



CMS: Tree Cover Estimates at 30 m Resolution for Mexico from 2000 to 2019

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Documentation Revision Date: 2025-08-22

Dataset Version: 2

Summary

This dataset provides 20-year tree cover (TC) estimates at 30-m spatial resolution for Mexico from 2000 to 2019 using Landsat time series, airborne LiDAR, and machine learning. The TC data (hereafter, CMS-TC) offers accurate and consistent national-scale percent tree cover estimates with an overall coefficient of determination (R squared) of 0.81 and a root mean square error (RMSE) of 11.90%. The CMS-TC product is essential for tracking tree cover and aboveground biomass changes, monitoring land use dynamics, supporting biodiversity conservation, and informing climate and land use policy decisions. The data are provided in GeoTIFF format.

There are 20 data files in GeoTIFF (.tif) format in this dataset that provide percent tree cover for Mexico at 30-m resolution for the years from 2000 to 2019.

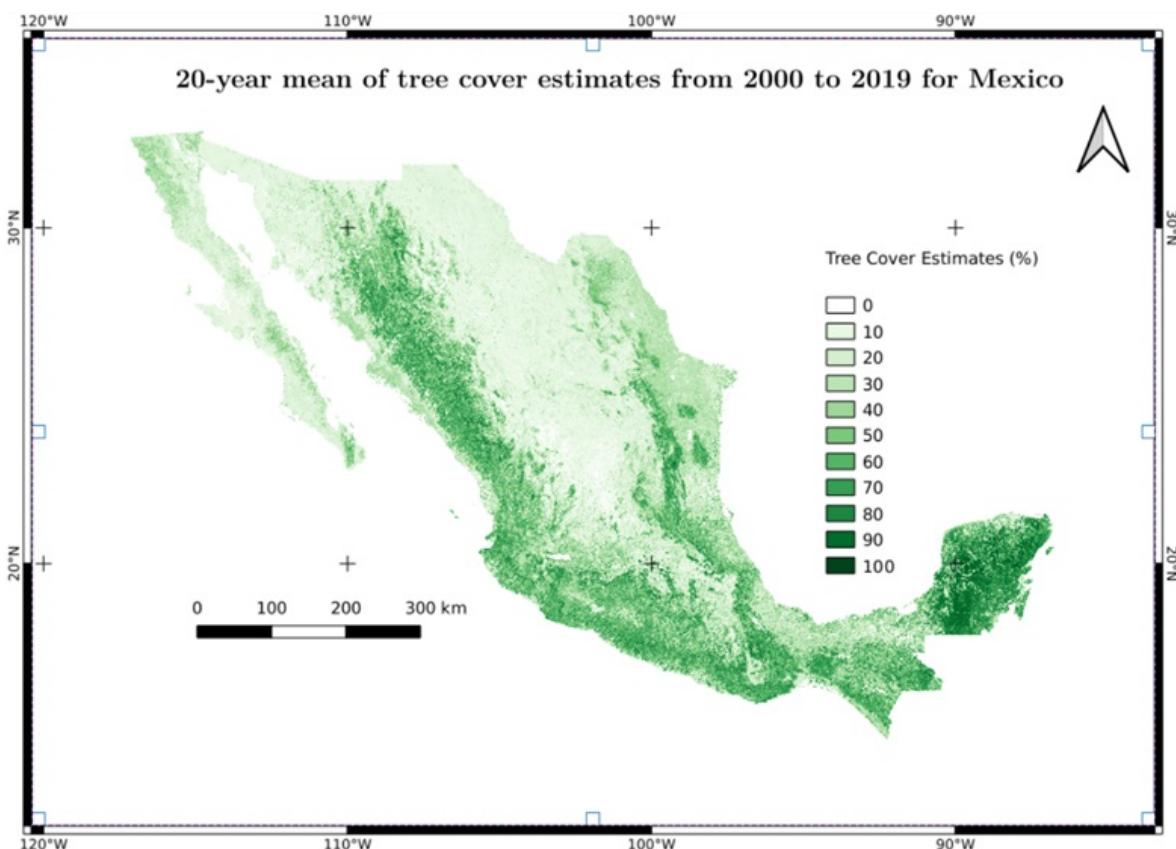


Figure 1. 20-year mean of percent tree cover for Mexico from 2000 to 2019.

Citation

Tran, K.H., M. Sarupria, R. Vargas, I.G. Brosnan, and T. Park. 2025. CMS: Tree Cover Estimates at 30 m Resolution for Mexico from 2000 to 2019. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/2445>

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1. Dataset Overview

This dataset provides 20-year tree cover estimates at 30-m spatial resolution for Mexico from 2000 to 2019. The CMS-TC product was generated through the integration of machine learning and multi-scale remote sensing data. The Continuous Change Detection and Classification (CCDC) algorithm was first applied to create synthetic Landsat surface reflectance time series at 30-m spatial resolution (Zhu and Woodcock, 2014). High-resolution canopy height model data at 1-m spatial resolution from NASA's Goddard LiDAR, Hyperspectral, and Thermal (G-LiHT) mission across Mexico in 2013 was spatially aligned with Landsat pixel grid to define sub-pixel TC labels using a threshold of 3-m height. The CCDC-derived Landsat time series and their corresponding G-LiHT-based tree cover labels were used to train a random forest regressor model. The model showed a robust predictive performance, achieving an overall coefficient of determination (R^2) of 0.81 and an RMSE of 11.90%. The trained model with top important features was then used to predict CMS-TC across the entire Mexico for all the years from 2000 to 2019. The CMS-TC product supports not only tree cover change monitoring but also enhances carbon accounting, tracks deforestation and agricultural expansion, aids biodiversity conservation, and informs climate, hydrological, and land use policy development.

Project: Carbon Monitoring System

The NASA Carbon Monitoring System (CMS) program is designed to make significant contributions in characterizing, quantifying, understanding, and predicting the evolution of global carbon sources and sinks through improved monitoring of carbon stocks and fluxes. The System uses NASA satellite observations and modeling/analysis capabilities to establish the accuracy, quantitative uncertainties, and utility of products for supporting national and international policy, regulatory, and management activities. CMS data products are designed to inform near-term policy development and planning.

Related Dataset

Park, T., and R. Vargas. 2022. Tree Cover Estimates at 30 m Resolution for Mexico, 2016-2018. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDaac/2137>

- Version 1 of this dataset

Related Publication

Tran, H.K., M. Sarupria, R. Vargas, I.G. Brosnan, and T. Park. 2025. Integrating airborne Lidar, Landsat time series, and machine learning for national-scale tree cover estimation across Mexico. In progress.

2. Data Characteristics

Spatial Coverage: Mexico

Spatial Resolution: 0.0002695 degrees (~30 m)

Temporal Coverage: 2000 to 2019

Temporal Resolution: Annual

Study Area: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Mexico	-119.226	-84.625	33.797	13.406

Data File Information

There are 20 data files in GeoTIFF (.tif) format that provide percent tree cover for Mexico at 30-m resolution for the years from 2000 to 2019.

The file naming convention is **CMS_TC_Mexico_30m_<YYYY>.tif**, where

<YYYY> indicates the year of TC estimates from 2000 to 2019.

Example file name: *CMS_TC_Mexico_30m_2000.tif*

GeoTIFF characteristics:

- Coordinate system: Mexico ITRF2008 / LCC (EPSG:6372); GRS80 datum; units = m
- Pixel values: percent cover; valid Range: 0 - 99
- Bands: 1
- No data value: 255
- Data type: Byte

3. Application and Derivation

The CMS-TC has various applications, such as tracking tree cover changes, improving estimates of the global carbon budget, monitoring deforestation and afforestation, detecting agriculture expansion, biodiversity conservation, climate and hydrological modeling, and the development of sustainable land use and environmental policies.

4. Quality Assessment

The proposed model was evaluated using 8,000 independent percent tree cover samples across Mexico derived from the G-LiHT airborne LiDAR

data. A grid search strategy was employed to optimize hyperparameters for the machine learning model, including the number of trees, maximum tree depth, minimum samples required to split a node, and minimum samples required at a leaf node. This systematic tuning aimed to reduce prediction error. A 5-fold cross-validation scheme was also used during the search, with negative mean squared error as the scoring metric, to identify the best parameter combination. Overall, the statistical evaluation confirmed that the machine learning model, driven by Landsat time series and G-LiHT LiDAR data, provided accurate predictions of percent tree cover for Mexico. The best model had a coefficient of determination (R^2) of 0.81 and an RMSE of 11.90%. Note that biases can be present in the areas of very low and very high percent tree covers (Figure 2).

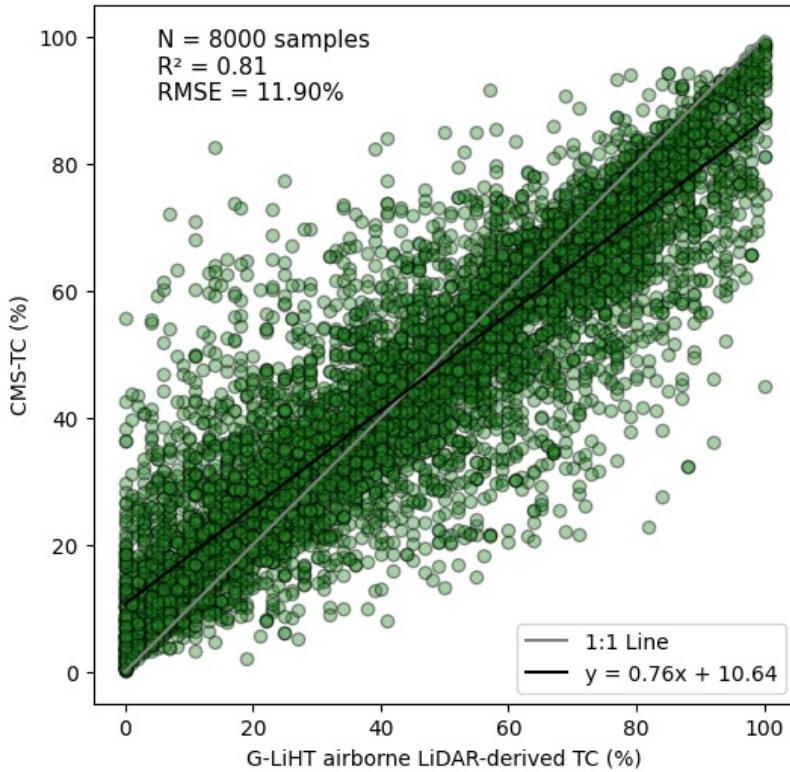


Figure 2. Overall accuracy of the CMS-TC product. The gray line indicates the 1:1 agreement.

5. Data Acquisition, Materials, and Methods

Data Acquisition

This study utilized three primary input datasets. First, all available Landsat Collection 2 Level-2 surface reflectance and thermal data from Landsat 4, 5, 7, and 8 (including bands for blue, green, red, near-infrared (NIR), shortwave infrared 1 and 2 (SWIR1, SWIR2), and thermal (TEMP) were accessed via Google Earth Engine (GEE), spanning the period from 1999 to 2020. These spectral and thermal bands were used as input features to capture vegetation structure, moisture content, and phenological dynamics relevant to tree cover. Second, NASA's Shuttle Radar Topography Mission (SRTM) data were incorporated to account for environmental heterogeneity influencing vegetation distribution, particularly elevation and derived topographic features (e.g., slope, aspect) were included as predictors because they play a critical role in shaping local tree cover patterns. The third input dataset was canopy height model (CHM) data from NASA's G-LiHT airborne imager, which provides high-resolution ($\times 1$ m) measurements of vegetation structure. The CHM data from 2013 across Mexico served as the basis for deriving tree cover training labels in this study.

Data preparation

The Continuous Change Detection and Classification (CCDC) algorithm, developed by Zhu and Woodcock (2014), was applied to all available surface reflectance and thermal Landsat data in Google Earth Engine (GEE) to generate synthetic, consistent, and continuous time series at 30-m spatial resolution, with one composite per month. In addition to the original Landsat bands (blue, green, red, NIR, SWIR1, SWIR2, and thermal), seven vegetation and spectral indices were calculated from the synthetic time series: the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Enhanced Vegetation Index 2 (EVI2), Normalized Burn Ratio (NBR), and the Tasseled Cap indices of Brightness, Greenness, and Wetness. These indices were included to provide a comprehensive representation of land cover dynamics, vegetation health, and surface conditions for improved tree cover estimation (Yang et al. 2012). As a result, 14 Landsat-derived features were generated per month, totaling 168 features across 12 months. To further enhance model performance, three topographic variables derived from NASA's SRTM (DEM, slope, and aspect; Yang et al. 2011) were included as static input features. This resulted in a total of 171 input features (14 features \times 12 months + 3 SRTM features) used to train the tree cover prediction model.

To generate tree cover training labels, the G-LiHT canopy height model (CHM) data (Bruce, 2021) from 2013 were spatially aligned with the Landsat grid. For each 30-m Landsat pixel, the proportion of 1-m CHM pixels were computed exceeding 3 m in height, which was used to define percent tree cover. A total of 40,000 stratified samples from 2013, each associated with CCDC-derived Landsat time series, SRTM topographic variables, and G-LiHT-derived tree cover labels, were used to train a random forest regressor model (Segal, 2004).

Machine learning model development

A machine learning based model was developed that used the random forest regressor to predict the percent tree cover across Mexico. A grid search methodology for hyperparameter optimization was implemented to train the model. The parameter grid encompassed the number of trees ('n_estimators': 100, 200, 300), maximum tree depth ('max_depth': none, 10, 20, 30), minimum samples required to split a node ('min_samples_split': 2, 5, 10), and minimum samples required at a leaf node ('min_samples_leaf': 1, 2, 4). This systematic variation of hyperparameters aimed to minimize prediction error. A 5-fold cross-validation approach was also utilized during the grid search process, with the negative mean squared error ('neg_mean_squared_error') serving as the scoring metric for optimal hyperparameter selection.

Following the identification of the best parameters, the model was trained on the 80% selected samples and independently tested on the remaining 20% selected samples. The best parameters are `n_estimators = 300`, `max_depth = 30`, `min_samples_split = 2`, `min_samples_leaf = 2`. This framework resulted in a well-calibrated and fine-tuned model, ready for accurate percent tree cover predictions. Further, the top 25 important features were identified after assessing variable importance for the best model, including `Green_Sep`, `NDVI_Jan`, `DEM`, `NDVI_Feb`, `SWIR2_Aug`, `BRIGHTNESS_Apr`, `TEMP_Oct`, `GREENNESS_Jun`, `NBR_Apr`, `slope`, `aspect`, `TEMP_Apr`, `NBR_Jul`, `NBR_Aug`, `NDVI_Aug`, `NBR_Feb`, `TEMP_Aug`, `TEMP_Mar`, `NBR_Mar`, `NBR_Jun`, `TEMP_Sep`, `TEMP_Nov`, `NBR_May`, `TEMP_Jan`, `TEMP_Dec` (Figure 3). These 25 features were used to evaluate the impact of reducing input features on model performance using RMSE and R^2 , which showed slight changes compared to the use of all 171 input features.

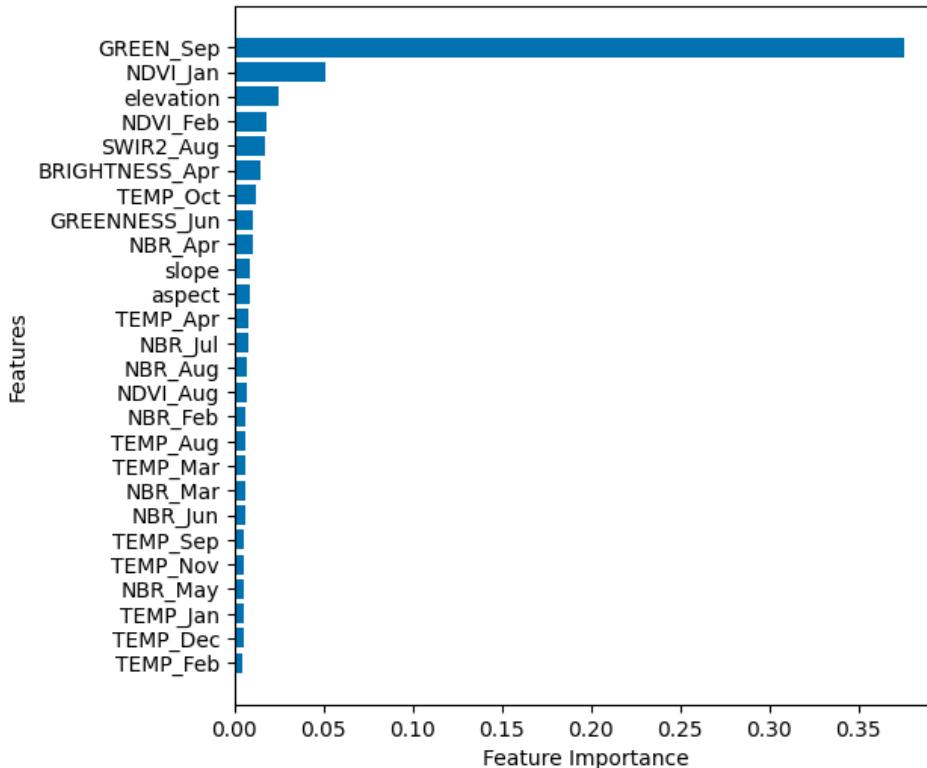


Figure 3. Top 25 important features contributing to the prediction of percent tree cover across Mexico.

Generation of the CMS-TC product:

The reduced model was then applied to the CCDC-derived Landsat time series to predict the CMS-TC for all 20 years from 2000 to 2019.

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

CMS: Tree Cover Estimates at 30 m Resolution for Mexico from 2000 to 2019

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

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8. Dataset Revisions

Version	Release Date	Revision Notes
2	2025-XX-XX	17 years of additional data were added to cover the period 2000-2019. Methods were updated. Additional input data sources were used in the model.
1	2023-02-15	Version 1 release (https://doi.org/10.3334/ORNLDAA/2137).



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