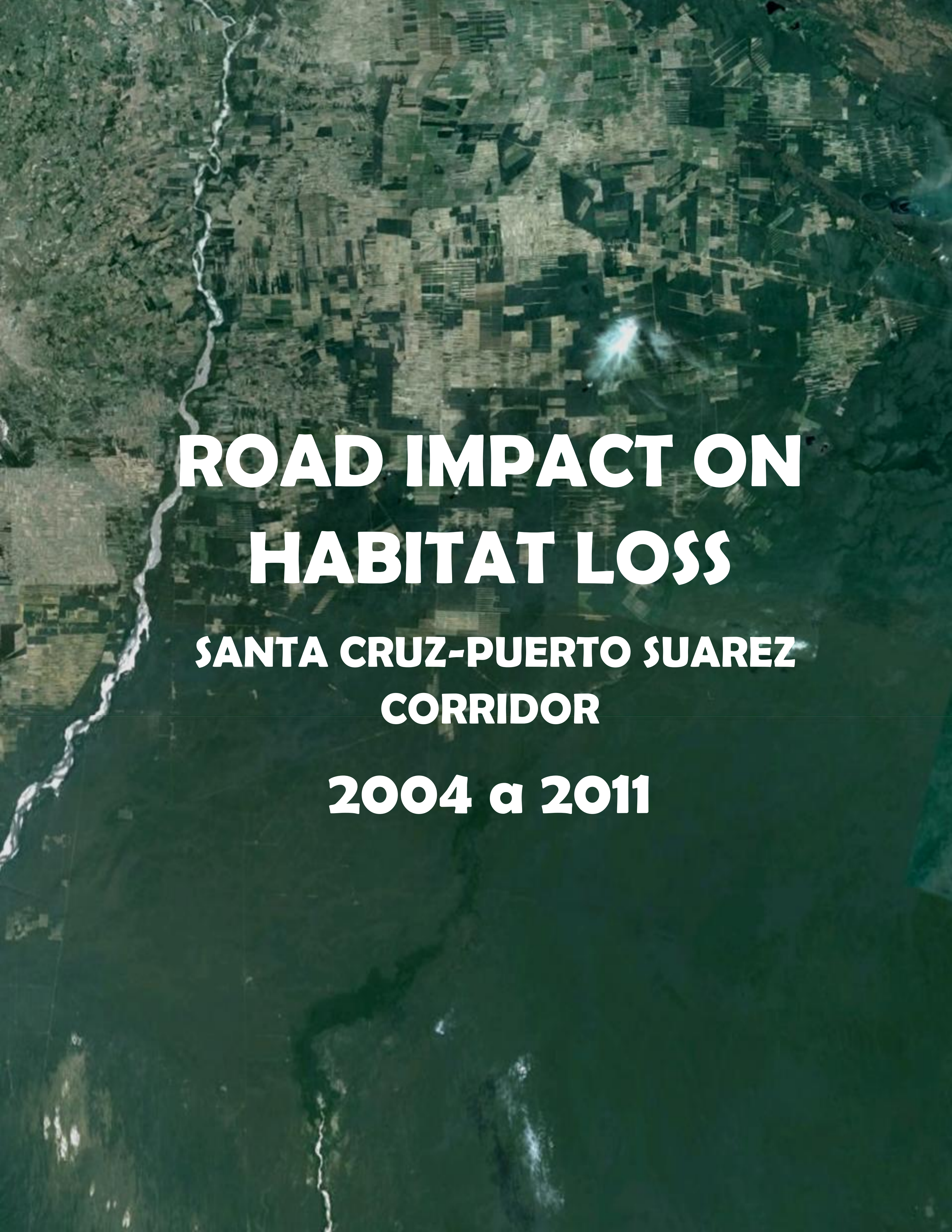

ROAD IMPACT ON HABITAT LOSS

SANTA CRUZ-PUERTO SUAREZ CORRIDOR

2004 a 2011

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SANTA CRUZ-PUERTO SUAREZ CORRIDOR
2004 a 2011

March 2012

Content

Acknowledgements

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Executive Summary

The following document presents a study of the environmental impact generated by the construction and development of the Santa Cruz – Puerto Suarez corridor in the department of Santa Cruz, Bolivia. The road is located in the Southeast of Bolivia between the coordinates 17º46’42.51’’S, 63º12’15,58”W and 18º57’55.22’’S, 57º47’53,65”W. It is approximately 636 kilometers in length and connects the towns of Santa Cruz de la Sierra and Puerto Suarez, located on the border with the state of Mato Grosso do Sul in Brazil. In addition, within a buffer of 50 km around the road are two protected areas with important ecological functions: the Gran Chaco National Park Kaa-Iya and the National Park Amboro.

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 Bolivia, Terra-i performed habitat status monitoring every 16 days from the 1^{st} of January 2004 until the 10^{th} of June 2011. During the 7.5 years studied it detected a cumulative habitat loss of 1,727,525 hectares, equivalent to a national average of 230,337 ha / year. This value corresponds to about 1.6% of the total analyzed area.

The department of Santa Cruz has one of the highest conversion rates nationwide, with a recorded 124,498 hectares per year. The greatest losses in Santa Cruz occurred in 2010, surpassing all historical records of habitat loss in this area. This figure is mainly due to forest fires that occurred during that year, according to official data. In Bolivia, fires occur because of agricultural practices that rely on "slash and burn" methods, which consist of burning certain areas of forest in order to expand the agricultural frontier, create new areas for livestock and even to restore the productivity of existing pastures.

In addition to forest fires, deforestation in Bolivia can be attributed to the following drivers in order of importance and magnitude: livestock production, conversion to industrial agricultural land, colonization of land by new settlers and to a lesser extent agricultural and livestock systems implemented by small farmers and indigenous peoples.

Study Area

The Santa Cruz-Puerto Suarez corridor is located in Southeastern Bolivia between the coordinates 17º46’42.51’’S, 63º12’15,58”W and 18º57’55.22’’S, 57º47’53,65”W. Its is approximately 636 kilometers in length and connects the towns of Santa Cruz de la Sierra and Puerto Suarez, located on the border with the state of Mato Grosso do Sul in Brazil.

The area is comprised of four easily distinguishable ecoregions: Pantanal, Dry Chaco, Chiquitano Dry Forest and Cerrado. In addition, protected areas with important ecological functions for the area are located within a 50 km buffer around the route, including the Gran Chaco National Park Kaa-Iya and Amboro National Park

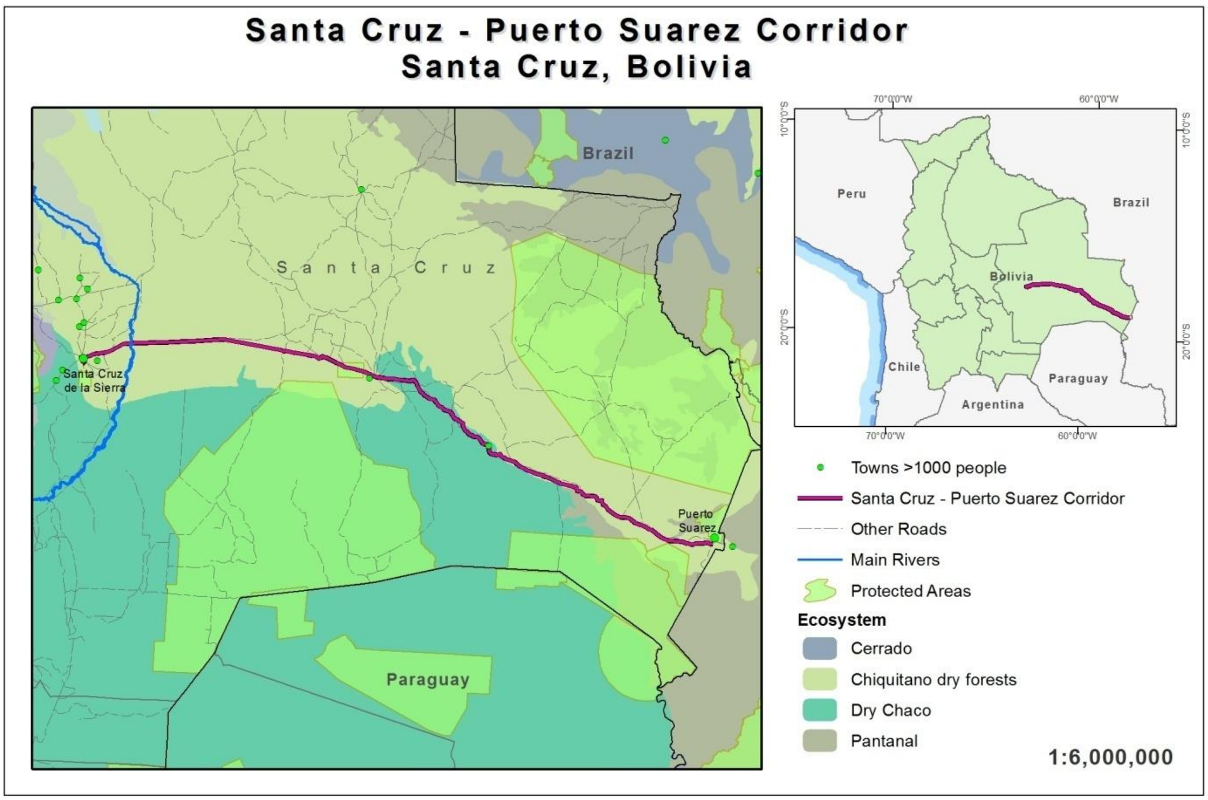

Figure 1. Study Area 9 Road in Santa Cruz, Bolivia.

Amazonian forests and the forests of Southeastern Bolivia, mainly in the department of Santa Cruz, are very important biodiversity hotspots that contribute to climate stability and moisture balances around the world. The Amazon contains great biological richness and represents the largest micrographic system in the world. The Bolivian region makes up about 1.27% of the entire Amazon. Similarly, the Chiquitano dry forest is endemic to Bolivia and has the highest levels of biodiversity among the American tropical dry forest formations. It has large areas of very well preserved ecosystem and provides economic and environmental benefits and services to the country and to the world (Uriostre 2010).

Habitat Change Monitoring

There are several biophysical indicators to measure and monitor the alteration of ecosystems. However, in Bolivia, as in most Latin American countries, there is a critical lack of information regarding the alteration of ecosystems. As a result it is necessary to focus on the rate of deforestation, as it is an alteration indicator that has been used and monitored in past analyses.

Up until 1975, 60% of Bolivia's territory was covered by various types of forests. In 1990s forest cutting began to grow steadily and since then the trend for deforestation rate has been steadily increasing. In three decades deforestation rates grew from about 168,000 hectares per year (between the years 1975 and 1993) to an annual rate of about 500,000 hectares per year by the end of the 1990s. These figures are from the department of Santa Cruz, where the greatest area of forest loss has been recorded (Villegas 2009).

Previous studies

Among the forest monitoring studies that have been carried out previously in the area is the work of the Forest Superintendent of Bolivia (BOLFOR), which recorded national level figures as described in FAO documents regularly assessing the status, management and uses of the world's forests through the Forest Resources Assessment Program.

Table 1. Historic deforestation in Bolivia.

Period	Anual deforestation rate (Hectares)	Source
Average 1993-2000	270,333	Tasa de deforestación de Bolivia 1993-2000; BOLFOR- Superintendencia forestal, 2003
2004	275,128	Avance de la deforestación en Bolivia Superintendencia forestal, 2004
2005	281,283	Avance de la deforestación en Bolivia Superintendencia forestal, 2005
2006	307,211	Avance de la deforestación en Bolivia Superintendencia forestal, 2006
2007	345,376	Avance de la deforestación en Bolivia Superintendencia forestal, 2007
Average 2004-2007	302,250	Calculated

These data were statistically estimated in some cases and in others measured using satellite imagery such as LANDSAT, MODIS, CBERS and/or variable resolution (to quantify deforestation in areas exceeding 4.5 hectares). In Bolivia, there are a great number of small scale (<4.5 hectares) clearing events that cannot be detected by remote sensing and are likely to increase significantly the real value of the annual deforestation rate. On the other hand, there may be recovery events in previously cleared areas that were not assessed and therefore are not included in the FAO figures (FAO 2010).

Terra-i 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). 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.

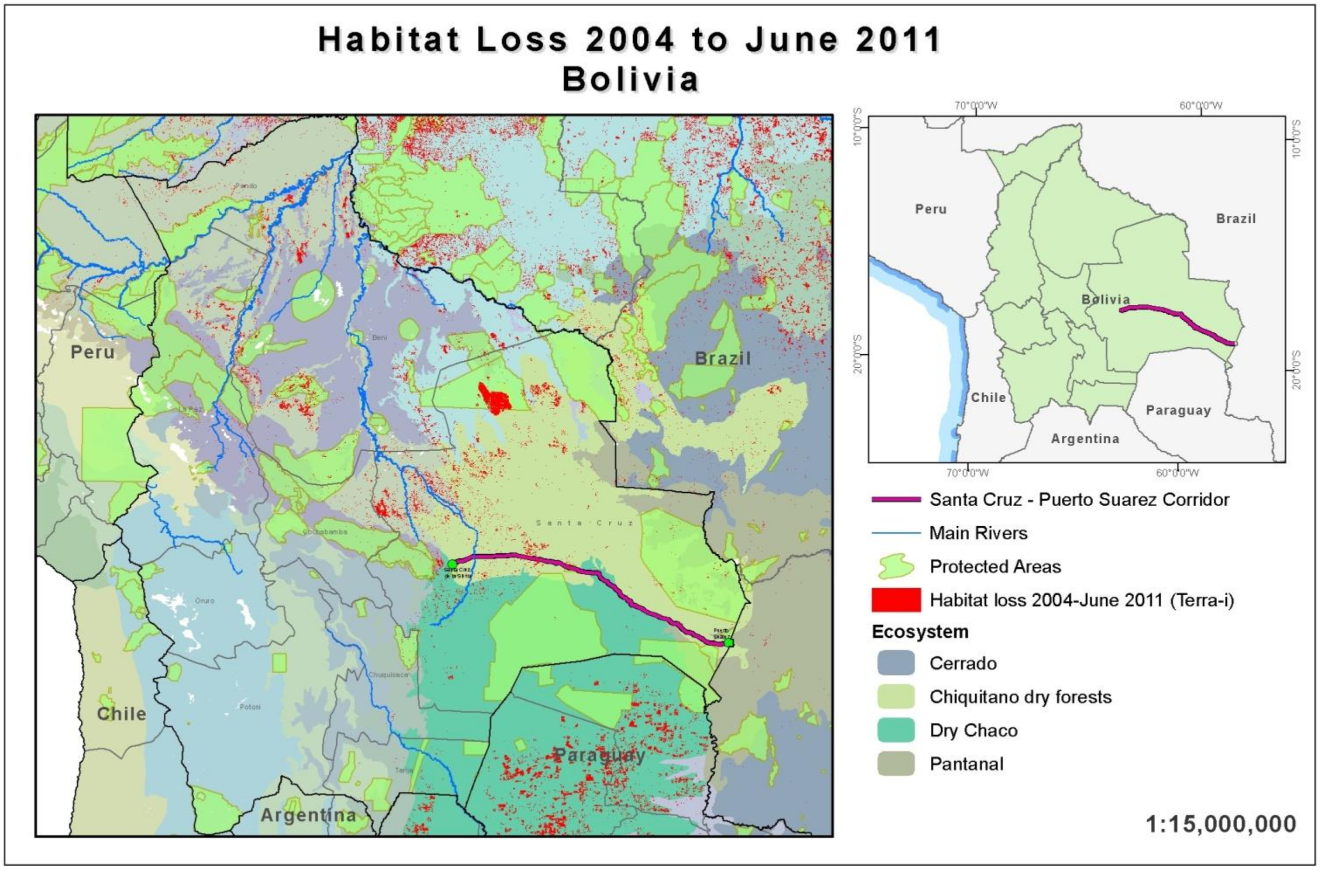

Figure 2. Habitat loss Map in Bolivia (2004-2011).

Table 2. Terra-i detection in Bolivia between January 2004 to June 2011.

Department	% NoData	2004	2005	2006	2007	2008	2009	2010	2011	2004-2011	Annual Rate	% Change Area
Beni	0.58%	14,131	50,294	37,175	18,456	48,338	20,031	305,256	41,394	535,075	71,343	2.5%
Chuquisaca	0.00%	6	44	75	6	81	531	6,700	-	7,444	993	0.1%
Cochabamba	0.00%	1,125	2,131	1,588	2,781	4,831	2,213	10,994	2,119	27,781	3,704	0.5%
La Paz	1.33%	956	7,831	5,719	2,681	8,756	6,063	59,538	6,056	97,600	13,013	0.7%
Oruro	4.87%	-	-	6	-	-	-	-	-	6	1	0.0%
Pando	0.01%	3,813	20,831	24,719	7,744	12,619	6,481	31,350	11,306	118,863	15,848	1.9%
Potosi	0.25%	-	-	-	-	-	-	-	-	-	-	0.0%
Santa Cruz	0.06%	79,094	52,013	42,800	73,725	87,913	21,975	552,013	24,200	933,731	124,498	2.6%
Tarija	0.00%	56	250	44	788	1,981	2,275	1,631	-	7,025	937	0.2%
Total Nacional	**0.56%**	**99,181**	**133,394**	**112,125**	**106,181**	**164,519**	**59,569**	**967,481**	**85,075**	**1,727,525**	**230,337**	**1.6%**

In Bolivia, Terra-i performed habitat status monitoring every 16 days from the 1st of January 2004 until the 10th of June 2011. During the 7.5 years studied it detected a cumulative habitat loss of 1,727,525 hectares, equivalent to a national average of 230,337 ha / year. This figure corresponds to about 1.6% of the total analyzed area.

The department of Santa Cruz has one of the nation's highest conversion rates, with 124,498 hectares per year recorded. The greatest losses in Santa Cruz occurred in 2010, surpassing all historical records of habitat loss in this area. This figure is mainly due to forest fires that occurred during that year, according to official data from the Authority of Social control of Forest and Land (ABT) (ABT 2011).

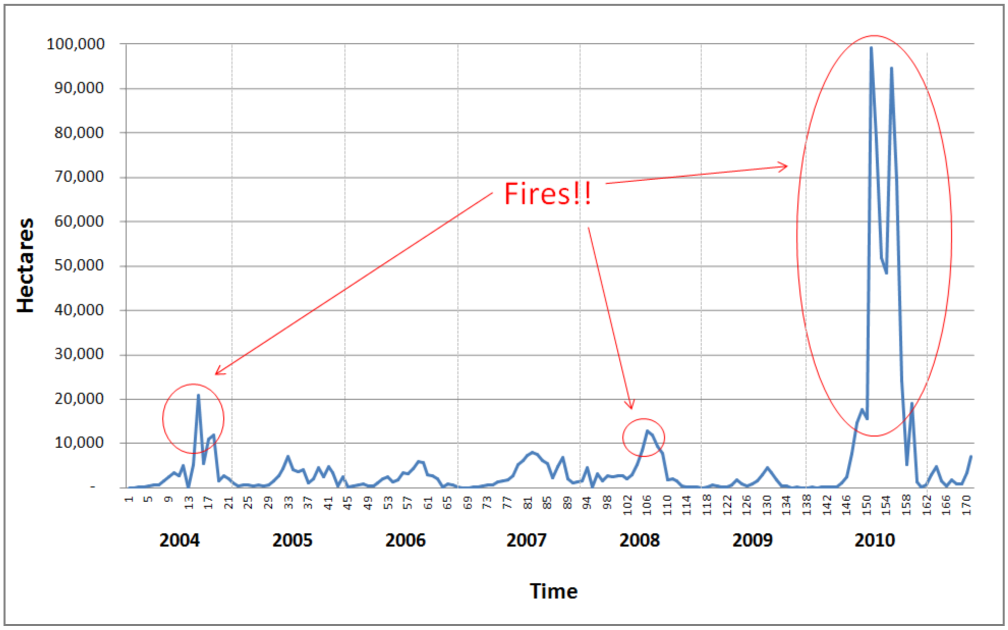

Figure 3. Terra-i Monitoring every 16 days in Santa Cruz, Bolivia.

In Bolivia, fires occur because of agricultural practices that rely on "slash and burn" methods, which consist of burning certain areas of forest in order to expand the agricultural frontier, create new areas for livestock and even to restore the productivity of existing pastures. These fires initially take place in small areas at the plot level, with no intention of consuming an ecosystem. However, high winds and dry conditions can carry the fire from plot to plot, eventually resulting in an uncontrollable forest fire. The department of Santa Cruz is one of the regions most affected by the flames.

Using high-resolution images from Landsat (30 m), it is possible to validate the results obtained by Terra-i with MODIS images and highlight the ecosystem damage caused by forest fires in the department of Santa Cruz during 2010.

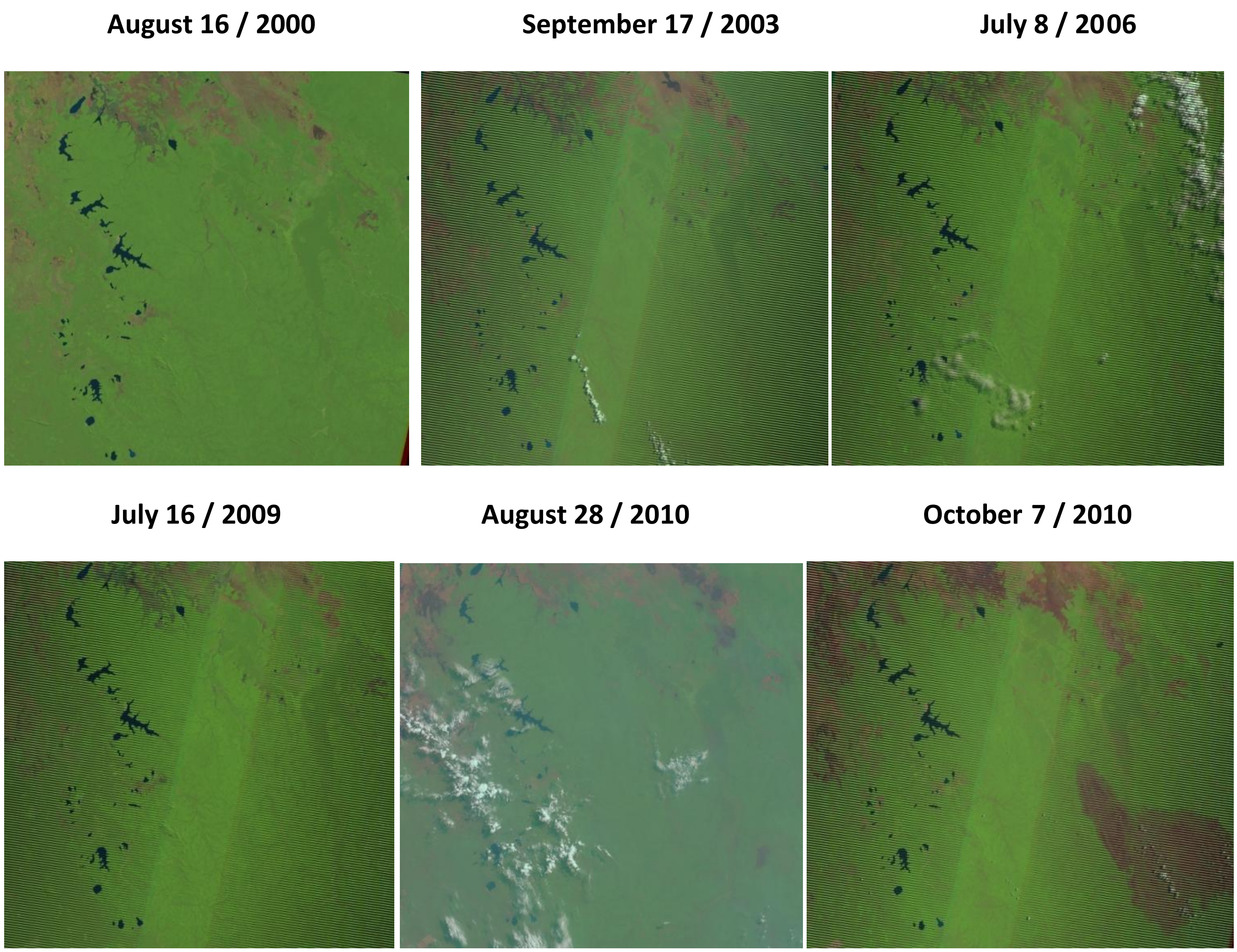

Figure 4. Time series of Landsat 30m spatial resolution in the department of Santa Cruz, Bolivia.

According to official data from the ABT, in 2010 there were a total of 59,962 heat spots; many of them were forest fires. That year the country may have broken the historic record of fire and, consequently, pollution. Through August 14th of 2011 some 5,093 hot spots were registered, almost a tenth of the number from the year prior. Regardless of the difference in the number of hot spots that occurred between years, most of the fires were clearly concentrated in the departments of Santa Cruz and Beni.

Figure 5. Record heat sources between 2000 and 2011 reported by the Environment and water ministry of Bolivia.

Despite being useful data for use by most of the existing reports on forest fires in Bolivia, it must be taken into account that heat sources are not always directly related to the area affected by forest or grass fires. The only way to identify fire damage is by quantifying the affected areas and assessing the response of fire-sensitive ecosystems.

Terra-i is not capable of discriminating the drivers of habitat change. Therefore it cannot give a direct figure for what percentage of the 967,481 hectares of lost habitat was due to fires. For this reason we supported the analysis with previous studies related with the habitat lost areas due to fire.

The study conducted by Friends of Nature in Bolivia with the financial support of the Netherlands in 2011 is one of the most complete. To evaluate historical fires in Bolivia, they used MODIS satellite images (product MCD45A1) with a resolution of 500 m for ten years (2000-2010), validating the quantification of area burned using prescribed fire normalized ratio (NBR) Landsat TM satellite imagery with a resolution of 30 m. Thus they were able to discriminate burn scars from habitat loss due to other causes.

Friends of Nature Foundation found that 46% of fires in the last decade were in new areas, and most were started by land conversion processes. In the last ten years (2001-2010), 22,012,910 hectares were burned, of which 20% (4,287,512 hectares) were forest fires. The highest rates of forest fire occurrence were recorded during the years 2007 and 2010, covering surfaces of 3,691,815 hectares and 4,343,156 hectares respectively. Assuming a cyclical trend, 2011 should experience a decrease in area burned of about 84% compared with the area reported in 2010 (Rodriguez Motellano 2010).

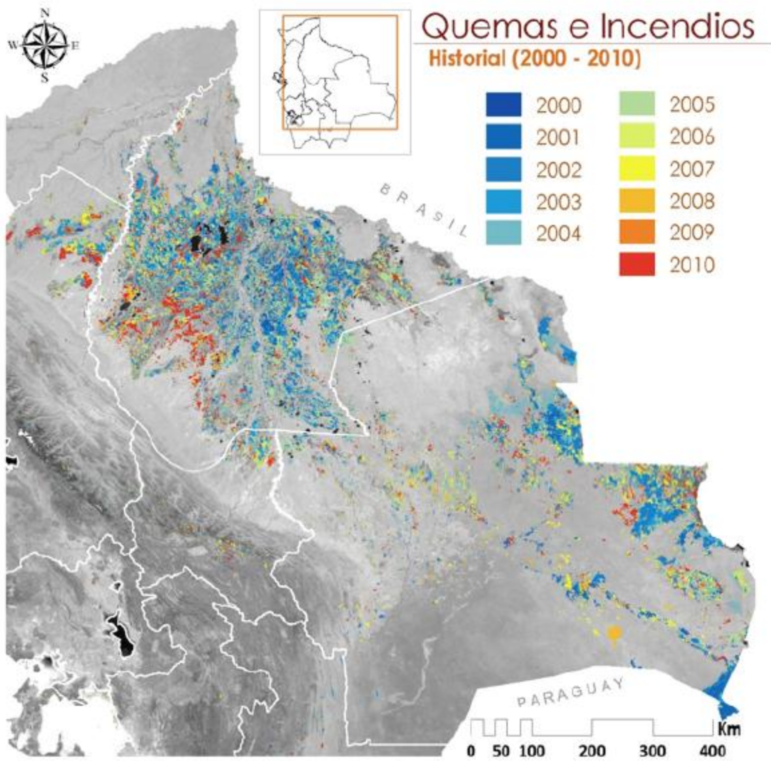

Figure 6. Map of fires and forest fires in Bolivia (2000 -2010).

Forest clearing occurs in all ecoregions of Bolivia, mainly in the Amazon, transition forest, Chiquitano dry forest and the Chaco. Historically, the main cause of rapid deforestation in Bolivia has been change in land use for agricultural purposes. This deforestation driver is also the largest source of Greenhouse Gases Emissions (GHGs) in the country, emitting 38.6 million tons of CO_2. A study led by Andersen and Mamani (2009) for a deforestation scenario by 2100 found that the expansion of the agricultural frontier will be the main cause of deforestation, possibly accounting for 33 million hectares of lost forest in Bolivia (Andersen and Mamani 2009).

Road Impact

Using habitat monitoring system Terra-i, we analyzed trends of habitat loss around the 636 km highway that connects the towns of Santa Cruz de la Sierra and Puerto Suarez.

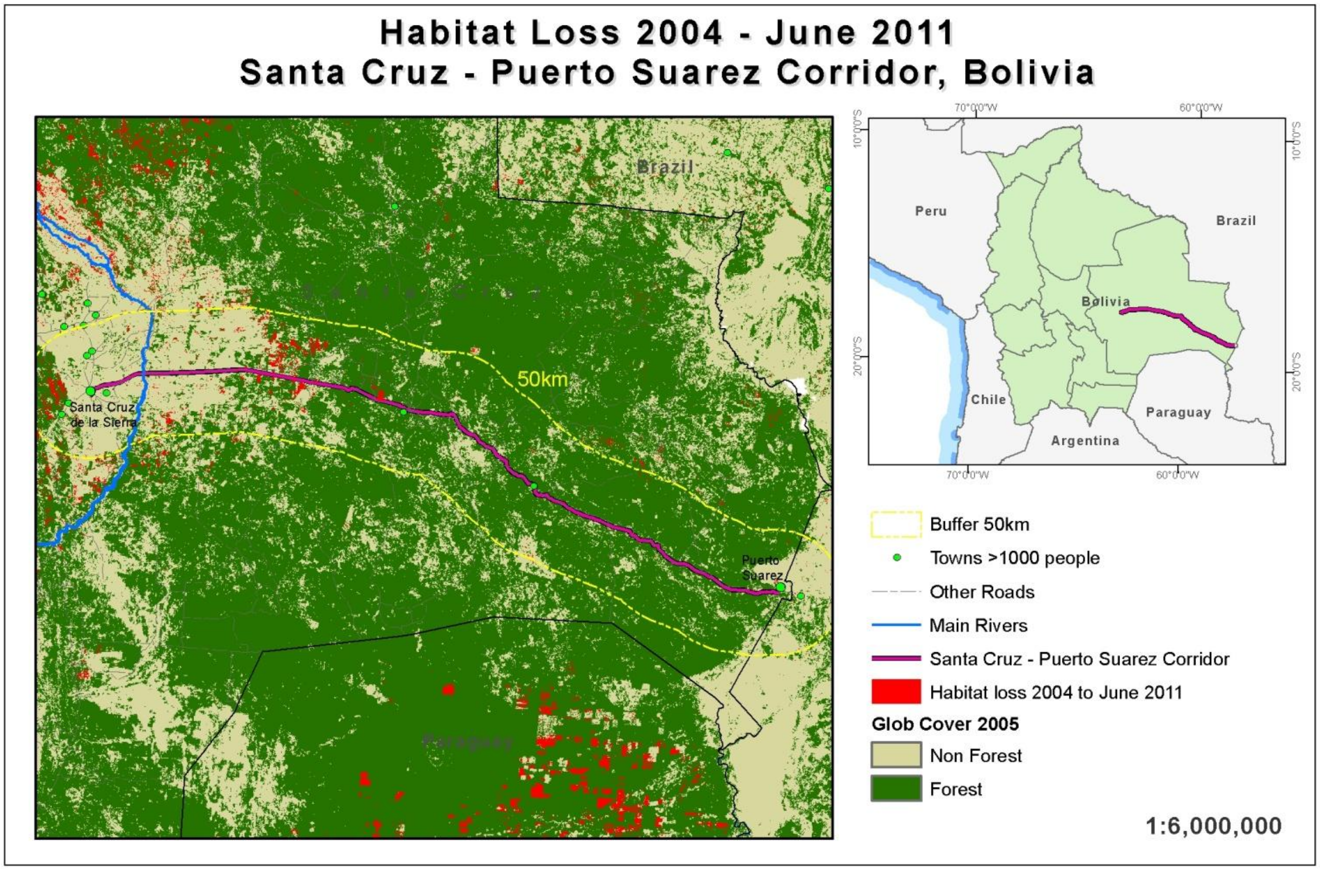

Figure 7. Map of habitat loss (2004-June 2011) monitored by Terra-i.

As shown in Figure 7, most of the habitat loss is recorded at 150 km from the town of Santa Cruz de la Sierra in a buffer zone of 50 km from the road.

Table 3. Annual habitat loss within 50 km from the Santa Cruz-Puerto Suarez Road, Bolivia.

Buffer(km)	2004	2005	2006	2007	2008	2009	2010	Jan-June 2011	Accumulative	Annual Rate
Road to 10	75	544	838	1,331	5,081	1,725	12,188	1,313	23,094	3,079
10 to 20	119	669	500	825	3,494	413	11,781	1,156	18,956	2,528
20 to 30	200	344	494	363	4,513	719	12,175	531	19,338	2,578
30 to 40	731	750	769	1,313	2,606	325	5,613	150	12,256	1,634
40 to 50	756	644	1,219	925	1,656	606	5,781	206	11,794	1,573
Road to 50	**1,881**	**2,950**	**3,819**	**4,756**	**17,350**	**3,788**	**47,538**	**3,356**	**85,438**	**11,392**

Most of the road's impact occurs in the area of direct influence, or 0 to 20 km from the road. Despite the forest fires in the department of Santa Cruz in 2010, the habitat loss trend shows a sudden increase in the rate of annual change from 3,788 hectares in 2009 to 47,538 ha in 2010. This spike is clearly not a direct consequence of the construction or immediate post-construction stage of the road. However, it can be interpreted as an enabling impact; the development of infrastructure encourages mobility, access (including access to markets) and the relocation of settlers who practice methods as "slash and burn" to establish agricultural crops and / or pasture areas.

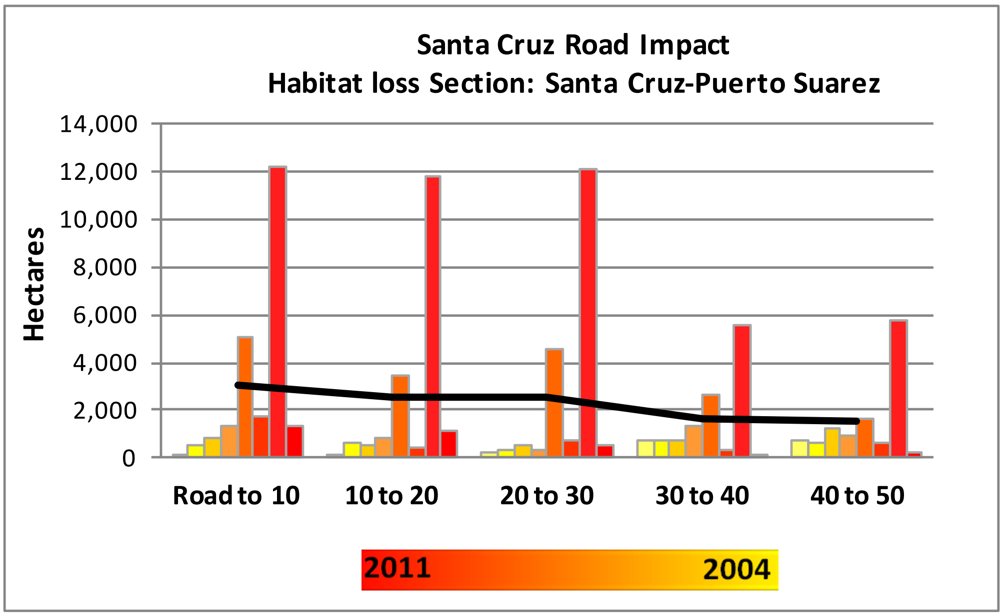

Figure 8. Graph of annual habitat loss 10, 20, 30, 40 and 50 km from the Santa Cruz-Puerto Suarez Road in Bolivia.

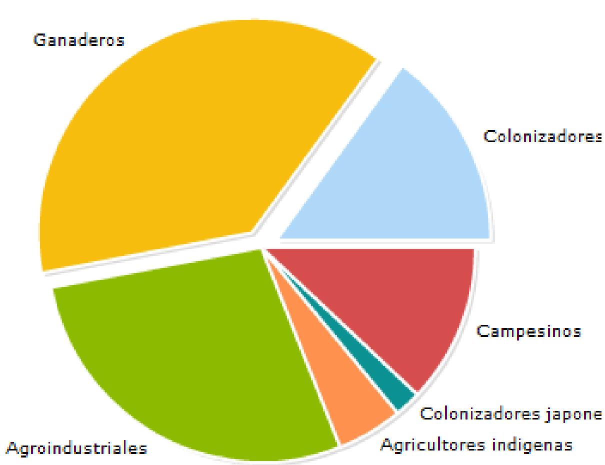

Figure 9. Drivers of Deforestation in Bolivia. Source: Autoridad de fiscalización y control social de bosques y tierra (ABT).

In addition to forest fires and in agreement with reports from the Audit Authority of Social Control of Forests and Land (ABT) in Bolivia, deforestation in the country between 1997 and 2010 can be attributed to the following drivers in order of importance and magnitude: livestock production, conversion to industrial agricultural land, industrial agro-business, colonization of land by new settlers and to a lesser extent agricultural and livestock systems implemented by small farmers, Indigenous peoples and Japanese colonizers.

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 Figure 10, in the department of Santa Cruz in areas close to the Santa Cruz-Puerto Suarez Road carbon stocks are less than 200 megagrams per hectare. They are even more critically low within a buffer area of 1OO km around the town of Santa Cruz (on the borders of the Amazon rainforest), at less than 50 megagrams per hectare. Deforestation occurs in all forest ecosystems of Bolivia, though mainly in the Amazon forest and transitional forest. Forest fires and certainly forest conversion for the implementation of agricultural systems directly influence global warming by increasing carbon emissions into the atmosphere as well as decreasing carbon forest reserves on the planet.

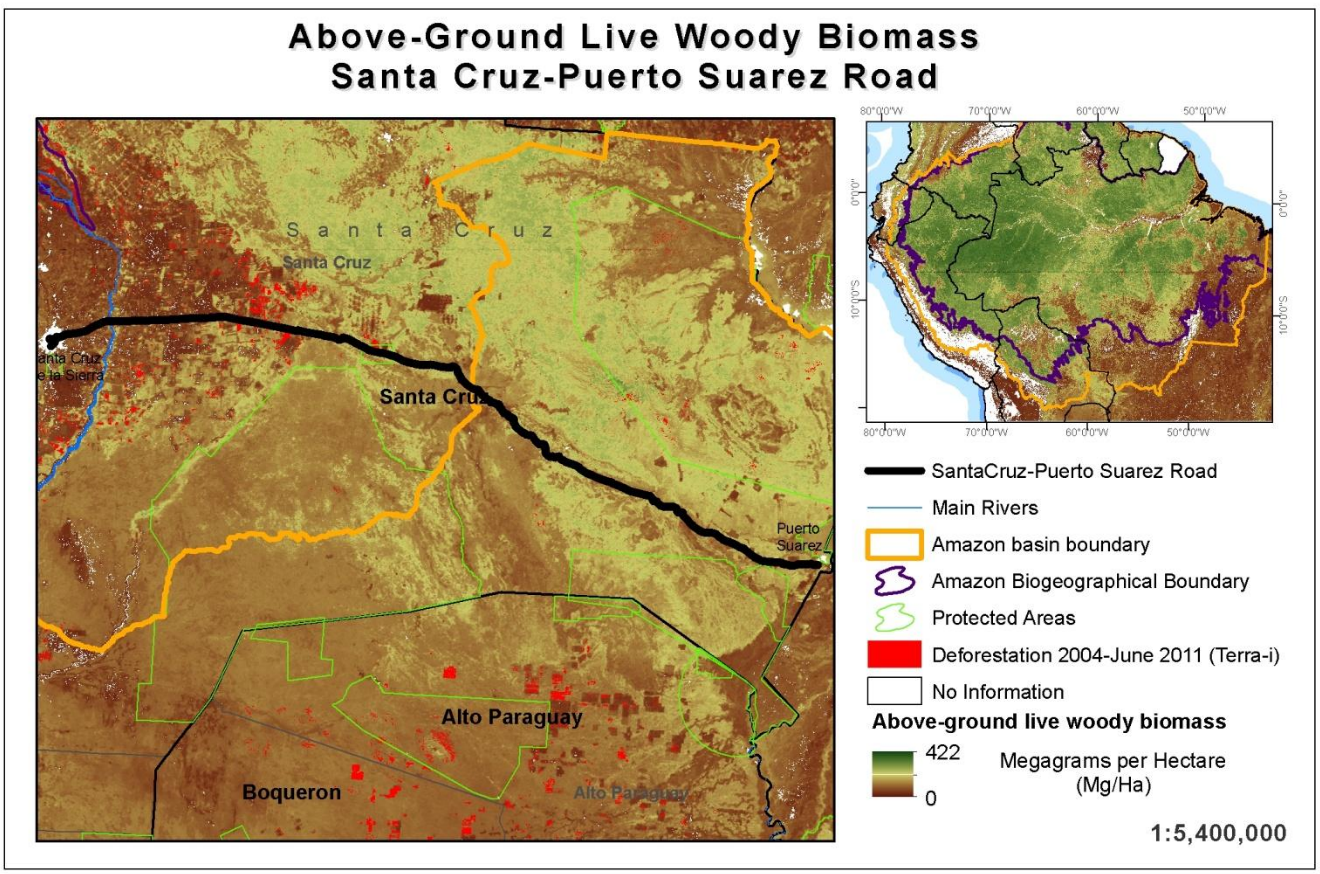

Figure 10. Above-ground live woody biomass in Bolivia.

In Addition, as shown in Figure 11, the northern part of the Bolivian territory is considered by Conservation International as a High Biodiversity Wilderness area. Bolivia is one of the 15 countries with the highest biodiversity levels on the planet. Its ecosystems are protected by 22 ecological reserves including national parks, biological reserves and other natural areas. Biodiversity conservation in Bolivia has great strategic importance because its sustainability will depend on further development and poverty reduction.

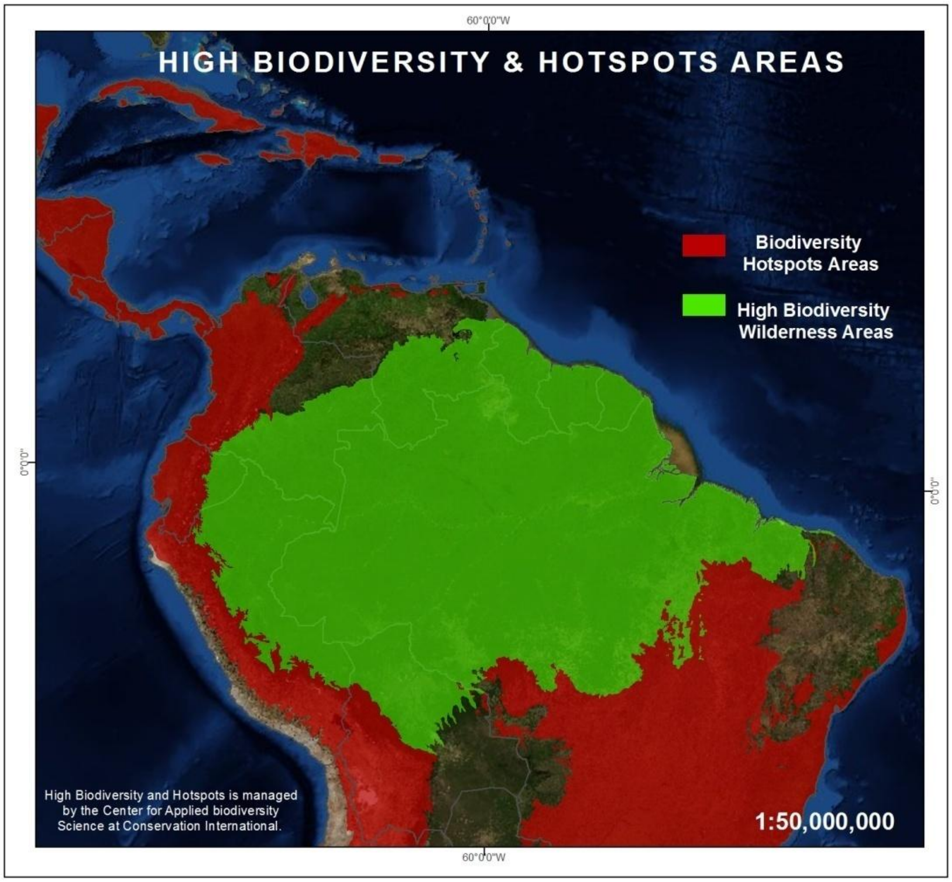

Figure 11. Biodiversity map in Latin America.

Conclusions

Investment in infrastructure and the implementation of strategic works is a key component of social and economic development in Latin America. However, the creation of such infrastructure has strong medium- to long-term impacts on ecosystems. It is therefore recommended that the environmental impacts and the options that exist to minimize negative effects on key ecosystems are carefully analysed before these projects are implemented. Our research on the Santa Cruz-Puerto Suarez road in Bolivia found that the road is essentially an enabling force that impacts ecosystems by easing access to markets and increasing mobility, subsequently allowing other factors to affect habitat change. The most important driver of habitat change, according to secondary sources, is an unsustainable agricultural practice called “slash and burn.” There is therefore a need to develop and implement sound, cross-sectoral national and regional policies and programs that promote sustainable practices and protect natural areas.

In Bolivia, Terra-i detected a cumulative habitat loss of 1,727,525 hectares during the 7.5 analyzed years (2004-June 2011), or the equivalent of a national annual rate of 230,337 ha / year. This figure corresponds to about 1.6% of the nation’s total terrestrial area. The department of Santa Cruz has one of the highest conversion rates nationwide: 124,498 hectares per year. Its greatest losses occurred in 2010, surpassing all historical records of habitat loss in the area. These high figures were mainly due to forest fires that occurred during that year, according to official data. In addition to forest fires, deforestation in Bolivia can be explained by the following drivers, in order of importance and magnitude: livestock production, conversion to industrial agricultural land, colonization of land by new settlers and to a lesser extent agricultural and livestock systems implemented by small farmers and Indigenous peoples.

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Gis Sources

Mapita gis de focos de calor: http://gis-usi.abt.gob.bo/focos_de_calor/default.aspx

Mapita gis de desmontes: http://gis-usi.abt.gob.bo/desmontes/default.aspx

*Descarga de datos GIS de Bolivia (GEO-Bolivia) http://www.geo.gob.bo/