Project "Collaboration for Forests and Agriculture"

CONSULTANCY TECHNICAL REPORT

Final product: Description of processes and methods used for reclassifying "Cropland" to "Agricultural Crops", "Implanted pastures" and "Agricultural Mosaic" of the entire national territory, 2000- 2016 period.

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1. INTRODUCTION

The role of forests in the global carbon cycle is critical, as they act as carbon deposits, but when they are replaced by other uses this carbon is released into the atmosphere contributing to the greenhouse effect and global warming (Gaspari, 2010). However, the problems caused by deforestation and forest degradation is quite complex, since there is a variety of processes in these, on which depend on biodiversity and consequently the quality of human life associated with the services and benefits sustained by them.

According to FAO 2000, deforestation is defined as "The conversion of forests to other land use long-term reduction of forest cover below 10%". This definition implies that the loss must be permanent and that the site has changed to other use (agriculture, grazing, dams, or urban areas).

According to recent data on change of global forest cover, dry tropical forests of South America had the highest rate in the world of tropical forest loss between 2000 and 2012 due to deforestation in the Chaco of Paraguay, Argentina and Bolivia (Walcott et al. 2015).

According to the forest cover changes map, Paraguay had 20,220,200 ha of forest in 1990, a figure that decreased to 17,674,124 ha by the year 2000 (Huang et. Al. 2009). Paraguay's UN-REDD+ National Programme with the National Forestry Institute through the Satellite System of Land Monitoring (SSMT) has recorded a total area of changes of 5,631,310 ha for the period 2000-2015 in the national territory (PNC UN-REDD +, 2016).

These data show a 31.86% conversion of the total area of forest land to other uses over a period of 15 years, with an annual average of 374,420 ha of conversion taking as reference the year 2000. This information highlights an alarming process of deforestation that occurs over the entire national territory but with greater intensity in Western Region.

The project “Collaboration for Forests and Agriculture” aims to promote the coordination and develop tools to help create an enabling environment, where market leaders can develop and implement commitments towards sustainable production of meat and soy in the Amazon, Cerrado and Chaco in Brazil, Argentina and Paraguay; reducing deforestation.

This consultancy is executed in order to support the activities carried out by the National Forestry Institute (INFONA) and have an impact on the achievement of project results, such as the operation of the National Forestry Information System Department (DSNIF) in which lies the Satellite Terrestrial Monitoring System (SSMT), for constant monitoring of the dynamics of change of coverage.

This document provides a technical report which presents in detail the processes and methods used for reclassifying “Cropland” (adapted from IPCC 2003) to “Implanted pastures” and “Agricultural crops” throughout the national territory, 2000-2016 period.

2. LITERATURE REVIEW

2.1 Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is an international scientific body that examines and assesses the latest scientific, technical and socioeconomic literature related to the understanding of change climate and produced worldwide. The IPCC does not carry out any investigation or monitor data or parameters related to climate (IPCC 2017).

2.2 IPCC categories

The IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003), defines six classes that form the basis of the estimation basis and reporting emissions and removals of greenhouse gases resulting from the activated land use and land change use. The main categories of land on inventories of greenhouse gases (GHGs) are as follows:

Table 1. The land use categories according to IPCC 2003.

Category	Short description
Forestlands	All land with woody and lower vegetation is expected to reach the threshold.
Cropland	Farmland, farming and agroforestry systems that do not reach the threshold used for the category of forest land
Grasslands	Pasture and grazing land not considered agricultural land, as well as below the threshold of land and forest land that is not expected to exceed.
Wetlands	Saturated ground water for all or part of the year
Settlements	Developed land, transportation infrastructure and human settlements of all sizes.
Other lands	Bare soil, rock, ice and other unmanaged lands which fall into the above categories.

Source: IPCC 2003.

2.3 Remote Sensing

It is a technique by which useful information of an object, area, or phenomenon is obtained through the analysis and interpretation of image data acquired by a computer that is not in physical contact with, the object, area, or phenomenon under investigation (IGAC 2007).

Olaya (2011) mentions that remote sensing is a primary source of data in GIS, and the true use of current products of remote sensing only occurs with the help of GIS and its data analysis and management capabilities.

2.4 Satellite imagery

León (2002) indicates that satellite images record electromagnetic energy electronically. These images are made up of squares of the same size called pixels and they represent the brightness of each frame corresponding to the ground by means of a numerical or digital value (representing the variation of an image or squares form a mesh or raster).

The same author cites some of the main advantages of satellite images as follows:

- Rapidly both in the frequency of acquiring new information and obtaining the same user.
- Low cost, especially when it comes to studying large areas, since in general, satellite images are cheaper than taking aerial photos.
- Accessibility to remote locations.
- Special features can be enhanced.
- Periodicity, each satellite again passes through the same area in a given period of time.

2.5 Landsat Program

The IGAC (Agustin Codazzi Geographic Institute) 2007, mentions that in July 1972 the National Aeronautics and Space Administration (NASA) launched the first of the Earth observation satellites, known as Landsat. Since then, seven more have been

launched, the first known under the name of Landsat 1, 2, 3, transported MSS technology (Multispectral Scanner System), the two later, Landsat 4 and 5, incorporated the Thematic Mapper (TM) sensor. Landsat 6 incorporated the sensor Enhanced Thematic Mapper (ETM) which had a failed launch in October 1993, finally the Landsat 7, launched in April 1999, has an onboard sensor called Enhanced Thematic Plus (ETM +).

Landsat 1, 2, 3 were equipped with two instruments: a camera system called Return Bean Vidicon (RBV) and the sensor (MSS). RBV was supposed to be the most relevant instrument, but MSS data were found superior (USGS 2013).

Landsat images are composed of 7 or 8 spectral bands, that when combined produce a range of color images that greatly increase their applications. Depending on the satellite and the sensor, a panchromatic and / or thermal channel is included, as well as spatial resolution of 15, 30, 60 and 120 m (INEGI s.f.).

Table 2. General characteristics of the Landsat satellite program.

Satellite	Sensor	Launching (End of operation)
Landsat 1	RBV	23/07/1972
	MSS	06/01/1978
Landsat 2	RBV	22/01/1975
	MSS	250/2/1982
Landsat 3	RBV	05/03/1978
	MSS	31/03/1983
Landsat 4	MSS	16/07/1982
	TM	15/06/2001
Landsat 5	MSS	03/01/1984
	TM	05/06/2013
Landsat 6	ETM failed launch	10/05/1993
Landsat 7	ETM +	15/04/1999
Landsat 8	OLI	11/02/2013
	TIRS	

Source: Own elaboration, based on USGS (2013).

2.6 Landsat 5 TM

Landsat 5 satellite was launched on March 1st, 1984 and decommissioned on June 5th, 2013, becoming the Earth Observation satellite that has been operating the longest. Its applications extend to fields such as detection of global changes, agriculture, water quality and resource management (Geocento 2015).

Table 3. Characteristics of the Landsat 5 satellite

bands	Wavelength (um)	Resolution (meters)
Band 1 - Blue	0.45 - 0.52	30
Band 2 - Green	0.52 - 0.60	30
Band 3 - Red	0.63 - 0.69	30
Band 4 - Near Infrared 1	0.76 - 0.90	30
Band 5 - Near Infrared 2	1.55 - 1.75	30
Band 6 - Near infrared means	10.4 - 12.5	120
Band 7 - Thermal Infrared	2.08 - 2.35	30

Source: USGS (2013).

2.7 Landsat 8

The Landsat 8 was launched in February 2013 and declared operational in May of the same year, the date on which the NASA gives control to the United States Geological

Survey (USGS) who is responsible for satellite control, generation and storage data (USGS 2013).

According to the same author Landsat 8 incorporates two scanning instruments: Operational Land Imager (OLI), and an infrared temperature sensor called Thermal Infrared Sensor (TIRs). Landsat 8 imagery obtained by the sensors (OLI) and (TIRs) consist of nine spectral bands with a spatial resolution of 30 meters for the bands 1 to 7 and 9. A band 1 (deep-blue) is useful for coastal studies and aerosols. The new band 9 is useful for the detection of cirrus, band 8 (panchromatic) has a resolution of 15 m, and thermal bands 10 and 11 are useful for providing more accurate surface temperatures and are taken at 100 m resolution.

Table 4. Characteristics of the Landsat 8 satellite

Bands	Wavelength (μm)	Resolution (meters)
Band 1 - Aerosol coastal	0.43 - 0.45	30
Band 2 - Blue	0.45 - 0.51	30
Band 3 - Green	0.53 - 0.59	30
Band 4 - Red	0.64 - 0.67	30
Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
Band 6 - SWIR 1	1.57 - 1.65	30
Band 7 - SWIR 2	2.11 - 2.29	30
Band 8 - Panchromatic	0.50 - 0.68	15
Band 9 - Cirrus	1.36 - 1.38	30
Band 10 - Thermal Infrared (TIRs) 1	10.60 - 11.19	100
Band 11 - Thermal Infrared (TIRs) 2	11.50 - 12.51	100

Source: USGS (2013).

3. METHODOLOGY

3.1 Baseline materials

In order to develop the "IPCC land use change map of Paraguay for the periods 2000-2005-2011-2013-2015-2016", the criteria defined by the document "The IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry" were adapted, which refer six classes corresponding to land use categories. From these classes, INFONA defined the general categories of land use, as well as the change of use categories, which are detailed in table 5 (INFONA 2014).

Table 5. Land use change categories.

Change category	Short description
Forest cover to Cropland	Changes that occur in a defined forest cover to croplands and tillage, being included those land for cattle raising activities.
Forest cover to Human settlements	Changes that occur in a defined forest cover to all developed land, including transportation infrastructure and settlements of all sizes.
Forest cover to Wetlands	Changes that occur in a defined forest cover to lands covered or saturated by water for all or part of the year.
Forest Cover to Other lands	Those changes that occur in a defined forest cover to unmanaged areas that not falling within any of the categories listed.
Natural fields to Wetlands	Natural pastures and natural fields to wetlands
Wetland to Cropland	Changes of land covered or saturated by water during all or part of the year to agricultural land.

Source: Own elaboration, based on INFONA (2014).

For the preparation of the map were generated vector files for each period, using the combined methodology for classifying land cover (through training samples and grouping pixels based on their spectral response) which was built on the Google Earth Engine platform (GEE), segmentation procedures using the Monteverdi software and

statistics areas calculations. Also it was calculated “majority” by segment using the ArcGIS software (PNC UN REDD + 2015).

It is noteworthy that, for the cover classification made in this work, images classified by GEE were downloaded and was developed a multitemporal mosaic, where the images considered were of a percentage of clouds less than 10%. The selected images correspond to a mosaic of 9 bands for the years 2000-2005-2011-2013-2015. They were used 3-band per year; RGB: 5, 4, 3 for the period 2000 to 2013 according to the images characteristics of Landsat 5 (PNC UNREDD + 2015). And also, from 2015 they were used satellite images of Landsat 8 with a 5, 6.4.RGB settings.

3.2 Materials

For the reclassification of the “Cropland” to “Implanted pastures” and “Agricultural crops” they were used shapefiles from the Land use change maps corresponding to the periods 2000-2005, 2005-2011, 2011-2013, 2013-2015. However, for the period 2015-2016 was necessary the direct classification of changes according to the methodology used for the above periods, with the difference that the classes corresponding to the differentiation of “Cropland” in “Implanted pastures”, “Agricultural crops” and “Agricultural mosaic” were added. Reclassifying coverage was made based on the above-mentioned mosaics.

Additionally, they were used the Google Earth Pro software, which offers satellite images of high resolution with wide temporal variation as well as the “Base Map” of ArcGIS software which has the same characteristics, always considering those images that corresponded to the studied period to verify areas that may present a higher degree of difficulty in identifying coverage.

The software used for reclassification was ArcGIS, specifically in its tool ArcMap 10.1, where the mosaic layers in raster format and the vector layers of the aforementioned baseline were added. In addition, a grid was used to divide the country into quadrants 100x100 km in order to facilitate the work and presentation of results. Thee Western Region was divided into 34 quadrants according to the grid used and the Eastern Region into 27 quadrants.

The mosaics were made up of images that corresponded to the Landsat program, in tables 5 and 6 are detailed images per year, indicating date range and bands used for the studied periods.

Table 5. Landsat images used for the 2000-2005-2011 period.

Satellite	Sensors	Year	Date range	Bands
Western region				
Landsat 5	MMS/TM	2000	01/01 to 30/09	4, 5, 3
		2005	01/01 to 30/11	
		2011	01/05 to 30/11	
Eastern region				
Landsat 5	MMS/TM	2000	01/05 to 30/10	4, 5, 3
		2005	01/04 to 30/10	
		2011		

Source: PNC ONU REDD+ (2015).

Table 6. Landsat images used for the 2011-2013-2015-2016 period.

Satellite	Sensors	Year	Date range	Bands
Western region				
Landsat 5	MMS/TM	2011	01/05 to 30/11	4, 5, 3
		2013	01/06 to 30/11	
Landsat 8	OLI/TIRS	2015	01/05 to 30/11	5,6,4
		2016	06/16 to 08/16	
Eastern region				
Landsat 5	MMS/TM	2011	01/04 to 30/10	4, 5, 3
		2013	01/05 to 30/10	
Landsat 8	OLI/TIRS	2015	01/03 to 31/12	5, 6, 4
		2016	06/16 to 08/16	

Source: PNC ONU REDD+ (2015).

3.3 Executed processes description

It is important to note that the processes described below, were used for the reclassification of both Western Region and Eastern Region. Thus, these processes were replicated exactly in the separate classification of the two regions and for each period, except for the period 2015-2016 as will be detailed later.

3.3.1 Configuration and establishment of the working environment in the software interface

Once the layers were added in ArcMap, a copy of the original layer of the baseline was made, which correspond, in this case, to the vector map segments of the Map of Changes of each period and region (figure 1).

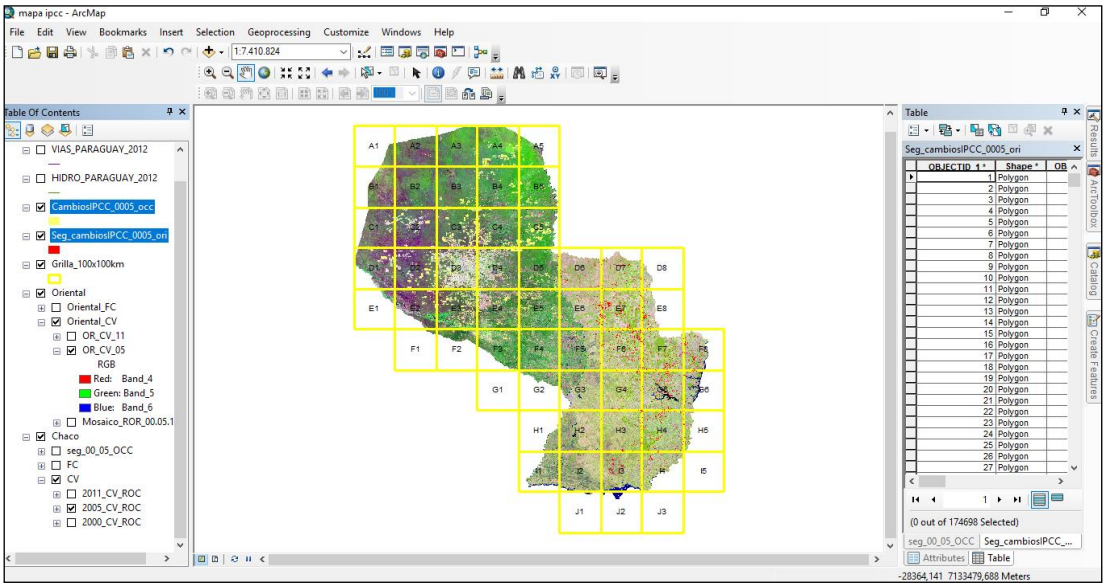

Figure 1. Image once aggregated layers on the ArcMap platform, ArcGIS software.

3.1.2 Selection and extraction of data to generate editable layers for the periods between 2000 and 2015

We proceeded to the selection and extraction of data for all records of the class "Changes in Forest Cover to Cropland 2000-2015" of "Clases_IPCC" field, using the *Select by Attributes tool* and *Export data* (figure 2).

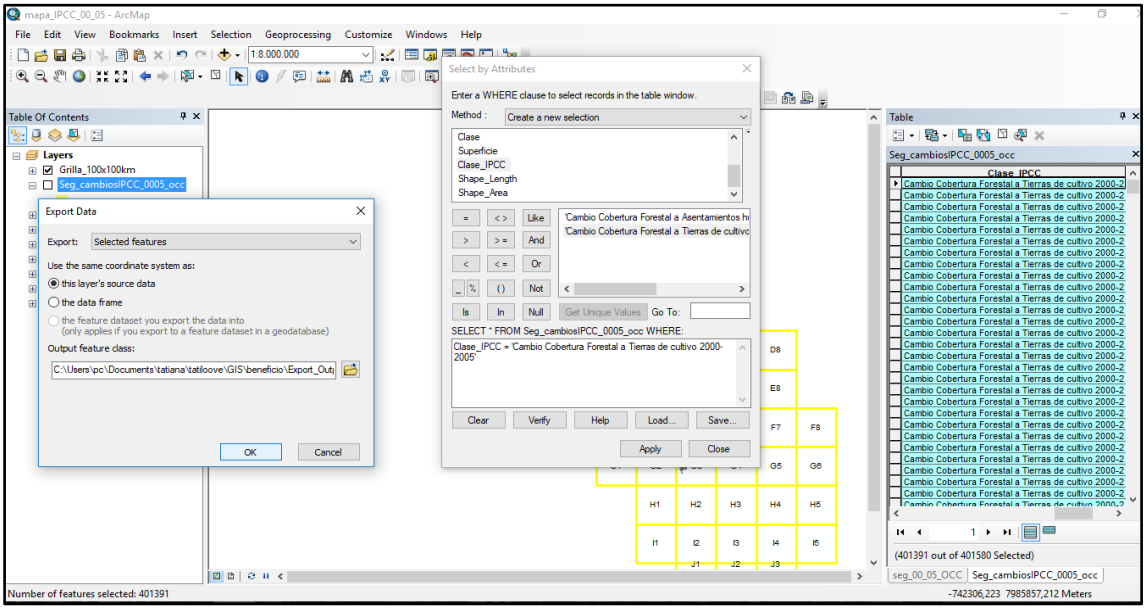

Figure 2. Selection process image, removal of records and creation of the new layer from these, Western Region.

In the case of the Eastern Region selection and data extraction was from classes "Changes Forest Cover to Cropland 2000-2015" and "Changes Wetlands to Cropland 2000-2015" (figure 3).

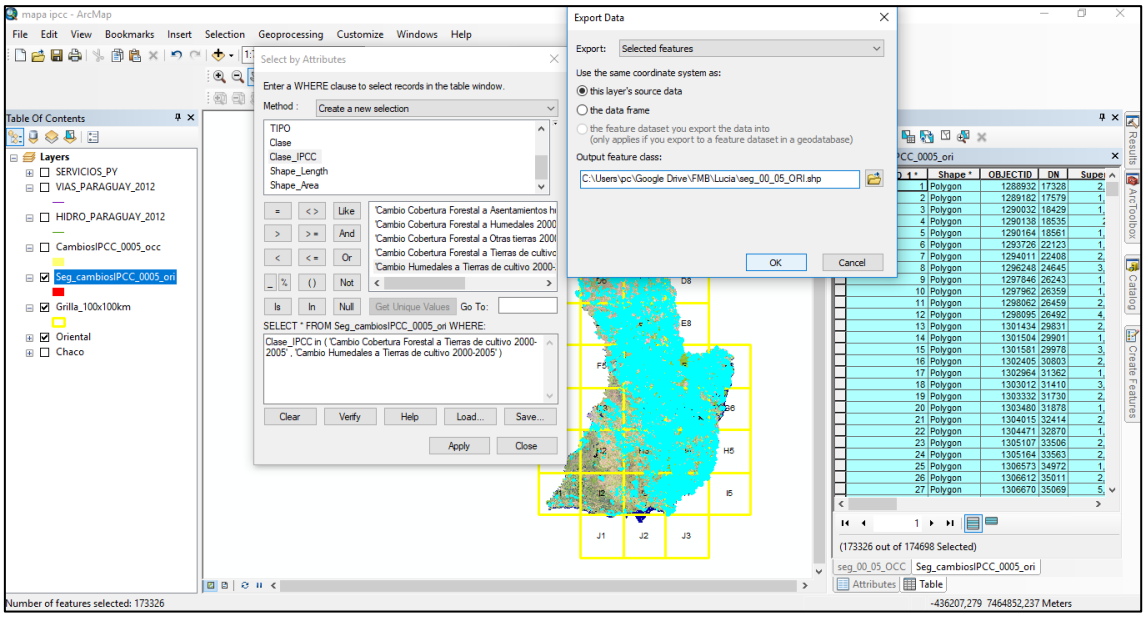

Figure 3. Image of the selection process, removal of records and creation of the new layer from these, Eastern Region.

From the selected data they were created layers that would contain exclusively records of the class “Changes Forest Cover to Cropland 2000-2015” in the case of the Western Region and Eastern Region records “Changes Wetlands to Cropland 2000-2015” and “Changes Forest Cover to Cropland 2000-2015”.

3.1.3 Generation of editable layers 2015-2016 period

For this period there was no classification of changes according to the IPCC 2003 methodology, so first, the segments corresponding to the changes were consolidated according to the classification of the national territory coverage, this because of the results of this were divided into grids mentioned above, so it was necessary to join them in order to obtain a layer for each region.

The landcovers of that classification corresponds to “Stable Forest”, “No stable forest” and “Changes”. This latter class was extracted for editing and subsequent classification into categories of the IPCC.

We proceeded to the selection of data of each grid, according to the value of the “majority” field, which in this case corresponded to “3” value of the changes for the period. Subsequently, the data was exported and fused by “Merge” tool, to finally obtain the layer of each region for the aforementioned period.

3.1.4 Adding and editing fields to use

Reclassification work was done in this stage, which mainly focused on the edition of the previously generated layers. In the attribute table of this layers a new field was add named "Reclass". In which the changes classification was recorded as these were being verified, according to the degree of difficulty that its identification required. This process was executed identically on the two layers (figure 4).

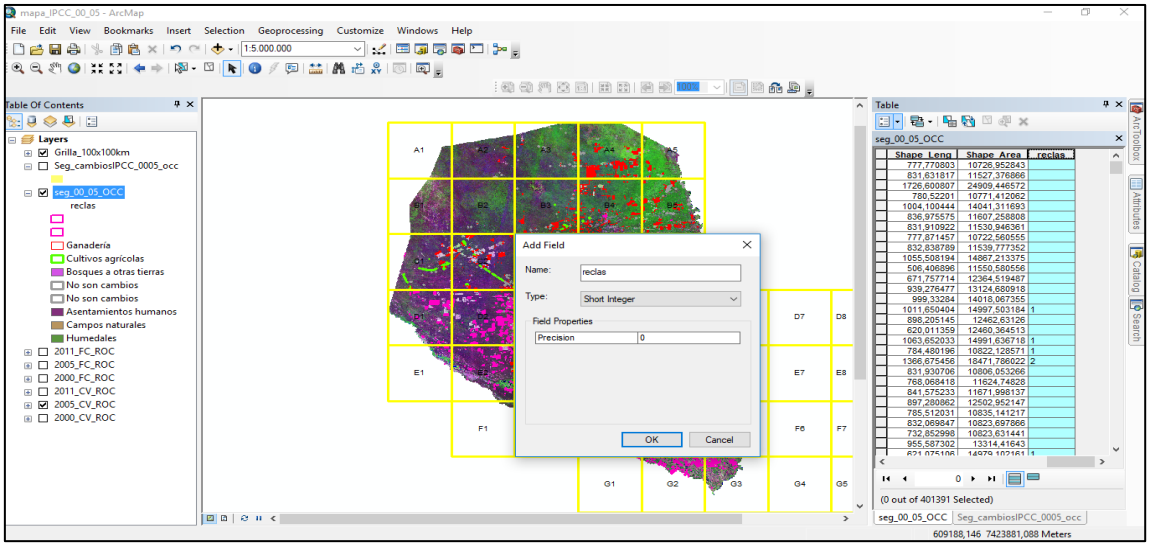

Figure 4. Image of the editing process of the 'seg_05_11_OCC' layer for subsequent reclassification.

3.3.3 Visual inspection and reclassification

Finally, we proceeded to itself reclassification, where the work was involved the visual interpretation of the original classification of baseline and comparison with satellite images so as to verify the change recorded and the current usage in which the forest cover was transformed.

Once the change was verified, the type to which this corresponded was determined, which proceeded to the manual edition of the records of the attribute table using the *Edit features tool* (figure 5).

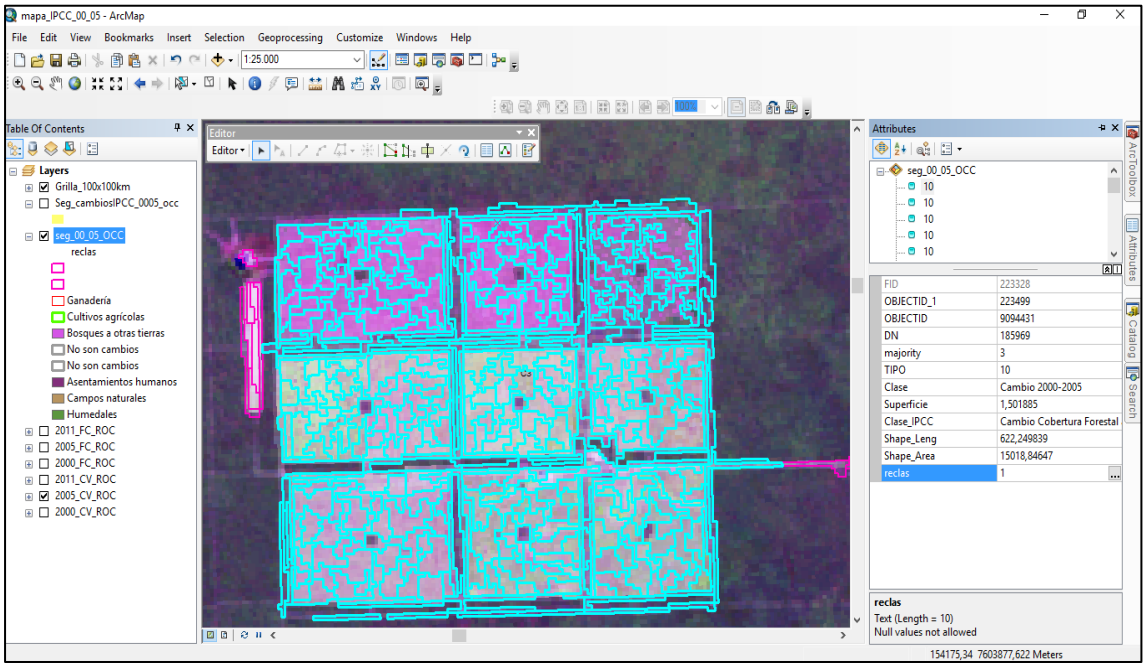

Figure 5. Image of the verification and reclassification process to "Implanted Pastures" Western Region.

For editing records of the "Reclass" field there were assigned codes from 1 to 8, which corresponded to the types of coverage changes identified and were adapted from the land use change categories used to make the baseline (table 6).

Table 6. Used codes for reclassification as identified coverage.

Land use change categories – "Reclass" field	Code
Change Forest Land to Implanted pastures	1
Change Forest Land to Agricultural crops	2
Change Forest Land to Other lands	3
Changes that are not changes	4
Change Forest Land to Human settlements	5
Change Forest Land to Natural fields	6
Change Forest Land to Wetlands	7
Change Forest Land to Agricultural mosaics	8

Source: Own elaboration

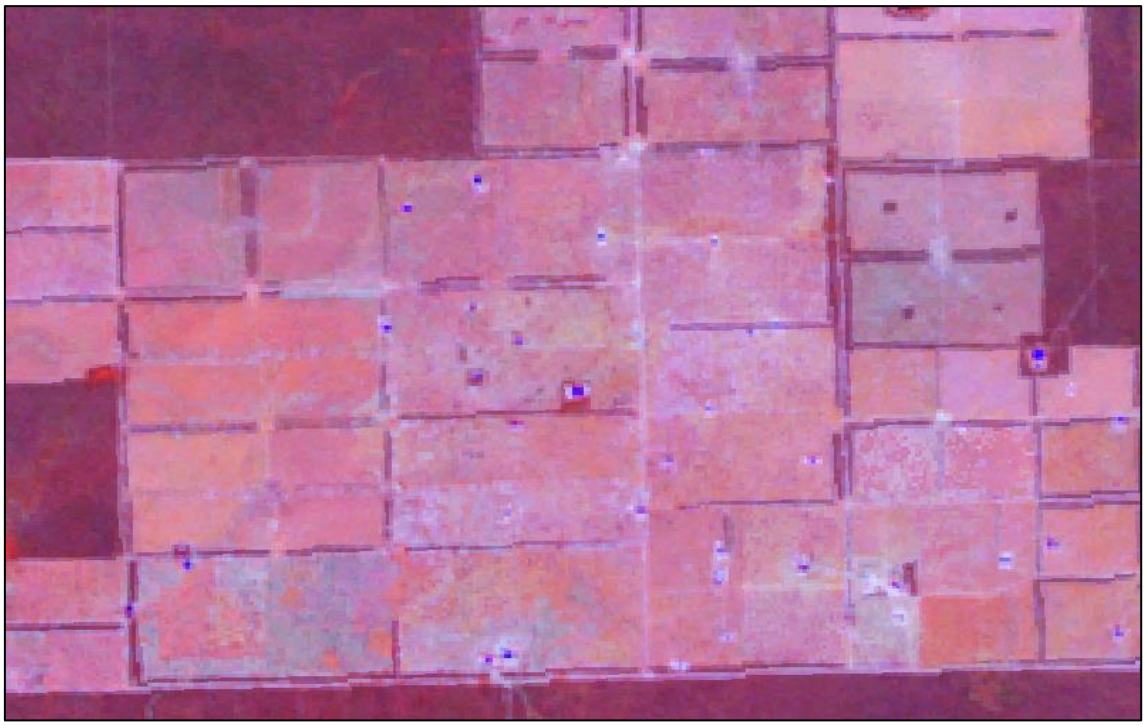

Figure 6 Satellite image used in the process of verification and reclassification to "Pastures implemented" Western Region.

The figure 6 shows the shape and distribution of land for livestock, they generally adopt forms of regular polygons in the Western Region, with a fairly orderly distribution in much of the territory of the same, agglomerating to a greater extend in the central Chaco area.

In the case of the Eastern region this same class presents a less orderly and asymmetric distribution, so it is not so common to take regular polygonal shapes, such land is concentrated in the departments of Concepción and Amambay in the case of the Eastern Region (figure 7).

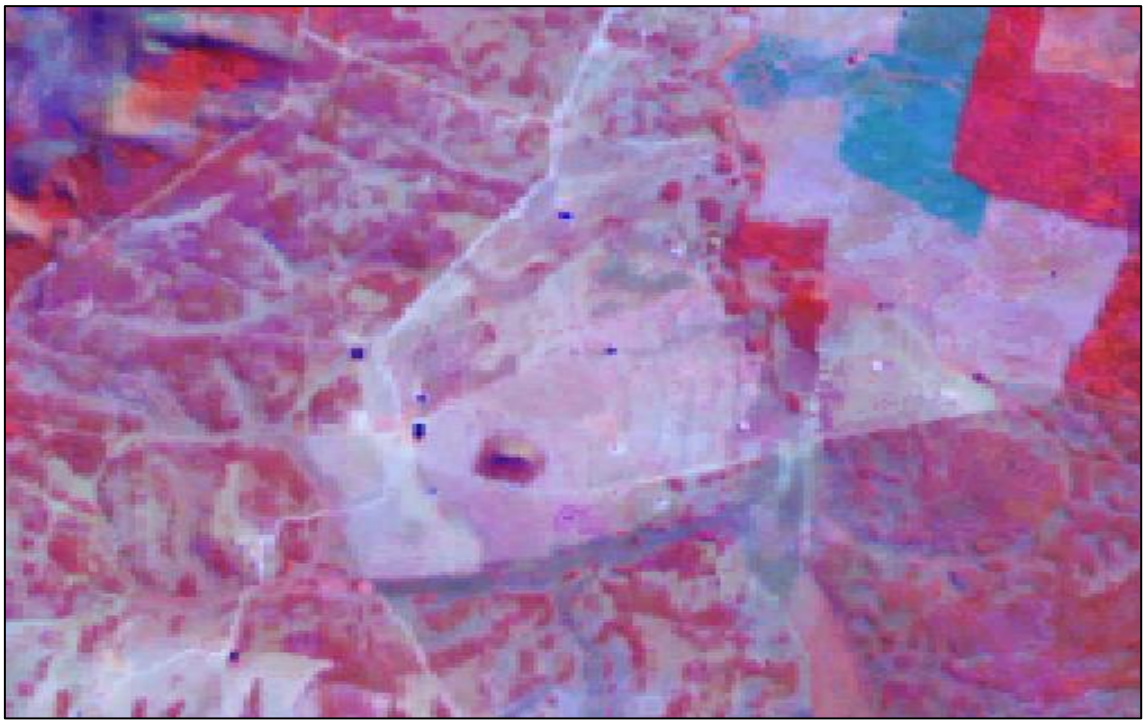

Figure 7. Image of the verification and reclassification process to “Pastures implemented” Eastern Region.

Regarding to Agricultural crops, there are major differences between the both regions in terms of shape and size, and also, a large contrast between the surfaces enabled for each region of this land use classes.

In general, in the Western region, the agriculture does not have a large area, compared with livestock. It is common to find this class in the central and under Chaco, mainly in the Boquerón and Presidente Hayes departments (figure 8).

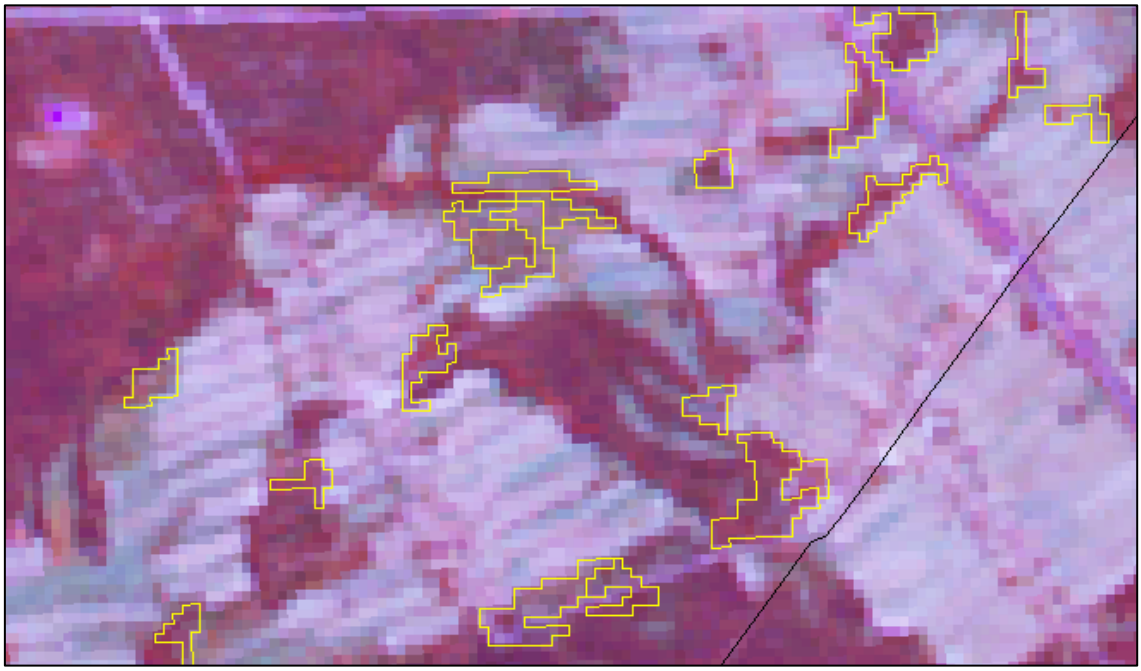

Figure 8. Satellite image of the verification and reclassification process to “Agricultural crops” Western Region.

It was noted that the enabled areas in this region, are usually accompanied or associated with livestock production, besides the surface per productive unit is much lower than in the Eastern region, as well as they are quite isolated, that is, there are no large territories that can be classified as agricultural or exclusively agricultural zones (figure 9).

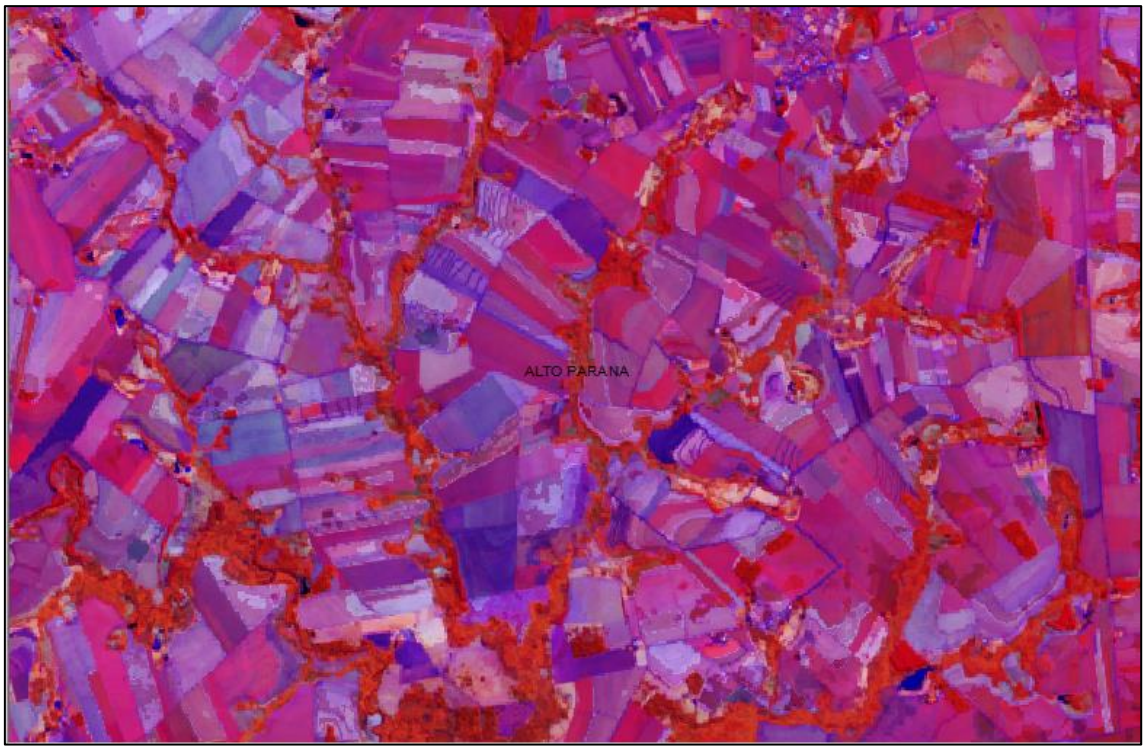

Figure 9. Satellite image of the verification and reclassification process to “Agricultural crops” Eastern Region.

From the 2005-2011 period onward, it was added the “Agricultural mosaic” class, which was implemented for the Eastern Region. Because in these areas it was very difficult to distinguish between the classes “Implanted pastures” and “Agricultural crops”, especially as regards the Eastern Region. In these areas lands constantly are enabled, either for crops or livestock, activities that are in turn agglomerated and because of the scale of work and mainly spatial resolution of the used images (30x30m), make the work of interpretation and reclassification take a considerable amount of time.

The main pattern by which this class is distinguished is the agglomeration of the aforementioned activities. In figure 10 shows small areas of both types in the same production zone, that is, the size of the production units and the diversity of activities are characteristic of those areas that could be considered rurban.

Figure 10. Image verification and reclassification process to "Agricultural Mosaic" Eastern Region.

It is noteworthy that subsequent completion of the nationwide reclassification, was conducted a review of work at regional level for each period in order to identify possible misinterpretations, which were made corrections topcoats so as to have a greater accuracy and quality analysis.

4. RESULTS

The results of the reclassification of the baseline map 2000-2015 period according to IPCC categories, as well as the classification results using the same methodology for the period 2015 to 2016 are presented.

As mentioned above, the data of the baseline period 2000-2015 were formed by segments taken from changes classes “Changes in Forest Cover to Cropland” and “Changes in Wetland to Cropland”, that is to say that the totality of changes was not reclassified, as it was for period 2015-2016, which did not have an according to the IPCC 2003 categories.

However, all the data presented were analyzed together considering that the “Changes in Forest Cover to Cropland” category constitutes 97.38% of total recorded changes according to Paraguay’s UN-REDD+ National Joint Programme and in this paper a reclassification was performed according to the same methodology.

Thus, for the present analysis, was taken into account the reclassified area from the baseline and the complete changes classification of the 2015-2016 period.

4.1. IPCC land use change classes in Paraguay: 2000-2016

They were classified a total area of 5,784,070.40 ha of which 87.85% corresponds to the “Implanted pastures” followed by 9.95% of the “Agricultural crops” and 1.61% of “Agricultural mosaics”, in which the remaining percentage corresponds to other types of use as detailed in table 7.

Table 7. Land use changes areas by class at national and regional level: 2000-2016

Change category	Western Region Area (ha)	Western Region Percentage (%)	Eastern Region Area (ha)	Eastern Region Percentage (%)	Paraguay	Paraguay Percentage (%)
Changes in Forest Cover to Implanted pastures	4,652,418.29	99.13	428,917.47	39.31	5,081,335.76	87.85
Changes in Forest Cover to Agricultural crops	11,786.24	0.25	563,880.21	51.68	575,666.45	9.95
Changes in Forest Cover to Agricultural mosaic	0.00	0.00	93,214.41	8.54	93,214.41	1.61
Changes in Forest Cover to Natural fields	12,386.24	0.26	1,163.09	0.10	13,549.33	0.23
Changes in Forest Cover to Wetlands	7,009.02	0.14	1,896.19	0.17	8,905.21	0.15
Changes in Forest Cover to Human settlements	5,689.26	0.12	362.34	0.03	6,051.60	0.10
Changes that are not changes	3,510.40	0.07	1,615.34	0.14	5,125.74	0.08
Changes in Forest Cover to Other lands	196,41	0.004	25.49	0.002	221.90	0.003
Total	**4.692.995,86**	**100**	**1.091.074,54**	**100**	**5.784.070,40**	**100**

At the regional level the “Implanted pastures” stands, which presented a significant percentage of changes in both regions, mainly in the Western with 99.1% of the total change area for the region, while in the Eastern was the second category in terms of area, after “Agricultural Crops” which presented 51.6% of change surface in that region.

In figure 11 we can observe the behavior of the categories in both regions according to surface changes during the 2000-2016 period. In the same becomes noticeable again, the big difference in terms of area of “Implanted pastures” with others.

This difference is mainly due to the predominance of this in the Western Region, which, because of limitations of use by climatic factors and infrastructure, this activity has been historically the most profitable option. It should be mentioned that, also exist legal factors have restricted the conversion of forests in the Eastern Region such as the Zero Deforestation Law, so that in the last decade, the production of productive land has been heavily turned to the Chaco.

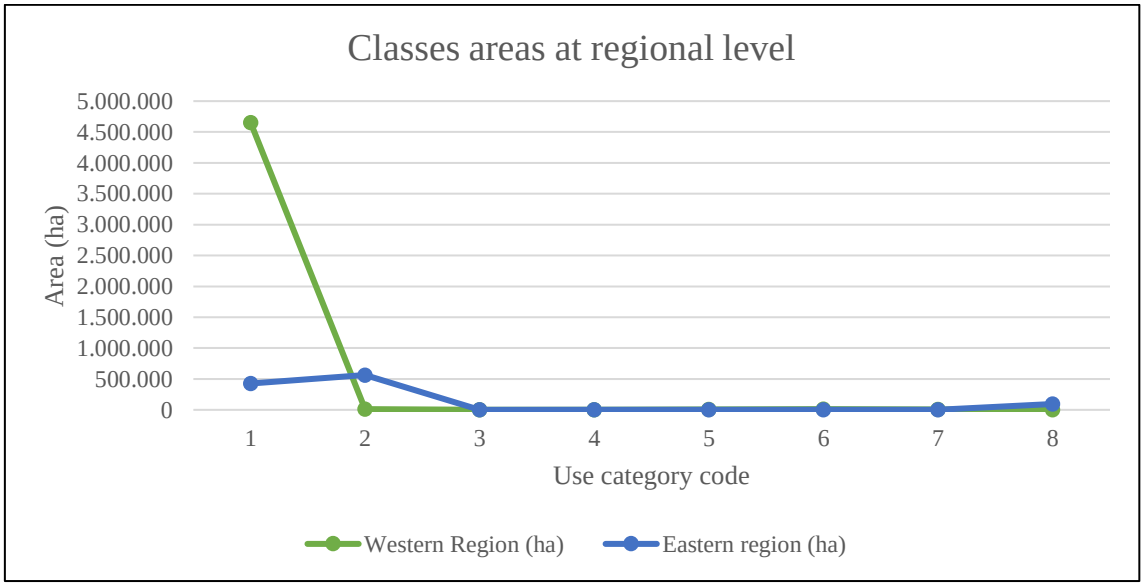

Figure 11. Changes surface at the regional level period 2000-2016

* Code use categories: (1) Changes of Forestland to Implanted pastures, (2) Changes of Forestland to Agricultural crops, (3) Changes of Forestland to Other lands (4) Changes that are not changes, (5) Changes Forestland to Human Settlements (6) Changes of Forestland to Natural fields, (7) Change Forestland to Wetlands, (8) Changes of Forestland to Agricultural mosaic

Regarding the surface changes was the 2005 to 2011 period which had the highest surface changes, with 2,607,570.38 ha, however it was the 2011-2013 period that presented the highest annual change surface with about 505,603.46 ha per year, thus ruling out a relationship between the amount of time and transformed surface (Table 8).

Table 8. Change area per period

Period of change	Area (ha)	Percentage of loss per period (%)	Annual change (ha/year) *	Annual loss rate (%)**
2000-2005	1.289.321,66	22,29	257.864,33	1,16
2005-2011	2.607.570,38	45,08	434.595,06	1,96
2011-2013	1.011.206,92	17,48	505.603,46	2,28
2013-2015	706.618,66	12,22	353.309,33	1,59
2015-2016	169.352,78	2,93	169.352,78	0,76
Total	**5.784.070,40**	**100**	**361.504,4**	**7,75**

* The annual area of change has been calculated based on the total area of change for that period.

** The loss rate was calculated based on the estimation of forest cover for year 2000 PNC UN-REDD + (2016)

Figure 12 compares the tendency of the surface changes Western Regional with general aggregate during the study period, a relationship between them due to surface changes recorded in the Chaco is observed, which has a strong influence of the "Implanted pastures".

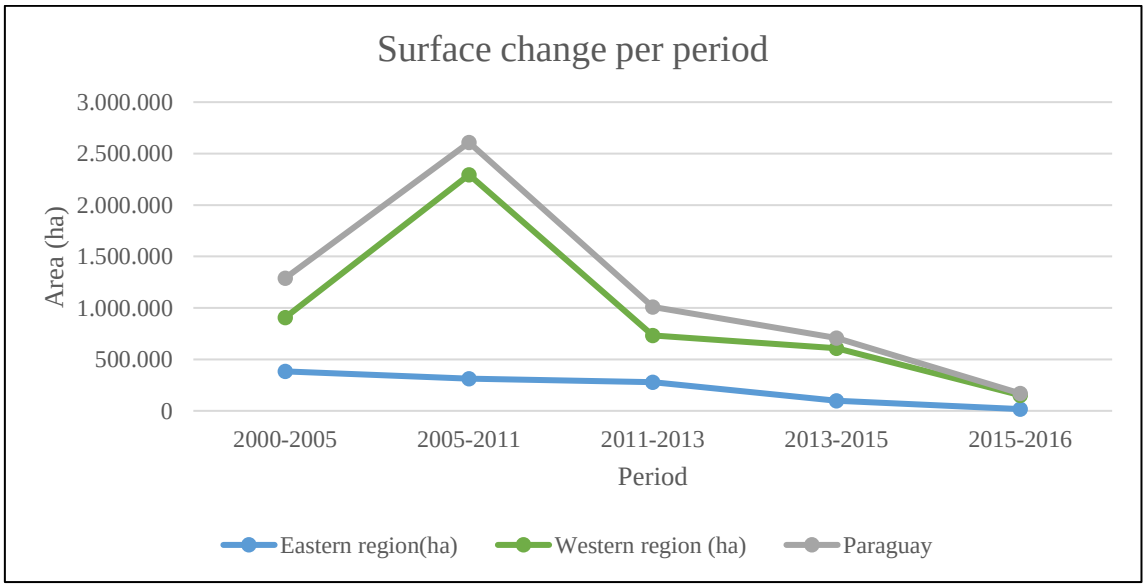

Figure 12. Surface changes at the regional level class period 2000-2016

In figure 13 shows the trend of annual surface change per period in which a progressive increase is demonstrated in the first three periods, reaching its peak in 2011-2013 with some 505,603.46 ha/year, then decreased again, reaching 169,352.78 ha/year in the period 2015-2016.

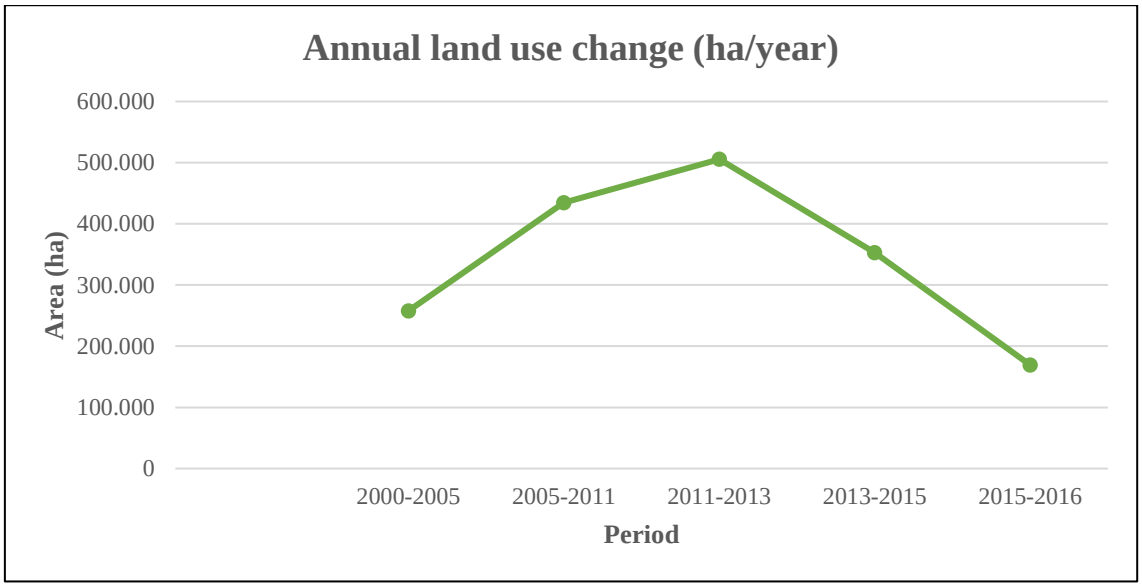

Figure 13. Annual surface changes per period.

Table 9 shows the results of surface changes are presented per period, both regionally and nationally.

Table 9. Change surfaces by class at regional and national level

IPCC change classes of Paraguay 2000-2016		Area (ha)			Percentage (%)
		Western region	Eastern Region	Paraguay	
2000-2005	Changes Forestland to Implanted pastures	891,526.67	138,639.92	1,030,166.59	79.90
	Changes Forestland to Agricultural crops	6,306.05	243,634.96	249,941.01	19.39
	Changes Forestland to Other land	89.03	-	89.03	0.01
	Changes that are not changes	3,212.99	951.01	4,164.00	0.32
	Changes Forestland to Human Settlements	1,354.22	98.59	1,452.81	0.11
	Changes Forestland to Natural fields	1,412.98	94.52	1,507.50	0.12
	Changes Forestland to Wetlands	1,976.65	24.07	2,000.72	0.16
	Total	**905,878.59**	**383,443.07**	**1,289,321.66**	**100**

IPCC change classes of Paraguay 2000-2016		Area (ha)			Percentage (%)
		Western region	Eastern Region	Paraguay	
2005-2011	Changes Forestland to Implanted pastures	2,288,307.74	107,227.44	2,395,535.18	91.87
	Changes Forestland to Agricultural crops	3,664.84	144,642.51	148,307.35	5.69
	Changes Forestland to Other lands	-	5.00	5.00	0.0002
	Changes that are not changes	42.82	377,20	420.02	0.02
	Changes Forestland to Human Settlements	390.88	6.54	397.42	0.02
	Changes Forestland to Natural fields	961.42	296.03	1,257.45	0.05
	Changes Forestland to Wetlands	796.93	121.17	918.10	0.04
	Change of Forestland to Agricultural Mosaic	-	60729.86	60729.86	2,33
	Total	**2,294,164.63**	**313,405.75**	**2,607,570.38**	**100**

IPCC change classes of Paraguay 2000-2016		Area (ha)			Percentage (%)
		Western region	Eastern Region	Paraguay	
2011-2013	Changes Forestland to Implanted pastures	722,414.16	145,974.41	868,388.57	85.88
	Changes Forestland to Agricultural crops	1,462.85	105,101.93	106,564.79	10.54
	Changes Forestland to Other lands	81.51	17.81	99.32	0.01
	Changes that are not changes	138.92	136.77	275.69	0.03
	Changes Forestland to Human Settlements	3,263.99	102.08	3,366.07	0.33
	Changes Forestland to Natural fields	3,429.50	686.71	4,116.21	0,41
	Changes Forestland to Wetlands	1,110.95	1,053.60	2,164.55	0,21
	Change of Forestland to Agricultural Mosaic	-	26231.71	26231.71	2,59
	Total	**731,901.89**	**279,305.03**	**1,011,206.92**	**100**

IPCC change classes of Paraguay 2000-2016		Area (ha)			Percentage (%)
		Western region	Eastern Region	Paraguay	
2013-2015	Changes Forestland to Implanted pastures	598,722.54	29700.52	628,423.06	88.93
	Changes Forestland to Agricultural crops	261.27	62737.12	62998.38	8.92
	Changes Forestland to Other lands	17.08	-	17.08	0,002
	Changes that are not changes	108.07	93.74	201.82	0.03
	Changes Forestland to Human Settlements	640.56	30.43	670.99	0.09
	Changes Forestland to Natural fields	6,051.89	22.70	6,074.59	0,86
	Changes Forestland to Wetlands	3,052.45	10.63	3,063.08	0,43
	Change of Forestland to Agricultural Mosaic	-	5,169.66	5,169.66	0,73
	Total	**608,853.86**	**97764.80**	**706,618.66**	**100**

IPCC change classes of Paraguay 2000-2016		Area (ha)			Percentage (%)
		Western region	Eastern Region	Paraguay	
2015-2016	Changes Forestland to Implanted pastures	151,447.18	7,375.18	158,822.36	93.78
	Changes Forestland to Agricultural crops	91.22	7,763.69	7,854.92	4.64
	Changes Forestland to Other lands	8.79	2,68	11.47	0.01
	Changes that are not changes	7.59	56.62	64.21	0.04
	Changes Forestland to Human Settlements	39.62	124.70	164.31	0.10
	Changes Forestland to Natural fields	530.45	63.12	593.58	0.35
	Changes Forestland to Wetlands	72.03	686.72	758.76	0.45
	Change of Forestland to Agricultural Mosaic	-	1,083.17	1,083.17	0,64
	Total	**152,196.89**	**17155.89**	**169,352.78**	**100**

5. LIMITATIONS AND RECOMMENDATIONS

It is noteworthy that all those changes constituted such infrastructure roads, embankments, australians tanks and other were classified into the category of either crop or livestock use, taking into account the purpose for which they were implemented.

Changes in the area of Medanos del Chaco ecoregion mostly were classified under the category “Natural fields” unless they belong to another category has been evident.

The areas where the Agricultural mosaics occur, were those that presented the highest degree of difficulty with respect to interpretation and reclassification due to the small size and variable shape of productive units, in addition to the existing agglomeration.

We also have to mention that the high-resolution images are fundamental as support for not having field data that support the data generated by remote sensing, especially in jobs that require a high degree of accuracy. As well as prior knowledge of the tool and especially as regards the spectral responses of different coverages and its contextualization.

It is recommended to submit this work to an assessment of accuracy to validate the results thereof, so as to be able to identify errors and difficulties in classification of different classes, as well as to use them in later work and refine future mapping methodologies.

It would be interesting to support the carrying out of research on analysis of the reflectance values of different categories, in order to obtain approximate ranges to streamline classification processes. As well as on the possibility of making classifications based of periods of drought and rains generally quite marked in the Western Region so as to obtain as homogeneous as possible mosaics.

6. CONCLUSIONS

In terms of surface changes, they were quantified and classified about 5,784,070.40 ha for the period 2000-2016, the 87.85% of these corresponds to the "Implanted pastures" followed by 9.95% of the category "Agricultural crops" and 1.61% of "Agricultural mosaic", the remaining percentage is constituted by the other categories of use, with a total less than 1% of the classified area.

The category "Implanted pastures" stands out among the others, as this has a marked influence on the total of results both at the regional and national levels. However, this denotes an alarming situation of deforestation and forest conversion, especially in the Western Region.

It is important to mention the usefulness of the implemented methodology in this work, which is focused on generating data for classification, as at this stage of the work to obtain recent and regular information on changes afflicting the territory. On this point becomes visible the importance of programs such as Landsat which provides remote data free of charge and with a time resolution that enables a periodic and relatively short monitoring depending on clemency nothing more than the weather.

It is essential to have this kind of monitoring tools, particularly with regard to Paraguay in its capacity as producer of food and consequently dependent on the use of the territory, with which the availability of accurate and updated information on the uses and coverage available is imperative, so that informed decisions can be made on technical basis for rational use of resources.

Finally, it should be mentioned that this consultancy has mainly been a tool of deep learning and encouraged interest in research and generation of data and information of relevance, through various methodologies and processes that were elucidated in the course of the same.

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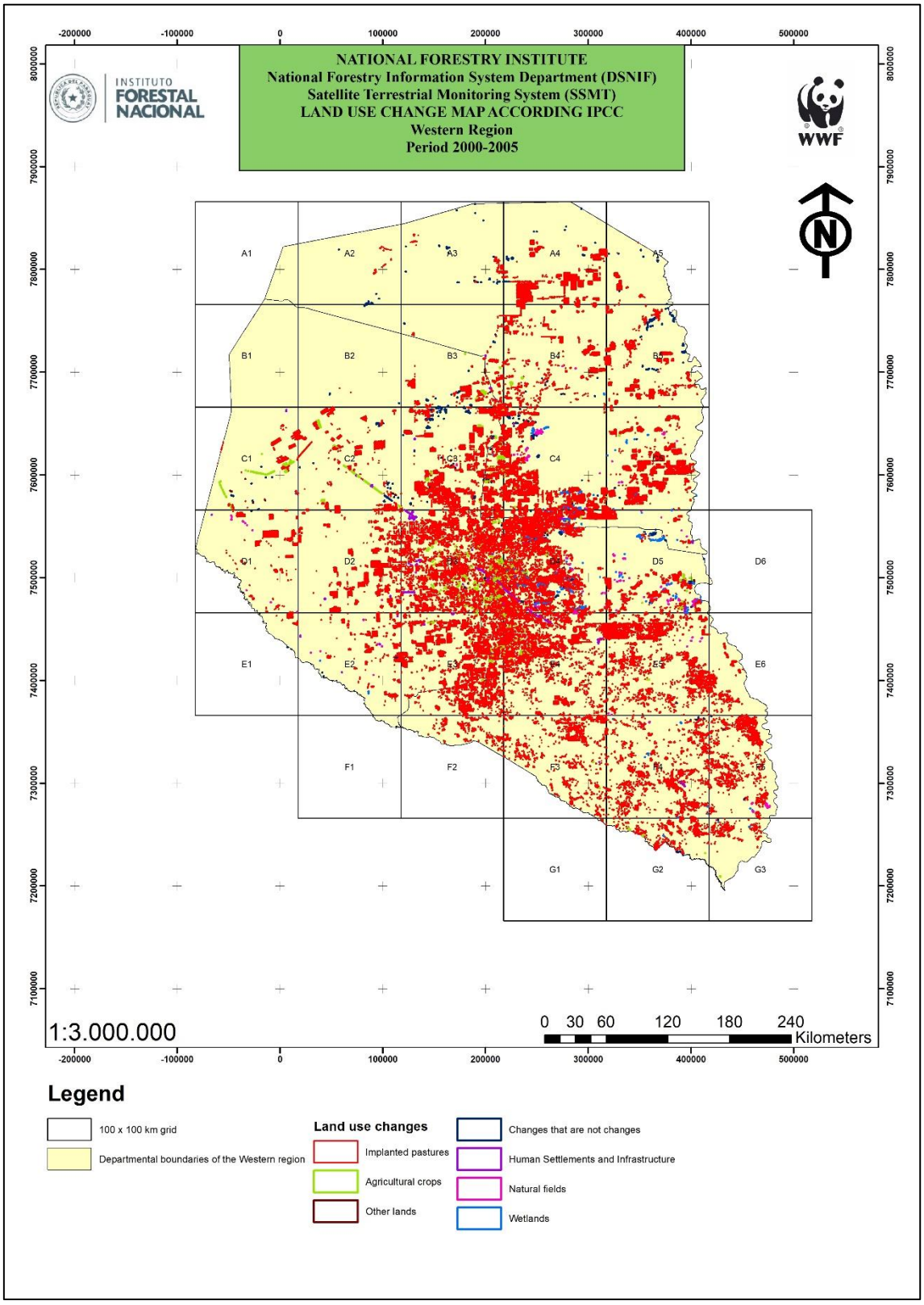
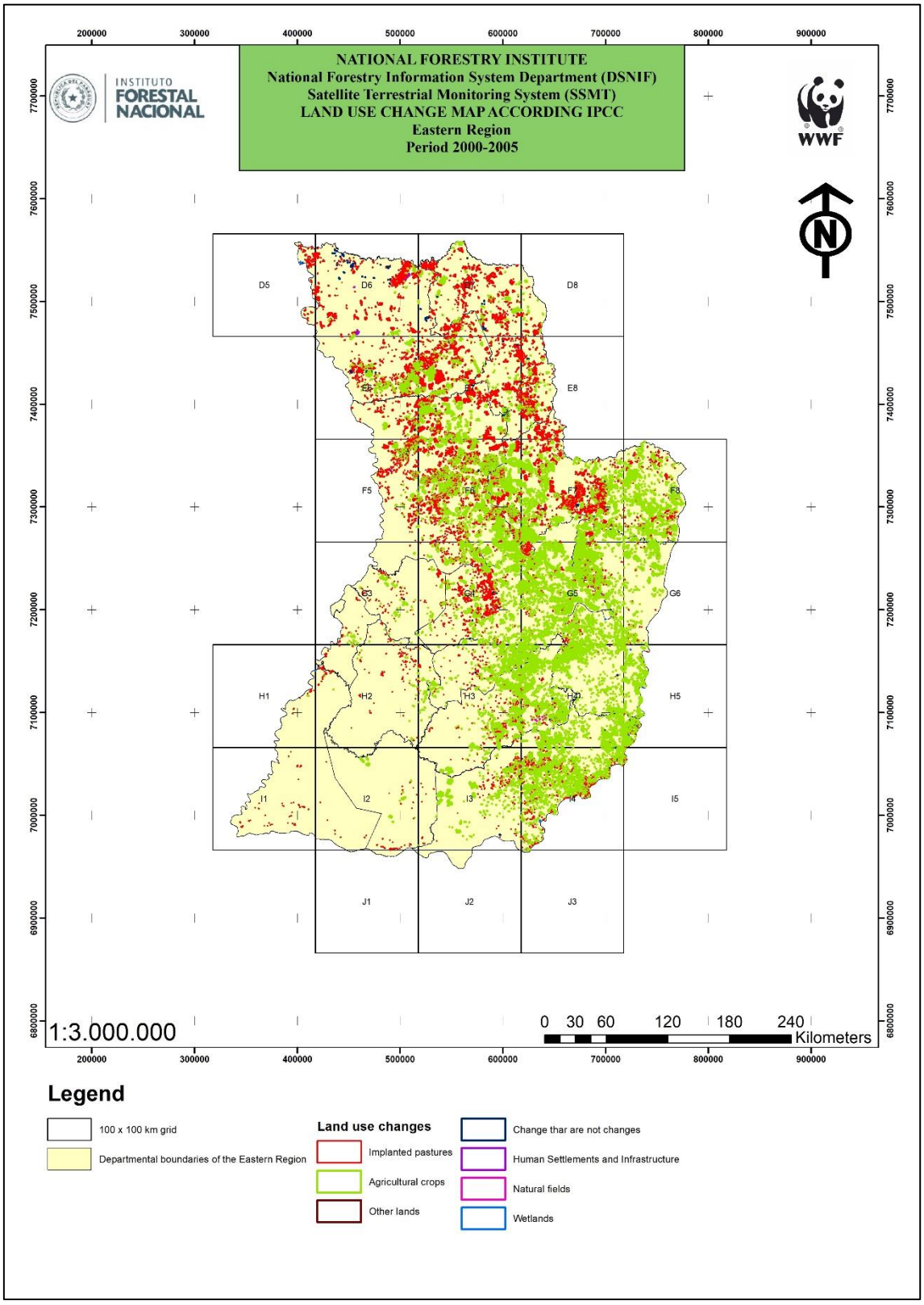
ANNEXES

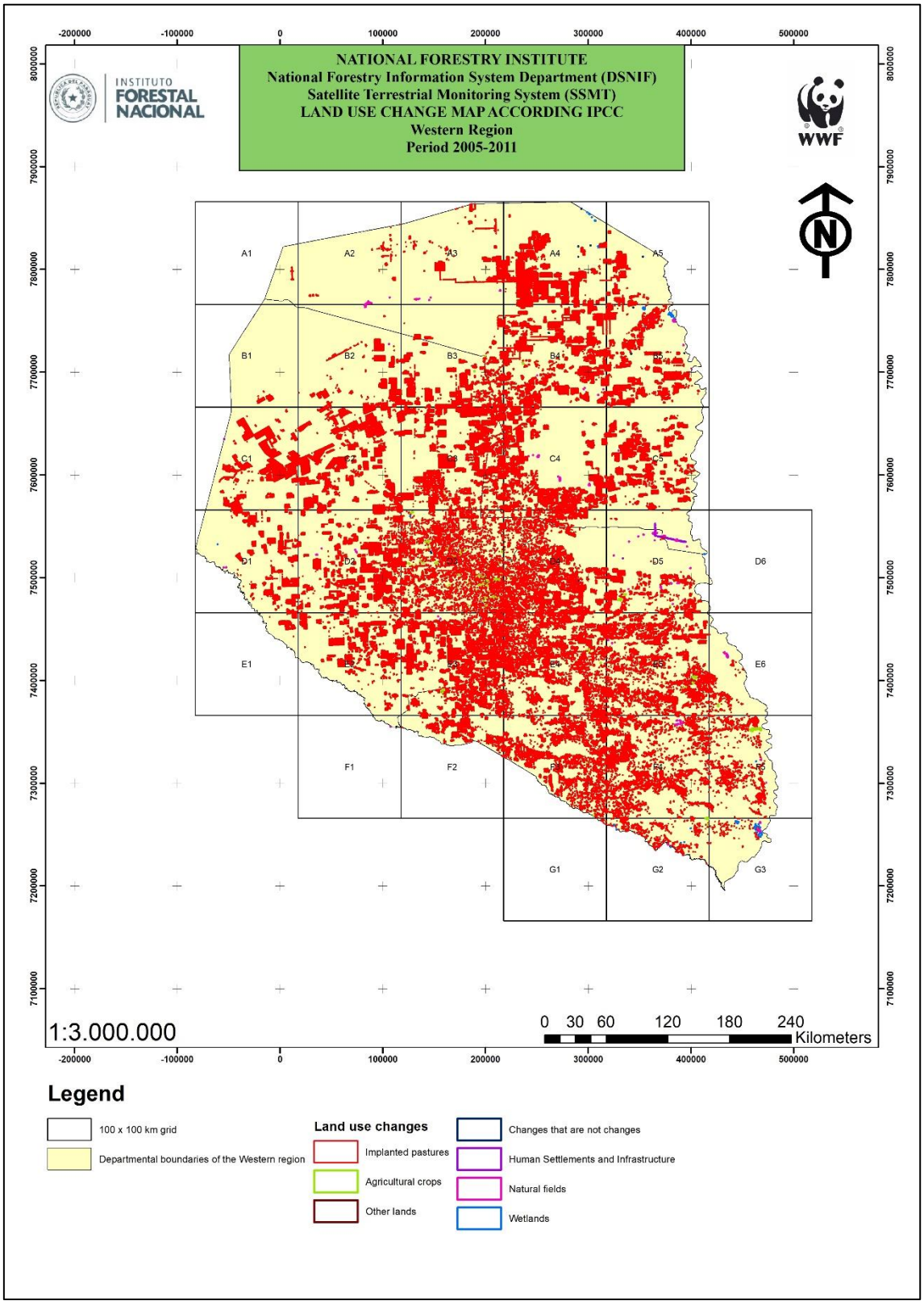
Annex 1. Land use change map according to IPCC period 2000-2005 (Western Region)



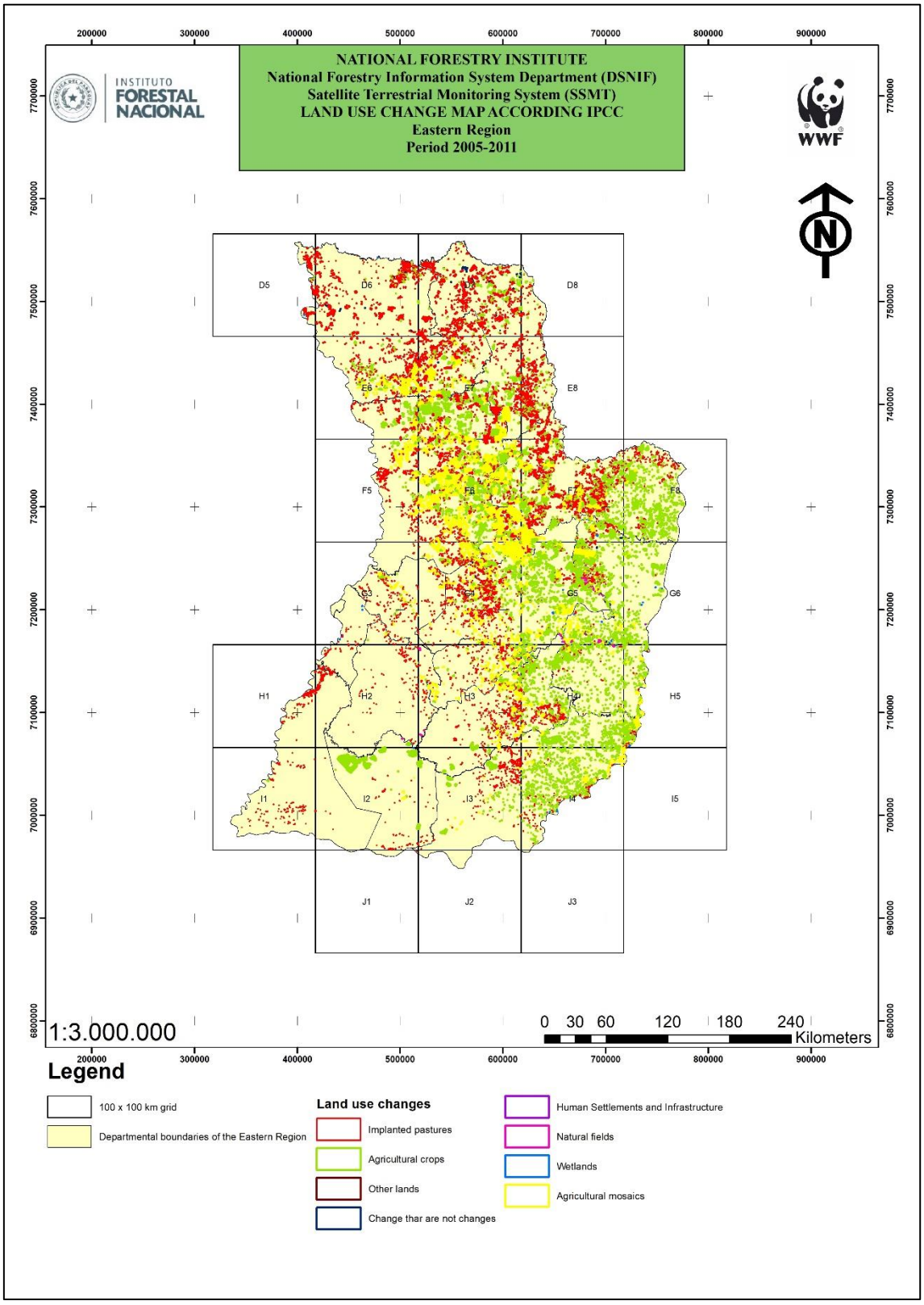
Annex 2. Land use change map according to IPCC period 2000-2005 (Eastern Region)



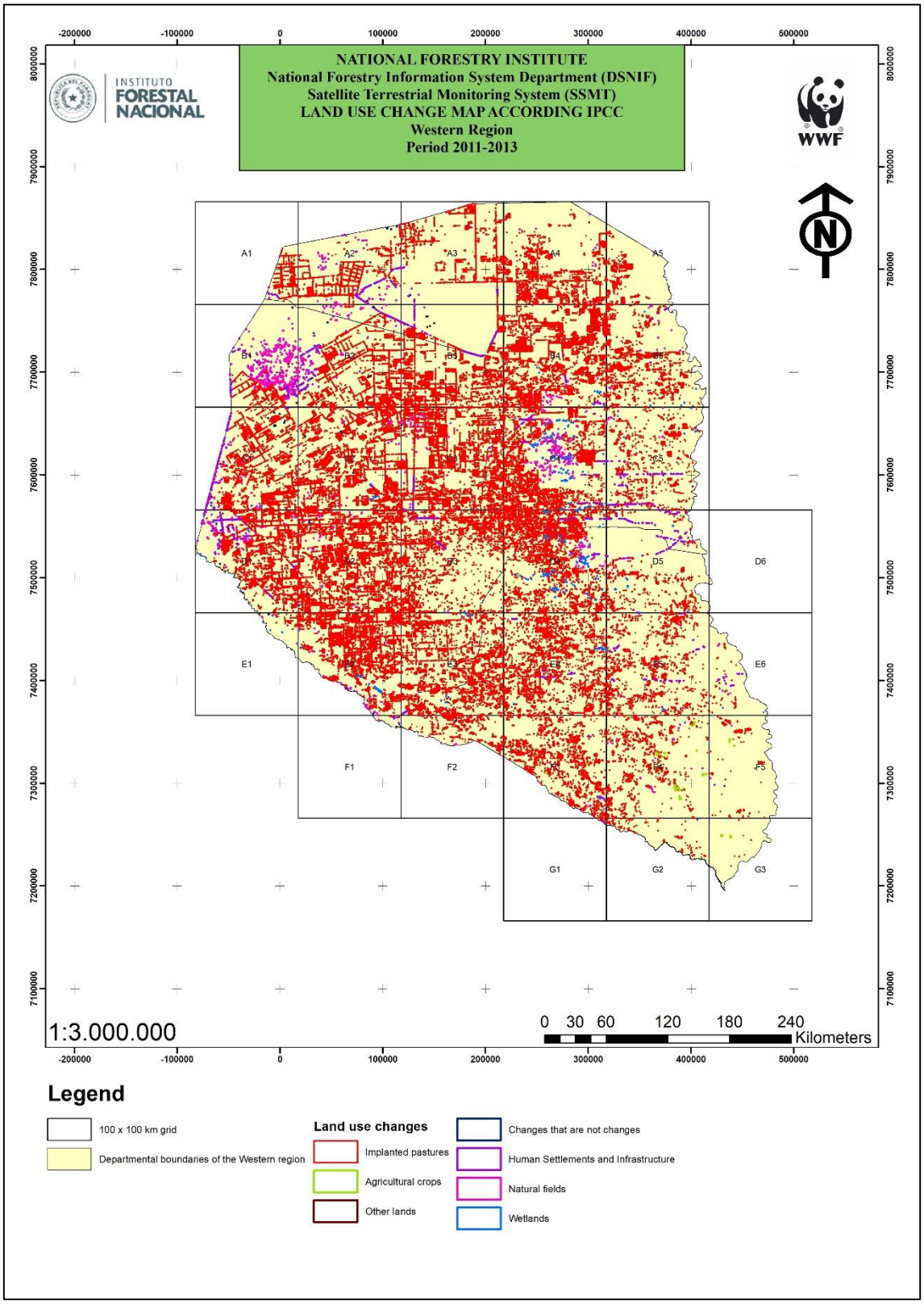
Annex 3. Land use change map according to IPCC period 2005-2011 (Western Region)



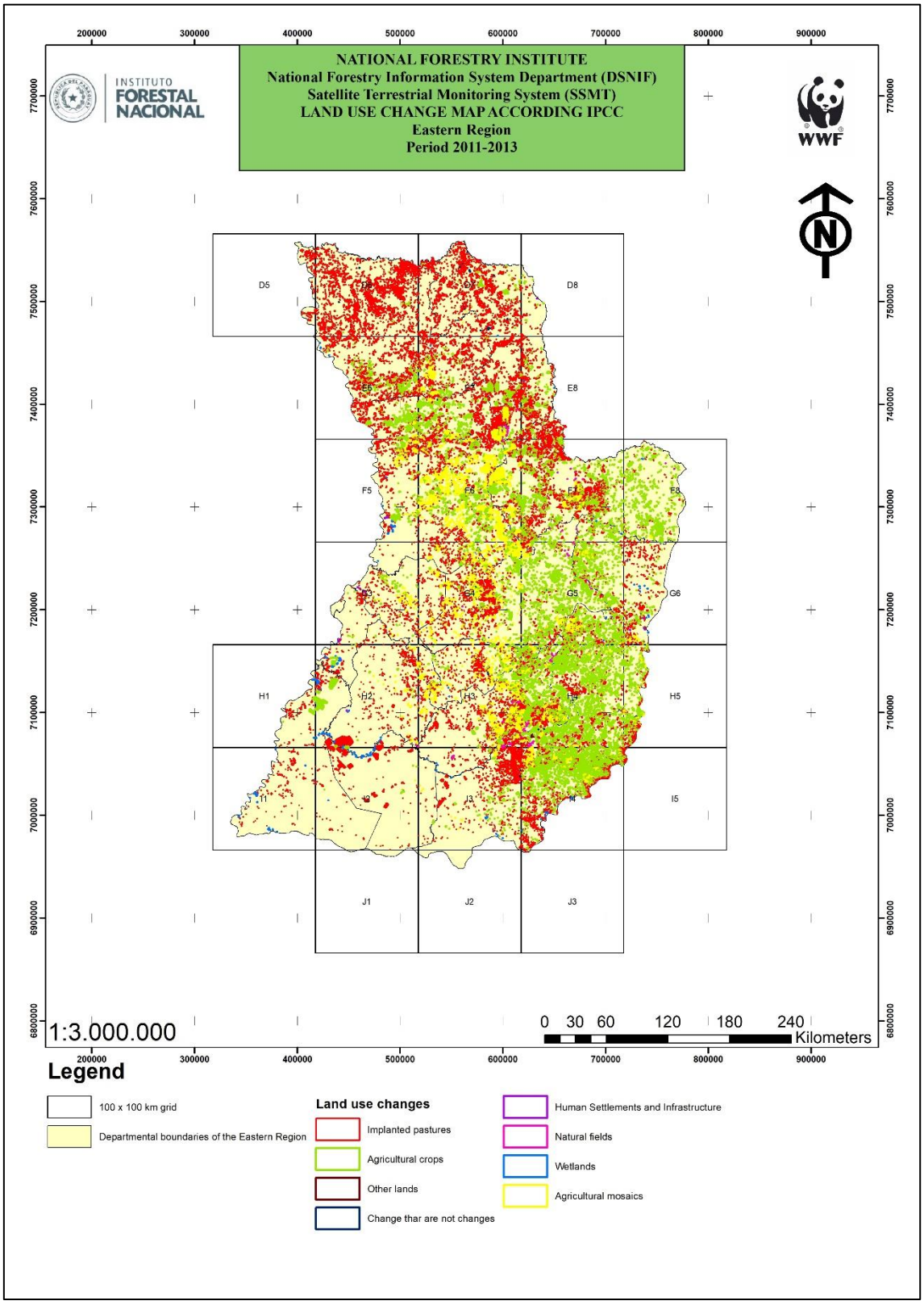
Annex 4. Land use change map according to IPCC period 2005-2011 (Eastern Region)



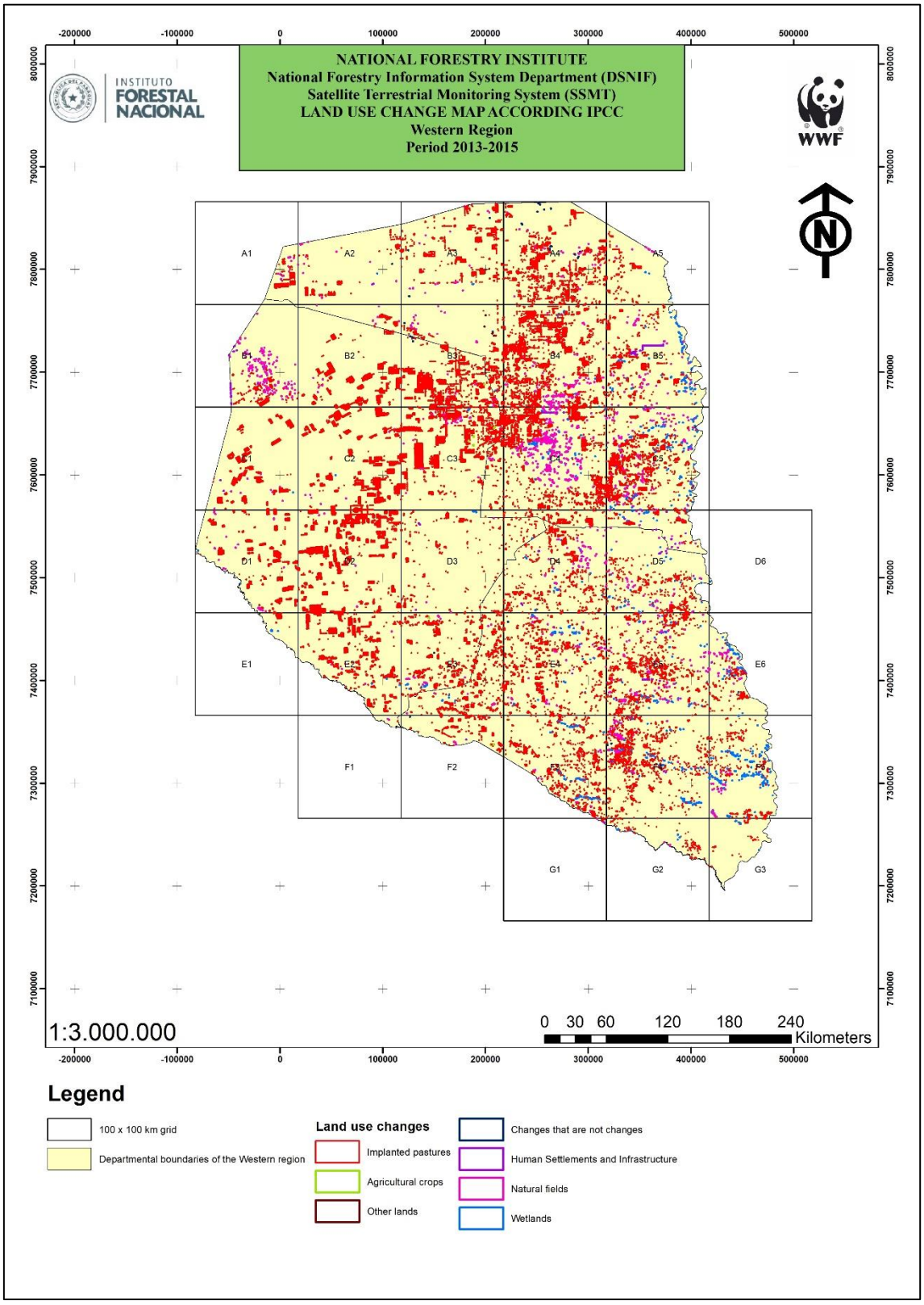
Annex 5. Land use change map according to IPCC period 2011-2013 (Western Region)



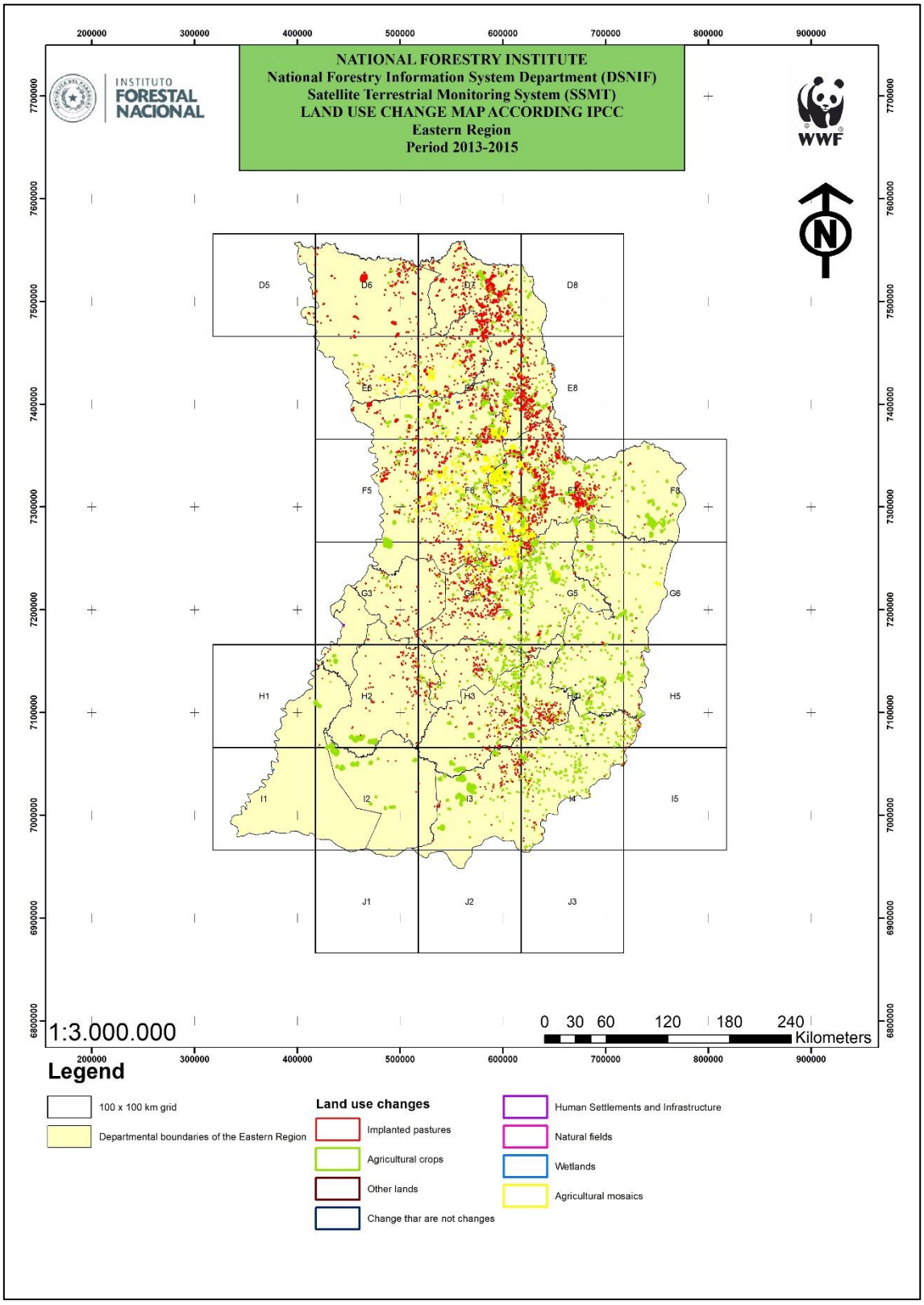
Annex 6. Land use change map according to IPCC period 2011-2013 (Eastern Region)



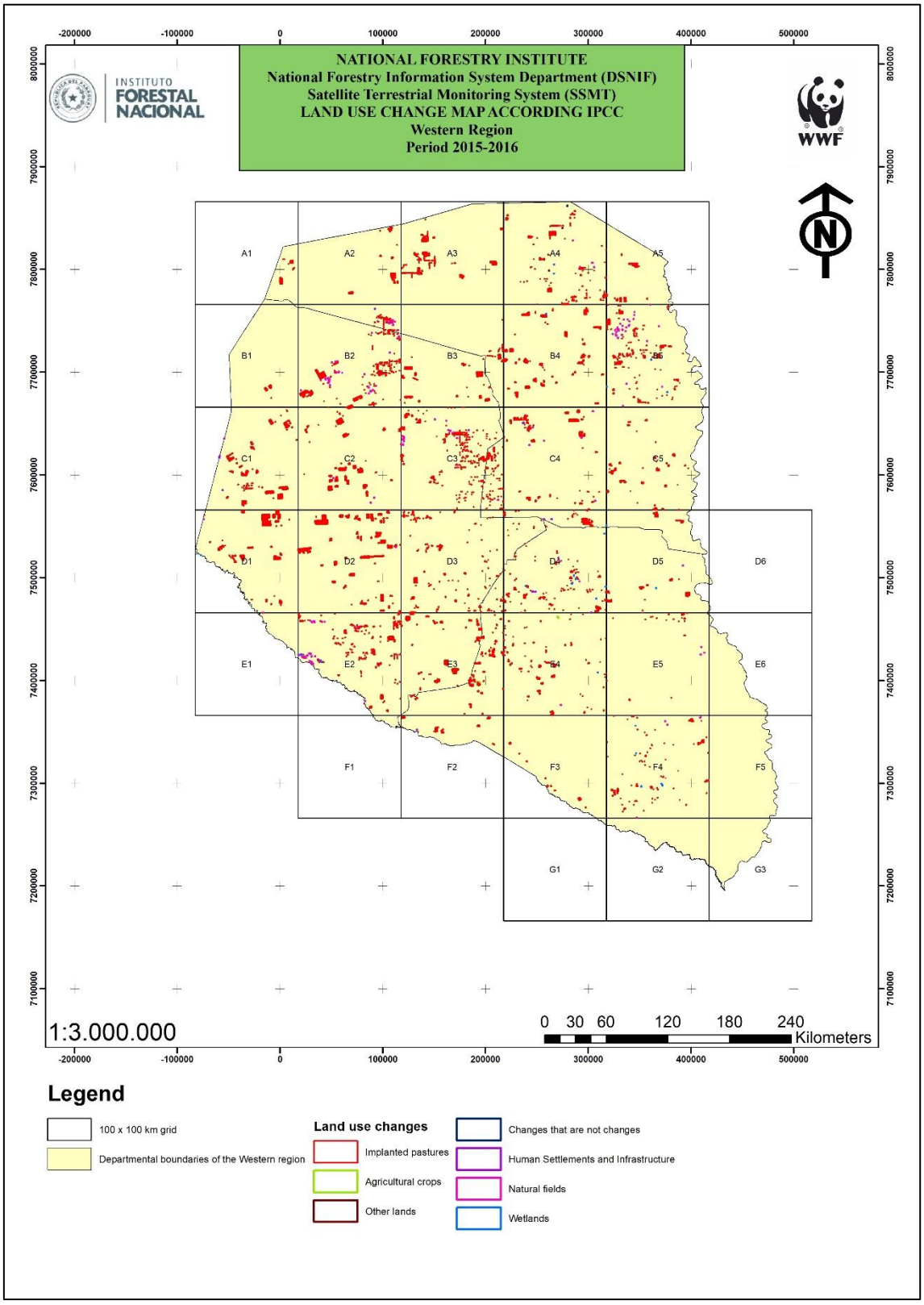
Annex 7. Land use change map according to IPCC period 2013-2015 (Western Region)



Annex 8. Land use change map according to IPCC period 2013-2015 (Eastern Region)



Annex 9. Land use change map according to IPCC period 2015-2016 (Western Region)



Annex 10. Land use change map according to IPCC period 2015-2016 (Eastern Region)