ARGENTINA

MapBiomas General “Handbook” Algorithm Theoretical Basis Document (ATBD)

Collection 3

Version 1

September, 2026

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1. Introduction

1.1. Scope and content of the document

The objective of this document is to describe the theoretical basis, justification, and methods applied to produce annual maps of land use and land cover (LULC) of MapBiomas Argentina. This collection is the result of the integration of 7 working groups and includes maps from 1985 to 2025. This document describes the classification methods of Collection 3, the approach to integrating the regions, background information, and a general description of the method applied. The specific procedures applied in each region are in the appendices. The classification algorithms are available on MapBiomas Argentina GitHub.

1.2. Overview

The MapBiomas project started in Argentina in August 2023, aiming to contribute to understanding LCLU dynamics in Argentina. The MapBiomas initiative combines people, algorithms, satellite information and large-scale processing in a methodology that has revolutionized the operational large-scale generation of LULC maps. MapBiomas provides an ideal environment to enhance and share skills and abilities by collaborators from different locations and perspectives but with the mutual core value of learning by doing. Thanks to Google Earth Engine and open source technology it was possible to access and process large-scale datasets of satellite imagery such as the one generated by the MapBiomas project.

MapBiomas collections aim to contribute to developing a fast, reliable, collaborative, and low-cost method to process large-scale datasets and generate historical time series of land use and land cover annual maps (Annex 1). All data, classification maps, codes, statistics, and further analyses are openly accessible through the MapBiomas Platform. This is possible thanks to i) the Google Earth Engine platform, which provides access to data, image processing, standard algorithms, and the cloud computing facilities; ii) the freely available Landsat time-series dataset; and iii) the MapBiomas collaborative network of organizations and experts that share knowledge and mapping tools. MapBiomas maps are an evolving product and subsequent collections will be available in the future.

Collection 1: from 1998 through 2022 (launched in May 2024)
Collection 2: from 1985 through 2024 (launched in September 2025)
Collection 3: from 1985 through 2025 (launched in September 2025)

1.3. Products of the MapBiomas Argentina Collection 3

The products of the MapBiomas Argentina Collection 3 are the following:

• Integrated Map of the Country and subproducts such as transitions, number of classes, stable areas, number of changes, natural and anthropic use.

• Regions and cross-cutting theme maps(Chaco, Pampas, Atlantic Forest, Puna, Monte and High Andes, Patagonia, Urban and Glaciars).

• Annual and accumulated deforestation maps (from 1987 to 2025) and subproducts such as frequency and last year

• Annual maps of secondary vegetation (from 1986 to 2025) and age of secondary vegetation maps.

• Image processing infrastructure and algorithms (scripts in Google Earth Engine and source code).

•LCLU transition statistics and spatial analysis with political territories, watersheds, protected areas and ecoregions.

• Pre-Processed feature mosaics generated from Landsat archive collections (Landsat 5, Landsat 7, Landsat 8 and Landsat 9).

• Quality assessment of the Landsat mosaics. Each scene may have a proportion of clouds and other interference. Thus, each pixel in a given year was qualified according to the number of available observations, varying from 0 to 23 observations per year. The quality assessment of the Landsat mosaics is available on the MapBiomas website.

• Validation of the land cover and land use maps will be available soon

1.3. Region of Interest

MapBiomas was created to produce LCLU annual maps for the entire Argentinian territory. The work was divided into 6 working groups: Chaco and Yungas, Pampas, Atlantic Forest, Puna, Monte and High Andes, and Patagonia and 2 cross-cutting theme Urban Areas and Glaciers (Fig. 1); each one with its own team and

methodological particularities. The working groups have different experiences related to the project:

- Chaco: Collection 6
- Pampas: Collection 5
- Atlantic Forest: Collection 5
- Puna, Monte and High Andes: Collection 3
- Patagonia: Collection 3
- Urban Áreas: Collection 2
- Glaciers: Collection 1

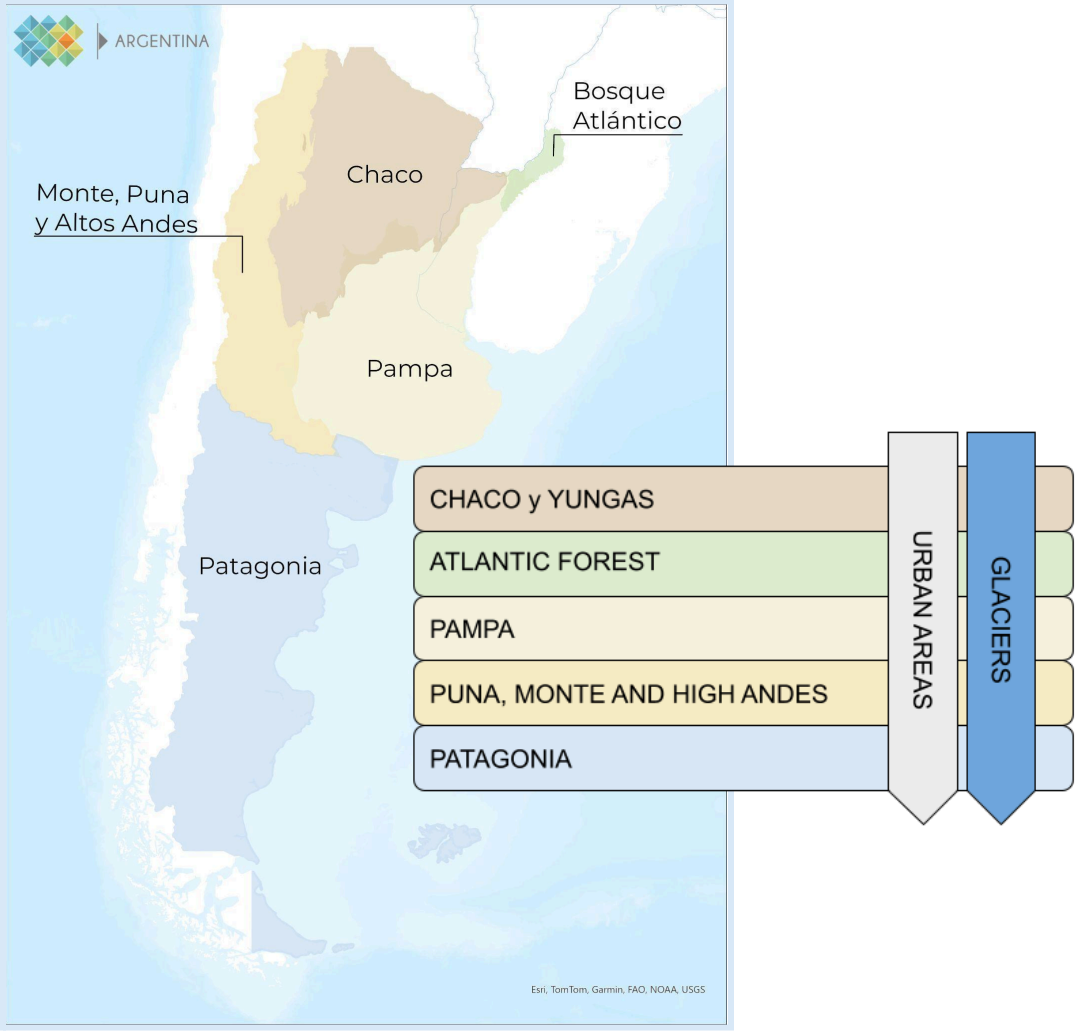

Figure 1. Scope of the different regions or working groups

2. Overview and Background Information

2.1. MapBiomas Global Network

We are a network of non-governmental organizations (NGOs), universities, research institutions and tech startups that produce and promote the use of qualified information to stewardship the land use and land cover in South America and other tropical and subtropical regions. As a network, we are committed to generating data, methods, tools and information to qualify the understanding, analysis and decision-making on conservation and sustainable management of continental natural resources.

The core product of MapBiomas is the Land Use & Land Cover Annual Maps, the Transitions Maps (the class differences between a selected period) and Statistics of Land Use & Land Cover Change. There is also the Quality Map (based on the number of observations available related to the proportion of clouds and other interference). In this initiative, we are dedicated to developing the most updated, completed, and detailed time series of annual maps covering 1985 onwards to support and advance sustainable management and conservation of natural resources. However, the network is constantly expanding thematically, making specific modules for different topics available. For example: 1) Deforestation (annual data, frequency, and cumulative area); 2) Areas of secondary vegetation (age and annual data); 3) Infrastructure (with buffer zones for each type of infrastructure); 4) Information on pastures (classified by level of degradation); 5) Mining (artisanal/garimpo and industrial); 6) Irrigation; 7) Temporal analysis. The Argentine network will incorporate different modules as new collections are added.

The geospatial tech company Ecostage is responsible for the workspace/backend and dashboard/website/frontend of MapBiomas. The Federal University of Technology - Paraná oversees the data repositories of the MapBiomas Network. Google provides the cloud computing infrastructure that allows data processing and analysis through Google Earth Engine and storage through Google Cloud Storage.

2.2. MapBiomas Argentina Network

2.2.1 Origin

In Argentina, MapBiomas began in 2017 with the mapping of the Gran Chaco Americano, together with Bolivia and Paraguay. In 2019, it was extended to the Atlantic Forest and Pampa regions, together with Paraguay, Brazil, and Uruguay. In August 2023, the initiative was consolidated at the national level, with the aim of

understanding the transformation processes occurring throughout the territory through the use of remote sensors, capitalizing on the experience of local groups in Argentina. The first collection of Mapbiomas Argentina was launched in 2024. Since then, a new collection of maps has been published every year, updating and improving the products.

MapBiomas Argentina represents a qualitative leap in automating processes, generating and disseminating spatially explicit information about Argentine territory openly, freely, and at no cost. Its goal is to produce annual collections of land cover and land use maps for the entire country based on the local adaptation of the methodology developed in Brazil in 2015, which is periodically updated. Additionally, the platform provides users with codes, technical reports, and protocols used in generating information, ensuring process transparency. The platform offers statistics and graphics to facilitate access for different audiences.

2.2.3 Institutions

MapBiomas Argentina is a collaborative network of NGOs, Universities, and Research Institutes that is constantly growing. The network is a group of specialists in remote sensing, ecology, Geographic Information Systems (GIS), and programming from different ecoregions of the country, focused on producing annual collections of land cover and land use maps of Argentina since 1985.

Table 1: Co-creators by regions and cross-cutting theme

Chaco y Yungas:	- GeoSimple - Instituto Nacional de Tecnología Agropecuaria (INTA) - Fundación Vida Silvestre Argentina (FVS) - Facultad de Agronomía - UBA (FAUBA)
Bosque Atlántico:	- Facultad de Agronomía - UBA (FAUBA) - Fundación Vida Silvestre Argentina (FVS) - Instituto de Biología Subtropical (IBS) - Facultad de Ciencias Forestales - UNaM (FCF) -Laboratorio de Análisis Regional y Teledetección (CONICET-FAUBA)
Pampa:	- Instituto Nacional de Tecnología Agropecuaria (INTA) - CONICET - Instituto de Ciencias de la Tierra, Biodiversidad y Ambiente (ICBIA) UNRC-CONICET - Fundación Vida Silvestre Argentina (FVS)

	- Universidad Nacional del Sur
Puna Monte y Altos Andes:	- Facultad de Agronomía - UBA (FAUBA) -Grupo de Estudios Ambientales - Instituto de Matemática Aplicada de San Luis (GEA - IMASL) -Instituto Argentino de Investigaciones de Zonas Áridas (IADIZA) - Instituto Nacional de Tecnología Agropecuaria (INTA) -Instituto de Investigaciones Fisiológicas y Ecológicas Vinculadas a la Agricultura (IFEVA/CONICET) -Laboratorio de Análisis Regional y Teledetección (LART-CONICET/FAUBA) - Fundación Vida Silvestre Argentina (FVS)
Patagonia:	- Fundación Vida Silvestre Argentina (FVS) -Instituto de Investigaciones en Biodiversidad y Medioambiente (INBIOMA) -Instituto de Investigaciones en Recursos Naturales, Agroecología y Desarrollo Rural (IRNAD- UNRN/CONICET) -Ministerio de Desarrollo Económico y Productivo- Rio Negro -Universidad Nacional del Comahue Bariloche (UNCO- CRUB) -Centro de Investigación y Extensión Forestal Andino Patagónico(CIEFAP) -Secretaria de Ambiente - Tierra del Fuego -Trama Viva
Urban areas:	-Universidad Nacional del Centro de la Provincia d Buenos Aires (UNICEN) -Fundación Vida Silvestre Argentina (FVS) -Instituto de Geografía, Historia y Ciencias Sociales (IGEHCS-CONICET/UNCPBA) -Instituto de Investigación para el Desarrollo Territorial y del Hábitat Humano (IIDTHH/UNNE-CONICET) -Universidad Nacional de General Sarmiento (UNGS) -Universidad Nacional de Cuyo (UNCuyo)
Glaciers	- Fundación Vida Silvestre Argentina (FVS) -Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA) - Facultad de Agronomía - UBA (FAUBA)

3. Methodological Description

3.1. Remote Sensing Data

The imagery dataset used in the MapBiomas project was obtained by the Landsat sensors Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and the Operational Land Imager and Thermal Infrared Sensor (OLI-TIRS), onboard of Landsat 5, Landsat 7, Landsat 8 and Landsat 9, respectively. The Landsat imagery collections with 30 meters pixel resolution were accessible via Google Earth Engine and produced by NASA and USGS. Specifically, the surface reflectance images from the 2 Tier 1 collection were used. This dataset contains atmospherically corrected surface reflectance and land surface temperature. These images contain 5 visible and near-infrared (VNIR) bands and 2 short-wave infrared (SWIR) bands processed to orthorectified surface reflectance, and one thermal infrared (TIR) band processed to orthorectified surface temperature. They also contain a QA band.

3.2 Google Earth Engine and MapBiomas Computer Applications

MapBiomas image processing is based on Google technology, which includes image processing in cloud computing infrastructure, programming with Javascript and Python via Google Earth Engine, and data storage using Google Cloud Storage. Google defines Google Earth Engine as a platform for petabyte-scale scientific analysis and visualization of geospatial datasets, both for public benefit and for business and government users.

3.3 Overview of methodological process

The common methodological procedures applied in the different working groups or “regions” included several steps (Figure 2). The first step was to generate annual Landsat mosaics comprising specific temporal windows to optimize the spectral contrast and better discriminate the LCLU classes across the regions. The second step was to derive all feature space attributes from the Landsat bands to train one random forest classifier (feature space definition) for each year (Breiman, 2001). Then, yearly training samples were acquired in each region according to its information availability and statistical needs. The output of the random forest classifier is one LCLU map per year for the entire territory based on the training

dataset of that year. Additionally, to improve the classification results, complementary samples were generated, defining georeferenced points of different classes by visual interpretation of historical satellite images (high resolution images) and time series of vegetation indices. Based on the adjusted training data set, a supervised classification using the random forest algorithm was run. Spatial-temporal filters were applied over the classified data for noise removal and temporal stabilization. For more details of each step, see the ATDB from each region. Subsequently, the filtered LCLU maps of each region were hierarchically merged (integrated) based on a set of prevalence rules. The integration rules were set using expert knowledge and are described in Table 1. The transitions and statistics of each class were derived from the annual LCLU maps. The statistical analysis covered different spatial categories, such as biome, state, municipality, watershed, and protected areas.

Due to the lack of images in Patagonia from 1986 to 1997, this region could only be classified in 1985 and then from 1998 to 2024. No changes were detected for this region between 1986 and 1997.

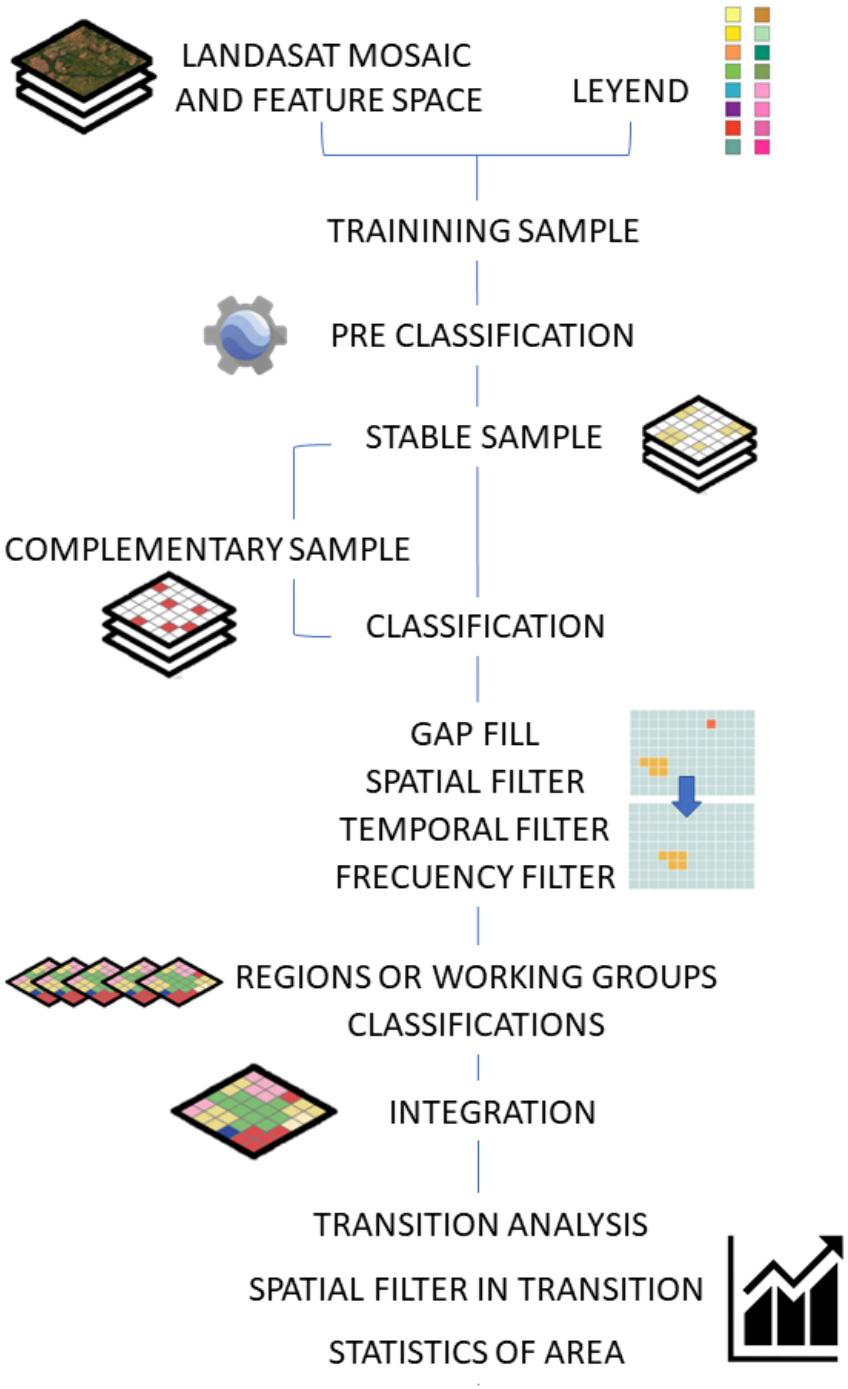

Figure 2. Overview of the classification process for MapBiomas Argentina.

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3.4 Integration

In order to integrate the regions, the legends of the regional maps up to level 2 were used. For the overlapping areas,a class hierarchy was generated , which prioritizes the natural classes.. The exception was the Atlantic forest region, which overlapped the rest. In some areas, exceptions were made by prioritizing a class over a region. In addition, the regional legends were readjusted, merging conceptually similar classes(Annex 2). Urban areas and Glaciers are added to the map at the end, taking precedence over all classes.

3.5 Map Legend

The classification for the MapBiomas Argentina initiative included 18 land use and land cover (LULC) classes (Table 1): Closed forest (3), Open forest (4), , Flooded forest(6), Closed shrublands (66), Open shrublands (77), Shrubs and herbaceous mosaic (63), Grassland (12), Flooded grasslands (12), Peatlands (73), Temporary crops (19), Perennial crops(36), Pasture (15), Forest Plantation (9), Agriculture and pasture mosaic (21), Urban Areas (24), Others non vegetated area (22), Clean-ice glaciers and perennial snow (34), River, lake or ocean (33) and Not observed (27). A full description of the legend is described in the document Legend Description.

Table 2. Land cover and land use classes for MapBiomas Argentina - Collection 3.

COLLECTION 3 - CLASSES	pixel id	Hexadecimal code	Color
1.Forest	**1**	**#1f8d49**	
1.1.Closed forest	3	#1f8d49	
1.2.Open forest	4	#7dc975	
1.3.Flooded forest	6	#007785	
2. Natural herbaceous and shrub vegetation	**10**	**#d6bc74**	
2.1.Closed shrublands	66	#a89358	
2.2. Open shrublands	77	#86b074	
2.3.Shrub and herbaceous mosaics	63	#C7E0AB	
2.4.Grassland	12	#d6bc74	
2.5.Flooded grassland	11	#519799	
2.6.Peatland	73	#6fc179	
3. Agricultural and livestock area	**14**	**#ffefc3**	
3.1.Agriculture	18	#E974ED	
3.1.1.Temporary crops	19	#C27BA0	
3.4. Perennial crops	36	#d082de	
3.1. Pasture	15	#edde8e	
3.3. Forest plantation	9	#7a6c00	
3.5. Mosaic of agriculture and pasture	21	#ffefc3	
4. Non-vegetated area	**22**	**#d4271e**	
4.1.Urban Areas	24	#d4271e	
4.2.Other non-vegetated areas	25	#db4d4f	
5. Water body	**26**	**#2532e4**	
5.1. River, lake or ocean	33	#2532e4	
5.2. Clean-ice glaciers and perennial snow	34	#93dfe6	
6. Not observed	**27**	**#ffffff**	

3.6 Subproducts of the land cover and land use module

Based on an analysis of the land cover and land use maps from this collection, various sub-products are generated such as transition maps, number of classes, stable areas, number of changes, natural and anthropic use.

Transition Maps: The pixel-by-pixel class differences between any two maps were computed for the following periods: (A) any consecutive years (e.g. 2001-2002); (B) five-year periods (e.g. 2000-2005); (C) all the years (1985-2025). The class transitions represent LCLU changes such as: Transitions from agricultural uses or urbanized areas to native vegetation cover (forests, shrublands, or natural grasslands); Transitions from native vegetation cover (forests, shrublands, or natural grasslands) to agricultural uses or urbanized areas; Transitions resulting in an increase or expansion of water surface area; Transitions resulting in a reduction or loss of water surface area.

Number of classes: The number of classes assigned to a pixel in its classification throughout the time series (1985–2025) is identified. This calculation is performed

on the final map of the collection, after the integration process and the application of spatial and temporal filters.

Stable areas: The maps of stable areas are derived from the annual land cover and land use mapping. This map shows pixels that show no change in classification over the course of the historical series. This selection is performed on the final map of the collection, after the integration process and the application of spatial and temporal filters.

Number of changes: The number of times a pixel's classification has changed over the course of the time series is counted. This calculation is performed on the final map of the dataset, after the integration process and the application of spatial and temporal filters.

Natural and anthropic use: This is a simplified version of the legend, allowing for a clearer visualization of the predominantly natural and anthropogenic classes. The reclassification used is presented in Table 3.

Table 3. Re-classification of land cover and land use classes into natural and anthropic - Collection 3.

EN	pixel id	Hexadecimal	Color
1. Natural	**1**	**#139912**	
Closed forest	3	#139912	
Open forest	4	#139912	
Flooded forest	6	#139912	
Closed shrublands	66	#139912	
Open shrublands	77	#139912	
Shrub and herbaceous mosaics	63	#139912	
Grassland	12	#139912	
Flooded grassland	11	#139912	
Peatland	73	#139912	
Clean-ice glaciers and perennial snow	34	#139912	
2. Anthropic	**2**	**#FFD966**	
Temporary crops	19	#FFD966	
Perennial crops	36	#FFD966	
Pasture	15	#FFD966	
Forest plantation	9	#FFD966	
Mosaic of agriculture and pasture	21	#FFD966	
Urban Areas	24	#FFD966	
3. Non defined	**27**	**#d5d5e5**	
Other non-vegetated areas	25	#d5d5e5	
River, lake or ocean	33	#d5d5e5	
Not observed	27	#d5d5e5	

3.7. Statistics

Zonal statistics of the mapped classes were calculated for different spatial units, such as the biomes, states, and municipalities, as well as watersheds and protected areas. A toolkit in the Google Earth Engine is available to upload user-defined polygons and download the LCLU maps.

3.9 Validation

We are currently conducting the validation analysis for the years 1986, 1999, 2006, 2015 and 2023, following the methodology proposed by Olofsson et al. (2014). Results will be available for review shortly. A total of 8.913 points were analyzed through photointerpretation of Landsat and high-resolution images and interpretation of spectral indices. Each point was interpreted independently by two interpreters and, if necessary—due to a lack of consensus on the class—by a third interpreter.

4. References

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- USGS. Landsat Collection 1 Level 1 Product Definition. 2017. Available online: https://landsat.usgs.gov/sites/default/files/documents/LSDS-1656_Landsat_Level-1_Pr oduct_Collection_Definition.pdf