Modelling the Effects of Tourism Development Scenarios on Land Use/Cover Change

GEO 511 Master's Thesis

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21.04.2024
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Acknowledgements

I would like to express my sincere gratitude to my supervisor Dr. Franziska Komossa for all her invaluable inputs and feedback, which helped me get on the right track at every stage of my thesis. Furthermore, I would like to thank the Palawan Council for Sustainable Development, especially the staff from the ECAN Monitoring and Evaluation Division, for helping me get in contact with the right stakeholders, providing me with data. Their assistance was invaluable in facilitating my research. I am especially grateful for their hospitality and the good food we were able to share during lunch break, which made my stay in Palawan a very pleasurable and memorable one.

At this point I also want to thank every participant and respondent who generously shared their time and insights during the interviews.

I also want to express my gratitude to my family and friends who supported me throughout my master thesis.

Lastly, I want to extend specials thanks to my sister, Jocelyn Pleisch and my friend, Claudio Falzinger, for taking their time to proofread my thesis.

Abstract

Tropical regions frequently benefit from tourism development for their economic growth. However, considering the influence of tourism development on local land use and land cover (LULC), it also significantly impacts the natural surroundings of tourist destinations. Modelling approaches have thus emerged as a popular methodology to explore the potential changes in future LULC patterns under different scenarios, which could aid in the establishment of management strategies and the implementation of policies. This thesis explored the effects of tourism development in the province of Palawan, Philippines, using the hybrid model approach of Dyna-CLUE. Future LULC change were simulated between 2020 and 2050 under a "business as usual (BAU)", "eco-agritourism with landscape protection (EALP)" and "uncontrollable tourism development (UCTD)" scenario, which were created using inputs from stakeholder interviews. The results showed a significant expansion of built-up areas in northern Palawan primarily at the expense of agricultural, eco-land and mangrove forest areas under the BAU and UCTD scenario. Conversely, the EALP scenario resulted in a smaller expansion of built-up area expansion, mainly at the expense of eco-land due to the retention of agricultural and mangrove forest areas. In southern Palawan expansion of growing LULC types under the BAU and UCTD scenarios, predominantly led to the loss of agricultural area. However, similarly to northern Palawan, the EALP scenario resulted in built-up area expansion primarily at expense of eco-land. A zonal statistics revealed that within the ECAN zones, comprising the spatial policies in Palawan, future built-up areas are likely to be found in zones designated in lower altitudes, suggesting expansion near or along the coastline. Scenarios lacking spatial policies observed additional built-up area expansion towards the uplands.

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1 Introduction and Research Goal

The tourism sector is among the fastest-growing industries in the world (Burbano et al., 2022). Notably island tourism has grown to be an important aspect of it as it has gained popularity among consumers as one of their preferred forms of tourism, owing to the wide range of offerings such as sunny weather, waves, beaches, reefs, blue sky and sea food (Zhang et al., 2022). Island tourism, which specifically refers to the development of tourism on an island, can push the advancement of tourist accommodation establishments (e.g., guesthouses, hostels, hotels etc.) and other related commercial areas, while incorporating the island's scenic spots (Yang et al., 2016). However, since tourism development is strongly linked to urbanisation and contributes to economic growth, a boost in tourism also directly causes changes to land use and land cover (LULC) demands and patterns (e.g., building of accommodation establishments, infrastructure expansion etc.). Tourism acts therefore as a crucial catalyst in LULC change, since land is being used as a versatile resource for a wide range of tourism-related activities (Shi et al., 2023; Portugal et al., 2016). Additionally, tourism also indirectly affects LULC changes through waste management, food production directed towards tourism-related establishments (e.g., hotels or restaurants) or the construction of residential buildings (Gössling, 2002).

The Philippines is part of the Asia Pacific Region, one of the fastest growing tourism markets in the world (PDOT, 2011). For the past decade, the tourism sector of the Philippines has been growing continuously with growth rates in both domestic and international tourist arrivals being above the global average (Kobayashi, 2017). Prior to the COVID-19 pandemic, the tourism sector accounted for 12.7% of the Gross Domestic Product (GDP) in 2019, with a record-breaking total of 8’260’913 tourist arrivals (Aquino & Porter, 2022). These numbers reflect the importance of the tourism sector as an economic pillar in developing countries such as the Philippines. However, as stated previously, tourism development can have drastic negative impacts on LULC, when not managed correctly. A prime example of such mismanagement and its consequences on LULC is evident in the example of the Boracay beach closure in 2019. The influx of tourists and lack of governing policies on the island caused a wide range of environmental problems with most of the island's LULC being converted to residential or commercial areas. This led to the loss of five out of nine wetlands, which were crucial to shore protection and flood prevention (Cruz & Legaspi, 2019). It is therefore imperative to firstly monitor the impact of LULC changes in space and time in order to better understand and comprehend the changing demands of a population and how human activities and natural phenomena's influence each other (Das & Angandi, 2022). The knowledge gained by closely monitoring LULC changes can aid in making informed decisions regarding spatial planning and resource management (Liu & Yang, 2015; Nuissl & Siedentop, 2022). However, simply monitoring the changes in LULC may not provide a complete understanding of the involved dynamic (Gómez et al., 2016). Therefore, employing modelling technique should be subsequently used to better understand LULC change dynamics and how they might unravel in the future (Gaur & Singh, 2023). This aspect will also be the central focus of this thesis.

Despite tourism being a critical driver of LULC change, limited empirical research has been conducted to understand the impact of tourism development on future LULC changes applying scenario modelling, let alone the Dyna-CLUE model. The general lack of research of LULC changes can be attributed to the challenge of determining, which specific LULC transitions were directly caused by tourism related activities (Boavida-Portugal et al., 2016). In LULC mapping, the classification of tourism as a distinct category is also often not considered. However, some researchers have begun to integrate factors such as points of interest (POI) to account for the influence of tourism on the LULC dynamics (Wang et al., 2019; Wang et al., 2022; Zhu, 2021; Sun et al., 2023).

This thesis aims to address the beforementioned research gap by employing the Dyna-CLUE, a hybrid-approach model to gain a deeper understanding of the environmental and socio-economic dynamic and influence of tourism on LULC in the province of Palawan, Philippines. Modelling future LULC changes considering different tourism development scenario in rising tourist places like Palawan is of utmost importance to avoid the negative consequences like those observed in Boracay. The scenarios to be modelled should reflect the wishes of the local stakeholders concerning future tourism development. The findings of this thesis should therefore support the decision-making process of local authorities, land managers and stakeholders concerning spatial planning and practices to foster sustainable tourism development in Palawan.

2 Background

2.1 Land Use and Land Cover (LULC)

Land, according to the UN, incorporates “the delineable area of the earth’s terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface”, which serves humans as a vital source for sustaining life and opportunities to pursue various recreational activities (FAO, 2023; Need et al., 2021). However, with the steadily growth of the global population and industrialisation, the pressure on land and its resources due to increasing demand for food and raw materials is rising as well and has therefore an inevitable effect on land cover and land use (Sakayarote & Shreshta, 2019). Land cover describes the observable features of the Earth’s surface, encompassing the spatial distribution of vegetation, water, soil, and other physical attributes, including anthropogenic elements such as human settlements. Land use on the other hand, refers to the way humans or settlements have been utilizing land, often within the context of pursuing economic endeavours. While land use and land cover (LULC) are two different sets of terminologies, they are often used interchangeably, as both aspects are tightly interconnected (Rawat & Kumar, 2015; Verburg et al., 2009).

2.2 LULC Change

LULC change has been part of human activity throughout history on a global scale (Hailu et al., 2020). LULC changes are the outcomes of intricate interactions between natural and socio-economic factors, intertwined with human activities unfolding over time and space, which collectively impact biophysical systems. In the context of LULC change, these factors are often referred to as “drivers” or “driving forces” and envelop all natural or human-induced factors that lead to changes in an ecosystem (Teixeira et al., 2013). Among these driving forces, population and economic growth within a region are widely acknowledged as crucial socio-economic components that significantly influence LULC changes. On the other hand, natural driving forces encompass aspects such as topography, slope condition, soil type, and climate, which further shape the evolving landscape (Tewabe & Fentahun, 2020).

Socio-economic factors are relatively active and therefore prone to constant changes, thus having a significant impact on short-term changes of LULC. Generally, human population growth is considered to be the primary driver of LULC change (Zhao et al., 2006). Population growth furthermore contributes to increased urbanisation, which plays a pivotal role in shaping contemporary land use systems as it causes drastic changes in the spatial distribution, quantity and type LULC (Crankshaw & Borel-Saladin, 2019; Domingo et al., 2021). Additionally, urbanisation serves as a catalyst for development and establishes a foundation for a good economy. Its influence extends beyond urban areas, impacting the economic growth of rural areas and steering it towards an increasingly urbanised lifestyle (Crankshaw & Borel-Saladin, 2019).

While socio-economic driving forces are the primary influence for short-term LULC changes, natural driving forces play a more significant in the long-term development of LULC due to their relatively stable nature. They therefore set environmental conditions, which determine or constrain the potential appearance of certain types of LULC. However, LULC driving forces are complex, diverse in their interaction and are not consistent across the globe but vary from region to region and change over time, making it a challenge to identify and quantify them (Zhai et al., 2020). Thus, identifying and understanding these driving forces has been a distinct focus in global change research over the past few decades (Li et al., 2016).

Given the direct implications of LULC changes on biophysical systems, they are directly connected with environmental processes. Consequently, they have become a serious concern related to sustainable management of the earth's surface on local, regional and global scale over the years as they are recognized as primary catalysts for negative environmental impacts on forest condition (Griffiths et al., 2014; Fu et al., 2022), forest carbon storage (Yang et al., 2020), loss of biodiversity (Trisurat et al., 2010), soil degradation (Aneseyee et al., 2020), global warming (Sarfo et al., 2022), water and air pollution (Lambin et al. 2003; Zhao et al., 2006) and the general availability of ecosystem services (Estoque & Murayama, 2011; Hasan et al., 2020).

2.3 LULC Monitoring

LULC monitoring involves two crucial aspects: classification, which involves categorizing LULC types, and the detection of the previously discussed LULC change, which focuses on identifying alterations or shifts of these types over time. Applying satellite remote sensing and geographic information systems (GIS) have found extensive use in accomplishing these objectives (Wu et al., 2006).

Remote sensing encapsulates the process of obtaining, processing and interpreting satellite images that interact with electromagnetic energy in order to gather valuable information about the earth's surface and its features at spatial, temporal and thematic scales (Gómez et al., 2016). LULC monitoring relies on the collection of remote sensing multi-spectral and multi-temporal data, which are acquired from either aerial or satellite images from synoptic and periodic earth observation missions, starting in 1972 with Landsat-1 (Gómez et al., 2016; Thyagharajan & Vignesh, 2019).

GIS applications are computer-based systems, which are designed to allow the user to capture, store, integrate, analyse, update and visually represent spatial data. In the context of LULC monitoring, GIS complements remote sensing by providing a platform for analysing the classified input data and measure changes between two or more time periods (Alqurashi & Kumar, 2013). For example, a wide range of GIS spatial analysis functions, spanning from overlay to cluster analysis, have been utilized to examine the spatial patterns of LULC change (Liu & Yang, 2015). GIS applications are especially advantageous in the context of product development for remote sensing data, such as thematic maps. They provide a highly versatile environment for users to select from various outputs in different formats to extract the desired information effectively and to tailor them to their liking (Alqurashi & Kumar, 2013).

During the past few decades, significant advancements in the fields of remote sensing, GIS and land inventory techniques have been made. This has enabled more reliable and regular land change monitoring at a higher resolution on a landscape scale (Rawat & Kumar, 2015). Additionally, researchers have improved methods and algorithms to detect the diverse forms of LULC and their evolution in time, which facilitate recognizing areas with significant changes (Nuissl & Siedentop, 2022; Verburg et al., 2009). In the end, results extracted from classifying and mapping past LULC changes should serve as a tool for stakeholders to take actions against degradation and destruction of natural resources (Thyagharajan & Vignesh, 2019).

2.4 LULC Modelling

As previously mentioned, while monitoring allows the analysis on how LULC has developed over the past, it does not necessarily provide adequate information or insights on the underlying processes driving the observed changes (Gómez et al., 2016). Employing a LULC modelling approach can fill this knowledge gap, as it offers a means to comprehend and explain the consequences of the dynamics of LULC (Ren et al., 2019). LULC modelling has thus gained significant popularity as a technique in the land system sciences (Verburg et al., 2015).

Generally, a model is considered to be the portrayal of a system in a simplified way, broken down to its core set of elements and principles with the purpose to achieve a deeper understanding of essential aspects of the world and how they might unveil in the future (Börner et al., 2012). In the context of LULC, models aim to add to the quality of LULC change analysis, by simulating the development of LULC change in the future in regard to the quantity and/ or spatial allocation, under defined circumstances (Verburg et al., 2004; Brown et al., 2013). The results of LULC models make it possible to address the multiple processes in various landscapes, which occur and influence each other simultaneously. Mapping these changes are crucial to anticipate and minimize negative effects on LULC, making it a valuable resource for sustainable LULC planning and management, as well as for the implementation of sustainable environmental, economic and social development policies (Pindozzi et al., 2016; Clarke & Johnson, 2020; Matci, 2023).

Ultimately, the objective of LULC modelling can be summarised into four different purposes (Clarke, 2018): (1) gaining insight of a process, usually based on the resulting spatial distribution of LULC, (2) attempting to simulate the process and therefore to try to predict where and when changes will occur (3) exploration of various scenarios by modifying future change conditions and (4) utilizing the model as a tool to raise awareness and educate others by improving comprehension of LULC change processes and its consequences.

2.4.1 LULC Model Types

LULC models have seen drastic improvements over the past decades, with the advances made in the detection of various LULC types, data acquisition techniques (e.g., satellite imagery, citizen science-based approaches or big-data platforms) and the overall improvement in performance of computational power (Verburg et al., 2015; Malek & Verburg, 2020; Gaur & Singh, 2023). Commonly, LULC models employ a combination of a top-down and a bottom-up approach to effectively serve their purpose. The top-down approach utilizes data derived from sources such as satellite imageries, census-based data and maps of relevant driving forces that have influenced LULC changes in the past. This approach then aims to simulate future LULC changes based on the historical trends observed from the data (Gaur & Singh, 2023). A top-down approach generally assumes that exogenous forces are the main reasons for LULC change at an individual location. Bottom-up approaches assume that the spatial dynamics of LULC change are mainly driven by local interactions (Li et al., 2014). These local interactions are results of analysis objects, where real actors involved in the LULC change processes and are usually based upon household surveys. This approach has gained popularity recently in the field of land system science (Ren et al, 2019).

Over the course of recent decades, a wide variety of models has been developed to investigate the dynamics and development of future LULC patterns and provide guidance in land management decisions (Ren et al., 2019). The US National Research Council (2014) divides the different approaches to modelling into six classifications:

(1) **Machine-Learning and Statistical Model:** Relies on historical LULC data in combination with predictors that are specific to both space and time

(2) **Cellular Automata Model:** Utilizes LULC suitability maps and neighbourhood characteristics to predict future changes based on expected shifts in LULC demand

(3) **Sector-Based Economic Model:** Represents the land demand within a region across various economic sectors, taking overall economic activity and trade into account through the application of partial and general equilibrium structural models

(4) **Spatially Disaggregate Economic Model:** Analyses spatial patterns in the land system based on reduced-form- or statistical economic models to investigate the relationship with key variables

(5) **Agent-Based Model:** Simulates the interaction between actors that are involved in LULC change, which would then affect the overall land system

(6) **Hybrid Model:** Combines different modelling approaches into one model

Having various models, which utilize different kind of techniques are important to understand the relation between historical spatial changes and their drivers, as LULC changes are dynamic and nonlinear processes (Noszczyk, 2019). This has also resulted in the utilization of LULC models in a wide variety of different research studies; Hua (2017) made a hybrid approach by combining a cellular automata (CA) with a statistical approach to investigate how a watershed in Malaysia might be affected due to LULC changes. Similarly, Mao et al. (2014) adopted a hybrid approach, utilizing a system dynamics model (SD) in combination with a CA approach to study the effects of tourism and land regulation on LULC in a river basin in China. Guzy et al. (2008) utilized an agent-based model to investigate the impact of urban expansion into farmlands and forests on future ecological impacts. A sector-based economic approach has been employed by Choi et al. (2011) to investigate the impact of LULC change on resulting carbon emissions. In the end however, the decision on which LULC model to use, is ultimately driven by the researcher's study objectives since there is no perfect model that can satisfy all requirements (Gaur & Singh, 2023).

While each LULC model employs a different approach, Lantman et al.'s (2011) extensive literature analysis observed that fundamentally, all such models are built upon at least one of the following four core principles of LULC change: (1) Extrapolation of past trends, (2) land suitability, (3) assessment of neighbourhood characteristics and (4) outcome of actor decision-making.

2.4.2 LULC Scenario Modelling

The idea of scenarios has existed since ancient times and has served as a means of envisioning the future of societies and institutions (Escobar et al., 2018). This idea has also found its way to envision the development of LULC in relation to the past trend, where LULC models make it possible to simulate these changes under alternative scenarios. Applying different alternative scenarios has shown to be integral to define suitable spatial policies (Mao et al., 2014). However, due to the complex interactions between the various natural and socio-economic factors, it is a monumental challenge to accurately model future LULC changes, as the uncertainty from a simulation also increases with time. Scenario modelling has been a methodology to deal with this challenge, as it considers a wide range of potential outcomes on how the future might unfold (Aduah et al., 2018; Brooks & Thompson, 2013; Mallampalli et al., 2016). Modelling a wide range of scenarios should also serve as a means to anticipate future opportunities and to minimise risks (Schwab et al., 2003). The International Permanent Committee on Climate Change (IPCC) (1994) defined such scenarios as "a coherent, internally consistent, and plausible description of a possible future state of the world". Another definition given in the field of sustainability science is that "scenarios may be thought of as coherent and plausible stories, told in words and numbers, about the possible co-evolutionary pathways of combined human and environmental systems". Based on these definitions, scenarios are not considered accurate predictions nor forecasts, but rather a means to deal with the uncertainties of the future more effectively (Swart et al., 2004).

2.5 Scenario Development

As previously stated, an approach to tackle the uncertainties of the future is to model various scenarios, which consider a wide range of outcomes. Scenario development describes the creation of dynamic, complex and uncertain future scenarios through creative thinking. These scenarios can encompass people's envisioned future states that are desired or future states, which should be avoided (Reed et al., 2013). In order to establish relevant scenarios, scenario building techniques focus on determining main concerns, the identification of influential drivers, stakeholders, trends, constraints, and other relevant elements (Amer et al., 2013).

2.5.1 Participatory Approach

Generally, future scenarios should not be developed by the researchers themselves, but rather in combination with stakeholders (Malek & Boerboom, 2015). Implementing a participatory approach in the development of scenarios has been increasing in recent years (Volkery et al., 2008). In the context of scenario development, participation is described as a form of collective decision-making. This can be the involvement of individuals from either similar or diverse backgrounds with the inclusion of individuals from institutional position. Such a collective could be comprised of policy makers, NGO representatives, farmers, scientists, business owner or the local population (Patel et al., 2007). This participative approach is needed in order for the scenarios to consider diverse perspectives on complex, uncertain problems and allows the chance to discuss, negotiate and reach agreements (Malek & Boerboom, 2015). It furthermore helps addressing relevant policy concerns in the scenario development process. Involving various stakeholders with different backgrounds into the scenario development process enhances the legitimacy, credibility and relevancy of the scenarios (Volkery et al., 2008; Malek & Boerboom, 2015). Moreover, it can have a profound impact on the perspectives of government and local authorities on existing agendas and policies, which may not be sufficient anymore for the future and thus inspire them to take transformative actions (Patel et al., 2007).

In comparison to the natural sciences, there is an abundant availability of resources on how to construct scenarios in collaboration with stakeholders in the fields of business and information sciences. As a result of the scarce availability of frameworks for scenario planning in the natural sciences, stakeholders and scientists are not profoundly determined to develop scenarios for collaborative decision-making (Mahmoud et al., 2009). Among those available, the frameworks developed by Alcamo (2001) and Henrichs et al. (2010) have emerged to be the most prominent to develop scenarios in addressing future environmental and socioeconomic challenges (Priess & Hauck, 2014).

Priess & Hauck (2014) have added enhancements to their own framework, which is based on the previously mentioned frameworks. Their conceptual framework for a participatory scenario development is divided into three components: (1) stakeholder participation, (2) knowledge integration, and (3) quality control. These three components will be discussed in more detail in the following three sub-chapters.

2.5.1.1 Stakeholder Participation

Generally, stakeholder participation should begin with identifying a diverse group of people in the community and informing, who are relevant to the issues and topics in question (Byrd, 2007). Priess & Hauck state that involving stakeholder with different backgrounds is a necessity in order to get the benefits, which is sought when developing scenarios. This should furthermore increase the legitimacy, credibility and relevancy of the scenarios.

There are various ways of letting stakeholders participate in the scenario development process, such as public hearings, advisory committees, surveys, focus groups, public deliberation, citizen review panels, collaboration, civic review boards, work groups, implementation studies and written comments, each having a different degree of participation (Byrd, 2007). In the case when time is not a constraint of the research study, Priess & Hauk consider workshops as necessary for enabling the exchange of opinions, knowledge sharing and consensus building. In cases where time is a constraint, Priess & Hauk recommend opting for expert discussions or interviews instead.

2.5.1.2 Knowledge Integration

Solely including relevant stakeholders in the scenario development process does not guarantee the integration of knowledge. To address this challenge, Priess & Hauk mention various methodologies from different frameworks to facilitate knowledge integration. They suggest the approach of Alcamo (2001) and Biggs et al. (2007), where the emphasize of knowledge integration should lie on quantification and numerical modelling. Another method involves the crafting of scenario storylines. The storylines should represent the assumptions made by the various stakeholders and should be crafted to cohesive and connected plots. However, depending on the objectives and the preferences of the researcher to use qualitative or semiquantitative scenarios, the approach changes.

2.5.1.3 Quality Control

In order for the scenarios to be more realistic and practical, it is imperative to establish that the scenarios are consistent in their assumptions, have scientific credibility and show transparency. On a larger scale, the researcher can appoint a review panel of scientist, a so called “scenario-panel”, to ensure that the aforementioned qualities are applied to the scenarios. Priess & Hauk also recommend alternative ways in their framework to conduct quality control in order to increase the transparency and salience for stakeholders, such as gathering stakeholder feedback regarding the workshop setup (e.g., organization, thematic focus, overall improvements), revising the story based on stakeholder inputs or evaluating the clarity and comprehensibility of the storyline through people, which were not part of the scenario development process.

2.6 LULC and Tourism

International travel, rising disposable incomes, transport developments and its remarkable swift growth has made tourism to a significant driver for socio-economic progress and has become one of the leading economic sectors on the globe (Williams & Shaw, 2009; Williams & Lew, 2014). Consequently, tourism has emerged as a favoured approach for promoting urbanisation in developing nations (Yang et al., 2022). Particularly in developing countries located in tropical regions, tourism development can strive with urbanisation. This in turn, affects population growth and develops workforces in the non-agricultural sector, which provides new employment opportunities and therefore increases the income of the community (Putri et al., 2021; Rimba et al., 2020; Wayasuri & Chotpantarat, 2022). Tourism development can furthermore provide communities with an improvement in their infrastructure network. Moreover, it has the potential to enhance a community's sense of pride in its local or national cultural heritage, leading to a stronger desire to preserve and safeguard it. Tourism can therefore play a substantial role in promoting environmental protection and conservation, by establishing national parks and wildlife sanctuaries. Additionally, it fosters greater public appreciation of the environment and raises awareness about environmental issues (Lakshmi & Shaji, 2016).

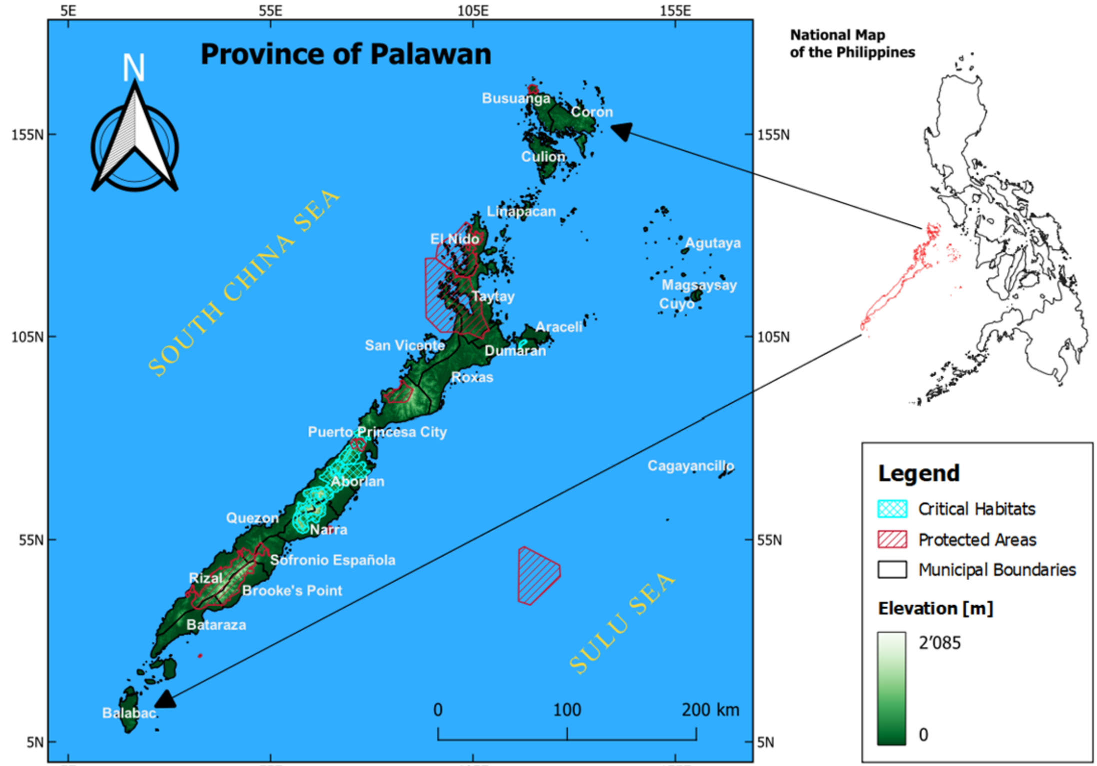
However, since land is used by humans for various recreational activities, tourism is a crucial driver of LULC change, which can result in a range of various negative effects on the natural surroundings of tourist destinations (Mao et al., 2014; Williams & Lew, 2014). There have been several research studies, mentioning drawbacks on the local environment related to massive boosts in the tourism sector such as, deforestation, the disruption of habitats and the resulting loss of biodiversity, various forms of pollution (e.g., air, water or noise), increased traffic congestion, the overexploitation of water resources or physical erosion of sites (Mao et al., 2014; Dela Cruz et al., 2014; Williams & Lew, 2014).

Mao et al. (2014) concluded, based on various studies, that the effects of tourism development on LULC change can generally be divided into five dimensions: (1) loss of forest, wetland and cropland area for the development of tourism infrastructure, (2) LULC change related to tourism development exerts further impacts on the natural environment (e.g., shoreline erosion), (3) development of low-density construction in tourist regions is at the expense of forest cover, (4) large land allocation for tourism establishments, such as theme parks, hot springs or golf clubs display potential eco-risks to the local environments, (5) socio-economic dynamics alongside tourism development indirectly affect LULC change.

Due to the significant impact tourism has on shaping future LULC patterns, researchers have undertaken studies that utilize the approach of LULC modelling to investigate how tourism development could affect future LULC changes under different scenarios. Mao et al. (2014) combined the top-down approach of a system dynamic model (SD) with the bottom-approach of a cellular automata (CA) to conduct a scenario analysis of the effect of tourism and LULC policies in China. Boavida-Portugal et al. (2016) created a scenario modelling based on the combination of Markovian transition probabilities and CA, where they investigated the impact of future tourism development on LULC near a coastline in Portugal. Akdeniz et al. (2023) and Rimba et al. (2020) utilized the land change modeler, a model that incorporates past land cover maps with a set of potential explanatory variables, to investigate how current spatial development policies will potentially affect future LULC patterns in tourist areas.

3 Study Area

The archipelagic province of Palawan, located southwest of the main Philippine chain of islands, will be the designated study area of this thesis. Politically, Palawan is subdivided into 23 municipalities, one independent city (Puerto Princesa City) and 431 barangays, which is the smallest political unit in the Philippines (Fig.1). Out of the 23 municipalities, eleven are located on the main island, while the other twelve are island municipalities, which are accessible by motorized bancas (boats). The island is the largest province of the Philippines in terms of land area with an area size of 14'649 km^2 (NEDA MIMAROPA, 2023). The topography is mainly hilly to mountainous, which makes up 63% of its terrain, while flatlands comprise 37% of its landscape. Palawan exhibits one of the most diverse vegetation in the Philippines. Its vast, relatively intact ecosystem is home to a high concentration of endemic species of flora and fauna, which are of high conservation value (PCSD, 2015; PCSD 2016). Palawan is thus known to be the last ecological frontier and considered as the ecotourism hub of the Philippines. In the year 1990, the island has been designated as a Mangrove Swamp and Biosphere Reserve by the UNESCO (Sajorne et al., 2021).



Map Author: Hans Peter Pleisch
Date: 20.06.2023
Sources: USGSS, NAMRIA Philippines, Provincial Planning and Development Office
Palawan

Figure 1: Study area for the present thesis

The province of Palawan can be divided into three different parts, each with its own primary focus. The northern part has its emphasis on the production of agricultural crops and tourism, whereas the southern part prioritizes agribusiness. Puerto Princesa, located in the middle part of Palawan, is the industrial centre of the province and is also one of the primary tourism hot spots (Gonzales & Reyes, 2018). Due to the constraints regarding the study area size in the Dyna-CLUE model, the island municipalities Agutaya, Cuyo, Magsaysay, Cagayancillo and Kalayaan Inset were excluded in this thesis, as they also exhibit the largest distances away from the main island of Palawan, where most of the tourism activities take place. Additionally, the study area was separated to "Northern Palawan (NP)" and "Southern Palawan (SP)", where the distinction was made starting at the boundary between the two municipalities Aborlan and Puerto Princesa City.

3.1 Republic Act No. 7611

The national government of the Philippines has recognized early on that it is integral to protect, develop and conserve the natural resources of Palawan. In 1992, they enacted the Republic Act No. 7611, also known as the "Strategic Environmental Plan (SEP) for Palawan Act". The SEP is a comprehensive framework to promote the sustainable development of Palawan and thus protect and enhance the natural resources and endangered environment of the province. As part of the SEP, an administrative machinery was established, called the Palawan Council for Sustainable Development (PCSD). The PCSD is guided by the SEP and carries the responsibility to govern, implement and direct policies of the SEP.

The main strategy for the PCSD lies in the Environmentally Critical Areas Network (ECAN) (Fig A.1), where the province is divided into five terrestrial zones, namely, core zone (CZ), buffer zone – restricted use (RUZ), buffer zone – controlled use (CUZ), buffer zone – traditional use (TUZ) and multiple use zone (MUZ) (Tab A.1). The establishment of ECAN zones was already mandated in the SEP for Palawan and are intended to serve as a graded system for local land use and development planning. In addition to the ECAN zones, Palawan has established nine protected areas, which have been expanded from 64'819 ha in 1990 to 541'565 ha in 2014 (PCSD, 2016)

3.2 Tourism in Palawan

Over the past few years, Palawan has emerged to be one of the Philippines most popular tourist destination, which has been skyrocketing since the Puerto-Princesa Subterranean River National Park (PPSRNP) got designated as a UNESCO World Heritage site in 1999 and has increased drastically from that point onward (Alejandria-Gonzalez, 2016; Kobayashi, 2017). The island has been crowned “World’s Best Island” in 2013 by Travel+Leisure Magazine, “Top Island” and “The Best Island in the World” in 2014 and 2015 by Condé Nast Traveller, both renowned travel magazines, which highlighted Palawan’s pristine beaches and waters, rich wildlife and the fact that Palawan is “Last Ecological Frontier” (PCSD, 2015). This rise in popularity has been evident in the tourist arrival numbers. Since 2000, which exhibited a total tourist arrival count of 126’958, the number has surged up to 1’987’605 by the year 2019, prior to the COVID-19 pandemic (PDOT, 2023).

However, the boost in tourism and the resulting economic growth, has left concerns about the degradation of the environment due to the expanding urbanisation of cities/ municipal centres. These are regarded as post-frontier realities by the PCSD and have been assigned as mandatory to monitor (Manalo, 2017; PCSD, 2016). In a report published by the PCSD (2022), results of a land cover monitoring research project, covering the years 2005-2015, conducted by the Environmental Monitoring and Enforcement Division (EMED) Staff Chief Engr. Jong Cabrestante, has revealed that there has been a major degradation of closed forest cover due to the booming tourist sector and kaingin (traditional farming practice for deforestation). Further studies (Fu et al., 2022; Nolos et al., 2022; PCSD, 2016) have determined additional drivers which contributed to the recent losses of forests and cultivated land such as mining activities, illegal activities within forest land, an increased demand for food, habitable land and economic development, which had been exacerbated by population growth.

4 Data & Methods

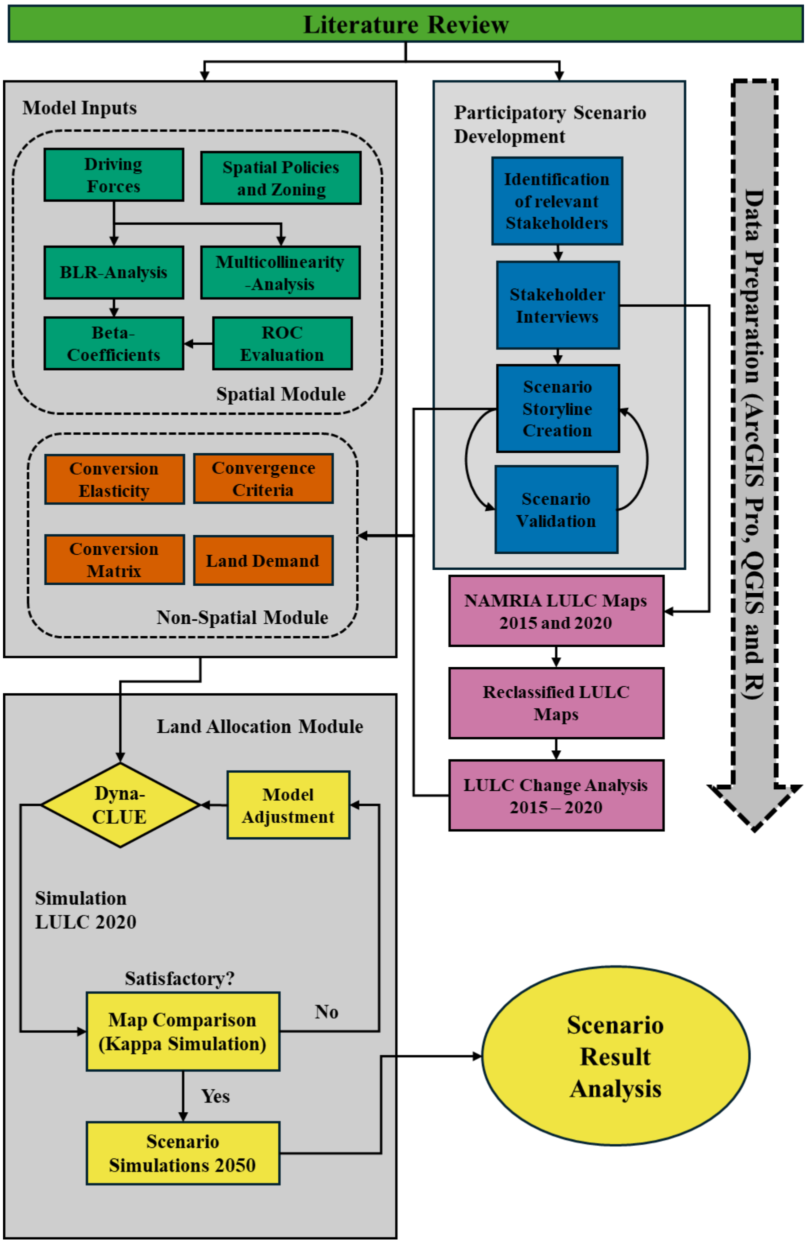


Figure 2: Workflow Illustrating the methodological framework employed for the present thesis

For this thesis, LULC Maps generated by the National Mapping and Resource Information Authority (NAMRIA) from the years 2015 and 2020 were used for the modelling purpose. The data required for the modelling process was obtained as from the Google Earth Engine catalogue (GEE), Open Street Map queries (OSM), the PCSD and various other official government units from the Philippines. The generation of layers required for the Dyna-CLUE model were processed using tools in ArcGIS Pro (Version 3.2.2), QGIS (Version 3.26.2) or scripts written in RStudio and ultimately converted to ASCII files with a spatial resolution of 100m x 100m, as this was the finest capable resolution for Dyna-CLUE, suitable for both NP and SP. The scenario development process followed the framework from Priess & Hauck (2014). Based on the obtained results and previous studies, the additional necessary files for the Dyna-CLUE model were generated, following the user guide provided by Verburg et al. (2021).

4.1 Reference LULC Maps

Officially generated LULC maps by NAMRIA from the years 2015 and 2020 were freely downloaded from the governmental Geoportal website of the Philippines, which are based on Landsat imageries with a spatial resolution of 30m. The reference maps were rasterized to a spatial resolution of 100m with the "Feature to Raster" tool of ArcGIS Pro. It is to note that only the pixels, which were shared between the LULC map from 2015 and 2020 were kept due to the requirements given by the Dyna-CLUE model. The final rasterized LULC map of 2015 served as the mask layer in generating all subsequent raster maps of the driving forces. The LULC map from 2015 was used as the base map, whereas the LULC map from 2020 was used as the reference map for the model validation and the subsequent simulations (Wang et al., 2018). Originally, the LULC maps were classified into 14 different types of LULC, however, as not all LULC are directly relevant to tourism development, LULC of the same type were aggregated. For the present thesis, the LULC types were ultimately reclassified to *Agriculture* (AG), *Eco-Land* (EL), *Mangrove-Forest* (MF), *Open/ Barren* (OB), *Built-up* (BU) and *Waterbodies* (WB). A more detailed rationale regarding the aggregation of the LULC types will be presented in upcoming chapters.

4.2 Driving Forces & Spatial Policies

To comprehend the spatial dynamics of Palawan and how it influences LULC, a total of eleven natural- and socioeconomic driving forces were. Among the natural driving forces were *altitude* (Alt), *slope* (Slp), *distance to coast* (DstCst), *distance to rivers* (Dstriv) and *precipitation* (Precip). For socioeconomic driving forces, *population density* (Popdens), *nighttime light* (NL), *distance to roads* (Dstrd) and *distance to built-up areas* (Dstbu) were chosen. In order to incorporate the influence of tourism two additional socioeconomic driving forces related to tourism, namely, *tourist arrivals* (TA) and *distance to tourism attractions*

(Dsttattr) were also included. For this thesis, only *population density* was regarded as the sole dynamic driving force due to data scarcity. The projection of future *population density* of Palawan followed the reported trend by the Philippine Statistic Authority (PSA) between 2015 and 2020 (PSA, 2021).

All of the driving forces were selected based on previous studies, which had tourism as one of their primary aspects (Tab. 1).

Table 1: Selected driving forces for the Dyna-CLUE model

Type	Driving Force	Resolution	Method	Source	Literature
Natural	Altitude (Alt)	30m	Aggregated to 100m in ArcGIS	Copernicus DEM GLO-30	Waiyasusri & Chotpantarat (2022)
	Slope (Slp)	100m	Calculated from DEM in QGIS	Based on DEM	Waiyasusri & Chotpantarat (2022)
	Precipitation (Precip)	500m	Downscaled to 100m using R script	OpenLandMap Precipitation Monthly	Shi et al. (2023)
	Distance to coastline (Dstcst)	100m	r.grow.distance tool in QGIS	OSM	Boavida-Portugal et al. (2016)
	Distance to rivers (Dstriv)	100m	r.grow.distance tool in QGIS	PCSD	Mao et al. (2014)
Socio-Economic	Population Density (Popdens)	1km	Downscaled to 100m using R script	Gridded Population of the World, V4	Boavida-Portugal et al. (2016)
	Nighttime Light (NL)	1km	Downscaled to 100m using R script	VIIRS Dataset	Lao et al. (2020)
	Tourist Arrivals (TA)	100m	Downscaled to Accommodations using R script	PDOT, PTPDOP and OSM	Boavida-Portugal et al. (2016)
	Distance to Tourist Attractions (Dsttattr)	100m	r.grow.distance tool in QGIS distance method	OSM	Widaningrum et al. (2020)
	Distance to road (Dstrd)	100m	r.grow.distance tool in QGIS	OSM	Mao et al. (2014)
	Distance to Builtup (Dstbu)	100m	r.grow.distance tool in QGIS	Based on rasterized LULC map 2015	Widaningrum et al. (2020)

Dyna-CLUE also allows the specification of areas where any kind of development is prohibited during the simulation. One of the most essential spatial policy tools in the province of Palawan are the ECAN zones. Notably, the Core Zone of the ECAN is referred to as a “No Touch” area, where all forms of developments are strictly prohibited. The official ECAN zone map can be viewed at the governmental Geoportal website of the Philippines. However, it is not available for download. A post-processed raster file of the ECAN zones, aligned to my specific requirements, was provided by the members of EMED. In addition to the ECAN zones, the protected areas and critical habitats of Palawan were included as well as part of the spatial policies and restricted areas in place. The spatial data was provided by the PPDOP.

4.3 Scenario Development

The subsequent chapters show the step-by-step incorporation of the knowledge of the various stakeholders into the scenario development process and the resulting scenarios, which were modelled with Dyna-CLUE.

4.3.1 Stakeholder Participation

The initial question that emerged during the preparation for the participatory scenario development, was to determine, which kind of people identify as stakeholder participants in the context of this thesis. The ultimate decision was made based on previous studies, which conducted a participatory scenario development in regard to tourism development or sustainable land management. Based on the findings from the following previous studies, it was determined that relevant stakeholders for this research included *local resident* (Byrd, 2007; Kim et al., 2022), *business owners* or *manager* (Hieu & Nwachukwu, 2019; Presenza & Coppaline, 2010), *city planner* (Byrd, 2007; Malek & Boerboom, 2015), *agriculture department* (Schwilch et al., 2012; Aseres, 2014), *environmental office* (Mafruhah et al., 2015), *tourism department* (Aseres, 2014), *natural area manager* (Hewitt et al., 2018) and *non governmental office (NGO)* (Aseres, 2014).

Following the identification of the relevant stakeholders, the next consideration was the determination of the specific locations within Palawan where the interviews should be conducted. Given that Palawan is the largest province in the Philippines and the constraints of my limited time staying there, the focus of the interviews was set on the three municipalities which have attracted the most tourist arrivals over the years. As indicated by the statistics provided by the PPDOP (Fig. A.4) this concerned the municipality of *Puerto Princesa City*, *Coron* and *El Nido*. However, due to the considerable travel duration to the island municipality of Coron, the decision was made to conduct the interviews with stakeholders located in the municipality of *San Vicente* instead, which exhibits the fourth highest tourist arrival count amongst the municipalities of Palawan.

The scenario development was set to involve a minimum of 20 participants. This criterion was determined based on the previous works from Kok et al. (2006) and Ernst et al. (2018), both of which had a focus around participatory scenario development.

4.3.2 Knowledge Integration

Due to the limited duration of my stay in Palawan, the recommendation provided by Priess & Hauk was taken into consideration that the degree of the stakeholder's participation in the scenario development will be through semi-structured interviews (SSI). SSI are conducted conversationally with one respondent at a time. The questions are already predetermined, however, the interviewer can follow them up with probing questions. This flexibility allows for the interview to still be focused on its primary goal, while also providing the opportunity to delve into ideas of more complex LULC dynamics presented by the interviewee. This in turn can enhance the understanding of the local LULC dynamics, which can enhance the LULC model structure (Adeoye-Olatunde & Olenik, 2021).

The interview was structured into five segments: *Introduction, Background Demographic, Past Changes, Potential Future Development* and *Final Remarks.* The interviews were set up in such a way so that they conformed to the "Guidelines on Ethics and Safety in Fieldwork for Researchers", set by the Human Geography Department at the University of Zurich.

(1) *Introduction:* The first segment of the interview was not recorded as it served to introduce myself to the stakeholder and to explain the purpose of the interview, what the research is about, why the interview is relevant for the study and how the data will be used and stored after. The interviewee was also made clear that the conversation will be recorded and that their identity will be kept anonymous. If the interviewee agreed to these terms, they were handed a consent form for them to sign. The consent form explained the aforementioned points again.

(2) *Background Demographic:* The second segment of the interview allowed the interviewee to introduce themselves and provided a closer insight into the interviewee's personal background.

(3) *Past Changes:* The focus of the third segment of the interviews was to identify, which specific LULC types in Palawan are relevant in the context of tourism development. The questions revolved around the interviewee’s perceived changes of the landscape over the past years and what they think were the reasons for these changes or developments. As the focus of the study is on tourism development, if there have been no mentions, the interviewee was also specifically asked about tourism development related changes.

(4) *Potential Future Development:* The focus of the fourth segment directly served the scenario building process. The interviewees were asked how their desirable form of tourism development would look like and how it would reflect on the landscape. Correspondingly, the same question was asked again, but for a non-desirable tourism development. After establishing the interviewee’s best- and worst-case scenario, they were asked a follow-up question concerning potential measures they could think of, which would either prevent or facilitate the respective scenario.

(5) *Final Remarks:* The last segment of the interview allowed the interviewee to share any remarks or comments they would like to share, which could also be not related to the topic of the interview. This question was included in order for the interview to be closed in a polite manner, but it also may provide additional insight on the interview topic.

4.3.3 Quality Control

For the created scenarios, quality control was undertaken by reviewing the final storylines by the means of holding a presentation, which showed on what basis the storylines were created. However, due to the difficulty of arranging a suitable schedule for all involved stakeholders and the additional time constraint, the presentation was only held in front of four members of the EMED section of the PCSD.

4.3.4 Qualitative Interview Analysis

After having interviewed all the participants, the interviews were transcribed and then analysed using MAXQDA. MAXQDA is a software tool for qualitative and mixed methods research and has seen applications in research globally (Gizzi & Rädiker, 2021). The interviews were systematically analysed on the beforementioned sections *Background Demographics, Past Changes* and *Potential Future Development*. The analysis utilized the multi-level coding system of MAXQDA to establish codes and sub-codes, which facilitated the analysis of the interview content. In this context a “code” represents segments of an interview transcript, which are labelled with the category pre-set by the researcher. The final codes were established after reviewing the interview transcripts and are based on concept definitions and codes used in previous studies. The primary goal following the coding, was for the analysis to satisfy the objectives set in the prior subsection.

4.4 Dyna-CLUE

The broad range of modelling approaches available allows for extensive applications in various domains and different scales. In the context of this thesis, the commonly used cellular-based hybrid model, Dyna-CLUE (Dynamic Conversion of Land Use and its Effects), developed by Verburg & Overmars (2009), was utilized to conduct future LULC change simulations up to year 2050. The year 2050 was determined based on previous spatial modelling papers such as from Waiyasusri & Chotpantarat (2022) or Aydin & Eker (2022), which had tourism as one of their primary aspects. The model is available as a free download on the website of the Environmental Geography department at Vrije Universiteit Amsterdam (https://www.environmentalgeography.nl/site/data-models/data/clue-model/).

Dyna-CLUE is part of the CLUE series models, which are among the most widely used LULC models in research globally. These models have also seen success in research ranging across multiple scales (Ren et al., 2019). The Dyna-CLUE model belongs to the third and most recent generation of the CLUE series and with improvements over its predecessor, CLUE-S. In comparison to the CLUE-S model, which uses a top-down approach of spatially allocating demands for different LULC types to individual cells (Verburg et al., 2002), the Dyna-CLUE model incorporates a hybrid approach. This involves the implementation of a bottom-up approach, allowing users to determine the conversions for specific land use transitions and demand-driven changes, which are incorporated in the algorithm. Such bottom-up approaches are generally underutilized in LULC models (Domingo et al., 2021).

By taking both, natural and socio-economic factors into account, the Dyna-CLUE model has been used in various studies investigating how future LULC change scenarios might influence hydrology (Tsegaye & Barti, 2022; Shirmohammadi et al., 2020; Sahoo et al., 2020), susceptibility to natural hazards (Aydin & Eker, 2022; Chowdhuri et al., 2021), food security (Siagian et al., 2022; Sakayarote & Shreshta, 2019) or ecosystem services (Hu et al., 2020; Yu et al., 2023). Although the Dyna-CLUE model has not been utilized in a research study within the Philippines, its predecessor, CLUE-S, has already seen applications in the country (Verburg et al., 2002; Verburg et al., 2004).

4.4.1 Model Structure

The Dyna-CLUE model is divided into a non-spatial and spatial module (Fig. 4). The non-spatial part of the model is represented in a demand module, describing the change of land demand over time in form of a text file. This module is not part of the downloadable interface and must be calculated separately. In addition to the land demand, conversion elasticity, conversion matrix and the convergence criteria are further components of the non-spatial

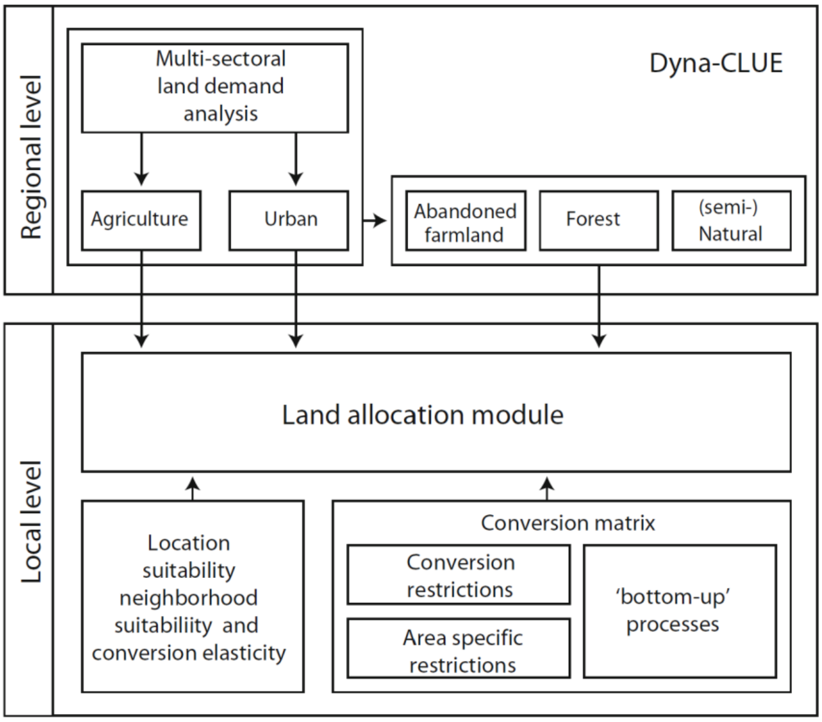


Figure 3: Overview of the inputs for the land allocation module of Dyna-CLUE (Verburg et al., 2009)

module (Loukika et al., 2023), which will be described in further detail throughout this chapter and following subchapters.

The spatial module allocates the land demand of each LULC type to individual grid cells (Fig. 5). This allocation process involves comparing the allocated area of a specific LULC type with the required area until the convergence criteria is satisfied. The convergence is a criteria, which lets the user define the average and maximum allowed discrepancy between the modelled land allocation and the determined land demand for each LULC type (Loukika et al. 2023). For the present thesis, the default settings were kept, which allows a maximum area discrepancy of 3% and average discrepancy of 0.35%.

Overall, Dyna-CLUE requires at least four out of five possible input files, namely, land demand, location suitability, spatial restrictions and conversion parameters. A neighbourhood suitability file can optionally be added to the Dyna-CLUE model (Zhang et al., 2015).

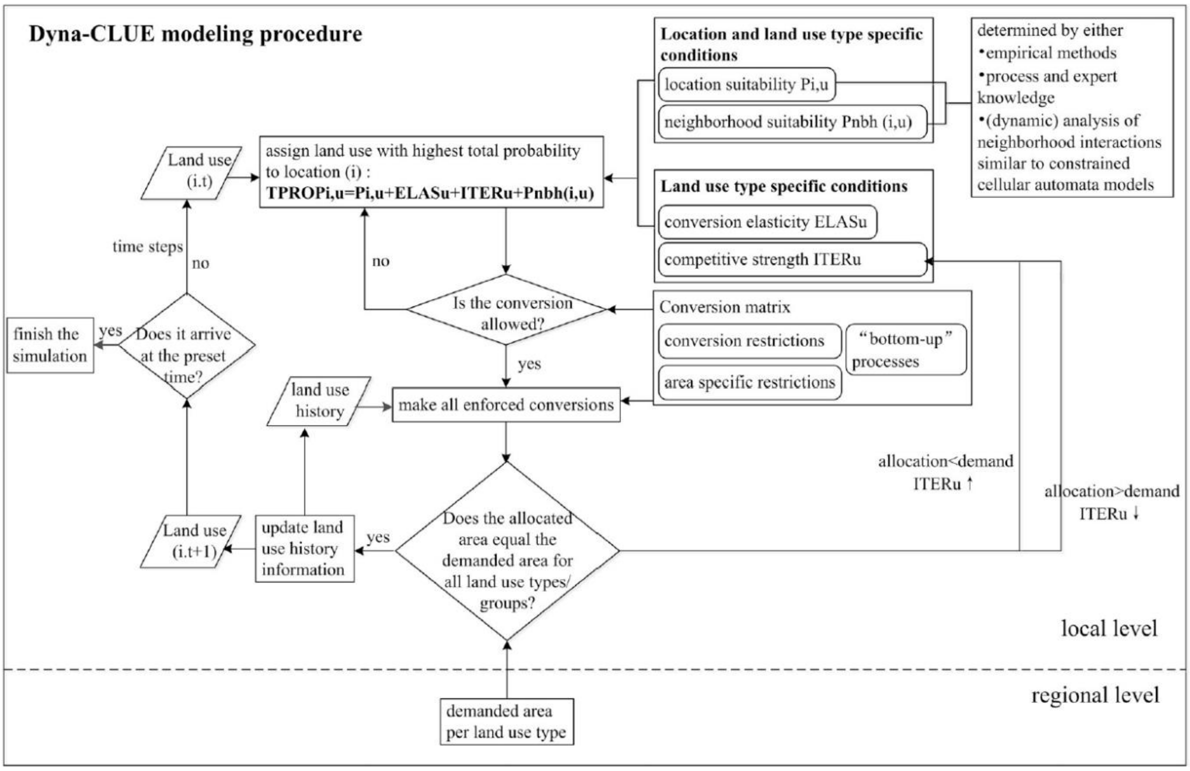


Figure 4: Overview of the modelling procedure of Dyna-CLUE (Ren et al., 2019)

The ultimate decision whether a LULC is being converted into a new type relies on the LULC *lu* that has the highest total probability at time *t* for the specific location *i.* The total probability is defined by the following formula, which is determined by the sum of the location preference

($Ploc_{i,t,lu}$), neighbourhood characteristic ($Pnbh_{i,\ t,\ lu}$), conversion elasticity ($Elas_{lu}$) and competitive advantage ($Comp_{t,\ lu}$):

$$Ptot_{i,t,lu} = \ Ploc_{i,t,lu} + \ Pnbh_{i,t,lu} + Elas_{lu} + \ Comp_{t,lu} \qquad (1)$$

In the case of this thesis, the neighbourhood characteristic, linked to the neighbourhood suitability, was not incorporated. Despite excluding this aspect, previous papers still exhibited satisfactory results (e.g., Chasia et al., 2023; Das et al., 2019; Loukika et al., 2023).

4.4.2 Land Demand

The land demand is calculated for the entirety of the study area. As the land demand constitutes the non-spatial module of the Dyna-CLUE model, there are various methodologies to calculate the future land demand. These methodologies range from trend analysis, simple demand models to complex multi-sectoral models. The future demand represents the total area change for each LULC and varies depending on the specific scenario. The Dyna-CLUE model limits the simulation scope as it requires the total area, denoted by the total individual grid cell count, to be consistent over the simulation years (Verburg & Overmars, 2009). For the model validation and the basis for the future scenario land demands, the land demand was based on the annual change between 2015 and 2020 derived from the LULC maps for Northern- and Southern Palawan (Tab. 2).

Table 2: Land area change detected from the LULC maps generated by NAMRIA between 2015 and 2020

	NP 2015		NP 2020		NP 2015 – 2020	SP 2015		SP 2020		SP 2015 – 2020
LULC	Area		Area		Annual Change	Area		Area		Annual Change
	ha	%	ha	%	ha	ha	%	ha	%	ha
AG	70004	8.65	65692	8.12	-862.4	184020		172641		-2275.8
EL	692472	85.60	691981	85.54	-98.2	387050		396167		1823.4
MF	33645	4.16	33398	4.13	-49.4	22558		23336		155.6
OB	883	0.11	992	0.12	21.8	1960		2213		50.6
BU	7941	0.98	12863	1.59	984.4	7214		8679		293
WB	4018	0.50	4037	0.50	3.8	5744		5510		-46.8

For the scenarios, which followed different transition rates, a combination of the extrapolation of historical trends and standardization using a scaling factor was used to estimate future LULC demands for the scenarios for each LULC type. As tourism-related establishments are generally embedded in the BU LULC type and tourism being one of the primary drivers for urban development in Palawan, the future LULC demand for the newly created scenarios was therefore primarily based on the adjustment of the expansion rates of BU areas. The quantification of BU expansion rates was based on approach by Iizuka et al. (2017), who modelled the future urban sprawl and the resulting LULC changes in the Laguna de Bay Area, also situated in the Philippines. To ensure that the total land area stays consistent throughout each simulation year, the following equation (Eq. 8) was used to calculate the scaling factor. The scaling factor was then applied to the LULC types, which needed standardization.

$$Standardized\ LULC\ Demand = \frac{D_{TLA} - \sum_j K_{LA}(j)}{\sum_j LA_{ST}(j)} \times LA_{ST} \quad (2)$$

D_{TLA} represents the desired total land demand, while K_{LA} encompasses the already known land demand for each LULC type. LA_{ST} encapsulates the land areas of the LULC types which have not been standardized yet.

4.4.3 Location Preference

It is generally assumed that LULC transitions occur where the highest preferences for a specific LULC type are found at that specific point in time, which are also influenced by spatial policies or set scenario rules. Preference of a location is defined by various factors from the socio-economical or biophysical domain, which have driven LULC change in the past (Sahoo et al., 2018). The calculation for the location preference is as follows:

$$R_{ki} = a_k X_{1i} + b_k X_{2i} + \ldots \quad (3)$$

R represents the preference to allocate LULC type *k* to location *i,* whereas X_1, X_2, X_{n+1}..., correspond to the socio-economical or biophysical characteristics present at location i. The parameters a_k and b_k are the relative influence of these characteristics on the preference for LULC type *k* (Sahoo et al., 2018).

4.4.4 Conversion Elasticity

Conversion elasticity is a parameter setting in the main file of the Dyna-CLUE model that indicates how flexible a LULC type is to be converted into other types. The elasticity values range from 0 to 1. This means that LULC types with larger values have a higher capital investment or have an irreversible impact on the environment and are therefore harder to convert into other LULC types, whereas lower values indicate a more easily convertible LULC type (Chasia et al., 2023). For the present study, the determination of the elasticity values was derived after performing model runs through the trial-and-error approach. For NP the elasticity values 0.1, 0.1, 0.6, 0.4, 0.8 and 0.7 were determined to give the most optimal result for the LULC types Agriculture, Eco-Land, Mangrove Forest, Open/ Barren, Built-up and Waterbodies, respectively. Elasticity values for SP only remained the same for EL. The other LULC type overall had higher elasticity value to get the most optimal results. AG had an elasticity value of 0.3, MF had 0.7, OB had 0.6, BU had 1.0 and WB had 0.9.

4.4.5 Conversion Matrix

The rules, whether a LULC type is permitted or prohibited to convert into a certain other LULC type, is determined by the conversion matrix. The conversion matrix assigns binary values of 1 and 0 between LULC type to represent if a conversion between the two is permitted or prohibited. The value 1 indicates that a conversion between the two LULC types is permitted, while the value 0 indicates that a conversion is prohibited. The conversion matrix was based on the transition probability matrix generated from the MOLUSCE plug-in in QGIS (Tab. A.5 & Tab. A.6), which was derived from the two reference maps. The transition probability matrix showed that each LULC was capable of converting into another LULC type. Therefore, every possible transition in the conversion matrix was initially to be received the value 1 (Tab. A.7).

4.5 Evaluation of Driving Forces

In order to quantitatively assess the compatibility between the spatial distribution of the various LULC types at the cell level, a binary logistic regression (BLR) model or logit model, was employed to assess the location suitability for each LULC type of the year 2015. The suitability is calculated using a method of weighted averages, which is based on empirical analysis that take current and historical preferences for a location (e.g., natural and socio-economic characteristics) into account (Loukika et al., 2023).

The logistic regression is calculated as followed (Verburg et al., 2002):

$$Log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \ldots + \beta_m X_{m,n} \qquad (4)$$

The variable P_i represents the probability of a LULC type i to occur in a specific location (e.g., grid cell). X_m are the considered driving forces determined by the user. The BLR results provide the β-coefficient, for each LULC type based on its corresponding driving forces. The BLR model's resulting β-coefficients and constants are subsequently saved in a .txt file. This file is essential for the Dyna-CLUE model, enabling it to incorporate these values into its calculations.

The goodness of fit of the BLR model was assessed by the relative operating characteristic (ROC) statistics. This was done by comparing the resulting probabilities of the logistic regression of each LULC type to their actual pattern from the year 2015. The area under the ROC curve (AUC) ranges in value from 0 to 1, where ROC values above 0.7, indicate that the selected driving forces have good explanatory capabilities for the specific LULC type (Sheng & Lian, 2023).

The selected driving forces were also analysed on the potential presence of a multi-collinearity, which could let the BLR model draw false conclusions when it comes to the significance of a driving factor in relation to a specific LULC type. This was done by testing the driving forces on variance inflation factors (VIF) and tolerance values (TV) by first using a regression model, which Chasia et al. (2023) depicted as followed:

$$\bar{x}_1 = b_2.x_2 + \ldots + b_k.x_k + a \qquad (5)$$

Where, $\bar{x}_1$ represent one of the chosen driving forces, which is then modelled against the other driving forces selected for the present study to calculate the coefficient of determination R^2_i. A multi-collinearity can then be determined by utilizing TV, derived from $1 - R^2_i$, for the calculation of VIF:

$$VIF = \frac{1}{1 - R_i^2} \qquad (6)$$

Driving forces, which exhibit VIF value greater than 10 and a tolerance value less than 0.1, indicate to have a severe level of multicollinearity among the other driving forces (Daoud, 2017). Other references also suggest that VIF values greater than 5 already indicate multicollinearity (Ainiyah et al. 2016).

Prior to these analysis, the ASCII files of the driving forces were transformed into a tabular format with the provided conversion tool of the Dyna-CLUE. The ready files were then imported into the IBM SPSS software, where the analysis was conducted.

4.6 Model Evaluation

In order to assess the predictive performance of this study's Dyna-CLUE model, a pixel-based comparison was conducted. The calculation was based on the two observed LULC maps from 2015 and 2020, and the simulated map of 2020.

Since it is feasible that most LULC will maintain their original classification in a location, the traditionally used Kappa coefficient values between the observed and simulated will be typically high. However, this does not necessarily reflect the accuracy of the model. Therefore, the extension of the traditionally used Kappa coefficient of agreement, namely, Kappa Simulation ($K_{Simulation}$), was preferred to quantitatively evaluate how well the model simulation performs. The difference lies in the assessment in the model simulation, where $K_{Simulation}$ views how consistent the simulated LULC transitions are compared to the LULC transitions of the reference LULC maps, whereas the traditional Kappa coefficient looks at the agreement between two categorical datasets. $K_{Simulation}$ is therefore better suited to illustrate the predictive ability of the model (van Vliet et al., 2011). Van Vliet et al. showcase the following equation for the calculation of $K_{Simulation}$:

$$K_{Simulation} = \frac{p_o - p_{e(Transition)}}{1 - p_{e(Transition)}} \qquad (7)$$

The variable p_o represents the relative observed consistency between the rasters, whereas $p_{e(Transition)}$ represents the anticipated fragment of agreement, taking the sizes of the class transitions into account. $K_{Simulation}$ can furtherly be broken down into the measures $K_{Transition}$ (Eq. 6) and $K_{TransLoc}$ (Eq. 7):

$$K_{Transition} = \frac{p_{\max\,(Transition)} - p_{e(Transition)}}{1 - p_{e(Transition)}} \tag{8}$$

$$K_{TransLoc} = \frac{p_{\mathrm{o}} - p_{e(Transition)}}{p_{\max\,(Transition)} - p_{e(Transition)}} \tag{9}$$

$K_{Transition}$ showcases the consistency between the amount of LULC transitions and $K_{Transloc}$ evaluates how well they agree in their spatial allocation.

The values for $K_{Simulation}$ range from -1 to 1, where scores above 0 indicate that the model has produced a satisfactory simulation result and vice versa (Wang et al., 2022). $K_{Transition}$ encompasses values within the 0 to 1 range. A value of 1 indicates that the total quantity of the simulated class transitions is identical to the reference, while a value of 0 indicates an absence of class transitions in both the simulation and reference. $K_{TransLoc}$ includes values ranging from -1 to 1. Values closer to 1 indicates the highest possible allocation based on class transition, whereas values closer to -1 indicate that the allocation is worse than a random allocation based on the class transitions (Kucsicsa et al. 2020).

The $K_{Simulation}$ statistics was conducted in the Map Comparison Kit, version 3.2.3, which is a software tool to compare raster maps by various algorithm means developed by Visser & de Nijs (2006). The software can be freely downloaded from the following link: http://mck.riks.nl/.

5 Results

The subsequent sections will present the scenarios and potential measures derived from stakeholder interviews, as well as the driving force analysis conducted with the BLR model. Additionally, it will include the evaluation and results from the scenario modelling conducted with Dyna-CLUE. The data and materials utilized to obtain these findings are accessible via the following SWITCHdrive link: https://drive.switch.ch/index.php/s/7dE6MkclMX1R4WN

5.1 Interview Analysis

5.1.1 Stakeholder Participants

A total of 27 interviewees were conducted in order to get a better understanding of the local LULC dynamics and possible future outlooks for tourism development in Palawan. Table A.8 summarises the distribution of the interview respondents by their respective stakeholder categories. Additionally, it outlines the municipalities, which were represented by the relevant stakeholders. In order to get a more varied viewpoint among each stakeholder group, at least two different individuals from different municipalities were interviewed

The biggest stakeholder group were *residents* with ten interviewees, which were conducted on the streets of El Nido, Puerto Princesa City and Población, San Vicente. A total of four interviews with *Business Owners/ Managers* related to the tourism industry were interviewed across the three selected municipalities. Following that¸ *city planners* were the third biggest stake holder group with three interviews. Two out of the three city *planners* were from offices located in Palawan. The third *city planner* was associated with a private planning agency based outside Palawan that had prior involvements in projects in Palawan. The stakeholder groups *agriculture department, environmental office, tourism department, natural area manager* and *NGO* each had two representatives from two different municipalities.

5.1.2 Background Demographic

Table A.9 provides a summary of the interview respondents demographic characteristics. Personal factors, which were age, gender and years living in Palawan were taken into account of each stakeholder, when their personal background was examined. The majority of the stakeholder interviewees were male participants, comprising 63%, while the remaining 37%

were female representatives. Same percentages were noticed for participants in both the age group between 25 and 45 and the age group between 46 and 65 with 40.7%. Only 3.8% of the participants were in the age group between 18 and 24 and only one participant was in the age group 66 and above. In terms of LGU representatives, 37% of the stakeholders were linked to an LGU, while the other 63% had no association with any LGU. Those who were part of an LGU were all stakeholders in the groups categorized in Table A.8 as, agriculture and tourism department, the environmental office and the natural area managers. Out of the three city planners, only one participant was not part of an LGU. Almost 89% of the participants have been living in Palawan for over 10 years, while only two individuals having resided in the province for less than 6 years and just one participant falling within the six-to-ten-year range.

5.1.3 Past changes – LULC Types

One of the key objectives in this section of the interview was to determine, which LULC types are to be reclassified into a single class in the context of tourism. For each time a new LULC type was mentioned in the progress of analysing all the interviews, a new code was created for it. Each mentioned LULC type was only counted once per interview, therefore, the frequency of a LULC type could not exceed 27, as this was the total number of interviews. This method

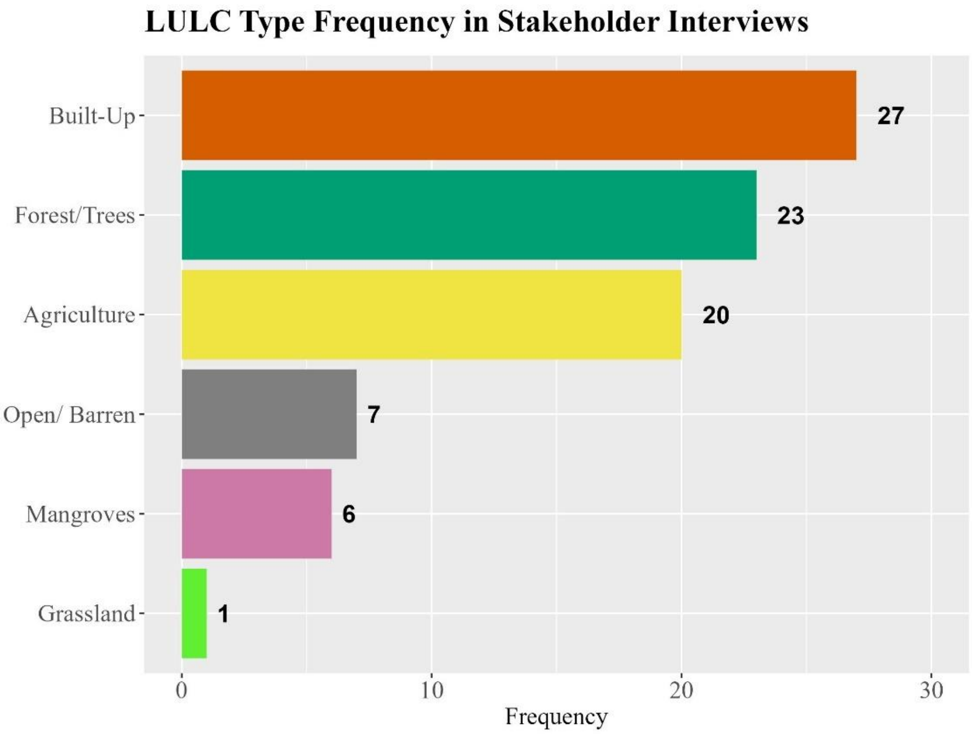


Figure 5: Occurrence frequency for the various mentioned LULC types in the stakeholder interviews

of analysing the frequency of all the created categories or sub-categories was applied for all subsequent analysis.

Figure 6 shows the frequency of the different coded LULC types throughout all interviews. The codes were similarly named after the official categories from the LULC Maps of Palawan generated by NAMRIA, as it should also facilitate the decision-making on what LULC types can be aggregated together for the purpose of this study. It can be seen that at least six different LULC types were identified throughout all 27 interviews. The most prevalent LULC types were *Built-Up, Forest/ Trees* and *Agriculture* with at least 20 stakeholders mentioning something related to them at least once throughout the interview. Less than half of the stakeholders every made any mentions concerning *Open/ Barren* and *Mangrove Forest*, with a frequency of six and seven respectively. For *Open/ Barren* it needs to be noted that all mentions were concerning mining sites, which are categorised as such by NAMRIA. The LULC type *Grassland* has only been mentioned once throughout the 27 interviews.

Resulting from the previous insights, it was determined that the following LULC types will be aggregated and reclassified (Tab. A.10). The classification of the LULC types *Mangrove Forest* (MF)*, Open/Barren* (OB), and *Built-up* (BU) remained consistent with the classification found in the LULC map from NAMRIA. In the case for agricultural land, the differentiation of *annual crop* and *perennial crop* was ultimately aggregated due to the predominate mentions of *agriculture* (AG) as a whole during the interviews. The two studies by Waiyasusri et al. (2016) and Waiyasusri (2022), treated annual and perennial crops as a collective as well.

The new LULC type classification of *Eco-Land* (EL) encompasses the previous four classes *Closed Forest, Open Forest, Brush/ Shrubs* and *Grassland*. The primary reasoning behind the aggregation stems from the work of Mao et al. (2014) and Rimba et al. (2020). Both studies explored the impact of tourism on LULC in a river basin in Guilin, China and on the island of Bali, Indonesia, respectively. In both cases, they opted to group these LULC types together. The name *Eco-Land* was taken from the study by Mao et al. (2014), where, based on previous literatures, they define *Eco-Land* as LULC types, which can provide ecological system service and enhance the environmental conditions of a region. Since Palawan is considered as “The Last Ecological Frontier”, the conservation of *Eco-Land*, inclines with the interest of the SEP.

The LULC type *Waterbodies* (WB) consists of the previously separated classifications *Marshland/ Swamp*, *Fishpond* and *Inland Water.* Even though any mentions of waterbodies have not been present during the stakeholder interviews, they are generally included in the modelling process (e.g., Boavida et al. 2016). *Marshland/ Swamp* were also included as *Waterbodies* since they are both components of the aquatic environment (e.g., Che & Wan, 2022; Naji & Abduljabbar, 2019).

5.1.4 Potential Future Development – Best-case Scenario

One of the goals for this section directly served the creation of the future scenarios, which were then used to simulate using the Dyna-CLUE model. In most cases, stakeholders did not summarize their best-case scenario as a specific form of tourism, but rather offered a general description of tourism and particular activities they considered beneficial. After reviewing the interview transcripts, the best-case scenarios resulted in having four different codes (Tab. A.11). These codes were derived from statements associated with sustainable forms of tourism discussed extensively in prior literature, namely, *Ecotourism* (UNEP, 2023)*, Agritourism* (Tew & Barbieri, 2012) and *Community-Based Tourism* (Arintoko et al., 2020). Additionally, *Urbanisation* was identified as a best-case scenario, where statements were associated as such, when they were linked to the definition provided by Bilozor & Cieslak (2021).

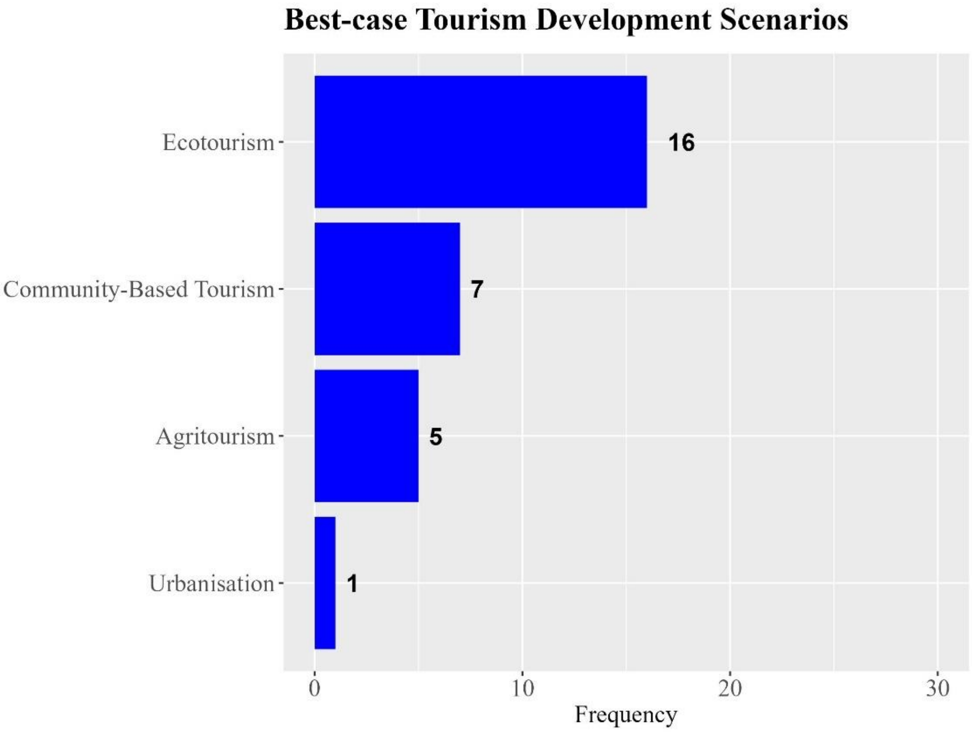


Figure 6: Occurrence frequency for best-case scenarios in the stakeholder interviews

Figure 7 illustrates the frequency of the identified best-case tourism developments throughout the interviews. Note that the total exceeds the total number of interviews, as there were two instances, where stakeholders mentioned more than one desired form of tourism.

As depicted, it is apparent that *Ecotourism* is the most preferrable form of tourism amongst sixteen stakeholder participants, which Palawan is actually already known for. The second most popular option, supported by seven stakeholders, is the *Community-Based Tourism.* Five stakeholders were also fond of the idea of tourism shifting its focus towards *Agritourism*. Their reasoning was based on the perceived conversion of agricultural land to commercialized tourism land, prompting concerns regarding food security among them. There was only one stakeholder participant who wished for tourism to help flourish a city-like development in the place they lived in.

5.1.5 Potential Future Development – Worst-case Scenario

Similarly to the best-case scenario, stakeholders most often depicted their worst-case scenario in general terms and actions they regarded unfavourable for the future development of tourism in Palawan. Upon analysing the interview transcripts, the statements were linked to three different tourism developments, known for their negative impacts on the social- and natural

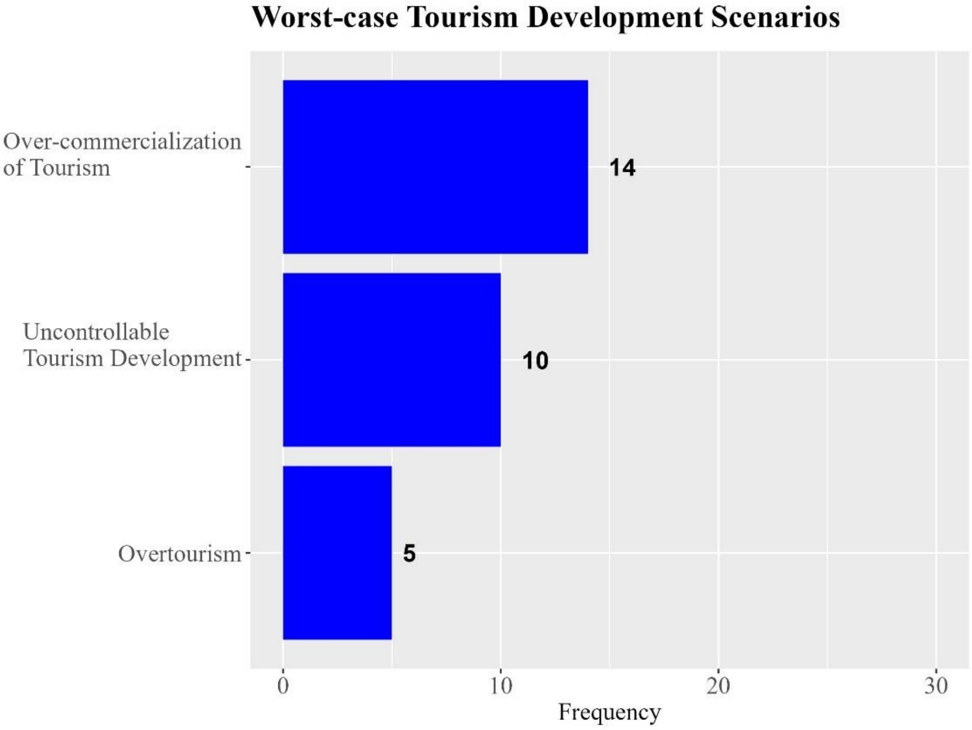


Figure 7: Occurrence frequency for the worst-case scenarios in the stakeholder interviews

environment (Tab. A.12): *Over-Commercialization of Tourism* (Sun et al., 2021), *Uncontrollable Tourism Development* (Ioncică et al., 2016) and *Overtourism* (Butler & Odds, 2022).

Using the mentioned developments as reference points, the interview statements were categorized accordingly (Fig. 8). The most occurring worst-case scenarios was *Over-commercialization of Tourism*, followed by *Uncontrollable Tourism Development* and *Overtourism* with frequencies of fourteen, ten and five, respectively.

5.1.6 Potential Future Development – Potential Measures

Following the questions concerning the stakeholders' best- and worst-case scenarios for future tourism development, they were subsequently asked about possible "Potential Measures" they could envision, which could either mitigate/ prevent the worst- or could facilitate the realization of their best-case scenario. While not all stakeholder participants were able to provide an immediate answer, 22 out of the 27 stakeholder participants shared their insight on the topic, with some of them suggesting multiple potential measures. The analysis of the transcript revealed five major potential measures (Tab. A.13), which were also discussed in previous studies in relation to tourism: *Political Interventions* (Isfahani et al., 2021)*, Preservation of*

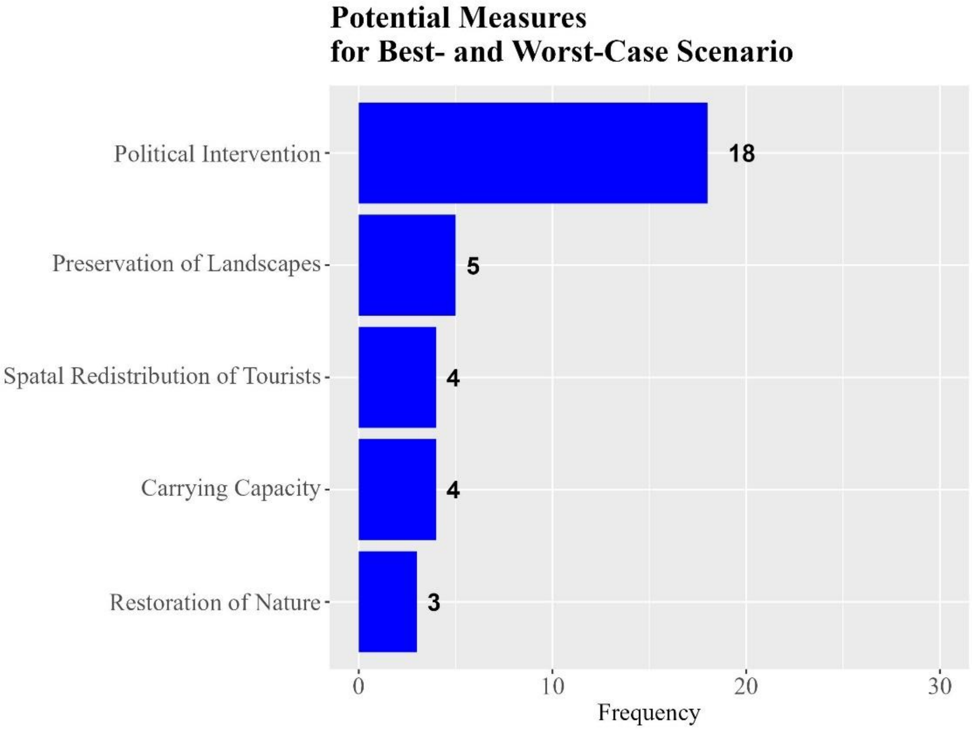


Figure 8: Occurrence frequency of potential measures for best- and worst-case scenarios

Landscapes (Grindsted et al., 2023)*, Spatial Redistribution of Tourists* (Marković & Klarić, 2015)*, Carrying Capacity* (Liabastre et al., 2022) and *Restoration of Nature* (EEA, 2023).

Looking at Figure 9, it is particularly notable that regulations implemented through *Political Interventions* received the most mentions throughout the interviews, indicating a strong support amongst the stakeholders for this approach. *Preservation of Landscapes* has showcased to be the second most favoured measure to prevent the worst- and to facilitate the best-case scenario. To avoid congestion, lessen the pressure on the environment and to disperse the economic benefits of tourism, four stakeholders suggest a *Spatial Redistribution of Tourists* by making municipalities, other than El Nido, San Vicente, Puerto Princesa City or Coron, more accommodating for tourism. Three stakeholders suggested to implement a *Carrying Capacity* across the province and *Restoration of Nature* as measure got the three mentions.

5.1.7 Future Tourism Development Scenarios

Following the suggestions made by Kok et al. (2006), three different scenarios, which include the continuation of the recent trend, a best- and worst-case scenario, were created. The storylines of the scenarios are built with these suggestions in mind and are based on the stakeholders' vision of tourism development and the feedback received from the members of EMED section members of the PCSD who were present during scenario presentation. However, not all suggestions were implemented as they are not feasible due to the lack of data (e.g., Carrying Capacity). Nonetheless, the scenarios should still directly contribute to the achievement of the research goal and address the problems and hopes the tourism industry of Palawan is facing:

5.1.7.1 Business as usual (BAU)

The effects of the current tourism development follow the trend of recent years. This leads to the continuation of the observed LULC transition trends observed between 2015 and 2020. The BAU scenario will not include any policy restrictions set by the DENR, PCSD or any other governmental institution in the Philippines, which is due to several mentions of illegal activities by investors and locals concerning LULC conversions already within the Core Zone (e.g., illegal logging) and the difficulty to effectively enforce the policies.

5.1.7.2 Eco-Agritourism with extensive Landscape Protection (EALP)

Under the EALP scenario further reduction of AG areas as part of an eco-agritourism focused development and in order to maintain food security, will be prohibited. Additionally, as a Mangrove Swamp reserve, the area coverage of MF remained static. To demonstrate a deceleration of the effects of tourism development, the rate of transition for BU in the LULC demand was set to be half of the BAU scenario. Additionally, spatial policies were considered, which encompassed no development within the CZ and RUZ, protected areas and critical habitats. Furthermore, the current easement zone of 20m set by the Department of Environment and Natural Resources (DENR, 2021) was further extended to 100m. Additionally, the elasticity value in NP for AG and EL was increased to 0.3, while MF's elasticity was increased to 0.8 for the northern part of Palawan (Yu et al., 2023). For SP, the elasticity value for AG, EL and MF were also adjusted accordingly to 0.5, 0.3 and 0.9, respectively. The values in the conversion matrix for the LULC types AG and MF were adjusted to 0 for the transitions to the LULC types BU or OB. Additionally, WB were not able to transition to BU as well. Otherwise, the conversion matrix remained the same (Tab. A.15).

5.1.7.3 Uncontrolled Commercial Tourism Development (UCTD)

This scenario should represent an urban development strongly driven by an uncontrolled commercialisation of tourism, which will be in the form of a drastic increase in the expansion of built-up areas (e.g., tourism accommodations, restaurants, malls, residential buildings etc.). Therefore, in this scenario, the transition rate for BU was established to be double of that, which was observed from 2015 to 2020. The only adjustments undertaken in the transition matrix was that any conversion of BU was restricted (Tab. A.16).

5.2 Driving Forces Analysis

5.2.1 BLR

Table 3 and Table 4 display the evaluated *β*-coefficients for each driving force, the corresponding constants and ROC value for each specific LULC type. In the case for *Distance to Built-up Areas,* the driving force was not considered in the BLR model for BU. This decision was made due to the driving force being directly derived from the LULC type, which in the result tables is denoted as "*". Therefore, the BLR model would perfectly predict the locations of BU without considering the other driving forces. The notation “n.s” (not significant) was assigned to the driving forces, which resulted not being significant in the 0.01 significant level.

5.2.1.1 Northern Palawan

The BLR analysis results for the topographic driving forces *altitude* and *slope* revealed a negative correlation across all LULC types except for EL. *Precipitation* as the only environmental driving force, exhibited a positive correlation for AG and MF, and a negative correlation for EL. Distance-related driving forces, while statistically significant, did not show any major correlation across the various LULC types except for *Distance to Coastline*, which showed a comparatively higher correlation with MF. *Population Density* was generally not analysed to be statistically significant in most cases except for EL and MF, where a negative and positive correlation was observed, respectively. *Nighttime Lights* observed negative correlations with vegetative LULC types and a positive correlation for BU. *Tourist Arrivals* exhibited to not be a statistically significant driving force except for their negative correlation with the spatial distribution of AG and MF.

ROC values across all LULC types were revealed to be higher than 0.8 with values of 0.903, 0.937, 0.971, 0.882, 0.94 and 0.896 for AG, EL, MF, OB, BU and WB, respectively.

Table 3: β-coefficients and ROC values for each driving forces from the BLR-Analysis for Northern Palawan for a significance level of 0.01

	Northern Palawan: β-coefficients					
Driver	AG	EL	MF	OB	BU	WB
Constant	-0.132	-1.135	0.815	-5.132	-2.587	-3.624
Altitude	-0.029	0.045	-0.098	-0.016	-0.036	-0.031
Slope	-0.094	0.152	-0.276	-0.049	-0.062	-0.131
Precipitation	0.101	-0.130	0.159	n.s	n.s	n.s
Distance to Coastline	0.00016	-0.00003	-0.001	-0.00042	-0.00013	0.00005
Distance to Rivers	n.s	n.s	0.00008	0.0001	0.00023	-0.001
Distance to Roads	-0.00044	0.000032	0.00009	n.s	-0.00025	0.001
Population Density	n.s	-0.017	0.029	n.s	n.s	n.s
Nighttime Lights	-0.271	-0.306	-1.004	n.s	1.085	n.s
Tourist Arrivals	-0.003	n.s	-0.011	n.s	n.s	n.s
Distance to Tourist Attractions	-0.000006	n.s	0.00001	n.s	-0.00007	-0.00006
Distance to Built-up Areas	-0.0002	0.00015	0.00021	0.00014	*	0.000095
ROC Value	0.903	0.937	0.971	0.882	0.94	0.896

5.2.1.2 Southern Palawan

For SP, the topographic driving forces displayed either exclusively negative or exclusively positive correlation with the spatial distribution of the various LULC types. However, OB exhibited a positive correlation with *Altitude* and a negative correlation with *Slope*. *Precipitation* showed a strong positive relation with AG and OB, while a negative influence was observed when correlated against EL, BU and WB. The proximity driving forces most often showed less notable correlation across all LULC types except for MF, BU and WB, where a limited influence was observed in certain cases. *Population Density* was found to be statistically significant driving force for all LULC types except WB, where a positive correlation with directly human-related LULC types were observed, whereas vegetative LULC types were observed to have a negative correlation. Similarly, *Nighttime Lights* was positively correlated with OB and BU, while the influence on AG and MF exhibited the opposite. *Tourist Arrivals* was only revealed to be positively correlated with BU, while AG, MF and OB showed a negative correlation.

The lowest ROC value was detected for WB at 0.843, whereas BU showed the highest value at 0.964. AG, EL, MF and OB exhibited values at 0.897, 0.935, 0.96 and 0.848, respectively.

Table 4: β-coefficients and ROC values for each driving forces from the BLR-Analysis for Southern Palawan for a significance level of 0.01

	Southern Palawan: *β*-coefficients					
Driver	AG	EL	MF	OB	BU	WB
Constant	-1.132	-0.756	0.492	-6.626	6.302	4.024
Altitude	-0.014	0.013	-0.102	0.001	-0.011	-0.006
Slope	-0.91	0.154	-0.119	-0.071	-0.222	-0.107
Precipitation	2.005	-1.438	n.s	1.06	-4.767	-4.760
Distance to Coastline	-0.00003	0.00017	-0.001	0.00011	n.s	n.s
Distance to Rivers	0.00006	0.00008	-0.00025	0.00018	-0.00013	-0.002
Distance to Roads	-0.00032	0.00012	0.0003	-0.00043	-0.01	0.001
Population Density	0.016	-0.316	-0.054	0.054	0.096	n.s
Nighttime Lights	-0.921	n.s	-1.032	0.382	0.186	n.s
Tourist Arrivals	-0.029	n.s	-0.155	-0.098	0.039	n.s
Distance to Tourist Attractions	-0.00013	0.00018	-0.00006	-0.0003	-0.00017	-0.00005
Distance to Built-up Areas	-0.00004	n.s	0.00009	0.00013	*	n.s
ROC Value	0.897	0.935	0.96	0.848	0.964	0.843

5.2.2 Multi-collinearity Analysis

The multi-collinearity analysis was conducted using the "collinearity diagnostics" statistics from the linear regression function in IBM SPSS. The linear model was fitted by using *altitude* as the predictor variable against the other ten driving forces for both the northern and southern part of Palawan. Based on the results (Fig. 10), the VIF values for NP range from 1.001 to 3.280. In the case of TV, values were observed from 0.305 to 0.999. Similar ranges for VIF and TF were also observed for SP.

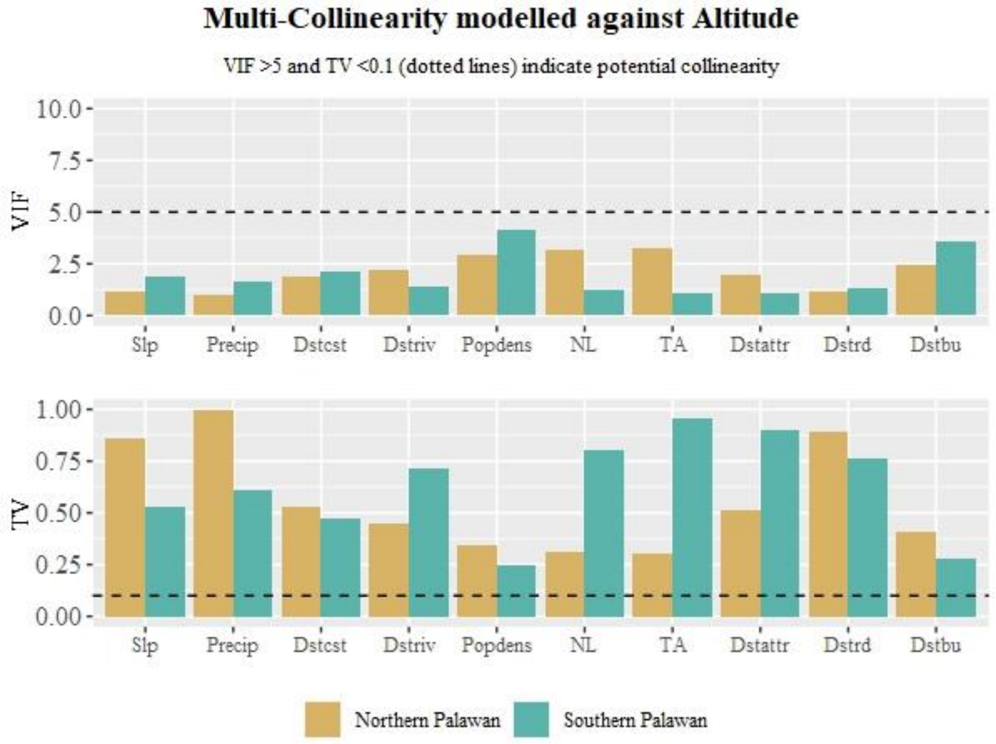


Figure 9: Results of the multi-collinearity analysis modelled against altitude

5.3 Model Validation

5.3.1 Northern Palawan

Figure A.4 displays the LULC maps for the reference years 2015 and 2020, alongside the simulated map of 2015 generated by the Dyna-CLUE model. The results of the $K_{Simulation}$, $K_{TransLoc}$ and $K_{Transition}$ validation of the model for all LULC types can be viewed at in Table 5. Overall, the $K_{simulation}$ for the northern part of Palawan is 0.214. AG and EL received the highest $K_{simulation}$ scores with 0.201 and 0.261, respectively. The LULC types MF (0.174), OB (0.047), BU (0.082) and WB (0.046), displayed values below 0.2. The analysis exhibited an overall value of 0.281 for $K_{TransLoc}$, which was observed to be lower compared to the $K_{Transition}$ value of 0.763.

Table 5: $K_{simulation}$ statistics result for the model validation of NP

Statistic NP	AG	EL	MF	OB	BU	WB	Overall $K_{simulation}$	Overall $K_{TransLoc}$	Overall $K_{Transition}$
$K_{simulation}$	0.201	0.261	0.174	0.047	0.082	0.046	0.214	0.281	0.763
$K_{TransLoc}$	0.267	0.327	0.209	0.105	0.121	0.141			
$K_{transition}$	0.753	0.798	0.829	0.444	0.681	0.325			

Table 6 shows the absolute and relative area covered of each LULC type in the beforementioned maps. Additionally, it shows the discrepancy of the absolute and relative area distribution between the observed and simulated LULC map of 2020. The simulated map showed absolute differences between -79 ha and 32 ha. Across all LULC types, the relative difference was hardly detectable and therefore represented as 0% in the table.

Table 6: Comparison of absolute and proportional distribution of LULC types between observed and simulated LULC maps from 2020 in NP

NP	Obs. 2020		Simulated 2020		Obs. – Sim	
LULC	Area		Area		Area	
	ha	%	ha	%	ha	%
AG	65939	8.10	65947	8.10	8	0
EL	695124	85.40	695135	85.40	11	0
MF	34651	4.26	34666	4.26	15	0
OB	1190	0.15	1111	0.14	-79	0
BU	13008	1.60	13021	1.60	13	0
WB	4042	0.50	4074	0.50	32	0

5.3.2 Southern Palawan

Also included in Figure A4. are the maps for both the base map and reference year, as well as the simulation result for 2020. The $K_{Simulation}$ statistics result from the SP model evaluation is displayed in Table 7. Overall, the $K_{simulation}$ for SP is slightly lower than NP with a value of 0.130. Similarly to NP, the LULC types AG (0.122), EL (0.164) demonstrated the highest values, whereas MF (0.053), OB (0.031), BU (0.035) and WB (0.011), displayed values below 0.1.

Consistent to NP, the overall $K_{Transition}$ value surpassed the overall $K_{TransLoc}$ value, with values of 0.667 and 0.195, respectively.

Table 7: $K_{simulation}$ statistics result for the model validation of NP

Statistic SP	AG	EL	MF	OB	BU	WB	Overall $K_{simulation}$	Overall $K_{TransLoc}$	Overall $K_{Transition}$
$K_{simulation}$	0.122	0.164	0.053	0.031	0.035	0.011	0.130	0.195	0.667
$K_{TransLoc}$	0.172	0.239	0.066	0.083	0.097	0.087			
$K_{transition}$	0.708	0.684	0.805	0.379	0.366	0.128			

The absolute discrepancies for the simulation results compared to the observed data in SP ranged from -36 ha to 64 ha, with the highest relative discrepancy being -0.01%, which were observed for OB, BU and WB. For AG, EL and MF the relative difference was very exceedingly minimal, thus, denoted as 0% (Tab. 8).

Table 8: Comparison of absolute and proportional distribution of LULC types between observed and simulated LULC maps from 2020 in SP

SP	Obs. 2020		Simulated 2020		Obs. – Sim	
LULC	Area		Area		Area	
	ha	%	ha	%	ha	%
AG	172992	28.38	172599	28.38	-9	0
EL	396306	65.01	396200	65.01	-14	0
MF	23795	3.90	22930	3.90	6	0
OB	2289	0.38	2358	0.37	-11	-0.01
BU	8703	1.43	8776	1.42	-36	-0.01
WB	5519	0.91	5683	0.92	64	-0.01

5.4 Modelled LULC Scenario Maps

The following chapters will illustrate the results generated from the Dyna-CLUE model. The simulations for the BAU scenario were based on the trend between the period of 2015 and 2020, which was then further extrapolated to the year 2050. The EALP scenario encompassed reducing the expansion of BU by half and the consideration of the ECAN zones, protected areas, critical habitats, the conservation of AG as part of an eco-agritourism focused development and in order to maintain food security. Additionally, as a Mangrove Swamp reserve, reduction of MF area was restricted and a coast easement zone of 100m was implemented. The UCTD scenario involved doubling the expansion rate of BU from the BAU scenario, which should show the desire to commercialise tourism without any consideration for the conversation of the natural resources. This growth was set to occur without enforcing any spatial policies and with little regard for the conservation of natural local resources. In the scenario modelling process, the actual LULC map of 2020 from NAMRIA was employed to simulate the changes in the spatial distribution of LULC for the different scenarios up to the year 2050 in Palawan.

The scenario results encompass maps illustrating the modelled spatial distribution under the three different scenarios (Fig. 11). Further insights to each scenario are given, including the variations in absolute and relative distribution among the scenarios compared to the base year 2020 (Tab. 9 and Tab. 10) and the transitions between the LULC types (Fig. 12 and Fig. 14), determined through cross tabulating the raster maps with the base year map of 2020. Additionally, the results also provide the proportional distribution of each LULC for all

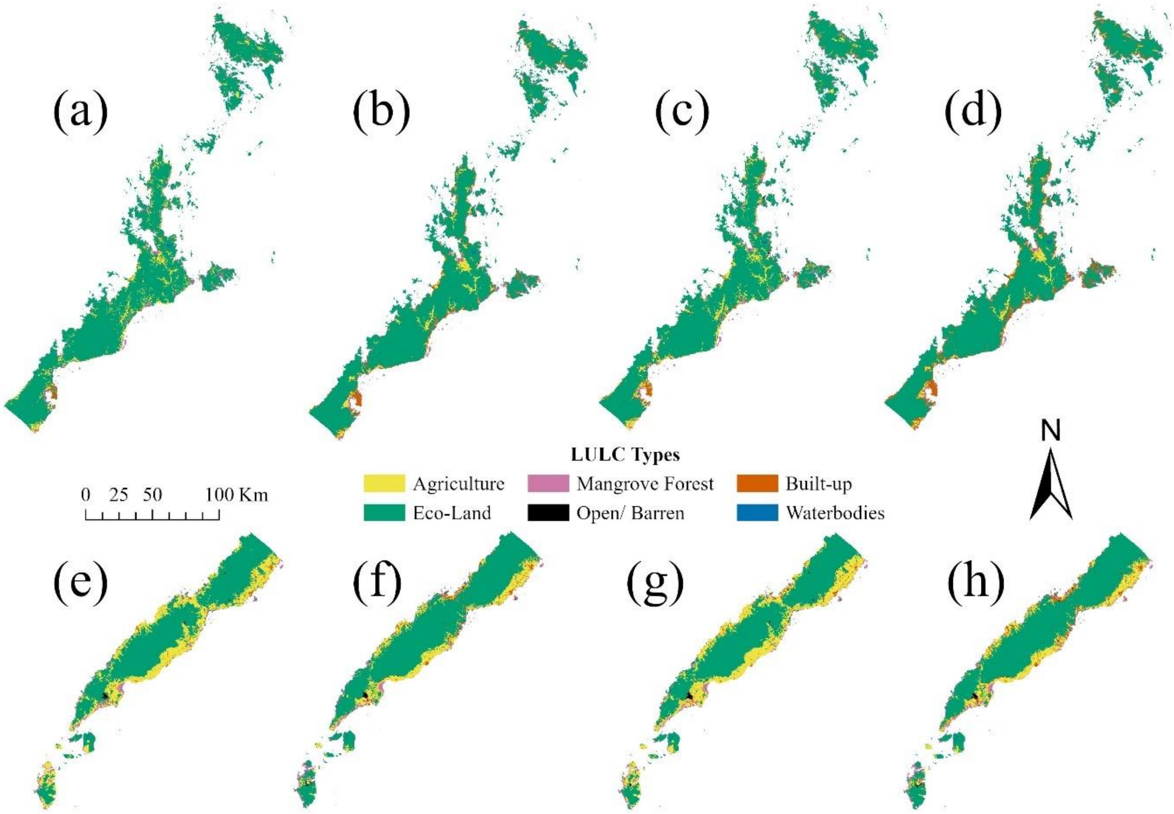


Figure 10: Visualization of scenario results for NP and SP: a) NP LULC Map 2020, b) NP BAU 2050, c) NP EALP 2050, d) NP UCTD 2050, e) SP LULC Map 2020, f) SP BAU 2050, g) SP EALP 2050 and h) SP UCTD 2050

scenarios (Fig. 13 and Fig. 15). Additionally, given that tourism in Palawan is considered as one of the main post-frontier realities regarding the degradation of the environment and urban development, and the ECAN zones serving as the main instrument to regulate urban expansion, a spatial analysis for both parts of Palawan was also conducted regarding the expansion of newly allocated BU areas within the different ECAN Zones (Tab. 11 & Tab. 12)

5.4.1 Scenario Results Northern Palawan

5.4.1.1 NP BAU

Comparing the modelled LULC map of the BAU scenario to the base map of 2020 revealed that AG will experience the highest loss in area with 25863 ha, which corresponds to an area decrease of -39.22%. The LULC type EL and MF will also be furtherly reduced by 2938 ha (-0.42%) and 1461 ha (-4.22%), respectively. In terms of land area gains, BU will have the largest gains with 29558 ha (227.23%), followed by OB with 574 ha (48.24%) and WB with 130 ha (3.2%)

Table 9: Absolute and relative change in area across the three different scenarios for NP in comparison to the LULC map of 2020

NP	BAU 2050		EALP 2050		UCTD 2050	
LULC	Area	Change [ha (%)]	Area	Change [ha (%)]	Area	Change [ha (%)]
AG	40076	-25863 (-39.22)	65947	13 (0.01)	38557	-27382 (-41.53)
EL	692186	-2938 (-0.42)	679737	-15382 (-2.21)	665516	-29608 (-4.26)
MF	33190	-1461 (-4.22)	34699	31 (0.14)	31931	-2720 (-7.85)
OB	1764	574 (48.24)	1731	543 (45.46)	1812	622 (52.27)
BU	42566	29558 (227.23)	27771	14768 (113.5)	71940	58932 (453)
WB	4172	130 (3.2)	4069	27 (0.67)	4198	156 (3.86)

The total gain of BU areas is mainly attributed at the expense of 14923 ha of AG and 12937 ha of EL. Additionally, MF contributed 1684 ha and WB 14 ha to the expansion of BU. Despite EL experiencing a net loss to BU and MF, its gains primarily derived from AG. Conversely, AG mainly experience losses with only a marginal gain from MF. Minor gains from OB resulted primarily from transitions of EL, and AG, while WB slightly expanded from AG, EL and MF.

Looking at the proportions of the various LULC type, there are notable changes for AG and BU. In 2020, AG covered 8.10% of NP, which in this scenario, declined to 4.92% for the year 2050, whereas BU saw an increase from 1.60% in 2020, up to 5.23% in 2050. Similarly to AG, EL and MF have seen a proportional decrease from 85.40% to 85.04% and from 4.26% to 4.08%, respectively. A slight increase in the proportion was also observed for both OB and WB. In 2020, OB has covered 4.15% of NP, exhibiting small increase to 4.26%. WB experienced a minimal increase of 0.1%, progressing from 0.50% to 0.51.

5.4.1.2 NP EALP

The modelled map of the EALP scenario for NP showed an increase of BU area by 14768 ha, resulting in an expansion of 113.5%. This scenario also observed a slight increase in area for AG by 13 ha (0.01%), MF by 31 ha (0.14%), OB by 543 ha (45.46%) and WB by 27 ha (0.67%). The expansion of the various LULC types resulted in a decrease of EL by 15382 ha (-2.21%).

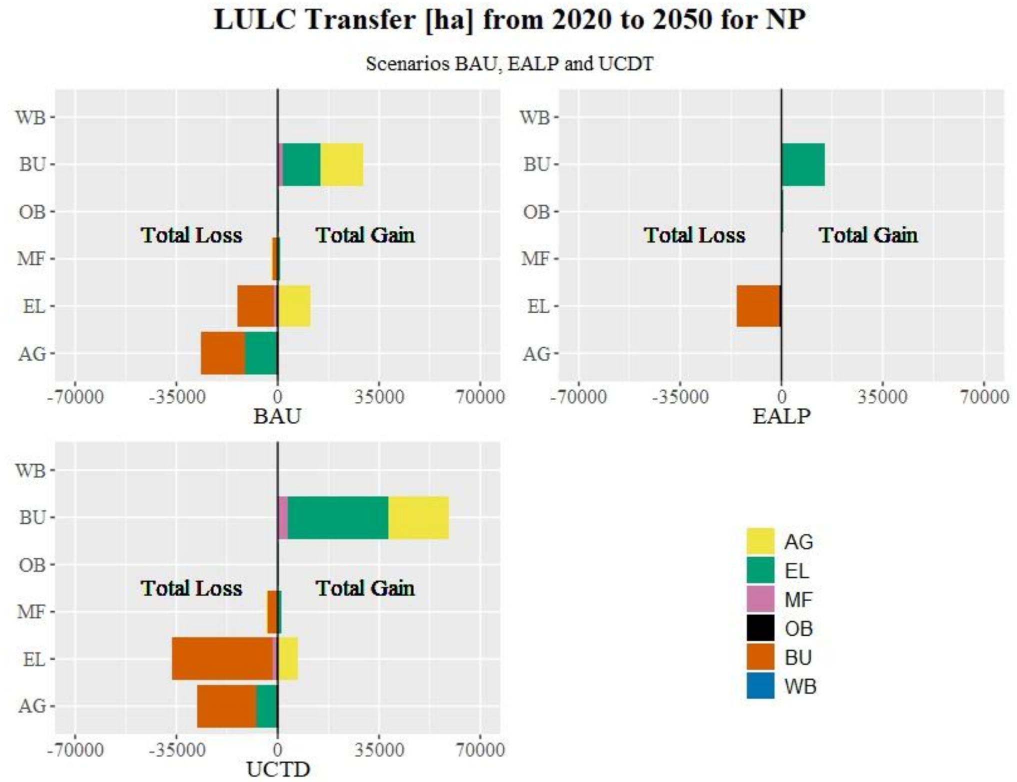


Figure 11: Stacked bar plot representing the various LULC transfers within the three different scenarios for NP

The majority of the decrease associated to EL, were mainly allocated to BU (14768 ha) and OB (543 ha). The slight gains from the other LULC were due to trade-offs in between them with gains at the expense of EL.

In terms of the proportional distribution, the LULC types AG, MF and WB remained constant to the year 2020 with 8.10%, 4.25% and 0.50%, respectively. The proportion of BU saw the highest gain, rising from 1.60% in 2020 to 3.41% by the year 2050. There was also a slight increase observed in the proportion for OB, increasing from 0.15% to 0.21%.

5.4.1.3 NP UCTD

The UCTD scenario observed major area losses for the LULC types EL, AG and MF. EL showed the most substantial area decrease with 29608 ha (-4.26%). AG experienced a similar loss with 27382 ha and MF with 2720 ha, or a decrease of -41.53% and -7.85%, respectively. As the scenario was set to have double the expansion rate of BU from 2015 to 2020, it is clearly visible that there has been a substantial increase in BU compared to 2020. The scenario resulted in having 71940 ha covered by BU, which is an increase of 58932 ha, or an area expansion of 453%, in contrast to 2020. OB and WB were observed to have smaller increases of 622 ha (52.27%) and 156 ha (3.86%), respectively.

The significant expansion of BU areas is primarily at the cost of 34944 ha of EL, followed by 20583 ha of AG, 3379 ha of MF and minor reduction of WB with 26 ha. Loss in area of EL is mainly due to the beforementioned expansion of BU. Additionally, comparatively small, the decrease of EL could be attributed to the expansion of OB. Although MF experiencing a net loss, it has gained some of its area due to the transition of EL to MF. AG experiencing the second highest reduction in area size, aside from the loss of due to the expansion of BU, additionally lost area due to its transition to EL. MF being the third LULC type to experience a decrease in area size, has mainly lost it due to conversions to BU and to a smaller extent, conversions to AG. WB has seen a marginal increase in area at the expense of all LULC types except BU.

Notable decrease in their proportion were observed for AG and EL. Especially EL compared to the other scenarios experienced a significant loss in its proportion from 85.40% in 2020 down to 81.76%. AG experienced a decrease from 8.10% to 4.74%, while MF has seen a decrease in its proportion from 4.26% to 3.92%. This led to a considerable increase in the proportion of BU. By the year 2050, the modelled map showed an 8.84% coverage of BU in NP. The proportion of OB resulted increased to 0.22% and WB has seen a marginal proportional growth, reaching 0.52%. NP. The proportion of OB resulted increased to 0.22% and WB has

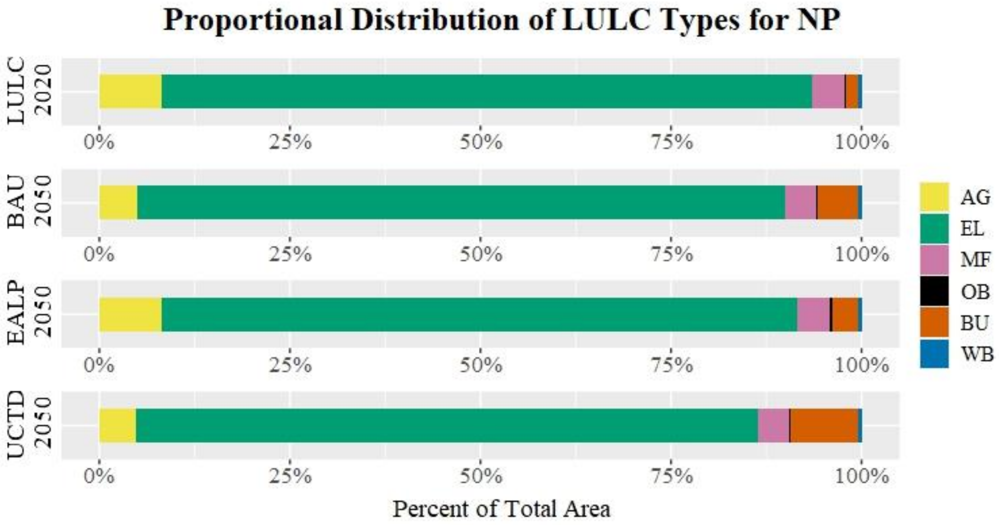


Figure 12: Stacked bar plot representing the proportional distribution of the various LULC types across the three base year 2020 and the three different scenarios for NP

5.4.2 Scenario Results Southern Palawan

5.4.2.1 SP BAU

Table 10: Absolute and relative change in area across the three different scenarios for SP in comparison to the LULC map of 2020

SP	BAU2050		EALP2050		UCTD2050	
LULC	Area	Change [ha (%)]	Area	Change [ha (%)]	Area	Change [ha (%)]
AG	104704	-68288 (-39.48)	172996	4 (0)	103130	-69862 (-40.39)
EL	451002	54696 (13.80)	390901	-5405 (-1.36)	444212	47906 (12.08)
MF	28452	4657 (19.57)	23809	14 (0.06)	28017	4222 (17.74)
OB	3791	1502 (65.62)	3250	961 (41.98)	3793	1504 (65.7)
BU	17477	8774 (100.82)	13102	4399 (50.55)	26271	17568 (201.86)
WB	4178	-1341 (-24.3)	5546	27 (0.49)	4181	-1338 (-24.24)

The modelled map for the BAU scenario in SP showed a significant decrease in AG and a notable increase in EL compared to 2020. More specifically, AG saw a loss of -68288 ha, or approximately a decrease if -39.48%, whereas EL saw a gain of 54696 ha, or an expansion of 13.80%. The scenario also showed an area gain for MF, OB and BU by 4657 ha (19.57%), 1502 ha (65.62%) and 8774 ha (100.82%), respectively. Aside from EL, WB also showed a reduction in area size by 1341 ha, or a decrease of -24.3% in relative terms.

The LULC transfer plot shows that AG was the primary source for the expansion of the LULC types EL, MF, OB and BU. EL in particular was the main beneficiary from AG areas. In addition to AG, EL area also experienced growth at the expense of WB. While BU got most of its new area allocated from AG, EL also played a significant role in its expansion. In contrast, the sacrifice of MF and WB were only very minimal. In the case of MF, the expansion was not only attributed to AG but also the result from conversions of EL, OB and WB. For OB, its gains primarily originated from AG, as mentioned previously, but also through EL.

With the substantial area decrease, AG has also seen a drastic decline in its proportionate distribution. In 2020, AG accounted for 28.38% of the total area in SP. However, based on this scenario showed that by 2050, AG might only comprise for 17.18% of the overall area. On the other hand, EL has a rise in its proportionate distribution from 65.01% in 2020 to 73.98% in 2050. MF increased its proportionate distribution from 3.90% to 4.67%, OB from 0.38% to 0.62% and BU from 1.43% to 2.87%. WB saw a slight proportional decrease, dropping from 0.91% to 0.69%.

5.4.2.2 SP EALP

For the EALP scenario, the modelled map only showed notable increases in of 4399 ha for BU and 961 ha for OB or area expansions of 50.55% and 41.98%, respectively. Expansions of the LULC types AG, MF and WB were very minor with 4 ha (0%), 14 ha (0.06%) and 27 ha (0.49%), respectively. EL was the only LULC type that observed a decrease in area, resulting in a loss of 5405 ha or approximately -1.36%.

The major area loss of EL primarily occurred from transitions to BU and OB, with additional minor conversions to AG and MF also being noted. Aside from that, the minor changes in LULC for this scenario occurred through gains and losses among the other LULC types.

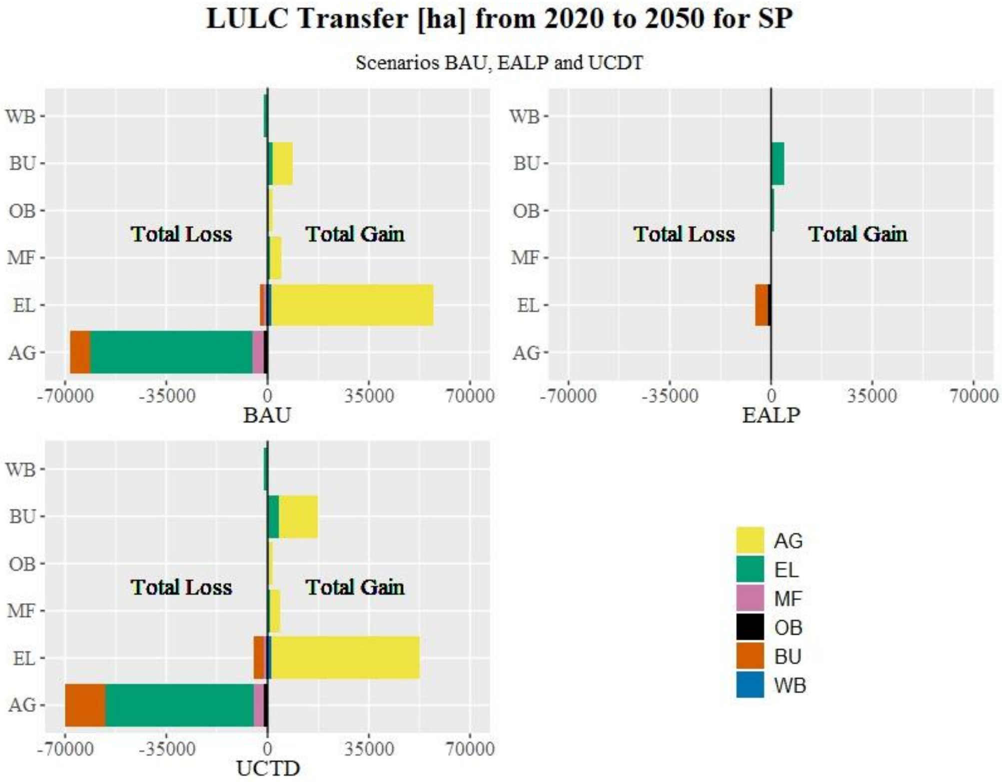


Figure 13: Stacked bar plot representing the various LULC transfers within the three different scenarios for NP

The minor changes in AG, MF and WB are also reflected in their proportional distribution. The proportional distribution for AG and WB remained the static, whereas MF saw a slight increase of 0.01% in its proportion compared to 2020, bringing its proportion to 3.91%. Due to the expansion of BU and OB, their proportion increased from 1.43% to 2.15% and 0.38% t 0.53%, respectively. As EL was the sole LULC type to experience area loss, its proportion was also the only one with a decrease. Specifically, it resulted in a decrease from 65.01% down to 64.12%.

5.4.2.3 SP UCTD

Comparing the modelled map of the UCTD scenario to the base map in 2020 it shows that there was a significant increase in area, especially for EL and BU. EL experienced the highest absolute expansion with 47906 ha, followed by BU with 17568 ha or relative expansion of 12.08% and 201.86%, respectively. MF was also observed to expand in area by 4222 ha (17.74%) and OB by 1504 ha (65.7%). In order for the other LULC types to expand, the LULC types AG and WB exhibited a reduction in area. Most of the area loss however, occurred at the expense of AG, adding up to 69862 ha, or a reduction in area by -40.39%. For WB, 1338 ha, approximately -24.24%, was converted to other LULC types.

The increased BU expansion under the UCTD scenario was revealed to be primarily attributed to transitions from AG and EL. EL's continued growth resulted mainly from the loss of AG and WB to a lesser extent. The LULC types MF and OB showed relatively minor increases, which, like BU and EL, came at the expense of AG area.

The major changes in AG, EL and BU are also visible in the change in the proportional distribution. In 2020, as mentioned before, AG covered 28.38% of the total area in SP, whereas in this scenario, by the year 2050, its proportion got reduced to 16.92%. On the other hand, the proportion of EL got increased from 65.01% to 72.87% and BU from 1.43% to 4.31%. MF and OB, which also experienced a gain in its area, saw a proportionate increase from 3.90% to 4.60% and 0.38% to 0.62, respectively.

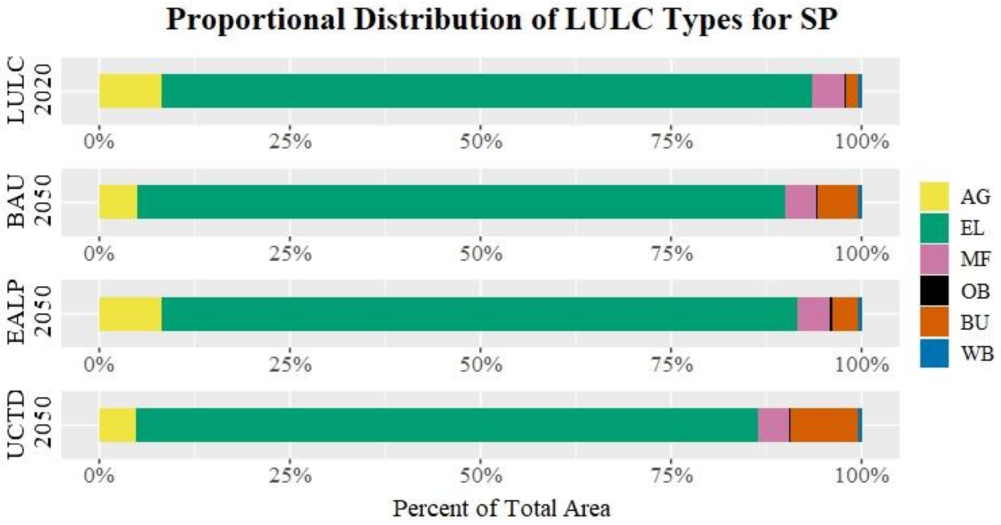


Figure 14: Stacked bar plot representing the proportional distribution of the various LULC types across the three base year 2020 and the three different scenarios for NP

5.4.3 BU Expansion within ECAN Zones

5.4.3.1 Zonal Statistics NP

The majority of BU areas in 2020 were allocated to MUZ, followed by TUZ, CUZ and RUZ (Tab. 11). Despite CZ being designated as an area of maximum protection, the LULC map of 2020 revealed the presence of BU areas. In the BAU scenario, MUZ observed the highest absolute increase of BU areas with 20682 ha (or 197.18%). The zonal statistics also revealed substantial BU area increase of 4032 ha, or an expansion of 838.3%, within the CZ by the year 2050. These was followed by a BU growth of 2005 ha (329.2%) in the TUZ, 1492 ha (275.3%) in the CUZ and a relatively minor growth of 342 ha (46.78%) in the MUZ.

As the EALP scenario considered spatial policies, including the ECAN Zones, no changes in the CZ and RUZ were detected. The MUZ saw the highest BU area growth with 10912 ha, or an expansion of 104.3%. CUZ and TUZ were observed to have an increase of 1471 ha and 1185 ha, which results in an area expansion of 271.4% and 194.6%, respectively.

Table 11: Results of the zonal statistics showing the amount of new allocation of BU areas within the ECAN zones for NP

BU NP Scenarios	LULC2020	BAU2050		EALP2050		UCTD2050	
ECAN Zone	Area	Area		Area		Area	
	ha	ha	Change [ha (%)]	ha	Change [ha (%)]	ha	Change [ha (%)]
CZ	481	4513	4032 (838.3)	481	0 (0)	7983	7502 (1559.7)
RUZ	233	342	109 (46.78)	233	0 (0)	579	346 (148.5)
CUZ	542	2034	1492 (275.3)	2013	1471 (271.4)	4963	4421 (815.7)
TUZ	609	2614	2005 (329.2)	1794	1185 (194.6)	5927	5318 (873.2)
MUZ	10489	31171	20682 (197.18)	21401	10912 (104.3)	49768	39279 (374.5)

For the UCTD, the zonal statistics revealed that an additional 39279 ha of BU area were newly allocated in the MUZ by the year 2050. In relative terms, this results to an area expansion of 374.5%. This was followed by an area growth of 7502 ha (1559.7%) in the CZ, 5318 ha (873.2%) in the TUZ and 4421 ha (815.7%) in the CUZ. The RUZ exhibited relatively minor gains with an increase of 346 ha, or an expansion of 148.5%.

5.4.3.2 Zonal Statistics SP

Constant to NP, the majority of BU areas in SP were allocated in the MUZ, followed by TUZ, CUZ, RUZ and with the identification of BU areas also in the CZ in the LULC map of 2020 (Tab. 12). Under the BAU scenario, the zonal statistics for the year 2050 revealed a major BU area growth in the MUZ. More specifically, 7772 ha of newly allocated BU areas, or a relative growth of 98.86%, was detected in that zone. In contrast, the remaining ECAN zones comparatively had minor absolute expansions, with all being below 200 ha. The CUZ was observed to have the highest growth with 185 ha (74.3%), followed by CZ with 155 ha (238.46%), TUZ with 131 ha (143.8%) and RUZ with 58 ha (252.17%).

The zonal statistics for the EALP scenario revealed no changes in the CZ and RUZ, as the scenario took spatial policies into consideration. Comparatively to the CUZ and TUZ, the MUZ saw the most notable expansion in BU with a growth of 3368 ha, or an expansion of 42.84%. The BU area growth for TUZ was observed to be 462 ha (154.5%) and 164 ha (65.86%) for CUZ.

The UCTD scenario again revealed a major increase in BU in the MUZ, showing an area growth of 14953 ha or an expansion of 190.2%. For the TUZ, the scenario result showed growth in BU of 1491 ha, approximately a relative increase of 398.7%. The ECAN zones CUZ, RUZ and CZ all showed increases below 1000 ha. Specifically, revealing 437 ha (189.9%), 150 ha (552.2%) and 503 ha (773.8%) in newly allocated BU areas, respectively.

Table 12: Results of the zonal statistics showing the amount of new allocation of BU areas within the ECAN zones for SP

BU SP Scenarios	LULC2020	BAU2050		EALP2050		UCTD2050	
ECAN Zone	Area	Area		Area		Area	
	ha	ha	Change [ha (%)]	ha	Change [ha (%)]	ha	Change [ha (%)]
CZ	65	220	155 (238.46)	65	0 (0)	568	503 (773.8)
RUZ	23	81	58 (252.17)	23	0 (0)	150	127 (552.2)
CUZ	249	434	185 (74.3)	413	164 (65.86)	473	4421 (189.9)
TUZ	299	430	131 (143.8)	761	462 (154.5)	1491	1192 (398.7)
MUZ	7862	15634	7772 (98.86)	11230	3368 (42.84)	22815	14953 (190.2)

6 Discussion

The province of Palawan has been able to maintain a relatively intact ecosystem, which flourishes a wide diversity of endemic species of flora and fauna and is thus still able to maintain its status as “The Last Ecological Frontier”. However, with the steadily rise in popularity as a tourist destination and its continuing growth in population, the island province has begun to experience degradations in its environment. This was particularly evident in the northern part of Palawan, where there have been area declines in EL and MF between 2015 and 2020, with the highest area loss observed for AG. These losses can be attributed to the rapid urban expansion, as reflected in the relatively high expansion rate of BU. On the other hand, the southern part saw an increase in EL and MF, alongside OB and BU. These gains greatly diminished the area of AG in the south. By utilizing the Dyna-CLUE model this paper attempted to model the future LULC changes in Palawan, based on relevant driving forces from existing studies and various tourism development scenarios derived from semi-structured interviews conducted with local stakeholders in three different municipalities.

6.1 Evaluation of Driving Forces and BLR Model

To assess the natural- and socioeconomic spatial dynamic of both parts of Palawan, a BLR model was utilized to analyse how the driving forces influence the spatial distribution of various LULC types. The analysis showed that the influence of each driving force varied on individual LULC types, however, across both regions, the overall influence was similar, suggesting that the spatial distribution is driven by similar factors. Overall, *altitude* and *slope* were observed to have the most prominent influence across all LULC types. The usual pattern observed a negative correlation except for EL, indicating that EL are more likely to be found and expand in higher elevation and steeper terrain. For the other LULC type the opposite was revealed. This could be attributed to the mountainous or hilly terrain of Palawan, which is less suitable for activities like agriculture or human settlements (Chasia et al., 2013). A similar pattern was observed in the coastal tourist city in Koh Chang, Thailand, where Waiyasusri & Chotpantarat (2022) studied and modelled the future spatial evolution of the coastal tourist city. Consistent with the findings of the previous study, *Population Density*, observed that more densely populated areas are more likely to be converted into urban areas. However, AG showed a positive correlation for SP, indicating that they tend to be located near residential areas. While distance-related driving forces are often included in LULC modelling studies, the BLR-analysis revealed only very minimal influence of these driving forces on the spatial distribution on the LULC types. This was consistent with the results Puangkaew & Ongsomwang (2020), where, though often significant, the coefficient value were very small for the respective LULC type in Phuket Island, Thailand. This could party be explained due to the overall low ground transport quality found across the Philippines (Yi, 2012). The effect of *precipitation* on the LULC types are constant with the observations made in the Thadee watershed in Southern Thailand, where Trisurat et al. (2016) explored future scenarios of LULC change in terms of forested watershed services. The influence of *Nighttime Lights* corresponded with the study of Islam et al. (2021), where they investigated the regional land cover dynamics in southeast Bangladesh, which highlighted it to be a key feature on the spatial distribution of LULC in the study area. Both BU and OB were positively correlated with *Nighttime Lights* as it is a proxy for economic activities or levels of urbanisation. Conversely, the negative correlation observed for the other LULC type can be explained by the opposite relationship (Lao et al. 2020). The effect of *Tourist Arrivals*, particularly on BU areas, aligns with the relationship mentioned in the study by Shi et al. (2023), where BU expansion is associated where there is an increase in tourist arrivals.

To evaluate how well the BLR model can estimate the spatial distribution of the LULC, the ROC method was applied. Overall, the values were above 0.8, indicating that the selected driving forces had the explanatory power to predict the spatial distribution of the LULC (Waiyasusri & Chotpantarat, 2022).

6.2 Performance Assessment of Dyna-CLUE

The Dyna-CLUE model was calibrated by adjusting the elasticity values of the LULC types throughout multiple simulation runs. The simulation results were then statistically evaluated using the $K_{Simulation}$ method within the Map Comparison Kit, version 3.2.3, by Visser & de Nijs (2006). The observed map of 2015 was used as the base- and 2020 as the reference map, which the model evaluation results of 2020 was compared to. The overall $K_{Simulation}$ for NP was 0.214 and 0.130 for SP. Therefore, the model was able to replicate the transitions better for NP than in SP. However, as both values exceeded the threshold value of 0, the model was considered to be fit for modelling purposes for both parts in Palawan. In both cases, $K_{Transition}$ for all LULC types was observed to show a higher value than $K_{TransLoc}$, indicating that the model was generally more accurate in capturing the LULC transitions in their quantity rather than in their location. Moreover, the generally higher $K_{Transition}$ values also imply that the model modelled the right transitions based on the different LULC demands (Ke et al., 2018).

6.3 Scenario Comparison Analysis

6.3.1 Scenarios Northern Palawan

The overall results in the BAU scenario showed a significant growth for BU land, accompanied by minor increases in OB and WB. However, these expansions were at the cost of land areas from AG, EL and MF. The model results for the BAU scenario in NP exhibited that in terms of area loss, AG was most affected by the tourism driven expansion of BU areas. This mirrors the trend in the results of Widaningrum et al. (2020), where they employed a modelling approach using the FLUS model in a tourism development area on Java Island, Indonesia, showing that the highest relative decline in favour for BU areas (including tourism areas) was at the cost of agricultural land. Waiyasusri and Chotpantarat (2022) also observed a similar pattern in their simulation results from the Dyna-CLUE model, in which forest and mangrove forest were diminished due to the expansion of BU and recreational areas for tourism.

Under the EALP scenario, BU expansion primarily occurred through the conversion of EL. The growth rate of BU was approximately half of the BAU scenario, which was expected as the expansion rate was assumed to be half for this scenario. This scenario also observed a greater decrease in EL compared to the BAU scenario, which can be attributed to the prioritization of protecting AG and MF areas. The simulation results are comparable to the study of Sakayarote & Shrestha (2019) on scenarios with varying degrees of food crop protection in northeast Thailand using the Dyna-CLUE model. Their results showed that a policy implementation with a higher degree of protection for potential paddy cultivation land, the higher the lost of forest land was. This scenario can help to illustrate the trade-offs involved regarding EL conservation versus an eco-agritourism focused tourism development, which requires the retention of AG. It furthermore highlights the need to find a balance between conservation efforts and ensuring food security, while also meeting the demand for the urban development, which comes along with tourism growth.

While the reduction of AG was also substantial in the UCTD scenario, in terms of absolute area, it was similarly high when compared to the BAU scenario. In contrast to the previous two scenarios, EL exhibited the highest area loss, which exceeded the reduction observed in the previous two scenarios by a significant margin. This aligns with the findings of the beforementioned study of Mao et al. (2014), where they observed that tourism development led to the loss of EL in favour of construction land in future years. However, their study suggests a shift in LULC pressure from EL to AG, whereas in the case for NP, the initial pressure shifted from AG to EL. Absolute land area loss of MF was almost doubled, while both OB and WB experienced a similar increase in area, slightly exceeding it compared to the BAU scenario. However, when contrasted to BU, the expansion of OB and WB was only marginal. Overall, this scenario highlights the necessity for implementing policies or conservation boundaries, such as the ECAN zones, to preserve the environmental integrity, which is one of the main aspects that characterizes Palawan popular as a tourist destination.

6.3.2 Scenarios Southern Palawan

Notable changes in the BAU scenario for SP were especially observed for AG and EL. Similarly to NP, the overall growth of the other LULC types were at the expense of AG. While BU expansion was dominant in NP, EL expansion was most notable in SP. Conversely, area growth for other LULC types were comparatively modest, including BU expansion, indicating the lesser emphasis on tourism development compared to the northern part. The drastic decrease in AG area for EL area growth could be partly explained by the local practice of “Kaingin”, where plots are cleared for agricultural practice for a limited time before being abandoned, where land would then eventually return to its natural state (Acero, 2020). While some communities still utilize this traditional practice, many have adopted other practices such as agroforestry in an attempt to reduce forest degradation (Dressler et al., 2018). At this time, distinguishing agroforestry systems from forest areas based on satellite images still poses a major challenge, which may explain the drastic increase in EL (Sharma et al., 2023). Moreover, Novellino (2015) studied the change in perception of “Kaingin” from the perspective of the Batak tribe, one of the three major tribes in Palawan. The study revealed a preference towards taking an academic pursuit and/ or off-farm employment opportunities among the younger generations in urban Palawan, notably Puerto Princesa City. This tendency stemmed from their perception that continuing agricultural practices, such as “Kaingin”, symbolized a lack of advancement. Especially employment in the tourism sector has been promoted by local government in Palawan as a way for economic growth where livelihoods are mainly generated from agriculture or fishing (Fabinyi, 2010). The transition away from agriculture towards more off-farm employment, particularly with tourism being one of the biggest economic sectors in

Palawan, alongside agricultural intensification, may have resulted in abandoned farmlands, a phenomenon observed in developing countries like the Philippines (Dressler & Pulhin 2010; Rajpar et al., 2019). Over time, these abandoned farmlands may have reverted back to grasslands or forests, which was the pattern exhibited in previous LULC change modelling studies in other regions across the globe (Verburg et al., 2009; Chen et al., 2021). The overall trend observed in SP could also be compared to the study conducted by Rimba et al. (2020), where they investigated LULC change in future years driven by tourism growth in Bali, Indonesia. Their results indicated that local farmers are likely to abandon their farmland in pursuit for employment in the tourism sector, further contributing to the growth of abandoned farmland and other land conversions.

Under the EALP scenario, future LULC changes were characterized by the expansions of BU and OB areas, which were more minor compared to the BAU scenario, at the expense of EL, similarly to NP. In this scenario EL was the sole LULC type which showed a decrease in area. The simulation results are again aligned with the findings of the beforementioned the study of Sakayarote & Shrestha (2019), as was compared prior to the EALP scenario for NP.

The worst-case scenario showed similar characteristics as the BAU scenario with a stronger decline of AG areas and higher expansions of EL and BU, with the possible explanations mentioned in the BAU scenario. This trend furthermore underscores the necessity to retain agricultural areas, which can provide livelihood in an eco-agritourism development but also provide food security.

6.3.3 BU allocation within ECAN Zones

For both parts of Palawan, all three scenarios showed an expansion of tourism driven BU areas mainly within the CUZ, TZ and MUZ, where development is allowed to varying degrees. This pattern also indicates that the BU expansion occurred in lower altitudes, meaning closer or along the coastline, which would align with the findings of the previously mentioned study of Waiyasusri and Chotpantarat (2022) and Boavida Portugal et al. (2016), who modelled the future LULC change in Alentejo, Portugal, which is known for its beaches, similar to Palawan. Additionally, the BLR analysis also indicated a location preference for BU in lower elevations and flatter terrain. However, in the UCTD scenario, although more prominently apparent in NP, a significant increase of BU areas in the CZ was observed, once more indicating the risk of urban encroachment towards upland areas if spatial policies are not upheld or abandoned altogether, which consequently, could negatively affect the environmental integrity of Palawan and therefore Palawan's appeal as a tourist destination.

6.4 Limitations and Future Research

Despite having similar ranges for the ROC values for each LULC type, compared to other studies, which evaluated their Dyna-CLUE model based on the $K_{Simulation}$ statistics (Li & Song, 2020; Kucsicsa et al. 2020; Chasia et al., 2023), the accuracy of the simulation results from this thesis is comparatively low. The relatively low accuracy could be attributed to multiple factors. Firstly, the optional neighbourhood module of the Dyna-CLUE was not utilized for the present thesis. Additionally, the original spatial and temporal resolution of the various datasets greatly differed from each other in certain cases (e.g., *tourist arrivals* and *precipitation*). Therefore, the datasets had to be rescaled, which further limits the data quality. Additionally, only *population density* was considered dynamic, while the other driving forces remained static. With ongoing development, these driving forces would be prone to change accordingly (Zhai et al., 2010). There is also the lack of datasets representing the influence of tourism on LULC change as they are also not readily available. While this thesis incorporated two driving forces to represent the influence of tourism on the spatial distribution of the LULC type, the BLR analysis revealed that the correlation was either relatively minimal or were frequently statistically insignificant. For future LULC modelling studies in Palawan, it could be beneficial include tourism related driving forces such as "most/ least attractive areas" or "areas of touristic potential". Boavida Portugal et al. (2016) implemented these aspects successfully into their model through collaborative stakeholder workshops. Another limitation of the model involves the calibration and validation, which was only done for the time period between 2015 and 2020 due to the significant spatial discrepancies observed in the LULC map of 2010 for certain parts in Palawan. Thus, it must be assumed that the model is only able to replicate LULC change from that time period. Additionally, while the model results show how the future spatial distribution might unfold under the various scenarios, it must be taken into consideration that the projected LULC demands are based on a trend of only five years, which is considered a limited time span (Kucsicsa et al., 2019). An alternative approach to be less reliant on existing LULC maps, could be to generate LULC maps based on satellite images captures over multiple years (e.g., Adhikari et al., 2020; Das et al., 2019). Moreover, although the storylines of the scenarios captured the wishes and concerns of the involved stakeholders, the quantification was relatively simplistic. Collaborating with stakeholders through workshops could be an approach to be considered for future research, as also suggested in the participatory scenario development framework of Priess & Hauck (2014).

7 Conclusion

This thesis modelled future LULC change over a 30-year period (2020-2050) in Palawan under three different tourism development scenarios using the Dyna-CLUE model. These scenarios, derived from stakeholder interviews, included a business as usual scenario (BAU), best-case scenario (EALP) and worst-case scenario (UCTD). The results for NP under the BAU and UCTD scenario exhibited a significant increase in tourism driven BU areas primarily at the expense of AG, as well as EL and MF. Conversely, the EALP scenario showed a significant loss in EL area due to the protection of AG and MF areas. Unlike NP¸ there was only a moderate BU area growth observed in SP across all scenarios, which may have showed the continued focus on agribusiness over tourism development. Similarly to NP, AG continued to have the highest decrease in both the BAU and UCTD scenario, underscoring the necessity to retain AG area to maintain food security in both parts of Palawan. Additionally, EL again saw the highest area loss in the EALP scenario. However, EL rather than BU, exhibited the highest growth in area across the BAU and UCTD scenario. This trend might be attributed to the ongoing shift towards off-farm employment from the younger generation. Across all scenarios, newly allocated BU areas were primarily observed in the MUZ, TUZ and CUZ, indicating a continuous expansion closer or along the coastline. However, further encroachment in future years into the uplands was noted in the results for the BAU and UCTD scenarios, highlighting the importance of spatial policies.

The findings of this thesis provide insights into potential future spatial patterns under different tourism development scenarios and impact of spatial policies on the province of Palawan. Thus, these insights could assist local stakeholders in preserving Palawan's appeal as "The Last Ecological Frontier" of the Philippines and in supporting sustainable tourism development. This could encompass efficient LULC planning based on the tourism development path determined by the province, while carefully weighing the balance between sustainable tourism and optimal LULC allocation (Mao et al. 2014; Boavida-Portugal et al., 2016).

8 References

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Appendix A Supplementary Figures and Tables

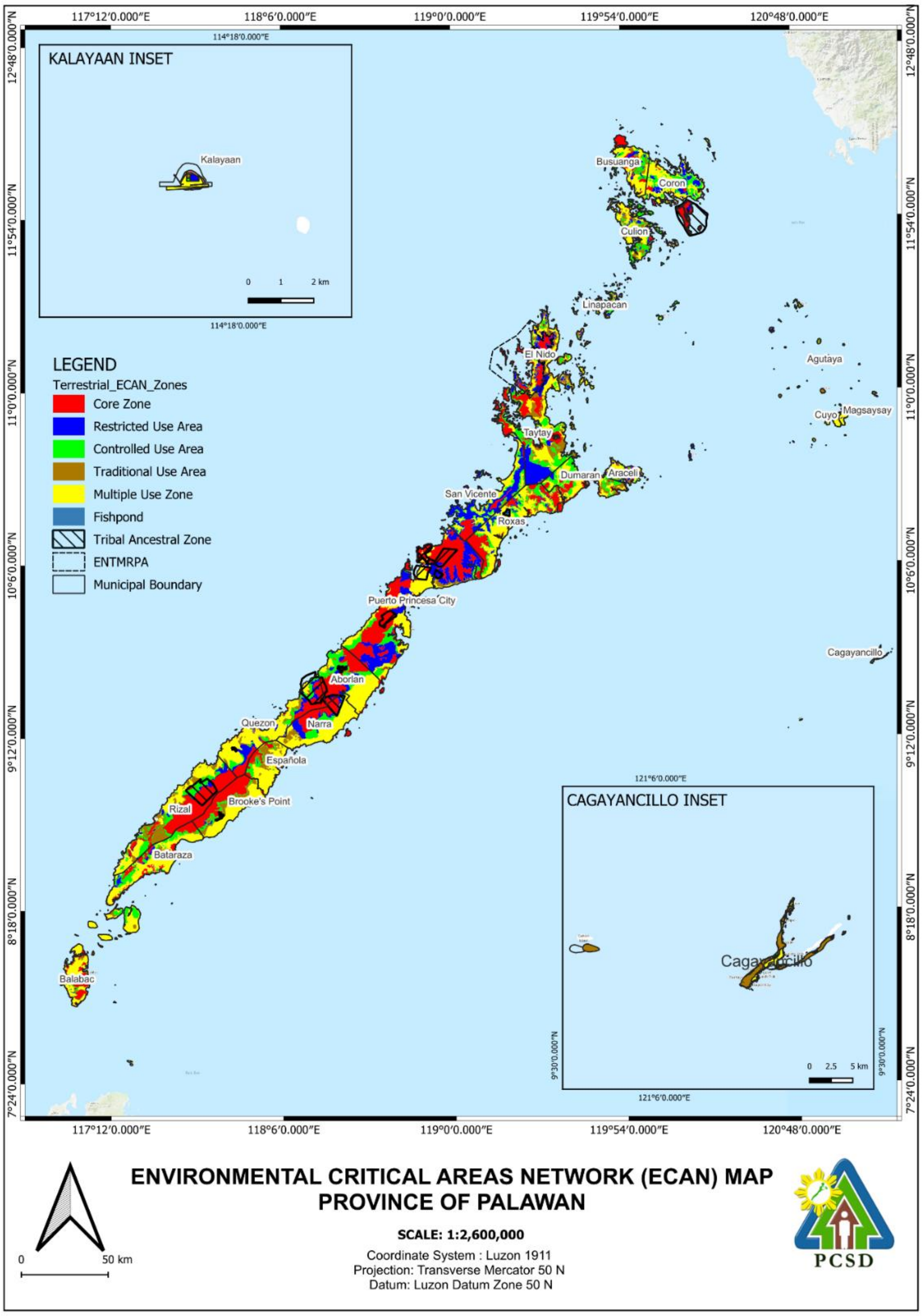


Figure A.1: Map visualisation of the ECAN Zones provided by the members of the Environmental Monitoring and Enforcement Division section (EMED) of the PCSD

Table A.1: Description of ECAN zones

ECAN ZONE	Description	Elevation[m]	Slope [°]	Land Cover	Habitat
Core Zone	Area of maximum protection	>1000	> 26.57	Virgin forest or primary growth forest	Critically threatened/ endangered habitats and habitats of rare endangered species or habitat of local endemic species of flora and faun
Buffer zone – Restricted use	Generally, surrounds the “Core Zone” and provides a protective barrier; Critical watersheds, which were identified, classified, or declared as such by the government	500 to 1000	19.80-26.57	Poor, stunted and sparse stands of semi-deciduous forest, which has low regeneration capacity	Areas designated as biodiversity hotspots and highly threatened by human activities based on scientific studies
Buffer zone – Controlled use	Encircles and provides the outer barrier to the Core Zone and Restricted use zone	300 to 500	10.20-19.80	—	—
Buffer zone – Traditional use	Edges of intact forests where traditional land use is already stabilized is being stabilized	<300	>10.20	Open, brushland or grassland areas that are still classified as timberland or public land	—
Multiple use zone	Areas where the landscape has been modified for different forms of land use such as intensive timber extraction, grazing and pastures, agriculture and infrastructure development	<300	<10.20	Built-up or settlement areas located in lowlands	—

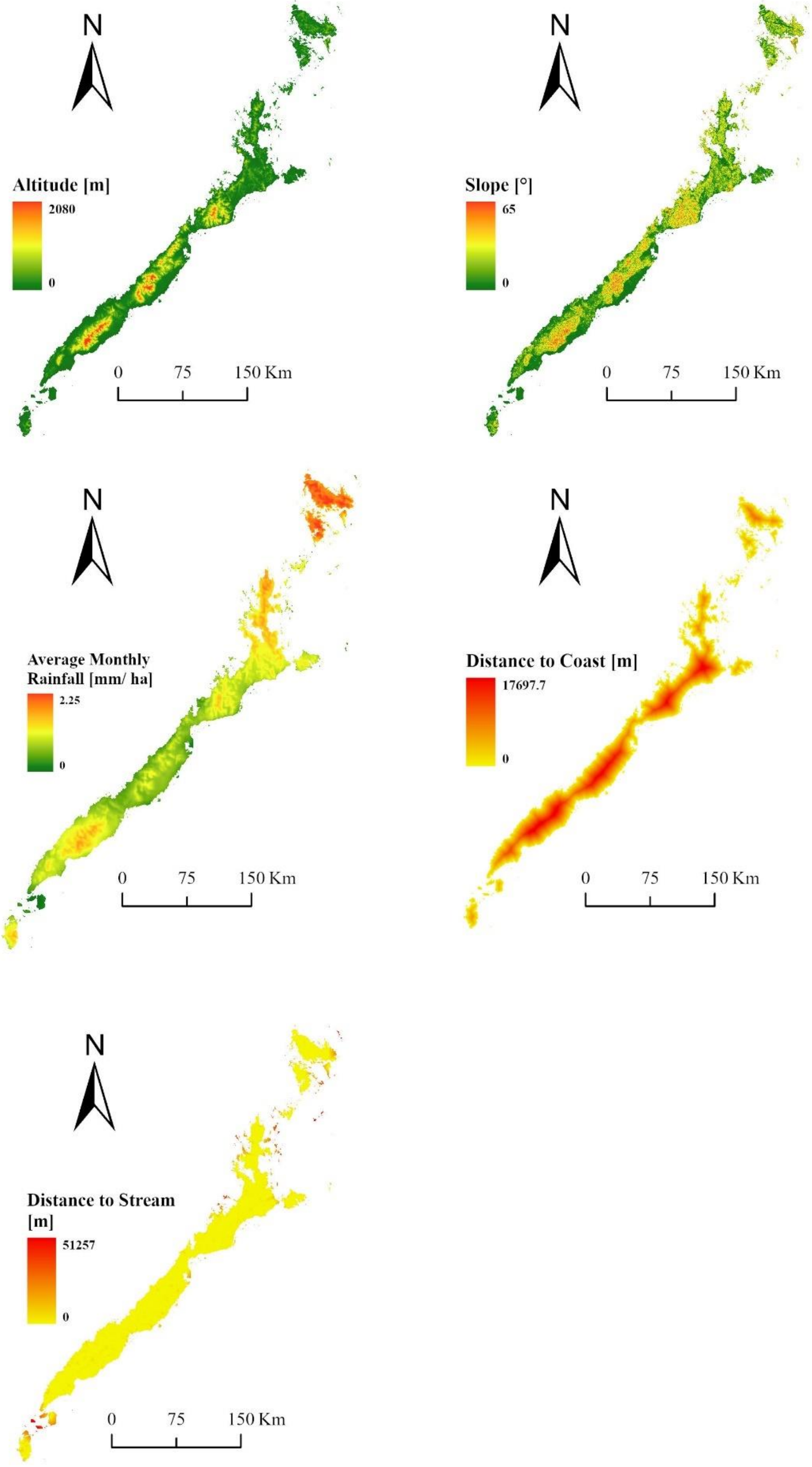


Figure A.2: Map visualisation of selected natural driving forces

Table A.2: In-depth description of the data preparation for natural driving forces

Natural Driving Force	Data Preparation
Altitude and Slope	Digital Elevation Models (DEM) consist of raster data with pixel values representing absolute elevation, providing information about the average altitude within the observed area. Since *altitude* and *slope* are generally considered important stable driving forces for LULC change, the DEM GLO-30, a global digital elevation model was extracted from the Google Earth Engine data catalogue. Since the DEM GLO-30 dataset has a resolution of 30m, the "Aggregate" tool in ArcGIS was utilized to aggregate the data to 100m. The corresponding slope was calculated using the "Slope" tool from the spatial analyst tool in ArcGIS Pro.
Precipitation	The OpenLandMap Precipitation Monthly from the GEE data catalogue, generated by Hengl & Parente (2022), was used for the Precipitation driving factor. The dataset has been downscaled to 1km based on precipitation data from SM2RAIN-ASCAT 2007-2018, IMERG, CHELSA Climate, and WorldClim. The dataset comprises 12 bands, each one representing the monthly average from the years 2007 to 2018. For the present study, an average image was calculated and afterwards resampled to a 100m resolution using a script written in RStudio. This script was utilized for all datasets, which needed to be resampled to a 100m resolution.
Distance to Coast	For the coastline, the boundary of the dissolved LULC map of 2015 was used. The distance was then calculated using the r.grow.distance tool from GRASS was utilized using the Euclidean method. This methodology was used for all driving forces, which required generating a distance map.
Distance to Stream	The shapefile from the river network of Palwan was given by the ECAN monitoring and evaluation division from the PCSD (EMED).

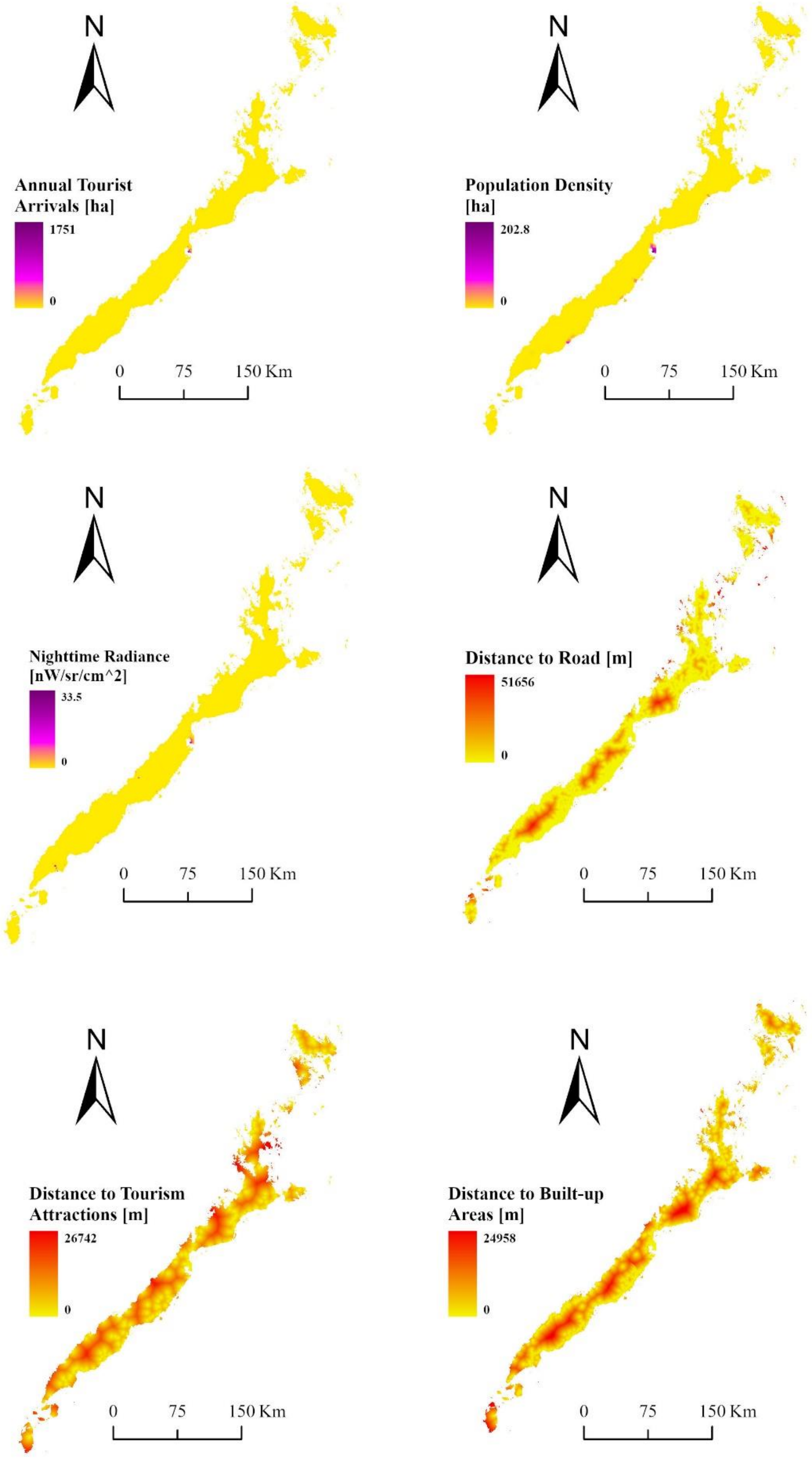
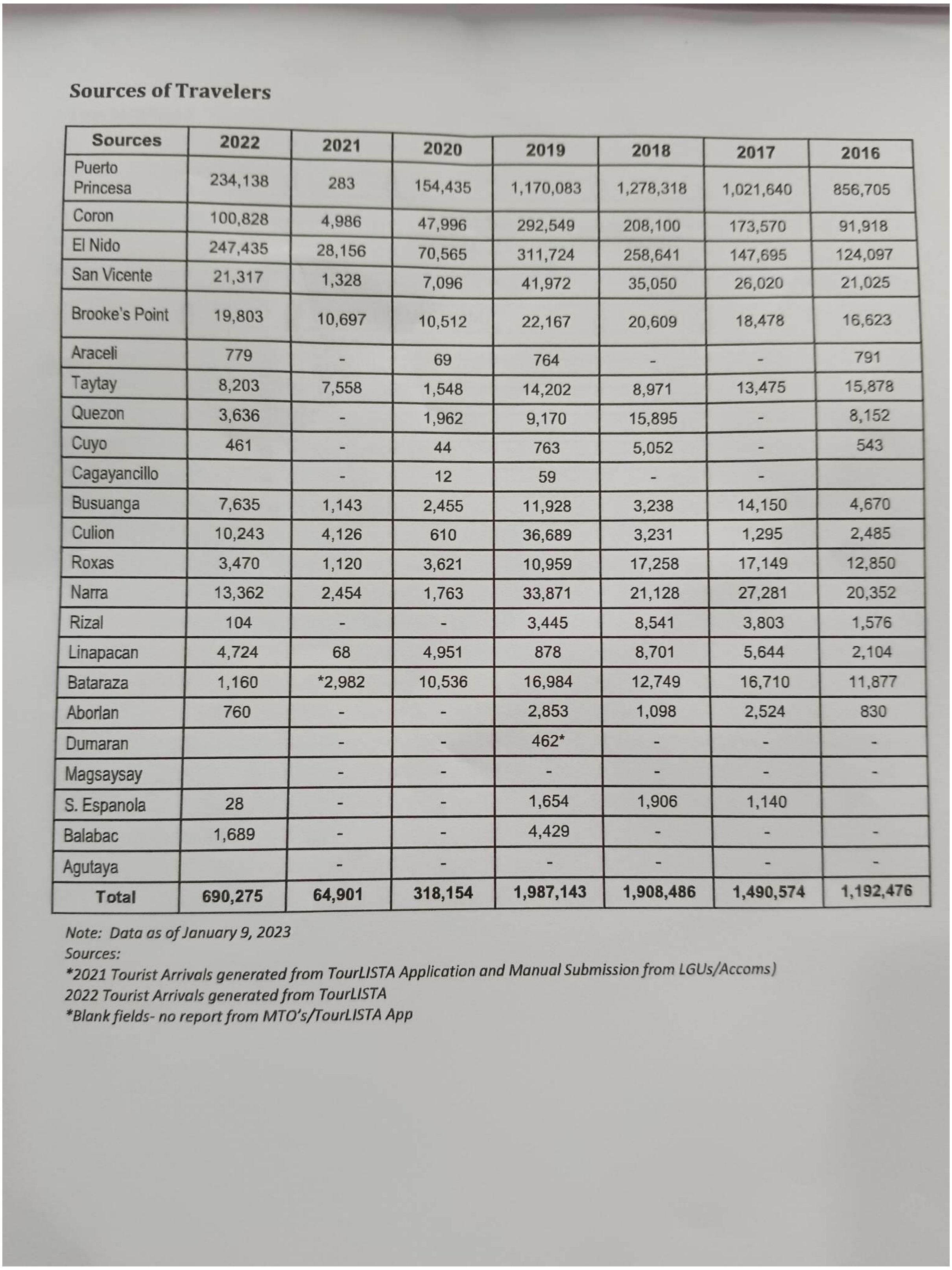


Figure A.3: Map visualisation of selected socio-economic driving forces



Sources of Travelers

Sources	2022	2021	2020	2019	2018	2017	2016
Puerto Princesa	234,138	283	154,435	1,170,083	1,278,318	1,021,640	856,705
Coron	100,828	4,986	47,996	292,549	208,100	173,570	91,918
El Nido	247,435	28,156	70,565	311,724	258,641	147,695	124,097
San Vicente	21,317	1,328	7,096	41,972	35,050	26,020	21,025
Brooke's Point	19,803	10,697	10,512	22,167	20,609	18,478	16,623
Araceli	779	-	69	764	-	-	791
Taytay	8,203	7,558	1,548	14,202	8,971	13,475	15,878
Quezon	3,636	-	1,962	9,170	15,895	-	8,152
Cuyo	461	-	44	763	5,052	-	543
Cagayancillo		-	12	59	-	-	
Busuanga	7,635	1,143	2,455	11,928	3,238	14,150	4,670
Culion	10,243	4,126	610	36,689	3,231	1,295	2,485
Roxas	3,470	1,120	3,621	10,959	17,258	17,149	12,850
Narra	13,362	2,454	1,763	33,871	21,128	27,281	20,352
Rizal	104	-	-	3,445	8,541	3,803	1,576
Linapacan	4,724	68	4,951	878	8,701	5,644	2,104
Bataraza	1,160	*2,982	10,536	16,984	12,749	16,710	11,877
Aborlan	760	-	-	2,853	1,098	2,524	830
Dumaran		-	-	462*	-	-	-
Magsaysay		-	-	-	-	-	-
S. Espanola	28	-	-	1,654	1,906	1,140	
Balabac	1,689	-	-	4,429	-	-	-
Agutaya		-	-	-	-	-	-
Total	**690,275**	**64,901**	**318,154**	**1,987,143**	**1,908,486**	**1,490,574**	**1,192,476**

Note: Data as of January 9, 2023
Sources:
**2021 Tourist Arrivals generated from TourLISTA Application and Manual Submission from LGUs/Accoms)*
2022 Tourist Arrivals generated from TourLISTA
**Blank fields- no report from MTO's/TourLISTA App*

Figure A.4: Tourist arrivals per municipality

Table A.3: In-depth description of the data preparation for socio-economic driving forces

Natural Driving Force	Data Preparation
Tourist Arrivals (Annual Tourist Arrivals)	The tourist arrivals were on the municipality scale and were acquired from the PDOT and the Provincial Tourism Promotions and Development Office of Palawan (PTPDOP). As tourist arrival data for certain municipalities was inconsistently gathered throughout, the temporal resolution representing the tourist arrivals varies between 2014 and 2017 with Tourist accommodations consisted of hotels, chalet, guest houses, apartment, hostel and motels, which had the key value "tourism" in OSM. The number of tourist accommodations in a 1km grid were counted using the "Count points in polygon" from the Vector analysis tool in QGIS and rasterized afterwards. Tourist arrivals were then distributed to different raster cells where accommodations were located. This step was done with a script written in RStudio, using municipal borders as the designated zones.
Population Density	Population density data was extracted from the Gridded Population of the World, Version 4 (GPWv4) dataset, by utilizing the GGE code editor. The dataset has a resolution of ~1km and was produced by the Center for International Earth Science Information Network (CIESIN) and published by the NASA Socioeconomic Data and Applications Center (SEDAC) in 2018.
Nighttime Lights (Nighttime Radiance)	Remote sensing nighttime light data have shown to be a reliable proxy indicator of the spatial distribution of gross domestic product (GDP) and has been used in previous LULC modelling studies with satisfying results (Lao et al. 2020). The dataset utilized for this study was the VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1 dataset, generated by the Earth Observation Group, Payne Institute for Public Policy, Colorado School of Mines, accessible through the GEE data catalogue. The dataset is computed monthly with a resolution of 463.83 meters, where an annual average image for the year 2015 was calculated and downloaded using the GEE code editor.
Distance to Road	The shapefile from the road network of Palwan was given by the ECAN monitoring and evaluation division from the PCSD (EMED).
Distance to Tourism Attractions	As previously mentioned, studies have started to use POI in order to associate built-up areas with tourism. The POI for this study were extracted from Open Street Map (OSM) using Overpass

	Turbo. The query search included POI nodes such as restaurants, beaches, attractions, scenic spots, transportation facilities, sports and leisure services and shopping facilities. The selection was based on the paper of Sun et al. (2023), where they investigated the interaction between LULC pattern and tourism development in a small karst basin in China.
Distance to Built-up Areas	The location and the distance to the built-up areas was calculated based on the pixels classified as built-up areas in the LULC map of 2015.

Table A.4: Elasticity values for the various LULC types for Northern- and Southern Palawan

LULC Type	**Elasticity**	
	Northern Palawan	**Southern Palawan**
Agriculture (AG)	0.1	0.3
Eco-Land (EL)	0.1	0.1
Mangrove Forest (MF)	0.6	0.7
Open/ Barren (OB)	0.4	0.6
Built-up (BU)	0.8	1.0
Waterbodies (WB)	0.7	0.9

Table A.5: Transition probability matrix (2015-2020) for NP

		New LULC Type					
		AG	EL	MF	OB	BU	WB
Old LULC Type	AG	0.686965	0.264224	0.006505	0.002064	0.037508	0.002733
	EL	0.023138	0.964864	0.003995	0.000622	0.005985	0.001396
	MF	0.015187	0.083329	0.8822	0.000745	0.004986	0.013554
	OB	0.128585	0.280296	0.044403	0.488437	0.049029	0.009251
	BU	0.089043	0.155701	0.011625	0.006184	0.733737	0.00371
	WB	0.048471	0.228188	0.120805	0.001989	0.012429	0.588118

Table A.6: Transition probability matrix (2015-2020) for SP

		New LULC Type					
		AG	EL	MF	OB	BU	WB
Old LULC Type	AG	0.870885	0.102402	0.006606	0.001313	0.012388	0.006406
	EL	0.024105	0.968889	0.001103	0.000431	0.002053	0.00342
	MF	0.029674	0.013121	0.948256	0.000261	0.000348	0.008342
	OB	0.042731	0.056974	0.003929	0.891945	0.003929	0.000491
	BU	0.179469	0.038685	0.001796	0.002072	0.77176	0.006217
	WB	0.177994	0.275508	0.052668	0.007474	0.003824	0.482531

Table A.7: Conversion matrix for model validation

		New LULC Type					
		AG	EL	MF	OB	BU	WB
Old LULC Type	AG	1	1	1	1	1	1
	EL	1	1	1	1	1	1
	MF	1	1	1	1	1	1
	OB	1	1	1	1	1	1
	BU	1	1	1	1	1	1
	WB	1	1	1	1	1	1

Table A.8: Summary table of the number of participants for each stakeholder group and the represented municipalities

Relevant Stakeholders	**Total Interviewees**	**Represented Municipalities**	**Source**
Resident	10	El Nido, Puerto Princesa City & San Vicente	Byrd (2007); Kim et al. (2022)
Business Owner/ Manager	4	El Nido, Puerto Princesa City & San Vicente	Hieu & Nwachukwu (2019); Presenza & Coppalina (2010)
City Planner	3	El Nido, San Vicente & Private Planning Agency	Byrd (2007); Malek & Boerboom (2015);
Agriculture Department	2	El Nido & San Vicente	Schwilch et al. (2012); Aseres (2014)
Environmental Office	2	Puerto Princesa City	Mafruhah et al. (2020)
Tourism Department	2	El Nido & San Vicente	Aseres (2014)
Natural area manager	2	El Nido & San Vicente	Hewitt et al. (2018)
NGO	2	Puerto Princesa City & San Vicente	Aseres (2014)
Total	**27**		

Table A.9: Demographic characteristics summary table of the stakeholder participants

Demographic Characteristics	Stakeholder Distribution	
	n	%
Gender		
Female	10	37
Male	17	63
Age Group		
18-24	4	14.8
25-45	11	40.7
46-65	11	40.7
66+	1	3.8
LGU Employees		
Yes	10	37
No	17	63
Years Living in Palawan		
0-5	2	7.4
6-10	1	3.8
11-20	5	18.5
21+	19	70.3

Table A.10: Aggregation of old LULC types to the newly defined LULC types for the present thesis

LULC Type Old	LULC Type New	Literature
Annual Crop Perennial Crop	Agriculture (AG)	Waiyasusri et al. (2016); Waiyasusri & Chotpantarat (2022); Semi-Structured Interviews
Closed Forest Open Forest Brush/ Shrubs Grassland	Eco-Land (EL)	Mao et al. (2014); Rimba et al. (2020); Semi-Structured Interviews
Mangrove Forest	Mangrove Forest (MV)	Semi-Structured Interviews
Open/ Barren	Open/ Barren (OB)	Semi-Structured Interviews; Boavida-Portugal et al. (2016)
Built-Up	Built-up (BU)	Semi-Structured Interviews
Marshland/ Swamp Fishpond Inland Water	Waterbodies (WB)	Che & Wan (2022); Naji & Aduljabbar (2019); Boavida-Portugal et al. (2016)

Table A. 11: Codes for best-case scenario with definition and respective example

Code	Definition	Example	Literature
Ecotourism	Ecotourism is characterised by a focus on appreciating and enjoying the pristine natural area and its cultural aspects of the destination. It furthermore promotes conservation efforts with minimizing visitor impact and the involvement of local communities	*"If I will choose the, ano [Filipino fill world (emm)], I must choose for the, emm, the, the sustainable development is okay, but we must protect our environment. Because we, there's so many ways to protect, even in the same way, we are the tourism, emm, the tourism municipality in Palawan. So, I think we just, just stay the, the nature, in El Nido." (City Planning from El Nido, 2023)*	UNEP (2023)
Agritourism	Agritourism involves activities where a visitor is involved in a farm or agricultural setting, be it to enjoy the rural scenery or actively participating in the processes for recreational or leisure purposes.	*"I would like, I would like Palawan to be in the future, not just to showcase coastal areas, but also terrestrial and even agriculture, agricultural tourism. So that we will not be very dependent on climate." (Reasearcher in Puerto Princesa City, 2023)*	Tew & Barbieri (2012)
Community-based Tourism	Community-based Tourism encompasses the tourism development of a location by emphasizing the active participation of the community. It involves the local community in a primary role in all aspects of decision making, planning and evaluation and aims to empower them with infrastructural and institutional support. The community should assume a primary role as they have the knowledge of potential natural and cultural selling points for tourism.	*"Community based sustainable development. For example, in the mangrove area. Paddle boat. Like underground river, like that. I'm not against on the tourism development." (NGO in Puerto Princesa City, 2023)*	Arintoko et al. (2020)

Urbanisation	Urbanisation encompasses a development, which ultimately leads to the development of a city, population growth and concentration, areal expansion of a location and the focus of the economic income other than from the agricultural sector	*"I hope after ten to twenty years this place, this area, San Vicente Palawan, make us, beautiful city. After ten years, fifteen years, beautiful city." (Resident in San Vicente, 2023)*	Biłozor & Cieslak (2021)

Table A.12: Codes for worst-case scenario with definition and respective example

Code	Definition	Example	Literature
Over-commercialization of Tourism	Over-commercialization of Tourism describes a phenomenon where tourism drives the mass-production of cultural products and the standardization of service offerings related to entertainment, services, and businesses, which ultimately can lead to less satisfactory tourist experiences in the location.	*“Emm, the influx of the commercialisation of the, the touri-, tourism area. So, the influx of coming tourist would affect also, the needs, the needs of the tourism. So, there would be, the influx of tourist requires more development’s structure that will also affect the landscape. So, if you have much more tourist coming in a, in a place, so you need more facilities and services. So, they will des- destroy more and for the needs of the service and facilities” (Environmental Office, El Nido (2023)*	Sun et al. (2019)
Uncontrollable Tourism Development	Uncontrollable tourism development is a path, which results in the exploitation of natural resources, having long-term negative effects, affecting the future generation as well.	*“Personal but. It's the, those people who have power, like, they build the building without permit and still on-going business, because they are powerful.” (Tourism Business in San Vicente, 2023)*	Ioncică et al. (2016)
Overtourism	Overtourism is a development, which results from an excessive number of tourist arrivals, inappropriate tourist behaviour, inconvenience or disturbance for residents and an undesirable outcome on the social- and physical environment.	*“Overcrowded. Overcrowding the tourism areas. Destructing the corals, lower customer satisfaction, because if you are a tourist and you have one thousand people with you is not good. So, you’ll not be happy and also food security and closing of the visual corridors.” (Tourism Office in El Nido, 2023)*	Butler & Dodds (2022)

Table A.13: Codes for potential measures with definition and respective example

Code	Definition	Example	Literature
Political Intervention	Political Interventions involve forms of rules control, integrated management or security	*"I think tourism development is good, as long as the local government have its guide, like the comprehensive land water use plan. So, we have also guided by the ECAN [...]" (City Planning in San Vicente, 2023)*	Isfahani et al. (2021)
Preservation of Landscapes	Preservation of Landscapes encompasses the maintenance of the existing manipulated natures as they are, discouraging re-naturalization and naturalization. The locals play a pivotal role in preserving the landscape and act in the best interest of nature	*"If I could choose, I would like to build emm, ecofriendly amenities or emm hotels or resorts that will never destroy the forest. So, we can still be the last frontier." (Resident in Puerto Princesa City, 2023)*	Grindsted et al. (2023)
Spatial Redistribution of Tourists	Spatial Redistribution of Tourists involves statements where the redistribution of tourists and facilities and products to diversify the tourism offers in Palawan is used as a measure to improve destination sustainability	*"I think the authorities, the PCSD and the local government [inaudible], they need to implement land use plan so we can have, we can preserve the limited food security we have. [...]. The DENR study already and we have to look for another areas, so that Bacuit Bay will be decongested, not too much tourism [...]" (Tourism Office in El Nido, 2023)*	Marković & Klarić (2015)
Carrying Capacity	Carrying Capacity is a planning tool, which determines the quantity of tourist arrivals at a tourist site at the same time without damaging its physical, economic and socio-cultural environment	*"Yes, that was our study before. Emm that it should be limit tourist. We introduce only 500 tourist in a day, but emm, so that it will be protected. Now they go as far as 1000." (Farmer in Puerto Princesa City, 2023)*	Calanog (2015)

Nature Restoration	Restoration of Nature measure encompasses the process of aiding the natural ecosystem towards or back to a good condition by active or passive involvement.	*"Maybe we need to restore the forest, restore the waterfalls, to bring back and we need, emm, and we need planted more trees, to bring back the, the, the scen-, ano, the nature." (Resident in Puerto Princesa Ctiy, 2023).*	EEA (2023)

Table A.14: Extended storylines of development scenarios

Scenario	Storyline
BAU	The effects of the current tourism development follow the trend of recent years. This leads to the continuation of the observed LULC transitions trends determined from previous LULC maps made by NAMRIA, which will be projected into the future. The BAU scenario will not include any kind of policy restrictions set by the DENR, PCSD or any other governmental institution in the Philippines, which is due to several mentions of illegal activities by investors and locals concerning LULC conversions already within the Core Zone (e.g., illegal logging) and the difficulty to effectively enforce the policies.
EALP	Tourism in the future focuses towards a more eco-agritourism centred development. Existing agricultural land will be maintained and incorporated as a tourism attraction. Thus, agricultural land will be preserved also in order to maintain food security. This mans that the amount of agricultural land will remain and is not to be allowed to be developed for tourism establishments, which would have a significant impact on LULC (e.g., Hotels, Resorts, Malls etc.). Additionally, any further loss of mangrove forests will also be prohibited since Palawan is a UNESCO recognized biosphere reserve. The land demand for WB also remained static and transitions to BU were prohibited as well. Investors and the locals will also be committed to adhere to the enforced development policies. As of right now, according to interviews conducted with the LGUs of San Vicente, an easement zone of 50 meters is being imposed in the development area of Long Beach, which is already higher than what is traditionally set at 20 meters by the Department of Environment and Natural Resources (DENR, 2021). However, interviews conducted with two tourism businesses along Long Beach revealed that they have the impression that it is not sufficient for the future due to rising water levels. Therefore, the setback for this specific scenario will be placed at 100 meters. Initially, the easement zone extension was set to 75m, however, due to the spatial resolution of the data, a 100-meter easement zone was set. Investors and locals will also strictly follow the ECAN zoning, where the Core Zone is with no doubt considered an “Area of maximum Protection” and therefore any kind of tourism related developments will not be allowed there. In this particular scenario, the “Restricted use area” of the Buffer Zone will also not be allowed to be a subject of change since those are designated biodiversity hotspots, which are highly threatened by human activities. Any kind of development will also not be allowed in designated protected areas or critical habitat zone.
UCTD	For several of the interviewed stakeholders, the commercialisation of tourism and the following uncontrollable development poses one of the biggest fears of losing the “Natural Beauty” of Palawan. In this scenario, part of the uncontrollable development of tourism is the reclassification of Buffer or Core zones to Multiple Use zones by the local authorities, allowing the expansion of built-up areas in the uplands. Additionally, the scenario should demonstrate a scenario where investors and locals disregard the conservation of the “Natural Beauty” of Palawan in favour of developments leading to urban spaces, while the provincial authorities do not punish them accordingly. Therefore, same with the BAU scenario, this scenario will not consider any form of spatial policies, as it should represent the development of Palawan driven by commercialized tourism without any policies, which should help to conserve the natural landscape of the province.

Table A.15: Conversion matrix for EALP scenario

		New LULC Type					
		AG	EL	MF	OB	BU	WB
Old LULC Type	AG	1	1	1	0	0	1
	EL	1	1	1	1	1	1
	MF	1	1	1	0	0	1
	OB	1	1	1	1	1	1
	BU	0	0	0	0	1	0
	WB	1	1	1	1	0	1

Table A.16: Conversion matrix for UCTD scenario

		New LULC Type					
		AG	EL	MF	OB	BU	WB
Old LULC Type	AG	1	1	1	1	1	1
	EL	1	1	1	1	1	1
	MF	1	1	1	1	1	1
	OB	1	1	1	1	1	1
	BU	0	0	0	0	1	0
	WB	1	1	1	1	1	1

Table A.17: Land demand BAU scenario 2021-2050 in hectares for Northern Palawan

NP BAU	**AG**	**EL**	**MF**	**OB**	**BU**	**WB**
2021	65077	695026	34602	1212	13992	4046
2022	64214	694928	34552	1234	14977	4050
2023	63352	694829	34503	1255	15961	4053
2024	62489	694731	34453	1277	16946	4057
2025	61627	694633	34404	1299	17930	4061
2026	60765	694535	34355	1321	18914	4065
2027	59902	694437	34305	1343	19899	4069
2028	59040	694338	34256	1364	20883	4072
2029	58177	694240	34206	1386	21868	4076
2030	57315	694142	34157	1408	22852	4080
2031	56453	694044	34108	1430	23836	4084
2032	55590	693946	34058	1452	24821	4088
2033	54728	693847	34009	1473	25805	4091
2034	53865	693749	33959	1495	26790	4095
2035	53003	693651	33910	1517	27774	4099
2036	52141	693553	33861	1539	28758	4103
2037	51278	693455	33811	1561	29743	4107
2038	50416	693356	33762	1582	30727	4110
2039	49553	693258	33712	1604	31712	4114
2040	48691	693160	33663	1626	32696	4118
2041	47829	693062	33614	1648	33680	4122
2042	46966	692964	33564	1670	34665	4126
2043	46104	692865	33515	1691	35649	4129
2044	45241	692767	33465	1713	36634	4133
2045	44379	692669	33416	1735	37618	4137
2046	43517	692571	33367	1757	38602	4141
2047	42654	692473	33317	1779	39587	4145
2048	41792	692374	33268	1800	40571	4148
2049	40929	692276	33218	1822	41556	4152
2050	40067	692178	33169	1844	42540	4156

Table A.18: Land demand EALP scenario 2021-2050 in hectares for Northern Palawan

NP EALP	**AG**	**EL**	**MF**	**OB**	**BU**	**WB**
2021	65939	694611	34651	1211	13500	4042
2022	65939	694097	34651	1232	13992	4042
2023	65939	693584	34651	1253	14485	4042
2024	65939	693071	34651	1274	14977	4042
2025	65939	692558	34651	1295	15469	4042
2026	65939	692045	34651	1316	15961	4042
2027	65939	691532	34651	1337	16453	4042
2028	65939	691019	34651	1358	16946	4042
2029	65939	690505	34651	1379	17438	4042
2030	65939	689992	34651	1400	17930	4042
2031	65939	689479	34651	1420	18422	4042
2032	65939	688966	34651	1441	18914	4042
2033	65939	688453	34651	1462	19407	4042
2034	65939	687941	34651	1483	19899	4042
2035	65939	687428	34651	1503	20391	4042
2036	65939	686915	34651	1524	20883	4042
2037	65939	686402	34651	1545	21375	4042
2038	65939	685889	34651	1565	21868	4042
2039	65939	685376	34651	1586	22360	4042
2040	65939	684863	34651	1607	22852	4042
2041	65939	684351	34651	1627	23344	4042
2042	65939	683838	34651	1648	23836	4042
2043	65939	683325	34651	1668	24329	4042
2044	65939	682813	34651	1689	24821	4042
2045	65939	682300	34651	1709	25313	4042
2046	65939	681787	34651	1729	25805	4042
2047	65939	681275	34651	1750	26297	4042
2048	65939	680762	34651	1770	26790	4042
2049	65939	680250	34651	1791	27282	4042
2050	65939	679737	34651	1811	27774	4042

Table A.19: Land demand UCTD scenario 2021-2050 in hectares for Northern Palawan

NP UCTD	**AG**	**EL**	**MF**	**OB**	**BU**	**WB**
2021	64996	694165	34559	1212	14832	4046
2022	64055	693204	34466	1234	16801	4050
2023	63116	692241	34374	1255	18769	4053
2024	62179	691276	34282	1277	20738	4057
2025	61243	690309	34190	1299	22707	4061
2026	60310	689340	34098	1321	24676	4065
2027	59379	688369	34005	1343	26645	4069
2028	58449	687396	33913	1364	28613	4072
2029	57522	686421	33821	1386	30582	4076
2030	56597	685444	33729	1408	32551	4080
2031	55673	684465	33637	1430	34520	4084
2032	54752	683484	33545	1452	36489	4088
2033	53833	682501	33453	1473	38457	4091
2034	52916	681516	33361	1495	40426	4095
2035	52000	680529	33269	1517	42395	4099
2036	51087	679540	33176	1539	44364	4103
2037	50176	678549	33084	1561	46333	4107
2038	49267	677556	32992	1582	48301	4110
2039	48360	676560	32900	1604	50270	4114
2040	47455	675563	32808	1626	52239	4118
2041	46552	674563	32716	1648	54208	4122
2042	45651	673562	32624	1670	56177	4126
2043	44753	672558	32532	1691	58145	4129
2044	43856	671552	32441	1713	60114	4133
2045	42961	670544	32349	1735	62083	4137
2046	42069	669534	32257	1757	64052	4141
2047	41179	668521	32165	1779	66021	4145
2048	40291	667507	32073	1800	67989	4148
2049	39405	666490	31981	1822	69958	4152
2050	38521	665472	31889	1844	71927	4156

Table A.20: Land demand BAU scenario 2021-2050 in hectares for Southern Palawan

SP BAU	**AG**	**EL**	**MF**	**OB**	**BU**	**WB**
2021	170716	398129	23951	2340	8996	5472
2022	168440	399953	24106	2390	9289	5425
2023	166165	401776	24262	2441	9582	5379
2024	163889	403600	24417	2491	9875	5332
2025	161613	405423	24573	2542	10168	5285
2026	159337	407246	24729	2593	10461	5238
2027	157061	409070	24884	2643	10754	5191
2028	154786	410893	25040	2694	11047	5145
2029	152510	412717	25195	2744	11340	5098
2030	150234	414540	25351	2795	11633	5051
2031	147958	416363	25507	2846	11926	5004
2032	145682	418187	25662	2896	12219	4957
2033	143407	420010	25818	2947	12512	4911
2034	141131	421834	25973	2997	12805	4864
2035	138855	423657	26129	3048	13098	4817
2036	136579	425480	26285	3099	13391	4770
2037	134303	427304	26440	3149	13684	4723
2038	132028	429127	26596	3200	13977	4677
2039	129752	430951	26751	3250	14270	4630
2040	127476	432774	26907	3301	14563	4583
2041	125200	434597	27063	3352	14856	4536
2042	122924	436421	27218	3402	15149	4489
2043	120649	438244	27374	3453	15442	4443
2044	118373	440068	27529	3503	15735	4396
2045	116097	441891	27685	3554	16028	4349
2046	113821	443714	27841	3605	16321	4302
2047	111545	445538	27996	3655	16614	4255
2048	109270	447361	28152	3706	16907	4209
2049	106994	449185	28307	3756	17200	4162
2050	104718	451008	28463	3807	17493	4115

Table A.21: Land demand EALP scenario 2021-2050 in hectares for Southern Palawan

SP EALP	**AG**	**EL**	**MF**	**OB**	**BU**	**WB**
2021	172992	396121	23795	2328	8850	5519
2022	172992	395936	23795	2366	8996	5519
2023	172992	395751	23795	2404	9143	5519
2024	172992	395567	23795	2442	9289	5519
2025	172992	395383	23795	2479	9436	5519
2026	172992	395200	23795	2516	9582	5519
2027	172992	395017	23795	2552	9729	5519
2028	172992	394834	23795	2589	9875	5519
2029	172992	394652	23795	2624	10022	5519
2030	172992	394470	23795	2660	10168	5519
2031	172992	394289	23795	2695	10315	5519
2032	172992	394108	23795	2729	10461	5519
2033	172992	393927	23795	2764	10608	5519
2034	172992	393746	23795	2798	10754	5519
2035	172992	393566	23795	2832	10901	5519
2036	172992	393386	23795	2865	11047	5519
2037	172992	393207	23795	2898	11194	5519
2038	172992	393027	23795	2931	11340	5519
2039	172992	392848	23795	2963	11487	5519
2040	172992	392670	23795	2995	11633	5519
2041	172992	392492	23795	3027	11780	5519
2042	172992	392314	23795	3058	11926	5519
2043	172992	392136	23795	3090	12073	5519
2044	172992	391959	23795	3120	12219	5519
2045	172992	391782	23795	3151	12366	5519
2046	172992	391605	23795	3181	12512	5519
2047	172992	391428	23795	3211	12659	5519
2048	172992	391252	23795	3241	12805	5519
2049	172992	391076	23795	3270	12952	5519
2050	172992	390900	23795	3300	13098	5519

Table A.22: Land demand UCTD scenario 2021-2050 in hectares for Southern Palawan

SP UCTD	**AG**	**EL**	**MF**	**OB**	**BU**	**WB**
2021	170632	397933	23939	2340	9289	5472
2022	168274	399557	24082	2390	9875	5425
2023	165918	401180	24226	2441	10461	5379
2024	163564	402800	24369	2491	11047	5332
2025	161213	404419	24512	2542	11633	5285
2026	158863	406036	24655	2593	12219	5238
2027	156516	407650	24798	2643	12805	5191
2028	154171	409263	24940	2694	13391	5145
2029	151829	410873	25083	2744	13977	5098
2030	149488	412482	25225	2795	14563	5051
2031	147150	414088	25367	2846	15149	5004
2032	144814	415693	25509	2896	15735	4957
2033	142480	417295	25651	2947	16321	4911
2034	140148	418895	25792	2997	16907	4864
2035	137818	420494	25934	3048	17493	4817
2036	135491	422090	26075	3099	18079	4770
2037	133166	423684	26216	3149	18665	4723
2038	130843	425277	26357	3200	19251	4677
2039	128522	426867	26498	3250	19837	4630
2040	126204	428455	26638	3301	20423	4583
2041	123888	430041	26779	3352	21009	4536
2042	121574	431625	26919	3402	21595	4489
2043	119262	433207	27059	3453	22181	4443
2044	116952	434787	27199	3503	22767	4396
2045	114645	436364	27339	3554	23353	4349
2046	112340	437940	27478	3605	23939	4302
2047	110037	439514	27618	3655	24525	4255
2048	107737	441085	27757	3706	25111	4209
2049	105438	442655	27896	3756	25697	4162
2050	103142	444222	28035	3807	26283	4115

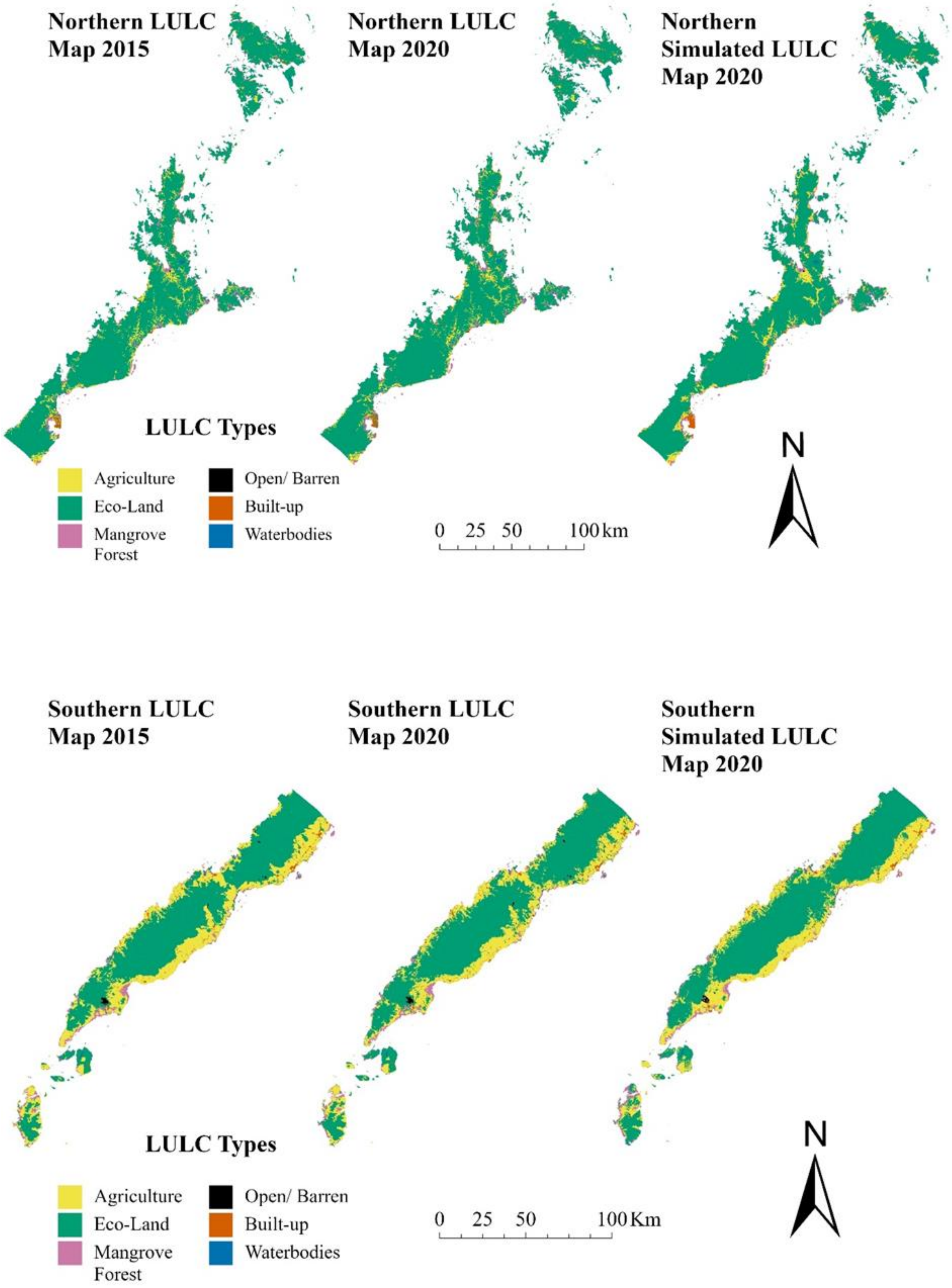


Figure A.5: Observed and simulated LULC map comparison of Northern and Southern Palawan from 2015 and 2020

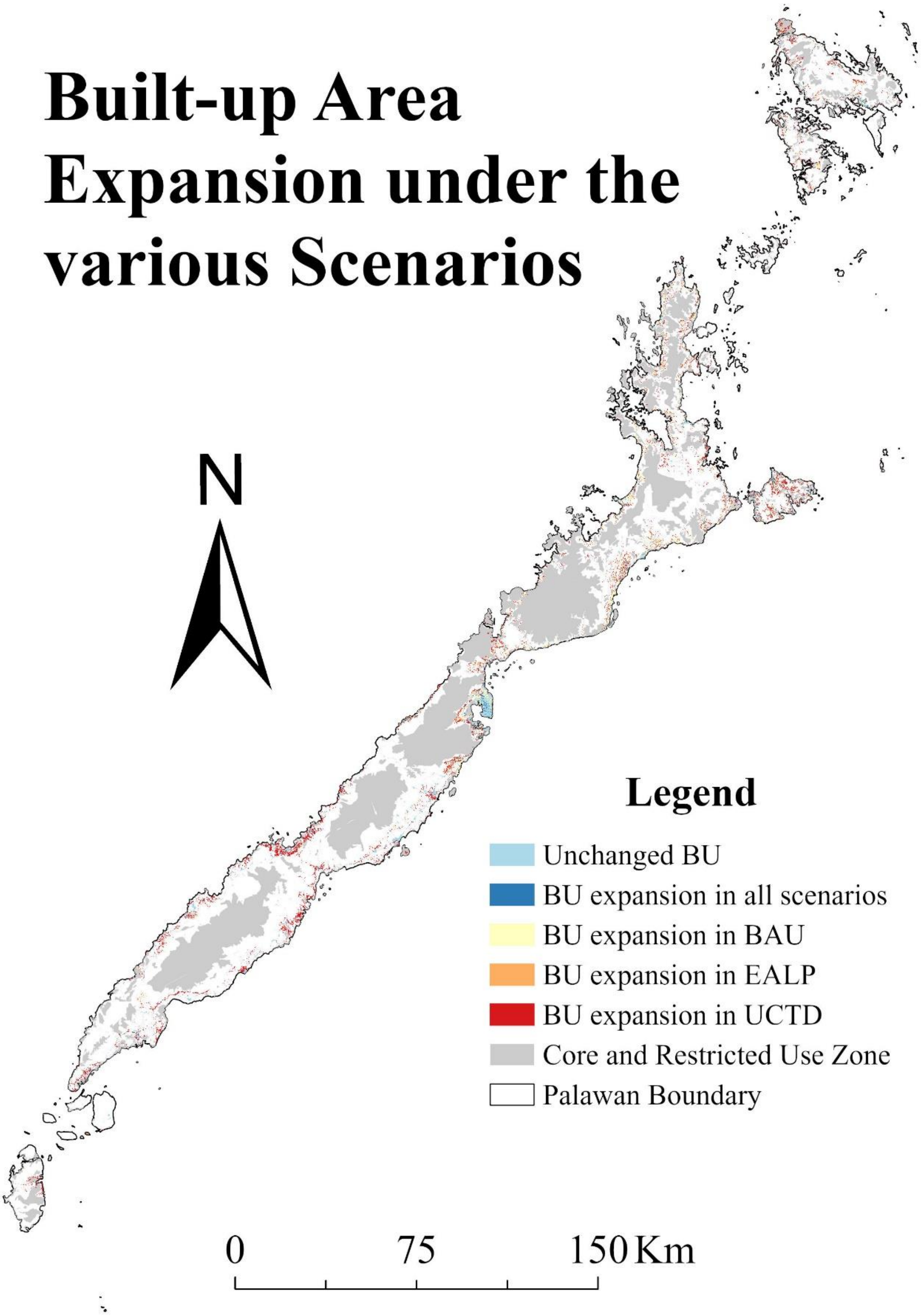
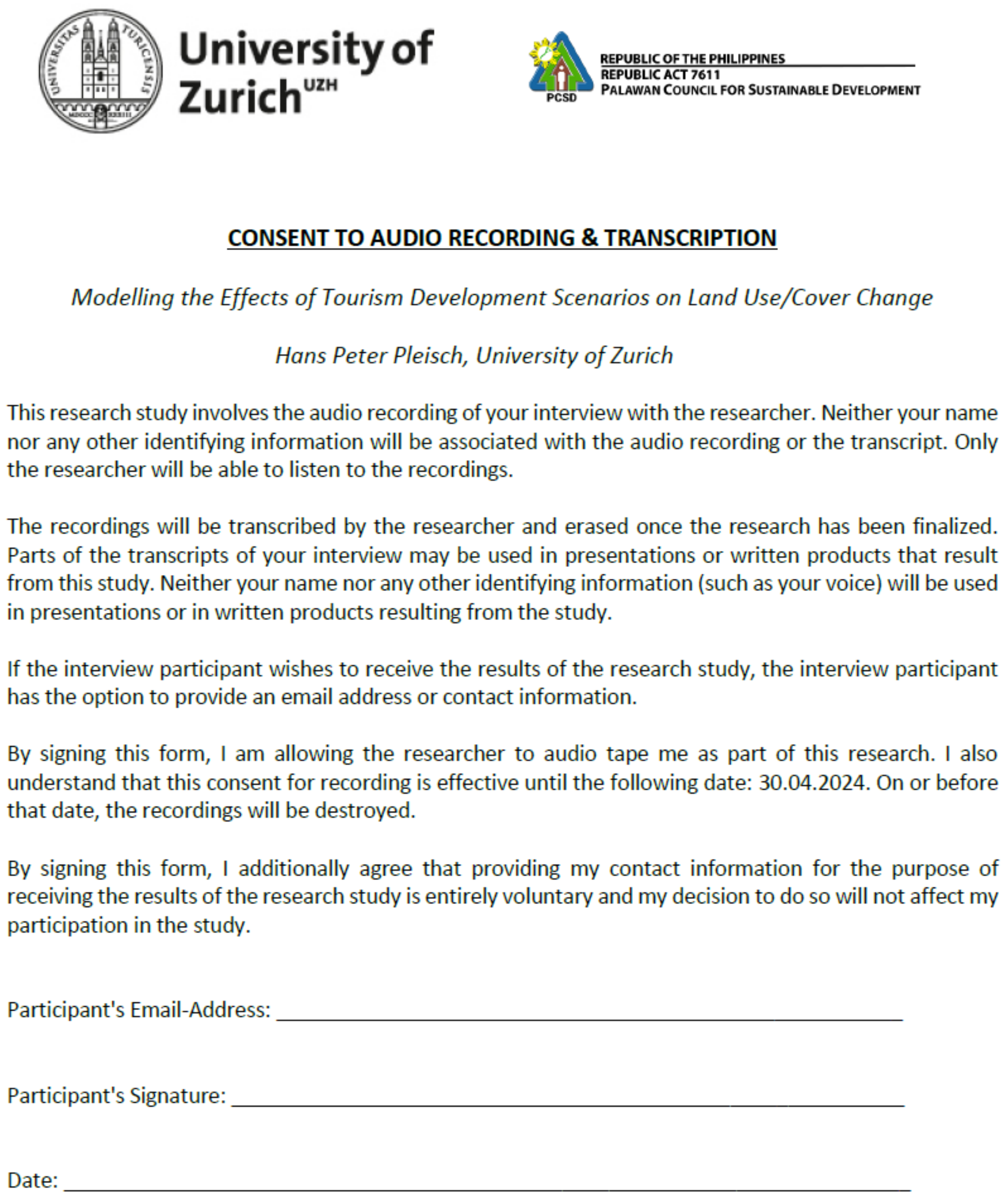


Figure A.6: Map visualisation of BU expansion under the various tourism development scenarios

Appendix B Interview Material



University of Zurich UZH

REPUBLIC OF THE PHILIPPINES
REPUBLIC ACT 7611
PALAWAN COUNCIL FOR SUSTAINABLE DEVELOPMENT
PCSD

CONSENT TO AUDIO RECORDING & TRANSCRIPTION

Modelling the Effects of Tourism Development Scenarios on Land Use/Cover Change

Hans Peter Pleisch, University of Zurich

This research study involves the audio recording of your interview with the researcher. Neither your name nor any other identifying information will be associated with the audio recording or the transcript. Only the researcher will be able to listen to the recordings.

The recordings will be transcribed by the researcher and erased once the research has been finalized. Parts of the transcripts of your interview may be used in presentations or written products that result from this study. Neither your name nor any other identifying information (such as your voice) will be used in presentations or in written products resulting from the study.

If the interview participant wishes to receive the results of the research study, the interview participant has the option to provide an email address or contact information.

By signing this form, I am allowing the researcher to audio tape me as part of this research. I also understand that this consent for recording is effective until the following date: 30.04.2024. On or before that date, the recordings will be destroyed.

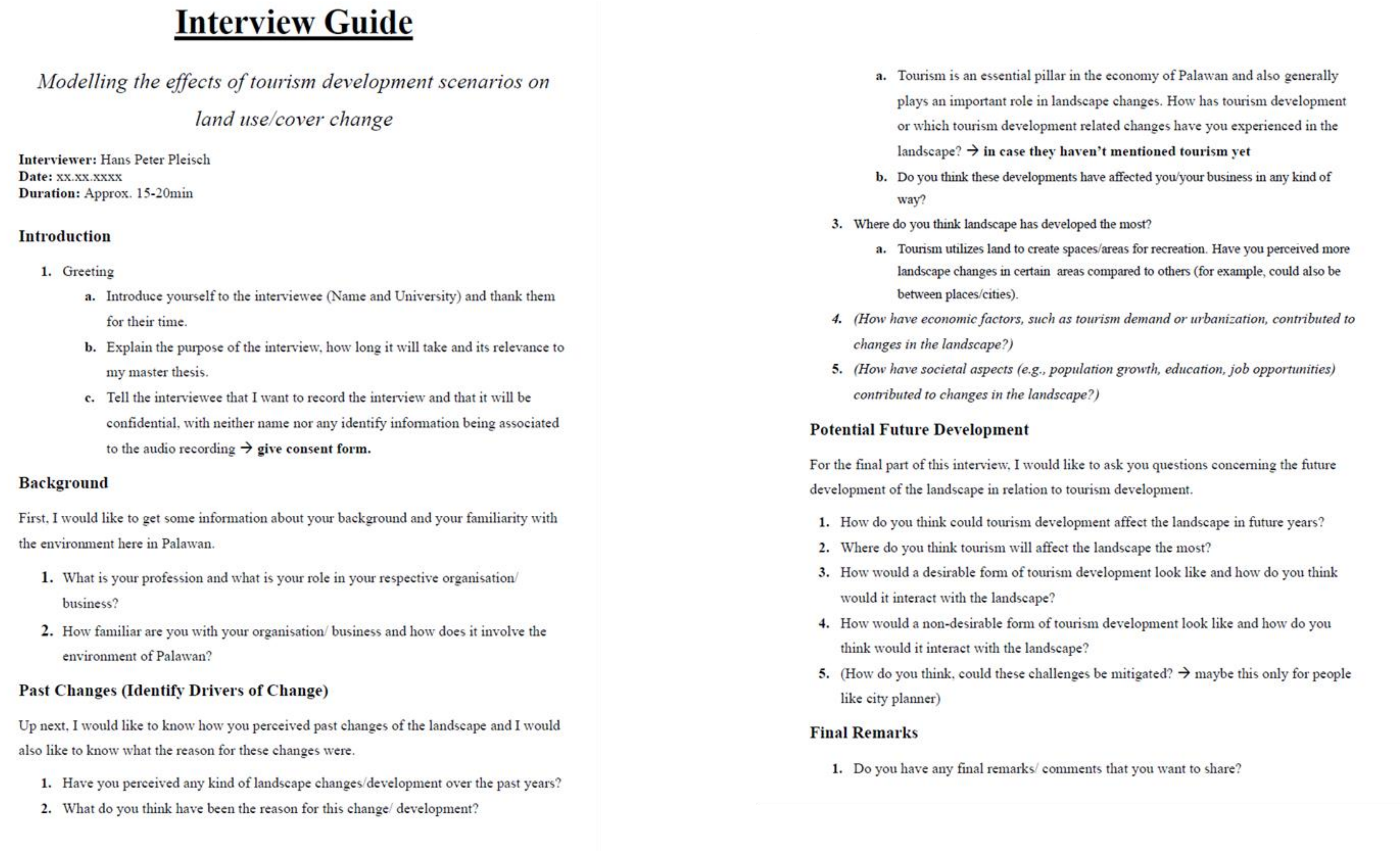
By signing this form, I additionally agree that providing my contact information for the purpose of receiving the results of the research study is entirely voluntary and my decision to do so will not affect my participation in the study.

Participant's Email-Address: ____

Participant's Signature: ____

Date: ____

Figure A.7: Interview consent form for stakeholder participants



Interview Guide

Modelling the effects of tourism development scenarios on land use/cover change

Interviewer: Hans Peter Pleisch
Date: xx.xx.xxxx
Duration: Approx. 15-20min

Introduction

1. Greeting
    a. Introduce yourself to the interviewee (Name and University) and thank them for their time.
    b. Explain the purpose of the interview, how long it will take and its relevance to my master thesis.
    c. Tell the interviewee that I want to record the interview and that it will be confidential, with neither name nor any identify information being associated to the audio recording → **give consent form.**

Background

First, I would like to get some information about your background and your familiarity with the environment here in Palawan.

1. What is your profession and what is your role in your respective organisation/ business?
2. How familiar are you with your organisation/ business and how does it involve the environment of Palawan?

Past Changes (Identify Drivers of Change)

Up next, I would like to know how you perceived past changes of the landscape and I would also like to know what the reason for these changes were.

1. Have you perceived any kind of landscape changes/development over the past years?
2. What do you think have been the reason for this change/ development?
    a. Tourism is an essential pillar in the economy of Palawan and also generally plays an important role in landscape changes. How has tourism development or which tourism development related changes have you experienced in the landscape? → **in case they haven't mentioned tourism yet**
    b. Do you think these developments have affected you/your business in any kind of way?
3. Where do you think landscape has developed the most?
    a. Tourism utilizes land to create spaces/areas for recreation. Have you perceived more landscape changes in certain areas compared to others (for example, could also be between places/cities).
4. *(How have economic factors, such as tourism demand or urbanization, contributed to changes in the landscape?)*
5. *(How have societal aspects (e.g., population growth, education, job opportunities) contributed to changes in the landscape?)*

Potential Future Development

For the final part of this interview, I would like to ask you questions concerning the future development of the landscape in relation to tourism development.

1. How do you think could tourism development affect the landscape in future years?
2. Where do you think tourism will affect the landscape the most?
3. How would a desirable form of tourism development look like and how do you think would it interact with the landscape?
4. How would a non-desirable form of tourism development look like and how do you think would it interact with the landscape?
5. (How do you think, could these challenges be mitigated? → maybe this only for people like city planner)

Final Remarks

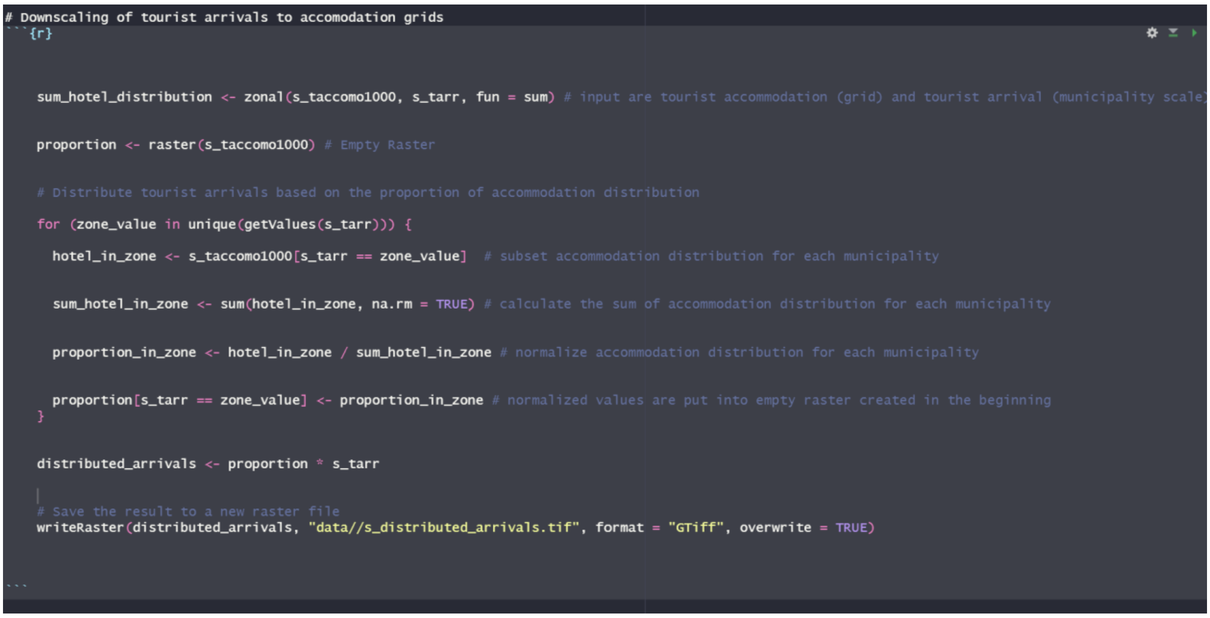
1. Do you have any final remarks/ comments that you want to share?

Figure A.8: Interview Guide for stakeholder interviews

Appendix C RStudio Scripts

~~~
# Disaggregate function
```{r}

  disaggregate <- function(oraster, resampled, output_folder, name){

    raster_disaggregated <- resampled*(prod(res(resampled)/res(oraster)))

    new_file_name <- file.path(output_folder, paste0(name, ".tif"))

    writeRaster(raster_disaggregated, filename = new_file_name, format = "GTiff", overwrite = TRUE)

    print("Raster was successfully disaggregated!")

    return(raster_disaggregated)

  }



```
~~~

Figure A.9: RStudio script to disaggregate raster data down to a 100m resolution



~~~
# Downscaling of tourist arrivals to accomodation grids
```{r}


  sum_hotel_distribution <- zonal(s_taccomo1000, s_tarr, fun = sum) # input are tourist accommodation (grid) and tourist arrival (municipality scale

  proportion <- raster(s_taccomo1000) # Empty Raster

  # Distribute tourist arrivals based on the proportion of accommodation distribution
  for (zone_value in unique(getValues(s_tarr))) {
    hotel_in_zone <- s_taccomo1000[s_tarr == zone_value]  # subset accommodation distribution for each municipality

    sum_hotel_in_zone <- sum(hotel_in_zone, na.rm = TRUE) # calculate the sum of accommodation distribution for each municipality

    proportion_in_zone <- hotel_in_zone / sum_hotel_in_zone # normalize accommodation distribution for each municipality

    proportion[s_tarr == zone_value] <- proportion_in_zone # normalized values are put into empty raster created in the beginning
  }

  distributed_arrivals <- proportion * s_tarr

  |
  # Save the result to a new raster file
  writeRaster(distributed_arrivals, "data//s_distributed_arrivals.tif", format = "GTiff", overwrite = TRUE)


```
~~~

Figure A.10: RStudio script to assign total tourist arrivals (municipality scale) to different raster cells where accommodations are located

Personal Declaration

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

Hans Peter Pleisch, April 2024