



Assessment of rate and drivers of deforestation and forest degradation in the lower-tropical region: a case of Punarbas Municipality, Nepal

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Abstract

Deforestation and forest degradation (D and D), the most imminent threats to the survival of species and the viability of forests as a whole, is crucial to research its rate, as well as the underlying causes. The present study examined the rate and drivers that contribute to D and D in the Punarbas Municipality of Kanchanpur district, Nepal. With the help of ArcGIS 10.8, an overall pattern and rate of D and D in the study area was identified using Land Satellite images from two different years (2000 AD and 2019 AD). 11 focus group discussions and 120 household surveys were carried out to collect data on key drivers of D and D. For data collection, stratified random sampling with a sampling intensity of 1% was used, and the Friedman test was applied for one-way repeated measures analysis of drivers by ranks. The study found that the annual rate of D and D of the study area from 2000 to 2019 AD was 0.63% and the major drivers were infrastructure development followed by illegal logging, agricultural expansion, livestock grazing forest fire, fuelwood collection, settlement/resettlement, alien invasive species, and flood and landslide. Awareness programs are highly suggested to uplift the understanding level of local people, so they can act for themselves in the conservation of their local forest and ecosystem resources.

Keywords: Deforestation, forest degradation, land satellite, LULC, stratified random sampling

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Introduction

Deforestation is defined as the removal of forest cover (Nepal, 2013), and a degraded forest is one whose structure, function, species diversity, or productivity has been irreversibly altered or lost as a consequence of deleterious components (Vásquez *et al.*, 2018). Forests cover around 31% of the planet's total surface area, and approximately 420 million hectares of forest land have been converted to other land uses since 1990 (Barbier *et al.*, 2020). The forest is both a sink and a source of carbon, and effective forest resource management contributes significantly to the lowering of atmospheric carbon levels through carbon sequestration

(FAO and UNEP, 2020). However, more than 2000 million hectares of the world's forest have been degraded (Stanturf *et al.*, 2014).

Degradation factors, also known as “drivers” of degradation, vary from place to place and are categorized as direct and indirect drivers (Acharya *et al.*, 2011), depending primarily on the socioeconomic and ecological condition of a site (Rudel *et al.*, 2009; Boucher *et al.*, 2011). Direct drivers are human activities and actions that directly impact forest cover and result in a loss in carbon stocks whereas indirect drivers are complex interactions of social, economic, political, cultural, and technological processes that affect the proximate drivers to

cause D and D (Kissinger *et al.*, 2012). Pandey *et al.* (2013) suggest that in developing countries the conversion of forests into farmlands, forest fires, grazing, encroachment, illegal harvesting, and infrastructural development are the main drivers for the degradation of the forest. New land for agriculture is the primary driver of deforestation, whereas logging is the primary driver of degradation (Houghton, 2012).

As per the report of the DFRS (2015), 44.74% of the total area of Nepal is covered by forests and the far western region has the lowest forest coverage (16.94%) out of the total area. Nepal's average deforestation rate is 1.7%, which is higher than both the Asian and world averages of 1% and 1.3%, respectively (Dhital, 2009). The average deforestation rate in tropical regions of the world is 0.5% per year (Van and Van, 2020). In the Lower Tropical regions of Nepal, the annual deforestation rate is about 0.44 % (1,648 ha/yr) (Rai *et al.*, 2017). Forest degradation in Nepal has negative and interconnected biological, environmental, and social consequences (Acharya *et al.*, 2011). Analysis of the causes of D and D is crucial for the formulation of policies and strategies aimed at changing present forest activity trends in favor of a more climate and biodiversity-friendly result (Jayathilake *et al.*, 2021; Hosonuma *et al.*, 2012). In the modern scenario REDD+, the identification of the major drivers of D and D is a critical task (Pandey *et al.*, 2013). For the enhancement of carbon stocks and reducing the emissions from D and D, the careful and systematic analysis of all the direct and indirect drivers of D and D should be of priority in every REDD+ country.

Several researchers such as Chaudhary *et al.* (2016), Chapagain and Aase (2020), and Oldekop *et al.* (2019), have investigated the conditions and trends of deforestation, but there is still a scarcity of information regarding the variables that influence forest degradation (Mon *et al.*, 2012). Such types of research are lacking in the lower tropical regions of Nepal. The D and D rate in lower tropical areas of Nepal is increasing. Thus, the study aims to find out the rate and drivers of D and D in the Punarbas Municipality, Nepal which is located in the lower tropical region. This study will be a baseline for other researchers and concerned authorities to manage and initiate forest conservation activities.

Materials and Methods

Study area

The study was conducted in the Punarbas Municipality (28°37'29.64"N and 80°29'36.38"E) of Kanchanpur district, Sudurpashchim Province, Nepal (Figure 1). Geographically, the district lies in the southwestern part of Nepal. The municipality occupies an area of 10,337.72 ha., and extends from altitudes range of 159 to 212 MSL in the lower tropical region. The annual temperature range of the municipality lies between 43°C to 5°C. The study area consists of tropical *Shorea robusta* (Sal) forest along with the mixed deciduous forest. The major floral species in the forests are *Shorea robusta* (Sal), *Terminalia tomentosa* (Saaj), *Syzygium cumini* (Jamun), etc. The total population of the municipality is 53, 633 (male: 24,907, and female: 28,726) (Household survey, Municipality, 2016).

Why punarbas municipality?

Between 2001 AD (population: 377899) to 2016 AD (population: 5,54,607), the Kanchanpur district experienced a population growth of 46.76 %, according to Nepal's Central Bureau of Statistics. Because of the low cost of land and ease of access to India for economic opportunities, there has been a surge in individuals' migration from the hills of Sudurpaschim province to study areas. As a result, the forest area has experienced a massive increment in D and D. Thus, the findings of this study helped to depict a general pattern of forest degradation and deterioration throughout the lower tropical region of the country, as the majority of forests confront the same sort of population pressure.

Data collection

Primary data collection

The primary data collection procedure was separated into two sections: satellite images and surveys.

Satellite image

For deforestation rate assessment, LULC (Land Use Land Cover) maps of 2000 and 2019AD were prepared. The acquisition of data was carried out in 2000 AD owing to the accessibility of Landsat-7 data (launched in

April 1999), because its preflight calibration is better than 4% in all bands when compared to previously available Landsat-5 data, and the standard deviation of the average difference implies a precision of the reflectance-based method on the order of 3%. (Austin *et al.*, 2019). The data were Landsat imageries (Landsat 7 for 2000 and Landsat 8 for 2019) downloaded from USGS earth explorer

(<https://earthexplorer.usgs.gov>) to prepare LULC maps in ArcGIS. The Multi-Spectral Remote Sensing data technology was used to compute the NDVI (Normalized Difference Vegetation Index), which refers to the vegetation and land cover condition at different NDVI threshold values between 2000 and 2019 (Austin *et al.*, 2019).

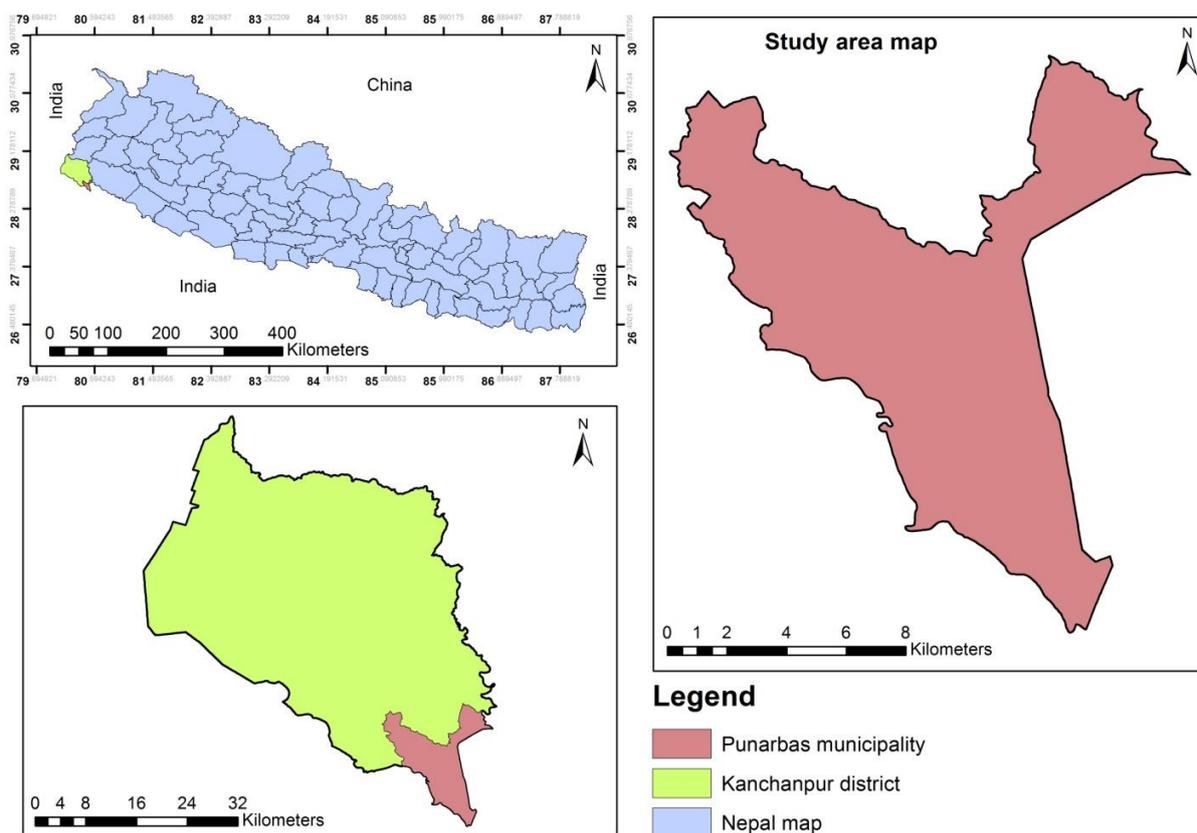


Figure 1. Study area map showing municipality.

Satellite	Years	Sensor	Total bands	Temporal resolution	Spatial resolution (m)	Path row	Date of acquisition
Landsat 7	2000	ETM ⁺	1-11	16 days	30*30	144/040	15 Sep 2000
Landsat 8	2019	OLI	1-14	16 days	30*30	144/040	8 Sep 2019

Table 1. Details of the remotely sensed data used in the study.

Survey

Data was acquired via stratified random sampling from the whole municipality, which was divided into 11 wards. 11 focus group discussions with ward officials and community forest members were conducted in each of Punarbaspur municipality's wards to identify major

drivers of D and D. Subsequently, out of a total of 12001 homes, a questionnaire survey was performed to rate the drivers of D and D from 120 households (sample intensity of 1%), with no repetition of individuals who participated in the focus group discussion.

Secondary data collection

Secondary data was gathered through internet portals, including Google Scholar, documents published by Punarbas Municipality, and the Central Bureau of Statistics.

Data analysis

The data analysis procedure was divided into two sections: satellite image analysis and survey data analysis, with secondary data analysis included in the aforementioned phase of the analysis.

Satellite image

Image processing and LULC class detection

ArcGIS 10.8 had been used to composite the bands together into a single layer utilizing the image analyst tool for image processing and supervised classification of the Landsat imageries. Then, using the clip raster tool in ArcGIS, the generated shape-file of Punarbas municipality was utilized to clip these imageries. These clipped images were then reprojected into the 44N zone of the Universal Transverse Mercator (UTM). Then, using ArcGIS, per-pixel signatures were assigned to Landsat images. A signature file was made around sample locations for each of the preset classes, describing minimal confusion amongst LULC to be mapped (Chowdhury *et al.*, 2020). As a result, using Google Earth, signatures were generated in the Landsat images. For image categorization, the maximum likelihood algorithm was applied.

Field survey and accuracy assessment

The evaluation of classification against ground-truth data to determine how well the classification represents realistic geographical reference data is known as accuracy assessment. To assess the classification accuracy, random points were applied in this study. Altogether 84 (42 and 42) ground truth positions were collected with the help of Google earth images for 2000 and 2019 AD respectively. Accuracy assessment was done using a confusion matrix, calculating the Kappa coefficient and overall accuracy. Correctly classified pixels were divided by the total number of pixels to calculate the classification accuracy. Similarly, user's and producer's accuracy were calculated to classify the accuracy of individual classes (Bharatkar

and Patel, 2013). Results are demonstrated using bar diagrams, pie charts, and tables.

$$\text{Overall accuracy (\%)} = \frac{\text{Number of correct pixels}}{\text{Total number of pixels}} * 100$$

$$\text{Users' accuracy (\%)} = \frac{\text{pixels classified correctly}}{\text{Total classified pixels}} * 100$$

$$\text{Producers' accuracy (\%)} = \frac{\text{pixels classified correctly}}{\text{Total reference pixels}} * 100$$

$$\text{Kappa coefficient (K)} = \frac{P_0 - P_e}{1 - P_e}$$

Where, P_0 =Proportion of pixels classified correctly and P_e =Proportion of pixels classified correctly expected by chance.

Calculation of annual rate of change for the specific land class was done using,

% Of land used area of a specific land class in 2019 – % of the land used area of that land class in 2000

19 (change in years)

Survey

MS Excel 2010 was used to organize and evaluate the information gathered from focus group discussions and household surveys. People's perceptions of drivers of forests D and D were analyzed using a Likert scale.

Similarly, the Friedman ANOVA test was applied to test differences among different drivers and It was calculated by using the following formula:

$$Q = \frac{12}{nk(k+1)} \sum_{j=1}^k R_j^2 - 3n(k+1)$$

Here, Q =Friedman statistics, k = the number of groups (treatments), n = the number of blocks, R_j is the sum of the ranks for the group j .

Results

Rate of deforestation between 2000 and 2019

The LULC maps for 2000 and 2019 were prepared (Figures 2 and 3). In the year 2000, the forest area has covered 43% of the total area which has decreased to 31% of the total area in 2019. Similarly, sparse vegetation has covered 42% of the total area which has decreased to 38.4% of the total area in 2019. In contrast to this, built-up area and bare land have been increased from 5% and 7% to 19% and 11% respectively (Figure 4). The annual rate of decrease in the forest was 0.63% while sparse vegetation was decreasing at the rate of 0.18%. The built-up area was increasing at the rate of 0.73% per year and bare land was increasing at

the rate of 0.21% per year (Figure 5). This definition of sparse vegetation includes Pasture, maize fields, potato fields, mustard fields, vines, woods, forests, lawns, vegetable gardens, non-asphalted roads, small patches of ruderal vegetation

(Martinez, 2010). Similarly, the month of the Satellite image is early November, during this time approximately all rice is harvested from the field for the wheat to be sown. Therefore, paddy fields are included in the category of Bareland.

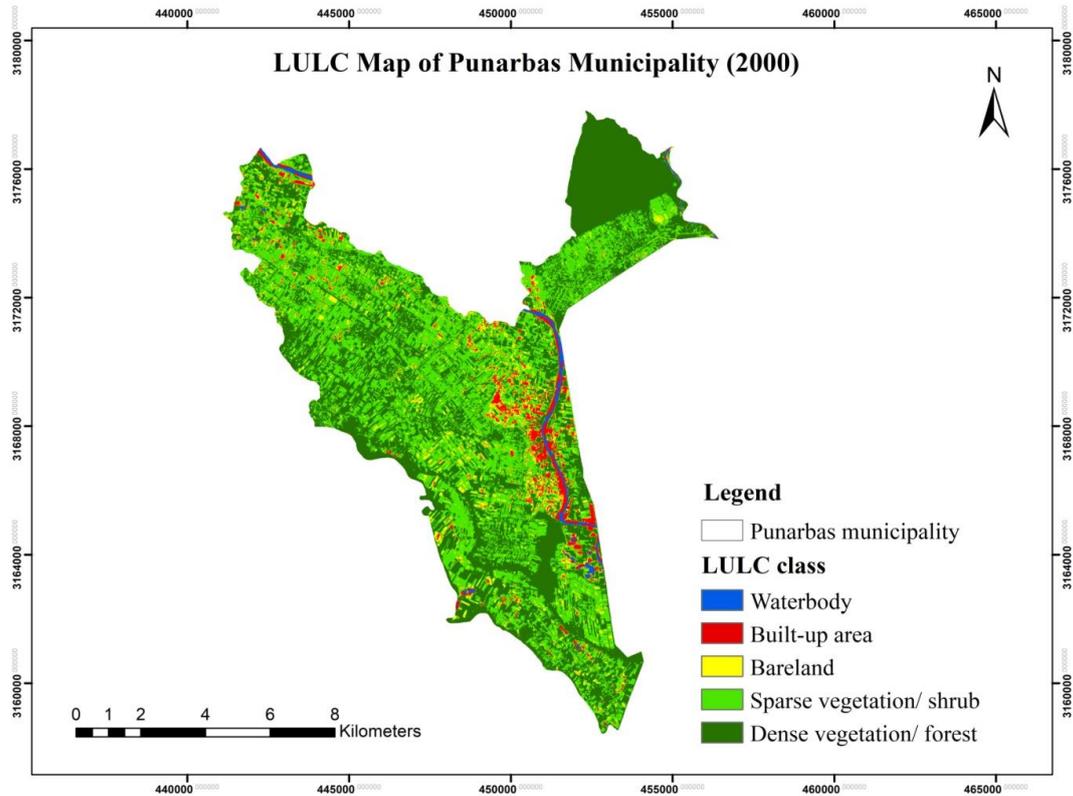


Figure 2. LULC Map of the municipality in 2000.

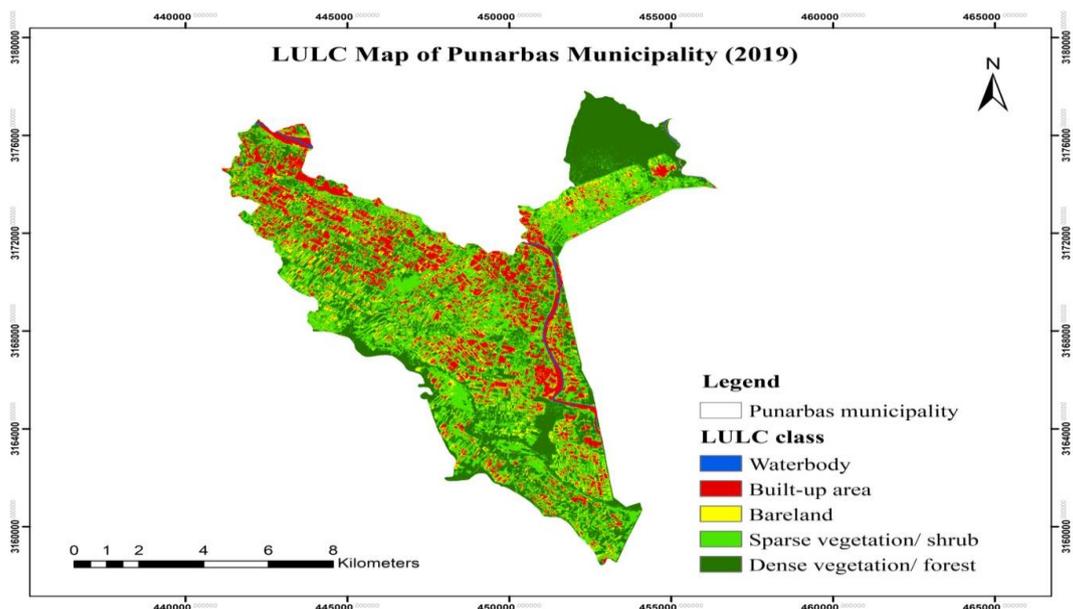


Figure 3. LULC Map of the municipality in 2019.

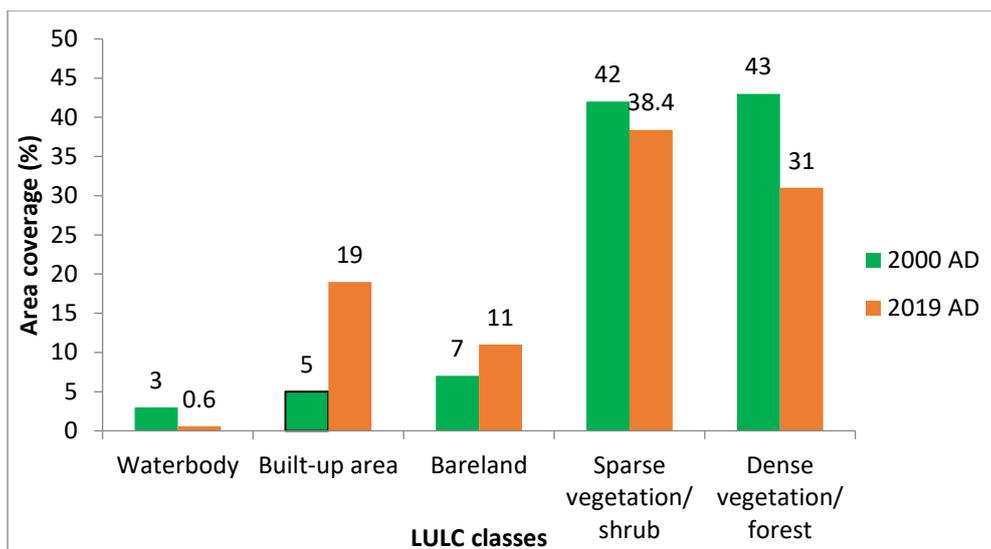


Figure 4. LULC Status of the municipality in 2000 and 2019.

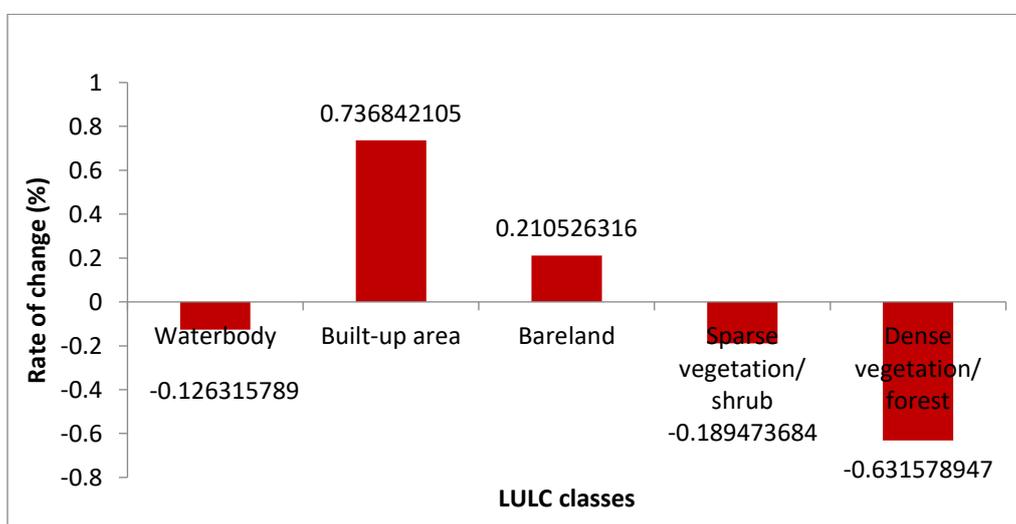


Figure 5. Annual rate of LULC change between 2000 and 2019.

Accuracy assessment for LULC maps

The overall accuracy was 76.19 for the year 2000, while it was 83.33 for the year 2019. The

kappa coefficient was 0.71 and 0.78 for the years 2000 and 2019 respectively (Table 2 and 3).

Table 2. Accuracy assessment for LULC map of the year 2000 AD.

2000/ truth	Ground truth	Waterbody	Built-up area	Bare land	Sparse vegetation / shrub	Dense vegetation / forest	Total	Users' accuracy (%)
Waterbody	4	0	0	2	0	6	67	
Built-up area	0	3	2	0	0	5	60	
Bare land	1	1	6			8	75	
Sparse vegetation/ shrub	0	0	2	11	1	14	79	
Dense vegetation/ forest	0	0	0	1	8	9	89	
Total	5	4	10	14	9	42		

Producers' accuracy (%)	0.80	0.75	0.60	0.79	0.89	Overall accuracy= 76.19
Kappa coefficient	0.71					

Table 3. Accuracy assessment for LULC map for the year 2019 AD.

2019/Ground truth	Waterbody	Built-up area	Bare land	Sparse vegetation/shrub	Dense vegetation/forest	Total	Users' accuracy (%)
Waterbody	3	0	1	1	0	5	60
Human buildup	0	9	1	1	0	11	81.82
Bare land	0	0	8	1	0	9	88.89
Sparse vegetation/shrub	0	1		10	1	12	83.33
Dense vegetation/forest	0	0	0	0	5	5	100
Total	3	10	10	13	6	42	
Producers' accuracy (%)	100	90	80	76.92	83.33		Overall accuracy=83.33%
Kappa coefficient	0.78						

Factors determining the level of D and D**Condition of the Forest**

Out of the total respondents surveyed, a remarkably high number of respondents (75%) believed that forest deforestation and degradation are happening in their forests. However, a very limited number of respondents (25%) still believed that deforestation and degradation of forest land were not happening in their forest land.

Sources of energy for Preparing food and other cooking stuff

Concerning the source of fuel, 45 % of the focus group reported their source of fuel as firewood followed by Kerosene 30%, cow dung 15%, LPG 7 %, and others (Bio-gas, etc.) 3 %. Similarly, 79% of focus groups have electricity as the source of their household lighting.

Fodder collection

The survey reveals that 75% of respondents go to the forest for the collection of fodder and 25% of respondents didn't practice animal husbandry.

Plantation of fodder trees on barren or Agricultural land for alternatives

The study shows that 33% of respondents plant a tree. Whereas 55% didn't plant on their barren land, and the remaining 12% didn't have open land for fodder tree plantation.

Analysis of major drivers causing forest deforestation and degradation

Table 4 lists the key drivers of forest deforestation and degradation, along with the underlying causes, based on 11 focus group discussions and secondary gathered from the document's municipality.

Table 4. Analysis of major drivers causing forest deforestation and degradation.

S. N	Direct Drivers	Underlying causes (Indirect Drivers)
1	Settlement/	➤ Political instability (Sukumbasi Basti) }

	Resettlement	➤ Population pressure in the Terai region (migration from the hilly region of SudurPaschim province was increased dramatically)
2	Illegal logging	➤ Weak enforcement of law ➤ Poverty and increasing demand for forest-related products ➤ Easy to transport forest products like valuable timber to India ➤ Furniture factories were established close to the forest area ➤ Establishment of brick kilns. ➤ Weak governance
3	Alien invasive species	➤ Increase in climate change ➤ Insufficient funds ➤ Ignorance of community people ➤ No effective measures of control ➤ Weak forest management practice
4	Agriculture expansion	➤ Increased in several migrations. ➤ Limited income-generating opportunities ➤ Political support. ➤ landlessness
5	Fuelwood collection	➤ sparse alternatives of fuelwood ➤ Easy access to forest ➤ Poverty and unemployment
6	Infrastructure Development	➤ No restrictions on government-managed forest ➤ Construction of roads, transmission lines, temples, etc. ➤ Political change ➤ Low valuation of forest land and area by responsible authorities and people of the locality
7	Forest fire	➤ Lack of awareness ➤ Carelessness ➤ Intentional (New coppice for grazing animals)
8	Livestock grazing	➤ Open access to forest ➤ Limited agricultural land ➤ Poverty ➤ Traditional farming ➤ Limited option/ alternative for fodder to livestock ➤ Improper monitoring and supervision
9	Flood and landslide	➤ Lack of proper research and improper monitoring ➤ Agricultural activities ➤ Insufficient funds ➤ Lack of development of soil and water-conserving structure

According to table 5, 120 household surveys were conducted in the municipality's 11 wards, with 11 respondents from Wards 1 to 10 and 10 respondents from Ward 11. All of the respondents who took part in the focus group discussions were not set to take part in the household survey.

Preference value ranking was assigned as used by Ishtiaque *et al.* (2017) for ranking each driver's factor in each ward or municipality, as shown in table 6. The following outcomes were created based on preference value ranking, as shown in the table below:

According to the respondents (n=23), infrastructure development is the main driver for D and D, followed by illegal logging (n=21), Agricultural expansion (n=19), Livestock grazing (n=16), Forest fire (n=12), Fuelwood collection(n=11), Settlement/re-settlement (n=9), Alien invasive species (n=7). Similarly, flood and landslide (n=1) is the least significant drives of D and D. An analysis of variance (ANOVA) suggested that there was a significant difference among different divers (P<0.05)

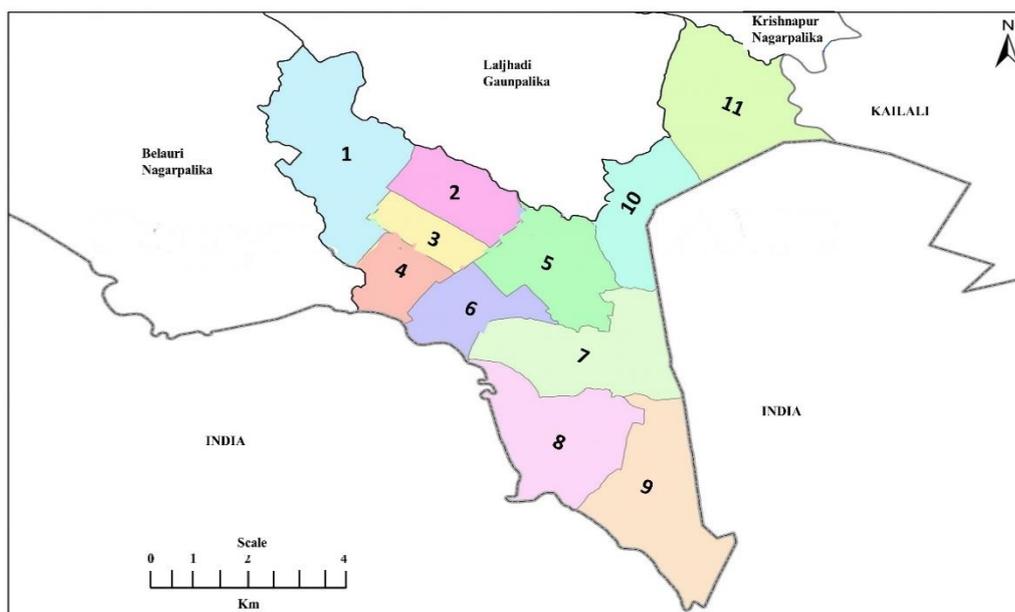


Figure 6: Wards of Punarbas municipality.

Table 5. Drivers of deforestation and forest deforestation according to wards.

Drivers	Wards											Total
	1	2	3	4	5	6	7	8	9	10	11	
Settlement/ Resettlement			4				1		4			9
Illegal logging	5	1	1		3		4	4			3	21
Alien invasive species					2			2	1		2	7
Agriculture expansion	2				5		2	5	1		4	20
Fuelwood collection		6	2						2	1		11
Infrastructure Development	3			8		2	3			6	1	23
Forest fire		4	1	1		4	1			1		12
Livestock grazing	1		3	2		5			3	3		17
Flood and landslide					1							1
Total sum	11	10	120									

Table 6. Ranking of drivers according to towards.

Ward No	Ranking of drivers
1	1 st : Illegal logging 2 nd : Infrastructure development 3 rd : Agriculture expansion
2	1 st : Fuelwood collection 2 nd : Forest fire

3	3 rd : Illegal logging 1 st : Settlement/Resettlement 2 nd : Grazing
4	3 rd : Fuelwood collection 1 st : Infrastructure development 2 nd : Livestock grazing 3 rd : Forest fire
5	1 st : Agriculture expansion 2 nd : Illegal logging 3 rd : Alien/ Invasive species
6	1 st : Livestock grazing 2 nd : Forest fire 3 rd : Infrastructure development
7	1 st : Illegal logging 2 nd : Infrastructure development 3 rd : Agriculture expansion
8	1 st : Agriculture expansion 2 nd : Illegal logging 3 rd : Alien/ Invasive species
9	1 st : Settlement/Resettlement 2 nd : Grazing 3 rd : Fuelwood collection
10	1 st : Infrastructure development 2 nd : Livestock grazing 3 rd : Forest fire
11	1 st : Agriculture expansion 2 nd : Illegal logging 3 rd : Alien/ Invasive species

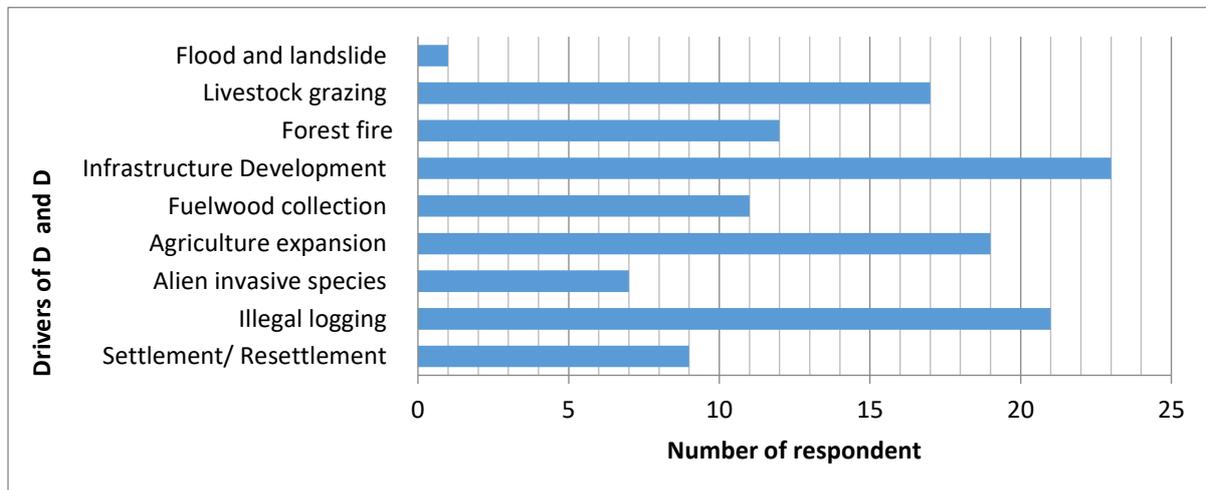


Figure 7. Drivers of D and D according to the respondent.

Discussion

The forests in the lower tropical zones have huge regulatory roles in hydrological and biogeochemical cycles (Eltahir and Bras, 1996; Warren *et al.*, 2011), their depletion at the current rate has harbored danger to the

biological diversity of the region (Myers *et al.*, 2000; Legal *et al.*, 2001). Our case study carried out in the municipality of Kanchanpur district depicts an exemplary scenario of the lower tropics where our results show that a considerable amount of forest land has changed

to other land used areas due to forest deforestation and degradation. The analysis of past trends of deforestation and degradation in the forests of lower tropical zones shows an increasing swing (Mas *et al.*, 2004; Chowdhury, 2006; Lele and Joshi, 2009). Our findings show a decrease in the forest area of the region at a rate of 0.64% annually from 2000 to 2019 AD compared with tropical deforestation rates of forests of Mexico (0.8%) (Bocco *et al.*, 2001; Turner *et al.*, 2001; Velaquez *et al.*, 2002), and Southeast Asia (0.76%) (Chowdhury, 2006), appears to be a little less. This could be attributed to the fact that the population of the region is dependent on forest resources only for subsistence livelihood and no accountable commercial felling has the region suffered. Comparing the LULC map of the study area of November 2000 AD and November 2019 AD showed a sharp increase in human buildup with a substantial decrease in dense and sparse vegetation along with water resources of the area. The recorded geospatial data (Land used land cover) for approximately 19 years obtained from USGS Earth Explorer and Copernicus helped to support the finding. Also, the findings of (Pandey *et al.*, 2013), during the period between 1990-2010, show a change of 24% in forest cover of Nepal only; similar have been the cases in Indonesia and Cambodia, facing a change of 23% and 22% respectively. If such is the case to remain, fewer and fewer patches of forest in the tropics will be left out.

It is to be understood that the understanding of direct drivers of D and D helps in robust policy and lawmaking process which eventually contribute to forest conservation. In our study area, we found a total of 9 proximate (directly affecting) drivers and 29 underlying (indirectly affecting) causes where the preference value ranking table demonstrates the major drivers of D and D ward-wise. Our study depicts that the major drivers seem to be similar in each ward but there is dissimilarity in the ranking of drivers according to wards which are due to differences in socioeconomic and physiographic conditions of the wards. Other research regarding the identification of major drivers of D and D carried out in lower tropics and their analysis exhibit common proximate drivers, only differing in their intensity levels. Human settlements (Mertens and Lambin, 2000; Zhao *et al.*, 2006), areas for agricultural expansion (Etter *et al.*, 2006), and illegal logging (Nawir and

Rumboko, 2007) can be majorly attributed to the rising issues of D and D in the lower tropics; similar appears to be the case in forests of Nepal, where agricultural expansion and infrastructural development has led to the topographical change in the lower tropical zonal forests followed by heavy deforestation and degradation (Panta *et al.*, 2009). Illegal logging, infrastructural developments, livestock grazing, agricultural expansion, fuelwood collection, invasion by invasive species, and forest fires were among the major drivers in our study area. Similar were the results of studies (Etter *et al.*, 2006; Kaimowitz, 2008; Miettinen *et al.*, 2011; Austin *et al.*, 2019; Zeb *et al.*, 2019; Khuc *et al.*, 2018) assessing the major drivers of D and D. Major issues of forest deforestation, later followed by degradation in the tropical forests of Terai of Nepal resulted after the malaria eradication programs of 1960 when the population in Terai region showed a rapid increase (Darsie and Pradhan, 1990) and the forests of Terai region being easily accessible started being converted to farmlands (Soussan *et al.*, 1995), similar was the issue in case of our study area as it was densely dominated by Sal forest in the past, but later was affected by deforestation due to new settlement establishment after malaria was eradicated from the region. The forests of lower tropics as such of our study area located close to cities and towns have always been more prone to D and D. Our study area being located close to the capital of the Far-western province suffered such issues; such similar findings were also presented in the study of (Mon *et al.*, 2012) carried out in Myanmar. The findings of our study were also similar to those (Panta *et al.*, 2009) which showed a rapid decline of forest area in Chitwan valley owing to similar proximate drivers as occurred in our study area.

In consideration of the observed changes in our study area, a poor fate has been shared by the forests of lower tropical zones of Columbia, Myanmar, Indonesia, Sumatra, Pakistan, Vietnam, and Mexico including other parts of Nepal. Not only the analytical and monitoring processes are poor but also there is a lack of firm efforts to limit D and D. Such comprehensive datasets deriving drivers of deforestation will help in the analysis of linkages and pathways responsible for D and D. Such studies will be contributing to REDD+ planning and formulation of new strategies to reduce carbon

emissions by identifying and linking the drivers with D and D issues eventually contributing to the conservation of forest land of Nepal and lower tropics.

Conclusion

The forest resources in the lower tropical zones are decreasing on a yearly trend, similar is the case of the study area. The dependency of people to fulfill their daily needs from forest resources for forage/firewood collection and the urge to establish new settlements and agricultural expansion to support the growing population of the area have caused a great loss of forest area. Forest degradation in the study area was majorly driven by multifactor including illegal felling, forest encroachment, permanent cultivation, resettlement, Sukumbasi Basti, fuelwood consumption, infrastructure development, livestock grazing, forest fires, etc. The establishment of new settlements and expansion of agricultural lands has grown rapidly without consideration of local vegetation and the environment. The region needs specific sustainable management practices controlling the drivers of D and D. Along with some afforestation and plantation programs degraded forests can be revived and bare land can be brought into better use in terms of ecosystem services. Awareness programs are highly suggested to uplift the understanding level of local people so they can act for themselves in the conservation of their local forest and ecosystem resources.

References

- Acharya, K.P., R.B. Dangi and M. Acharya 2011. Understanding forest degradation in Nepal. *Unasylva*, **62**(2): 238.
- Austin, K.G., A. Schwantes, Y. Gu and P.S. Kasibhatla 2019. What causes deforestation in Indonesia? *Environmental Research Letters*, **14**(2): 024007. doi:<https://doi.org/10.1088/1748-9326/aaf6db>
- Barbier, E.B., R. Lozano, C.M. Rodríguez and S. Troëng 2020. Adopt a carbon tax to protect tropical forests. <https://doi.org/10.1038/d41586-020-00324-w>
- Bharatkar, P.S. and R. Patel 2013. Approach to accuracy assessment for RS image classification techniques. *International Journal of Scientific and Engineering Research*, **4**(12): 79-86.
- Bocco, G, M., Mendoza and O.R. Masera 2001. The dynamics of land-use change in the State of Michoacán: A methodological proposal for the study of deforestation processes. *Investigaciones geográficas*, **44**: 18-36.
- Boucher, D., P. Elias, K. Lininger, C. Tobin, S. Roquemore and E. Saxon 2011. *The root of the problem: what's driving tropical deforestation today?*. Union of Concerned Scientists.
- Chapagain, P.S. and T.H. Aase 2020. Changing forest coverage and understanding of deforestation in Nepal Himalayas. *Geographical Journal of Nepal*, **13**: 1-28. <https://doi.org/10.3126/gjn.v13i0.28133>
- Chaudhary, R.P., Y. Uprety and S.K. Rimal 2016. Deforestation in Nepal: Causes, consequences and responses. Biological and environmental hazards, risks, and disasters, 335-372. <http://dx.doi.org/10.1016/B978-0-12-394847-2.00020-6>
- Chowdhury, M., M.E. Hasan and M.M. Abdullah-Al-Mamun 2020. Land use/land cover change assessment of Halda watershed using remote sensing and GIS. *The Egyptian Journal of Remote Sensing and Space Science*, **23**(1): 63-75. <https://doi.org/10.1016/j.ejrs.2018.11.003>
- Chowdhury, R.R. 2006. Driving forces of tropical deforestation: The role of remote sensing and spatial models. *Singapore Journal of Tropical Geography*, **27**(1): 82-101. <https://doi.org/10.1111/j.1467-9493.2006.00241.x>
- Darsie, J.R.F. and S.P. Pradhan 1990. The mosquitoes of Nepal: their identification, distribution and biology. *Mosquito Systematics*, **22**(2): 69-130.
- Dhital, N. 2009. Reducing emissions from deforestation and forest degradation (REDD) in Nepal: exploring the possibilities. *Journal of Forest and Livelihood*, **8**(1): 57-62.
- Eltahir, E. A. and R.L. Bras 1996. Precipitation recycling. *Reviews of geophysics*, **34**(3): 367-378. <https://doi.org/10.1029/96RG01927>
- Etter, A., C. McAlpine, K. Wilson, S. Phinn and H. Possingham 2006. Regional patterns

- of agricultural land use and deforestation in Colombia. *Agriculture, ecosystems and environment*, **114**(2-4): 369-386. <https://doi.org/10.1016/j.agee.2005.11.013>
- Hosonuma, N., M. Herold, V. De Sy, R.S. De Fries, M. Brockhaus, L. Verchot and E. Romijn 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, **7**(4): 044009. doi:<https://doi.org/10.1088/1748-9326/7/4/044009>
- Houghton, R.A. 2012. Carbon emissions and the drivers of deforestation and forest degradation in the tropics. *Current Opinion in Environmental Sustainability*, **4**(6): 597-603. <https://doi.org/10.1016/j.cosust.2012.06.006>
- Ishtiaque, A., M. Shrestha and N. Chhetri 2017. Rapid urban growth in the Kathmandu Valley, Nepal: Monitoring land use land cover dynamics of a himalayan city with landsat imageries. *Environments*, **4**(4): 72. <https://doi.org/10.3390/environments4040072>
- Jayathilake, H.M., G.W. Prescott, L.R. Carrasco, M. Rao and W.S. Symes 2021. Drivers of deforestation and degradation for 28 tropical conservation landscapes. *Ambio*, **50**(1): 215-228. doi: <https://doi.org/10.1007/s13280-020-01325-9>
- Kaimowitz, D. 2008. The prospects for reduced emissions from deforestation and degradation (REDD) in Mesoamerica. *International Forestry Review*, **10**(3): 485-495. <https://doi.org/10.1505/ifor.10.3.485>
- Kissinger, G.M., M. Herold and V. De Sy 2012. *Drivers of deforestation and forest degradation: a synthesis report for REDD+ policymakers*. Lexeme Consulting.
- Legal, L., M. Valet, O. Dorado, J.M.D. Jesus-Almonte and R. Céréghino 2020. Lepidoptera are relevant bioindicators of passive regeneration in tropical dry forests. *Diversity*, **12**(6): 231. <https://doi.org/10.3390/d12060231>
- Lele, N. and P.K. Joshi 2009. Analyzing deforestation rates, spatial forest cover changes and identifying critical areas of forest cover changes in North-East India during 1972–1999. *Environmental monitoring and assessment*, **156**(1): 159-170. <https://doi.org/10.1007/s10661-008-0472-6>
- Martinez, N. 2012. Sparse vegetation predicts clutch size in Common Redstarts *Phoenicurus phoenicurus*. *Bird Study*, **59**(3), 315-319. doi: <https://doi.org/10.1080/00063657.2012.672949>
- Mas, J.F., H. Puig, J.L. Palacio and A. Sosa-López 2004. Modelling deforestation using GIS and artificial neural networks. *Environmental Modelling and Software*, **19**(5): 461-471. [https://doi.org/10.1016/S1364-8152\(03\)00161-0](https://doi.org/10.1016/S1364-8152(03)00161-0)
- Mertens, B. and E.F. Lambin 2000. Land-cover-change trajectories in southern Cameroon. *Annals of the association of American Geographers*, **90**(3): 467-494. <https://doi.org/10.1111/0004-5608.00205>
- Miettinen, J., C. Shi and S.C. Liew 2011. Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology*, **17**(7): 2261-2270. <https://doi.org/10.1111/j.1365-2486.2011.02398.x>
- Mon, M.S., N. Mizoue, N.Z. Htun, T. Kajisa and S. Yoshida 2012. Factors affecting deforestation and forest degradation in selectively logged production forest: A case study in Myanmar. *Forest Ecology and Management*, **267**: 190-198. <https://doi.org/10.1016/j.foreco.2011.11.036>
- Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A. Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature*, **403**(6772): 853-858. <https://doi.org/10.1038/35002501>
- Nawir, A.A. and L. Rumboko 2007. Forest rehabilitation in Indonesia: where to after more than three decades?. Center for International Forestry Research (CIFOR).
- Nepal, F.R.A. 2015. State of Nepal's forests. Forest Resource Assessment (FRA).
- Nepal, W.W.F 2013. Chitwan annapurna landscape (CHAL): a rapid assessment. World Wildlife Fund Nepal: Kathmandu, Nepal. <https://www.wwfnepal.org/hariyobanprogram/>

- Oldekop, J.A., K.R. Sims, B.K. Karna, M.J. Whittingham and A. Agrawal 2019. Reductions in deforestation and poverty from decentralized forest management in Nepal. *Nature Sustainability*, **2**(5): 421-428. <https://doi.org/10.1038/s41893-019-0277-3>
- Pandey, S.S., G. Cockfield and T.N. Maraseni 2013. Major drivers of deforestation and forest degradation in developing countries and REDD+. *International Journal of Forest Usufructs Management*, **14**(1): 99-107.
- Panta, M., K. Kim and C. Joshi 2008. Temporal mapping of deforestation and forest degradation in Nepal: Applications to forest conservation. *Forest Ecology and Management*, **256**(9): 1587-1595. <https://doi.org/10.1016/j.foreco.2008.07.023>
- Rai, R.K., M. Nepal, B.S. Karky, E. Somanathan, N. Timalisina, M.S. Khadayat and N. Bhattarai 2017. Costs and benefits of reducing deforestation and forest degradation in Nepal. ICIMOD Working Paper, (2017/5).
- Rudel, T.K., L. Schneider, M. Uriarte, B.L. Turner, R. DeFries, D. Lawrence and R. Grau 2009. Agricultural intensification and changes in cultivated areas, 1970–2005. *Proceedings of the National Academy of Sciences*, **106**(49): 20675-20680. <https://doi.org/10.1073/pnas.0812540106>
- Soussan, J., B.K. Shrestha, and L.P. Uprety 1995. The social dynamics of deforestation: a case study from Nepal. Parthenon Publishing Group.
- Stanturf, J.A., B.J. Palik and R.K. Dumroese 2014. Contemporary forest restoration: a review emphasizing function. *Forest Ecology and Management*, **331**: 292-323. <https://doi.org/10.1016/j.foreco.2014.07.029>
- Turner, B.L., S.C. Villar, D. Foster, J. Geoghegan, E. Keys, P. Klepeis and C. Vance 2001. Deforestation in the southern Yucatán peninsular region: an integrative approach. *Forest Ecology and Management*, **154**(3): 353-370. [https://doi.org/10.1016/S0378-1127\(01\)00508-4](https://doi.org/10.1016/S0378-1127(01)00508-4)
- van Best, S and S. van Dijk 2020. Tropical forests—the facts and figures.
- Van Khuc, Q., B.Q. Tran, P. Meyfroidt and M.W. Paschke 2018. Drivers of deforestation and forest degradation in Vietnam: An exploratory analysis at the national level. *Forest policy and economics*, **90**: 128-141. <https://doi.org/10.1016/j.forpol.2018.02.004>
- Vásquez-Grandón, A., P.J. Donoso and V. Gerding 2018. Forest degradation: when is a forest degraded?. *Forests*, **9**(11): 726. <https://doi.org/10.3390/f9110726>
- Velázquez, A., J.F. Mas, J.L. Palacio-Prieto and G. Bocco 2002. Land cover mapping to obtain a current profile of deforestation in Mexico. *Unasylva*, **53**(210): 37-40.
- Warren, R., J. Price, A. Fischlin, S. de la Nava Santos and G. Midgley 2011. Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise. *Climatic Change*, **106**(2): 141-177. <https://doi.org/10.1007/s10584-010-9923-5>
- Zeb, A., A. Hamann, G.W. Armstrong and D. Acuna-Castellanos 2019. Identifying local actors of deforestation and forest degradation in the Kalasha valleys of Pakistan. *Forest Policy and Economics*, **104**: 56-64. <https://doi.org/10.1016/j.forpol.2019.04.005>
- Zhao, S., C. Peng, H. Jiang, D. Tian, X. Lei and X. Zhou 2006. Land use change in Asia and the ecological consequences. *Ecological Research*, **21**(6): 890-896. <https://doi.org/10.1007/s11284-006-0048-2>

