GRS-50806

# Geo-information Science BSc. Research Project

## Forest Cover Change in Prime Chimpanzee Habitat in the Boé Region of Guinea-Bissau, West-Africa

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## Abstract

The study aimed to increase the understanding of a priority protection site for West African Chimpanzee in Boé Sector, Gabú, Guinea-Bissau, West Africa. Online, free datasets were analyzed with the focuses on forest cover change and burned area through GIS applications. Recommendations of potential future work for Foundation Chimbo were given with reviews of literature regarding the concerns from the organization. The rates of deforestation vary from one percent to three percent depending on the different definitions of forest and locations. Relatively, forest with 10%-30% canopy closure suffered a smaller degree of deforestation. Burned area analysis showed a worrying trend where the field preparations were still performed in late-dry season, against what the Foundation Chimbo has been promoting. However, the analysis can only be used as a reference where more processing is needed for a more accurate measurement. Potential work includes the utility of unmanned aerial vehicle assisting the fire detection at a local scale and determination of cashew plantation with remote sensing by experienced technicians.

## 1. Introduction

In 2003, World Conservation Union (IUCN) issued Status Survey and Conservation Action Plan – West African Chimpanzees listed the Boé Sector in Gabú, Guinea-Bissau a priority site for chimpanzee conservation (Kormos *et al.*, 2003). As reviewed by IUCN in March 2016, *Pan troglodytes ssp. verus*, commonly known as Western Chimpanzee or West African Chimpanzee was listed as the "Critically Endangered", The major threats are habitat loss and fragmentation, due to slash-and-burn agriculture, which is commonly called shifting cultivation and swidden cultivation in the literature (Mertz *et al.,* 2009), and commercial agriculture, cashew plantations for instance (Humle *et al*., 2016). Vasconcelos *et al*. (2015) provide evidence that cashew plantations degrade biodiversity in Guinea-Bissau. Species abundance and richness have also proven to be significantly affected in the case.

The Foundation Chimbo, a Dutch NGO established in 2007 for the conservation and restoration of the chimpanzee population in West Africa hopes to take actions in conduction of survey and monitoring program in the Boé area in line with the "Regional Action Plan for the Conservation of Chimpanzees in West Africa". The Plan further recommends the establishment of education and awareness campaigns and improvement of the regional management plan. (Kormos & Boesch, 2003; Foundation Chimbo, 2017)

As a result, Foundation Chimbo is looking for more information regarding the general loss of the forest cover. Furthermore, the data of fire-events aids the early-fire program Foundation Chimbo has been advocating, where fires are to be set from October to December in the slash-and-burn farming. Fires on humid grass prevent uncontrollable damage to the forest area. (Foundation Chimbo, 2016) As suggested by Foundation Chimbo, this project aims to determine the rate of habitat loss in Boé Sector using primarily existing geo-data, due to the time limitation and scale of the project. Drawing datasets collected and processed by scholars, this report aims to demonstrate the analyses of geo-data mapping the forest cover change and fire-events specifically in Boé.

## 2. Methodology

### 2.1 Data Selection

Due to the nature and time constrain of this project, readily available datasets are considered in the first place. Concerning the two main focuses of the project, the analysis of forest cover change and the burned area, two separate studies from the University of Maryland provide datasets that can be downloaded through online portal and FTP server.

The quantification of global forest cover change study published by Hansen *et al.* (2013) offers datasets of forest cover, loss and gain from 2000 to 2012. The most recent updated data collection of forest loss includes data until 2014, in grid cells of 1 arc-second, or 30 meters at the equator. Raster data in GeoTIFF are available online at (https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.3.html) in tiles of 10x10 degree.

Burned Area Products, as officially called the Moderate Resolution Imaging Spectrometer (MODIS) product MCD64A1, are generated from the Terra and Aqua spacecraft collected data by algorithm from David Roy (1999). The official MODIS products come in HDF-EOS format while they are re-projected by the University of Maryland to GeoTIFF and Shapefile formats. Shapefiles of monthly data from January 2000 until March 2017 are provided on the FTP server of Geographical Sciences Department, University of Maryland.

## 2.2 Data Processing

### *2.2.1 General Data*

Due to the lack of studies in the project area, there are no individual geo-tagged file, GeoTIFF or simple shapefile, of the Sector Boé online. As a result, the sector must be isolated from the Region Gabú for further processing and clipping of the data. Permanent waterbodies were derived from the forest cover change studies by Hansen *et al.*, where all the waterbodies are coded in the raster dataset.

### *2.2.2 Forest Cover*

The map tiles of the forest cover, loss and gain were downloaded with the top-left corner at 10N, 20W where the 10x10 degree granule covers the project area, Boé. All the raster datasets were first clipped to fit the project area and then converted into polygons. Fifteen layers of forest loss were selected and separated by year from 2000 to 2014. All the polygon layers were projected to "WGS_1984_Web_Mercator_Auxiliary_Sphere", the same as the original projection coordinate system as the Boé boundaries shapefile. The coordinate system outputs the shape length and shape area in meters instead of degrees in the original coordinate system.

As the polygons in the forest cover layer are coded with the percentage of canopy closure, which is often considered a synonym of canopy cover (Paletto & Tosi, 2009), selection of forest area with a minimum of 10% canopy closure and 0.5 hectares was performed (5-meter threshold of trees was automatically considered in the dataset), according to the definition of "forest" provided by Food and Agriculture Organization of the United Nation in the Global Forest Resource Assessment (2001). Additionally, a minimum of 30% canopy closure which is also commonly used for forest analysis was considered to provide insight (Owens & Lund, 2009). Forest loss layers are erased from the forest cover baseline layers to produce the final forest covers in 2014.

After the first meeting with the Annemarie Goedmakers and Piet Wit from Foundation Chimbo, it was suggested that the area east of Rio Corubal was separated for further analysis. Four final shapefiles were expected, including the 30% and 10% forest closure on the whole Boé Sector, as while as the area east of the river.

### *2.2.3 Fire Events*

The Burned Area Products have a lower spatial resolution because of the nature of MODIS where the satellites of the collection obtain images in resolutions 500m (Roy et al., 2005). The MCD64A1 products are available in 500m resolution while the actual cell size of a "500m" MODIS grid cell is 463.313m (Boschetti *et al.*, 2015). The shapefiles containing the polygons of burned area coded with "BurnDate" in Julian Day were first clipped with the boundaries of the Boé. The data were then merged by year, and outputted into Microsoft Excel for table-view of data. Furthermore, data dated by seasons were also produced for a better understanding of early and late field fire preparations in the area. Dry seasons are classified "early" and "late", where the "early" is from October to December, while the "late" dry seasons are January to May. Those processes were all done by models in ArcMap and the data, including raw data from server and processed data, are all saved in geodatabases for future uses and analyzes.

## 3. Result

### *3.1 Forest Cover Change*

The analysis revealed a constant and low rate of deforestation since 2001. However, a surge of deforestation in 2013 and 2014 is observed, regardless of the location and the percentage of canopy closure (figure 1). Forest with 30% canopy closure suffers from a larger degree of deforestation where 2-3% are lost since 2001, while 10% canopy forest only has lost 1% (table 1). Comparatively, there was less forest loss with 10-30% canopy closure but it is difficult to determine as the base area is different. These results showed a worrying trend where the rate of deforestation has been speeded up.

Table 1

Forest cover loss by year from whole Boé Sector and east of Rio Corubal in 10% and 30% canopy closure in $km^2$

| | Boé Sector | | East of Rio Corubal | |
|---|---|---|---|---|
| Year | 30% Canopy Closure | 10% Canopy Closure | 30% Canopy Closure | 10% Canopy Closure |
| 2001 | -0.24 | -0.56 | -0.21 | -0.53 |
| 2002 | -0.61 | -0.99 | -0.52 | -0.90 |
| 2003 | -0.17 | -0.25 | -0.08 | -0.15 |
| 2004 | -0.37 | -0.76 | -0.24 | -0.62 |
| 2005 | -0.94 | -1.20 | -0.58 | -0.83 |
| 2006 | -0.13 | -0.17 | -0.09 | -0.13 |
| 2007 | -1.76 | -2.15 | -1.13 | -1.50 |

| | | | | |
|---|---|---|---|---|
| 2008 | -1.15 | -1.25 | -0.62 | -0.71 |
| 2009 | -1.44 | -1.69 | -0.70 | -0.94 |
| 2010 | -0.89 | -1.04 | -0.56 | -0.71 |
| 2011 | -0.84 | -0.96 | -0.48 | -0.60 |
| 2012 | -0.76 | -1.07 | -0.37 | -0.66 |
| 2013 | -7.01 | -11.67 | -4.51 | -9.06 |
| 2014 | -3.76 | -5.51 | -2.54 | -4.24 |
| Total Loss | -20.08 | -29.27 | -12.63 | -21.59 |
| Total Area | 722.737049 | 2703.181685 | 414.133353 | 2177.868416 |
| Percentage Loss | 2.78 | 1.08 | 3.05 | 0.99 |

Table 1

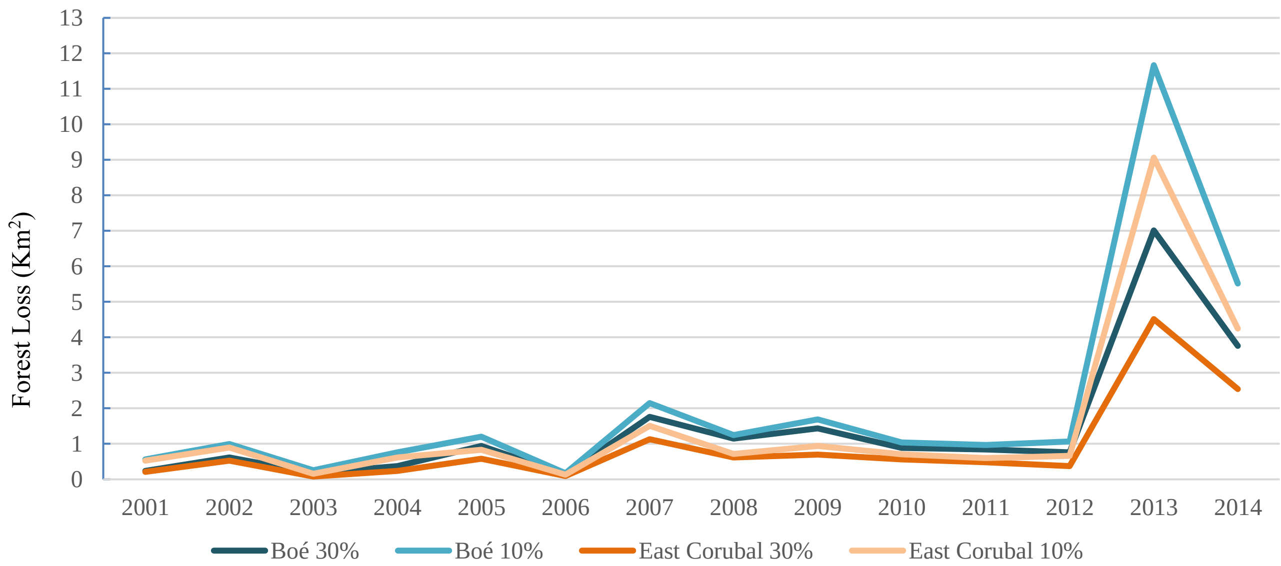


Figure 1: Forest Cover Loss. This figure illustrates the forest cover loss by year in different locations and definitions of forest (10% and 30% canopy closure).

### *3.2 Fire Events*

The daily image collection of MODIS compromises the spatial resolution, producing raster datasets with a pixel size of 463m. Each cell coded with a burn date only marks the occurrence of fire events with a cell. The number of fire events and the percentage of the burned area remains unknown. As a result, only the counts of pixel cells could be concluded. The result in table 2 showed a distinct wet and dry season when field preparations of slash-and-burn were done. It starts mid-October and continues until late May, as the rain seasons generally stretch from June until mid-October. The early-dry season field preparation promoted by Foundation Chimbo resulted in a worrying trend as the ratios of the number of the incident in early-dry seasons and late-dry seasons have not been significantly decreasing (figure 2).

The affected area in $km^2$ is unavailable in this stage because of the sinusoidal projection used is not commonly included in ArcGIS for processing. Further algorithm development or raster-processing is needed but precise counts of fire events are still not possible with MODIS satellites.

Table 2

Frequency of fire events based on counts of marked pixel coded with burn date in Julian day

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 389 | 337 | 90 | 4 | 89 | 0 | 0 | 0 | 0 | 7 | 14 | 21 | 614 |
| 2002 | 247 | 514 | 109 | 3 | 70 | 0 | 0 | 0 | 0 | 8 | 32 | 110 | 579 |
| 2003 | 430 | 168 | 99 | 24 | 195 | 0 | 0 | 0 | 0 | 32 | 25 | 225 | 1198 |
| 2004 | 154 | 220 | 180 | 26 | 265 | 0 | 0 | 0 | 0 | 3 | 56 | 123 | 1027 |
| 2005 | 285 | 437 | 34 | 148 | 205 | 0 | 0 | 0 | 0 | 25 | 151 | 165 | 1450 |
| 2006 | 154 | 268 | 159 | 58 | 342 | 0 | 0 | 0 | 0 | 74 | 25 | 145 | 1225 |
| 2007 | 175 | 338 | 30 | 11 | 350 | 0 | 0 | 0 | 0 | 4 | 8 | 71 | 987 |
| 2008 | 181 | 281 | 39 | 22 | 121 | 0 | 0 | 0 | 0 | 0 | 21 | 94 | 759 |
| 2009 | 286 | 303 | 66 | 21 | 124 | 0 | 0 | 0 | 0 | 13 | 81 | 71 | 965 |
| 2010 | 188 | 192 | 79 | 23 | 299 | 0 | 0 | 0 | 0 | 5 | 26 | 52 | 864 |
| 2011 | 100 | 367 | 102 | 91 | 542 | 0 | 0 | 0 | 0 | 35 | 159 | 51 | 1447 |
| 2012 | 373 | 261 | 66 | 73 | 66 | 0 | 0 | 0 | 0 | 0 | 14 | 256 | 1109 |
| 2013 | 159 | 326 | 131 | 26 | 255 | 0 | 0 | 0 | 0 | 1 | 68 | 237 | 1203 |
| 2014 | 88 | 450 | 28 | 161 | 101 | 0 | 0 | 0 | 0 | 26 | 22 | 156 | 1032 |
| 2015 | 58 | 483 | 23 | 43 | 145 | 0 | 0 | 0 | 0 | 15 | 33 | 43 | 843 |
| 2016 | 390 | 272 | 59 | 96 | 583 | 1 | 0 | 0 | 0 | 7 | 2 | 146 | 1556 |

Table 2

Table 3

Frequency of fire events based on early-dry seasons and late-dry seasons by years

| EDS | Oct | Nov | Dec | Sub-total | LDS | Jan | Feb | Mar | Apr | May | Sub-total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 7 | 14 | 21 | 42 | 2002 | 247 | 514 | 109 | 3 | 70 | 943 |
| 2002 | 8 | 32 | 110 | 150 | 2003 | 430 | 168 | 99 | 24 | 195 | 916 |
| 2003 | 32 | 25 | 225 | 282 | 2004 | 154 | 220 | 180 | 26 | 265 | 845 |
| 2004 | 3 | 56 | 123 | 182 | 2005 | 285 | 437 | 34 | 148 | 205 | 1109 |
| 2005 | 25 | 151 | 165 | 341 | 2006 | 154 | 268 | 159 | 58 | 342 | 981 |
| 2006 | 74 | 25 | 145 | 244 | 2007 | 175 | 338 | 30 | 11 | 350 | 904 |
| 2007 | 4 | 8 | 71 | 83 | 2008 | 181 | 281 | 39 | 22 | 121 | 644 |
| 2008 | 0 | 21 | 94 | 115 | 2009 | 286 | 303 | 66 | 21 | 124 | 800 |
| 2009 | 13 | 81 | 71 | 165 | 2010 | 188 | 192 | 79 | 23 | 299 | 781 |
| 2010 | 5 | 26 | 52 | 83 | 2011 | 100 | 367 | 102 | 91 | 542 | 1202 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 | 35 | 159 | 51 | 245 | 2012 | 373 | 261 | 66 | 73 | 66 | 839 |
| 2012 | 0 | 14 | 256 | 270 | 2013 | 159 | 326 | 131 | 26 | 255 | 897 |
| 2013 | 1 | 68 | 237 | 306 | 2014 | 88 | 450 | 28 | 161 | 101 | 828 |
| 2014 | 26 | 22 | 156 | 204 | 2015 | 58 | 483 | 23 | 43 | 145 | 752 |
| 2015 | 15 | 33 | 43 | 91 | 2016 | 390 | 272 | 59 | 96 | 583 | 1400 |

*Note*. EDS = early-dry season and LDS = late-dry season. The early-dry season in earlier year combines with the late-dry season in latter year as one whole dry season.

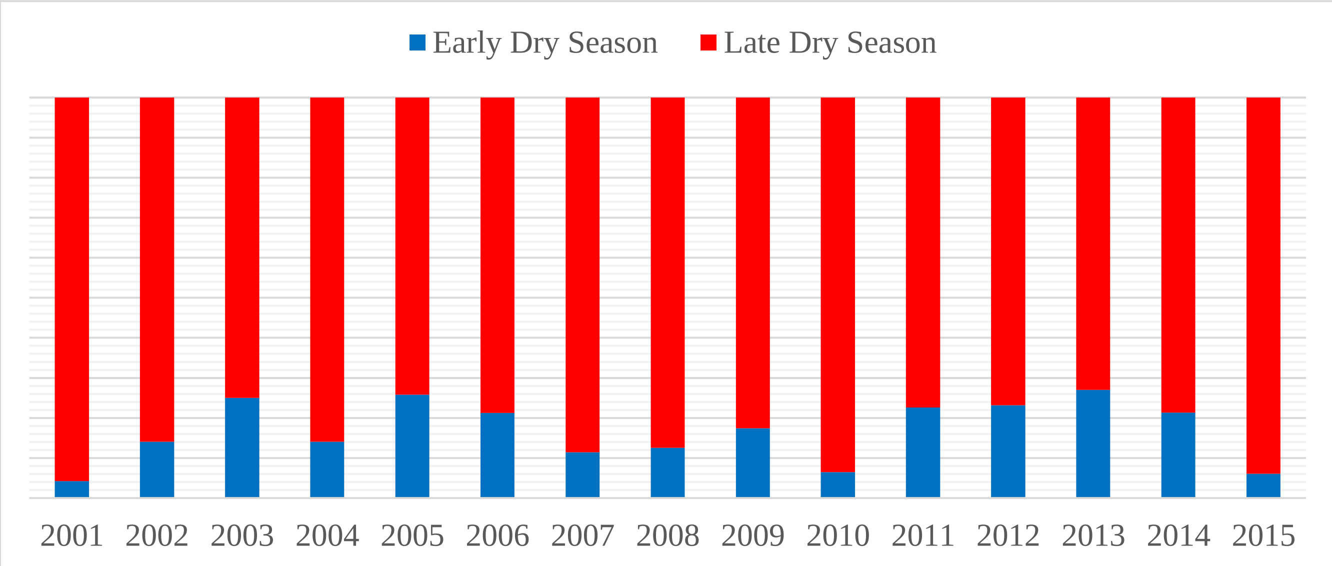


Figure 2: Ratio of the pixel count of early-dry season fire and late-dry season fire. This figure illustrates the ratio between the fire event frequency in early-dry seasons and late-dry seasons.

## 4. Discussion

It was agreed by the Foundation Chimbo during meetings that the size and numbers of cashew plantations have been expanding, due to the rapid-growing price of cashew (Chau, 2016). This might lead to an increasing rate of deforestation in the area. Although the Hansen’s dataset gives information regarding the extent of deforestation, the algorithms developed are not tailor-made for the project area. As cashew trees height varies from 5 to 14 meters, it is very possible that the cashew plantations are included in the forest dataset. The natural forest may suffer from different degrees of disturbance, where many more trees have been removed for plantations. The extent of deforestation remains unclear.

Furthermore, the counts of fire events by pixel do not accurately reflect the truth on ground, where there were many more fire events on-site. Various fires could have been set within the same pixel cell without being detected by the MODIS satellite. Overall, the MODIS satellite is incapable of fire detection at a local scale (Tang & Shao, 2015). Allison *et al.* concluded for frequent satellite operation, regrettably, the spatial resolution cannot provide a precise image collection that reflects the occurrence of small and local fire events. The review listed the possibilities of unmanned aerial vehicles (UAVs) and manned aircraft which promise “flexibility of spatial and temporal resolution”. Martinez-de Dios *et al.* (2011) and Merino *et al.* (2012) have demonstrated the UAV systems that can provide long-term, low cost and real-time fire detection on a more localized scale. Fire detection in Boé Sector should move towards the utility of drones for a more accurate estimation.

For the cashew plantation determination, Avatar *et al.* (2013) demonstrated the possibility of identifying cashew plantations through Landsat and AVNIR-2 satellite with the assistance of ground control-points during fieldwork. It is possible to map cashew plantations that can be further excluded from the dataset by Hansen *et al* and provide information regarding the expansion of them. Deployment of experienced technicians is needed for a more accurate assessment of natural forest cover.

## 5. Reference


1. Avtar, R., Takeuchi, W., & Sawada, H. (2013). Monitoring of biophysical parameters of cashew plants in Cambodia using ALOS/PALSAR data. *Environmental Monitoring and Assessment, 185*(2), 2023-2037. doi:10.1007/s10661-012-2685-y
2. Boschetti, L., Roy, D., Hoffmann, A., Humber, M. (2013). *Collection 5 MODIS Burned Area Product User Guide Version 3.0.1*.
3. Chau, M. (2016, November 1). Cashew Prices Are About to Go Nuts. *Bloomberg*. Retrieved June 23, 2017, from https://www.bloomberg.com/news/articles/2016-10-31/snack-food-sticker-shock-for-cashew-eaters-after-vietnam-drought
4. Food and Agriculture Organization of the United Nations. (2001). Global forest resources assessment 2000. *Main Report. Food and Agriculture Organization of the United Nations. Rome, PAO Forestry Paper*.
5. Foundation Chimbo. (2016). *Annual Report 2015* (Rep.). Foundation Chimbo.
6. Foundation Chimbo. (2017). *Annual Report 2016* (Rep.). Foundation Chimbo.
7. Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., . . . Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science (New York, N.Y.), 342*(6160), 850-853. doi:10.1126/science.1244693
8. Humle, T., Boesch, C., Campbell, G., Junker, J., Koops, K., Kuehl, H. & Sop, T. 2016. *Pan troglodytes ssp. verus*. (2016) The IUCN Red List of Threatened Species 2016: e.T15935A102327574. http://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T15935A17989872.en. Downloaded on 14 June 2017.
9. Kormos, R., & Boesch, C. (2003). *Regional action plan for the conservation of chimpanzees in West Africa*.
10. Kormos, R., Boesch, C., Bakarr, M. I., & Butynski, T. M. (2003). Status survey and conservation action plan: West African chimpanzees. *IUCN/SSC Primate Specialist Group, Gland*.
11. Martínez-de Dios, J. R., Merino, L., Caballero, F., & Ollero, A. (2011). Automatic forest-fire measuring using ground stations and unmanned aerial systems. *Sensors (Basel, Switzerland), 11*(6), 6328-6353. doi:10.3390/s110606328
12. Merino, L., Caballero, F., Martínez-de-Dios, J. R., Maza, I., & Ollero, A. (2012). An unmanned aircraft system for automatic forest fire monitoring and measurement. *Journal of Intelligent & Robotic Systems, 65*(1), 533-548. doi:10.1007/s10846-011-9560-x
13. Mertz, O., Padoch, C., Fox, J., Cramb, R. A., Leisz, S. J., Lam, N. T., & Vien, T. D. (2009). Swidden change in Southeast Asia: Understanding causes and consequences. *Human Ecology, 37*(3), 259-264. doi:10.1007/s10745-009-9245-2
14. Owens, J. N., & Lund, G. (2009). *Forests and Forest Plants* (Vol. 1) (*pp.* 119-120). EOLSS Publications. Retrieved from June 28, 2017, from

https://books.google.ca/books?id=htqpCwAAQBAJ&pg=PA120&dq=Owens,+J.+N.,+%26+Lund,+G.Forests+and+Forest+Plants&hl=en&sa=X&ved=0ahUKEwjjveevk5bVAhUK2WMKHQJjD9QQ6AEIKDAA#v=onepage&q&f=false

15. Paletto, A., & Tosi, V. (2009). Forest canopy cover and canopy closure: Comparison of assessment techniques. *European Journal of Forest Research, 128*(3), 265-272. doi:10.1007/s10342-009-0262-x
16. Roy, David P. (1999) Multi-temporal active-fire based burn scar detection algorithm. *International Journal of Remote Sensing* 20.5: 1031-1038.
17. Tang, L., & Shao, G. (2015). Drone remote sensing for forestry research and practices. *Journal of Forestry Research, 26*(4), 791-797. doi:10.1007/s11676-015-0088-y
18. Vasconcelos, S., Rodrigues, P., Palma, L., Mendes, L. F., Palminha, A., Catarino, L., & Beja, P. (2015). Through the eye of a butterfly: Assessing biodiversity impacts of cashew expansion in West Africa. *Biological Conservation, 191*, 779-786. doi:10.1016/j.biocon.2015.08.032