



ROAD IMPACT ON HABITAT LOSS

TRANS-CHACO ROAD IN PARAGUAY

2000 to 2010

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March 2012

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Executive Summary

The following document presents a study of the environmental impact generated by the construction and development of the Trans-Chaco road located in the Occidental Region of Paraguay, a region characterized by the Chaco ecosystem.

The Terra-i monitoring system was used to quantify the impact of the road on the ecosystems present in the area. Terra-i is a near-real time monitoring system that mines satellite based rainfall and vegetation data to detect deviations from the usual pattern of vegetation change, which it interprets as possible anthropogenic impacts on natural ecosystems. As Terra-i is based on vegetation index data, it cannot identify the root causes of vegetation change. Therefore, all information on deforestation drivers in this report is derived from secondary sources.

In Paraguay, Terra-i performed habitat status monitoring every 16 days from the 1st January 2004 until the 31th of December 2010. During the 7 years studied it detected a cumulative habitat loss of **1,767,163 hectares**, equivalent to an annual national loss rate of 252,452 ha / year. The departments of Boquerón and Alto Paraguay registered the highest losses, with 1,015,363 hectares and 471,988 hectares lost respectively between the years 2004 and 2010.

The most impacted ecoregion was the Dry Chaco, which registered 93% of the deforestation that occurred in Paraguay during the 10 years analysed. This ecosystem is present in both the departments of Boquerón and Alto Paraguay. Closed Deciduous forests within the Dry Chaco were the most heavily affected ecosystems.

For this road impact analysis, Landsat images were used to complement and calibrate Terra-i detections in the Dry Chaco ecoregion. Using Landsat datasets we calculated a total habitat loss of 545,317 hectares between the years 2000 and 2004. Using Terra-i we calculated a total habitat loss of 1,657,931 between 2004 and 2010. By analyzing the impact in a 20 km buffer zone around the Trans-Chaco Highway, we recorded a total habitat loss of 229,445 hectares during the 10 years studied (2000-2010). In a 100 km buffer around the road other infrastructure present in the region, such as the Pilcomayo River or the network of secondary roads branching out from the Trans-Chaco, increased habitat loss even more.

The main deforestation drivers in the area, according to secondary sources, are a weak regulatory and enforcement framework disconnected from the reality of the country, incentive systems and the indiscriminate conversion of forest to pasture and agricultural land encouraged by higher commodity prices, land colonisation and a near absence of land-use control.

Area of Study

The South American Gran Chaco is a mosaic of environments that encompasses the largest forested area on the continent after the Amazon. Its 1,066,000 km² span four different countries: Argentina (62.19%), Paraguay (25.43%), Bolivia (11.61%) and Brazil (0.77%) (TNC 2006).

The Paraguayan Chaco is an alluvial plain with a semi-arid to sub-humid climate (500 to 1,300 mm of annual rainfall in summer incidence), subdivided into dry and wet zones. The semi-arid High Chaco is characterized by a xerophytic forest, deciduous and thorny vegetation and soils of a silty-clay texture. The central part of the Chaco has colmated paleochannels of sand and silt, which form regosols in 15% of the total area. In contrast, the sub-humid lower Chaco is partially flooded and is a mixture of temporarily flooded grasslands and palm groves on one side, and topographically elevated residual forests on the other. The Trans-Chaco road is located in the north of this ecoregion.

The Trans-Chaco highway runs north-west from Asuncion, the capital of Paraguay, between the coordinates 21°40'21.15''S, 62°27'31,24''W and 22°37'09.01''S, 59°47'41,23''W.

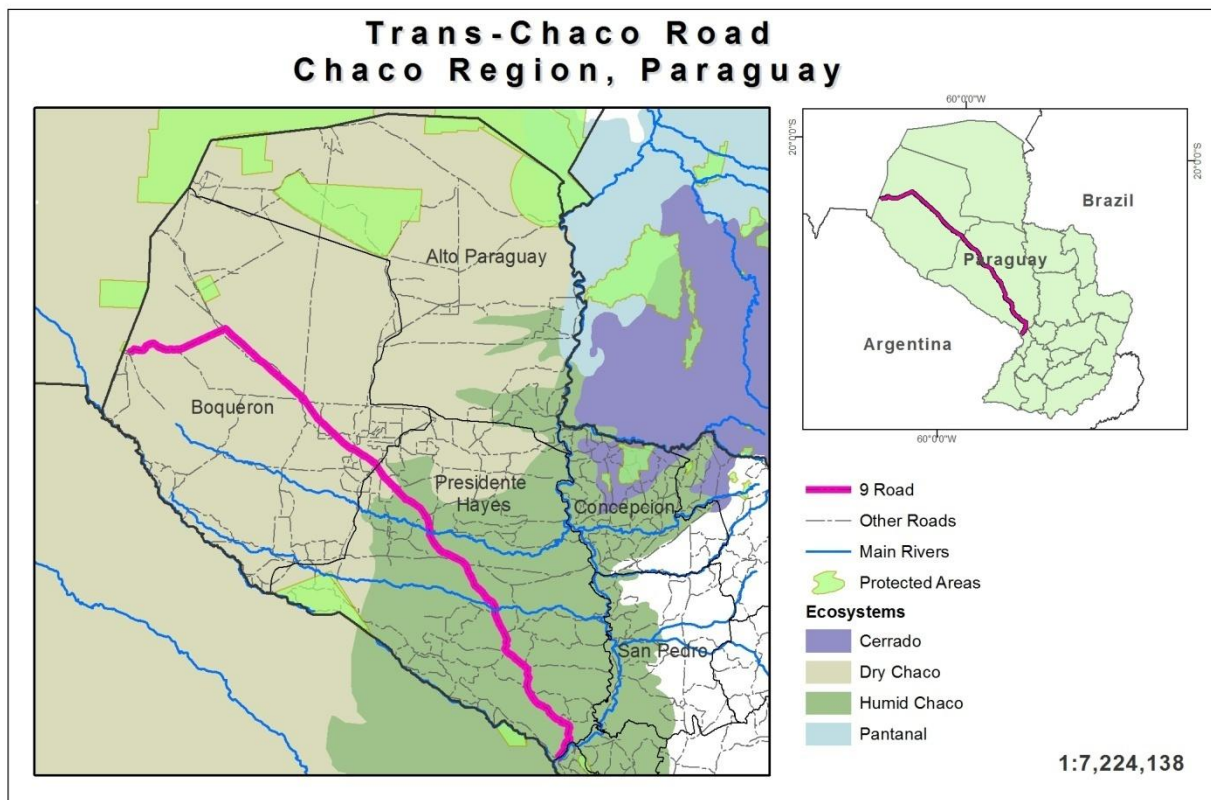


Figure 1. Study Area: Trans-Chaco Road in Paraguay.

Its is approximately 736 kilometers in length, extending from the boundary between Bolivia and Paraguay near the military post Mayor Infante Rivarola in the department of Boquerón until it intersects with the 9th Road. It then runs through the Dry Chaco in Boquerón, continues through the department of Presidente Hayes, crosses the humid Chaco region, and finally ends in the Asuncion metropolitan area in the Central Department.

Paraguay contains only 24 protected areas. Its system is insufficient to protect critical environmental areas, when according to international standards all countries should have at least 10% of their territory under protection. The Paraguayan Chaco hosts 4 national parks: Defensores del Chaco (720,000 Ha), Tinfunqué (280,000 Ha), Teniente Enciso (40,000 Ha), Rio Negro (30,000 Ha) and the Natural Cerro Cabrera-Timáne Reserve.

Habitat Change Monitoring

Paraguay Monitoring

Terra-i is a near-real time monitoring system that mines satellite based rainfall and vegetation data to detect deviations from the usual pattern of vegetation change, which it interprets as possible anthropogenic impacts on natural ecosystems. The model uses a multilayer Perceptron (MLP) neural network combined with Bayesian theory (MacKay 1992) (Bishop 2002) to identify abnormal behaviour in a time-series of vegetation change. The implementation of the system pan-tropically is a considerable challenge from a computer science perspective, as the resolution of the MODIS sensor (250m) means that even the Amazonian basin alone represents more than one billion individual values for each time-frame (every 16 days).

In Paraguay, Terra-i performed habitat status monitoring every 16 days from the 1st January 2004 until the 31th of December 2010. During the 7 years studied it detected a cumulative habitat loss of **1,767,163 hectares**, equivalent to an annual national loss rate of 252,452 ha / year.

Table 1. Habitat Loss in Paraguay by department, Terra-i detection.

| Department | %NoData | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Accum | Annual Rate |
|------------------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------------------|----------------|
| Alto Paraguay | 0% | 15,606 | 41,575 | 37,975 | 74,744 | 65,394 | 80,188 | 156,506 | 471,988 | 67,427 |
| Alto Parana | 1% | 7,538 | 3,869 | 1,925 | 4,013 | 1,156 | 1,244 | 681 | 20,425 | 2,918 |
| Amambay | 0% | 1,069 | 869 | 363 | 638 | 650 | 81 | 131 | 3,800 | 543 |
| Boqueron | 0% | 48,688 | 68,206 | 72,781 | 169,306 | 112,444 | 332,344 | 211,594 | 1,015,363 | 145,052 |
| Caaguazu | 0% | 2,281 | 875 | 419 | 1,381 | 225 | 350 | 538 | 6,069 | 867 |
| Caazapa | 0% | 1,469 | 1,131 | 413 | 575 | 1,019 | 1,219 | 569 | 6,394 | 913 |
| Canindeyu | 0% | 8,663 | 6,069 | 1,125 | 5,081 | 2,175 | 781 | 1,263 | 25,156 | 3,594 |
| Central | 0% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Concepcion | 0% | 19 | 0 | 25 | 294 | 50 | 100 | 6 | 494 | 71 |
| Cordillera | 0% | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 1 |
| Guaira | 0% | 0 | 0 | 38 | 13 | 6 | 0 | 0 | 56 | 8 |
| Itapua | 5% | 4,706 | 3,100 | 1,769 | 1,325 | 875 | 1,281 | 563 | 13,619 | 1,946 |
| Misiones | 0% | 44 | 6 | 19 | 19 | 0 | 6 | 63 | 156 | 22 |
| Neembucu | 0% | 88 | 0 | 0 | 0 | 6 | 175 | 25 | 294 | 42 |
| Paraguari | 0% | 0 | 0 | 0 | 31 | 0 | 88 | 0 | 119 | 17 |
| Presidente Hayes | 0% | 10,644 | 13,531 | 17,594 | 53,581 | 24,363 | 52,719 | 24,688 | 197,119 | 28,160 |
| San Pedro | 0% | 1,381 | 1,019 | 613 | 1,694 | 825 | 356 | 219 | 6,106 | 872 |
| Total | 7% | 102,194 | 140,250 | 135,056 | 312,694 | 209,188 | 470,938 | 396,844 | 1,767,163 | 252,452 |

The departments of Boquerón and Alto Paraguay were the most heavily impacted, losing 1,015,363 hectares and 471,988 hectares respectively between 2004 and 2010.

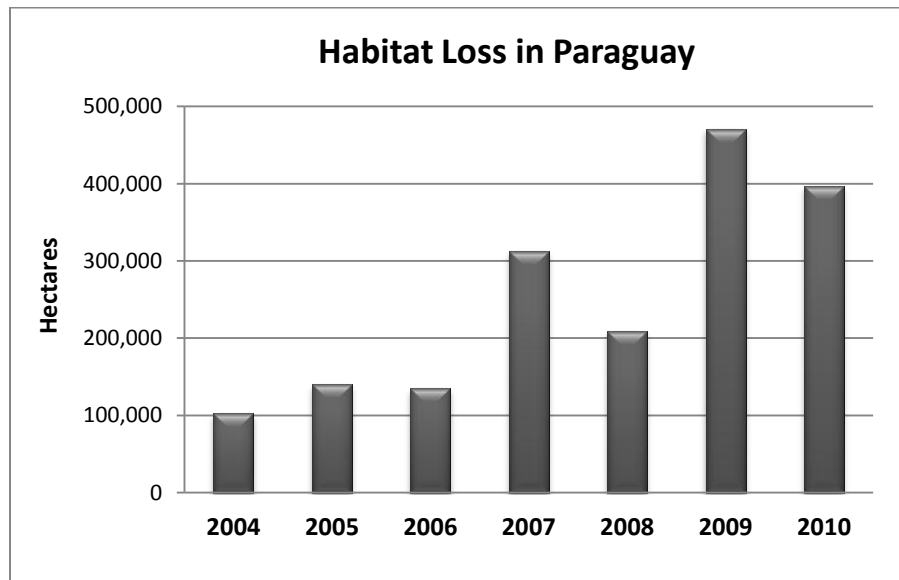


Figure 2. Habitat Loss in Paraguay per year, Terra-i detection.

According to a study conducted by the WWF in the year 2011, some of the drivers of deforestation in Paraguay are:

- Contradictory laws which are disconnected from the reality of the country,
- Indiscriminate conversion of forest to pasture and agricultural land driven by population growth, land colonization and a near absence of land-use control, and exacerbated by the weakness of government institutions in implementing forest law (due to low budgets, poor salaries and under-valued human resources),
- Lack of governance within the state institutions charged with the administration of forest resources, and impunity against prosecution for those who can afford it,
- Inadequate forest management, with policy being geared exclusively towards the exploitation of forested resources, and the absence of a 'forest police force' to ensure compliance with forest laws,
- Poorly conceived incentives for loans, and the financing of agricultural development without requiring an evaluation of environmental impact analyses (EIA), and,
- Lack of public knowledge and appreciation for the importance and value of the forests beyond their economic potential, resulting in forested lands being sold at low prices and massive over-development of agriculture and ranching.

Dry Chaco Monitoring

Two data sets were used to monitor changes in the Dry Chaco ecoregion. Images from the high spatial resolution satellite Landsat 4 Thematic Mapper Sensor were used to detect the deforestation events between 2000 and 2004. The Terra-i system was used to detect deforestation events between 2004 and 2010. By combining these two datasets we were able to calculate the total deforestation between 2000 and 2010 in the Dry Chaco ecoregion through which the Trans-Chaco Highway passes.

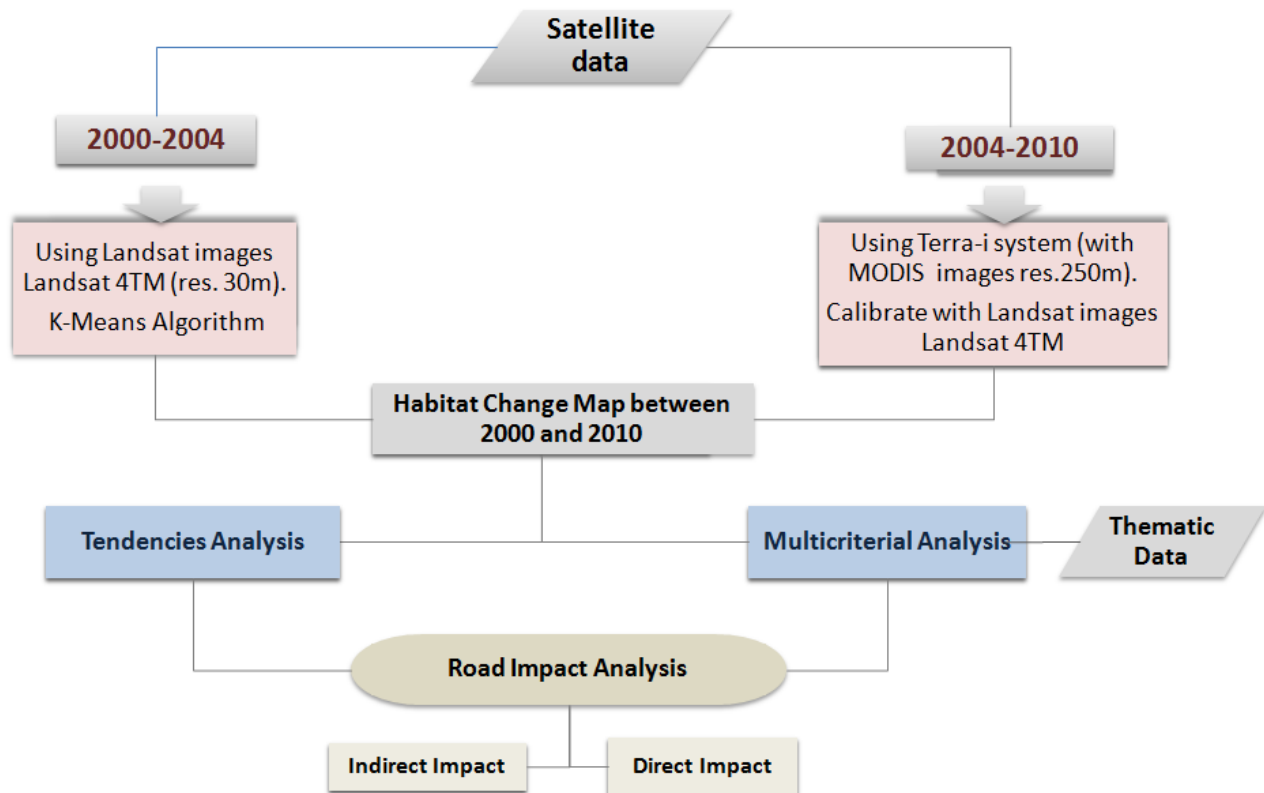


Figure 3. Change Detection Methodology.

Dry Chaco Habitat Loss from 2000 to 2004 using Landsat

Images from the high spatial resolution Landsat 4 Thematic Mapper Sensor were used to detect vegetation changes between the years 2000 and 2004. 12 images from 6 Landsat 4 tiles were downloaded, covering most of the Dry Chaco ecoregion in Paraguay. 80% of the of the 18,000,000 hectares that constitute the Paraguayan Dry Chaco were analyzed using Landsat images, as shown in Figure 4.

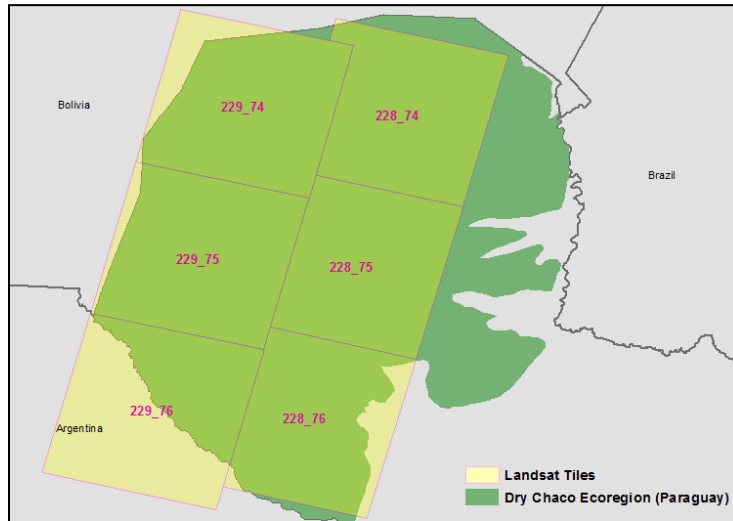


Figure 4. Landsat tiles download for the study.

These Landsat images were first clustered into different groups of similar pixels using the unsupervised K-Means Algorithm. Then, using the ArcGIS software, the resulting cluster was manually classified into two land cover maps for the years 2000 and 2004.

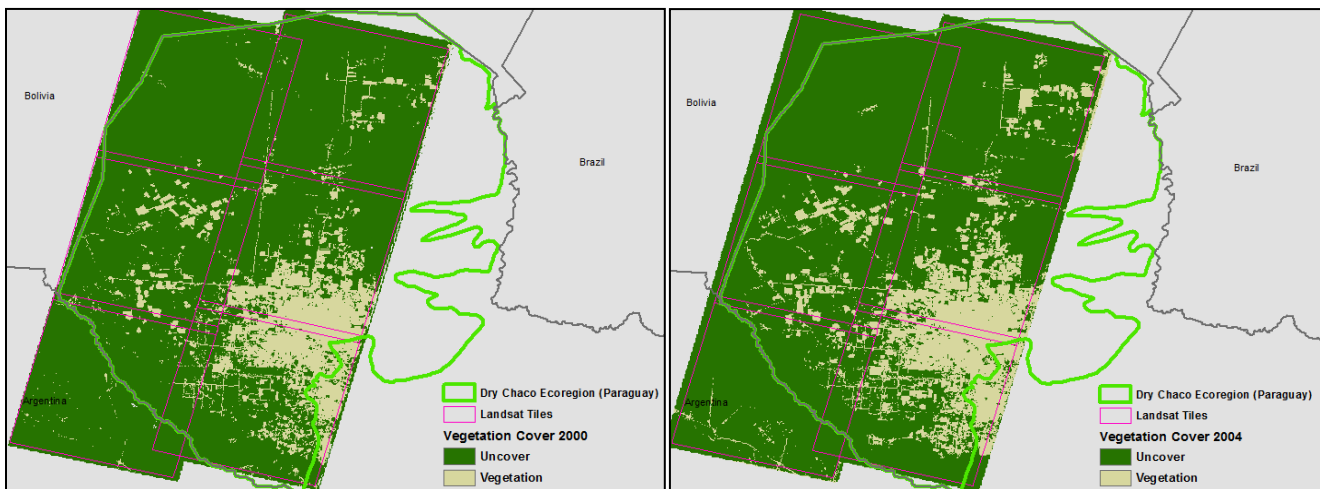


Figure 5. Vegetation Cover Map from 2000 and 2004.

With these maps it was possible to create a map of the deforestation that occurred between the years 2000 and 2004: a total of **545,317 deforested hectares**.

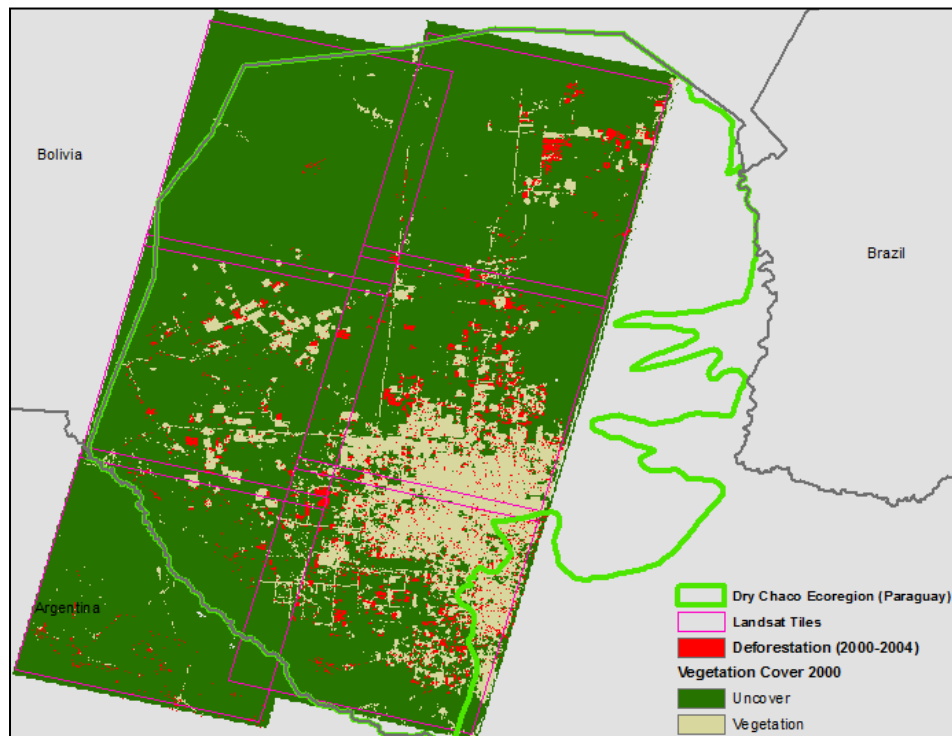


Figure 6. Map of the deforestation detection 2000-2004 using Landsat data in the Dry Chaco.

Dry Chaco Habitat Loss from 2004 to 2010 using Terra-i

The Terra-i system was used to detect habitat changes between 2004 and 2010 in the Dry Chaco Ecoregion. Terra-i detected a total deforested area between the years 2004 and 2010 of **1,657,931 hectares**, equivalent to an annual average rate of 236,847 hectares per year.

Table 2. Habitat Loss in Paraguay by Ecoregion, Terra-i detection.

| Department | % Area | %NoData | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Accum | Annual Rate |
|------------------|-------------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------------------|----------------|
| Alto Parana Atla | 22% | 0% | 26,075 | 16,519 | 6,369 | 14,156 | 6,475 | 5,219 | 3,925 | 78,738 | 11,248 |
| Cerrado | 2% | 0% | 906 | 394 | 238 | 425 | 313 | 69 | 44 | 2,388 | 341 |
| Dry Chaco | 44% | 0% | 74,306 | 120,775 | 125,113 | 287,556 | 197,094 | 461,806 | 391,281 | 1,657,931 | 236,847 |
| Humid Chaco | 32% | 1% | 906 | 2,531 | 3,338 | 10,556 | 5,306 | 3,844 | 1,556 | 28,038 | 4,005 |
| Pantanal | 1% | 0% | 0 | 31 | 0 | 0 | 0 | 0 | 38 | 69 | 10 |
| Parana flooded s | 0% | 3% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 100% | 3% | 102,194 | 140,250 | 135,056 | 312,694 | 209,188 | 470,938 | 396,844 | 1,783,181 | 237,758 |

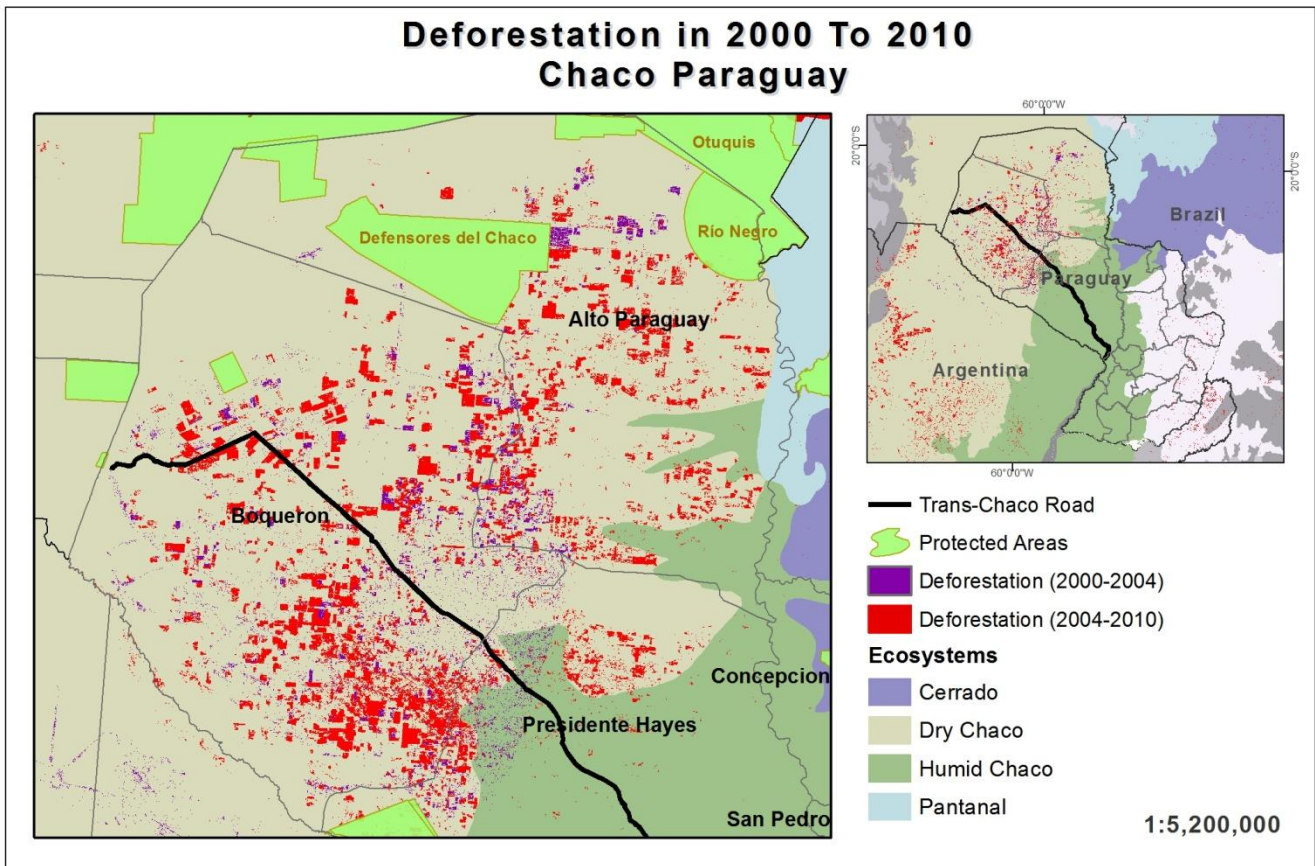


Figure 7. Map of the deforestation detection 2004-2011 using Terra-i system in the Dry Chaco

In summary, **545,317 hectares** of habitat loss were detected in the Dry Chaco Ecoregion using Landsat imagery between the years 2000 and 2004. The Terra-i system (calibrated with Landsat imagery, to be explained in the following section) detected a total of 1,657,931 hectares of habitat loss between the years 2004 and 2010. Cumulatively, this represents a loss of **2,203,248 hectares** between the years 2000 and 2010, equivalent to an average annual rate of **220,325 hectares/year** over 10 years.

Calibration of Terra-i data using Landsat

We used maps of deforestation generated using high spatial resolution images from the Landsat 4 Thematic Mapper Sensor to calibrate Terra-i detections between 2004 and 2010. 12 images from 6 Landsat 4 tiles were downloaded for the years 2004 and 2010. These Landsat images were first clustered into different groups of similar pixels using the unsupervised K-Means Algorithm. Then, using the ArcGIS software, the resulting cluster was manually classified into two land cover maps for the years 2004 and 2011.

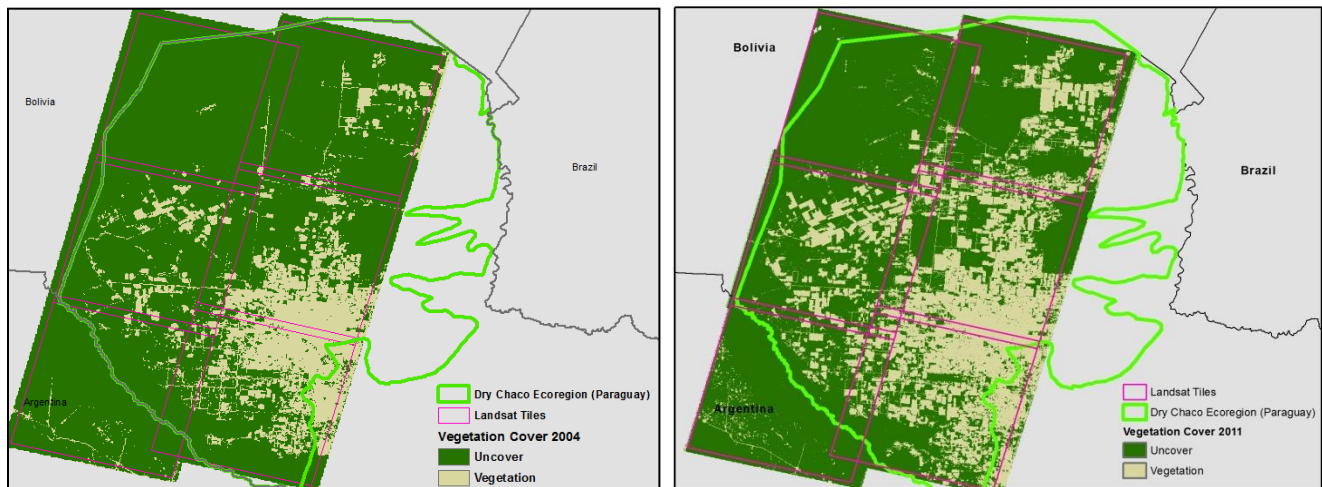


Figure 8. Vegetation Cover Map from 2004 and 2011.

With these results it was possible to create a map with the Landsat resolution of the deforestation that occurred between the years 2004 and 2010: a total of 1,880,636 deforested hectares. We calibrated the Terra-i detection using this set of maps. As described in detail in the Terra-i methodology document, such images are used in order to define the best parameters to run Terra-i models.

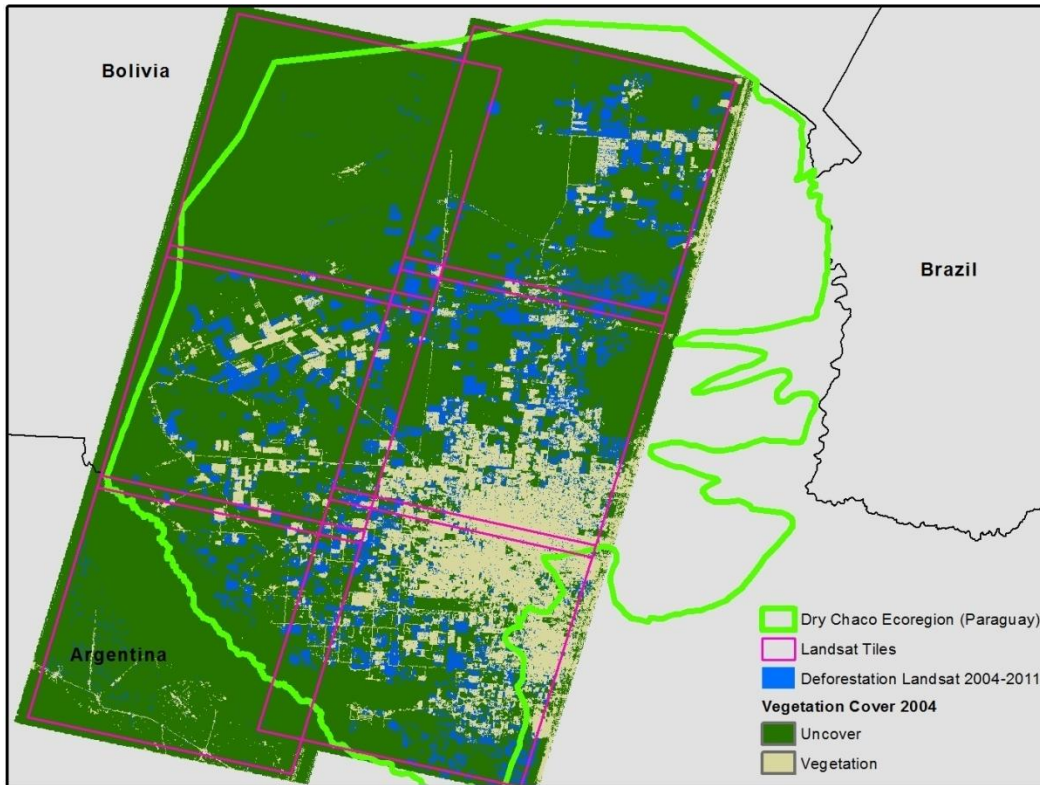


Figure 9. Map of the deforestation detection 2004-2011 using Landsat data in the Dry Chaco.

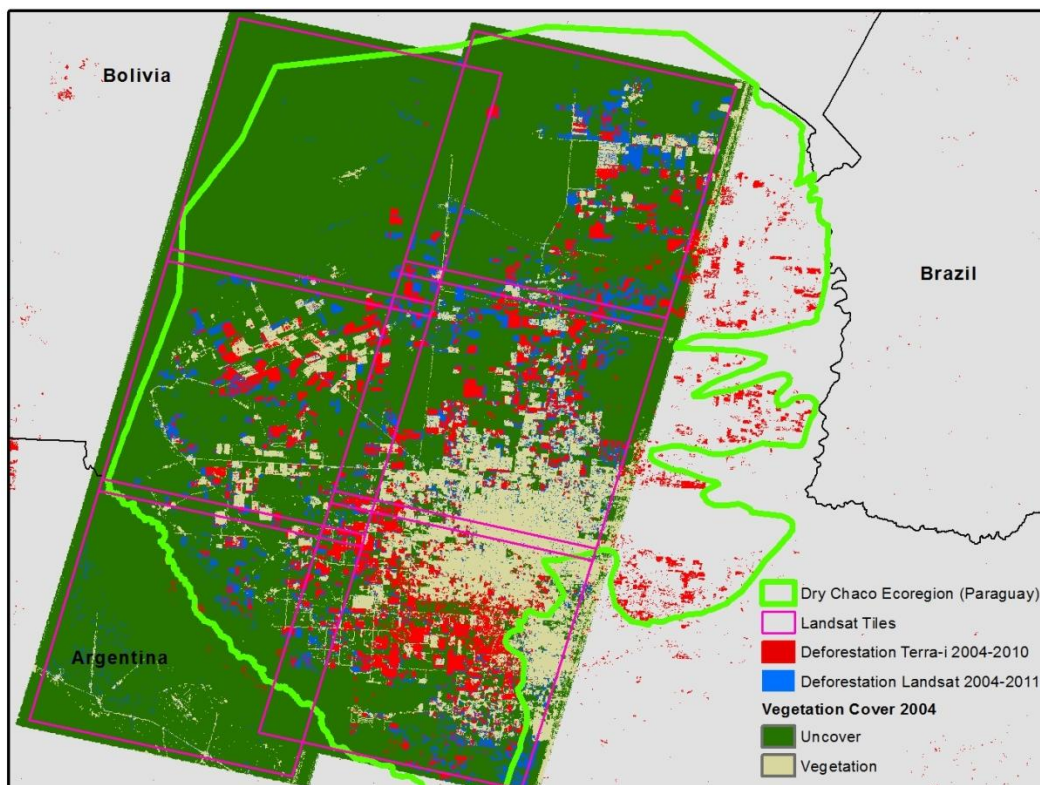


Figure 10. Comparison between Landsat and MODIS deforestation data in the Dry Chaco.

Comparison with other studies

Among the studies of land use changes in the American Gran Chaco is a monitoring initiative developed by the Association GUYRA PARAGUAY, a civil non-profit organization that works to defend and protect the biological diversity of this region and that has monitored land use changes in the South American Gran Chaco since 2010.¹

The GUYRA reported a total of 240,549 deforested hectares in the South American Gran Chaco – of which 201,375 hectares occurred in the Paraguayan Chaco – in the period from January 21st, 2010 to November 26th, 2010. This study was based on images from the medium resolution MODIS sensor (Guyra 2010).

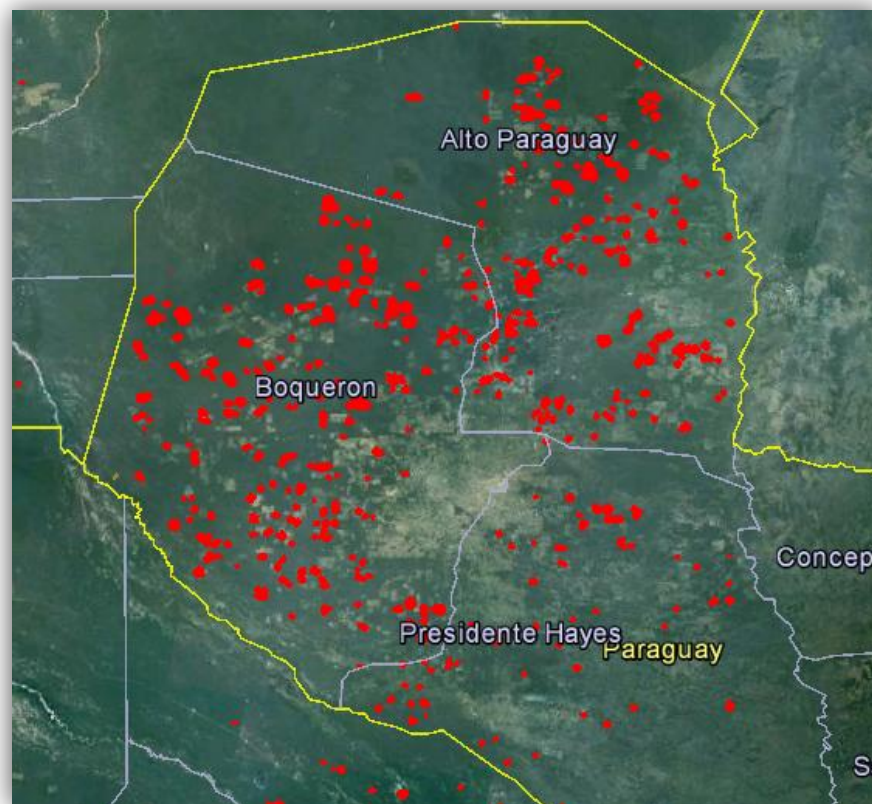


Figure 11. Deforestation detected by the GUYRA in Paraguay between the 21st of January 2010 and the 26th of November 2010.

By comparing the deforestation data generated by GUYRA in the Paraguayan Chaco in 2010 (201,375 hectares) with the average annual rate calculated from the Terra-i data (220,325 hectares/year), and by comparing the distribution of the detection using the map on Figure 7, one can see that the two models are quite similar.

¹ Asociación GUYRA PARAGUAY

<http://www.guyra.org.py/index.php/reportes-de-cambios-de-uso-de-la-tierra-del-gran-chaco-americano>

Ecosystems Impact

According to the Corine Land Cover map in Table 3, the Dry Chaco ecoregion had 54% of its area covered by closed deciduous forests in the year 2000.

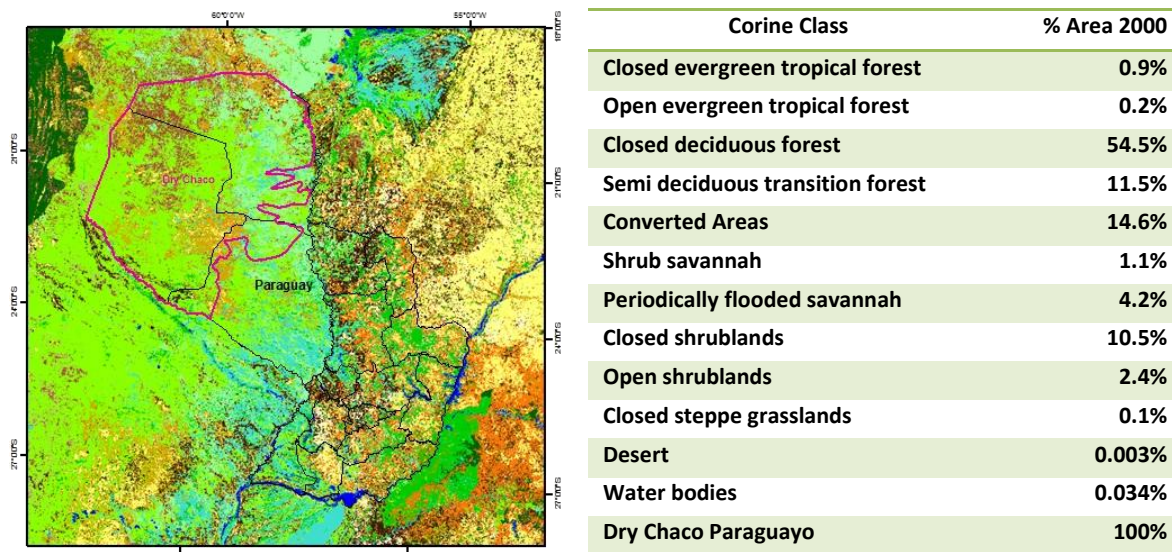


Table 3. Corine Land Cover in the Dry Chaco Ecoregion.

Based on these classes and by taking the raster of deforestation from 2000-2004 and 2004-2010 we calculated which ecosystems were the most impacted. We found that 60% of the total deforestation that occurred between 2000 and 2011 happened in closed deciduous forests and 13% in Semi-deciduous transition forest.

Table 4. Percentage of Change by Ecosystem Type.

| Corine Class | Area | Deforested Hectares (2000-2010) | % of Change |
|--|-----------|---------------------------------|-------------|
| Closed evergreen tropical forest | 142,431 | 14,525 | 10% |
| Open evergreen tropical forest | 41,794 | 2,169 | 5% |
| Closed deciduous forest | 8,780,213 | 1,239,831 | 14% |
| Semi deciduous transition forest | 2,449,306 | 259,181 | 11% |
| Agriculture - intensive | 393,638 | 23,069 | 6% |
| Mosaic agriculture / degraded vegetation | 1,843,475 | 196,581 | 11% |
| Mosaic agriculture / degraded forests | 287,213 | 18,975 | 7% |
| Shrub savannah | 225,594 | 8,769 | 4% |
| Periodically flooded savannah | 647,606 | 86,638 | 13% |
| Closed shrublands | 2,218,663 | 163,950 | 7% |
| Open shrublands | 460,813 | 37,325 | 8% |
| Closed steppe grasslands | 48,013 | 644 | 1% |
| Desert | 475 | 0 | 0% |

Road Impact

The Trans-Chaco Highway has a length of 736 kilometers, beginning at the border between Bolivia and Paraguay and ending in Asuncion, the capital of Paraguay. It crosses the departments of Boquerón and Presidente Hayes.

We analysed deforestation in buffer areas of 10, 20, 30, 40, and 50 km around the Trans-Chaco Highway to determine its impact on the Dry Chaco and Humid Chaco ecosystems.

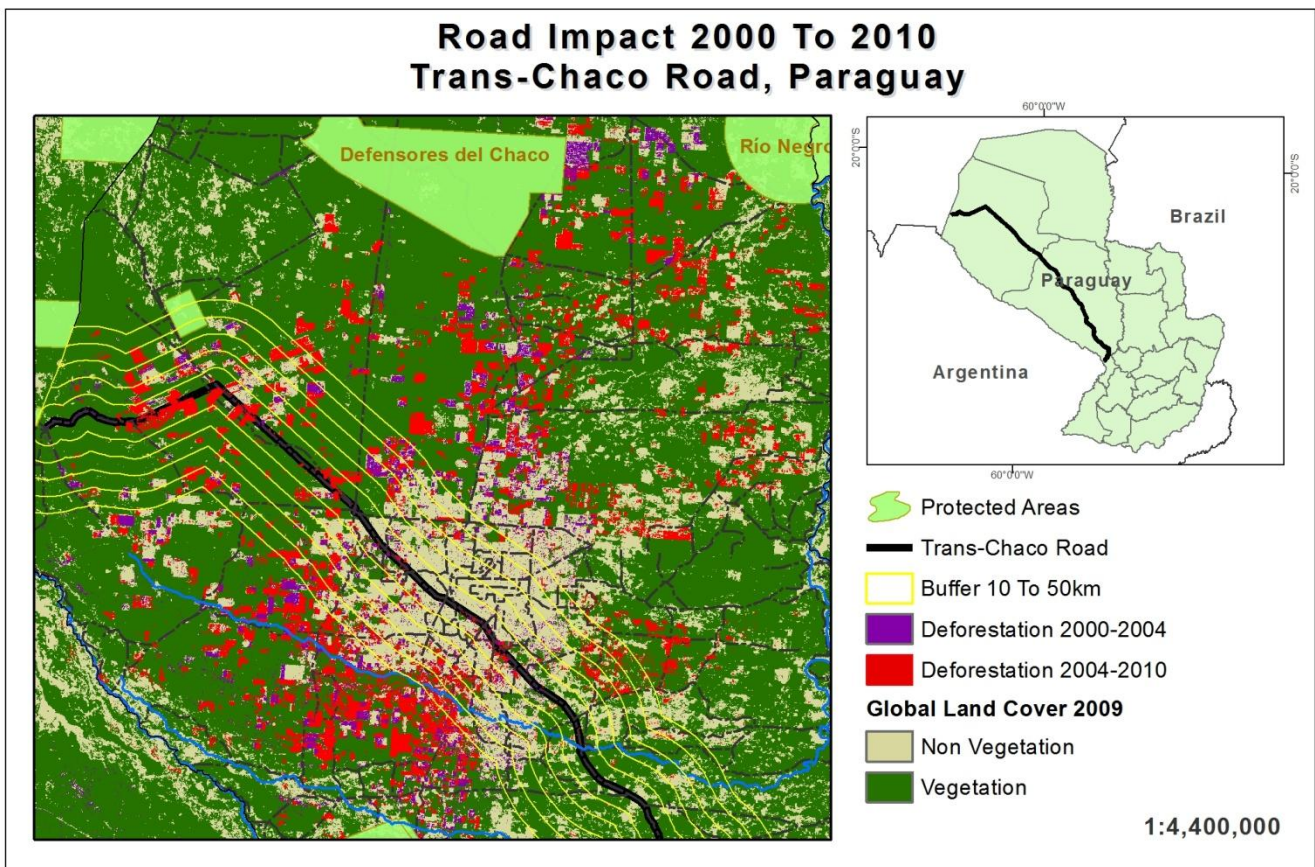


Figure 12. Trans-Chaco Road habitat loss map, Terra-i monitoring (2004-2011).

As shown Figure 15 and Table 5, the buffer zone of 10 km around the trans-Chaco Road registered a total of 133,481 deforested hectares between January 2000 and 2010. The trend in this area is for deforestation to increase over the years, going from 3,075 hectares in 2004 to 28,375 hectares in 2010.

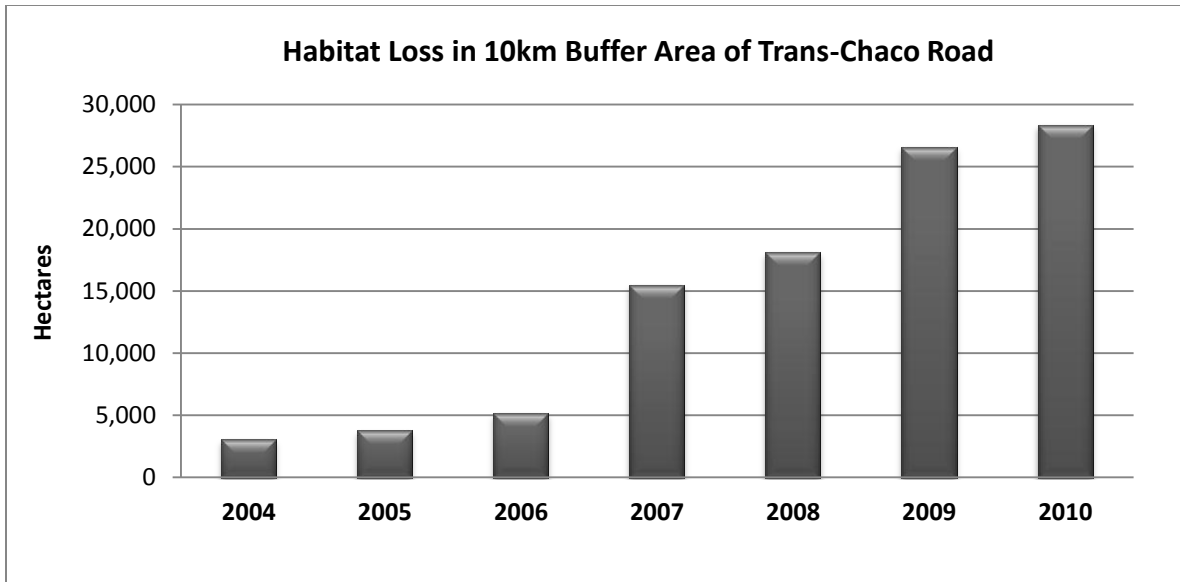


Figure 13. Habitat loss in 10 km Buffer Area of Trans-Chaco Road.

The increase in deforestation rates within a buffer area of 20 to 50 km from the road is due to the presence of the Pilcomayo River located near the Trans-Chaco Road.

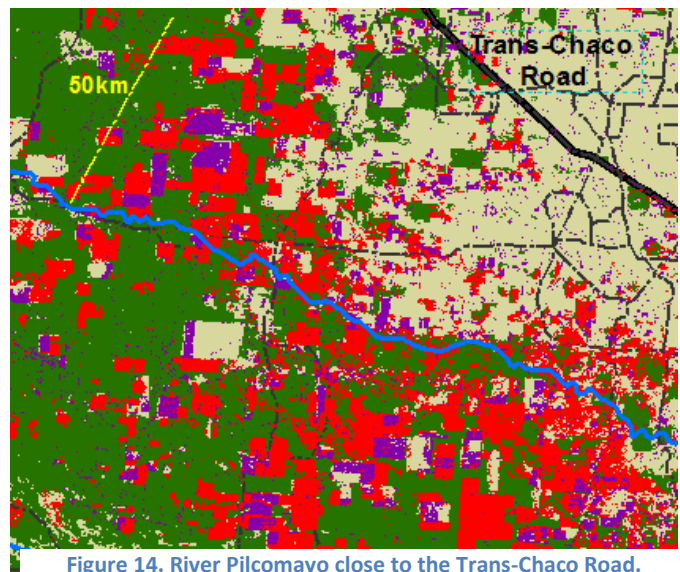


Figure 14. River Pilcomayo close to the Trans-Chaco Road.

Table 5. Annual habitat loss within 50 km from the Trans-Chaco Highway.

| Buffers (km) | 2000-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total Loss |
|--------------|-----------|--------|--------|--------|--------|--------|---------|---------|------------|
| Road to 10km | 32,906 | 3,075 | 3,769 | 5,163 | 15,500 | 18,119 | 26,575 | 28,375 | 133,481 |
| 10km to 20km | 33,927 | 1,719 | 2,800 | 2,350 | 6,038 | 13,300 | 14,556 | 21,275 | 95,964 |
| 20km to 30km | 44,290 | 3,769 | 6,869 | 5,788 | 9,963 | 10,569 | 21,369 | 17,006 | 119,621 |
| 30km to 40km | 46,780 | 4,706 | 6,650 | 7,113 | 20,544 | 7,856 | 31,644 | 21,375 | 146,668 |
| 40km to 50km | 37,173 | 2,775 | 5,638 | 7,156 | 20,056 | 8,363 | 49,750 | 24,894 | 155,804 |
| Area to 50km | 195,076 | 16,044 | 25,725 | 27,569 | 72,100 | 58,206 | 143,894 | 112,925 | 651,538 |

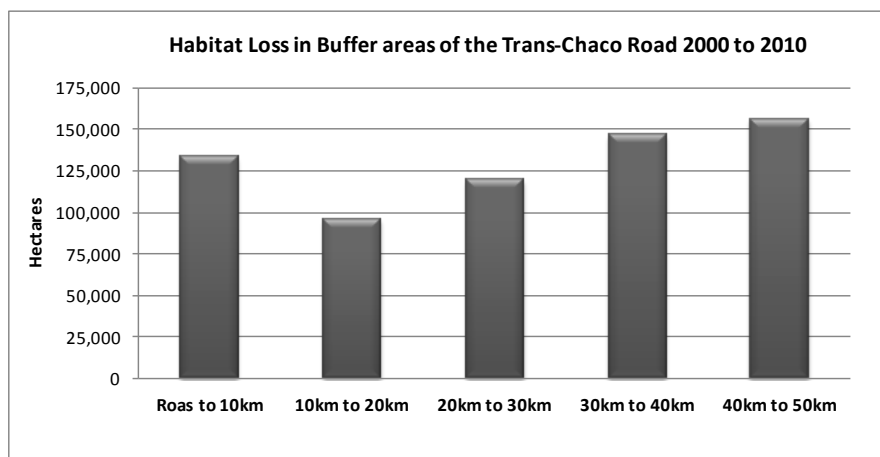
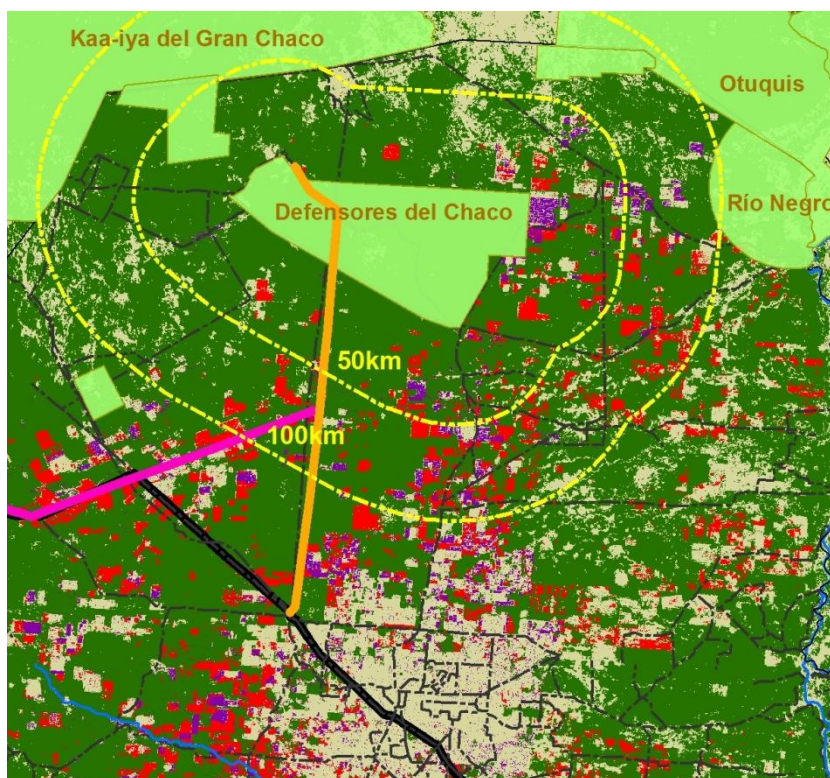


Figure 15. Loss of habitat in the buffer area of Trans-Chaco Highway.



As shown in Figure 15, the impact on habitat can be observed in a buffer area of 0 to 20 km from the road. From there, the strong influence of the network of secondary roads, rivers, and diversity of soils favoring agricultural expansion in the area becomes apparent. Tables 6, 7 and 8 show two others roads that had a great influence on habitat conversion between the year 2000 and 2010. A buffer of 10 km around the road from Mariscal to Estigarriba registered a cumulative habitat loss area of 38,405 hectares, and a 10 to 20 km buffer registered 60,157 hectares.

Table 6 Mariscal - Estigarriba road impact

| Buffers (km) | 2000-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total Loss |
|--------------|-----------|-------|-------|-------|-------|-------|--------|--------|------------|
| Road to 10km | 14,718 | 581 | 2,575 | 1,900 | 2,669 | 1,469 | 3,938 | 10,556 | 38,405 |
| 10km to 20km | 14,444 | 2,406 | 1,919 | 1,269 | 5,519 | 5,444 | 10,300 | 18,856 | 60,157 |

The deforestation rate around the Mariscal – Estigarriba road sharply increased during the year 2010, growing from 3,938 hectares deforested in 2009 in the 10 km buffer zone to 10,556 hectares in 2010.

Another important road in this area is the road linking Mayor Infante and Roble. Table 7 shows that this road registered a cumulative habitat loss area of 100,225 hectares within a buffer area of 10 km around the road, and 70,822 hectares in a buffer area 10 to 20 km from the road.

Table 7: Mayor Infante - Roble road impact

| Buffers (km) | 2000-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total Loss |
|---------------------|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------------|
| Road to 10km | 10,381 | 400 | 1,900 | 2,163 | 12,463 | 15,869 | 24,006 | 33,044 | 100,225 |
| 10km to 20km | 17,322 | 1,238 | 2,088 | 4,181 | 3,838 | 7,181 | 11,663 | 23,313 | 70,822 |

The rate of change around the Mayor Infante – Roble Road sharply increased from 2004 to 2010, from 400 hectares deforested within a 10 km buffer in 2004 to an alarming 33,044 hectares deforested in 2010. This rate is even higher than the one observed in a buffer zone of 10 km around the Trans-Chaco Highway in 2010, which was 28,375 hectares.

Table 8 Trans-Chaco Highway impact

| Buffers (km) | 2000-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total Loss |
|---------------------|------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------------|
| Road to 10km | 32,906 | 3,075 | 3,769 | 5,163 | 15,500 | 18,119 | 26,575 | 28,375 | 133,481 |
| 10km to 20km | 33,927 | 1,719 | 2,800 | 2,350 | 6,038 | 13,300 | 14,556 | 21,275 | 95,964 |

Protected Areas

The Defenders of the Chaco National Park is one of the country's first protected areas, created in 1975 with the purpose of conserving unique and representative samples of the Chaco. It protects the biodiversity, ecological and cultural processes that are critical to the natural balance of the region.²

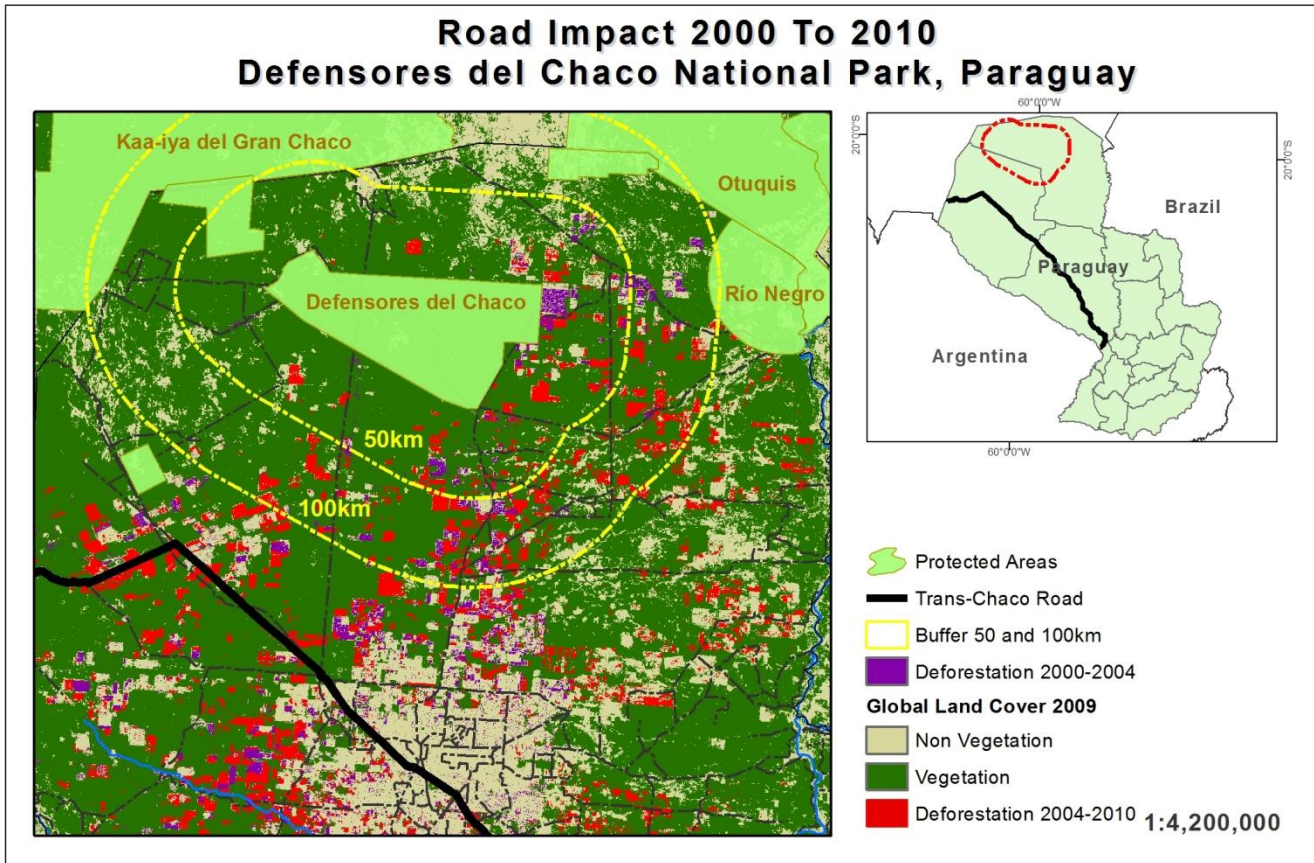


Figure 16. Map of Impact in Defensores del Chaco National Park, Terra-i detection.

Between the years 2000 and 2010 there was a total loss of 107,040 hectares in a buffer area 25 km from the Defensores del Chaco Park with an annual increasing trend; losses grew by 25% from 2007 to 2008 and 50% from 2009 to 2010.

In addition to this alarming rate around the immediate borders of the protected area, we observed a spike in habitat loss in the area between the national park and the Trans-Chaco highway, where the road connecting Mariscal and Estigarriba passes. This increase is demonstrated by an alarming total loss of habitat of 162,134 hectares between the years 2000 and 2010 in a buffer area of 75 to 100 km around the protected area.

² Parque Nacional Defensores del Chaco. http://www.guyra.org.py/gestion_compartida/defensores.php

Table 9. Impact in Defensores del Chaco National Park, 2000 to 2010.

| Buffers (km) | 2000-2004 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total Loss |
|---------------|----------------|---------------|--------------|---------------|---------------|---------------|---------------|----------------|----------------|
| Area | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 |
| Area to 25km | 35,190 | 4,463 | 244 | 2,750 | 11,138 | 15,013 | 12,944 | 25,300 | 107,040 |
| 25km to 50km | 31,473 | 1,675 | 206 | 5,138 | 9,000 | 15,644 | 13,800 | 27,813 | 104,748 |
| 50km to 75km | 34,914 | 2,544 | 5,744 | 7,006 | 12,250 | 23,681 | 29,231 | 45,669 | 161,039 |
| 75km to 100km | 31,253 | 2,750 | 2,288 | 10,138 | 20,181 | 18,713 | 22,988 | 53,825 | 162,134 |
| Area to 100km | 132,830 | 11,431 | 8,481 | 25,031 | 52,569 | 73,050 | 78,963 | 152,613 | 534,968 |

Despite the great pressure of habitat change around the Defensores del Chaco National Park, the park itself seems to be effective means of habitat protection as there were no habitat loss events detected within the park (Figure 17).

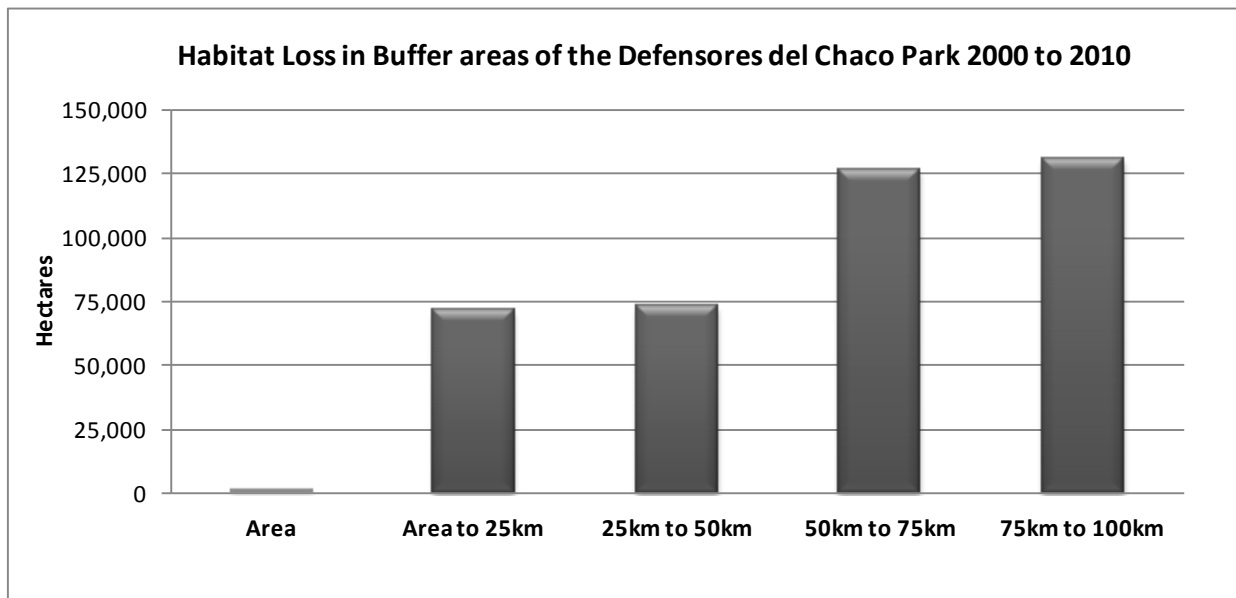


Figure 17. Habitat loss in buffer areas of the Defensores del Chaco Park 2000 to 2010

The Trans-Chaco Road is located at a distance of about 150 km of the Defensores del Chaco National Park and therefore does not have a great influence on this area. On the other hand, the road connecting Mariscal and Estigarriba passes through this protected area and inflicts strong pressure on the region. Rates of deforestation are highest in zones closest to the road and, over time, barring drastic changes in conservation policies or implementation of land-use policies, deforestation will continue its progress towards the protected area.

Carbon Stocks and Biodiversity

As part of ongoing projects in the pan-tropical region, Woods Hole Research Center scientists and their collaborators generated a national level aboveground dataset for tropical countries. Using a combination of co-located field measurements, LiDAR observations and imagery recorded from the Moderate Resolution Imaging Spectroradiometer (MODIS), WHRC researchers produced national level maps showing the amount and spatial distribution of aboveground carbon (WHRC n.d.).

As shown in the map, carbon stocks in the Paraguayan Dry Chaco are on average about 150 megagrams per hectare. In the department of Boquerón, in the area bordering the departments of Alto Paraguay and Presidente Hayes, deforested areas have on average less than 50 megagrams per hectare.

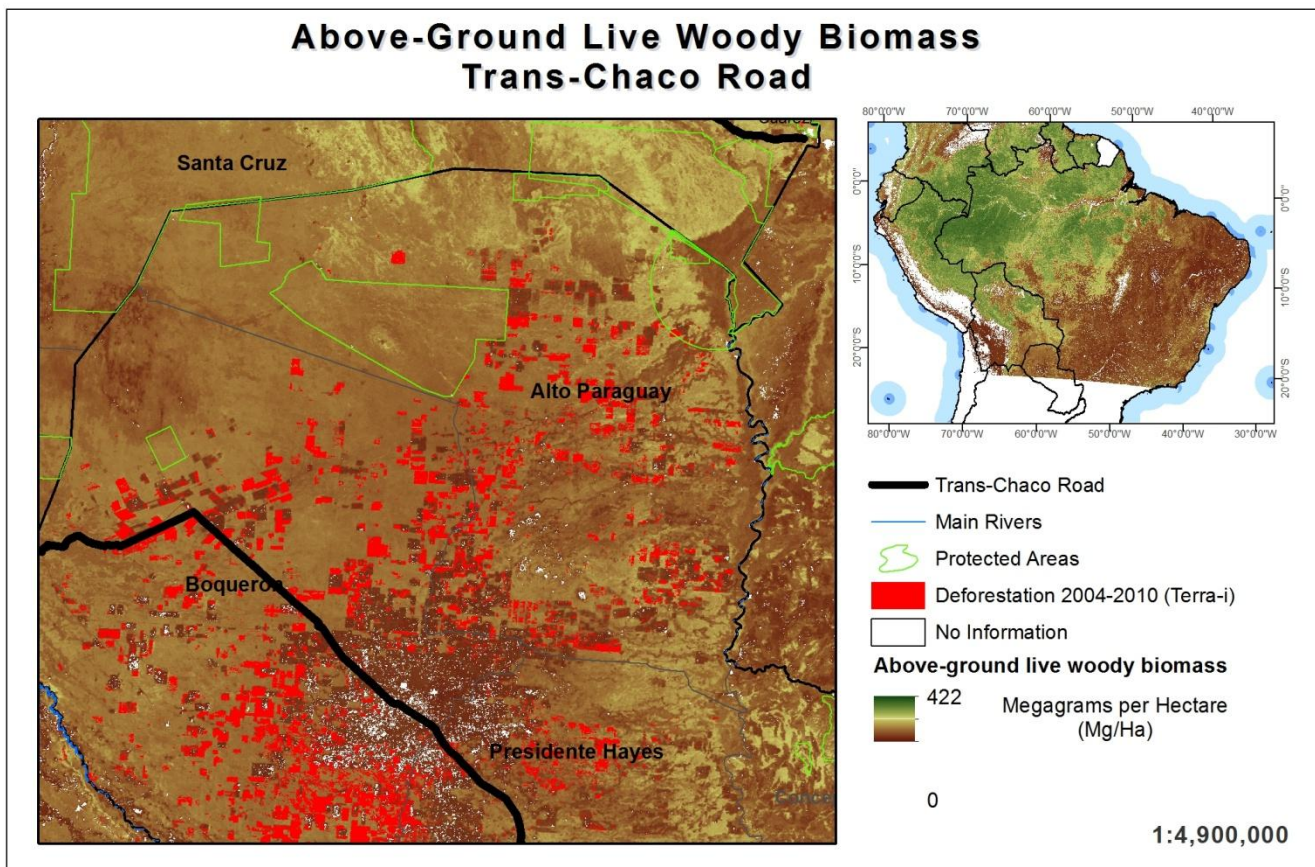


Figure 18. Above-ground live woody biomass in Paraguay.

Paraguay has an economy based mainly on farming and forestry. This has historically resulted in deforestation events which in turn threaten biodiversity conservation. In Paraguay, forest formations contain high biodiversity and endemism. The country also encompasses large swathes of grassland and discontinuous forest, in addition to wetlands composed of a complex mosaic of periodically flooded grasslands and forests and home to a wide variety of migratory birds and fish. These regions are highly biodiverse, and it is estimated that they host between 13,000 and 20,000 plant species, 100,000 species of invertebrates, 250 species of fish, 685 species of birds, 175 mammals, 150 reptiles and 70 species of amphibians (FAO, DIA 2008).

Conclusions

In Paraguay, Terra-i monitored habitat status every 16 days from the 1st of January 2004 until the 31th of December 2010. It detected a cumulative habitat loss during the 7 years analysed of 1,767,163 hectares nationwide, equivalent to an annual rate of 252,452 ha / year. The departments with the highest habitat loss rates were Boquerón, which registered a total loss of 1,015,363 hectares between 2004 and 2010, and Alto Paraguay, which registered a total loss of 471,988 hectares during the same time period. Among the main drivers explaining such a high rates in Paraguay are a weak regulatory and enforcement framework disconnected from the reality of the country, incentive systems and the indiscriminate conversion of forest to pasture and agricultural land encouraged by high commodity prices, land colonisation and a near absence of land-use control.

The most impacted ecoregion was the Dry Chaco, which registered 93% of the deforestation that occurred in Paraguay during the 10 years analysed. Closed Deciduous forests within the Dry Chaco were the most heavily affected ecosystems.

For this road impact analysis, Landsat images were used to complement and calibrate Terra-i detections in the Dry Chaco ecoregion. Using Landsat datasets we calculated a total habitat loss of 545,317 hectares between the years 2000 and 2004. Using Terra-i we calculated a total habitat loss of 1,657,931 between 2004 and 2010. Thus, a total area of 2,203,248 hectares was lost in the Paraguayan Dry Chaco Ecoregion during the 10 analyzed years. Such high rates of conversion show that the road can be considered a enabling force, easing access to remote areas and resulting in considerable negative impact within its area of influence (between 0 km to 50 km from the road). The construction of roads should therefore always be undertaken in the context of development plans that consider strategic areas of conservation. Furthermore, there should be strong environmental and agricultural policies in place which are enforced by local and regional authorities. These two strategies could considerably reduce the negative environmental impacts associated with road infrastructure development. Otherwise, such projects can be the catalysts that start a complex process of degradation and desertification.

By analyzing the impact in a 20 km buffer zone around the Trans-Chaco Highway, we recorded a total habitat loss of 229,445 hectares during the 10 years studied (2000-2010). In a 100 km buffer around the road other infrastructure present in the region, such as the Pilcomayo River and the network of secondary roads branching out from the Trans-Chaco, increased habitat loss even more.

Finally, one can observe that the Trans-Chaco Road is located at a distance of about 150 km from the Defensores del Chaco National Park and therefore does not have a direct influence on deforestation around the park's borders. Nevertheless, deforestation from the road that connects Mariscal and

Estigarriba and from the secondary roads present in the area is putting an alarming amount pressure on this and other protected areas. Over time, barring drastic changes in conservation policies or implementation of land-use policies, deforestation will continue its progress towards the protected areas. Therefore, infrastructure development requires robust national institutional frameworks and environmental policies in place that minimize potential negative environmental impacts.

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