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Land transformation through the development of oil palm plantations in the ex-mega rice project (EMRP) area, Central Kalimantan

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Abstract: The Mega Rice Project in Central Kalimantan was a government initiative started in 1995 to convert up to one million hectares of dominantly peat swamp forest to rice cultivation. However, the project eventually ended up in failure before the whole area was land cleared, among others was due to inappropriate canalling design that caused excessive drainage which was exacerbated by a prolonged drought and all together resulted in subsequent burnt of remaining forest vegetation and the peat layer leading to a drastic change of the land and soil condition namely became very poor for rice cultivation. Since then, various overcoming programs have been implemented in this Ex-Mega Rice Project (EMRP) and the main program was the governmental peatland ecosystem restoration program. Overlapping with this restoration program implementation period, parts of the EMRP area were then used mainly by private companies for oil palm plantation. The objective of this research is to elaborate the pattern and impact of land use change within the area of the EMRP into oil palm plantation. This study analyzed land use change in the EMRP area between 2015 and 2024, focusing on the transition to oil palm plantations. Using high-resolution satellite imagery from Landsat 8 and Sentinel 2, this study applied supervised classification with the Support Vector Machine (SVM) method to classify land cover types. Land cover changes were analyzed using a Sankey diagram to visualize transitions across classes over time. The results revealed that forest cover decreased from 58.1% (858,383 ha) in 2015 to 48.2% (711,973 ha) in 2024, while oil palm plantation expanded to cover 18.1% (265,000 ha) of the total study area. The oil palm plantation has significant economic implications, including employment creation, export increment, and infrastructure enhancement. The expansion of oil palm plantation in the EMRP has become a very significant part of the growth of the oil palm sector in the surroundings that eventually will attract more investments and generate more employment, and therefore increasing the region's economic growth as well as impacting the national economy.

Keywords: Peatland Reclamation, Ex-Mega Rice Project (EMRP), Land Use Change, Oil Palm Plantation.

Introduction

The reclamation of peatlands in Central Kalimantan, initiated by the Indonesian government in the mid-1990s, was part of an ambitious effort to achieve national self-sufficiency in rice production. Known as the Mega Rice Project (MRP), this initiative aimed to convert over one million hectares of peatland into productive rice paddies. Governed by Presidential Decrees No. 82/1995, No. 74/1998, and No. 133/1998, the MRP was eventually terminated in 1999 through Presidential Decree No. 80/1999, after it became evident that the project had failed to achieve its intended goals. Rather than creating productive agricultural land, the MRP resulted in severe environmental degradation, marked by extensive drying of wetlands and frequent peat fires that exacerbated ecological damage in the region (Suwito et al., 2022). As part of the effort to create viable agricultural land, the project involved the construction of an extensive network of primary, secondary, and tertiary drainage canals, which inadvertently over-drained the peatlands, leading to the depletion of water from peat domes and accelerating the drying process. The subsequent peat fires resulted in the loss of the surface peat layer, exposing the underlying mineral soils (Budiman et al., 2020; Yuwati et al., 2021). Peat domes, which naturally store rainwater and prevent flooding during the dry season, became severely compromised. The construction of drainage canals to cross-cut these domes disrupted the natural water balance, causing land subsidence and altering water levels (Suwardi et al., 2005).

In addition, the peatlands in Central Kalimantan typically overlie marine sediments rich in pyrite (FeS_2). Due to the exposure of the pyrite-containing mineral layer to the surface of the ground, the pyrite is oxidized resulting in very acidic soil (Firmansyah, 2014). Such soils are widely known as acid sulfate soils and classified as Sulfaquents or Sulfaquepts under the Soil Taxonomy system. Highly acidic sulfate soils can pose a serious risk to the health of the plants including the harm of abundant soluble Aluminum ion, and in general in very acidic condition essential nutrients are easily leached out from the soil. Consequently, many plant species cannot grow well or even will die, leaving the acid-tolerant ones (Suwardi et al., 2009). With poor soil conditions (dry, low pH, and nutrient deficiencies), the growth and hence yield of rice planted in the MRP area during the project were extremely poor. As a result, farmers abandoned their rice fields and the lands were then overgrown with bushes. (Novitasari et al., 2018). For further agricultural development in such acidic soils, some soil amendments including organic materials, humic substances, lime, fly ash, as well as fertilizers are indispensable with proper manners in application, to counter the adverse conditions and improve productivity (Suwardi, 2019).
Following the termination of the MRP project, vast areas within the MRP area have become the so called lahan bongkor, which refers to peatlands that are tremendously degraded or damaged that are abandoned and, ultimately, become idle land (Irwani et al. 2022). In response to these issues, peatland restoration emerged as a potential solution to mitigate the environmental damage happen in the Ex-Mega Rice Project EMRP area. Restoration efforts had focused on reestablishing the peatland's structure and function, allowing it to retain water, retard soil acidification, and restore ecosystem balance. However, these efforts faced numerous challenges, including economic, social, and environmental trade-offs, which often led to differing priorities among stakeholders. The success of peatland restoration depends not only on aligning these diverse priorities but also on improved governance and capacity building (Hergoualc'h et al., 2018; Wicaksono and Zainal, 2022).
The development of oil palm plantation in Indonesia has a positive impact on economic and social conditions. Development of oil palm plantations are being carried out on peatlands elsewhere in Indonesia, but several things need to be tightly considered in the operation. Considering that peatland is fragile and susceptible to change the soil onto acid sulfate soils when the underlying mineral sediment is composed of sulfidic material, then sustainable management is of big concern, especially the water management (Sari et al., 2019).
The objective of this research is to analyze the land use changes of the Ex-Mega Rice Project (EMRP) area in Central Kalimantan to oil palm plantation and to assess the impacts of oil palm development in this area.

Results and discussions

Land use changes

Table 1 shows the changes in land use within the EMRP area in Central Kalimantan over the years 2015, 2020, and 2024 and Figure 1 shows the spatial pattern. Significant trends are observed in the transitions between land use types, highlighting shifts in forest cover, shrubland, and the expansion of oil palm plantations. There is a consistent decrease in forest cover from 58.1% (858,383 ha) in 2015 to 48.2% (711,973 ha) in 2024. On the other hand, oil palm plantation has increased rapidly, from 11.5% (169,946 ha) in 2015 to 20.9% (308,894 ha) in 2024. This indicates a loss of forested areas, likely due to direct conversion to other uses, especially oil palm plantation. Concerning the whole Central Kalimantan, oil palm expansion is a primary driver of deforestation in this province, with projections indicating continued growth in plantation areas (Sumarga, 2015). Deforestation and oil palm expansion in Central Kalimantan remain among the highest in Indonesia, with ongoing conversion of forest into plantation and the associated loss of ecosystem services (Sumarga and Hein, 2016). Central Kalimantan is experiencing a deforestation rate of 1.36% annually (Aguswan, 2019). Deforestation for oil palm plantation in Central Kalimantan, therefore, is a significant environmental concern regardless it was driven by legal or illegal land use practices.
In addition to oil palm expansion, rubber plantations have also contributed to deforestation in the EMRP area. Rubber plantation expanded significantly from 2.1% (31,049 ha) in 2015 to 5.0% (73,377 ha) in 2020 but then reduced to 3.5% (50,994 ha) in 2024. This could indicate shifts in land use priorities or management changes in rubber production. This pattern of land use shifts is comparable with the finding of Sibhatu (2019) in that farmer in Jambi province, Sumatra are relatively specialized in plantation crops, such as rubber, oil palm, or a combination of both. This suggests that farmers who do not adopt oil palm cultivation are likely those who specialize in rubber cultivation. In contrast, households that adopt oil palm likely transitioned from rubber farming. Additionally, land-use change through oil palm adoption significantly improves the diets of farm households in the tropics.
The conversion of forest to rubber and oil palm plantations is a major driver of deforestation in Indonesia. A study evaluating deforestation between 2000 and 2021 found significant tree cover loss, with 82% of primary forest lost in the country. During this period, oil palm plantation areas increased by 650%, while rubber-harvested areas expanded by 54% (Rahman et al., 2023). Many farmers in the region have shifted their traditional rubber agroforestry system to monoculture oil palm plantation. Now, all forest and most local jungle rubber have disappeared to the profit of roughly 2/3 of the area planted with oil palm both as estates and smallholders and 1 per 3 with clonal rubber for smallholders, either in monoculture or agroforestry (Penot and Ilahang, 2021).
Open areas in the EMRP area decreased significantly from 4.1% (60,002 ha) in 2015 to 3.7% (54,025 ha) in 2020 and down to just 0.1% (1,417 ha) in 2024. This decrease suggests that open areas are land those being converted to other land uses particular to oil palm plantation, and likely to settlement. Conversion of open areas therefore may be attributed to the efforts of land optimization. Settlement areas show a gradual increase, from 0.2% (3,052 ha) in 2015 to 0.4% (6,081 ha) in 2024. Although the area remains small, this growth indicates gradual development and urbanization within the study area.
The percentage of land used for rice fields decreased from 0.5% (6,953 ha) in 2015 to 0.1% (2,180 ha) in 2024. The decrease in rice cultivation area most likely is a result of poor soil conditions or a change in agricultural priorities. This trend aligns with the documented challenges of cultivating rice in acidic, nutrient-poor soils that dominate the EMRP area (Sari 2020). Rice fields experienced a significant decline, from 0.5% (6,953 ha) in 2015 to 0.1% (2,180 ha) in 2024, reflecting the challenges of rice cultivation on degraded peatlands with poor soil quality and water conditions (Medrilzam et al., 2017). The conversion of rice field area within the EMRP into more economically viable land uses, such as oil palm plantation or settlement, suggests that there is change in land use priorities in response to agronomic hindrance and economic pressures.

Table 1. Land Use Change in the EMRP Area in Central Kalimantan (2015, 2020, and 2024).

Land use	Area					
	2015 (ha)	2015 (%)	2020 (ha)	2020 (%)	2024 (ha)	2024 (%)
Forest	858,383	58.1%	798,183	54.1%	711,973	48.2%
Rubber Plantation	31,049	2.1%	73,377	5.0%	50,994	3.5%
Open Area	60,002	4.1%	54,025	3.7%	1,417	0.1%
Settlement	3,052	0.2%	4,333	0.3%	6,081	0.4%
Rice Field	6,953	0.5%	5,778	0.4%	2,180	0.1%
Oil Palm	169,946	11.5%	265,389	18.0%	308,894	20.9%
Shrub	329,432	22.3%	257,733	17.5%	377,278	25.6%
Water	17,749	1.2%	17,749	1.2%	17,749	1.2%
Total	1,476,566	100.0%	1,476,566	100.0%	1,476,566	100.0%

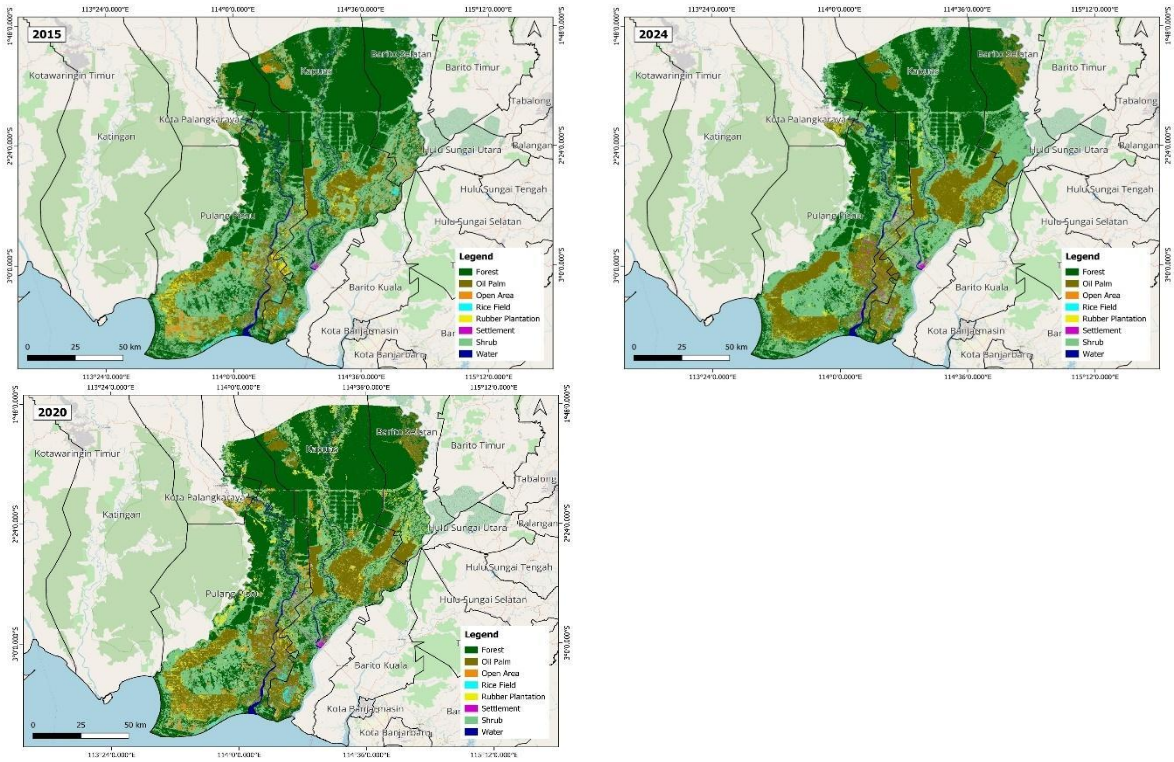

Figure 1. Land use change map of the EMRP area in Central Kalimantan for the years 2015, 2020, and 2024.

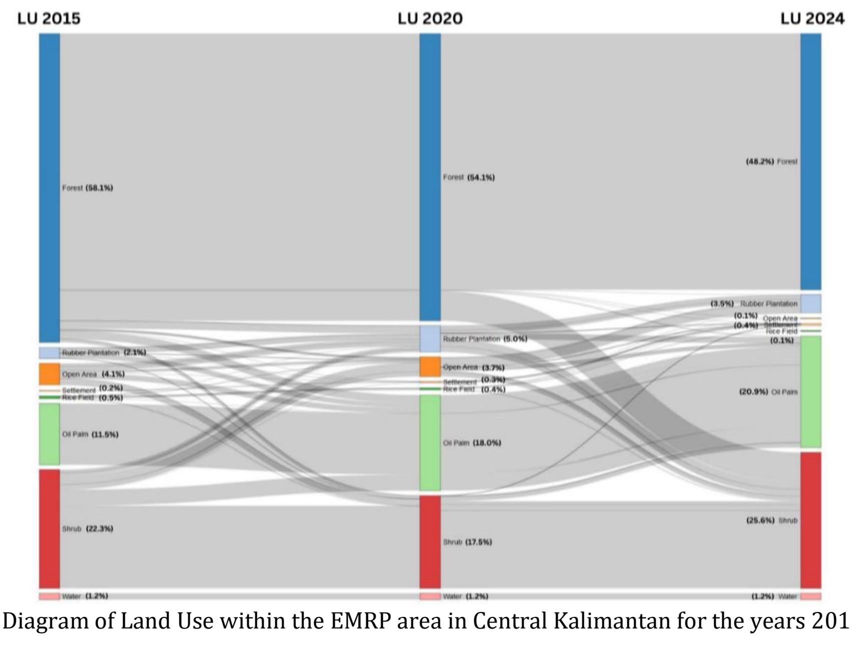

Figure 2. Sankey Diagram of Land Use within the EMRP area in Central Kalimantan for the years 2015, 2020, and 2024.

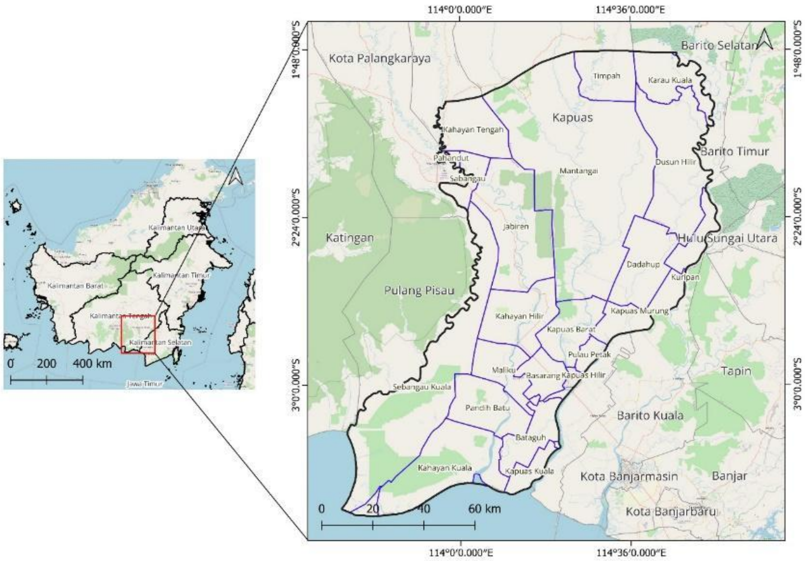

Figure 3. Map of the EMRP area in Central Kalimantan, Indonesia.

Shrub areas decreased between 2015 (22.3%) and 2020 (17.5%) but increased again to 25.6% (377,278 ha) by 2024. This rebound in shrub cover is likely due to natural regrowth or vegetation recovery in abandoned and degraded lands particularly those previously cleared but not converted into oil palm or rubber plantations. Such areas may have been left unmanaged due to poor soil conditions, hydrological constraints, or economic unfeasibility, allowing secondary vegetation (shrubland) to reestablish. This suggests that there is a dynamic interchange between land abandonment, natural regrowth, and the impacts of human activities in certain areas.

Land use dynamics in the EMRP area (1999–2024)

The Sankey diagram (Figure 2) illustrates significant shifts in land use within the EMRP area from 1999 to 2024. The most prominent trend is the large-scale conversion of forested area and open land into oil palm plantation. Forests that are vital for biodiversity, carbon storage, and peatland hydrology have been extensively cleared to make way for oil palm, driven by strong economic incentives. Similarly, open land has nearly vanished as they are increasingly converted into plantation or residential settlement.

The MRP project as an attempt to develop the area for rice cultivation have largely failed due to unsuitable soil and water conditions on the degraded peatland and the adjacent originally non peat area. As a result, rice farming has nearly ceased by 2024. Interestingly, the diagram also shows a resurgence of shrubland during the later period, which likely reflects the natural regeneration of previously cleared or abandoned land. This reversion may indicate land-use inefficiencies or disinvestment in certain areas.

Settlement area shows gradual expansion, likely driven by migration and labor demand associated with the growth of the oil palm sector. However, this pattern also points to increasing population pressure and potential future competition for land.

Overall, the Sankey diagram reveals a complex and dynamic landscape transformation shaped by economic drivers, environmental limitations, and policy gaps. While oil palm development has brought economic opportunities, the corresponding loss of forest cover and emergence of degraded or underutilized land raise serious concerns about long-term sustainability. Balancing agricultural expansion with ecosystem restoration and effective peatland governance will be essential to ensuring the resilience and productivity of the EMRP region in the decades to come.

Socio-Economic and Environmental Impacts

Recent studies indicate that oil palm cultivation has brought significant socio-economic benefits to smallholder farmers. Research by (Chrisendo et al., 2022) highlights that oil palm farming has improved household incomes, living standards, and human capital development among smallholder communities. On the other hand, (Ariesca et al., 2023) found that transitioning oil palm cultivation from peat soils to mineral soils can reduce greenhouse gas emissions by up to 65.43% while increasing fresh fruit bunch (FFB) production by 17.16% annually. Those two underline the potential of utilization of peatland, especially those degraded for improving both economic and environmental outcomes through proper land selection and management.

However, smallholder-driven expansion often results in unsustainable land conversions, leading to environmental degradation (Schoneveld et al., 2019). In areas like Central Kalimantan, where oil palm plantations are developed on peatlands, Wahyunto et al., (2014) discusses the importance of sustainable water management to mitigate greenhouse gas emissions, prevent soil subsidence, and reduce environmental degradation. While oil palm cultivation has the potential to drive economic growth and improve livelihoods, its success depends on implementing proper land and water management strategies.

Conversely, Sumarga et al., (2016) raises concerns that converting peatlands into oil palm plantation may lead to soil subsidence and increased flood risks, rendering the land unsuitable for cultivation after 100 years. This underscores the need for sustainable land use practices to balance short-term economic gains with long-term land productivity and ecological stability.

The utilization of the EMRP remains a contentious issue. Past failures in developing this peatland predominated area have sparked both support and opposition for further cultivation efforts. According to (Yeny et al., 2022), successful utilization of the EMRP must account for land suitability, socio-economic conditions, and local cultural practices. These considerations are critical to minimize environmental degradation, land conflicts, and ensure sustainable productivity for future generations.

Materials and methods

Location of the Study

This study was conducted in the EMRP area in Central Kalimantan, Indonesia (Figure 3). The EMRP was part of a government initiative launched in 1995 to convert approximately one million hectares of mostly peat swamp forest into rice fields. The area spans multiple administrative regions and is characterized by varying levels of land degradation, from fully drained and burnt peatlands to intact forest and shrublands. The EMRP can be categorized into several land use zones based on their historical use and current condition: forest, oil palm plantation, rubber plantation, rice fields, shrub, settlement, water bodies, and open areas. These categories formed the basis of the classification system used in this study.

Land Use/Land Cover (LULC) Classification

High-resolution satellite imagery from Landsat 8 (LANDSAT/LC08/C02/T1_L2) was obtained from Google Earth Engine for the years 2015, 2020, and 2024. These images required no additional correction processes, as they met the necessary quality standards for analysis. The images were subsequently cropped into a sub-set to focus specifically on the study area by using the boundary coordinates.

Representative training sites for each land cover class were selected based on visual interpretation of the image and prior knowledge of the area. These training sites included clearly identifiable areas for the following classes: forest, rubber plantation, open area, settlement, rice field, oil palm, shrub, and water.

The Maximum Likelihood Classification (MLC) algorithm was used to classify land cover types. MLC was chosen for its effectiveness in handling statistical variability in data and its capability to assign probabilities to each class. This method assumes that the statistical distribution of each class is normal and uses the mean and covariance of each class to calculate the probability of a particular pixel belonging to a specific class (Rawat et al., 2024; Talukdar et al., 2020). Land cover classes were defined based on spectral signatures and textural features observed in the image.

After classification, a post-processing step of a majority filter was applied to reduce noise and smooth the classification map, ensuring more coherent spatial patterns. For temporal analysis, change detection techniques were used to identify and quantify land cover changes over the study period by comparing classification maps from different years.

Sankey diagram for land cover changes

To visualize the land cover transitions, a Sankey diagram was created to illustrate land cover changes over time (Vatitsi et al., 2023). This diagram was used to visualize the flow of changes between different land cover classes for the years 2015, 2020, and 2024. The data required to create this diagram were derived from the classification results that identify the source and target of each land cover class transition.

The process of creating the diagram began by gathering the change for each land cover class and calculating the area that transitioned from one class to another over the defined time period. The Sankey diagram was then constructed using RStudio, utilizing packages such as networkD3, which enables a clear and informative graphical representation of land cover changes. This diagram assists in understanding land cover change patterns and provides insights for further analysis on the environmental impacts and land use in the study area.

Conclusion

The one-million-hectare Mega Rice Project (MRP) in Central Kalimantan was failed due to poor planning, including the clearing of critical peat domes and upstream areas, which disrupted the water balance and made rice cultivation unsustainable. Between 2015 and 2024, forest cover declined from 58.1% to 48.2%, while oil palm plantation expanded significantly to 20.9% of the area. Rice fields and open area were largely converted to oil palm plantation, reflecting a shift toward more economically viable land uses. The development of oil palm plantation on part of the EMRP area with peat soil or acid sulfate soils has provided significant economic benefits and it has also contributed to the deforestation and land abandonment solution, hence underlining the need for more rigidly structured sustainable management from now on.

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