# Forest Transparency
## Legal Amazon

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## SUMMARY

In November 2010, SAD detected 65 square kilometers of deforestation in the Legal Amazon. This represented a reduction of 13% in relation to November 2009 when the deforestation totaled 75 square kilometers.

The accumulated deforestation between August 2010 and November 2010 totaled 598 square kilometers. In comparison to the previous period (August 2009 to November 2009) when the deforestation totaled 757 square kilometers, there was a reduction of 21%.

In November 2010, the states with greater deforested area was Mato Grosso (38%) followed by Pará (29%) and Rondônia (20%). The remaining deforestation occurred in Roraima (5%), Amazonas (5%) and Acre (3%).

The degraded forests in the Legal Amazon totaled 188 square kilometers in November 2010. Compared to November 2009, when the degradation totaled 29 square kilometers, there was a highly significant increase of 548%. Majority (51%) of the forest degradation occurred in Pará followed by Mato Grosso (39%).

The accumulated forest degradation between August 2010 and November 2010 totaled 2,805 square kilometers. This represented a significant increase (256%) compared to the previous period (August 2009 to November 2009) when the forest degradation totaled 789 square kilometers.

In November 2010, the deforestation detected by SAD affected 4 million tons of $CO_2$ equivalent, which represents a decrease of 21% in relation to November 2009. In the accumulated value during the period (August – November 2010) the deforestation affected 36 million tons of $CO_2$ equivalent. This represents a reduction of 23% in relation to the previous period (August 2009 to November 2009) when forest carbon affected by deforestation was about 47 million tons of $C0_2$ equivalent.

Through SAD it was only possible to monitor 30% of the forest area of the Legal Amazon in November 2010. The remaining 70% were covered by clouds, which made monitoring of the region difficult, especially in Amapá, Rondônia, Pará e Mato Grosso that had more than 70% of the forest area covered by clouds. Based on this, the deforestation and degradation data for November may be underestimated.

## 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 November 2010 affected 65 square kilometers (Figure 1 and Figure 2). This represented a 13% reduction in the deforestation of November 2010 in comparison to the deforestation detected in November 2009 when the deforestation affected 75 square kilometers.

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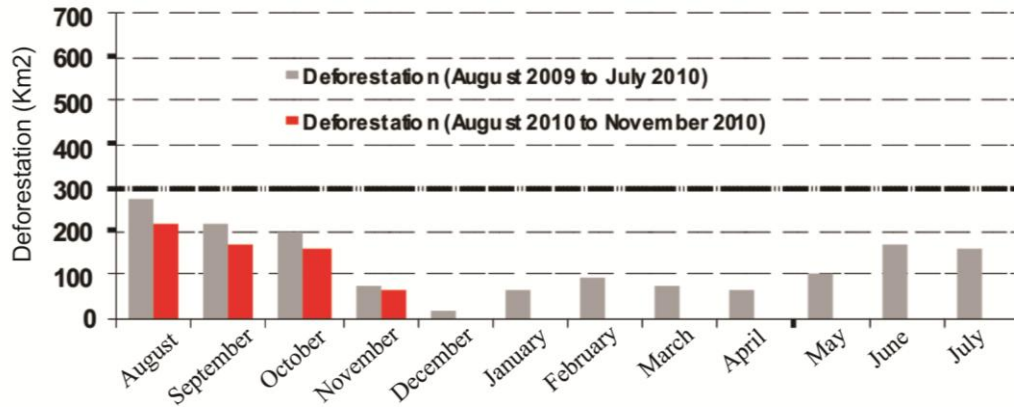MEIO AMBIENTE DA AMAZÔNIA

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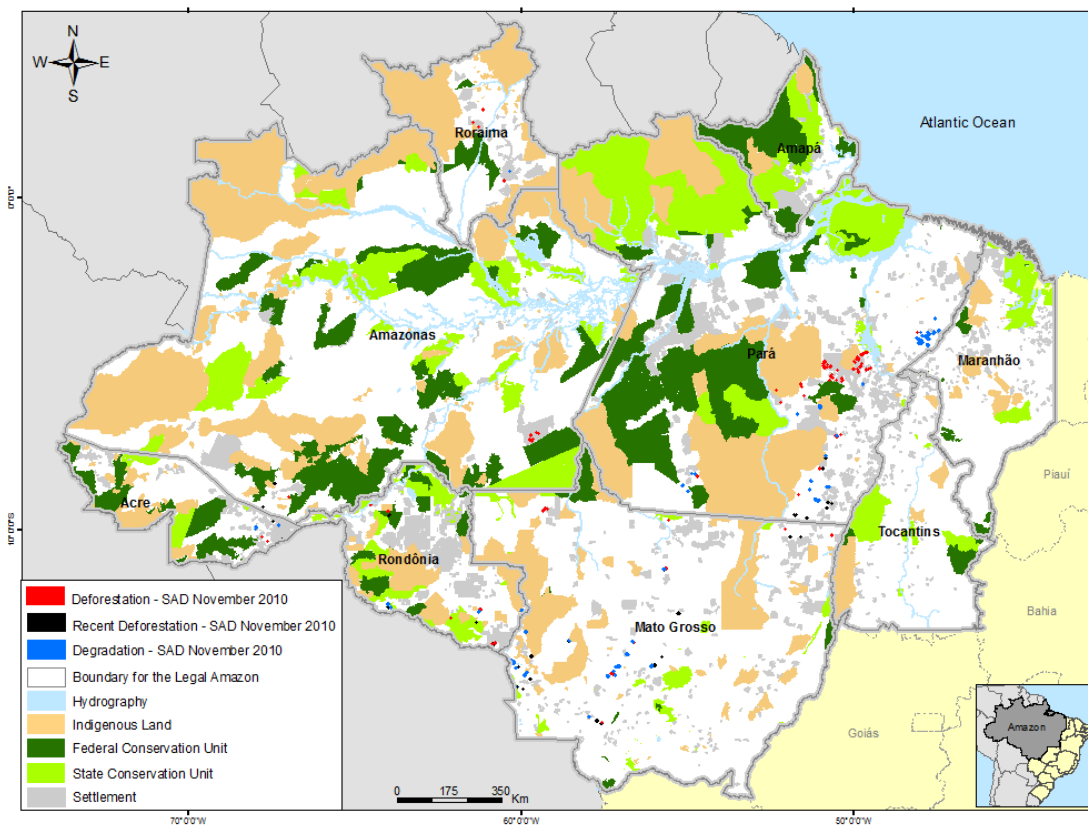


**Figure 2.** Deforestation and Forest Degradation in November 2010 in the Legal Amazon (Source: Imazon/SAD).
*The recent deforestation may have occurred in November or in previous months, however, it was only possible to detect it now when there was no cloud over the region.

The accumulated deforestation between August 2010 and November 2010[1], corresponding to the first four months of the official deforestation measurement

calendar, affected 598 square kilometers. This represents a 21% decrease in the accumulated deforestation of this period (August 2010 to November 2010) compared to the same period the previous year (August 2009 to November 2009) when the deforestation affected 757 square kilometers.

In November 2010, Mato Grosso contributed with 38% of the total deforested area in the Legal Amazon (Figure 3). Followed by Pará with 29% and Rondônia with 20%. The deforestation in the other States was proportionally smaller, with Amazonas contributing with 5%, Roraima with 5% and Acre with 3%.
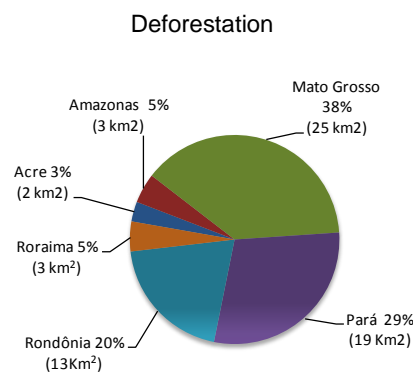
Deforestation



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

Considering the first four months of the current deforestation calendar (August 2010 to November 2010), Pará leads the ranking with 35% of the total deforestation in the period. Followed by Mato Grosso with 26%, Rondônia with 16% and Amazonas with 15%. 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 November 2010 with the same period the previous year (August 2009 and November 2009), there was a 21% decrease in the deforestation of the Legal Amazon (Table 1). In relative terms, this reduction was more significant in Roraima (-82%), followed by Pará (-49%) and Amazonas (-1%). On the other hand, there was an increase of 53% in Mato Grosso, Acre (50%) and Amazonas (5%).

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[1] The official deforestation measurement calendar begins in the month of August and ends in the month of July.

In absolute terms, Pará leads the accumulated deforestation ranking with 208 square kilometers, followed by Mato Grosso (155 square kilometers), Rondônia (98 square kilometers) and Amazonas (89 square kilometers).

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

| State | August 2009 to November 2010 | August 2010 to November 2010 | Variation (%) |
|---|---|---|---|
| Acre | 28 | 42 | + 50 |
| Amazonas | 90 | 89 | - 1 |
| Mato Grosso | 101 | 155 | + 53 |
| Pará | 408 | 208 | - 49 |
| Rondônia | 93 | 98 | + 5 |
| Roraima | 22 | 4 | - 82 |
| Tocantins | - | 2 | - |
| Amapá | 15 | - | - |
| **Total** | **757** | **598** | **- 21** |

*The data of Maranhão were not analyzed.

### Forest Degradation

In November 2010, SAD registered 188 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 548% compared to the same period the previous year (November 2009) when the forest degradation affected 29 square kilometers. From the total, majority (51%) of this degradation occurred in Pará, followed by Mato Grosso (39%), Rondônia (9%), Acre (1%) and Roraima (1%).
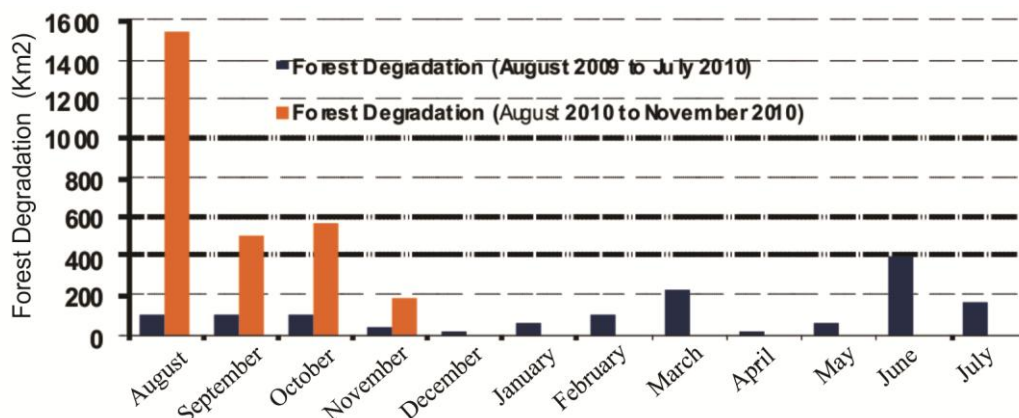
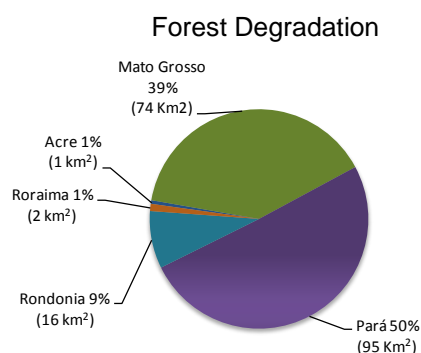**Figure 4.** Forest Degradation of August 2009 to November 2010 in Legal Amazon (Source: Imazon/SAD).



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

The accumulated forest degradation between August 2010 and November 2010[2], (first four months of the official deforestation measurement calendar) affected 2,805 square kilometers. This represents a 256% decrease in the accumulated forest degradation in this period (August 2010 to November 2010) compared to the same period the previous year (August 2009 to November 2009) when the forest degradation affected 789 square kilometers (Table 2).

In relative terms, Tocantins presented a significant increase of 2,300%, however, in absolute terms, the increase was highly reduced, changing from only 1 square kilometer between August 2009 and November 2009 to 24 square kilometers between August 2010 and

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[2] The official deforestation measurement calendar begins in the month of August and ends in the month of July.

November 2010. Other states also contributed to the increased forest degradation: Acre (+ 417%), Mato Grosso (+ 378%), Amazonas (+295%), Rondônia (+154%) and Pará (+146%).

Mato Grosso leads the ranking with 55% of the total accumulated degraded forest areas between August 2010 and November 2010, followed by Pará with 26% and Rondônia with 11%. These three states were responsible for 92% of the forest degradation in the Legal Amazon during this period. The remaining 8% occurred in Amazonas, Acre, Tocantins and Roraima

In absolute terms, Mato Grosso leads the ranking of accumulated forest degradation with 1,538 square kilometers, followed by Pará (732 square kilometers), Rondônia (302 square kilometers), Acre (124 square kilometers), Amazonas (83 square kilometers), Tocantins (24 square kilometers) and Roraima (2 square kilometers).

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

| State | August 2009 to November 2010 | August 2010 to November 2010 | Variation (%) |
|---|---|---|---|
| Acre | 24 | 124 | + 417 |
| Amazonas | 21 | 83 | + 295 |
| Mato Grosso | 322 | 1538 | + 378 |
| Pará | 297 | 732 | + 146 |
| Rondônia | 119 | 302 | + 154 |
| Roraima | 4 | 2 | - 50 |
| Tocantins | 1 | 24 | + 2.300 |
| Amapá | 1 | - | - |
| **Total** | **789** | **2.805** | **+ 256** |

*The data of Maranhão were not analyzed.

**Carbon Affected by the Deforestation**

In November 2010, the 65 square meters of deforestation detected by SAD in Legal Amazon affected 1.1 million tons of carbon (with an error margin of 205 thousand tons). This amount of affected carbon results in 4 million tons of $CO_2$ equivalent (Figure 6). This represents a

drop of 21% in relation to November 2009 when the affected forest carbon was 1.4 million tons.

The forest carbon affected by the deforestation from August 2010 to November 2010 (first four months of the current deforestation calendar) was 9.8 million tons (with an error margin of 215 thousand tons), which represented about 36 million tons of $CO_2$ equivalent (Figure 6). In relation to this same period of the previous year (August 2009 to November 2009) there was a 23% reduction in the amount of carbon affected by the deforestation. The same occurred in the relative reduction of deforestation, which was 21% compared to the two periods.
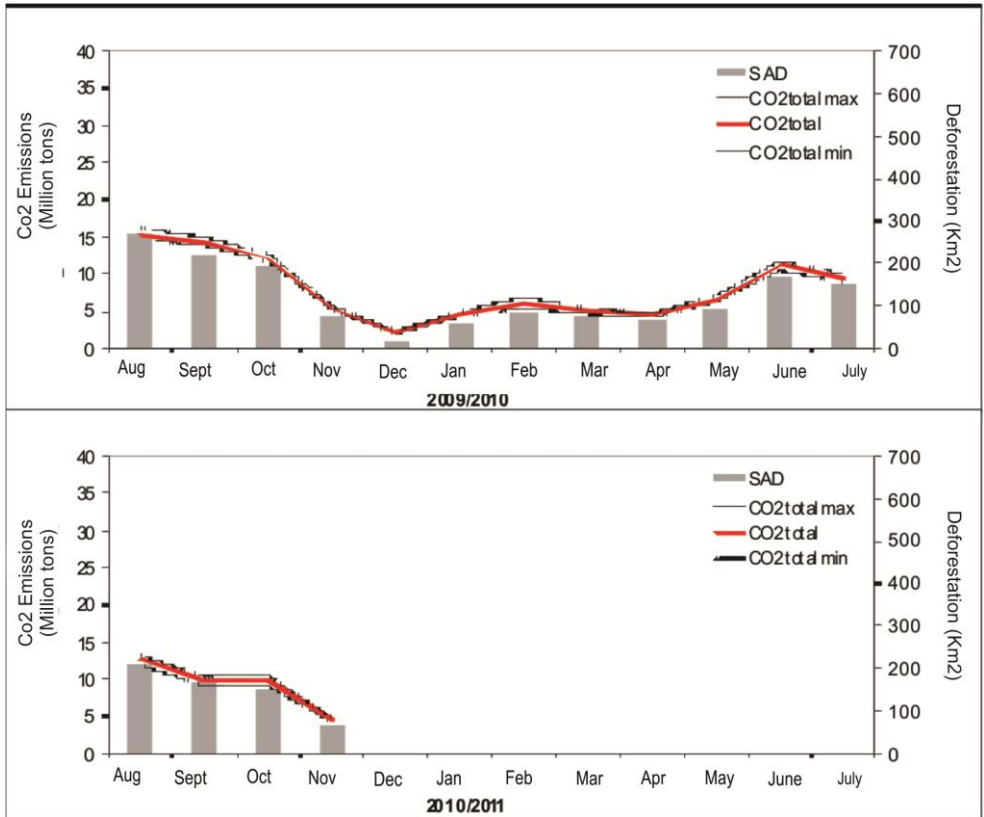
**Figure 6.** Deforestation and total emissions of Carbon Dioxide (CO) equivalent from August 2008 to November 2010 in Legal Amazon (Source: Imazon).

## Geography of the Deforestation

Regarding the land title status in November 2010, majority (82%) of the deforestation occurred in private areas or in areas under different stages of ownership. The remaining deforestation was recorded in Agrarian Reform Settlements (14%), followed by Conservation Units (3%) and Indigenous Lands (2%) (Table 3).

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

| Category | November/2010 | |
|---|---|---|
| | km² | % |
| Agrarian Reform Settlement | 9 | 14 |
| Conservation Units | 1.7 | 3 |
| Indigenous Lands | 1.2 | 2 |
| Private, Owned & Vacant[3] | 53 | 82 |
| Total (km²) | 65 | 100 |

## Agrarian Reform Settlements

SAD registered 9 square kilometers in the Agrarian Reform Settlements during November 2010. The Settlements most affected by the deforestation were Rio Juma (Apuí; Amazonas), Jacaré-Açú (Marabá; Pará), and Pedro Peixoto (Plácido de Castro; Acre) (Figure 7).
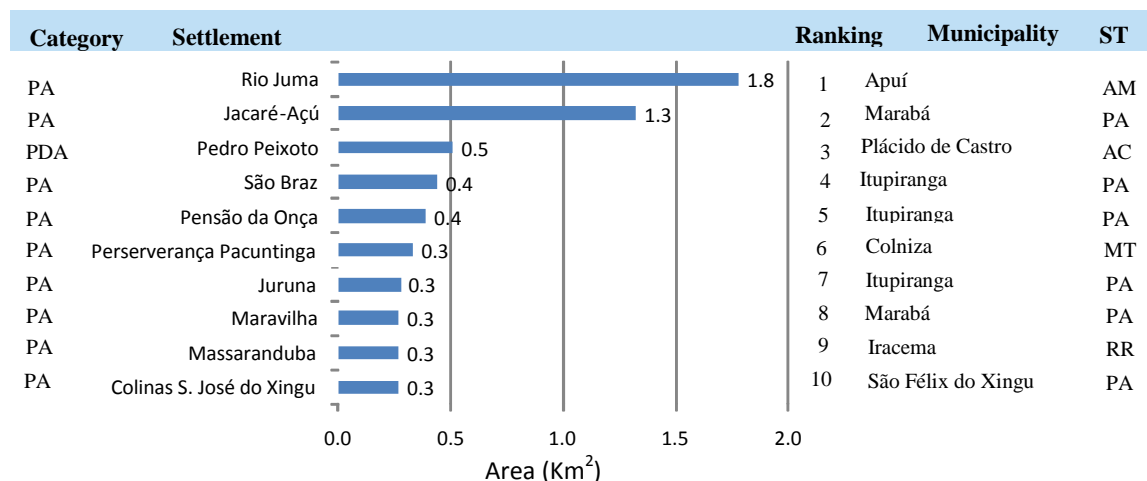


| Category | Settlement | Area (Km²) | Ranking | Municipality | ST |
|---|---|---|---|---|---|
| PA | Rio Juma | 1.8 | 1 | Apuí | AM |
| PA | Jacaré-Açú | 1.3 | 2 | Marabá | PA |
| PDA | Pedro Peixoto | 0.5 | 3 | Plácido de Castro | AC |
| PA | São Braz | 0.4 | 4 | Itupiranga | PA |
| PA | Pensão da Onça | 0.4 | 5 | Itupiranga | PA |
| PA | Perserverança Pacuntinga | 0.3 | 6 | Colniza | MT |
| PA | Juruna | 0.3 | 7 | Itupiranga | PA |
| PA | Maravilha | 0.3 | 8 | Marabá | PA |
| PA | Massaranduba | 0.3 | 9 | Iracema | RR |
| PA | Colinas S. José do Xingu | 0.3 | 10 | São Félix do Xingu | PA |

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

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[3] Includes private areas (owned or not) and unprotected public forests.

## Protected Areas

SAD detected only 1.7 square kilometers of deforestation in the Conservation Unit (Figure 8). The Conservation Units that suffered deforestation were: PES Serra Ricardo Franco (Mato Grosso), APA do Lago do Tucuruí (Pará), and Flona do Bom Futuro (Rondônia).

In the case of Indigenous Lands, only 1.2 square kilometers were detected in November 2010. The two deforested Indigenous Lands were Karitiana (Rondônia) and Apyterewa (Pará) (Figure 9).
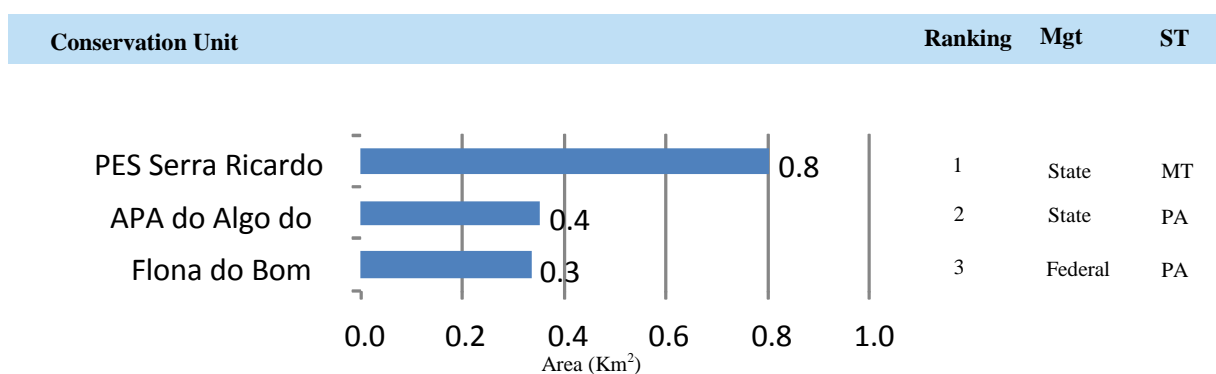
| Conservation Unit | Area (Km²) | Ranking | Mgt | ST |
|---|---|---|---|---|
| PES Serra Ricardo | 0.8 | 1 | State | MT |
| APA do Algo do | 0.4 | 2 | State | PA |
| Flona do Bom | 0.3 | 3 | Federal | PA |

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

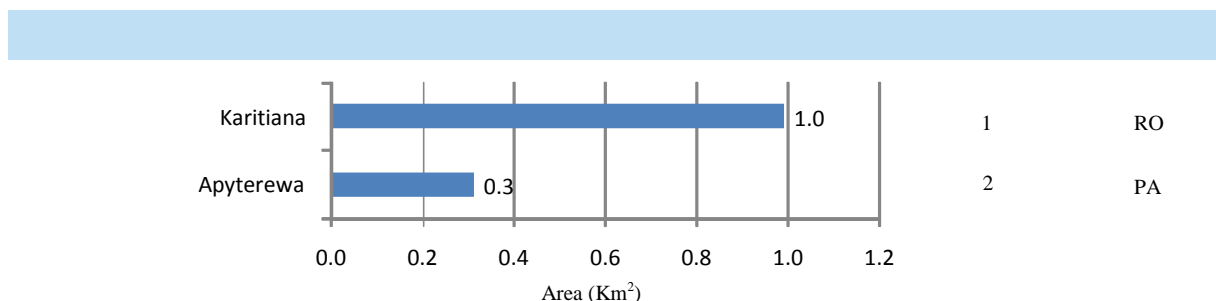| | Area (Km²) | Ranking | | ST |
|---|---|---|---|---|
| Karitiana | 1.0 | 1 | | RO |
| Apyterewa | 0.3 | 2 | | PA |

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

## Critical Municipalities

The most deforested municipalities in November 2010 were: Pimenteiras do Oeste (Rondônia), Vera (Mato Grosso) and São Félix do Xingu (Pará) (Figures 10 and 11).
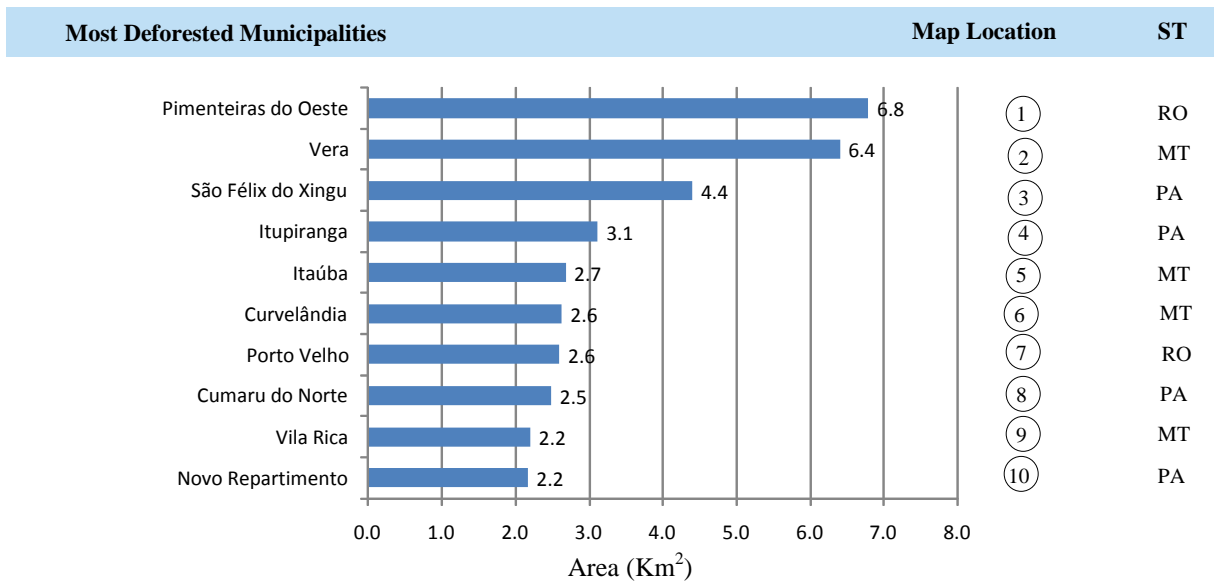
| Most Deforested Municipalities | | Map Location | ST |
|---|---|---|---|
| Pimenteiras do Oeste | 6.8 | 1 | RO |
| Vera | 6.4 | 2 | MT |
| São Félix do Xingu | 4.4 | 3 | PA |
| Itupiranga | 3.1 | 4 | PA |
| Itaúba | 2.7 | 5 | MT |
| Curvelândia | 2.6 | 6 | MT |
| Porto Velho | 2.6 | 7 | RO |
| Cumaru do Norte | 2.5 | 8 | PA |
| Vila Rica | 2.2 | 9 | MT |
| Novo Repartimento | 2.2 | 10 | PA |

Area (Km$^2$)

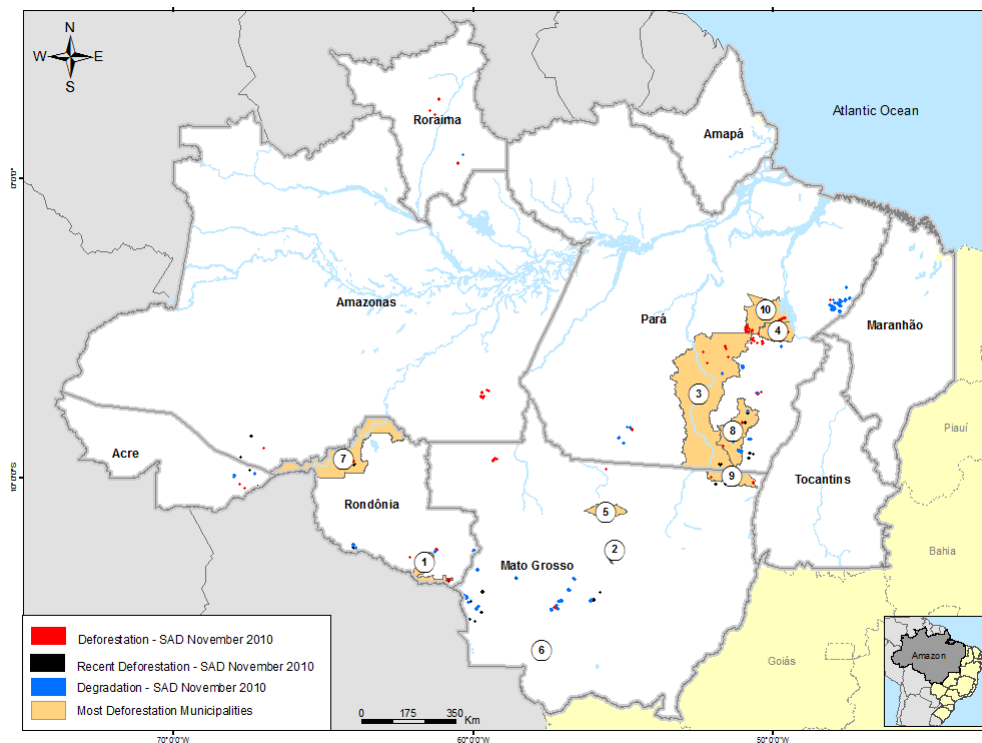**Figure 10.** Most deforested municipalities in Legal Amazon in November 2010 (Source: Imazon/SAD).

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

*The recent deforestation may have occurred in November 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

Through SAD it was only possible to monitor 30% of the forest area in the Legal Amazon in November 2010. The remaining 70% of the land was covered by clouds, which made the monitoring difficult, especially in Amapá, Pará, Mato Grosso and Rondônia (Figure 12). These states had over 70% of the forest land covered by clouds. Due to this, the deforestation data of these States may be underestimated in November 2010.

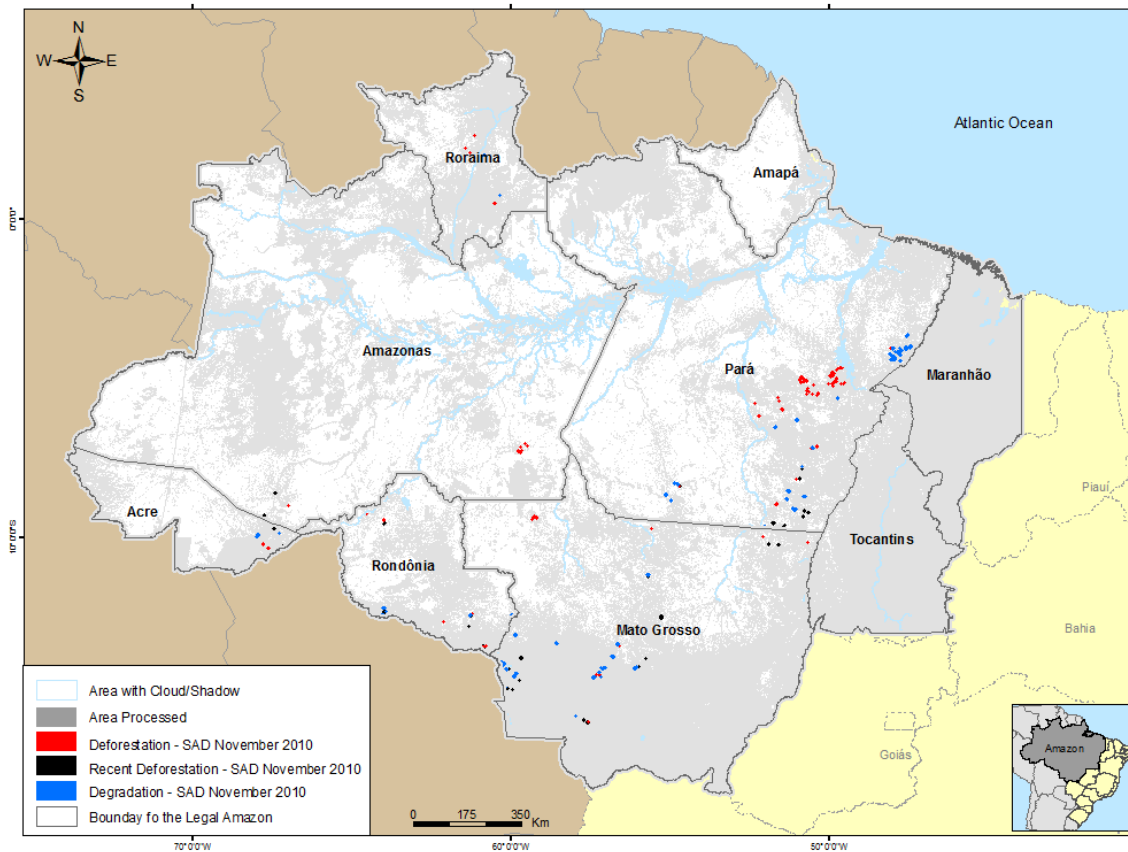* The part of Maranhão that is part of the Legal Amazon was not analyzed.



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

*The recent deforestation may have occurred in November 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 November 2010, 30% of the deforestation detected by SAD was confirmed with the Landsat images (Figure 13). The remaining 70% were not confirmed due to the high occurrence of clouds in the Landsat and CBERS images provided at the time.
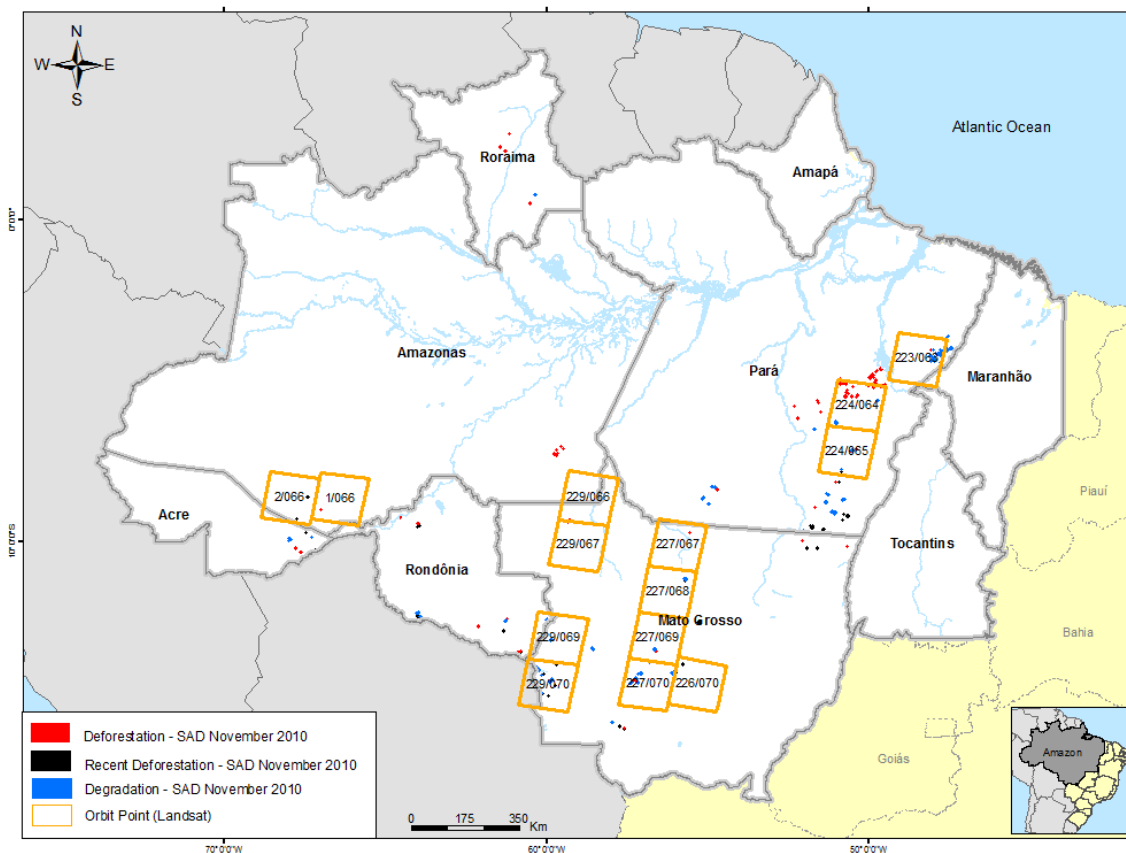


**Figure 13**. Landsat orbit points used in the validation of the deforestation polygons detected by SAD in November 2010.

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

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## 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.

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

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

$$VGs = Vegetation/(1-Shade)$$

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 November 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:

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

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

$$BPF = ff * AGLB$$

$$BAS_0 = bf * AGLB$$

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 $CO_2$ equivalent.

### References:

D.C. Morton[1], M.H. Sales[2], C.M. Souza, Jr.2, B. Griscom[3]. 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:**

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*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/

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Environmental State Secretariat of Pará (SEMA)
Environmental Secretariat of Mato Grosso (SEMA)
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State Public Ministry of Pará
State Public Ministry of Roraima
State Public Ministry of Amapá
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