K&C Phase 4 – Status report

National Forest Monitoring System For REDD+ in Mozambique
(Ground Based Forest Monitoring Radar analysis)

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Ministry of Land, Environment and Rural Development

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Technical assistance
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Project outline and objectives

The project is intended to contribute to Establishment of a REDD+ system in Mozambique **(i)** developing a forest resource information platform, **(ii)** developing an infrastructure for measurement, reporting, and verification (MRV) using that platform, **(iii)** forming Reference Emissions Levels or Reference Levels (FREL/FRL) for deforestation and forest degradation, and **(iv)** development data sets for estimation of forest biomass and carbon volumes. Also implementing regular and appropriate monitoring of forest resources after completion of the project.

Anticipation of useful of PALSAR-2 data.

- ✓ To do the Ground Truth survey in unsurvey area;
  - →There are deforestation area due to many activities;
- ✓ To obtain the samples data that are insufficient for the threshold setting;
- ✓ To compare the difference value -3, -4, -5 between the images before and after 1 year;
- ✓ To record the Non-forest area (Thicket) in order to identify the threshold between forest/non-forest;

Back ground of GBFM-radar analysis

Upper Goal	Deforestation area is detected by the radar analysis in about one year interval and the detection is utilized for deforestation countermeasures.
Purpose	Ground Truth(GT) survey for acquiring the training data for the radar satellite analysis as the GBFM.
Activities	i. Radar image analysis for finding deforestation area; ii. Blackish areas considered as no forest stock are divided into several patterns; iii. GBFM(Ground Truth) for each pattern; iv. Improve the accuracy of the radar image analysis thereafter, using the GBFM data;

Survey done in
- Cabo Delgado
- Gaza
- Manica
- Zambesia

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Additional study for threshold setting

- Threshold for Forest/Non-forest(F/NF)

  Threshold of before must consider the border line between F/NF

- Accuracy assessment

  The detected are by RED,GREEN and BLUE will be assessed

- Wide area(Province) analysis

  Validate each threshold line in the province level in reference to Hansen data

- Capture analysis

  Make the capture for each threshold line and compare it.

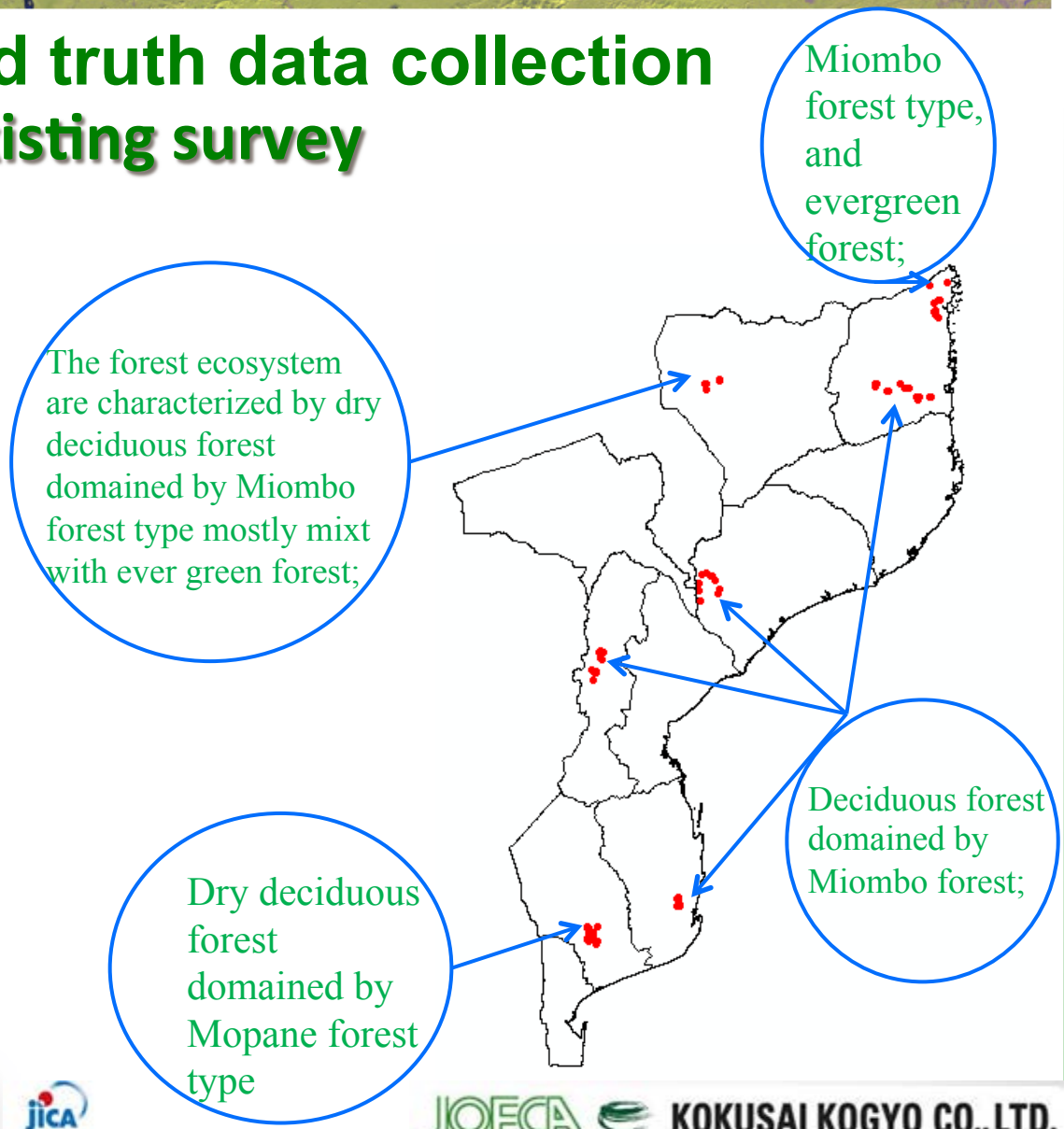
- Mask in water area

  Misdetections are confirmed in water area(e.g. swamp)

Project area(s) of Ground truth data collection
Review from existing survey

- **As a reference data, field record(GPS) was used for identifying ideal threshold value in order to detect "Tree Loss" area by using ALOS2 PALSAR 2.**

- Field survey was conducted in 76 plots in Cabo Delgado, Gaza, Manica, Zambezia, Inhambane and Niassa



Basic condition for the analysis

- Satellite image

  ALOS2 PALASAR2 (25m resolution) ←Free!!

- Necessary number of reference data

  Set following conditions:

  Error rate 15%, Confidence level 95%,

  Population rate 50% (when the population rate is unknown)

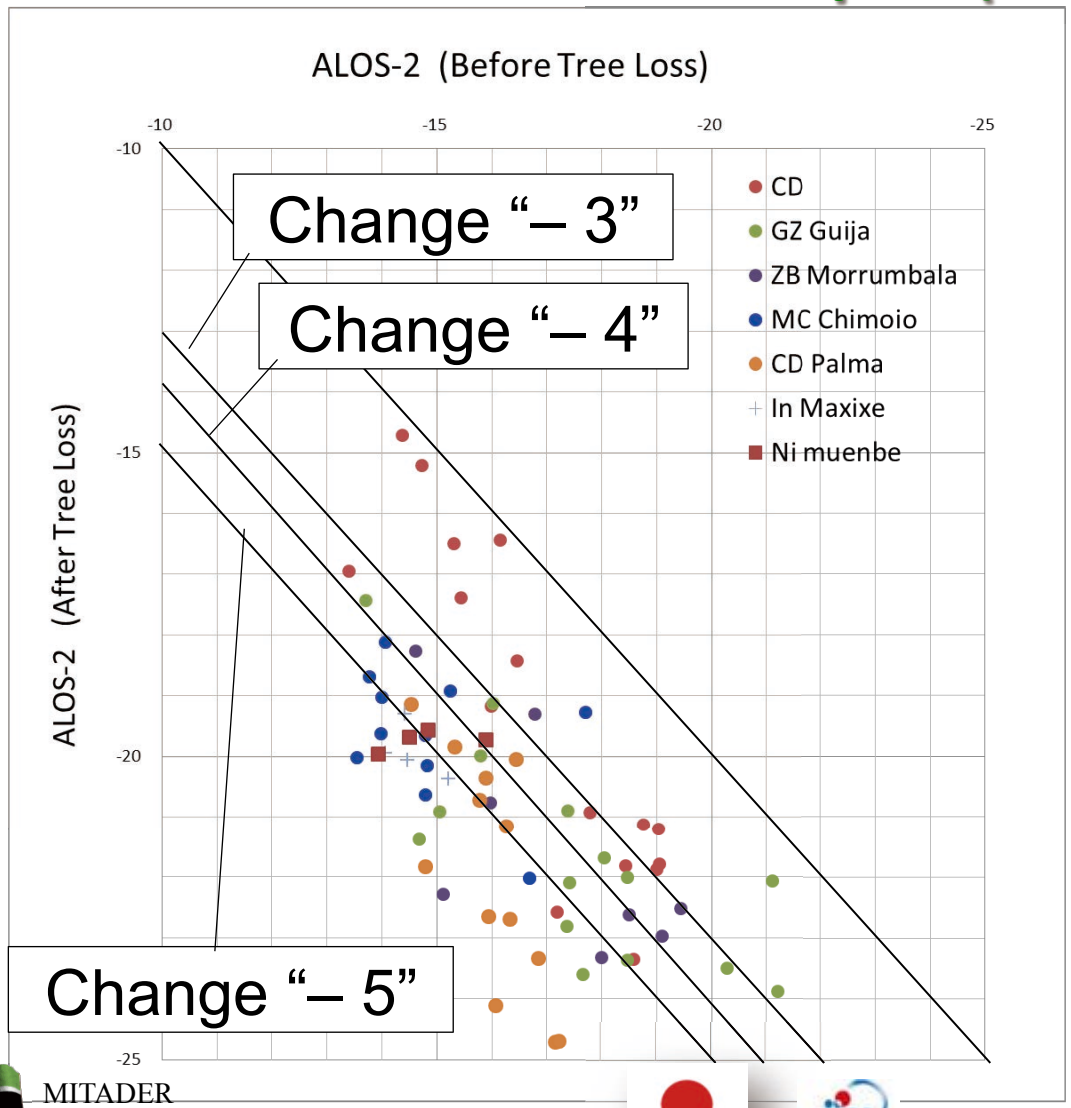
  → Minimum number of data:43

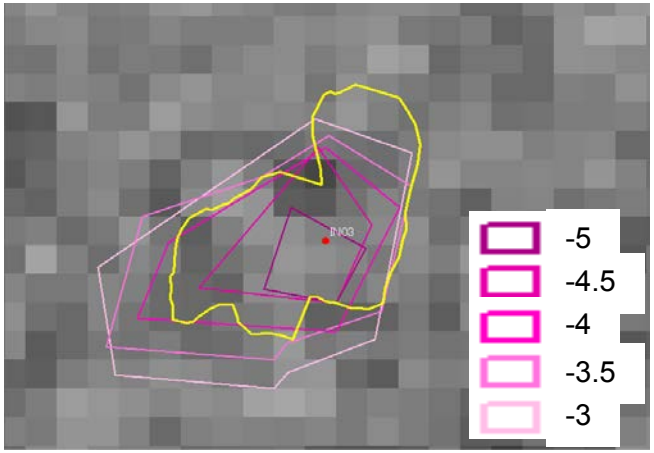
- Minimum area of reference data

  Since the error of the backscattering coefficient is large, if the number of pixels(area) is small, standard deviation in the extracted range becomes high.

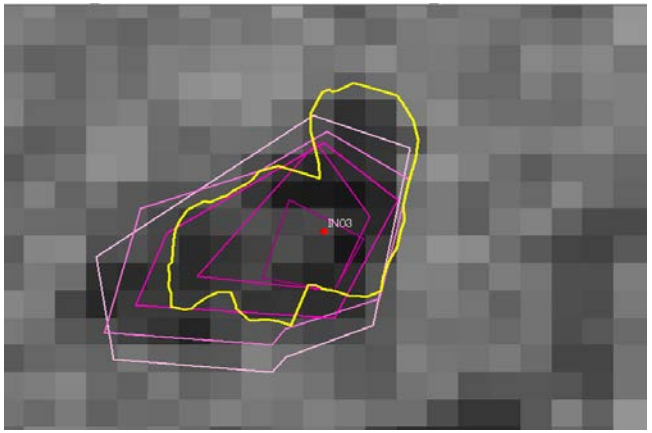
  →At least 3 × 3 pixels (75 m × 75 m = 0.56 ha) are necessary for threshold examination. Thus minimum area is set 1.0 ha (16 pixels)

Scatter plot (All data)





06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

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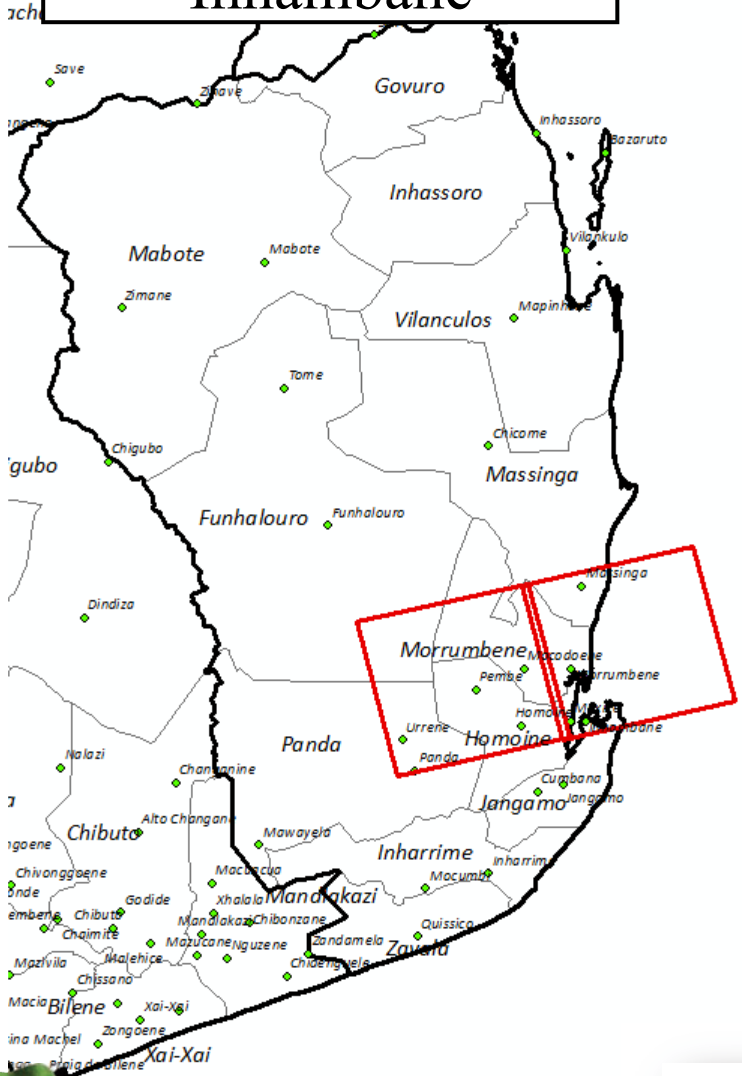
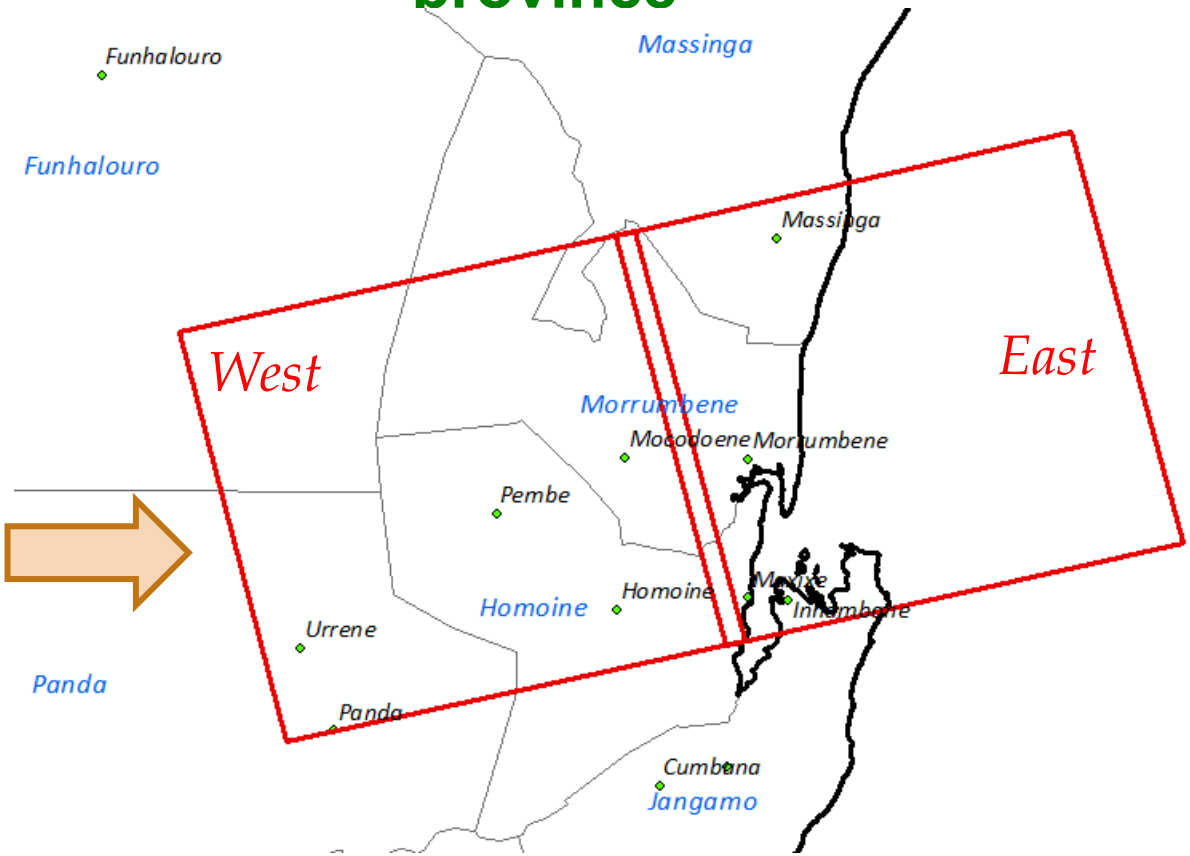
Inhambane

Survey Location in Inhambane province





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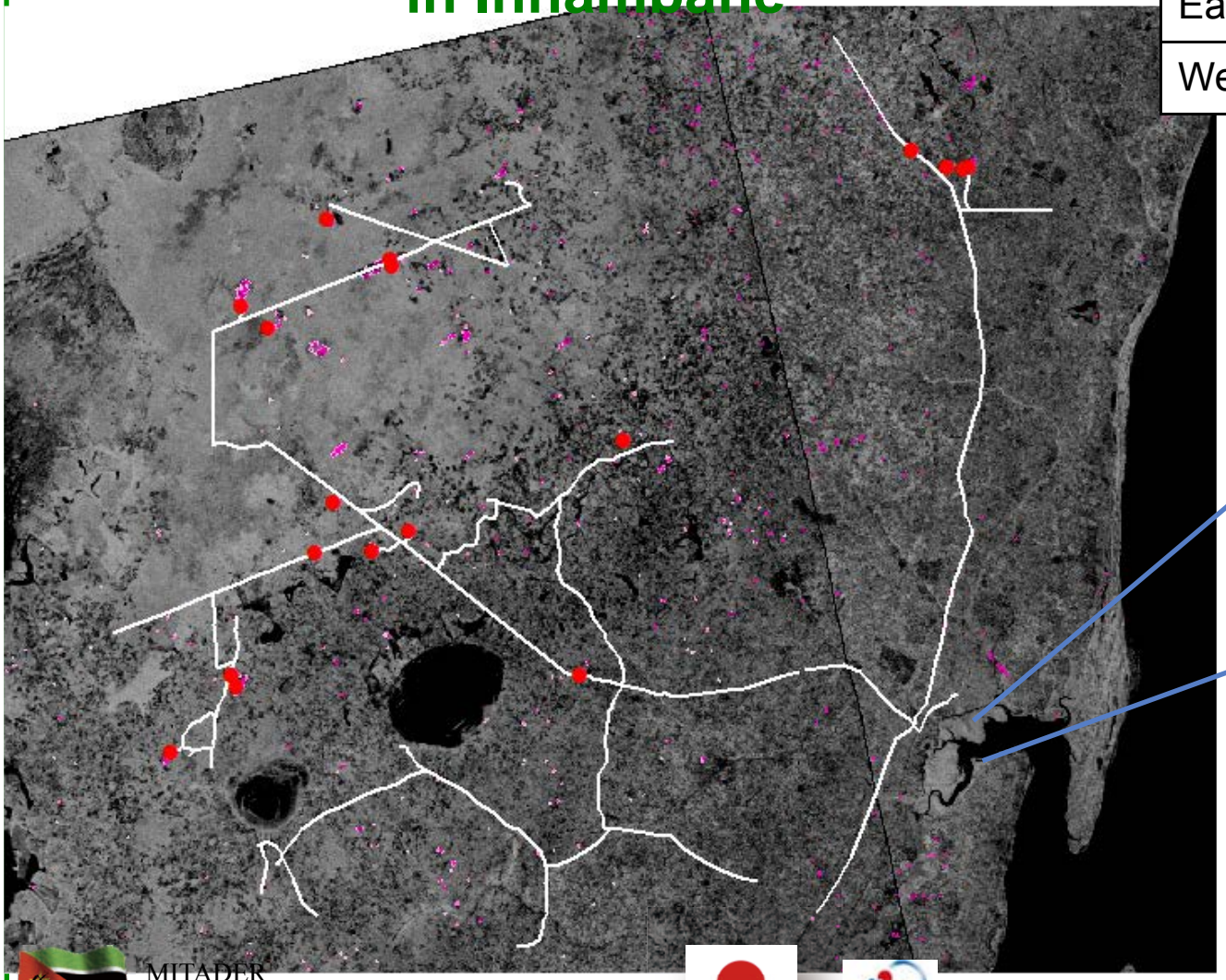
Overview of ALOS-2 Image survey point in Inhambane

	Before	After
East	01/Aug/2015	30/July/2016
West	06/Dec/2014	05/Dec/2015



Survey point

Morrumbene

Inhambane

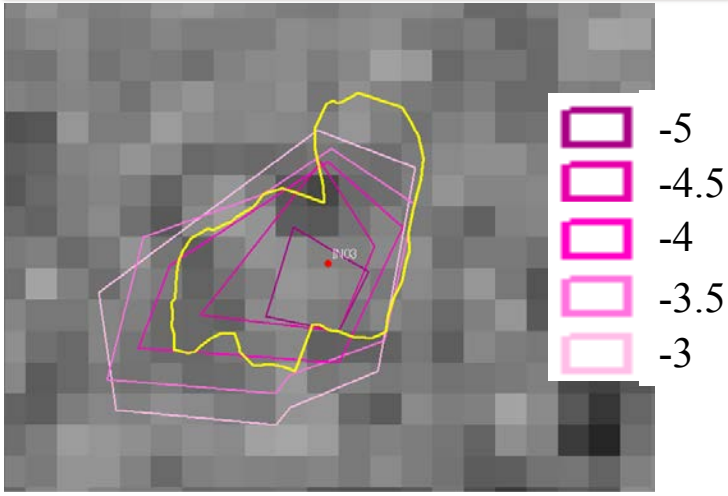
Survey result in Inhambane province

No.	PoinyNo.	F/NF	Current Crown Cover	Deforestation or not	Cause of deforestation	Timing of deforestation	Type	Height	Density	Others
1	INH03	NF	15%	Deforestation	Slush & burned cultivation	Not sure, at least 2015	Deciduous	10 m	Medium	None, burned, selective
2	INH13	NF	10%	Deforestation	Slush & burned cultivation	2015	Deciduous	10 m	Dense	Selective
3	INH14	NF	5%	Deforestation	Slush & burned cultivation	2015	Miombo	15 m	Dense	Selective
4	INH 09	NF	10%	Deforestation	Forest fire	None	Miombo	10 m	Medium	Burned
5	INH04	NF	0%	Deforestation	Slush & burned cultivation/ Charcoal production	2015	Miombo	15 m	Medium	Clear-cut
6	INH05	F	40%	Not Deforestation		None	Miombo	15 m	Open	Burned
7	INH06	NF	0%	Deforestation	Slush and burned cultivation	2015	Deciduous	15 m	Dense	Clear-cut
8	INH08	NF	10%	Deforestation	Slush and burned cultivation	Aug to Sep 2015	Deciduous	20 m	Dense	Burned/Clear-cut
9	INH15	NF	0%	Deforestation	Construction (Electric cable)	None	Tree crop	15 m	Medium	Clear-cut
10	INH17	NF	30%	Not Deforestation	Forest fire	2015	Tree crop	15 m	Open	Burned
11	INH18	F		Not Deforestation		None	Tree crop	10 m	Open	None, burned.
12	GZ02	NF		Deforestation	Construction	None	Deciduous	10 m	Medium	

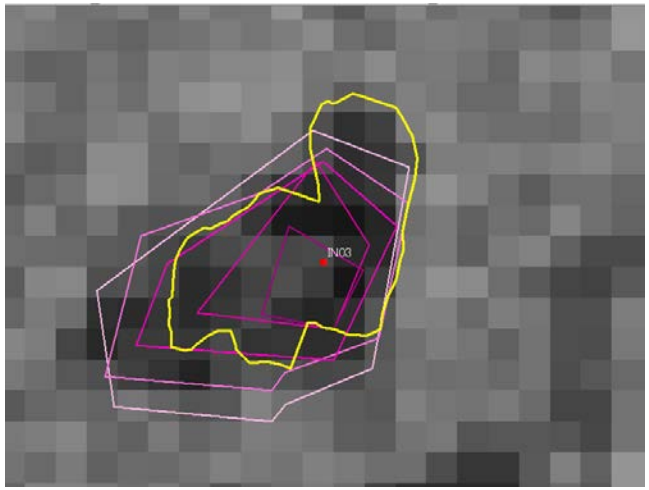
- Conducted survey in 12 areas
- 9 Deforestation area (6S&B, 1Charcoal, 2Construction, constraction)

Yellow: GPS track Red: GPS point

IN03



06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

North

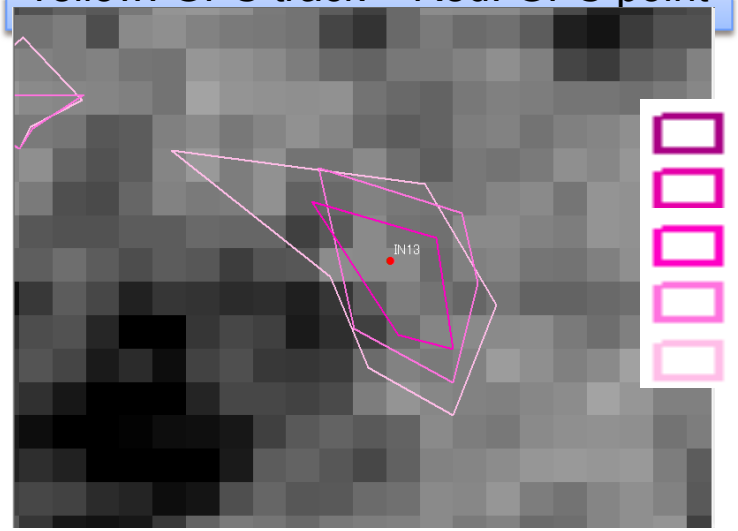
East

West

South

- Deforestation(D)
- Cause of D is S&B
- Area is 2.6 ha
- There are some remaining tree
- Soil moisture is very low

Yellow: GPS track Red: GPS point



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-4.5
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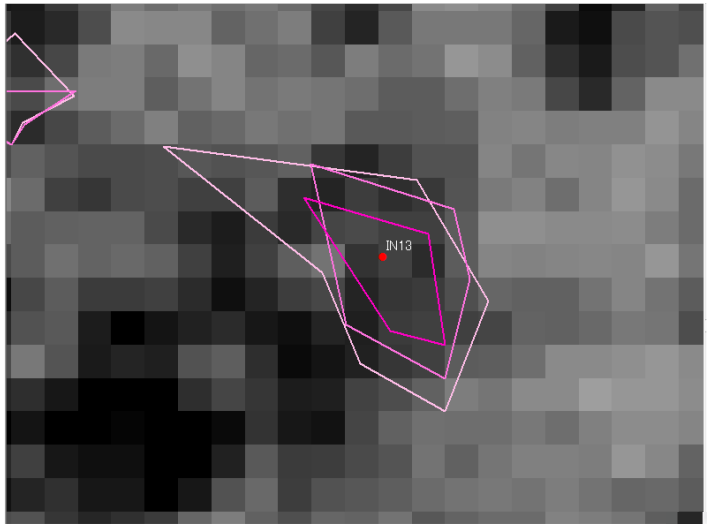
06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

IN13

North

East

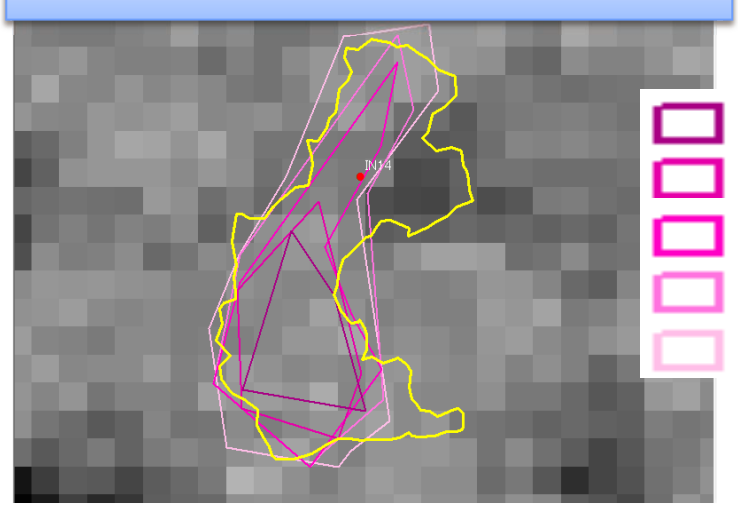
West

South

- Deforestation(D)
- Cause of D is S&B
- No track data due to unclear border
- Remaining tree is less than “IN03”

Yellow: GPS track Red: GPS point

IN14



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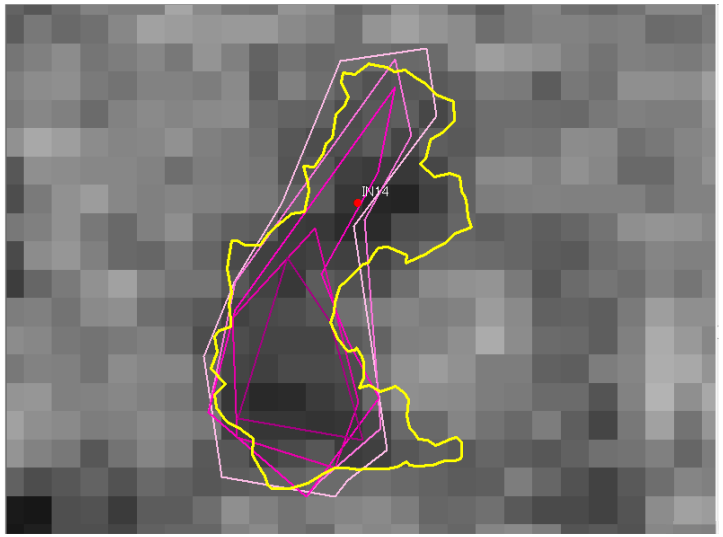
06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

North

East

West

South

- Deforestation(D)
- Cause of D is S&B
- Area is 4.5 ha
- Area is still expanding

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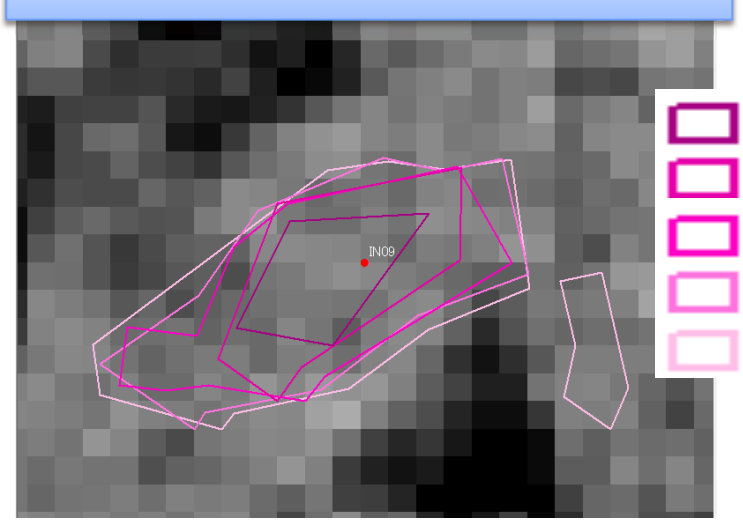
IN09

Yellow: GPS track Red: GPS point



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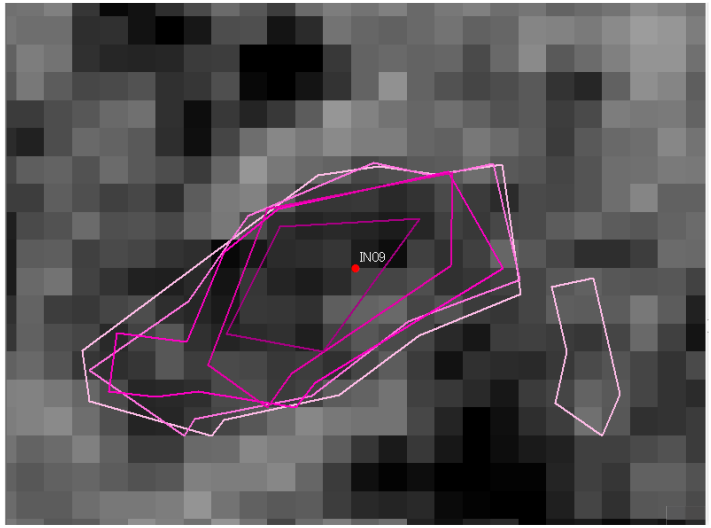
06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

North

East

West

South

- Deforestation(D)
- Cause of D is Forest fire
- No track data due to unclear border
- Soil is very dry
- Regression is started

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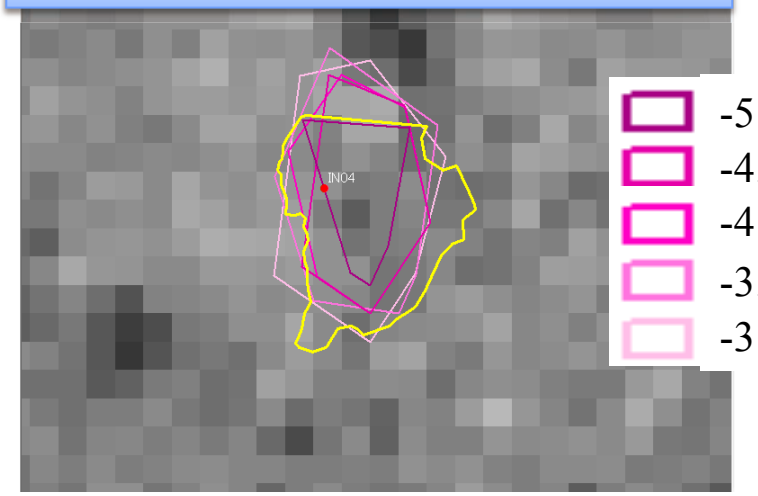
Yellow: GPS track Red: GPS point

IN04



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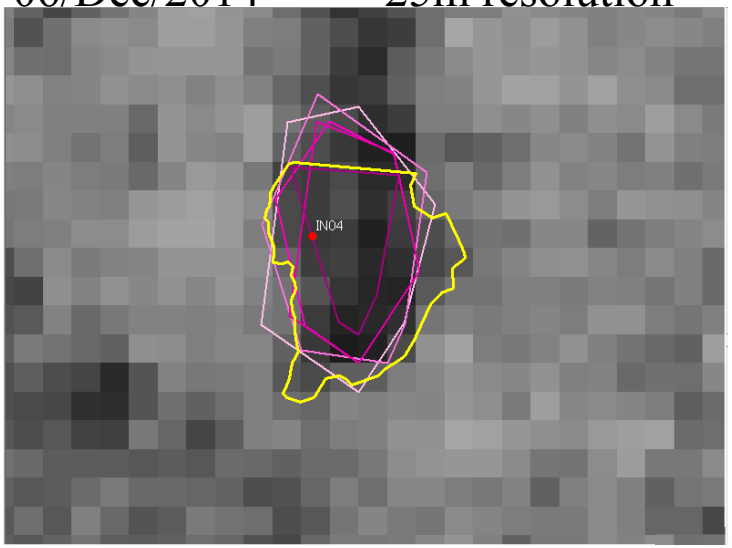

05/Dec/2015 25m resolution

North

East

West

South

- Deforestation(D)
- Cause of D is S & B
- Area is 2.4ha

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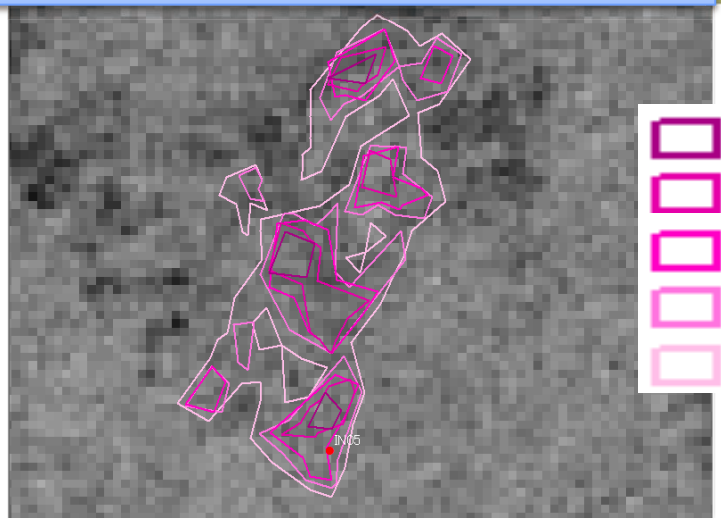
IN05

Yellow: GPS track Red: GPS point



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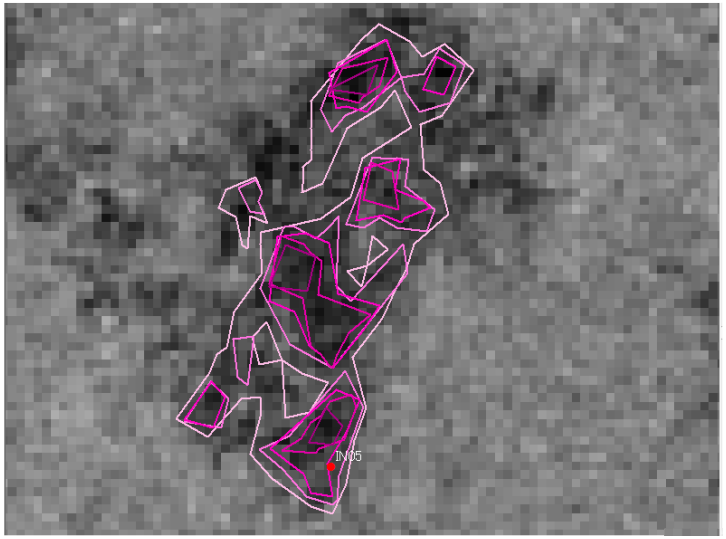
06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

North

East

West

South

- Not Deforestation(D)
- No human signal
- It has a forest fire
- Lots of branch was fallen down
- Some standing tree are dead

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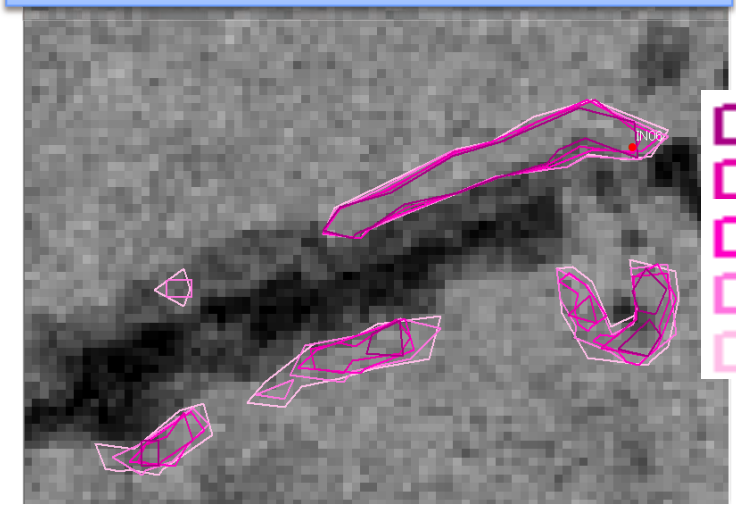
Yellow: GPS track Red: GPS point

IN06



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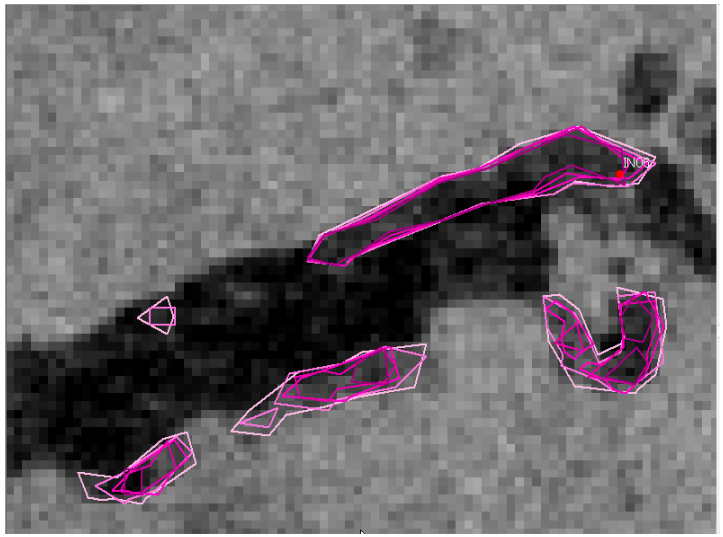
06/Dec/2014 25m resolution



05/Dec/2015 25m resolution

North

East

West

South

- Deforestation(D)
- Cause of D is S & B
- Company manage this area
- Chainsaw was used for tree cutting

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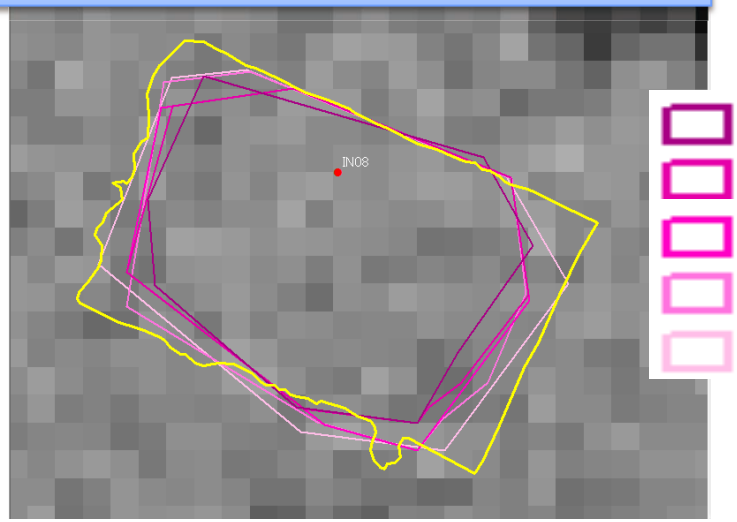
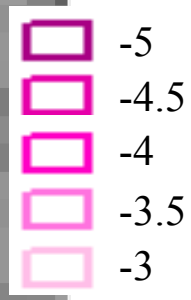
Yellow: GPS track Red: GPS point





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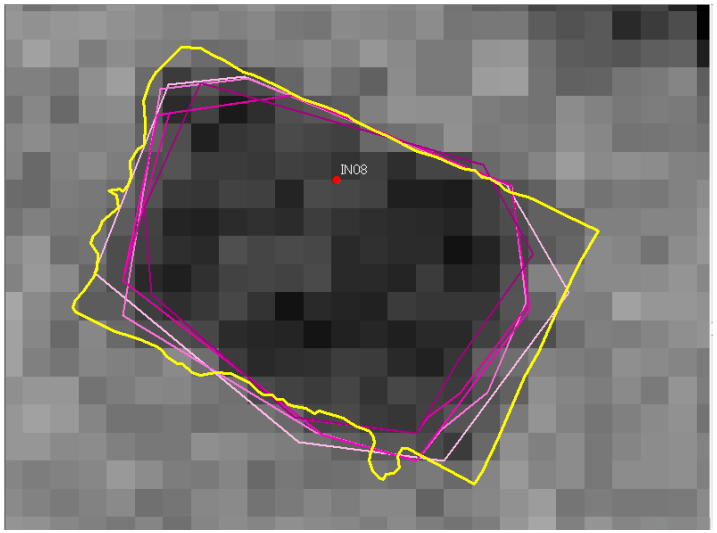

05/Dec/2015 25m resolution

North

East

West

South

- Deforestation(D)
- Cause of D is S & B
- Area is 10.2ha
- Manual - Katana was used for tree cutting

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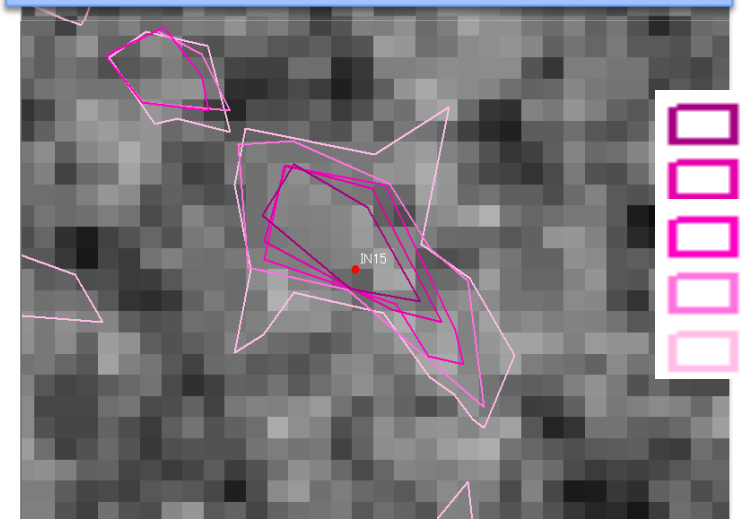
Yellow: GPS track Red: GPS point

IN15



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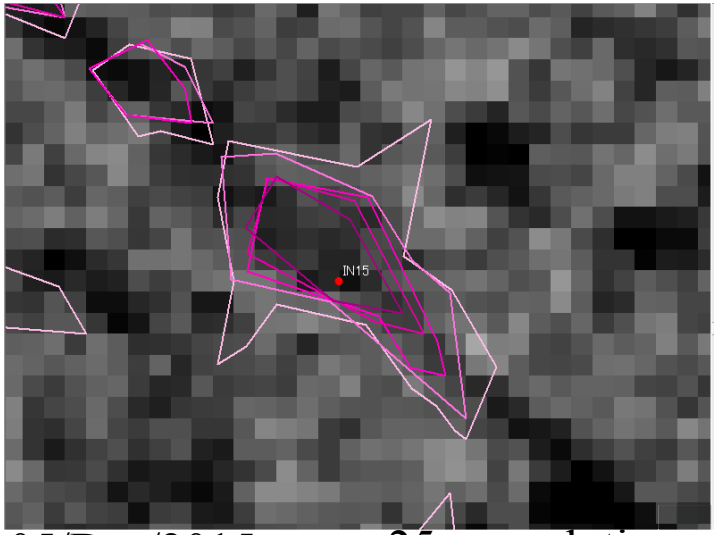

05/Dec/2015 25m resolution

North

East

West

No photo

South

- Deforestation(D)
- Cause of D is development of electrical power line
- This area included big trees removal

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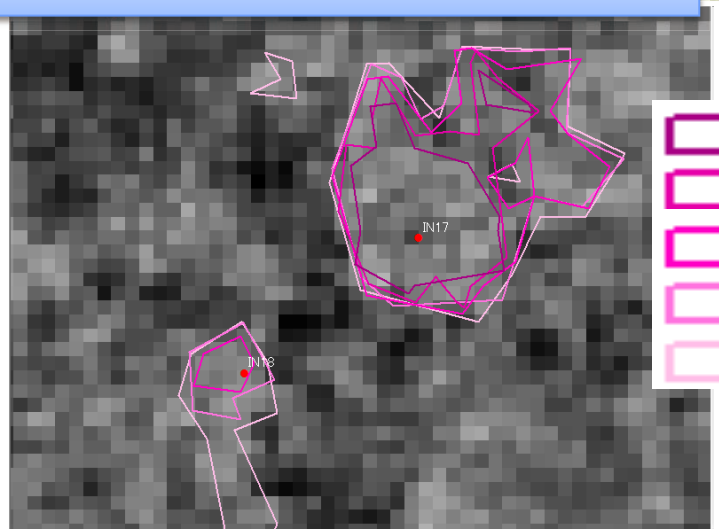
Yellow: GPS track Red: GPS point

IN17&18



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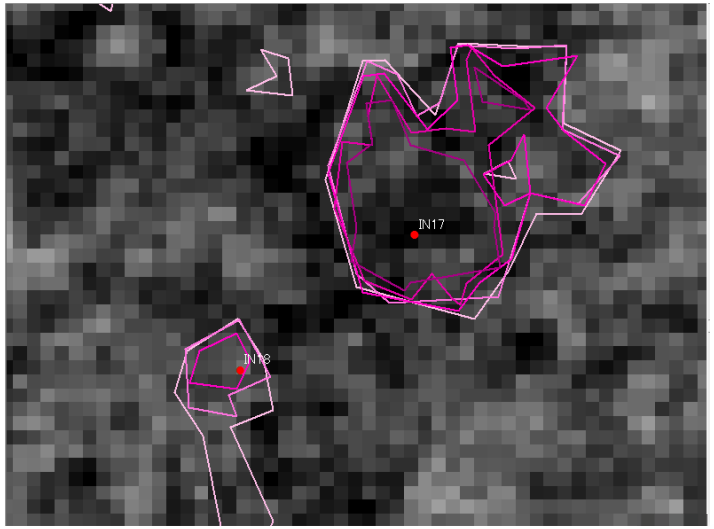

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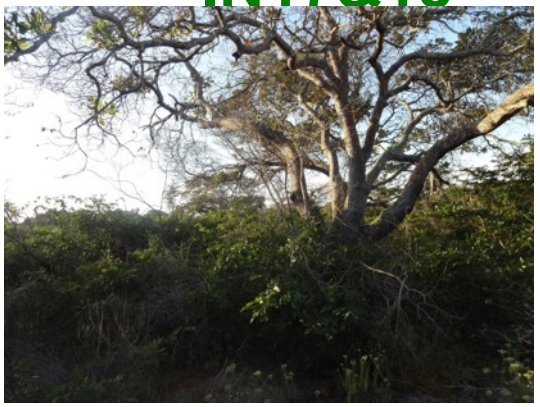
North



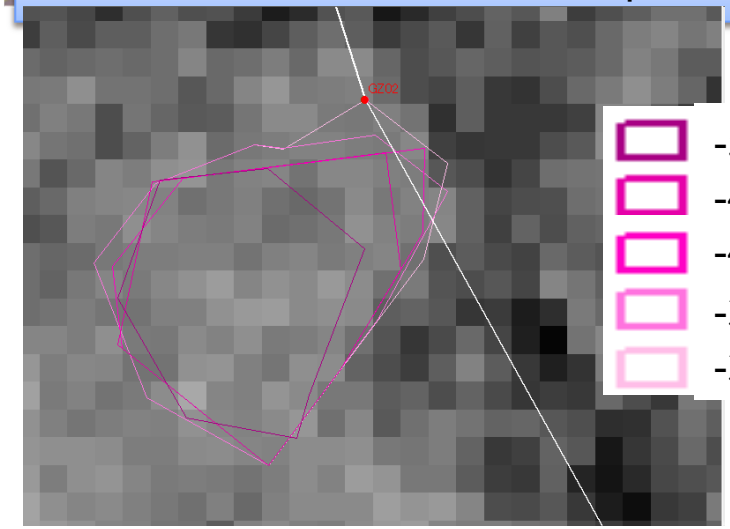
East

West

South

- No Deforestation(D)

Yellow: GPS track Red: GPS point



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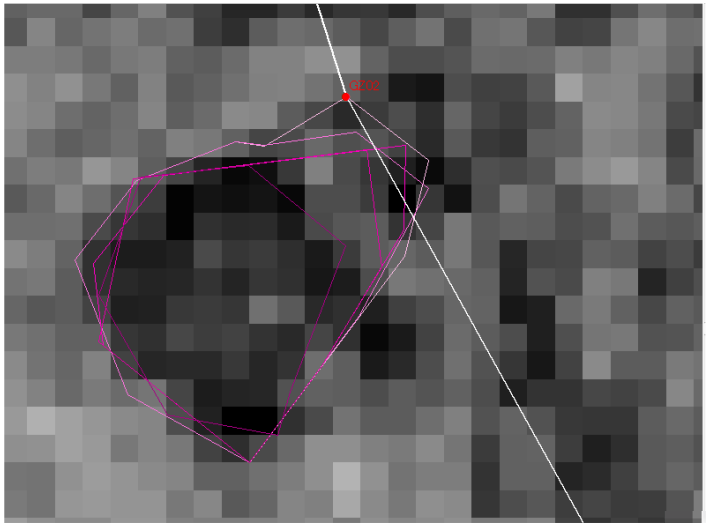
06/Dec/2014 25m resolution



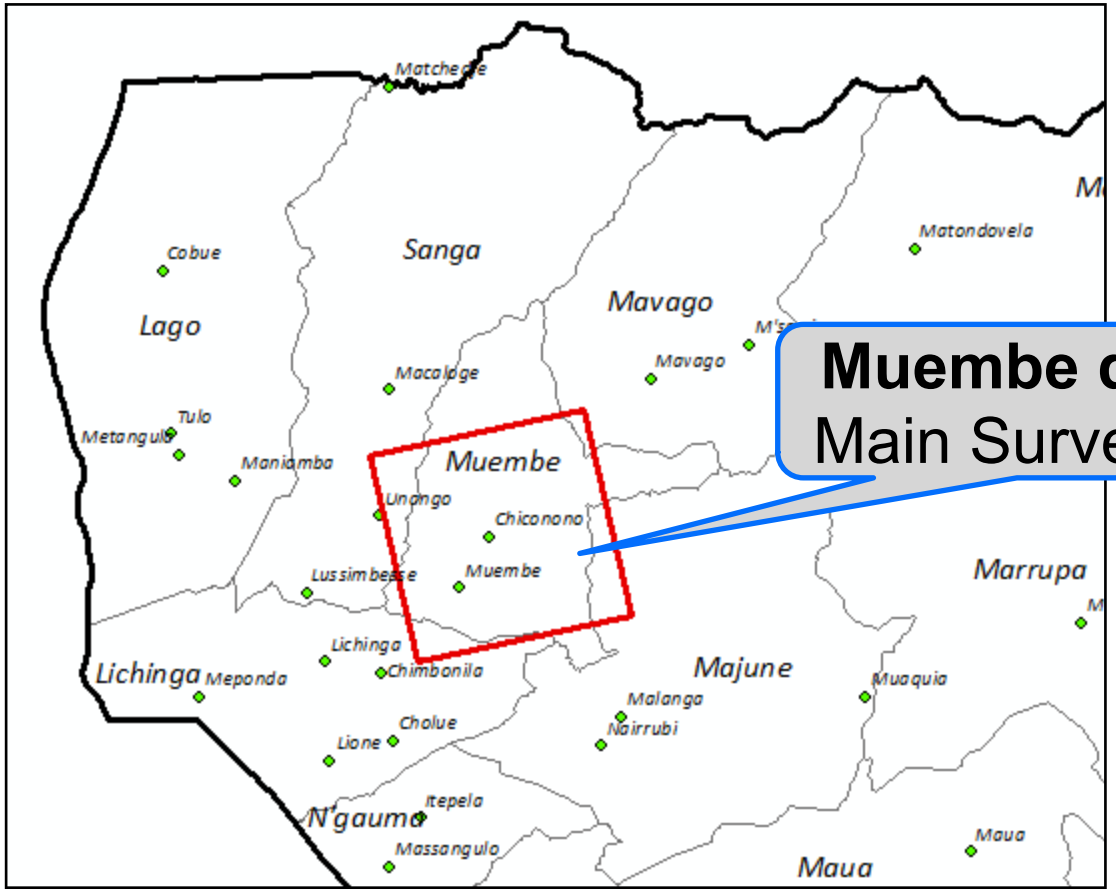
05/Dec/2015 25m resolution

GZ02

- Deforestation(D)
- Cause of D is construction
- No track data due to fence

Survey Location in Niassa Province

Niassa Proince

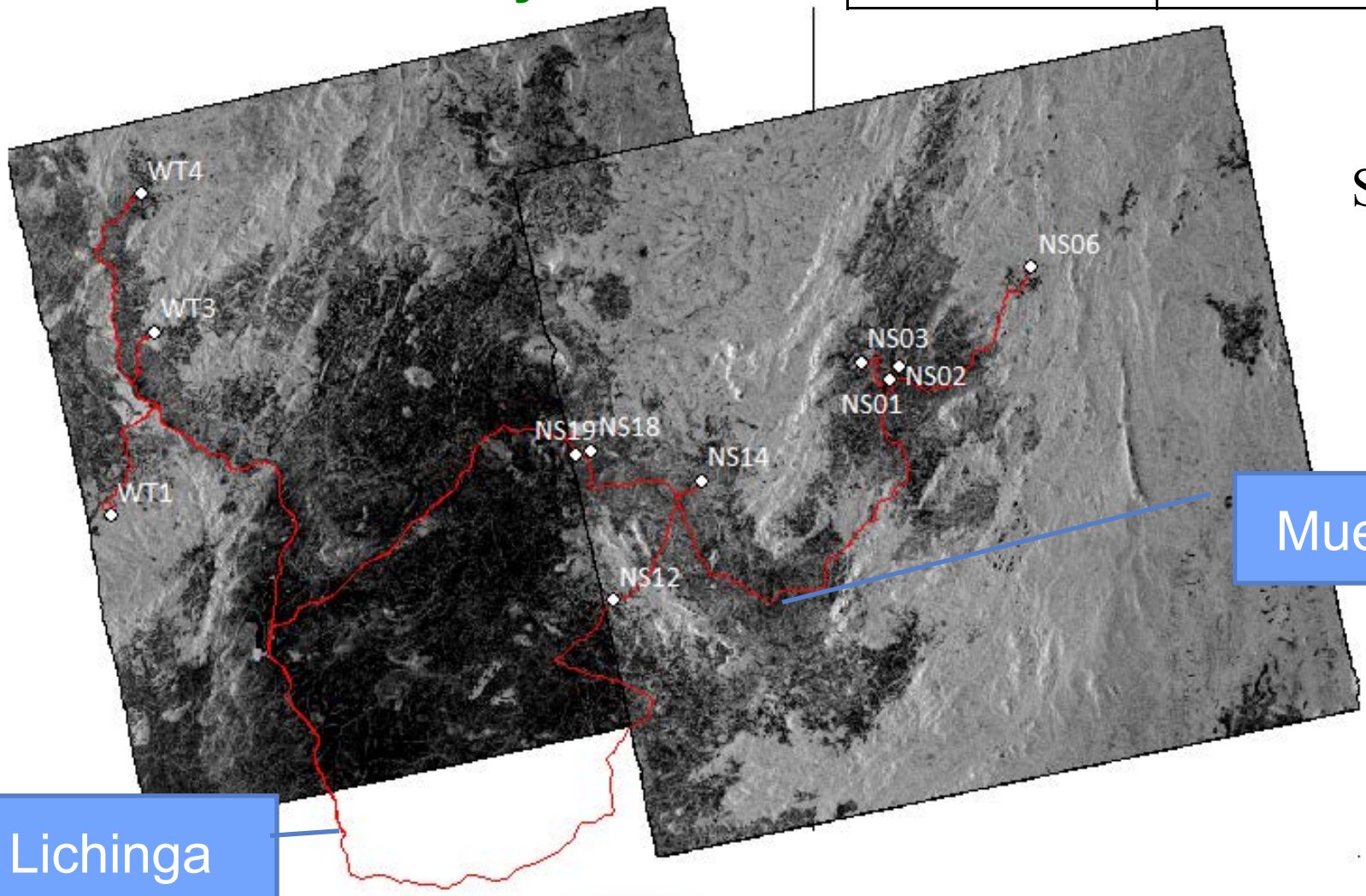


Muembe district
Main Survey Area

ALOS

Survey Point

	Before	After
East (Muembe)	19/Oct/2015	27/June/2016
West (Lichinga)	---	06/July/2016



Survey point

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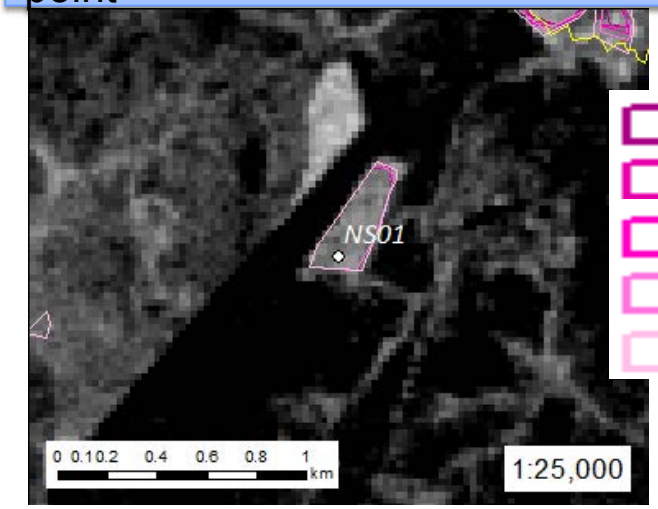
Survey result in Niassa province

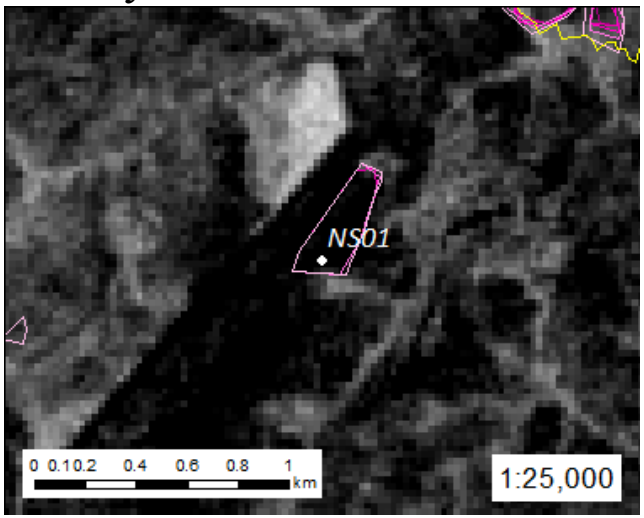
No.	PoinyNo.	F/NF	Current Crown Cover	Deforestation or not	Cause of deforestation	Timing of deforestation	Type	Height	Density	Others
1	NS01	NF	0%	Not Deforestation	Slush & burned , logging	2015	Evergreen (Pine)	20m	Dense	Burned/Clear-cut
2	NS02	NF	0%	Not Deforestation	Slush & burned	2015	Evergreen (Pine)	20m	Dense	Clear-cut
3	NS03	NF	0%	Not Deforestation	Forest fire	None	Evergreen (Pine)	10m	Dense	Burned
4	NS06	NF	0%	Deforestation	Slush & burned cultivation	March to Apr. 2016	Evergreen	15m	Dense	None
5	NS12	NF	0%	Deforestation	Slush & burned cultivation	2015	Deciduous	15m	Dense	None
6	NS14	NF	0%	Deforestation	Slush & burned cultivation	2015	Deciduous	10m	Dense	None
7	NS19	NF	0%	Not Deforestation	Slush & burned cultivation	2015	Thicket	-	-	-
8	NS20	NF	0%	Not Deforestation	-	None	Falbw land	-	-	-
9	NS18	NF	0%	Deforestation	Slush & burned cultivation	2015	Deciduous (Miombo	15m	Open	None
10	WT1	NF	0%	Deforestation	Slush & burned cultivation	2013-2015	Deciduous	20m	Dense	None
11	WT3	NF	0%	Deforestation	Slush & burned cultivation	2012-2013	Deciduous (Miombo	15m	Medium	None
12	WT4	NF	0%	Deforestation	Slush & burned cultivation	2016	Deciduous	10m	Open	None

- 7 Deforestation area (7 S&B)
- 5 Not Deforestation area (2 Plantation (logging), 1 Forest fire, 2 Thicket and Fallowland)

Yellow: GPS track White: GPS point



08/July/2015 25m resolution



06/July/2016 25m resolution

-5
-4.5
-4
-3.5
-3

NS01

North

East

West

South

- Forest Pine Plantation (It means “not deforestation”).
- Large area was cut (logging of forest plantation).
- The owner is Timber Association in [illegible]inga. Many w[illegible] here

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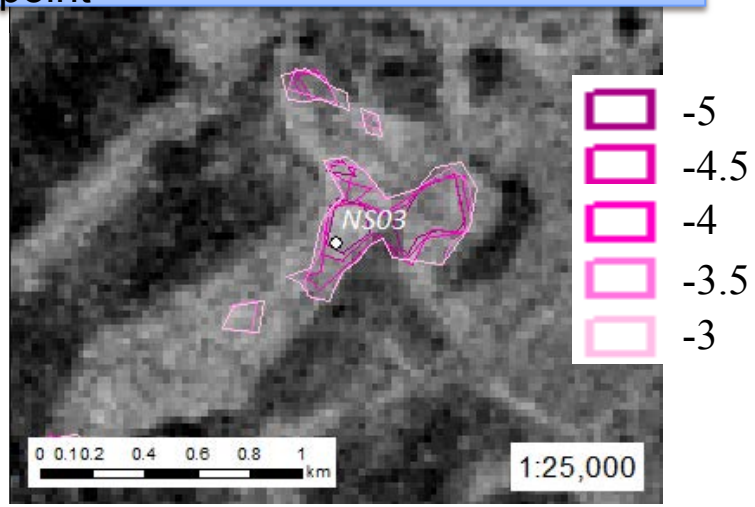
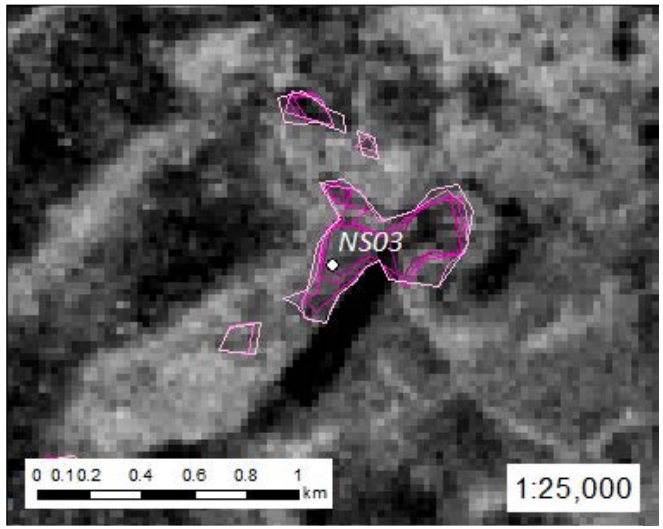
Yellow: GPS track White: GPS point



08/July/2015 25m resolution



06/July/2016 25m resolution

NS03

North

East

West

South

- Pine trees (plantation).
- Dead trees due to forest fire.

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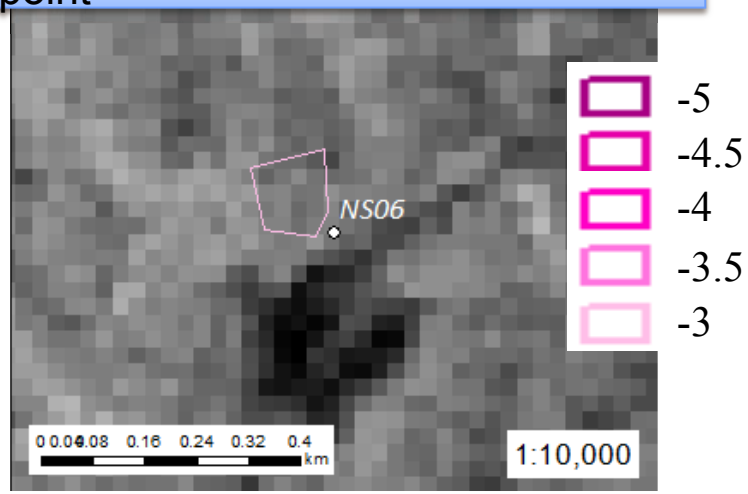
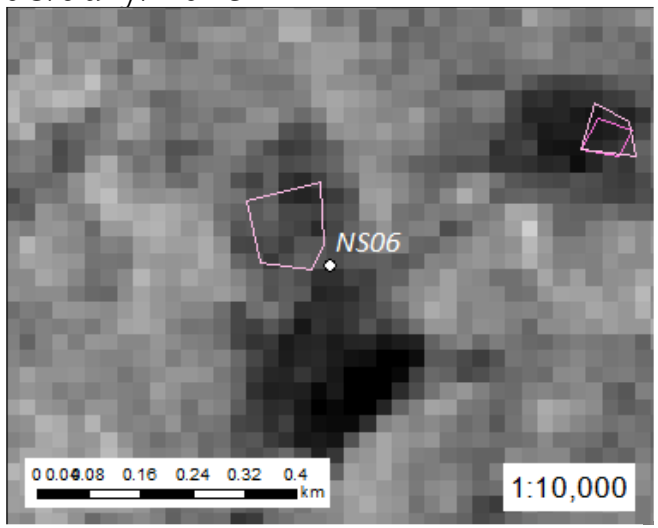
Yellow: GPS track White: GPS point

NS06



08/July/2015 25m resolution



06/July/2016 25m resolution

North

East

West

South

- Clear cut for Tobacco.
- They will plant Tobacco in few months. (Tobacco grows rainy season.)
- Past forest type is Evergreen (Massuco).

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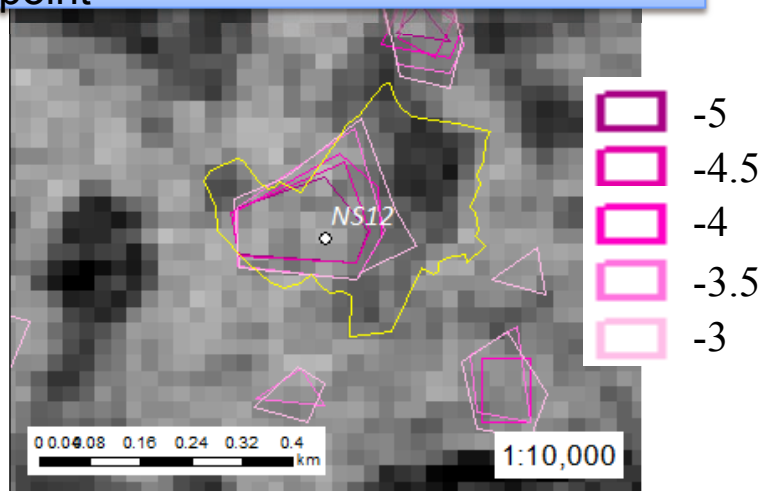
ALOS

K&C Initiative

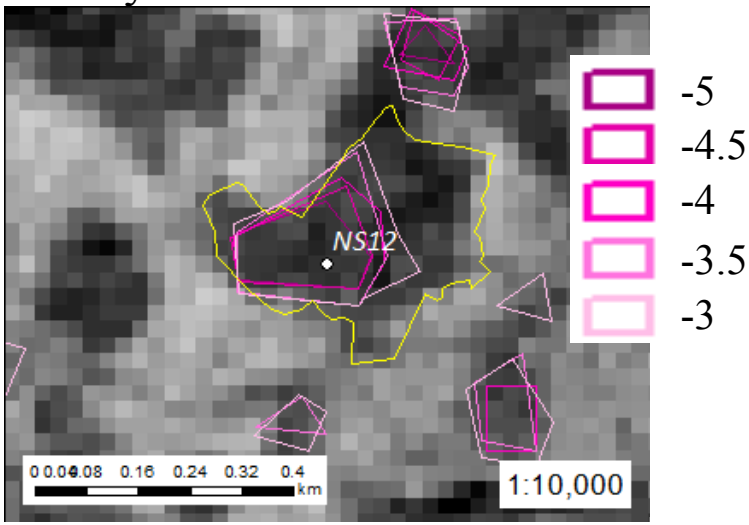
An international science collaboration between JAXA

NS12

Yellow: GPS track White: GPS point



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) .

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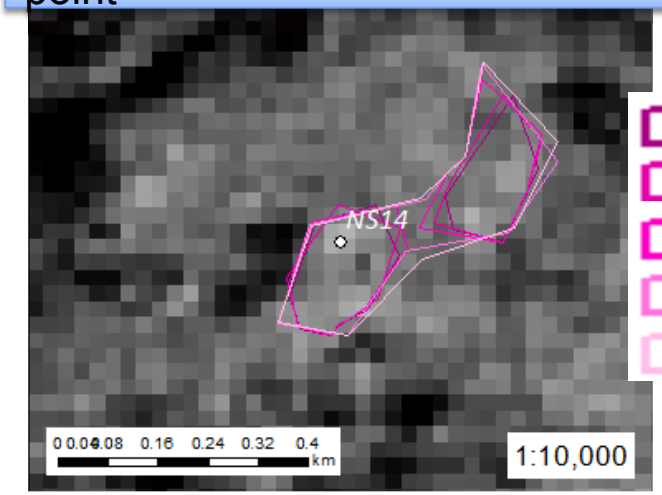
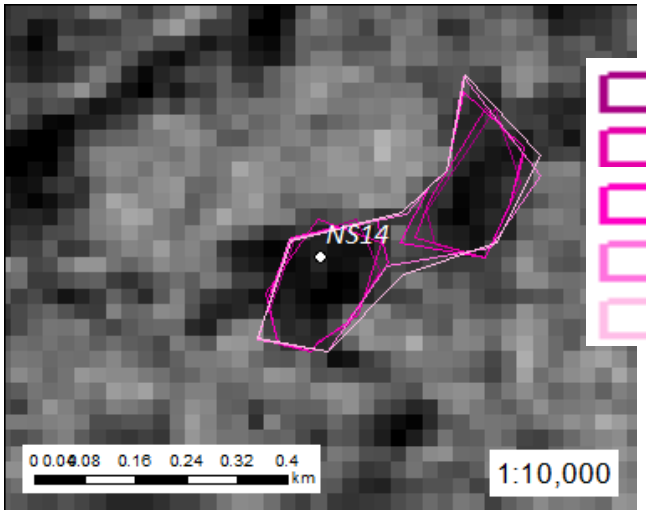
Yellow: GPS track White: GPS point

NS14



-5
-4.5
-4
-3.5
-3

08/July/2015 25m resolution



-5
-4.5
-4
-3.5
-3

06/July/2016 25m resolution

North

East

West

South

- Slush and Burned cultivation for Maize.

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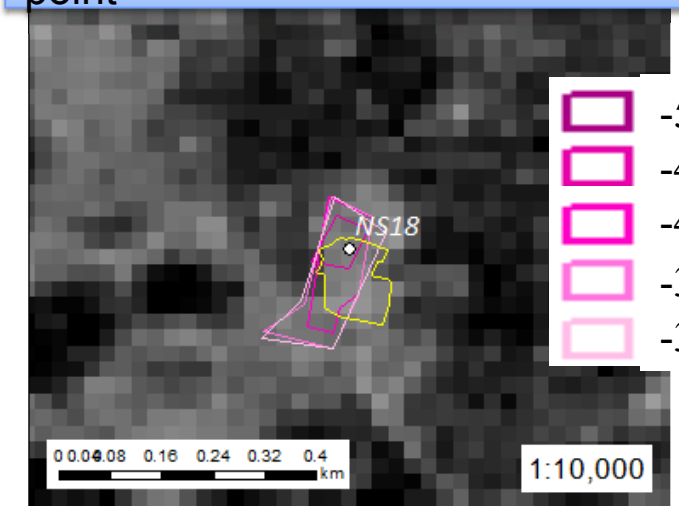
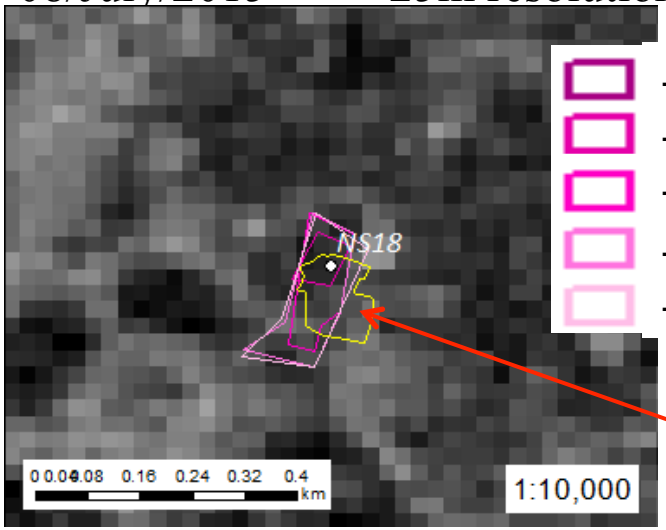
Yellow: GPS track White: GPS point



08/July/2015 25m resolution



06/July/2016 25m resolution

NS18

North

East

West

South

- Slush and Burned cultivation for Maize

Recent deforestation (after 06/July)

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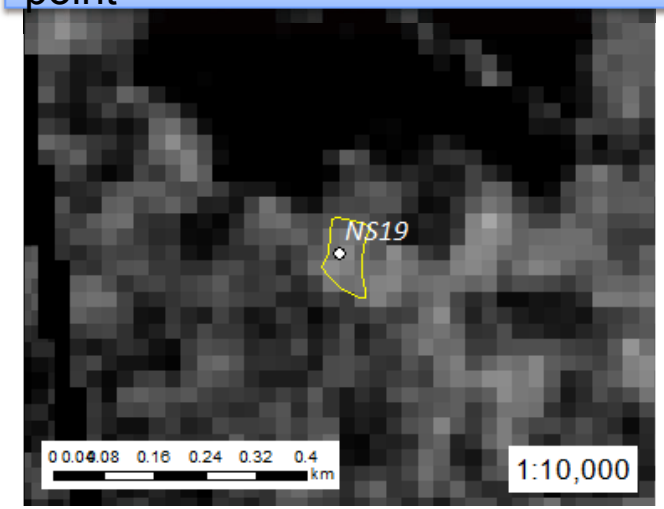
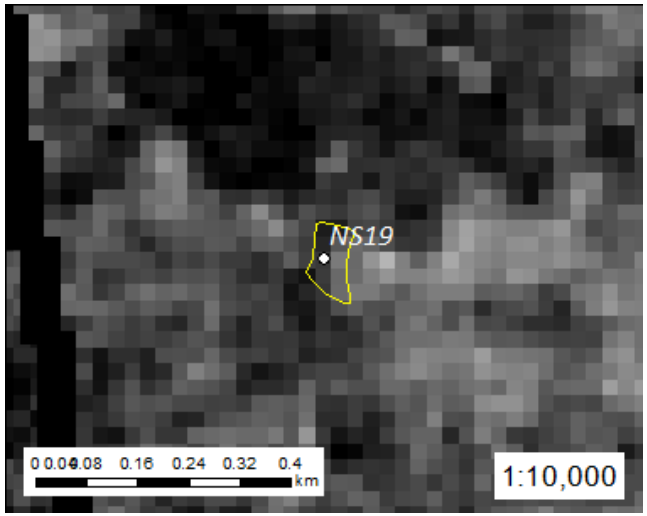
Yellow: GPS track White: GPS point

NS19



08/July/2015 25m resolution



06/July/2016 25m resolution

North

East

West

South

- Mango trees can be seen. It means this area was fallow land for 10-15 years. For now, farmer is coming back this area and started agriculture for Maize

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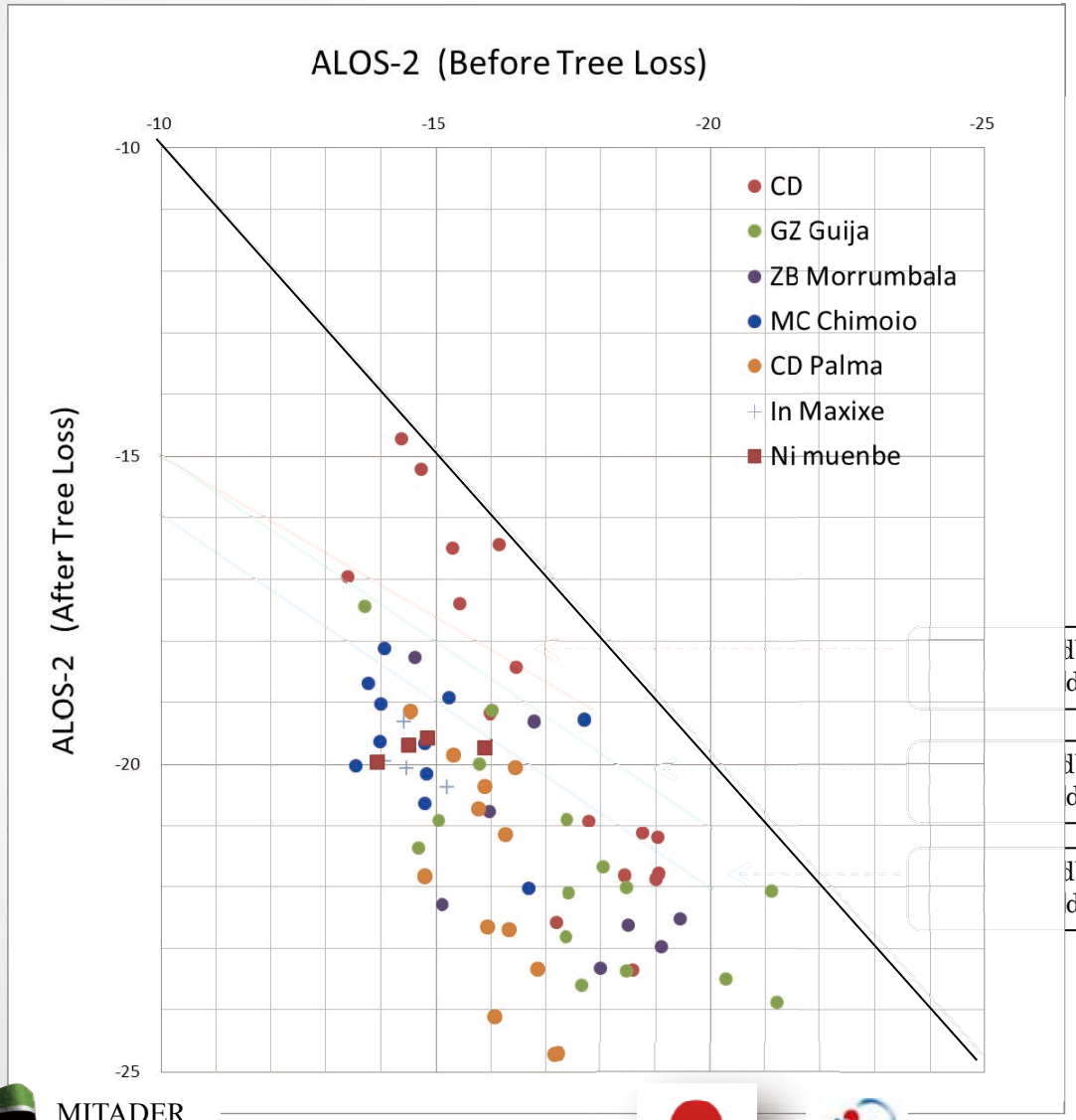
Scatter plot (Data: > 1ha)



Dense Forest

Big difference

Open Forest

Small difference

db -- > -5.0db
db -- > -1.0db

db -- > -5.0db
db -- > -1.0db

db -- > -6.0db
db -- > -2.0db

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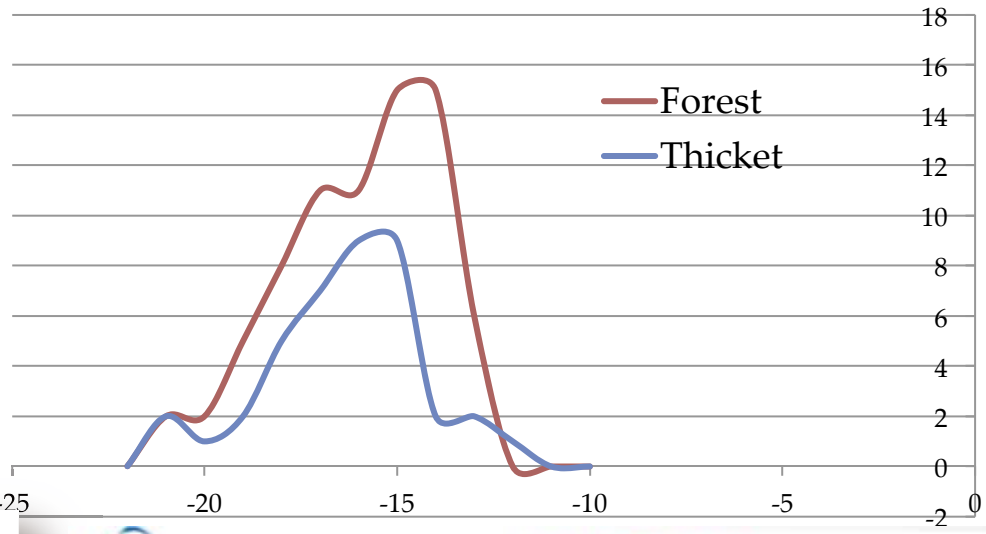
Threshold for Forest/Non-forest(F/NF)

- Comparing threshold between F/NF

  - Collect the threshold of Forest and Thicket, which were recorded in the field.

	Reference data #	
DB value	Thicket	Forest
-22	0	0
-21	2	2
-20	1	2
-19	2	5
-18	5	8
-17	7	11
-16	9	11
-15	9	15
-14	2	15
-13	2	6
-12	1	0
-11	0	0
-10	0	0
Total	40	75

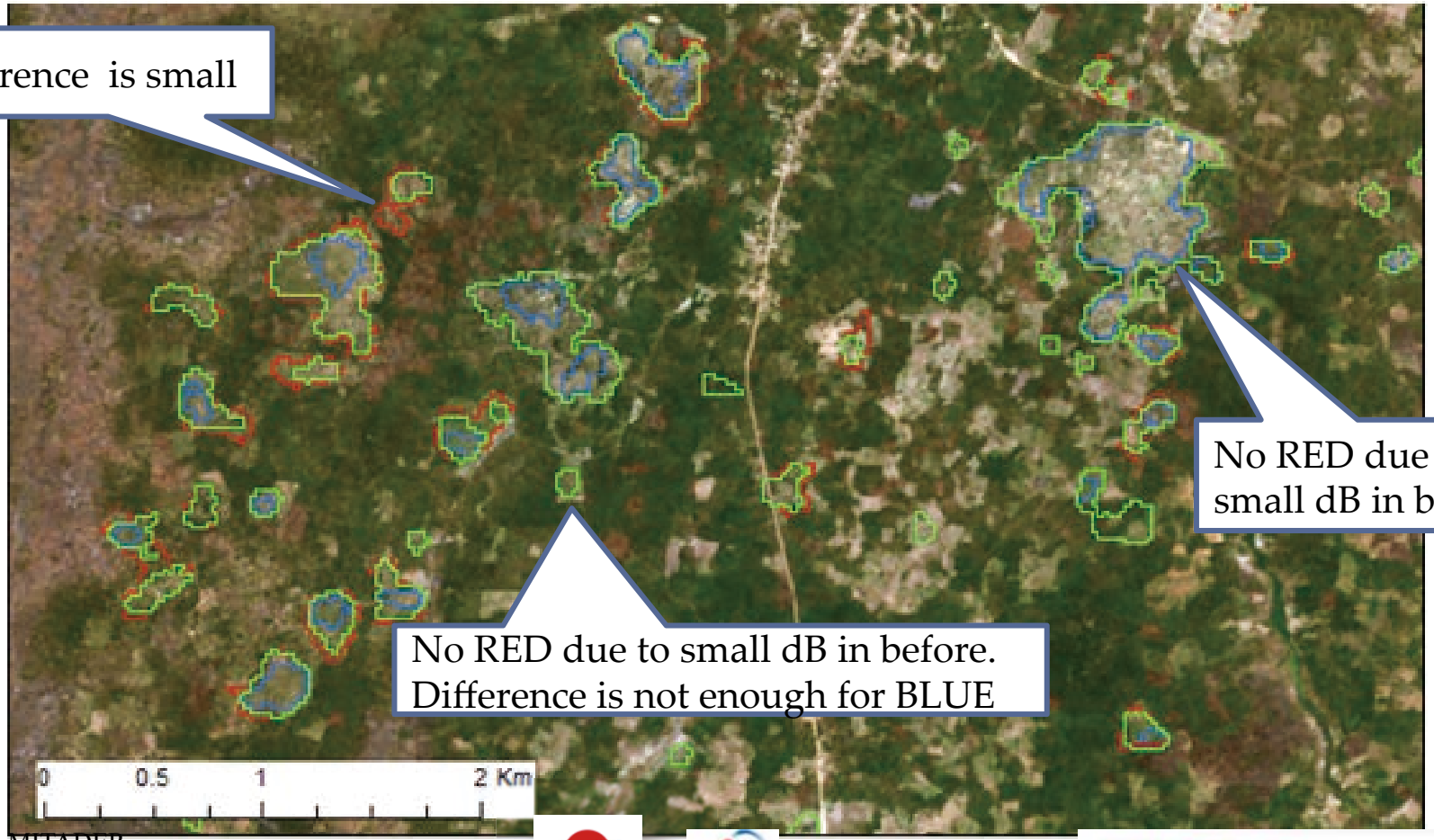
No clear border between Forest and Thicket



Tree Loss area in Mossuril, Nampula

ALOS 2 Before(2015/7/26), After(2016/7/24)

Background image: Sentinel 2 _10m resolution (2016/10/2)



Accuracy assessment

➢ Assessment method

Random selected detected polygons(100) was inspected one by one based on Sentinel 2 image. In here, it is positive if tree can not be confirmed in a later state.

➢ Result of Accuracy assessment

Mossuril, Nampula

BLUE(-20)

Class	#	Accuracy
Non-Forest	90	94.8%
Forest	5	92/97 (Excluding cloud)
Cloud(Shade)	3	
Water area	2	
Total	100	

BLUE(-19)

Class	#	Accuracy
Non-Forest	90	97.8%
Forest	2	90/92 (Excluding cloud)
Cloud(Shade)	8	
Water area	0	
Total	100	

BLUE(-18)

Class	#	Accuracy
Non-Forest	61	100.0%
Forest	0	61/61 (Excluding cloud)
Cloud(Shade)	8	
Water area	0	
Total	69	

GREEN(-20)

Class	#	Accuracy
Non-Forest	87	97.8%
Forest	2	90/92 (Excluding cloud)
Cloud(Shade)	8	
Water area	3	
Total	100	

Green(-19)

Class	#	Accuracy
Non-Forest	88	96.7%
Forest	3	88/91 (Excluding cloud)
Cloud(Shade)	9	
Water area	0	
Total	100	

Green(-18)

Class	#	Accuracy
Non-Forest	92	98.9%
Forest	1	92/93 (Excluding cloud)
Cloud(Shade)	7	
Water area	0	
Total	100	

Accuracy assessment

➢ Result of Accuracy assessment

Palma, Cabo Delgado

BLUE(-20)

Class	#	Accuracy
Non-Forest	58	100.0%
Forest	0	69/69 (Excluding cloud)
Cloud(Shade)	31	
Water area	11	
Total	100	

BLUE(-19)

Class	#	Accuracy
Non-Forest	47	100.0%
Forest	0	63/63 (Excluding cloud)
Cloud(Shade)	37	
Water area	16	
Total	100	

BLUE(-18)

Class	#	Accuracy
Non-Forest	47	98.2%
Forest	1	55/56 (Excluding cloud)
Cloud(Shade)	44	
Water area	8	
Total	100	

GREEN(-20)

Class	#	Accuracy
Non-Forest	55	100.0%
Forest	0	65/65 (Excluding cloud)
Cloud(Shade)	35	
Water area	10	
Total	100	

Green(-19)

Class	#	Accuracy
Non-Forest	64	100.0%
Forest	0	70/70 (Excluding cloud)
Cloud(Shade)	30	
Water area	6	
Total	100	

Green(-18)

Class	#	Accuracy
Non-Forest	66	100.0%
Forest	0	72/72 (Excluding cloud)
Cloud(Shade)	38	
Water area	6	
Total	100	

Issue of Accuracy assessment

➢ Newly confirmed issue

- ✓ Confirmed Non-forest area in the before image
- ✓ Mainly, misclassification are confirmed in the water are

→ The influence of water is limited because ALOS2 images were obtained in dry season(July~September).

It is assumed that herbaceous(grass) is the cause of misdetection.

Number of Non-Forest polygon in before image

		-20	-19	-18
Nampula	BLUE	9(5)	5(5)	9(4)
	GREEN	14(6)	7(3)	15(9)
Cabo Delgado	BLUE	13(13)	20(20)	16(16)
	GREEN	12(11)	9(8)	15(9)

() shows the number of polygon, which are located in water area

➢ Additional analysis method!?

- ✓ Apply 2 period images as the data of “before”
- ✓ Select the stable area

Wide area(Province) analysis

- Validate each threshold line in the province level
  - Collect the threshold of Forest and Thicket, which were recorded in the field.
  - Calculate average loss area in order to compare with Hansen

Detected Tree Loss area in CD

BLUE (-20)	Area (ha)	Average (ha/year)
All polygon	265,380	53,076
Polygon>0.09	262,982	52,596
Polygon>1.0	237,558	47,512

GREEN (-20)	Area (ha)	Average (ha/year)
All polygon	454,191	90,838
Polygon>0.09	450,755	90,151
Polygon>1.0	406,495	81,299

BLUE (-19)	Area (ha)	Average (ha/year)
All polygon	198,339	39,668
Polygon>0.09	198,339	39,668
Polygon>1.0	184,224	36,845

GREEN (-19)	Area (ha)	Average (ha/year)
All polygon	326,981	65,396
Polygon>0.09	326,981	65,396
Polygon>1.0	306,503	61,301

BLUE (-18)	Area (ha)	Average (ha/year)
All polygon	152,920	30,584
Polygon>0.09	152,920	30,584
Polygon>1.0	140,792	28,158

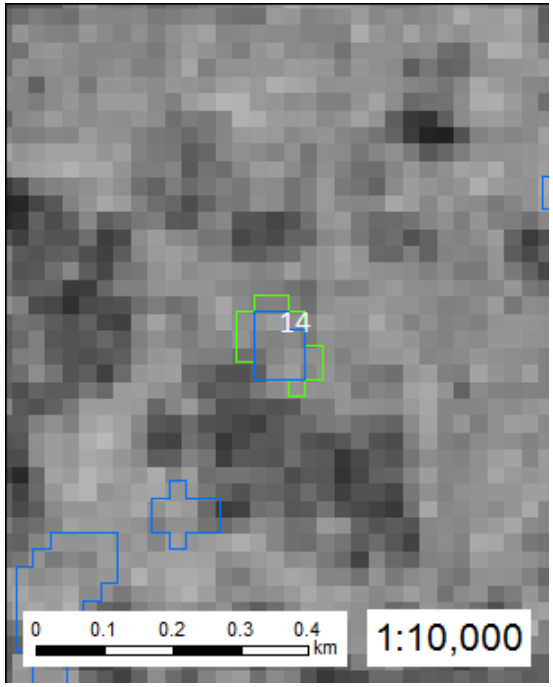
GREEN (-18)	Area (ha)	Average (ha/year)
All polygon	246,756	49,351
Polygon>0.09	246,756	49,351
Polygon>1.0	229,712	45,942

Hansen Tree Loss in CD

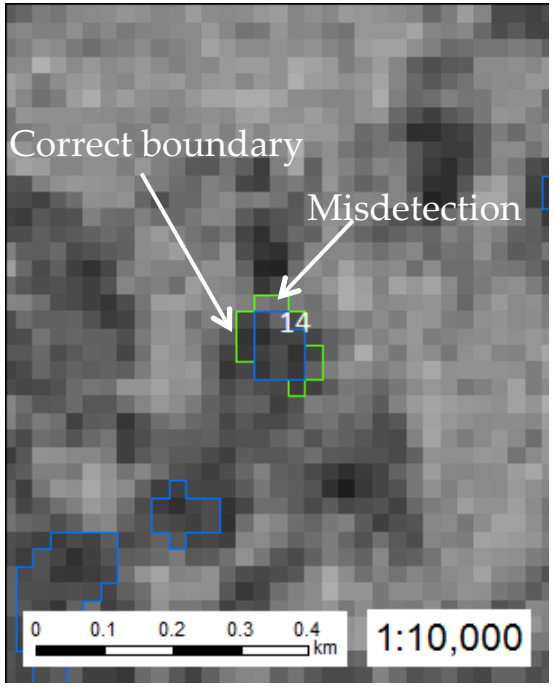
Year	Loss area (ha)
2010	17,831
2011	17,786
2012	17,087
2013	34,258
2014	19,952
Ave	21,383

Capture analysis

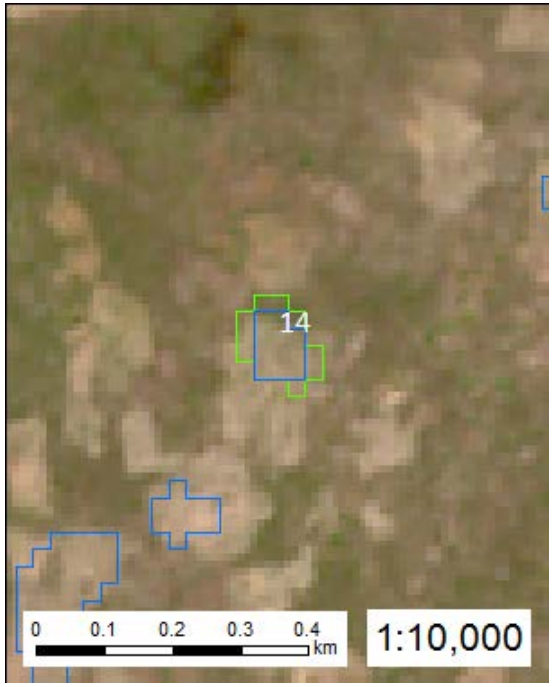
- Examples of boundary difference



ALOS-2 Before (2015)



ALOS-2 After (2016)

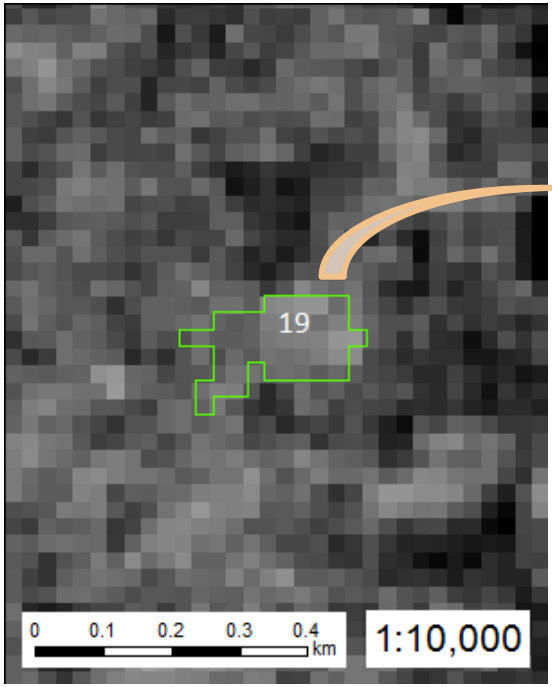


Sentinel-2 (2016/10)

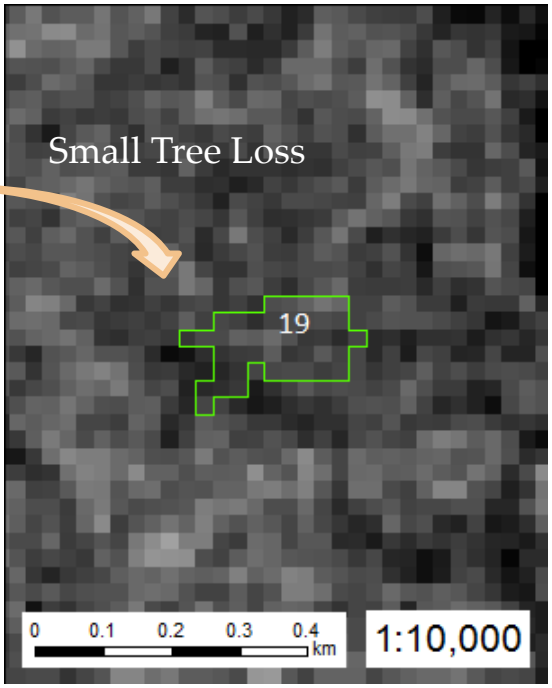
GREEN(-18dB) polygon can detect pixels with proper boundary, however, Non-tree loss area is also detected. BLUE(-18dB) polygon can detect solid pixels of tree loss area, although BLUE(-18dB) polygon is underestimated tree loss area.

Capture analysis

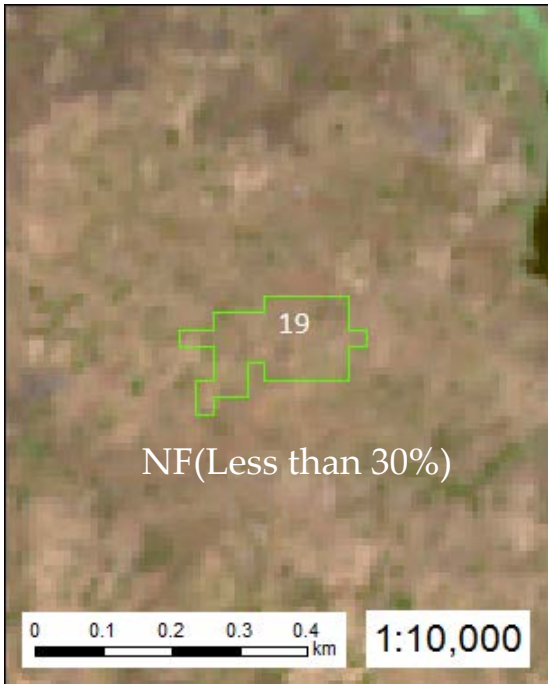
- Detected only Green Line case



ALOS-2 Before (2015)



ALOS-2 After (2016)



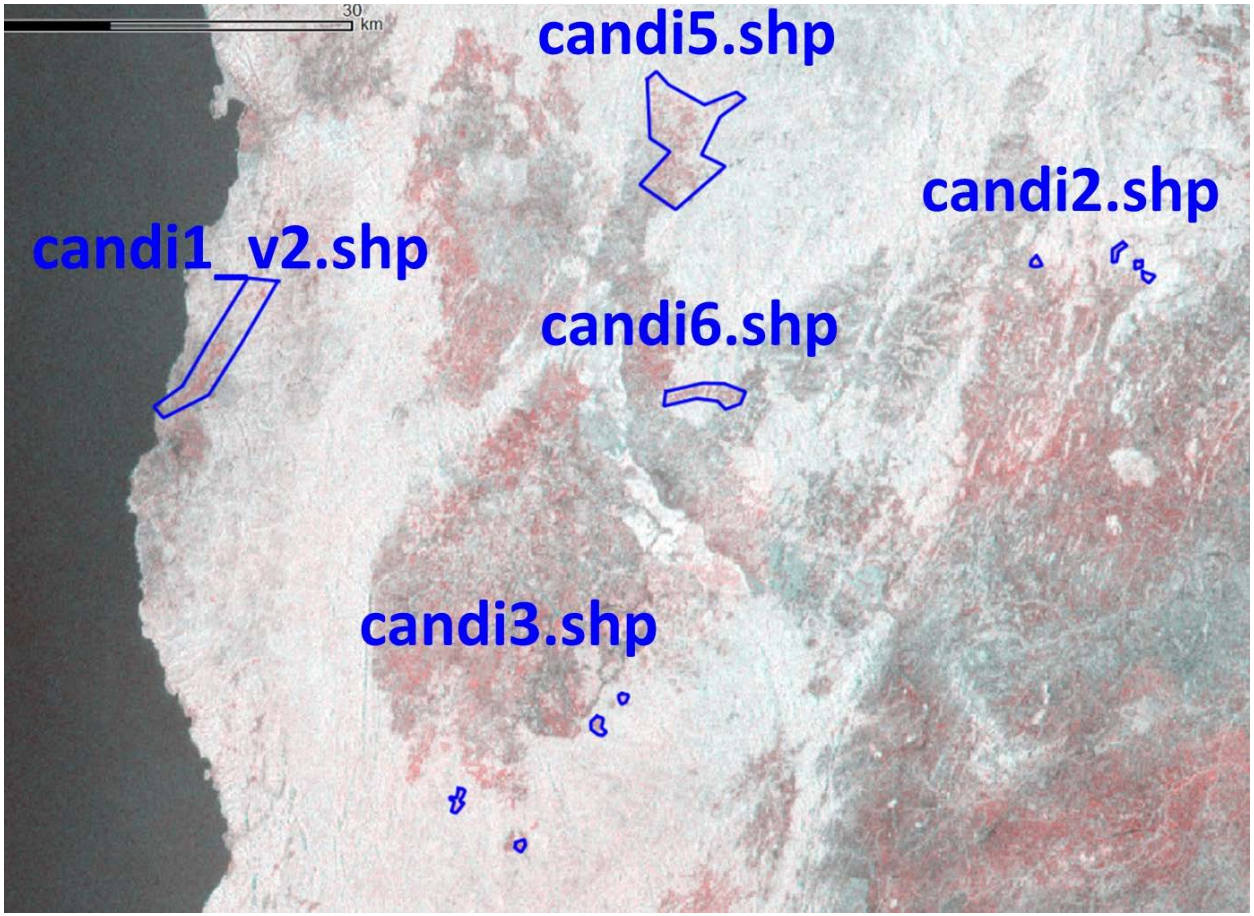
Sentinel-2 (2016/10)

BLUE(-18dB) polygon does not detect here as “Tree loss”. Only GREEN(-18dB) polygon can detect tree loss area. From sentinel-2 optical imagery, this area may be non-forest (less than 30% tree canopy density).

Cooperate with Watanabe-san for developing JJ-FAST system (by ScanSAR)

- ✓ To do the Ground Truth survey and check the deforestation areas which are detected by ScanSAR analysis (Lago district, Niassa).
  - →Most of deforestation areas are large scale
- ✓ It is difficult to survey the deforestation boundaries, then we do check the situation of deforestation areas and take overall pictures.

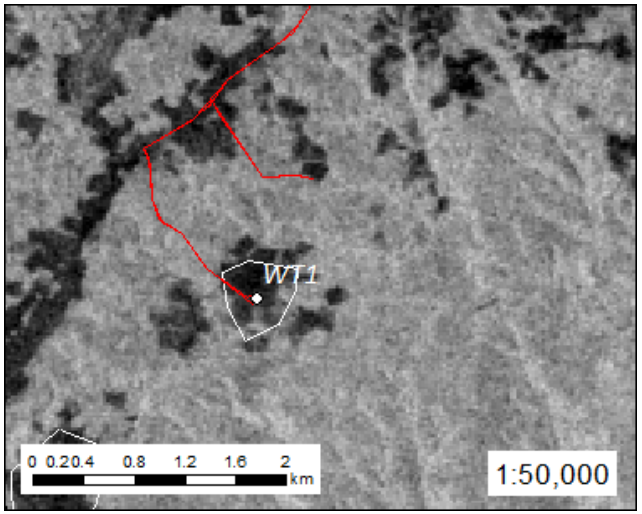
Detected areas from ScanSAR analysis



Red: 30/Mar/2015 Green and Blue: 4/Jan/2016

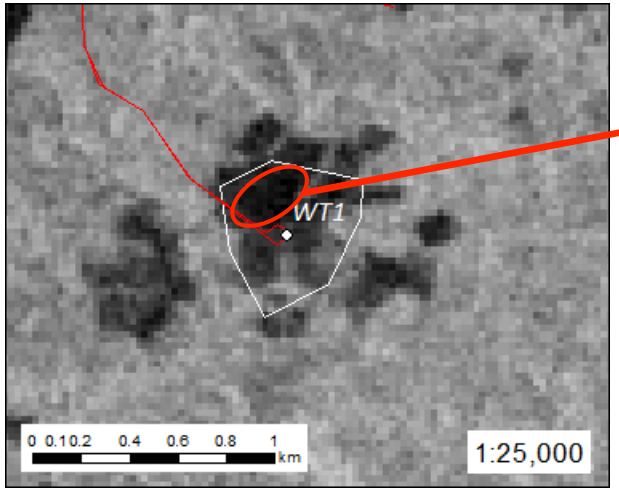
Red: GPS track White: Detected area by ScanSAR

WT01



North

West



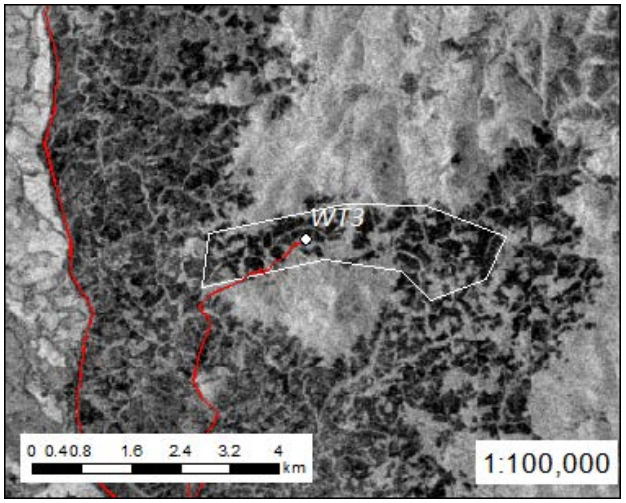
Panoramic Photo

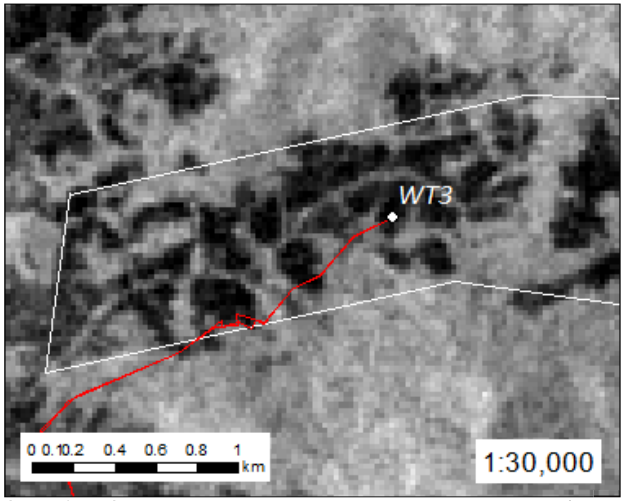
- Maize and Beans
- Past forest type is Mixed Forest (Miombo and Evergreen (Massuco).

06/July/2016 25m resolution

Red: GPS track White: Detected area by ScanSAR

WT03





North

East

Overview 1

Overview 2

- These areas are deforestation area for agriculture (Maize and Beans)
- It seems these areas are developed from 3-4 years ago to this year.(not only last year)

06/July/2016 25m resolution

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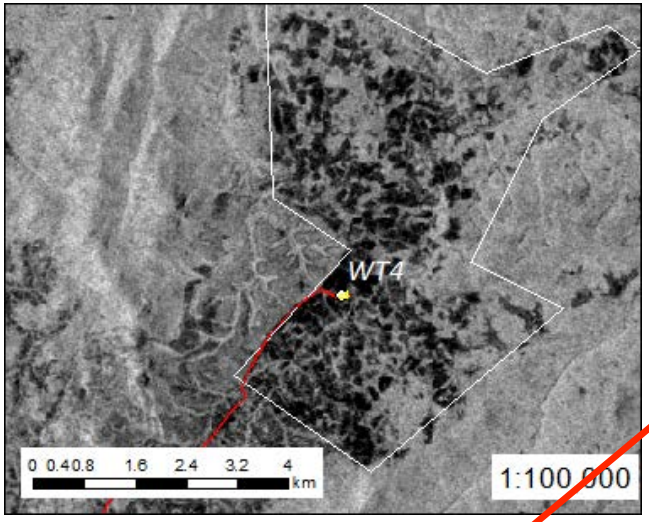
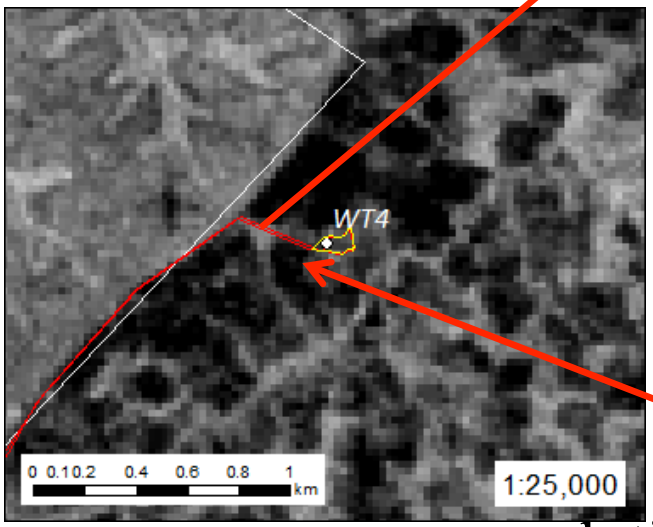
Red: GPS track White: Detected area by ScanSAR

WT04





Overview at the road

Overview at the point

- Large tree loss area.
- These areas are deforestation areas for agriculture.(developed from 2 years ago)
- In this point, some cut tree stems and branches can be seen on the ground.(It means this point was cut th

- Southwest area was developed last year. (Interview to villager)

06/July/2016

25m resolution

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Issue of Capture Analysis

- New threshold line between BLUE and GREEN?
  - ✓ Tree loss areas were detected by BLUE(-18dB) show exactly correct polygons. However, total tree loss area is underestimation.
  - ✓ Detected tree loss areas by GREEN(-18dB) show better boundary than BLUE(-18dB)' one. However, some misdetection areas can be seen.
- "confidence" index?
  - ✓ To consider and develop the confidence index.

Mask data for water area

- As mentioned “Newly confirmed issue” on Slide above, Mis-detection happened in water area.
- One of the solution is mask processing.
- It is not small work to produce water area mask in whole Mozambique…
- Google Earth Engine can support to producing water area mask.

【Blue】 Water area
【Red and Green】
changeable area between
dry season and wet season

ALOS

PALSAR/PALSAR-2 data access

(1) Requested:

- 114 scenes

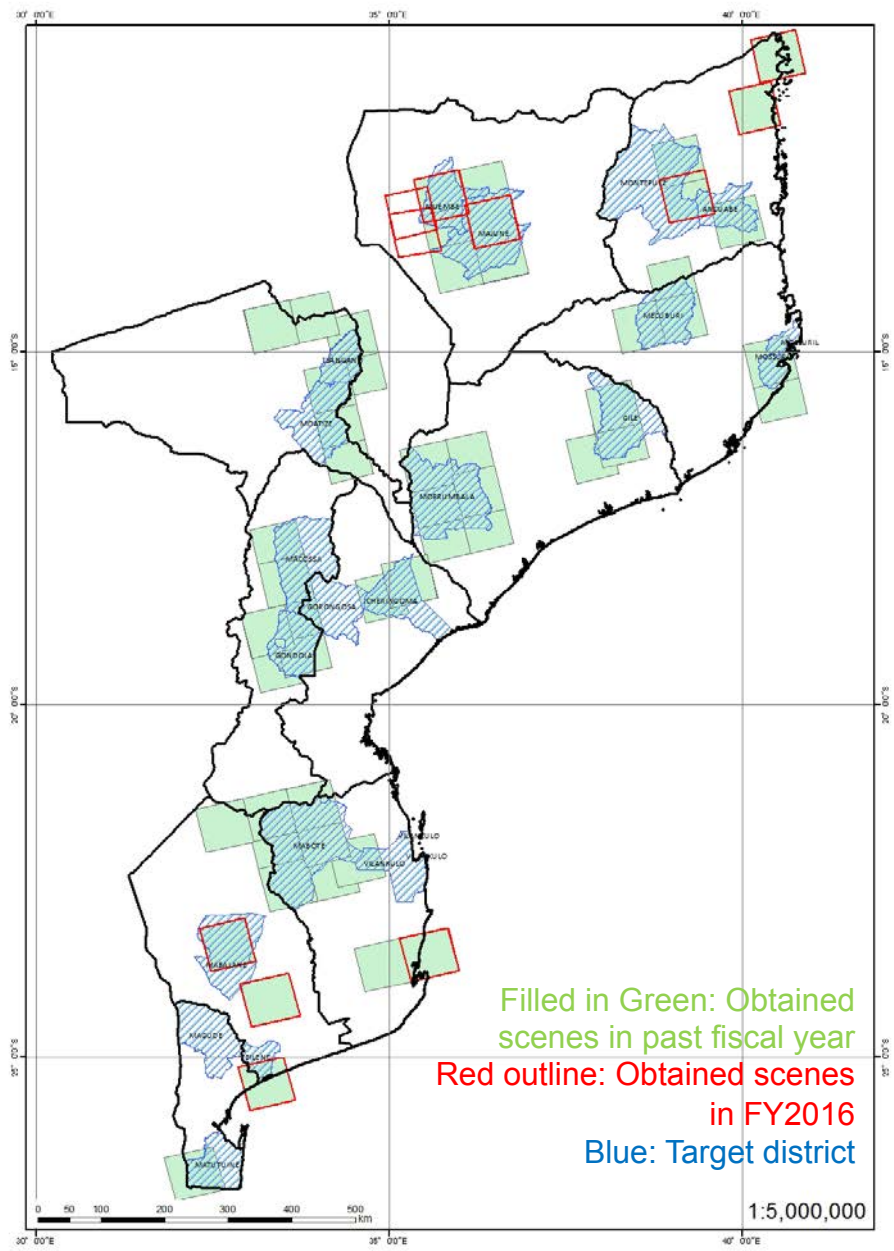
(2) Obtained:

- PALSAR-1: 0 scene;

- PALSAR-2: 114 scenes (end of Dec., 2016).

50(FY2014) + 50(FY2015) + 14(FY2016)

We had enough data and information for our research.
We did field survey ourselves to check deforestation area.



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Project milestones

- Detect deforestation(Tree loss) location;
- Confirm deforestation(Tree loss) area;
- Utilize as ”M(Measurement)” of MRV
- Specify the hotspot area from changes over the year;
  →Will utilize as forest management plan
- Driver of deforestation will be confirmed by Ground Truth(GT) survey, though it is limited data;
- Confirm forest type and geological feature which has been influenced by deforestation(tree loss);
- Develop forest monitoring;

【In the future】

- Utilize for developing forest cover map.

Deliverables

Deforestation area from PALSAR-2 imagery;

- Updated Ground Truth data (GPS, Photos, Forest type, Condition, deforestation area by GARMIN, etc.) ;
- Analysis of deforestation;

Forest biomass dynamic maps

Learnings from the survey

- Some Pine plantation areas can be seen and cut large areas (ex. 47ha and 9.4ha) in Muembe district.
- Altitude in Niassa is high (around 1,000m to 1,500m), there are many pine plantation areas.
- In Lichinga and Lago, many field crop areas can be seen. Especially, Lago is the famous district to produce beans. These beans are shipped to Lichinga and Maputo.

- At the NS03, mis-detection is occurred due to forest fire.
- At the NS12, only -3.0dB threshold can detect deforestation. Because some branches on the ground are affected.

ALOS

K&C Initiative

An international science collaboration led by JAXA