Land Cover Change of Klaja Karst Watershed, General Santos City, Philippines

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ABSTRACT

Effective land management and sustainable development necessitate an understanding of land usage's scope and mechanism. This study aims to identify changes in land cover in the Klaja Karst watershed due to urbanization, development, and ongoing population growth, as well as to create projections for the area's land cover twenty (20) years from the completion of the study. The study created land cover maps spanning 2003 to 2020 to investigate patterns and changes in the area's land cover. Furthermore, projection maps for 2030 and 2040 were created using a dataset derived from the abovementioned maps. The predicted maps show steady growth of perennial crop cover and built-up areas. The most prominent variables leading to this increase are urbanization, population growth, and overall development. The city's residents, on the other hand, have relied on the growth of perennial crops to meet their demands and produce sustenance. Conversely, the increase in built-up areas and perennial crops has reduced the coverage of other land types, particularly annual crops, open forests, and grasslands. Based on the information presented above, the researcher devised an action plan that prioritized improved land management, conservation, and utilization. The plan calls for strengthening the implementation of environmental laws and policies, providing farmers with additional farm inputs, financial assistance, and promoting co-management of the study area with neighboring municipalities. Part of the consideration is the formation of a Watershed Management Council for the Klaja Karst Watershed, as well as the possibility of declaring the study area a local conservation area and developing a long-term strategy. In general, the study and its findings represent a significant step forward not only for the city and region but also for a wide range of sectors, particularly land planners and environmentalists who are developing management plans that are economically viable, socially acceptable, and environmentally sustainable.

Keywords: Karst Watershed, Land Cover, Urbanization, Population Growth, Development

INTRODUCTION

Background of the Study

Land Use and Land Cover (LULC) change is a key source of not only an environmental problem in many developing countries but also a root cause of social unrest and problems in many developing countries [1]. Constant population growth and continuous economic development, coupled with rising food demand, have placed enormous strain on environmental resources, causing fast LULC changes [2]. Global Land Use Land Cover changes are mainly driven by industrialization, urbanization and increase crop production, as well as extraction of natural resources from forest and other areas of nature [3].

In the Philippines, land cover changes are unavoidable in developing areas and even protected areas. Based on a national forest cover assessment carried out in the country between 2000 to 2012, a large portion of the country's protected areas have experienced decreased forest cover [4]. The results showed that LULC change happened when built-up areas increased by 117% despite the regulations implemented. The impetus for land cover changes has been attributed to the direct drivers of deforestation, including unsustainable forest product extraction, agricultural expansion, and infrastructure construction [5].

On the other hand, the limestone karst ecosystem, which is crucial for maintaining the hydrological integrity of watersheds and providing complex habitats for a variety of organisms, also has its own share of struggles in relation to the continuous changes in land cover. In General Santos City, Klaja Karst Watershed comes in first place as one of the most popular tourist destinations [6] and the source of groundwater for eleven barangays and nearby municipalities is considered as one of the country's least studied karst regions from a biological standpoint. Klaja Karst watershed lies within the city of General Santos with a total land area of 14,204.98 hectares or covers about 26 percent of the city's land area and supply the domestic water of around 45% of the population of the city [7].

Like any other watershed, it also experienced forest disturbance due to land cover changes. Narratives from the City Land Use Plan (CLUP) of General Santos City and the watershed characterization conducted by DENR have recorded anthropogenic activities in the area, including harvesting of non-timber forest products, rampant illegal production of charcoal, grazing, timber and wildlife poaching, illegally established structures for settlement, industrial, and commercial purposes. Despite of that, the extent of land cover change in Klaja Karst has not been examined, and the need to describe the extent of land cover needs to be done through a comprehensive assessment. This will serve as guide for government agencies, environmental planners, business establishments, and legislators of the City of General Santos in drafting a management plan for the protection, conservation, and management of Klaja Karst Watershed.

Similarly, this study represents significant preliminary steps in assessing the overall condition of Klaja Karst watershed and will raise awareness among regulatory government institution and the Local Government of General Santos about the importance of adopting local conservation policies and strategies to protect and manage the Klaja Karst Watershed.

The Karst Watershed and Limestone Ecosystem

Southeast Asia is like a bouquet of flowers, with 11 countries blooming like vibrant petals. According to Sodhi et al. (2004), the following nations are included in this group: Myanmar, Vietnam, Laos, Thailand, Cambodia, Malaysia, Singapore, Indonesia, Brunie, East Timor, and the Philippines were come together to create a tapestry of diversity and beauty. According to Day and Urich (2000) [8], the region is comparable to a treasure trove of colossal limestone landscapes. Nearly ten (10) percent of the overall land area in Southeast Asia is comprised of this region, which spans an area of around 460,000 square kilometers (km2).

It is well known that the Philippines is home to a vast number of trees that cover limestone areas. A significant portion of the country's land area, approximately 30,000 km2, consists of Karst landscapes. However, considering the government and institutional sectors' lack of financing and importance, a large portion of this went untouched by scientific communities. A comprehensive plan must be developed to protect and manage the country's unique ecology [9].

In this context, there is a distinct lack of focus placed on safeguarding and studying the Philippine Karst, which raises worries. Karst landscapes represent approximately ten percent of the country's land surface, offering a fragile ecosystem and natural environments for a wide variety of species of fauna and plants. Experts have yet to examine a significant portion of this ecosystem [10]. Dr. Diesmos (2016) [10] identified lack of research data on karst environments, which are vulnerable to human-induced disruptions. These activities include mining, land conversion, and other damaging practices. Furthermore, estimations show that the current survey covering of the country's karst ecosystem is just about 10%. This is partly due to a lack of a unified approach to incorporating Karst research, preservation, and conservation goals and the research initiatives of key organization and academic institutions.

Therefore, it is crucial to have accurate data on land use and land cover, as well as the potential for their most efficient utilization. This information is necessary for the identification, design, and execution of land use strategies that can effectively address the growing requirements for fundamental human necessities and well-being. This information also aids in tracking the fluctuations in land utilization due to the evolving needs of the growing population.

Before it was only considered that Klaja Karst Watershed only occupies a certain parcel of land situated in Brgy. Conel, Brgy. Mabuhay, Brgy. Olympog, and Brgy. Upper Labay in General Santos City but just recently through the collaboration of DENR RO XII and its line agencies, USAID Safe Water, and the Local Government of the City of General Santos it found out that Klaja Karst Watershed occupies a larger track of lands which covers a portion of Brgy. Tinagacan, Brgy. Katangawan, Brgy. Ligaya, San Isidro, Lagao, Brgy. Bula, and Brgy. Lagao. Due to this development, the Klaja Karst Watershed land area expanded to 14,274.01 hectares which qualified to be recognized as a medium-scale watershed per DENR watershed Categorization. Klaja Karst Watershed covers 26% of the total land area of the City of General Santos which is 53,606 hectares [11].

Drivers of Land Cover Changes

Land is a vital and irreplaceable natural asset that has a critical role in diverse social, economic, and environmental functions. The issues of land use and land cover change persist as a result of societal advancements and environmental influences. Land use and land cover changes are significant phenomena that take place on the Earth's surface and have profound impacts on society as a whole, the environment, ecological diversity, hydrological cycles, ecological systems, biogeochemical processes and other processes [12] [13] [14]. The deterioration of watersheds and karst areas has made the ecosystem more vulnerable to the frequency and intensity of extreme weather events [15]. Although land cover changes occur naturally and gradually, they can also occur quickly and abruptly due to human activity [16]. After carefully examining land cover change, Renault et al. on their study on land-use change and impacts on 2020 came to the conclusion that it is a major factor contributing to worldwide changes [17].

The conversion of undeveloped landscape into populated regions has a long-term impact on the ecosystem. According to Karen C. Seto on her study on Sustainability in an urbanizing planet on 2017, it causes an increase in the loss of highly productive agricultural activities, changes usage of energy, alters temperature, messes with water cycles, upends ecosystems, and speeds up the extinction of species [18]. When the land

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cover is drastically changed—forests being converted to other uses, for example—long-term changes to the land surface occur [19]. Major changes in land usage and land cover, as well as regional and global land surface, have been brought about by the proliferation of cities worldwide and the influence of population increase on urban development [20].

To keep up with the various activities of the expanding population, a sizable amount of natural land covers has been wiped out and transformed into other land use types, such as agricultural land and urban areas [21]. Urban infrastructures including housing, sanitation, water supply, transportation, electricity, health care, and education, is under tremendous strain due to the ongoing increase in urban residents, which is a result of both natural development and migrations [22].

Song et al. on their study on Efficiency of urban land use in China's resources-based cities found that 60% of worldwide land use and cover changes from 1982 to 2016 were human-induced. Other changes were caused by indirect processes like environmental degradation [23].

Scientific literature states demographic, socio-economic, institutional, technological and biophysical factors as the main factors shaping land use and land cover change in different countries across the globe, with some of these factors prevailing more or less in certain regions depending on the specifics of the study area and local context [24]. According to Lambin, the history of land use, which influences land practices, is another significant factor influencing land use change. According to their most recent research, remittances from migrants and other indirect factors have a significant influence on land systems, which in turn affects land transformation.

According to Cheruto M. et al. [25], the primary factors influencing LU/LC shift can also be linked to the growing population's consumption needs, which is a significant worry in connection to environmental change.

Theoretical Framework

In their 2021 study titled "Urbanization and Land Use Change," Nuissl and Siedentop acknowledge that the expansion of human civilization has not only involved agricultural activities but also the conversion of agricultural land for residential and associated purposes, leading to encroachment on natural ecosystems. The observable consequence of land use change resulting from urbanization is the physical expansion of developed areas (which entails a substantial modification of land surface characteristics), accompanied by shifts in the spatial arrangement and physical shape of urban areas. In addition to the well-documented consequences of urbanization such as global warming, acid rain, and ozone depletion, it is argued that urbanization also has a significant influence on the accessibility of cultivable land, resulting in deforestation in many regions across the globe [27]. Another new trend is the loss of prime land farmland areas to urban expansion. Because cities were often founded near the prime farmland areas, expansion of cities due to population growth leads to an encroachment of built-up areas on to some of the world's best agricultural soils. While this is not significant yet on a global scale, regional scale trends area alarming [28].

Studies by Bruggeman, et al. (2016) [29] and Yangchen, et al. (2015) [30] also confirmed infrastructure development especially by rapidly growing cities such as Thimphu as a primary cause of forest loss in Bhutan. In the study of LULC change detection and prediction in Bhutan's high-altitude city of Thimphu, using cellular automata and Markov chain, Sonam Wangyel Wang [31], confirms that the rapid development of urban built will lead to sharp declines in forest and agriculture and increase in urban population.

The LULC change is a driver of global environmental change such as emission of greenhouse gases (MEA, 2005), habitat loss/ fragmentation and biodiversity loss [32] [33], and reduce the quality of human wellbeing [34]. Rapid increase in human population and associated economic development further exacerbates the rate of these changes especially in fast growing urban areas [35]. Generally, cities in developing nations area characterized by poor infrastructural plans, high immigration rates, growing squatter settlements, etc. this demand addressing unique challenges and opportunities for urban adaptation and mitigation responses and for mainstreaming them into urban development plans.

MATERIALS AND METHODOLOGY

The Application of Geographic Information System (GIS) for Tracing and Predicting Changes in Land Cover

Geographic Information Systems (GIS) and Remote Sensing are important instruments when it comes to studying how land has been utilized, either changed or unchanged, for different purposes over a period. Although there exist many types of land use/climate data sources such as: satellite pictures, rainfall histories and population density but they may not be helpful if they can't be integrated effectively with actual conditions on the ground. Spatially-specific data from these technologies on the location and magnitude of these changes enables more accurate and effective management strategies [26].

A bundle of state-of-the-art methodologies for mapping and enquiring the Earth and human civilization generally is what makes up geoinformatics. Since they were initially developed, many changes have been done on these instruments. This field allows individuals to collect georeferenced data which they can use for modeling, evaluations, simulations, and visualizations. A system that was designed with geographic concepts was called a Geographical information system (GIS). Basically, it's a complete system used for gathering, organizing and evaluating spatial based data.

Conceptual Framework

In order to achieve this goal, the researcher came up with a conceptual framework that integrates input, output, and process as key components. In this framework, input refers to the resources or factors that are used in a system or process. In this framework, input refers to the resources or factors that are used in a system or process. These can include information or other inputs that are necessary for the functioning of the system. Output, on the other hand, refers to the results or outcomes that are produced by the system or process. This can include historical maps, projected maps, and action plans that are generated. Process refers to the activities or steps that were undertaken to transform the inputs into outputs. It involves the various actions that occur within the system.

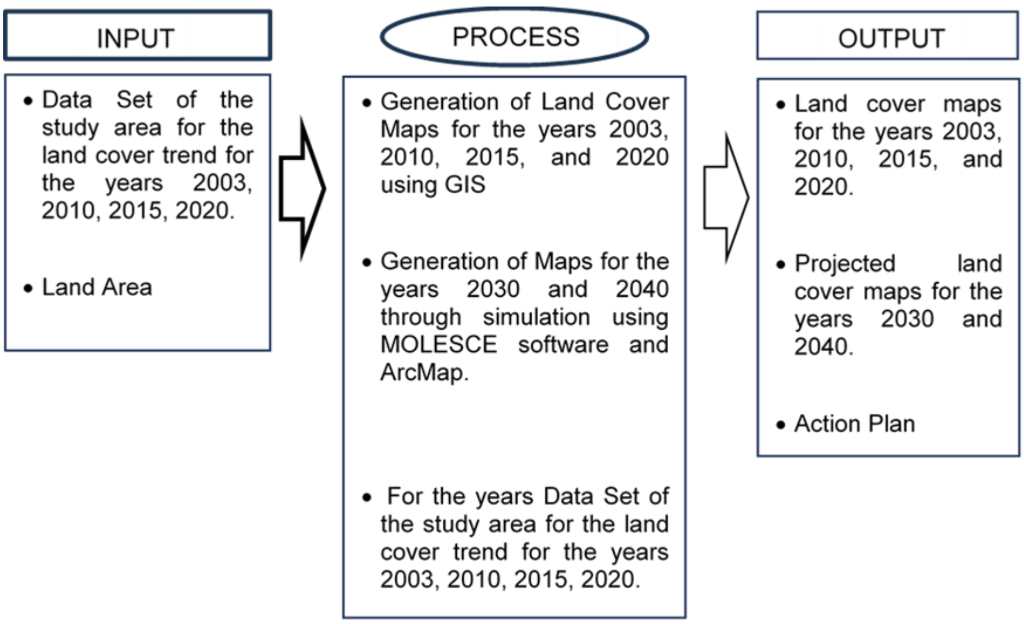

Figure 1. The conceptual framework of the study.

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Location of the Study

The Klaja Karst Watershed is located in General Santos City, South Cotabato, where we conducted the study. The study area is specifically located within the geographical coordinates 6011’655.724” N, longitude 125011’5.217” E, and it falls on the southern portion of Mt. Matutum, a declared Protected Landscape (Mt. Matutum Protected Landscape) located at the boundaries of the municipalities of Tupi and Polomolok, South Cotabato, Philippines, that supplies 25% of the water requirements of the SOCCSKSARGEN (Acronym for the region’s four provinces and one of its cities: South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos City) area (Foundation for the Philippine Environment). The study area encompasses eleven barangays in General Santos, with Brgy. Upper Labay, Brgy. Tinagacan, and Brgy. Mabuhay bordering it on the north-east, and Brgy. Bula and Brgy. San Isidro on the south-west. Originally, Klaja Karst watershed was believed to only cover the barangays of Conel, Mabuhay, Olympog, and Upper Labay. However, just early 2023, the DENR found out that the actual areas covered by the Klaja Karst watershed include the barangays of Baluan, Bula, Katangawan, Lagao, Ligaya, San Isidro, and Tinagacan (Figure 2).

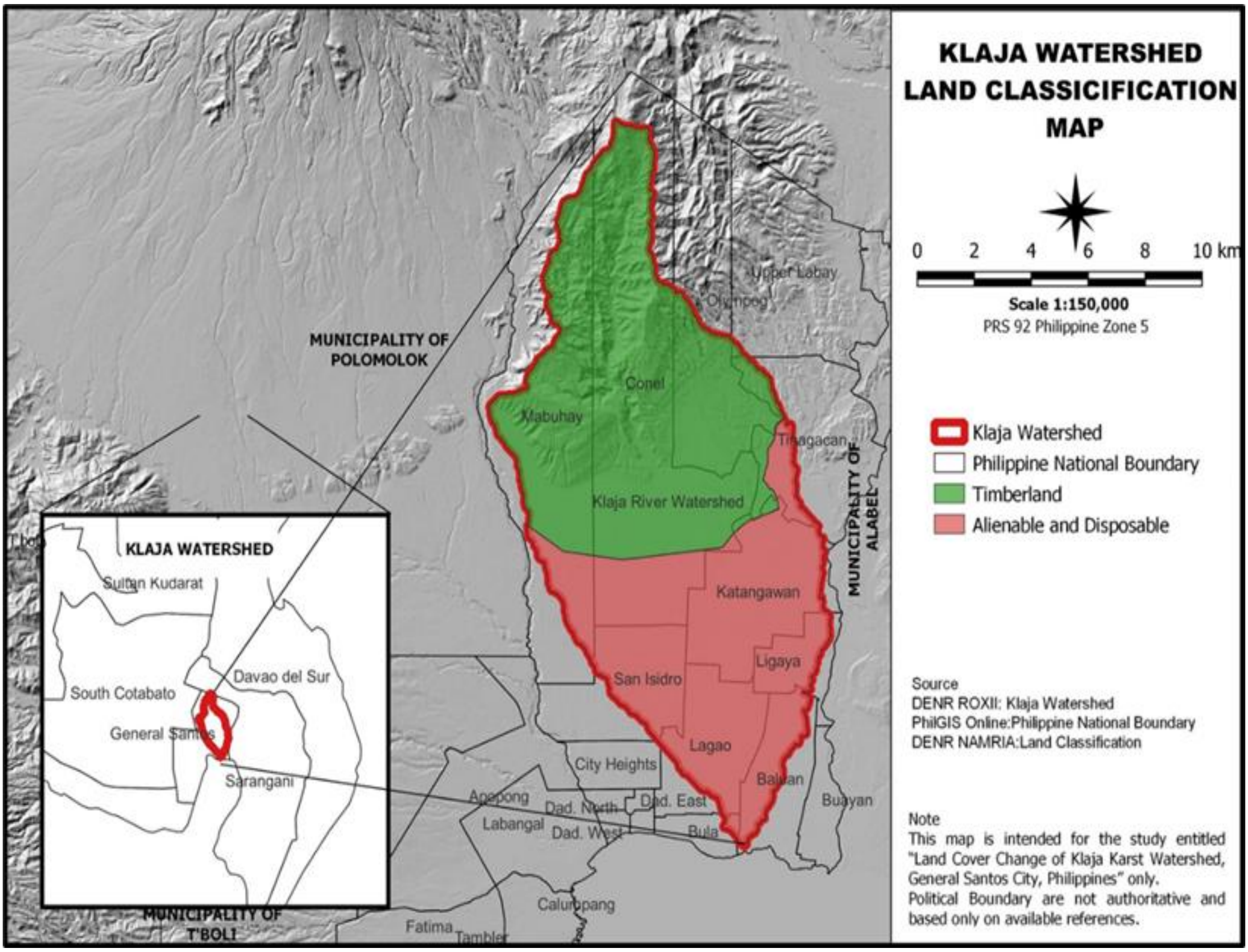

Figure 2. Land classification map of Klaja Karst Watershed, General Santos City.

The Klaja Karst Watershed encompasses 14,274.01 hectares, or approximately 26 percent of General Santos' total land area of 53,606 hectares. The research area is categorized into two primary land classifications: 70% is alienable and disposable land, while 30% is designated as timber land. Yet private ownership of various individuals and corporations has already claimed the vast majority of the land, encompassing both alienable and disposable areas, as well as forestland.

Table 1. Barangays within the Klaja Karst Watershed

BARANGAY	AREA IN HECTARES (ha.)	PERCENT (%) COVERAGE
Baluan	881.44	6.18
Bula	65.03	0.46
Conel	4,377.98	30.67
Katangawan	1,795.96	12.58
Lagao	1,061.71	7.44
Ligaya	430.20	3.01
Mabuhay	2,784.34	19.51
Olympog	1,334.94	9.35
San Isidro	889.90	6.23
Tinagacan	634.88	4.45
Upper Labay	17.63	0.12
Total	**14,273.01**	**100.00**

Table 2. Land classification distribution per barangay within the Klaja Karst Watershed

BARANGAY	LAND CLASSIFICATION	
	ALIENABLE & DISPOSABLE (ha.)	TIMBERLANDS (ha.)
Baluan	881.44	0.00
Bula	65.03	0.00
Conel	2,320.26	2,057.72
Katangawan	1,795.96	0.00
Lagao	1,061.71	0.00
Ligaya	430.20	0.00
Mabuhay	1,147.08	1,637.26
Olympog	913.19	421.75
San Isidro	889.90	0.00
Tinagacan	634.37	0.50
Upper Labay	12.14	5.49
Total	**10,151.28**	**4,122.73**

Despite the inclusion of eleven barangays as stipulated on Tables 1 and 2, only Barangay Conel, Barangay Mabuhay, Barangay Olympog, and Barangay Upper Labay are located in the highland portion of the Klaja Karst Watershed. However, only the barangays of Conel, Mabuhay, and Olympog have significant timber areas. Despite Barangay Upper Labay's location in the mountainous region and its extensive forest cover, the Klaja Karst Watershed only encompasses approximately 5 hectares of its area, with the majority falling under the Buayan-Malungon Watershed, another watershed system. The remaining barangays are located in the lowland regions. The lowland barangays of Baluan, Bula, San Isidro, and Lagao not only function as the discharge areas of the Klaja Karst Watershed but also house the city's business center, a hub for trade and commerce. The city also classifies the lowland barangays of Tinagacan, Ligaya, and Katangawan as agricultural barangays.

Research Design

The Klaja Karst’s watershed changing land cover was evaluated using a descriptive quantitative research approach to assess the alteration in land cover caused by the city’s expansion and development overtime. Figure 4 illustrates the analytical framework of the study.

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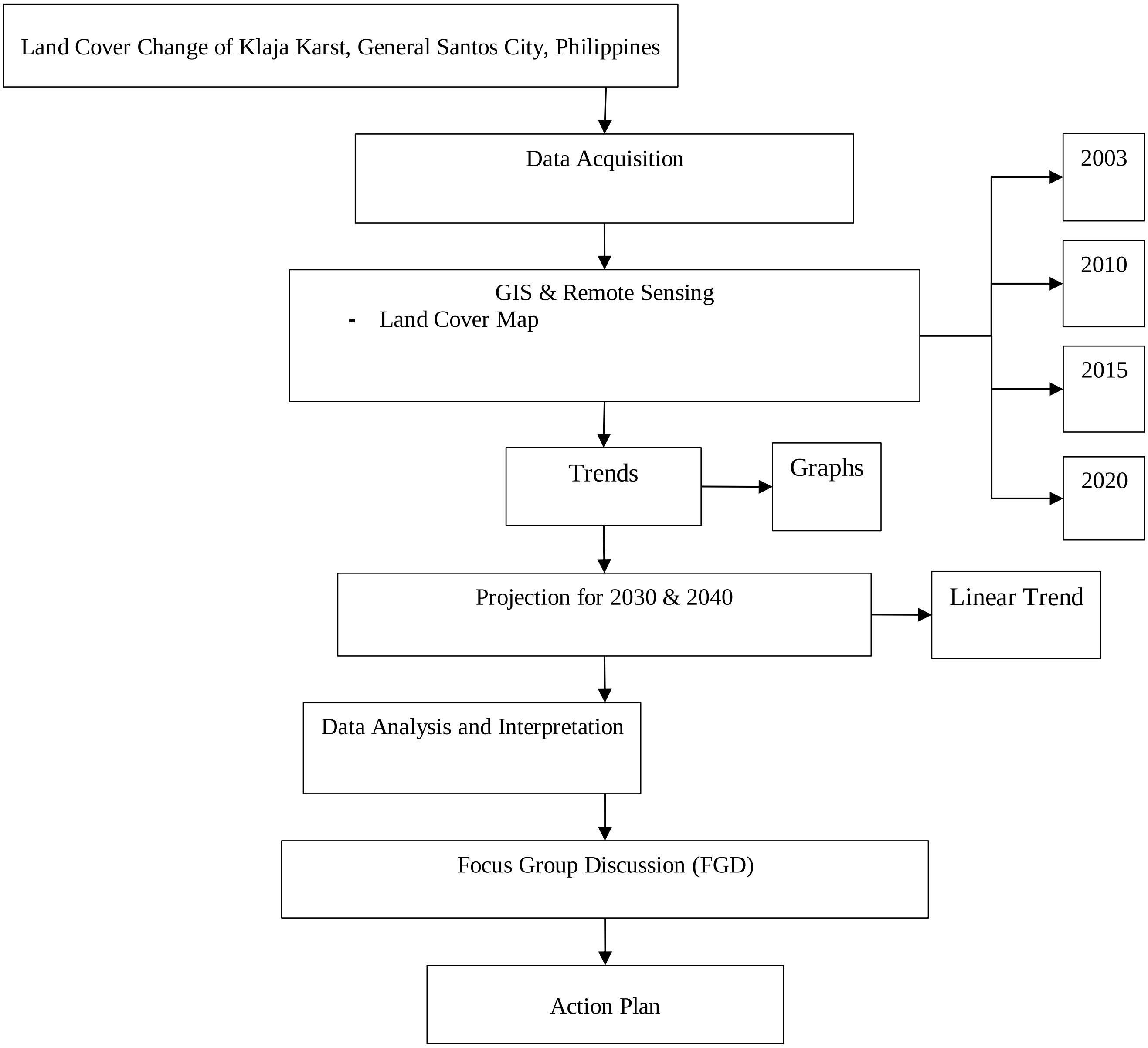

Figure 3. The analytical Framework of the study

RESULTS

Land Cover Maps of Klaja Karst Watershed

The maps in Figures 4, 5, 6, and 7 were obtained from DENR. Each map displays land cover classifications. However, through time and due to the evolution and changes in areas covered by each land cover type and the validation conducted by NAMRIA and DENR, additional land cover types were added to the maps of 2015 and 2020, as shown in Figures 6 and 7. Open Forest land cover type in 2003 was being excluded on the succeeding maps since the areas covered by the open forest land cover type were being distributed to other land types, the changes in land cover types over each period show the evolution of the changes in land cover types in the study area.

The four maps displayed in the images of the above-cited figures reveal that land cover changes throughout a period of time, as seen by the constant shift of distinct land-use classes, whereas land-use change consists of an alteration in the way certain area of land is being used or managed by humans [36]. The changes and conversion of different land use cover is the result of complex interactions between humans and the physical

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environment [37]. Land Use and Land Cover Changes is a major driver of global change and has a significant impact on ecosystem processes, biological cycles and biodiversity [38].

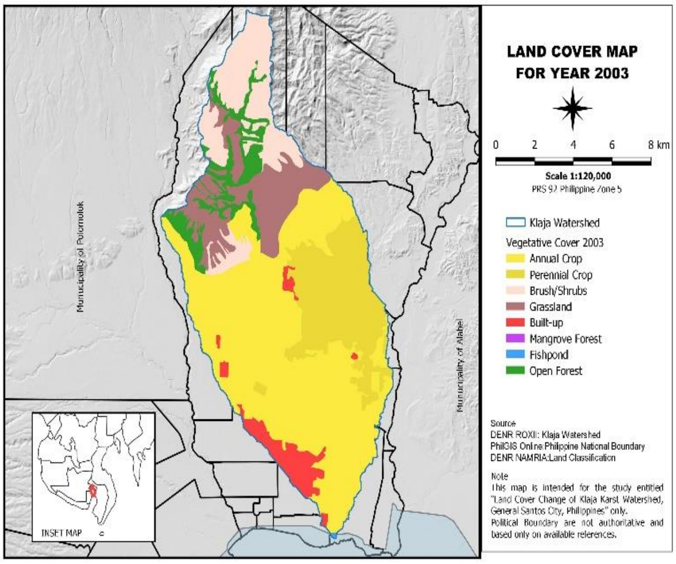

Figure 4. Land cover map of Klaja Karst Watershed in 2003

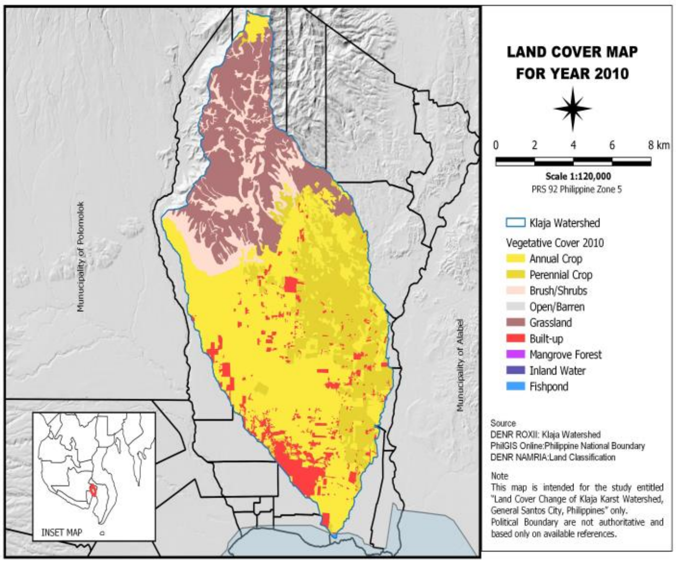

Figure 5. Land cover map of Klaja Karst Watershed in 2010

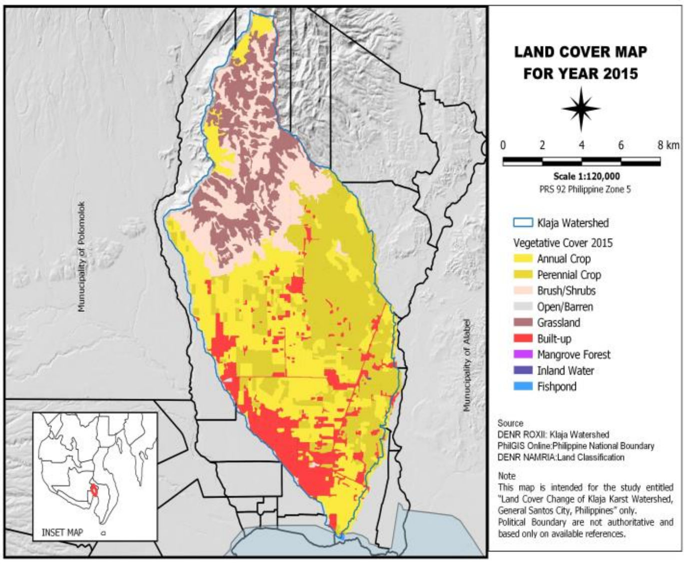

Figure 6. Land cover map of Klaja Karst Watershed in 2015

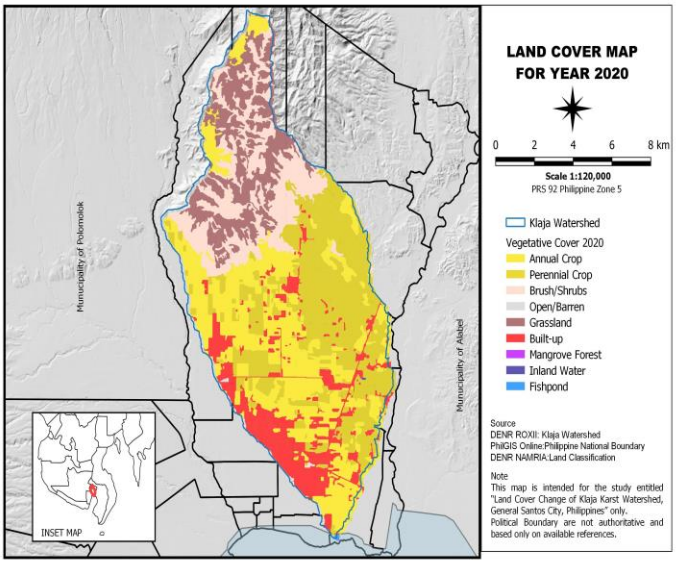

Figure 7. Land cover map of Klaja Karst Watershed in 2020

Each land cover class area percentage for each study year was presented in Table 3 and Figure 8. The generated numerical values reflected in Table 3 were derived from land cover maps from 2003, 2010, 2015, and 2020. As specified in the legend of each map in Figures 4, 5, 6, and 7, land cover types were being classified into annual crops, built-up area, fishponds, grasslands, mangroves, open forests, open barrens, perennial crops, shrubs and bushes, and inland water. In 2000, annual crops, perennial crops, shrubs and brushlands, grasslands, and open forests were the predominant land cover types in the study area. During the above period, the three most dominant land cover types were the annual crop, which covered 6,799.24 hectares, representing 47.87% of the study area, followed by the perennial crop, which covered a total area of 2,368.87 hectares, equivalent to 16.68% of the Klaja Karst Watershed. The three land cover types with the fewest portions were the built-up type, which only covered 629.23 hectares, or equivalent to only 4.43% of the study area, and the fishpond, with an area of 6.37 hectares, equivalent to 0.04%. While the mangrove cover type only covered 0.60 hectares, which is very negligible in terms of percentage if we quantify it against the total area of the Klaja Karst Watershed.

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Table 3. Changes on the land cover distribution of Klaja Karst Watershed

LAND COVER TYPE	PERIOD							
	2003		2010		2015		2020	
	AREA (HA.)	% COVER	AREA (HA.)	% COVER	AREA (HA.)	% COVER	AREA (HA.)	% COVER
Annual Crop	6,799.24	47.87	5,996.04	42.21	4,108.00	28.92	3,243.15	22.89
Built-up	629.23	4.43	1,020.63	7.18	1,823.07	12.83	2,335.93	16.49
Fishpond	6.37	0.04	4.22	0.03	6.06	0.04	30.61	0.22
Grassland	1,695.63	11.94	2,992.70	21.07	1,908.30	13.43	2,020.95	14.26
Inland Water	-	-	-	-	4.47	0.03	6.71	0.05
Mangrove	0.60	0.00	-	-	0.18	0.00	0.40	0.00
Open Barren	-	-	-	-	5.56	0.04	4.53	0.03
Open Forest	929.85	6.55	-	-	-	-	-	-
Perennial Crops	2,368.87	16.68	2,749.20	19.35	4,135.33	29.11	3,973.63	28.04
Shrubs/Brush	1,775.19	12.50	1,442.69	10.16	2,214.73	15.59	2,553.30	18.02

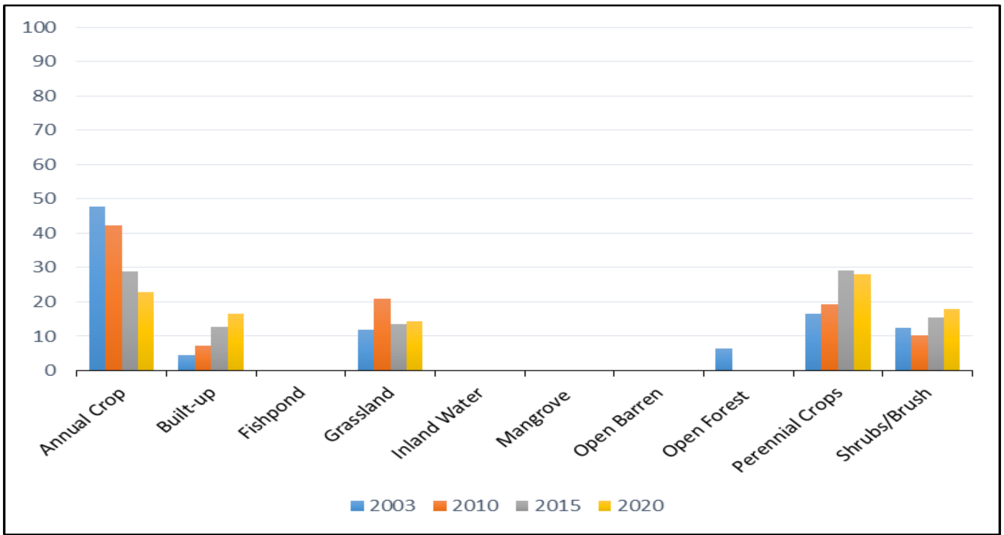

Figure 8. Percentage of land cover type of Klaja Karst Watershed

In 2010, although the area covered by annual crops dropped by around 800 hectares, it was still the dominant land cover type of the study region, with a total land area of 5,996.04 hectares (-803.2 has.), followed by Open Forest land cover type from 929.85 hectares turned into 0.00 hectare, a total wipe-out of the said land cover type (-929.82 has.), including the mangrove land cover type which was also turned to 0.00 from 0.60 hectares (-0.60 ha.). While, shrub/brushland from previously 1,775.19 hectares decreased into 1,442.69 hectares (-332.5 has.). On the other hand, the land cover types that benefits on the decrease of the abovementioned land cover were the Built-up area from 629.23 hectares (4.43%) increased into 1,020.63 hectares (+391.4 has.), Grassland from 1,695.63 hectares (11.94%) increased into 2,992.70 hectares (+1,297.07 has.) equivalent to 21.07% or an increase of 9.13%. and the last one was the Perennial Crops from 2,368.87 hectares (16.68%) increased into 2,749.20 hectares or an additional of 380.33 hectares with a total percent cover of 19.35% from previously 16.68% (+2.67%). On the study of Land use and land cover change effect on surface temperature over eastern India by Gogoi, et al. (2009) [39], confirmed that largest changes were linked to changing vegetation cover. Given that the current trend of LULC is mainly triggered by building infrastructure in face of limited size of various land use types, it won't be long before the city's growth will use the available bare ground and expand development into existing forest, riparian areas, and may even continue encroaching into the government reserve forests on the surrounding hills.

For the year 2015, the continued decrease of the annual crop was still evident. From 5,996.04 hectares in 2010, it decreased to 4,108.00 hectares, or a decrease of 1,888.04 hectares. Followed by grassland, which also lost a substantial amount of area from 2,992.70 hectares in 2010 to 1908.30 hectares. Total loss of grassland was 1,084.4 hectares, which resulted in 7.64% land cover loss. The substantial loss of areas of annual crop and grassland resulted in an increase in the area coverage of other land cover types, particularly the built-up area, which increased from 1,020.63 hectares in 2010 to 1,823.07 hectares (+802.44 ha). The fishpond also increased from 4.22 hectares (0.03%) to 6.06 hectares, and an increase of 1.84 hectares resulted in an increase of 0.04% in the percent coverage of the fishpond. In this period also emerged the inland water, which was not present in the 2003 and 2010 land cover types. The emergence of inland water is the result of the dynamic movement of the land cover of the study area through the years. Contributing factors to the emergence of inland water were the continued depletion of forest resources, the continued increase of built-up areas, and the possible poor drainage system in the area. The total area of inland water was 4.47 hectares (0.03%). During this period, the mangroves also started to recover, which showed a 0.18 ha. from previously 0.00 ha. Aside from inland water, open barrens also emerged during this period, which had a total area of 5.56 hectares, equivalent to 0.04%. Perennial crops also increased to 4,135.33 ha. From 2,749.20 hectares (+1,386.13) in 2010. Thus, the increase resulted in a 9.76% increase in area covered by perennial crops, or a total of 29.11% area coverage. Lastly, shrubs and bushlands, which were losing around 300 hectares in 2010, gained 772.04 hectares. The additional areas resulted in a total of 2,214.73 hectares of shrubs and brushland, equivalent to 15.59% of the total area covered.

For the year 2020, the annual crop loss will be another 864.85 hectares to other land cover types. The total area loss of the annual crop from 2003 to 2020 totaled 3,556.09 hectares, equivalent to 52.30% land cover loss. For this period, perennial crop loss, which was steadily increasing from the previous year's loss of 161.7 hectares for the first time, was equivalent to 1.07% land cover loss. Open barren area coverage also decreased from 5.56 hectares to 4.53 hectares (-1.13 ha). On the other hand, the loss of area of other land cover types was the gain of built-up area, which again increased from 1,823.07 hectares in 2015 to 2,335.93 hectares (+512.86 ha.), equivalent to 16. 49% of the area covered. Fishpond also accumulated substantial area, with a total of 24.55 hectares, which increased from 6.06 hectares in 2015 to 30.61 hectares (0.22%). On the other hand, the grassland, which experienced a slight decrease in land cover in 2015, gained an additional 112.65 hectares, which resulted in 2,020.95 hectares (14.26%). While inland water gained another land area from 4.47 hectares in 2015 to 6.71 hectares in 2020 (+2.24 ha). Mangroves gained 0.22 hectares from 0.18 hectares in 2015; they increased to 0.40 hectares. And the last land cover type that also gained substantial area was the shrub or brushland, with a total land area of 2,214.73 hectares in 2015; it increased to 2,553.30 hectares in 2020, an increase of 338.57 hectares, equivalent to 18.02%.

Lastly, to easily determine the gain and loss of each land cover type from 2003 to 2020, Annual crop loss: a total area of 3,556.09 hectares, from 6,799.24 hectares in 2003, reduces to 3,243.15 hectares in 2020, equivalent to a total of 47.70% land cover loss. Mangrove also loses minimal area compared to other land cover types; in 2003, mangrove had a total area of 0.60 hectares, while in 2020 it was 0.40 hectares (-0.20 ha.). On the other hand, the loss of annual crop and mangrove area was also the gain of other land cover types. The built-up area only covered 629.23 hectares (4.43%) in 2010, but increased to 2,335.93 hectares (22.89%), for a total of 1,706.7 hectares. Fishpond with 6.37 hectares in 2003 increased to 30.61 hectares (+24.24 hectares). Grassland also gained 325.32 hectares from 1,695.63 hectares to 2,335.93 hectares. While inland water, which only appeared in 2015 with an area of 4.47 hectares, increases to 6.71 hectares (+2.24 ha.), though mangrove had fluctuating changes from 2003 to 2020, it finally settles at 0.40 hectares from the original land area of 0.60 hectares (-0.20 ha.). Same with inland water, which only appeared in 2015, open barren loss a total of 1.03 hectares from the initial land cover area of 5.56 hectares into 4.53 hectares in 2020. Open forest, which initially had a land cover area of 929.85 hectares, was totally wiped out of the map, and its area was being distributed to other land cover types. Perennial crops, which had a total area of 2,368.87 hectares in 2003, increased to 3,973.63 hectares (+1,604.76 ha.), and the last cover type, which is shrubs and brushland,

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with an initial area of 1,775.19 ha, increased to 2,553.30 ha (+778.11 ha).

Land Cover Trends

Land cover trends of the Klaja Karst Watershed from 2003 to 2020, particularly the percentage changes in each land cover type, are presented in Table 4 and Figure 9. Changes can either bring positives or negatives; in this study, the negative effect of change is considered a reduction of land area or loss of areas, while the positive effect is gaining additional or expanding areas. Between 2003 and 2020, built-up areas increased by 12.06%; from 629.23 hectares in 2003, it increased to 2,335.93 hectares (+1,706.7 has.). Followed by perennial crop cover type from 2,368.87 hectares into 3,973.63 hectares (+1,604.76 has.). Shrubs and brush land also saw a total increase of 5.52% (+778.11 has.) in the region from 2003 to 2020, equivalent to 2,553.30 hectares from 1,775.19 hectares.

Table 4. Percentage of land cover change of Klaja Karst Watershed

LAND COVER TYPE	2003-2010	2010-2015	2015-2020
Annual Crop	-5.66	-13.29	-6.03
Built-up	2.74	5.65	3.66
Fishpond	-0.01	0.01	0.83
Grassland	9.13	0.03	0.02
Inland Water	0.00	0.03	0.02
Mangrove	-0.60	0.00	0.00
Open Barren	0.00	0.04	-0.01
Open Forest	-6.55	0.00	0.00
Perennial Crops	-2.67	9.76	-1.07
Shrubs/Brush	-2.34	5.43	2.43

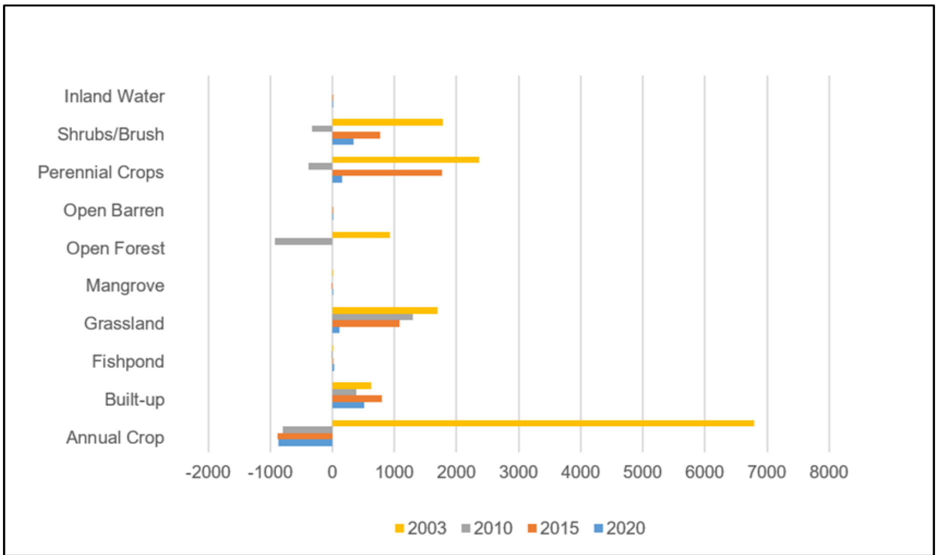

Figure 9. Land cover trends in hectares (gain and Losses) in Klaja Karst Watershed

Annual crops, on the other hand, lost a large amount of area between 2003 and 2020, dropping from 6,799.24 hectares in 2003 to 3,243.15 hectares (-3,556.09 ha.), or a -24.98 percent loss. Open forests had an initial area of 929.85 hectares in 2003, but over the period from 2003 to 2020, this area eventually decreased to zero (-929.85 ha). The reductions or losses in the aforementioned areas demonstrate that some land cover types benefited from the loss of others by significantly increasing their respective areas, particularly the built-up perennial crops, shrubs, brushlands, and grasslands. Aside from the mentioned land cover types, fishponds, inland water, and open barrens also gained a minimal increase in area, which impacted the region's overall landscape.

As the center of trade and commerce in the southern region, General Santos City's thriving economy could be a possible explanation for its notable buildup. Apart from an economic perspective, the population's continuous growth also contributes significantly to the study area's total landscape disruption. The shifting land cover is a reflection of the growing demands placed on land resources by population and economic expansion. The rapid increase of the population in urban areas, both natural and through migration, has put significant demand on public amenities including housing, sanitation, transport, water, electricity, health, and education, which caused the expansion of the built-up areas. The expansion of built-up areas can result in air pollution, noise pollution, water pollution, land pollution, and an unusual rise in temperature that disturbs the environment [40].

Table 5. Hectarage of land cover change of Klaja Karst Watershed.

LAND COVER TYPE	2003-2010	2010-2015	2015-2020
Annual Crop	-803.20	-1,888.04	-864.85
Built-up	391.40	802.44	512.86
Fishpond	-2.15	1.84	24.55
Grassland	1,297.07	-1,084.40	112.65
Inland Water	0.00	4.47	2.24
Mangrove	-0.60	0.18	0.22
Open Barren	0.00	5.56	-1.03
Open Forest	-929.85	0.00	0.00
Perennial Crops	380.33	1,386.13	-161.70
Shrubs/Brush	-332.50	772.04	338.57

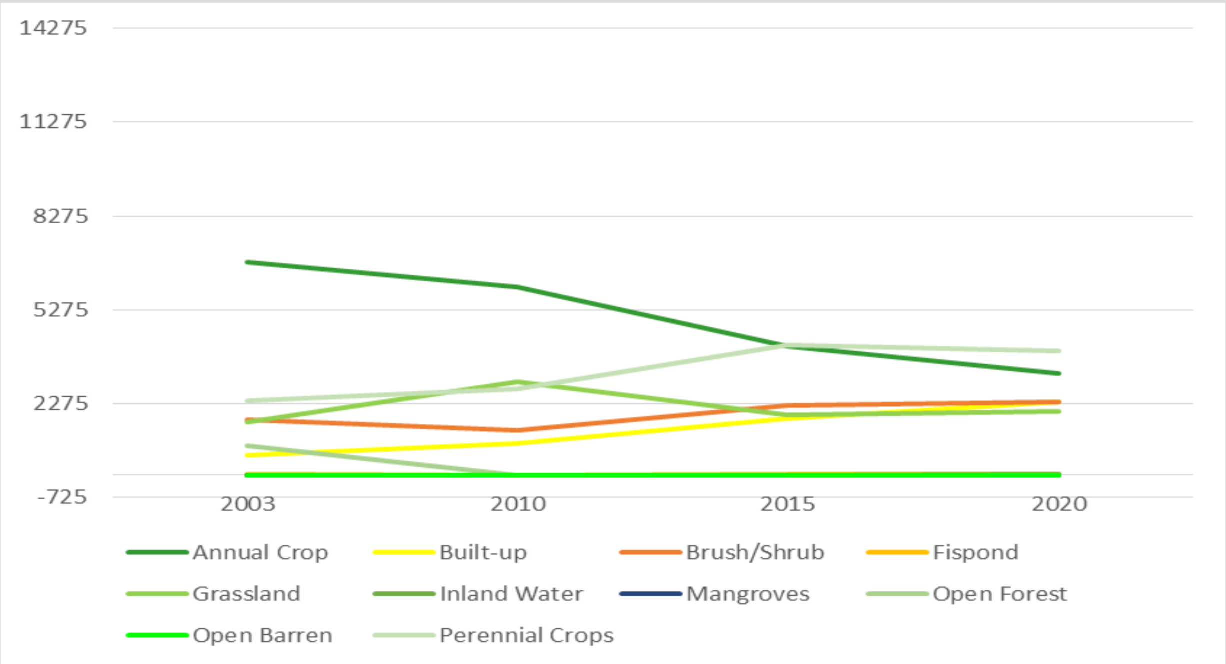

Figure 10. Graphical presentation of the land cover trend of Klaja Karst Watershed

Land Cover Projection Model

The researcher created two LULC change maps by estimating the spatiotemporal changes and computing the

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume VIII Issue IX September 2024

LULC transition between the research intervals (2003-2010, 2010-2015, and 2015-2020) using Modules for Land-Use Changes Simulation (MOLUSCE) plugin in ArcMap. The study employed the Artificial Neural Network (ANN) multilayer perception technique for transition potential modeling. The Digital Elevation Model (DEM), the slope, the population data, and the separation from roadways were employed as explanatory variables. Because theses variables offer repeatable information on the natural and man-made influences on LULC dynamics, they are frequently used in LULC change analysis.

Figures 11 and 12 show the projected maps of the study area for 2030 and 2040, respectively. Generated maps indicate that for 2030 and 2040, annual crop loss was a total of 294.28 hectares, down from 3,243.15 hectares in 2020 to 2,948.87 hectares. The additional loss of area for the annual crop from 2003 to 2020 resulted in a total loss of 3,850.37 hectares, equivalent to 43.37% land cover loss from 2003 to 2040 if the projection becomes a reality. Aside from the annual crop, fishponds and mangroves also lose a minimal amount of area, with a combined total loss of 5.51 hectares. The loss of the above areas goes to other land cover types. The loss of areas of the abovementioned land cover was due to the gain of other land cover types. However, unlike the other land cover types mentioned above, open forest was completely eradicated in the study area, from 929.85 hectares in 2003, equivalent to 6.55% of the study area's land cover, to 0.00 hectares. As stated above, the loss of other land cover types is also the gain of other land cover types. Built-up areas are one of the land cover types that benefitted from the loss of other land cover by increasing its area of coverage from only 629.23 hectares in 2003, equivalent to 4.43%; it increased to 2,427.92 hectares (+1,798.69 hectares), equivalent to 17.12% (+12.69%). Aside from built-up areas, perennial crops also gained a substantial amount of area from 1,775.19 hectares (16.68%) in 2003; it increased to 4,145.43 hectares (+1,776.56 hectares), equivalent to 29.23%. Shrub/brushland also gained a substantial amount of area, from 1,775.19 hectares, equivalent to 12.50%, to 2,562.87 hectares, equivalent to 18.07%. increased, giving an additional 1,776.56 hectares to shrubs and brushland from 2003 to 2040. Grassland also gained an additional 358.03 hectares, wherein, from 1,695.63 hectares in 2003, it increased to 2,053.66 hectares, equivalent to 14.48% (+2.54%). Lastly, the two land cover types, open barren and inland water, which only emerged in 2015 due to the evolution of land cover changes in the study area, gained a combined total of 43.58 hectares, equivalent to 0.3 percent of the land cover in the study area.

Table 6. Data from 2003 to 2040 of the land cover change of Klaja Karst Watershed.

LAND COVER TYPE	**PERIOD**											
	2003		**2010**		**2015**		**2020**		**2030**		**2040**	
	AREA	**%**	**AREA**	**%**	**AREA**	**%**	**AREA**	**%**	**AREA**	**%**	**AREA**	**%**
Annual Crop	6,799.24	47.87	5,996.04	42.21	4,108.00	28.92	3,243.15	22.89	3,150.76	22.20	2,948.17	20.79
Built-up	629.23	4.43	1,020.63	7.81	1,823.07	12.83	2,335.93	16.49	2,259.19	15.91	2,427.92	17.12
Fishpond	6.37	0.04	4.22	0.03	6.06	0.04	30.61	0.22	30.33	0.21	1.42	0.01
Grassland	1,695.63	11.94	2,992.70	21.07	1,908.30	13.43	2,020.95	14.26	2,016.34	14.21	2,053.66	14.48
Inland Water	0.00	0.00	0.00	0.00	4.47	0.03	6.71	0.05	6.64	0.05	6.07	0.04
Mangrove	0.60	0.00	0.00	0.00	0.18	0.00	0.40	0.00	0.04	0.00	0.04	0.00
Open Barren	0.00	0.00	0.00	0.00	5.16	0.04	4.53	0.03	40.28	0.28	37.51	0.26
Open Forest	929.85	6.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perennial Crops	2,368.87	16.68	2,749.20	19.35	4,135.33	28.04	3,973.63	28.04	4,138.69	29.16	4,145.43	29.23
Shrubs/Brush	2,368.87	12.50	1,442.69	20.16	2,214.73	18.02	2,553.30	18.02	2,552.11	17.98	2,562.87	18.07

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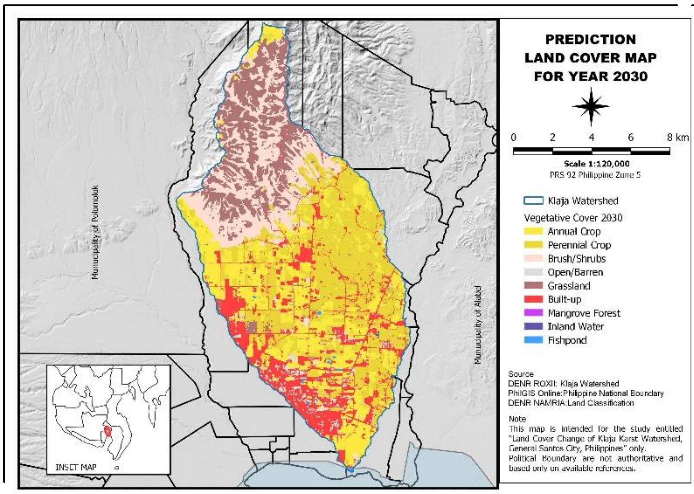

Figure 11. Land cover map of Klaja Karst Watershed in 2030

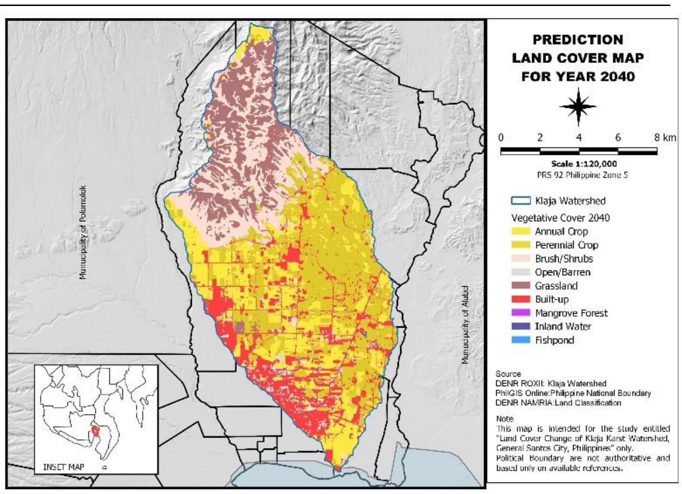

Figure 12. Land cover map of Klaja Karst Watershed in 2040

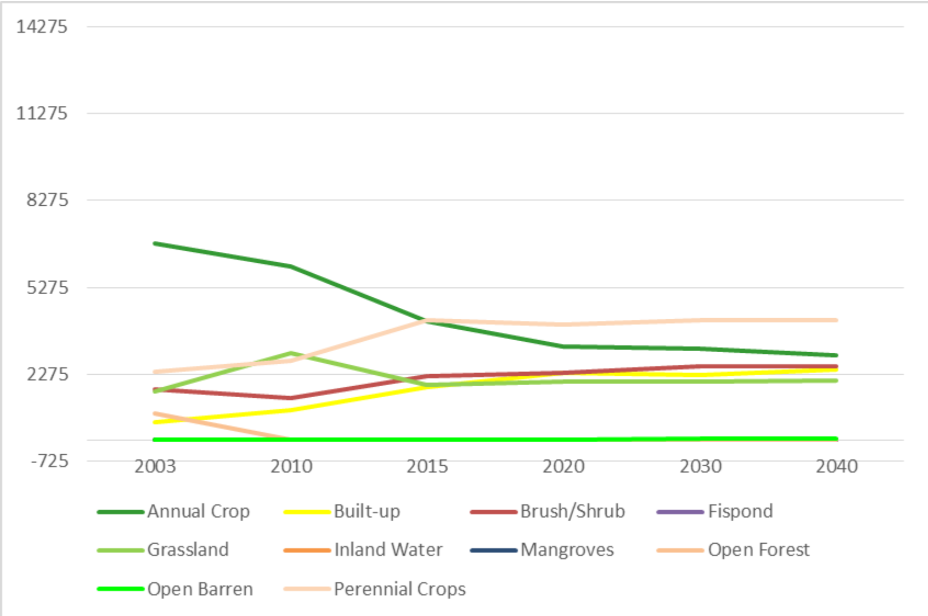

Figure 13. Projected land cover trend of Klaja Karst Watershed

DISCUSSION

Action Plan to Conserve the Study Area

Natural resources can be both a blessing and a curse, depending on the resources and their management. Many regions reached socioeconomic development through the utilization of natural resources, even though it has not always been done in accordance with sustainable development. Over exploitation of natural resources leads to environmental degradation, a path that is not always reversible. General Santos City, being acknowledged as the only highly urbanized city in the region and known as the "booming city of the south," is positioned as the economic hub of SOCCSKSARGEN (South Cotabato, Cotabato, Sultan Kudarat, Sarangani, and General Santos City) because of its location and accessibility to communication, services, and financial intermediaries that are already in place. The regions of four provinces and one densely populated metropolis mentioned above are collectively referred to as SOCCSKSARGEN. As such, not only the biggest population of the region resides in General Santos, but also the commercial and industrial center of the region.

However, history demonstrates that progress has both positive and negative effects on society and the

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume VIII Issue IX September 2024

environment. It brings about technological advancements and new freedoms, as well as social, cultural, and environmental implications. Overexploitation of natural resources and alteration of the natural landscape for development might, simultaneously, lead to environmental degradation.

Uncontrolled urban growth and noncompliance with the city's land use plan and zoning ordinance were the most serious difficulties that the city faced in balancing environmental protection with progress in development to keep the city's economy moving. According to the City's Land Use Plan (CLUP) for 2018-2026 [7], forestland or timberland were the land uses that were negatively impacted by development and rising population. As stated in the cited CLUP, timberland areas face numerous challenges, including the continued encroachment of humans into forested areas in search of land, timber to be poached, charcoal production, wildlife hunting, unabated gathering of flora, loss of endemic biodiversity, use of non-environment-friendly farm inputs, and many others. In this regard, the Klaja Karst Watershed contains the majority of the city's forestland and timberland and if this cannot be mitigated or the current trend continues, it will undoubtedly have an irreversible negative impact on the environment and the inhabitants of the city. As part of the goal of the study, the researcher proposed an action plan that would help the local government unit of the city manage its land resources properly, specifically the Klaja Karst Watershed. Table 6 presents the action plan made in the study.

Table 7. Action plan for the conservation of Klaja Karst Watershed.

ACTIVITIES	OBJECTIVES	EXPECTED OUTCOME
Conservation and Protection of Agricultural and timberland by planting cover crops and perennial.	• To maintain a suitable area for crop production to ensure the sustenance of the city's inhabitants. • To increase farm input subsidies for farmers. • To promote incentive mechanisms in the agricultural and forestry sector. • To engage the community in the formulation and implementation of programs related to preserve the remaining timberland and agricultural land of the city. • To improve social services for upland communities and poverty-stricken families. • To limit or prohibit land conversion or reclassification. • Strictly implement the zoning ordinance.	• Agricultural Land and timberland will be conserved and protected. • Active participation from the community level on the conservation and protection of the environment through effective planning and decision-making, the city's land resources can be managed accordingly, and the detrimental effects of development can be minimized, if not eliminated.
Review the City's Land Use Plan (CLUP) and Forest Land Use Plan (FLUP) and the implementation of its plans and programs including the zoning.	• To identify the areas to be converted and develop into other land uses, and areas to be conserved or preserved. • To control urbanization growth or development in certain areas. • To conduct periodic review of the CLUP/FLUP for a proper town planning.	• Review the CLUP/FLUP and the implementation of its plans and programs including the zoning. • Legislate policies that will support the programs of CLUP/FLUP.
Strengthen the enforcement of environmental laws and policies.	• To control the development or restrict the establishment of infrastructure on Agricultural and Timberland in the absence of necessary permits.	• Compliance of stakeholders with the implementation of existing laws and ordinances.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume VIII Issue IX September 2024

Impose penalties and file appropriate legal cases against violators.	• To eliminate improper conversion of land. • To conserve and protect the land and water resources of the city. • To legislate ordinances that will protect the Environment and Resources of the city.	• Reduction in non-compliance with CLUP zoning and land use plans. • Limit development and urban sprawl to Agricultural and Timberland. • Develop mechanisms for the mandatory allocation of budgets for environmental conservation program from the CSR of Business Sector
Strengthen Information, Education Campaign	• To promote awareness about the impacts of urbanization on Agricultural and timber lands. • To conduct periodic review of the CLUP/FLUP for a proper town planning. • To increase people's awareness of the importance of the preservation of agricultural and timber land, not only for food security but also for other values it can brings. • To develop environment- friendly citizens that will help the government protect and nourish the remaining resources of the city.	• Increased public awareness will result in a reduction in illegal conversions of Land and abuses of natural resources
Creation of Klaja Karst Watershed Management Council	• To establish management council that will oversee the Klaja Karst Watershed. • To develop management plan for Klaja Karst Watershed • To encourage multi-sectoral approach on the management of the study area.	• Opportunity to ensure the conservation of the program. • Maximize the funding opportunity from various government agencies for the conservation and protection program of Klaja Karst Watershed. • Limit if not totally eliminated the illicit activities by certain individuals that only serve their own personal interest at the expense of the resources of Klaja Karst Watershed.
Consider the Co-management approach of the watershed through the inter-LGU Management Approach.	• To strengthen enforcement and monitoring activities. • To consider the inclusion of Klaja Karst Watershed in the environmental management of neighboring municipalities that is also benefiting the resources of the watershed particularly the water resources.	• The conservation and rehabilitation program for the watershed will be quick and prompt. • Increase funds for the implementation of Environmental Programs in the watershed.
Encourage engagement of Academe sector for Research and Development.	• To provide LGU and other concerned government agencies additional information or data that can be used in Planning and managing the resources of the watershed	• The information that will be acquired from the research and development will help the city formulate a management plan that is realistically applicable to the ground. Likewise, the results of the studies will serve as a guide for

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume VIII Issue IX September 2024

		legislators and the city in legislating a law that will protect the resources of the watershed against various anthropogenic activities that cause harm to the environment.

CONCLUSION

This study determined the changes in land cover from different periods and identified the areas within the study area with high and low development and changes.

Similarly, it also determined that there were indeed significant changes on the land cover of the study area through scientific determination. Similar to other developing regions, the continuous increase of built-up areas to accommodate the constant growth of population and development brought about by urbanization is the main driving force behind land cover changes. Therefore, to meet the demands for settlement housing, industrial facilities, economic infrastructure support facilities, and food requirements, land cover changes are necessary. As a result of the aforementioned development, natural land cover types such as forests, grasslands, and brushlands often experience a reduction in their covered area.

The significant decrease in annual crop and other land cover types can be attributed to the shift in the area covered by these other types. Development and urbanization play a major role in shaping the changes in land cover types in the study area. Although other land cover types will also increase, projections indicate that the city's current development and urbanization, in addition to the ongoing population growth, will significantly increase the built-up area along the way. If unchecked, the projected increase in built-up could potentially pose serious environmental concerns to the city in the near future.

Based on the focus group discussion, the study was able to develop an action plan. The action plan contains activities, objectives, and the expected outcome. This action plan could be used by the Local Government Unit of the City of General Santos and nearby municipalities to consider the findings of this study and enhance their planning when it comes to the management of Klaja Karst Watershed and other similar areas with similar concerns.

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