

Dynamics and drivers of deforestation in the Philippines

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ABSTRACT. Deforestation is one of the biggest environmental problems in the world. It is an old ecological problem, yet the deforestation rates and causes are still debated in many areas. In the Philippines, there are numerous but conflicting forest cover estimates. Also, there is no agreement on the causes of deforestation, and information on contemporary causes is limited. This research aims to shed light on the rate and causes of deforestation in the Philippines by conducting a literature review from 1980 to 2020. This study shows that estimating deforestation rates is difficult because of the differences in methodology, data used, and forest definition in quantifying the forest cover of the Philippines. Nevertheless, various sources indicated that forest cover decreased from 1980 to 2010 and increased from 2010 to 2020. Proximate causes of deforestation were primarily agricultural expansion, wood extraction, and built-up extension. Underlying causes were mainly demographic and poverty factors; market demand and economic development factors; and governance, policy, and institutional factors. The results also revealed that the different causes were linked to each other. Temporal analysis of the causes of deforestation showed that wood extraction was an important driver from 1980 to 2020. Infrastructure development had increasing significance from 1980 to 2020. Agricultural expansion remained an important driver of deforestation throughout the study period. The perpetuation of agricultural expansion and the rise of infrastructure development as drivers of deforestation calls for proper land use planning, land classification, and stronger protection of protected areas. It is also suggested to further investigate wood extraction as a driver of deforestation.

Keywords: forest area, forest loss, land cover change, temporal analysis

Article Information

Received 19 January 2023

Accepted 13 July 2023

Published online 16 October 2023

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INTRODUCTION

Deforestation remains one of the biggest global environmental problems (IUCN, 2017). According to Food and Agriculture Organization (FAO) (2012), deforestation is the “conversion of forest to other land use or the permanent reduction of tree canopy cover below the minimum 10 percent threshold.” It includes forested areas converted to other land uses, such as agriculture, pasture, water reservoirs, and urban regions. The latest State of the World’s forest resources report by FAO (2020) states that forests globally are slowly increasing. Still, deforestation remains huge at around 10 M ha of forests lost annually from 2015 to 2020.

Deforestation impacts biodiversity, ecosystem services, livelihoods, climate, and food security

(FAO, 2020). The loss of forest cover is the leading cause of the 20,334 tree species being added to the International Union for the Conservation of Nature (IUCN) red list and putting more than 1,400 tree species into the list of critically endangered species needing immediate action (IUCN, 2017). It also affects around 1.6 B people whose livelihoods depend on forest resources (IUCN, 2017). Forests are also sources of ecosystem services, such as food and water, climate regulation, culture, and scenic and landscape for tourism (Lindberg *et al.*, 1997). Deforestation and forest degradation are also significant contributors to global greenhouse gas emissions of 5.8 GtCO₂ yr⁻¹ (Nabuurs *et al.*, 2007). These pose a considerable concern not only globally but also at the national level.

The Philippines has suffered severe deforestation. Hughes (2017) mentioned that around 93% of the primary forests had been removed. The problem of deforestation in the country has caused a loss of biodiversity (Pang *et al.*, 2021), food and water insecurities, displacement of indigenous peoples (Walpole, 2011), and claimed thousands of lives due to flooding and landslides (Hance, 2011). The severe impact of deforestation in the Philippines has led the 2011 Philippine Government to implement a nationwide moratorium on logging (Executive Order No. 23, s. 2011) and the National Greening Program (NGP) (Executive Order No. 26, s. 2011). As a result, the Philippines was listed as one of the top ten countries with increased forest cover from 2010 to 2015 (FAO, 2016). However, deforestation is still in place, especially in areas not subject to NGP (Perez *et al.*, 2020). Thus, it is still relevant to talk about deforestation in the country.

Previous deforestation studies cited numerous drivers (Bee, 1987; Acosta, 1989; Kummer, 1992; Liu *et al.*, 1993; Carter, 1999; Hosonuma *et al.*, 2012; Carandang *et al.*, 2013; Hughes, 2017). Some studies cite a single cause of deforestation, such as logging (Wertz & Kongphan, 2008). Others name numerous direct or proximate drivers (*e.g.*, Bee, 1987; Kummer, 1992) and underlying drivers (*e.g.*, Acosta, 1989; World Bank, 1989). In reality, these different causes of deforestation work in a system linked to each other (Geist & Lambin, 2002; Carandang *et al.*, 2013). Thus, it is essential to look at deforestation from a broader perspective where different drivers are at play (FAO, 2020).

Further, these drivers vary across time (Kummer, 1992; Bankoff, 2007; Carandang *et al.*, 2013) and space (Hosonuma *et al.*, 2012). With the change in administration, political interests could also change from forest production to protection (Kummer, 1992). Thus, the state of deforestation also changes. Similarly, the situation and context vary in every place. For example, Latin America is into agri-business; therefore, agricultural expansion in cattle ranching and soya production is the primary driver (Hosonuma *et al.*, 2012). Whereas in Southeast Asia, they are known for their timber and palm oil. Thus, deforestation due to logging and tree plantations is rampant (Wertz

& Kongphan, 2008; Hughes, 2017). Deforestation is a dynamic environmental problem. Hence, it is necessary to have an up-to-date understanding of its drivers to develop policies and strategies that fit the current situation (Hosonuma *et al.*, 2012). Further, a local identification of causes of deforestation is also essential to have a more informed decision in developing projects at the local level (FAO, 2020).

In the Philippines, information on the contemporary causes of deforestation remains limited (The Philippines REDD-plus Strategy Team, 2010). The latest synthesis on the drivers of deforestation by Carandang *et al.* (2013) used drivers listed in the Philippine REDD-plus strategy that were solicited from forest users and experts (The Philippines REDD-plus Strategy Team, 2010). Also, Carandang *et al.* (2013) focused only on four sites in the Philippines – Quezon, Southern Leyte, Palawan, and Misamis Occidental. With the recent implementation of new policies that promote forest conservation in the Philippines (*i.e.*, Executive Order No. 26, s. 2011; Executive Order No. 23, s. 2011), there have been changes in the state of deforestation in the country that were not covered by Carandang *et al.* (2013).

This study responds to the call for a more complex perspective of understanding the drivers of deforestation. It aims to compare forest cover estimates of the Philippines and identify the causes of deforestation from 1980 to 2020. The outcomes shall provide the latest information about deforestation in the Philippines, which is beneficial in policymaking and developing national REDD-plus strategies.

METHODOLOGY

Literature search and screening

This study conducted two literature searches. One literature search for forest cover estimates and another for the causes of deforestation. Sources published from 1980 to 2020 were obtained using the Scopus, Web of Science Core Collection, and Google Scholar platforms. In addition, Google Web Search was also used for forest cover sources to capture government reports (*i.e.*, DENR, FAO).

Keywords used for the sources of forest cover were forest cover, forest area, and the Philippines. While for the causes of deforestation papers, the keywords used include deforestation, forest loss, forest decline, land use/cover change, causes/drivers of deforestation, and Philippines.

The search was done on 19 February 2021, for the causes of deforestation sources and on 23 March 2021, for the forest cover sources. In total, 734 papers on the causes of deforestation and 234 sources for the forest cover were exported to CADIMA. This free web-based tool supports systematic reviews, systematic maps, and literature reviews for subsequent screening.

A two-stage review in CADIMA was done to examine the articles' relevance to the study's objectives. First, the title and abstract were reviewed. Followed by full-text screening. The criteria used in each stage are presented in **Table 1**. After the full-text screening, the final number of papers used in this study was 130 for causes of deforestation and 33 for the forest cover estimates.

Data extraction and analysis

The forest cover estimates were extracted and compared from each source. The 2003, 2010, 2015, and 2020 land cover data of DENR were further analyzed by doing crosstabulations to determine the transitions of forested areas and where these changes are concentrated. General classes such as agriculture, open/barren, brush/shrubs, grassland, forest, and built-up addressed the differences in the land cover classes used in each period. Annual and perennial crops were grouped into agriculture, and fallow areas were included in barren/open.

Meanwhile, the analysis of the causes of deforestation followed the framework of Geist & Lambin (2002), wherein the causes of deforestation may be classified into proximate and underlying causes. The broad and specific proximate and underlying causes of deforestation were extracted and counted. The papers were then classified into single, two-factor, three-factor, and four-factor causations.

The relationships of the different causes of deforestation were also noted to establish the various causal chain relationships. For simplicity, up to the second level of association was done in this study. The papers with the causal chain relationship were classified based on the following:

1. PROX – PROX – proximate causes driving other proximate cause/s (*e.g.*, logging companies constructed road networks inside the forest)
2. PROX – UNDER – proximate causes having feedback on underlying cause/s (*e.g.*, construction of roads enhancing market access)
3. UNDER – UNDER – underlying causes driving other underlying cause/s (*e.g.*, unemployment causing upland migration)
4. UNDER – PROX – underlying causes driving proximate cause/s (*e.g.*, upland migration causing shifting cultivation in the uplands)

To know how deforestation developed through time, the period when the causes of deforestation were reported was also noted. The causes of deforestation were classified into four periods – 1980-1989, 1990-1999, 2000-2009, and 2010-2020.

RESULTS

Forest cover estimates

Estimates of the forest cover of the Philippines varied from one source to another (**Figure 1**). Only the Philippine Forestry Statistics (PFS) of DENR and Forest Resources Assessment (FRA) of FAO had historical records of the Philippine forest cover.

The Forest Management Bureau (FMB), under the DENR, was responsible for publishing the PFS annually. The 1991 to 1997 forest cover was a projection from the 1988 Philippine-German Forest Inventory Project (P-GFIP). The P-GFIP was the second comprehensive forest inventory following the 1969 forest inventory conducted by the Philippine government (FMB, 1988). After the 1997 PFS, the next release of forest cover statistics was in 2003, 2010, 2015, and 2020. These were

Table 1. Criteria used in the two-stage screening process.

	Forest cover source	Cause of deforestation source
Title and abstract screening	a. The study covers the entire Philippines; and b. The focus of the study is on the forest ecosystem.	a. The study involves the Philippines or is conducted in the Philippines; and b. The focus is on the terrestrial forest ecosystem.
Full-text screening	a. The paper has a quantification of national forest cover; and b. The forest cover is from 1980 to 2020.	a. It talks about deforestation from 1980 to 2020; and b. It discusses the causes of deforestation.

based on forest inventories conducted by the National Mapping Resources and Information Authority (NAMRIA). From 1997 to 2010, the country's forest cover is decreasing, and it starts to increase from 2010 to 2020.

The FRA estimates were based on country reports. The FMB was responsible for preparing the Philippines' report to FAO, which was mainly coming from the PFS. Despite collecting country data from government agencies, variations were still observed in the PFS and FRA data. It was only in FRA 2020 that the DENR's and FAO's estimates were the same. It was also evident that the various editions of the FRA offered different historical estimates of forest cover.

Other estimates of forest cover were also collected from projects and published research. In 1988, two independent nationwide forest inventories were conducted – the 1988 Philippine-German Forest Inventory Project (P-GFIP) and a forest inventory commission by the World Bank and the Swedish Space Corporation (SSC). Comparing 1988 P-GFIP and SSC estimates, the SSC was higher by around 645,400 ha. The Environmental Science for Social Change (ESSC) also mapped the country's land cover in 2002 to compare it with the 2003 PFS. A difference of more than 1 M ha was found in the ESSC and PFS estimates of forest cover in 2002 and 2003, respectively. Meanwhile, a study by Estoque *et al.* (2018) estimated the 2010 forest areas from different remotely sensed images, namely CCI300, Landsat, MODIS250, MODIS500, GTCANOPY30, ALOS 25, and GLOBELAND30. Despite having the same period, the various remote sensing products showed different estimates of forest cover.

Forest transitions

Deforested areas across three periods were generally decreasing (**Table 2**). The majority of the forest loss in 2003-2010 and 2010-2015 were located in Region 4B, Region 2, and CAR. Meanwhile, in 2010-2015 and 2015-2020, most deforested areas were in CAR, Region 4B, and Region 13. These were also the regions where most forested areas can be seen.

Deforested areas transitioned to brush/shrub has increased from 40% of deforested areas in 2003-2010 to 65% in 2010-2015 and 69% in 2015-2020. Forested areas converted to brush/shrub were mostly seen in CAR, Region 4B, and Region 13. Regarding agricultural expansion, 24% of deforested areas in 2003-2010 and 2010-2015 were converted to agricultural areas and 16% in 2015-2020. Most transitioned areas to agriculture were in Regions 2, 4B, 5, 8, 13, and CAR.

Forest conversions to built-up areas were relatively increasing from 0.46% of deforested areas in 2003-2010 to 0.92% in 2010-2015 and 1.60% in 2015-2020. Increasing conversion to built-up areas was observed in regions such as Regions 1, 3, 4B, 6, 9, 11, and 12.

Causes of deforestation

The majority of the papers cited two factors of deforestation (47%, N=130) followed by single-factor (35%), three-factor (16%), and four-factor (2%). Of which, the tandem of wood extraction and agricultural expansion stands out, with 45 papers (35%) mentioning their relevance (**Table 3**).

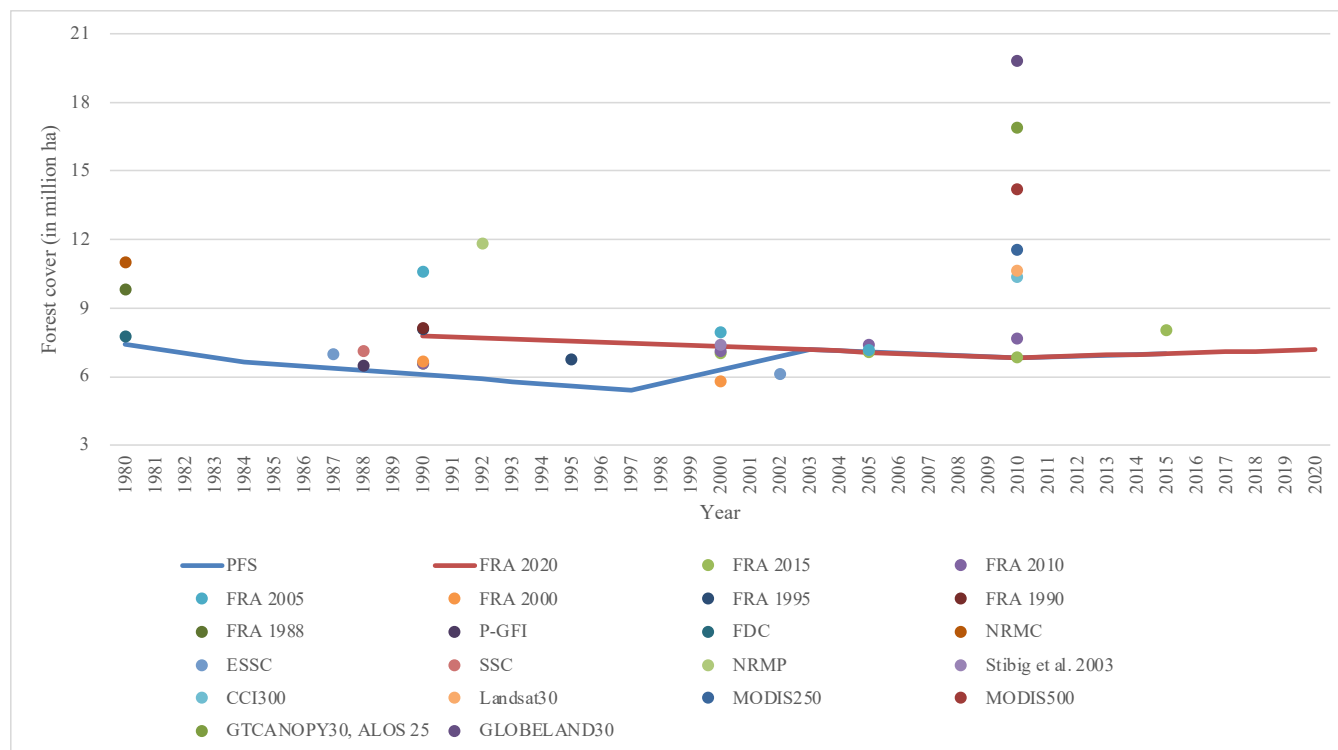


Figure 1. Study location showing Barangay Sta. Catalina.

Regarding specific proximate causes, most papers mentioned upland agriculture (52%, N=130), including agricultural cropping done by upland farmers, whether shifting or static cultivation (Table 4). Commercial logging (48%) and timber poaching (27%) dominated wood extraction. The difference between these examples of wood extraction was that the former was run by logging companies (Lasco *et al.*, 2001; Carandang *et al.*, 2013), while timber poaching was done by local individuals and displaced logging company workers and operating in a smaller scale than commercial logging (Hayama, 2000; Wallace, 2011).

These proximate causes were driven by underlying causes which were mostly single factors (38%, N=130), wherein more than half of the papers (53%, N=49) cited demographic and poverty factors (Table 5). This was followed by three-factor (21%, N=130), where most papers (74%, N=27) mention demographic and poverty factors, market demand and economic development, and governance, policy, and institutional factors. In terms of specific underlying factors, the majority

of the papers mentioned (Table 6) the increase in population (40%), upland migration (28%), and poverty (18%).

The linkages between proximate and underlying causes revealed that an underlying cause may drive two to three proximate causes. This was observed in demographic and poverty factors driving agricultural expansion (45%, N=130), wood extraction (14%), and infrastructure extension (4%). Market demand and economic development also influenced agricultural expansion (14%), wood extraction (19%), and infrastructure extension (5%). The governance, policy, and institutional factors contributed to agricultural expansion (15%), wood extraction (25%), and infrastructure extension (5%).

Aside from underlying causes driving proximate causes, other interlinkages and feedback among the proximate and underlying causes were also observed. A feedback loop among underlying causes was seen. For instance, demographic and poverty factors also drove other factors (19%, N=130). This was observed in poverty,

Table 2. Forest transitions for the period of 2003-2010, 2010-2015, and 2015-2020.

Region	Period	Agriculture	Brush/ Shrubs	Built-up	Grassland	Open/ Barren
NCR	2003-2010		7	3		
	2010-2015					
	2015-2020	7	19	18	1	
CAR	2003-2010	20,518	54,749	825	65,439	508
	2010-2015	20,287	80,380	1,793	13,457	281
	2015-2020	4,908	39,316	975	5,686	476
1	2003-2010	4,833	34,437	190	52,387	48
	2010-2015	905	14,835	172	2,407	36
	2015-2020	577	6,898	222	1,045	14
2	2003-2010	35,114	56,218	901	113,411	770
	2010-2015	20,665	50,142	758	12,365	1,049
	2015-2020	7,161	20,022	435	4,579	661
3	2003-2010	12,612	50,738	679	72,064	706
	2010-2015	9,526	22,743	398	4,906	566
	2015-2020	2,051	19,901	426	5,212	893
4A	2003-2010	25,225	36,316	640	3,372	491
	2010-2015	19,723	15,379	323	349	75
	2015-2020	3,574	6,062	164	819	156
4B	2003-2010	103,829	192,707	1,192	119,919	670
	2010-2015	17,021	84,264	487	7,000	932
	2015-2020	2,714	33,636	577	7,173	357
5	2003-2010	29,266	29,808	931	2,538	522
	2010-2015	20,328	13,747	573	2,893	396
	2015-2020	8,004	7,511	172	622	33
6	2003-2010	16,020	48,079	250	49,259	268
	2010-2015	8,975	15,658	310	4,481	61
	2015-2020	3,059	10,947	332	3,019	80
7	2003-2010	15,794	15,389	647	7,607	19
	2010-2015	4,064	18,839	513	302	74
	2015-2020	2,716	6,390	285	1,089	37
8	2003-2010	51,836	37,576	556	22,345	224
	2010-2015	25,598	31,453	570	1,274	185
	2015-2020	7,051	14,309	306	1,670	74
9	2003-2010	21,983	12,655	218	20,496	140
	2010-2015	15,447	17,959	169	2,971	46
	2015-2020	3,285	10,983	443	2,339	37
10	2003-2010	23,609	24,172	156	12,473	3
	2010-2015	10,350	28,133	508	8,334	60
	2015-2020	3,425	14,822	469	4,819	100
11	2003-2010	9,895	32,222	93	14,900	28
	2010-2015	6,631	61,353	283	5,414	443
	2015-2020	2,284	18,009	284	1,574	157
12	2003-2010	22,266	47,002	107	57,075	26

Table 2. (Con't)

Region	Period	Agriculture	Brush/ Shrubs	Built-up	Grassland	Open/ Barren
13	2010-2015	2,226	16,869	113	3,084	12
	2015-2020	1,858	10,460	274	1,997	21
	2003-2010	20,751	49,070	853	22,038	448
	2010-2015	8,628	49,435	481	1,560	643
	2015-2020	5,203	39,458	667	3,913	776
ARMM	2003-2010	13,761	11,855	107	4,684	91
	2010-2015	8,622	19,457	205	4,579	344
	2015-2020	3,061	9,784	166	2,199	620

Table 3. Frequency of broad proximate causes of deforestation in the Philippines.

Causation	Abs (N=130)	Rel (%)
Single-factor	45	
Agricultural expansion (Agro)	19	15
Wood extraction (Wood)	12	9
Infrastructure extension (Infra)	13	10
Othera	1	1
Two-factor	60	
Agro-wood	45	35
Agro-infra	6	5
Agro-other		
Wood-infra	5	4
Wood-other	2	2
Infra-other	1	1
Three-factor	21	
Agro-wood-infra	13	10
Agro-wood-other	8	6
Agro-infra-other		
Wood-infra-other		
Four-factor (All)	3	2
Unspecified	1	1
Total	130	100

Note: Abs=absolute frequency, Rel=relative percentage;

^aOthers such as fires, typhoons, landslides, floods, and climate change

landlessness, and lack of opportunities in the lowlands led to upland migration. Governance, policy, and institutional factors also drove demographic and poverty factors (11%), such as policies favoring commercial agriculture deprived

smallholder farmers of their lands, eventually leading to upland migration. Logging bans also displaced many workers, which contributed to poverty, and they remained in the upland to practice upland agriculture and timber poaching.

Table 4. Frequency of specific proximate causes of deforestation in the Philippines.

Specific proximate cause	Abs (N=130)	Rel (%)
Agricultural expansion	78	
Upland agriculture	67	52
Commercial agriculture	19	15
Expansion of pastureland	2	2
Infrastructure extension	51	
Mining	15	12
Settlement	13	10
Roads	10	8
Urbanization	7	5
Public service	4	3
Tourism infrastructure	2	2
Wood extraction	82	
Commercial logging	62	48
Illegal logging	35	27
Woodfuel collection	23	18
Other factors	14	
Fires	13	10
Typhoons, landslides, flood	4	3
Climate change	1	1

Note: Abs=absolute frequency, multiple counts possible; Rel=relative frequency, relative to the total number of papers (N=130).

Multiple counts were allowed in each paper as papers mention numerous particular causes.

^aIncludes shifting cultivation and smallholder agriculture.

^bIncludes fuelwood and charcoal.

The feedback loop among proximate causes was mostly seen in wood extraction, opening the forest for agricultural expansion (13%).

The feedback of proximate causes to underlying causes was also evident. Most papers cited wood extraction affecting demographic and poverty factors (9%), market demand, and economic development (4%). Commercial logging brought workers inside the forest, eventually contributing to upland migration. The construction of logging roads also encouraged upland migration and improved access to markets and urban centers.

The temporal analysis (**Figure 2**) of the causes of deforestation revealed changes in the most important cause over time. It is evident in Figure 2 that wood extraction and agricultural expansion were the most cited causes of deforestation from 1980 to 1999. The number of papers mentioning wood extraction has significantly declined

starting 2000, but agricultural expansion remained a significant cause of deforestation. From 2000, the rise of papers mentioning infrastructure extension as a cause of deforestation was observed. It is now one of the most cited proximate causes of deforestation and agricultural expansion.

DISCUSSION

Comparative analysis of forest cover estimates

There is no agreement on the forest cover of the Philippines. The variations in forest cover estimates can be attributed to their definition of forest, data used, and methodology. Very often, the increase in forest cover from 1997 to 2003 in PFS is attributed to the government's efforts to restore degraded forests in the country (e.g., FAO, 2006). Although there are reforestation projects all over the country, the abrupt increase in forest

cover from 1997 to 2003 may be due to the change in the definition of forest from a minimum of 1 ha to 0.5 ha in 2003 to have the same definition of forest with FAO. Starting in FRA 2000, the FAO adopted a new minimum forest area from 100 ha to 0.5, which also explains the variations among various editions of FRA. These changes in the definition of forest have increased areas that can be classified as forests and may not necessarily imply an increase in forest cover.

The spatial resolution of remote sensing images used in classifying land cover also affects the accuracy of the estimates. This is evident in *Estoque et al. (2018)*, where various remote sensing products with varying resolutions were used to estimate the forest cover of the Philippines and yielded different results.

In 2002, the ESSC conducted a national land cover mapping following the approach of NAMRIA in 2003. Still, the results yielded more than a 1 M ha

Table 5. Frequency of broad underlying causes of deforestation in the Philippines.

Causation	Abs (N=130)	Rel (%)
Single-factor	49	
Demographic and poverty factors (Pop)	26	20
Market demand and economic development (Econ)	12	9
Technological factors (Tech)	1	1
Governance, policy, and institutional factors (Gov)	10	8
Cultural factors (Cult)		
Two-factor	25	
Pop-econ	7	5
Pop-tech		
Pop-gov	12	9
Pop-cult		
Econ-tech		
Econ-gov	4	3
Econ-cult		
Tech-gov	1	1
Tech-cult		
Gov-cult	1	1
Three-factor	27	
Pop-econ-tech	1	1
Pop-econ-gov	20	15
Pop-econ-cult	1	1
Pop-tech-gov	1	1
Pop-tech-cult		
Pop-gov-cult	3	2
Econ-tech-gov		
Econ-tech-cult		
Econ-gov-cult	1	1
Tech-gov-cult		
Four-factor	5	
Pop-econ-tech-gov	3	2
Pop-econ-tech-cult	1	1
Pop-econ-gov-cult	1	1
Pop-tech-gov-cult		

Table 5. (Con't)

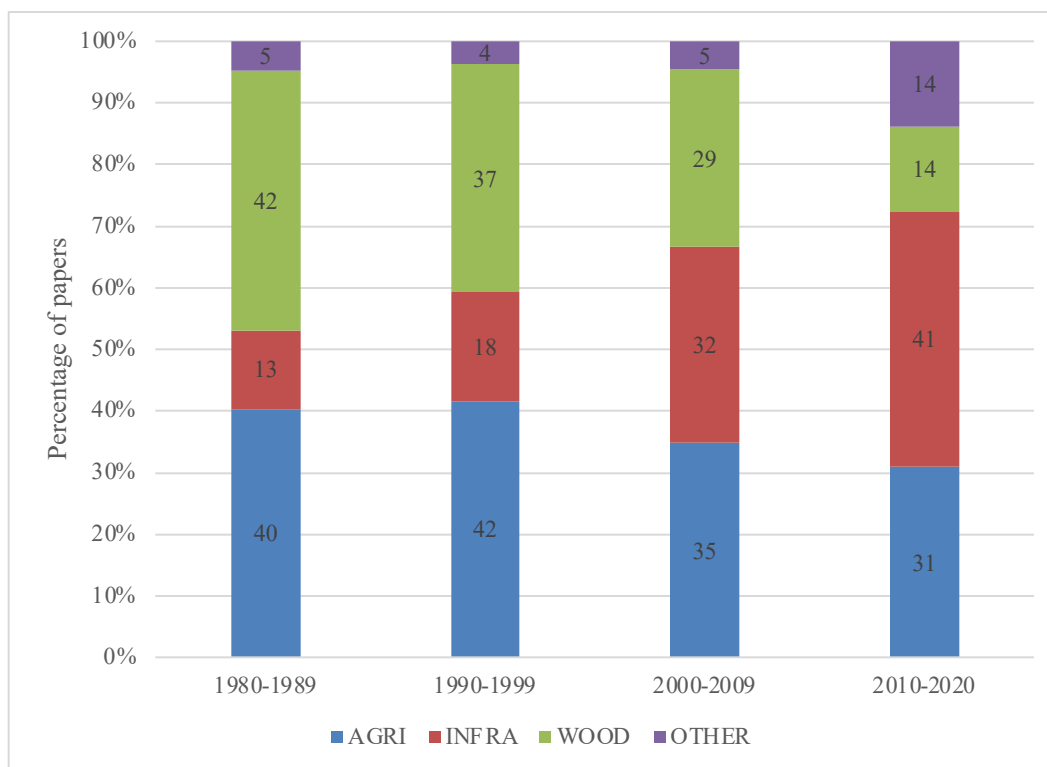
Causation	Abs (N=130)	Rel (%)
Single-factor	49	
Econ-tech-gov-cult		
Five-factor (All)	2	2
Unspecifie	22	17
Total	130	100

Note: Abs=absolute frequency, multiple counts possible; Rel=relative frequency, relative to the total number of papers (N=130).

Table 6. Frequency of specific underlying causes of deforestation and forest degradation.

Specific underlying cause	Abs (N=130)	Rel (%)
Demographic and poverty factors	76	
Increase in population	52	40
Upland migration	37	28
Poverty	24	18
Landlessness	18	14
Unemployment	15	12
Market demand and economic development	52	
Proximity to market, village, and urban centers	20	15
Increase in demand	19	15
Economic growth	9	7
Industrialization	7	5
Increase in price	5	4
Commercialization	5	4
Low-cost production	1	1
Technological factors	9	
Use of logging machinery	5	4
Improved production technologies	3	2
Chainsaws	2	2
Governance, policy, and institutional factors	60	
Corruption	28	22
Poor monitoring and law enforcement	27	21
Formal policy	22	17
Political support	13	10
Property rights	11	8
Low fees and taxes	10	8
Lack of policies	4	3
Unstable and conflicting law	2	2
External debts	1	1
Cultural factors	7	
Attitude	6	5
Lack of awareness	2	2

Note: Abs=absolute frequency, multiple counts possible; Rel=relative frequency, relative to each category.



Note: AGRI – agricultural expansion; INFRA – infrastructure extension; WOOD – wood extraction; OTHER – other factors such as fires, floods, typhoons, landslides, and climate change.

Figure 2. Number of papers discussing the different broad proximate causes across four periods.

difference. These differences may be due to the subjective judgment of the classifier (Weiers *et al.*, 2002). Image interpretation is subject to the biases of the interpreter. Thus, the results in land cover classification may still be different.

Despite the differences in forest cover estimates, the general trend of Philippine forest cover from 2010 to 2020 shows a slow increase in forest cover, which supports the findings of some studies (Matthews *et al.*, 2010; Youn *et al.*, 2017; Liu *et al.*, 2017) where the country is already at the post-transition stage. It has reached the point of increasing forest cover through reforestation (Hosonuma *et al.*, 2012).

Causes of deforestation

Mapping the causes of deforestation in the Philippines shows the complexity of deforestation in the country. Multiple factors cause deforestation, and they also vary across the country. It is caused mainly by the tandem

of agricultural expansion and wood extraction. Specifically, it is caused by upland agriculture, commercial logging, and timber poaching. The cross-tabulation of land cover maps revealed that agricultural expansion is mostly in Regions 2, 4B, 5, 8, 13, and CAR. This coincides with the study sites of papers mentioning agricultural expansion, which include Nueva Vizcaya, Oriental Mindoro (Lasco *et al.*, 2001), Palawan (Dressler *et al.*, 2018), and CAR (Prill-brett, 1994; Carandang *et al.*, 2013). Meanwhile, the large forested areas converted to brush/shrub may not be entirely attributed to wood extraction as not all areas with a high transition to brush/shrub has high log production (DENR-FMB, 2021).

Regarding underlying causes, most papers cite demographic and poverty factors, whereas most papers relate deforestation to the increase in population. The interactions of the different proximate and underlying causes are also evident in the papers. Expectedly, underlying causes drive

proximate causes, where one underlying cause drives two to three proximate causes. Agricultural expansion is driven mainly by demographic and poverty factors. In contrast, wood extraction is mainly driven by governance and institutional factors. The reverse (*i.e.*, proximate causes driving underlying causes) is also seen in some papers. Commercial logging contributed to upland migration by bringing people into the forest and building road networks inside the forest. Also, feedback is observed within broad proximate and underlying causes. Demographic and poverty factors such as upland migration and increasing upland population affect each other. Commercial logging, commercial agriculture, and mining also include the construction of roads. These show that deforestation in the country is not caused by a single factor but by a complex relationship of different proximate and underlying causes.

The temporal analysis of the causes of deforestation and cross-tabulation of land cover maps shows the changing pattern of deforestation through time and across the country. The decrease in papers mentioning wood extraction as a cause of deforestation may be attributed to the expiration of wood companies' Timber License Agreements (TLAs). Most of the reported cases of deforestation are from TLA holders (*e.g.*, Carandang *et al.*, 2013; van den Top, 2003; Lasco *et al.*, 2001). Since no more TLAs were issued after 1987, recent papers focused on post-logging drivers of deforestation, such as forest migrants converting logged-over areas into upland agriculture (Carandang *et al.*, 2013) and displaced logging company workers conducting illegal logging (Hayama, 2000; van den Top, 2003). TLAs were replaced by new tenurial instruments, which include Integrated Forest Management Agreement (IFMA), Socialized Forest Management Agreement (SIFMA), and Community-Based Forest Management Agreement (CBFMA) (Bugayong, 2006). However, no studies assess these new instruments' effectiveness in addressing deforestation.

Agricultural expansion remains a significant cause of deforestation. This is because the Philippines is still an agricultural country, and there are plans to expand, especially its oil palm

plantations (Carandang *et al.*, 2011; Villanueva, 2011; Philippine Palm Oil Industry Road Map 2014-2023). With the increasing population, the demand for food will continue to rise and may be at the expense of forested areas (Lapniten, 2020). The increase in the significance of infrastructure extension may be attributed to accelerating infrastructure development in the country and increased demand for housing. Expansion of roads and expressways may lead to opening forested areas and encourage migration and encroachment (Baehr *et al.*, 2021). Deforestation in the Philippines has already changed from wood extraction dominated in the 18th century to agricultural expansion and infrastructure extension, and policy changes played a significant role in this observed evolution of deforestation. With increasing population and economy, it is unavoidable that land resources are utilized through agricultural expansion and infrastructure extension to serve the country's needs. Hence, proper land use planning and land classification and stronger protection of protected areas should be done to ensure the sustainability of various ecosystem services.

Limitations of the study

Literature review studies are subject to publication, quality, discussion, and selection biases (Haddaway *et al.*, 2015). Publication, quality, and discussion biases are inherent in the papers reviewed. Since the papers reviewed are from peer-reviewed journals and books, the author believes the papers are already reviewed against biases before publication.

In addition, this study is also subject to author biases. Since the sole author conducted the study, no consistency checks were conducted. Most of the papers also consider deforestation and forest degradation. This study focuses on deforestation only, and there were difficulties in distinguishing the drivers of deforestation and forest degradation from the papers. Although the Geist & Lambin (2002) framework was used to help identify the causes of deforestation, some causes were not included as the author thinks they do not fit the definition of deforestation (FAO, 2012). For instance, the extraction of non-wood forest

resources (e.g., rattan, bamboo, almaciga resin, wild honey, vines, medicinal plants, and fauna) does not necessarily lead to deforestation because they do not involve wide forest clearances (i.e., Callo, 1995; Eder, 2006). Also, pests and diseases are not included as only selected species are affected, which does not necessarily lead to deforestation (i.e., Briones *et al.*, 2017). Meanwhile, illegal logging and wood fuel extraction are still included in the analysis of causes of deforestation despite their minimal impact on forest cover because of the many papers mentioning them.

CONCLUSION

This study collated forest cover estimates of the Philippines from 1980 to 2020 from various sources such as the DENR, FAO, and independent studies. The different sources have varying estimates of forest cover due to varying data, methodology, and definitions of forest used. These differences made comparison and computation of deforestation rates difficult. Despite the differences in the forest cover estimates, the general trend of forest cover from 2010 to 2020 is slowly increasing.

The analysis of the causes of deforestation also reveals that deforestation in the Philippines is caused by multiple factors, mainly agricultural expansion and wood extraction. Specifically, upland agriculture and commercial and illegal logging are the leading proximate causes. In terms of underlying causes, this study shows that deforestation is not only driven by demographic and poverty factors. It is also driven by governance, policy, and institutional factors, such as corruption, poor monitoring and law enforcement, formal policy, market demand, and economic development, such as proximity to market, village, and urban centers and increase in demand. Further, this study has shown the relationships between the various causes of deforestation. It reveals that underlying causes and vice versa drive proximate causes. There are also interactions between proximate and underlying causes.

Temporal analysis of the causes of deforestation and cross-tabulation of land cover maps revealed the increasing relevance of agricultural expansion and infrastructure extension as causes of deforestation. Thus, it is recommended to have proper land use planning and land classification and stronger protection of protected areas to ensure the sustainability of the various ecosystem services. Future studies may validate the importance of wood extraction, especially in areas under tenurial agreements, as a driver of deforestation. The huge areas transitioning to brush/shrub should also be investigated to determine the causes of such change.

ACKNOWLEDGMENTS

The author is thankful for Dr. Christian Pilegaard Hansen's contribution to supervising her during this study as part of her master's thesis at the University of Copenhagen, Denmark. Also, to Dr. Øystein Juul Nielsen for his valuable comments to improve the study.

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