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## **SUMMARY**

In October 2010, SAD detected 153 square kilometers of deforestation in the Legal Amazon. This represented a reduction of 21% in relation to October 2009 when the deforestation totaled 194 square kilometers.

The accumulated deforestation between August 2010 and October 2010 totaled 534 square kilometers. In comparison to the previous period (August 2008 to July 2009) when the deforestation totaled 682 square kilometers, there was a reduction of 22%.

In October 2010, the states with higher deforested area were Rondônia (34%) followed by Amazonas with 30%. The remaining deforestation occurred in Mato Grosso (16%), Pará (10%) and Acre (10%).

Through SAD it was possible to monitor 60% of the forest area of the Legal Amazon in October 2010. This may affect the deforestation ranking among the States.

In October 2010, 153 square kilometers of deforestation detected by SAD in the Legal Amazon compromised 9.5 million tons of CO<sup>2</sup> equivalent, which represents a decrease of 20% in relation to October 2009.

The accumulated deforestation between August 2010 and October 2010 resulted in the compromise of 31.6 million tons of CO<sup>2</sup> equivalent. This represents a reduction of 24% in relation to the previous period (August 2009 to October 2009) when forest carbon affected by deforestation was about 42 million tons of CO<sub>2</sub> equivalent.

Degraded forests in the Legal Amazon totaled 562 square kilometers in October 2010. Compared to the previous period (October 2009), there was a significant increase of 446% when the forest degradation totaled 103 square kilometers. Majority (59%) of the forest degradation occurred in Mato Grosso (59%).

The accumulated forest degradation between August 2010 and October 2010 totaled 2,617 square kilometers. This represented a significant increase (244%) compared to the previous period (August 2009 to October 2009) when the forest degradation totaled 760 square kilometers.

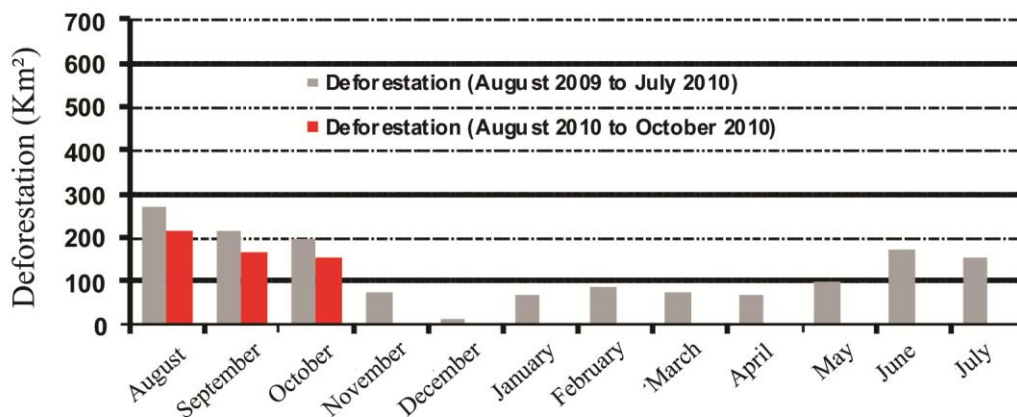
## **Deforestation Statistics**

According to Imazon's Deforestation Alert System (SAD), deforestation (that is, full suppression of the forest with soil exposure) in the Legal Amazon in October 2010 affected 153 square kilometers (Figure 1 and Figure 2). This represented a 21% reduction in the deforestation of October 2010 in comparison to the deforestation detected in October 2009 when the deforestation affected 194 square kilometers.

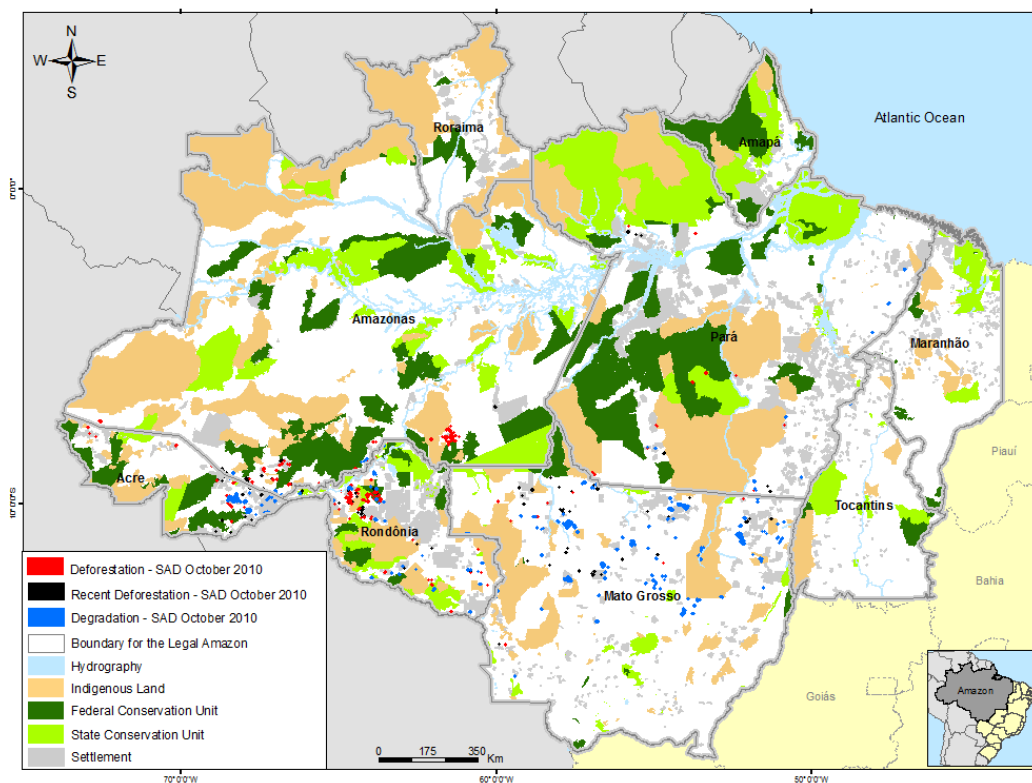


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## Legal Amazon



**Figure 1.** Deforestation of August 2009 to October 2010 in Legal Amazon (Source: Imazon/SAD).

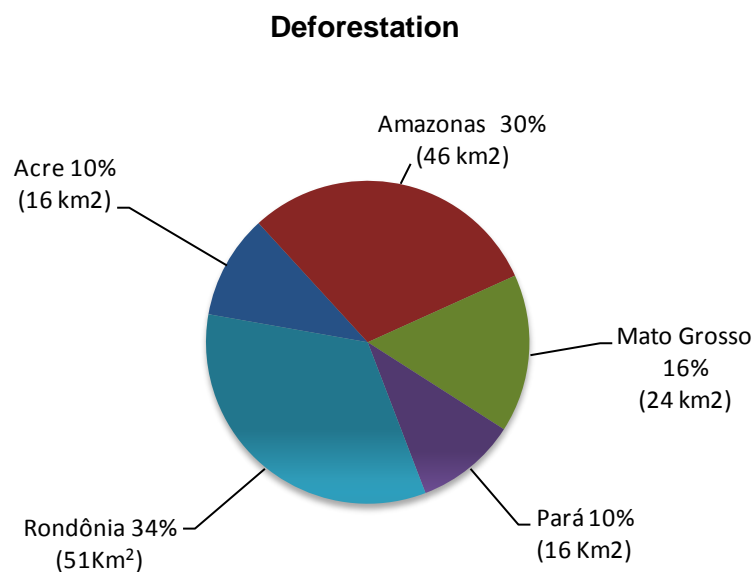


**Figure 2.** Deforestation and Forest Degradation in October 2010 in the Legal Amazon (Source: Imazon/SAD).

\*The recent deforestation may have occurred in October or in previous months, however, it was only possible to detect it now when there was no cloud over the region.

The accumulated deforestation between August 2010 and October 2010<sup>1</sup>, corresponding to the first three months of the official deforestation measurement calendar, affected 534 square kilometers. This represents a 22% decrease in the accumulated deforestation of this period (August 2010 to October 2010) compared to the same period the previous year (August 2009 to October 2009) when the deforestation affected 682 square kilometers.

Through SAD it was possible to monitor 60% of the forest area in the Legal Amazon in October 2010. The other 40% were covered by clouds, which made the monitoring in the region difficult, especially in Pará where 56% of its forest area was covered by clouds. This may affect the deforestation ranking among the States during these months. In fact, during this month, Rondônia (34%) and Amazonas (30%) remained in front of Mato Grosso (16%) and Pará (10%) (Figure 3). The remaining deforestation occurred in Acre (10%).



**Figure 3.** Deforestation (%) in the States of the Legal Amazon in October 2010 (Source: Imazon/SAD).

Considering the current twelve months of the deforestation calendar (August 2010 to October 2010), Pará continues to lead the ranking with 34% of the total deforestation in the period. Followed by Mato Grosso with 24%, Amazonas with 16% and Rondônia with 16%. These four states are responsible for 92% of the deforestation that occurred in the Legal Amazon during this period. The remaining (8%) deforestation occurred in Acre, Roraima and Tocantins.

Comparing the deforestation that occurred between August 2010 and October 2010 with the same period the previous year (August 2009 and October 2009), there was a 22% decrease in the deforestation of the Legal Amazon (Table 1). In relative terms, this reduction was more significant in Roraima (-91%), followed by Pará (-47%) and

<sup>1</sup> The official deforestation measurement calendar begins in the month of August and ends in the month of July.



# Forest Transparency

## Legal Amazon

Rondônia (-4%). On the other hand, there was an increase of 65% in Acre, Mato Grosso (+35%) and Amazonas (+6%). The considerable 47% deforestation reduction in Pará may have been influenced by the large cloud cover since 56% of the forest area of the State was covered by clouds in October 2010, affecting the deforestation monitoring of the region.

In absolute terms, Pará leads the accumulated deforestation ranking with 189 square kilometers, followed by Mato Grosso (130 square kilometers), Amazonas (86 square kilometers), Rondônia (85 square kilometers) and Acre (40 square kilometers).

**Table 1.** Evolution of deforestation between the States of Legal Amazon from August 2009 to October 2009 and August 2010 to October 2010 (Source: Imazon/SAD).

State	August 2009 to October 2010	August 2010 to October 2010	Variation (%)
Acre	24	40	+ 67
Amazonas	81	86	+ 6
Mato Grosso	96	130	+ 35
Pará	357	189	- 47
Rondônia	89	85	- 4
Roraima	19	2	- 89
Tocantins	-	2	-
Amapá	15	-	-
<b>Total</b>	<b>682</b>	<b>534</b>	<b>- 22</b>

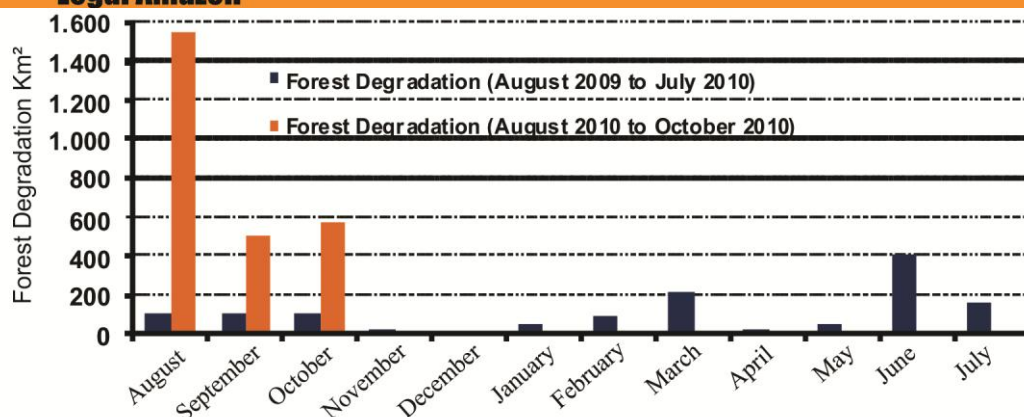
\*The data of Maranhão were not analyzed.

### Forest Degradation Statistics

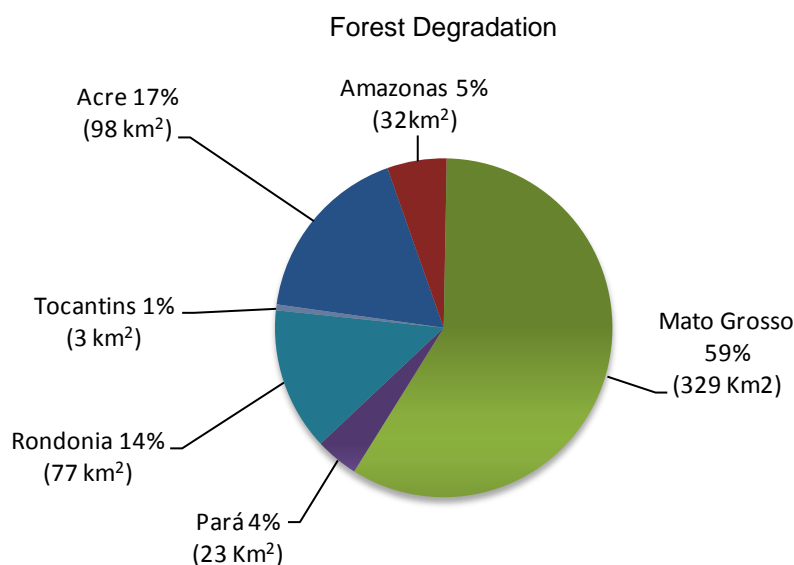
In October 2010, SAD registered 562 square kilometers of degraded forests (forests intensely explored by the timber activity and/or fires) (Figures 2 and 4). This corresponds to an extremely significant increase of 446% compared to the same period the previous year (October 2009) when the forest degradation affected 103 square kilometers. From the total, majority (59%) of this degradation occurred in Mato Grosso, followed by Acre (17%), Rondônia (14%), Amazonas (5%) and Pará (4%) (Figure 5).

# Forest Transparency

## Legal Amazon



**Figure 4.** Forest Degradation of August 2009 to October 2010 in Legal Amazon (Source: Imazon/SAD).



**Figure 5.** Forest Degradation (%) in the States of Legal Amazon in October 2010 (Source: Imazon/SAD).

The accumulated forest degradation between August 2010 and October 2010<sup>2</sup>, (first three months of the official deforestation measurement calendar) affected 2,617 square kilometers. This represents a 244% decrease in the accumulated forest degradation in this period (August 2010 to October 2010) compared to the same period the previous year (August 2009 to October 2009) when the forest degradation affected 760 square kilometers (Table 2).

<sup>2</sup> The official deforestation measurement calendar begins in the month of August and ends in the month of July.





# Forest Transparency

## Legal Amazon

In relative terms, Tocantins presented a significant increase of 2,840%, however, in absolute terms, the increase was highly reduced, changing from only 1 square kilometer between August 2009 and October 2009 to 24 square kilometers between August 2010 and October 2010. Other states also contributed to the increased forest degradation: Mato Grosso (+ 364%), Amazonas (+292%), Pará (+126%) and Rondônia (146%).

Mato Grosso leads the ranking with 56% of the total accumulated degraded forest areas between August 2010 and October 2010, followed by Pará with 24% and Rondônia with 11%. These three states were responsible for 91% of the forest degradation in the Legal Amazon during this period. The remaining 9% occurred in Amazonas, Acre and Tocantins

In absolute terms, Mato Grosso leads the ranking of accumulated forest degradation with 1,464 square kilometers, followed by Pará (637 square kilometers), Rondônia (286 square kilometers), Acre (123 square kilometers), Amazonas (83 square kilometers) and Tocantins (24 square kilometers).

**Table 2.** Evolution of forest degradation between the States of Legal Amazon from August 2009 to October 2009 and August 2010 to October 2010 (Source: Imazon/SAD).

State	August 2009 to October 2010	August 2010 to October 2010	Variation (%)
Acre	20	123	+ 515
Amazonas	21	83	+ 295
Mato Grosso	315	1,464	+ 365
Pará	282	637	+ 126
Rondônia	116	286	+ 147
Roraima	4	-	-
Tocantins	1	24	+ 2,300
Amapá	1	-	-
<b>Total</b>	<b>760</b>	<b>2,617</b>	<b>+ 244</b>

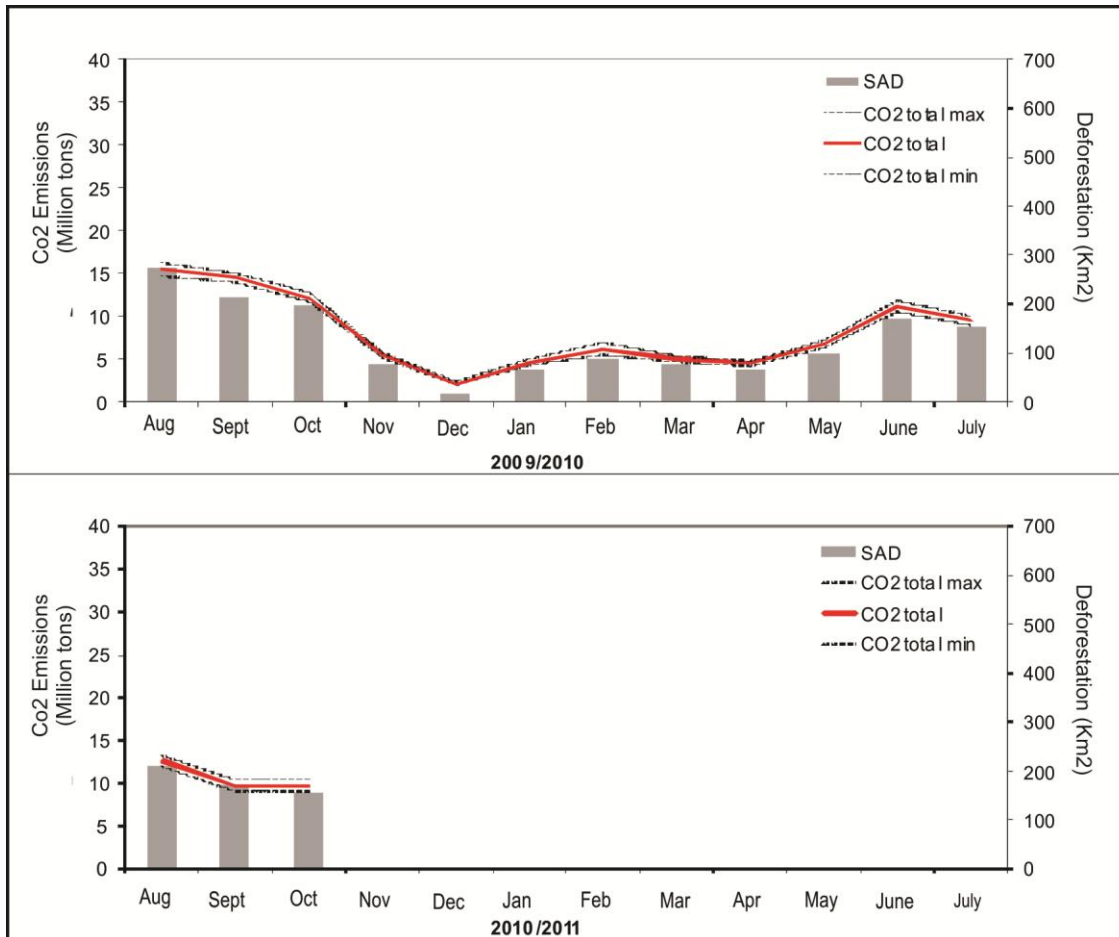
\*The data of Maranhão were not analyzed.

### Carbon Affected by the Deforestation

In October 2010, the 153 square meters of deforestation detected by SAD in Legal Amazon affected 2.6 million tons of carbon (with an error margin of 385 thousand tons). This amount of affected carbon results in 9.5 million tons of CO<sup>2</sup> equivalent (Figure 6). This represents a drop of 20% in relation to October 2009 when the affected forest carbon was 3.2 million tons.

The forest carbon affected by the deforestation from August 2010 to October 2010 (first three months of the current deforestation calendar) was 8.6 million tons (with an error margin of 190 thousand tons), which represented about 31.6 million tons of CO<sub>2</sub> equivalent (Figure 6). In relation to this same period of the previous year (August 2009 to October 2009) there was a 24% reduction in the amount of carbon affected by the

deforestation. The same occurred in the relative reduction of deforestation, which was 22% compared to the two periods.



**Figure 6.** Deforestation and total emissions of Carbon Dioxide (CO) equivalent from August 2008 to July 2010 in Legal Amazon (Source: Imazon).

## Geography of the Deforestation

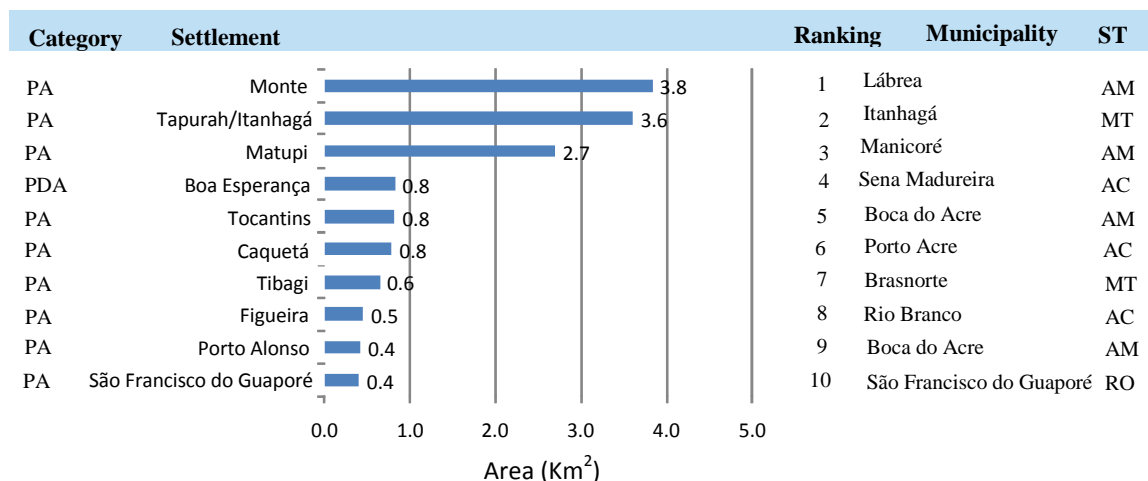
Regarding the land situation in October 2010, majority (65%) of the deforestation occurred in private areas or in areas under different stages of ownership. The remaining deforestation was recorded in Agrarian Reform Settlements (13%), followed by Conservation Units (14%) and Indigenous Lands (8%) (Table 3).

**Table 3.** Deforestation per land category in October 2010 in the Legal Amazon (Source: Imazon/SAD).

Category	October 2010	
	km <sup>2</sup>	%
Agrarian Reform Settlement	20	13
Conservation Units	21	14
Indigenous Lands	13	8
Private, Owned & Vacant <sup>3</sup>	99	65
<b>Total (km<sup>2</sup>)</b>	<b>153</b>	<b>100</b>

## Agrarian Reform Settlements

SAD registered 20 square kilometers in the Agrarian Reform Settlements in October 2010. The settlements most affected by the deforestation were Monte (Lábrea; Amazonas), Tapurah/Itanhagá (Itanhagá; Mato Grosso), and Matupi (Manicoré; Amazonas) (Figure 7).



**Figure 7.** Most deforested Agrarian Reform Settlements in October 2010 in Legal Amazon (Source: Imazon/SAD).

## Protected Areas

SAD detected 14 square kilometers of deforestation in the Conservation Unit (Figure 8). The Conservation Units that suffered deforestation the most were: Resex do Rio Jaci-

<sup>3</sup> Includes private areas (owned or not) and unprotected public forests.



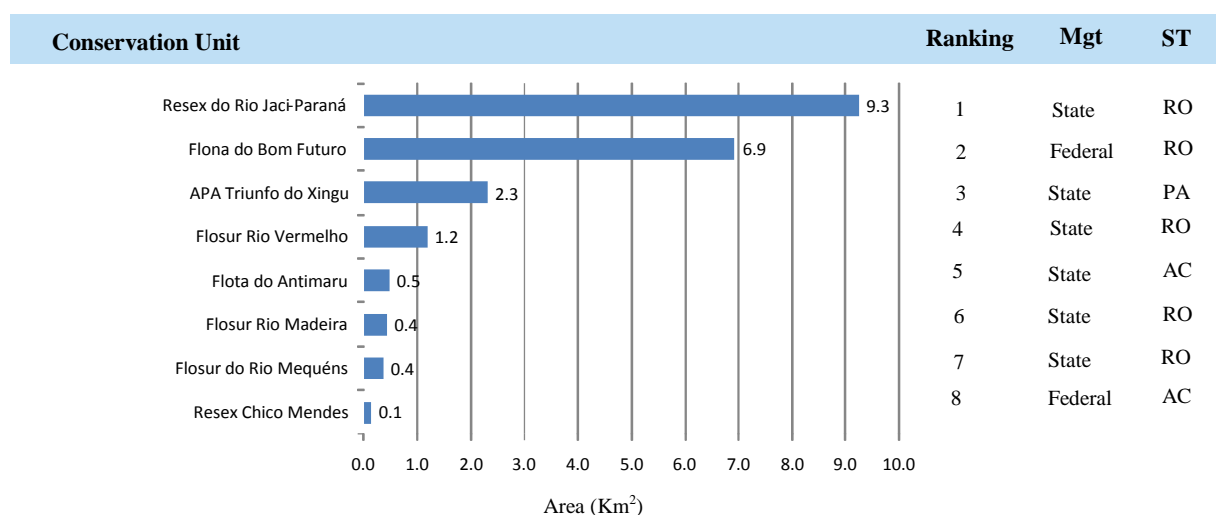


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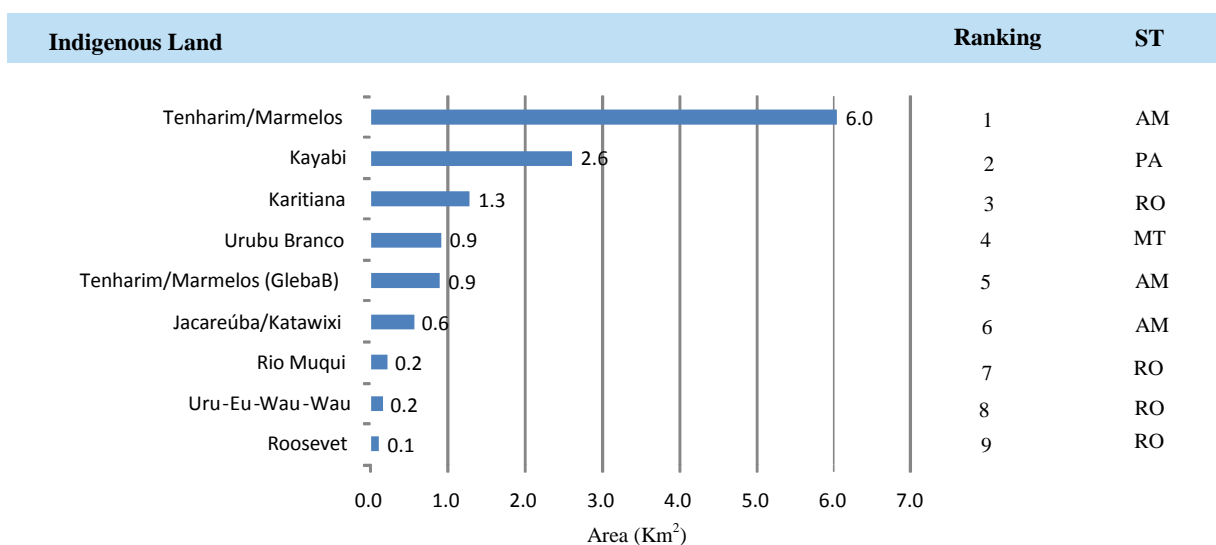
## Legal Amazon

Paraná (Rondônia), Flona do Bom Futuro (Rondônia) and APA Triunfo do Xingu (Pará).

In the case of Indigenous Lands, 8 square kilometers were detected in October 2010. The most affected were Tenharim/Marmelos (Amazonas), Kayabi (Pará) and Karitiana (Rondônia) (Figure 9).



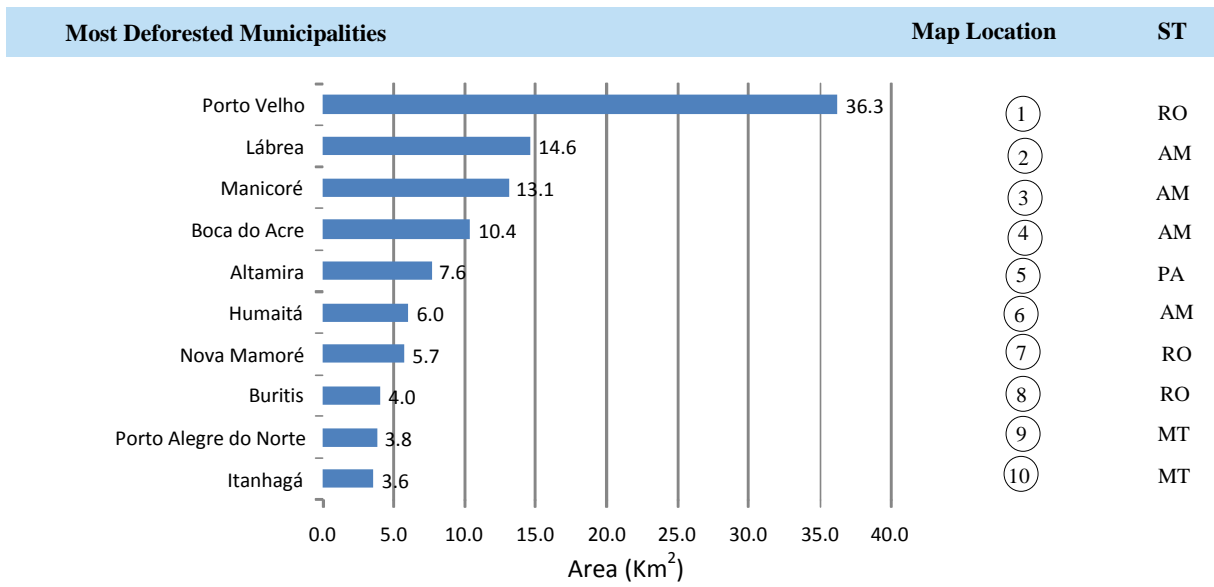
**Figure 8.** Most deforested Conservation Units in Legal Amazon in October 2010 (Source: Imazon/SAD).



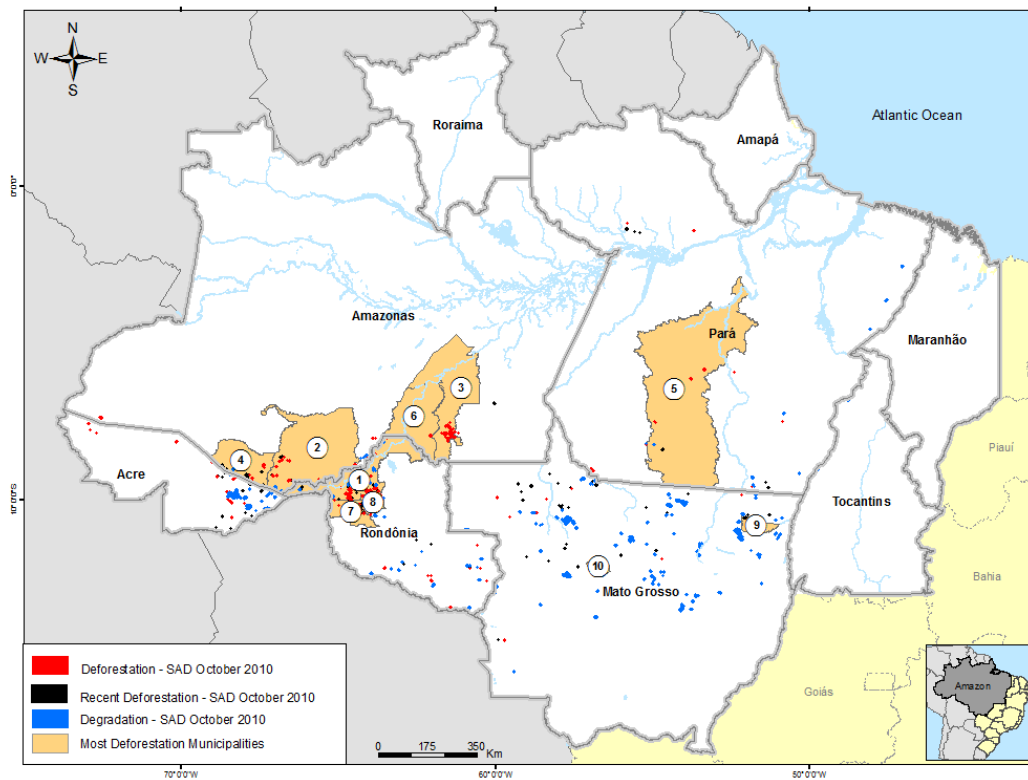
**Figure 9.** Most deforested Indigenous Lands in Legal Amazon in October 2010 (Source: Imazon/SAD).

## Critical Municipalities

The most deforested municipalities in October 2010 were: Porto Velho (Rondônia), Lábrea (Amazonas) and Manicoré (Amazonas) (Figure 10 e 11).



**Figure 10.** Most deforested municipalities in Legal Amazon in October 2010 (Source: Imazon/SAD).



**Figure 11.** Most deforested municipalities in October 2010 (Source: Imazon/SAD).



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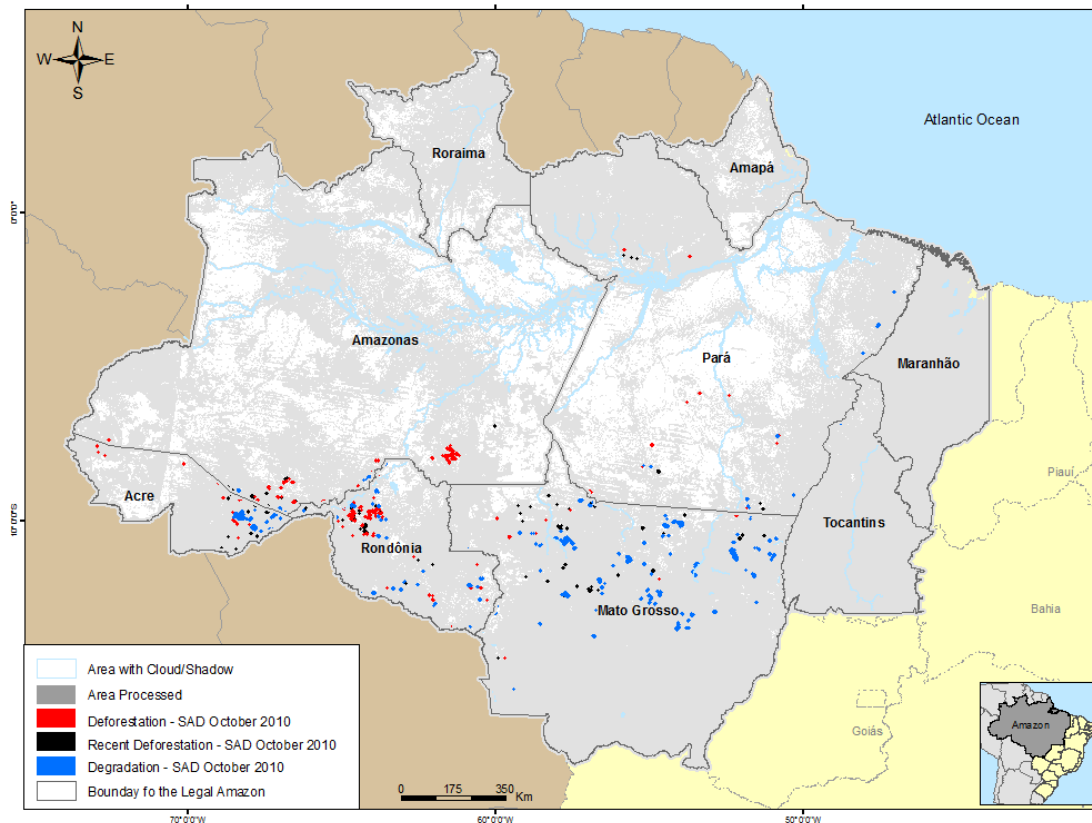
## Legal Amazon

\*The recent deforestation may have occurred in October or in previous months, however, it was only possible to detect it now when there was no cloud over the region.

### Cloud and Shade Cover

In October 2010, it was possible to monitor 60% of the area with forest cover in the Legal Amazon. The remaining 40% of the land was covered by clouds (Figure 12). Pará and Amazonas were the States with the highest cloud cover over their forest areas

\* The part of Maranhão that is part of the Legal Amazon was not analyzed.



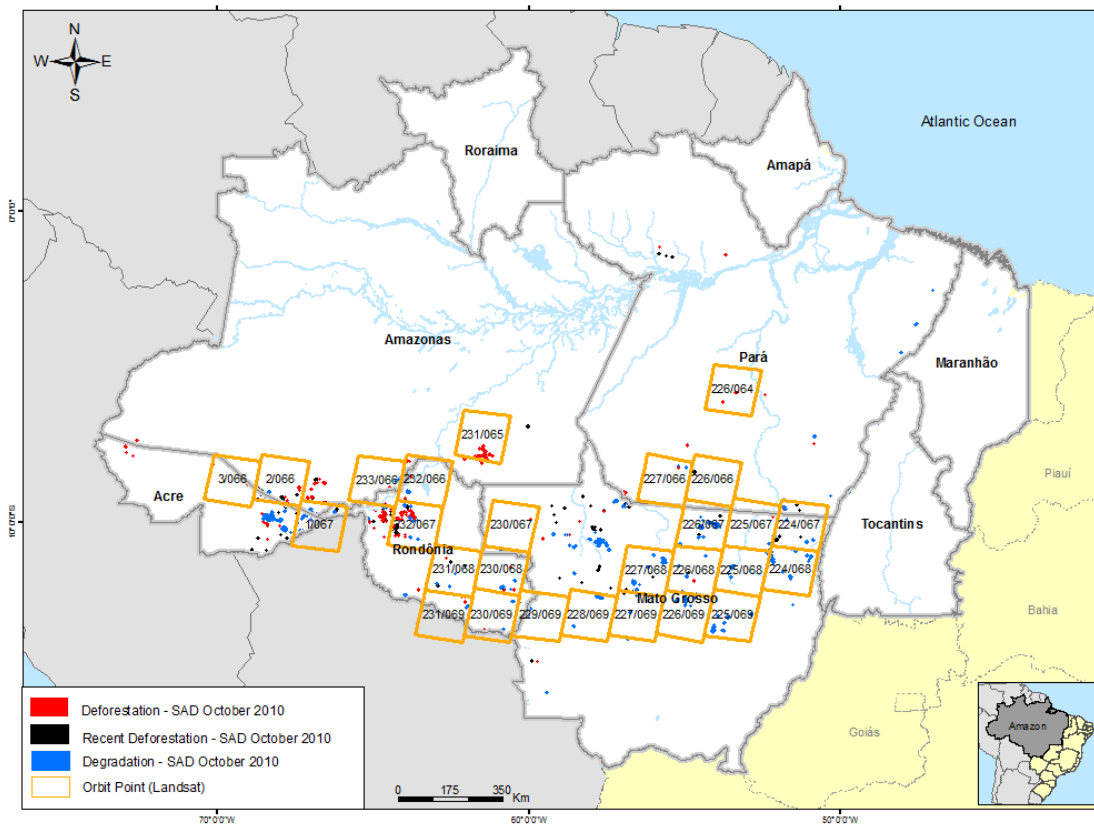
**Figure 12.** Area with cloud and shade in October 2010 in Legal Amazon.

\*The recent deforestation may have occurred in October or in previous months, however, it was only possible to detect it now when there was no cloud over the region.

## Validation of SAD data using Landsat and Cbers Imaging

SAD data are validated using CBERS and Landsat imaging (higher spatial resolution) provided by the National Institute for Space Research (Inpe). The images available soon after the month analyzed by SAD are used. All deforestation polygons detected by SAD are checked using the detailed images. Deforestation less than 6.25 hectares, that is, below the detection capacity of SAD, are not included in the statistics, in case they occur in the images with more detailed resolution. However, in the case of confirmation of false deforestation signals detected by SAD, these are removed from the monthly statistics.

In October 2010, 55% of the deforestation detected by SAD was confirmed with Landsat images (Figure 13). The remaining 45% were not confirmed due to the high occurrence of clouds in the Landsat and CBERS images provided at the time.



**Figure 13.** Landsat orbit points used in the validation of deforestation polygons detected by SAD in October 2010.

\*The recent deforestation may have occurred in October or in previous months, however, it was only possible to detect it now when there was no cloud over the region.

## Section I: SAD 3.0

Since August 2009, SAD presented some innovations. First, a graphic interface was created to integrate all image processing programs used in the SAD. Secondly, we began computing the deforestation in areas that were covered by clouds in the previous months under a new class. Lastly, the deforestation and degradation were detected with pairs of NDFI images in a change detection algorithm. The main method continues to be the same as SAD 2 as shown below.

SAD generates temporary MODIS mosaic images daily from the products MOD09GQ and MOD09GA for cloud filtration. A fusion technique for different spectral resolution bands, that is, with pixels of different sizes, was then used. In this case, the 5 bands scale with a pixel of 500 meters of the MODIS was changed to 250 meters. This allowed the improvement of the spectral pixel mixture model, providing the ability to estimate the abundance of Vegetation, Soils and Non-Photosynthetic components (NPV) (Vegetation, Soil and Shade) to calculate the NDFI with the equation below.

$$\text{NDFI} = \frac{(\text{VGs} - (\text{NPV} + \text{Soil}))}{(\text{VGs} + \text{NPV} + \text{Soil})}$$

Where VGs is the Vegetation component normalized for shade given by:

$$\text{VGs} = \text{Vegetation} / (1 - \text{Shade})$$

NDFI varies from -1 (pixel with 100% of exposed soil) to 1 (pixel with > 90% with forest vegetation). Therefore, we have a continuous image showing the transition of the deforested areas, passing through degraded forest until it reaches forests without signs of disturbance.

This month the detection of the deforestation and degradation had different NDFI images of consecutive months. Therefore, a reduction in the NDFI values between -200 and -50 indicated possibly deforested areas and between -49 and -20 with signs of degradation.

SAD 3.0 Beta is compatible with the previous versions (SAD 1.0 and 2.0) because the deforestation detection threshold was calibrated to generate the same type of response obtained by the previous method.

SAD is already operating in the state of Mato Grosso since August 2006 and in Legal Amazon since April 2008. This bulletin presents the monthly data generated by SAD from August 2006 to September 2010.

## Section II: Carbon affected by the deforestation

The carbon estimates are generated based on the combination of SAD deforestation maps with simulations of the spatial biomass distribution for the Amazon. A carbon emission estimation model called *Carbon Emission Simulator* (CES) was developed based on the stochastic simulation (*Morton et al*, in prep.). One thousand (1000) spatial biomass distribution simulations in the Amazon were generated using a geostatic model (*Sales et al.*, 2007), and these biomass simulations were transformed into C-stocks using biomass conversion factors for C from literature, according to the formula below:

$$C_t = \sum C(S)_t$$

$$C_t(S) = S_D \times \left[ (BVAS - BPF) \times (1 - fc) \times (t == 0) + (BAS_0 \times pd \times e^{(-pd \times t)}) \right]$$

$$BPF = ff * AGLB$$

$$BAS_0 = bf * AGLB$$

where:

t: time (month)

$C_t$ : Carbon emitted in month t.

$C_t(S)$ : Carbon emitted from a deforested polygon at time t.

$S_D$ : Deforested area:

BVAS: Biomass aboveground at the deforested region  $S_D$ .

BPF: Biomass from forest products removed from forests before deforestation.

fc: coal fraction (3 to 6%).

$BAS_0$ : Underground biomass before deforestation.

pd: monthly decomposition parameter of the underground biomass after deforestation (0.0075).

$pd \times e^{(-pd \times t)}$ : Monthly decomposition rate of underground biomass after deforestation.

To apply the CES model using SAD data, only the carbon affected by the deforestation was considered, which is the fraction of forest biomass made up of carbon (50%) subject to instant emissions caused by forest fires from the deforestation and/or future decomposition of the remaining forest biomass. Also, the CES model was modified to estimate the forest carbon affected by deforestation on a monthly scale. Lastly, simulations enabled the estimation of affected carbon uncertainty, represented by the standard deviation (+/- 2 fold) of simulations of the carbon affected each month.

Apply the value 3.68 to convert carbon values to CO<sub>2</sub> equivalent.

### References:

D.C. Morton<sup>1</sup>, M.H. Sales<sup>2</sup>, C.M. Souza, Jr.<sup>2</sup>, B. Griscom<sup>3</sup>. Baseline Carbon Emissions from Deforestation and Forest Degradation: A REDD case study in Mato Grosso, Brazil. Ongoing.

Sales, M.H. et al., 2007. Improving spatial distribution estimation of forest biomass with geostatistics: A case study for Rondônia, Brazil. *Ecological Modelling*, 205(1-2), 221-230.





**Notes:**

**Team Responsible:**

*General Coordination:* Sanae Hayashi, Carlos Souza Jr, and Adalberto Veríssimo (Imazon)

*Team:* Marcio Sales (Modeling and statistics), Rodney Salomão, Amintas Brandão Jr., João Victor (Geoprocessing) and Bruno Oliveira (Communication)

**Data Source:**

The deforestation statistics are generated from SAD data (Imazon);

INPE Data - Deforestation (PRODES)

<http://www.obt.inpe.br/prodes/>

**Support**

David & Lucille Packard Foundation through CLUA (Climate Land Use Alliance)

Gordon & Betty Moore Foundation

Vale Fund

Environmental State Secretariat -SEMA-PA

**Partnerships:**

Environmental State Secretariat of Pará (SEMA)

Environmental Secretariat of Mato Grosso (SEMA)

Federal Public Ministry of Pará

State Public Ministry of Pará

State Public Ministry of Roraima

State Public Ministry of Amapá

State Public Ministry of Mato Grosso

Instituto Centro de Vida (ICV- Mato Grosso)