6 A Trade-Off Analysis of Sustainable Landscape Planning: A Case Study of Sintang Regency (Heart of Borneo), Kalimantan

Sopian Hidayat, Rina Wulandari, Noor Aini Zakaria, and Christy Desta Pratama

Abstract

Forest in Indonesia is among one of the richest biodiversity in the world. However, this forest is currently under threat due to several factors such as illegal logging, forest fire, and forest conversion. Considering the ecological and economic importance of this forest, the local government is committed to its protection and sustainable use under the umbrella of "Green Regency" and has been working with several organizations to develop long-term landscape planning. This research focuses on Sintang, West Kalimantan, that has a vast tropical forest with high biodiversity of flora and fauna. In 2016, the Sintang Regency has declared its commitment as a sustainable regency and committed to protecting the forest within the framework of the Sustainable Development Goals (SDG). The research aims are to analyze land use and land cover (LULC) changes from 2006 to 2016 and forecast the land use and land cover on business as usual (BAU) and green scenario. The analysis used Land Change Modeler (LCM) module in TerrSet software to project the land cover. Based on the analysis of land cover change from 2006 to 2016, the secondary forest area experienced the largest decrease (−87,680 ha), while the plantation area had the largest increase (87,540 ha). The BAU scenario projected that plantations would grow to 253,571 ha in 2030 while only 180,300 ha under the Sintang Lestari scenario (green scenario). The results of the Sintang Lestari scenario showed that

S. Hidayat (✉) · C. D. Pratama
Conservation Strategy Fund (CSF) Indonesia, Jakarta, Indonesia

R. Wulandari
Independent Researcher, Bogor Utara, Jawa Barat, Indonesia

N. A. Zakaria
Malaysian Environmental Economics Association (MEEA), c/o Institute of Forestry and Forest Products (INTROP), Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia

Z. Samdin et al. (eds.), *Tropical Forest Ecosystem Services in Improving Livelihoods For Local Communities*, https://doi.org/10.1007/978-981-19-3342-4_6

significant plantation development can still be achieved while protecting the remaining forest cover. However, limiting the expansion of plantation areas is only possible if current spatial plans are monitored and non-compliance with spatial planning is strictly enforced. The findings of the analysis can serve as a strong basis for future land development in Sintang Regency.

Keywords

Sustainable landscape · Land use · Land cover · Sustainable Development Goals (SDG) · Indonesia

6.1 Introduction

Forest plays a major role in supporting human life. Forest provides its services through the source of food and energy, reserving water supply, maintaining soil fertility, preventing humans from natural disasters such as floods and land erosion control, education and research, natural tourism, and others (García-Nieto et al., 2013; Nowak et al., 2015; Brockerhoff et al., 2017; Aznar-Sánchez et al., 2018). García-Nieto et al. (2013) and Brockerhoff et al. (2017) highlighted that forest diversity plays an important factor in sustaining human life through ecosystem function and the provision of ecosystem services. Protecting the forest means preserving the natural habitats and their ecosystem including sustaining the human-life balance (Aznar-Sánchez et al., 2018).

In Indonesia, as in many other parts of the world, population growth, economic growth, and climate change issues turn out to increase pressures on natural resources. These challenges need to be addressed simultaneously. Studies have proven the relationship between economic growth and CO_2 emissions (Fankhauser & Tol, 2005; Hwang & Yoo, 2012; Shahbaz et al., 2013; Knight & Schor, 2014). Higher growth rates result in higher emissions, which contribute to climate change. Climate change has a direct impact on the economy and caused global warming and reduced future welfare (Fankhauser & Tol, 2005). Future development should be consistent with the implementation of the green growth plan while simultaneously focusing on economic growth with low carbon emissions and, finally, achieving the Sustainable Development Goals (Noorbakhsh & Ranjan, 1999; Knight & Schor, 2014). Sustainable development is a development that meets the needs of the present without compromising future generations' ability to meet their own needs (Pearce et al., 1994), and natural capital owned by regions must be preserved in the long run (Noorbakhsh & Ranjan, 1999).

Indonesia forest stands are under severe threat due to deforestation and forest degradation which have occurred in both mineral soil and peatland. Deforestation has contributed to CO_2 emissions as a result of forest conversion to other land uses particularly oil palm plantation expansion which creates an additional source of greenhouse gas emissions (Schebek et al., 2018). Emission from mineral lands mostly comes from forest encroachment, forest conversion to other land use, and forest fires (Malahayati & Masui, 2019; Afriyanti et al., 2019). Emission from peatlands originates in forest conversion, degradation, peat decomposition, peat fires, and mangrove conversion. Margono et al. (2014) highlighted that Indonesia forest cover loss between 2000 and 2012 was about 16 million ha of which 38% of it occurred within the Indonesian primary forest. From that period, the average forest cover loss was increased by 47,600 ha/year. Kalimantan Island is the second-highest forest loss after Sumatra Island. Most of the primary forest loss occurred in the lowland areas. Studies indicate that agricultural area expansion is the main driving factor causing deforestation in Kalimantan (Gunarso et al., 2013; Laurance et al., 2014; Margono et al., 2014; Abram et al., 2017). The remaining tropical forest in Kalimantan is under threat caused by the growing agricultural demand in the region.

6.1.1 Sintang and Sustainable Regency (Sintang Lestari)

Sintang is one of the regencies in West Kalimantan that has a vast tropical forest with high biodiversity of flora and fauna. In 2019, it has a total population of 403,000 people and a population density of 19 people/km^2 (Central Bureau of Statistic Indonesia, 2020). Of the total area (21,638 km^2), 59% of the regency area is designated as a forest area, and it also has a national park located in the southern part of the regency (Bukit Baka Bukit Raya National Park). The total forest area is 1,286,944 ha which consists of limited production forest (28%), protected forest (21%), production forest (6%), conservation area (3%), and convertible production forest (1%). Among the forested area, 396,566 ha is categorized as primary dryland forest and mostly located in the protected forest, limited production forest, and conservation areas. Despite its large designated forest area, the Sintang Regency experiencing the highest rates of deforestation, forest degradation, and forest fires. Deforestation in Sintang is primarily caused by high demand for land-based products (agriculture, plantation, and mining), encroachment, and other economic activities. Most people rely on agriculture as a source of income, and the agricultural sector plays an important role in the Sintang economy with high job opportunities. However, Sintang Regency faces serious development challenges, including the poverty rate of its population, which is currently among the highest in West Kalimantan, economic growth that is still below target, inadequate and inequitable basic infrastructure provision, and other issues. At the same time, pressure on natural resources is increasing. More than a hundred thousand indigenous people who live in the forest rely on it for a living, and most of them rely on the environmental services it provides, such as clean water and high air quality.

Since declaring its commitment as a Sustainable Regency in 2016, the local government has continued to improve itself and strive to provide greater welfare for its people while still paying attention to the sustainability of natural resources, particularly forests and land, and environmental conditions. This commitment certainly requires synergy between all elements of stakeholders in the Sintang District, including the district government and civil society. In addition, Sintang Regency has committed its district to move sustainably in the landscape and development planning. In light of the ecological and economic importance of the forest, the local government is committed to its protection and sustainable use under the framework of Sustainable Development Goals (SDG). With the commitment, the Sintang Government had conducted a multi-stakeholder and institutional design towards the sustainable regency and green growth pathways. This process accumulated stakeholders' voices in formulating a shared vision of the future landscape, with the forested area remaining constant or even expanding due to no room for deforestation. In addition, the government commitment to the green pathway needs to be assessed as the regency relies on natural and land-based resources for attracting economic growth.

In general, the purpose of this research is to conduct a trade-off analysis of sustainable landscape planning of the Sintang Regency. The research has two goals: (1) to analyze land use and land cover (LULC) changes from 2006 to 2016 (past 15 years) and (2) to project the land use and land cover on business as usual (BAU) and green scenario from 2016 to 2030. The outcomes of this research will be utilized to help the government make decisions and comprehend past land use changes. Furthermore, this will serve as a solid foundation for future land use projects aimed at achieving sustainable regency.

6.2 Data and Methodology

6.2.1 Study Area

The study covers an area of Sintang Regency, West Kalimantan Province. Sintang Regency is one of 14 regencies in West Kalimantan Province with a high forest cover. Sintang Regency is the third largest district in West Kalimantan Province, after Ketapang Regency (31,240 km^2) and Kapuas Hulu Regency (29,842 km^2). Sintang Regency has a total area of 21,638 km^2 and is divided into 14 sub-districts. The regency is endowed with an abundance of natural resources and forest ecosystems, which serve as the economic foundation for both the government and the local community. The topographic condition of the Regency is mostly hilly (62.74%) with elevation ranging from 8 to 2040 m above sea level (Fig. 6.1).

Sintang has two major rivers, Kapuas and Melawi, which were once the primary modes of community transportation. Currently, Sintang Regency's total forest area is 59% of its total area, accounting for 1.3% of Indonesia's total forest area (Central Bureau of Statistic Indonesia, 2020). Sintang Regency is committed to achieving sustainable development by preserving the remaining forest area.

6.2.2 Data

Data is gathered from both primary and secondary sources. Primary data were obtained through direct interviews with government stakeholders of the Sintang Regency. The study used secondary data, both spatial and non-spatial data. Spatial

Fig. 6.1 Sintang Regency. (Source: Indonesia Geospatial Agency (2006))

data includes administration boundary, series of the land cover map, and forest status. Administration data and base map derived from Indonesia Geospatial Agency (BIG), while data related to land cover and forest status derived from the Ministry of Environment and Forestry (MoEF). Land cover data from 2006 to 2016 were used in this study to analyze the trend of land use and land cover changes (LULCC), which was then used as the basis for the land use projection model for the year 2030 (Table 6.1).

Table 6.1 Data description

Data	Description	Source
Land cover (2006 and 2016)	Land cover in 2006 and 2016 in the Sintang Regency	Ministry of Environment and Forestry (KLHK)
The road	National roads, provinces, districts, and sub-districts/villages	Geospatial Information Agency; scale 1: 50,000
The river	Big river	Geospatial Information Agency; scale 1: 50,000
Hub (central activity)	Hub location	Geospatial Information Agency; scale 1: 50,000
Mills	Location of mills	World Wildlife Fund (WWF)
Business use permits and location permits	Business use permits and location permits in the Sintang Regency	Business use permits from National Land Agency (BPN) and location permit from spatial planning (RTRW)
Forest cover 2016	Forest cover in 2016	Ministry of Environment and Forestry (KLHK)
Deforestation 2006–2016	Deforestation areas between 2006 and 2016	Ministry of Environment and Forestry (KLHK) analyzed by Hatfield Indonesia
Plantation 2006–2016	Plantation area between 2006 and 2016	Ministry of Environment and Forestry (KLHK)

6.3 Methodology

6.3.1 Land Projection Model

Land projection analysis was performed by comparing two scenarios: Business as Usual (BAU) and *Sintang Lestari* scenario (SL) or known as a green scenario. The definition of scenario planning was obtained from a series of discussions and workshops facilitated by the Conservation Strategy Fund (CSF) and the Sintang Regency Government.

The projection model is based on the analysis of historical land cover changes, transition potential, and factors driving land use change. Land use projections for both scenarios were projected until 2030, following the above scenario's planning targets.

1. *Scenario Development*
   The scenario was developed in collaboration with relevant stakeholders in Sintang through the Focus Group Discussion (FGD). Scenario planning was carried out through a multi-stakeholder process from October 1–5, 2018. The facilitators for this scenario planning were representatives from academic institutions, Non-Government Organizations, Civil Society Organizations, and government staff in Sintang with a total of 15 facilitators. Each institution sends representatives of five people. The facilitators were trained for 2 days by the CSF team on how the scenario planning process took place and how to facilitate these

Table 6.2 Key indicators for the SL model scenario

Indicator	Model description	Model application
Zero deforestation	Forest cover based on land cover in 2016 must be protected, and conversion is prohibited	Zero deforestation (applies to primary and secondary forests)
Sustainable utilization of natural resources without damaging the environment		
Forests are protected to maintain river water quality		
Protected forests are free from illegal farming and illegal logging		
Follow/respect rules of strategic environmental assessment (KLHS) and spatial planning (RTRW)	Cultivation areas are restricted. No planting is permitted outside the current concession area	Plantations are restricted

activities. The scenario planning was attended by 60 representatives from cross-institutional/stakeholder participants.

During the FGD process, the land projection model scenario was defined and agreed upon by the stakeholders. The definition of each modelling scenario is as follows:

(a) BAU scenario: This scenario is based on the current district planning, where each land allocation is defined as in the District Spatial Plan. Under this scenario, no restrictions are implemented for areas allocated as development areas. Forested land is categorized under development areas and is allowed to be cleared.

(b) SL scenario: This scenario is generated based on land cover in 2016 in which forest cover must be protected and conversion is forbidden, cultivation area is restricted and planting is not allowed outside the current concession area. Land cover predictions are generated with the following limitations:
   - Zero deforestation: forest cover is considered as a protected area and no conversion of forest cover is allowed.
   - Plantation restrictions: plantation is restricted outside the current concession area.

Limitations used in the SL scenario are taken from indicators in the policy direction matrix in the regional medium-term development plan (RPJMD) of the Sintang Regency for the 2016–2021 period. The planning documents have been aligned with sustainable district goals which are reflected through several indicators including forest and protected area conservation, air and environmental quality improvement, and others. Indicators included in the model are only those that can be displayed spatially. Furthermore, selected indicators were treated as a limiting factor for development areas in the modelling of the SL scenario as shown in Table 6.2.

2. *Projection of Land Use and Land Cover (LULC)*

We used the Land Change Modeler (LCM) module in TerrSet software to project the land cover. LCM predicts land change based on historical changes that occurred at two points in time. In this study, land cover in 2006 and 2016 is used as initial data to see trends in historical change. Land cover prediction is carried out for 2030. In general, there are three steps in LCM, namely, change analysis, transition potential, and change prediction, as follows (Eastman, 2021):

(a) The change analysis stage compares and analyzes land cover between two periods. At this stage, the most dominant land cover changes can be identified and mapped so that the driving factors for each change can be determined.
(b) The transition potential stage identifies and maps potential changes that may occur based on historical change data. Change projections can be made on one transition or multiple transitions based on the same driving factor. The change probability modelling is done using Multi-Layer Perceptron (MLP). MLP was chosen because it can model more than one change at the same time. Driving factor use was defined based on their influence on the transition. In this study, distance from the road, distance from the open area, and distance to existing plantation area are considered as the most influencing factors to land change in Sintang.
(c) Change projection is the last stage of the modelling process. At this stage, LCM projects land cover for the year 2030. The model determines how the variables influence future change and how much change took place between 2006 and 2016 and then calculate a relative amount of transition to the year 2030. To make the model more robust, Land Change Modeler allows for the incorporation of constraints or limiting factors; in this study forest cover on the year 2016 and plantation permits are treated as a limiting factor for deforestation and plantation expansion. The workflow for the model is shown in Fig. 6.2.

6.4 Results and Discussion

6.4.1 Land Use and Land Cover Changes (LULCC) in Sintang from 2006 to 2016

Land use and land cover (LULC) maps for the period 2006–2016 are used as a basis for mapping historical LULC changes in Sintang Regency. Between 2006 and 2016, the total LULCC in Sintang Regency was 226,311 ha, contributing to 10% of the total regency boundary (Fig. 6.3). Historical land cover change trends were obtained from land cover maps in 2006 and 2016. During this period, land cover change in Sintang Regency was dominated by plantation expansion (e.g., oil palm or rubber) (4.19%), secondary forest loss (−4.08%), and swamp shrub loss (0.98%). Further analysis showed that the conversion of the secondary forest was mostly to plantation (35%), shrubs (32%), and mixed dryland agriculture (29%). From the result, it can be seen that the increase in plantations occurred quite rapidly between the period of 2006 and 2016. This can be observed in the contribution of the Agriculture, Plantation, Forestry, and Fisheries sector, which reached 30% in 2011, followed

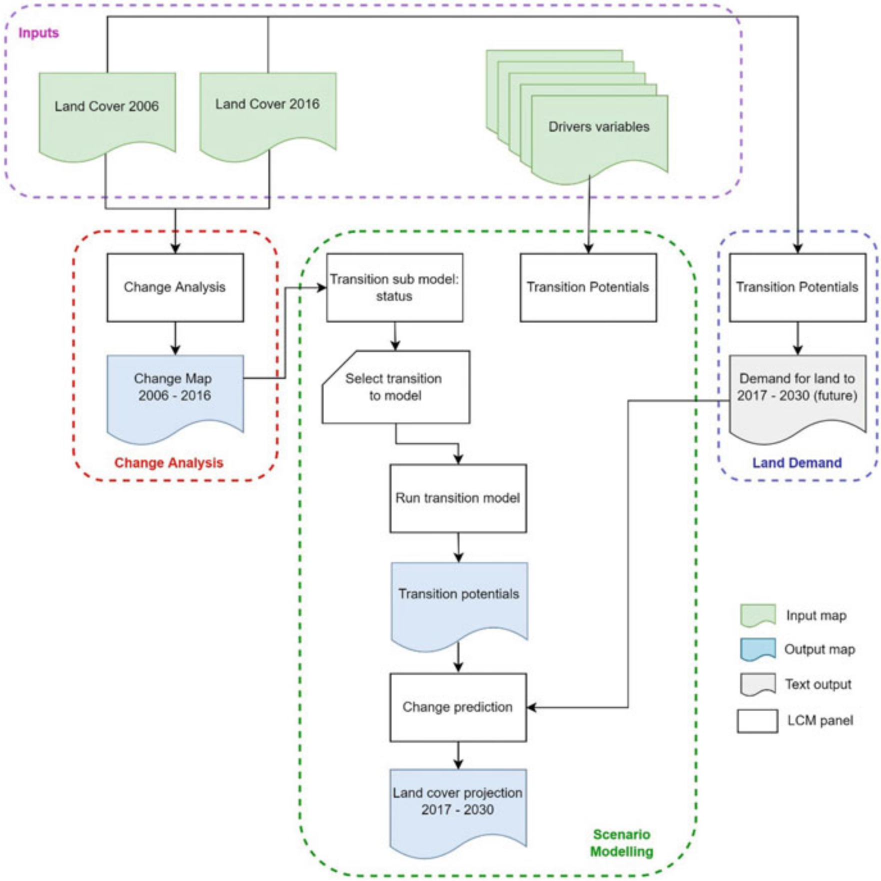

Fig. 6.2 The methodology used to analyze land use and land cover in Sintang using Land Change Modeler (LCM) software

by the Trade, Hotel, and Restaurant sector (20%) and other sectors (Central Bureau of Statistics, 2012).

This is also supported by the increase in the number of plantation crops, especially in oil palm plantations. The increase in the number of plantations in Sintang is almost the same as the decrease in the number of deforested areas in secondary forests. This means that the process of changing land status from forest to plantation has begun by changing from secondary forest to plantation. The main contributor to the increase in plantations during this period in Sintang Regency was secondary forest conversion. This trend is expected to be continued in the future, especially for oil palm plantations to meet the production target set by the government.

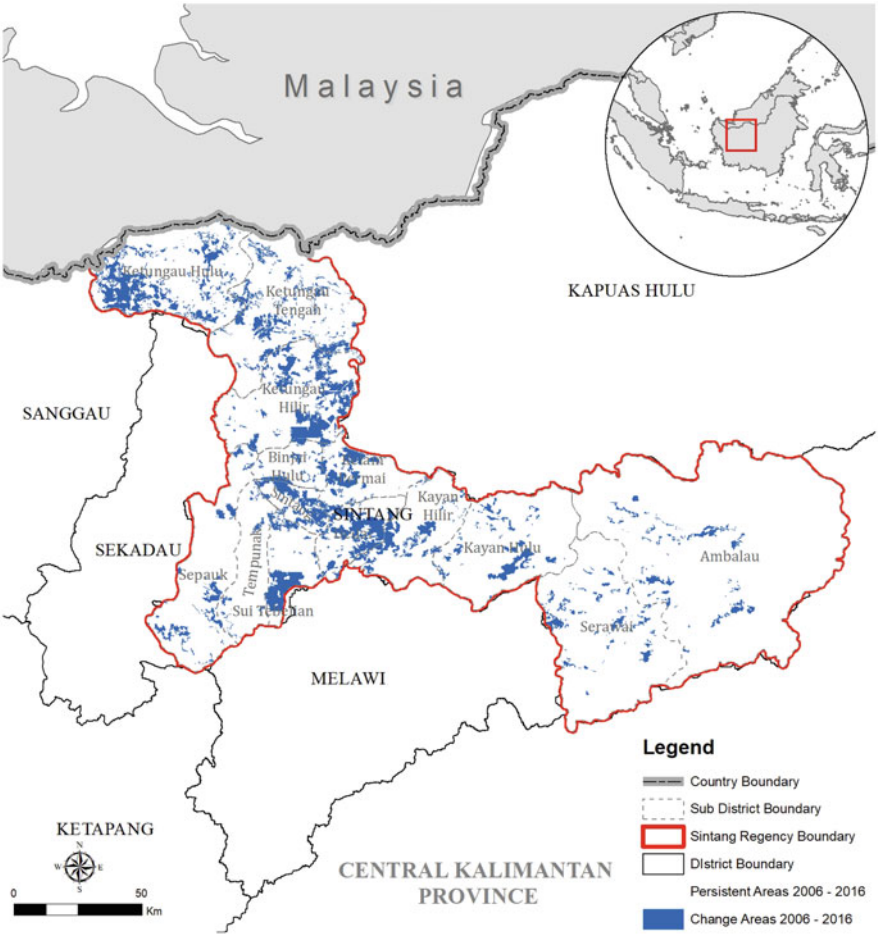

Fig. 6.3 Land use and land cover changes in Sintang from 2006 to 2016. (Source: Map produced based on the analysis)

6.4.1.1 Projection of Changes in Land Use and Land Cover from 2016 to 2030

BAU Scenario

The result of the BAU scenario in Fig. 6.4 is generated using Land Change Modeler Software. Under the BAU scenario, the software projected the future land cover based on the information from historical changes that occurred within the area. There are no limiting factors applied in the scenario. The result showed that, under the BAU scenario, by the year 2030 the regency expects to continue secondary forest loss (107,000 ha) and primary forest loss (10,000 ha). Plantation and open land are expected to be increased continuously to meet the government's development target

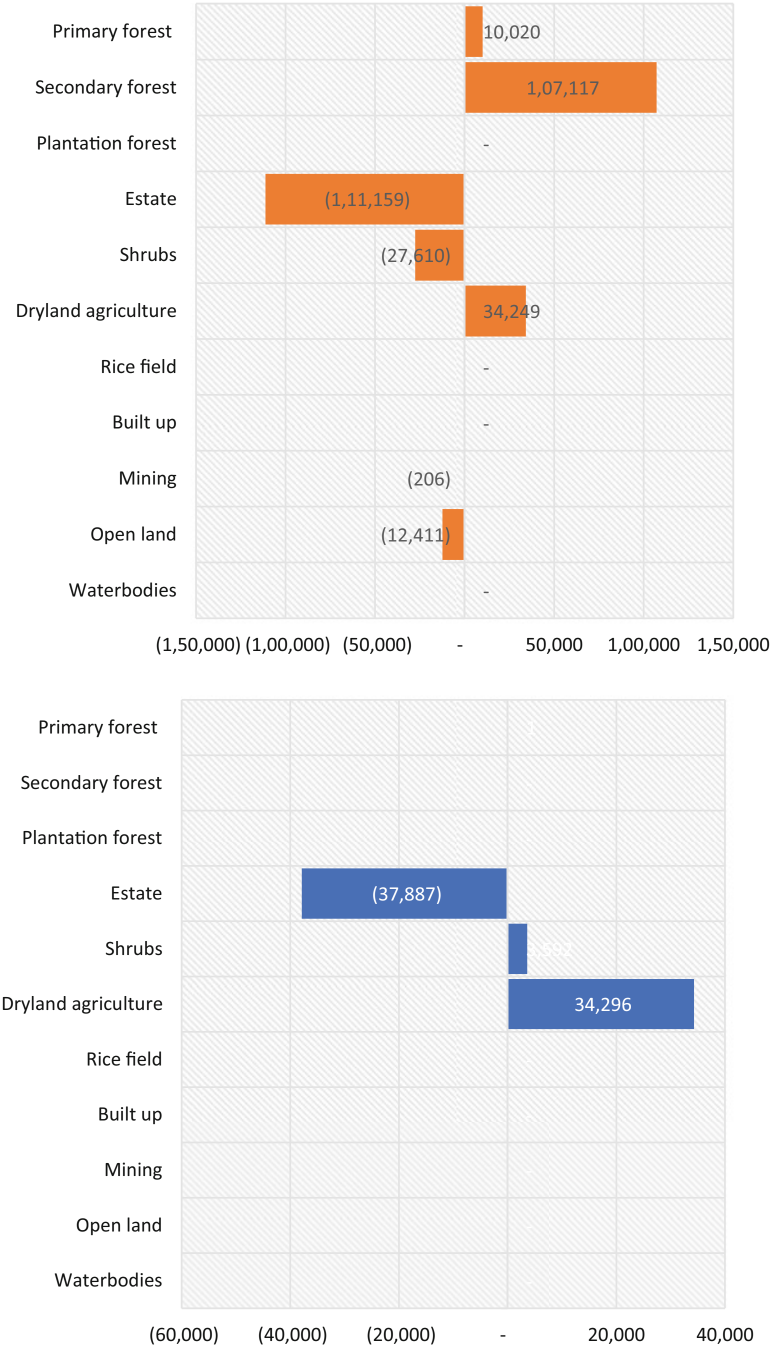

Fig. 6.4 Land cover projection under BAU and *Sintang Lestari* scenario from 2016 to 2030

of 2030. By 2030, some forest areas will be replaced by plantations, shrubs, dryland agriculture, mining, and open land. The majority of deforestation is expected to occur in secondary forest areas. This is assumed due to the accessibility factor of the forest area, where the secondary forest is located in a flat and accessible location compared to the primary forest area.

Sintang Lestari (SL) Scenario

The result of the Sintang Lestari scenario in Fig. 6.4 is generated using Land Change Modeler Software. The SL Scenario expects LULCC to implement a zero-deforestation policy, which means that existing forested land will remain the same in 2030. Plantation areas, shrubs, and mixed agricultural land are expected to change. As a result of the increased plantation area, the agricultural area, scrub, and mixed dryland are expected to decrease. Expansion of plantation areas will be limited as a result of implementing constraints for areas outside the current cultivation permit.

Compared to the BAU scenario, the SL scenario reduces plantation expansion by more than 50% in 2030. This is due to the implementation of a zero-deforestation commitment that preserves the remaining forest cover in 2016. Moreover, the second constraint implemented in this scenario only allows plantation expansion under existing permits. Changes in land cover from 2006 to 2016 showed that secondary forest is the biggest contributor to the increase in plantations, so this limits the massive plantation expansion. However, plantation land is still experiencing expansion from shrubs (3592 ha) and conversion to dryland agriculture (34,295 ha). This is in line with finding from Sharma et al. (2019) using three scenarios (BAU, conservation, and sustainable-intensive scenario) of land use projection in West Kalimantan which showed that oil palm plantation will continue increasing up to 3.2 million ha in 2030, while the conservation scenario is only 0.53 and 2.8 million ha under sustainable-intensive scenario.

BAU Scenario Vs. Sintang Lestari Scenario

Figure 6.5 illustrates a comparison of the LULC for 2016 conditions, the BAU 2030 scenario, and the SL 2030 scenario. Under the BAU scenario, forest cover almost disappears in the northwest, near the border with Malaysia, as a result of plantation development. In the southwest, forest cover has shifted to mixed scrub and dryland agriculture, leaving a small patch of forest cover. Deforestation is also found in the eastern part of the district, which is an ecotone area between forest and non-forest. This condition is inconsistent with the district's spatial plan, where the eastern part of the district is allocated as a forestry development area.

The most significant difference in land change between the BAU and SL scenarios occurred in the southwest of the district. Additional information can be obtained by running the BAU and SL scenarios on an annual basis to determine annual trends in LULC changes. In both scenarios, the results showed a similar pattern for changes in the plantation area. Under the BAU scenario, plantations are expected to grow and then decline gradually. However, the SL scenario revealed no changes in primary forest, secondary forest, open land, or mining.

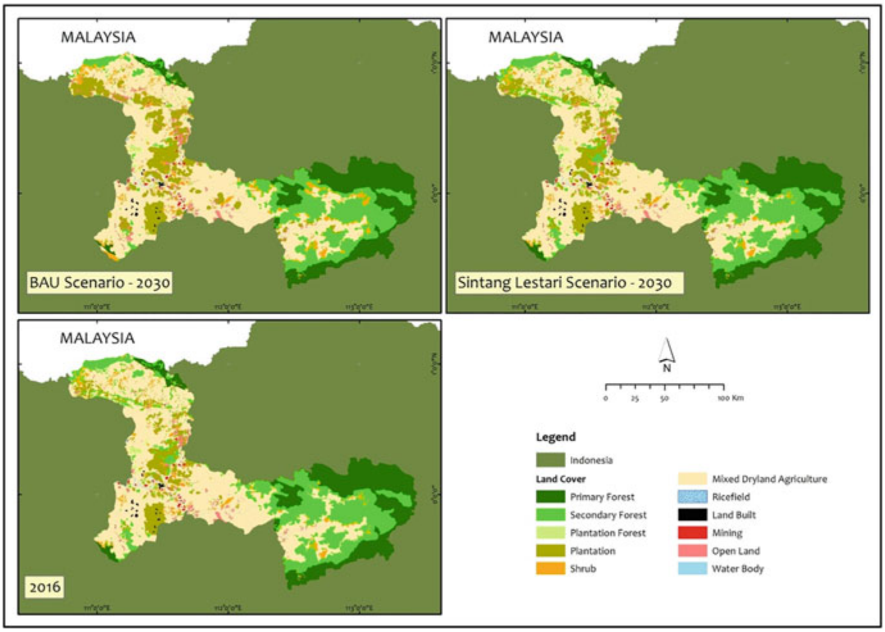

Fig. 6.5 Comparison of the LULC for 2016, the BAU 2030, and the SL 2030 scenarios

Generally, the total change in the area of Sintang Regency from 2006 to 2016 is 226,311 ha or 10% of the regency area. The high rate of deforestation in secondary forests is due to Sintang's economic structure, which still relies on natural resources and land. Deforestation also occurs in bushland and primary forest, but at a slower rate than in the secondary forest. Previous studies discovered that the status of the deforested land area had changed its function into plantations, shrubs, and dryland agriculture (Sukri et al., 2020). Meanwhile, the number of plantation crops, particularly oil palm plantations, has increased. The increase in the number of plantations in Sintang is almost the same as the deforested areas in secondary forests. This means that the process of converting land from forest to plantation has started by converting secondary forest to the plantation. Our findings were consistent with previous research indicating the rapid expansion of plantations, particularly oil palm, in Kalimantan (Carlson et al., 2012; Siregar et al., 2018). From 1992 to 2012, the pattern of forest conversion in West Kalimantan Province started with forest conversion to other land use (mostly rain-fed paddy fields or shrubs), followed by conversion to the plantation as the final land use (Siregar et al., 2018).

6.4.1.2 Further Analysis and Comparison with More Recent Landscape Planning and Sintang Lestari Regulations Is Needed

The scenarios presented in this analysis are not based on the most recent data, nor are they compared to the most recent Sintang landscape planning and policy documents. However, by the time the scenario was completed, the government of Sintang was made aware of these results, and open discussions with relevant agencies (viz., the Landscape and Spatial Planning Agency, and the Development Planning Agency) were held to inform on their further planning.

By 2022, Sintang plans to revise its primary landscape planning document (the Regional Spatial Plan) and also to have a detailed sectoral spatial planning (or the *Rencana Detail Tata Ruang*). The scenarios presented here need to be further updated with recent data and aligned with Sintang priorities. And at the same time, the leading agency of landscape planning would need to use the updated version to inform their decision-making as well as to further align the trade-off presented in the scenarios to actual planning.

6.5 Conclusion

Land use in Indonesia is very dynamic and changes over time. Understanding landscape dynamics and ongoing processes within the landscape requires an understanding of land use change. It is used to assist the government in making decisions. Understanding historical land use change can also serve as a strong basis for future land use projects. This is to comprehend the consequences of current planning practices and to design government interventions in a landscape for future benefits.

Based on the analysis of land cover change from 2006 to 2016, the secondary forest area experienced the largest decrease (−87,680 ha), while the plantation area had the largest increase (87,540 ha). Further analysis showed that most of the secondary forest was converted to plantations. This trend is projected to continue under the BAU scenario in which plantations will grow to 253,571 ha in 2030. The SL scenario (green scenario) predicted only 180,300 ha of plantation growth by 2030. However, the projection results for the SL scenario used "zero deforestation," indicating that significant plantation development can still be achieved while protecting the remaining forest cover in Sintang Regency.

If the government chooses the SL scenario, it can still maintain economic growth, but it will require significant efforts to improve the value added of current forest and land-based resources, increase the current productivity of agricultural and plantation products, and shift the GDP main sectors from land-based resources to other sectors such as service and financial sectors, communication, and others to generate GDP.

However, limiting the expansion of plantation areas is only possible if current spatial plans are monitored and enforcement on non-compliance with spatial planning is implemented. The trade-offs should also be acknowledged and described clearly in the forthcoming planning documents.

Acknowledgements This research is part of the author project on Sustainable Landscape Planning in Sintang, West Kalimantan, Indonesia. The authors would like to express their sincere gratitude to the David and Lucile Packard Foundation for funding this project. The authors would also like to acknowledge the support from Hatfield Indonesia, an institution that provides training and analysis during the implementation of this project.

References

Abram, K. N., Meijaard, E., Wilson, A. K., et al. (2017). Oil-palm community conflict mapping in Indonesia: A case for better community liaison in planning for development initiatives. *Applied Geography, 78*, 33–44. https://doi.org/10.1016/j.apgeog.2016.10.005

Afriyanti, D., Hein, L., Kroeze, C., et al. (2019). Scenarios for withdrawal of oil palm plantations from peatlands in Jambi Province, Sumatra, Indonesia. *Regional Environmental Change, 19*, 1201–1215. https://doi.org/10.1007/s10113-018-1452-1

Aznar-Sánchez, J. A., Belmonte-Ureña, L. J., López-Serrano, M. J., et al. (2018). Forest ecosystem services: An analysis of worldwide research. *Forests, 9*(8), 453. https://doi.org/10.3390/f9080453

Brockerhoff, E. G., Barbaro, L., Castagneyrol, B., et al. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation, 26*(13), 3005–3035. https://doi.org/10.1007/s10531-017-1453-2

Carlson, K. M., Curran, L. M., Ratnasari, D., et al. (2012). Committed carbon emissions, deforestation, and community land conversion from oil palm plantation expansion in West Kalimantan, Indonesia. *Proceedings of the National Academy of Sciences, 109*, 7559–7564.

Central Bureau of Statistic Indonesia. (2020). *Kabupaten Sintang Dalam Angka 2019*. Badan Pusat Statistik. Retrieved from www.sintang.bps.go.id

Central Bureau of Statistics. (2012). Retrieved from https://www.bps.go.id

Eastman, J. R. (2021). *TerrSet 2020 geospatial monitoring and modelling system. Manuals*. Clarklab.

Fankhauser, S., & Tol, R. S. J. (2005). On climate change and economic growth. *Resource and Energy Economics, 27*, 1–17. https://doi.org/10.1016/j.reseneeco.2004.03.003

García-Nieto, A. P., García-Llorente, M., Iniesta-Arandia, I., et al. (2013). Mapping forest ecosystem services: From providing units to beneficiaries. *Ecosystem Services, 4*, 126–138. https://doi.org/10.1016/j.ecoser.2013.03.003

Gunarso, P., Hartoyo, M. E., Agus, F., & Killeen, T. J. (2013). *Oil palm and land-use change in Indonesia, Malaysia and Papua New Guinea*. Reports from the Technical Panels of the 2nd Greenhouse Gas Working Group of the Roundtable on Sustainable Palm Oil (RSPO). RSPO.

Hwang, J. H., & Yoo, S. H. (2012). Energy consumption, CO_2 emissions, and economic growth: Evidence from Indonesia. *Quality & Quantity, 48*(1), 63–73. https://doi.org/10.1007/s11135-012-9749-5

Indonesia Geospatial Agency. (2006). Retrieved from https://tanahair.indonesia.go.id/portal-web/

Knight, K. W., & Schor, J. B. (2014). Economic growth and climate change: A cross-national analysis of territorial and consumption-based carbon emissions in high-income countries. *Sustainability, 6*, 3722–3731. https://doi.org/10.3390/su6063722

Laurance, W. F., Sayer, J., & Cassman, K. G. (2014). Agricultural expansion and its impacts on tropical nature. *Trends in Ecology & Evolution, 29*(2), 107–116. https://doi.org/10.1016/j.tree.2013.12.001

Malahayati, M., & Masui, T. (2019). The impact of green house gas mitigation policy for land use and the forestry sector in Indonesia: Applying the computable general equilibrium model. *Forest Policy and Economics, 109*, 102003. https://doi.org/10.1016/j.forpol.2019.102003

Margono, B. A., Potapov, P. V., Turubanova, S., et al. (2014). Primary forest cover loss in Indonesia over 2000–2012. *Nature Climate Change, 4*, 1–6. https://doi.org/10.1038/NCLIMATE2277

Noorbakhsh, F., & Ranjan, S. (1999). A model for sustainable development: Integrating environmental impact assessment and project planning. *Impact Assessment and Project Appraisal, 17*(4), 283–293. https://doi.org/10.3152/147154699781767684

Nowak, D. J., Poudyal, N. C., McNulty, S. G. (2015). Chapter 4: Forest ecosystem services: Carbon and air quality. In *Trees at work: Economic accounting for forest ecosystem services in the U.S. South*. Retrieved from https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs226/gtr_srs226_ch4.pdf

Pearce, D. W., Atkinson, G. D., & Dubourg, W. R. (1994). The economics of sustainable development. *Annual Review of Energy and the Environment, 19*, 457–474.

Schebek, L., Mizgajski, J. T., Schaldach, R., & Wimmer, F. (2018). Land-use change and CO_2 emissions associated with oil palm expansion in Indonesia by 2020. In B. Otjacques, P. Hitzelberger, S. Naumann, & V. Wohlgemuth (Eds.), *From science to society. Progress in IS*. Springer.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Leitão, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews, 25*, 109–121.

Sharma, S. K., Baral, H., Laumonier, Y., Okarda, B., Komarudin, H., Purnomo, H., & Pacheho, P. (2019). Ecosystem services under oil palm expansion scenarios in West Kalimantan, Indonesia. *Ecosystem Services, 39*. https://doi.org/10.1016/j.ecoser.2019.100978

Siregar, P. G., Supriatna, J., Koestoer, R. H., & Harmantyo, D. (2018). System dynamics modeling of land use change in West Kalimantan, Indonesia. *BIOTROPIA-The Southeast Asian Journal of Tropical Biology, 25*(2), 103–111. https://doi.org/10.11598/btb.2018.25.2.792

Sukri, W., Oktavianus, B., Anastasia, F. P., Prawiyanto, Y., Isnandar, A., Subariyanti, E., Hermanto, F., Epi, P., Perdana, Z. H., Susanti, S., Setiawan, H., Putri, S. C., Wihastuti, S. J., Pasaribu, P. R., Istanti, R. P., & Peteru, S. (2020). Sintang District, West Kalimantan, Indonesia. In C. Stickler et al. (Eds.), *The state of jurisdictional sustainability*. EII/CIFOR.