Deforestation in Dharmasraya District, West Sumatra, Indonesia

A Causal Loop Diagrams (CLD) Model

[1]Yurike, [2]Yonariza, [3]Rebecca Elhmirst, [4]Syafruddin Karimi and [2*]Rudi Febriamansyah,

[1]Graduate Program, Andalas University, Padang, West Sumatra 25163, Indonesia

[2]Department of Agribusiness, Faculty of Agriculture, Andalas University, Padang, West Sumatra 25163, Indonesia.

(*Corresponding author email: rudifeb@yahoo.com LiveDNA: 62.20247

Scopus ID: 55845909600 Tel: +628126861612115)

[3]School of Environment and Technology, University of Brighton, UK

[4]Department of Economics Studies, Faculty of Economic, Andalas University, Padang, West Sumatra 25163, Indonesia

Author's Contribution

YRK formulated the research question, reviewed the literature, and collected and analyzed the data. YNRZ supervised the work, assisted in the research process, and assisted with article writing and editing. RE supervised the work and assisted in the conceptualization of the work. SK supervised the work and assisted in the conceptualization of the work. RF supervised the work, assisted in the research process, and assisted with article writing and editing.

Significance Statement

This study addresses the dynamic interaction of indigenous peoples with forest land (property rights) leading to increased investment and increased productivity of plantations as well as to deforestation by actors who play a role in middle-class households. This is important in understanding the dynamic interaction of drivers of deforestation at the local level. This study

identifies new actors from deforestation that have not been mentioned in the previous literature, especially in Indonesia.

Abstract

Background and Objective: This study was motivated by changes in forest conversion to plantations and high rates of deforestation in the Dharmasraya district. By decree of the Ministry of Forestry in 2013, this area is designated as a Production Forest Management Unit area (PFMU) because of its potential for regional timber production. This study aims to understand the dynamics of the interaction between economic, social and ecological factors associated with deforestation in PFMU Dharmasraya. **Materials and Methods:** This research uses analysis of system thinking by modeling the causal loop diagram. Focus is placed on dynamics modeling of land use change in several related aspects. **Result:** The dynamic system model can illustrate that deforestation is triggered by weak law enforcement to provide an opportunity for people to make encroachment. This leads to the buying and selling of land, which encourages population growth as large numbers of migrants invest in this area. The increase in income will increase demand for land; thus, if regulations are not applied to the market mechanism, demand for land and plantations will outweigh the need for sustainability. C**onclusion:** The modeling of forest land conversion systems into plantations in PFMU areas shows that the existing system is not sustainable because it has not been able to preserve the existing system for long–term use. Land management policies are needed that can encourage sustainable development.

Key words: Causal loop analysis, deforestation, land conversion, middle-class households, sustainable development, system dynamics

INTRODUCTION

Indonesia is one of the countries in the tropical region that has the largest forest area; however, the degradation rate of this natural forest is relatively high[1]. The main causes of forest degradation are encroachment[2], land occupation[3], and agricultural expansion[4,5]. Deforestation can lead to local and global climate change[6,7]. Efforts to increase forest cover will only succeed if the root cause of deforestation is addressed[8].

Since the 1950s, the Indonesian government has implemented various programs. Recently, the UN-REDD Programme, which stands for the United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation, was established by the UNFCCC in 2008 to reduce carbon dioxide emissions by forest conservation and restoration[9]. Despite these efforts, in 2013, total carbon sequestration accounted for only 0.5% of the total volume of carbon trade[10,11].

The program budget of government and international donors and allocation are focused on the technical aspects. Institutions, empowerment, and other non-technical aspects have not been developed effectively. In addition, conflicts over land ownership occur because of overlapping tenure, as occurred in the case of the district of Dharmasraya.

Dharmasraya district is one of 19 districts/municipalities in West Sumatra Province; it has an area of 302,958 ha and 92,150 ha, with 31.12% of the area designated as forest[12]. According to the Minister of Forestry Decree No. 304/Menhut-II/2011, this forest, in addition to providing environmental services in support of agriculture, is also an economic resource that supports the welfare of the people. Based on this Decree, in the year 2013, the Ministry of Forestry has set a unit of forest management in this District, called PFMU Dharmasraya (Unit VIII), with a total area of 33,550 hectares[13].

Within the last decade, the forest cover in this PFMU area has lost as many as 27.216.57 ha[14]. Encroachment by local people who turned the land into plantations was indicated as a main factor that has caused forest degradation and deforestation in this forest area. Sterman[15] stated that with the destruction of the environment, human beings are not only destroying society but also the economic system. Therefore, in order to understand the problems of deforestation in Dharmasraya, this study uses a system thinking approach and causal loop diagram analysis.

According to Nguyen & Bosch[16], systems thinking is a trans-disciplinary framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots. Critical systems thinking is a way for development practitioners to conceptualize and act toward the integration of the social, environmental and economic dimensions of sustainability, which support communities in addressing the challenges of improving both human and ecosystem well-being. In this regard, Bosch *et al*.[17] agreed that the use of a systems thinking approach indeed helps to leverage management complexity relative to other approaches.

The challenges of sustainability are complex and ever changing and require the development of effective mental models in the face of rapid social, political, economic and technological changes that support the adaptive transition to sustainability. Causal Loop Diagram is a comprehensive thinker tool that when applied systematically, can assist decision making[18]. A causal circle diagram describes a system as a set of components and their interactions. By capturing this interaction, and generating the loop, we can analyze the overall behavior of the system[19].

This helps provide a deeper understanding of complex causal relationships, thereby enabling more effective problem solving[18]. The purpose of this study is to understand the dynamics of the interaction between economic, social and ecological factors associated with deforestation in the PFMU Dharmasraya.

MATERIALS AND METHODS

Data collection was conducted from April to October of 2016 at the site of the Dharmasraya Production Forest Management Unit (PFMU). The study employed a variety of data collection techniques: field observation, historical data, secondary and documentary data, and key informant interviews. Several stakeholders (key informants) associated with the research topics have been interviewed; namely, the Forestry Service, PFMU Dharmasraya, community leaders such as village trustees, clan leaders, and farmers met in the field during the field observation.

The collected data are related to the history of forest areas, characteristics of the social and ecological aspects related to changes in land use in the PFMU working area. This element of the social aspects that are embedded in the forest encroachers and plantation companies include education attainment and migration status. Elements of the ecological aspects related to changes in land use include topography, land degradation, flooding, drought, and land use in the FMU Region. Elements of the economic aspects include income and employment. These elements were then analyzed and modeled to graph interactions relationships using a causal loop diagram.

Causal loop diagrams show elements of a system connected by arrows indicating a causal relationship. A positive or negative sign placed at the head of the connecting arrow tells whether the relationship between the two quantities is direct (positive) – meaning the variables increase together or decrease together — or inverse (negative), meaning the variables change in opposite directions; a decrease in the first causes an increase in the second and vice versa[20].

A causal loop diagram dynamic model is used to show the decrease in forest area in PFMU Dharmasraya using variables that may influence the encroachment. The analytical method used in this study was modeling system thinking using a causal loop diagram. System thinking is a mindset that views the system and its subcomponents as closely interconnected and

interconnected, increasing our understanding of how things function well in interpreting mutual relationships and interactions within and between systems[21,22].

System thinking creates a deeper understanding of system behavior, which is an approach to problem solving that views problems as part of a wider dynamic system[23]. The use of modeling system thinking in this study aims to understand and model the dynamics of interaction between social, economic and ecological aspects related to the land-use change in Dharmasraya.

RESULTS

Status and Trend of Deforestation

The diagram (Figure 1) is an overview of forestland ownership changes that occurred within the area PFMU Dharmasraya based on field observations; it first shows changes in land use of forest plantations by locals; second, changes in land use by migrants through direct purchase of land from local indigenous community leaders; and lastly, changes in land use made by the oil palm plantation companies who obtained a forest use permit in PFMU Dharmasraya through a compensation payment to indigenous communities.

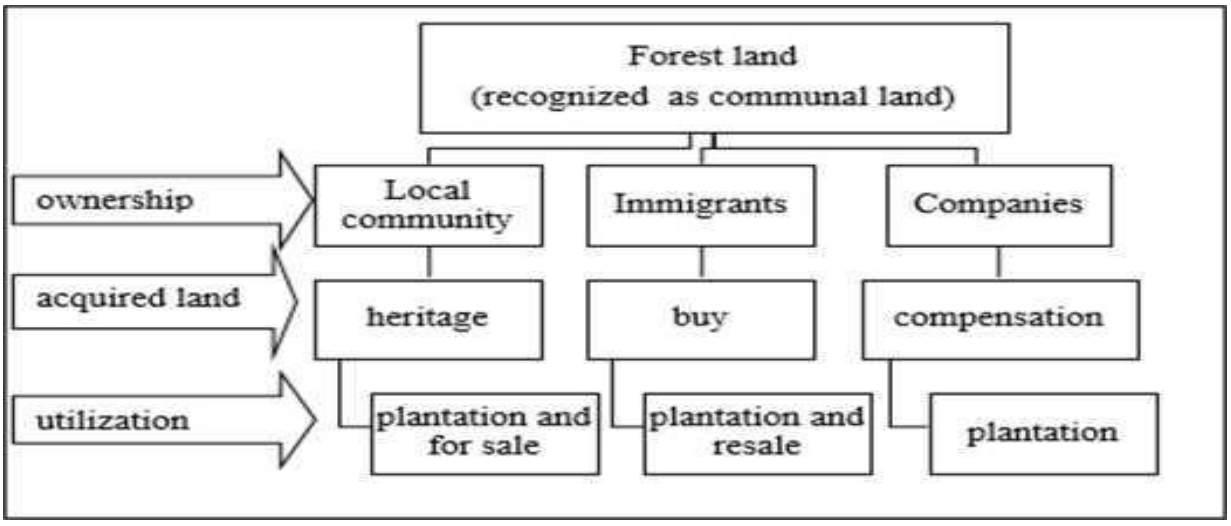

Figure 1. Overview of land ownership changes in the area FMU Dharmasraya

The working areas of PFMU Dharmasraya (± 33,550 ha) are heavily burdened with forest use permits to PT. Dhara Silva Lestari (15,357 ha) and PT. Inhutani (13,721.68 ha) for local tree species enrichment. Hence, on paper, the working area of PFMU Dharmasraya is almost entirely encumbered by forest exploitation permits. However, based on field observations, the reality in the field is different; those two forest companies did not implement their permits; they left their forest area without any activities or control.

According to key informants, currently, around 25% of the local population are migrants from neighboring districts and even provinces. The trend in deforestation increased with the increase in the rate of migration and the resistance of indigenous people against the previous forest concession.

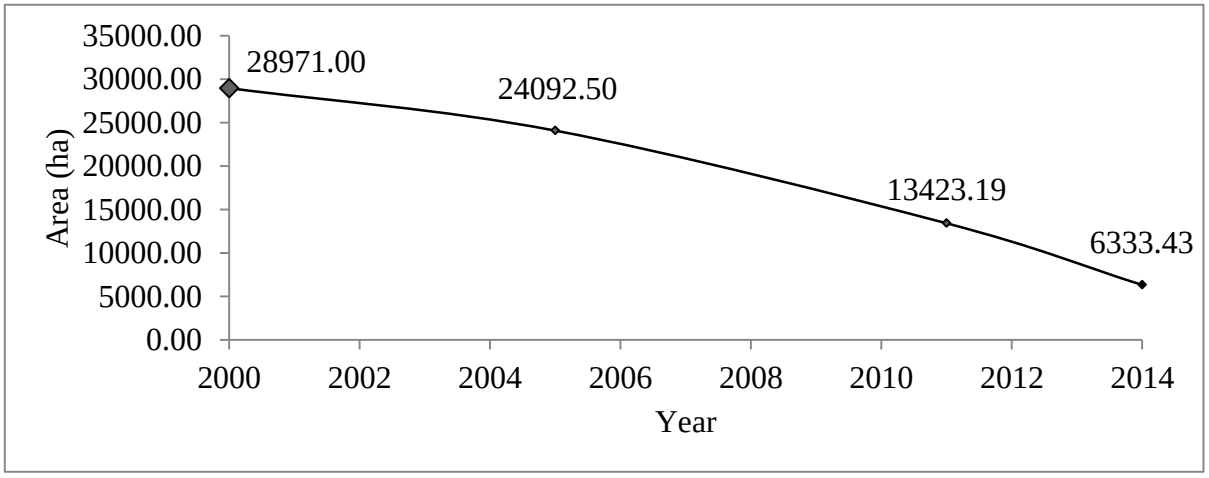

Figure 2. Decline of forest cover in the District over the years

Over a 14-year period from 2000 to 2014, the forest cover in PFMU Dharmasraya forest has declined sharply. The PFMU has lost as many as 27,216.57 ha of their 33,550 ha forest area during this period. This sharp change is mainly due to land conversion to plantations, settlement and resettlement areas, and functional changes of the area to oil palm plantations is the most common.

Causal Loop Diagram Modeling of Deforestation in FMU Dharmasraya

The dynamics of the interaction between social, economic and ecological factors associated with deforestation in the PFMU Dharmasraya are analyzed using the causal loop diagram. The causal loop diagram presents an overview of the relationships of economic, social and ecological aspects in the circle of causality (causal loops and feedback loops), whether they are positive or negative. The result of the causal loop diagram of this study is shown in Figure 3.

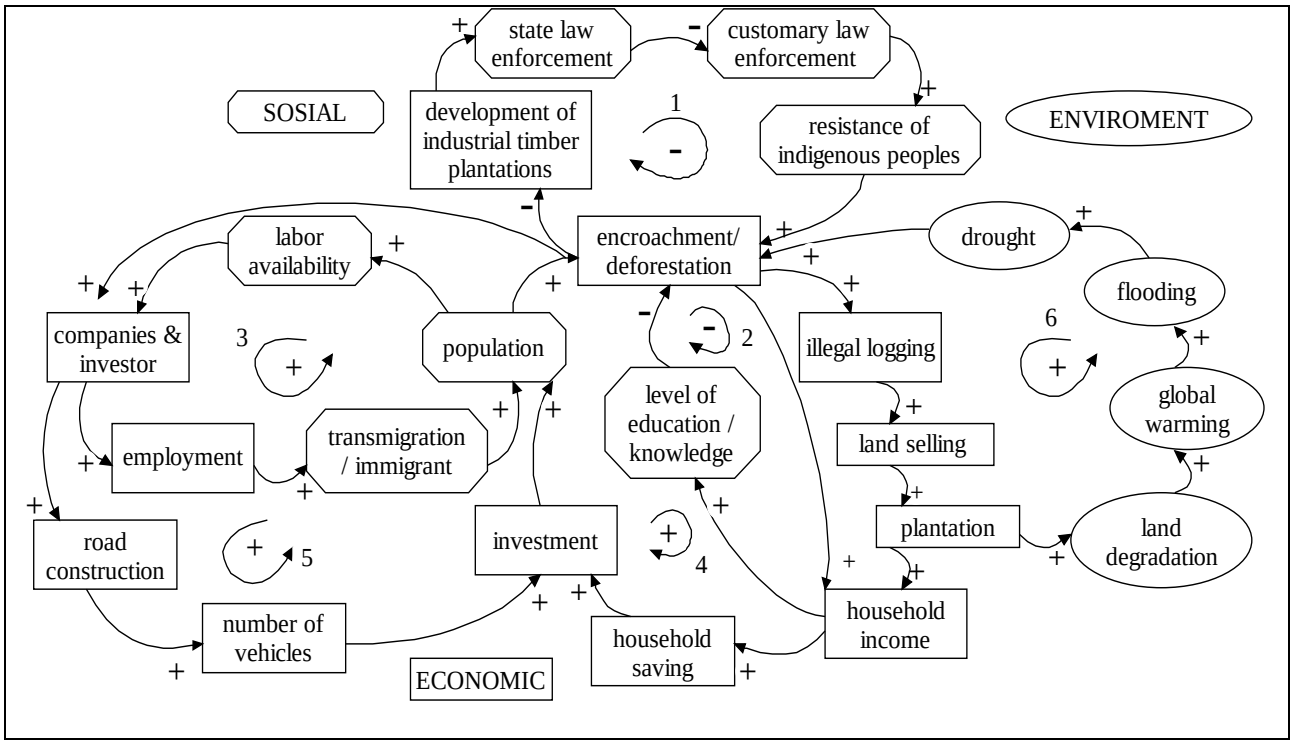

Figure 3. Causal loop diagram modeling deforestation in FMU Dharmasraya. The arrows marked positive (+) means the cause or causes will increase as a result of influence and effect in the same direction of change. The arrows are marked negative (-) to show that it will reduce the effect or because it affects a result in changes in the opposite direction.

Figure 3 gives an overview of the interactions that occur with respect to the phenomenon of land change in the Dharmasraya region in the circumference of causation both positive and negative. In general, this figure shows that encroachment is influenced by socio-economic factors

such as welfare, education, and public attitudes. Rising incomes encourage the community to expand the land, thus also increasing low levels of education, and community knowledge about forests will increase forest encroachment. The increasing encroachment will increase global warming and land degradation, which in turn increases flooding and drought. Increased forest dwellers will increase the use of land as well as increasing deforestation, as described in detail in a causal diagram (*causal loop diagram*).

Social Aspects

- Feedback Loop 1 (-): State law enforcement →customary law enforcement → resistance of indigenous people against forest concession → encroachment → development of industrial timber plantations → state law enforcement
- Feedback Loop 2 (-): Level of education/knowledge → encroachment/deforestation → income →level of education/knowledge
- Feedback Loop 3 (+): population → encroachment/deforestation → companies and investor → employment → transmigration/immigrant → population

Referring to the causal loop diagram, the conversion of forest land to plantations by local people occurs because of the resistance of indigenous peoples to state forest land given concessions to PT. HPH Ragusa. The existence of a gap between the transition of PT. Ragusa and Inhutani causes communities to reclaim their customary lands and clear forest into plantations. Lack of government oversight and weak state law enforcement have increased the resistance of indigenous peoples to the exploitation of forests they claim to be their customary lands and trigger the sale and purchase of land. They sell forest land so that it opens opportunities for migrants to develop smallholder plantations in this area. Land purchased Forest

land acquisition is a very serious problem, especially in forested areas where land use competition is high.

This causes permit utilization in the field to not run properly. The rise in occupation by the public makes it difficult for permit holders to carry out activities. If the permit holder wants to carry out management activities, the customary authority asks for land compensation at a price of between 5 - 10 million rupiah per ha depending on the conditions of the land to be freed from occupation by the community. On the one hand, there are people who uphold the principles of indigenous customary rights. On the other hand, the planters feel entitled to control the land because they have entered into lease contracts and received concessions from the government and are considered as legitimate land owners. This cannot be separated from the low level of education and community knowledge about forests.

Economic Aspects

Feedback Loop (+)

- Feedback Loop 4 (+): encroachment/deforestation → illegal logging → land selling → plantation → household income → household saving → investment → population → encroachment/ deforestation
- Feedback Loop 5 (+): population → labor availability → companies & immigrant → road construction → number of vehicles → investment → population

Increased incomes will increase the purchasing power of forest land, benefitting the forest communities but also providing opportunities for migrants to invest, meaning that higher incomes lead to higher deforestation and increased gaps among communities. The more land owned will surely increase the income of the community. With the existence of a land selling system, there are more competitors and less available forest land.

People who have the capital will have more land, while the poor do not have the land because they do not have the capital to clear forest land. A wave of global investment has made land an investment opportunity to maximize profits. The land is synonymous with money, while money is synonymous with power; more land means more money, and more money means more power and more land. This means that the rate of deforestation in Dharmasraya is dominated by middle- to upper-class households.

The influx of immigrants and plantation companies certainly creates employment opportunities because they need labor to cultivate and maintain their land. Encroachers with large capital tend to expand the agricultural land occupation. They provide capital and management of the garden and pay workers from outside of the family a monthly salary or offer share cropping. Finally, palm oil has its own agency as it carries different meanings among the communities. The development of plantations in Dharmasraya is influenced by the economic motivation to increase investment.

Overall, PFMU Dharmasraya is a lowland forest with undulating topography. The existence of the company has an impact on the opening of the road to the forest. The access road to the forest is wide open, so that the number of vehicles entering the forest will increase. These roads were former timber concession road. Local governments also provide support by building bridges to facilitate access to plantations and marketing processes.

Environmental Aspects

Feedback Loop 6 (+): encroachment/deforestation → illegal logging → land selling →plantation → land degradation → global warming → flooding → drought → encroachment/deforestation

Indigenous peoples' resistance is indicated by the increasing plantation area. Increased palm oil plantations have an impact on the environment, causing deforestation when forest land is

used for expansion. The higher deforestation due to illegal logging and forest encroachment certainly increases the risk of disasters such as floods and drought for the community. River water in this region is reduced; even small rivers around the palm oil plantations become dry, and well water becomes more difficult to access.

The practice of conversion of natural forests for palm oil development is often the main cause of natural disasters such as flooding since the land is changed. Rain often creates floods in the village. River water overflows into the village because no trees can absorb the water. In addition, according to key informants, the temperature in Dharmasraya grows hotter.

DISCUSSION

This study has identified that the deforestation problems in the study area are related to a number of interrelated factors; weak law enforcement and hight resistance of local communities, the population growth and its dynamics, low education level of inhabitants, as well as the pressure of natural resources and environmental changes. This causal loop analysis shows that no one factor directly affects deforestation activity in the study area. Findings on the interlinkages of many factors in deforestation have also been revealed by Jusys[24] who explored the causes of deforestation in the Brazilian Amazon region using a global approach. Jusys's study revealed several important factors affecting deforestation, among others; population, gross domestic product (GDP), forest stock, livestock, timber value, and road conditions. Furthermore, Caliskan[25] has also identified relevant factors in the Turkish region, are; the factor of opening road access to forests also contributed to the increasing of society's activities of substantial environmental damage to the forest.

In addition, other causes of deforestation due to the low level of public education that causes low levels of human resources and certainly affect the behavior, perception and work

undertaken[26]. A third of the district's population is migrants from various regions who moved to exploit the idle land in this district as well as creating new jobs. This transmigration process occurred between 1976 and 2002. Previously, this area was largely jungle. Then, in 1979, transmigration began to occur. In the first year, the immigrants initially only relied on the allocation of the government; after assistance ended with crops, the community began to switch to rubber and oil palm plantations. This behavior certainly increased deforestation.

This is also supported by Chaudhary *et al*.[27] in a study in Nepal. They stated that the cause of deforestation is a mix of direct and indirect causes, such as high dependence on forest resources, unsustainable and illegal harvesting practices, forest fires, natural disasters, grazing, infrastructure development, and lack of good governance. Furthermore, Ceddia e*t al*.[28] also reveals that the most important direct cause of deforestation is agricultural expansion, while the interaction between socio-economic, technological and institutional factors is the fundamental drivers. Chakravarty *et al*.[29] also added that although a farmer only clears land on a small scale with a shifting cultivation system, the impact would be devastating when the peasant population is high.

The study that was conducted with this causal loop analysis model, more specifically has found a new fact that deforestation actors in the study sites are generally from middle to upper class communities (not from the poor or lower classes), who came from the region itself and support each other. This becomes very specific, as many previous studies highlight the drivers of deforestation are the poor around the forest[30,31].

For example, a study conducted by Medrilzam *et al*.[32] observing socio-ecological drivers of forest degradation at the community level in Central Kalimantan, Indonesia, found that in addition to land tenure uncertainty which accelerate community land tenure activities, the community livelihoods and activities are the main drivers of land and forest cover changes.

Similarly, Zwane[30] research in Peru concludes the reality of the relationship between poverty and deforestation. It is then identified that small increases in the income of poor households would reduce the activities of deforestation. Economic researchers, it seems, are more likely to argue that property ownership is one of the most effective ways to improve the lives of the poor, which often lack property rights[33].

Furthermore, the study also found the fact that while in other regions indigenous peoples maintain the sustainability of the forests and prevent outside interference[34,35], in study site the success of communities re-occupying their communal lands does not mean that they able to manage their forest land in the right way. Indigenous peoples have also undertaken activities that may not be common, namely the selling of their customary right land in its territory, through the granting of permits for land clearing in areas that are physically customary forests. This means that customary land recognition does not guarantee the welfare of indigenous peoples when the communal land rule lies in those who cannot preserve communal lands. This causal loop model presents a mechanistical fact, beginning with the issue of the transfer of ownership over the customary right forests. The high probability of acquiring ownership rights over customary forest lands has increased the investment activities, especially for efforts to increase the production of plantation commodities, which are carried out through deforestation activities.

There is no single factor in deforestation, but interplay among them. If the drivers of deforestation are not addressed, local reforestation efforts will be weighed down by wider deforestation trends[36]. Various studies have tried to analyze the different scales at which deforestation occurs, but few investigate the dynamic interaction of deforestation drivers[37]. Hence, system thinking is required to understand the process of deforestation. Clearly, certain driving forces affecting forest cover depend largely on the geographical location and scale of the study area[38]. Hence, it supports the argument of Moneen *et al.*[39] that there is a need for more

research at the local level. For this purpose, the research is done so that it can fill in the existing void of research at the local level.

CONCLUSION

The modeling of forest land conversion systems into plantations in PFMU areas shows that the existing system has not been sustainable because it has not been able to maintain the existing system in the long term. Environmental impacts that occur beyond the carrying capacity of the environment and the consumption of natural resources have not been minimized. Land use change in the Dharmasraya ex-concession forest area has resulted in reduced forest cover over time. This change is caused by several factors including the resistance of indigenous peoples, economic factors (to increase investment), weak law enforcement and low levels of education and knowledge about forests, which affect the mindset of the people. Enforcement of regulations is important in forest management. The government needs to improve the forest encroachment control program. This requires policy interventions that will ensure that lands that support ecological functions are not changed into economic or social functions. The model in this paper is believed to be common; important variables can be adjusted to the field condition without having to change the overall model.

Conflict of interest Statement

The authors have declared that no competing interest exists.

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