Environment and Ecology Research 9(6): 419-425, 2021
DOI: 10.13189/eer.2021.090608 http://www.hrpub.org

The Impact of Population and Deforestation on Climate Change in Malaysia: A Causal Loop Diagram

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Received August 27, 2021; Revised October 20, 2021; Accepted December 20, 2021

Cite This Paper in the following Citation Styles

(a): *[1] Musthaza Mohammad, Wan Laailatul Hanim Mat Desa, Norazura Ahmad, Norhaslinda Zainal Abidin , "The Impact of Population and Deforestation on Climate Change in Malaysia: A Causal Loop Diagram," Environment and Ecology Research, Vol. 9, No. 6, pp. 419 - 425, 2021. DOI: 10.13189/eer.2021.090608.*

(b): *Musthaza Mohammad, Wan Laailatul Hanim Mat Desa, Norazura Ahmad, Norhaslinda Zainal Abidin (2021). The Impact of Population and Deforestation on Climate Change in Malaysia: A Causal Loop Diagram. Environment and Ecology Research, 9(6), 419 - 425. DOI: 10.13189/eer.2021.090608.*

Abstract It is well recognised that numerous demands from the human population, such as food and housing, have resulted in widespread deforestation, which has been directly linked to climate change. These demands impose negative impacts on the environment, resulting in the problem of global warming and eventually climate change, hence inflicting an existential threat to our environment. Therefore, this paper discussed the development of a hypothesis of the cause-and-effect relationships between population and deforestation towards climate change in Malaysia. Using a causal loop diagram (CLD), a hypothetical framework depicting the cause-and-effect interactions of the connected variables of deforestation and population on climate change was built based on various reports from government agencies and a review of existing literature. The developed CLD shows that the impact of population and deforestation on climate change has negatively affected the sea level and excessive rainfall. The dynamic hypothesis enables the modeller to grasp the complex behaviour of the interrelated variables. This dynamic hypothesis will be used as a basis for the development of a dynamic simulation model in future work.

Keywords Causal Loop Diagram, Climates, Deforestation, Dynamic Hypothesis, Population.

1. Introduction

Forests bear numerous benefits to nature, humans, and animals. Other than that, it also gives benefits to air, water quality, biodiversity, livelihood and national income of a country [1]. In general, forests are divided into three types, namely boreal forests, temperate forests, and tropical forests. In Malaysia, the forest is categorized as tropical forests, which can be further classified into seven types of forests, namely (i) ericaceous forest, (ii) montane forest, (iii) upper dipterocarp forest, (iv) hill dipterocarp forest, (v) lowland dipterocarp forest, (vi) peat swamp forest and (vii) mangrove forest stated by Forestry Department Peninsular Malaysia.

Despite the diversity of forests found in the country, data on forest coverage in Malaysia shows a steady trend where the area in hectarage remains between 17.81 and 18.78 ha over 26-year period as referred to Table 1. According to the Malaysia Third Biennial Report to the United Nations Framework Convention on Climate Change (UNFCC), Malaysia faces threats of deforestation due to human activities that convert forest areas for housing construction, agriculture, urbanization and industrialization [2, 3]. In the context of discussion, deforestation refers to forest clearance for serving human activities.

Table 1. Total Forested Areas (million ha)

Year	Peninsular Malaysia	Sabah	Sarawak	Total
1990	6.27	4.44	8.07	18.78
1995	5.86	4.42	7.68	17.96
2000	5.92	4.42	7.86	18.2
2005	5.83	4.36	7.62	17.81
2010	5.86	4.44	7.63	17.93
2011	5.81	4.44	7.69	17.94
2012	5.79	4.42	7.8	18.01
2013	5.83	4.43	7.8	18.06
2014	5.80	4.44	8.03	18.27
2015	5.79	4.56	8.05	18.40
2016	5.77	4.56	7.91	18.24

(Source: Malaysia Third Biennial Report to UNFCC, 2018)

The effects of human activities may affect climate change [2]. Climate change does not only increase the global temperature that leads to global warming, but also causes other extreme climate conditions, such as rising sea levels, changes in precipitation patterns, droughts, and heatwaves [4]. Deforestation activities and climate change events have had many negative impacts. As of August 2021, there have been many extreme consequences resulting from climate change worldwide. Numerous reports from local and foreign media have wide coverage on these occurrences, for example wild fires in Turkey and Greece [5], drought in South America (Brazil and Argentina) [6], as well as heavy rains that turned to massive flood and landslides in China and India which caused 21 and 125 fatalities, respectively [7, 8].

Apart from international occurrences, Malaysia has also been affected by climate change. Previously, Malaysia can be considered as a free zone country from the effect of climate change, however mild climate effect such as floods and droughts are becoming more frequent lately [9]. For instance, in early 2021, several states such as Johor, Kelantan, Pahang, Perak, Terengganu, and Selangor have reported that flooding occurred due to continuous heavy rain, which caused the displacement of 16,500 victims to evacuation centers [10].

Most recently in August 2021, the state of Kedah experienced flash floods and landslides [11]. These incidents are alarming signs that require policy makers to understand the big picture of the consequences of deforestation in the country, hence work to design the most effective strategies to manage the impact of unintended consequences.

Although the net deforestation rate has remained stable since 2009, with Malaysia's population growing every year (see Figure 1) and expecting to reach 40 million people by 2040, there are concerns that the demand for food, transportation, and various infrastructures will put significant strain on the forests [12]. With all of these issues, it is critical to research and determine the impacts of population growth and deforestation activities on climate change. As a result, the purpose of this research is to better understand the dynamic linkages between population size and deforestation activities as they are directly linked to climate change. This paper established a framework to describe the cause-and-effect relationship of these components using causal loop diagram (CLD) approach as a result of its findings.

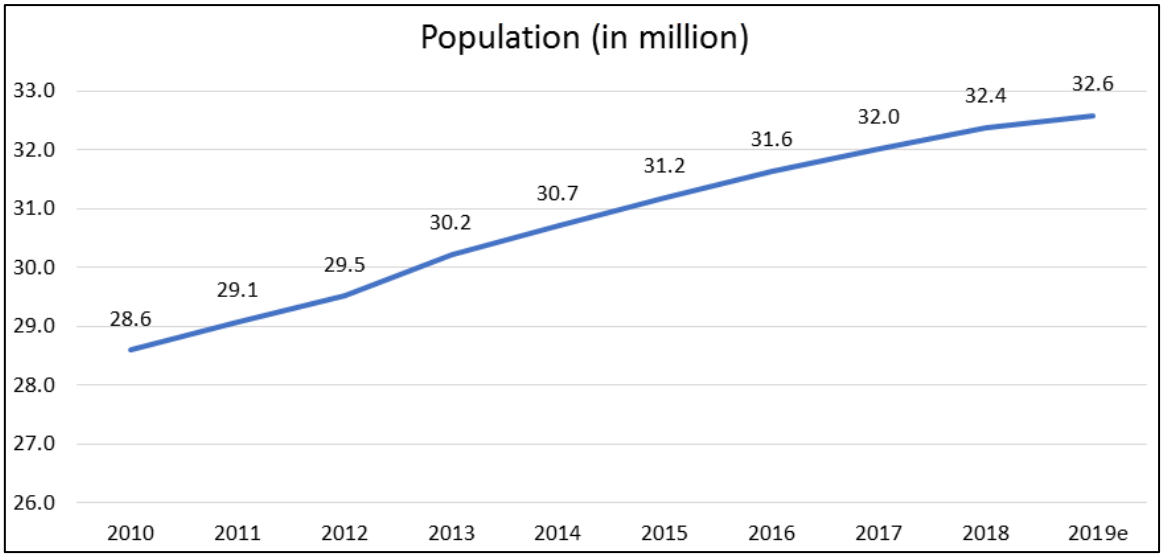


Figure 1. Population in Malaysia between year 2010 and 2019. Source from Department of Statistics Malaysia (DOSM), 2021

The following sections will be systematically presented in this paper. In the next sections, reviews of previous works are presented, followed by the methodology, where detailed steps to develop the CLD are discussed. Finally, the paper ends with a brief conclusion and the direction of future research

2. Literature Review

This section will be divided into several sections: the definition of deforestation, factors of deforestation, and studies by past researchers on deforestation.

Technically deforestation and climate change are interrelated because one of the factors of climate change is deforestation (WWF). According to Food and Agriculture (FAO) report, 2020 [13] deforestation and forest degradation occur at an alarming rate globally, thus threatening the quality of human life and biodiversity. [14] highlighted that deforestation itself has several meanings. Deforestation can be characterised as a process of general forest ecosystem disruption that takes place when trees are destroyed on a massive scale [15]. Meanwhile, [16], defined deforestation as forests changing in the form of permanent loss of protection against intact, separated, and scattered coverings and transitions. On the other hand, [17] defined deforestation as an act of cutting down forests and clearing them for other kinds of land use.

A few studies have been conducted about deforestation and climate change. Among them is [16] who identified the factors and effects of deforestation in the Riau region. He uses survey analysis and satellite image data in his study processor. According to [18] the opening of new agricultural areas such as converting forest areas to tea cultivation and rice fields, livestock grazing, urbanization, rural development and expansion of the industrial area are influencing the largest extent deforestation. [19] conclude that technology advancements are among the factors that affecting deforestation. Economy also plays a vital role in deforestation as stated by [20], who cited its growth has influenced over the future risk of deforestation.

[21] conducted a forest study in Pahang, Malaysia with several objectives; to identify the amount of carbon stock lost due to changes in land use, to identify information on the conditions of mangrove forests in Pahang caused by deforestation and to identify the changes in carbon stock in the recent decades to the ecosystem there. For this study, researchers used Allometric equations to achieve their objectives. [22] used Autoregressive Distributed Lag to create a growth model to identify the primary components that constitute the determinants of forestry growth in Peninsular Malaysia. In this study, the researcher stated that the forestry sector in Malaysia did not get much attention from Malaysian government thus illegal logging activities often happened which consequently affected the environment. [23] used the Poisson and negative binomial models to identify the impacts of deforestation on flood events and found that conversion of forest lead to floods.

These previous studies, however, did not study the cause-and-effect relationship of deforestation activities and climate change and do not allow the development of future scenarios resulting from the relationship. Therefore, the development of CLD in this paper is a preliminary attempt to study the deforestation impact using the system dynamic modelling approach.

3. Methodology

This study uses Causal Loop Diagram (CLD) to determine the cause and effects of population and deforestation on climate change in Malaysia. In this work, system dynamics: (SD) modelling consists of five stages of (i) Problem Articulation, (ii) Formulation of Dynamic Hypothesis, (iii) Development of Simulation Model, (iv) Testing the Model, and (v) Policy Design and Evaluation [24]. However, the focus of this paper is on stage (i) and stage (ii), which are the problem articulation to the formation of a dynamic hypothesis since the objective of this paper is to present a clear picture of how population and deforestation affect climate change via a cause-and-effect framework through the development of the dynamic hypothesis stage.

The Principle of Causal Loop Diagram

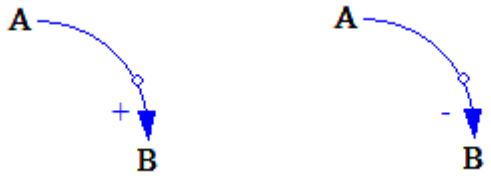
After the problem has been identified, a working theory called the dynamic hypothesis is developed based on the reference mode behaviour over time [25] and [26]. The dynamic hypothesis is a concept of what structure in reference modes could be used to generate such behaviour. At this stage, the dynamics of the hypothesis can be illustrated using causal loop diagrams (CLD) or in other words, cause and effect relationship diagram [27]. [28] highlighted CLD as a system technique that is helpful for viewing variables in a complicated system. Furthermore, CLD is widely used because of its ability to solve complex problems [27], and since forest and climate are both complex systems, CLD is an effective way to graphically picture the cause and effect of the system interlinkage factors in a holistic manner.

CLD has its unique set of characteristics that must be observed. One of them is the relationship between the variables. According to [29], CLD has a relationship, either positive or negative, between one and the next loop variable. A positive relationship means that when one variable increases then the other will increase and vice versa (Figure 2a.). Meanwhile, a negative relationship means that if one variable increases, the other variables will decrease (Figure 2b.). This relationship can be shown using the polarity of the relationship, denoted by a positive or negative sign.

Apart from the relationship between the variables, the crucial thing about the CLD is, it must have a feedback loop. There are two types of feedback loop, which are the

Reinforcing loop (positive loop) and the Balancing loop (negative loop). The simplest way to determine, a reinforcing loop or balancing loop is by counting the number of negative relationships [25].

A loop is considered as a reinforcing loop when the total number of negative relationships is even. On the other hand, a loop is considered as s balancing loop when the total number of negative relationships is odd. Figure 3 provides the basic illustration of feedback loops.



a. b.

Figure 2. a. Positive relationship (+) and b. Negative relationship (-)

Steps in Developing CLD

In general, there are three steps in developing CLD for this work. An explanation for each of the steps is as follows

Step 1: Identifying the problem and objective

Aforementioned, deforestation in Malaysia has been stabilised since 2009, but with an increasing population which predicts that population will reach 40 million in 2040, it will put great pressure on the forest area in Malaysia since the demand for housing infrastructure will significantly increase [12]. Thus, this paper focuses one cause-and-effect of the impact of population and deforestation on climate change in Malaysia.

Step 2: Identifying the elements of the systems

At this step, the key elements were derived from the literature reviews and reports from the Ministries of Environment and Water (KASA). Some key elements are also derived from non-governmental organization (NGO), for instance, World Wildlife Fund (WWF). The key elements for the factors and its effects on deforestation and climate change are presented in Table 2.

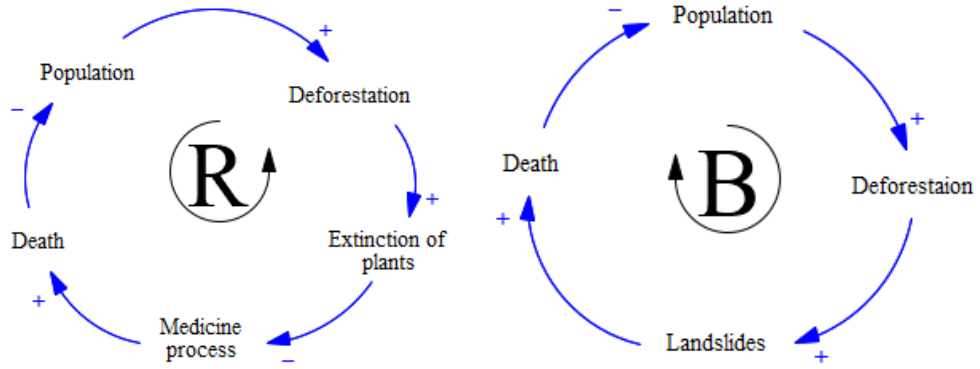


Figure 3. Reinforcing Loop (R) and Balancing loop (B)

Table 2. Factors and effects of deforestation and climate change

Factor(s)	Description	Source(s)
Population	The total number of human populations in Malaysia is increasing due to low infant mortality, better healthcare, and an increase in life expectancy.	[12], [18]
Infrastructure	The demand for infrastructure such as railways, airports and highways due to population growth in Malaysia	[12], [18], [30]
Housing	With the increase in population, the demand for houses also increases thus the forest needs to be cleared to fulfil the demand.	[15], [17]
Agriculture	Planting and harvesting crops such as palm oil, rubber and rice where forests are often cleared to make way for new fields and plantations.	[17], [14], [32], [33]
Greenhouse gases	Emissions of abundant gases such as carbon dioxide, methane, nitrous oxide, and chlorine, in the atmosphere from the use of fertilizers and fuel combustion.	[9],[34]
Effects	**Description**	**Source(s)**
Climate change	The changes in global temperature	[12], [17], [32], [31]
Rainfall	2,000 mm to 4,000 rainfalls during north monsoon, east coast Peninsular Malaysia, northeast Sabah and southern Sarawak experience heavy rain lasting for about three days, which can lead to a severe flood.	[2], [9], [35]
Death	Death can be caused by the effects of climactic changes such as a rise in sea level, excessive rainfall, and a temperature rise.	[2], [9], [34], [36]
Sea level	The West Coast of Peninsular Malaysia will experience a maximum sea-level rise of 0.05- 0.10 m in 2030 while East Cost Peninsular Malaysia sea level can rise by 0.003- 0.007 m in 2030. Sabah and Sarawak will experience 0.11-0.15 m and 0.04 – 0.12 m respectively.	[9], [12],[34]
Temperature	For the past 46 years, there has been a positive trend in temperature increase.	[9], [12], [34]

Step 3: Determining the category of variables

In this step, the identified variables must be classified as endogenous and exogenous variables. An endogenous variable is an influencing system variable while an exogenous variable is an influenced variable of another variable. Identifying the endogenous and exogenous variables is important because system dynamics focuses on endogenous which is "how the problem arises" [37]. By identifying the endogenous in the system, it can generate the interaction in the model. Table 3 and 4 show the related endogenous and exogenous variables that are discussed in this study.

Causal Loop Diagram of Climate Change

Table 3. Endogenous variables

Endogenous	Key variables
	Population
	Demand for house
	Deforestation/land- use change
	Transportation
	Climate change effects
	Commercial infrastructure
	Rainfall volume
	Number of vehicles on the road
	Sea level
	Road construction
	Temperature
	Greenhouse gases
	Death

Table 4. Exogenous variables

Exogenous	Key Variables
	Life span
	Infant mortality
	Healthcare

Figure 4 below shows that Malaysia has low infant mortality rate, which results in an increase in population in Malaysia. Apart from the declining trend in infant mortality, based on [12] the improving health system and increasing life expectancy have also contributed to the increase in national population.

Due to the growing population, the demands for food, housing, infrastructure, and transportation also proportionally increase which put significant pressure on the forest as deforestation will be carried out to meet these demands. Apart from deforestation to meet these demands, increasing human activities in transportation and agriculture will also impact the climate. For example, the majority of vehicles in Malaysia runs on fossil fuels and agricultural cultivation utilizes fertilizers which further release greenhouse gases that has direct effect on the climate. Hence, climate change is varied and seasonal in Malaysia.

The effects are identified and listed as a rise in sea level, rise in temperature, and excessive rainfall (see Figure 5). The rising sea level can cause deaths because of events such as flash floods. Meanwhile, the impact of climate change also can cause an increasing temperature in Malaysia. When all these happen, it will endanger human health and eventually results in death. In addition, excessive rainfall is also one of the deaths causes to the population in Malaysia because a large amount of rainfall can cause flood disasters and landslides.

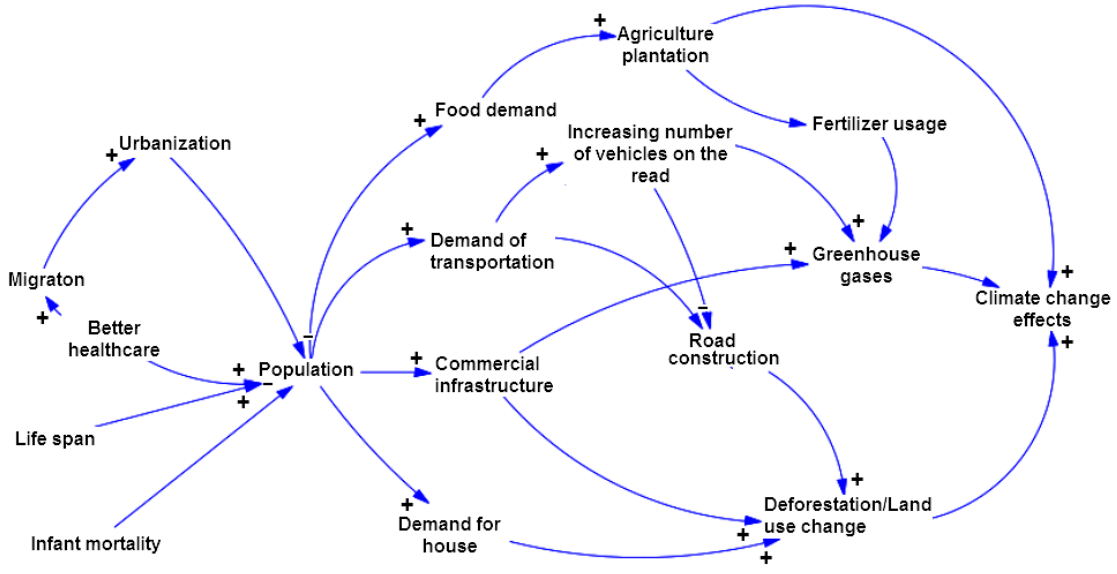


Figure 4. CLD of Deforestation

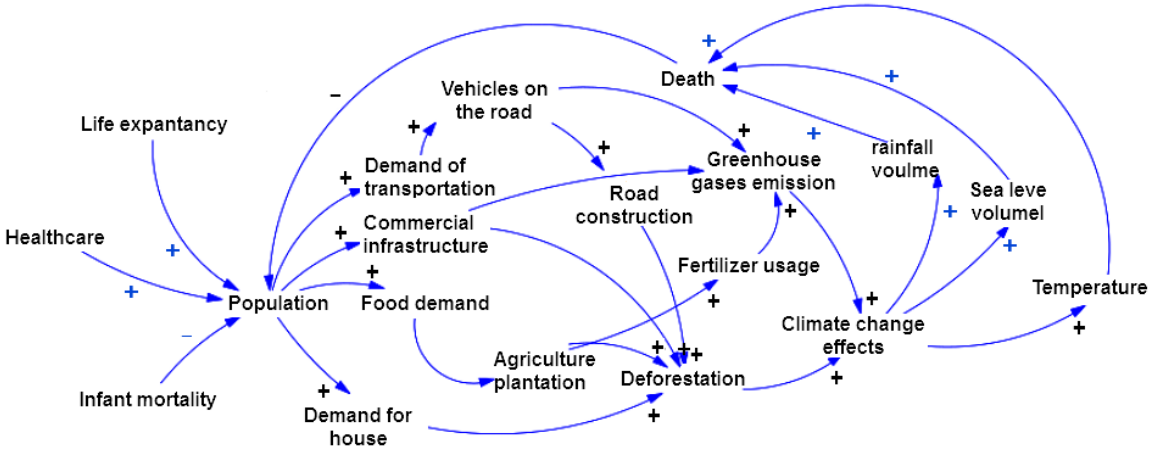


Figure 5. The Effects of Population and Deforestation on Climate Change

4. Conclusion and Future Work

This paper discusses the use of causal loop diagram (CLD) in developing the dynamic hypothesis to gain the insight on the effects of population and deforestation on climate in Malaysia. The main driving factor of deforestation activities is the increasing population size which will consequently increase the demand for food, house, agriculture plantation and road construction. Thus, this will further lead to several deforestation activities such as clearing of forest areas to build the highways, houses, as well as opening new agricultural plantations. When deforestation activities take place, it will negatively impact our climate due to excessive rainfall, sea-level rise, and temperature rise. The impacts of these phenomena directly linked to the cause of several disastrous weather events such as floods, landslides, and heatwaves which are consequent to the sudden death of people. Thus, immediate action needs to be taken to mitigate the deforestation activities and climate change impacts in Malaysia. Hence, the dynamic hypothesis is developed to assist researchers in determining the problems that may arise due to the complexity of the forests and climate systems. In the future works, once the CLD has been developed, it can be translated to a stock-flow diagram (SFD) for analysis and to further determine appropriate interventions of the deforestation problems.

Acknowledgement

This research was supported by Ministry of Higher Education (MoHE) of Malaysia through Fundamental Research Grant Scheme for Research Acculturation of Early Career Researchers(RACER/1/2019/STG06/UUM//2) with S/O code: 14455. We also want to thank Universiti Utara Malaysia management for assistance and cooperation along this research.

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