Draft
Methodology for generating a global forest management layer

Abstract
The first ever global map of forest management was generated based on remote sensing data. To collect training data, we launched a series of Geo-Wiki (https://www.geo-wiki.org/) campaigns involving forest experts from different world regions, to explore which information related to forest management could be collected by visual interpretation of very high-resolution images from Google Maps and Microsoft Bing, Sentinel time series and normalized difference vegetation index (NDVI) profiles derived from Google Earth Engine. A machine learning technique was then used with the visually interpreted sample (280K locations) as a training dataset to classify PROBA-V satellite imagery. Finally, we obtained a global wall-to-wall map of forest management at a 100m resolution for the year 2015. The map includes classes such as intact forests; forests with signs of management, including logging; planted forests; woody plantations with a rotation period up to 15 years; oil palm plantations; and agroforestry. The map can be used to deliver further information about forest ecosystems, protected and observed forest status changes, biodiversity assessments, and other ecosystem-related aspects.

Training data collection
We generated a random stratified sample of 110,000 sites globally, using two maps for the stratification: WWF Terrestrial Ecoregions (Olson et al., 2001) and the Copernicus Land Cover version 2 for 2015 produced as part of the Copernicus Global Land Service (Buchhorn et al., 2019). Each sample site was classified by at least three different participants. Only sites with a consistent response were used for future analysis. An additional 170,000 sites were randomly selected in the second stage for regions with the highest uncertainties.

A special branch of Geo-Wiki (https://www.geo-wiki.org/) was designed for the classification of the sample sites (Figure 1). This application serves the satellite imagery from Google Maps and Bing Maps, Sentinel time series and Normalized Difference Vegetation Index (NDVI) profiles derived from Google Earth Engine (GEE).

Figure 1. Screenshot of the Geo-Wiki interface showing a very high-resolution image from Google Maps and a sample site as a 100m blue square which the participants classify, as well as various tools and the legend.

Forestry experts from different regions around the world were asked to classify the sample sites into the following classes:

- Naturally regenerating forest with no signs of human impact
- Naturally regenerating forest with signs of human activities, e.g., logging
- Planted forest, which includes those with a relatively long rotation time
- Plantations, which includes fast growing tree species (with a rotation period of less than 15 years) cultivated primarily for timber
- Oil palm plantations
- Agroforestry, which includes fruit trees, gardens, tree shelterbelts, etc.

Wall-to-wall map generation

To produce the wall-to-wall map, we applied a workflow that was developed as part of the production of the Copernicus Global Land Cover (CGLS-LC100) product. A very detailed explanation of this workflow, including detailed technical descriptions of the algorithms, the ancillary data used, and the intermediate products generated, can be found in the Algorithm Theoretical Basis Document (ATBD)(Buchhorn et al., 2019). This processing workflow is not sensor- or resolution-specific and can be applied to any satellite data. The CGLS-LC100 Collection 2 product is based on PROBA-V sensor data. The forest management map was generated by combining the training dataset described above with the PROBA-V time series imagery.

The final forest management layer (Figure 2) can be found in the Geo-Wiki portal (https://www.geo-wiki.org/) – section Land Cover / Human Impact on Global forests. It has a 100 m resolution and represents the status for the year 2015. The map contains the classes listed in Table 1.

Table 1. Legend of the forest management layer

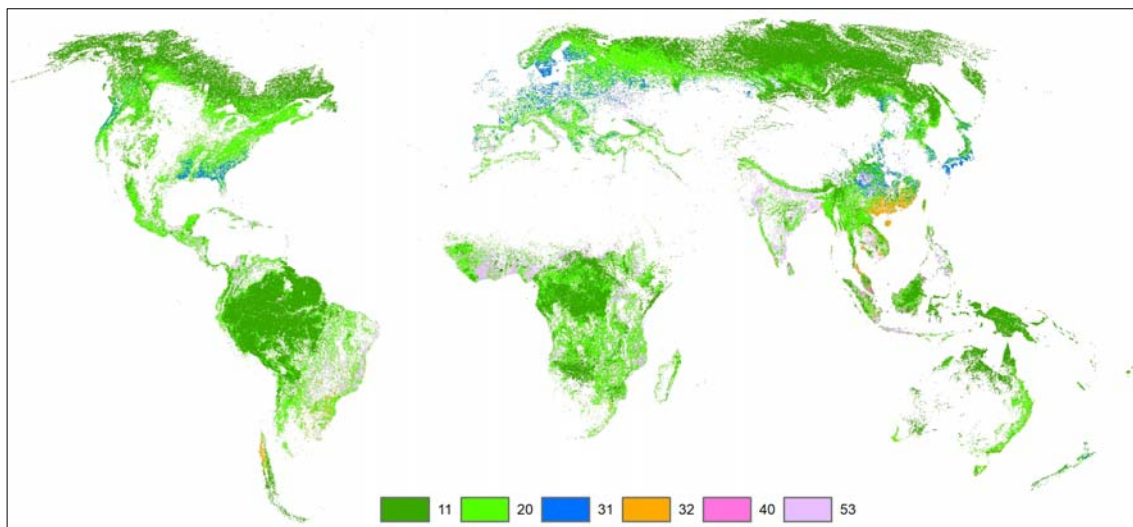| Raster value	Class
10	Naturally regenerating forest without any signs of human activities (e.g., primary forests)
20	Naturally regenerating forest with signs of human activities, e.g., logging, clear cuts, etc.
31	Planted forest
32	Short rotation plantations for timber
40	Oil palm plantations
53	Agroforestry

Figure 2. Global map of forest management (see the detailed legend in Table 1).

References

Buchhorn, M., Bertels, L., Smets, B., Lesiv, M., Tsendbazar, N.-E., 2019. Copernicus Global Land Service: Land Cover 100m: version 2 Globe 2015: Algorithm Theoretical Basis Document. Zenodo. https://doi.org/10.5281/zenodo.3606446

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R., 2001. Terrestrial Ecoregions of the World: A New Map of Life on EarthA new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. BioScience 51, 933–938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2