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planet.

The effect of satellite image resolution and minimum mapping unit on the accuracy of forest cover maps

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Master's Thesis

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Overview

1. Introduction
2. Theoretical background
3. Test areas and data
4. Forest cover mapping and accuracy assessment
5. Results and discussion
6. Conclusions
7. Future work

1. Introduction

1.1 Context

1.2 Motivation

1.3 Research questions

1.1 Context

- Reducing emissions from deforestation and forest degradation (REDD+)

UN-REDD PROGRAMME

- REDD+ MRV

Measurement
Reporting
Verification

- Forest Degradation Monitoring with Satellite Data (FORMOSA)

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esa European Space Agency

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1.2 Motivation

- Carbon stock changes can be quantified accurately only if forest cover is mapped with high accuracy.

- How does the accuracy of forest cover maps vary in relation to the spatial and spectral resolution of satellite imagery and possible Minimum Mapping Units (MMUs) utilized for mapping forest?

- Quantifying the accuracy of forest cover maps can help REDD+ countries decide on the satellite imagery spatial resolution and MMU to be used for monitoring deforestation and forest degradation.

1.3 Research Questions

- How do different high- and medium-resolution satellite sensors affect the accuracy of forest cover mapping?
- How does the size of MMUs affect the accuracy of forest cover mapping?

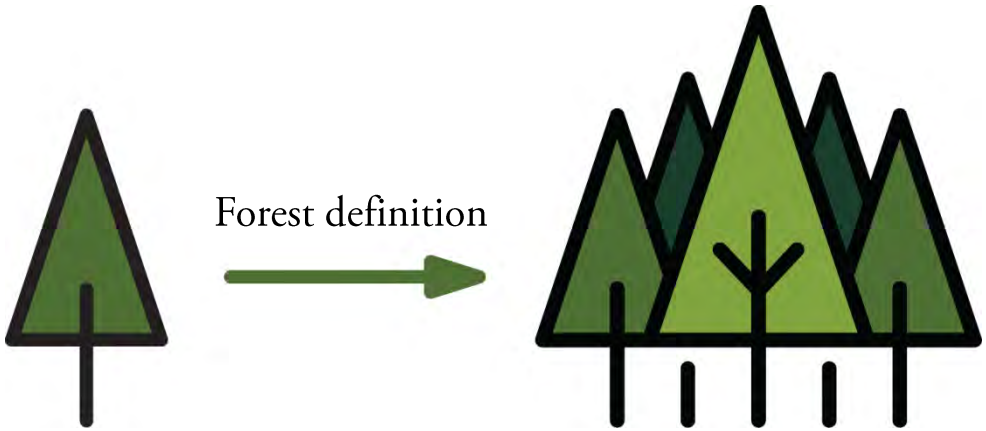
2. Theoretical Background

2.1 Forest mapping with remote sensing data

2.2 Minimum mapping unit in forest cover mapping

2.3 Accuracy assessment of remotely sensed data

2.1 Forest mapping with remote sensing data



High-resolution satellite imagery
Magdon et. al.

→ Hierarchical classification scheme

Medium-resolution satellite imagery
Asner et. al.

→ Subpixel decomposition method

2.2 Minimum Mapping Unit (MMU)

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Magdon and Kleinn	→	Investigated the MMU and crown cover threshold relationship on forest edge models	→ Different MMUs and fixed crown cover threshold affect the proportion of mapped forest and its pattern
Kleinn	→	Relationship between crown cover threshold and MMU with respect to the forest cover area estimates	→ MMU and crown cover threshold affect total forest cover area estimates

2.3 Accuracy Assessment

Thematic accuracy assessment: measurest the agreement between the feature labels on the map and the feature labels from the reference data.

Components of rigorous accuracy assessment:

- The sampling design
- The response design
- The analysis

Error/Confusion Matrix:

		Reference				
		1	2	⋯	q	
Map	1	p_{11}	p_{12}	⋯	p_{1q}	p_{1+}
	2	p_{21}	p_{22}	⋯	p_{2q}	p_{2+}
	⋮	⋮	⋮	⋯	⋮	
	q	p_{q1}	p_{q2}	⋯	p_{qq}	p_{q+}
		p_{+1}	p_{+2}	⋯	p_{+q}	

Figure 2: Error matrix for q classes

3. Test areas and data

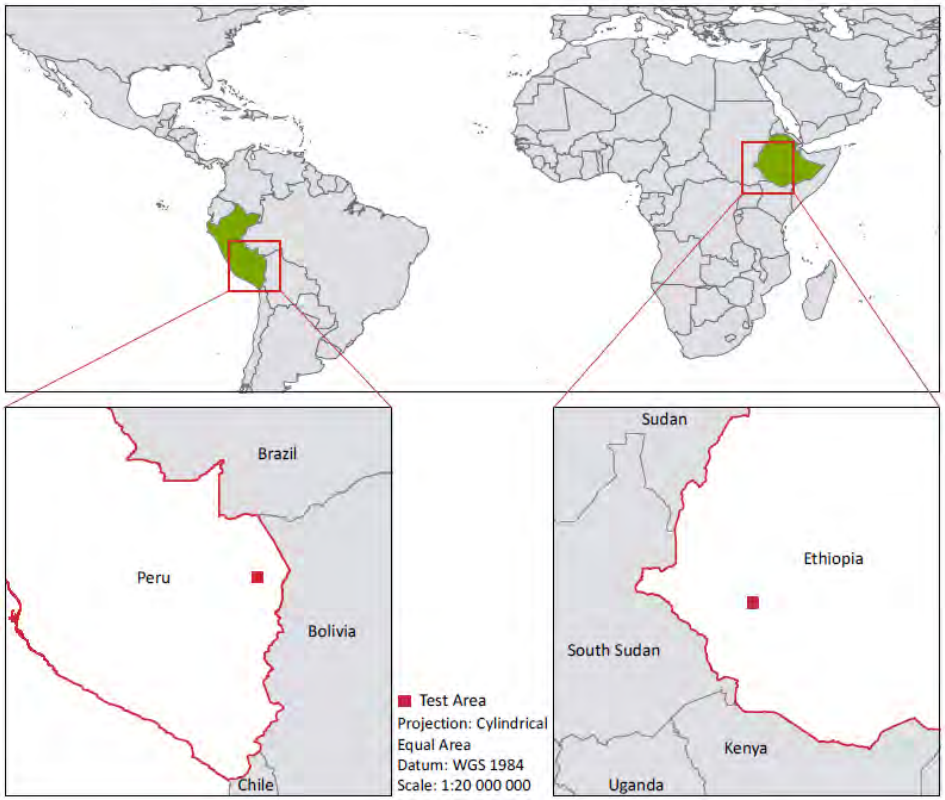

Figure 1: Accuracy assessment test areas

Satellite	Spatial resolution	Number of spectral bands	Processing level
RapidEye	5 m	5	3A
Landsat-8	30 m	11	1T
Sentinel-2	10 m	13	1C

Table 1: Satellite specifications

4. Forest cover mapping and accuracy assessment

4.1 Image pre-processing and Forest cover mapping for REDD+ MRV

4.2 Forest cover mapping from high-resolution satellite imagery

4.3 Forest cover mapping from medium-resolution satellite imagery

4.4 Accuracy test of forest maps derived from high- and medium-resolution imagery

4.5 Minimum mapping unit forest map accuracy test

4.1 Image pre-processing and Forest cover mapping for REDD+

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Image pre-processing:

- Co-registration

Automatically and manually

- Atmospheric Corrections

ATCOR IDL 8.4

- Haze reduction

ATCRO PCI Geomatics

- Clipping

PCI Geomatics

Forest definition:

- Minimum forest area (MMU)
- Minimum tree crown cover threshold

Ethiopia:

- 20% tree crown cover
- 0.5 ha MMU
- 2 m minimum height

Peru:

- 10% tree crown cover
- 0.09 ha MMU
- 5 m minimum height

4.2 Forest cover mapping from high-resolution satellite imagery

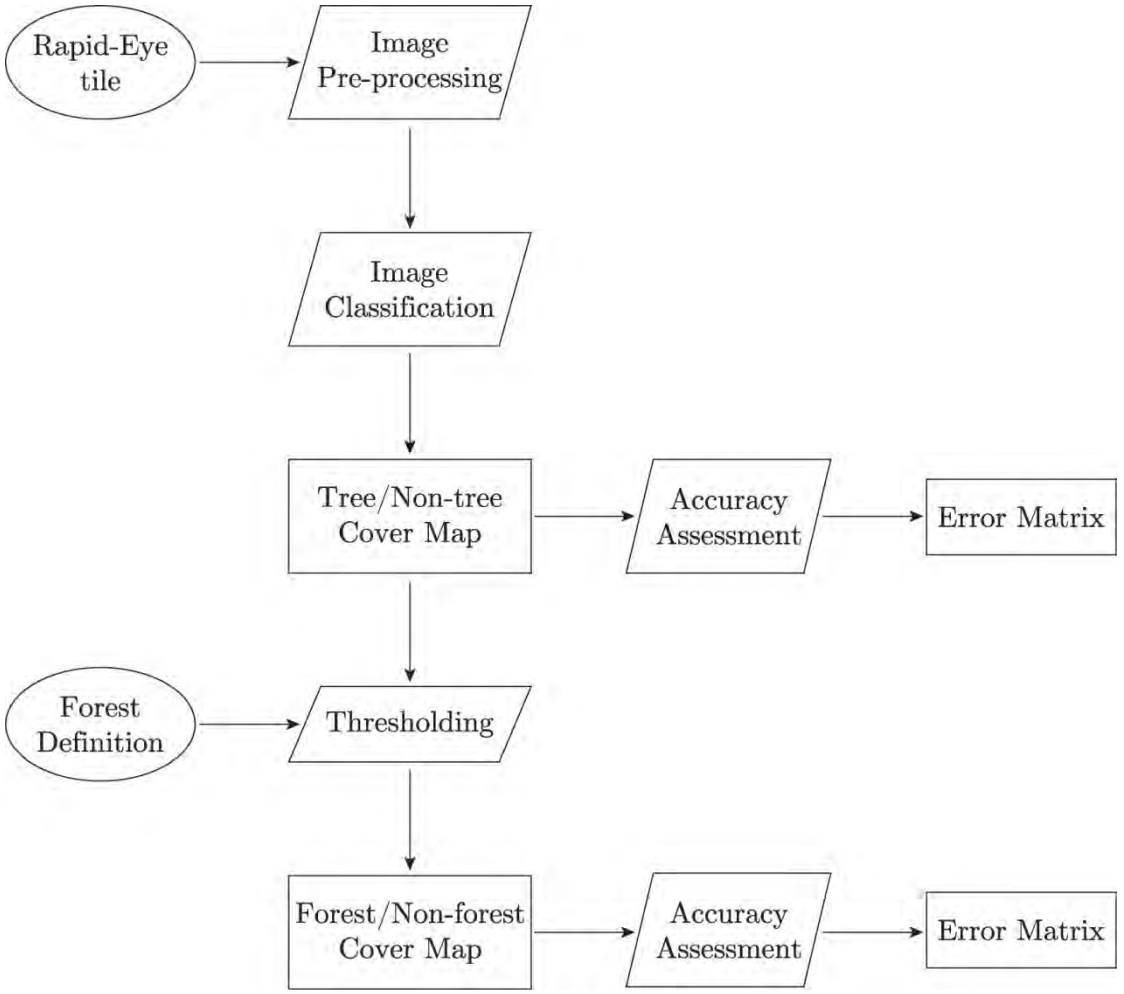

Figure 2: Forest cover mapping workflow for high-resolution imagery

4.3 Forest cover mapping from medium-resolution satellite imagery

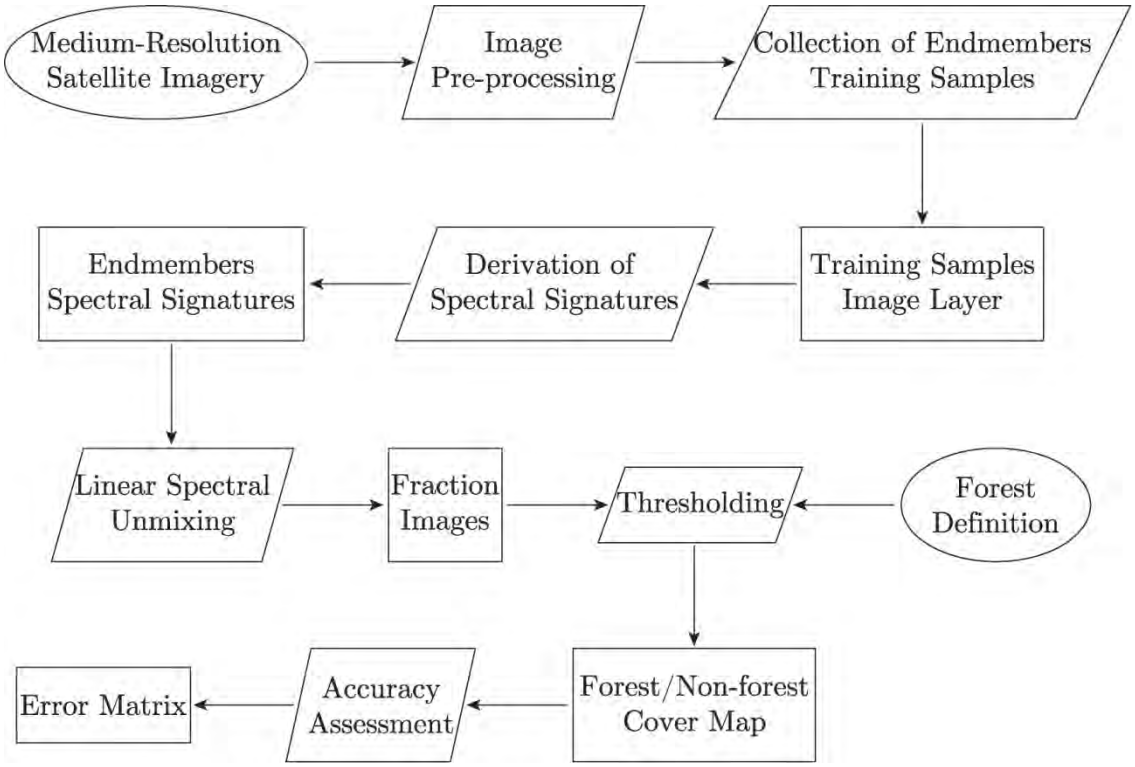

Figure 3: Forest cover mapping workflow for medium-resolution imagery

4.4 Accuracy test of forest maps derived from high- and medium-resolution imagery

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- Quantified the effect of image resolution on the accuracy of forest cover maps

- Simple random sampling approach
- 302 sample points
- Dot-grid sampling technique

Test area	Satellite	Forest cover map MMU	Forest cover mapping method
Ethiopia & Peru	RapidEye	15 m x 15 m	4.2.1
Ethiopia & Peru	Landsat-8	30 m x 30 m	4.2.2
Ethiopia & Peru	Sentinel-2	10 m x 10 m	4.2.2

Table 2: List of forest cover maps that were assessed for accuracy

Test area	Satellite	Reference datasource	Spatial assessment unit	MMU	Reference classification scheme
Ethiopia & Peru	RapidEye	Google Earth	15 m	15 m	Forest; Non-forest
Ethiopia & Peru	Landsat-8	Google Earth	30 m	30 m	Forest; Non-forest
Ethiopia & Peru	Sentinel-2	Google Earth	10 m	10 m	Forest; Non-forest

Table 3: Components of response design protocol

4.5 Minimum mapping unit forest map accuracy test

- Quantified the effect MMU on the accuracy of forest cover maps
- Simple random sampling approach
- 1449 sample points
- Reference data: tree cover map
- Point sample unit

Test area	Satellite	Forest cover map MMU [m]	Forest cover map MMU [pixels]
Ethiopia & Peru	RapidEye	15 x 15	3 x 3
		30 x 30	6 x 6
		50 x 50	10 x 10
		70 x 70	14 x 14
		100 x 100	20 x 20
		150 x 150	30 x 30
		200 x 200	40 x 40
		250 x 250	50 x 50
		300 x 300	60 x 60

Table 4: List of forest cover maps assessed for accuracy

5. Results

5.1 Accuracy test of forest maps derived from high- and medium-resolution imagery

5.2 Minimum mapping unit forest map accuracy test

5.1 Accuracy test of forest maps derived from high- and medium-resolution imagery

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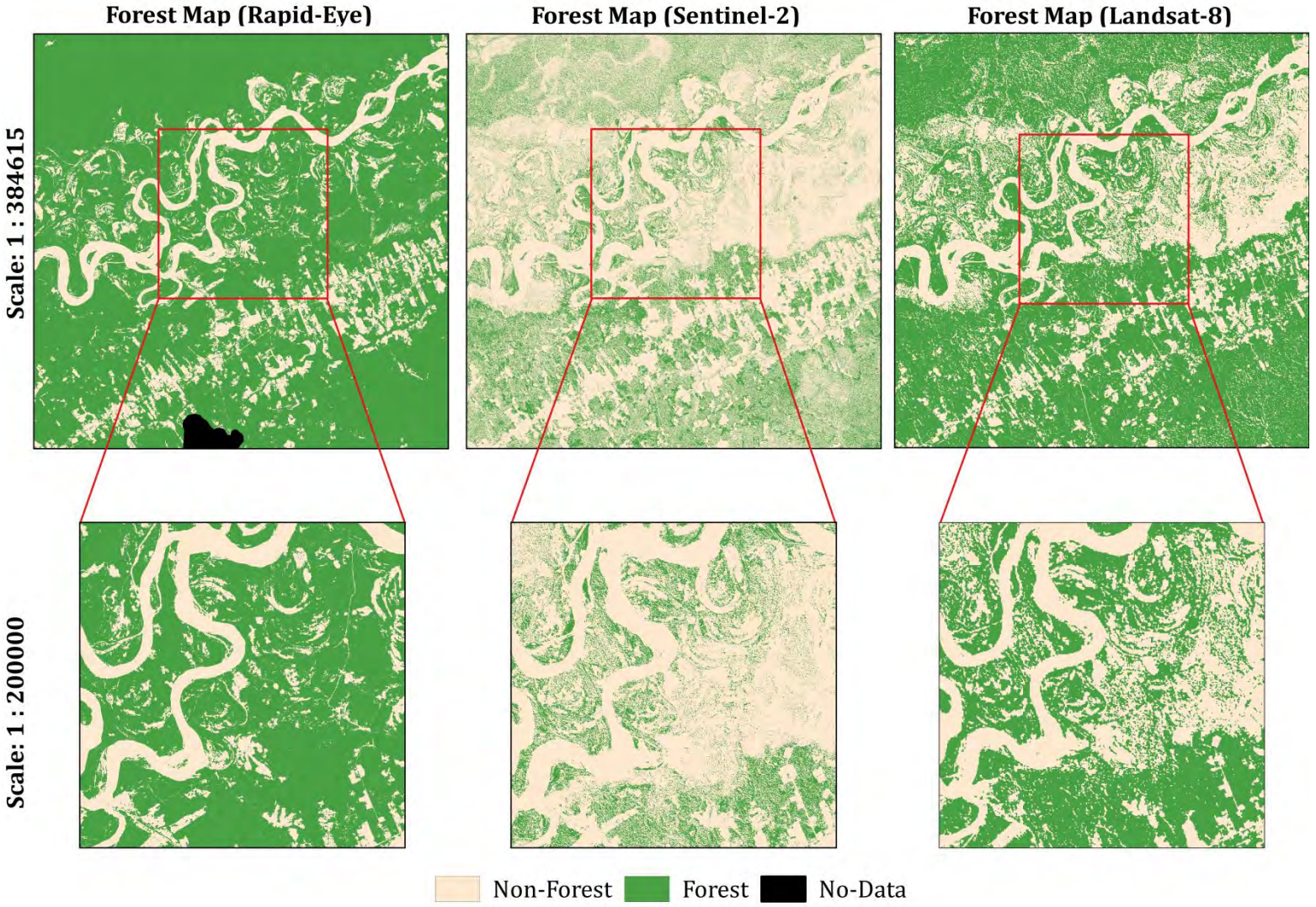

5.1 Accuracy test of forest maps derived from high- and medium-resolution imagery

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Satellite sensor	Overall accuracy
RapidEye	95.56% ± 2.31%
Sentinel-2	52.63% ± 4.70%
Landsat-8	78.25% ± 4.06%

Table 5: Overall accuracies with confidence intervals

Satellite sensor	Mapped area		Corrected area	
	Forest	Non-forest	Forest	Non-forest
RapidEye	80.1%	19.9%	76.47% ± 2.30%	23.53% ± 2.30%
Sentinel-2	27.3%	72.7%	76.81% ± 5.77%	23.19% ± 5.77%
Landsat-8	61.8%	38.2%	77.87% ± 5.11%	22.13% ± 5.11%

Table 6: Mapped and corrected area proportions with confidence intervals

5.1 Accuracy test of forest maps derived from high- and medium-resolution imagery

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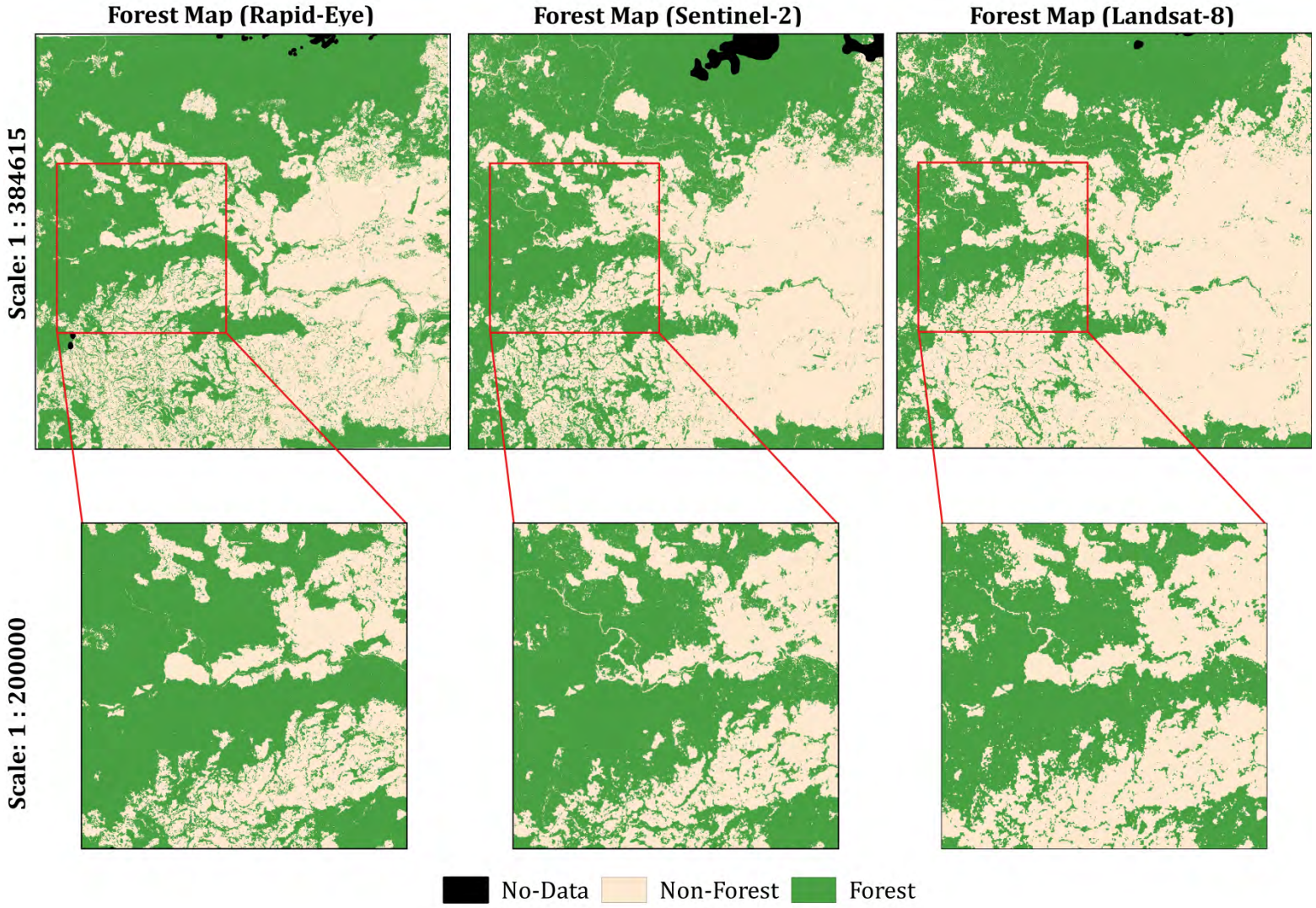

5.1 Accuracy test of forest maps derived from high- and medium-resolution imagery

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Satellie sensor	Overall accuracy
RapidEye	94.72% ± 2.52%
Sentinel-2	87.00% ± 3.80%
Landsat-8	86.77% ± 3.66%

Table 7: Overall accuracies with confidence intervals

Satellite sensor	Mapped area		Corrected area	
	Forest	Non-forest	Forest	Non-forest
RapidEye	52.6%	47.4%	51.28% ± 2.60%	48.72% ± 2.60%
Sentinel-2	48.2%	51.8%	49.87% ± 4.08%	50.13% ± 4.08%
Landsat-8	41.8%	58.2%	53.72% ± 3.88%	46.28% ± 3.88%

Table 8: Mapped and corrected area proportions with confidence intervals

5.2 Minimum mapping unit forest map accuracy test

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MMU 3 x 3 pixels

5.2 Minimum mapping unit forest map accuracy test

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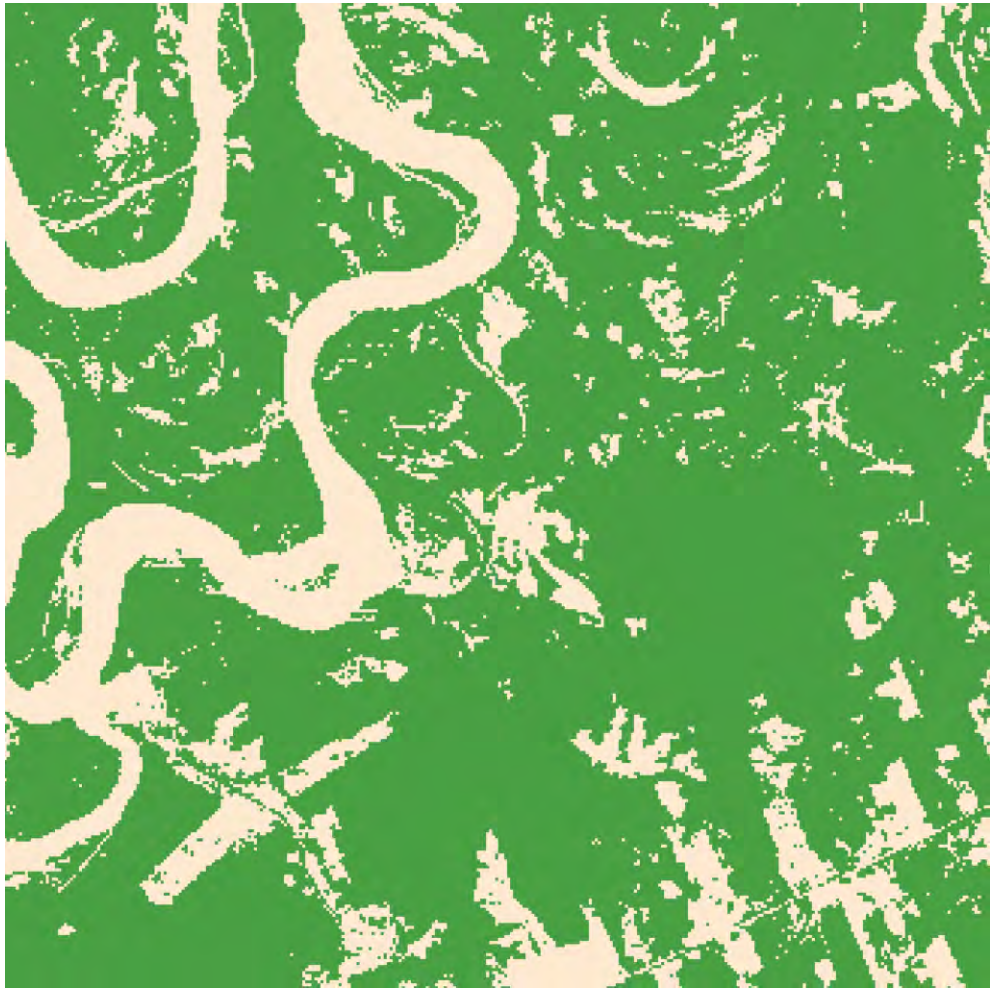

MMU 6 x 6 pixels

5.2 Minimum mapping unit forest map accuracy test

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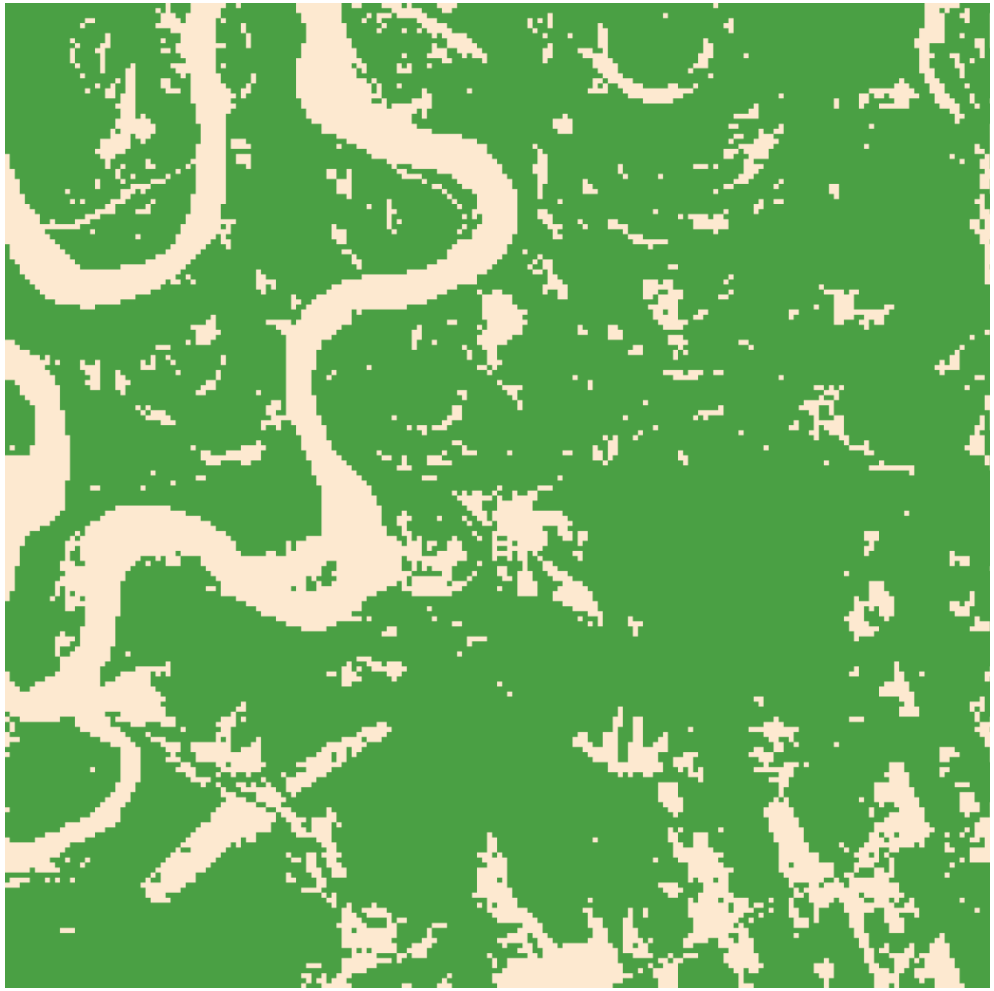
PERU



MMU 10 x 10 pixels

5.2 Minimum mapping unit forest map accuracy test

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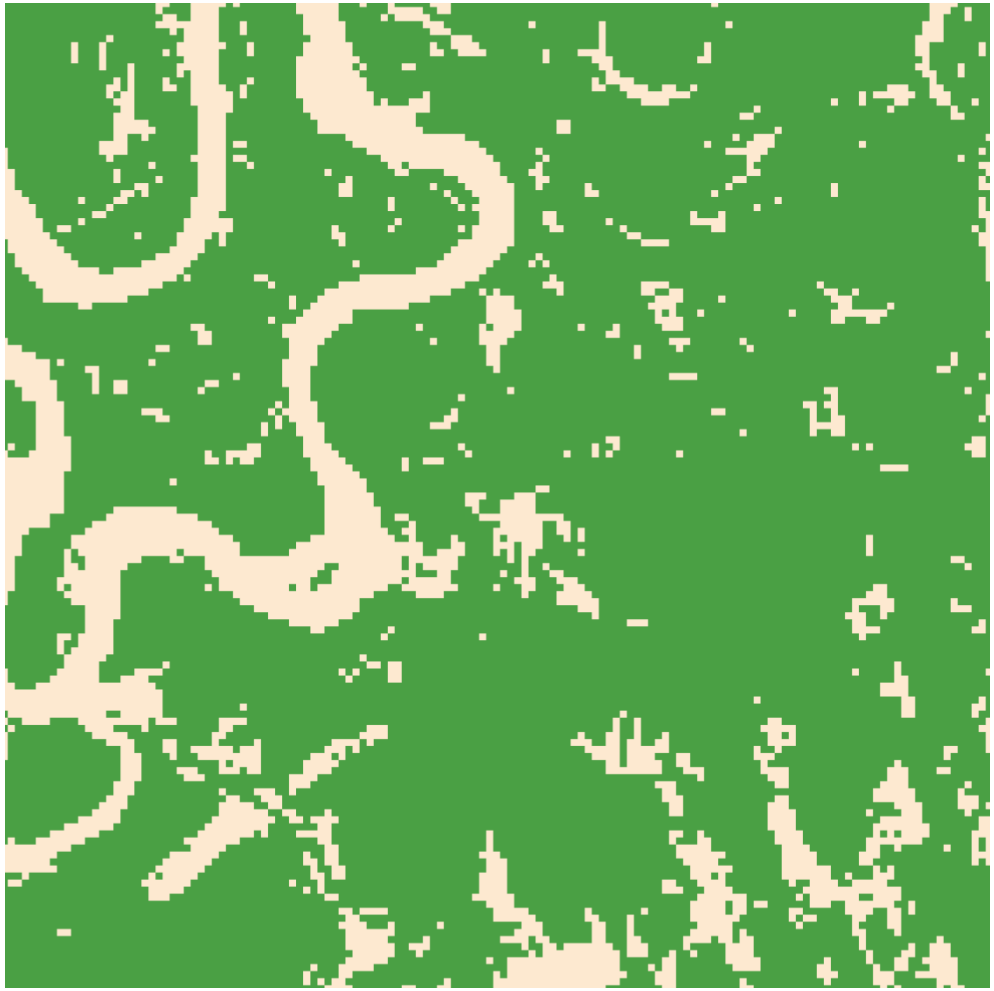
PERU



MMU 14 x 14 pixels

5.2 Minimum mapping unit forest map accuracy test

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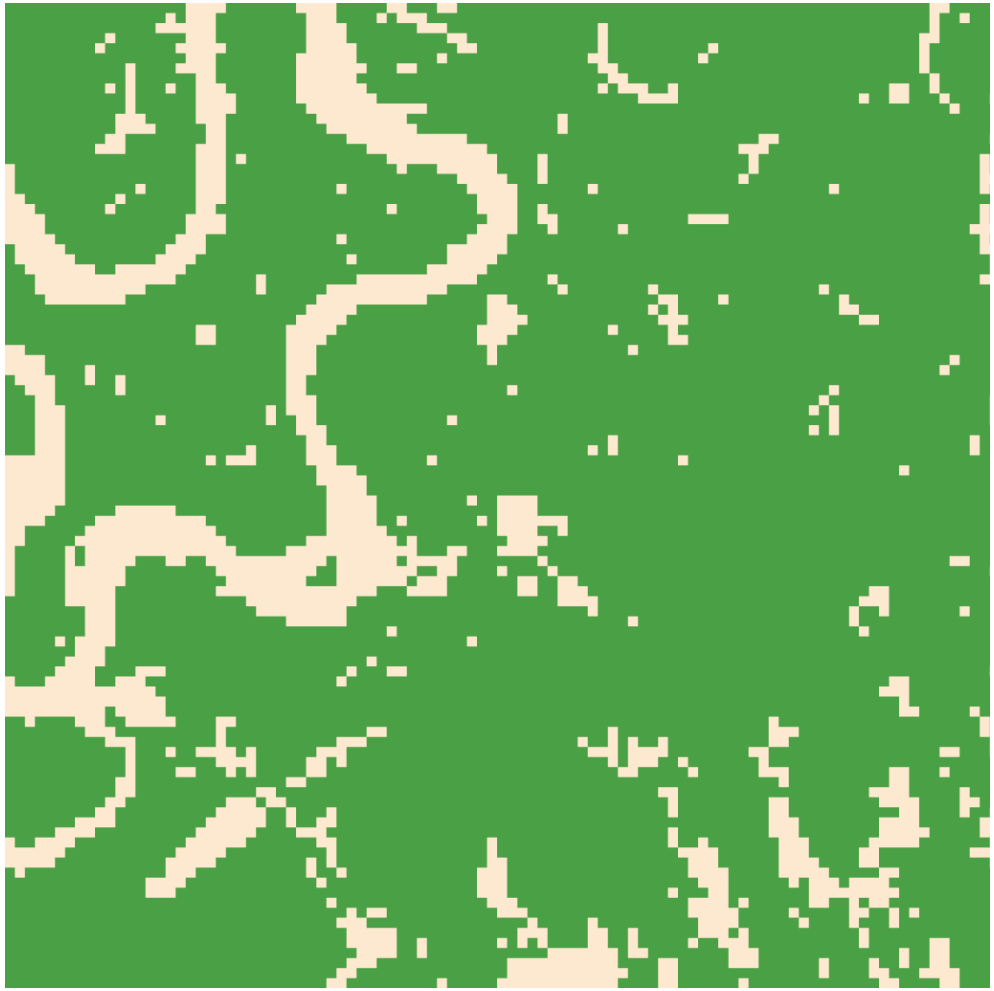
PERU



MMU 20 x 20 pixels

5.2 Minimum mapping unit forest map accuracy test

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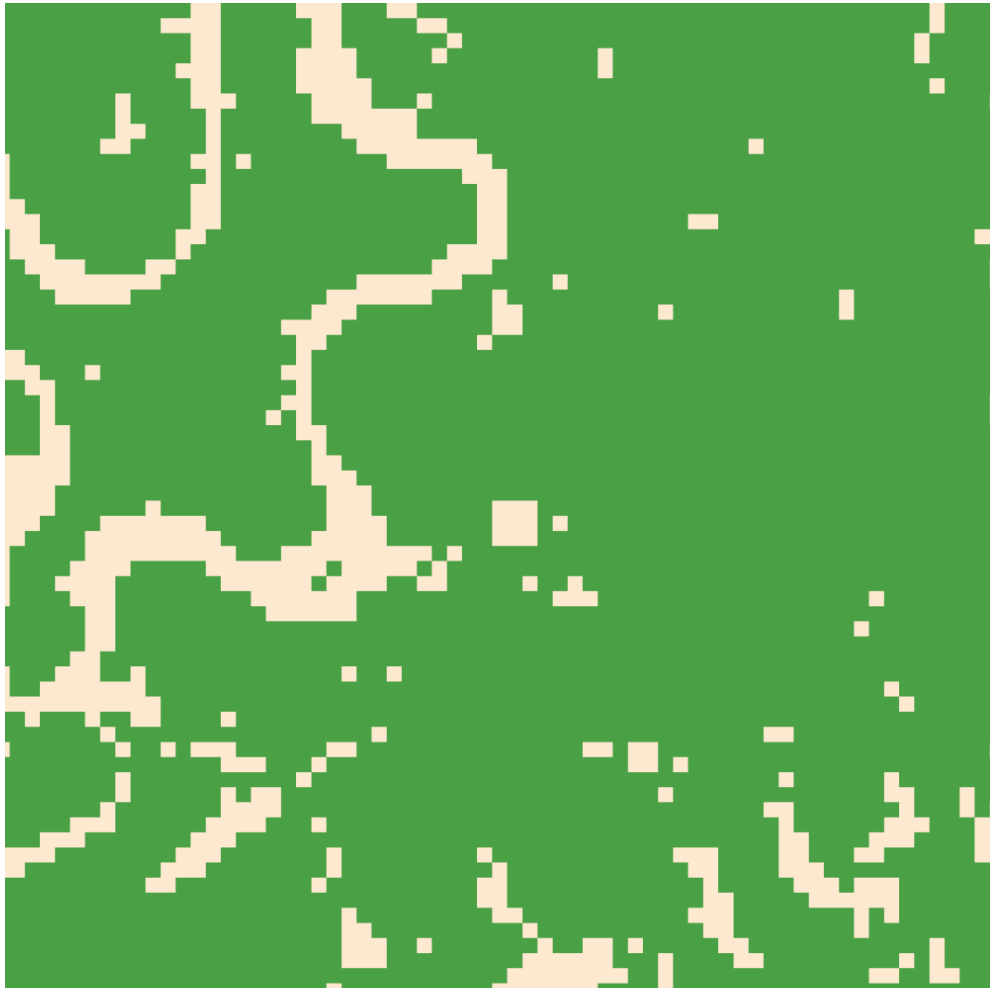
PERU



MMU 30 x 30 pixels

5.2 Minimum mapping unit forest map accuracy test

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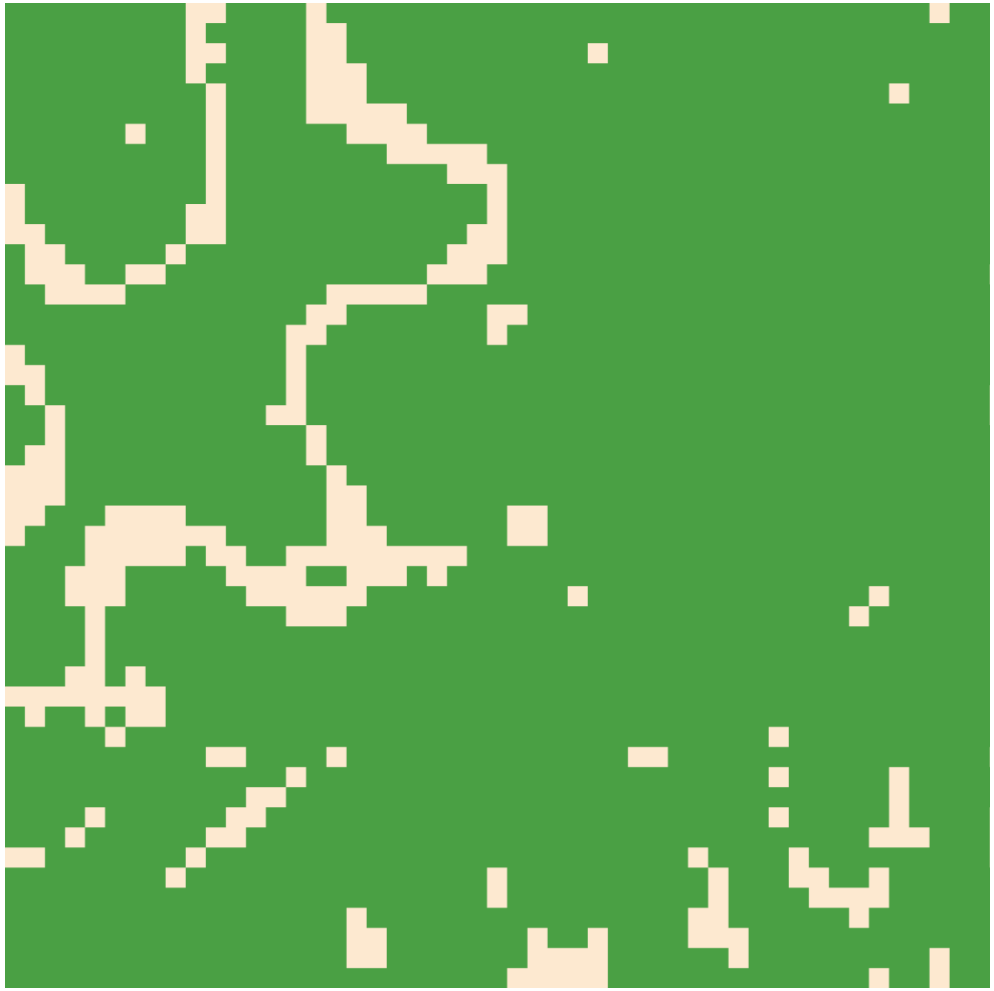

MMU 40 x 40 pixels

5.2 Minimum mapping unit forest map accuracy test

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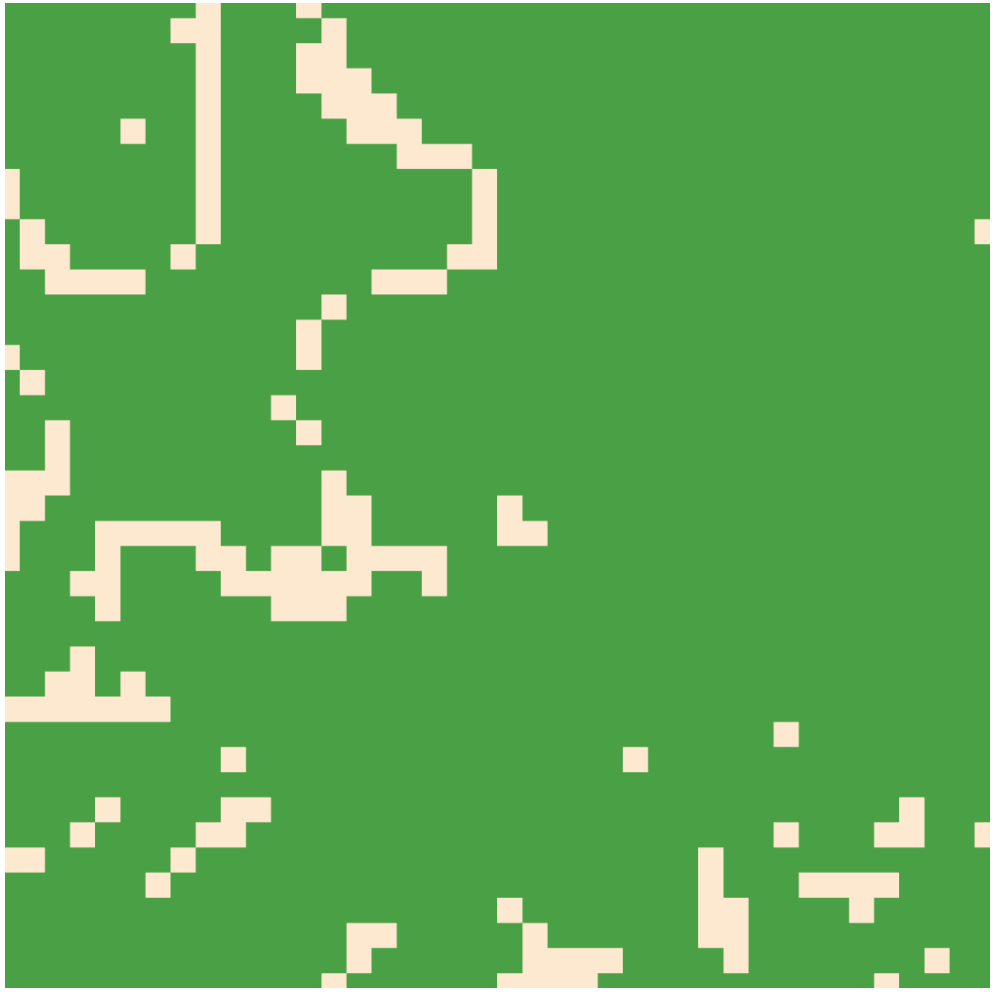
PERU



MMU 50 x 50 pixels

5.2 Minimum mapping unit forest map accuracy test

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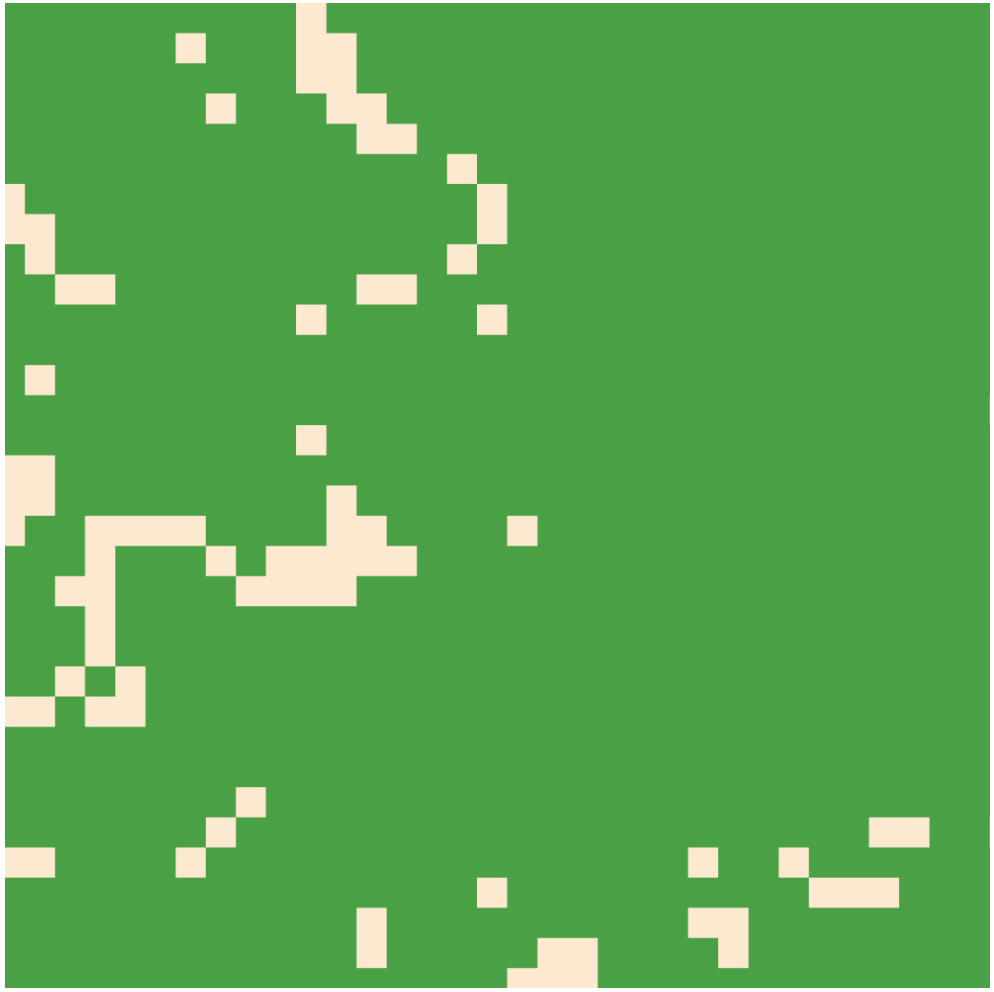
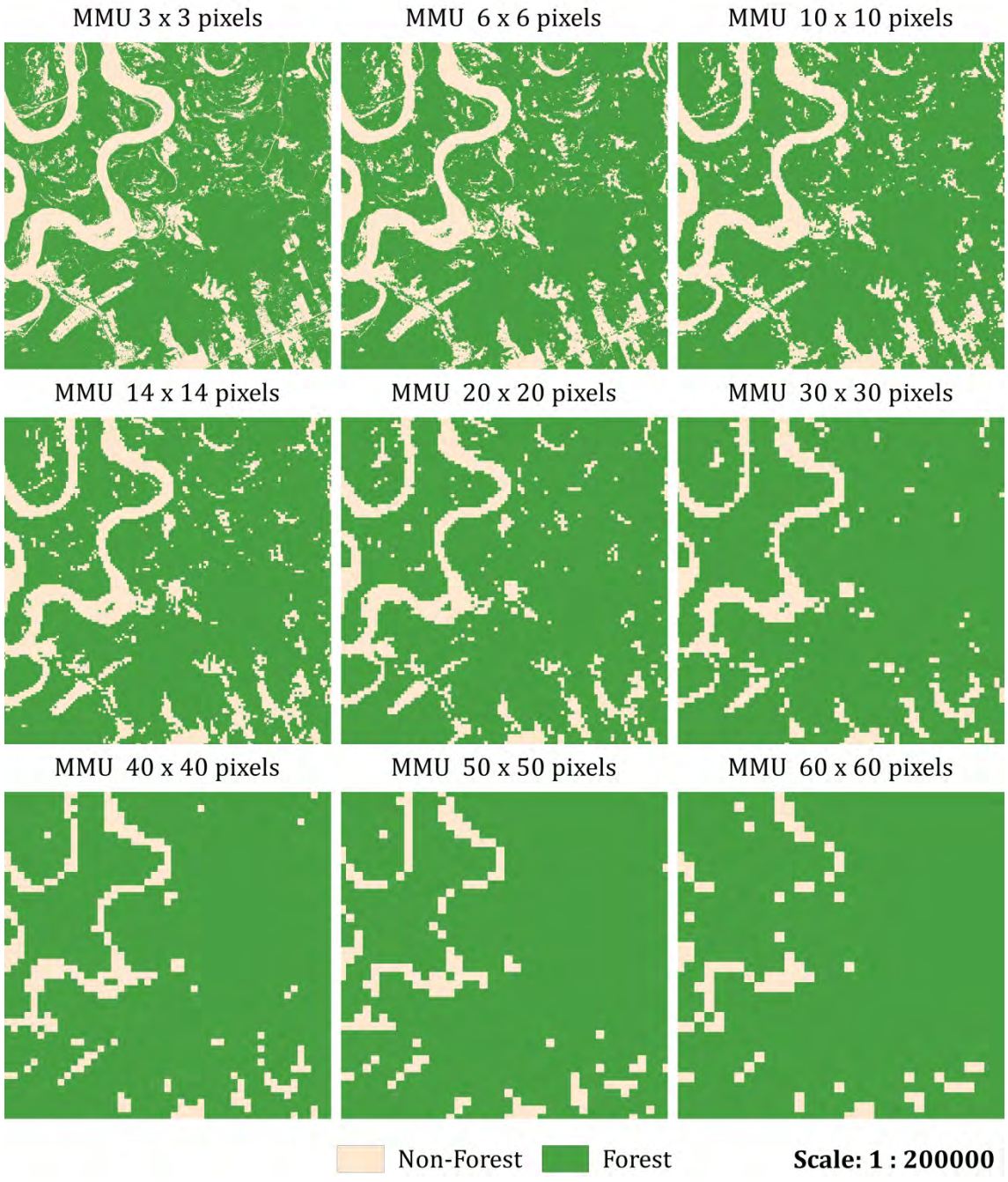
PERU



MMU 60 x 60 pixels


MMU 3 x 3 pixels
MMU 6 x 6 pixels
MMU 10 x 10 pixels
MMU 14 x 14 pixels
MMU 20 x 20 pixels
MMU 30 x 30 pixels
MMU 40 x 40 pixels
MMU 50 x 50 pixels
MMU 60 x 60 pixels
Non-Forest
Forest
Scale: 1 : 200000

5.2 Minimum mapping unit forest map accuracy test

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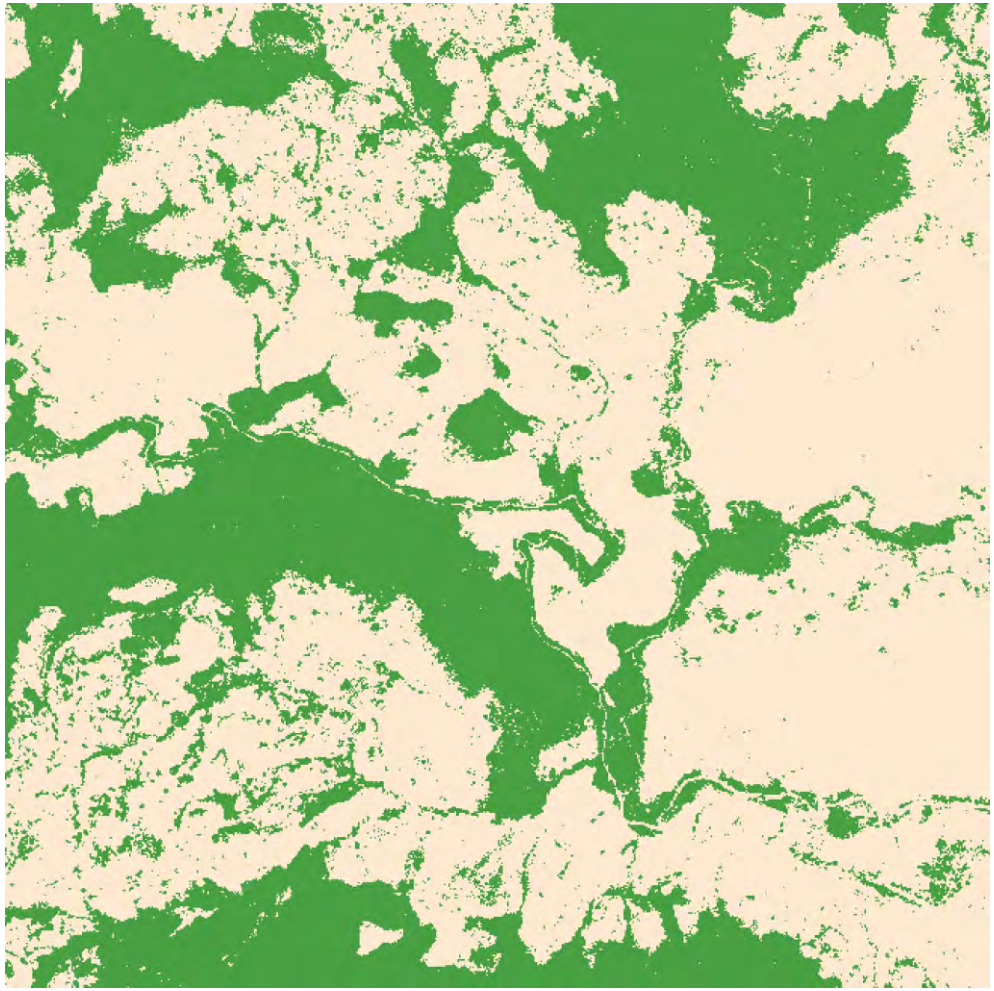

MMU 3 x 3 pixels

5.2 Minimum mapping unit forest map accuracy test

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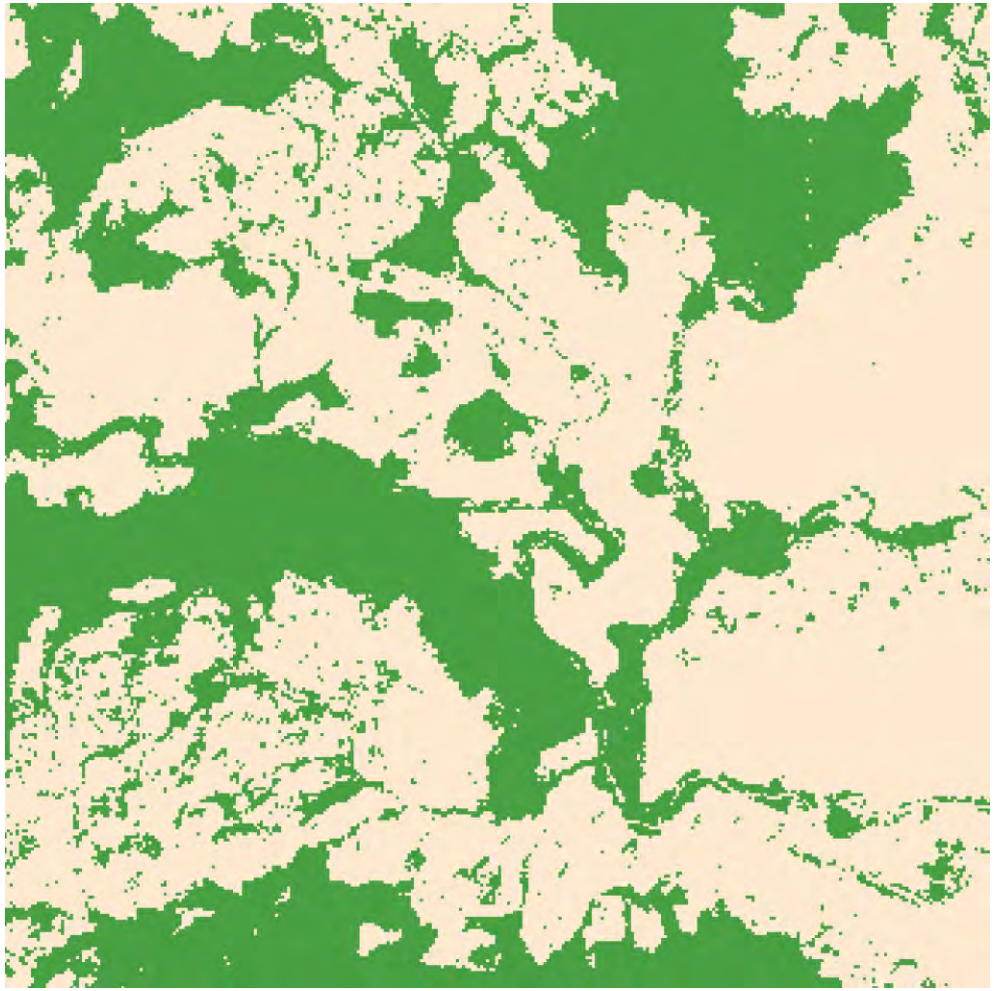

MMU 6 x 6 pixels

5.2 Minimum mapping unit forest map accuracy test

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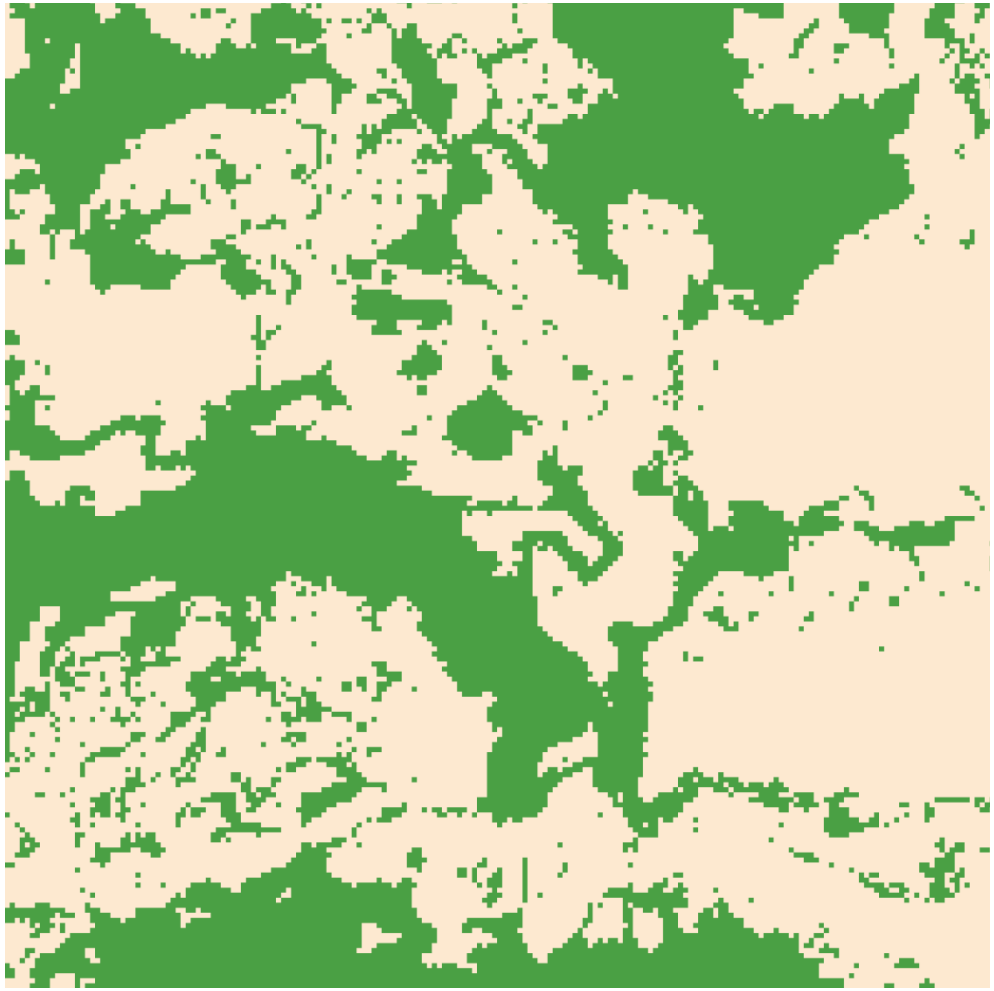
ETHIOPIA



MMU 10 x 10 pixels

5.2 Minimum mapping unit forest map accuracy test

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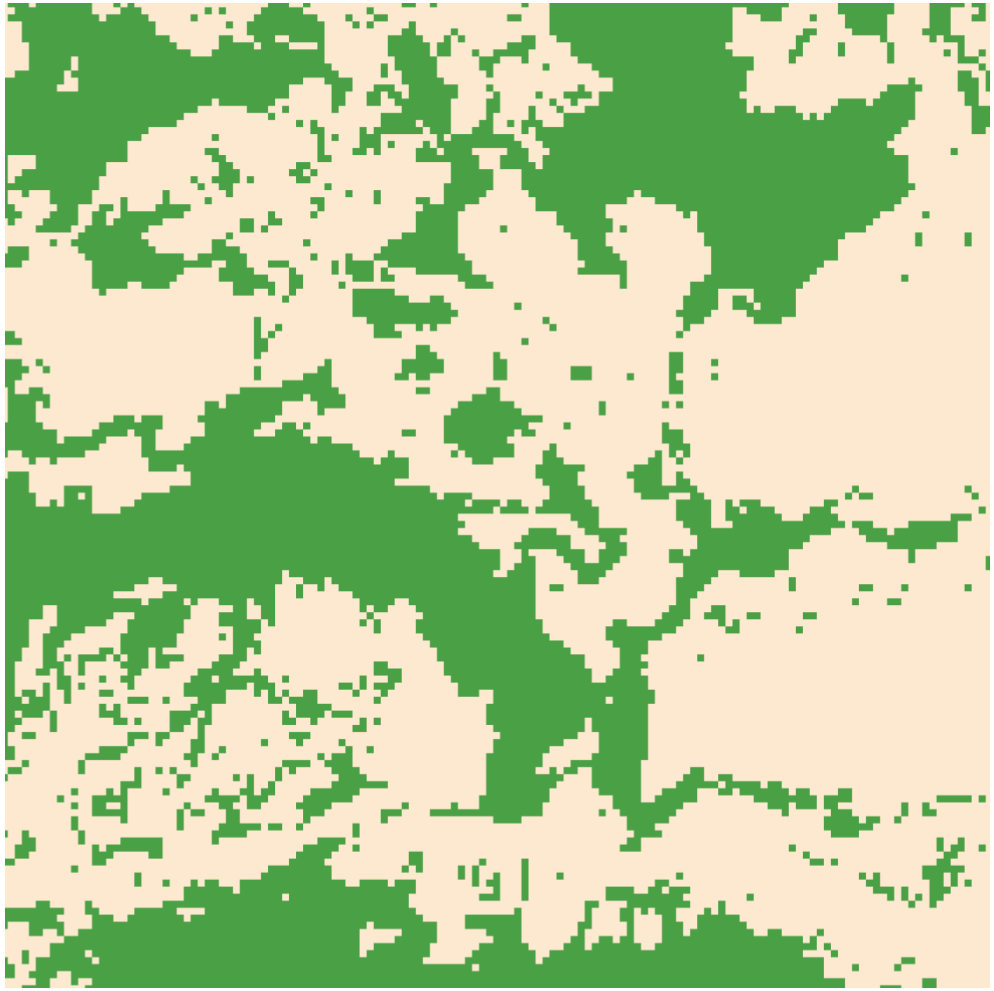

MMU 14 x 14 pixels

5.2 Minimum mapping unit forest map accuracy test

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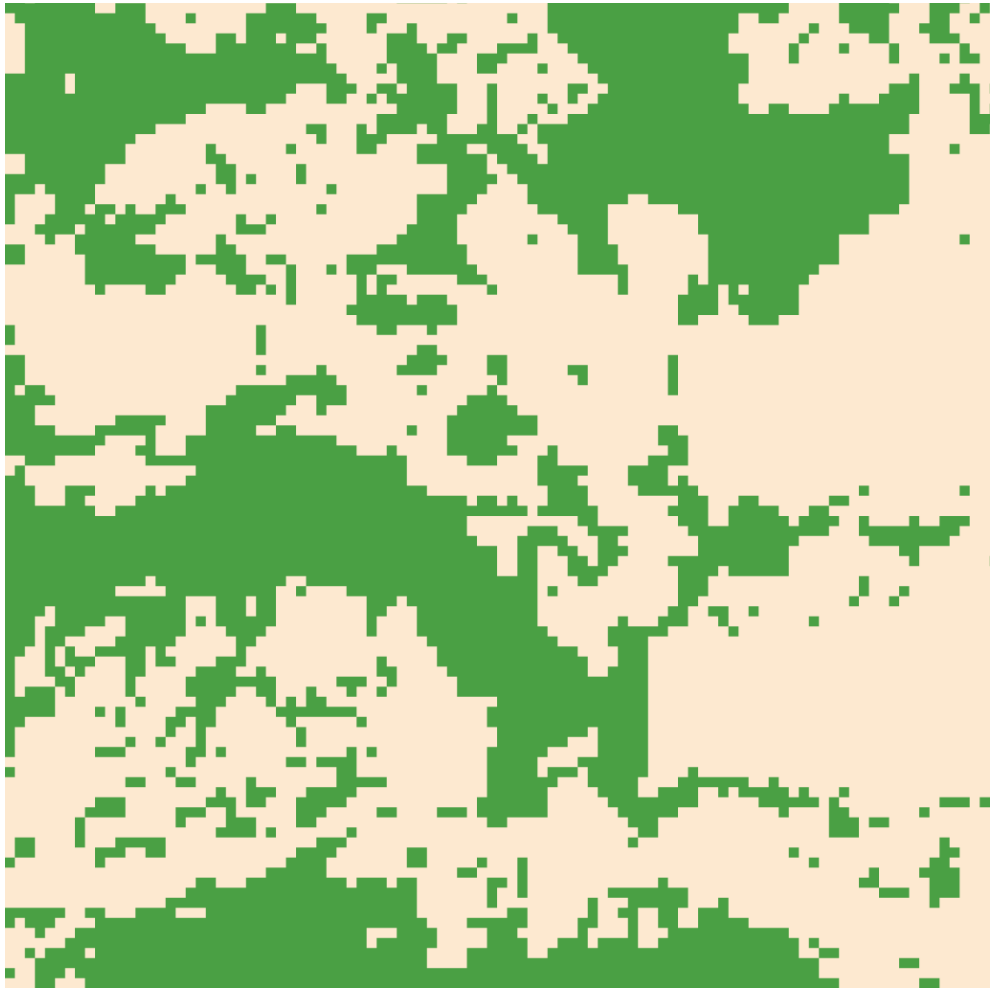

MMU 20 x 20 pixels

5.2 Minimum mapping unit forest map accuracy test

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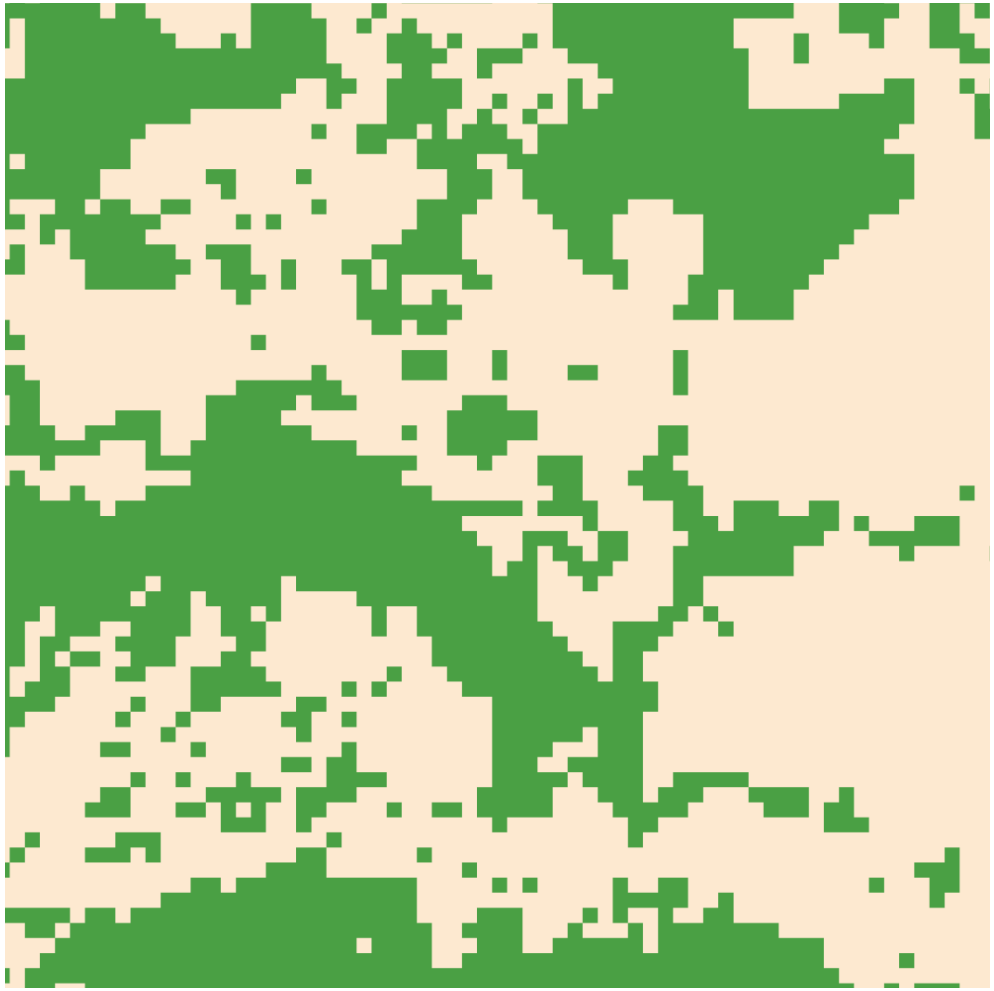

MMU 30 x 30 pixels

5.2 Minimum mapping unit forest map accuracy test

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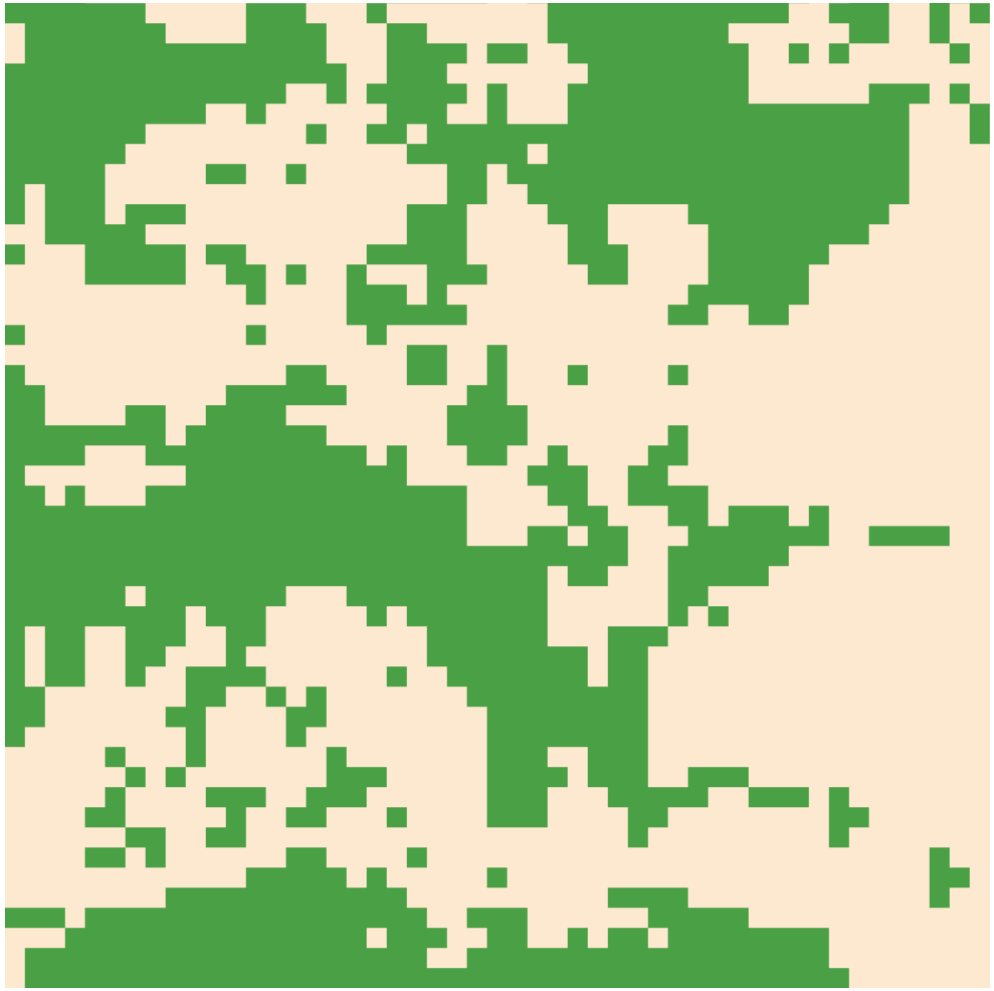
ETHIOPIA



MMU 40 x 40 pixels

5.2 Minimum mapping unit forest map accuracy test

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MMU 50 x 50 pixels

5.2 Minimum mapping unit forest map accuracy test

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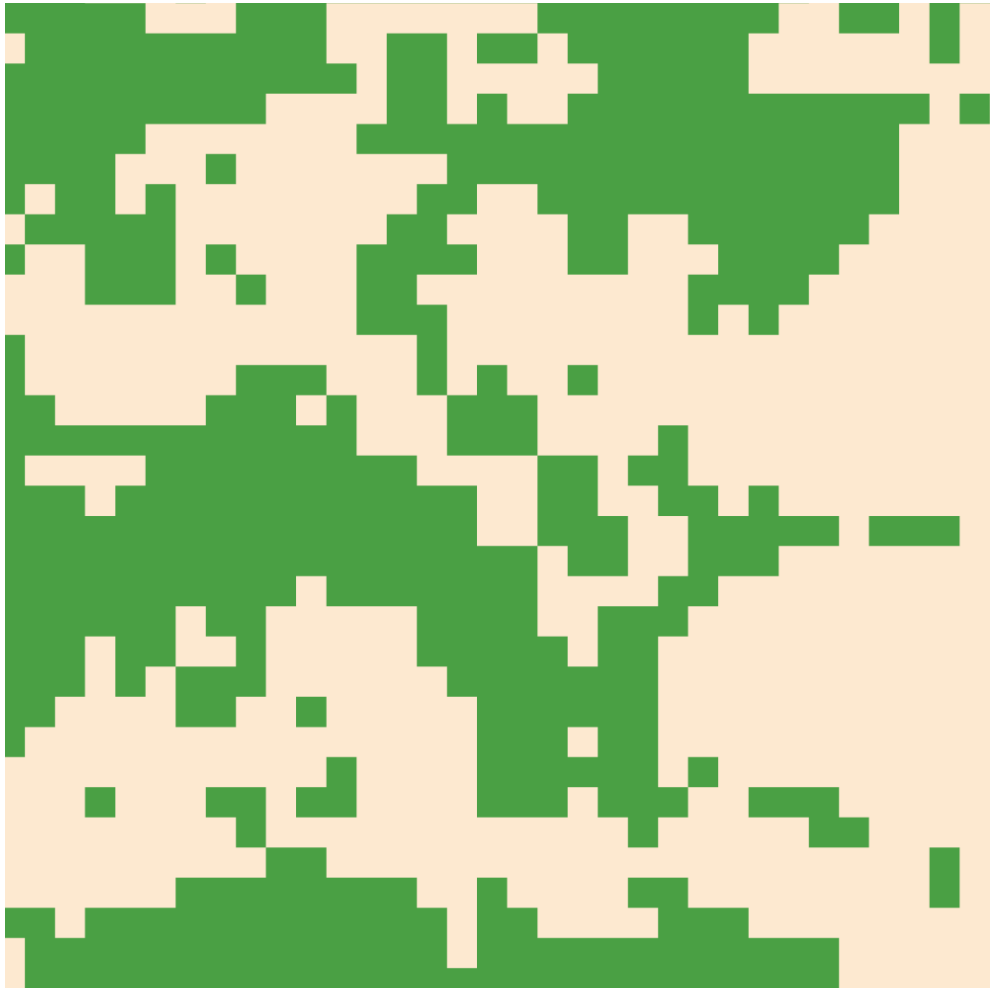
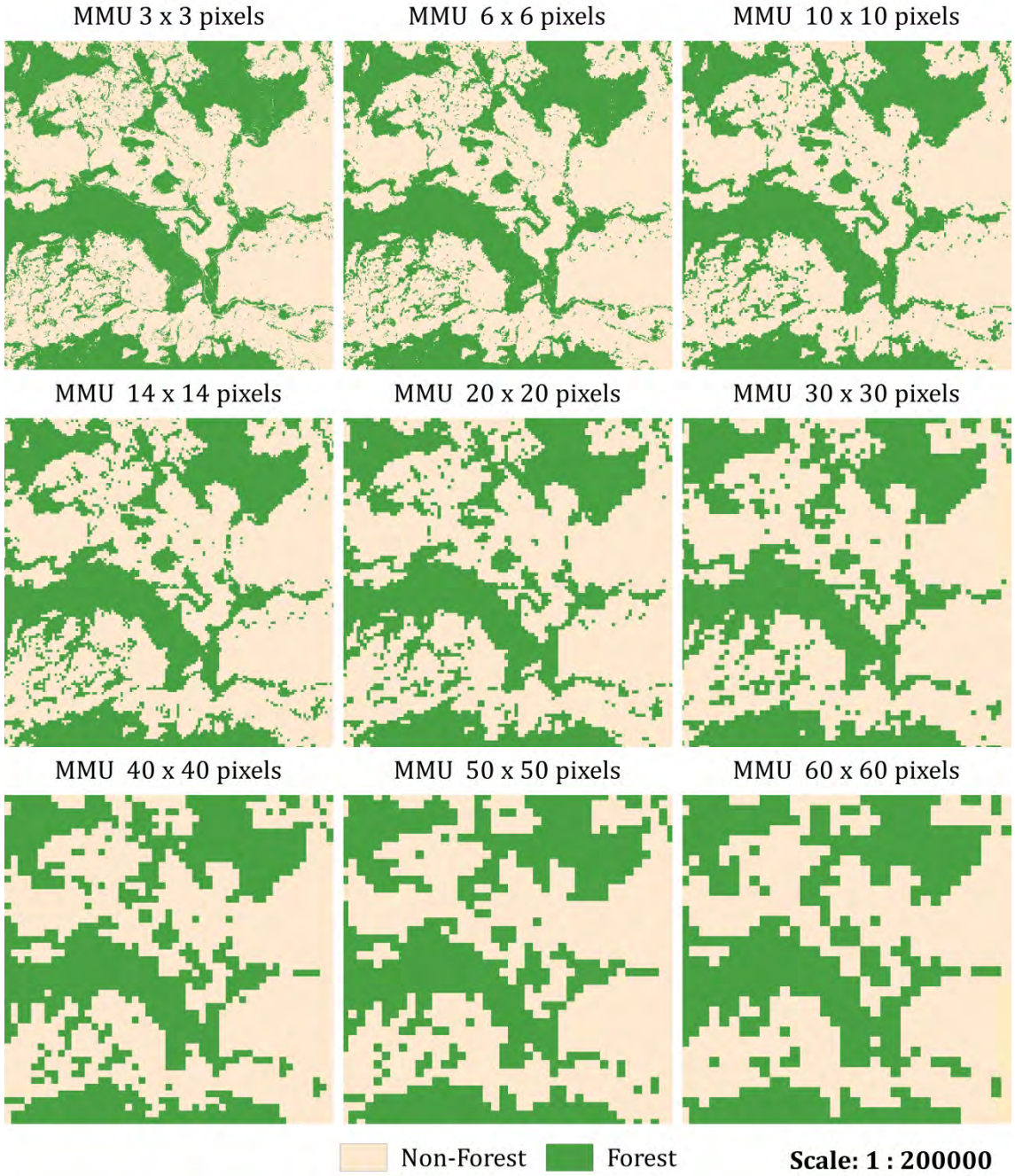


MMU 60 x 60 pixels


MMU 3 x 3 pixels
MMU 6 x 6 pixels
MMU 10 x 10 pixels
MMU 14 x 14 pixels
MMU 20 x 20 pixels
MMU 30 x 30 pixels
MMU 40 x 40 pixels
MMU 50 x 50 pixels
MMU 60 x 60 pixels
Non-Forest
Forest
Scale: 1 : 200000

5.2 Minimum mapping unit forest map accuracy test

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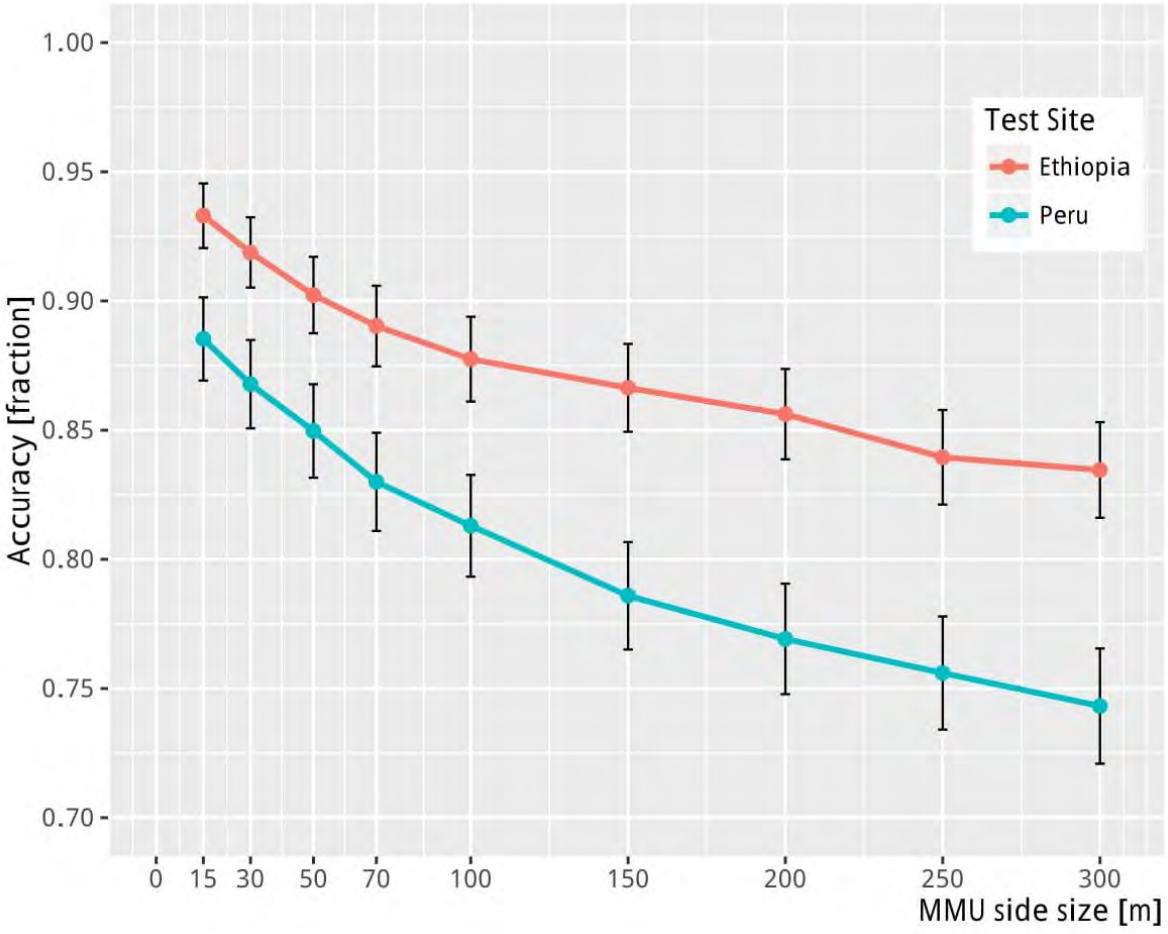
MMU [m]	Forest proportion	Non-forest proportion
15 x 15	0.7950	0.2050
30 x 30	0.8125	0.1875
50 x 50	0.8312	0.1688
70 x 70	0.8486	0.1514
100 x 100	0.8670	0.1330
150 x 150	0.8923	0.1077
200 x 200	0.9105	0.0895
250 x 250	0.9237	0.0763
300 x 300	0.9391	0.0609

Table 8: Forest cover area map proportions for Peru

MMU [m]	Forest proportion	Non-forest proportion
15 x 15	0.5255	0.4745
30 x 30	0.5289	0.4711
50 x 50	0.5373	0.4627
70 x 70	0.5447	0.4553
100 x 100	0.5496	0.4504
150 x 150	0.5591	0.4409
200 x 200	0.5649	0.4351
250 x 250	0.5730	0.4270
300 x 300	0.5778	0.4222

Table 9: Forest cover area map proportions for Ethiopia

5.2 Minimum mapping unit forest map accuracy test



Average forest cover maps overall accuracies with corresponding confidence intervals with respect to MMU for Peru and Ethiopia.

6. Conclusions

- This thesis provides accuracy measure for mapping forest from high- and medium-resolution satellite imagery and at different MMUs.
- Accurate forest maps generated from high-resolution satellite imagery.
- Considerable, non-stable loss of accuracy for medium-resolution satellite imagery.
- Accuracy assessment confirrmed the decrease of forest cover mapping accuracy when comparing high- and medium-resolution satellite data.
- Accuracy of forest cover maps decreases with increasing the size of MMU.

7. Future work

- Ground visits as reference data.
- Test effect of landscape properties and crown cover threshold.
- REDD+ countries can decide which satellite imagery spatial resolution and MMU to use for forest cover mapping.