ACR IMPROVED FOREST MANAGMEENT METHODOLOGIES

TOOL FOR COMPARABLE PROPERTIES ANALYSIS

VERSION 1.0

July 2024

ACR AT WINROCK INTERNATIONAL

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ACR℠

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ABOUT ACR℠

ACR is a leading global carbon crediting program operating in regulated and voluntary carbon markets. Founded in 1996 as the first private voluntary greenhouse gas (GHG) registry in the world, ACR creates confidence in the integrity of carbon markets to catalyze transformational climate results. ACR ensures carbon credit quality through the development of environmentally rigorous, science-based standards and methodologies as well as oversight of GHG project verification, registration, and credit issuance and retirement reporting through its transparent registry system. ACR is governed by Environmental Resources Trust LLC, a wholly owned nonprofit subsidiary of Winrock International.

Acknowledgements

The original version of this tool was authored by ACR with contributions from Anew Climate. ACR is grateful to have received input from many partners, through public comments and additional stakeholder engagement, which further shaped the development of this tool. ACR looks forward to continued collaboration on IFM baselining with all our partners.

Acronyms

AGB	Aboveground biomass
DEM	Digital Elevation Model
ESA	European Space Agency
FIA	Forest Inventory and Analysis Program of the USDA Forest Service
GHG	Greenhouse gas
GIS	Geographic information system
GLAD	Global Land Analysis & Discovery
IBTrACS	International Best Track Archive for Climate Stewardship
IFM	Improved forest management
LCMS	Landscape Change Monitoring System
NLCD	National Land Cover Database
SOP	Standard operating procedures
USDA	United States Department of Agriculture
USGS	United States Geological Survey

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1 Introduction

1.1 Summary

This document, the *ACR IFM Methodologies Tool for Comparable Properties Analysis*, is a supplemental tool for greenhouse gas (GHG) projects that adhere to an ACR improved forest management (IFM) Methodology. A comparable properties analysis is a geospatial exercise to determine baseline Harvest Intensities based on observed harvest treatments on similar properties in the region. This tool provides the requirements for conducting this analysis and a demonstration of an approved method.

To conduct a comparable properties analysis, eligible properties are identified using cadastral data (i.e., tax parcel boundaries) and eligibility criteria. Harvests are identified using remote sensing methods and data sources, and properties are stratified based on forest cover. Eligible comparable properties are evaluated for similarity to the project area using 7 different parameters, resulting in a list of the 8 most similar (or matched) comparable properties. The matched properties are subjected to an outlier detection test, potentially rejecting the most aggressively harvested property. Of the remaining matched comparable properties, one is selected for stratum-specific constraint development.

Harvest Intensities determined by a comparable property analysis are subject to dynamic evaluation using the *ACR IFM Methodologies Tool for Dynamic Evaluation of Baselines*.[1]

1.2 Applicability

This tool is applicable to the ACR IFM Methodologies' versions which specifically refer to it by name for the purpose of determining baseline Harvest Intensities.

As of the publication of this version, this tool is available for use only for projects adhering to the ACR *Methodology for Improved Forest Management on Non-Federal U.S. Forestlands* version 2.1 (Methodology). Projects selecting Option 1 to determine baseline Harvest Intensities (comparable properties analysis; Methodology Section 4.1.3.2) are required to use this tool. If employing Option 1, the comparable properties analysis is required when developing initial *ex-ante* projections to be included in the GHG Project Plan and when performing a Periodic Modeling Assessment as part of a dynamic evaluation (*ACR IFM Methodologies Tool for Dynamic Evaluation of Baselines*) throughout the Crediting Period. When performing an Observed Conditions Assessment as part of a dynamic

[1] Available under the Program Resources section of the ACR website.

evaluation (*ACR IFM Methodologies Tool for Dynamic Evaluation of Baselines*), only the Harvest Intensities check (Section 5.3) is required.

1.3 Companion Calculator

This document references the Comparable Properties Analysis Calculator[2] and the worksheets found therein: the Filtered Properties worksheet, the Eligible Comparable Properties worksheet, the Outlier Detection worksheet, and the Harvest Intensity Calculations worksheet. Whenever a comparable properties analysis is performed, completion of this workbook is required.

1.4 Example Demonstration

This tool and its companion calculator demonstrate an approved method to determine baseline Harvest Intensities using an example project area located in Georgia, USA. This region primarily consists of industrially managed pine plantations. The example property is approximately 21,000 acres and is owned by a private industrial timber company. The example project Start Date is in 2024.

Except for cadastral data, which can be unavailable to the public for free in certain geographies, and data from Google Earth Engine, this demonstration relies solely on publicly available data. It utilizes ArcGIS Pro, but other Geographic Information System (GIS) software may be used to attain the same results. This demonstration is one approved method to perform a comparable properties analysis, but other methods may be utilized if they adhere to the requirements of this tool.

[2] Found on this tool's website.

2 Lookback Period Definition

Projects must first define a lookback period to evaluate Harvest Intensity on comparable properties. The lookback period must consist of at least 5 consecutive years within the previous 10 years, counting backwards from the most recent year for which data is readily available at the end of the Reporting Period. To ensure that recent market and management conditions are reflected, the lookback period may not exceed 10 years.

For example, if a remote sensing dataset does not publish its annual data until 2 years after collection and a GHG Project is verifying a Reporting Period ending 2025 (i.e., when the most recently available annual data is from 2023), the lookback period must include 2023 as its final year, and it must start at least 5 years prior (2019) and no more than 10 years prior (2014).

The example demonstration's lookback period has been defined as 5 years. 2022 is the year for which data is most recently available, so the lookback period starts in 2018 and ends after 2022.

3 Eligible Comparable Property Identification

This section describes the criteria for eligible comparable properties, the data sources and methods required to determine the list of eligible comparable properties, and the steps taken to determine eligible comparable properties for the demonstration's example project.

3.1 Eligibility Criteria

Projects must identify eligible comparable properties at the property level according to the specifications below:

- **Harvest Occurrence**: Have an observed harvest during the lookback period, and harvest at least 0.2% of their forestland per year.[3]
- **Geographic Size:** Composed of acreage meeting the following specifications:
  - At least the greater of either: 25% of the geographic size of the project area, or 1,000 acres;
  - No greater than 200% of the geographic size of the project area;
  - Multiple parcels belonging to a single owner (or whose timber is managed by the same entity) may be combined to be treated as a single property for determining geographic size, other eligibility criteria, and all proceeding calculations.
  - Only forestland shall be considered when determining whether a comparable property meets the geographic size specifications. Forestland acres should be determined according to Section 3.1.5.4;
  - In regions with significant access constraints (e.g., interior Alaska), only forestland within a defined access threshold (e.g., within 4 aerial miles of an existing transportation network) needs to be considered when determining whether a comparable property meets the geographic size specifications. Projects seeking to implement this option must obtain advance written approval from ACR;
  - If the project area is composed of multiple non-contiguous parcels, one of three approaches may be used (suggestions for appropriate usage are not considered requirements):
    - Use the total project area acreage to define the geographic size specifications. This option is most appropriate when a single parcel is significantly larger than other included parcels,

[3] Harvesting less than 0.2% of forestland per year is not considered indicative of common practice forest management.

such that its management can be expected to represent overall forest management practices.

- Use the median parcel acreage to define the geographic size specifications. This option is most appropriate when parcels composing the project area are generally similar in size, such that the median can reasonably be expected to represent each individual parcel; or
- Define multiple parcel size categories to represent the range of parcels composing the project area. This option is most appropriate for projects composed of a many parcels of varying sizes. Each parcel must be assigned to a category. For each category, a single parcel must be identified (the representative parcel) for the purpose of all proceeding calculations. The procedures of this tool are repeated for each category (e.g., eligible comparable properties are identified using each category's representative parcel, a single comparable property is selected for each category, Harvest Intensity constraints are calculated for each category). Please note that the selected comparable properties for each category may be owned by unique entities. As a final step, a project-level Harvest Intensity constraint is calculated by averaging each category's Harvest Intensity, weighted by project area acreage within each category.

- **Ecological Region:** Located within the same Ecological Region(s) as the project area.[4]
  - Projects located in multiple Ecological Regions may consider properties located in each respective Ecological Region;
  - Properties in other Ecological Regions can be eligible with verifiable evidence of the same species and product mixture as the project area;[5]
  - Properties in other nations (e.g., Canada, Mexico) are deemed to be in different legal and economic environments, such that they are ineligible.
- **Ownership:** Owned (or timber controlled) by a non-federal entity and by an entity of the same timber ownership class as the project area (Section 3.1.4).
  - Assignment of timber ownership classes should conform to the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) owner classification;
  - The project area or other properties owned (or timber controlled) by a participating entity but outside the project area may be eligible comparable properties.
  - If the timber rights of the project area were recently acquired (within less than 5 years of the project Start Date), the timber ownership class of the previous ownership may be used.

[4] Ecological Regions are spatially defined areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources (Omernik, 1987; Omernik and Griffith, 2014). The Level II Ecological Region delineation is required. Spatial files are available at: https://www.epa.gov/eco-research/ecoregions-north-america

[5] For example, forest type maps or other products showing similar timber types as the project area: https://data.fs.usda.gov/geodata/rastergateway/forest_type/

- Properties owned by an entity of a timber ownership class with an equal or lesser discount rate (per Table 1) may be designated as eligible at the Project Proponent's discretion.
- Properties enrolled in a carbon project that incentivizes reduced harvesting may be designated as ineligible at the Project Proponent's discretion.
- Properties whose ownership is unknown after good faith efforts to determine its ownership are assumed to be in the Private Non-Industrial timber ownership class.

- **Proximity:** Located within a 150-mile buffer of the perimeter of the project area[6] (Section 3.1.1).
    - Either aerial miles or road miles may be used.
    - If the Project Proponent can verifiably demonstrate the utilization of timber markets beyond the 150-mile buffer, by either the project area or another property in the same transportation network yet further from the timber market, the buffer may be expanded to match the distance to the furthest timber market utilized.
    - If the 150-mile buffers of any non-contiguous portions of the project area do not overlap, each non-contiguous portion must be treated independently when applying the procedures of this tool, resulting in Harvest Intensity constraints for each portion. As a final step, a project-level Harvest Intensity constraint is calculated by averaging each portion's Harvest Intensity, weighted by project area acreage within each portion.

The first step to identify eligible comparable properties is to acquire cadastral data (i.e., tax parcel boundaries) for the 150-mile buffer. Acceptable sources for cadastral data include public agencies, academic resources, and commercial data providers. In some cases, individual counties and states will provide this data for free upon request. In other cases, this data must be purchased. Whenever practicable, the full extent of cadastral data required by this approach (i.e., all parcels within the 150-mile buffer) must be utilized. Portions of the required cadastral data may be excluded from consideration only with verifiable evidence of a good faith effort to obtain the data from multiple sources, including both relevant public agencies and commercial data providers. The cadastral data utilized must be the most recently available version as of the Reporting Period end date.

The following steps establish a procedure to expand eligibility criteria in the case that too few eligible comparable properties are identified. The following procedure must be implemented by projects that have identified fewer than 8 eligible comparable properties, and they may be optionally implemented by projects that have identified fewer than 12 eligible comparable properties:

Step 1 **Expand the buffer around the project area.** The buffer must be expanded in 50-mile increments. After each expansion, the project must determine whether a sufficient number of eligible comparable properties (i.e., at least 8 and no more than 12) can be identified. If 12 or more such properties have been identified, the eligibility expansion

[6] 150 miles is a generalized maximum hauling distance based on: Pokharel, R., & Latta, G. S. (2020). A network analysis to identify forest merchantability limitations across the United States. *Forest policy and economics, 116*, 102181. https://doi.org/10.1016/j.forpol.2020.102181

process shall end. This process must be repeated at least up to a 300-mile buffer before proceeding onto Step 2, and it may be repeated up to a 500-mile buffer total.

Step 2 **Expand the maximum geographic size threshold.** The threshold must be expanded in 100% increments. After each expansion, the project must determine whether a sufficient number of eligible comparable properties (i.e., at least 8 and no more than 12) can be identified. If 12 or more such properties have been identified, the eligibility expansion process shall end. The maximum geographic size threshold must be expanded to 300% before proceeding onto Step 3, and it may be expanded up to 400% of the geographic size of the project area total.

Step 3 **Include properties of different timber ownership classes.** When determining which properties of different timber ownership classes to include for potential eligibility, both closeness of the assigned discount rates and conservatism must be considered. The project must determine whether a sufficient number of eligible comparable properties (i.e., at least 8 and no more than 12) has been identified after each of the following expansion rules have been applied. If 12 or more such properties have been identified, the eligibility expansion process shall end. If the project's identified ownership (Section 3.1.4) is either Private Non-Industrial or Tribal, properties of the same discount rate yet different timber ownership class must be included first. Next, properties of a timber ownership class with a discount rate one percent less than the project's discount rate are included. Next, properties of a timber ownership class with a discount rate one percent more than the project's discount rate are included. If the project has still not identified enough eligible comparable properties, properties of a timber ownership class with a discount rate two percent less than the project's discount rate are included, and so forth.

The following sections describe the process of filtering the cadastral data by the eligibility criteria to determine a final list of eligible comparable properties.

3.1.1 PROXIMITY

Cadastral data must be filtered by location within a 150-mile buffer of the perimeter of the project area. The following is an approved method to filter by proximity using road miles:

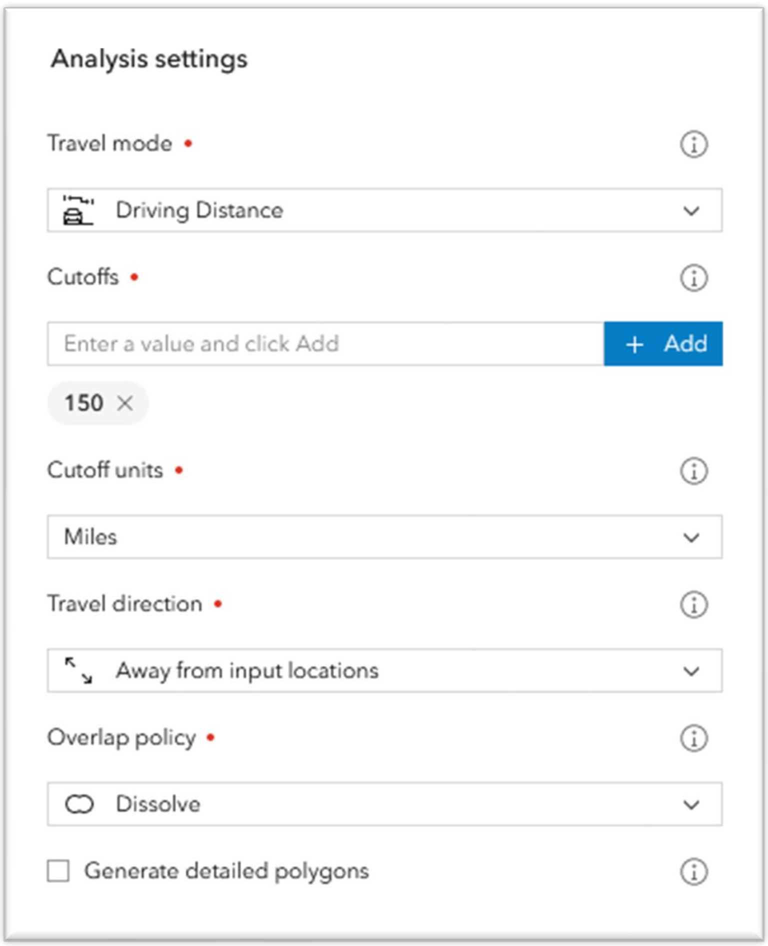
Step 1 Transform the project area polygon into a line shapefile using the Polygon to Line tool. Then create points along the project boundary using the Generate Points Along Lines tool. The distance between points may be set to 3,000 feet to balance accuracy of boundary representation with sufficient quantity of point data.

If the project boundary point shapefile has too many points, the Generate Travel Areas tool can run slowly. To improve performance, points in the inner part of the boundary may safely be eliminated, because the travel areas for inner points will be absorbed by the travel areas for more external points, thus reducing redundancies.

Step 2 Share the output layer as a web layer to upload it to ArcGIS Online.

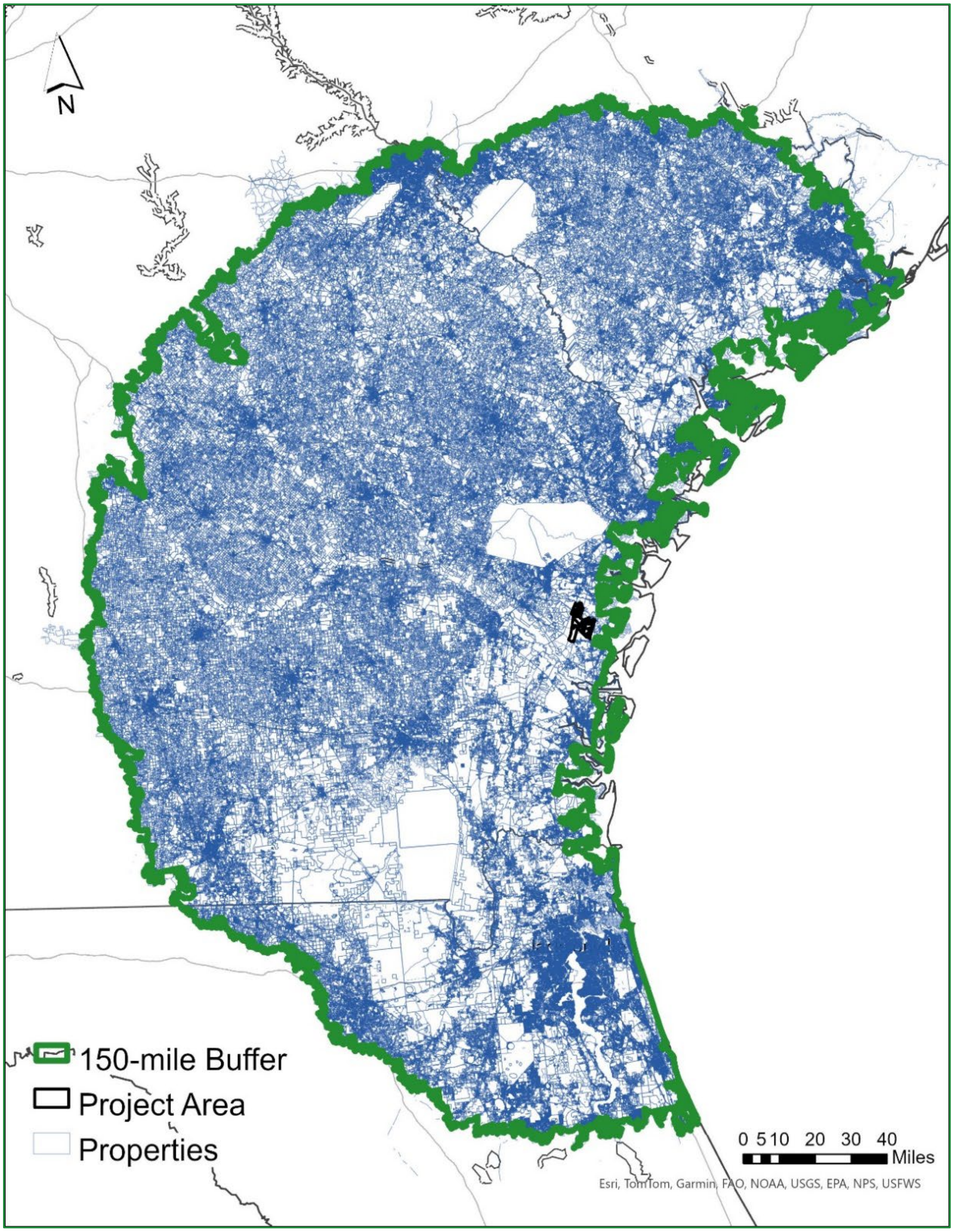
Step 3 Use the Generate Travel Areas tool and select "Driving Distance" as the travel mode with a cutoff of 150 miles. Travel direction should be "away from input locations," and the overlap policy "Dissolve" (Figure 1). The output will be called the Buffer layer.

Figure 1: ArcGIS Online Generate Travel Areas tool



Step 4 Load the Buffer layer in ArcGIS Pro and intersect it with the cadastral data to select all the properties within a 150-road mile buffer of the perimeter of the project area. The output layer should contain only properties intersecting with the buffer, and it will be referred to as the Properties layer (Figure 2).

Figure 2: Cadastral data filtered by 150-road mile buffer



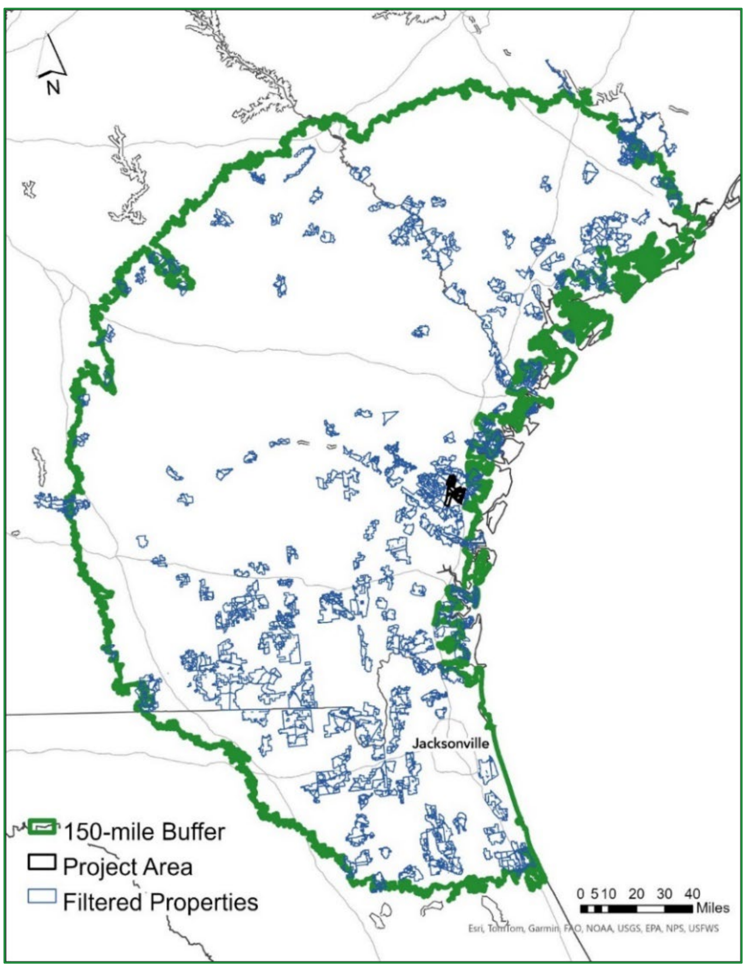
3.1.2 GEOGRAPHIC SIZE

Eligible comparable properties must meet the geographic size specifications laid out in Section 3.1 (i.e., between 25% and 200% of the geographic size of the project area). Prior to filtering for geographic size, parcels with the same owner or timber manager may be combined as single properties. Filtering by geographic size may be performed as follows:

Step 1 Calculate the acreage of all properties in the Properties layer using the Calculate Geometry tool.

Step 2 Select all properties from the Properties layer with acreage meeting the geographic size specifications using the Select by Attribute tool. In the demonstration, eligible comparable properties must be greater than 5,236.79 acres and less than 41,894.35 acres. Create a new layer using the Make Layer From Selected Features tool. Make sure to keep a unique identifier (ID) for each property. The output layer will be referred to as the Properties By Size layer (Figure 3).

Figure 3: Cadastral data filtered by 150-road mile buffer and geographic size



3.1.3 ECOLOGICAL REGION

Eligible comparable properties must be located within the same Ecological Region(s)[7] as the project area. The following steps may be used to filter the Properties By Size layer by Ecological Region:

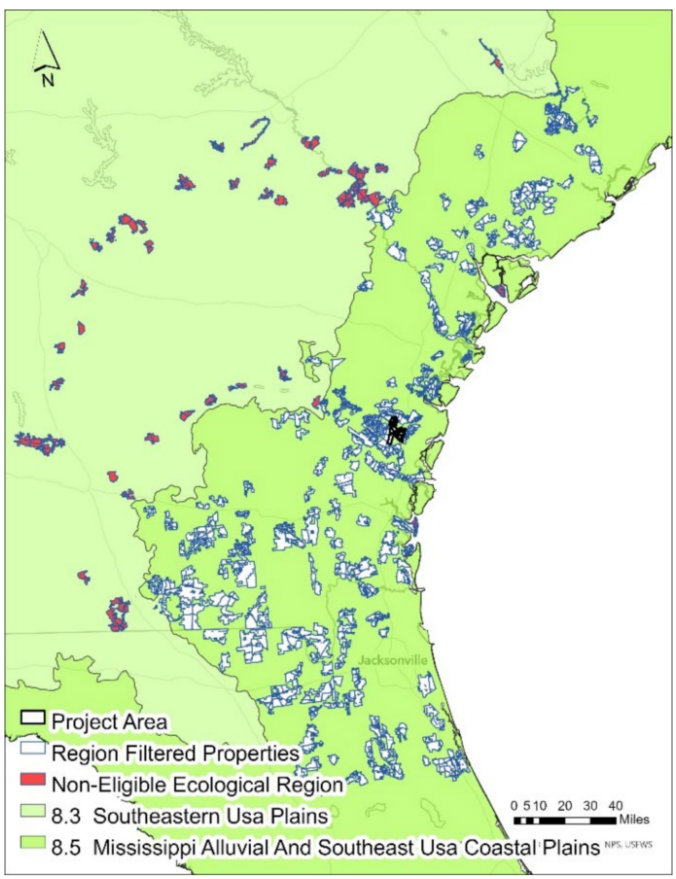
Step 1 Add the EPA's Ecological Regions of North America Level 2 data from ArcGIS Online.

Step 2 Select the Ecological Region in which the project area is located.

Step 3 Use the Select by Location tool to select all the properties intersecting with the selected Ecological Region.

Step 4 Create a new layer that contains the selected properties within the same Ecological Region as the project area. The output layer will be referred to as the Filtered Properties layer (Figure 4).

Figure 4: Cadastral data filtered by 150-road mile buffer, geographic size, and Ecological Region



[7] https://www.epa.gov/eco-research/ecoregions-north-america

The Filtered Properties layer is the basis for the property list included in the Filtered Properties worksheet found in the Comparable Properties Analysis Calculator.[8] The final steps for determining eligible comparable properties (determining ownership and harvest occurrence) contain steps performed within the GIS environment but also in this spreadsheet.

3.1.4 OWNERSHIP

Eligible comparable properties must be owned by a non-federal entity and by an entity of the same timber ownership class as the project area. Filtering by ownership may be performed as follows:

Step 1 Obtain ownership data for all properties in the Filtered Properties layer and assign them to timber ownership classes (Table 1 below). Timber ownership classification must correspond to the USFS FIA owner classes.[9] Ownership data may be provided in the cadastral data layer. Ownership data can be identified as belonging to timber ownership classes using public business registries and other online resources. Properties whose ownership is unknown after good faith efforts to determine its ownership can be assumed to be in the Private Non-Industrial timber ownership class. Parcels with the same owner or timber manager may be combined as single properties.

Table 1: Discount Rates for Net Present Value Determinations by U.S. Forestland Timber Ownership Classes

TIMBER OWNERSHIP CLASS	CORRESPONDING FIA OWNER CLASS VALUE	ANNUAL DISCOUNT RATE
Private Industrial	41	6%
Private Non-Industrial	43, 45	5%
Tribal	44	5%
Non-Federal Public	31, 32, 33	4%
Non-Governmental Organization	42	3%

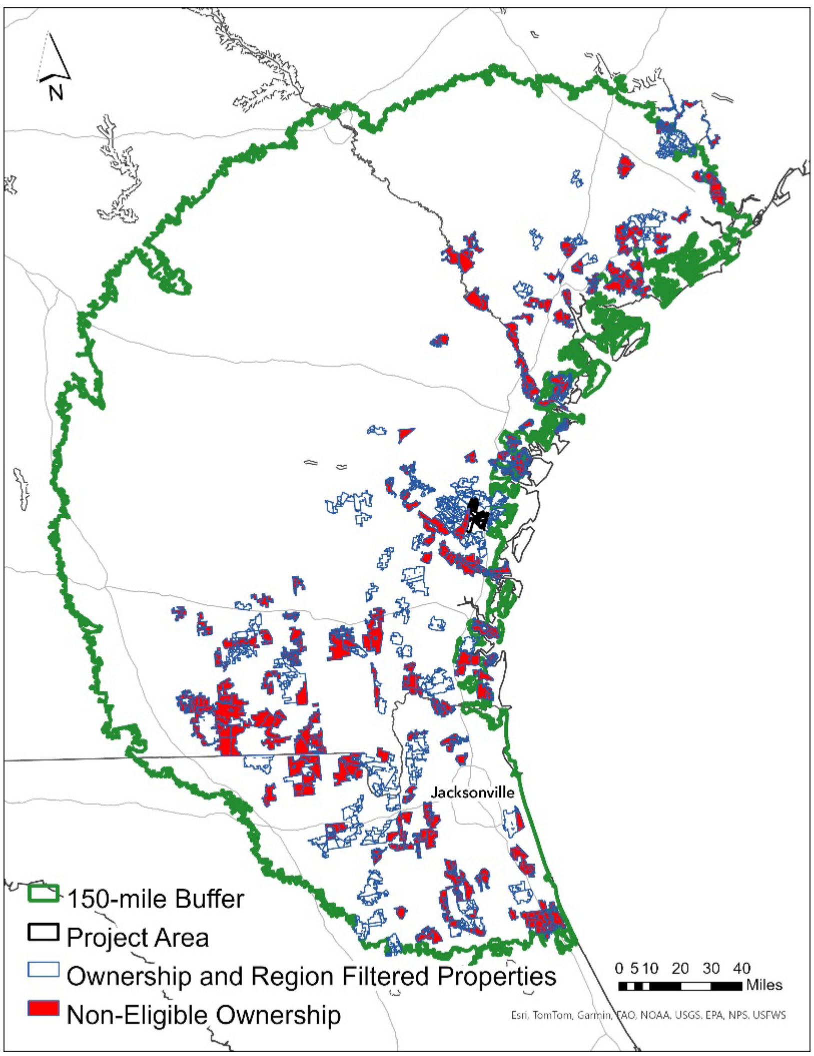
[8] Found on this tool's website.
[9] See section 2.5.7 of the following document for descriptions of FIA owner classes:
U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program. (2023) Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.3. https://www.fs.usda.gov/research/understory/nationwide-forest-inventory-field-guide

Step 2 Select all properties of the same timber ownership class as the project area. Section 3.1 provides further guidelines for utilizing properties by timber ownership class (e.g., timber ownership classes of equal or lesser discount rates at the Project Proponent's discretion, etc.).

Step 3 Create a new layer with the selected properties, which will be referred to as the Similar Ownership Filtered Properties layer (Figure 5).

Step 4 Replace the GHG Project's property polygon in the Similar Ownership Filtered Properties layer with the project area polygon, since this is the most up-to-date boundary for that property. To do so, select all the polygons of the property that overlay with the GHG Project and press delete. Join the Similar Ownership Filtered Properties with the GHG Project polygon using the Merge tool.

Figure 5: Cadastral data filtered by 150-road mile buffer, geographic size, Ecological Region, and ownership



The Filtered Properties worksheet contains examples of the ownership determination process. Column B ("Ownership Description") provides a broad characterization of the owning entity. Column C provides the corresponding Timber Ownership Class. Column D ("Reason to Exclude") provides a brief explanation of why a property was or was not included in the final list. This final list is found in the Eligible Comparable Properties worksheet, found in the Comparable Properties Analysis Calculator.[10]

3.1.5 HARVEST OCCURENCE

Eligible comparable properties must have an observed harvest during the lookback period and harvest at least 0.2% of their forestland per year (Section 3.1). In addition to identifying eligible comparable properties, harvest identification is also a key input in the calculation of Harvest Intensity (Section 5). This process involves first identifying areas of forest loss, then removing areas of natural disturbance, and lastly removing areas smaller than a minimum mapping unit.

The following sections describe the steps taken for this tool's example demonstration using approved datasets and methods (i.e., GLAD and LCMS). However, other datasets and methods may be utilized. To utilize other models for identifying forest loss, they must be tested and approved for use according to Section 6. Regardless of the forest loss model used, areas of natural disturbance must be removed from the forest loss areas.

3.1.5.1 Forest Loss Identification

This demonstration's approved method combines the Global Land Analysis & Discovery (GLAD) forest loss and the Landscape Change Monitoring System (LCMS) fast forest loss datasets to leverage each dataset's distinct approach to forest loss detection. Both datasets are publicly available and updated annually. An approved method to identify forest loss is as follows:

Step 1 Download the most recent GLAD forest loss (lossyear) layer. If multiple tiles are required, combine them into a single layer using the Mosaic to Raster tool.

Step 2 Download the most recent LCMS fast forest loss layer.

Step 3 Add both layers to the map. Project both layers to the same projection and snap one layer to another using the Project Raster tool. In this example, the LCMS layer is snapped to the GLAD layer.

Step 4 Create a buffer around the Similar Ownership Filtered Properties layer of at least the pixel size of the raster layers. In this example, a 30-meter buffer is created. This layer will be referred to as the 30-m Buffered Properties layer.

[10] Found on this tool's website.

Step 5 Clip the GLAD forest loss and LCMS fast forest loss layers raster using the 30-m Buffered Properties layer. Clipping the raster data using a buffered layer avoids missing pixels intersecting with the boundary.

Step 6 Select forest loss data only from years during the lookback period using the Extract by Attribute tool. In this example, GLAD and LCMS data from the years 2018 to 2022 are selected, because these are the most recent 5 years available. To aid in the selection of annual data, the following equivalence table may be used as a reference (Table 2):

Table 2: Landscape Change Monitoring System and Global Land Analysis & Database values and their equivalent years, 2018 to 2022

YEARS	LCMS VALUE	GLAD VALUE
2018	48	18
2019	49	19
2020	50	20
2021	51	21
2022	52	22

Step 7 Transform both forest loss raster into polygons using the Raster to Polygon tool, choosing to not simplify polygons.

Step 8 Dissolve the layer using the field “gridcode” (raster value) to dissolve all polygons by database and year of forest loss. This will be referred to as the Forest Loss layer.

3.1.5.2 Natural Disturbance Removal

Next, areas of natural disturbance must be removed from the Forest Loss layer. The types of natural disturbance and associated methods to account for them will vary by region, but in all cases, forest loss due to wildfire should be removed. The following steps demonstrate an approved method for removing areas impacted by wildfire using the GLAD forest loss due to fire dataset. Other reputable and verifiable datasets and sources for determining areas impacted by wildfire (and other natural disturbances) may be used.

Step 1 Download the most recent GLAD forest loss due to fire layer. Add this layer to the map using the same projection as the forest loss layers. In this example, since the LCMS layer was snapped to the GLAD forest loss layer, and since the GLAD forest loss and GLAD forest loss due to fire layers were created using the same imagery, they should match. If they do not, snap the GLAD forest loss due to fire layer to the Forest Loss layer.

Step 2 Clip the GLAD forest loss due to fire layer with the 30-m Buffered Properties layer. Filter the clipped GLAD forest loss due to the fire layer by years in the lookback period (in this example, from 2018 to 2022) using the Extract by Attribute tool.

Step 3 Convert the clipped GLAD forest loss due to the fire layer to polygons using the Raster to Polygon tool, choosing to not simplify polygons. This will be referred to as the Fires layer.

Step 4 Select all polygons from the Forest Loss layer with the values 18, 19, 48, and 49 to select the forest loss in 2018 and 2019 using the Select by Attribute tool. This is the forest loss that could be due to a fire in 2018. Forest loss in years 2018 and 2019 could both be affected by 2018 fire due to differences in the timing of satellite imagery collection for each layer. The forest loss due to fire layer uses an imagery time series that captures the full year. In contrast, GLAD and LCMS forest loss use imagery taken as late as September in the CONUS area. Thus, forest loss due to fires after September will appear the following year in the GLAD and LCMS forest loss layers.

Step 5 Create a new layer using the Make Layer From Selected Features tool. This layer will be referred to as the 2018 and 2019 Forest Loss layer.

Step 6 Select all polygons from the Fires layer that occurred in 2018 using the Select by Attribute tool. Create a new layer using the Make Layer From Selected Features tool. This layer will be referred to as the 2018 Fires layer.

Step 7 Remove all areas in the 2018 and 2019 Forest Loss layer that overlap with the 2018 Fires layer using the Erase tool. The output is a layer that contains forest loss not due to fire occurring in 2018 (and most of 2019).

Step 8 Select all polygons in the Forest Loss layer with the values 18, 19, 48, and 49 using the Select by Attribute tool. Press delete to remove them. Merge the resulting layer with the layer that contains forest loss not due to fire occurring in 2018.

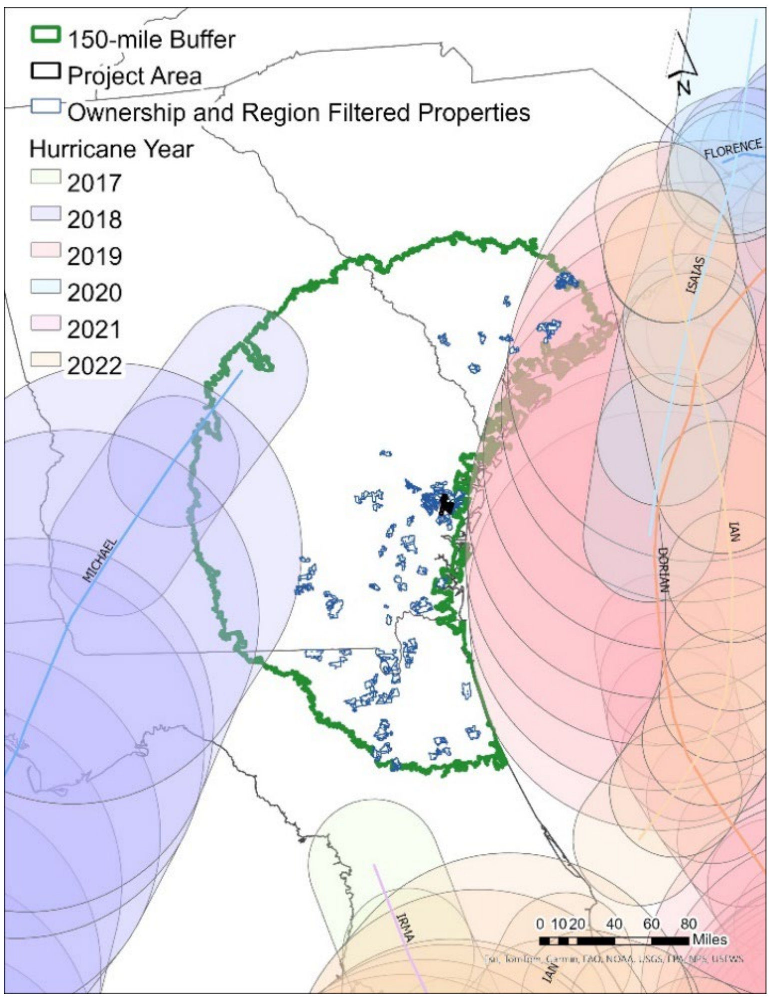
Step 9 Repeat Steps 4 through 8 for the remainder of the lookback period, substituting the forest loss layer with the output layer from Step 8 on each iteration. Remember to use both the year of interest and the following year each iteration.

In addition to removing areas impacted by wildfire, efforts should be made to identify areas impacted by other large-scale natural disturbances. This demonstration's example project area is prone to windthrow from hurricanes. The following steps demonstrate an approved method to identify forest loss due to hurricane damage and remove the associated areas from the Forest Loss layer. This method may be adopted and modified for identifying areas impacted by other types of large-scale windthrow events. It uses the International Best Track Archive for Climate Stewardship (IBTrACS) to determine hurricane paths and potential impact areas. High-resolution imagery is then used to determine whether forest loss in the potential impact area is indeed due to hurricanes. Lastly, all forest loss due to hurricanes is removed:

Step 1 Download the IBTrACRS dataset. Add this layer to the map using the same projection as the forest loss layers. Filter by attributes to only select hurricanes occurring during the lookback period (for this example, between 2018 and 2022) with a Saffir-Simpson Hurricane Wind Scale category of one or higher.

Step 2 Create a 35-mile buffer for hurricanes of category 1 and 2 and a 150-mile buffer for hurricanes of category 3, 4, and 5.[11][12] This conservatively estimates areas that may have forest loss due to hurricane-force winds (Figure 6).

Figure 6: International Best Track Archive for Climate Stewardship hurricane path data buffered by Saffir-Simpson Hurricane Wind Scale category



[11] Anatomy of a Hurricane, National Park Service: https://www.nps.gov/articles/anatomy-of-a-hurricane.htm
[12] Community Hurricane Preparedness: https://www.unidata.ucar.edu/data/NGCS/lobjects/chp/structure/

Step 3 Determine whether forest loss within the buffered areas was due to hurricanes using timestamped high-resolution imagery (>50-centimeter to ≤ 2-meter resolution), such as the high-resolution imagery available on Google Earth Pro (used in Step 7 below). If it is determined that there was no forest loss due to hurricanes, skip Steps 4 through 8 and continue with the next section. Otherwise, proceed with Steps 4 through 8. In this demonstration's example, upon inspecting high-resolution imagery for visual indicators, it is determined that there was no forest loss due to hurricanes.

Step 4 Determine a more exact spatial extent for hurricane damage. Shapefiles of affected areas may be available. Digitizing maps of affected areas may be required. This will be referred to as the Damage layer.

Step 5 Determine in which year the forest loss due to hurricanes is reflected in GLAD and LCMS by comparing the hurricane date with the imagery collection dates for GLAD and LCMS, whose imagery is collected as late as September in the CONUS area.

For hurricanes after September 30th: Forest loss due to hurricanes will be reflected in GLAD and LCMS in the following year. To determine if any forest loss was due to a particular hurricane, select forest loss in the potentially impacted area of the Forest Loss layer, in the year following the hurricane, using the Select by Attribute tool. Create a new layer using the Make Layer From Selected Features tool. The output layer will be referred to as the Forest Loss Potentially Due to Hurricane layer.

For hurricanes before September 30th: Imagery for GLAD and LCMS could have been collected before or after the hurricane happened, and there is no systematic way to determine which year of GLAD and LCMS data will reflect the hurricane's forest loss. Both years (the year of the hurricane and the following year) should be contrasted with high-resolution imagery to determine if there is forest loss due to hurricanes and the year it is reflected in GLAD and LCMS. To determine if any forest loss was due to a particular hurricane, select forest loss in the potentially impacted areas of the Forest Loss layer in both years using the Select by Attribute tool. Create a new layer using the Make Layer From Selected Features tool. The output layer will be referred to as the Forest Loss Potentially Due to Hurricane layer.

Step 6 Clip the Forest Loss Potentially Due to Hurricane layer to the Damage layer. Export the clipped area to a KML format using the Layer to KML tool.

Step 7 Add the KML layer to Google Earth Pro. Visually inspect the layer for forest loss not due to harvesting operations. Toggle between imagery taken before and after the hurricane to see changes in the forest cover. If the forest loss was due to a hurricane, the imagery before the hurricane should show undisturbed forest cover, and imagery after the hurricane should show fallen trees and no signs or tracks of machinery associated with harvesting operations (Figure 7).

Figure 7: Google Earth Pro imagery before (upper) and after (lower) Hurricane Michael in October 2018

Step 8 If forest loss due to hurricanes is detected, determine in which year it is reflected in LCMS or GLAD. Select the polygons from LCMS or GLAD from the affected year using the Select by Attribute tool and create a new layer using the Make Layer From Selected Features tool. This layer will be referred to as the Hurricane Forest Loss layer. Remove areas of forest loss in the Hurricane Forest Loss layer from the Forest Loss layer using the Erase tool. Since large-scale differentiation between forest loss due to harvests and forest loss due to windthrow is difficult, this method conservatively assumes that all forest loss in the year of the hurricane overlapping with the Damage layer due to the hurricane.

Step 9 Optionally, replace forest loss data for the areas and years affected by the hurricane with forest loss data (from GLAD and LCMS) from the first year directly prior to the defined lookback period not affected by a hurricane. For example, if a lookback period started in 2018, forest loss data from 2017 would be used for replacement, unless 2017 also included areas affected by a hurricane (in which case 2016 would be used, and so forth). Note that, if pursuing this option, replacement data must be applied for entire properties (only those affected areas by hurricanes) and the number of years affected by hurricanes must be replaced on a one-to-one basis. Follow all the steps to identify forest loss (Section 3.1.5.1) with the replacement data, adding an extra step to clip the new forest loss layers to the Damage layer. Follow previous steps to remove areas of natural disturbance (Section 3.1.5.2). If any of the replacement data is affected by hurricanes, replace yet again with the next prior year not affected by a hurricane, following the instructions in this step. This layer will be referred to as Forest Loss Replacement layer.

Step 10 Merge the Forest Loss layer (after erasing the Hurricane Forest Loss areas; Step 8) with the Forest Loss Replacement layer.

Step 11 Repeat Steps 3 to 10 for each hurricane buffer that overlaps with eligible comparable properties.

Areas of natural disturbance may be subject to salvage logging which may be undetected as forest loss and therefore not inform the calculation of Harvest Intensity. Salvage logging is operationally expensive[13] and may displace harvests on the landscape which would otherwise inform the calculation of Harvest Intensity. As such, projects may propose approaches to estimate areas of salvage logging. Precise locations need not be estimated, but rather a simple proportion of the total area of natural disturbance on each property may be assumed to be subject to salvage logging. If following the approved method of this example demonstration, 20% of the total area of natural disturbance per forest cover stratum may be assumed to be harvested in the year following a natural disturbance, up to a maximum of 10% stratum area harvested per year (inclusive of both assumed salvage logging and detected harvests).

3.1.5.3 Minimum Mapping Unit Application

Projects may apply a minimum mapping unit, below which areas of forest loss are likely to be due to either detection errors or slivers remaining after erasing areas of natural disturbance, neither of which should inform the calculation of Harvest Intensity.

If using the approved methods of this tool's example demonstration, the minimum mapping unit shall be 1 acre, and all areas less than 1 acre must be removed from the Forest Loss layer. If using another model tested and approved for use per Section 6, a minimum mapping unit may be determined by the project. Projects choosing to either not apply a minimum mapping unit or to apply a minimum mapping unit less than 1 acre must substantiate their choice with verifiable evidence of precise forest loss detection at the proposed threshold. Partial pixels should be excluded.

[13] Iranparast Bodaghi, A., Nikooy, M., Naghdi, R., Venanzi, R., Latterini, F., Tavankar, F., & Picchio, R. (2018). Ground-based extraction on salvage logging in two high forests: A productivity and cost analysis. *Forests*, *9*(12), 729. https://doi.org/10.3390/f9120729

Given the spatial resolution of the GLAD and LCMS datasets, forest loss due to harvests may appear as disaggregated pixels, some of which may fall below the minimum mapping unit. This may be especially true for partial harvests (i.e., thinning). To avoid removing these harvested areas, polygons within 300 feet may be aggregated into multipart polygons before determining their size and whether they exceed the minimum mapping unit. The following steps demonstrate an approved method to apply the minimum mapping unit.

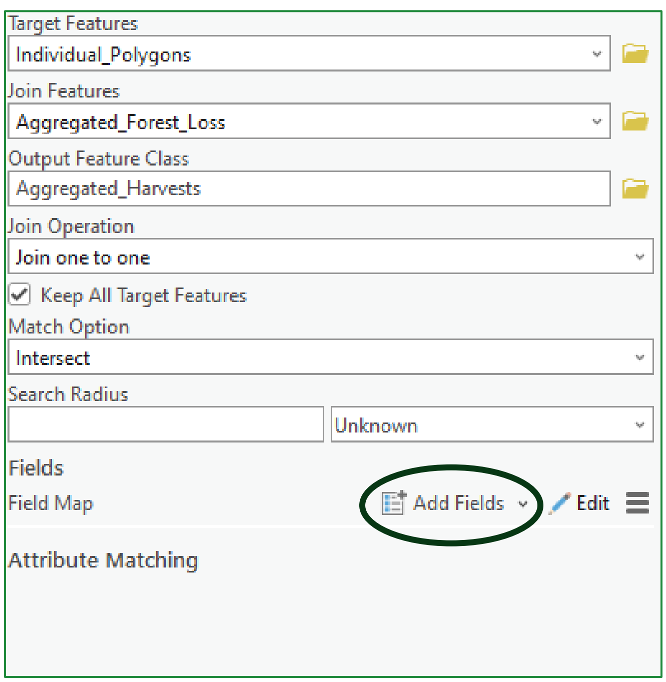
Step 1 Clip the Forest Loss layer to the Similar Ownership Filtered Properties layer.

Step 2 Disaggregate all the polygons using the Multipart to Singlepart tool. The output layer will be referred to as the Individual Polygons layer.

Step 3 Aggregate the Independent Polygons layer using the Aggregate Polygons tool. The Aggregation Distance should be 300 feet and the Aggregate Field should be "gridcode". The output layer will be referred to as the Aggregated Forest Loss layer.

Step 4 Give each polygon in the Independent Polygons layer the ID of their associated polygon in the Aggregated Forest Loss layer using the Spatial Join tool. This groups the disaggregated harvest polygons without adding new area to connect them. If the Aggregated Forest Loss layer's ID field is not available in the Spatial Join tool's fields section, it should be added (Figure 8). The output layer will be referred to as the Aggregated Harvests layer.

Figure 8: Adding a field in the Spatial Join tool

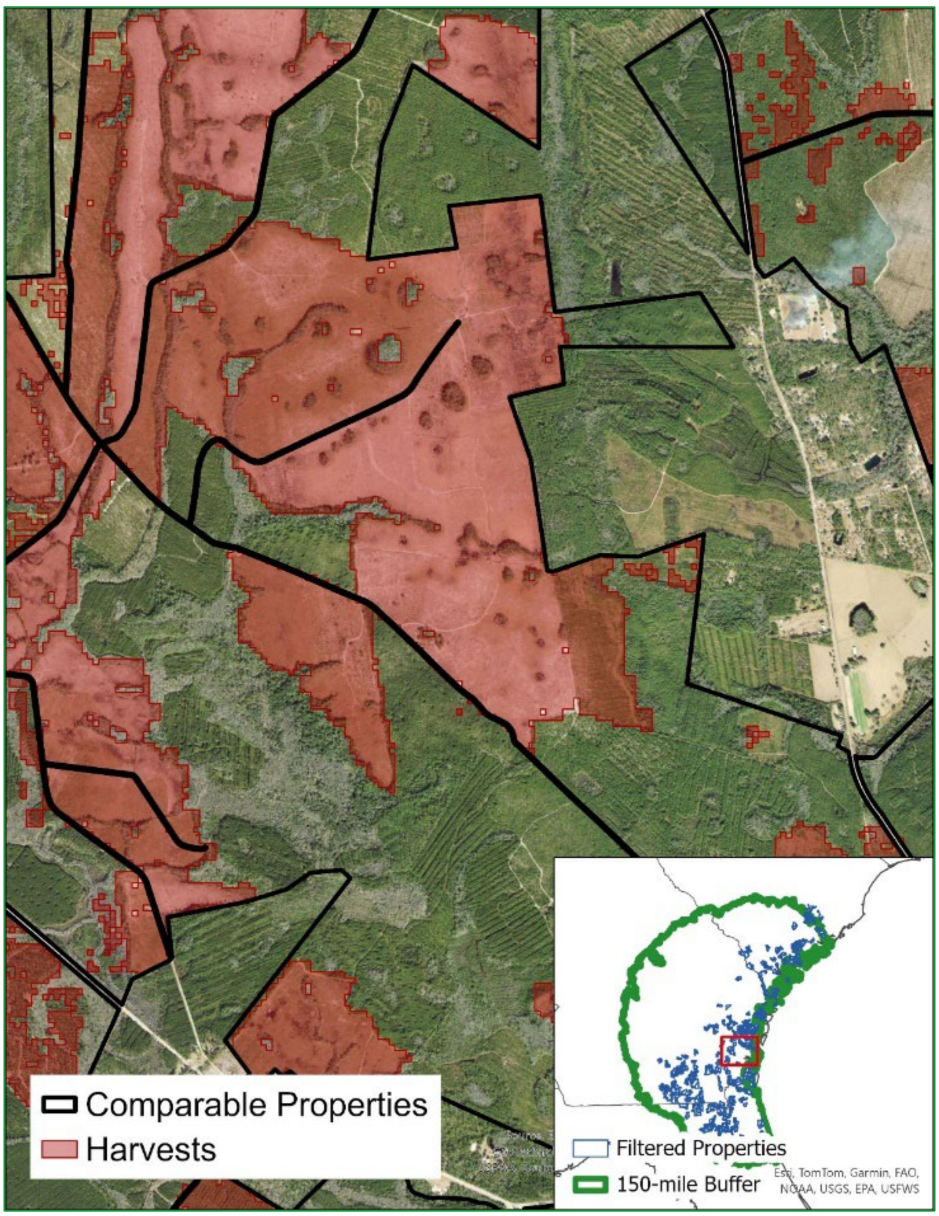


Step 5 Dissolve the Aggregated Harvests layer using the Aggregated Forest Loss layer's ID field.

Step 6 Calculate the acreage of all polygons in the Aggregated Harvests layer using the Calculate Geometry tool. Delete all polygons less than 1 acre in size.

Step 7 Dissolve all polygons in the Aggregated Harvests layer. The output layer will be referred to as the Harvests layer (Figure 9), and it is used in Section 6 if testing and approving a model other than GLAD and LCMS to identify harvested areas.

Figure 9: Harvests layer after removing areas of natural disturbance and areas smaller than the minimum mapping unit



3.1.5.4 Forest Cover Stratification

Since silvicultural practices vary across ecological conditions, Harvest Intensities must be substantiated for each forest cover type. This process is distinct from stratification for the purpose of carbon stock estimation (Methodology Section 3), although the same stratification may be used for both purposes as applicable.

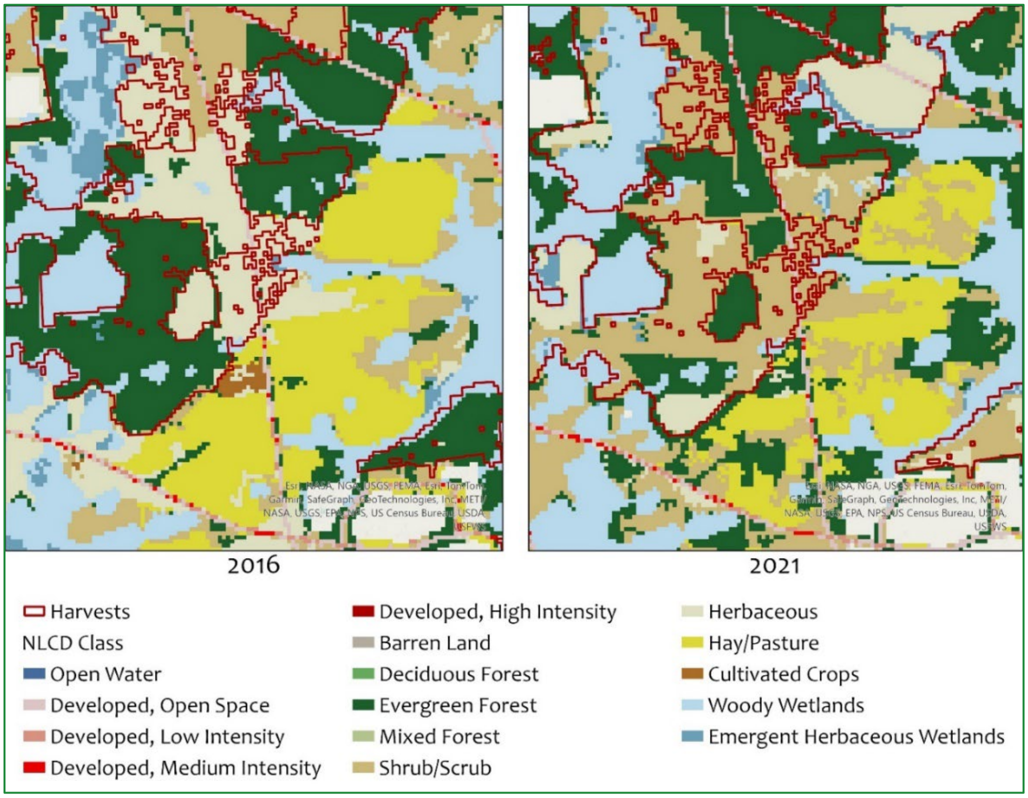
Forest cover stratification is also necessary to determine the extent of forestland, which is required to determine whether the minimum harvest threshold (i.e., harvesting at least 0.2% of forestland per year) has been met for eligibility.

After creating the Harvests layer, the next step is to stratify the project area and eligible comparable properties, consistently applying the same methods and datasets. At minimum, forest cover strata must use the classifications of the National Land Cover Database (NLCD),[14] which include Deciduous Forest, Evergreen Forest, Mixed Forest, Woody Wetlands, and others. More refined forest cover stratifications (e.g., by species or FIA forest type) must be accompanied by verifiable evidence supporting the improved accuracy of the proposed stratification system relative to NLCD.

This demonstration utilizes the most recently published version of the NLCD. The NLCD shows the most recent cover type; however, recently harvested areas may be assigned a non-forest stratum such as Barren Land, Shrub/Scrub, Herbaceous, or Hay/Pasture. To overcome this, recently harvested areas (i.e., the Harvests layer) should be stratified using the version of the NLCD most recently preceding the lookback period, and reasonable efforts should be made to correct the classification of recently harvested lands. NLCD data is available for the years 2013, 2016, 2019, and 2021. In this demonstration, the 2021 data is first applied to determine an initial forest cover stratification layer, and then the 2016 data is substituted for areas of identified harvests (Figure 10).

[14] The most recent NLCD data (as of this methodology publication) is available here: https://www.mrlc.gov/data/nlcd-2021-land-cover-conus. For a general overview of the NLCD, please visit: https://www.usgs.gov/centers/eros/science/national-land-cover-database#overview

Figure 10: Comparison of National Land Cover Database stratification of recently harvested areas from 2016 and 2021



The acreage in each forest cover stratum is required to calculate Harvest Intensity of observed harvest treatments. The following steps are an approved method to stratify comparable properties and their harvested areas. The results of Step 12 may be input into Table 1 of the Harvest Intensity Calculations worksheet:

Step 1 Download the most recent NLCD layer (hereafter referred to as the 2021 NLCD layer), and the NLCD layer that most closely precedes the lookback period (hereafter referred to as the 2016 NLCD layer).

Step 2 Clip both the 2021 NLCD layer and the 2016 NLCD layer to the 30-m Buffered Properties layer. This creates new layers containing NLCD data for only the eligible comparable properties.

Step 3 Project the clipped NLCD layers to the same coordinate system as the other layers.

Step 4 Obtain 2016 NLCD data for the pixels overlapping with the Harvests layer using the Extract by Mask tool.

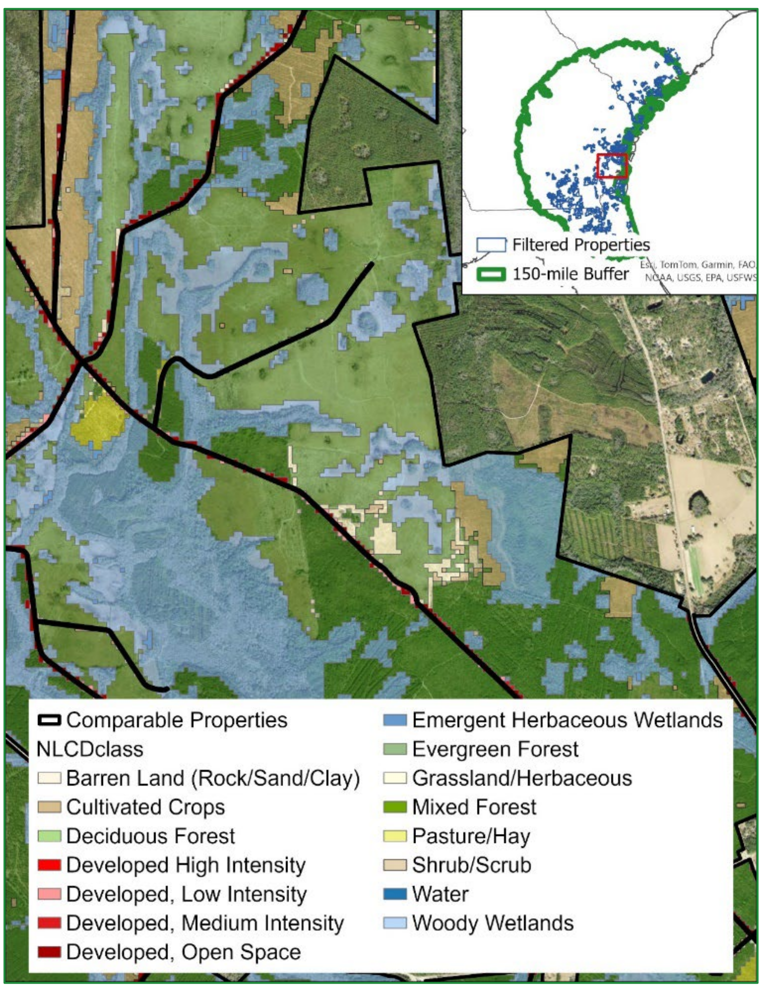
Step 5 Using the Extract by Attributes tool, extract the 2016 NLCD pixels (from Step 4) that belong to the classes of interest: Deciduous Forest, Mixed Forest, Evergreen Forest, and Woody Wetlands.

Step 6 Replace the 2021 NLCD pixels overlapping with the Harvests layer with the extracted pixels from the 2016 NLCD using the Mosaic to New Raster tool. Note that the order in which the layers are added is important. The first layer should be the extracted pixels from the 2016 NLCD and the second layer should be the 2021 NLCD layer. Ensure the Mosaic Operator is set to First.

Step 7 Convert the new NLCD raster into polygons using the Raster to Polygon tool, choosing to not simplify polygons.

Step 8 Intersect the NLCD polygons layer with the Eligible Comparable Properties layer. The output layer should contain NLCD data for each property and will be referred to as the NLCD Properties layer (Figure 11).

Figure 11: NLCD data from 2016 and 2021 for eligible comparable properties



Step 9 Dissolve the layer created in the previous step using the property ID and NLCD classes.

Step 10 Select the NLCD classes considered forestland using the Select by Attribute tool. The NLCD classes to be considered forestland are Deciduous Forest, Mixed Forest, Evergreen Forest, and Woody Wetlands. Select each class individually and create four new layers (using the Make Layer From Selected Features tool) for each forestland NLCD class.

Step 11 Calculate the acreage for each forestland NLCD class layer using the Calculate Geometry tool. Make sure to identifiably name the acreage fields for each different layer. For example, the Evergreen Forest layer's acreage field could be named "EvergreenAcreage" and the Deciduous Forest layer's acreage field could be named "DeciduousAcreage".

Step 12 Merge the four forestland NLCD class layers. Dissolve the output layer by property ID. This layer will be referred to as the Forestland layer, and it will be used in Section 4 below.

Step 13 Join the calculated acreages for each of the four NLCD class layers to the Eligible Comparable Properties layer using the Join Field tool and the property ID.

Step 14 Sum the acreages for each NLCD class inside each property using the Calculate Field tool to obtain the forestland acres per property.

Step 15 Divide the summed acreages for each NLCD class per property by the total forestland acres per property using the Field Calculator tool. This calculates the percentage of forestland in each NLCD class per property.

In regions with significant access constraints (e.g., interior Alaska), projects may define a geographically delineated access threshold (e.g., within 4 aerial miles of an existing transportation network), within which forestland is considered accessible and beyond which it is not. This access threshold may be overlaid on the NLCD-derived forestland layers to calculate the total *accessible* forestland acres per property, to be used in place of total forestland acres per property in all proceeding steps. Projects seeking to implement this option must obtain advance written approval from ACR.

The harvested acreage per stratum is required to calculate Harvest Intensity of the observed harvest treatments. The following steps are an approved method to identify the number of acres harvested in each stratum (Section 5, Step 1). The results of Step 5 (below) may be input into Table 2 of the Harvest Intensity Calculations worksheet:

Step 1 Intersect the NLCD Properties layer with the Harvests layer. The output layer should contain the harvested areas in each property for all NLCD classes.

Step 2 Dissolve the layer created in the previous step using the property ID and NLCD classes.

Step 3 Select the NLCD classes considered forestland (Deciduous Forest, Mixed Forest, Evergreen Forest, and Woody Wetlands) using the Select by Attribute tool. Select each class individually and create four new layers (using the Make Layer From Selected Features tool) with the acreages of their respective forestland NLCD class.

Step 4 Calculate the harvested acreage for each forestland NLCD class layer using the Calculate Geometry tool. Make sure to identifiably name the acreage fields for each different layer. For example, the Evergreen Forest layer's harvested acreage field could be named "EvergreenHarvAcreage" and the Deciduous Forest layer's harvested acreage field could be named "DeciduousHarvAcreage".

Step 5 Join the calculated harvested acreages for each of the four NLCD class layers to the Eligible Comparable Properties layer using the Join Field tool and the property ID.

Step 6 Sum the harvested acreages for all forestland NLCD classes inside each property using the Calculate Field tool to calculate each property's forestland acreage harvested during the lookback period.

Step 7 Divide the harvested forestland acreage of each property by the forestland acreage on each property using the Calculate Field tool. This calculates each property's percentage forestland acreage harvested during the lookback period, which will be used in Section 4.3 below.

Once the percentage forestland harvested has been calculated, eligible comparable properties may be filtered to only those with harvest levels during the lookback period that are indicative of common practice forest management.

Step 1 Multiply the duration (years) of the defined lookback period by 0.2% to calculate the minimum percentage forestland harvested. Select all properties in the Eligible Comparable Properties layer with less than the minimum using the Select by Attributes tool.

Step 2 Press delete to remove the properties. The resulting output layer (the Eligible Comparable Properties layer) is the final list of eligible comparable properties.

The Eligible Comparable Properties layer is the basis for the property list included in the Eligible Comparable Properties worksheet found in the Comparable Properties Analysis Calculator. The following sections for determining similarity contain steps performed within the GIS environment but also in this spreadsheet.

4 Comparable Property Matching and Selection

Once eligible comparable properties have been determined and stratified, a matching process is implemented to determine the 8 most similar comparable properties which are selectable for final Harvest Intensity constraint development.

4.1 Similarity Criteria

The criteria for determining similarity are as follows:

Table 3: Similarity criteria and approved sources

CRITERIA	APPROVED SOURCE	UNITS; NOTES
Forestland Acreage	NLCD; the denominator of Step 12, Section 3.1.5.4	Acres
Distance from Project Area	GIS	Meters; Euclidian distance from the centroid of the properties
Mean Slope	United States Geological Survey (USGS) Digital Elevation Model (DEM); Section 4.1.1	Degrees; ≤10-meter spatial resolution
Mean Elevation	USGS DEM; Section 4.1.1	Meters; ≤10-meter spatial resolution
Aboveground Biomass (AGB)	European Space Agency (ESA) Global Forest Above Ground Biomass; Section 4.1.2	Metric tons AGB per hectare; ≤100-meter spatial resolution, use a version representing a point in time one year prior to the lookback period start date or more recent
Percent forestland in each forest cover stratum (e.g., Deciduous Forest, Mixed	NLCD; results of Step 15, Section 3.1.5.4	Percent

Forest, Evergreen Forest, Woody Wetlands)		
Percent forestland in each merchantability category: Pre-Merchantable Timber; Poletimber; Sawtimber (Merchantability)	ETH Global Sentinel-2 10 meter Canopy Height; Section 4.1.3	Percent; ≤10-meter spatial resolution, use a version representing a point in time one year prior to the lookback period start date or more recent

Other sources may be utilized, subject to verification and advance written approval by ACR. Once approved, verification should focus on the process of applying the approved source, rather than the results for any given property. The following sections provide details on the approved sources and how to utilize them to calculate the criteria used in similarity matching (Section 4.2).

4.1.1 SLOPE AND ELEVATION

Slope and elevation are included in the similarity ranking and matching process because topography informs the operability and accessibility of a given property for timber harvest and extraction. The following steps are an approved method to calculate the mean slope and mean elevation of eligible comparable properties for input into the matching process:

Step 1 Download the tiles of a USGS DEM with at least 10-meter resolution to overlap with the Eligible Comparable Properties layer. If downloading the 10-meter resolution layer, select the 1/3 arc-second DEM (Figure 12).

Step 2 Add the DEM layer to the map.

Step 3 Calculate the slope, selecting the DEM as the "Input surface raster", using the Surface Parameters tool. The 30-m Buffered Properties layer may be used as the "Input analysis mask" to improve performance.

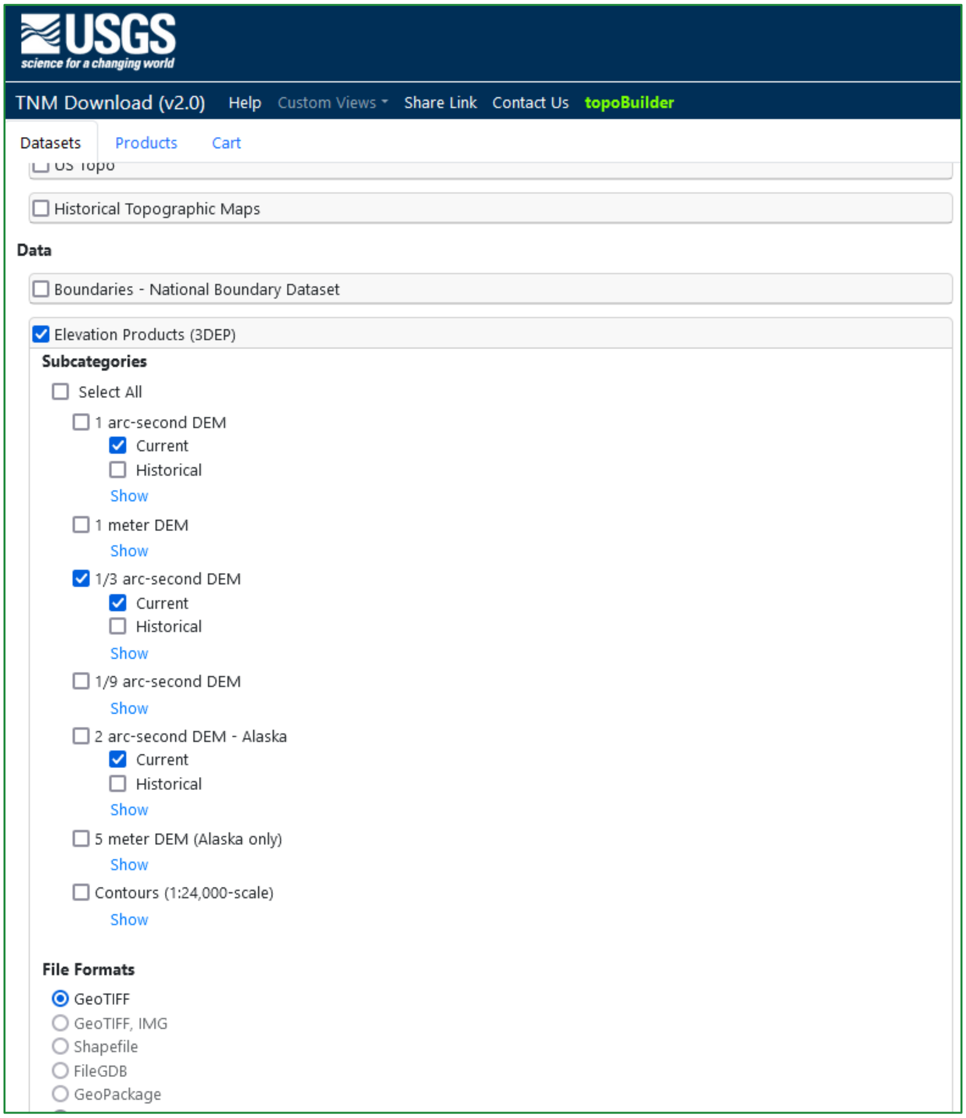
Step 4 Project the elevation and slope layers to the coordinate system used by the other layers.

Step 5 Calculate the mean elevation of each property's forestland, selecting the property ID as the "Zone Field", using the Zonal Statistics as Table tool with the Forestland layer created in Step 12 of Section 3.1.5.4.

Step 6 Join the mean elevation to the Eligible Comparable Properties layer using the Join Field tool and the property ID. The result will be the mean elevation in meters.

Step 7 Repeat Steps 5 and 6 with the slope layer. The result will be the mean slope in degrees.

Figure 12: Downloading the United States Geological Survey Digital Elevation Model



4.1.2 ABOVEGROUND BIOMASS

Aboveground Biomass (AGB) is included in the similarity ranking and matching process because it indicates how much timber is available for harvest and thus factors into the forest management of a property. The following steps are an approved method to calculate AGB of eligible comparable properties for input into the matching process:

Step 1 Download the ESA Global Forest Above Ground Biomass layer that is most representative of the lookback period start date and project it to the same coordinate system as the other layers. The downloaded layer may be clipped to the 30-m Buffered Properties layer to improve performance. This is an example of a Google Earth Engine code that can be used to download the AGB data (and the canopy height data; Step 1 of Section 4.1.3). Add the 30-m Buffered Properties layer to the asset, import it into the code, and change its name to "area".

Step 2 Add the AGB layer to the map. Calculate the mean AGB for each eligible comparable property using the Zonal Statistics as a Table tool and the Forestland layer created in Step 12 of Section 3.1.5.4.

Step 3 Join the mean column of the output table of the previous step with the Eligible Comparable Properties layer using the Join Field tool and the property ID.

4.1.3 MERCHANTABILITY

The merchantability of a property's standing timber plays an important function in determining its management (i.e., whether to harvest or not). While merchantability is difficult to directly assess with publicly available datasets, canopy height may be used as a readily available proxy. Thus, the similarity ranking and matching process includes the distribution of canopy height into three broad categories representing states of merchantability: pre-merchantable timber, poletimber, and sawtimber. Definitions of height thresholds between these categories should be informed by regional merchantability standards. Verifiable evidence justifying the selected thresholds must be presented.[15] This demonstration's example defines pre-merchantable timber as less than 10 meters height; poletimber as between 10 and 17 meters height; and sawtimber as greater than 17 meters height. Height thresholds should be defined using the same unit as the approved canopy height dataset.

The Global Canopy Height 2020 dataset from ETH at 10-meter resolution is an approved source for determining canopy height. The higher resolution (1-meter) Global Canopy Height Map from Meta and the World Resources Institute may also be used, although its utilization is more computationally demanding. The following steps are an approved method to calculate the canopy height distribution (i.e., merchantability) of eligible comparable properties for input into the matching process:

Step 1 Download the Global Canopy Height 2020 dataset and project it to the same coordinate system as the other layers. The downloaded layer may be clipped to the 30-m Buffered Properties layer to improve performance.

[15] Sources may include USFS regional documentation or attestation from a Professional Forester. Merchantability standards may be expressed in terms other than height (e.g., diameter at breast height). If diameter at breast height is used, forest inventory data for the project area may be used to determine mean height at the specified diameters.

Step 2 Select pixels within the canopy height layer less than or equal to the pre-merchantable timber height threshold (in this example, less than or equal to 10 meters height) using the Extract by Attribute tool. This creates a pre-merchantable timber layer.

Step 3 Convert the pre-merchantable timber layer into polygons using the Raster to Polygon tool, choosing to not simplify polygons. Dissolve the polygons.

Step 4 In the NLCD Properties layer, select the classes of Deciduous Forest, Mixed Forest, Evergreen Forest, and Woody Wetlands.

Step 5 Intersect the pre-merchantable timber polygon layer with the Forestland layer created in Step 12 of Section 3.1.5.4.

Step 6 Dissolve the output layer by property ID.

Step 7 Calculate the acreage of pre-merchantable timber inside each property using the Calculate Geometry tool on the intersection's output.

Step 8 Join the calculated acreage to the Eligible Comparable Properties layer using the Join Field tool and the property ID.

Step 9 Repeat Steps 2 to 8 for poletimber and sawtimber, first selecting pixels (in Step 2) within the canopy height layer meeting the poletimber threshold (in this example, more than 10 and less than or equal to 17 meters), and then selecting pixels (in Step 2) within the canopy height layer meeting the sawtimber threshold (in this example, more than 17 meters).

Step 10 Divide the acreages of pre-merchantable timber, poletimber and sawtimber by each property's total forestland acreage using the Field Calculator tool. This calculates each property's percent forestland in each canopy height category.

Step 11 Export the Eligible Comparable Properties layer's tabular data using the Export Table tool. This allows calculations for the following sections to be performed in a spreadsheet program.

4.2 Similarity Matching

Using the criteria defined above (Section 4.1), eligible comparable properties are evaluated for similarity to the project area using a *k*-nearest neighbors matching method, resulting in a similarity index for each property ($\overline{\mathrm{Sim}_1}$). The similarity index is then used to rank properties by their similarity to the project area. The eight most similar properties are considered matched.

The normalized Euclidian distance must be utilized to measure the relative similarity of each comparable property to the project area for each criteria. The following steps are required to determine the eight most similar comparable properties:

Step 1 Normalize the values of each criterion using the following formula:

Equation 1: Criteria Value Normalization

$$Z_{i,j} = \frac{x_{i,j} - \overline{x}_j}{\sigma_j}$$

WHERE

$Z_{i,j}$	Z-score normalized value for criterion **j** for property **i**.
$x_{i,j}$	Value for criterion **j** for property **i**.
$\overline{x}_j$	Mean of criterion **j** values for all properties.
σ_j	Standard deviation of criterion **j** values for all properties.

Step 2 After all criteria values have been normalized, calculate the Euclidian distance (Equations 2 and 3). This step determines the similarity between the project area and each comparable property for each criterion.

For the criterion of distance from the project area (i.e., physical distance), use the following formula with centroid coordinates:

Equation 2: Normalized Distance from Project Area

$$Dist_i = \sqrt{(Z\_x_{project} - Z\_x_i)^2 + (Z\_y_{project} - Z\_y_i)^2}$$

WHERE

$Dist_i$	Distance from the normalized project area centroid to the normalized property **i** centroid.
$Z\_x_{project}$	Normalized X coordinate of the centroid of the project area.
Z_x_i	Normalized X coordinate of the centroid of property **i**.

$Z\_y_{project}$	Normalized Y coordinate of the centroid of the project area.
Z_y_{i}	Normalized Y coordinate of the centroid of property **i**.

For all other criteria, use the following formula:

Equation 3: Normalized Similarity

$$\mathbf{Sim_{i,j}} = \sqrt{\left(\mathbf{Z_{project,j}} - \mathbf{Z_{i,j}}\right)^2}$$

WHERE

$Sim_{i,j}$	Similarity between the normalized values for criterion **j** for the project area and for property **i**.
$Z_{project}$	Normalized value for criterion **j** for the project area (Equation 1).
$Z_{i,j}$	Normalized value for criterion **j** for property **i**.

Step 3 For the criteria of forest cover stratification, calculate a weighted forest cover strata composition metric using the following formula:

Equation 4: Weighted Forest Cover Strata Composition

$$\mathbf{WFCS_i} = \sum_{l=1}^{n} \mathbf{Sim_{i,l}} \times \mathbf{fcAc\%_{i,l}}$$

WHERE

$WFCS_{i}$	Weighted forest cover strata composition for property **i**.
$Sim_{i,l}$	Similarity for forest cover strata acreage for forestland NLCD class (Deciduous Forest, Mixed Forest, Evergreen Forest, Woody Wetlands) **l**.
$fcAc\%_{i,l}$	Percentage of forest cover strata acreage in forestland NLCD class (Deciduous Forest, Mixed Forest, Evergreen Forest, Woody Wetlands) **l**.

Step 4 For the criteria of canopy height (i.e., merchantability), calculate a weighted canopy height composition metric using the following formula:

Equation 5: Weighted Merchantability Composition

$$WM_i = \sum_{k=1}^{n} Sim_{i,k} \times chAc\%_{i,k}$$

WHERE

WM_i	Weighted merchantability composition for property i.
$Sim_{i,k}$	Similarity for merchantability category (pre-merchantable timber, poletimber, sawtimber) k.
$chAc\%_{i,k}$	Percentage of merchantability category (pre-merchantable timber, poletimber, sawtimber) k.

Step 5 Calculate the mean similarity relative to the project area for each comparable property using the following formula:

Equation 6: Similarity Index

$$\overline{Sim_i} = \frac{\left(\sum_{j=1}^{4} Sim_{i,j}\right) + Dist_i + WFCS_i + WM_i}{n}$$

WHERE

$\overline{Sim_i}$	Similarity index. The mean similarity relative to the project area for property i.
$Sim_{i,j}$	Similarity for criteria j for property i, excluding criteria for distance from the project area, forest cover stratification, and canopy height.
$Dist_i$	Distance from the normalized project area centroid to the normalized property i centroid.
$WFCS_i$	Weighted forest cover strata composition for property i.
WM_i	Weighted merchantability composition for property i.
n	Number of criteria. In this demonstration, n equals 7.

Step 6 Rank the eligible comparable properties by their similarity index ($\overline{\mathrm{Sim}_1}$; result of Equation 6). A lower similarity index indicates a better match and more similarity with the project area. Excluding the project area itself, select the eight properties with the lowest similarity index. These are the matched comparable properties.

4.3 Outlier Detection

Once the eight most similar (i.e., matched) comparable properties have been identified (Section 4.2), they are evaluated using a Dixon's Q test to identify and reject outliers. This process ensures that the final list of matched comparable properties available for selection does not contain a property harvesting far above or below common practice, relative to the other matched properties. This test is performed in a single iteration, one-tailed, with a significance level of 10% on the percentage forestland acreage harvested during the lookback period (final Step 7, Section 3.1.5.4). At the Project Proponent's discretion, the project area itself may be considered matched, subject to outlier detection and potentially available for selection. If opting to do so, nine properties will be included in the Dixon's Q test. The following steps are required to identify and reject outliers from the matched properties:

Step 1 Copy and paste the details for the eight (or nine) matched comparable properties, including the percentage forestland acreage harvested during the lookback period (hereafter referred to as percentage harvested), to the Outlier Detection worksheet found in the Comparable Properties Analysis Calculator.[16]

Step 2 Sort the copied properties by their percentage harvested from lowest to highest.

Step 3 Calculate the Q value for the highest percentage harvested value using the Outlier Detection worksheet and the following formula:

Equation 7: Dixon's *Q* test

$$\mathbf{Q_n} = \frac{\mathbf{\%FH_n} - \mathbf{\%FH_{n-1}}}{\mathbf{\%FH_n} - \mathbf{\%FH_1}}$$

WHERE

Q_n	Q value for the property with the highest percentage harvested value.
$\%FH_n$	Highest percentage harvested value.

[16] Found on this tool's website.

$\%FH_{n-1}$	Second highest percentage harvested value.
$\%FH_1$	Lowest percentage harvested value.

Step 4 Compare the calculated Q value (Q_n; Equation 7) with the Q critical value. The Q critical value at the 10% significance level for eight properties ($n=8$) is 0.3979, and the Q critical value at the 10% significance level for nine properties ($n=9$) is 0.3704.[17] If the calculated Q value is greater than the Q critical value ($Q_n > 0.3979$, or $Q_n > 0.3704$), the highest percentage harvested is considered an outlier. This property must be removed from the list of matched comparable properties available for selection. Otherwise, all values are accepted and no matched properties are rejected.

4.4 Comparable Property Selection

Once any outliers have been identified and removed from the list of matched comparable properties, select one of the remaining matched properties to be used to calculate Harvest Intensity.

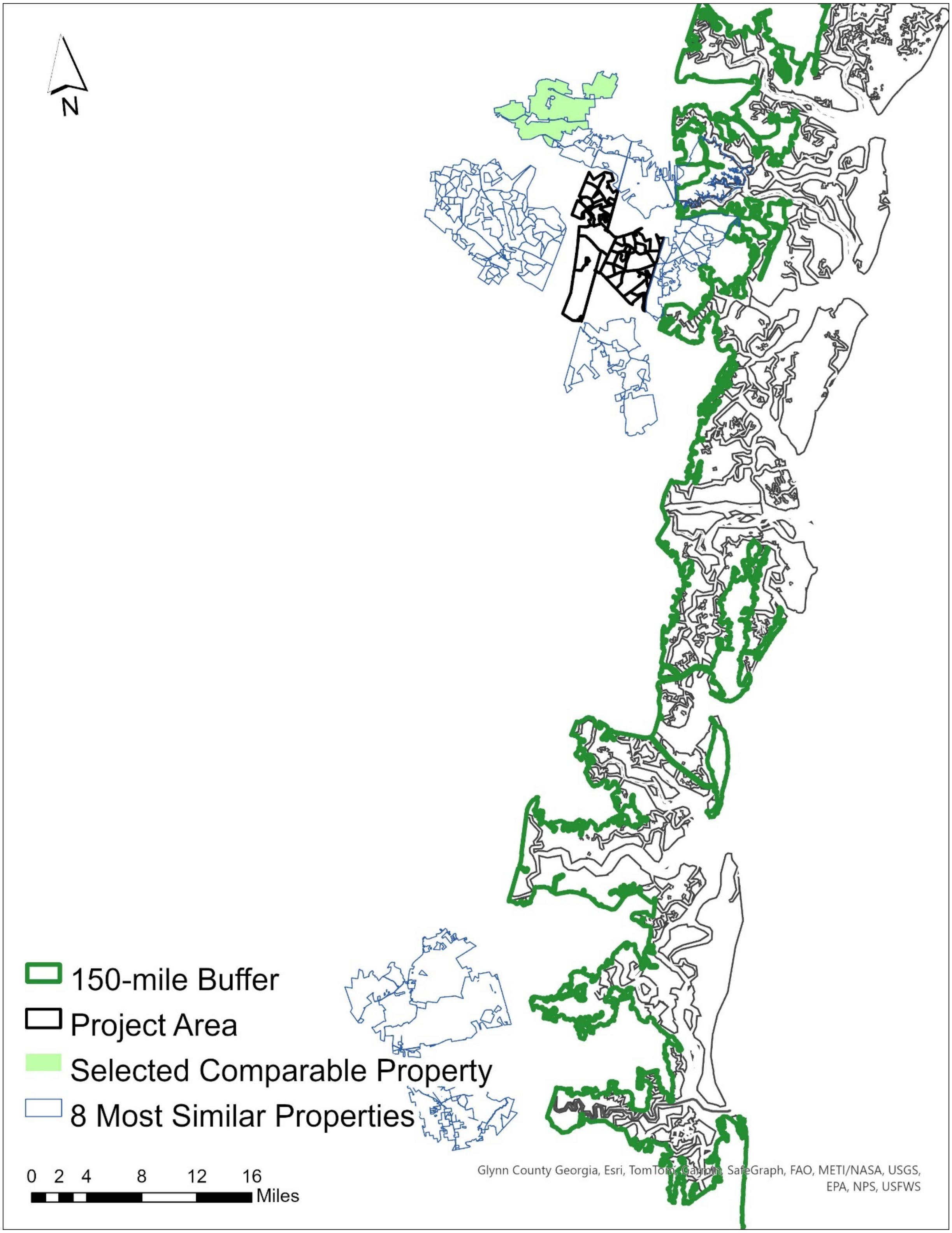
In this demonstration's example, the highest percentage harvested value was not considered an outlier, so all matched properties are available for selection. The property with the highest percentage harvested value is selected (Table 4 and Figure 13).

[17] Verma, S. P., & Quiroz-Ruiz, A. (2006). Critical values for six Dixon tests for outliers in normal samples up to sizes 100, and applications in science and engineering. *Revista mexicana de ciencias geológicas*, *23*(2), 133-161. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1026-87742006000200003

Table 4: Similarity criteria and other attributes of example project area and selected comparable property

CRITERIA AND ATTRIBUTES	EXAMPLE PROJECT AREA	SELECTED COMPARABLE PROPERTY
Percentage Forestland Acreage Harvested during the Lookback Period	39%	50%
Similarity Index ($\overline{\text{Sim}_1}$)	0.00	0.33
Ownership Description	Private Industrial Timber Company	Private Industrial Timber Company
Forestland Acreage	18,945 acres	12,916 acres
Distance from Project Area	0 miles	3 miles
Mean Slope	4.8°	4.4°
Mean Elevation	4.7 meters	4.4 meters
Aboveground Biomass (AGB)	97.2 metric tons/hectare	104.4 metric tons/hectare
Percent forestland in each forest cover stratum: Deciduous Forest; Mixed Forest; Evergreen Forest; Woody Wetlands	0%; 0%; 67%; 33%	0%; 0%; 63%; 37%
Percent forestland in each merchantability category: Pre-Merchantable Timber; Poletimber; Sawtimber	10%; 21%; 66%	8%; 13%; 79%

Figure 13: Matched comparable properties and the selected comparable property



5 Harvest Intensity Calculations

Once a comparable property is selected, projects must determine the Harvest Intensity of its observed harvest treatments.

The following general steps are followed when calculating the Harvest Intensity of a harvest treatment within a given forest cover stratum.

Step 1 **Identify the number of acres harvested in each stratum.** The number of acres harvested must consider all harvest treatments of similar percent biomass removed per acre.

Step 2 **Identify the average percent biomass removed per acre.** The percent biomass removed is relative to the sum of the above and belowground live biomass carbon and above and belowground standing dead wood (if included) pools. Harvest treatments may be separated by distinct treatment type or may be grouped together and averaged for each forest cover stratum.

Step 3 **Divide the number of acres harvested by the total stratum acres to calculate the percent stratum area harvested.** The stratum acres must consider the forest cover stratification determined according to Section 3.1.5.4.

Step 4 **Divide the percent stratum area harvested by the number of years to calculate an annual harvest rate for each stratum.**

Step 5 **Multiply the percent biomass removed per acre by the percent stratum area harvested per year to calculate Harvest Intensity.** Harvest Intensity is expressed as a percentage.

The Harvest Intensity Calculations worksheet (found in the Comparable Properties Analysis Calculator[18]) and tables found therein are referenced in the sections below and must be utilized.

5.1 Comparable Property Harvest Intensity

The general steps (Section 5) are applied to the selected comparable property (Section 4.4), which results in a determination of Harvest Intensities that are then used in constraint development (Section 5.2). Tables 1 and 2 of the Harvest Intensity Calculations worksheet must be completed following the Directions found therein to calculate the comparable property Harvest Intensity per forest cover

[18] Found on this tool's website.

stratum. If using the approved methods demonstrated by this tool (i.e., using GLAD and LCMS), the average percent biomass removed per acre may be assumed to be 100% (Table 2; row 10), given the technical limitations of detecting areas of partial harvests (i.e., thinning).[19,20] If using other forest loss models, the percent biomass removed per acre must be determined according to Section 6.

For the purpose of calculating comparable property Harvest Intensity, management records may be used in addition to (or in place of) harvest information derived from remote sensing. Management records (e.g., past timber sale data) may be used if the harvested spatial extent and percent biomass removed per acre can be verifiably determined. Management records may come from a participating entity (e.g., Project Proponent, landowner) or another landowner/forest manager and must be based on verifiable evidence (e.g., published data of harvests on public lands, Professional Forester attestation, mill reports, scaling tickets).

5.2 Constraint Development

To develop constraints for parameterizing the baseline model based on the Harvest Intensities of the selected comparable property, projects must first identify the baseline's average percent biomass removed per acre (Table 4 of the Harvest Intensity Calculations worksheet) using modeled outputs from the baseline scenario. Within each forest cover stratum, percent biomass removed per acre may be averaged for similar harvest treatments. Projects then develop constraints by applying the inverse operations of the general steps for Harvest Intensity calculation (Section 5; Table 5 of the Harvest Intensity Calculations worksheet).

Constraining baseline harvests in a single year to the selected comparable property's Harvest Intensity may inappropriately limit inter-year harvest variation. This may be exacerbated on smaller project areas, which may be subject to periodic harvests of higher relative intensity. To account for the effect of averaging time in the Harvest Intensity calculation, projects must calculate a scaling factor to be used in determining the annual constraint (Equation 8). The Annual Harvest Intensity Factor may range from 1.25 to 3, depending on the total project area acreage.

[19] Stehman, S. V., Pengra, B. W., Horton, J. A., & Wellington, D. F. (2021). Validation of the us geological survey's land change monitoring, assessment and projection (LCMAP) collection 1.0 annual land cover products 1985–2017. *Remote sensing of environment*, *265*, 112646. https://doi.org/10.1016/j.rse.2021.112646

[20] Despite recent improvements to selective logging detection, the GLAD dataset (lossyear) is still described as "[f]orest loss during the period 2000-2022, defined as a stand-replacement disturbance, or a change from a forest to non-forest state." https://data.globalforestwatch.org/documents/941f17325a494ed78c4817f9bb20f33a/explore

Equation 8: Annual Harvest Intensity Factor

$$\text{if } [\text{Area}_{\text{project}} < 5,000] \text{ then } \text{HI}_F = \left(\left[\frac{(5,000 - \text{Area}_{\text{project}})}{5,000}\right] \times 1.75\right) + 1.25$$

or

$$\text{if } [\text{Area}_{\text{project}} \geq 5,000] \text{ then } \text{HI}_F = 1.25$$

WHERE

HI_F	Annual Harvest Intensity Factor (unitless).
$\text{Area}_{\text{project}}$	Total project area (acres).

This factor is multiplied by the acres harvested per year (based on comparable property Harvest Intensity and the baseline percent biomass removed per acre) to calculate the annual constraint (Table 5 of the Harvest Intensity Calculations worksheet). The cumulative constraint is calculated by multiplying the acres harvested per year by the number of years in the Crediting Period (20).

5.3 Harvest Intensities Check

Once a baseline harvest schedule has been developed (Methodology Section 4.1.4), final checks must be performed to ensure proper implementation and standardize validation/verification. For *ex-ante* projections at initial validation, checks ensure that Harvest Intensities of the selected comparable property were not exceeded, both in each single year (Table 6 of the Harvest Intensity Calculations worksheet) and cumulatively during the Crediting Period (Table 7 of the Harvest Intensity Calculations worksheet).

Baseline harvest treatments included in these checks are inclusive of any regeneration or partial harvests. Intermediate treatments (e.g., pre-commercial thinning) and other non-commercial harvest treatments should not be included.

These checks are also performed as part of the dynamic evaluation (according to the *ACR IFM Methodologies Tool for Dynamic Evaluation of Baselines*). Harvest Intensities for the Reporting Period are checked during the Observed Conditions Assessment (Table 8 of the Harvest Intensity Calculations worksheet). Harvest Intensities for the remainder of the Crediting Period are checked during the Periodic Modeling Assessment (Table 9 of the Harvest Intensity Calculations worksheet).

To prepare for these checks, Harvest Intensities of multiple harvest treatments (i.e., percent biomass removed per acre) in the same forest cover stratum must be combined, which calculates the total Harvest Intensity per forest cover stratum.

When checking annual or Reporting Period Harvest Intensities, comparable property Harvest Intensity must be multiplied by the Annual Harvest Intensity Factor (Equation 8; Tables 6 and 8).

When checking cumulative Harvest Intensities, percent stratum area harvested must be divided by the number of years remaining in the Crediting Period (20 years at validation, or less during a Periodic Modeling Assessment; Tables 7 and 9) to calculate an annual harvest rate prior to calculating Harvest Intensity.

If the selected comparable property's Harvest Intensity (Table 2) exceeds the total Harvest Intensity per forest cover stratum, then the baseline Harvest Intensities applied to that forest cover stratum are substantiated. For any forest cover stratum that cannot be substantiated, the baseline Harvest Intensities must be reduced such that they are equal to or less than the comparable property Harvest Intensities per forest cover stratum.

6 Approval Process for Forest Loss Identification Models

This section describes the requirements for testing and approving models that identify harvested areas using remote sensing technology. The datasets and methods utilized by this tool's example demonstration (i.e., GLAD and LCMS) are considered approved and do not require testing per this section.

Projects may utilize one of the following two options:

Option 1 **Internally developed model (developed by project participants).** Entities involved in GHG Project implementation may develop custom models. These models may integrate the GLAD and LCMS datasets for identifying forest loss, but the model as a whole (including areas identified by GLAD and LCMS) is subject to testing for approval. The average percent biomass removed per acre must be estimated using a systematic approach, to be applied to all areas of forest loss, including areas identified by GLAD and LCMS (if applicable). Internally developed models may be shared amongst multiple GHG projects, but the model approval process must be applied to each project.

Option 2 **Externally developed model (developed by non-project participants).** Projects may utilize models developed by entities not involved in GHG Project implementation, such as government agencies, universities, academic or research cooperatives, or private companies. The average percent biomass removed per acre must be estimated using a systematic approach, to be applied to all areas of forest loss.

Both internally and externally developed models must make predictions at a spatial resolution (i.e., pixel size) of 30 meters or finer and a temporal resolution (i.e., frequency of data collection/processing) of 1 year or less.[21] Both are subject to testing to confirm they have higher precision than the combined GLAD and LCMS datasets (i.e., the Harvests layer; Section 3.1.5.3) in the project region (Section 6.2).

6.1 Labeling Data Sources

To test the forest loss model, its output must first be classified as either harvested or non-harvested (i.e., labeled) using independent data sources that identify harvests. Extra post-processing or modeling approaches may be used to remove areas of natural disturbance from the model's output,

[21] Gao, Y., Skutsch, M., Paneque-Gálvez, J., & Ghilardi, A. (2020). Remote sensing of forest degradation: a review. *Environmental Research Letters*, *15*(10), 103001. https://doi.org/10.1088/1748-9326/abaad7

and a minimum mapping unit may be applied to remove areas of forest loss likely due to detection errors. This labeling process forms the basis for assessing model performance. Labeling data sources may include:

- High-resolution imagery within the 150-mile buffer, subject to visual interpretation. Imagery should have a spatial resolution of 2 meters or finer[22] and a temporal resolution of 1 year or less. However, if such imagery is unavailable for the given geography, it must minimally be of higher quality (higher spatial and/or temporal resolution) than the datasets used by the forest loss models (if the forest loss model utilizes imagery);[23] or
- Spatially explicit harvest data within the 150-mile buffer from public records, public agencies, or other landowners.
    - At minimum, the boundaries of harvested areas and coordinates of the polygons must be included.
    - Harvest data must be timestamped and within the defined lookback period (Section 2).
    - Harvest data must be spatially and temporally complete (i.e., all harvests and non-harvests within its specified area and time period must be included).

More than one labeling data source may be used. The same labeling data source(s), area of interest, and time period must be used for both the project's forest loss model and the combined GLAD and LCMS datasets (i.e., the Harvests layer; Section 3.1.5.3).

6.2 Model Performance Assessment

The model's performance assessment shall follow an out-of-sample prediction bootstrapping approach,[24] subject to advance written approval from ACR. First, the performance assessment produces an error matrix based on the results of the labeling process for each bootstrap sample. Next, the following metrics are produced: overall accuracy, precision, recall, and F1 score. These steps are repeated with the combined GLAD and LCMS dataset outputs, minus areas of natural disturbance or less than a minimum mapping unit of 1 acre (i.e., the Harvests layer; Section 3.1.5.3), such that its

[22] Neigh, C. S., Bolton, D. K., Williams, J. J., & Diabate, M. (2014). Evaluating an automated approach for monitoring forest disturbances in the Pacific Northwest from logging, fire and insect outbreaks with Landsat time series data. *Forests*, *5*(12), 3169-3198. https://doi.org/10.3390/f5123169

[23] Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., & Wulder, M. A. (2014). Good practices for estimating area and assessing accuracy of land change. *Remote sensing of Environment*, *148*, 42-57. https://doi.org/10.1016/j.rse.2014.02.015

[24] For example: Tsamardinos, I., Greasidou, E., & Borboudakis, G. (2018). Bootstrapping the out-of-sample predictions for efficient and accurate cross-validation. *Machine learning*, *107*, 1895-1922. https://doi.org/10.1007/s10994-018-5714-4

precision is calculated. Last, the model's precision is evaluated in relation to the precision of the combined GLAD and LCMS datasets to determine whether the model is approved for use.

Projects must construct an error matrix that compiles the results of the labeling process comparison for each bootstrap sample, expressed in terms of the proportion of area. The error matrix is constructed by identifying the following instances and reporting them according to Table 5:

- True Positives (TP): Proportion of area correctly predicted as harvested.
- True Negatives (TN): Proportion of area correctly predicted as non-harvested.
- False Positives (FP): Proportion of area incorrectly predicted as harvested.
- False Negatives (FN): Proportion of area incorrectly predicted as non-harvested.

Table 5: Error matrix for model performance assessment

		PREDICTED	
		HARVESTED	NON-HARVESTED
OBSERVED	HARVESTED	TP	FN
	NON-HARVESTED	FP	TN

Following the construction of an error matrix, metrics are produced for the purpose of publicly reporting model performance and, in the case of precision, to determine whether the project's model is approved for use:

Equation 9: Overall Accuracy

$$\mathit{Overall\ Accuracy} = \frac{(\mathbf{TP} + \mathbf{TN})}{(\mathbf{TP} + \mathbf{FP} + \mathbf{TN} + \mathbf{FN})}$$

WHERE

$\mathit{Overall\ Accuracy}$	Proportion of area (both harvested and non-harvested) correctly predicted.
TP	True Positives. Proportion of area correctly predicted as harvested.
TN	True Negatives. Proportion of area correctly predicted as non-harvested.
FP	False Positives. Proportion of area incorrectly predicted as harvested.

FN	False Negatives. Proportion of area incorrectly predicted as non-harvested.

Equation 10: Precision

$$\boldsymbol{Precision} = \frac{\mathbf{TP}}{(\mathbf{TP} + \mathbf{FP})}$$

WHERE

Precision	Proportion of area predicted as harvested that was harvested.
TP	True Positives. Proportion of area correctly predicted as harvested.
FP	False Positives. Proportion of area incorrectly predicted as harvested.

Equation 11: Recall

$$\boldsymbol{Recall} = \frac{\mathbf{TP}}{(\mathbf{TP} + \mathbf{FN})}$$

WHERE

Recall	Proportion of harvested area that was correctly predicted as harvested.
TP	True Positives. Proportion of area correctly predicted as harvested.
FN	False Negatives. Proportion of area incorrectly predicted as non-harvested.

Equation 12: F1 Score

$$\boldsymbol{F1\ Score} = \frac{(\mathbf{2} \times \boldsymbol{Precision} \times \boldsymbol{Recall})}{(\boldsymbol{Precision} + \boldsymbol{Recall})}$$

WHERE

F1 Score	Harmonic mean of precision and recall.
Precision	Proportion of area predicted as harvested that was harvested.

Recall	Proportion of harvested area that was correctly predicted as harvested.

Using the distribution of bootstrapped results for each metric, calculate the lower (2.5th percentile) and upper (97.5th percentile) bounds of the 95% confidence interval. Each metric should be reported as the mean of their distribution, accompanied by their respective 95% confidence interval.

The process for producing a mean precision metric (Equation 10) must be repeated with the combined GLAD and LCMS datasets (i.e., the Harvests layer; Section 3.1.5.3), including an error matrix. Other metrics (e.g., overall accuracy) are not required for the combined GLAD and LCMS datasets. The same labeling data source(s), methods, area of interest, and time period must be applied. Prior to performance assessment, areas of natural disturbance and areas less than a minimum mapping unit of 1 acre must be removed from the GLAD and LCMS dataset outputs.

For the project's model to be approved for use, its mean precision (Equation 10) must be equal to or greater than mean precision of the combined GLAD and LCMS datasets.

If the project's model detects and classifies forest loss into distinct types, the overall accuracy, precision, recall, and F1 score and their respective 95% confidence intervals can be reported for each harvest type. Since GLAD and LCMS do not differentiate harvest types, all areas of forest loss identified by the model should be aggregated before conducting the precision comparison.

7 Reporting and Verification

7.1 Reporting

Whenever a comparable properties analysis (Sections 2, 3, and 4) is performed, the following reporting is required and must be provided as a publicly available appendix to either the GHG Project Plan (at validation) or the Monitoring Report (later in the project term):

- The Comparable Properties Analysis Calculator, [25] including all inputs and calculations within each worksheet (Filtered Properties worksheet, Eligible Comparable Properties worksheet, Outlier Detection worksheet, and Harvest Intensity Calculations worksheet), resulting in the annual and cumulative Harvest Intensity baseline constraints and checks. Ownership details (including specific location) for properties owned by entities not participating in the GHG Project should be redacted;
- A Comparable Properties Analysis standard operating procedures (SOP) document, including the following:
  - The defined lookback period length, and its start and end years.
  - Description of the methods and data sources for applying eligibility criteria (Section 3.1) to determine eligible comparable properties, including:
    - Calculation of the threshold for percentage forestland harvested;
    - Calculation of the geographic size thresholds applied;
    - If the project area is composed of multiple non-contiguous parcels, which approach is used;
    - Ecological Region(s) applied;
    - Timber ownership classes applied;
    - Buffer applied from the perimeter of the project area; and
    - Any steps taken in the case that too few eligible comparable properties are initially identified (e.g., expanding the buffer, different ownerships), and the results of each step taken.
  - Description of the methods and results for identifying harvests, including:
    - Methods and data sources for determining forest loss;
      - GHG Projects that utilize an internally-developed forest loss model must provide details that summarize the methodology, the type of algorithm used (e.g., random forest, support vector machine), the training or calibration data and processes, and the source data (e.g., satellite, Lidar, SAR, IFSAR). In addition, a metadata document with further details about the model methodology and assessment must be provided.

[25] Found on this tool's website.

- GHG Projects that utilize an externally-developed forest loss model (other than GLAD and/or LCMS) must provide documentation on the models utilized, including the authors, affiliation, model methodology, source data (e.g., satellite, Lidar, SAR, IFSAR), model performance, associated publication (if available), and other relevant details on the applicability for forest loss detection.
- All GHG Projects that utilize a forest loss model other than GLAD and/or LCMS must describe the validation process and report model performance per Section 6, including:
  - A description of the labeling data source(s) and how it conforms to Section 6.1;
  - Error matrix;
  - The mean overall accuracy, mean precision, mean recall, and mean F1 score, and their respective 95% confidence intervals.
  - Error matrix and mean precision for the combined GLAD and LCMS datasets, demonstrating equal or greater precision using the project's forest loss model.
  - A description of any post-processing or modeling performed to remove areas of natural disturbance (if applicable).
  - A description of the minimum mapping unit applied and the substantiating evidence for the proposed threshold (if applicable).
  - A description of the methods for determining the percent biomass removed per acre must be described.
- GHG Projects that utilize GLAD and LCMS following the methods of this tool's example demonstration need to declare that these data sources and methods are employed. Any deviations from the approved methods described by this tool must be fully described.

- Methods for identifying and removing areas of natural disturbance, including the types of natural disturbance considered, data sources utilized, and the results of the removal process;
- Imagery visually depicting identified harvests on the selected comparable property.

- Description of the methods and data sources for stratifying by forest cover. If using a stratification system other than NLCD, describe the evidence supporting the stratification system.
- Description of the similarity criteria applied and their associated data sources.
- Table listing the similarity criteria and other attributes of the project area and selected comparable property (similar to Table 4, above), including:
  - Percentage forestland acreage harvested during the lookback period;
  - Similarity index (use 0 for the project area);
  - Ownership description (including both timber ownership class and other anonymized descriptive details);
  - Forestland acreage;
  - Distance from project area (use 0 for the project area);

- Mean slope
- Mean elevation;
- Aboveground biomass;
- Percent forestland in each forest cover stratum; and
- Percent forestland in each merchantability category.

7.2 Verification

The entirety of the comparable properties analysis is subject to verification, but given its complexity, a risk-based approach may be applied when determining steps and datasets to inspect more closely, as informed by project reporting in the Comparable Properties Analysis Calculator and the Comparable Properties Analysis SOP document.

All underlying source material used to identify and match comparable properties must be supplied to verifiers. However, if replication of results (for each interim step as well as the final Harvest Intensity constraints) is not possible due to differing data sources or other limitations, verifiers may strategically review the project's data sources, data management systems, and data processing steps to reach a reasonable level of assurance. When verifying the spatial extent of properties not participating in the GHG Project, discrepancies less than 1 acre are generally deemed low risk and acceptable, unless the verifier has reason to believe that the downstream impact on the total Harvest Intensity constraint for the stratum may shift more than 0.5%. Verifiers should consider discrepancies and their impacts cumulatively.

This tool's example demonstration is one approved method to perform a comparable properties analysis utilizing ArcGIS Pro, but other methods and GIS software may be utilized. When evaluating other methods and software, verifiers should evaluate the intention and sequencing of data processing steps to determine whether sufficient attention has been paid to achieve reasonably similar results. These results do not need to be directly compared with results of the approved method described by this tool's example demonstration if reasonable assurance can be reached through other means.

8 Definitions

Commercial Harvesting	Any type of harvest producing merchantable material at least equal to the value of the direct costs of harvesting. Harvesting of dead, dying, or threatened trees (regardless of merchantability) is specifically excluded from this definition where a signed attestation from a Professional Forester is provided, confirming the harvests are in direct response to isolated forest health (insect/disease) or natural disaster event(s) not part of a long-term harvest regime.
Harvest Intensity	For the purposes of this document, percent biomass removed per acre per year, relative to a property's relevant stratum size.
Parcel	A portion of land with boundaries defined for the purpose of tax assessment.
Professional Forester	An individual engaged in the profession of forestry. If a project is in a jurisdiction that has professional forester licensing laws, the individual must be credentialed in that jurisdiction.[26] Otherwise, the individual must be certified by the Society of American Foresters[27] or Association of Consulting Foresters[28] with multiple years of professional experience in the state or region.
Property	One or more Parcels with the same owner or timber manager.
Ton	A unit of mass equal to 1,000 kg.

[26] For projects located in multiple jurisdictions with professional forester licensing laws, the individual must be credentialed in at least one of the jurisdictions.

[27] https://www.eforester.org/Main/Certification_Education/Certified_Forester/Main/Certification/Certification_Home.aspx?hkey=53f11286-5500-4c13-a371-251dd0df0d7a

[28] https://www.acf-foresters.org/

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