ROAD IMPACT ON HABITAT LOSS

BR-364 HIGHWAY IN BRAZIL

2004 to 2011

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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 Cruzeiro do Sul-Rio Branco corridor located in the department of Acre and the Rio Branco- Porto Velho corridor in the department of Rondônia, both part of the BR-364 Highway in Brazil. The road is located between the coordinates 7º43’53.45”S and 72º37’38.96” in Cruzeiro do Sul to 8º46’19.74”S and 63º52’41.06”in Porto Velho.

The highway length is approximately 1,183 kilometers, and it connects the towns of Cruzeiro do Sul, Rio Branco and Porto Velho. About 195 protected areas and indigenous reserves are located within the area of influence of the studied corridors, including Kulina do Medio Jurua, Rio Gregorio and Vale do Javari, Cazumbá-Iracema, Riozinho da Liberdade, Chico Mendes and Rio Pacaás Novos extractive reserves, and the National Park Serra do Divisor.

The monitoring system Terra-i 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.

In Brazil, 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 40,850 hectares in the Acre department and 1,849,494 in the department of Rondônia, equivalent to an annual loss rate of 40,850 ha/year and 246,599.2 ha/year respectively.

Area of Study

To complete the BR-364 highway between Porto Velho and Rio Branco in the states of Rondônia and Acre, the IDB approved two loans in 1985 for paving 502 kilometers in the Porto Velho-Rio Branco section to connect the state capitals of Rondonia and Acre. Afterwards, another institution funded the pavement of 1,500 kilometers between Cuiabá, Mato Grosso and Porto Velho. The BR-364 was finally completed as part of the Acre Sustainable Development Project which started in 2002 (IDB Brazil Report).

For this study, the Cruzeiro do Sul – Porto Velho road was analysed in two different sections. The first corresponds to a corridor of 623 km connecting the towns of Cruzeiro do Sul and Rio Branco in the state of Acre, Brazil. This section passes through a large biological corridor in the state of Acre which is composed of 39 adjoining protected areas. These protected areas include: Katukina Indigenous area, Riozinho da Liberdade Extractive Reserve, Rio Liberdade State Forest and Mogno State Forest, the latter of which is directly crossed by the road.

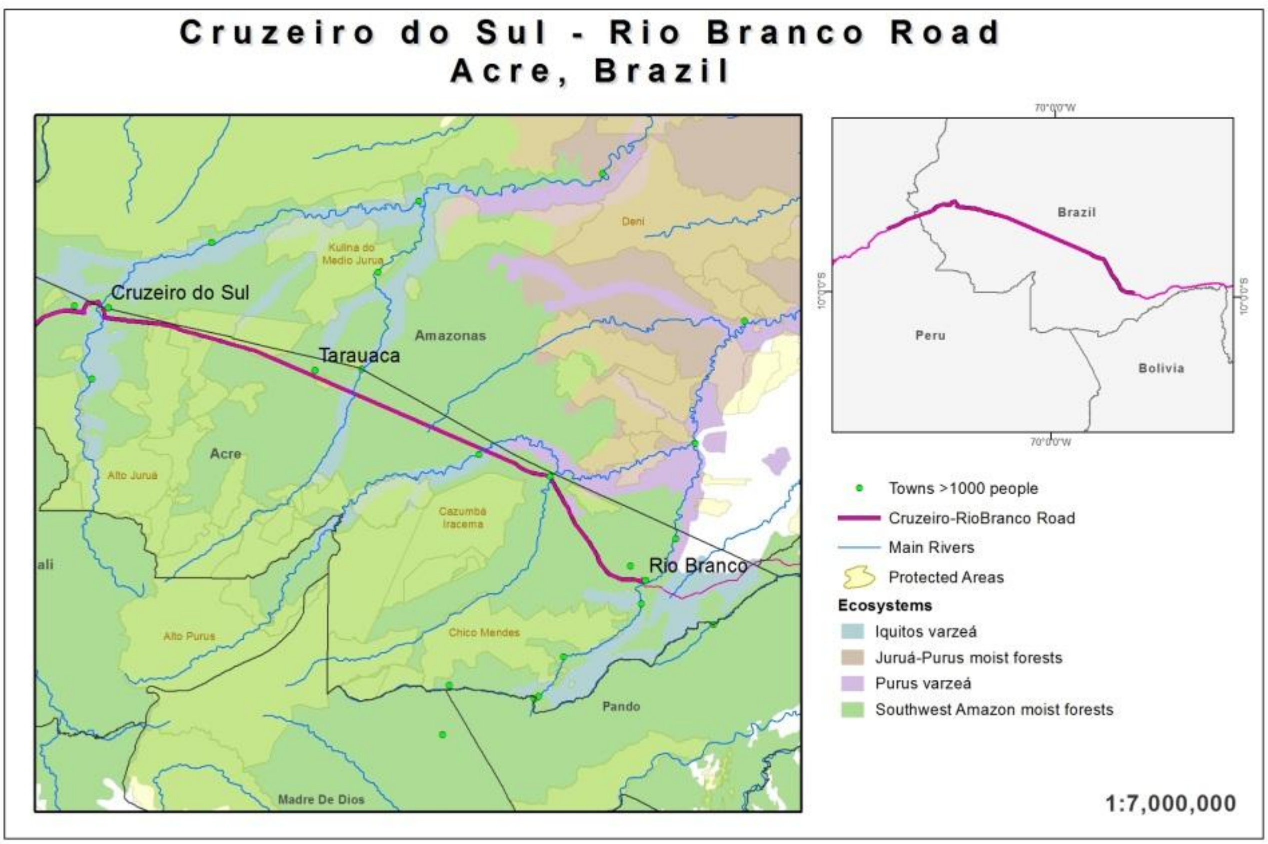


Figure 1. Cruzeiro do Sul-Rio Branco Road, Brazil.

Acre is located in the northwest of Brazil, south of the Amazon state, and east of Rondônia. It is bordered in the South by Bolivia and in the west by Peru. The state's economy is based on livestock, agriculture (mainly soybeans) and the extraction of rubber and Brazil nuts.

The main Ecoregion in the department of Acre is the Southwest Amazon moist forest. However, the Madeira-Tapajos Moist Forest, Juruá-Purus Moist Forest and Iquitos Varzeá can also be found in this area. The strategy implemented in order to protect the ecoregions present in this area is mainly the establishment of protected forests, indigenous reserves, national parks, national forests, and extractive reserves.

The second segment of the road consists of a 515 km corridor which connects the towns of Rio Branco in the state of Acre and Porto Velho in the state of Rondônia. Rondônia is located in the north-western part of the country. It is bordered by the state of Acre (west), the state of Amazonas (north), the state of Mato Grosso (east), and Bolivia (south).

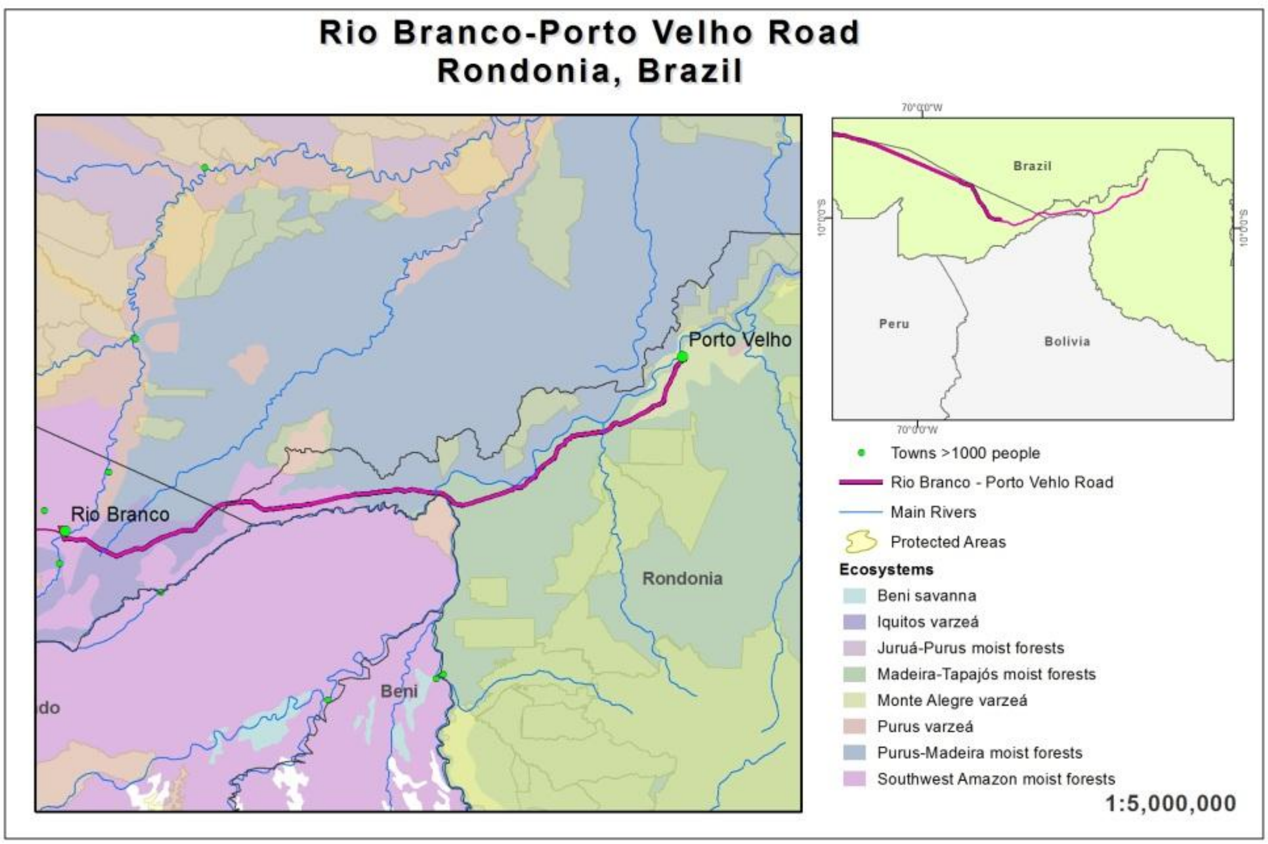


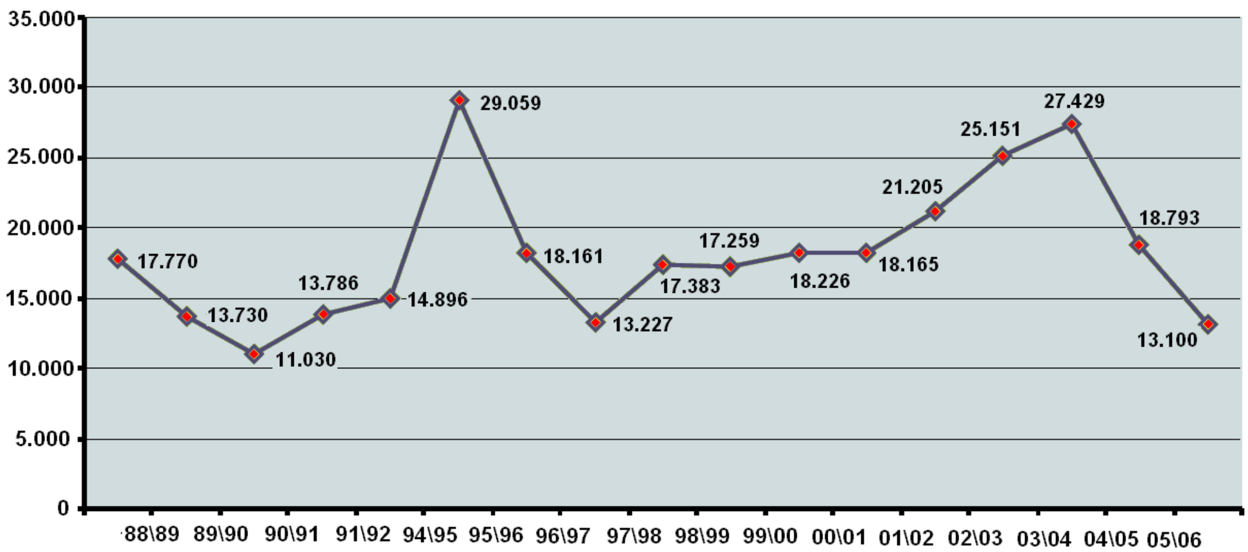
Figure 2. Rio Branco-Porto Velho Road in the states of Acre and Rondonia.

Habitat Change Monitoring

Previous studies

The Brazilian territory is about 8,514,876.6 km^2 in area and occupies almost half (47%) of the terrestrial surface of South America. There are about 4,617,915 km^2 of forests in Brazil, which is equivalent to 54.2% of the total area of country. The most widespread forest ecosystem present in Brazil is the Amazon biome (MMA, PNUMA, UNESCO 2007).

Since 1978, the National Institute for Space Research - INPE has produced annual estimates of average deforested areas as part of the Project of Deforestation Estimation in the Amazon (PRODES).



Source: Data from the "Instituto de Investigaciones Espaciales" (INPE) - PRODES, 2007.

Figure 3. Deforestation in the Brazilian legal Amazon 1988 to 2006 (km^2/year).

Based on data released by the INPE (Figure 3), deforestation in Legal Amazonia underwent a period of decline, reaching its lowest point during the years 1990/1991, after which it accelerated and grew at an alarming rate to reach its highest historical value (29,059 km^2) during the period 1994/1995. In the subsequent years the annual deforestation rate slowed, gradually increased again until 2004, and since then has fallen sharply. The recent decline can be attributed in large part to the actions taken by the Brazilian government since 2004, within the Action Plan for Prevention and Control of Deforestation in the Legal Amazon (MMA, PNUMA, UNESCO 2007).

The System of Deforestation Detection in Real Time (DETER) is another tool developed by INPE for the calculation of deforested areas. This system integrates the Plan of Action against Deforestation in the Legal Amazon and allows the production of updated maps every two weeks showing the location of deforestated areas.

Terra-i Monitoring in Brazil

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 behavior 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 Brazil, 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 40,850 hectares in the Acre department and 1,849,494 in the department of Rondônia, equivalent to an annual loss rate of 40,850 ha/year and 246,599.2 ha/year respectively.

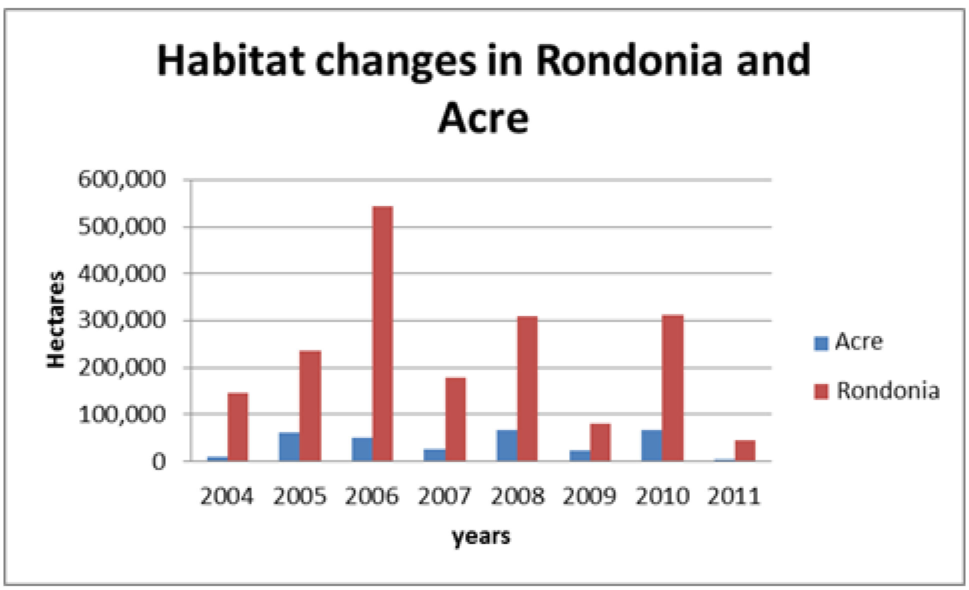


Figure 4: Habitat changes in hectares in Rondonia and Acre.

According to Terra-i data from the rest of Brazil, Rondonia is the department 3rd most affected by habit changes while Acre is the 8th most affected (Table 1). The cumulative area converted in both departments accounts for about 16% of the total area converted in Brazil between 2004 and June 2011.

State	2004	2005	2006	2007	2008	2009	2010	June 2011	Accum.	Rate
Acre	9,456	61,106	50,063	24,938	67,569	23,663	65,900	3,856	306,550	40,873
Alagoas	150	663	144	175	550	194	63	69	2,006	268
Amapa	2,106	5,394	4,231	4,894	5,088	4,419	6,956	16,063	49,150	6,553
Amazonas	67,794	98,413	144,806	68,081	119,594	110,156	139,919	146,806	895,569	119,409
Bahia	64,325	35,769	24,394	117,056	73,931	30,588	39,813	13,156	399,031	53,204
Ceara	288	4,800	694	2,006	1,006	63	3,088	38	11,981	1,598
Distrito Federal	238	138	144	481	38	31	181	31	1,281	171
Espirito Santo	3,606	1,156	2,200	4,294	1,206	894	575	13	13,944	1,859
Goias	27,325	21,269	9,544	40,144	13,750	2,956	21,631	938	137,556	18,341
Maranhao	62,606	110,456	45,075	180,369	100,869	27,581	55,700	3,056	585,713	78,095
Mato Grosso	739,544	687,063	492,125	386,500	737,325	114,219	364,125	104,050	3,624,950	483,327
Mato Grosso S	25,350	15,363	11,044	15,081	9,381	10,831	28,081	3,513	118,644	15,819
Minas Gerais	25,669	23,275	14,413	48,888	28,419	9,856	25,138	2,719	178,375	23,783
Para	473,919	651,681	622,844	472,681	956,200	358,769	260,569	123,769	3,920,431	522,724
Paraiba	6	0	0	0	38	19	19	0	81	11
Parana	35,263	87,181	54,613	45,850	25,963	24,438	33,725	7,950	314,981	41,998
Pernambuco	344	575	194	413	294	31	38	0	1,888	252
Piaui	30,900	30,225	10,056	75,106	18,263	16,388	72,875	4,900	258,713	34,495
Rio De Janeiro	544	600	1,319	4,306	513	906	975	150	9,313	1,242
Rio Grande No	69	113	25	100	119	56	88	0	569	76
Rio Grande Sul	15,331	17,994	11,506	12,569	13,306	12,263	11,613	1,581	96,163	12,822
Rondonia	145,225	234,763	544,075	178,963	308,950	80,550	311,913	44,519	1,848,956	246,528
Roraima	6,525	8,644	13,206	17,400	17,113	23,819	11,431	13,281	111,419	14,856
Santa Catarina	20,500	30,931	40,413	17,356	15,500	16,744	18,363	3,744	163,550	21,807
Sao Paulo	36,569	32,431	32,956	18,831	9,956	7,400	9,394	1,206	148,744	19,833
Sergipe	19	900	300	213	594	369	25	119	2,538	338
Tocantins	18,619	17,481	7,150	33,013	22,525	3,463	15,800	1,744	119,794	15,973
Total Country	**1,812,288**	**2,178,381**	**2,137,531**	**1,769,706**	**2,548,056**	**880,663**	**1,497,994**	**497,269**	**13,321,888**	**1,776,252**

Table 1: Habitat changes in hectares for each Brazilian department from2004 to 2011.

The cumulative national loss detected by Terra-i during the period 2004 - June 2011 in Brazil was approximately 13,321,888 hectares, equivalent to an annual deforestation rate of 1,776,252 hectares. The greatest annual loss was detected in the states of Para and Mato Grosso, where losses of 522,724 and 483,327 ha / year were recorded respectively. The main drivers of change in these two states are the extension of grazing land for livestock and the implementation of large monoculture farms, particularly soybeans (Araújo 2008).

The growth of livestock activity has accelerated the destruction of the Amazon rainforest as the complex ecosystems that it hosts are replaced by pastureland. According to the Brazilian Institute of Geography and Statistics (IBGE), between 1996 and 2006 grazing areas in the Amazon region grew approximately 10 million hectares (Araújo 2008).

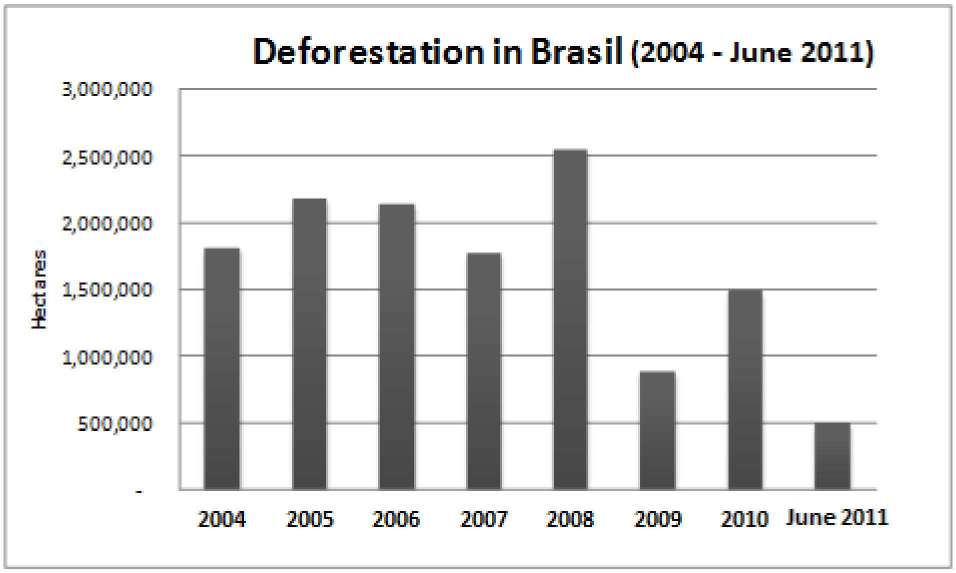


Figure 5. Deforestation in Brazil per year detected by Terra-i.

Overall the trend shows a slight reduction of habitat loss in Brazil when compared to 2004. However, the figures of loss of habitat mainly in tropical moist forests in Brazil and specifically in the Brazilian Amazon are still alarming, and signify that the current situation in the Amazon requires the framing and enforcement of strong government environmental policies.

Road Impact

The substantial difference in deforestation rates is immediately apparent when comparing the road segment from Cruzeiro do Sul to Rio Branco to the segment from Rio Branco to Porto Velho. While the loss in a buffer area of 50 km around the Cruzeiro do Sul – Rio Branco segment was measured at an average of about 19,542 hectares per year, an equally-sized buffer around the Rio-Branco – Porto Velho segment lost an average of about 79,783 hectares per year.

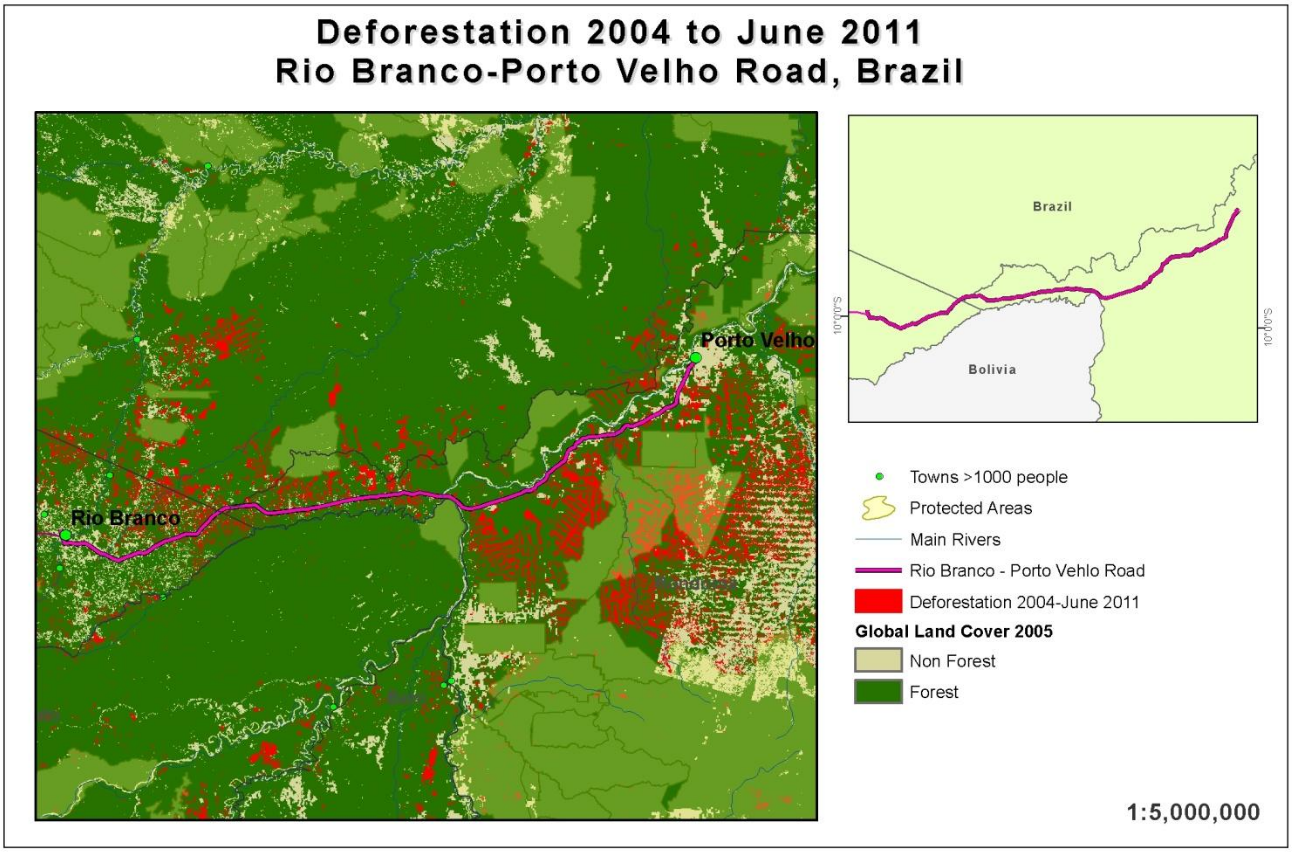


Figure 6. Deforestation 2004-2011, Rio Brancon - Porto Velho.

Table 2. Deforestation in hectares for different buffers areas around the Cruzeiro do Sul-Rio Branco Road.

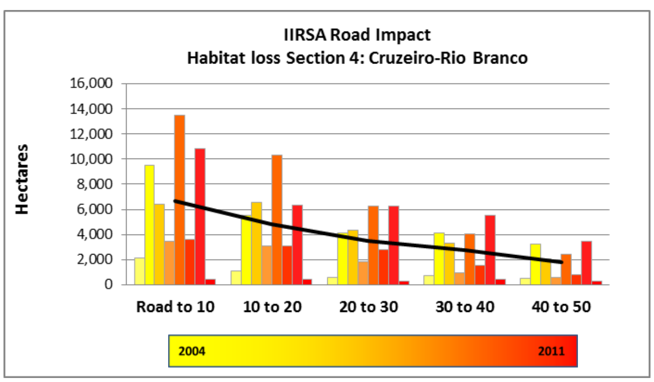
Buffer(km)	2,004	2,005	2,006	2,007	2,008	2,009	2,010	June 2,011	Accum	Annual Rate
Road to 10	2,119	9,544	6,381	3,431	13,506	3,638	10,838	463	49,919	6,656
10 to 20	1,075	5,531	6,525	3,069	10,288	3,100	6,344	438	36,369	4,849
20 to 30	606	4,125	4,319	1,800	6,281	2,763	6,244	294	26,431	3,524
30 to 40	706	4,131	3,294	938	4,013	1,531	5,488	406	20,506	2,734
40 to 50	531	3,231	2,019	600	2,450	825	3,438	244	13,338	1,778
Road to 50	5,038	26,563	22,538	9,838	36,538	11,856	32,350	1,844	146,563	19,542

Table 3. Deforestation in hectares for different buffers areas around the Rio Branco-porto Velho Road.

Buffer(km)	2,004	2,005	2,006	2,007	2,008	2,009	2,010	June 2,011	Accum	Annual Rate
Road to 10	8,131	19,413	36,994	11,125	16,425	5,450	18,075	2,669	118,281	15,771
10 to 20	13,025	18,625	39,031	10,644	18,225	5,275	28,656	1,906	135,388	18,052
20 to 30	9,156	14,906	31,869	10,425	18,869	7,231	27,575	3,050	123,081	16,411
30 to 40	12,138	14,725	29,144	14,200	21,200	6,488	24,013	1,919	123,825	16,510
40 to 50	10,150	14,138	24,094	9,925	16,888	5,831	15,081	1,694	97,800	13,040
Road to 50	52,600	81,806	161,131	56,319	91,606	30,275	113,400	11,238	598,375	79,783

Another interesting difference between the two segments is the contrasting spatial distribution of deforestation. Losses are distributed relatively equally around the Rio Branco – Porto Velho road (15,771 ha/year in a 10 km buffer, compared to 13,040 ha/year in a 40-50 km buffer). On the other hand, deforestation along the Cruzeiro do Sul – Rio Branco section is mostly distributed in areas closest to the road (6,656 ha/year in a 10 km buffer, compared to 1,778 ha/year in a 40-50 km buffer).

The fact that the deforestation is already equally distributed within a 50 km buffer around the road segment from Rio Branco to Porto Velho, mostly located in Rondonia, seems to indicate that large scale industry is already heavily entrenched around this segment. In contrast, the conservation policies implemented in the segment between Cruzeiro do Sul and Rio Branco seem to have been much more effective. This interpretation is supported by Keck (2001), who cited the case of Acres as a political success story in which those who wanted to conserve the forest created a coalition to fight against land use change policies in their local government.



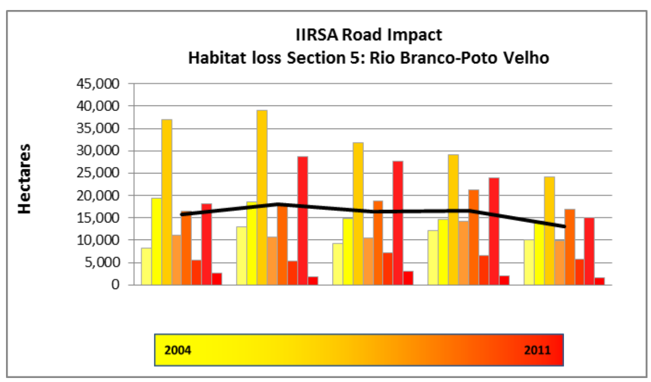


Figure 7: Deforestation around the BR-364 Highway segments for different buffer sizes.

Figure 8 shows that the deforestation patterns in the area are mainly of the fishbone and geometric types. Secondary roads generally branch off from the main road, and crops are perpendicularly distributed in arrays around it (Detail: Figure 9).

These patterns are some of the most commonly seen in the Brazilian Amazon (Pedlowskia 1997). Legal and illegal roads open access to remote parts of the forest, allowing industrial and small-scale farmers alike to move to these newly available areas and clear the forest to establish crops. Eventually, fish bones patterns tend to collapse into almost completely cleared areas.

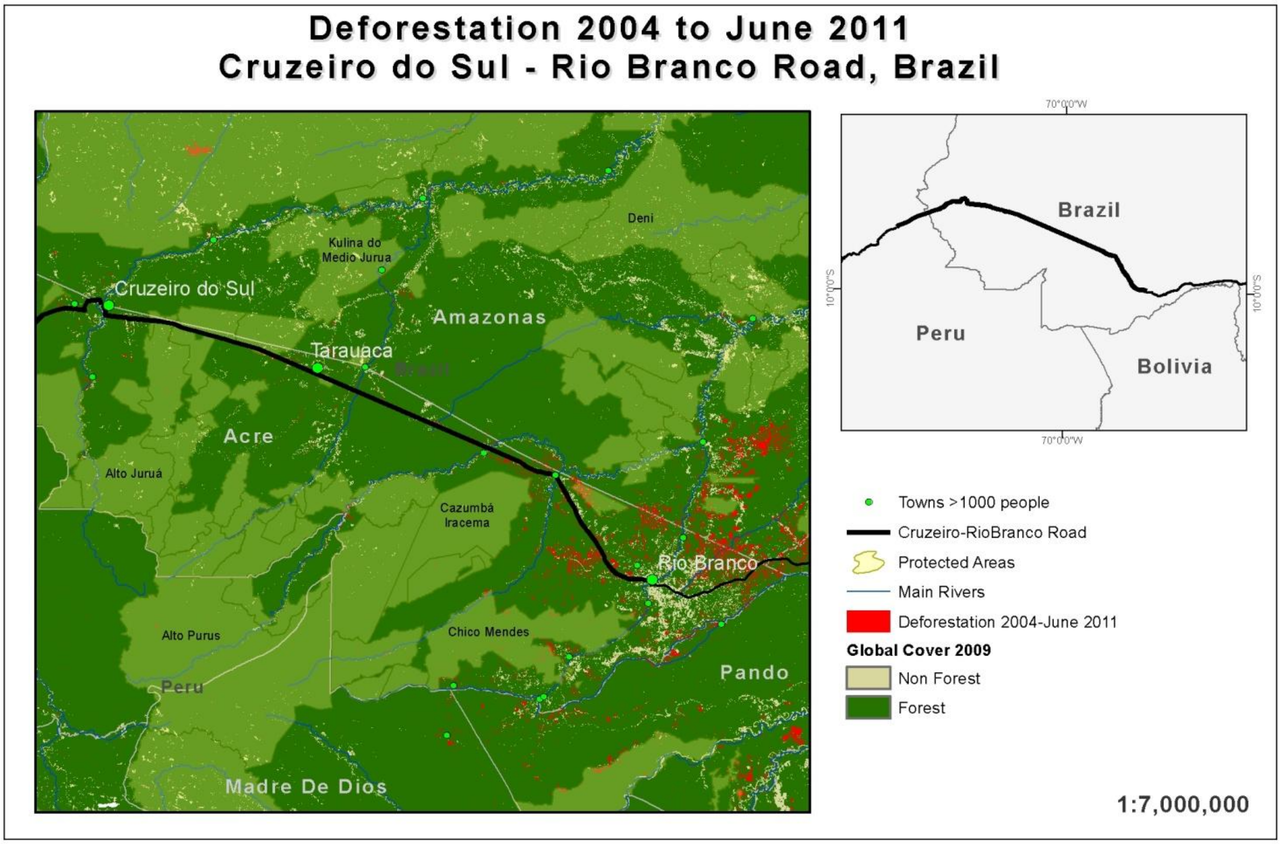


Figure 8: Deforestation maps in the studied area

Protected Areas

As Shown on Figure 9 and highlighted in Table 5, Bom Futuro and Jaciparaná are the two protected areas most affected by deforestation in Rondônia and are located next to the analyzed road, within a buffer area of 20 km.

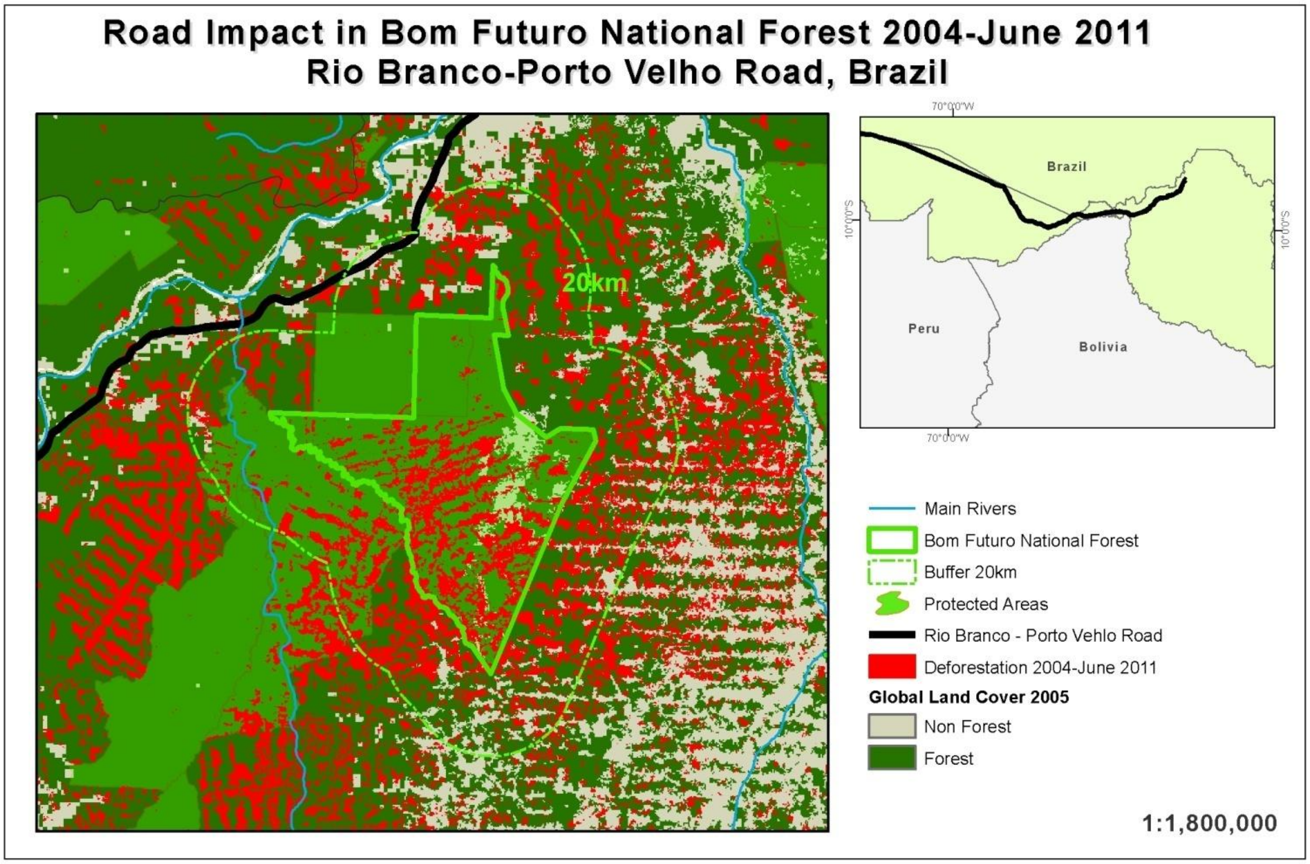


Figure 9. Road Impact Map in Bom Futuro National Forest.

The Bom Futuro Nacional Forest is a protected area designated for sustainable use, located in the municipalities of Ariquemes and Porto Velho in Rondonia state. It was created in 1988 with the aim of promoting the management of timber stocks in the region. It is administered by the Chico Mendes Institute for Biodiversity Conservation (ICMBio).

The illegal occupation and deforestation of the protected area have led the Brazilian government to withdraw farmers and cattle producers from the region.[1]

[1] Pequenos produtores da Flona Bom Futuro não serão prejudicados, diz Minc a Moreira, http://portal.pps.org.br/portal/showData/149838

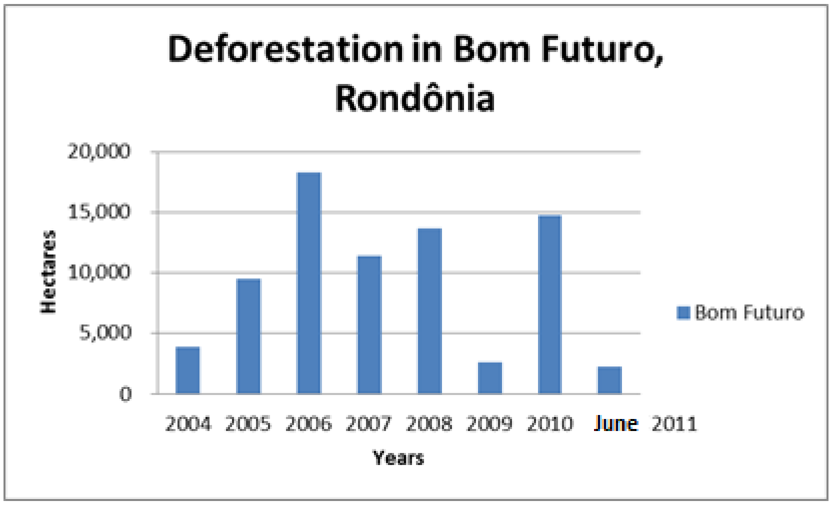


Figure 10. Graphic of deforestation in Bom Futuro National Forest.

In fact, the deforestation rate in Bom Futuro has been 10,188 hectares per year for the past 7.5 years (for a total conversion of 76,406 hectares), compared to 6,337 hectares per year for the past 7.5 years in Rio Jaciparaná (a total conversion of 47,525 hectares).

Table 4. Protected Areas experiencing major impacts.

Protected Area	2004	2005	2006	2007	2008	2009	2010	Jan-Jun 2011	Accum.	Rate
Bom Futuro	3,906	9,531	18,325	11,381	13,675	2,619	14,738	2,231	76,406	10,188
Rio Jaciparana	3,838	5,594	12,288	7,300	3,563	2,494	10,925	1,525	47,525	6,337
Uru-Eu-Wau-Wau	219	450	1,238	656	1,125	575	7,000	1,494	12,756	1,701
Rio Ouro Preto	263	744	1,613	550	206	100	3,006	131	6,613	882
Corumbiara	1,313	1,894	956	1,081	531	94	550	75	6,494	866
Pacaas Novas	0	75	275	2,488	194	225	2,306	663	6,225	830
Mutum	50	100	1,231	656	525	288	2,331	369	5,550	740

According to a recent publication by the Institute of Human and Environment in the Amazon (Imazon) and the Socio-Environmental Institute (ISA), half of all land clearing that occurred in protected areas happened during the last decade, between 1998 and 2009. In addition, vast networks of illegal roads are located within and around the protected areas. For every 1,000 km^2 of land under protection there are about 17.7 km of roads. Many of these pathways are associated with illegal logging, mainly in the states of Para and Mato Grosso.

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 11, Brazil has large reserves of carbon. The states of Acre and Rondonia, located in the Amazon, have many protected areas that contribute to the conservation of these carbon stocks (some large areas store more than 300 Megagrams per hectare) by slowing down deforestation. However, there are clearly large patches of deforestation around the towns of Porto Velho and Rio Branco which continue to expand. The red in Figure 11 is highlighting the detections of Terra-i from 2004 to 2011, which are mainly located around already deforested areas.

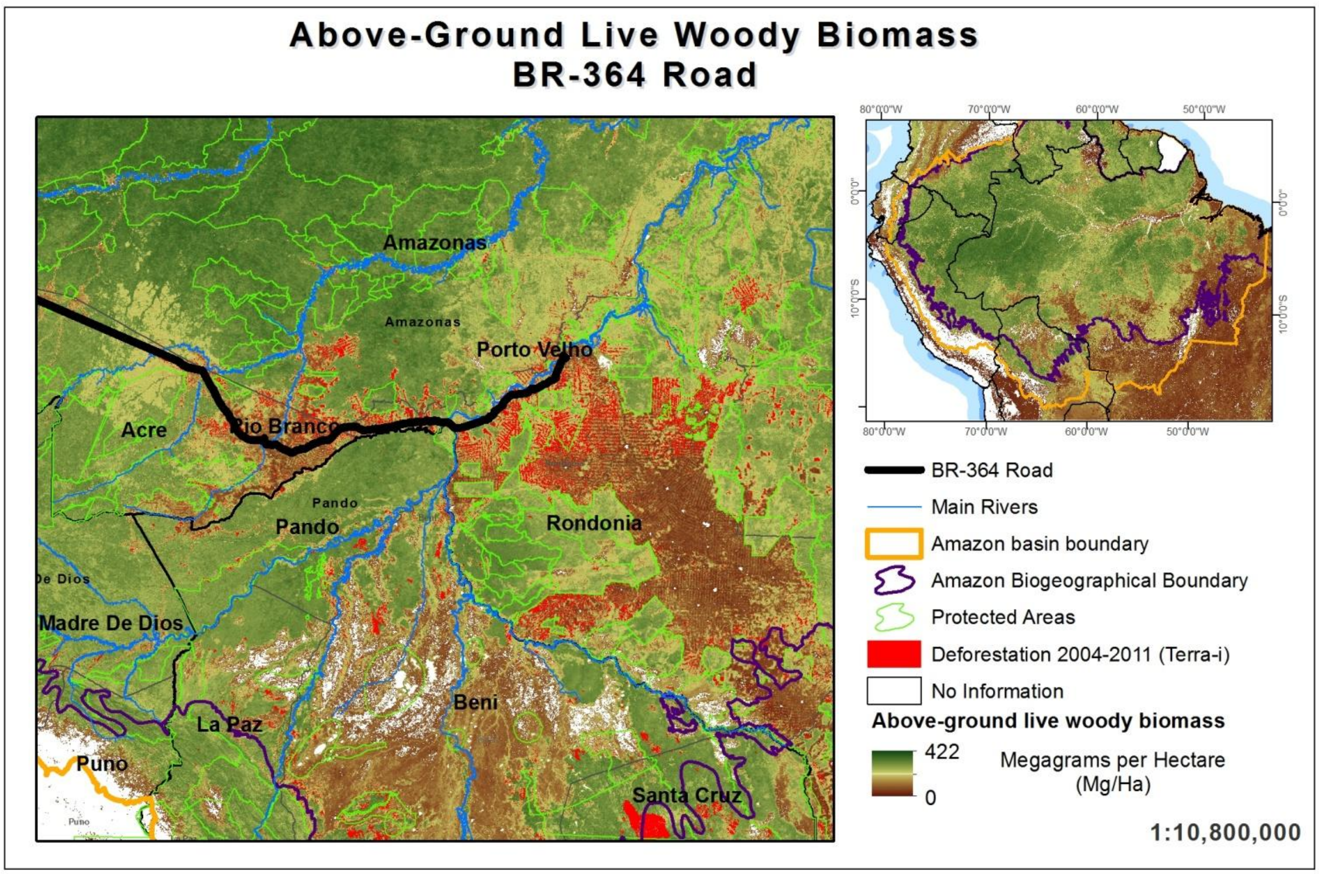


Figure 11. Above-ground live woody biomass in Brazil.

In addition, 100% of the Brazilian Legal Amazon is registered by the Center for Applied Biodiversity Science at Conservation International as a High Biodiversity Wilderness Area.

The value of protected areas in Brazil is undeniable and of consummate importance for the conservation of biodiversity, not only in the Amazon but all over the world. The last seven years (2003 to 2010) saw the creation of 47.3% of the Conservation Units (CUs) in the region. Currently, protected areas represent 43.9% of the Amazon territory. Despite the fact they are protected by the laws, these CUs are under constant threat. The fact that the Amazon region is incredible rich in resources (including the products of biodiversity, the vast hydroelectric potential of rivers and rich mineral deposits) whose economic value is only increasing attracts a variety of interests, both benign and otherwise. The integrity of its ecosystems and its socio-environmental diversity is therefore at continual risk for exploitation.

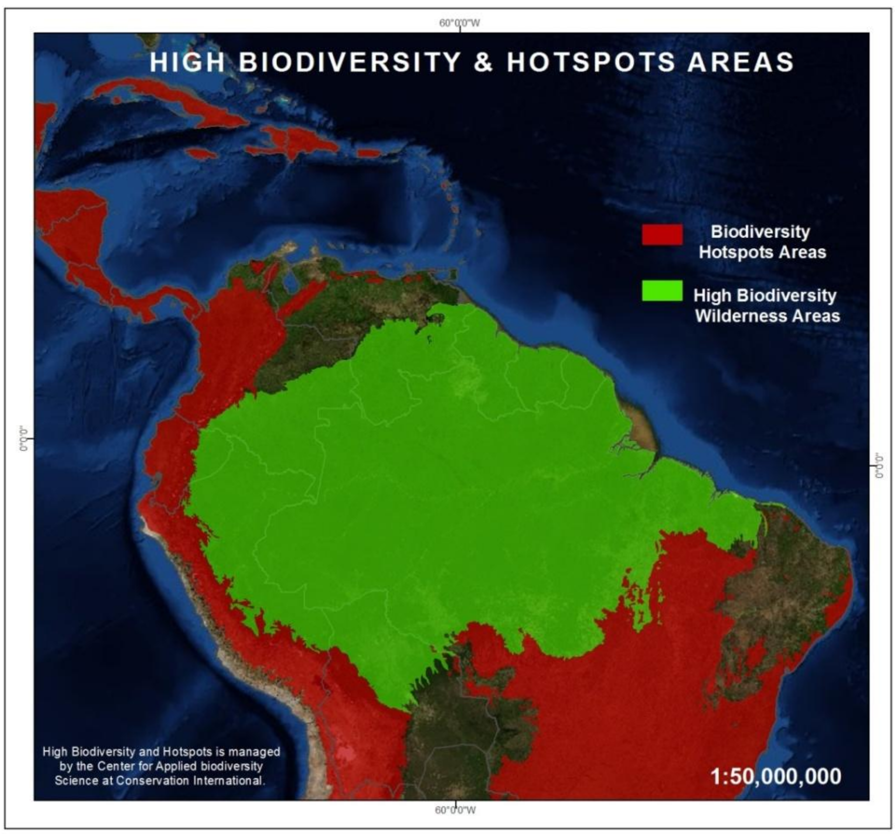


Figure 12. Biodiversity map in Latin America.

Future Habitat Change Scenarios

The algorithm implemented for this study can be divided into three steps. During the first step, a dataset of inputs and outputs is extracted to train a multilayer perceptron neural network. The neural network is trained to infer the probability that a given pixel will be deforested given topological information (such as the distance to the nearest road, or the elevation) and the state (deforested or not) of the pixels present in a given radius around the analyzed pixel. During the second step, the well-trained neural network is applied to every pixel of the studied area so as to generate a map of potential deforestation. In the third step, a given number of pixels are selected to be deforested. The higher the potential deforestation value calculated by the neural network, the higher the likelihood that a pixel will be selected as deforested. The default deforestation rate is constant, but it can also be set as a function of time. Finally, steps two and three can be repeated several times in order to simulate the evolution of deforestation in time and in space.

As proof of concept, this methodology was applied for the area of the second segment (Rio Branco – Porto Velho) from the 1st of January 2004 to the 10th of June 2011 and compared with actual detections from Terra-i. The constant deforestation rate was set to 10,000 hectares per 16 day period (equal to the average rate recorded by Terra-i in this area), and 10,000 pixels were sampled to train the neural network. Figure 13 shows the potential deforestation for the 1st of January 2004, where the pixels directly adjacent to already deforested areas are the most likely to be deforested. Likewise, the more remote a pixel is the lower its probability of being deforested.

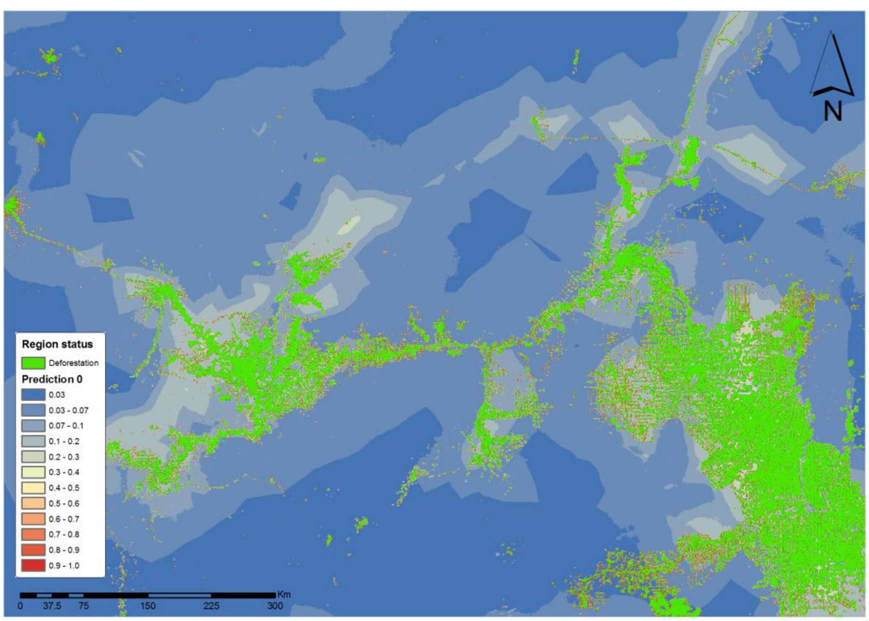
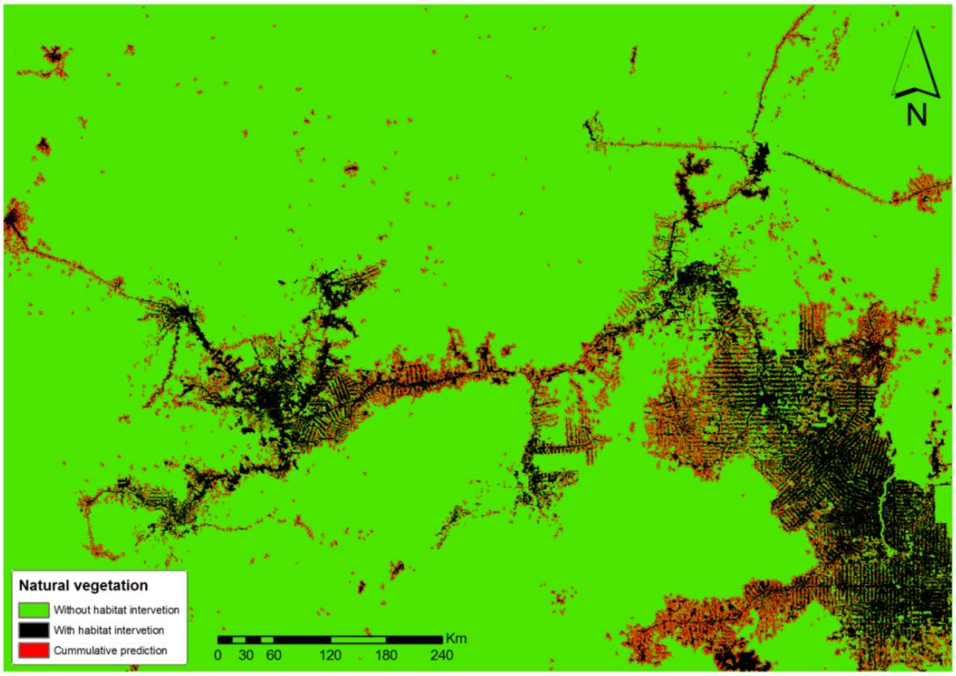


Figure 13: Potential deforestation at t=0 (1st of January 2004) for the segment from Rio Branco to Porto Velho.

Figure 14 shows how deforestation is modeled by the algorithm. Most of the pixels that the tool selects as cleared are located around already deforested areas and roads.



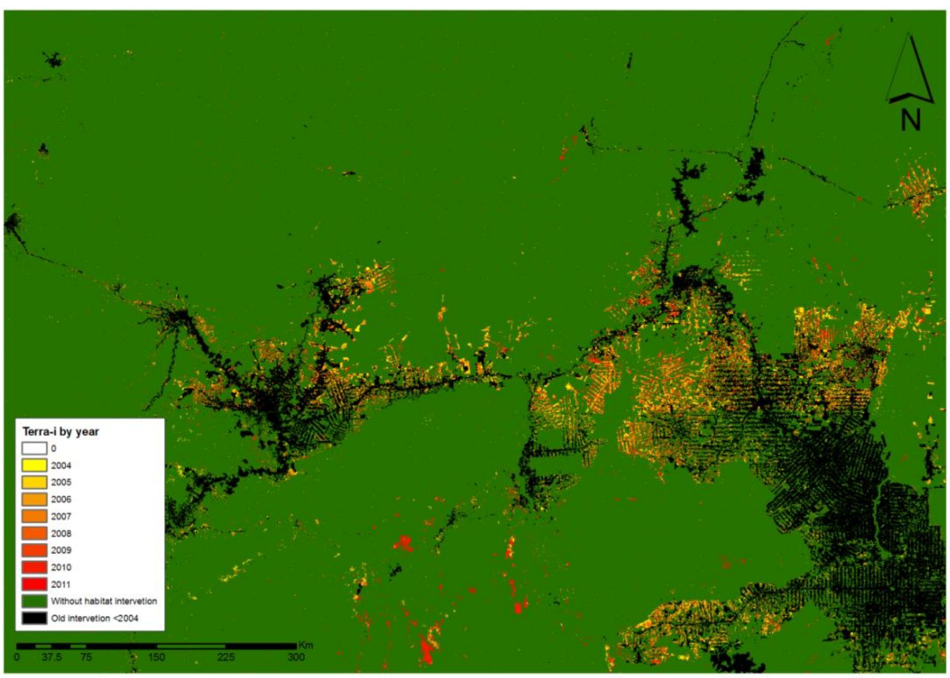


Figure 14: Top: Base map with predicted deforestation. Bottom: Base map with Terra-i detection.

The general patterns of deforestation are quite similar when comparing the resulting modeled deforestation (top) with the actually detected deforestation (bottom).

Some noise in the base map (individual pixels wrongly flagged as deforested) generated patches at the top of the studied area. Additionally, some large events located at the bottom of the area were missed by the model. These errors show that the base map is an important input and must be created carefully, a task which can be difficult depending on the attributes of the analyzed area.

This implementation of the methodology to generate future scenarios of deforestation is presented here as proof of concept. It gave encouraging results that compare favorably with Terra-i's actually detected deforestation. The general patterns resulting from the simulation are convincing and quite similar to the real events.

Conclusions

In Brazil, 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 40,850 hectares in the Acre department and 1,849,494 in the department of Rondônia, equivalent to an annual loss rate of 40,850 ha/year. The highest rates of deforestation were detected in departments located in the Amazon, such as Pará y Mato Grosso. The main drivers of change in these two states are the extension of grazing land for livestock and the implementation of large monoculture farms, particularly soybeans (Araújo 2008).

For this study, the Cruzeiro do Sul – Porto Velho road was analysed in two different sections. The first corresponds to a corridor of 623 km connecting the towns of Cruzeiro do Sul and Rio Branco in the state of Acre, Brazil. This section passes through a large biological corridor in the state of Acre which is composed of 39 adjoining protected areas. The second segment corresponds to a 515 km corridor connecting the towns of Rio Branco in the state of Acre and Porto Velho in the state of Rondônia. Rondônia is located in the north-western part of the country.

The substantial difference in deforestation rates is immediately apparent when comparing the road segment from Cruzeiro do Sul to Rio Branco to the segment from Rio Branco to Porto Velho. While the loss in a buffer area 50 km around the Cruzeiro do Sul – Rio Branco segment was measured at an average of about 19,542 hectares per year, an equally-sized buffer around the Rio-Branco – Porto Velho segment lost an average of about 79,783 hectares per year. What's more, the spatial distribution of the deforestation is quite different for the two sections. Losses are distributed relatively equally around the Rio Branco – Porto Velho road (15,771 ha/year in a 10 km buffer, compared to 13,040 ha/year in a 40-50 km buffer). On the other hand, deforestation along the Cruzeiro do Sul – Rio Branco section is mostly distributed in areas closest to the road (6,656 ha/year in a 10 km buffer, compared to 1,778 ha/year in a 40-50 km buffer).

The fact that the deforestation is already equally distributed within a 50 km buffer around the road segment from Rio Branco to Porto Velho, mostly located in Rondonia, seems to indicate that large scale industry is already heavily entrenched around this segment. On the other hand, the conservation policies implemented in the segment between Cruzeiro do Sul and Rio Branco seem to have been more or less effective. This interpretation is supported by Keck (2001), who cited the case of Acres as a political success story in which those who wanted to conserve the forest created a coalition to fight against land use change policies in their local government.

High rates of conversion around the analyzed road show that it enables ease of access to remote areas and therefore has a considerable negative impact within its area of influence (from 0 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.

Furthermore, the implementation of protected areas without politic support does not seem to be effective. This notion is supported by the alarming deforestation rate measured within the Bom Futuro protected area: 10,188 hectares per year for a total of 76,406 hectares converted in 7.5 years. According to a recent publication by the Institute of Human and Environment in the Amazon (Imazon) and the Socio-Environmental Institute (ISA), half of all land clearing that occurred in protected areas happened during the last decade, between 1998 and 2009. In addition, vast networks of illegal roads are located within and around the protected areas. For every 1,000 km^2 of land under protection there are about 17.7 km of roads. Many of these pathways are associated with illegal logging, mainly in the states of Para and Mato Grosso.

Finally, the implementation of the methodology to generate future scenarios of deforestation gave encouraging results that compare favorably with Terra-i’s actually detected deforestation. The general patterns resulting from the simulation are convincing and quite similar to the real events. However, various improvements could be instigated. For example, the tool currently only takes into account topographic variables. Ideally, other inputs such as administrative information (protected areas, country), social information (small farmers, industrial exploitation, community managed forest) and vegetation types (rather than a single measure for all deforestation) should be included in the analysis as well.

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