ROAD IMPACT ON HABITAT LOSS

PASTO-MOCOA ROAD IN COLOMBIA

2004 to 2011

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CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture
Consultative Group on International Agricultural Research

IDB

BMZ Federal Ministry for Economic Cooperation and Development

The Nature Conservancy
Protecting nature. Preserving life.™

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

CONSERVATION BIOLOGY INSTITUTE
Bridging conservation science and practice

terra-i
An eye on habitat change

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Content

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Executive Summary

The IDB has approved two projects involving the **Pasto-Mocoa road in Colombia**. The first is a reported US$ 1.45 million **Technical Cooperation** grant (CO-T-1038) associated with the final design and environmental licensing for construction of part of this road, approved in **November 2006** and signed the next month, which is reportedly still under implementation. The second is a US$ 53 million **loan** (CO-L-1019), approved in **December 2009** and signed in May 2010, for the **San Francisco-Mocoa Alternate Road Project** – Phase I (IDB 2011).

In Colombia, 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 814,391 hectares, equivalent to a national average of 108,586 ha/year. The highest deforestation rate during the analysis was recorded for the Caquetá department. 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.

The first road section analyzed, between Pasto and San Francisco, was built long before Terra-i was operational (during the 1930's). The other section, between San Francisco and Mocoa, was still under construction when this study was performed. Additionally, the area where the road passes through has an almost permanent cloud cover which made land cover change assessment using Terra-i impossible in more than 50% of the studied area. Even other datasets such as Landsat images could not be used to assess habitat changes in these heavy cloud-cover areas. All of these factors complicated to a large extent the impact assessment of the analyzed road. This report is therefore focused on the possible impact of the road on more remote areas such as the Amazonian rainforest present in the department Putumayo.

The length of analyzed road is about 98 km. It passes through the departments of Nariño and Putumayo where deforestation rates of 12,525 and 7,481 hectares per year were recorded. These rates fall far below the national average deforestation rates.

There was not a high rate of habitat loss in the areas of influence of the road. Nevertheless, it is possible to observe the migration processes of the poor, rural and indigenous populations from mountainous regions to flat areas where it is easier to establish agriculture. Therefore, one can assume that the road eases the migration process of these poor populations and thus indirectly contributes to the habitat loss in the Colombian Amazon.

Study Area

The Pasto-Mocoa road is located in the south-west of Colombia between the coordinates 1°12’38.33’’N, 77°16’40,67”W and 1°09’03.96’’N, 76°38’43,38”W.

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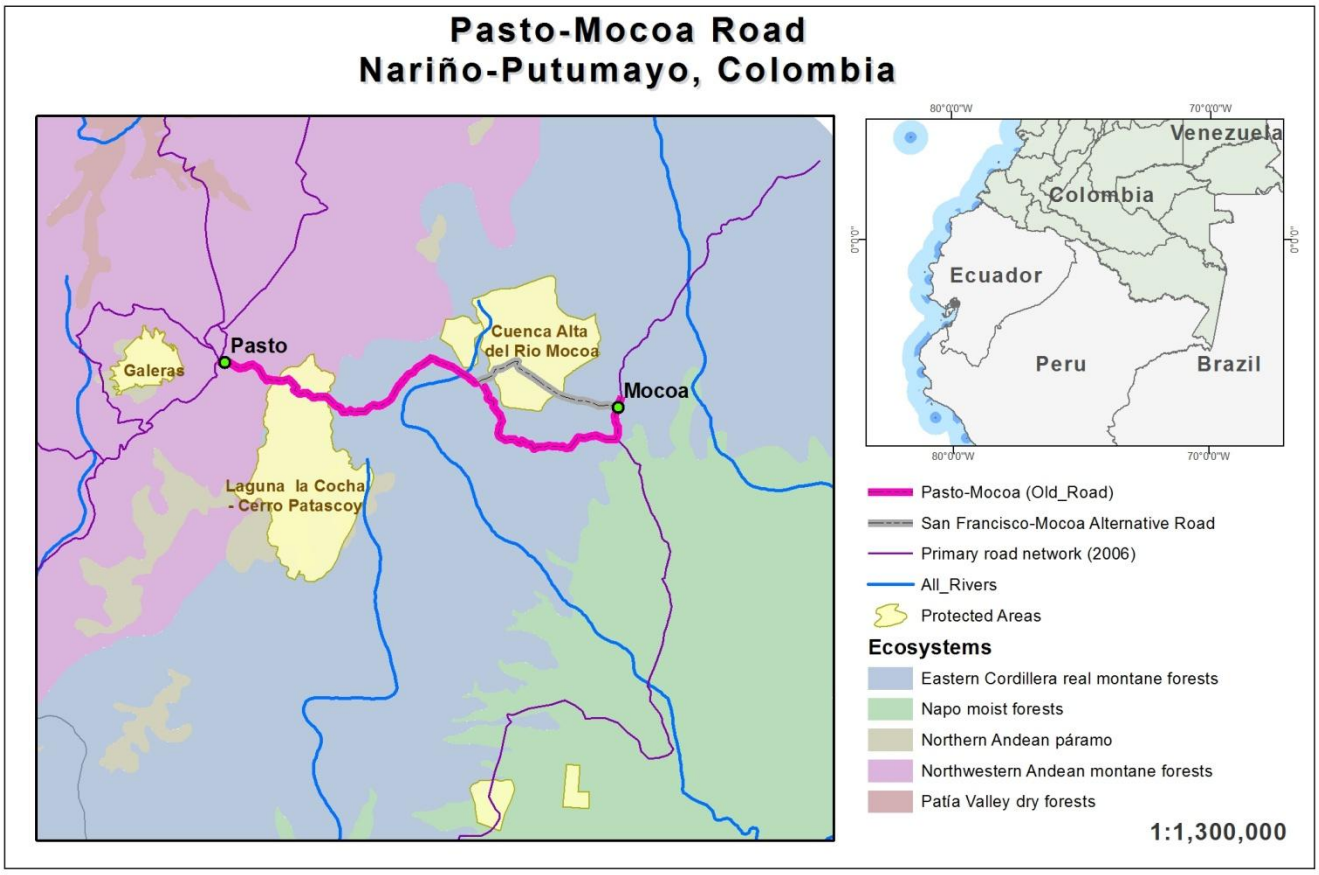


Figure 1. Study Area, Pasto-Mocoa Road.

The Pasto-Mocoa corridor built in the 1930's is split into two sections. The first section covers the 56 km between Pasto and San Francisco. The second section connects the towns of San Francisco and Mocoa with a total length of 42 km. This section of the road has serious limitations, such as long stretches that are only 4 m wide (leaving space for only one vehicle at the time), steep slopes, unstable areas, constant cloud cover and deep canyons. Indeed, its high accident rate makes it one of the most dangerous roads in the country. This lack of accessibility and poor connectivity has resulted in serious restrictions on the development of low cost alternatives, as well as the stunting of the competitiveness of the primary sector and the high levels of poverty in the region (INVIAS 2010). For this reason, the San Francisco-Mocoa turn-off was built along the Amazon foothills. Nevertheless, 68% of this alternative road crosses the Forest Shield Reserve of the Upper Basin of the Mocoa River. Although there are no indigenous communities living in the area of influence of the alternative road, these communities have close sociocultural relationship with the Reserve, making it an environmentally sensitive location. The turn-off was therefore designed to minimize environmental impacts and its construction followed the protocol of the Plan of Integrated Environmental and Social Management and Development (PMASIS) (INVIAS 2010).

The Pasto-Mocoa road is part of the Amazon Multimodal Axis which includes three Colombian departments – Nariño, Putumayo and Amazonas – as well as the countries of Ecuador, Peru and Brazil. It is split into three regions distinguishable by their biophysical, economic and cultural features: the Pacific plain, the Andes and the Amazon rainforest. The studied road crosses numerous permanent and intermittent drainages, mainly belonging to the Mocoa River basin (86.2%) and secondarily to the Putumayo basin (13.8%). The Mocoa and Putumayo rivers are the recipients of all the effluent drainages crossed by the road (Flórez 2007).

Habitat Change Monitoring

Previous studies

Originally, 80% of the Colombian territory was covered by natural forests (tropical moist forest, mountain forest, dry forest, mangroves etc). By 2003 this proportion had been reduced to 50%, mainly due to expansion of the agricultural frontier, development of infrastructure, establishment and eradication of illegal crops (such as cocaine and marijuana), consumption of wood for energy, open pit mining and forest fires (Ministerio del Medio Ambiente de Colombia 1998).

According to the map of changes in vegetation cover in Colombia between 1986 and 2001 generated by the Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), the areas most affected by vegetation change were forests. The deforestation rate for these areas was about 101,303 ha / year, or the equivalent of an annual reduction of 0.18% of the total forested area (IDEAM 2004).

In the case of the Colombian Amazon, logging for the cultivation of illegal crops, expansion of the agricultural frontier, new settlements and extensive cattle ranching are the main causes of deforestation. The rates vary from 0.97% to 3.73% in highly populated areas, and are about 0.23% in sparsely populated areas (Armenteras, y otros 2006).

In 2009 the IDEAM, as part of the project "Institutional Capacity to support Technical and Scientific Projects to Reduce Emissions from Deforestation REDD in Colombia," made a preliminary estimate of deforestation at the national level (scale 1:500.000), using MODIS images with a spatial resolution of 250 m for the years 2000 and 2007. The results indicate that the country lost about two million hectares of forest between 2000 and 2007. Therefore, one can estimate the average annual deforestation rate to be 336,000 ha / year (Cabrera, et al. 2011).

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 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). 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 Colombia, 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 814,391 hectares, the equivalent of a national average of 108,586 ha / year. This rate is very different from the one reported by the IDEAM, a difference explained mainly by the lack of good quality input data for Terra-i near-real time monitoring in the Chocó department and in the Andean regions (shown in white in Figure 2). This difference can also been explained by discrepancies in the methodologies (the IDEAM study is not near-real time) and calibrations used.

Figure 2. Map of habitat loss in Colombia, Terra-i monitoring (2004-2011).

Table 1. Habitat loss detected by Terra-i in hectares per department, per year.

Department	%NoData	2004	2005	2006	2007	2008	2009	2010	2011	Accum.	Annual Rate
Amazonas	0.2%	6038	963	1,594	919	3,131	3,044	2,844	2,910	21,441	2,859
Antioquia	12.9%	3331	6356	5,963	7,131	10,750	12,500	18,800	10,194	75,025	10,003
Arauca	6.2%	388	269	325	1,888	1,463	1,344	4,856	1,100	11,631	1,551
Atlantico	3.9%	0	6	50	6	63	88	88		300	43
Bolivar	0.7%	475	2656	4,225	2,300	5,363	7,169	10,031	11,394	43,613	5,815
Boyaca	8.6%	138	300	381	338	313	181	563	425	2,638	352
Caldas	10.0%	400	1031	1,056	494	331	863	844	769	5,788	772
Caqueta	3.3%	4875	6881	8,775	20,788	28,594	14,844	20,063	29,106	133,925	17,857
Casanare	0.5%	2019	4444	2,569	11,613	5,400	6,406	2,044	3,869	38,363	5,115
Cauca	22.9%	1500	3350	4,713	3,056	2,013	6,294	3,781	3,150	27,856	3,714
Cesar	1.0%	2206	4075	3,919	3,881	6,938	8,844	3,750	2,800	36,413	4,855
Choco	59.0%	963	1344	1,613	1,175	2,275	2,244	3,731	2,969	16,313	2,175
Cordoba	10.8%	119	413	700	1,338	606	738	2,531	2,300	8,744	1,166
Cundinamarca	12.3%	113	338	631	575	381	1,469	919	519	4,944	659
Guainia	0.0%	1469	1000	1,294	1,288	819	338	2,000	3,644	11,850	1,580
Guajira	2.1%	81	144	13	413	706	281	188	94	1,919	256
Guaviare	0.0%	3913	1950	2,506	6,038	5,663	5,781	6,744	19,431	52,025	6,937
Huila	44.4%	6	44	69	38	113	606	31	131	1,038	138
Magdalena	3.6%	1319	613	3,381	3,625	6,256	8,075	8,250	631	32,150	4,287
Meta	4.3%	3525	6163	8,938	18,319	19,838	12,669	12,269	27,144	108,863	14,515
Narino	40.0%	813	1494	1,925	1,206	1,188	2,425	1,806	1,669	12,525	1,670
Norte De Santand	3.7%	913	988	1,294	1,406	1,575	3,438	5,256	2,038	16,906	2,254
Putumayo	7.3%	1563	1419	1,769	1,406	1,563	1,544	2,581	5,638	17,481	2,331
Quindio	61.5%	13	6	19	6	13	44	25	50	175	23
Risaralda	45.4%	50	138	344	88	69	231	163	138	1,219	163
Santander	1.2%	4738	4944	6,925	7,275	7,319	10,913	11,675	7,119	60,906	8,121
Sucre	0.7%	50	138	444	313	456	738	1,438	1,756	5,331	711
Tolima	27.9%	213	688	1,269	631	713	4,006	850	1,850	10,219	1,363
Valle Del Cauca	42.9%	781	1725	2,981	3,075	1,206	4,075	3,231	5,838	22,913	3,055
Vaupes	0.0%	1375	513	988	913	1,406	763	1,306	3,763	11,025	1,470
Vichada	0.0%	2069	1594	4,906	2,775	1,969	1,531	1,294	4,719	20,856	2,781
Nacional	**9%**	**45,450**	**55,981**	**75,575**	**104,313**	**118,488**	**123,481**	**133,950**	**157,154**	**814,391**	**108,586**

As shown in Table 1, the departments with the greatest habitat loss during the 7.5 analyzed years (2004-2011) were Caquetá and Meta, where cumulative areas of 133,925 and 108,863 hectares respectively were detected by Terra-i. The main drivers explaining deforestation in these two departments are the expansion of the agricultural frontier and the conversion of extensive areas for livestock (Armenteras, y otros 2006).

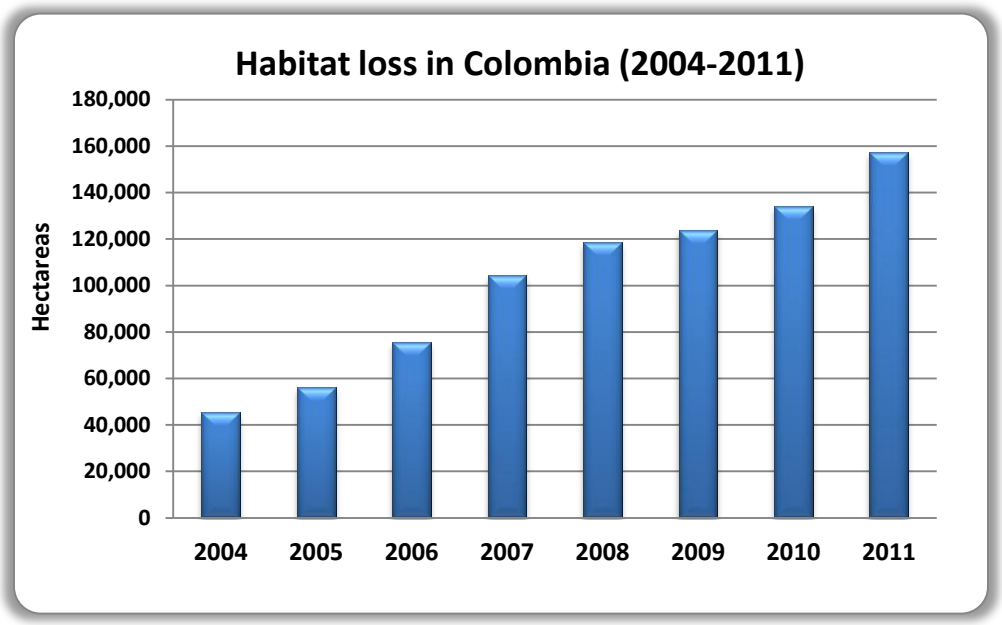


Figure 3. Annual habitat loss in Colombia.

As shown in Figure 3, the annual trend of national deforestation has been steadily increasing. Table 1 and Figure 2 show that habitat loss events happened mainly in the departments located in the Colombian Amazon.

The studied road segment passes through the departments of Nariño and Putumayo where deforestation rates of 12,525 and 7,481 hectares per year were recorded. These rates fall well below the national average deforestation rates.

Road Impact

The departments in Southwestern Colombia are characterized by a dense cloud cover, impeding temporal analysis of vegetation cover using remote sensing due to the low quality of satellite images.

In the Nariño department, 40% of the studied area could not be analyzed due to cloud cover. In the department of Putumayo, 7% of the area could not be analyzed. These unassessed areas are mainly located in the mountainous zones through which the Pasto-Mocoa road passes, complicating the process of an impact analysis for the road.

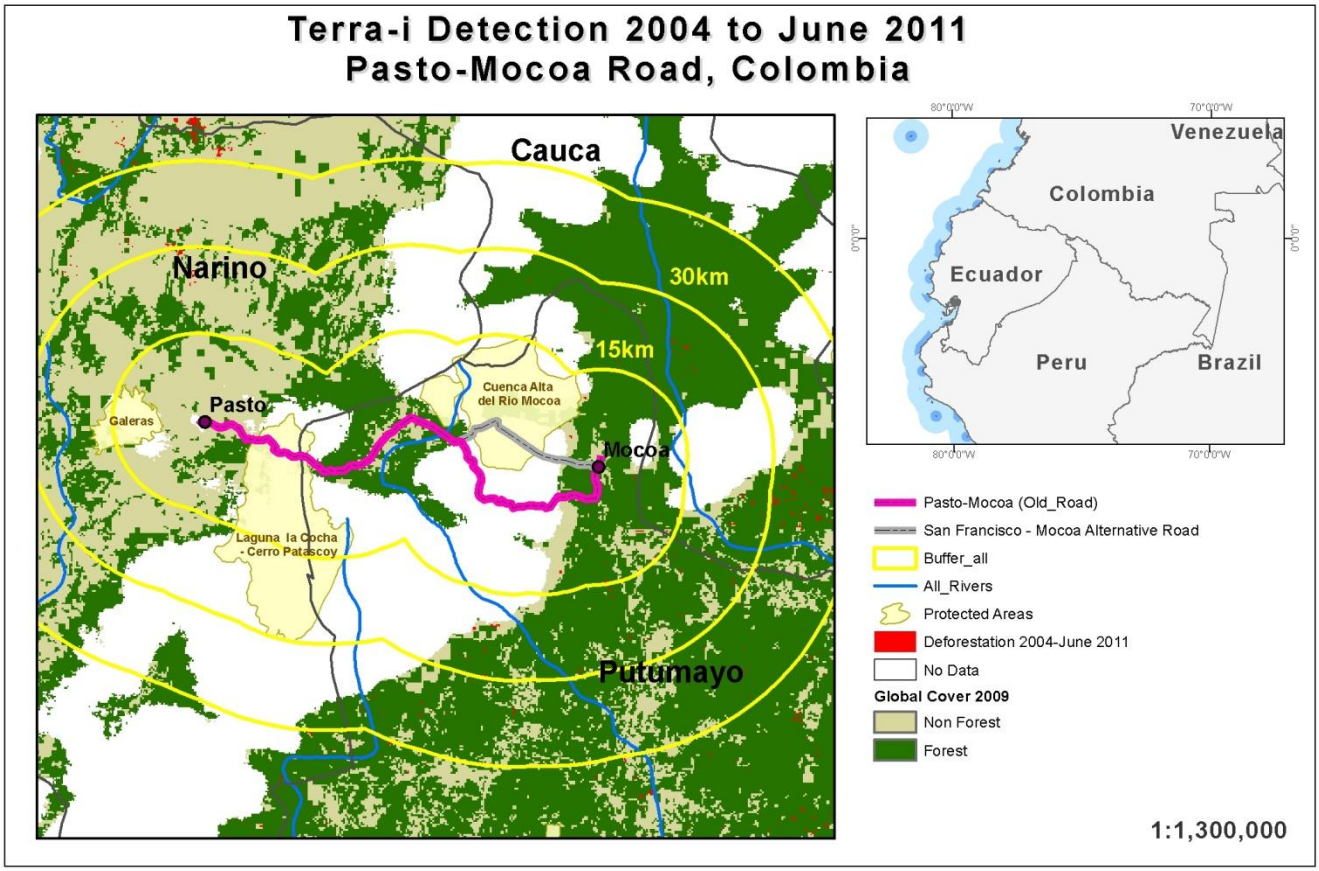


Figure 4. Pasto-Mocoa Road habitat loss map, Terra-i monitoring (2004-2011).

There is a change of 0.02% in the 68% of the area that could be analyzed, using data from habitat changes detected by Terra-i and the analysis of buffer zones 15, 30, and 45 km from the road.

Table 2. Habitat loss detection in buffers of 15, 30 and 45 km from Pasto-Mocoa Road.

Buffer(km)	%NoData	2,004	2,005	2,006	2,007	2,008	2,009	2,010	2,011	Accum.	Annual Rate
Road to 15	47.0%	6	0	44	31	13	25	31	44	194	26
15 to 30	33.8%	69	119	100	13	56	163	219	88	825	110
30 to 45	20.6%	56	69	63	88	138	588	131	94	1,225	163
Road to 50	31.5%	131	188	206	131	206	775	381	225	2,244	299

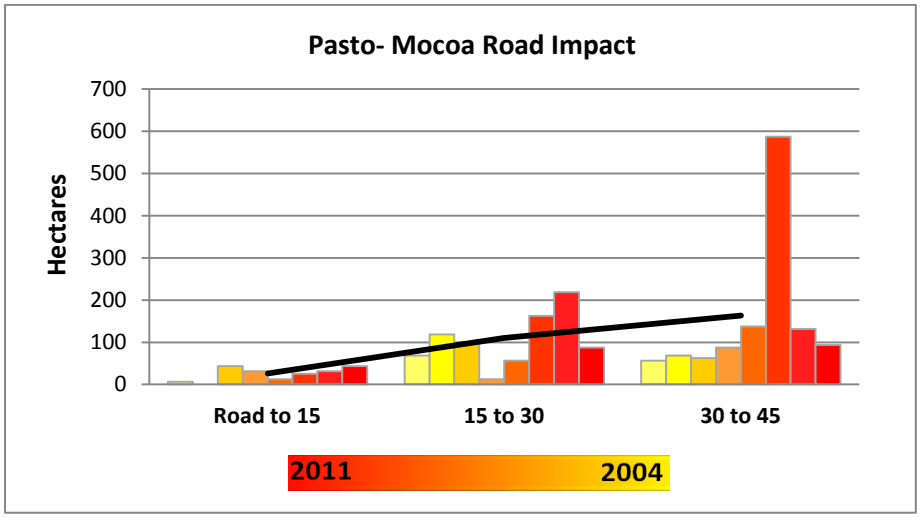


Figure 5. Annual impact from the Pasto-Mocoa Road in the buffer areas.

The impact generated by the analyzed road between the years 2004 and mid 2011 in the area of direct influence (a buffer zone of 15 km around the road) is negligible. This can be explained by the fact that this road was built during the 30's and any direct impact resulting from its construction happened years before the period of analysis. Around the new road section (San Francisco-Mocoa) which was built after May 2010, Terra-i did not record any changes. This can be explained in part by the very high cloud density in this area which made a comprehensive analysis difficult, but it can also be explained by the newness of the road. This analysis should therefore be performed again in the near future to ensure that the impact of the road remains low.

Furthermore, Figure 5 demonstrates that the impact of the road is much greater in flat areas. This could be explained by the continuous process of rural migration. Such migration processes have been observed moving from the mountainous areas of Nariño, in direction of the departments of Putumayo and Valle del Cauca, as well as to the municipality of Santo Domingo de los Colorado. Poor farmers and landless migrants from the Andean region are aiming to settle in these areas and eventually continue to work in the farming sector (Ramos and Céron n.d.).

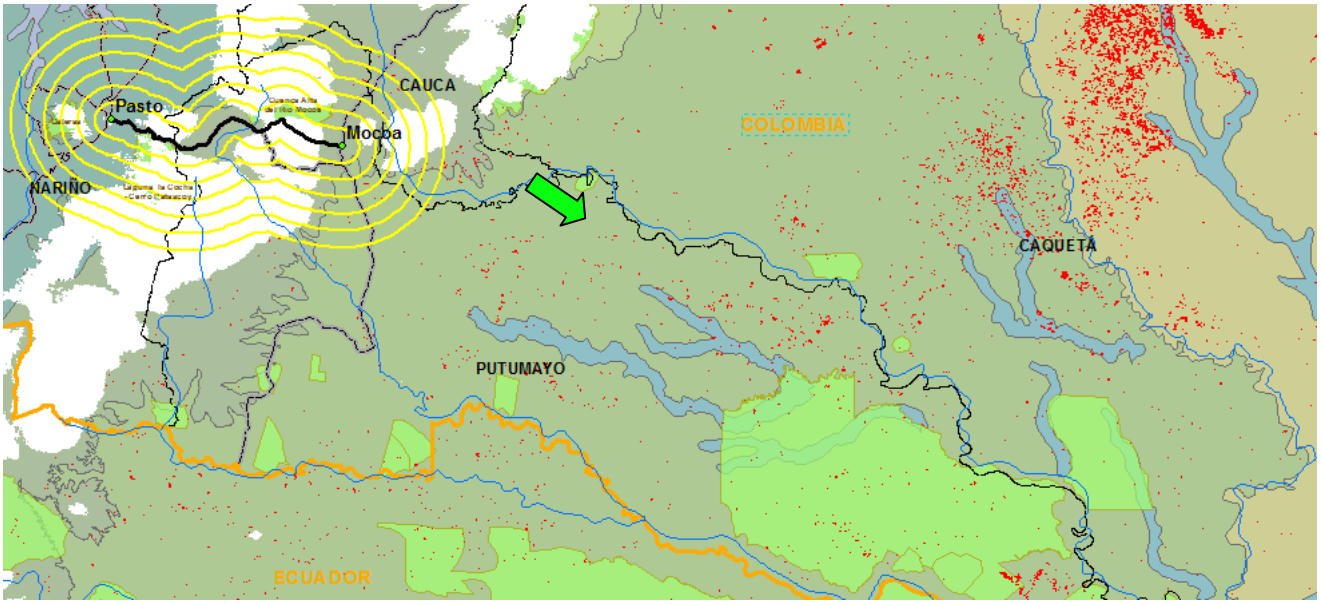


Figure 6. Terra-i detection in Putumayo.

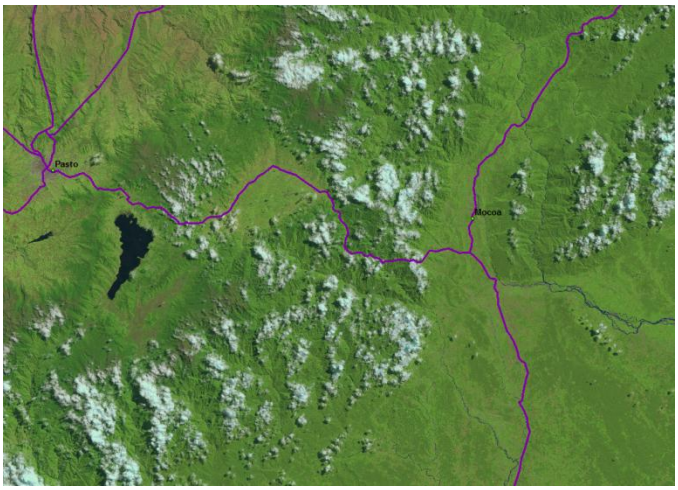
In red: Deforestation (2004-2011), in white: Cloudy areas, in green: Protected Areas, in yellow: Buffers of the road 5 to 30km, other colors: different Ecosystems types

As shown by Florez (2007), Putumayo's economy is mainly based on the exploitation of oil resources, agricultural production (banana, cassava, corn, potato, sugarcane and livestock in the foothills of the department), and forestry. The oil industry is the most important source of departmental revenue. Oil is transported by the trans-Andean pipeline to the port of Tumaco on the Pacific Ocean coast. Tumaco is located at the western endpoint of the Colombian Amazon Multimodal Axis.

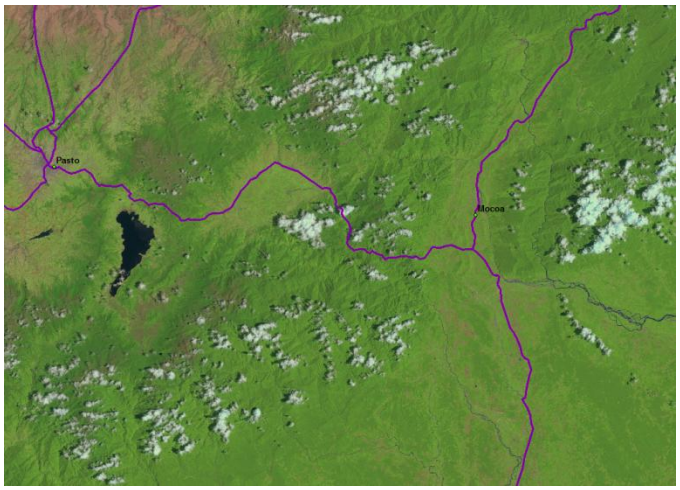
Validation with Landsat

Terra-i is based on the analysis of MODIS imagery which has a spatial resolution of 250m, meaning that small scale habitat change events can be missed by the system. We therefore used multi-temporal Landsat imagery, with a spatial resolution of 30 m, to improve and validate the analysis.

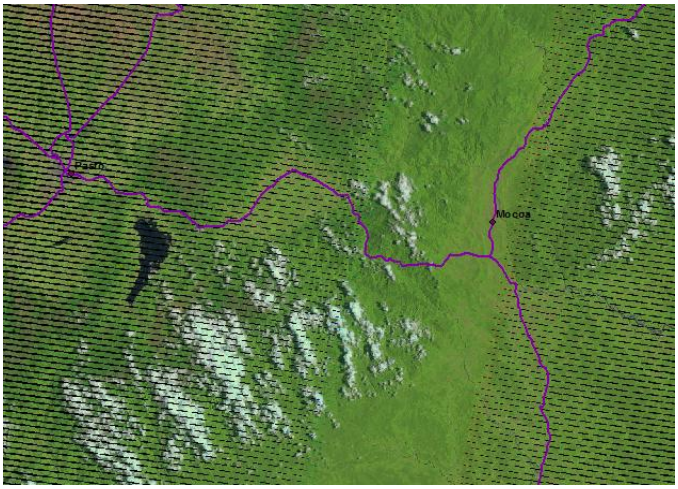
1999



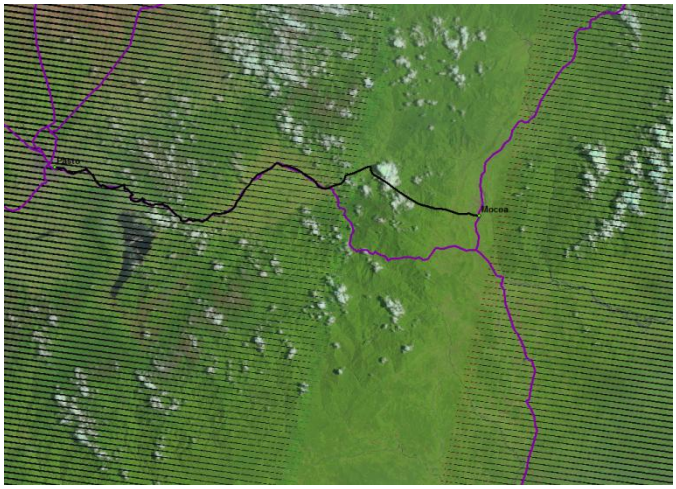
2002



2008



2010



After making the analysis of the high resolution Landsat images, no clear changes were visible in the area of influence of the road between the years 1999, 2010 and 2011. This validates the low rates registered by Terra-i within the same area. When this analysis was performed, there were no good quality, recent images available to assess the impact of the construction of the new section between San Francisco and Mocoa.

Conclusions

The Pasto-Mocoa road is part of the Amazon Multimodal Axis which includes three Colombian departments – Nariño, Putumayo and Amazonas – as well as the countries of Ecuador, Peru and Brazil.

In Colombia, 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 periods studied it detected a cumulative habitat loss of 814,391 hectares, equivalent to a national average of 108,586 ha/year. The departments with the greatest habitat loss during the same time frame (2004-2011) were Caquetá and Meta, where a cumulative loss of 133,925 and 108,863 hectares respectively was registered by Terra-i. The main drivers identified to explain deforestation in these two departments are the expansion of the agriculture frontier and the settlement of extensive livestock areas (Armenteras, y otros 2006). The analyzed road passes through the departments of Narino and Putumayo where deforestation rates of 12,525 and 7,481 hectares per year were recorded. These rates fall well below the national average. Putumayo's economy is mainly based on the exploitation of oil resources, agricultural production of banana, cassava, corn, potato, sugarcane and livestock (mainly in the foothills), and forestry (Flórez 2007).

The departments in Southwestern Colombia are characterized by a dense cloud cover, impeding temporal analysis of vegetation cover using remote sensing due to the low quality of satellite images.
In the Nariño department, 40% of the studied area could not be analyzed due to cloud cover. In the department of Putumayo, 7% of the area could not be analyzed. These unassessed areas are mainly located in the mountainous zones through which the Pasto-Mocoa road passes, complicating the process of an impact analysis for the road.

The impact generated by the analyzed road between the years 2004 and 2011 in the area of direct influence (a buffer zone of 15 km around the road) is negligible. This can be explained both by the lack of good quality imagery and by the age of the road, which was built more than 80 years ago. Therefore, any direct impact resulting from its construction happened years before the period of analysis. Nevertheless, even if the direct impact of the road is low, it has a strong indirect impact on other areas. Effectively, the improvement of mobility of the local population eases the continuous process of rural migration from the mountainous areas of Nariño to the departments of Putumayo and Valle del Cauca, as well as to the municipality of Santo Domingo de los Colorado, creating opportunities for habitat destruction due to agricultural expansion and land clearing for livestock.

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