Title:	Using Landsat to Examine Deforestation in Brazil
	Part I: Identify forested and deforested areas
	Part II: Calculate carbon emissions from deforestation
Product Type:	Curriculum
Developer:	Helen Cox (Professor, Geography, California State University, Northridge): helen.m.cox@csun.edu Laura Yetter (Research Asst., Institute for Sustainability, California State University, Northridge)
Target audience:	Undergraduate/Graduate
Format:	Tutorial (pdf document)
Software requirements*:	ArcMap 9 or higher (ArcGIS Desktop) (Parts I, II), ArcGIS Spatial Analyst (Part I)
Data:	Data provided: 1990 Landsat image subset and 2011 Landsat image subset
Estimated time to complete:	All parts: 4 hrs
	Part I: 2 hr.
	Part II: 2 hr.
Alternative Implementations:	• Part I provides a standalone exercise comparing forest areas in 1990 and 2011. In addition students compute the rate of deforestation for the image area. • Parts I and II together relate the deforestation rate in this area to carbon emissions and have students extrapolate results to the country of Brazil comparing emissions to those in the U.S.
Learning objectives:	Part I: • Understand the role that forests play in sequestering carbon dioxide from the atmosphere • Understand and use Landsat images • Understand and calculate the Normalized Difference Vegetation Index • Identify forested and un-forested areas • Calculate deforestation over two decades
	Part II: • Calculate carbon dioxide release as a result of deforestation in Brazil • Compare to U.S. annual emissions of carbon dioxide

*Tutorials may work with earlier versions of software but have not been tested on them

Using Landsat to Examine Deforestation in Brazil
Part II: Calculate carbon emissions from deforestation

Objectives:

- Calculate carbon dioxide release as a result of deforestation in Brazil
- Compare to U.S. annual emissions of carbon dioxide

This exercise continues from Part I.

7. Carbon emissions from deforestation in this region

When trees die and decompose or are burned, the carbon is released back into the atmosphere. Harris et al. (2012) (http://www.sciencemag.org/content/336/6088/1573.full#T1) discuss estimates of carbon stock and carbon emissions from forests around the world. We will use their table (http://www.sciencemag.org/content/336/6088/1573/T1.expansion.html) to calculate carbon loss due to deforestation in Mato Grosso.

Table 1

Top carbon emitters from gross forest cover loss per region, 2000–2005. Countries are listed in order of highest to lowest carbon emissions between 2000 and 2005. Forest area and area loss values are based on (*14*), and average forest carbon density values are derived from (*15*).

Region	Country	Forest area 2000 (Mha)	Gross forest cover loss, 2000–2005 (Mha year^{-1})	Average forest carbon density (Mg C ha^{-1})	Carbon emissions, 2000–2005 (Tg C year^{-1})
Latin America and Caribbean	Brazil	458	3292	116	340
	Colombia	63	137	138	14
	Bolivia*	61	129	90	11
	Argentina*	49	437	24	10
	Venezuela*	49	115	134	9
Sub-Saharan Africa	Democratic Republic of the Congo	167	203	128	23
	Mozambique*	34	196	42	9
	Tanzania*	23	149	45	7
	Zambia	29	134	43	7
	Cameroon	26	54	142	7
South and Southeast Asia	Indonesia	107	701	155	105
	Malaysia	22	233	179	41
	Myanmar	33	186	155	29
	India	42	206	104	18
	Thailand	17	134	126	16

Table from: Harris et al. (2012), Baseline Map of Carbon Emissions from Deforestation in Tropical Regions Science 22 June 2012: vol. 336 no. 6088 1573-1576.

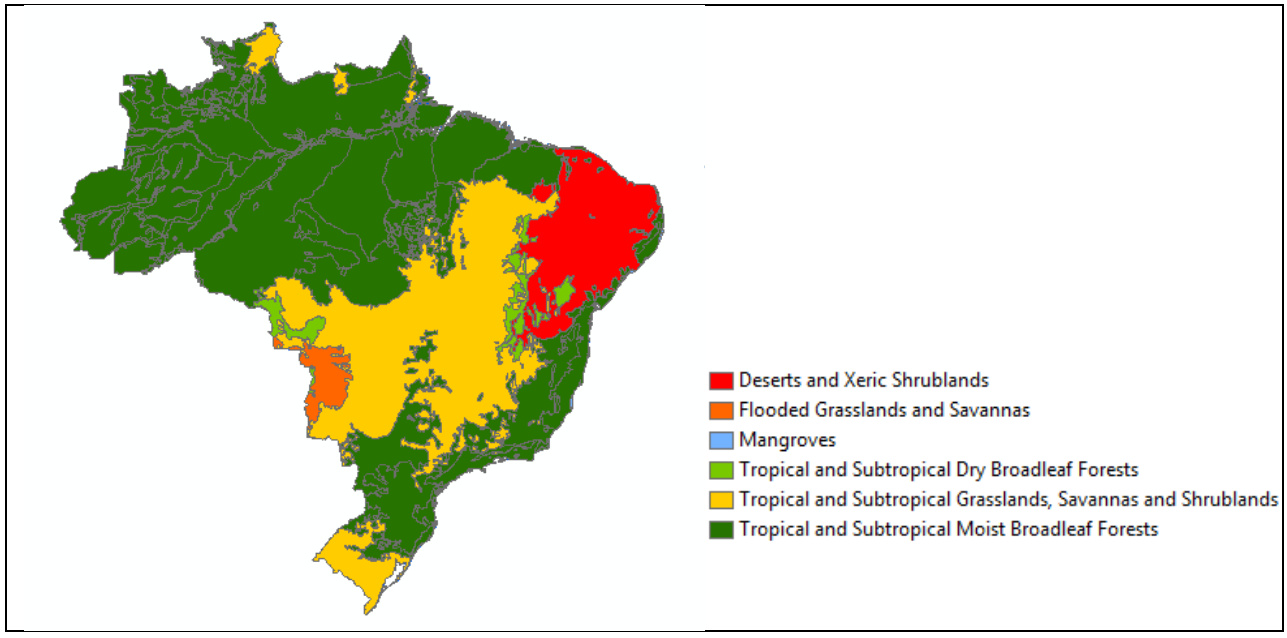
10. Using the data for average forest carbon density (Mg C ha^{-1}) in Brazil and your data from Pt I, calculate how many metric tons of carbon were lost due to deforestation in this region from 1990 to 2011?

8. **Carbon emissions from deforestation throughout Brazil**

We will now attempt to answer this question: "If the rest of Brazil is losing tropical forest at the same rate as the Mato Grosso region, what would be the resulting loss in carbon stock by deforestation in Brazil over the same 21 year period?"

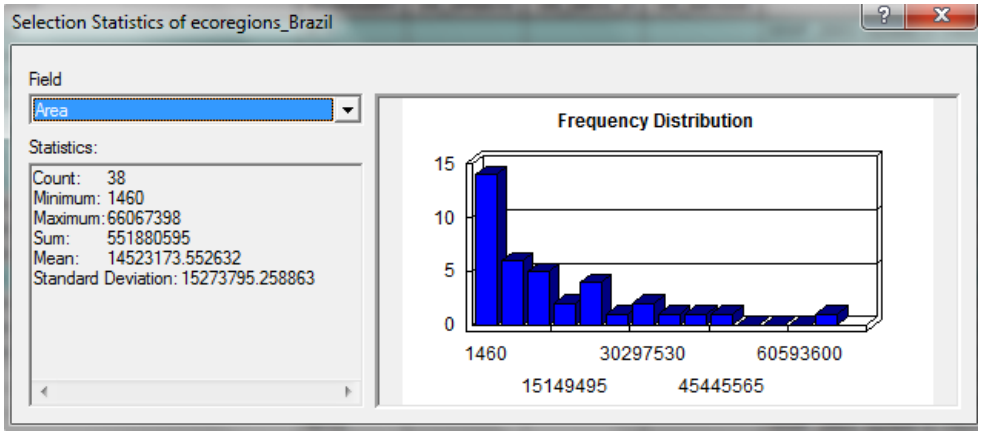
We need the area of forest in Brazil to compute this. Locate GIS data for the outline showing the country of Brazil. This is available from GeoCommunity: http://www.geocomm.com/. Data is free but requires you to set up an account. Another good site to get data is http://www.naturalearthdata.com or you can use other online sites.

Next locate GIS data for biomes. You can download this from the Nature Conservancy: http://maps.tnc.org/gis_data.html under Terrestrial Ecoregions. Add this layer to your map. Clip the data to the outline of Brazil (Toolbox-> Analysis->Extract->Clip). Choose the ecoregions layer as the Input Features and Brazil as the Clip Features. Save the output Feature Class and display it using Categories -> Unique Values with a Value Field of WWF_MHTNAM. Choose colors appropriately.



Add a column to your attribute table in which to store the area for each biome type. (Open attribute table -> Options -> Add Field. Use name "Area". Make it a long integer.) Calculate the area. (Right click on column name Area, select Calculate Geometry. Choose area with units of hectares. If you are using a geographical coordinate system instead of a projected coordinate system the property area lists "Area-Disabled" and the Units option is not enabled. In this case right click data frame >Properties> Coordinate System. Expand Predefined> Projected> Continental> South America> South America Albers Equal Area Conic.) Now select the forest biomes (both dry and moist broadleaf forests). (Choose Selection by Attribute with "WWF_MHTNUM" <= 2.) When you open the attribute table now you should see just the polygons corresponding to forest selected.

Right click on Area and choose Statistics. You should see the statistics of the selected regions:



(Your histogram should look very similar but may have small differences.)

11. Using the "Sum" value, calculate how many hectares of land are potentially lost per year using a loss rate of 0.72% per year Hansen et al (2010) http://www.pnas.org/content/107/19/8650.full.pdf+html

*12. Using the Harris et al. (2012) value for average forest carbon density (Mg C ha^{-1}) in Brazil (*http://www.sciencemag.org/content/336/6088/1573/T1.expansion.html*), how much carbon loss does this amount to?*

13. How does this compare to the value given by Harris et al. for Brazil?

14. When carbon decomposes in the atmosphere it combines with 2 oxygen atoms to make carbon dioxide, CO_2. The mass of one molecule of CO_2 is 44/12 times that of an atom of carbon. Calculate the amount of CO_2 released by deforestation in Brazil per year.

15. To get a feel for the magnitude of this, see how it compares to the total CO_2 emissions from the United States every year?

(You can get these data from Google Public Data: http://www.google.com/publicdata/directory

Choose World Resources Institute and then GHG emissions by country. Select United States as the country, select Greenhouse Gas Emissions, and then choose Carbon Dioxide under gases.)

References

Gibbs, Brown, Niles and Foley, Environ. Res. Lett., 2 (2007) 045023 (13pp), doi:10.1088/1748-9326/2/4/045023

Harris, Brown, Hagen, Saatchi, Petrova, Salas, Hansen, Potapov, and Lotsch, "Baseline Map of Carbon Emissions from Deforestation in Tropical Regions", Science, 22 June 2012: 336 (6088), 1573-1576. doi:10.1126/science.1217962