Analysis of land cover change in the Capitão-Poço, Pará region over a 20-year period based on Landsat MSS, TM and the Advanced Line Imager (ALI) data

Thomas Stone[1], Arlete Silva de Almeida[2], Ima Célia G. Vieira[2] and Eric Davidson[1]
[1]The Woods Hole Research Center, Woods Hole, Massachusetts, USA, [2]Museu Paraense Emílio Goeldi, Belém, Pará, Brasil
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Abstract
We analyzed the common area of five dates of Landsat imagery (P/R 223-61) and one date of Advanced Line Imager (ALI) data from the region of Capitão-Poço, Pará. We used TM imagery from 1984, 1994, 1999, 2001 and 2002 and ALI imagery from 2004. Using newer ALI imagery from a different sensing platform provided a challenge and opportunity to examine its utility.

This region is an area of older colonization where forest clearing has occurred since the opening of the Belém-Brasilia highway in the 1960s. The study area covers 1,800 km^2 arranged along a N-S swath chosen to cover a mosaic of 4 strips of ALI data acquired October 14, 2004. The area is unusual in the region in that there remain two large intact forest patches, one covering 37 km^2 and one covering 9 km^2 . In contrast, in 1984 the largest mature forest patch was more than 243 km^2.

Over the 1984-2004 period, we found a continuing loss of mature forest and a large increase in pasture. From analysis using the 1984 TM data, the region was 35% forest, 28 % secondary forest, 12% pasture, 23 % degraded forest, and 1.3% exposed soil and agriculture. Based on the ALI data, in 2004 the region was composed of 11% forest, 38% secondary forest, 40% pasture, 5% degraded forest and 6% exposed soil.

What is ALI?
The EO-1 ALI (**Advanced Line Imager**) is a NASA test instrument launched in November 21, 2000. Its focal plane has four sensor chip assemblies (SCA) and it operates in a pushbroom fashion at 705 km altitude. It provides "Landsat type" panchromatic and multispectral bands designed to mimic six Landsat bands with three additional bands covering 0.433-0.453, 0.845-0.890, and 1.20-1.30 µm. It is designed to demonstrate comparable or improved Landsat spatial and spectral resolution using a lighter, smaller, and cheaper imager. The ALI also contains wide-angle optics designed to provide a continuous 15° x 1.63° field of view with 30-meter resolution for the multispectral pixels and 10-meter resolution for the panchromatic pixels. **See: http://eo1.usgs.gov/ali.php**
Also on the EO-1 platform is the hyperspectral imager Hyperion.

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Methods
The study area was defined to be that coincident with the imagery acquired by the EO-1 ALI.

After radiometric correction of the Landsat Data and geocorrection to a UTM projection, we subsetted all dates of Landsat data. We mosaicked the ALI strips together and trimmed off the non-data fringes.

Available imagery and their dates are listed in Table 1. They cover a span of 20 years and are from three different platforms: Landsat TM5; Landsat 7 ETM; and EO-1 ALI. We did not have ALI panchromatic data for analysis.

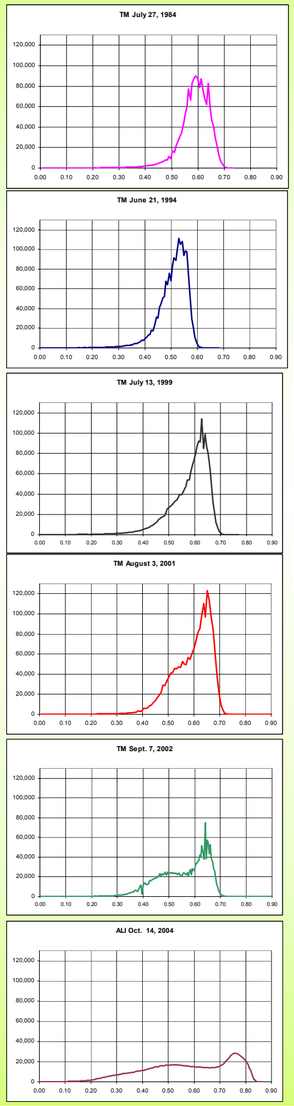
We examined NDVI data for all imagery and looked the frequency distribution their histograms.

We examined how the landcover changed over time based on supervised classifications and by examining 1024 random points. The most recent classifications were aided by extensive field work in the region and by comparisons with GPS points with defined land cover. This allowed us to not only look at gross change over time but also to create a transition matrix of land cover from one date to the next.

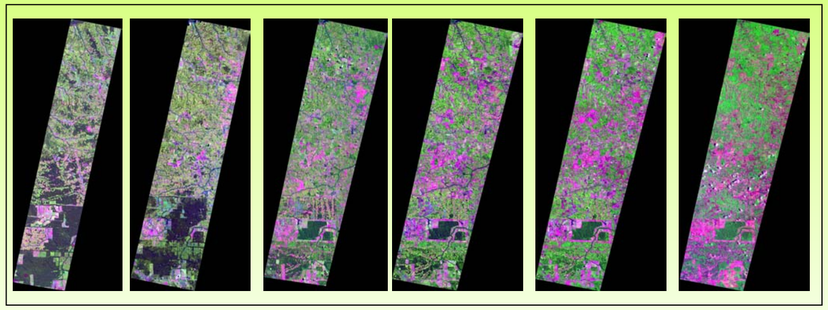
Table 1: Imagery

Landsat TM5	Jul. 27, 1984	8 bit
Landsat TM5	Jun. 21, 1994	8 bit
Landsat TM	Jul. 13, 1999	8 bit
Landsat ETM	Aug. 3, 2001	8 bit
Landsat ETM	Sept. 7, 2002	8 bit
EO-1 ALI	Oct. 14, 2004	16 bit

NDVI histograms over time



These six histograms (above) illustrate the frequency distribution (# of pixels, Y-axis) of NDVI values (X-axis) from the imagery. Over time, the shape of the curves changes from a sharp peak with high NDVI values in 1984, to broader curves with a strong skew towards lower NDVI values. Although differences in times of year of the various dates of imagery used can explain some of the changes, it is clear that less vigorous vegetation covers, which implies lower overall productivity, are coming to dominate the region.



Capitão-Poço study area, from left to right: TM5 1984, TM 1994, TM 1999, ETM 2001, ETM 2002, ALI 2004

Table 2 (below): This table is based on 1024 random points and what type of land cover they are coincident with over time. The original land cover is named and what percentage of that land cover either remained the same or was transformed to another type of land cover over the time between two dates of imagery.

For instance, (starting at the upper left) from 1984 to 1994, 48.8% of mature forest ("mata") remained as mature forest, 9.9 % was degraded (either by logging or burning), 10.1% became "dirty" or shrubby pasture ("pasto sujo"), 0.8 % became exposed soil, 11.5% became secondary forest ("capoeira") and 18.6% became clean pasture ("pasto limpo") and so forth for other intervals and land covers. Values do not sum to 100% as water, clouds, shadows and bad data are not included.

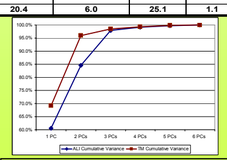
Mata							
from/to	# of years	To: Mata	Degraded Forest	Pasto Sujo	Solo	Capoeira	Pasto Limpo
1984:1994	10	**48.8**	9.9	10.1	0.8	11.5	18.6
1994:1999	5	**41.1**	10.8	15.1	2.8	17.5	12.7
1999:2001	2	**82.7**	0.0	3.4	0.0	10.2	3.4
2001:2002	1	**78.4**	0.0	5.6	0.0	9.9	0.6
2002:2004	2	**33.6**	7.0	6.1	1.4	48.6	2.3
PCT	avg.	**56.9**	**5.5**	**8.1**	**1.0**	**19.5**	**7.5**

Capoeira							
from/to	# of years	To: Mata	Degraded Forest	Pasto Sujo	Solo	Capoeira	Pasto Limpo
1984:1994	10	3.0	1.2	27.4	2.7	**16.6**	48.8
1994:1999	5	5.0	2.8	40.4	4.3	**31.2**	16.3
1999:2001	2	21.0	0.0	11.5	0.6	**49.0**	16.6
2001:2002	1	22.9	0.0	15.7	0.0	**43.2**	0.8
2002:2004	2	4.2	4.8	9.7	1.2	**70.9**	9.1
PCT	avg.	**11.2**	**1.8**	**20.9**	**1.8**	**42.2**	**18.3**

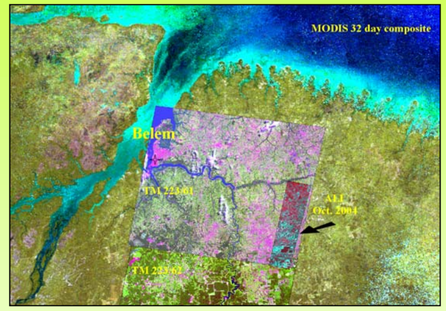
Pasto Limpo							
from/to	# of years	To: Mata	Degraded Forest	Pasto Sujo	Solo	Capoeira	Pasto Limpo
1984:1994	10	3.3	0.0	23.3	3.3	10.0	**56.7**
1994:1999	5	0.5	1.4	52.8	3.0	8.7	**33.1**
1999:2001	2	1.4	0.0	23.3	2.8	4.2	**68.4**
2001:2002	1	5.4	0.0	32.8	3.0	8.6	**23.7**
2002:2004	2	0.8	1.7	22.0	2.5	2.5	**70.3**
PCT	avg.	**2.3**	**0.6**	**30.8**	**2.9**	**6.8**	**50.4**

Pasto Sujo							
from/to	# of years	To: Mata	Degraded Forest	Pasto Sujo	Solo	Capoeira	Pasto Limpo
1984:1994	10	3.0	1.5	**39.7**	0.0	4.4	50.0
1994:1999	5	2.7	2.3	**46.3**	6.4	18.8	22.9
1999:2001	2	2.8	0.0	**17.8**	0.0	59.0	20.4
2001:2002	1	6.5	0.0	**53.4**	0.9	7.3	15.9
2002:2004	2	2.8	4.4	**39.6**	1.2	24.9	26.5
PCT	avg.	**3.6**	**1.6**	**39.4**	**1.7**	**22.9**	**27.1**

Degraded Forest							
from/to	# of years	To: Mata	Degraded Forest	Pasto Sujo	Solo	Capoeira	Pasto Limpo
1984:1994	10	11.0	**2.4**	23.4	1.0	18.7	42.6
1994:1999	5	33.3	**15.6**	17.8	2.2	8.9	22.2
1999:2001	2	17.0	**0.0**	34.0	0.0	23.4	19.1
2001:2002	1	-	-	-	-	-	-
2002:2004	2	-	-	-	-	-	-
PCT	avg.	**20.4**	**6.0**	**25.1**	**1.1**	**17.0**	**28.0**

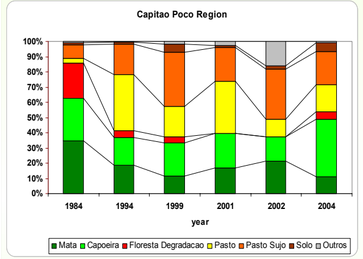


One measure of the modestly improved utility of ALI over ETM is from a principal components analysis of a 232 km^2 area common to the 2004 ALI data and the 2002 ETM data. TM data uses 2 PC to describe > 90% of the variance but the ALI sensor requires 3 PCs. This shows a slightly greater information content in the ALI data.



As this ALI image is on the extreme eastern edge of TM Path 223, it provides a challenge in finding matching imagery.

The graph (right) shows trends in land cover for the Capitão-Poço region based on 6 dates of imagery over the 1984-2004 span. There is a consistent decline in mature forest "(mata") and a continual shift between "clean" and "dirty" pasture ("pasto limpo" and "pasto sujo") as farmers manage the lands. Degraded (logged and burned) mature forest are less common over time as the area of mature forests declines.



Summary

From 1984 to 2004, the area of mature forest in this region has declined from 35% of the area to about 11% of the area while the amount of "pasto limpo" plus "pasto sujo" has increased from 12 % to 40% of the area. Over the 20-year period examined, the amount of secondary forest has ranged from 16 to 38% of the area. Currently, it is the most common land cover.

If NDVI is a measure of vegetative productivity, then the productivity of the region has declined significantly over time as mature forest is cleared and as pasture becomes the dominant land cover.

Examining the transitions reveals that from 1984 to 1999 almost half the remaining mature forest or "mata" was converted each time interval with similar fractions becoming "pasto sujo", "pasto limpo" and degraded forest. In later intervals, there was less conversion to degraded forest presumably because the small amount of remaining mature forest was in a more stable ownership. This also means that the fate of the two remaining patches of mature forest rests in the hands one or two individuals.

Secondary forest or "capoeira" in the first two time intervals showed little conversion back to forest and tended to remain as "capoeira". Lesser amounts were converted to "pasto limpo" and "pasto sujo" respectively.

Clean pasture or "pasto limpo" also tended to remain as "pasto limpo" or convert to "pasto sujo". These types of pasture also are the ones most likely to be identified as exposed soil in later intervals. Dirty pasture or "pasto sujo" was most likely to be converted to "pasto limpo" or to "capoeira", respectively.

Finally, the area identified as degraded forest (i.e. logged and burned) tended to be converted in following interval to "pasto limpo" and "pasto sujo" respectively. Only in one interval was there a large component of degraded forest that appeared to revert to mature forest or "mata".