Forest Monitoring Systems in Brazil

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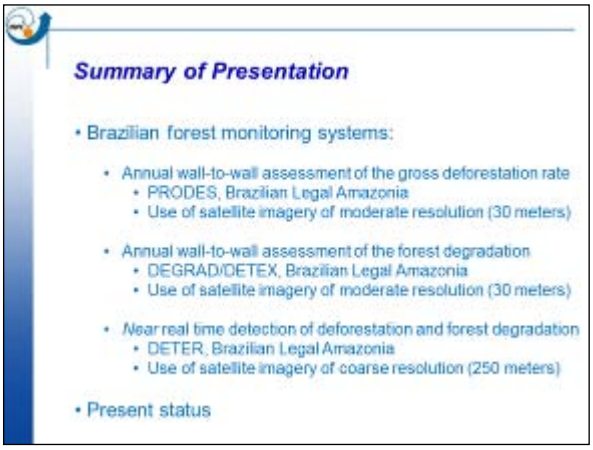
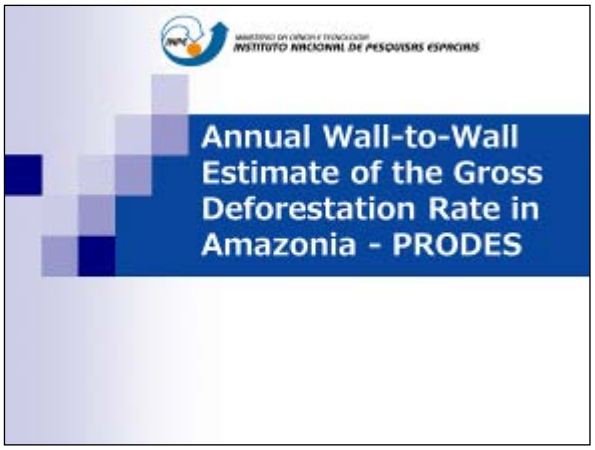
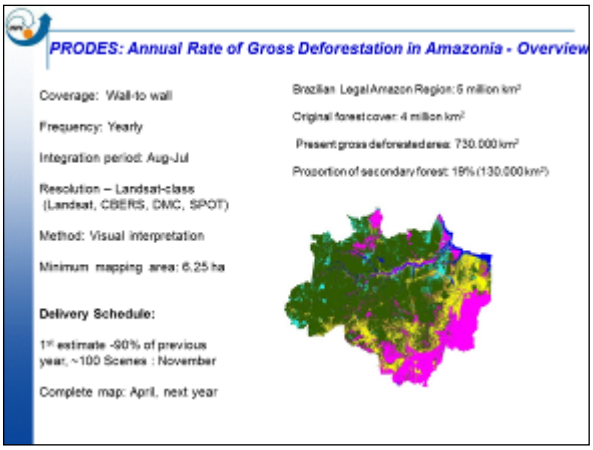
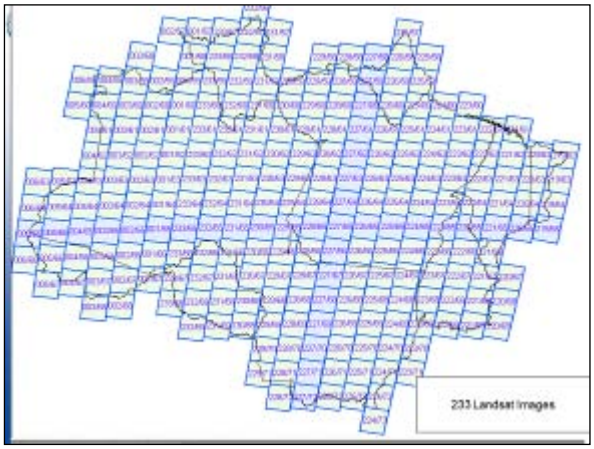


I was asked by the organizers to present the Brazilian forest monitoring systems. As such, I have planned my presentation to cover three systems. PRODES, which provides the official annual rate of gross deforestation in the Brazilian Amazonia. DETER, which continuously monitors the forest cover in the Brazilian Amazonia. And finally, DEGRAD/DETEX, which is a system to assess and estimate forest degradation and monitor management plans. All these systems are based on remotely sensed data, mainly from optical systems. To finalize my presentation, I will provide some of the challenges faced by Brazil to ensure national REDD+ implementation.

Unfortunately, due to the 15 minutes allocated for my presentation, it will not be possible for me to profoundly elaborate on the technical elements of the systems. But, I hope to be able to provide a flavor of what is being achieved through them. I am also going to do something that I seldom do, which is to read my notes as the slides are projected, to ensure that I will not go beyond my the 15 minutes. It is too much information.

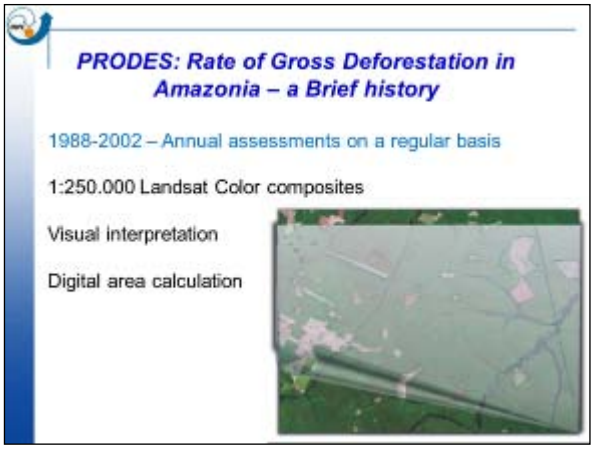


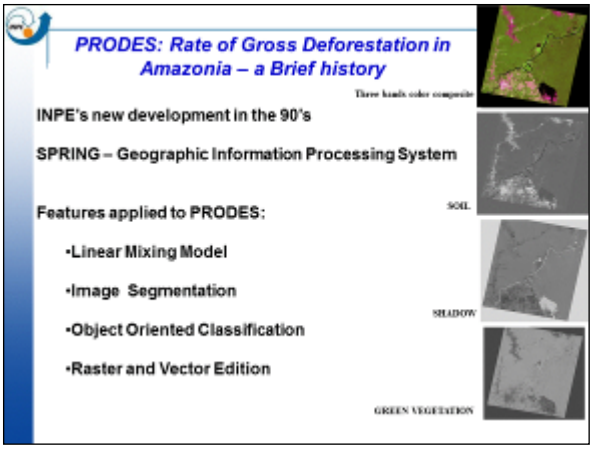




I will start with our oldest system called PRODES. It has been implemented on an annual wall-to-wall basis since 1988, covering an area of primary forest of approximately 400 million hectares. It is huge. It provides the annual rate of gross deforestation and for Brazil, deforestation refers to clear-cut forest. Until now, the accumulated deforestation has been estimated at 73 million hectares, about 18% of the original primary forest. Of these, about 30 million hectares are now classified as secondary forest. The land has been abandoned and left to re-grow. The major satellite data used is Landsat, the American satellite data, with a spatial resolution of 30 meters. But other data are also used to filling gaps in data due to cloud cover.

To cover the Amazonia region, we need to 233 Landsat images and this covers approximately 60% of the entire Brazilian territory.





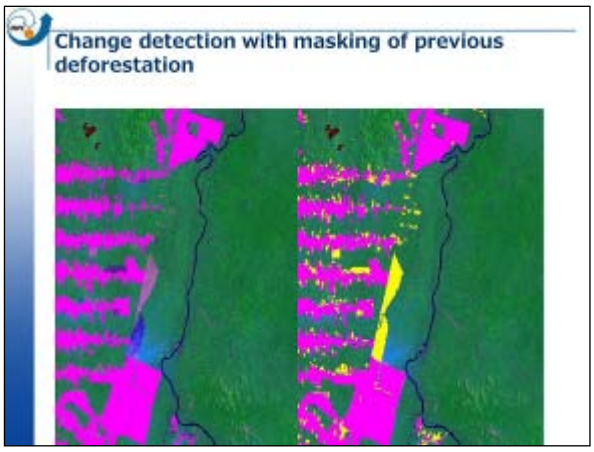
Until 2002, the estimates of gross deforestation were generated through visual interpretation of satellite imagery. It was a huge and dedicated task. I remember of a Chinese lady at INPE who used to map the tiny increments of deforestation in overlays, one by one, by hand. We now keep these overlays as a museum piece, but at that time it was extremely interesting to see.

Other researchers in America who were producing estimates of deforestation for Brazil would look at the

satellite imagery and would just draw a circle around areas where deforestation was happening. They were not so precise. We mapped each increment (polygon) by hand. After that, we transitioned to a digital analysis, ensuring the consistency between the visual and digital systems. Transition to a digital system made it possible to create a consistent georeferenced time series that is annually downloaded to the Internet. This, together with the satellite imagery, allows anyone to carry out the verification of the results. They can reproduce our deforestation rates. This verification is in fact carried out by some NGOs and also by some state environmental secretaries. Whenever we have any discrepancy, we can discuss that, but that has never occurred so far.

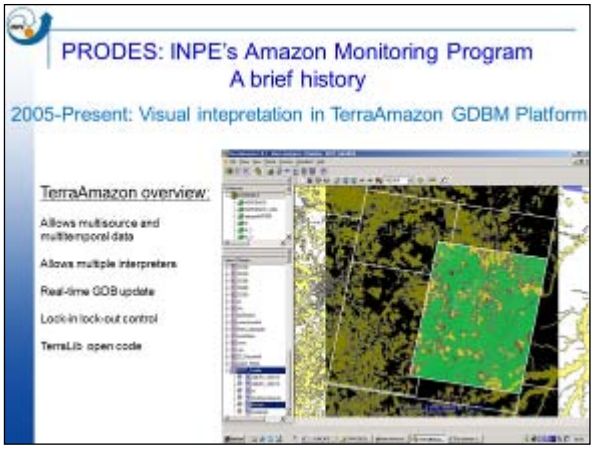
Just on that point, this is what I call the true verification system. You do not need to have only a third party to do the verification, you can have anyone, anywhere in the world to assess all the data that led to the results you produced.

In parallel, we continuously invested in the development of methodologies that could facilitate image classification. One of these methodologies used a linear mixing model, which generated images based on the amount of vegetation, soil and shade within each pixel in the image. The shadow image was found to be very useful for identifying clusters of pixels with similar values associated to deforestation event. To facilitate the identification of deforestation patches in the imagery, a digital classification was first generated and was followed by visual interpretation and refinement on the screen. Let me clarify that. Although, we do use digital processing at some stage just to have a first go, now it is only visual. You would put the image, have a digital classification, but then you would sit down with an analyst and he would check if the machine has done a good job or a bad job. Every piece of the image was checked by an analyst. Today, we find it simpler to do just by visual classification.

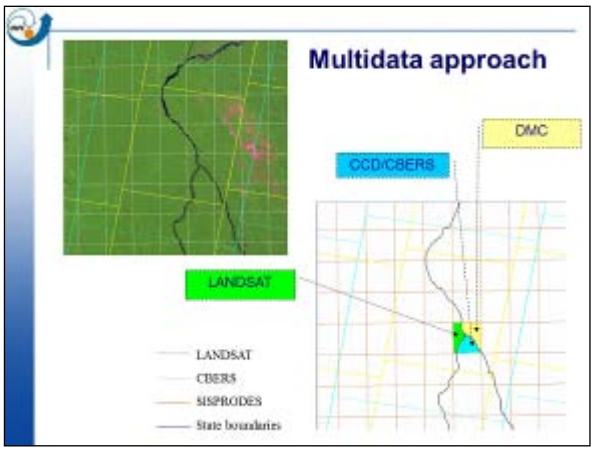


Each year, the deforestation identified in the previous year is aggregated with the old deforestation like what you see in red for instance is aggregated deforestation from previous years. What you see in yellow is the actual year when you are mapping your new polygons of deforestation. Next year those yellow become pink and you aggregate the new one, so you have like spatially split time series. You know where your deforestation patches are each year. The yellow polygons are aggregated with the previous

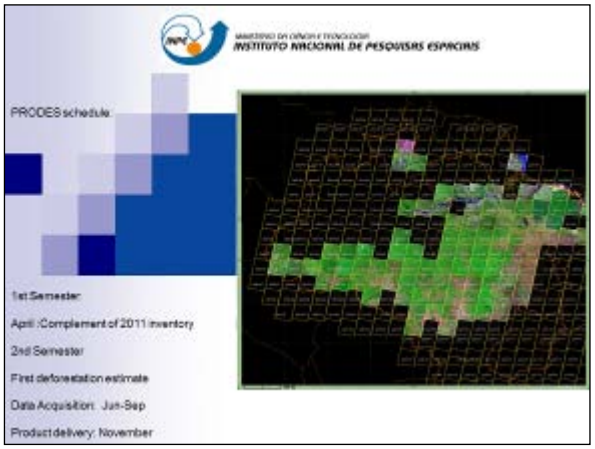
deforestation (represented in pink) creating a mask of non-forest which is no longer looked at. This is why we call it gross deforestation. For the purposes of the PRODES, we are interested in what happens after the land is deforested even though part of it re-grows afterwards and left to regenerate.

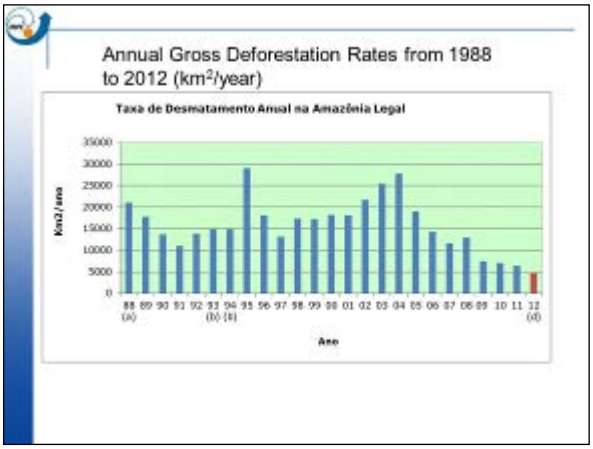


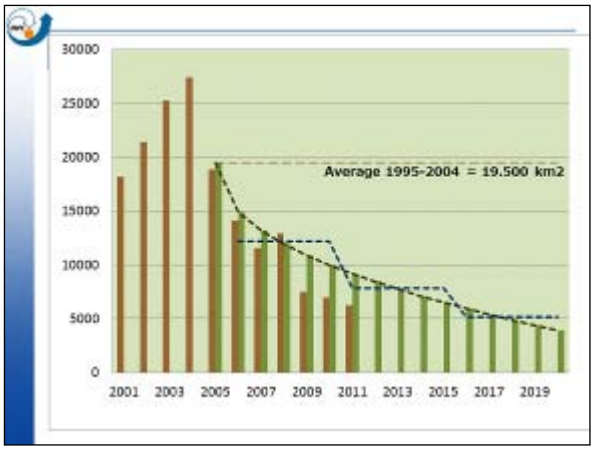
From 2005 onwards, a visual processing tool, which is called TerraAmazon was developed in-house. It allows for multiple data sources and multi-temporal imagery to be easily used in a single system. In addition, you can have several analysts working simultaneously in different parts of the same image, which is continuously updated. This avoids the need to have an administrator that would receive all the interpretation from the analysts. The system updates itself continuously and tells you whoever had done what in the imagery. That is also checked for quality control later on. The new system is now being transferred to other countries - , we now have, for instance, the TerraCongo, which is an adaptation of the TerraAmazon system.

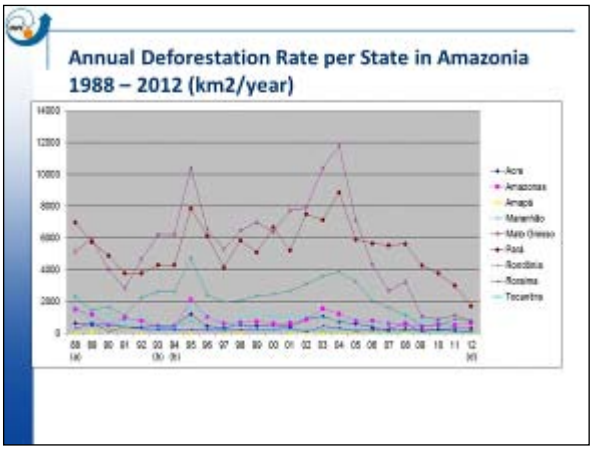


Before that, you see that I can use imagery from different systems like Landsat, radar imagery, optical systems of different resolution, I can do many things within this system, and it works very automatically. It almost reduced by half the time we had to take using the previous system. We are continuously improving to make this system become more operational and quicker.









The spatially split time series allows us to understand the dynamics of deforestation and the hotspot areas. It is interesting to know that about 80% of the annual deforestation concentrates in only 50 of the Landsat images. We have 233 images to cover the Brazilian Amazonia and in only 50 of them you have 80% of the deforestation in an area that we call the arc of deforestation. Hence, because our analysis extends from July of the previous year to August of the present year, we usually provide the government with a pre-estimate of the rate of gross deforestation in Brazil. We deliver that before the meeting of the Conference of the Parties to the Climate Change Convention in December. We have from September

until December to provide a pre-estimate. Normally, this pre-estimate errs, or has an uncertainly of about 5%. So, it is quite precise.

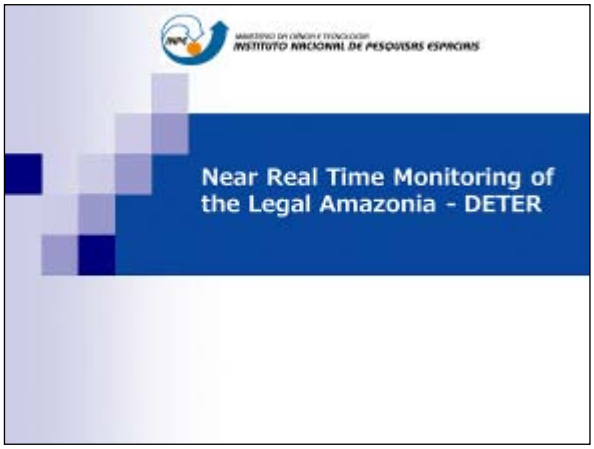
The graph in this figure shows the deforestation rates since 1988. The graph is provided here in the square kilometers. You can see a steady decrease from 2004 onwards. What you see in pink there is the pre-estimate that was extrapolated for 2012. Those numbers are going to be confirmed by possibly April or May, when you have the red bar changed into a blue bar. A steady decrease since 2004, when the government launched the national plan to convert and prevent deforestation in Amazonia with a series of planned measures.

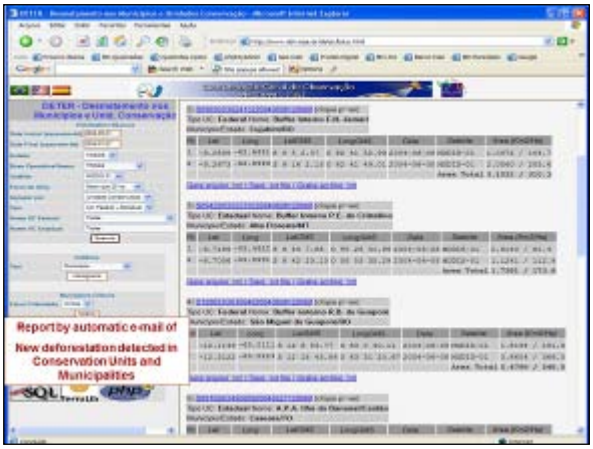
This shows the previous graph plotted against the planned reduction in the deforestation rate in Amazonia as included in the Brazilian climate change policy, which now became legislation. It is a law in Brazil approved by congress. Among several planned mitigation efforts, the Brazilian government voluntarily committed itself to a reduction of the deforestation rate by 80% by 2020, relative to a historical reference level, which is the average that you see on that dashed line.

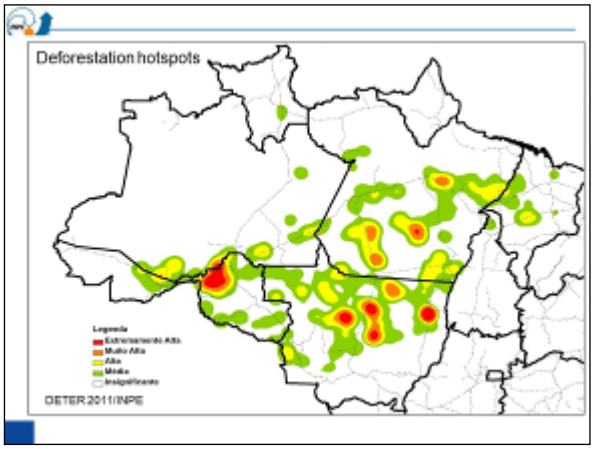
If you look, the green one is the planned decreased until 2020 and what you see in brown is the actual rate that we have been able to decrease since 2004. We have almost accomplished the commitment that Brazil has for Amazonia. A reduction in the deforestation rate in the Cerrado biome, which is next to the Amazonia and is the second largest biome in Brazil, is also planned within this policy. I will talk a little about that at the end of my presentation.

Since PRODES provides spatially split information, the deforestation rates can be disaggregated at a state or county level, thus facilitating the identification of potential drivers and thus helping in the process of public policy development. This aggregation provides a lot of data for the state and county level.

As I previously mentioned, all the information is downloaded to the Internet and can be reproduced by anyone willing to do so allowing continuous verification.





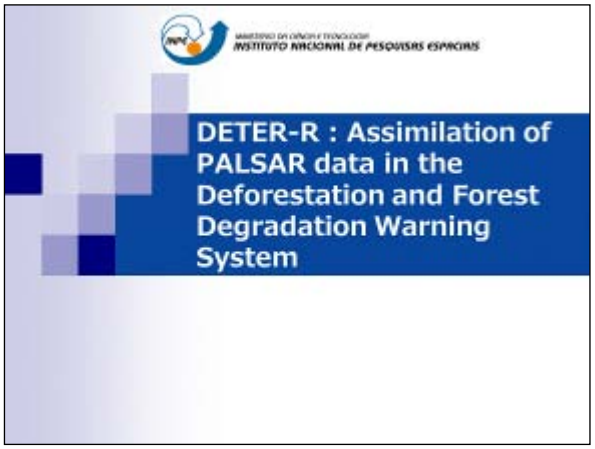


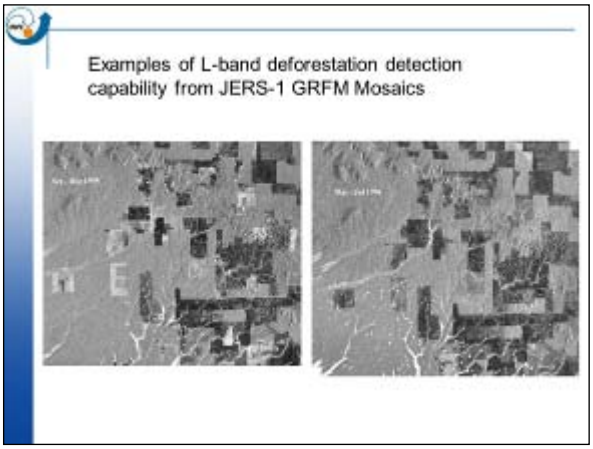
One of the measures contained in the plan to combat and prevent deforestation entailed the development of a system to provide the environmental agencies from the Ministry of Environment near real-time information about changes in forest cover in Amazonia. PRODES provides only one figure per year. So, the government said that. "This is so little for us. We need a system that helps us track and enforce the legislation." This gave origin to what we call the DETER system, which is based on more coarse satellite data. The MODIS data, which has a special resolution of 250 meters, but has daily revisits. The use of this data represented a compromise between a refined spatial resolution, which allows me to see more on the ground and the need to have more real-time information to guide the actions from the environmental agencies.

Part of the success to reduce deforestation since 2004 is attributed to the DETER system, which orients the control and enforcement agencies against the deforestation and forest degradation. This is a very typical and interesting example of a research institute working closely with the enforcement agency from the Ministry of the Environment. We go hand to hand, INPE does not do the actions, but provides georeferenced information to the enforcement agencies on a daily basis and we see if they are doing something. They go by helicopters, but when they get there sometimes people just run away. It is difficult to catch the real people doing deforestation even if you know where they are.

The DETER system makes available on a daily basis georeferenced information about changes in forest cover, which may not necessarily be related to deforestation or degradation because of the coarse resolution of the satellite data we are using.

DETER also provides for the identification of hotspot deforestation areas on the basis of recurrent deforestation events in any given area. The government particularly likes these maps because it can have a focused action in those areas.





In addition to the MODIS data, radar satellite imagery from the PALSAR sensor on both the Japanese ALOS[1] satellite developed by JAXA[2], also proved to be helpful to fill in gaps of information from optical systems. Unfortunately, ALOS had died recently. We are looking for the launching of ALOS this year again to retake not only research, but also to continue to use it to fill in gaps of information from optical systems.

Finally, here is an image from September to December 1995, May-July 1996, you can see some deforestation. You can clearly identify deforestation spots using ALOS data as well.

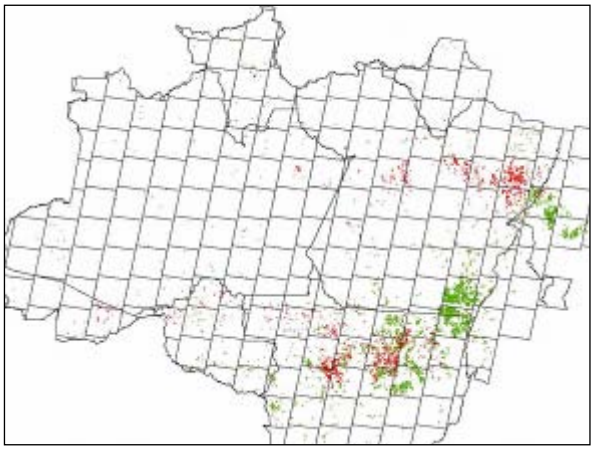
The last system, the DEGRAD, was developed to estimate the area affected by forest degradation, which in Brazil related to selective logging activities and biomass burning. This is our definition of forest degradation, what we can pick up from the satellite imagery. The fact that PRODES only provides estimates of clear-cut forest areas and considering the relevance of degradation activities, Brazil started since 2008 to map forest degradation also using mainly optical satellite data. What you see in the continuous pink is deforestation. In this area like popcorn, those are degradation from selective logging.

[1]Advanced Land Observation Satellite

[2]Japan Aerospace Exploration Agency: http://www.jaxa.jp/index_e.html

These are deforestation things and what is left either it is from biomass burning or from selective logging.

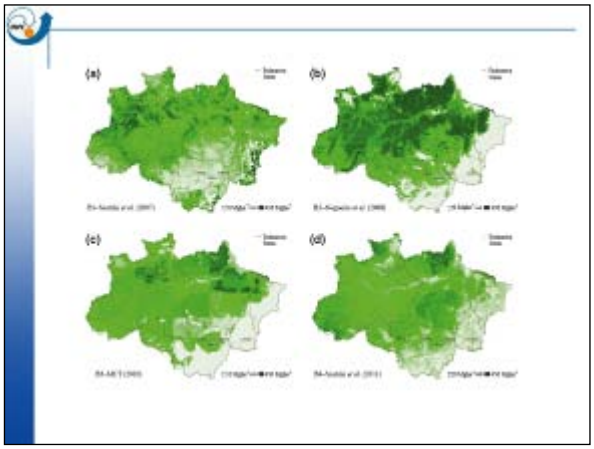
Now it differentiates much better. What you see in bright white are areas burnt and what you see elsewhere are areas of selective logging. However, the system did not discriminate between illegal selective logging activities from those related to forest management plans, which are not understood by the Brazilian environmental agencies as being forest degradation. For them, they are forest management plans, different from illegal. This is why it gave origin to the DETEX, which is the system that separates illegally logged areas from areas that are logged as part of management plans. You can do that with our system now.

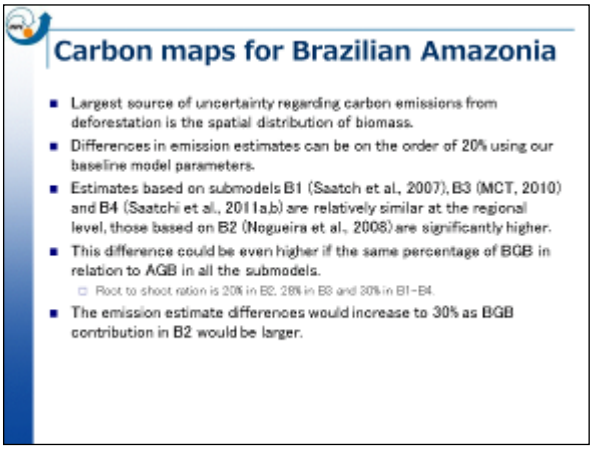


This shows the deforestation and degradation spots, the importance of degradation activities in Brazil. For REDD+, this is an important element to be considered. REDD+ allows developing countries to choose its REDD+ activities among the five agreed; reducing emissions from deforestation, reducing emissions from forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of carbon stocks. Countries could choose. However, in a country like Brazil, reducing emissions from deforestation is only part of the story. So, negotiators were aware of this issue and have agreed that significant sources of emissions need also be addressed, regardless of the activity chosen by the developing country engaged in REDD+. So, if Brazil chooses to reduce emissions from deforestation, it

also has to do degradation due to the relevant source of emissions from degradation.

Our experience confirms the general understanding of the potential of satellite imagery to estimate the area affected by deforestation and some types forest degradation. However, for REDD+, a reduction in the area of the forest does not suffice as they remaining deforestation may be expanding to more biomass intensive areas. Even if I reduce the deforestation, but deforestation is happening in areas of more intense biomass, only having the areas decreased does not solve the problem. We still find in Brazil it is very challenging to estimate biomass and its change using satellite imagery. However, the results of a recent study published by the Global Change Biology indicates the following for those that are interested in the biomass:



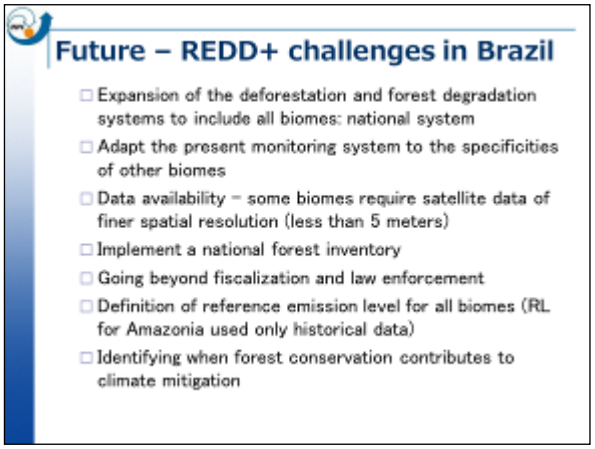


They have analyzed four different biomass maps for Amazonia in Brazil. All of them are from different sources. The one in there, B3, is the one that we use for the national communication of Brazil and it is based on data that we have acquired underground in this mid-70s together with allometric equations development by Niro Higuchi from the National Institute for Amazonian Research. We developed that map there on the basis of this information.

The other maps are a mixture of satellite data, some ground data coming from the same source. If you

look, you see they are very different. However, when you are looking at the effect of the use of any of them to estimate the regional emissions coming from Amazonia, you would notice a difference of 20% in the final result. If you include the below ground biomass, which is normally estimated using a root to shoot ratio, then that difference can be increased to 30%. I do not find it too big a difference to tell you the truth when you are talking about it globally. Locally, the differences might be much more than that. The uncertainties are much more than that.

The results they got, is that the largest source of uncertainty for biomass regarding the carbon emissions from deforestation are related to the spatial distribution of the biomass.



Now, going to my last part. The challenges that still Brazil faces today related to expanding the present systems to cover all forest biomass. I remember that when REDD+ was put on the table, everybody thought that, okay REDD+ is only for Brazil. Brazil is ready for REDD+ and I was always saying, "No, Brazil is not ready for REDD+. Brazil is going to be ready for REDD+ in 8, 10 years for phase 3." I continue to say after 8 years that it is going to take us 8 to 10 years. We have not been able so far to implement a national forest inventory on the ground. All information that we have comes basically from satellite imagery. The accuracy that we have on those results are pretty good. Especially good because you have clear-cut, you do not have thresholds for forest. Either I go from being a forest or nothing the next year. Either I see green or I see pink in my color composite images from one year to another. No need to go to the ground, I just say forest is gone, no need for ground. But, if it comes to biomass then I am not so sure that we are going to be able in the very, very near 2, 3 years' time to cover for that gap.
As I said, to expand the systems for our other biomes is a not simple as that. If I take the forest in the Mata Atlantica, one of our biomes, it requires an area change assessment that has higher resolution data, 5 meters or less. It is not just apply what you know and then is going to be a success story for all the biomes that you have. Other biomes are much more complex. For instance, in the Cerrado, fire is needed not to compromise the biodiversity in the biome. The system needs to pick up that as well.

To finalize, each biome requires a different approach. Constructing a robust reference emission level for each biome, respecting seasonality as I said, there is the fire that annually affect the forest biomass is

another challenge as always, changing biomass due to natural disturbances. In order to properly address deforestation, end forest degradation, drivers should be identified and this may be very challenging. The identification of these drivers is only the easiest part. The development and effective implementation of policies and measures to address deforestation and forest degradation is the major issue to ensure a successful REDD+ in developing countries. I hope that developed and developing countries or industrialized and non-industrialized countries or whatever you want to call it, can join hands and work for the successful REDD implementation in developing countries.