Suomen luonnonsuojeluliitto
Finnish Association for Nature Conservation

Mapping forest intactness / degradation:

the map analysis of pilot sites in Andasibe, Ranomafana and Manombo

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Why to measure forest intactness / degradation?

- The forest biodiversity is sensitive to human influence and depends on the level of the forest transformation
- So, the intactness of forest is important for decision-making on conservation priorities
- Forest transformation/degradation map is required for better understanding the transformation reasons and making decisions for more sustainable landuse

How to measure the level of forest intactness / degradation?

- Such a measuring is a technically challenging task as the “intactness” is not directly visible in satellite images and other spatial datasets

- The most of existing maps do not take the degradation level too much into account – mapping primarily forest cover changes or general, climate-dependent forest types

Assumptions

1. Forest degradation influences the forest canopy structure
2. More degraded forests usually have more simple canopy structure – while more intact forests have more complex canopy structure formed by trees of diverse sizes *(at least so for humid evergreen tropical forests, also proven for a number of types of boreal and temperate forests of Eurasia)*
3. This structure reflected in satellite images – texture characteristics and a spectral response

Assumptions

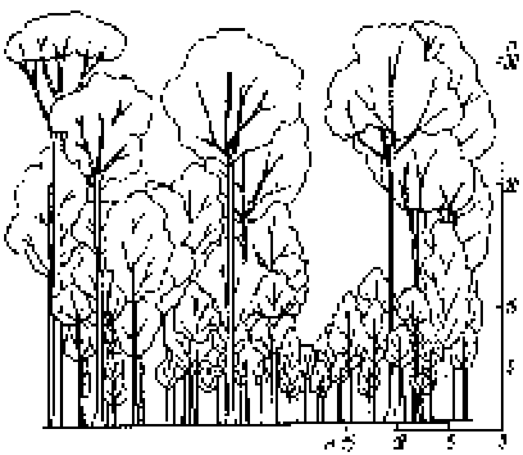
- Intact / old-growth forests usually have the more than 1 layer of closed canopy (Multi-layer – ML)
- Degraded / secondary forests have a single layer of closed canopy (Single-layer – SL)
- Intact forests may have a simple canopy structure (single layer) only in specific habitats or landscape positions (SL "on top of ridges")

Simple forest canopy structure classification

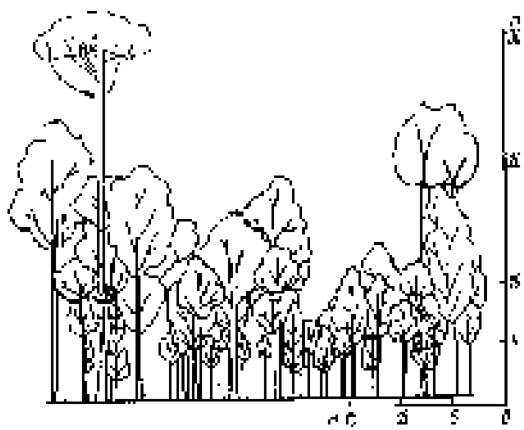
A. Multi-layer (ML)

B. Single layer with big tress (SL BT)

C. Single layer (SL)



A



B

C

How to measure it?
The idea

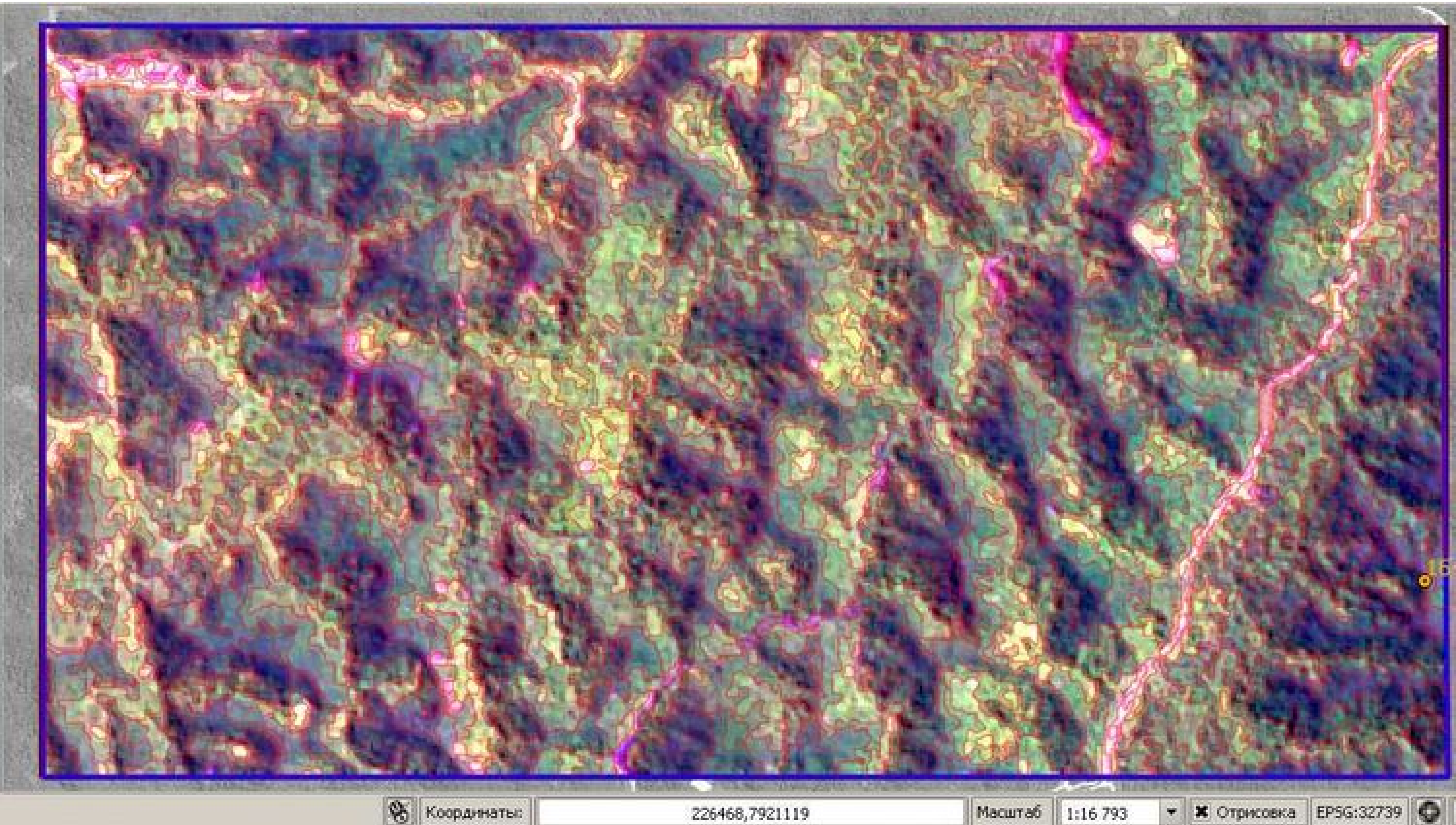
- Using SPOT-5 (also SPOT-6/7 in the future) panchromatic channel (detailed enough to detect single trees crowns and canopy irregularities)

- Mapping tree crown shadows marking irregularities in the canopy (a kind of “reversed” single trees crown mapping method)

- Calculating density of shadows and classifying forest stands polygons on this base

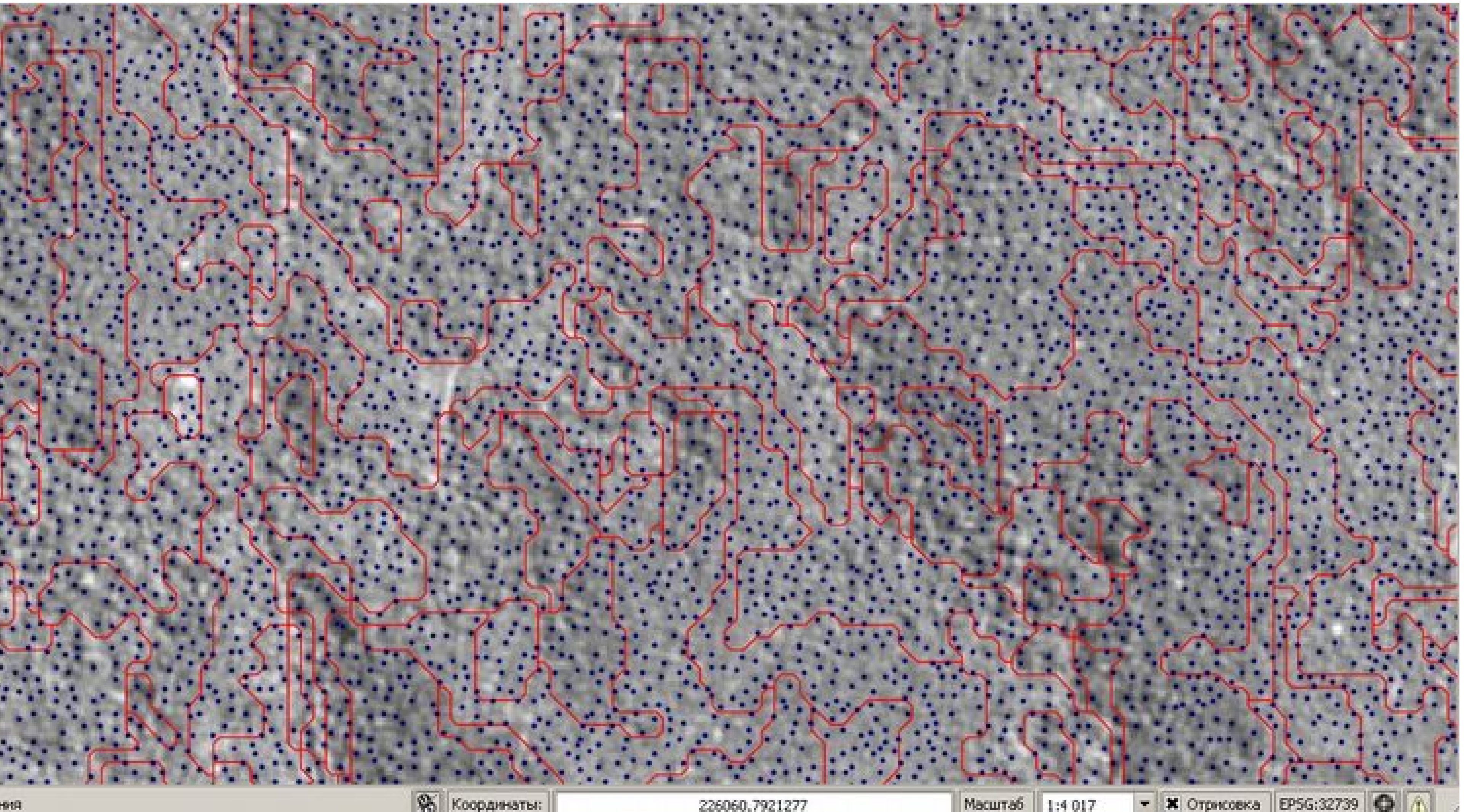
Algorithm details

Segmentation by SPOT spectral channels
(spatial resolution – 10 m; min. area – 50 pixels)



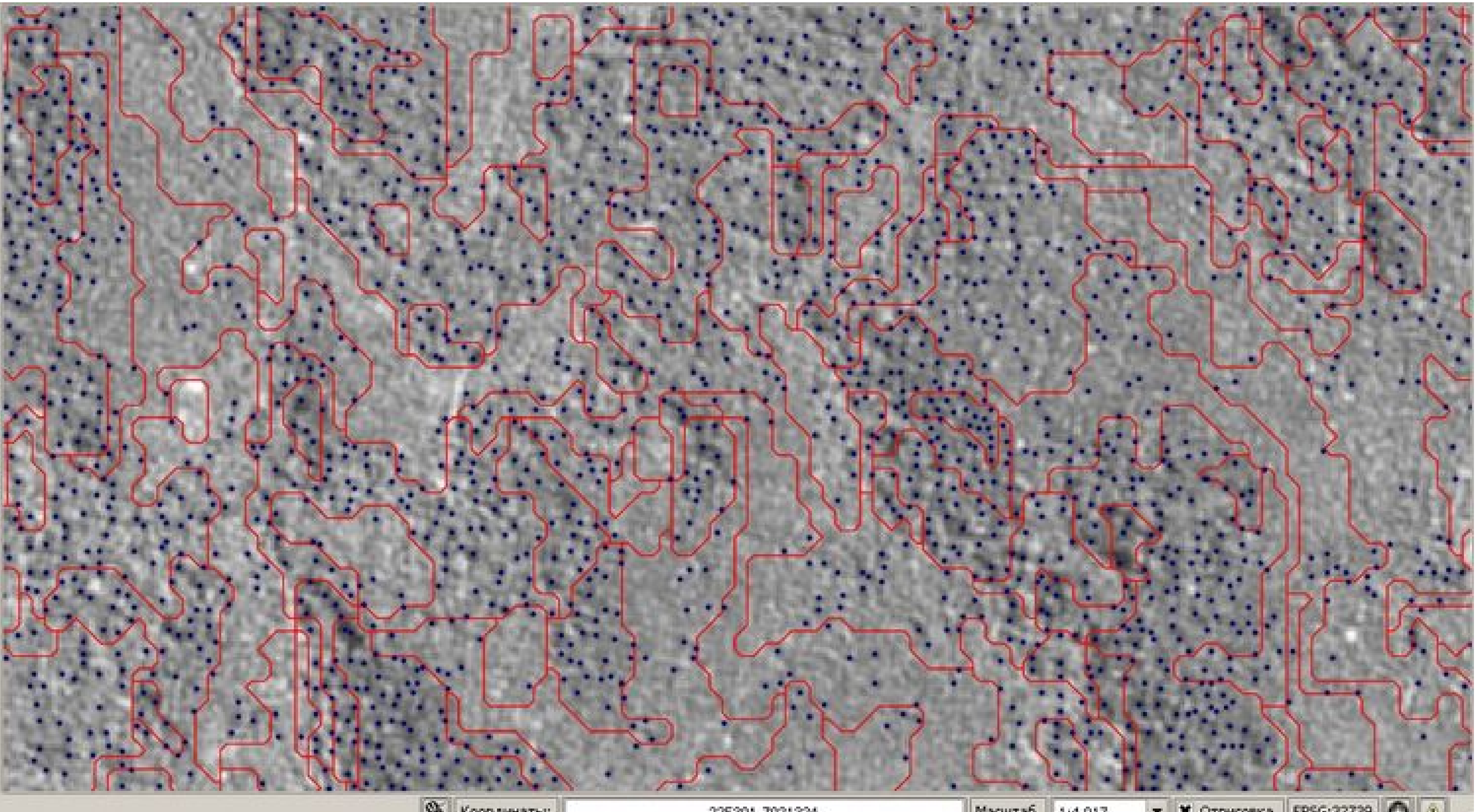
Algorithm details

Calculating local minimum reflections pixels in SPOT panchromatic channel (resolution – 2.5 m; window – 5x5 pixels)



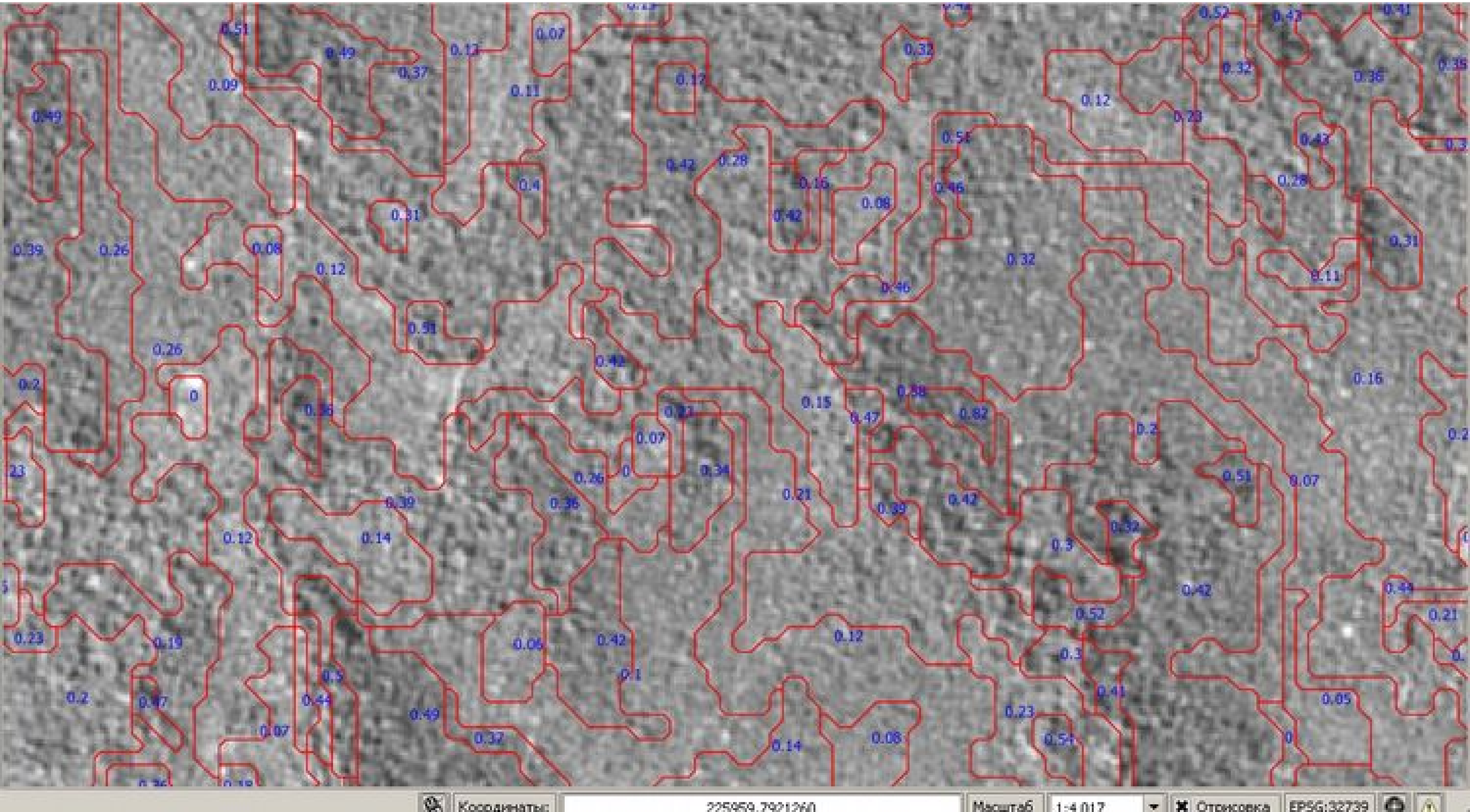
Algorithm details

Selecting canopy shadows of different size – local minimum pixels
with the reflection below 60-80 DN



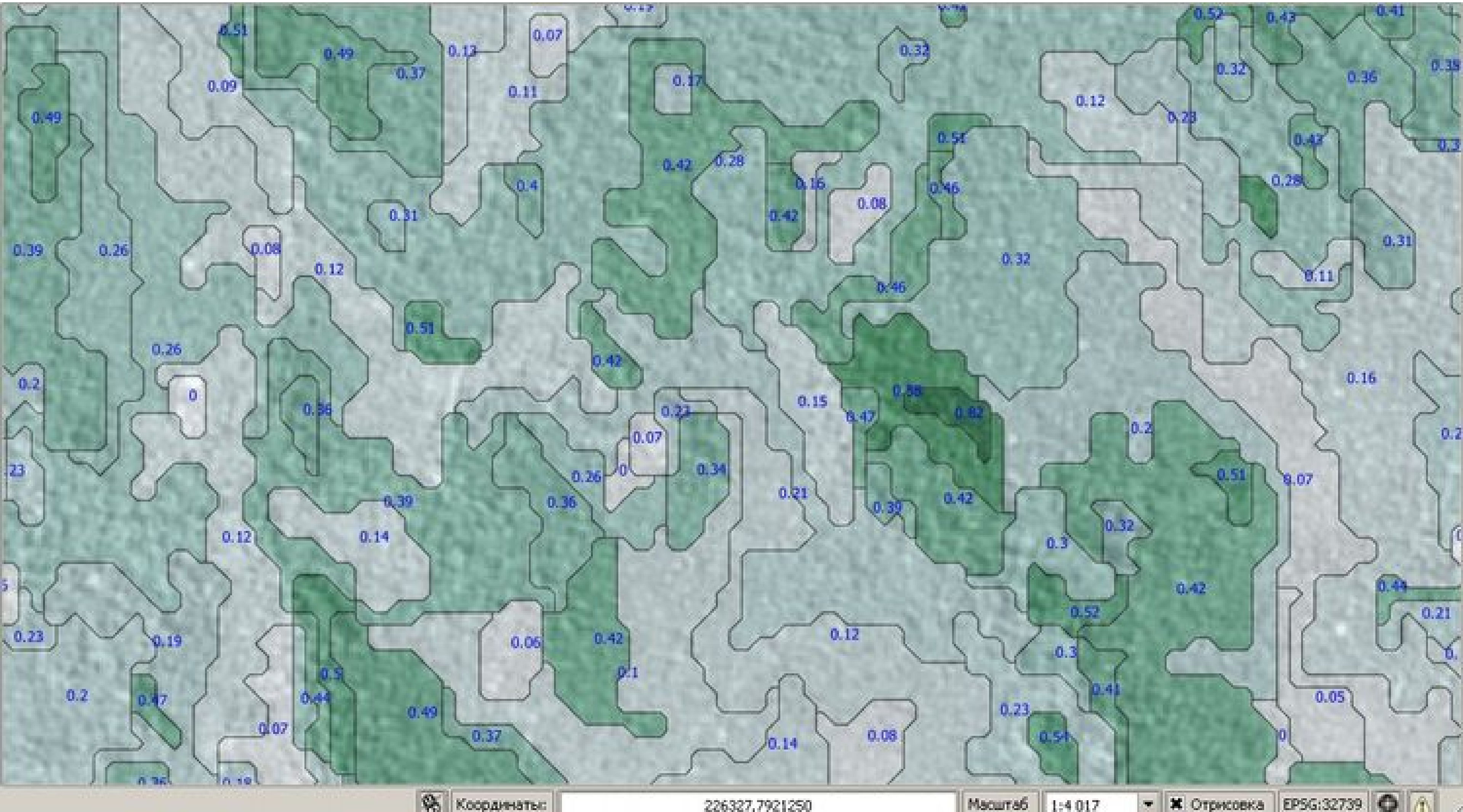
Algorithm details

Calculate density of shadow – counting the pixels for each polygon/area, (shadow pixels number / area of a polygons * 100)



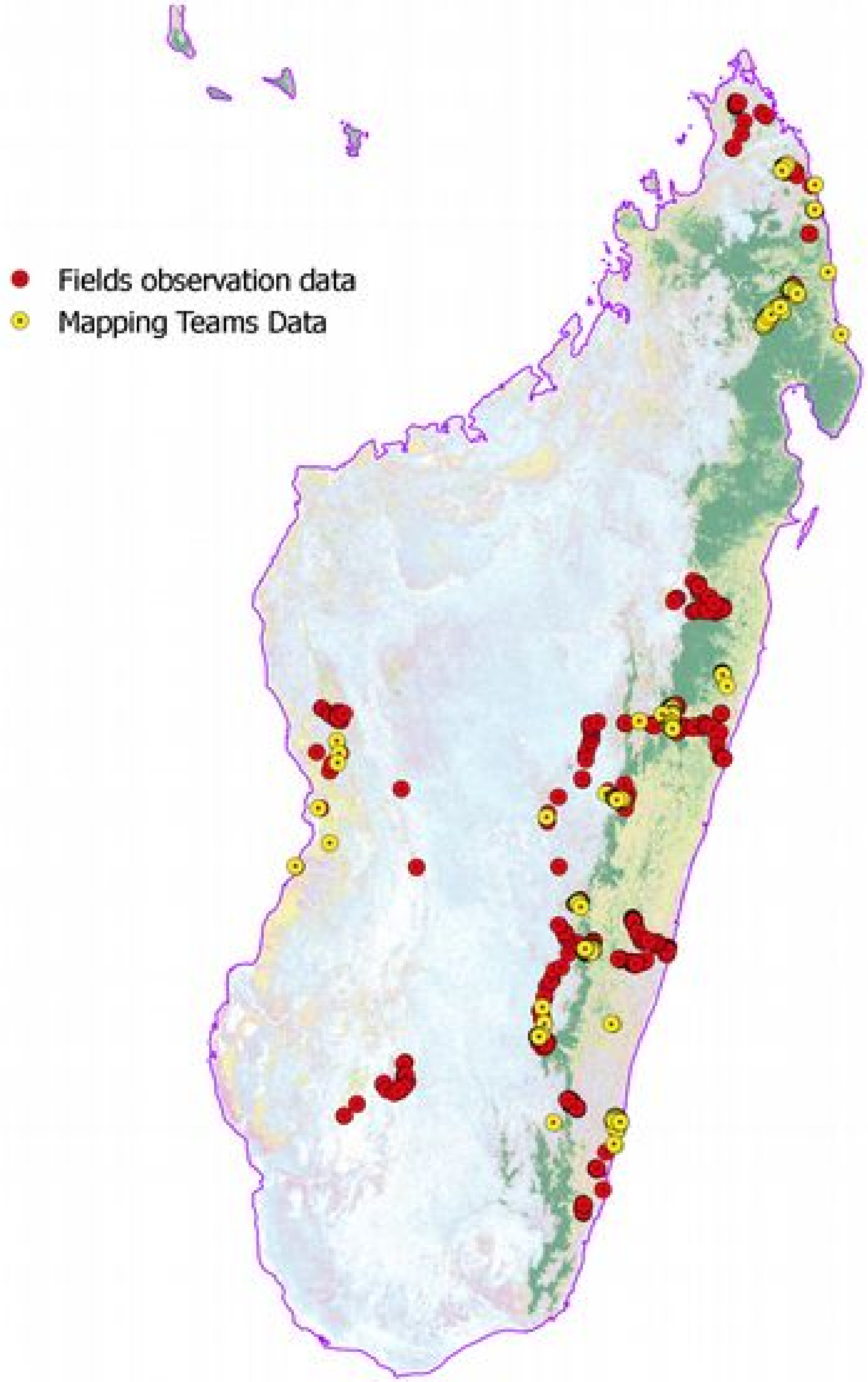
Algorithm details

Maps of forest structure complexity based on density of shadows



The classification
based on the canopy complexity measurement

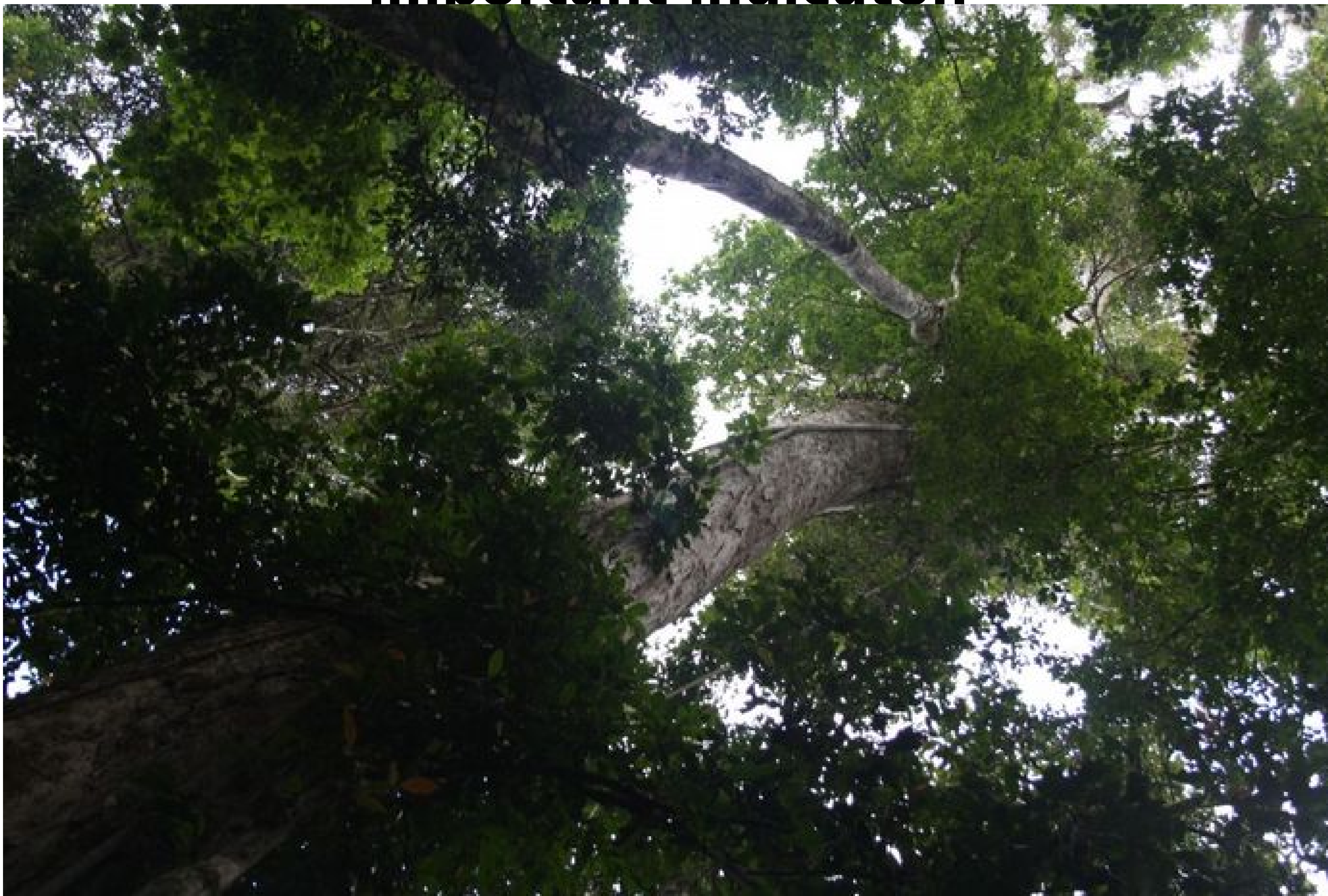
- Shadows density below 0.1 – **Non-forests**
- Shadows density 0.1-0.2 – **Single layer (SL) forests**
- Shadows density 0.2-0.3 – **Single layer forests with big tress (SL BT)**
- Shadows density over 0.3 – **Multi-layer (ML) forests**



Field surveys of various forests in eastern Madagascar by Malagasy colleagues from local associations and by joint Malagasy-FANC-TW teams

The field observations proved that the canopy complexity alone does not reflect the whole diversity of human-made and natural disturbances.

Both, Malagasy and international experts, concluded that canopy coverage is another important indicator.



Multi-layer forest with closed canopy, Mantadia National Park


Multi-layer forests with canopy gaps,
Andringitra National Park

Multi-layer forest with large canopy gaps, Andringitra National Park

Extending the classification – taking canopy coverage into account

(percentages are indicative only and require field measurements for verification – the coverage has been visually identified with high-resolution images)

- High coverage canopy (over 70% coverage ??)
- Medium coverage canopy (40-70% ??)
- Low coverage canopy (20-40% ??)
- Very low coverage canopy (below 20% ?? – non-forest)

Forest degradation classes scheme

Canopy coverage				
High	Bush lands & woodlands	SL closed	-- (not found yet)	ML closed
Medium	Transition from grasslands to bush lands	SL sparse	SL with big trees	ML with gaps
Low				ML with large gaps
Very low	Grasslands & bare ground	--	--	--
	Non-forest	Single layer	SL with big trees	Multilayer
	Canopy structure complexity			

What real forests are in these classes?

<table>
<tr><th>Canopy coverage</th><th>Non-forest</th><th>Single layer</th><th>SL with big trees</th><th>Multilayer</th></tr>
<tr><td>High</td><td>Bush lands
Invasive species thickets
Native pioneer species thickets</td><td>Secondary forests with native species
Closed eucalyptus & pine plantations</td><td>--</td><td>Closed intact forests on slopes</td></tr>
<tr><td>Medium</td><td rowspan="2">Early stages of forest restoration

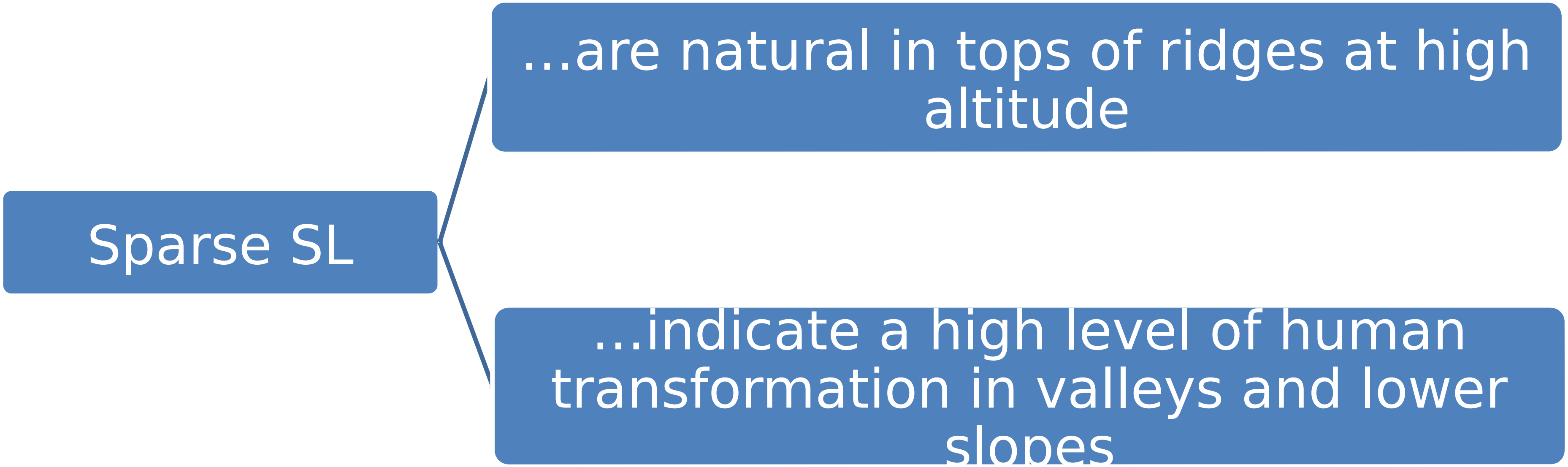
Mosaic of fields, grazing areas and introduced species

Ravenala in mixture with other trees & bushes</td><td rowspan="2">Secondary forests with serious recent disturbance

Intact sparse forests at high altitude, usually on top of ridges</td><td rowspan="2">Intact sparse forests on tops of ridges

Slightly disturbed forests on slopes and valleys</td><td>Intact forest in lower slopes & river valleys
Some disturbed forests</td></tr>
<tr><td>Low</td><td>Intact forests in valleys / affected by cyclones
Disturbed with zebu grazing / logging</td></tr>
<tr><td>Very low</td><td>Natural rocks
After tavy areas
Degraded lands</td><td>--</td><td>--</td><td>--</td></tr>
</table>

Other characteristics also should be taken into account – like the altitude and the location in the relief



SPOT spectral channels could also help separating native trees forests from introduced tree species planted, as well as various forest types

- SL closed
  - SL forests by native species
  - Eucalyptus plantations
  - Pine plantations
- SL with big trees
  - Mountain forests (Andasibe, Ranomafana)
  - Low-land forests (Manombo)
  - Littoral forests

The final classification scheme

<table>
<tr><th>Canopy coverage</th><th>Non-forest</th><th>Single layer</th><th>SL with big trees</th><th>Multilayer</th></tr>
<tr><td>High</td><td>4.1a. Savoka & Savoka with single trees
4.1b. Pure bamboo thickets - ??
4.1c. Pure ravenala thickets - ??
4.1d. Filippia thickets - ??</td><td>3.1a. SL closed – mountain forests
3.1b. SL closed – lowland forests
3.1c. SL closed – littoral forests
3.1d. – Eucalyptus plantations
3.1e. – Pine plantations</td><td>--
(not found yet)</td><td>1.1. ML closed</td></tr>
<tr><td>Medium</td><td rowspan="2">4.2. Mosaic of ramarasana, crops, savoka & woodlands</td><td rowspan="2">3.2a. SL sparse – high altitude forests

3.2b. SL sparse – slopes & valleys</td><td rowspan="2">2.1a. SL with big trees – top of ridges forests
2.1b. SL with big trees – lowland forests
2.1c. SL with big trees – littoral forests</td><td>1.2. ML with gaps</td></tr>
<tr><td>Low</td><td>1.3. ML with large gaps</td></tr>
<tr><td>Very low</td><td>4.3a. Bare ground
4.3b. Ramarasana
4.3c. Roranga</td><td>--</td><td>--</td><td>--</td></tr>
</table>

The final list of classes

Clas s №	Class Name	Canop y compl exity	Canop y densit y	Spectral features 4-1-3 channels	Location in the landsca pe	Real ecosystems included
1.1	ML closed	> 0.3	high	Dark-green	Slope	Intact humid forest
1.2	ML with gaps	> 0.3	mediu m	Dark-green to bright-yellow-green	Valley, Lower slope	Intact humid forest
1.3	ML with large gaps	> 0.3	low	Bright-yellow-green	Valley	Humid forest with cyclone dynamic or slightly selectively logged
2.1a	SL with BT on tops	0.2-0.3	med.-low	Blue-green to grey -green	Top, upper slope	Intact forest on top of the ridge, could be selectively logged

The final list of classes (continued)

Class №	Class Name	Canopy complexity	Canopy density	Spectral features 4-1-3 channels	Location in the landscape	Real ecosystems included
2.1b	SL with BT lowland	0.2-0.3	med.-low	Bright-light-green	Lower slope, valley	Most intact forest in lowlands
2.1c	SL with BT littoral	0.2-0.3	med.-low	Blue-green	Flat,valley	Most intact forest in lowlands
3.1a	SL closed mountain	0.1-0.2	high	Blue-green to grey	all	Heavy selectively logged or secondary forest after “tavy” in mountain region
3.1b	SL closed lowland	0.1-0.2	high	Bright-green	all	Secondary forest in lowlands with Ravenala

The final list of classes (continued)

Class №	Class Name	Canopy complexity	Canopy density	Spectral features 4-1-3 channels	Location in the landscape	Real ecosystems included
3.1c	SL closed littoral	0.1-0.2	high	Blue-green	Flat,valley	Secondary forest
3.1d	Eucalyptus closed	0.1-0.2	high	Acid-green	all	Plantation
3.1e	Pine closed	0.1-0.2	high	Green to red-grey	Slope,top	Plantation
3.1f	Eucalyptus,Pine mixed with native	0.2-0.3	high	Dark-green to grey	all	Old plantations or forest on border with native
3.1g	Fruits plantation, gardens near villages, Ravenala in lowlands??	0.1-0.2	Medium,low	Bright yellow-green	flat	Plantation near settlements, Ravenala forests??

The final list of classes (continued)

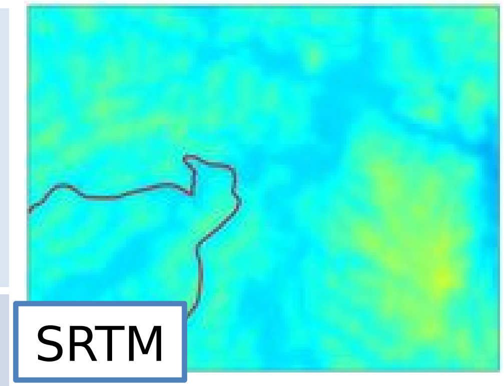
Class №	Class Name	Canopy complexity	Canopy density	Spectral features	Location in the lanscape	Real ecosystems included
3.2a	SL spare high altitude	0.1-0.2	med.-low	Grey – green with purple colors	tops, high altitude	Intact or cyclone affected forests on high altitude tops of ridges
3.2b	SL spare on slopes/valleys	0.1-0.2	med.-low	Bright-yellow with bright green	slopes, valleys	Selectively logged or secondary valley forests
4.1a	Savoka	< 0.1	high	Bright yellow	all	Shrubland after disturbances
4.3a	Bare ground, fields	< 0.1	very low	Bright red to white	Slope,top	Tavy, rocks, crops
4.3b	Ramarasana	< 0.1	very low	Blue-white to bright light green	all	grasslands, shrubs

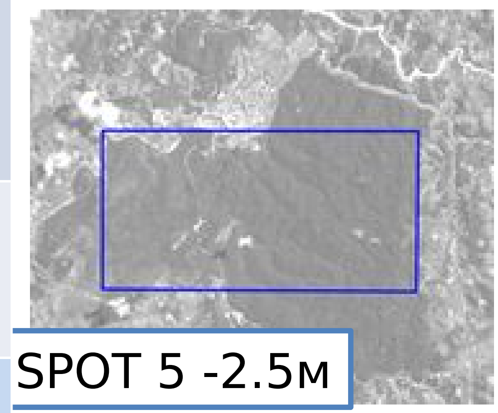
The final list of classes (continued)

Class №	Class Name	Canopy complexity	Canopy density	Spectral features	Location in the lanscape	Real ecosystems included
4.3c	Roranga	< 0.1	very low	Dark red	all	long-term grassland
4.1b	Bamboo thickets	< 0.1	high	Not selected yet	-	-
4.1c	Ravenala thickets	< 0.1	high	Not selected yet	-	-
4.1d	Filippia thickets	< 0.1	high	Not selected yet	-	-
4.2	Mosaic of crops, ramarasana, savoka	< 0.1	med.-low	Grey to red	all	

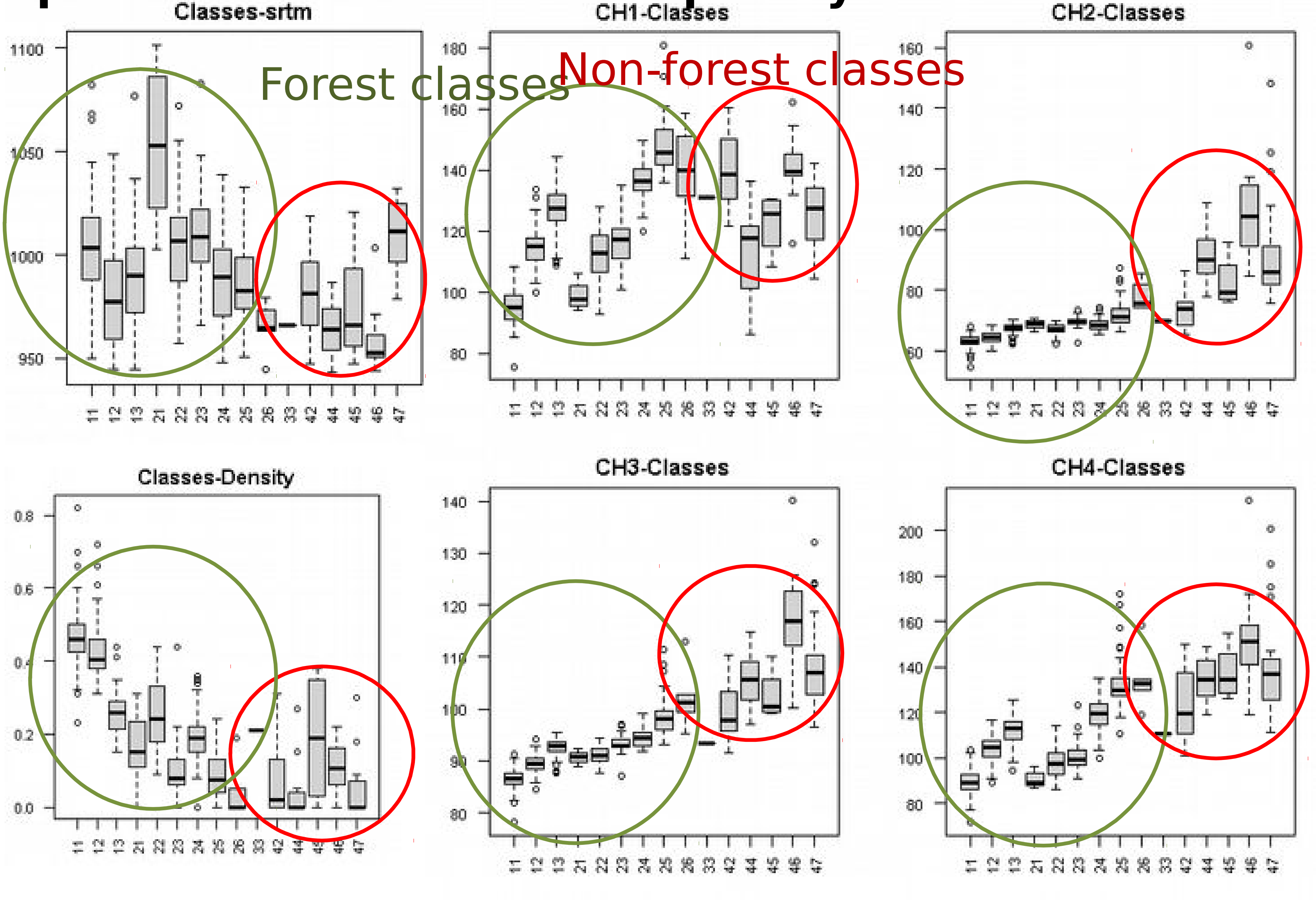
Employing the Random Forests algorithm for classifying forest stands by all their parameters measured by DEM and SPOT images (using GRASS; R-randomForest; QGIS)

STEP 1	Segmentation of SPOT images by spectral channels, 10m resolution (GRASS GIS module i.segment with the following parameters: min area – 10 pixels, similarity threshold = 0.3 for spectral channels).
STEP 2	Adding main statistical parameters from spectral image channels and DEM data to each polygon: mean, standard deviation, minimum, maximum, range to each polygon; as well as canopy complexity data.
STEP 3	Creating educational set of data, using high-resolution image and field observation data as needed.
STEP 4	Creating model using the advanced decision trees algorithm - R:randomForest. Estimate model of classification, data statistics for each class, inner model quality and errors.
STEP 5	Applying model to whole set of data and export result map (QGIS).





Analyzing all data together: importance of DEM, spectral channels and complexity data



Example of model quality (ANDASIBE)

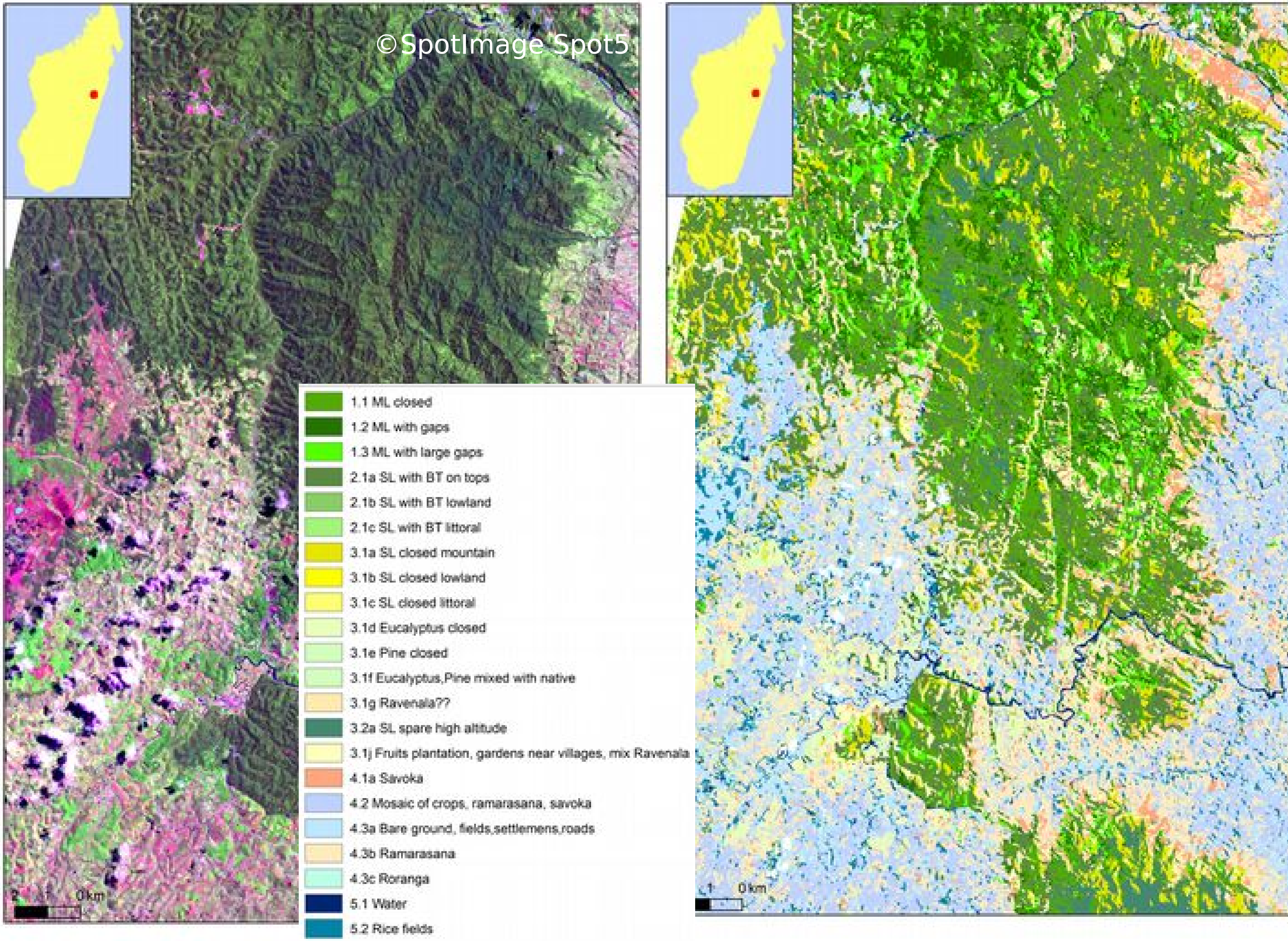
```
Call:
 randomForest(formula = as.factor(test$CLASSID) ~ ., data = test
               Type of random forest: classification
                     Number of trees: 10000
No. of variables tried at each split: 10

        OOB estimate of  error rate: 29.02%
Confusion matrix:
```

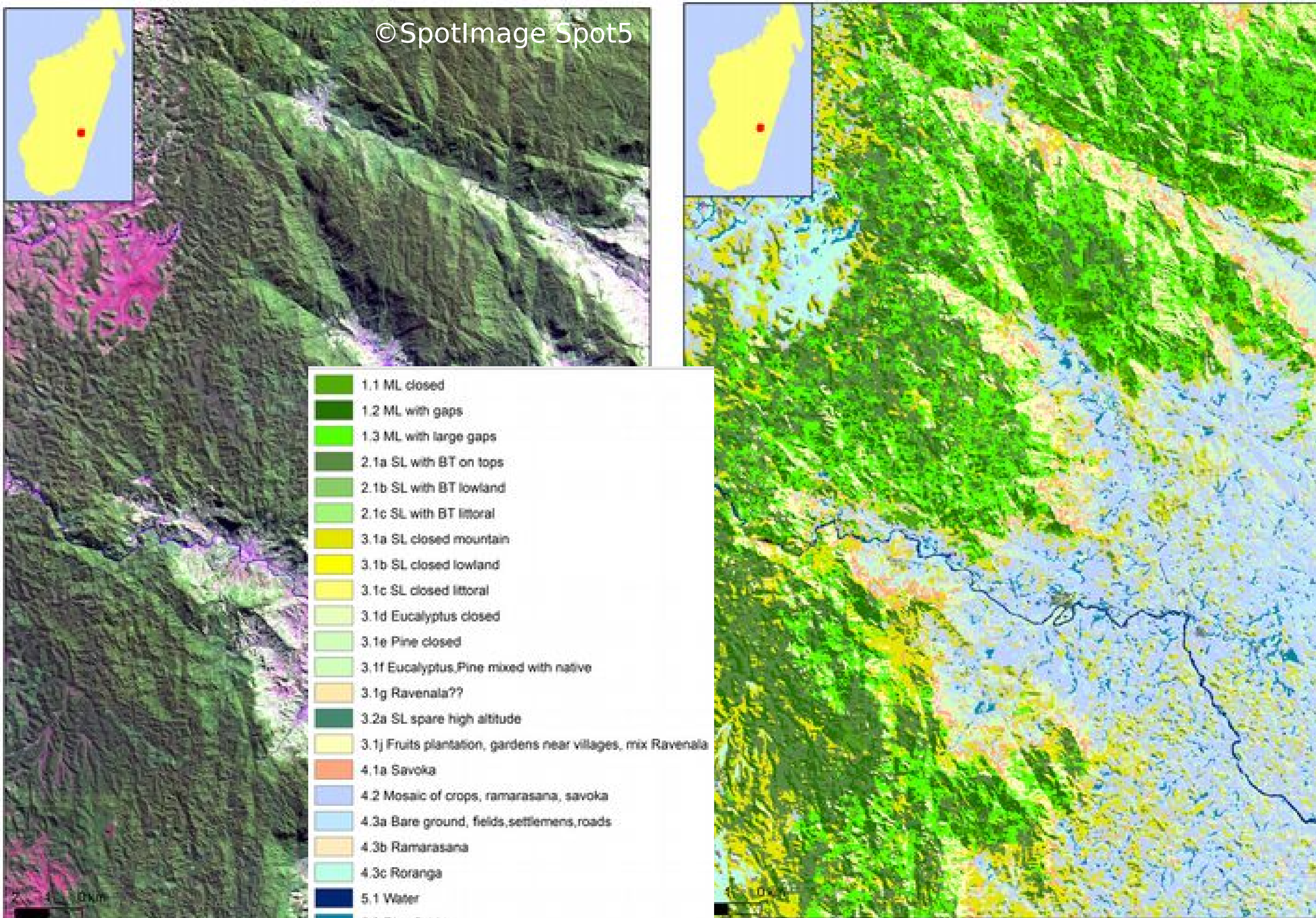
	11	12	13	21	22	23	24	25	26	33	42	44	45	46	47	class.error
11	73	7	0	0	4	0	0	0	0	0	0	0	0	0	0	0.13095238
12	5	73	4	0	2	0	0	0	0	0	0	0	0	0	0	0.13095238
13	0	7	46	0	7	2	14	0	0	0	0	0	0	0	0	0.39473684
21	0	0	0	3	4	1	0	0	0	0	0	0	0	0	0	0.62500000
22	3	5	7	0	47	8	0	0	0	0	0	0	0	0	0	0.32857143
23	1	0	1	0	7	35	2	0	0	0	0	0	0	0	0	0.23913043
24	0	0	13	0	0	1	50	13	0	0	0	0	0	0	0	0.35064935
25	0	0	0	0	0	0	11	35	1	0	2	0	0	1	0	0.30000000
26	0	0	0	0	0	1	0	3	0	0	1	1	0	0	0	1.00000000
33	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1.00000000
42	0	0	2	0	0	1	7	8	0	0	1	0	0	0	0	0.94736842
44	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1	0.08333333
45	0	1	0	0	0	0	1	0	0	0	0	2	0	0	0	1.00000000
46	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0.07142857
47	0	0	0	0	0	1	0	1	0	0	0	0	0	0	19	0.09523810

```
>
```

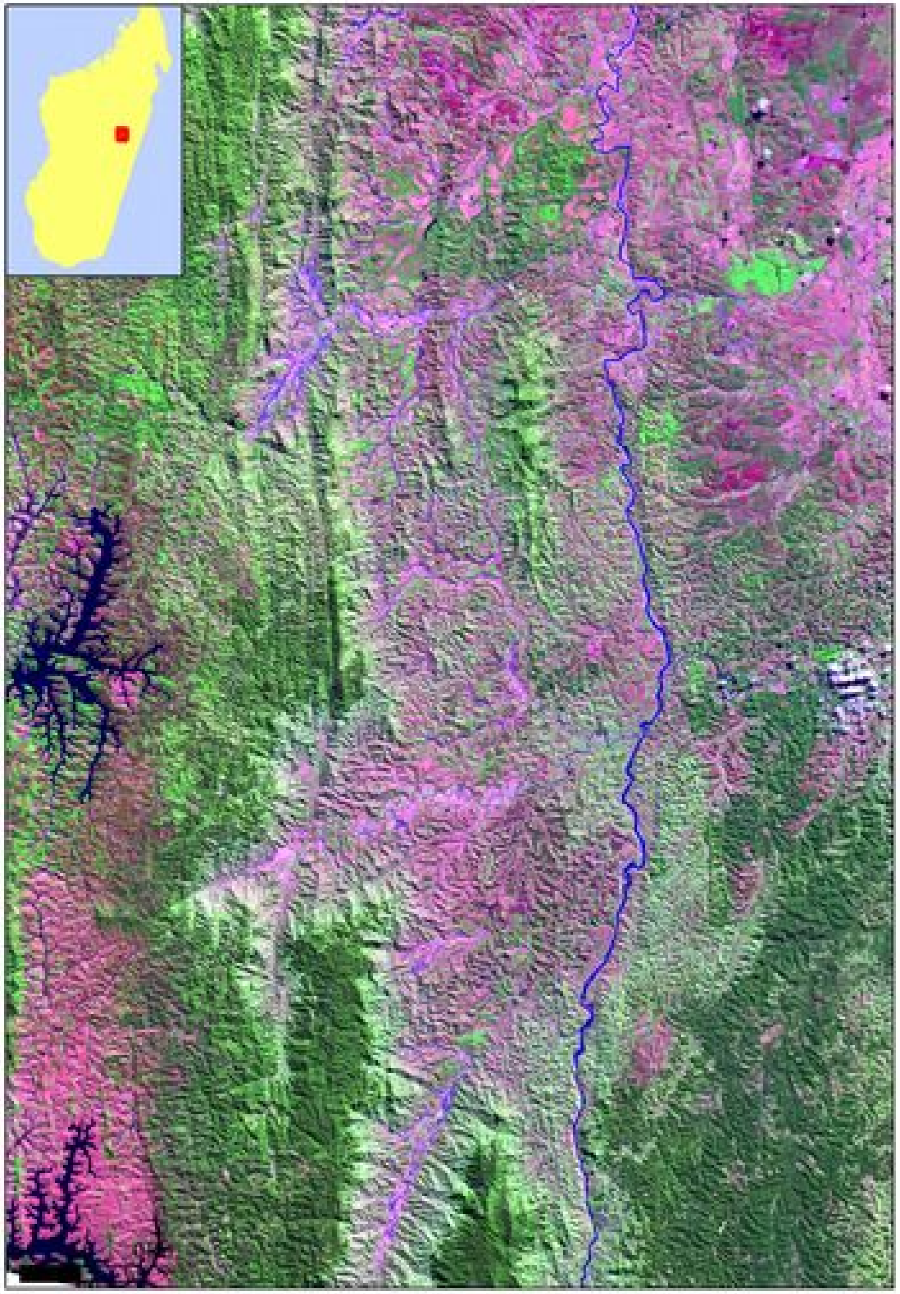
RESULTS: Mantadia

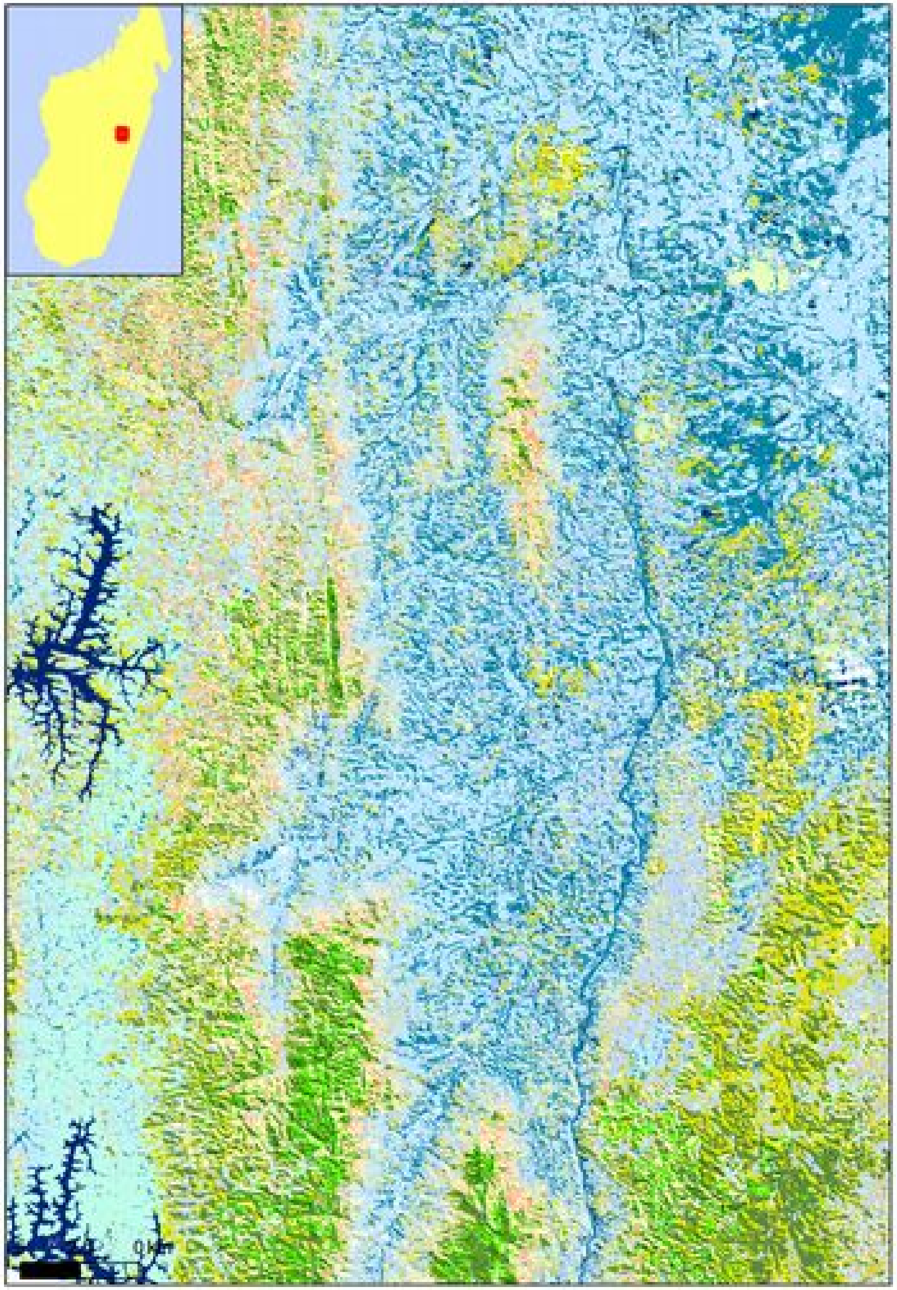


RESULTS: Ranomafana

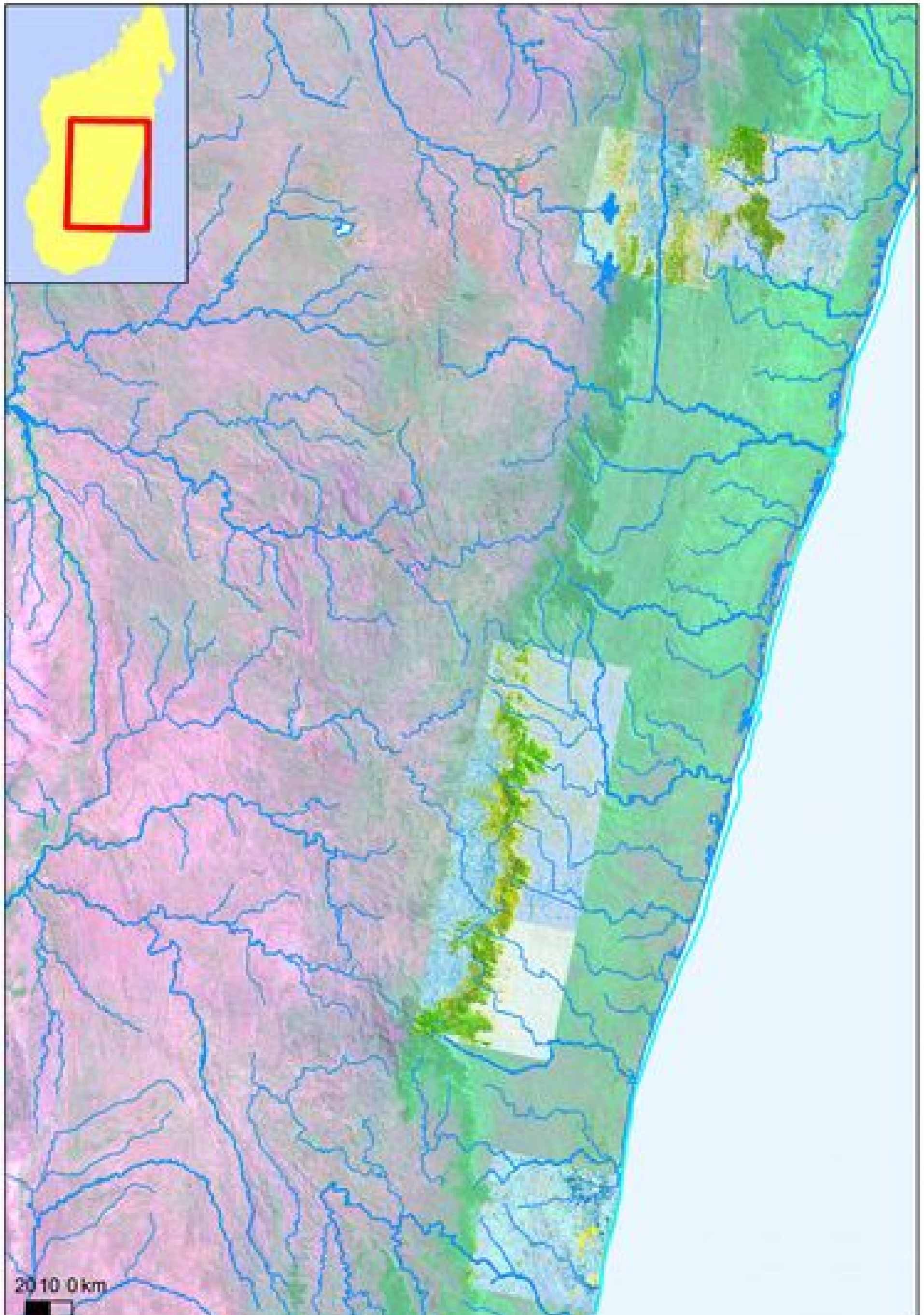


RESULTS: Andasibe-West





RESULTS: Maps for pilot areas



- 1.1 ML closed
- 1.2 ML with gaps
- 1.3 ML with large gaps
- 2.1a SL with BT on tops
- 2.1b SL with BT lowland
- 2.1c SL with BT littoral
- 3.1a SL closed mountain
- 3.1b SL closed lowland
- 3.1c SL closed littoral
- 3.1d Eucalyptus closed
- 3.1e Pine closed
- 3.1f Eucalyptus,Pine mixed with native
- 3.1g Ravenala??
- 3.2a SL spare high altitude
- 3.1j Fruits plantation, gardens near villages, mix Ravenala
- 4.1a Savoka
- 4.2 Mosaic of crops, ramarasana, savoka
- 4.3a Bare ground, fields,settlemens,roads
- 4.3b Ramarasana
- 4.3c Roranga
- 5.1 Water
- 5.2 Rice fields

Further plans

- Completing the forest intactness / transformation map for the whole moist forests of Madagascar
- Field verification and adjusting the classes accordingly
- Expanding for semi-dry and dry forests
- Developing the forest degradation monitoring system based on the maps and measuring methods (by local people)
- Cooperation with the Global Forest Watch (initiative of the World Resources Institute, DC, USA) starting the project in Madagascar next year (www.globalforestwatch.org)

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