National Directorate of Forestry
Ministry of Lands, Environment and Rural Development
Mozambique

Development of forest monitoring methods and forest degradation issues in Mozambique

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Joaquim A. Macuácua

GIS and RS Expert

Head of division of mapping and Data management

REDD Research and Development Center Japan

JICA ジャイカ

JOFCA KOKUSAI KOGYO CO.,LTD.

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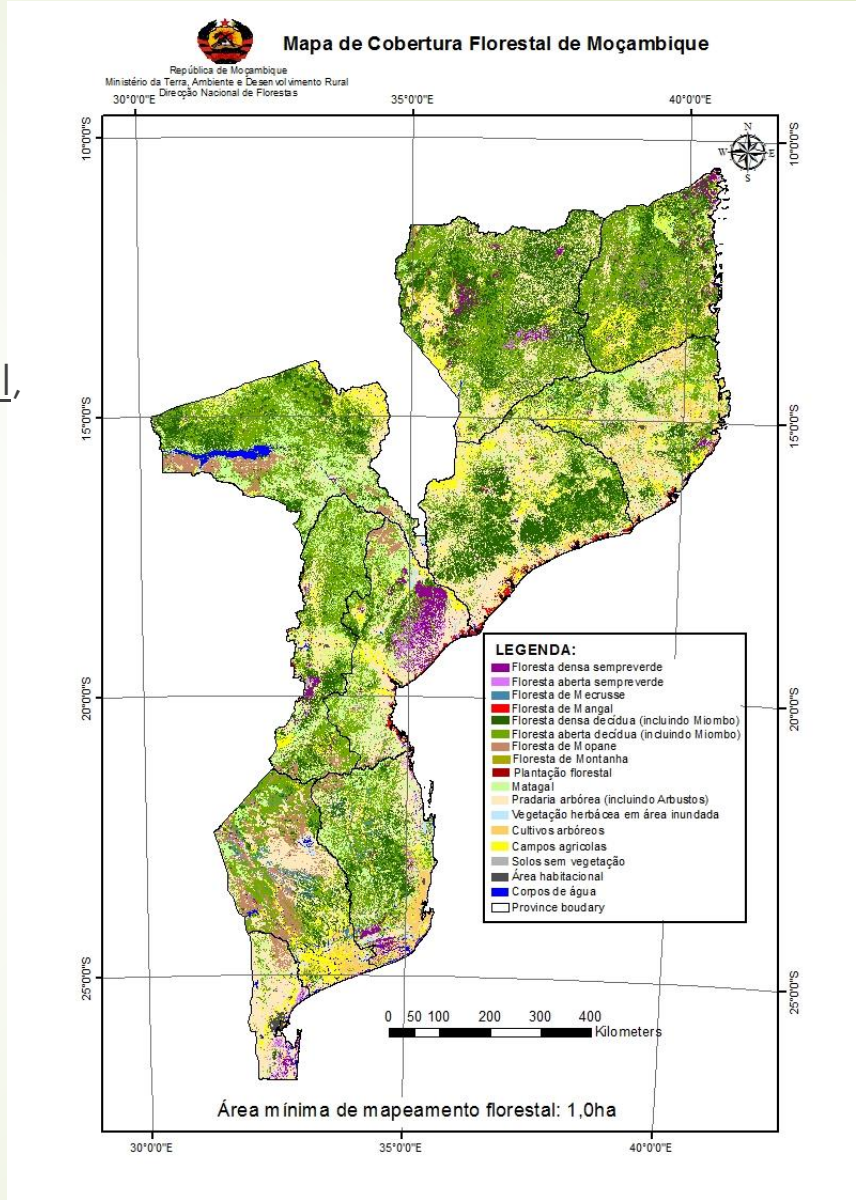
General information

- **Area** ~ 801 590 Sq km;
- **Population** ~ 27.216.000 (2017 census projection);
- **Economy** – Agro-based (cashew nuts, cotton);
  - **Resources**: Water, Wood Products, Shrimps, Natural Gas, Coal, Hydro-energy;
- **Tropical climate** with two seasons:
  - wet season from October to March, and
  - dry season from April to September;
- **Institution responsible for Forest:** National Directorate of Forestry under Ministry Land, Environment and Rural Development.
- **Deforestation rate:** 0.79%/year with 34 Million ha of forest ? (NFI, DINAF 2018);
- **Supported by JICA and technical assistance of JOFCA & KOKUSAI KOGYO CO, LTD** within 5 years project;
- **Supported by JAXA** in **K&C#3 –K&C#4** initiatives.



2013 based forest map (DINAF, 2018)

Objectives

To develop potential improved methodologies for satellite monitoring of tropical dry forest landscape, focusing on deforestation and forest degradation assessment for national forest monitoring system for REDD+ in the country.

The assessment aims the following output:

- ✓Enhance forest national monitoring;
- ✓Up-to-date forest monitoring products;
- ✓Building a relationship for forest monitoring;
- ✓Contribution to existing country projects and programs;



Specific Objectives?

- Identify the land affected by deforestation (xha)
- Identify the land area affected by forest degradation? (x ha)
- Measure the intensity of deforestation and forest degradation? (x %, C/yr)
- Define the nature of deforestation and forest degradation? (**logging, overgrazing, small scale forest clearing for faming for subsistence purposes which include livelihood cash income, tree harvesting for firewood and charcoal, constructions, fire**…)

Proposed operational definition is based on forest definition

Forest definition:

Minimum tree height	:3 m
Minimum tree cover	: >30 %
Minimum area	:1 ha

Forest degradation is a direct human-induced long-term loss (persisting for X years or more) of at least Y% of forest carbon stocks (and forest values) since time T and not qualifying as deforestation or an elected activity under Article 3.4 of the Kyoto Protocol. IPCC (2003a)

Forest degradation : Change in Forest land remaining forest land

⇒ Mask out Non Forest land and measure change in remaining forest land

⇒ Decrease of tree cover but not < 30% in a minimum area of 1 ha

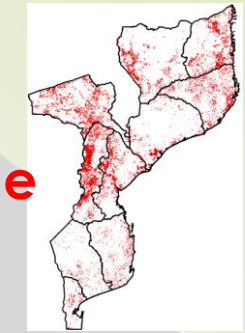
Suitable for small scale forest clearing type of forest degradation

Methodology

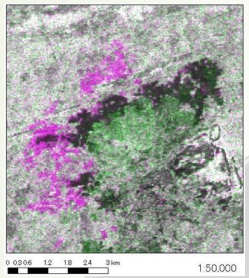
- ✓Boundary mapping and pixel based detection of deforested and forest depredated areas;
- ✓Ground Truth survey in unsurvey area of Plantations and natural forest to support JICA project and national forest monitoring;
- ✓Obtain the samples data that are insufficient for the threshold setting;
- ✓Comparison of different values (-3, -4, -5 dB) between the images before and after 1 year for deforestation including Non-forest area (Thicket) in order to identify the threshold between forest/non-forest;
- ✓Measuring forest degradation based on tree cover loss in a minimum area;
- ✓Ground Truth survey to support LTS International alongside the University of Edinburgh with European Space and WB for utilising Radar and Optical (sentinel 1 and 2 data with developed toll for cloud free) of dense time series for continuous change monitoring and proxies of forest changes, and degradation using ALOS PALSAR mosaic in tropical dry forest;
- ✓Ground Truth survey to support JICA- JAXA, for data calibration of JJ-FAST system (analysed by SAR imagery) with technical support of Tokyo Denky University.

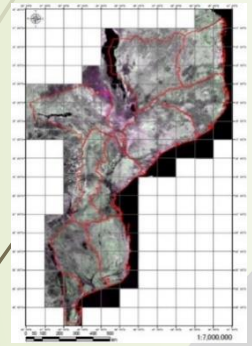
Activities overview of RS of 5 years JICA project

- **Detection of deforestation areas at national level**
- **Evaluation how to make the use of the methodology**



- Ground survey for validation of the deforestation and linear value





2014

- Understanding of IR characteristics
- Detection test of deforestation

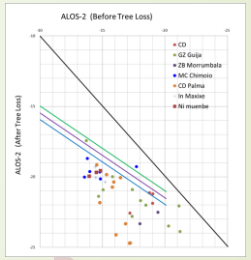
2015

- Visual and Automatic detection of deforestation

2016

- Evaluation of the linear value
- Analysis of precision
- Water body and water strim Masking

2017



2013

- Theory study
- Radar images acquisition

Basic traing on IR

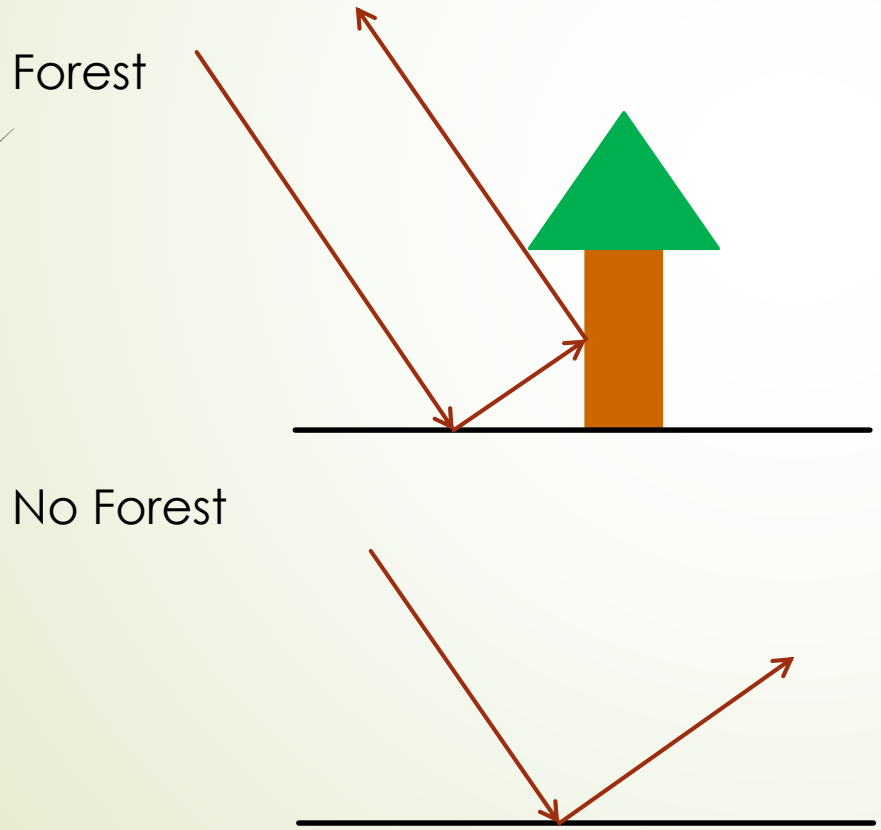
Training on job in Moz. and Jp. on IR

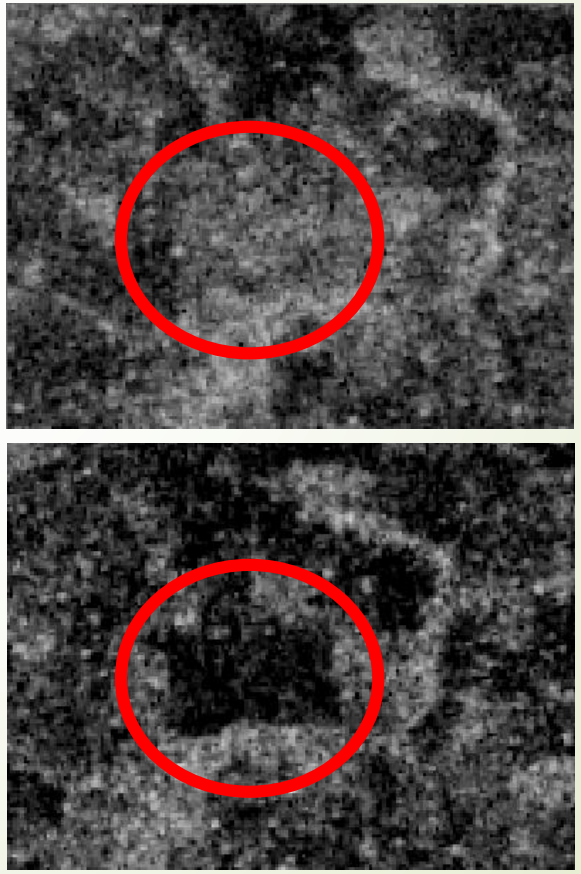
Aplaied Practical training on IR

Traing in Japan in aplaied areas analysis

Principles of dectation of Radar images

Deforestation sites are detected by comparing radar images (ALOS-2) at two time series. The **deforestation** sites are those that indicate **decrease of back-scattering** (return) of radar waves. Therefore, **higher return** (forest) sites with **light color** and **lower return** (non-forest) **dark color**.

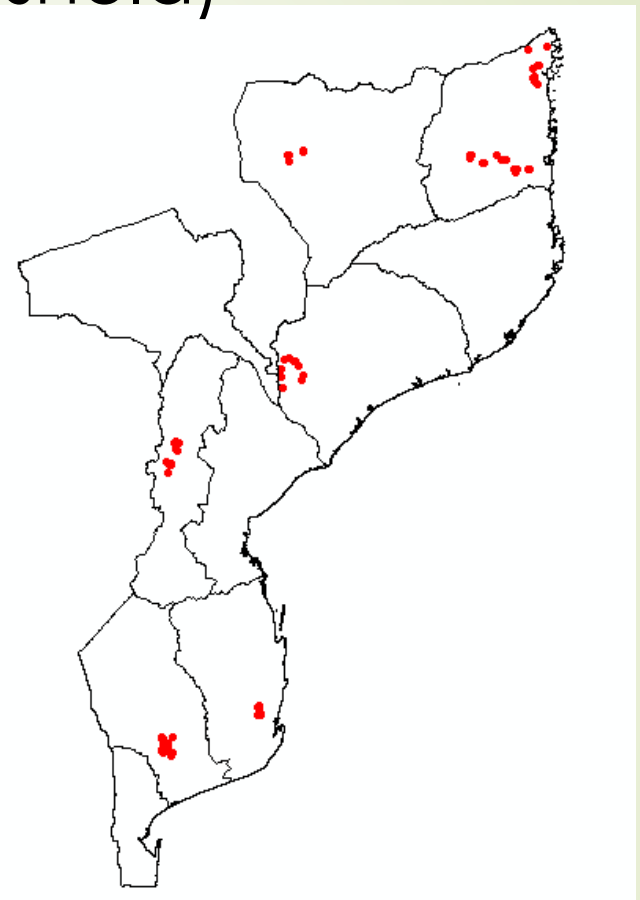


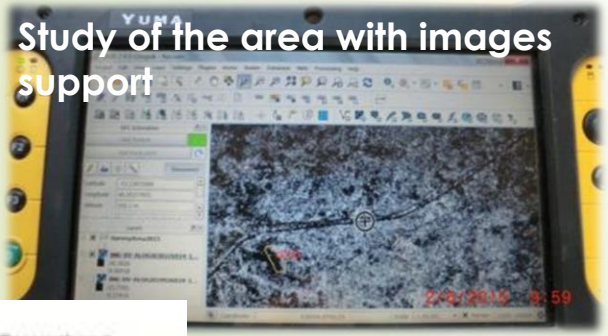


- Spatially explicit biomass estimates (no land cover classes needed)
- Can detect small changes over large areas (low bias)
- No cloud contamination, day/night acquisition

Determination of linear value (threshold)

Sampling in Field (Ground Truth)
The threshold values of temporal differences of the deforested areas were collected in **76 samples** from Cabo Delgado, Niassa, Zambezia, Manica, Inhambane and Gaza.




Study of the area with images support


Deforested area


Interview with local people

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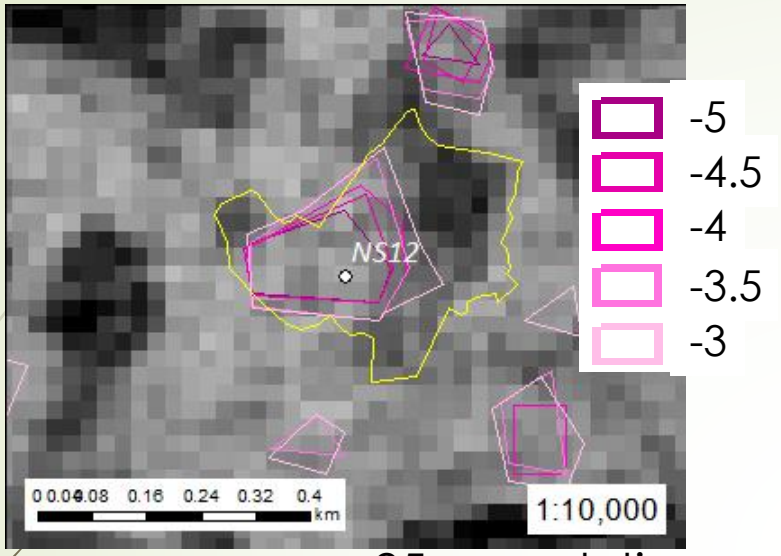
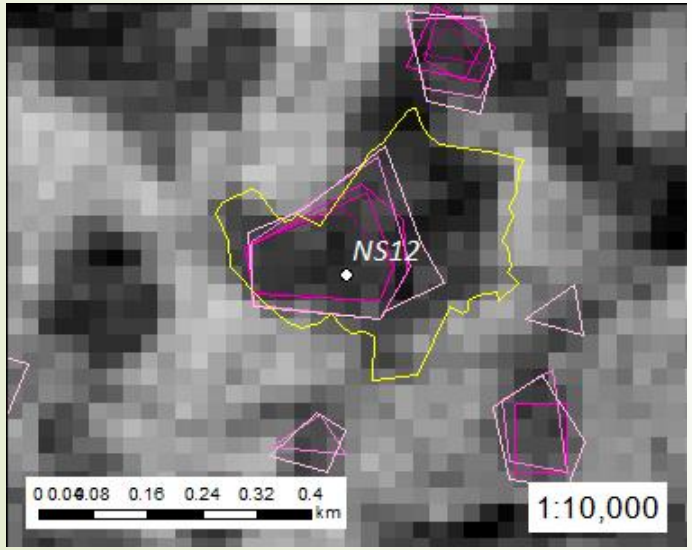
Yellow: GPS track White: GPS point

NS12



08/July/2015 25m resolution



06/July/2016 25m resolution

North

East

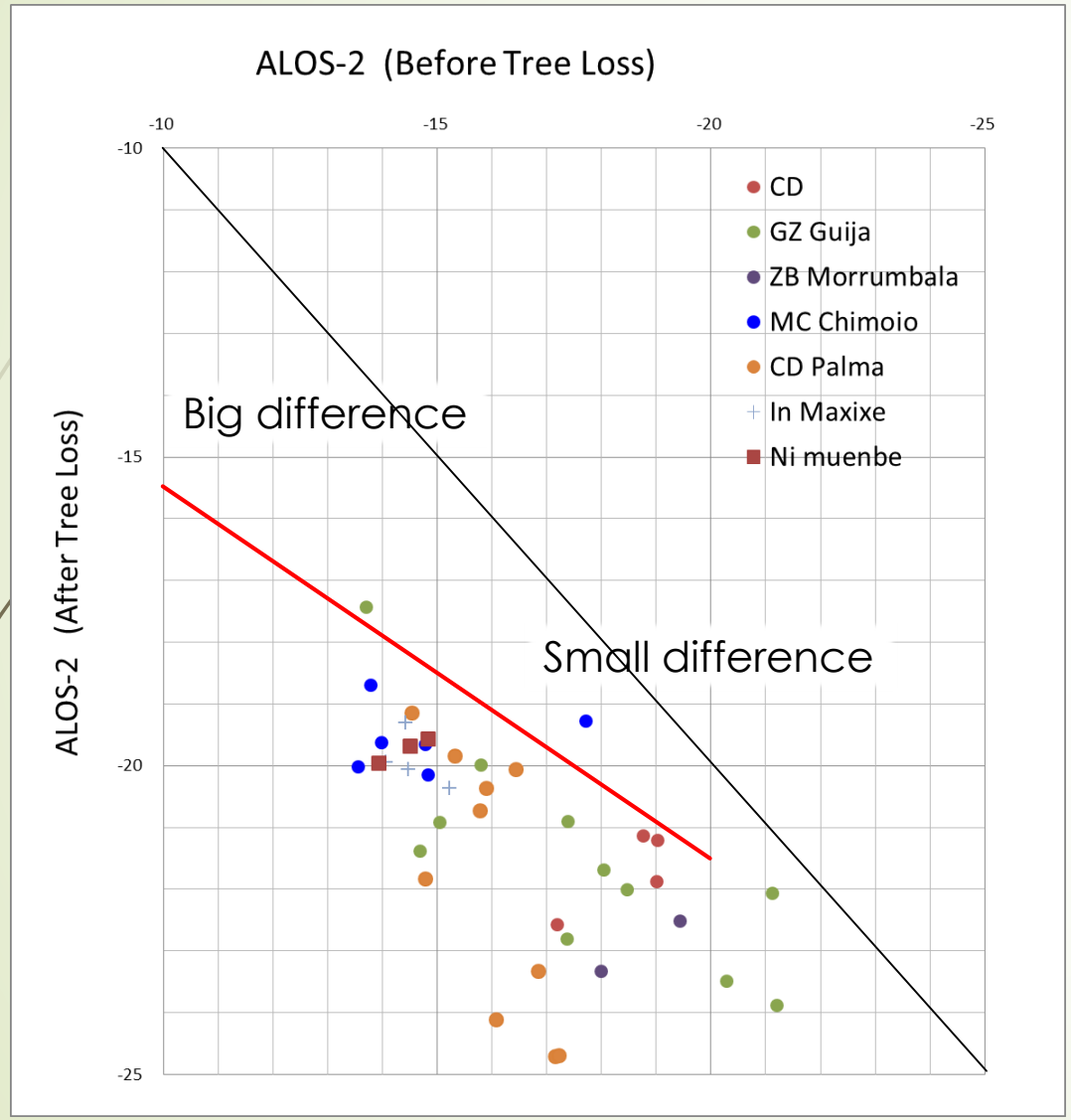
West

South

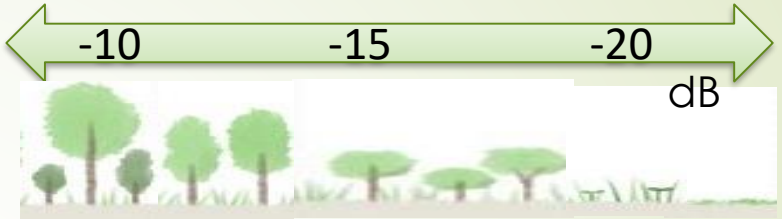
- Deforestation for Maize. Past forest type is Mixed forest.
- Deforestation area is 9.4 ha.
- Big trees are deciduous (h=15m),Lower trees are evergreen (Massuco, h= around 7m) .

Identification of deforested areas by Radar Image Analysis

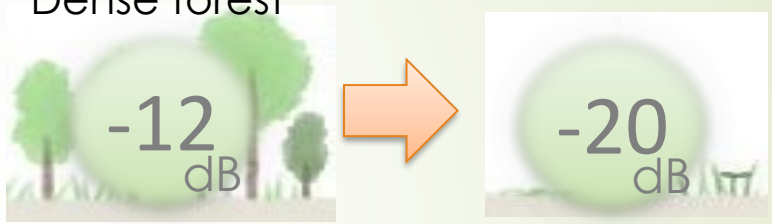
Determination of the linear value to detect the deforested area



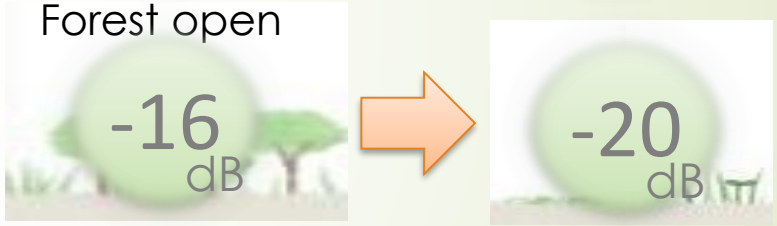
※ Only deforestation data greater than 1.0 ha

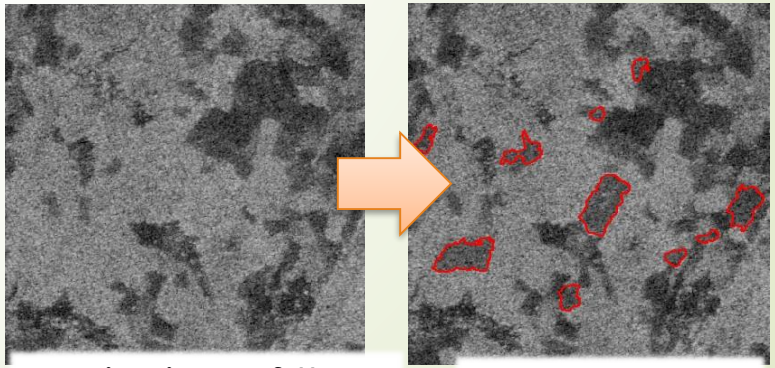


Dense forest



Forest open



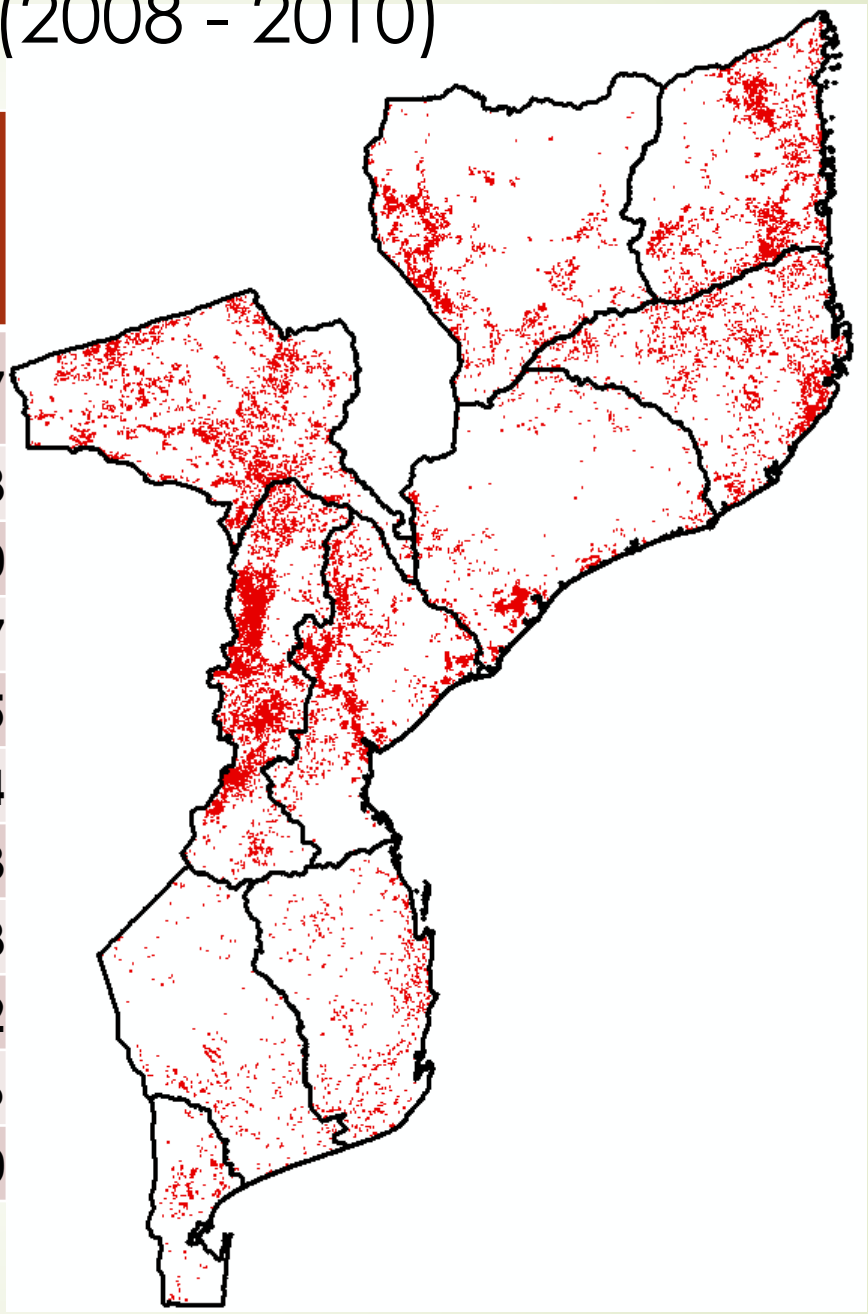


Beginning of the period

End of period

Result of areas of forest loss(2008 - 2010)

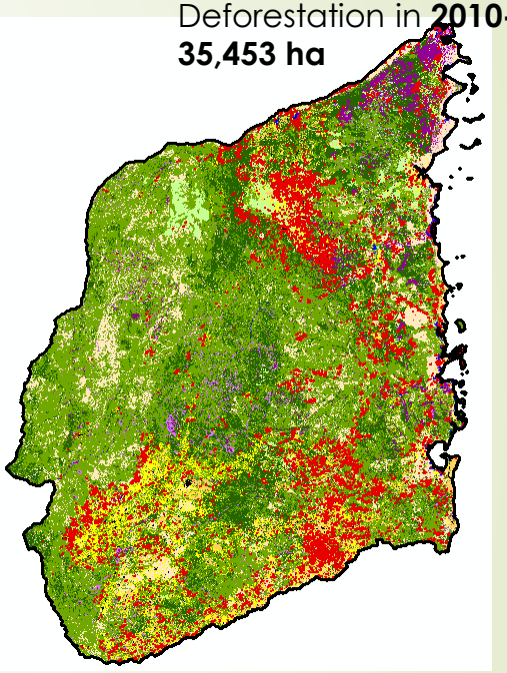
Province	No. of sites indicating forest loss	Deforested area (ha/year)
Cabo Delgado	**12.600**	**19.267**
Niassa	**10.098**	**21.158**
Nampula	**10.571**	**14.250**
Zambézia	**4.425**	**21.037**
Tete	**17.345**	**24.765**
Manica	**22.667**	**37.354**
Sofala	**11.415**	**26.413**
Inhambane	**3.947**	**4.488**
Gaza	**1.748**	**2.852**
Maputo	**1.042**	**3.156**
Total	**95.858**	**174.740**



How to leverage information

Size of deforested area by forest type (CD):
We identified the area deforested by forest type, from C. Delgado, overlapping the image with the 2008 forest coverage map.

Deforested area (ha)	(Semi-) dense ever green	Semi-open ever green	Mangrove	(Semi-) deciduous dense	(Semi-) deciduous Open	Total (ha)
1 ~ 2	**279**	**122**		1.915	3.137	**5.452**
2 ~ 3	**202**	**63**		1.070	1.794	**3.129**
3 ~ 4	**119**	**45**		657	1.171	**1.992**
4 ~ 5	**124**	**48**	4	501	871	**1.548**
5 ~ 6	97	22		388	835	**1.341**
6 ~ 7	91	19		368	486	**964**
7 ~ 8	90	8		304	240	**641**
8 ~ 9	43			288	400	**731**
9 ~ 10	47			180	238	**465**
10 ~	696	73		2.204	3.348	**6.321**
Total	**1.787**	**399**	**4**	**7.875**	**12.519**	**22.585**
% of forest cover	**0,81%**	**0,26%**	**0,01%**	**0,49%**	**0,34%**	**0,39%**



Map of forest cover and land use 2008

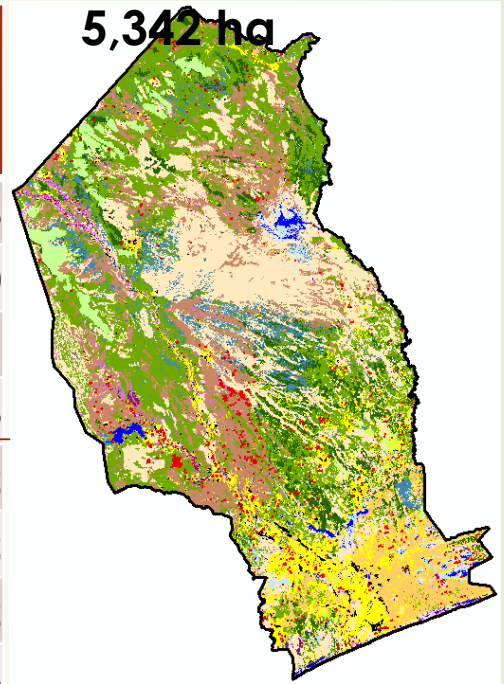
※2 years during 2008 - 2010

How to leverage information

Size of deforested area by forest type (GZ):
We identified the deforested area by forest type, from Gaza, overlapping the image with the forest cover map of 2008.

Deforested area (ha)	(Semi-) dense green	(Semi-) dense ever green	Mecrusse	(Semi-) dense deciduous	(Semi-) open deciduous	Mopane	Total (ha)
1 ~ 2	**31**	**52**	16	133	370	314	**918**
2 ~ 3	**45**	**36**	13	56	149	162	**460**
3 ~ 4	**17**	**45**	10	51	123	143	**389**
4 ~ 5	**14**	**23**		18	50	93	**198**
5 ~ 6	22	16		6	33	65	**142**
6 ~ 7	19	7		6	13	58	**102**
7 ~ 8	15	7		8	30	52	**112**
8 ~ 9	8	25		9	9	42	**93**
9 ~ 10					38	57	**95**
10 ~	51	13		125	203	869	**1.261**
Total	**222**	**223**	**39**	**413**	**1.017**	**1.855**	**3.770**
% of forest cover	**0,58%**	**0,21%**	**0,01%**	**0,09%**	**0,05%**	**0,17%**	**0,09%**

Deforestation in **2010-2013**:
5,342 ha

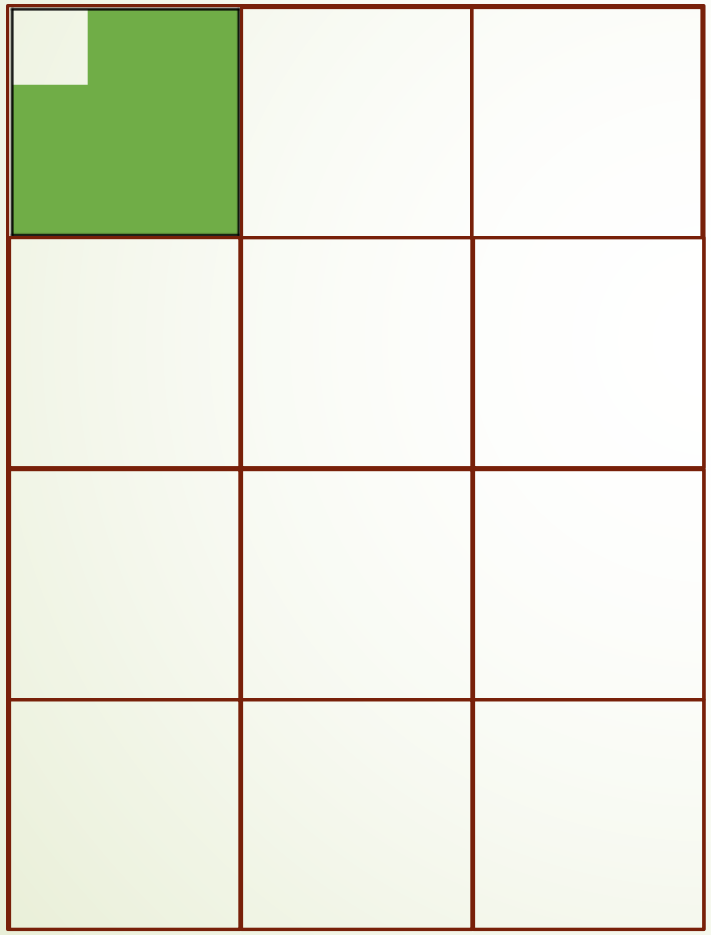


Map of forest cover and land use 2008

※ 2 years during 2008 - 2010

Measuring forest degradation based on tree cover loss in a minimum area(approach from JRC-ISPRA)

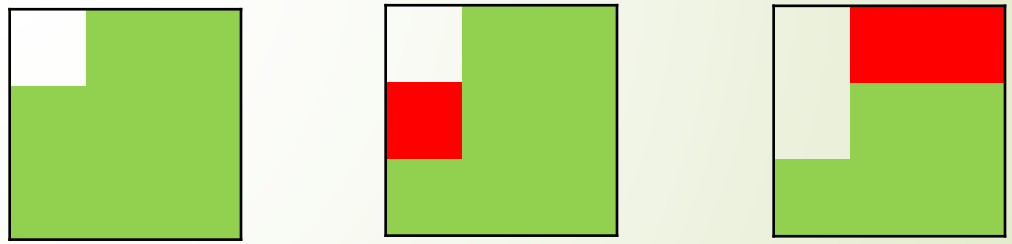
Forest area (T1)



If grid size = Minimum area for forest definition

Forest degradation could be measured by the % of change (tree cover to non-tree cover) inside a cell

If the % of non-tree cover is > 70 % = deforestation
If the % of non-tree cover is < 70 % and there is a change from tree cover to non-tree cover = forest degradation



T1 NTC=10%

T2 NTC=20%

T3 NTC=40%

Forest degradation=
Decrease of TC [T1- T2] 10%, [T2-T3] 20%

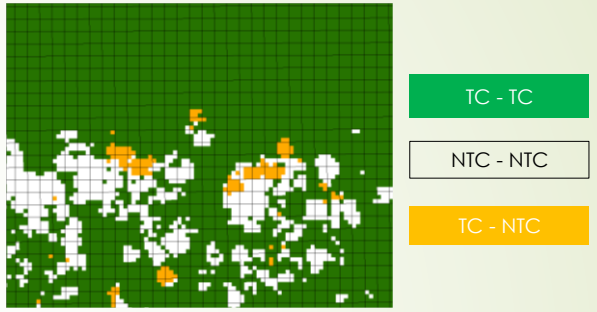
Application of IMPACT toolbox and GUIDOtoolbox developed by JRC-ISPRA

Definition of forest degradation based on forest definition
Forest = Tree cover > 30 % Minimum area of 1ha

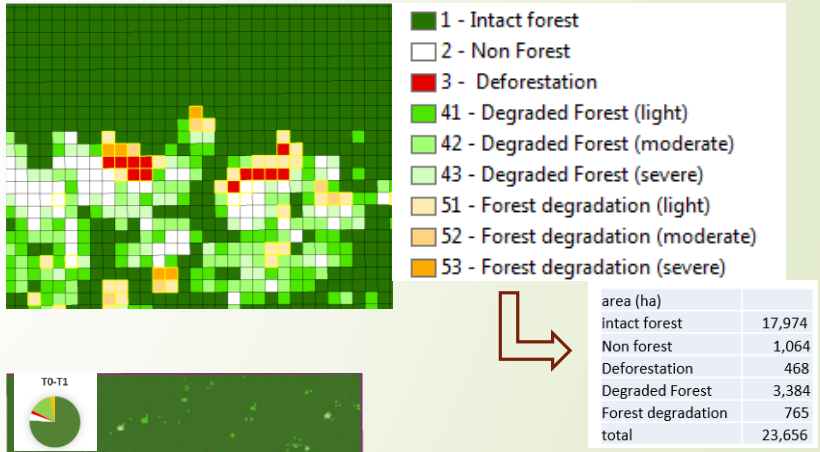
Step 1:
Landsat map (2 dates T1 – T2): Tree cover – Non Tree Cover
Grid of 3*3 pixels (0.81 ha)
Counting of pixels in each cell:
X_{TC-TC} =number of pixels that stayed TC
$X_{NTC-NTC}$ = number of pixels that stayed NTC
X_{TC-NTC} = number of pixels that changed from TC to NTC

Step 2:
Classification of each cell based on X_{TC-TC} $X_{NTC-NTC}$ X_{TC-NTC}
Intact Forest (X_{TC-TC} = 9)
Non Forest (X_{TC-TC} < 3 AND X_{TC-NTC} = 0)
Deforestation (X_{TC-TC} < 3 AND $X_{NTC-NTC}$ < 7)
Degraded forest (X_{TC-TC} > 2 AND X_{TC-NTC} = 0)
light ($X_{NTC-NTC}$ = 1 or 2) **moderate** (3 or 4) **severe** (5 or 6)
Forest degradation (X_{TC-TC} > 2)
light (X_{TC-NTC} = 1 or 2) **moderate** (3 or 4) **severe** (5 or 6)
Measurement of area affected by deforestation, forest degradation (light, moderate or severe) (+ non forest and degraded forest)

Step 3:
Track over time: add a second time period T2-T3 over the same grid (record of state for each cell)



Basics of IMPACT



area (ha)	
intact forest	17,974
Non forest	1,064
Deforestation	468
Degraded Forest	3,384
Forest degradation	765
total	23,656

		1	2	3	4	5	
intact forest	1	20830		406		954	22190
Non forest	2		1314				1314
Deforestation	3		578				578
Degraded Forest	4			253	3443	482	4178
Forest degradation	5			296	389	260	945
		20830	1892	955	3832	1696	29205

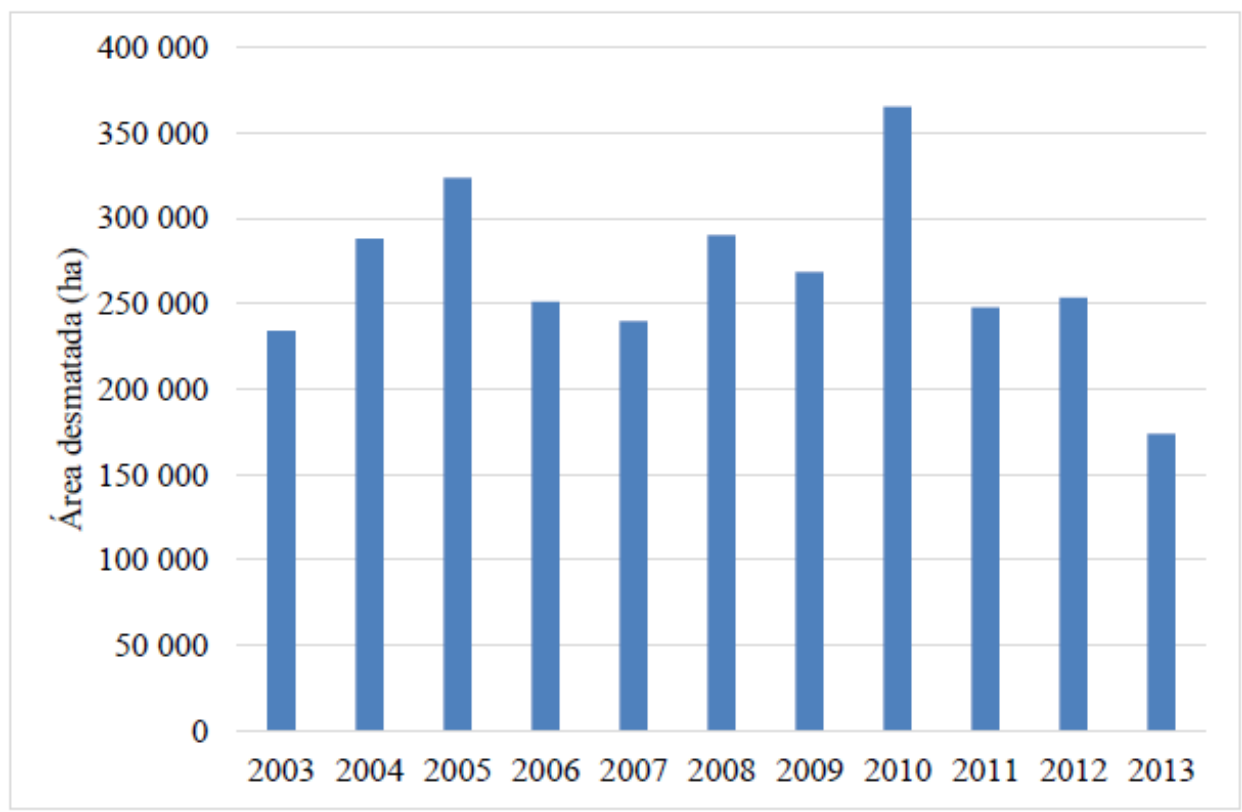
For this method we have not done the ground truth to checked the accuracy in our tropical dry forest (desk results)

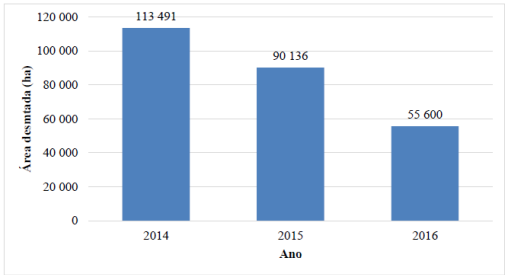
Recent Ground truth for JJ-Fast Calibration data in dry forest with Japan TDU and DINAF

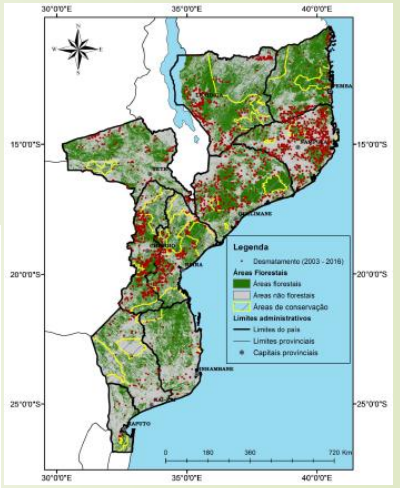
Collect Earth method

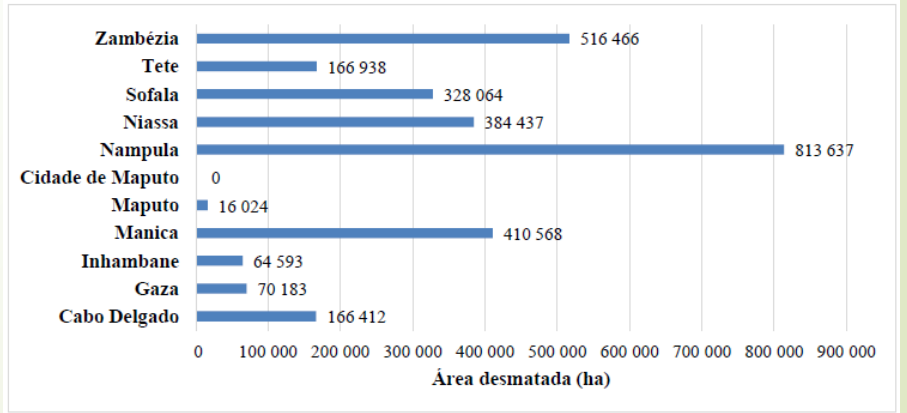
The data collection using this method was based in sampling visual interpretation of activity data using high, medium and low resolution satellite data from the repository of **Google Earth, Bing maps, Earth Engine Explorer and Code Editor.** Used a grid sampling method of 48 894 samples covering the whole country to estimate deforestation (FAO method).

The evaluated period was from 2003 to 2016, executed by FNDS with Support of World Bank.









This method shows that the country lose 267 209 ha/year with the tax rate of 0,79% deforestation

Note: No ground truths was done on this method

Challenges?

Long-term effects **How to differentiate between long-term decline or persistent decline and temporal variability due to normal/good management or annual variability?** How to differentiate between forest **degradation and sustainable management** of forest (cfr Forest code of practice? National/at logging company?)

Exclusion of deforestation **How to be sure that forest degradation will not be reclassify as deforestation in the future** (precursor to deforestation)? (long-term reduction of carbon stocks but tree cover, height and area are not under the threshold defined for forest land). **How to define when the threshold for forest has been crossed**?

Loss of forest carbon stock in forest land remaining forest land. The change should lead to a change in carbon stocks. Emissions due to forest degradation will depend on carbon stock available for release and degree/nature of the process (idem for removals);

Has to be operational, has quantifiable and measurable/detectable thresholds within a defined time frame, be part of **the GHG inventory** (must **be human-induced**, describe **change in carbon stocks** at least), can be applied consistently in the same biome, must be possible to quantify/verify the change;

Key challenges to **implement and provision technologies and data sources of forest inventories using unmanned aerial vehicles (UAVs) or drone platforms to acquire both LiDAR and Very High Spatial Resolution (VHSR) imagery** with high operational capacity to capture detailed data with less **cost of hardware infrastructure, advanced techniques of large extracted amount of data and store**.

Definition of the most **precise**, **accurate method** considering the **consistency** with the **reliable results** for data comparison in the county when **forest management is being carried out. Full knowledge of the current ground field is deed to support Remote Sensing** ;

Radar Signal **saturates in dense tropical forests**, **Limited availability of long-wavelength** radar data and **Data cost**;

Conclusions

1. Use of ALOS data provided by **wall to wall** forest cover map resulted in **forest base map (2013)** of the country to estimation changes of the forest cover is a good methodology to detect a time series of **deforestation, forest remaining forest and gains.**
2. **Deforested areas and forest degradation** can be identified by RADAR image analysis and ScanSAR can be produced for any weather and sunlight independent, Penetrates through canopy, Signal 'scattered' from trunks and branches, Interacts with woody biomass,
3. Measuring forest degradation based on **tree cover loss in a minimum area methods require ground truth survey at large scale and biomass assessment and carbon estimation to confront the challenges aforementioned** in the our dry tropical forest due to the **existence of certain species with wide canopy cover** (e.g Brachystegia sp) in order to be avoid bias;
4. The used of **Collect Earth Tool** to get reliable results **needs experienced technical staff** with full **knowledge of the ground** to get **accurate results with statistical sample approach** to have a minimum acceptable error and the **factor of expansion needs to be more elaborated** and clear based in ecological area rather than administrative boundaries;
5. Scanning **deforested areas using drone** for small assessment and carbon of inaccessible areas is much **efficient and less costly** compared to large satellite data of low resolution;

Thank you !!

Arigato !

Joaquim Macuácua
joaquimmacuacua@gmail.com

Obrigado !

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