Paradigm

GEOSCAPE

ORIGINAL PAPER

Geospatial information in local planning decisions: land cover and its change as support for optimal spatial development in Prieto Diaz, Sorsogon (Philippines)

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Abstract

This study addresses the lack of updated land cover and land cover change data in Prieto Diaz, Sorsogon (Philippines), while also identifying land use policy clusters and formulating spatial development options to guide the local planning. Land cover analysis was conducted using remote sensing techniques via Google Earth Engine and spatial analysis tools in QGIS. Year-on-year data from 2017 to 2022 revealed significant increases in tree cover within mangrove areas and in flooded vegetation across seagrass zones. The gradual expansion of built-up areas in urban and urbanizing barangays highlighted a noticeable rural-urban population shift and marked zones where built development – whether planned or unplanned – is likely to occur. Based on these findings, four development clusters were identified: Agroforestry, Agriculture, Commercial-Residential, Conservation. The three spatial development options were subsequently formulated and presented to the Local Development Council, from which participants then selected the Conservation-Enterprise option as the spatial development strategy most likely to realize their town's vision. This approach centers focus on the interdependence between the local economy and livelihood on the stability of the town's environment, thereby reinforcing incentives for environmental sustainability.

Highlights for public administration, management and planning:

- The study integrates open-access geospatial tools into local planning to support data-driven and cost-efficient decision-making.
- We employ Ridge-to-Reef Conservation-Enterprise framework to balance development and environmental protection, and we suggest strengthening participatory planning to ensure inclusive, community-based land use management.
- The study provides analytical and conceptual framework to regulate urban expansion through zoning and infrastructure planning to safeguard coastal ecosystems.

Keywords

GIS,
Remote Sensing,
Mapping,
Environmental Planning,
Local Development

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1 Introduction

In the Philippines, planning is regarded as – and aims to be – an integral part of governance: a technical and political exercise that necessitates balancing empirical facts with the political and social needs and desires of the people (DILG 2008). While the rationalized planning system in the Philip-

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pines emphasizes that planning is not merely a technical pursuit but a political one (HLURB 2014), the value of relevant and reliable data in decision-making cannot be ignored (Serote 2004). Moreover, the need for up-to-date information in land use and land cover changes is essential for responsive policy, since existing land use practices are continually affected by climate change (Abante et al. 2021). Previous studies and current environmental planning practices highlight the technical gaps and gaps within local planning structures and demonstrate how Remote Sensing (RS) and Geographic Information Systems (GIS) can address these challenges (Becedas et al. 2018). The long-standing adoption of geospatial technologies in urban environmental studies and land use planning has proven effective in delivering seamless solutions and informed decisions (Salleh et al. 2014; Isa et al. 2018). Yet overexploitation of natural resources remains a pressing concern for sustainable development: humanity must ensure the responsible use of these natural resources (Foronda 2011) even as ecological problems emerge from poverty intensified by resource depletion in pursuit of economic growth (Foronda 2007). Comprehensive knowledge of current land cover in Prieto Diaz – a fifth income class municipality (COA 2022) – is lacking. Aside from general overviews of approximate land cover and use, detailed data and analyses of land cover change over time are unavailable, leaving the study of change patterns pending. Various factors, notably climate change, have altered land cover, and communities exposed to extreme weather events - severe typhoons and prolonged rains that trigger floods and landslides- are increasingly concerned about these impacts, which inflict significant damage on infrastructure and agricultural (Foronda 2012). The absence of updated land cover and change-detection data hampers effective monitoring of land-use policies and spatial development strategies. Without a clear understanding of how past and current policies and the municipality's socio-economic conditions affect natural resources, Prieto Diaz risks adopting strategies that exacerbate land use problems or overlook critical resource challenges (Cuevas et al. 2015). Studying land use and land cover is crucial for evaluating the impacts and effectiveness of planning on urban and rural livelihoods and climate resilience (Isa et al. 2020). Moreover, Estrella et al. (2015) emphasize that comprehending socio-ecological dynamics across different areas is essential for informed land use planning. Ultimately, balancing natural resource management with community livelihood is fundamental to achieving sustainable development.

To help direct the towns' development towards responsive and responsible land use, one of the objectives of this study is to identify the preferred spatial development strategy which would optimize spatial land development which improves the social and economic situation as well as protect the stability of the environment. Spatial land use optimization involves refining the distribution and structure of local land resources alongside human socio-economic activities to achieve a balanced spatial layout. This process aligns with principles of demographic, environmental, and resource equilibrium, aiming to maximize economic, social, and ecological benefits. It also seeks to harmonize human interventions with the preservation of ecological systems and natural assets, thereby promoting the sustainable development of the human–environment relationship (Liu et al. 2022). The responsible planning and allocation of land uses plays a vital role in reconciling the challenges of urban expansion with the need to safeguard ecosystems, particularly through strategic land use. Moreover, thoughtful land-use planning directly influences overall quality of life, requiring careful evaluation and governance of land allocation across social, economic, environmental, and ecological dimensions to reduce conflicts and support long-term, equitable development (Yao et al. 2019).Since the 1980s, participatory methods in development planning have emerged as a response to conventional top-down approaches, reflecting a shift toward more inclusive frameworks that actively engage intended beneficiaries in shaping plans and projects. This transition was influenced by liberal perspectives advocating stakeholder involvement in decision-making processes (Yabes 1991). In public hearings and workshops, communicative planning builds upon rational planning by ensuring that information is shared early, fostering a shared understanding among all participants. This approach requires the government to convene diverse stakeholders, facilitate dialogue, and guide discussions toward consensus. Central to communicative planning is the early and meaningful involvement of the public, emphasizing empowerment throughout the planning process (Ascano et al. 2021).

This study recognizes that restrictions such as paywalls, and the limited access to tools and expertise hinder the production of reliable data and information, which in turn affect the quality of decisions made by local planners and executives. Small LGUs in lower-income classes, like Prieto Diaz in Sorsogon Province, face significant challenges due to constrained resources and technical capacity for collecting the data needed to guide development decisions within their political and administrative jurisdictions.

The primary objective of this study is to detect and assess land cover changes in Prieto Diaz between 2017 and 2022 and use those findings to identify and select a preferred spatial development option. Specifically, the study pursues the following aims:

- Classify the land cover in Prieto Diaz for 2017, 2018, 2019, 2020, 2021, and 2022.
- Identify patterns of land cover change and assess their effects on the socio-economic conditions of the area.
- Develop spatial development options for the Local Government to consider when prioritizing development.

The study's activities were confined to the terrestrial administrative boundaries of the Municipality of Prieto Diaz, Province of Sorsogon, Philippines, and excluded municipal waters and other areas with submerged ground features. Because the technologies and tools employed were not designed to penetrate surface water, submerged features such as seagrass beds, seaweed beds, coral reefs, and other underwater elements were not included.

The data gathered and analyzed are limited to the best available images (Janiola & Puno 2018) for each year in the period 2017-2022. These years were chosen for two reasons: first, 2022 offers the most recent set of high-quality images with less than 20% cloud cover; second, the six-year span corresponds to the terms of the municipality's mayors and local councilors, during which the impacts of LGU decisions on land cover would be expected to manifest.

This study is limited to the use of free, publicly available Sentinel-2 images, Google Earth Engine, and processing tools in QGIS. Sentinel-2 has proven highly effective for land cover and land use monitoring, particularly in crops, forests, urban areas, and water resources. Its widespread adoption is driven by its superior spatial (10 m) and temporal (5-day) resolution, red-edge bands, and seamless integration with other remote sensing data, which enhances overall accuracy. The platform's free access policy makes it especially valuable in resource-limited settings. Studies report classification accuracies above 80% using machine learning algorithms like SVM and Random Forest, though traditional methods such as maximum likelihood remain in use. Despite its strengths, Sentinel-2 faces limitations, including mismatches with Landsat OLI-8, absence of thermal bands, and varying spatial resolutions across its spectral bands. Nonetheless, it holds strong potential for advancing land cover/use assessments (Phiri et al. 2020). This study intentionally omitted any materials and methods that require paywalls, subscriptions, or purchases, as such requirements would undermine the goal of democratizing science and technology. It also selected tools that can be readily replicated by the intended beneficiaries, excluding methods that demand advanced training in remote sensing, geographic information systems, or cloud computing.

2 Study area

Prieto Diaz is a 5th Class Municipality in the Province of Sorsogon. As of 2021, its total assets were PHP 279 476 893.29, with an income of PHP 104 689 368.11. Between the fiscal years 2020 and 2021, its total assets increased by 21.52%, but its Total Income decreased by 32.60% (COA 2022).

According to the 2020 census, Prieto Diaz (Fig. 1) had a population of 22 664, characterized by a relatively young demographic: about 36% are young dependents (ages 0-14), nearly 58% comprise the labor force (ages 15-64), and roughly 6% are elderly dependents (aged 65 and older). In 2020, 83% of the working-age males were gainfully employed, many as skilled agricultural, forestry, or fishery workers, while 37% of working-age females were employed, primarily in elementary occupations, service and sales, and managerial roles. Agriculture is the main livelihood in the town's northern and southern areas – dominated by rice, coconuts, and other high-value crops – whereas coastal communities rely primarily on fishing and fishery-related industries including gleaning, capture fishing, aquaculture, fish processing, and fish vending.

3 Materials and methods

The design of this study is to identify a practical solution to a real problem affecting organizations and communities by applying science and technology. Specifically, Remote Sensing (RS) and Geographic Information Systems (GIS) were used to classify land cover for 2017-2022 and to identify areas that experienced land cover changes (Zhu et al. 2018). The accuracy of the 2022 classifications was assessed using the Kappa-Coefficient of the Confusion Matrix, a method employed for evaluating the accuracy of classified images.

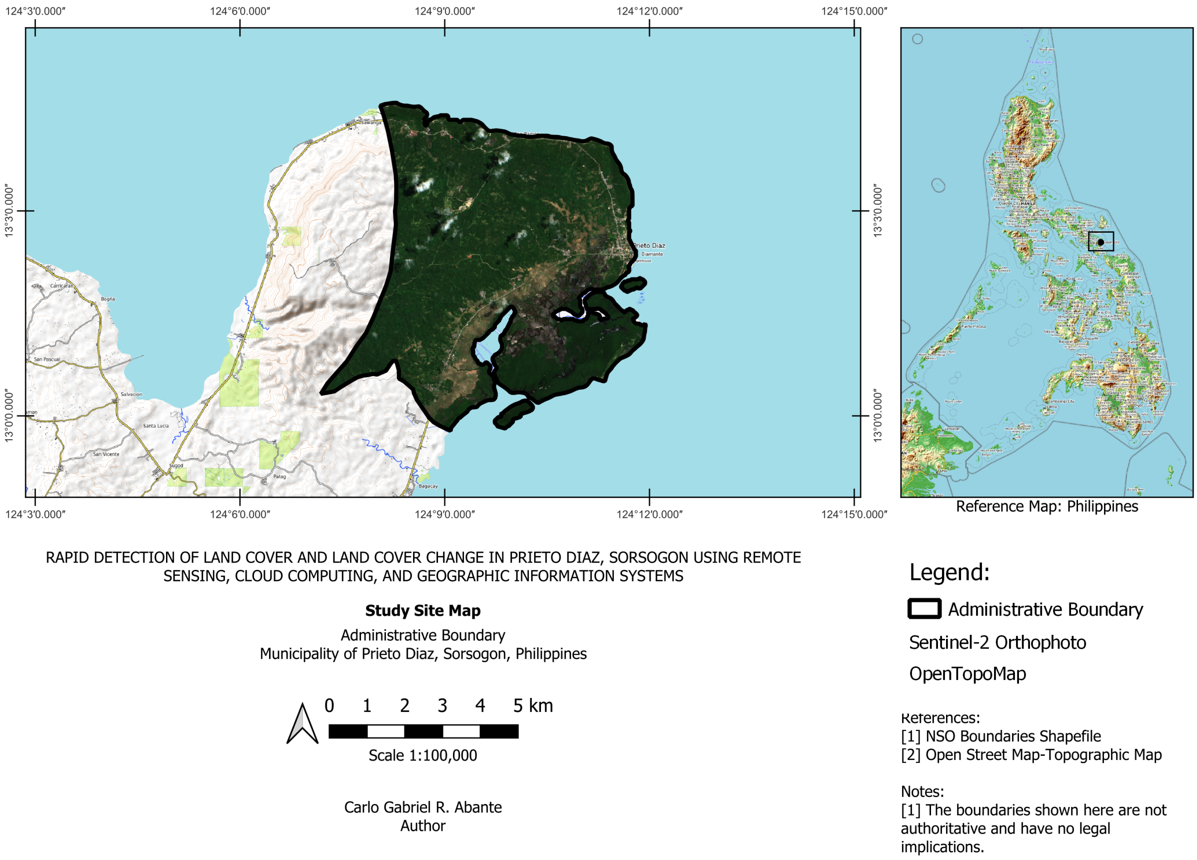

Fig. 1 The terrestrial administrative boundaries of the Municipality of Prieto Diaz, Sorsogon Province, Bicol Region, Philippines

Remotely sensed images are produced by organizations and platforms that operate satellite ground receiving stations. Of the many satellites and sensors orbiting the Earth, only a few provide publicly accessible images free of charge, and higher resolution products incur a cost to local planning authorities. This study used images from the Sentinel-2 satellite, an Earth-observation satellite developed and operated by the European Space Agency. Sentinel-2 was selected for its sensors' ability to capture red, green, and blue reflectance bands as well as bands used for vegetation and water detection. These capabilities make Sentinel-2 products suited for land cover observation, agricultural monitoring, vegetation and forest parameter generation, and coastal and in-land water studies.

To ensure accurate land cover classification, images with the least cloud cover were used; only those with less than 10% cloud cover were selected. The following table lists the products used in this study, all sourced from the United States Geological Survey (USGS) Earth Explorer portal. These images were downloaded as a registered user in accordance with the portal's terms and conditions.

Remotely sensed Sentinel-2 images and the Dynamic World image classification model were accessed and run using Google Earth Engine. The output included annual land cover classification composites and true color images, which were subsequently exported. Spatial analyses to detect and classify land cover change were performed using Quantum GIS (QGIS). The accuracy of the land cover data was assessed using the Kappa Coefficient Confusion of Agreement method (AcATaMa-SMByC 2022; Kamusoko 2021). This statistical test compares predicted land cover classifications with validated field data, evaluating the performance against random assignment of classifications or values (Hudson 1987).

$$\kappa = \frac{N \sum_{i=1}^{n} m_{i,i} - \sum_{i=1}^{n} (G_i C_i)}{N^2 - \sum_{i=1}^{n} (G_i C_i)} \quad (1)$$

where,

i is the class number

N is the total number of classified values compared to truth values
$m_{i,i}$ is the number of values belonging to the truth class i that have also been classified as class i
C_i is the total number of predicted values belonging to class i
G_i is the total number of truth values belonging to class i
Kappa Coefficient values span from 1.00, indicating perfect agreement between predicted and validated values, to 0.00, indicating no agreement between producer and user classes and essentially an incorrect classification (Hudson 1987). In remote sensing studies, a Kappa Coefficient ranging (Tab. 1) from 0.61 to 0.80 is considered good, while values exceeding 0.80 are deemed very good—particularly given the current spatial resolution of the images used in this study (Kamusoko 2021).

Table 1 Interpretation of the Kappa values (Elachi & Jakob 2021)

Value of κ	Strength of the Agreement
0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.80	Very Good

The Kappa Coefficient accuracy assessment was conducted for the 2022 land cover data. Literature on using the Kappa Coefficient Confusion Matrix recommends stratified-random sampling to determine and acquire validation points, with the number of user (validation) points proportional to the total number of classified objects. Using this method, the number of user (validation) points is proportional to the total number of classified objects. Additional studies advise distributing validation points as widely possible and ensuring each class has at least 30% validation points relative to the producer points. The Tab. 2 shows the number of classified points and the minimum user (validation) points per class.

Table 2 Number of Producer Points and Minimum Validation Points for the Kappa-Coefficient Confusion Matrix

Land Cover Classes	Digital Numbers (DN)	Total Classified Objects	User (Validation) Points
Water	0	0	0
Trees	1	201	60
Grass	2	161	48
Flooded Vegetation	3	278	83
Crops	4	182	55
Shrub and Scrub	5	114	34
Built Area	6	54	16
Bare Ground	7	27	8
Mud or Sand	8	4	1
Total		1021	305

The number of samples validated (User Points) was determined using a stratified sampling method, sampled by an area-based proportion using the overall standard deviation error. The computation was done automatically in the AcATaMa-SMByC QGIS plugin based on the total number of classified objects (see Tab. 2). Points were then randomly generated in the QGIS plugin to determine the sites validated in the study (Fig. 2). A total of 305 points were then visited and validated in situ using a handheld GPS device to locate the points on the field. This was done with the help of local field assistants and guides. A DJI Mavic Air drone was also used to validate points which were inaccessible due to the lack of paths or roads to access the area.
After establishing the reliability of the land cover classification, a year-on-year comparison was made by first intersecting two layers (years) using the Intersect geoprocessing tool in QGIS. Then comparing the Digital Number (DN) value of each classified object in the resulting intersected layer by using the following script in the QGIS field calculator (Fig. 3).
Information from land cover and land cover change analyses was used to identify various development clusters within the municipality (Hussain et al. 2019). After establishing patterns of historical and current land cover and land use change, the study —drawing on the local planners' and leaders' intimate knowledge — identified potential areas for sustainable development and natural resource use. Combined with an analysis of demographic growth trends between urban and rural areas and the most recent socio-economic parameters, including employment data, and the results of a Vision-Reality Gap assessment, the study formulated spatial development options. Projected popu-

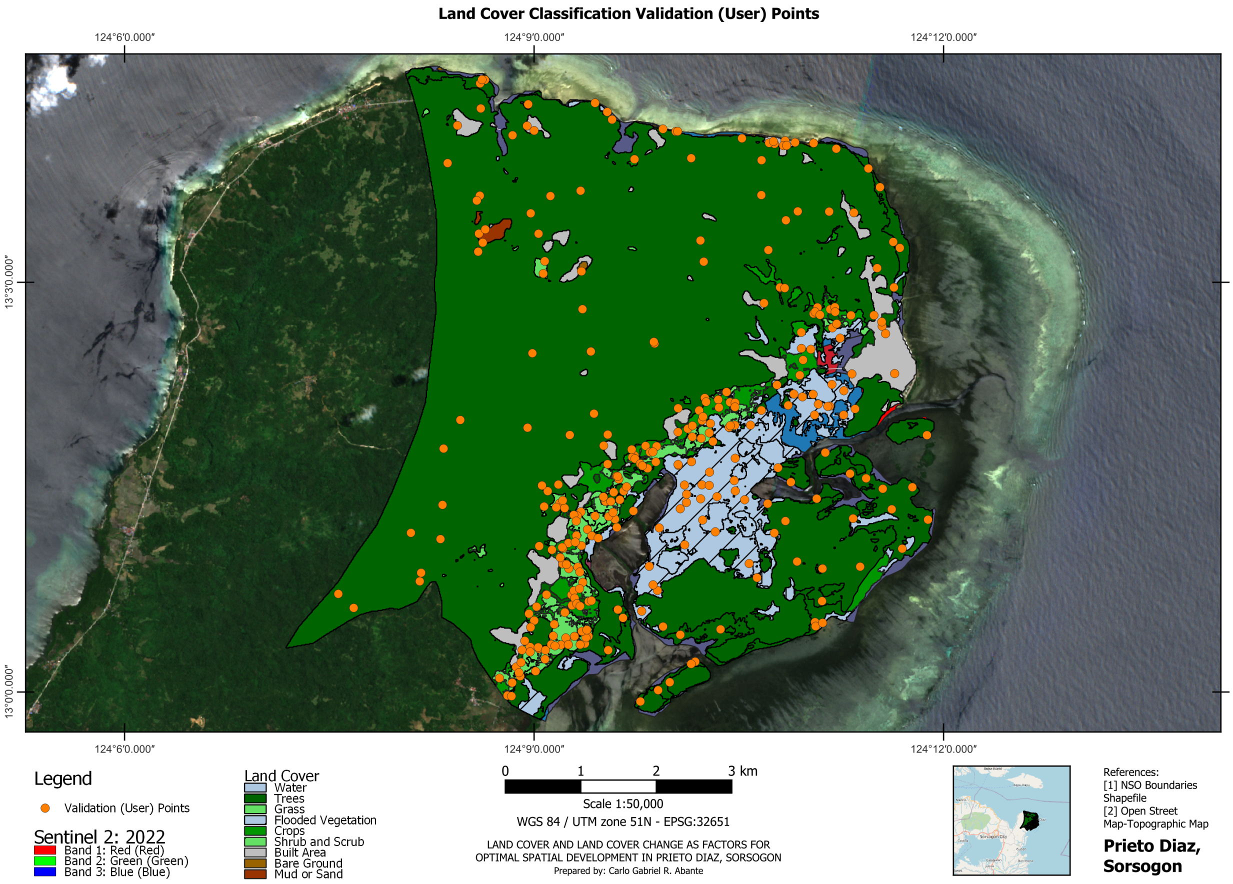

Fig. 2 Location of Validation (User) Points visited in situ during the field validation of classified land cover information in Prieto Diaz, Sorsogon. These points were generated randomly based on a stratified sampling technique in the AcATaMa-SMByC QGIS plugin

lation changes, housing and utilities issues, demand for government services, and livelihood needs were used as reference points in workshops with members of the Local Development Council. Although links between socio-economic conditions and land cover change and land use decisions remain primarily theoretical, the participants' local knowledge and insights underscore that a detailed understanding of current land cover and its change patterns is a necessary baseline for sound Local Government Unit land use decisions.

The options underwent presentation, deliberation, and decision-making within a participatory process involving the 36 members of the Local Development Council (LDC). Attendees included representatives from local government unit departments, members of the Sangguniang Bayan, the town mayor and vice mayor, barangay captains, representatives of vulnerable sectors, the agriculture and aquaculture sectors, non-government organizations, civic organizations, and cooperatives. A matrix, that averaged each sector's rated preferences within the LDC was used to select the preferred spatial development option for Prieto Diaz.

4 Results and discussion

The predominant land cover in Prieto Diaz is trees, covering approximately 80% of the municipality as of 2022. These areas are mainly concentrated in the upland regions of the town's barangays and along the coast, where extensive mangrove forests are located. Flooded vegetation, which constitutes about 7% of the land cover, is largely found in coastal areas. Built-up areas – comprising a mix of residential, commercial, and institutional land uses – are primarily located along the major highways parallel to the coast. Agricultural land follows a similar pattern to the built areas, with most cropland situated in the lowland barangays (villages). The accuracy assessment indicates that the current classification is sufficiently reliable for making

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```
with
  classes := array(
    'Water',
    'Trees',
    'Grass',
    'Flooded Vegetation',
    'Crops',
    'Shrub and Scrub',
    'Built Area',
    'Bare Ground',
    'Mud or Sand'
  )

CASE
  WHEN DN = DN_2 THEN 'No Change'
  WHEN DN >= 0 AND DN < length(classes) AND DN_2 >= 0 AND DN_2 < length(classes)
    THEN classes[DN] || ' to ' || classes[DN_2]
  ELSE 'NULL'
END
```

Fig. 3 The script used to compare and identify land cover changes between two layers (years). This script compares two land cover classifications—DN and DN_2—and returns a descriptive label indicating whether there was a change between them. If the values differ, it constructs a transition label (e.g., "Water to Trees"); if they're the same, it returns "No Change"; and if either value is invalid, it outputs "NULL".

general land use decisions; however, it is limited by the pixel resolution of Sentinel-2 data, and precise geodetic measurements require in-situ or proximal sensing techniques.

4.1 Land cover change

Between 2017 and 2022, tree cover consistently dominated the municipality, accounting for 81% of the total land area in 2017 and 80% in 2022. Other land cover classes showed minimal annual change: grass cover changed by 0-1%, flooded vegetation in coastal areas fluctuated between 7-9%, crops varied by 4-5%, shrub and scrub changed by 0-2%, the built area shifted by 3-5%, while bare ground and mud/sand exhibited virtually no change. The Tab. 3 shows year-to-year land-cover changes in Prieto Diaz. The table indicates a gradual increase in the built area, reflecting the expansion of residential, commercial, or institutional land uses likely driven by population growth and rising housing demand.

In Tab. 3, the largest land cover classification corresponds to DN=1 "Trees," indicating that various tree species occupy most of the land area. However, none of these trees are classified by the Department of Environment and Natural Resources (DENR) as "Forested," since the entire town is designated 'Alienable and Disposable' under current land use regimes. The only exception is the mangrove forests which are protected by law. The decrease in tree cover in the Prieto Diaz is largely attributable to an infrastructure project by the Department of Public Works and Highways and the National Irrigation Authority, which constructed an irrigation dam and distribution system in the upland barangay of San Antonio. Moreover, the built-up area has grown from 136.88 hectares in 2017 to 182.82 hectares in 2022, reflecting the expanding residential zones driven by a rising population. Between 2018 and 2022, the municipality's south-eastern quadrant experienced steady gains in tree cover and flooded vegetation, especially in the barangays Brillante, San Isidro, Bulawan, Lourdes, Ulag, Calao, San Fernando, and Carayat,

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Table 3 Land Cover Classification in Hectares, 2017-2022. The table shows the area of each classified land cover from 2017-2022, showing how they changed over time.

DN	Land Cover Classification	Total Area (in Hectares)					
		2017	2018	2019	2020	2021	2022
0	Water	138.41	133.35	95.88	126.04	121.93	92.93
1	Trees	3582.19	3571.13	3513.97	3512.4	3532.27	3,549.83
2	Grass	45.32	14.67	33.91	39.89	9.78	62.61
3	Flooded Vegetation	287.71	415.96	382.07	297.96	262.27	329.59
4	Crops	163.95	181.06	212.79	225.47	245.03	135.50
5	Shrub and Scrub	36.23	37.44	42.71	10.96	2.43	86.24
6	Built Area	136.88	140.97	171.00	214.63	176.8	182.82
7	Bare Ground	0.09	0.76	5.17	6.29	4.31	5.24
8	Mud or Sand	6.26	0.00	0.00	0.00	0.05	9.03

where mangrove forests and seaweed/seagrass beds prevail. The rise in mangrove cover reflects the town's restoration of previously denuded forests under the Mangrove Stewardship Agreement (MSA) awarded by the Department of Environment and Natural Resources (DENR) to SEAMANCOR Eco-Developers, Inc., and the Local Government Unit of Prieto Diaz; each party now manages 500 hectares of mangrove forest. By linking stewardship of fishermen's livelihoods, the agreement fosters a strong of ownership and responsibility among resource users, driving mangrove conservation and further expansion. Likewise, the proliferation of seaweed and seagrass beds stems directly from the municipality's targeted coastal conservation and protection initiatives.

Between 2017 and 2022, Prieto Diaz experienced significant land cover changes, particularly in tree cover, with a net loss of 91.87 hectares. Most of this loss occurred in developing barangays—San Fernando, Calao, Ulag, Santa Lourdes, Bulawan, San Isidro, Gogon, Manincay de Oro, Perlas, Diamante, Tupaz, Rizal, Quidolog, Lupi, San Ramon, Manlabong, Talisayan, and San Antonio —where residential and commercial land uses expanded. Additional reduction in tree cover resulted from constructing an irrigation dam in San Antonio. Fig. 4 illustrates the annual net gains and losses for each land cover category, reflecting the expansion and contraction of different land covers. Built-up areas also grew from 136.88 hectares in 2017 to 182.82 hectares in 2022, underscoring how population growth drives residential development.

While tree cover declined in developing areas coastal zones —particularly the mangrove forests along the municipality's eastern shores —experienced gains. From 2017 to 2022, the mangrove increased by 167.71 hectares, even as141.93 hectares were lost to other land cover categories, chiefly flooded vegetation, suggesting a transition to seagrass beds or low-lying vegetation. Fig. 5 illustrates mangrove gains and losses over this 5-year period, highlighting the concerning loss to flooded vegetation and built-up areas concerns particularly. The observed increase in mangrove cover from 2019 to 2022 indicates either new growth or the expansion of existing canopies.

To enhance the accuracy of land cover classifications, it is crucial to address the confusions between similar or adjacent land cover categories. The most frequent misclassifications occur between water and flooded vegetation, and between flooded vegetation and grass—especially in agricultural areas where planting schedules can vary. As a result, neighboring rice fields may be at different growth stages: bare soil, transplanted, or vegetative. To improve future land cover classification efforts, it is recommended to gather more training points across these crop growth stages and focus particularly on agricultural zones, where land cover changes are more frequent throughout the year.

Continuing socio-economic development will drive population growth and concentration in areas offering essential environmental, social, and economic services. Urbanization – defined as the increase in the proportion of people living in urban areas – occurs alongside development. Consequently, regions with economic opportunities will attract in-migration and experience rising populations.

Projections indicate that Prieto Diaz's population will reach nearly 35 000 by 2030, with urban barangays growing faster than rural ones. Although the rural population is still expected to outnumber the urban population by approximately 11 000 individuals in 2030, the urban growth rate continues to exceed the rural rate – a trend observed since the year 2000. Five barangays – Brillante, Perlas, Diamante, Tupaz, and Manincay De

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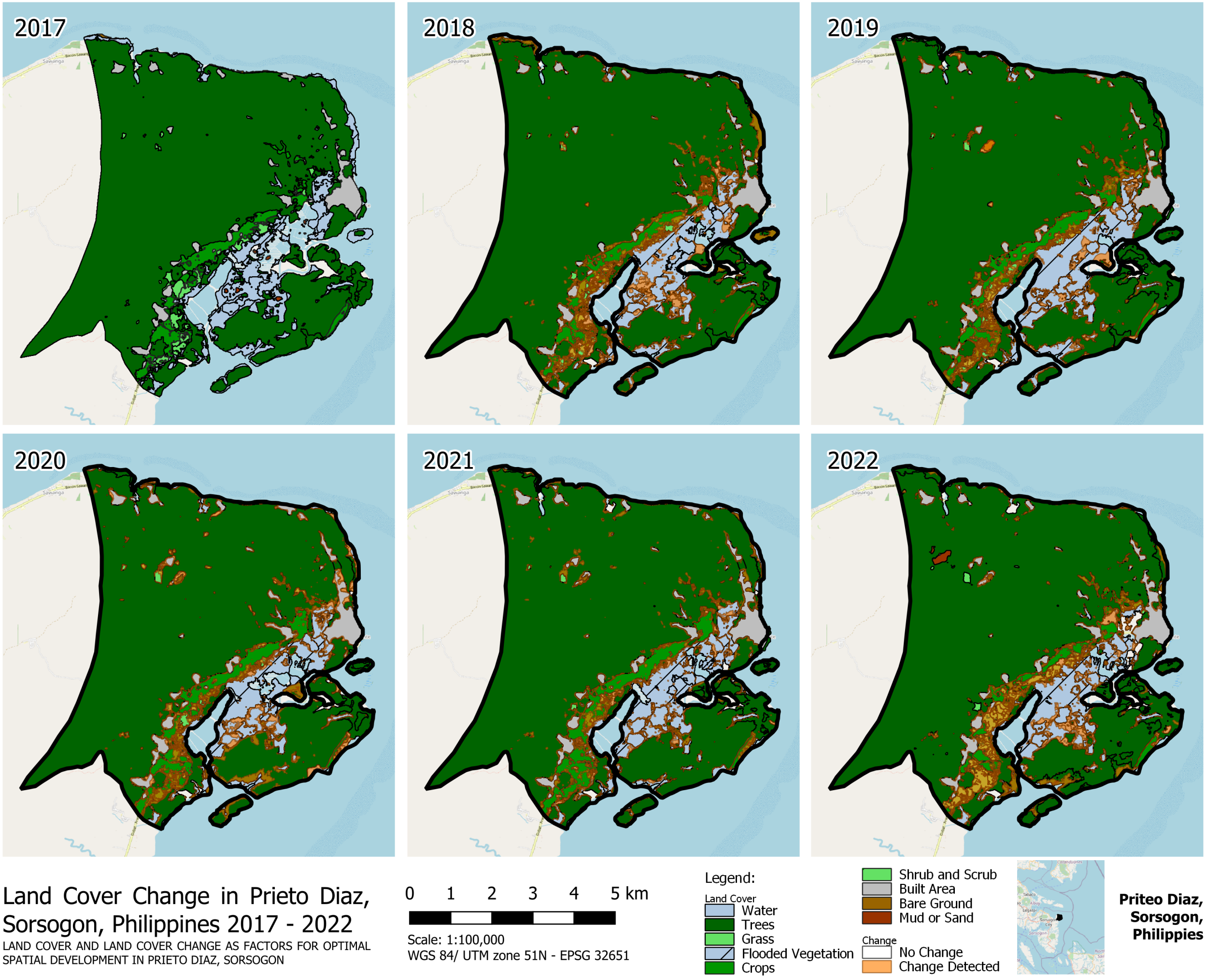

Fig. 4 Year-on-Year Land Cover Change in Prieto Diaz, 2017-2022. Areas highlighted in orange show where land cover changes occurred between the present and previous years.

Oro – are considered urban barangays, and according to the 2010 and 2015 censuses, these urban barangays recorded an annual growth rate of 6.52 %, compared to the 0.89 % in rural areas. Previous planning efforts addressed demographic changes and the resulting increases in demand for economic development, social services, infrastructure, and land use without considering the municipality's patterns of land cover and land use change, because updated information on these changes over time was unavailable.

4.2 Land cover change and sectoral priorities

The marked increase in tree cover across the town, particularly in its mangrove areas, reflects the community's strong commitment to rehabilitating and expanding mangrove forests as a strategy to stabilize coastal zones and support aquatic habitats vital to the fisheries sector. Notably, Prieto Diaz was awarded first prize for its exemplary mangrove rehabilitation efforts in the Bicol Region (Gonzales 2020-07-09). This land cover trend underscores the priority placed on sustaining the fisheries sector, which is reflected in the fishermen's positive ratings on having a stable and sustainable livelihood. This focus on rehabilitating and expanding the mangrove forests seem to have had an impact on the locals' perception on food security and climate change adaptation, as seen in the Vision-Reality Gap assessment done during public consultation. However, more can be done to improve the town's situation along food security, livelihood, economic services, and human settlements.
Aside from the noticeable changes in tree land cover, most of the observed land cover changes occurred in the town's 1 102.2 hectares of rice fields, which are located primarily in the lowland

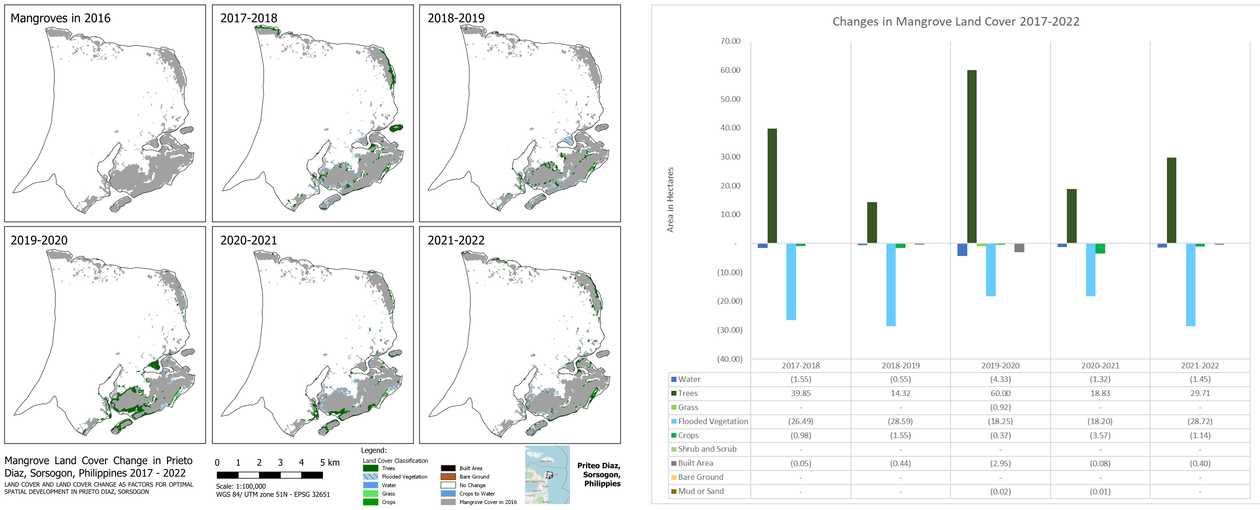

Fig. 5 Mangrove Land Cover Change in Prieto Diaz 2017-2022, overlay with the 2016 data. Areas in dark green show the location where tree cover increased within mangrove areas.

barangays (villages) along the national highway. This reflects the town's dependence on its agricultural sector as a source of livelihood with 644 rice farmers relying on a stable and sustainable environment for rice planting.

Several basic service and livelihood dimensions – Quality of Life, and Water Security – cluster around the 2.06 to 2.08 range, reflecting moderate progress (Fig. 6). More complex investments – Economic Services with a rating of 1.79 suggests technical or resource bottlenecks. The consistency of moderate scores hints at broad consensus on partial achievement but also shared frustration at incomplete realization. Shared frustration over unmet development goals drives communities to demand that land use policies be more responsive, equitable, and participatory. When residents feel their visions – whether for secure housing, productive farmland, or resilient coastal buffers – aren't being realized, they push local governments to reorient zoning, tenure arrangements, and infrastructure plans toward community-defined priorities (Sebunya & Gichuki 2024).

4.3 Identified development clusters and spatial development options

Economic and social development in the municipality is constrained by both economic and environmental conditions that limit growth. Among the identified challenges are meteorological calamities such as typhoons and El Niño, that disrupt agricultural production. The local government also documented the high cost of agricultural inputs that affect yield as a challenge; limited farm machinery and post-harvest facilities; insufficient irrigation; the absence of alternative livelihoods for farmers and fishers; low technology adoption rates resulting in idle farmland; poor marketing connections due to the town's distance from Asian Highway 21 (AH21); lack of external support; and inadequate tourism facilities and infrastructure.

Prieto Diaz has been divided into four development clusters (Fig. 7) that group similar conditions, challenges, and opportunities based on economic characteristics and population growth trajectories. These clusters are the Agroforestry Cluster in the upland barangays; the Agricultural Cluster in the lowlands; the Commercial and Institutional Cluster situated in the urban barangays; and the Coastal Conservation-Enterprise Cluster along the western seaboard of the town.

Drawing on these clusters – together with identified land-cover change patterns and demographic shifts – this study proposes three spatial development options for the municipality

Option 1: Business-as-usual Option

The do-nothing development option entails continuing the existing development initiatives without intervention or modification. This preserves the status quo, allowing only modest, incremental gains in environmental conservation and socio-economic development.

Option 2: Aquatic Ecosystem Services Development Option

Prieto Diaz is endowed with vast mangroves spanning nineteen coastal barangays. These forests cover approximately 1,000 ha, half (500 ha.) of which falls under a Mangrove Stewardship Agreement (MSA) awarded by the Department of Environ-

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Sectoral Priorities	Farmers	Fishermen	Professionals	People's Organizations Representatives	Non-Government Organizations Representatives	Government Officials and Civil Servant	Barangay Captains and Officials	Sangguniang Bayan Members	Average
Quality of Life	2.00	0.00	2.00	2.00	4.00	2.50	2.17	1.83	**2.06**
Food Security and Sufficiency	2.50	1.25	2.00	1.50	1.75	2.63	2.33	1.89	**1.98**
Water Security	2.60	2.80	1.53	1.30	2.40	2.28	2.23	1.51	**2.08**
Stable and Sustainable Livelihood	2.60	2.20	1.93	1.10	2.20	2.41	2.10	1.31	**1.98**
Stable and Sustainable Economic Services	2.00	1.70	1.80	1.00	2.20	2.21	2.06	1.33	**1.79**
Stable and Sustainable Social Services	2.86	1.14	2.43	1.79	2.86	2.45	2.36	1.59	**2.18**
Human Settlements	2.00	1.00	1.67	0.50	2.00	1.75	2.40	1.29	**1.58**
Climate Change Adaptation and Disaster Risk Reduction Management	2.25	1.50	2.92	1.63	2.00	2.69	2.92	2.14	**2.26**

Fig. 6 The result of the Vision-Reality Gap workshop of the representatives of the different sectors of Prieto Diaz. The ratings ranging from 1-4 (4 being the highest) show the agreement of the participants if the sectoral priorities (Vision) are being met or achieved (Reality). The sectoral priority most perceived as achieved in the existing land use policy scenario is Climate Change Adaptation and Disaster Risk Reduction Management, with an average rating 2.26 on a 4-point scale. Stable and Sustainable Social Services trails behind, scoring 2.18. Overall, no sectoral priority exceeded a 3.0 average, indicating a notable gap between vision and reality and signaling room for improvement across all areas.

ment and Natural Resources to SEAMANCOR Eco-Developers, Inc., while the other half is managed by the Local Government Unit's Municipal Agriculture Office. To date, local authorities have identified eighteen mangrove species in the rehabilitated areas.

This development option aims to leverage the town's rich coastal resources by expanding the market reach for seaweed and dried fish products. It focuses on creating additional jobs and strengthening related industries in the coastal barangays.

Option 3: Ridge-to-Reef Conservation-Enterprise Development

The Ridge to Reef Conservation Enterprise Development Option is a planning strategy complemented by environmentally-sound soil and water management practices and by mechanisms that foster greater responsibility and engagement among individuals, groups, communities, and other stakeholders benefiting from these conservation areas. This integrated approach promotes Prieto Diaz's 'ridge-to-reef' land and coastal resources, addressing the risk and realities faced by upland, midland, lowland, dryland, and wetland communities.

The preferred development thrust is expected to help balance and sustain the municipality's growth by ensuring that local natural resources continue providing services that support the livelihoods of farmers, fisherfolks, residents, ecotourism, local industries, and other socioeconomic activities.

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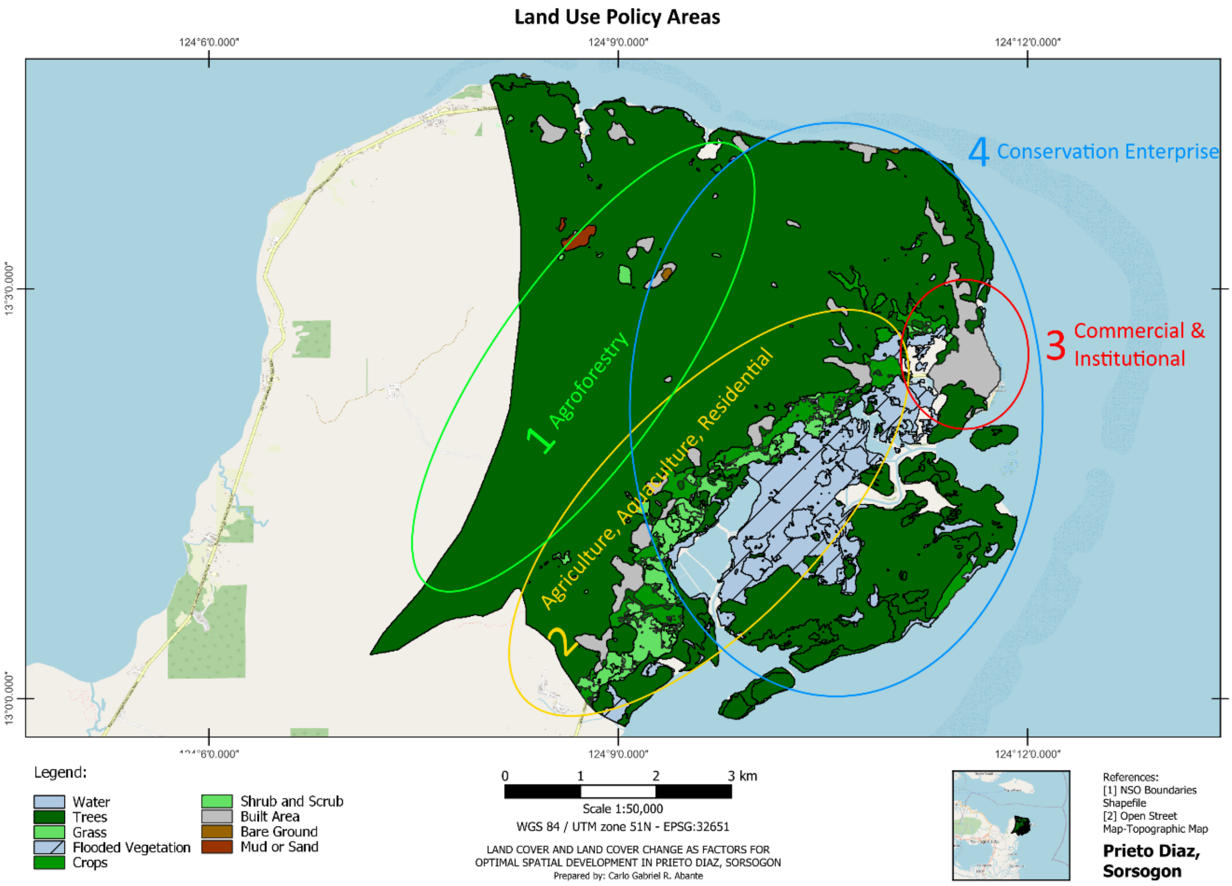

Fig. 7 Development Clusters based on Land Cover, Land Use, Ecosystem, and Socio-Economic Conditions. These development clusters are the foundation for deciding the land use policy areas and in identifying the preferred spatial development option.

Prieto Diaz's vision centers on preventing or reducing potential disasters by adopting the Ridge to Reef Conservation Enterprise Development Spatial Framework as its medium to long-term development strategy. This framework guides decisions, directions, and actions toward achieving greater stability and resilience across the municipality. it delivers meaningful risk reduction and supports recovery by restoring and enhancing living conditions from ridge to reef. By promoting the prudent use of land, water, and natural resources, it advances preparedness, reestablishes physical and environmental balance, and fosters sustainable development in line with the Sendai framework. Ultimately, forward-thinking risk governance emerges from informed decision-making and timely, targeted interventions that optimize resource use and build preparedness for today's generation.

The Fig. 8 presents the outcomes of a consultative meeting attended by staff from various departments of the Local Government Unit of Prieto Diaz, municipal councilors, the town mayor and vice mayor, barangay captains, private sector representatives, professionals, fishermen, farmers, and representatives of various People's Organizations. It shows which of the proposed options they prefer for achieving the parameters of the town's vision.

Government-cluster respondents favor the Ridge to Reef Conservation Enterprise Development Spatial Development Framework over all other options. Non-government respondents, by contrast, appear to prefer the 'No-Intervention' strategy. However, given how closely their ratings align with those for the conservation-enterprise option, this study still has that option as a viable strategy for their group.

This slight preference margin among non-government respondents may reflect their view that existing programs and projects adequately address the municipality's vision parameters, even as they remain open to exploring alternative development strategies.

The production area is one of four land use policy areas used by the Philippine government to match

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Average Ratings per Option	Government Respondents	Non-Government Respondents
No Intervention Spatial Strategy	2.68	2.96
Aquatic Ecosystem Services Development Option	2.87	2.90
Ridge to Reef Conservation Enterprise Development Spatial Development Framework	2.92	2.90

Fig. 8 Summarized Ratings on the Spatial Development Options between Government and Non-Government Respondents. Ratings in green show the preferred option between the two participant groups.

policies with the general land use categories, namely: protected areas, settlement areas, infrastructure areas, and production areas (DILG 2008). The preference for the Conservation Enterprise spatial development option highlights the desire and need of the locals to develop its production areas to improve socio-economic conditions. As a 5th income class municipality, the town's economy mainly relies on fisheries and agriculture, with fishermen and farmers working in elementary occupations during off seasons. It is understandable that during the public consultations and workshops, the interests and priorities of the stakeholders align with their sector. The fisheries sector wanted to focus on expanding the dried fish and seaweed industries and coastal tourism. Meanwhile, the stakeholders from the agriculture sector favor policies and programs that would develop post-harvest facilities, improve market links for agricultural products, and subsidize farming inputs, equipment, and facilities. To accommodate or bridge these two varying stakeholder priorities, the study proposed the Conservation Enterprise Spatial Development Option as a compromise wherein the local government will push for policies and programs promoting sustainable livelihood that takes advantage of the town's richness in coastal resources, while exploring ways to develop agroforestry in the upland villages, expand assistance to farmers, while stabilizing its urban growth and expansion.

The chosen development option would focus on creating economic opportunities by utilizing the town's natural resources and features, without sacrificing the stability of the environment. The development would center on the relationship between livelihood and environmental stability to promote and ensure environmental conservation. This will be done by integrating the preferred spatial development option as a key policy feature of the town's comprehensive land use plan – a legally binding document that sets the policy framework for the town's land use development for the next ten years.

Between 2018 and 2022 the municipality's southeastern quadrant experienced steady gains in tree and flooded-vegetation cover, particularly within the mangrove forests and seaweed/seagrass beds of barangays Brillante, San Isidro, Bulawan, Lourdes, Ulag, Calao, San Fernando, and Carayat. The increase in mangrove cover reflects ongoing restoration of degraded forests under the Mangrove Stewardship Agreement (MSA) awarded by the Department of Environment and Natural Resources to SEAMANCOR Eco-Developers, Inc., and the Local Government Unit of Prieto Diaz; each party now manages 500 hectares of mangroves. By linking fishermen's livelihoods, this collaboration fosters a strong sense of ownership and responsibility among resource users driving further expansion.

Likewise, the proliferation of seaweed and seagrass beds – evident in increased flooded-vegetation cover – is directly credited to the municipality's conservation and protection efforts. These measures include the enactment of the Prieto Diaz Seagrasses Bed Reserve Ordinance (Municipal Ordinance No. 2002-03) and the provision of trainings, seedlings, and material inputs since 2010.

Since the year 2000, urban population growth has consistently outpaced rural growth. The five coastal urban barangays – Brillante, Diamante, Manincay de Oro, Perlas, and Tupaz – are projected to grow at an annual rate of 6.52%. Current projections indicate that by 2030 the urban population will increase by 11.67%, while the rural population will decline by the same proportion. This trend reflects migration from rural areas to urban barangays, where most of the physical, social, and economic infrastructure is located. As a result, a gradual expansion of built-up areas – especially residential developments – to accommodate the growing urban population, can be anticipated.

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5 Conclusions

This study generated valuable, reasonably accurate land cover data using open-access datasets and tools. It highlights how small LGUs can leverage these free platforms and services to overcome limited access to commercial data. While integrating this approach into routine local planning will require substantial capacity and capability development, it remains achievable with targeted investments in human capital.

Over the past few years, Prieto Diaz's landscape has undergone significant change. Despite a small economy and slow urbanization, the expansion of built-up areas in the urban barangays reflects population growth and increased reliance on natural resources. Examining the socio-ecological status of the town's coastal areas offers valuable insights into the complexities of land use planning in dynamic environments. By applying geospatial methods and data to assess land cover changes, policymakers can develop effective strategies to promote sustainable development, ensuring the resilience and well-being of both ecosystems and local communities.

Contrary to expectations that urbanization eventually leads to environmental degradation, coastal development in Prieto Diaz has not caused a net loss of mangrove cover. On the contrary, mangrove area has increased thanks to intensive conservation efforts.

Supported with a clear understanding of land cover change patterns and the municipality's growth trajectory, stakeholders agree that despite its higher costs, the Ridge-to-Reef Conservation Enterprise spatial development option best addresses the needs of all sectors. Development should build on the municipality's strengths in the coastal areas while also meeting the needs of its upland communities.

With the results of this study, local governments can now leverage freely available satellite imagery and open-source geospatial tools to overcome budgetary constraints, shifting the power dynamics of data ownership toward bottom-up planning. By investing in human capital and technical training, small LGUs can transform one-off research projects into sustained operational capacities, embedding geospatial analysis into routine policy cycles. The Prieto Diaz case challenges the prevailing assumption that urban growth invariably degrades ecosystems: targeted stewardship interventions coincided with a net increase in mangrove cover, illustrating how development and conservation can advance hand in hand. These insights enable more nuanced Ridge-to-Reef governance models that address coastal livelihoods, upland agroforestry, and hazard mitigation in a single, integrated framework.

Beyond practical applications, this study contributes to theory by demonstrating the democratization of geospatial knowledge and extending participatory planning frameworks through open-access data platforms. It offers empirical evidence that urbanization needs not compromise ecosystem services when deliberate conservation measures are in place, advancing scholarship on sustainable urbanization and nature-based solutions. By bridging land use planning theory with socio-ecological systems analysis, the research underscores how iterative monitoring of land cover can inform adaptive governance in dynamic coastal environments.

Finally, the Conservation Enterprise development option emerges as a novel hybrid model – fusing economic opportunity with ecosystem stewardship – and highlights the critical role of stakeholder consensus in legitimizing higher-cost conservation strategies, reinforcing theories of collective action and policy co-production in resource-dependent communities.

The analysis of land cover changes in the municipality, combined with demographic shifts, provides essential inputs for policy formulation and review. Adaptive, science-informed, and collaborative policies are recommended. Balancing economic development with environmental protection and ensuring sustainable land use practices for the benefit of both present and future generations should be prioritized.

To conclude, our results and recommendations can be summarized in the following four areas:

(i) Challenges in Land Cover Classification: While changes in tree and forest cover are well-understood, other land cover shifts are driven by human activities and the local economy, especially agriculture and aquaculture. Misclassifications among croplands, grasslands, shrubs, scrub, and flooded vegetation stem from the limitations of Sentinel-2 Images (10x10 resolution). Although higher-resolution commercial sources would more effectively resolve these issues, budget constraints compel us to improve in situ observations and refine our supervised-classification techniques.

(ii) Conservation and Restoration Policies: The observed increase in mangrove and seagrass highlights the success of conservation efforts. Initiatives such as the Mangrove Stewardship Agreement (MSA) and the Seagrasses Bed Reserve Ordinance should continue to recieve support through local policies to maintain and expand these critical

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ecosystems. Any expansion of the town's programs and projects —whether through additional fund allocation or increased community participation —should promote sustainable practices that protect and restore mangrove and seagrass habitats, given their ecological importance and the benefits they provide to local communities, particularly for livelihoods.
(iii) Agricultural and Livelihood Policies: Recurring land cover changes within agricultural areas reflect the local economy's reliance on farming. Approximately fifty percent of municipality's population work in forestry, agriculture, and fisheries sectors. Recognizing agriculture as a critical livelihood source, policies should promote sustainable farming practices. Through training programs, seedling distribution, and provision of material inputs agricultural productivity can be enhanced while minimizing negative impacts on land cover. These policies should address land preparation, planting, cultivation, and harvesting activities to balance economic needs with environmental conservation.
(iv) Anticipated Urban Expansion: Projected population growth will drive a gradual expansion of built-up areas-especially residential development – especially residential development – to accommodate the growing urban population. Policies must guide this urban growth and infrastructure rollout, particularly given these barangay's proximity to mangrove forests and seagrass-seaweed beds. Well-planned neighborhoods, efficient transportation networks, and adequate social amenities are essential for urban barangays experiencing population growth. Also, preventing solid and liquid waste from contaminating the coastal resources critical for the livelihood of these communities should be prioritized.
Finally, policy frameworks should foster community engagement and resource ownership. Offering incentives for responsible land use —such as participatory management schemes and livelihood benefits —will strengthen conservation efforts.

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