Forest Cover Dynamics in Maine (2000-2023)

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Introduction

Forests provide highly valuable ecosystem services including recreation, water (quality and quantity), carbon sequestration, food, air filtration, social and cultural values, timber and other forest products, as well as fish and wildlife habitat and biodiversity. In Maine, the forest product industry accounts for nearly 4.2% of the state's gross domestic product (Zhao et al., 2022). However, around 77% of forest cover in Maine State experienced disturbance in the past two decades due to various reasons such as insects and climate (Kosiba et al., 2018). Tracking changes in land use is important for analyzing factors affecting forest loss (diversion) and forest gain (reversion).

Objectives

1. Measure and visualize the extent of forest cover change from 2000 to 2023
2. Analyze the factors of forest change, including climate, and socio-economy
3. Analyze nature of forest fragmentation, which affect the biodiversity and ecosystem functions

Study Area

The study was conducted in Maine, USA. Total area of the state is around 19.74 million acres. Northern Maine has a subarctic climate, central Maine has a humid continental climate, southern Maine has a humid subtropical climate, and coastal Maine has a maritime climate. Balsam fir, red maple, red spruce, American beech, paper birch, and northern white-cedar are the major tree species found in Maine.

Data Sources

Table 1. Information of the Dataset collected for the study

Data	Resolution	Data Sources
Tree Canopy Cover Tree Loss and Gain Year	30m	Earth Engine Partners
Precipitation and Climate	4000m	PRISM Climate Group
Digital Elevation Mode	30m	USGS
Land Use Land Cover	10m	ESRI
Maine Road Feature	Vector	Maine GIS

Methods

Global Forest Change data introduced by Hansen et al., (2013) is used for the study. The data results from time-series analysis of Landsat images characterizing forest extent and change. Trees are defined as vegetation taller than 5m in height and are expressed as a percentage per output grid cell. The projection used for our map is 'NAD 1983 UTM Zone 19' and the Datum is 'D North American 1983'

- For objective 1, the 2000 tree canopy cover raster and the forest loss/gain year raster is used to produce the tree canopy cover for 2023 to analyze the forest change in these 23 years.
- For objective 2, data was collected for 7 different possible forest change drivers and regression was applied on them against forest loss to calculate their possible significance in deriving the change. The complete flow of the processing can be found in Figure 1.
- For objective 3, the forest loss/no loss binary raster data was used and converted to polygon vector. Statistics analysis on the polygons were used to study fragmentation on forest lands from 2000 to 2023.

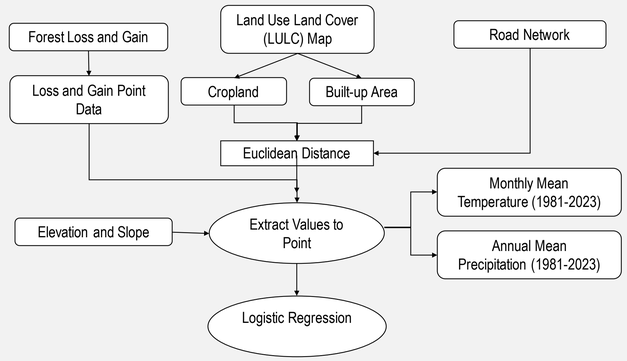

Figure 1. Flow chart for studying the drivers of forest change *(Tools used in ArcGIS Pro: Reclassify, Raster to Point, Raster to Polygon, Euclidean distance, Extract Values to Point, Extract by Mask, etc.)*

References

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- Ma, J., Li, J., Wu, W. *et al.* Global forest fragmentation change from 2000 to 2020. *Nat Commun* **14**, 3752 (2023)
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Results

Objective 1: Total forest land in 2000 was about 17.90 million acres which has reduced to 15.17 million acres of forest land in 2023. It is observed that majority of forest lands are now converted to rangelands followed by built-up areas.

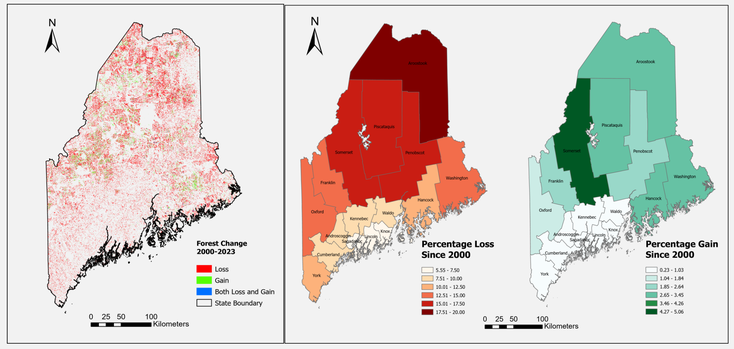

Figure 2.(a) Forest Cover Change (2000-2023) (b) Forest Loss and Gain by County (2000-2023)

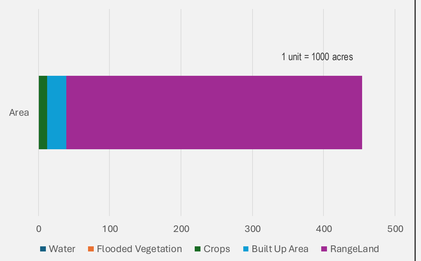

Figure 2. Gross area of forest loss by land use land cover category

Objective 2: Table summarizing the result of regression applied on the 7 collected data sources against forest loss is given below. If a β-coefficient is negative, it means that as the corresponding feature increases, the log-odds of the target decrease. Significance level of 0 indicates that the observed effect is highly unlikely to occur by chance.

Driver	β-coefficient	Significance level
Distance to Crop	-8.224e-06	0.009 **
Distance to Built-up Area	1.234e-05	0.028 *
Distance to Road	3.744e-05	0.051
Average Monthly Temperature	0.0169	0.000 ***
Average Annual Precipitation	-0.0167	0.000 ***
Elevation	0.0013	0.000 ***
Slope	0.0001	0.217

'***' < 0.001, '**' < 0.01, '*' < 0.05

Table 2. Driver wise β-coefficient and their corresponding significance level as derived from logistic regression for TCC gain and loss

Objective 3: Forest Fragmentation result shows an increased number of patches and reduced mean area patch size.

Cover Type	Total No of Patches		Mean Patch Area (Acre^2)		Maximum Patch Area (Acre^2)	
	2000	2023	2000	2023	2000	2023
Forest	83,563	391,204	214.9	2.23	1,72,50,360	56,719

Table 3: Fragmentation analysis for the year 2000 and 2023

Conclusion

- Maine lost a significant area of forest land, accounting for around 15% of forest loss from 2000 to 2023
- Aroostook county has the highest forest loss whereas Somerset county has the highest forest gain among all the counties
- Among various land use categories, Rangeland covers the most forest loss area, followed by the Built-up area, indicating a significant forest area was converted into a Built-up area
- Moreover, variables such as Distance to Crop, Elevation, Temperature and Precipitation showed a significant relation with forest loss.
- Mean forest patch area has significantly reduced from 214 acre^2 to 2 acre^2 during 2000-2023 indicating possible biodiversity loss and ecosystem degradation (Ma, et al., 2023)