, soil erosion controls and management of flashfloods in Mount Mayapay using endemic species may easily be funded or supported, especially that it is proposed in the congress to be included in the National Integrated Protected Areas System through House Bill No. 2267 in the 18th Congress.
- Several universities are present that can collaborate on sustainable infrastructure planning, particularly on the technical viabilities of projects. Among these are Father Saturnino Urios University and Caraga State University. Universities play a vital role in advancing sustainable infrastructure planning and implementing NbS by research to inform planners of best practices, facilitating knowledge transfer through outreach programs and partnerships with local governments, and fostering interdisciplinary collaboration across fields such as engineering, ecology, and urban planning. Universities can also provide research findings and expert recommendations to policy makers and planners in creating resilient communities that effectively utilize NbS.

VI. References

Adler, M. W. Pasidis, I. Levkovich, O., Lembcke, A. C. & Ahrend, R. (2020). Roads, market access and regional economic development. https://www.oecd-ilibrary.org/deliver/8b9eca17-en.pdf?itemId=/content/paper/8b9eca17-en&mimeType=application/pdf

Albert, C., Schröter, B., Haase, D., Brillinger, M., Henze, J., Herrmann, S., ... & Matzdorf, B. (2019). Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute?. Landscape and urban planning, 182, 12-21.

Anand, J., & Sailor, D.J. (2023). How can we combine urban cooling strategies to effectively cool cities over the entire diurnal cycle? Building and Environment, 242, 110524. https://doi.org/10.1016/j.buildenv.2023.110524

Aribal, L. G., & Fernando, E. S. (2018). Plant diversity and structure of the Caimpugan peat swamp forest on Mindanao Island, Philippines. *Mires & Peat*, *22*.

Asian Development Bank. (2008). Technical Assistance Completion Report: Master Plan for the Agusan River Basin Project – Final Report. Project Number 36540-01. Accessible from: https://www.adb.org/sites/default/files/project-documents//36540-phi-tacr.pdf

Bagstad, K., Cohen, E., Ancona, Z., McNulty, S., & Sun, G. (2018). The sensitivity of ecosystem service models to choices of input data and spatial resolution. Applied Geography, 93, 25-36. https://doi.org/10.1016/j.apgeog.2018.02.005

Benra, F., De Frutos, A., Gaglio, M., Alvarez-Garreton, C., Felipe-Lucia, M., & Bonn, A. (2021). Mapping water ecosystem services: Evaluating InVEST model predictions in data scarce regions. Environmental Modelling & Software, 138, 104982. https://doi.org/10.1016/j.envsoft.2021.104982

Berame, J. S. (2017). Assessment of Macro-Invertebrates Biodiversity and Plant Species in a Riparian Zone of Taguibo Watershed, Butuan City, Philippines. *International Journal of Agricultural and Environmental Research, 3*(3), 260-265.

Berame, J., Bulay, M. L., & Mercado, R. M. (2021). Sustaining angiosperms' diversity of Bood Promontory and Eco-Park, Butuan City, Philippines: Step towards a community based-protection management program. *Biodiversitas Journal of Biological Diversity*, *22*(6), 2519-2527.

Beroya-Eitner, M. (2016). Landslides in the Philippines: Geo-Physical Controls, Triggers and Examples (Vol. 4). International Journal of Landslide and Environment.

Betco, G. L., Demetillo, M. T., Salanatin, C., Along, A. A., & Goloran, A. B. (2021). Preliminary Assessment of Chiropteran Fauna within Kayam Forest (Inocarpus fagifer) in Barangay Pagatpatan, Butuan City, Philippines. *Open Access Library Journal*, *8*(3), 1-6.

Bliss-Ketchum, L. (2019). *The Impact of Infrastructure on Habitat Connectivity for Wildlife*. Portland State University. Retrieved from https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=5904&context=open_access_etds

Blumstein, M., & Thompson, J.R. (2015). Land-use impacts on the quantity and configuration of ecosystem service provisioning in Massachusetts, USA. Journal of Applied Ecology, 52(4), 1000-1019. https://doi.org/10.1111/1365-2664.12444

Bose, S., Mazumdar, A. (2023). Urban flood risk assessment and mitigation with InVEST-UFRM model: a case study on Kolkata city, West Bengal state (India). Arab J Geosci 16, 320. https://doi.org/10.1007/s12517-023-11412-2

Brewbaker, J. L. (2004). Tree breeding, practices | nitrogen-fixing tree improvement and culture. *Encyclopedia of Forest Sciences*, 1490–1501. https://doi.org/10.1016/b0-12-145160-7/00083-1

Brinck, K., Fischer, R., Groeneveld, J., Lehmann, S., De Paula, M.D., Pütz, S., Sexton, J.O., Song, D.X., & Huth, A. (2017). High resolution analysis of tropical fragmentation and its impact on the global carbon cycle. Nature Communications, 8(1), 14855. https://doi.org/10.1038/ncomms14855

Bündnis Entwicklung Hilft and Ruhr University Bochum – Institute for International Law of Peace and Armed Conflict (IFHV). (2023). WorldRiskReport 2023. Berlin: Bündnis Entwicklung Hilft. Retrieved from ISBN 978-3-946785-16-3

Butuan City Local Climate Change Action Plan 2022-2026.

Butuan City Water District (n.d.) Adopt-a-Forest Project of Butuan City Water Distrcit in Taguibo River Forest Reserve. Butuan City Water District. https://bcwd.gov.ph/watershed/pdf/a.pdf

Calder, B. J. (1977). Focus groups and the nature of qualitative marketing research. Journal of Marketing research, 14(3), 353-364.

Cao, W., Li, Q., Xu, H., & Zhang, Z. (2024). Vegetation dynamics regulate baseflow seasonal patterns of the Chaohe watershed in North China. Journal of Hydrology: Regional Studies, 53, 101797. https://doi.org/10.1016/j.ejrh.2024.101797

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). Nature-based solutions to address global societal challenges. *IUCN: Gland, Switzerland*, *97*, 2016-2036.

Cerutti, E. M., & Li, Y. (2021). The Agricultural Exodus in the Philippines: Are Wage Differentials Driving the Process?. IMF Working Papers, 2021(220). Retrieved Oct 1, 2024, from https://doi.org/10.5089/9781513590097.001

Chaplin-Kramer, R., Johnson, J., Sharp, R.P., Chatterton, J., Weil, C., Baccini, A., & Sim. S. (2021). Spatial heterogeneity in forest carbon storage affects priorities for reforestation. bioRxiv. https://doi.org/10.1101/2021.07.06.450936

Chaplin-Kramer, R., Ramler, I., Sharp, R., Haddad, N.M., Gerber, J.S., West, P.C., Mandle, L., Engstrom, P., Baccini, A., Sim, S., Mueller, C., & King, H. (2015). Degradation in carbon stocks near tropical forest edges. Nature Communications, 6, 10158. https://doi.org/10.1038/ncomms10158

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C. A., Kapos, V., ... & Seddon, N. (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. Global Change Biology, 26(11), 6134-6155.

Chung, J., Kim, J., & Sung, K. (2024). Analysis of Heat Mitigation Capacity in a Coastal City Using InVEST Urban Cooling Model. Sustainable Cities and Society, 113, 105669. https://doi.org/10.1016/j.scs.2024.105669

Chikiamco, C.V. (2022). Land consolidation is the answer. Philippine Institute for Development Studies. https://www.pids.gov.ph/details/news/in-the-news/land-consolidation-is-the-answer

Butuan City Climate and Disaster Risk Assessment 2023.

Climate Central. (2019, October 30). Report: Flooded future: Global vulnerability to sea level rise worse than previously understood. https://www.climatecentral.org/report/report-flooded-future-global-vulnerability-to-sea-level-rise-worse-than-previously-understood

Crismundo, M. (2024, February 08). 13 barangays in Butuan City placed under state of calamity. Manila Bulletin. https://mb.com.ph/2024/2/7/13-barangays-in-butuan-city-placed-under-state-of-calamity

Dai, K., Shen, S., Cheng, C., & Song, Y. (2023). Integrated evaluation and attribution of urban flood risk mitigation capacity: A case of Zhengzhou, China. Journal of Hydrology: Regional Studies, 50, 101567. https://doi.org/10.1016/j.ejrh.2023.101567

Dass, B., Daniel. D., Saxena, N., Sharma, A., Sen, D., & Sen, S. (2023). Informing watershed management in data-scarce Indian Himalayas. Water Security, 19, 100138. https://doi.org/10.1016/j.wasec.2023.100138

Department of Interior and Local Government (DILG). (2014). Memorandum circular No.2014-39 - 2014 Seal of good local governance: Pagkilala sa katapatan at kahusayan ng pamahalaang lokal. Retrieved from: https://lcp.org.ph/12/62/dilg-memorandum-circular-no--2014-39

DILG. (2022). Memorandum circular no. 2022-026 - 2022 Seal of good local governance: Pagkilala sa katapatan at kahusayan ng pamahalaang lokal. Retrieved from: https://dilg.gov.ph/issuances/mc/2022-Seal-of-Good-Local-Governance-Pagkilala-sa-Katapatan-at-Kahusayan-ng-Pamahalaang-Lokal/3519

Department of Science and Technology – Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA). (2024). Climate Change Projection 2024. Accessible at: https://www.pagasa.dost.gov.ph/climate/climate-change/dynamic-downscaling

Department of Transportation. *Environmental Impact Assessment Report – Mindanao Railway Project – Tagum-Davao-Digos Segment (MRP-TDD)*. 2020, https://eia.emb.gov.ph/wp-content/uploads/2020/09/MRP-ESP-English.pdf

Department of Public Works and Highways. (2021). 15 National Roads Closed Due to Odette. https://www.dpwh.gov.ph/DPWH/news/24765

Department of Public Works and Highways. (2022). Philippine National Road Network. https://www.dpwh.gov.ph/dpwh/DPWH_ATLAS/06%20Road%20WriteUp%202022.pdf

Dong, X., Ye, Y., Yang, R., & Li, X. (2023). Planning for green infrastructure based on integration of multi-driving factors: A case study in pilot site of sponge city. Sustainable Cities and Society, 93, 104549. https://doi.org/10.1016/j.scs.2023.104549

Dong, Z., Bian, Z., Jin, W., Guo, X., Zhang, Y., Liu, X., Wang, C., & Guan, D. (2024). An integrated approach to prioritizing ecological restoration of abandoned mine lands based on cost-

benefit analysis. Science of The Total Environment, 924, 171579. https://doi.org/10.1016/j.scitotenv.2024.171579

Droste, N., Schröter-Schlaack, C., Hansjürgens, B., & Zimmermann, H. (2017). Implementing nature-based solutions in urban areas: financing and governance aspects. Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice, 307-321.

Eggermont, H., Balian, E., Azevedo, J. M. N., Beumer, V., Brodin, T., Claudet, J., ... & Le Roux, X. (2015). Nature-based solutions: new influence for environmental management and research in Europe. GAIA-Ecological perspectives for science and society, 24(4), 243-248. http://dx.doi.org/10.14512/gaia.24.4.9

ESCAP/WMO. (2009). ESCAP/WMO Typhoon Committee. Chiang Mai: ESCAP/WMO

Environmental Science for Social Change (2015a, October 26). *Forests and rivers of a Thousand Years*. Institute of Environmental Science for Social Change. https://essc.org.ph/content/archives/7527

Eviota, M. P., Jumawan, J. C., Joseph, C. C. D., & Samson, N. L. (2016). Geometric morphometric analysis of three spot gourami, Trichopodus trichopterus in Masao River, Butuan City, Mindanao, Philippines. *Aquaculture, Aquarium, Conservation & Legislation*, *9*(5), 1011-1019.

Fahey, D. W., S.J. Doherty, K. A., Hibbard, A. R., & Taylor, P. C. (2017). Physical Drivers of Climate Change. In D. J. Wuebbles, D. W. Fahey, K. A. Hibabrd, D. J. Dokken, B. C. Stewart, & T. K. Maycock, Climate Science Special Report: Fourth National Climate Assessment, Volume I (pp. 73-113). Washington, DC, USA: U.S. Global Change Research Program. doi:10.7930/J0513WCR

Fern, E. F. (1982). The use of focus groups for idea generation: the effects of group size, acquaintanceship, and moderator on response quantity and quality. Journal of marketing Research, 19(1), 1-13.

Frantzeskaki, N. (2019). Seven lessons for planning nature-based solutions in cities. Environmental science & policy, 93, 101-111.

Geneletti, D., Cortinovis, C., Zardo, L., & Adem Esmail, B. (2020). Planning for ecosystem services in cities. Springer International Publishing. https://doi.org/10.1007/978-3-030-20024-4 Global Infrastructure Hub. (2021, November 19). The vital role of infrastructure in economic growth and development. Retrieved from: https://www.gihub.org/articles/the-vital-role-of-infrastructure-in-economic-growth-and-development/

Global Infrastructure Hub. (2021, November 19). The vital role of infrastructure in economic growth and development. Retrieved from: https://www.gihub.org/articles/the-vital-role-of-infrastructure-in-economic-growth-and-development/

Goloran, A. B., Laurence, C., Glenn, B., & Tricia, M. A. (2020). Species composition, diversity and habitat assessment of mangroves in the selected area along Butuan Bay, Agusan Del Norte, Philippines. *Open Access Library Journal*, *7*(4), 1-11.

Guisiano, P.A., Santoni, S., Huneau, F., Mattei, A., & Garel, E. (2024). Using natural tracers and calibrated analytical filter to highlight baseflow contribution to mountainous

Mediterranean rivers in a context of climate change. Journal of Hydrology, 641, 131842. https://doi.org/10.1016/j.jhydrol.2024.131842

Gunawardena, K.R., Wells, M.J., & Kershaw, T. (2017). Utilizing green and blue space to mitigate urban heat island intensity. Science of The Total Environment, 584-585, 1040-1055. https://doi.org/10.1016/j.scitotenv.2017.01.158

Hamel, P., Valencia, J., Schmitt, R., Shrestha, M., Piman, T., Sharp, R., Francesconi, W., & Guswa, A.J. (2020). Modeling seasonal water yield for landscape management: Applications in Peru and Myanmar. Journal of Environmental Management, 270, 110792. https://doi,org/10.1016/j.envman.2020.110792

Holden, W. N., & Marshall, S. J. (2018). Climate Change and Typhoons in the Philippines: Extreme Weather Events in the Anthropocene. Integrating Disaster Science and Management, 407–421. https://www.sciencedirect.com/science/article/abs/pii/B9780128120569000245

Hu, Y., Wang, C., & Li, J. (2023). Assessment of Heat Mitigation Services Provided by Blue and Green Spaces: An Application of the InVEST Urban Cooling Model with Scenario Analysis in Wuhan, China. Land, 12(5), 963. https://doi.org/10.3390/land12050963

Huo, Y., Li, B., Müller, F., Fu, Q., & Chen, W. (2018). A conservation decision-making framework based on ecosystem service hotspot and interaction analyses on multiple scales. Science of The Total Environment, 643, 277-291. https://doi.org/10.1016/j.scitotenv.2018.06.103

Intergovernmental Panel on Climate Change (IPCC). (2001). Climate Change 2001: Synthesis Report. IPCC. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-01.pdf

Intergovernmental Panel for Climate Change (IPCC). (2014). The Fifth Assessment Report (AR5), IPCC, 2014, Accessed at: https://www.ipcc.ch/report/ar5/

Intergovernmental Panel for Climate Change (IPCC). (2022). Climate Change 2021: The Physical Science Basis (Summary for Policymakers). Retrieved from https://unfccc.int/documents/310264?gclid=Cj0KCQiA6fafBhC1ARIsAIJjL8kKu2b0wGZQAG7VLp6fJFME6Qi7BMWyeLPwWeJbbE3anyLyx8UMLwoaAu0AEALw_wcB

Intergovernmental Panel for Climate Change (IPCC). (2023) Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

International Federation of Red Cross and Red Crescent Societies. (2021). 18 floods HR. Geneva, Switzerland: IFRC. Retrieved from https://www.ifrc.org/sites/default/files/2021-06/18-FLOODS-HR.pdf

International Union for the Conservation of Nature (IUCN). (2020). IUCN Global Standard for Nature-based Solutions. https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf

Kabisch, N., Stadler, J., Korn, H., & Bonn, A. (2017). Nature-Based solutions for societal goals under climate change in urban areas–Synthesis and Ways Forward. Nature-based solutions to

climate change adaptation in urban areas: Linkages between science, policy and practice, 323-336.

Kehew, A. E. (1988). General geology for engineers. New Jersey: Prentice-Hall.

Lam, W.Y., Chatteron, J., Sim, S., Kulak, M., Beltran, A.M., & Huijbregts, M.A.J. (2021). Estimating greenhouse gas emissions from direct land use change due to crop production in multiple countries. Science of The Total Environment, 755(2), 143338. https://doi.org/j.scitotenv.2020.143338

Leaf Foundation Incorporated. (2007). Terminal Report. Taguibo Watershed Management and Development Plan Formulation. 26 pages. Retrieved from https://www.cepf.net/sites/default/files/final-report-11782.pdf

Lopez, A. (2021, December 23). Zero casualty in Agusan Norte during 'Odette' onslaught. Philippine News Agency. https://www.pna.gov.ph/index.php/articles/1225243

Lopez, A. (2024). Butuan City under state of calamity due to extreme water shortage. Philippine News Agency. https://www.pna.gov.ph/index.php/articles/1225243

Luino, F. (2016). Floods. Turin: Italian National Research COuncil. doi:10.1007/978-3-319-12127-7_126-1

Lyu, R., Clarke, K. C., Zhang, J., Feng, J., Jia, X., & Li, J. (2021). Dynamics of spatial relationships among ecosystem services and their determinants: Implications for land use system reform in Northwestern China. Land Use Policy, 102, 105231.https://doi.org/10.1016/j.landusepol.2020.105231

Manandhar, B., Cui, S., Wang, L., & Shrestha, S. (2023). Urban Flood Hazard Assessment and Management Practices in South Asia: A Review. Land, 12(3), 627. https://doi.org/10.3390/land12030627

Mascarinas, E.M. (2023, January 10). 1,000 people displaced by flooding in Butuan City. The Philippine Daily Inquirer. https://newsinfo.inquirer.net/1714998/1000-people-displaced-by-flooding-in-butuan-city

Maes, J., & Jacobs, S. (2017). Nature-based solutions for Europe's sustainable development. *Conservation letters*, *10*(1), 121-124.

McQuaid, S., Rhodes, M. L., & Ortega, A. E. (2021). A Key Actors Governance Framework (KAGF) for nature-based solutions to societal challenges. In Handbook of Collaborative Public Management (pp. 164-178). Edward Elgar Publishing.

Mendelow, A.L. (1981). 'Environmental Scanning - The Impact of the Stakeholder Concept,' ICIS 1981 Proceedings, 20.

Millenium Ecosystem Assessment. (2005). Ecosystem and Human Well-being: Wetlands and water Synthesis. World Resources Institute, Washington, DC.

Mishra, B.K., Kumar, P., Sarawat, C., Chakraborty, S., Gautam. A. (2021). Water Security in a Changing Environment: Concept, Challenges and Solutions. Water, 13(4), 490. https://doi.org/10.3390/w13040490

Morgan, D. L., & Spanish, M. T. (1984). Focus groups: A new tool for qualitative research. Qualitative sociology, 7(3), 253-270.

National Economic and Development Authority. (2021, October 6). Butuan Executes Infrastructure Master Plan. Published at NEDA website. Butuan executes Infrastructure Master Plan | National Economic and Development Authority Caraga (neda.gov.ph)

National Mapping and Resource Information Authority (n.d.) - https://www.geoportal.gov.ph/

Nesshöver, Carsten, Timo Assmuth, Katherine N. Irvine, Graciela M. Rusch, Kerry A. Waylen, Ben Delbaere, Dagmar Haase et al. "The science, policy and practice of nature-based solutions: An interdisciplinary perspective." Science of the total environment 579 (2017): 1215-1227.

Ommer, J., Bucchignani, E., Leo, L. S., Kalas, M., Vranić, S., Debele, S., Kumar, P., Cloke, H. L., & Di Sabatino, S. (2022). Quantifying co-benefits and disbenefits of Nature-based Solutions targeting Disaster Risk Reduction. *International Journal of Disaster Risk Reduction*, *75*, 102966. https://doi.org/10.1016/j.ijdrr.2022.102966

Owuor, S.O., Butterbach-Bahl, K., Guzha, A.C., Rufino, M.C., Pelster, D.E., Diaz-Pines, E., & Breuer, L. (2016). Groundwater recharge rates and surface runoff response to land use and land cover changes in semi-arid environments. Ecological Processes, 5 (16). https://doi.org/10.11186/s13717-016-0060-6

Paz, S. L., Ngoprasert, D., Nuneza, O. M., Mallari, N. A. D., & Gale, G. A. (2013). Philippine-endemic and Mindanao-endemic bird communities on Canticol and Mt. Hilong-hilong, Philippines. *Asian Journal of Biodiversity*, *4*(1), 135-168.

Penn Wharton Budget Model. (2018, February 9). Options for infrastructure investment: dynamic modeling. Retrieved from: https://budgetmodel.wharton.upenn.edu/issues/2018/2/9/infrastructure-investment-dynamic-modeling?Rq=complement

PhilAtlas. (2024). Butuan. https://www.philatlas.com/mindanao/caraga/butuan.html#sources

Philippine Statistics Authority (PSA). (2020). 2020 Census of Population and Housing (2020 CPH) Population Counts Declared Official by the President. Retrieved from: https://psa.gov.ph/content/2020-census-population-and-housing-2020-cph-population-counts-declared-official-president

Philippine Statistics Authority PSA. (2020). Damages Due to Natural Extreme Events and Disasters Amounted to PhP 463 Billion. Retrieved from: https://psa.gov.ph/content/damages-due-natural-extreme-events-and-disasters-amounted-php-463-billion

Philippine Statistics Authority PSA. (2021). Highlights of the Region XIII (Caraga) Population 2020 Census of Population and Housing (2020 CPH). Retrieved from: https://psa.gov.ph/statistics/population-and-housing/node/165008

Philippine Statistics Authority PSA. (2022). Urban Population of the Philippines (2020 Census of Population and Housing) Retrieved from: https://psa.gov.ph/content/urban-population-philippines-2020-census-population-and-housing

Philippine Statistics Authority PSA. (2024). 11 out of 18 Regions Recorded Significant Decreases in Poverty Incidence in 2023. https://psa.gov.ph/statistics/poverty

Quagliolo, C., Roebeling, P., Matos, F., Pezzoli, A., & Comino, E. (2023). Pluvial flood adaptation using nature-based solutions: An integrated biophysical-economic assessment. Science of The Total Environment, 902, 166202. https://doi.org/10.1016/j.scitotenv.2023.166202

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., ... & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science & Policy, 77, 15-24.

Ronchi, S., Salata, S., & Arcidiacono, A. Which urban design parameters provide climate-proof cities? An application of the Urban Cooling InVEST Model in the city of Milan comparing historical planning morphologies. Sustainable Cities and Society, 63, 102459. https://doi.org/10.1016/j.scs.2020.102459

Rosso, R., Rulli , M. C., & Vannucchi, G. A. (2006). A Physically Based Model for the Hydrologic Control on Shallow Landsliding. Water Resources Research, 42. doi: https://doi.org/10.1029/2005WR004369

Sahle, M., Saito, O., Fürst, C., & Yeshitela, K. (2019). Quantifying and mapping of water-related ecosystem services for enhancing the security of the food-water-energy nexus in tropical data-sparse catchment. Science of The Total Environment, 646, 573-586. https://doi.org/10.1016/j.scitotenv.2018.07.347

Sanguila, M. B., Plaza, J. L., Mahinay, M. Y., Edma, R. C. J., & Brown, R. M. (2020). Herpetological assemblages in tropical forests of the Taguibo Watershed, Butuan City, Eastern Mindanao, Philippines. *Philippine Journal of Science*, *150(S1):* 415–431. https://doi.org/10.56899/150.S1.31

Saro, J. M., Pascual, K. B., & Coquilla, D. P. (2022). Aquatic Macrophytes Composition and Diversity in Selected Sites of Lumbocan River, Butuan City, Agusan del Norte, Philippines. *American Academic Scientific Research Journal for Engineering, Technology, and Sciences, 89*(1), 1-14.

Satoyama Initiative. *Paris declaration on the "Satoyama Initiative"*. https://satoyama-initiative.org/wp-content/uploads/2011/09/Paris_Declaration_EN_april2010_revised03_low.pdf

Schröter, M., Remme, R.P. (2016). Spatial prioritisation for conserving ecosystem services: comparing hotspots with heuristic optimisation. Landscape Ecology, 31, 431–450. https://doi.org/10.1007/s10980-015-0258-5

Seddon, N., Chausson, A., Berry, P., Girardin, C. A., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B, 375(1794), 20190120.

Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J. Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang, 2012: Changes in climate extremes and their impacts on the natural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 109-230.

Serviano, J. L., Amora, A. M., Gingo, A. L., Santillan, J. R., & Santillan, M. M. (2017). Identification of Potential Water Source for Butuan City Northeastern Mindanao Philippines through Watershed Delineation and Characterization. In *ACRS Proceedings*.

Sia, L.A. (2009, Februry 04). Discovering the Ancient Kingdom of Butuan. The Philippine Star. https://www.philstar.com/cebu-lifestyle/2009/02/04/436928/discovering-ancient-kingdom-butuan

Silveira, C., Dias, A., Amaral, F.G., Gois, G., & Piston, N. (2024). The importance of private gardens and their spatial composition and configuration to urban heat island mitigation. Sustainable Cities and Society, 112, 105589. https://doi.org/10.1016/j.scs.2024.105589

Solania, C. L., & Seronay, R. A. (2017). Reproductive aspects of the native Sharpnose hammer croaker, Johnius borneensis (Bleeker, 1850) from Agusan River Estuary, Caraga region, Philippines. *Journal of Entomology and Zoology Studies*, *5*(5), 220-228.

Spanó, M., Leronni, V., Lafortezza, R., & Gentile, F. (2017). Are ecosystem service hotspots located in protected areas? Results from the study in Southern Italy. Environmental Science & Policy, 73, 52-60. https://doi.org/10.1016/j.envisci.2017.04.008

Susi, C. G. O., & Ladesma, J. I. A. (2023). Floral assessment in Kayam Forest in Brgy. Pagatpatan, Butuan City, Agusan del Norte, Philippines. *Journal of Biodiversity and Environmental Sciences*, *17*(02), 1-4.

Sustainable Infrastructure Partnership. (2022). Ecosystem-based disaster risk reduction as "natural infrastructure" in Japan. *Green Policy Platform*. Retrieved from https://www.greenpolicyplatform.org/case-studies/ecosystem-based-disaster-risk-reduction-natural-infrastructure-japan

Thacker S., Adshead D., Fantini C., Palmer R., Ghosal R., Adeoti T., Morgan G., & Stratton-Short S. (2021). Infrastructure for climate action. Retrieved from: https://content.unops.org/publications/Infrastructure-for-climate-action_EN.pdf?mtime=20211008124956&focal=none

Tian, S., Xu, J., & Wang, Y. (2020). Human infrastructure development drives decline in suitable habitat for Reeves's pheasant in the Dabie Mountains in the last 20 years. *Global Ecology and Conservation, 22*, 1-13. https://doi.org/10.1016/j.gecco.2020.e00940

Tichavský, R., Ballesteros-Cánovas, J. A., Šilhán, K., Tolasz, R., & Stoffel, M. (2019). Dry Spells and Extreme Precipitation are The Main Trigger of Landslides in Central Europe. Scientific reports, 9(1), 14560. https://doi.org/10.1038/s41598-019-51148-2

Tiempo, J., Blancia, J., Canelio, K., Mercado, J., Corbita, V., & Sarmiento, R. (2023). Population Assessment and Threats to Long-Tailed Macaques (*Macaca fascicularis* Raffles) in Areas Outside Sumile Botanical and Zoological Park, Butuan City, Philippines. *East Asian Journal of Multidisciplinary Research*, *2*(4), 1539-1548.

Thacker S., Adshead D., Fantini C., Palmer R., Ghosal R., Adeoti T., Morgan G., & Stratton-Short S. (2021). Infrastructure for climate action. Retrieved from: https://content.unops.org/publications/Infrastructure-for-climate-action_EN.pdf?mtime=20211008124956&focal=none

United Nations Office of Disaster Risk Reduction. (2015). Global Assessment Report on Disaster Risk Reduction. ISBN/ISSN/DOI: 9789211320428, 316 p.

United Nations Office of Disaster Risk Reduction. (2017). Online Glossary. UNDRR. United Nations, Geneva, Switzerland

United Nations Office for Disaster Risk Reduction. (2022). Technical Guidance on Comprehensive Risk Assessment and Planning in the Context of Climate Change. Geneva 2, Switzerland: United Nations Office for Disaster Risk Reduction.

United Nations Educational, Scientific and Cultural Organization. (2024). Agusan Marsh Wildlife Sanctuary. Retrieved from: https://whc.unesco.org/en/tentativelists/6716/

United Nations Office for Disaster Risk Reduction (2009). 2009 UNISDR terminology on disaster risk reduction. https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

Vagliasindi, M. (2022, April 18) How does infrastructure support sustainable growth? Retrieved from: https://blogs.worldbank.org/digital-development/how-does-infrastructure-support-sustainable-growth

Vári, A., Podschun, S.A., Erös, T., Hein, T., Pataki, B., Iojă, I.C., Adamescu, C., Gerhardt., A., Gruber, T., Dedić, A., Ćrirć, M., Gavrilović, B., & Báldi, A. (2021). Freshwater systems and ecosystem services: Challenges and chances for cross-fertilization of disciplines. Perspective, 51, 135-151. https://doi.org/10.1007/s13280-021-01556-4

Wang, F., Harindintwali, J.D., Yuan, Z., ... & Chen, J. (2021). Technologies and perspectives for achieving carbon neutrality. The Innovation, 2(4), 100180. https://doi.org/10.1016/j.xinn.2021.100180

Wu, Q., Wang, L., Wang, T., Ruan, Z., Du, P. (2024). Spatial-temporal evolution analysis of muti-scenario land use and carbon storage based on PLUS-InVEST model: A case study in Dalian, China. Ecological Indicators, 166, 112448. https://doi.org/10.1016/j.ecolind.2024.112448

World Resources Institute (2022). World Risk Report 2022. Retrieved From: https://weltrisikobericht.de/wp-content/uploads/2022/09/WorldRiskReport-2022_Online.pdf

World Resources Institute (2023). World Risk Report 2023. Retrieved From: https://weltrisikobericht.de/wp-content/uploads/2024/01/WorldRiskReport_2023_english_online.pdf

Xu, Z., Ma, J., Zheng, H., Wang, L., Ying, L., Li, R., & Yang, Y. (2024). Quantification of the flood mitigation ecosystem service by coupling hydrological and hydrodynamic models. Ecosystem Services, 68, 101640. https://doi.org/10.1016/j.ecoser.2024.101640

Zawadzka, J.E., Harris, J.A., & Corstanje, R. (2021). Assessment of heat mitigation capacity of urban greenspaces with the use of InVEST urban cooling model, verified with day-time land surface temperature data. Landscape and Urban Planning, 214, 104163. https://doi.org/10.1016/j.landurbplan.2021.104163

Zhang, B. W. (2020). The Effect of Aerosols to Climate Change and Society. Journal of Geoscience and Environment Protection, 8(8), 55-78. doi:10.4236/gep.2020.88006

About the Team

Samantha Geraldine G. De Los Santos	**Gemmalyn M. Trespalacio**
Assistant Professor College of Public Affairs and Development University of the Philippines Los Baños College, Los Baños, Laguna 4031 sgdelossantos@up.edu.ph +639771413012	S&T Fellow I Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (PCAARRD) Brgy. Timugan, Los Baños, Laguna 4030 gmtrespalacio@up.edu.ph +639171833600
Nico Jayson C. Anastacio, PhD	**Jan Joseph V. Dida**
University Researcher College of Public Affairs and Development University of the Philippines Los Baños College, Los Baños, Laguna 4031 ncanastacio@up.edu.ph +639175527384	Assistant Professor College of Forestry and Natural Resources (CFNR) University of the Philippines Los Baños College, Los Baños, Laguna 4031 jvdida@up.edu.ph +639985777255
Danesto B. Anacio, PhD	**Malvin G. Biguerras**
Associate Professor School of Environmental Science and Management University of the Philippines Los Baños College, Los Baños, Laguna 4031 dbanacio@up.edu.ph +63932863943	Senior RS-GIS Specialist BGP Environmental Consulting Group, Co. Mulanay, Quezon, Philippines malvinbiguerras@gmail.com +639955506025