Pampa - Appendix

Collection 3

Version 1

General coordinator
Heinrich Hasenack

Team
Eduardo Velez-Martin
Eliseu José Weber
Bruna Zanatta Moraes
Carmen Viviane de Oliveira
Fernando Pires Pinto
Gabriel Selbach Hofmann
Jones Souza da Silva

1 Landsat image mosaics

1.1 Definition of the temporal period

The image selection period for the Pampa biome was defined aiming to minimize confusion between natural and cultivated vegetation due to phenological changes, while trying to maximize the coverage by useful Landsat images after cloud removing/masking. Unlike most of other Brazilian biomes, climate of the Pampa biome does not have a defined dry season, with seasonal variation of temperature being the main factor determining the physiological behavior of vegetation throughout the year.

Forest, although classified mostly as Seasonal Deciduous Forest and to a lesser extent as Semi-Deciduous, expresses minor deciduousness. In fact, only a small fraction of species in tree communities loses leaves during winter, so that Pampa forests are expected to show less variation in spectral response over the year than other types of vegetation cover.

On the other hand, herbaceous vegetation typologies in terrestrial environments tend to present a characteristic seasonal pattern. Figure 1 presents a schematic diagram of the seasonal behavior of grasslands and of the most significant summer crops in the Pampa biome, markedly rice and soybean. During autumn, the photosynthetic production of herbaceous vegetation begins to decline, reaching its lowest point in winter, when a significant portion of the leaf biomass reaches a senescent stage. From late winter and early spring on, annual species germinate and perennial species begin to regrowth, shooting new leaves and increasing progressively the photosynthetically active biomass, which will reach its peak in the summer.

Rice and soybean are summer crops. During late winter and early spring, soil preparation takes place, which can result, giving the different agronomic management techniques, in exposed soil (conventional planting), dried vegetation (no-tillage) due to herbicide application, or flooded in the case of rice planting. In such areas it is also usual to sow winter pastures, for providing soil cover and supplemental forage for the livestock. Consequently, during winter there are patches with photosynthetically active herbaceous vegetation in the landscape, contrasting with the senescent native grasslands. Summer planted pastures have less expression than winter pastures, and their peak of photosynthetic activity coincides with that of the grassland vegetation during January and February (Figure 2).

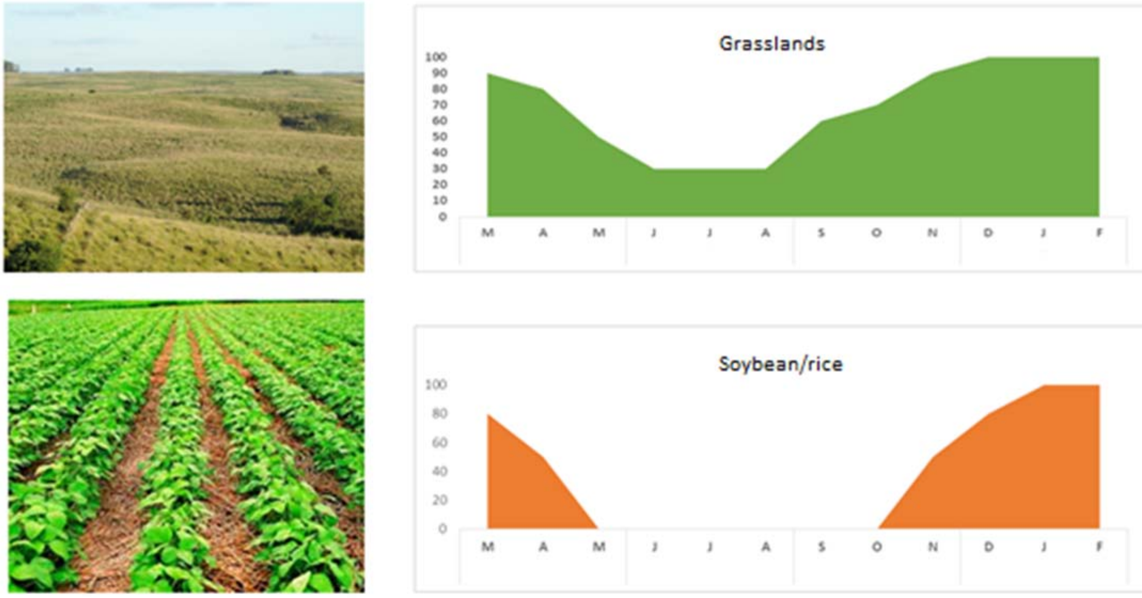

Figure 1. Scheme of phenological patterns of natural grasslands, and soybean/rice crops in the Pampa biome. The y-axis corresponds to photosynthetic biomass production with merely illustrative values.

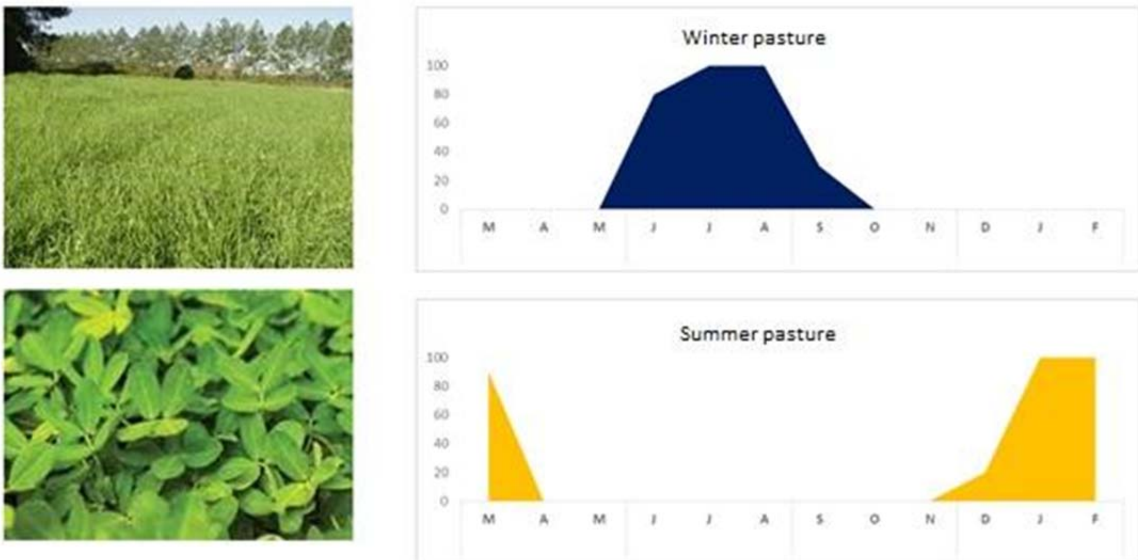

Figure 2. Scheme of phenological patterns of winter and summer pasture in the Pampa biome. The y-axis corresponds to photosynthetic biomass production with merely illustrative values.

The period of the year allowable to distinguish between natural vegetation, agricultural crops, pastures with exotic species and forestry through remote sensing in the Pampa biome was defined taken the known phenological patterns. It is expected that more contrast will be found between these land cover typologies from September to November, when summer crop areas are under preparation for planting, cultivated pastures are off their photosynthetic peak, and native grasslands are in beginning of regrowth and development of new leaves (Figure 3).

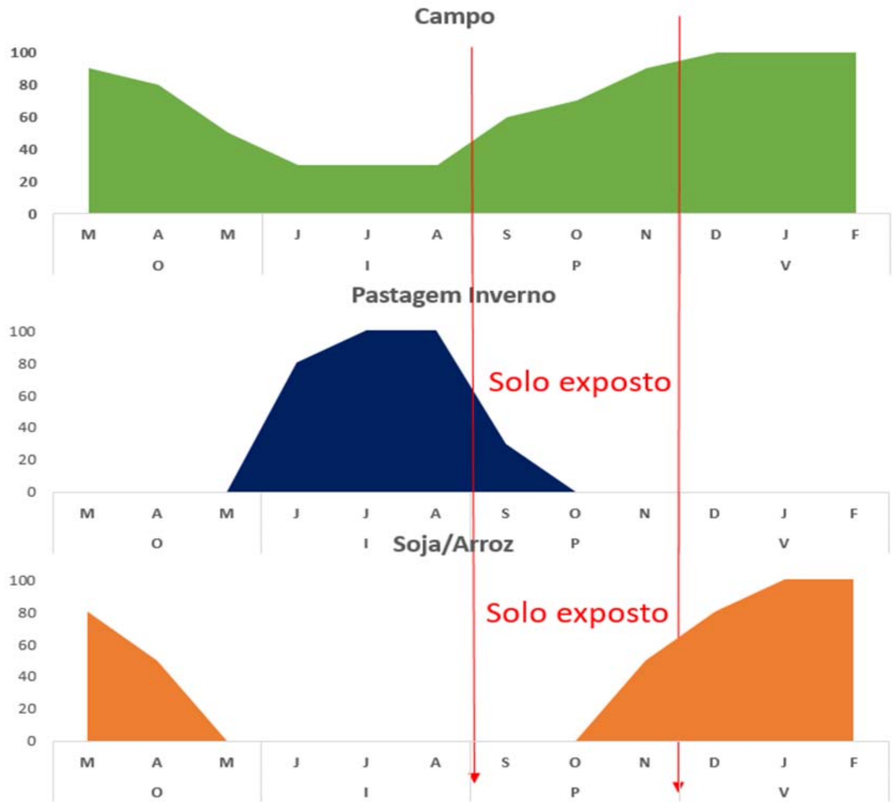

Figure 3. Schematic phenological pattern of grasslands, summer crops and winter pastures in the Pampa biome, indicating the temporal window ensuring greater contrast for the purpose of satellite imagery classification.

1.2 Image selection

For the selection of Landsat scenes to build the mosaics of each chart for each year, within the acceptable period, a threshold of 90% of cloud cover was applied (i.e., any available scene with up to 90% of cloud cover was accepted). This limit was established based on a visual analysis, after many trials observing the results of the could removing/masking algorithm. When needed, due to excessive cloud cover and/or lack of data, the acceptable period was extended to encompass a larger number of scenes in order to allow the generation of a mosaic without holes. Whenever possible, this was made by including months in the beginning of the period, in the winter season.

In most cases, at least one additional month had to be included in order to provide enough images for the mosaic (Table 1), with an overall mean of 3,9 months. In some specific cases it was needed to extend significantly the temporal period, while in others it was shortened. Extension was more frequent for years 1990 and 2007, with an average of 6 months, while shortening was noticeable for year 2012, when the acceptable period of four charts had to be reduced to only 2 months (April and May) due to the low quality of the available Landsat 7 scenes.

1.3 Final quality

Considering the 23 charts of the Pampa biome and the 33 years of Collection 3, a number of 759 mosaics was produced. As a result of the selection criteria, all of them presented satisfactory quality. Eventually, small portions of some individual mosaics remained with no data pixels, but ever smaller than 10% of the chart

Table 1. Temporal range (number of months) for selection of Landsat scenes to be used for building the mosaics of each chart of the Pampa biome for each year in the period 1985-2017.

	1985	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**Mean**
SH-21-V-D	4	4	3	3	3	6	3	3	3	3	7	3	3	3	4	3	3	3	3	3	6	3	8	3	3	3	3	3	3	3	6	3	3	4
SH-21-X-A	3	3	3	3	3	6	3	3	5	4	3	3	4	4	3	3	4	4	3	3	4	3	8	3	3	10	3	3	3	3	6	3	3	4
SH-21-X-B	3	4	8	3	6	5	3	3	6	4	7	4	4	4	3	5	3	5	3	3	3	4	8	3	3	4	3	2	3	3	3	3	3	4
SH-21-X-C	4	4	3	3	3	7	3	3	5	3	8	4	5	3	4	3	4	3	3	3	4	3	8	3	3	3	3	3	3	3	6	3	3	4
SH-21-X-D	5	5	3	3	3	4	3	3	4	5	8	4	5	3	3	5	4	5	3	3	3	3	7	3	3	8	3	2	3	3	3	3	3	4
SH-21-Y-B	4	4	3	3	3	6	3	3	3	3	7	3	3	4	3	3	3	3	3	3	5	3	8	3	3	3	3	3	3	3	5	3	4	4
SH-21-Z-A	4	3	7	3	3	5	3	3	7	3	5	3	3	4	3	3	4	3	3	4	3	3	8	3	3	3	3	3	3	3	3	3	4	4
SH-21-Z-B	5	3	3	4	3	4	3	3	4	5	8	3	3	3	3	3	4	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3
SH-21-Z-C	7	3	3	3	3	6	7	4	5	3	4	3	3	4	4	3	3	3	3	3	3	3	8	3	3	3	3	3	3	3	3	3	5	4
SH-21-Z-D	5	4	3	4	3	4	3	3	3	7	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
SH-22-V-A	3	5	8	3	4	4	3	3	3	3	4	5	3	3	3	3	4	5	3	3	3	3	4	3	3	3	3	2	3	3	3	3	4	4
SH-22-V-C	5	4	8	4	3	4	3	5	3	5	3	6	5	4	3	6	3	7	3	3	3	3	5	3	3	3	3	2	3	3	3	6	3	4
SH-22-V-D	3	3	8	3	3	4	3	4	3	4	3	7	8	4	3	3	4	3	4	6	8	3	5	3	5	3	3	3	3	4	4	5	3	4
SH-22-X-C	3	3	3	3	9	5	3	4	3	4	3	6	4	5	3	3	5	5	4	3	6	3	4	3	3	3	8	3	3	3	3	3	3	4
SH-22-Y-A	5	3	7	5	3	6	3	8	3	3	3	7	4	3	3	5	4	3	4	3	3	3	5	3	3	3	3	3	3	3	3	9	3	4
SH-22-Y-B	8	4	6	4	3	5	3	12	3	7	3	6	5	4	3	5	3	3	4	3	5	3	6	3	3	5	3	3	3	3	6	5	3	4
SH-22-Y-C	7	3	6	4	3	6	3	3	3	3	3	6	3	3	3	3	4	3	3	3	3	3	3	3	3	4	3	3	3	3	3	6	4	4
SH-22-Y-D	8	4	5	3	4	8	4	3	3	7	3	5	5	6	3	3	4	3	3	3	6	6	6	3	3	8	3	3	3	3	6	4	3	4
SH-22-Z-A	3	3	3	3	6	3	3	9	3	5	4	8	4	5	3	3	4	7	4	3	4	4	6	3	3	3	3	3	3	3	5	3	4	4
SH-22-Z-C	5	3	3	3	4	5	3	3	3	4	3	6	4	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3
SI-22-V-A	6	5	6	3	3	8	8	3	3	3	3	7	5	3	3	3	5	3	3	3	3	3	6	3	3	3	3	3	3	3	3	5	3	4
SI-22-V-B	3	7	3	3	4	11	5	3	3	7	3	5	5	5	3	3	3	3	3	3	5	6	4	3	3	3	3	3	3	3	7	5	3	4
SI-22-V-C	5	5	3	3	6	7	5	4	6	4	3	5	8	3	3	3	3	3	3	3	3	3	5	3	3	8	3	3	3	3	3	5	3	4
Mean	5	4	5	3	4	6	4	4	4	4	4	5	4	4	3	3	4	4	3	3	4	3	6	3	3	4	3	3	3	3	4	4	3	

2 Classification

2.1 Classification scheme

The digital classification of the Landsat mosaics for the Pampa biome aimed to individualize a subset of seven land use and land cover (LULC) classes from the MapBiomas Collection 3 legend (Table 2), which were integrated with the cross-cutting themes in a further step.

Table 2. Land cover and land use categories considered for digital classification of Landsat mosaics for the Pampa biome in the MapBiomas Collection 3.

Legend class of Collection 3	Numeric ID	Color
1.1.1. Forest Formation	3	
2.1. Wetland	11	
2.2. Grassland Formation	12	
3.3 Mosaic of Agriculture and Pasture	21	
4.4. Rocky Outcrop	29	
5. Water	26	
6. Non Observed	27	

2.2 Feature space

The feature space for digital classification of the categories of interest for the Pampa biome comprised a subset of 29 variables (Table 3), taken from the complete feature space of MapBiomas Collection 3. These variables include the original Landsat reflectance bands, as well as vegetation indexes, spectral mixture modeling-derived variables, terrain morphometry (slope), and a spatial texture measure. Definition of the subset was made based on the expected usefulness of each variable to discriminate the targets of concern, taking into account local knowledge about their spectral, spatial and temporal dynamics.

Table 2. Feature space subset considered in the classification of the Pampa biome Landsat image mosaics in the MapBiomas Collection 3 (1985-2017).

ID	Variable	Description	Statistics	Temporal range	Script acronym	Group
1	Blue	Landsat band	median	mosaic months	'median_blue'	Landsat band
2	Green	Landsat band	median	mosaic months	'median_green'	Landsat band
3	Near Infrared (NIR)	Landsat band	median	mosaic months	'median_nir'	Landsat band
4	Red	Landsat band	median	mosaic months	'median_red'	Landsat band
5	Shortwave Infrared (SWIR) 1	Landsat band	median	mosaic months	'median_swir1'	Landsat band
6	Shortwave Infrared (SWIR) 2	Landsat band	median	mosaic months	'median_swir2'	Landsat band
7	Evi 2	Enhanced Vegetation Index 2	median	mosaic months	'median_evi2'	Vegetation Index
8	Ndvi	Normalized Difference Vegetation Index	median	mosaic months	'median_ndvi'	Vegetation Index
9	Ndvi Dry	Normalized Difference Vegetation Index	median	year -below first quartile	'median_ndvi_dry'	Vegetation Index
10	Ndvi Wet	Normalized Difference Vegetation Index	median	year - above third quartile	'median_ndvi_wet'	Vegetation Index
11	Savi	Soil-adjusted Vegetation Index	median	mosaic months	'median_savi'	Vegetation Index
12	Sefi	Savanna Ecosystem Fraction Index	median	mosaic months	'median_sefi'	Vegetation Index
13	Sefi	Savanna Ecosystem Fraction Index	standard deviation	complete year	'stdDev_sefi'	Vegetation Index
14	Ndwi	Normalized Difference Water Index	median	mosaic months	'median_ndwi'	Water Index
15	Ndwi Dry	Normalized Difference Water Index	median	year -below first quartile	'median_ndwi_dry'	Water Index
16	Ndwi Wet	Normalized Difference Water Index	median	year - above third quartile	'median_ndwi_wet'	Water Index
17	Gv	green vegetation fraction	median	mosaic months	'median_gv'	Spectral Mixture Modeling
18	Gvs	GV / (100 - shade)	median	mosaic months	'median_gvs'	Spectral Mixture Modeling
19	Ndfi	Normalized Difference Fraction Index	median	mosaic months	'median_ndfi'	Spectral Mixture Modeling

20	Ndfi	Normalized Difference Fraction Index	standard deviation	complete year	'stdDev_ndfi'	Spectral Mixture Modeling
21	Ndfi Dry	Normalized Difference Fraction Index	median	year -below first quartile	'median_ndfi_dry'	Spectral Mixture Modeling
22	Ndfi Wet	Normalized Difference Fraction Index	median	year - above third quartile	'median_ndfi_wet'	Spectral Mixture Modeling
23	Npv	npv fraction	median	mosaic months	'median_npv'	Spectral Mixture Modeling
24	Npv	npv fraction	standard deviation	complete year	'stdDev_npv'	Spectral Mixture Modeling
25	Shade	shade fraction	median	mosaic months	'median_shade'	Spectral Mixture Modeling
26	Soil	soil fraction	median	mosaic months	'median_soil'	Spectral Mixture Modeling
27	Soil	soil fraction	standard deviation	complete year	'stdDev_soil'	Spectral Mixture Modeling
28	Green spatial texture	Spatial texture	median	mosaic months	'textG'	Spatial Texture
29	Slope	Slope	-	permanent	'slope'	Geomorphometric

2.3 Classification algorithm, training samples and parameters

Digital classification was performed chart by chart, year by year, using a Random Forest algorithm (Breiman, 2001) available in Google Earth Engine. Training samples for each chart were defined following a strategy of using pixels for which the LULC remained the same along the 33 years of Collection 3, so named "stable samples". An ensemble taken from three main sources of samples was made: extracted from Collection 2.3; manually drawn polygons; and complementary samples.

2.3.1 Stable samples from Collection 2.3

The extraction of stable samples from the previous Collection 2.3 followed several steps aiming to ensure their confidence for use as training areas. First, based on a visual analysis, a threshold was established for each class, specifying a minimum number of years in which a pixel should remained with that class to be eligible as a stable sample. A layer of pixels with a stable classification along the 17 years of Collection 2.3 was then generated by applying such thresholds. Later, a set of polygons delineating zones with errors in some classes (*e.g.*, omission or commission) was drawn and used as a mask to delete misclassified pixels. A second cleaning was performed by comparing the stable pixels with a reference map of the year 2009 (see item 4.1), excluding all pixels whose class disagreed with it. From the resulting layer of stable samples, a subset of 10,000 pixels was randomly selected and used as training areas to classify all charts for each of the 33 years with the Random Forest algorithm, by running 50 iterations.

After classification, a temporal filter (see item 3.1) was applied to each chart in order to improve the classification consistency of each pixel along the period 1985-2017. The output of the temporal filter was then submitted to the same procedures described above: definition and application of a threshold for the selection of stable pixels along the 33 years, followed by the exclusion of misclassified pixels by drawing mask polygons, and by comparison with a reference map of 2009.

2.3.2 Manually drawn polygons

Manually drawn polygons were used to add samples for classes with little occurrence, as well as to help to enrich class representation in zones which presented classification problems in the Collection 2.3. Drawing was performed using *WebCollect application*, developed by the MapBiomas project, and false-color composites of the Landsat mosaics as backdrop. Again, the concept of stable samples was applied: each of the polygons should delineate areas in which LULC remained unchanged, checking the mosaics for all the 33 years.

2.3.3 Preliminary classification

From both the sets of stable samples, a subset of 3,000 pixels was randomly selected and used as training areas to classify all charts for each of the 33 years with the Random Forest algorithm, now running 100 iterations. A number of 2,000 training pixels was selected from the stable samples extracted from Collection 2.3, while 1,000 were selected from the manually drawn polygons.

2.3.4 Complementary samples

The need for complementary samples was evaluated by visual inspection and by comparing the output of the preliminary classification for the year 2009 with a reference map of the same year (see item 4.1). The former was applied mainly to detect edge-matching problems between charts, while the second aimed to detect disagreements. When adjacent charts presented class discontinuities in some year, or some class and/or some portion of a chart presented a certain degree of disagreement with the reference of 2009, new samples were added aiming to improve classification for such specific cases. Complementary sample collection was also done by means of drawing polygons, but using **Google Earth Engine Code Editor** instead of the **WebCollect** application. The same concept of stable samples was applied, checking the false-color composites of the Landsat mosaics for all the 33 years during the polygon drawing.

2.3.5 Final classification

Final classification was performed only for charts/years that had the need for complementary samples. These were previously merged with that from the manually drawn polygons in WebCollect, and then used as a source of training pixels for the Random Forest algorithm. Now 1,000 training pixels were randomly selected from this merge product, with the other parameters maintained the same used in the preliminary classification.

3 Post-classification

3.1 Temporal filter

The temporal filter rules were adapted for the LULC classes used in the Pampa biome and were complemented by specific rules to adjust for cases where a pixel appeared two subsequent years in the class "Non Observed". A number of 79 rules, distributed in three groups, were used: a) rules for cases not observed in the first year (RP); (b) rules for cases not observed in the final year (RU); (c) rules for cases of implausible transitions or not observed for intermediate years (Table 3).

Table 3. General and specific rules of the temporal filter for the Pampa biome in the MapBiomas Collection 3. RG = General Rule, RP = First Year Rule, RU = Last Year Rule, FF = Forest Formation, AU = Wetland, FC = Grassland, AG = Mosaic of Agriculture and Pasture, AR = Rocky Outcrop, CD = Water Bodies, NO = Non Observed.

Rule	Type	Kernel	Active	Notes	Tminus2	Tminus1	T	Tplus1	Tplus2	Result
R1	RP	3	1	AG-FF-FF	null	21	3	3	null	3
R2	RP	3	1	NO-NO-FF	null	27	27	3	null	3
R3	RP	3	1	NO-NO-FC	null	27	27	12	null	12

R4	RP	3	1	NO-NO-AU	null	27	27	11	null	11
R5	RP	3	1	NO-NO-AG	null	27	27	21	null	21
R6	RP	3	1	NO-NO-CD	null	27	27	26	null	26
R7	RP	3	1	NO-NO-AR	null	27	27	29	null	29
R8	RP	3	1	NO-FF-FF	null	27	3	3	null	3
R9	RP	3	1	NO-FC-FC	null	27	12	12	null	12
R10	RP	3	1	NO-AU-AU	null	27	11	11	null	11
R11	RP	3	1	NO-AG-AG	null	27	21	21	null	21
R12	RP	3	1	NO-CD-CD	null	27	26	26	null	26
R13	RP	3	1	NO-AR-AR	null	27	29	29	null	29
R14	RG	3	1	CD-NO-NO	null	26	27	27	null	26
R15	RG	3	1	FF-NO-NO	null	3	27	27	null	3
R16	RG	3	1	AU-NO-NO	null	11	27	27	null	11
R17	RG	3	1	FC-NO-NO	null	12	27	27	null	12
R18	RG	3	1	AG-NO-NO	null	21	27	27	null	21
R19	RG	3	1	AR-NO-NO	null	29	27	27	null	29
R20	RG	3	1	FF-FC-FF	null	3	12	3	null	3
R21	RG	3	1	FF-AU-FF	null	3	11	3	null	3
R22	RG	3	1	FF-AG-FF	null	3	21	3	null	3

R23	RG	3	1	FF-CD-FF	null	3	26	3	null	3
R24	RG	3	1	FF-AR-FF	null	3	29	3	null	3
R25	RG	3	1	FC-FF-FC	null	12	3	12	null	12
R26	RG	3	1	AU-FF-AU	null	11	3	11	null	11
R27	RG	3	1	AG-FF-AG	null	21	3	21	null	21
R28	RG	3	1	CD-FF-CD	null	26	3	26	null	26
R29	RG	3	1	FC-AU-FC	null	12	11	12	null	12
R30	RG	3	1	FC-AG-FC	null	12	21	12	null	12
R31	RG	3	1	FC-CD-FC	null	12	26	12	null	12
R32	RG	3	1	FC-AR-FC	null	12	29	12	null	12
R33	RG	3	1	AU-FC-AU	null	11	12	11	null	11
R34	RG	3	1	AU-AG-AU	null	11	21	11	null	11
R35	RG	3	1	AU-CD-AU	null	11	26	11	null	11
R36	RG	3	1	AG-AU-AG	null	21	11	21	null	21
R37	RG	3	1	AG-FC - AG	null	21	12	21	null	21
R38	RG	3	1	AG-CD-AG	null	21	26	21	null	21
R39	RG	3	1	AG-AR-AG	null	21	29	21	null	21
R40	RG	3	1	AG-FF-CD	null	21	3	26	null	21
R41	RG	3	1	AG-AU-CD	null	21	11	26	null	21

R42	RG	3	1	CD-FF-AG	null	26	3	21	null	21
R43	RG	3	1	CD-AU-AG	null	26	11	21	null	21
R44	RG	3	1	FF-NO-FF	null	3	27	3	null	3
R45	RG	3	1	AU-NO-AU	null	11	27	11	null	11
R46	RG	3	1	AG-NO-AG	null	21	27	21	null	21
R47	RG	3	1	FC-NO-FC	null	12	27	12	null	12
R48	RG	3	1	CD-NO-CD	null	26	27	26	null	26
R49	RG	3	1	AR-NO-AR	null	29	27	29	null	29
R50	RG	3	1	FF - NO - FC	null	3	27	12	null	3
R51	RG	3	1	FF - NO - AU	null	3	27	11	null	3
R52	RG	3	1	FF - NO - AG	null	3	27	21	null	3
R53	RG	3	1	FF - NO - CD	null	3	27	26	null	3
R54	RG	3	1	FF - NO - AR	null	3	27	29	null	3
R55	RG	3	1	FC - NO - AU	null	12	27	11	null	12
R56	RG	3	1	FC - NO - AG	null	12	27	21	null	12
R57	RG	3	1	FC - NO - CD	null	12	27	26	null	12

R58	RG	3	1	FC - NO - AR	null	12	27	29	null	12
R59	RG	3	1	AU - NO - FF	null	11	27	3	null	11
R60	RG	3	1	AU - NO - FC	null	11	27	12	null	11
R61	RG	3	1	AU - NO - AG	null	11	27	21	null	11
R62	RG	3	1	AU - NO - CD	null	11	27	26	null	11
R63	RG	3	1	AG - NO - FF	null	21	27	3	null	21
R64	RG	3	1	AG - NO - FC	null	21	27	12	null	21
R65	RG	3	1	AG - NO - AU	null	21	27	11	null	21
R66	RG	3	1	AG - NO - CD	null	21	27	26	null	21
R67	RG	3	1	CD - NO - FF	null	26	27	3	null	26
R68	RG	3	1	CD - NO - FC	null	26	27	12	null	26
R69	RG	3	1	CD - NO - AU	null	26	27	11	null	26
R70	RG	3	1	CD - NO - AG	null	26	27	21	null	26

R71	RG	3	1	AR - NO - FF	null	29	27	3	null	29
R72	RG	3	1	AR - NO - FC	null	29	27	12	null	29
R73	RU	3	1	AG-AG-F	null	21	21	3	null	21
R74	RU	3	1	FF-FF-NO	null	3	3	27	null	3
R75	RU	3	1	FC-FC-NO	null	12	12	27	null	12
R76	RU	3	1	AU-AU-NO	null	11	11	27	null	11
R77	RU	3	1	AG-AG-NO	null	21	21	27	null	21
R78	RU	3	1	CD-CD-NO	null	26	26	27	null	26
R79	RU	3	1	AR-AR-NO	null	29	29	27	null	29

3.2 Integration with cross-cutting themes

The products of digital classification after the application of the temporal filter, for each of the 33 years in the period 1985-2017, were then integrated with the cross-cutting themes, by applying a set of specific hierarchical prevalence rules (Table 4). As output of this step, a final LULC use map for each chart of the Pampa biome for each year was obtained.

Table 4. Prevalence rules for combining the output of digital classification with the crosscutting themes in the Pampa biome, Collection 3.

Order	Class	Font
1	4.1. Beach and Dune	Crosscutting Theme
2	1.1.3. Mangrove	Crosscutting Theme
3	5.2. Aquaculture	Crosscutting Theme
4	5. Water	Biome
4	5.1. River, Lake and Ocean	Biome
5	2.3. Salt Flat	Crosscutting Theme
6	1.2. Forest Plantation	Crosscutting Theme
7	3.2. Agriculture	Crosscutting Theme
7	3.2.1. Annual and Perennial Crop	Crosscutting Theme
7	3.2.1. Semi-Perennial Crop	Crosscutting Theme
8	1.1.1. Forest Formation	Biome
8	1.1.4. Secondary Forest	Biome
9	4.2. Urban Infrastructure	Crosscutting Theme

10	4.4. Mining	Crosscutting Theme
11	1.1.2. Savanna Formation	Biome
12	4.5. Rocky Outcrop	Biome
13	2.1. Wetland	Biome
13	3.2.3. Mosaic of Crops	Crosscutting Theme
14	2.2. Grassland Formation	Biome
14	2.4. Other non forest natural formation	Biome
14	3.1. Pasture	Crosscutting Theme
15	4.3. Other non vegetated Area	Biome
16	3.3 Mosaic of Agriculture or Pasture	Biome
17	6. Non Observed	Biome

4 Validation strategies

4.1 Use of reference maps

Overall, there have been few previous initiatives on LULC mapping in the Pampa biome with spatial and thematic detail compatible with the MapBiomas Project. There are available basically three maps that depict the years of 2002 (Hasenack et al., 2015), 2009 (Weber et al., 2016) and 2015 (Hofmann et al., 2018) for the state of Rio Grande do Sul, which includes the Pampa biome.

All of the mentioned maps were produced through visual interpretation of Landsat imagery, seeking to ensure level of spatial detail compatible with cartographic scale 1:250,000. Their thematic richness, on the other hand, comprises a number of categories of natural vegetation cover and anthropic uses larger than those adopted in Collection 3 of the MapBiomas project. Thus, for validation purposes, the three available maps were reclassified to the MapBiomas classes (Figures 4, 5, 6). After then, an analysis of agreement was performed with the MapBiomas final classification maps of the same years.

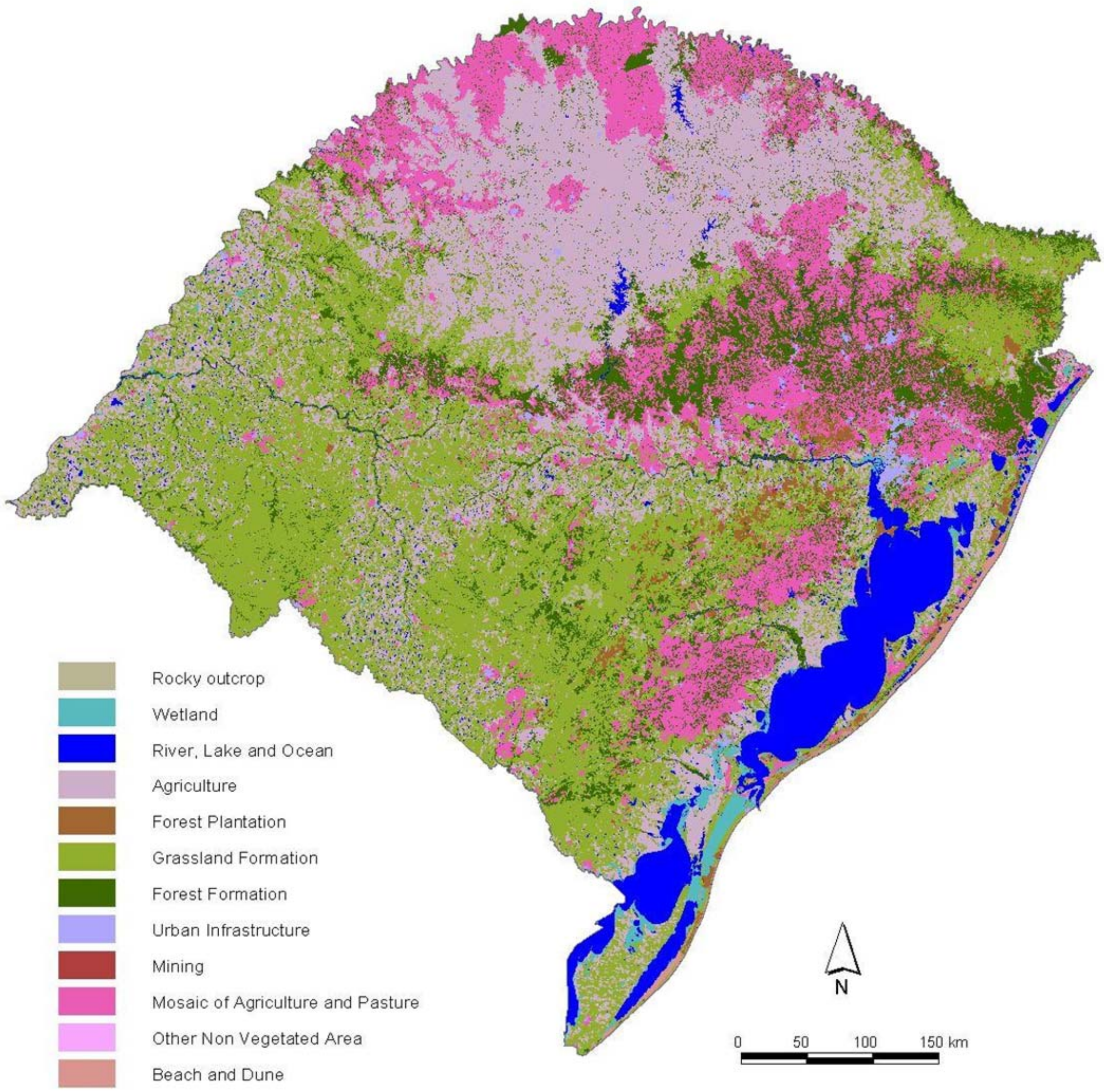

Figure 4. Reference map for the Pampa biome, year 2002 (Hasenack et al., 2015), reclassified to the legend of Collection 3 of the MapBiomas project.

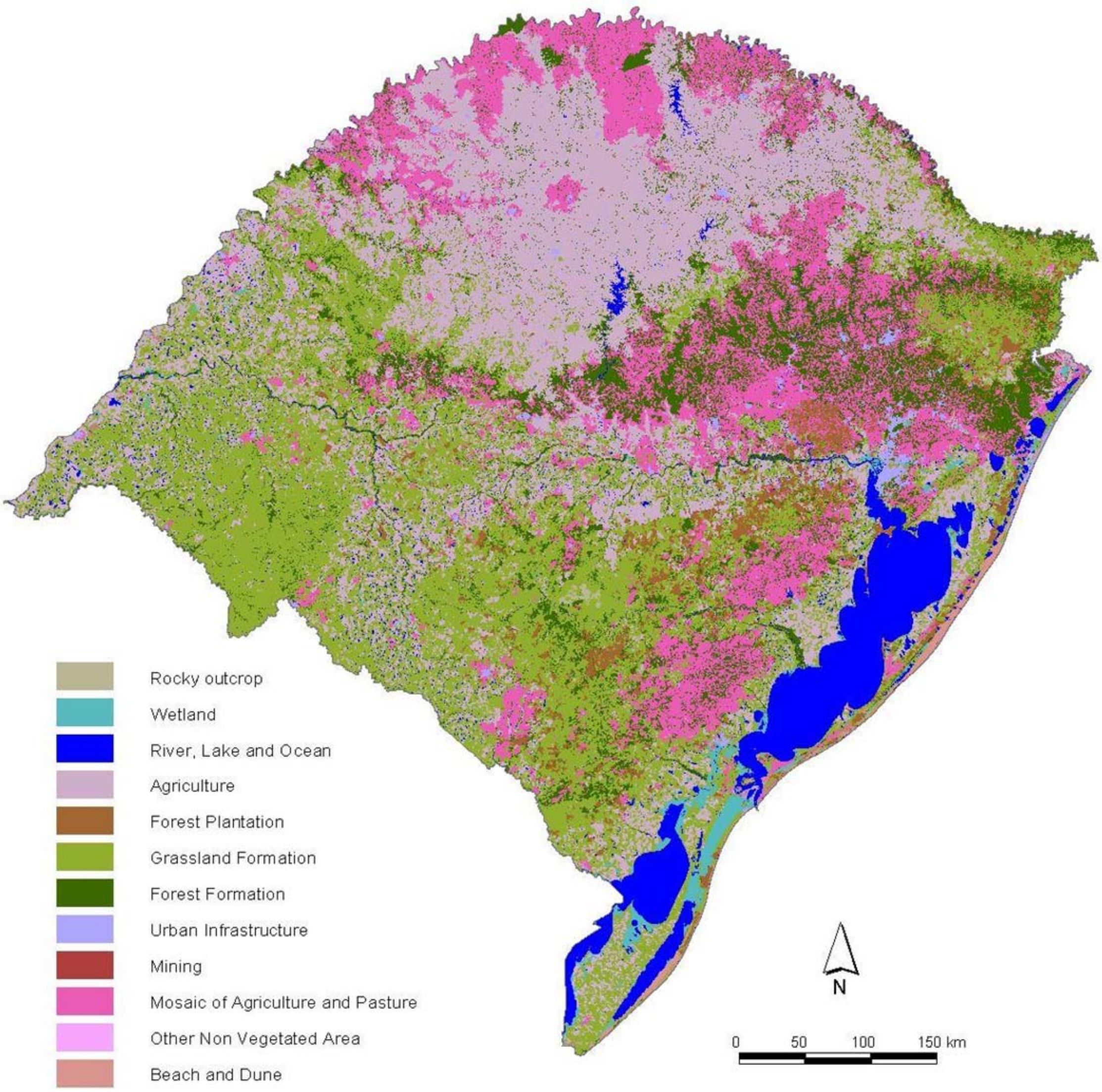

Figure 5. Reference map for the Pampa biome, year 2009 (Weber et al., 2016), reclassified to the legend of Collection 3 of the MapBiomas project.

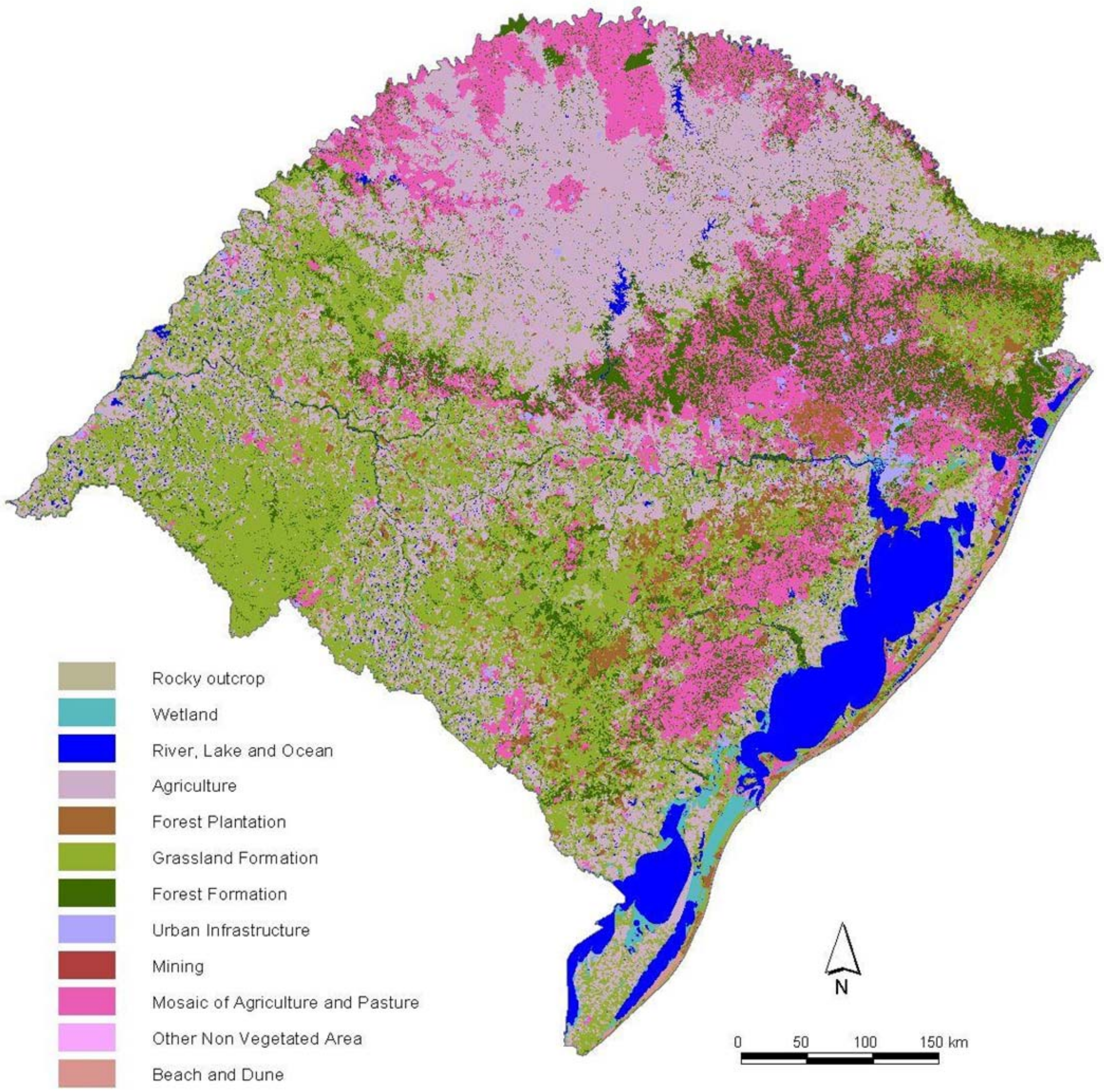

Figure 6. Reference map for the Pampa biome, year 2015 (Hofmann et al., 2018), reclassified to the legend of Collection 3 of the MapBiomas project.

5 References

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