Tasmanian Forest Agreement Verification:
Indicative assessment using currently available remotely sensed imagery of forest disturbance in the areas proposed to be reserved under the Intergovernmental Forest Agreement

Report to the Independent Verification Group

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Purpose

The purpose of this phase of the assessment was to "Provide to Professor Brendan Mackey of the Independent Verification Group (IVG) an indicative assessment utilising currently available remotely sensed imagery (1) whether the 572,000 hectares of forest identified by ENGO's as being of High Conservation Value have a native forest cover and (2) if there are any areas within the 572,000 hectares which appear to (a) have been cleared or heavily disturbed by human use or (b) have a non-native forest cover such as plantation forest."

Background

We have been asked by the Independent Verification Group (IVG) to use satellite imagery and spatial analysis techniques to identify heavily disturbed and non-native forest cover within the proposed High Conservation Value forest areas. The advantage of using satellite imagery is that it covers the whole state at a sufficient level of detail to assess land use and land cover. We decided to use the RapidEye satellite image mosaic of Tasmania collected between November 2009 and January 2010. This imagery was kindly provided by NRM Cradle Coast. Despite the time discrepancy between the image acquisition and the present date we decided that this dataset was most suitable for the task given the following reasons:

- It is the most recent high-resolution satellite imagery that covers the whole State. It is therefore a consistent data source for the whole State
- The imagery has a spatial resolution of 5 x 5 m and has five spectral bands, blue, green, red, red-edge, and near-infrared, enabling effective interpretation of vegetation cover.
- It was collected within a 3-month timeframe, which is remarkably fast for an image mosaic at such high resolution. This short timeframe reduces the seasonal effects on image interpretation.

After trialling automated image analysis techniques based on object-based image analysis (OBIA) we decided that manual interpretation and digitisation of the imagery would be most accurate efficient.

Methods

Datasets

Natural Resource Management (NRM) Tasmania (http://www.nrmtas.org) recently obtained state-wide satellite imagery from the RapidEye satellite constellation (http://www.rapideye.de). RapidEye is a constellation of five small satellites (150 kg and 1 m^3 each) in a low earth orbit. The five identical satellites allow a large amount of imagery to be collected and allow for short revisit cycles (< 5 days). The swath width of the sensors is 78 km. The satellite sensors have five bands: blue, green, red, red edge, and NIR at 5 m spatial resolution (Fig. 1). The satellites were launched on 29 August 2008 and have been commercially operational since February 2009. NRM Cradle Coast has kindly made the RapidEye imagery for Tasmania available for this project. The imagery was collected between November 2009 and January 2010 (Fig. 2). Orthorectified level3A imagery was used for this project. The individual 25x25 km image tiles were block shifted by AAM (Australian RapidEye distributor) to geometrically match the imagery with the 1:25,000 DPIPWE road network. The geometric accuracy of the imagery is within 30 – 40 m as established in an earlier project (Rowena Price, pers. comm. 2011). This means that any spatial features derived or digitised from this imagery can be expected to be within 40 m of their true location.

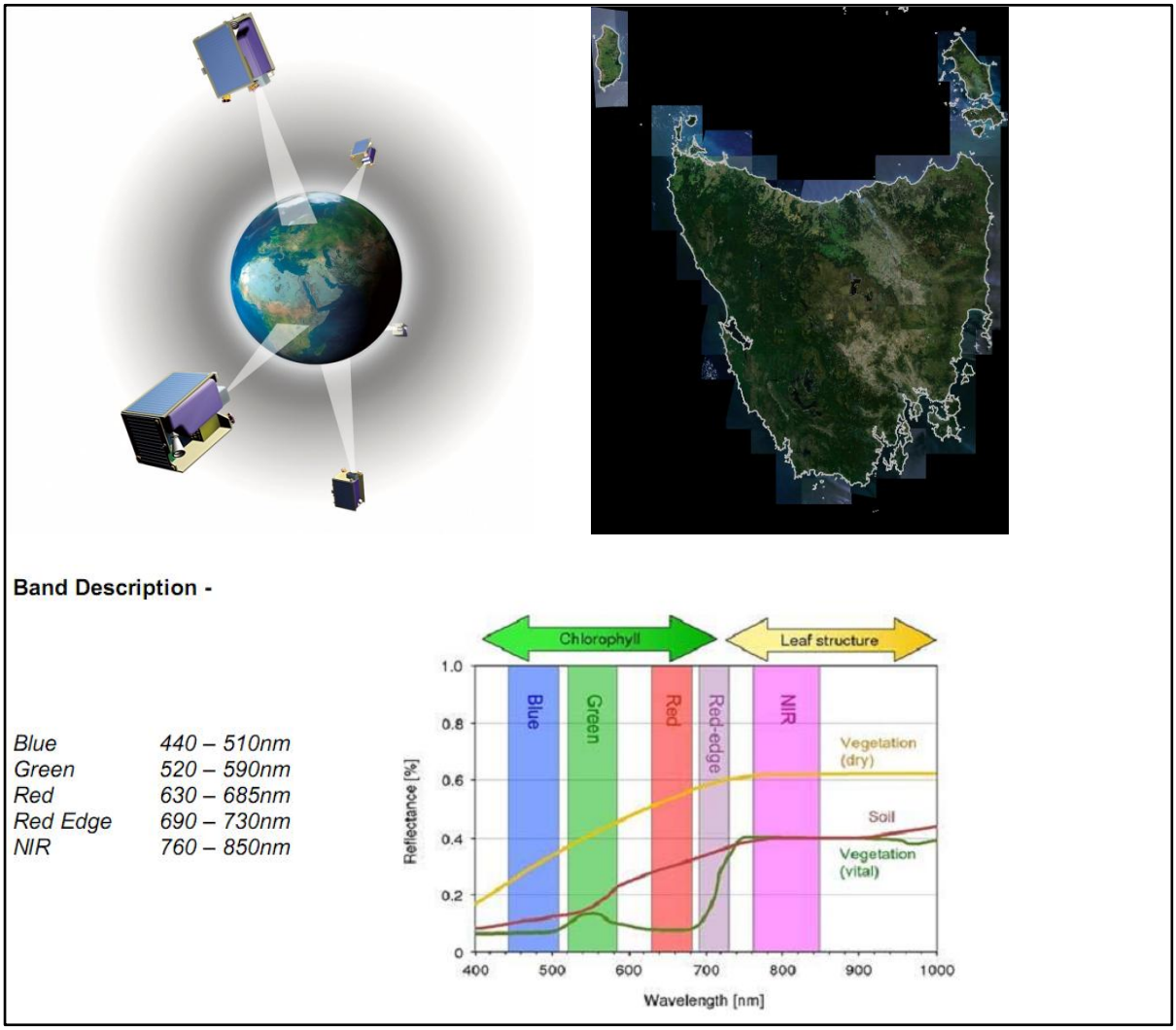


Fig. 1. RapidEye satellite constellation with its five satellites, which enabled the collection of a state-wide 5m resolution image with five spectral bands (source: AAM and RapidEye).

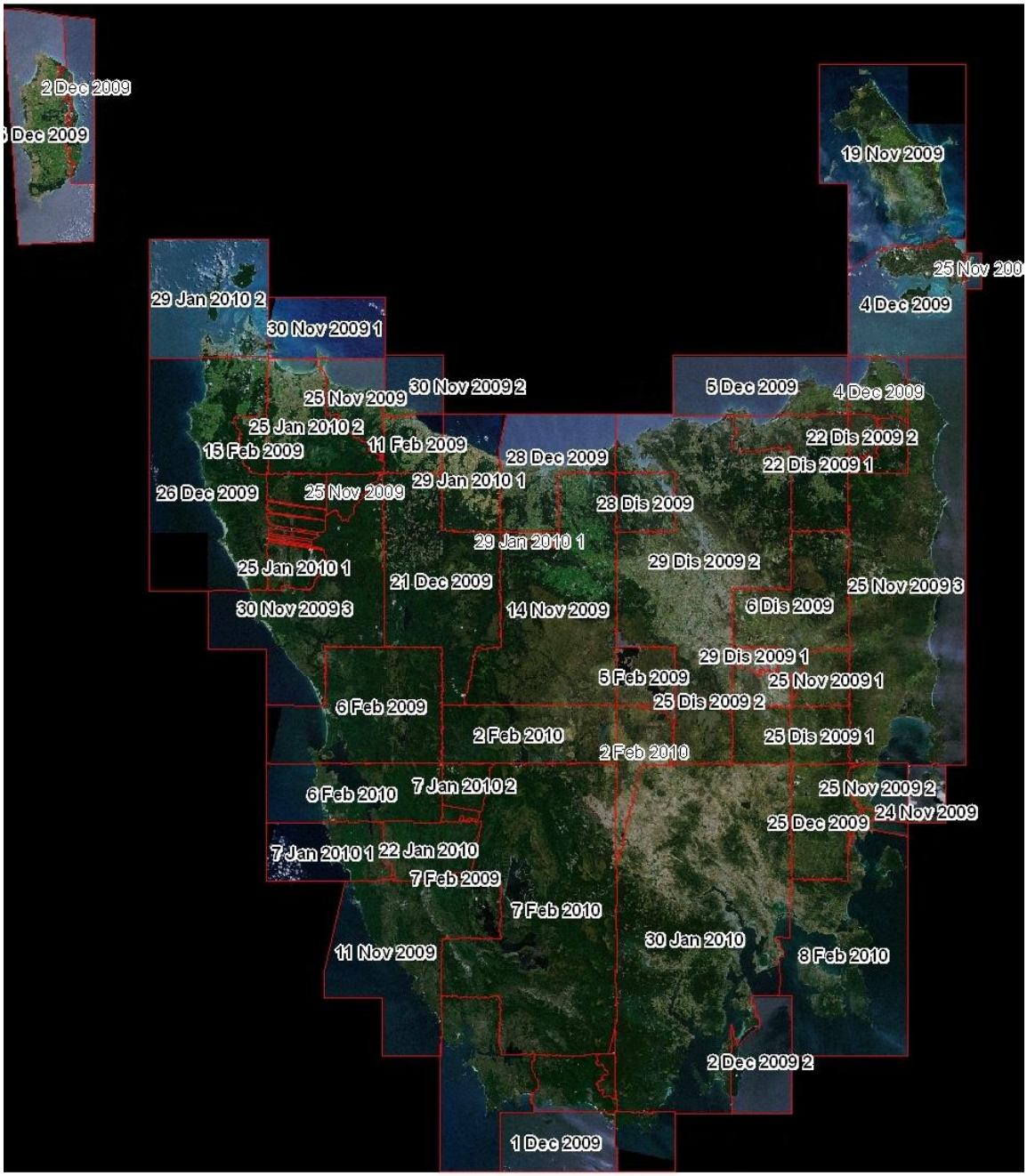


Fig. 2. RapidEye image mosaic showing the collection dates (source: AAM).

In addition, we were provided with a vector layer (Shapefile) outlining the proposed IGA High Value Conservation forest polygons. The layer was initially provided to us in early November. The final layer was provided on the 7th of December.

Preparation of the RapidEye imagery

There were 122 RapidEye tiles (each 25 x 25 km) that intersected the ENGO proposed reserve. These were evaluated for their suitability. ArcGIS10 was used to convert RapidEye imagery to an optimum format for vegetation analysis. Bands 5 (near infrared), 3 (blue) and 2 (green) were selected for visualisation. Where there was cloud cover or missing data over part of the tile a second or in some cases third alternative tile was prepared so that all of the target area was visible. Formatted tiles were renamed according to a town or other geographic feature located within the tile. Where there

were multiple overlapping tiles they were given a numbered suffix in reverse chronological order (number 1 being the latest dated tile). A tile index shapefile was produced, listing the original tile name, the new tile name and the image acquisition date.

Digitisation

Digitisation of forest areas from RapidEye imagery was conducted using Landscape Mapper software. Identification of features was assisted by use of Google Earth imagery, in particular the identification of plantation areas which usually could not be easily distinguished from non-plantation vegetation with RapidEye imagery alone. RapidEye tiles were digitised individually to produce polygon shapefiles which outlined visible areas of forest activity. Where there were multiple overlapping tiles the latest dated tile was used unless obscured by cloud in which case the next latest date was used. In addition to cleared areas, regeneration areas which were clearly distinguishable from surrounding uncleared areas were digitised.

After completion of digitisation of all tiles an image date field was added to the digitised layers and populated with the image dates from the tile index shapefile. Further processing was conducted using ArcGIS10 including union of the polygon shapefiles and consolidation of single date and classification fields from source individual tiles. The output digitised layer was converted to a geodatabase.

Classification Scheme

Digitisation categories are as described in Table 1. These categories were based on appearance in RapidEye and Google Earth imagery and examples are further described in Examples of Classifications below.

Table 1. Classification Scheme

Category	Decription (Google image)	RapidEye false colour	Native Vegetation
Cleared Recent	Ground bare or with slash cover.	Bluish green. May have darker speckles.	No
Cleared	Cleared but with vegetation regrowth. Possible early regeneration or weed growth. Too early to distinguish if it is a plantation.	Part bluish green to greyish interspersed with mottled pink patches.	Ambiguous
Regen	Uniform vegetation regrowth, not in rows.	Red.	Yes
Thinned	Sparse trees evenly spaced with cleared areas between. Ground cover may be largely undisturbed. Signs of forestry activity. Roads in the area followed a pattern consistent with forestry activity.	If heavily disturbed appears as bluish green with many darker speckles. If less disturbed can appear similar to undisturbed areas but with pink and/or bluish green areas.	Yes
Plantation	Regeneration with trees visible in rows.	Red. May be striped. May be bluish green if newly planted.	Not counted as native
Agriculture	Indistinguishable from adjoining agricultural land	Pink	No

Where a coupe had been classed as “Thinned” an assessment was also made of whether it was or was not heavily disturbed. This assessment was to some extent subjective as it depended on the quality of the available imagery. All other categories would be regarded as heavily disturbed.

Native vegetation was assumed to be present for “Regen” and “Thinned” categories. Plantations (“Plantation”) were not counted as native even though native species may be planted. Recently cleared areas with bare earth (“Cleared Recent”) were counted as not having native vegetation present at the time of assessment. Presence of native vegetation on cleared areas with some early vegetation regrowth (“Cleared”) was counted as ambiguous as it was too early to distinguish the nature of the vegetation.

Examples of Classifications

The figures below show examples of the different classes outlined in Table 1:

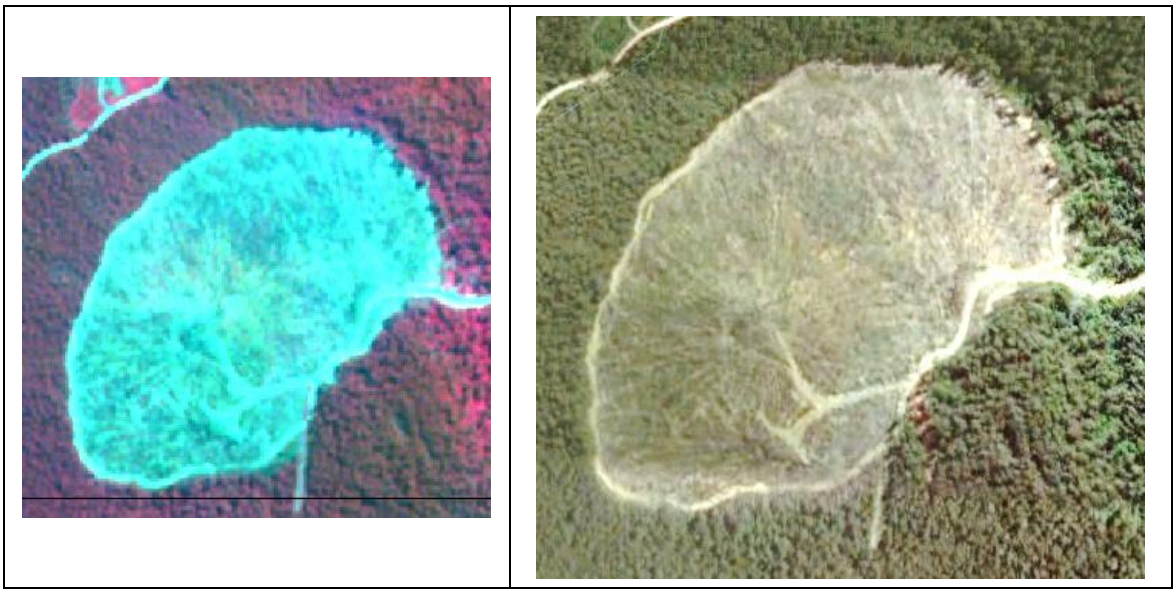


Fig. 3. An example of a cleared coupe counted as "Cleared Recent". Ground surface is bare as indicated by bluish green colouring. Some speckling may be due to slash cover. No standing trees remain on this coupe as visible in Google Earth image on right.

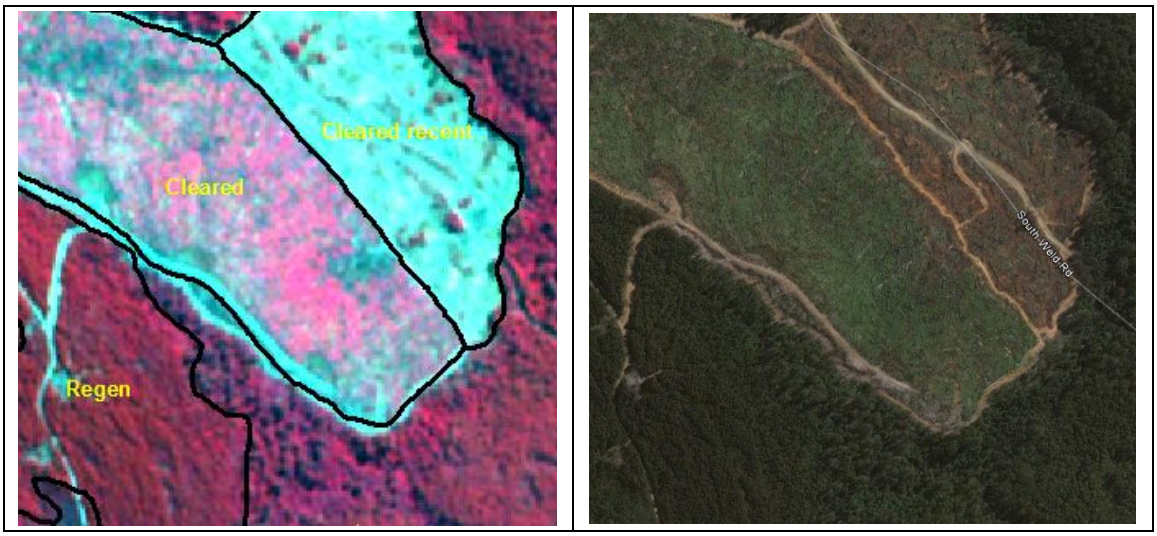


Fig. 4. Example showing the difference between "Cleared", "Cleared Recent" and "Regen". For "Cleared Recent" the Ground surface is bare as indicated by bluish green colouring in the RapidEye image. Presence of vegetation in "Cleared" shows as green in Google Earth image and as pink with blue-grey mottling in the RapidEye image. It is not possible to distinguish whether the vegetation is due to early forest regeneration, weed growth or plantation at this stage. The "Regen" coupe to the left in the RapidEye image identified by red colouring has individual trees visible which are not in rows. Darker vegetation to the right in this image is undisturbed forest.

A range of forest sites were given the classification ‘thinned’. In most cases these could be distinguished from the surrounding ‘un-thinned’ forest by the more sparse vegetation and the presence of associated forestry roads (Fig. 6 – 9). In some cases the ground surface was bare, however in other cases regeneration vegetation was present. Some thinned coupes were almost indistinguishable from cleared coupes, especially where there had been extensive disturbance of the ground surface.

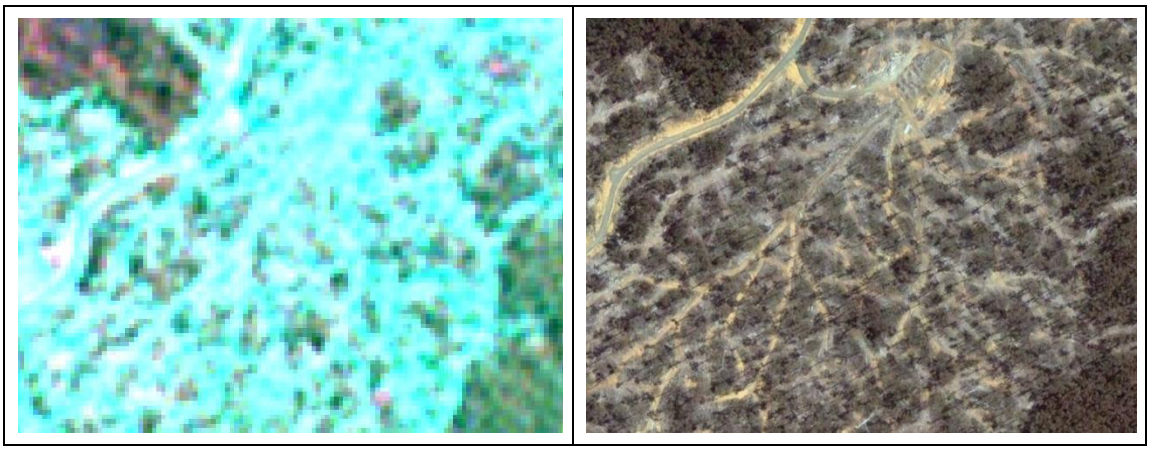


Fig. 5. A “Thinned” coupe that was less heavily disturbed as indicated by less disturbance of the ground surface (shown right in Google Earth image). This coupe had a speckled appearance in the RapidEye imagery (left) but due to the overall bluish green colour was classified as heavily disturbed.

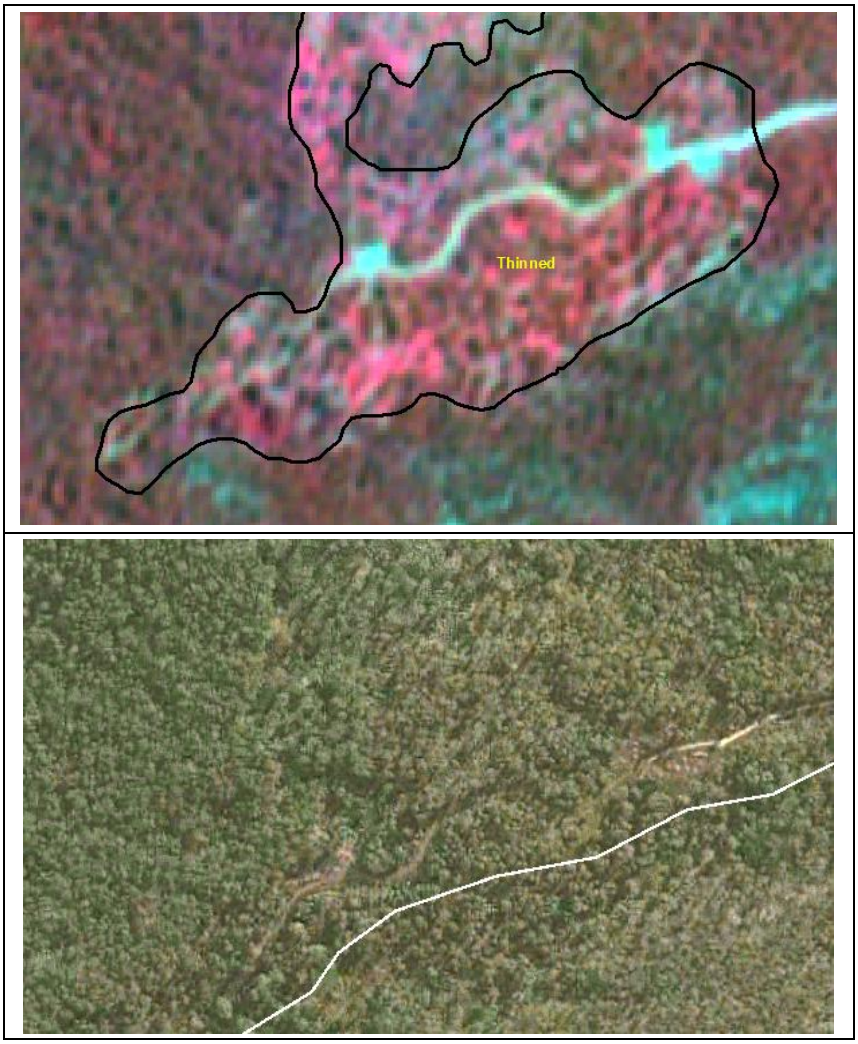


Fig. 6. A coupe identified as "thinned" but regarded as not being heavily disturbed. Vegetation appears different to surrounding undisturbed forest. Red colour in RapidEye image indicates possible regrowth. Google Earth image below shows vegetation on upper right is sparser than undisturbed vegetation on left.

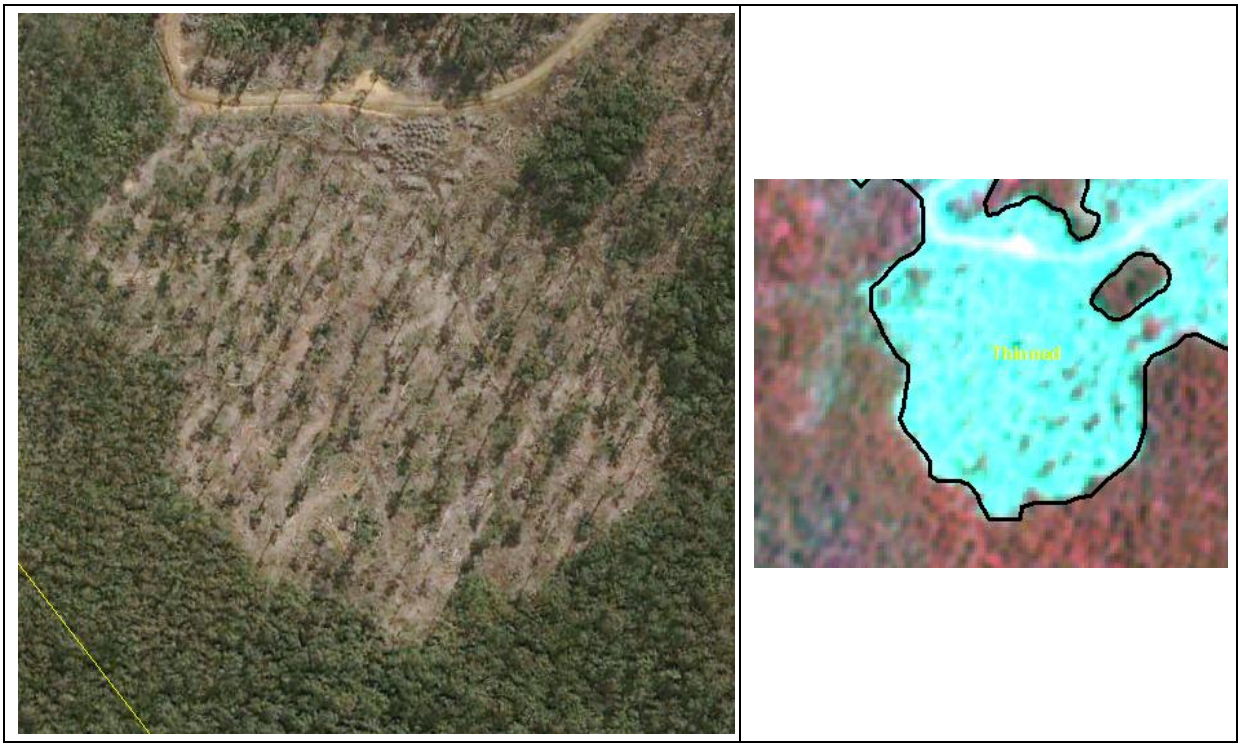


Fig. 7. A thinned coupe counted as being heavily disturbed as the ground surface had been almost entirely disturbed and remaining trees were sparse. Almost complete disturbance of the ground surface is indicated by the bluish green colouring visible in RapidEye imagery (right).

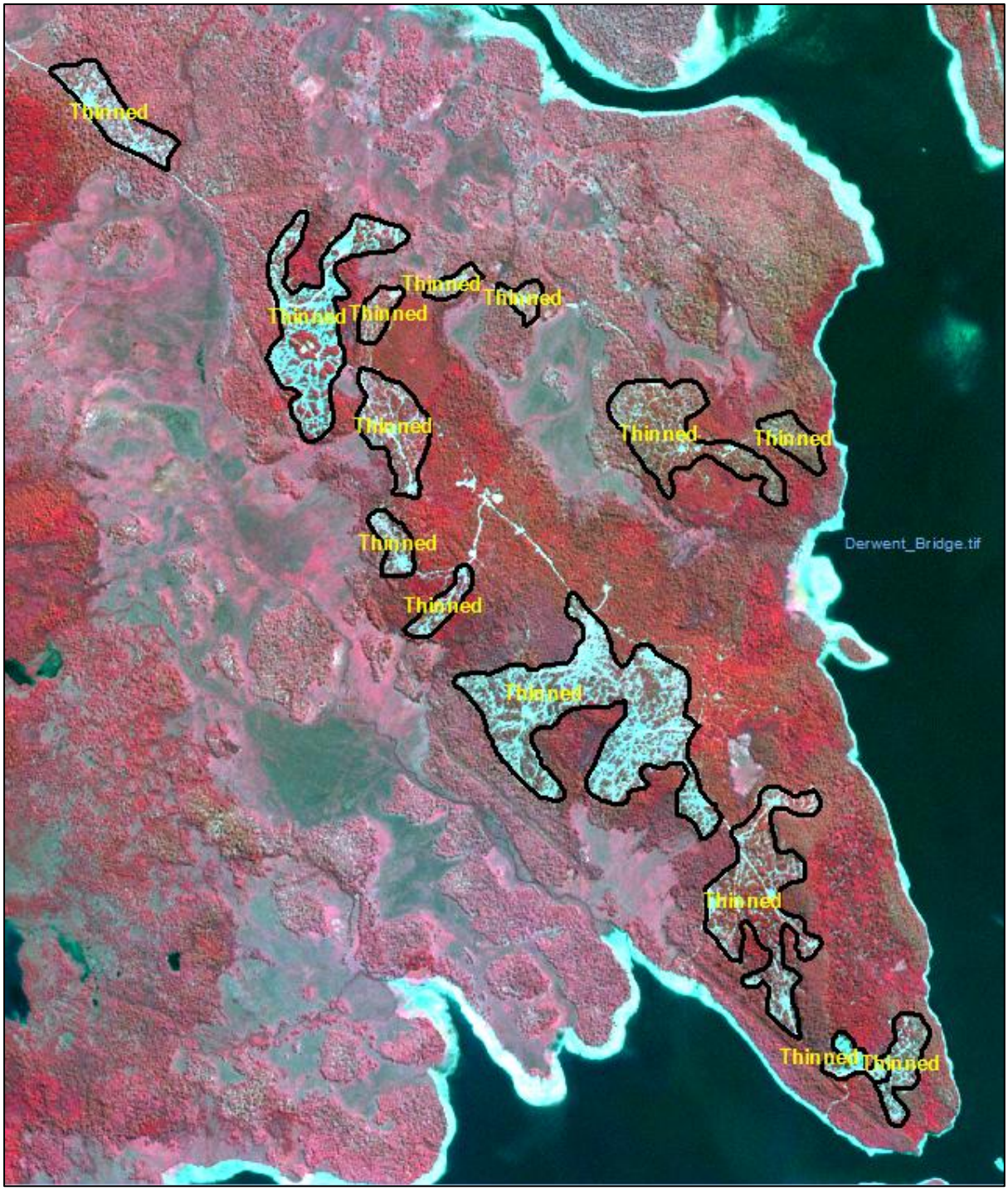


Fig. 8. A group of coupes with varying levels of disturbance and identified as being "thinned", on the western side of Lake King William.

Fig. 9. The same area as viewed with Google Earth. Yellow outline shows boundary of the ENGO proposed reserve.

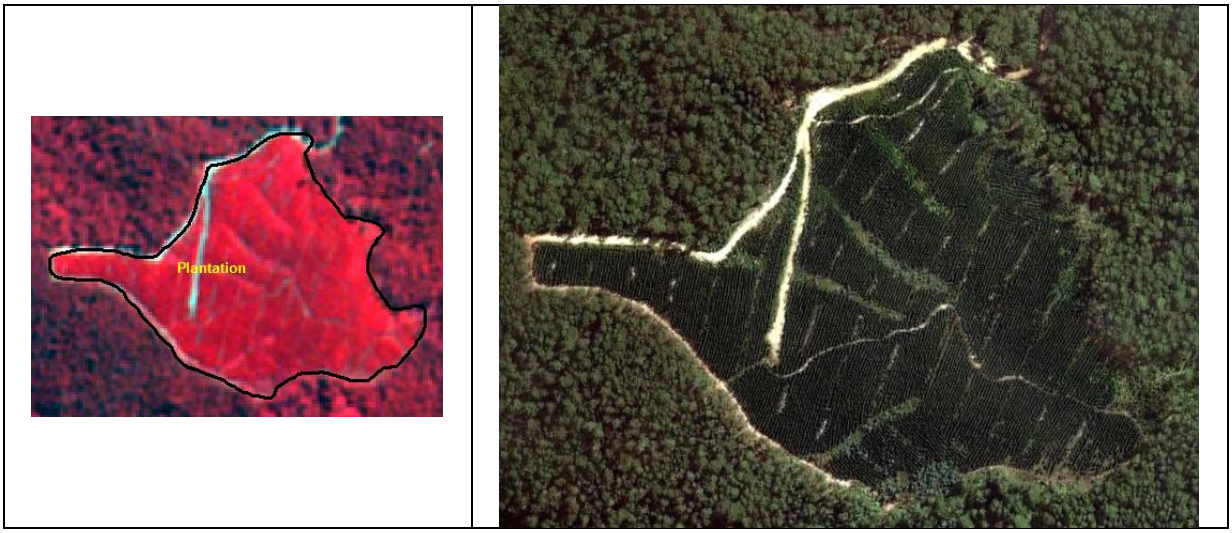


Fig. 10. Plantations were usually identifiable by bright red colouration in RapidEye imagery due to vigorous vegetation growth. Often plantations also had a road that went around the boundary. Note trees are in rows as visible in Google Earth imagery on right.

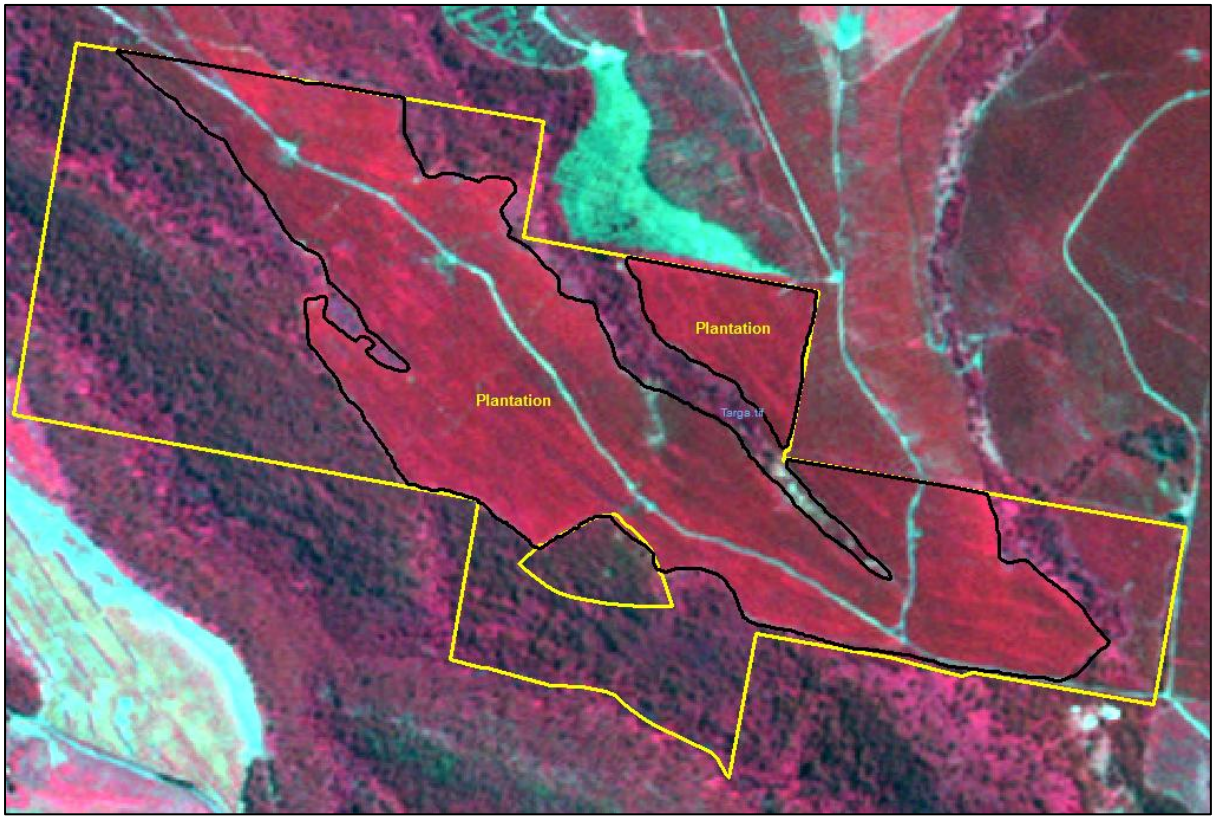


Fig. 11. Another plantation as viewed within RapidEye imagery. Yellow outline shows boundary of the ENGO proposed reserve.

Fig. 12. Detail of plantation shown in previous figure as viewed in Google Earth, showing arrangement of recently established trees in rows. The yellow line is the boundary of the ENGO proposed reserve.

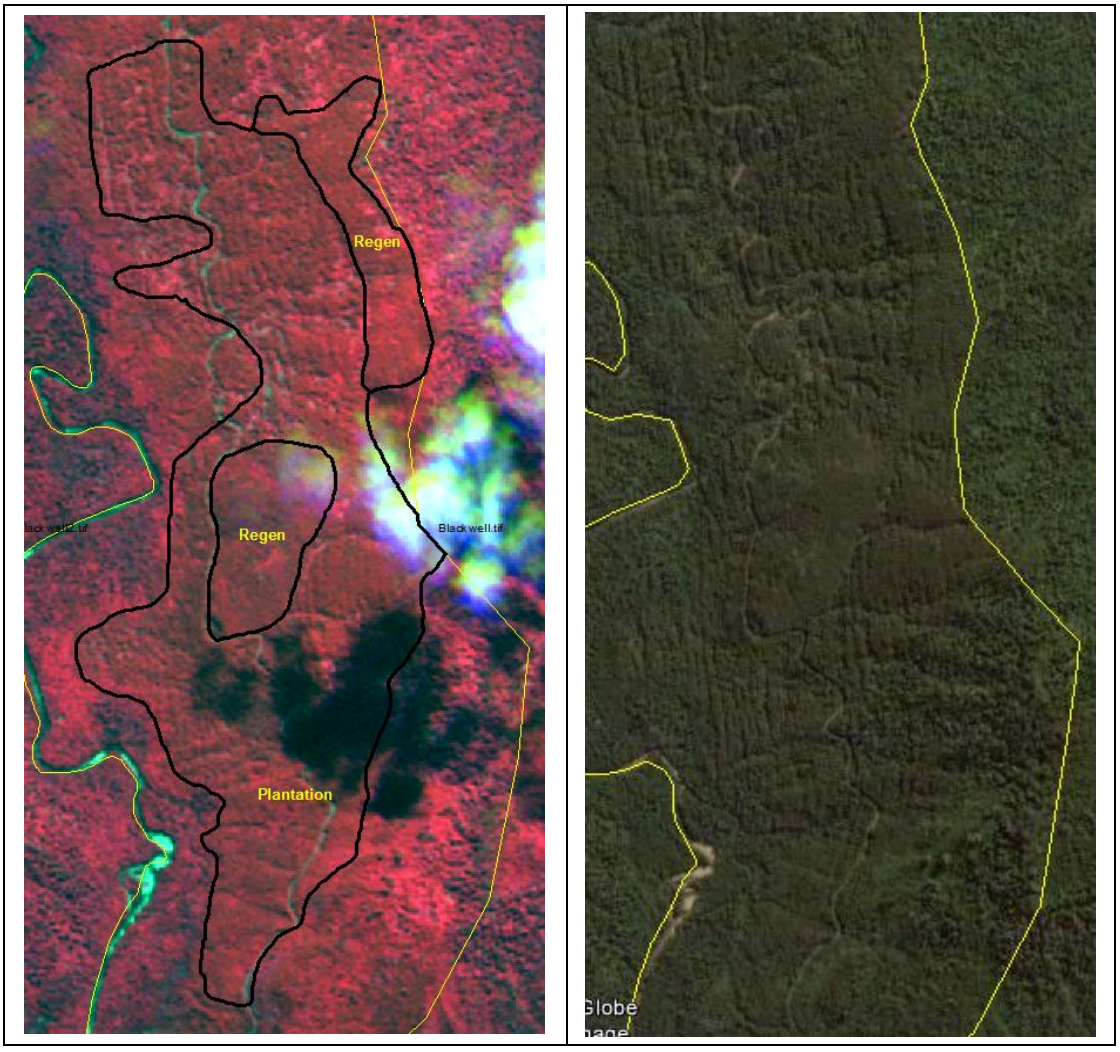


Fig. 13. A region identified as a mature plantation with associated non-plantation regeneration areas as indicated by black boundary lines. Yellow line shows boundary of the ENGO proposed reserve. Cloud obscures part of the forest in this RapidEye image.

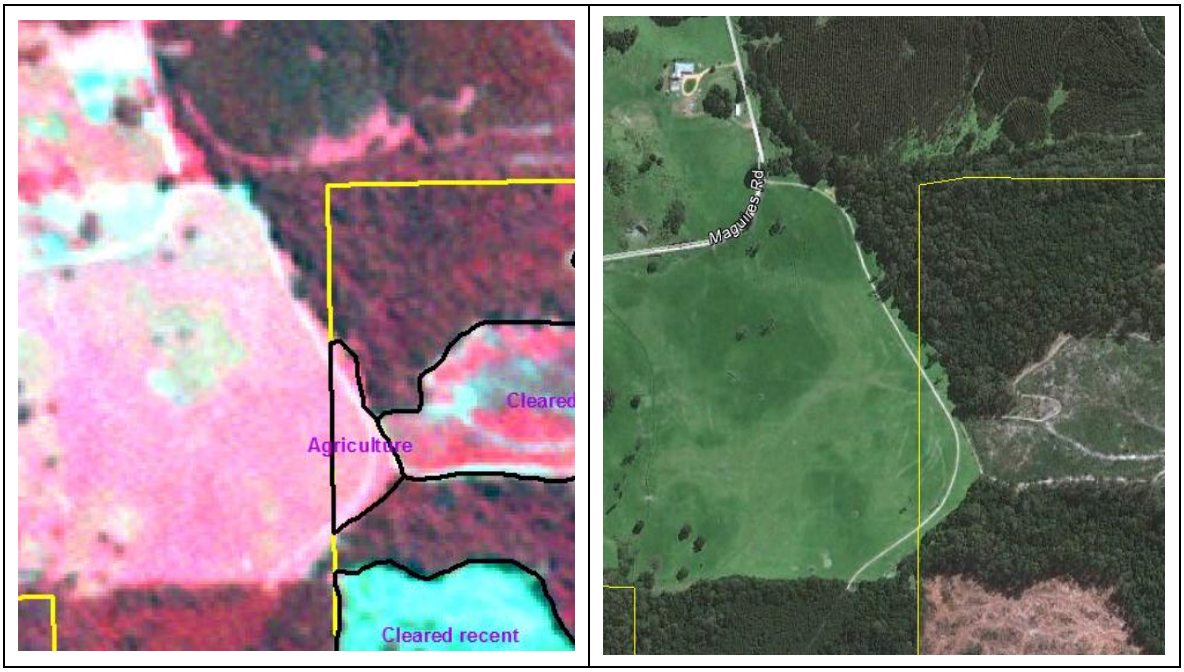


Fig. 14. In some places agricultural land overlapped with the IAG proposed reserved area. Where this was clearly discernible it was classed as "Agriculture". The yellow line is the boundary of the ENGO proposed reserve.

Results

The products of this project are in the form of a spatial layer of digitised polygons within the ENGO proposed reserve in geodatabase format. Attributes of this layer include: classification; area in metres; RapidEye image date; and where the classification was assessed as "Thinned" also includes an assessment of whether the area was considered heavily disturbed. Maps showing the extent of forest clearing, thinning and plantations within the IGA forest reserve area are included in **Appendix A**. Copies of the RapidEye imagery from which categorised polygons were digitised will also be provided to the IVG in electronic format.

A summary of assessed areas for non-"Regen" categories are presented in Table 2. Note that the ENGO proposed reserve area was measured as 563,683 hectare and this differs from the 572,000 hectares originally identified in the Terms of Reference. The area of 563,683 hectare is the polygon area of the final version of the "ENGO proposed area" shapefile which has been edited to remove mapping errors.

Table 2. Areas of digitised categories within the IGA forest reserve area in hectares and as a percentage of the IGA forest reserve area.

Category	Area (hectares)	Percentage of IAG Forest Reserve Area
ENGO Proposed Reserve	**563,683**	
Thinned and heavily disturbed	6,715	1.2
Thinned and not heavily disturbed	10,830	1.9
Plantation	2,126	0.4
Cleared	3,432	0.6
Cleared recent	5,233	0.9
Agriculture	193	<0.1
Total	**28,529**	**5.1**

Phase 2: Updated satellite imagery and change assessment

The results generated in this project are based on RapidEye imagery that was acquired between November 2009 and January 2010. This means that the digitised polygons reflect the land use at this period. In order to assess the changes in land use between Jan 2010 (acquisition of RapidEye) and the present date we proposed to use MODIS imagery. MODIS imagery is collected every day for the whole globe. The spatial resolution is 250 m per pixel. The imagery would be too coarse to identify new coupes, clearings, or thinning, however, the proposal was to identify coarse scale change based on MODIS imagery. We could then purchase more detailed imagery, such as RapidEye, for the changed areas to assess the recent changes within the last two years. MODIS imagery is freely downloadable from https://lpdaac.usgs.gov/ using the GLOVIS viewer https://lpdaac.usgs.gov/lpdaac/get_data/glovis. For this project we used the 16-day composite Enhanced Vegetation Index (EVI, product MOD13Q1). The advantage of using the EVI composite is that it highlights vegetation and reduces the effect of cloud cover in the 16-day composite. Band differencing was applied to calculate the difference in EVI between Jan. 2010 and Nov. 2011. A decrease in EVI is an indication of loss of vegetation, which could be used to identify forestry activities.

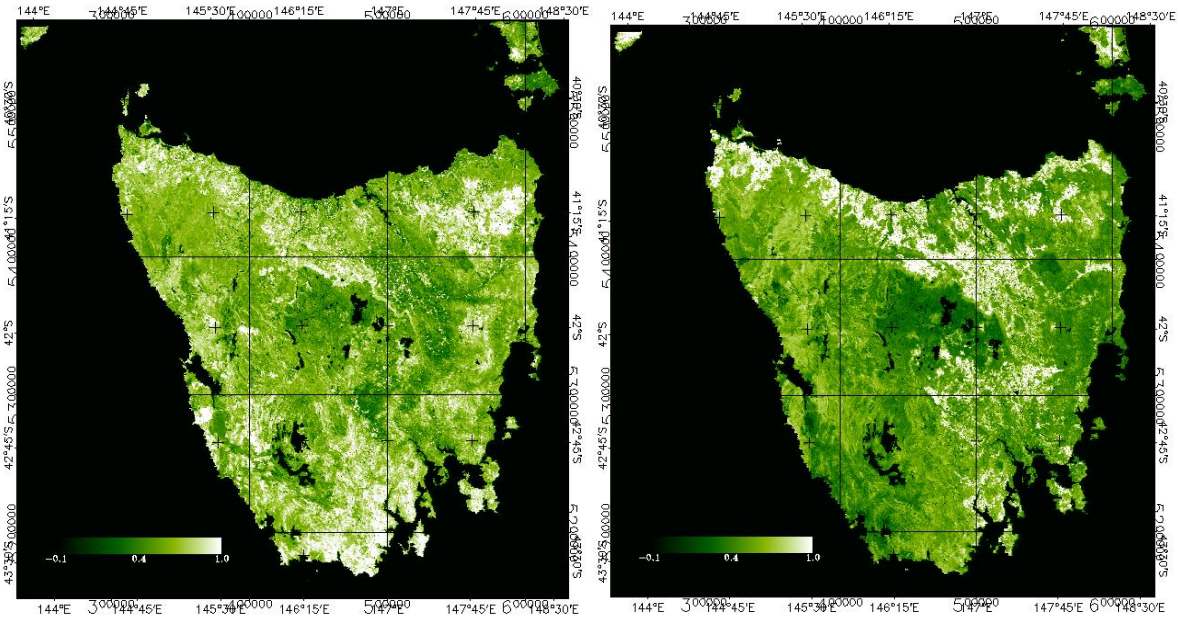


Fig. 15. MODIS Enhanced Vegetation Index (EVI) images for January 2010 (top), corresponding to the state of the vegetation at the time of RapidEye acquisition, and the second half of November (bottom), corresponding to the present state of the vegetation in Tasmania.

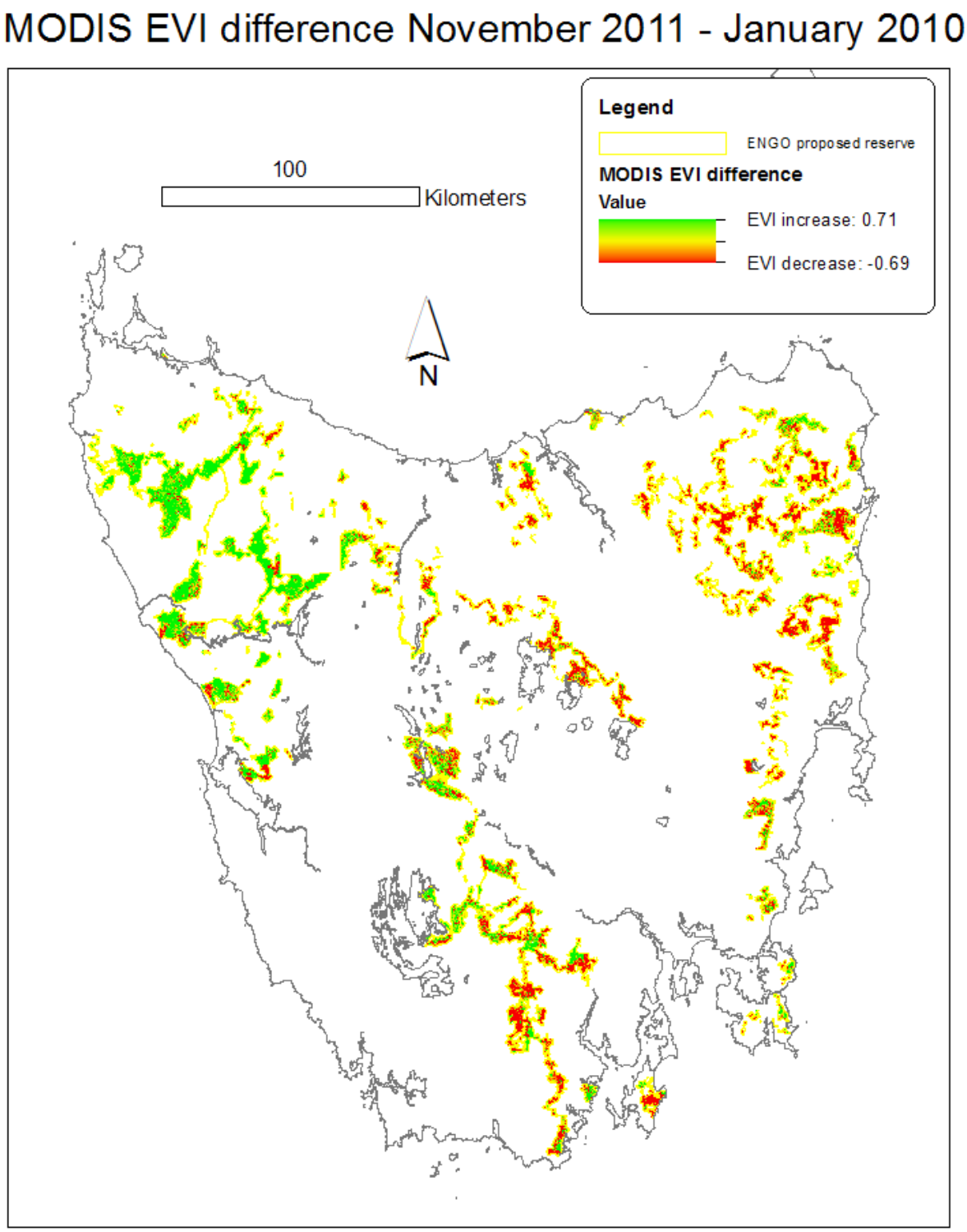


Fig. 16. MODIS EVI difference highlighting difference in vegetation density and cover between the two MODIS EVI images presented above.

The MODIS EVI difference image above did not result in the desired outcome. The image above highlights many differences in vegetation that are likely due to seasonal differences, images differences, and atmospheric differences. The proposed approach based on MODIS imagery is therefore unsuitable for the detection of recent forestry activities.

One other option we tested was to use freely available Landsat 7 ETM+ imagery, which has recently been made available by the USGS and NASA. Landsat has six multispectral bands at 30 m spatial resolution and one thermal band at 90 m resolution. The figures below illustrate cleared areas digitised on the Jan. 2010 RapidEye imagery (left) compared to more recent Landsat imagery (middle). The brown patch on the right side of the originally cleared areas shows recent activity. The thermal sensor of Landsat (right) also clearly highlights this land use change.

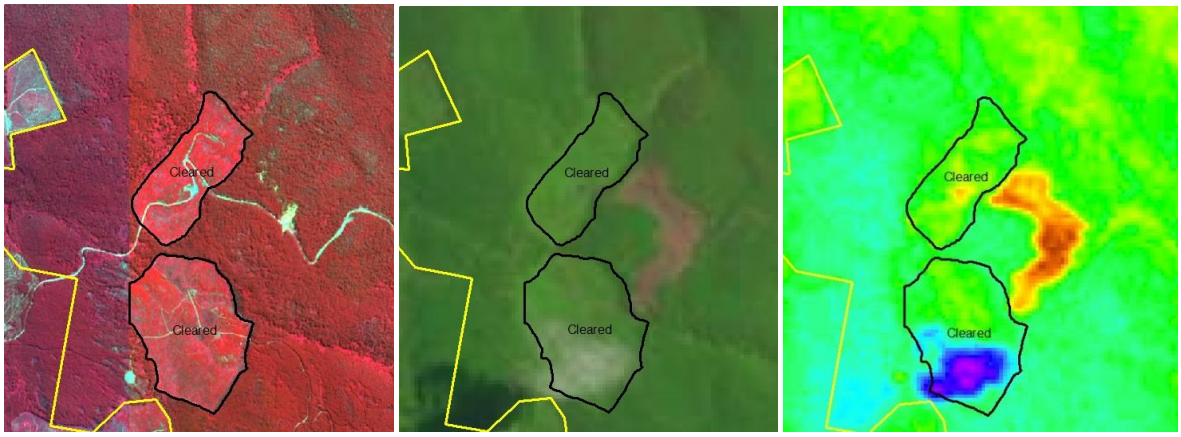


Fig. 17. Recent Landsat 7 ETM+ imagery middle (visible) and right (thermal) shows a recent clearing, compared to the Jan. 2010 RapidEye image (left).

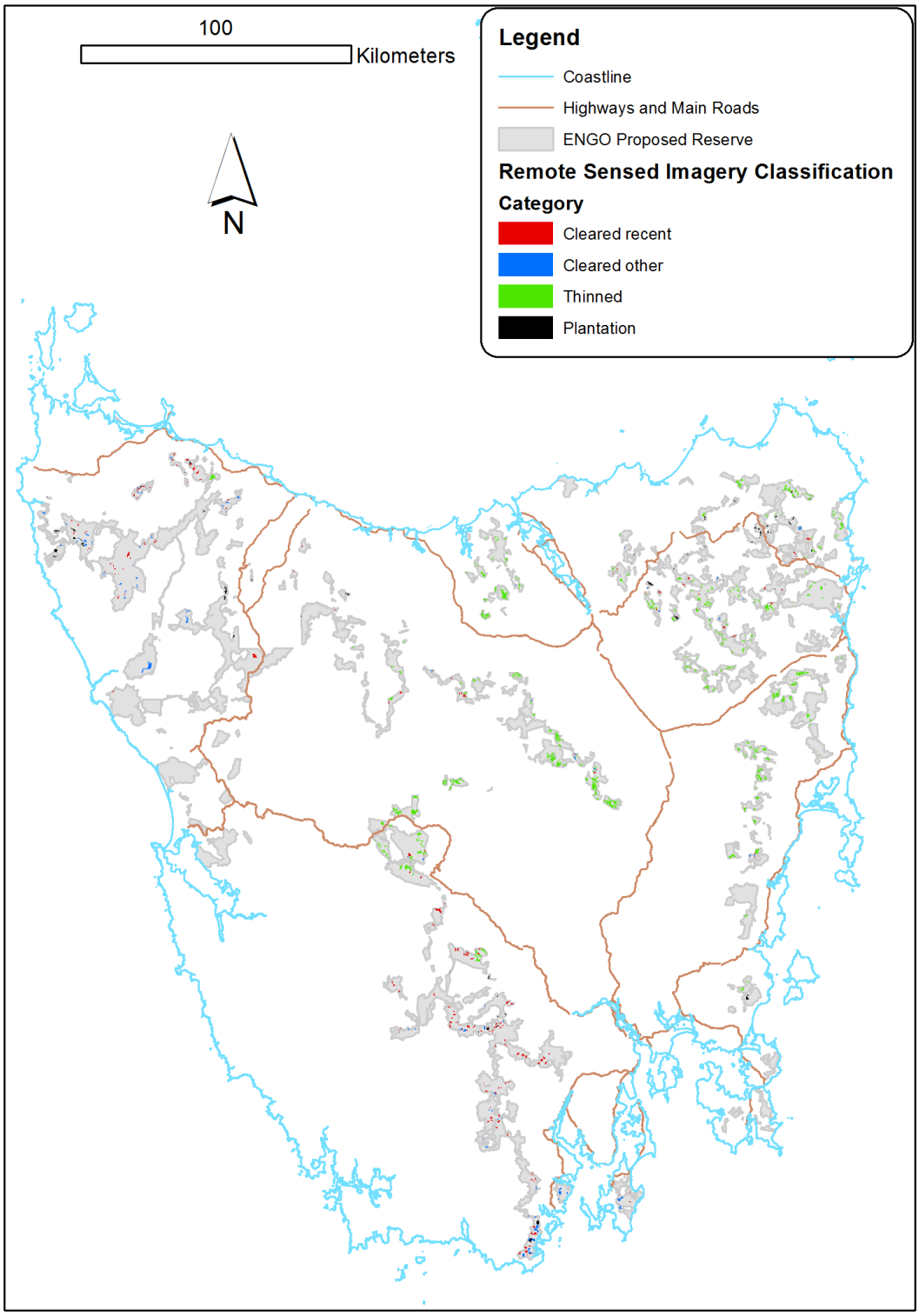
Phase 2 recommendation

For Phase 2 of this project we recommend the initial use of Landsat to identify the most recent land use changes. The spatial resolution of Landsat is lower than RapidEye at 30 m, however, it will provide a cost-effective solution. For more detailed surveys and the absolute latest changes, additional RapidEye imagery can be purchased. Alternatively, we could request coupe information and information on logging history from Forestry Tasmania. Based on this information we can identify the changes during the last two years (since the RapidEye acquisition) and acquire new RapidEye imagery for these areas for verification. This will most likely offer the most accurate solution and fill the spatial information gap of the last two years.

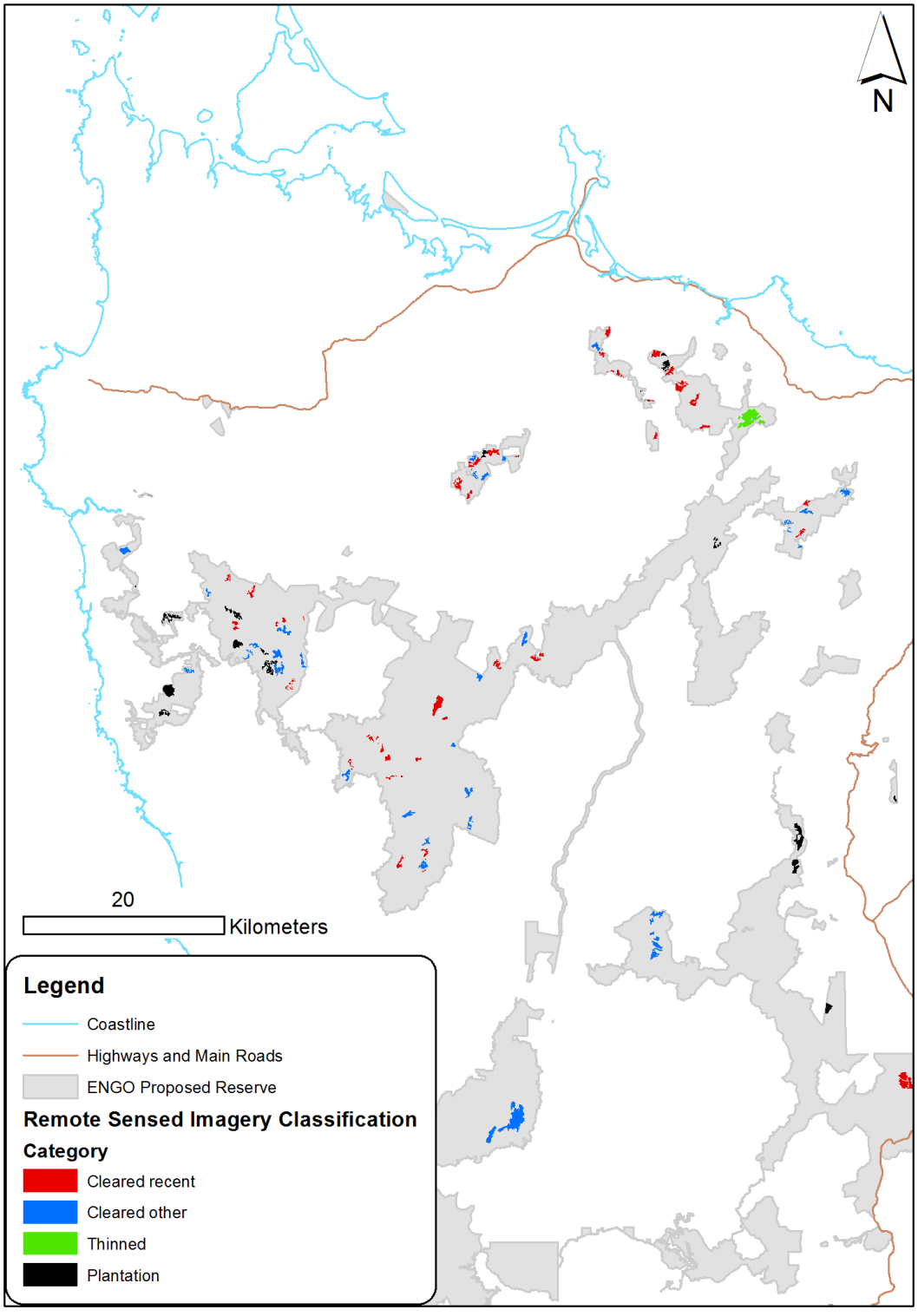
Appendix A

Maps showing the extent of forest clearing and plantations within the ENGO proposed reserve as determined from available RapidEye satellite imagery.

Statewide



North West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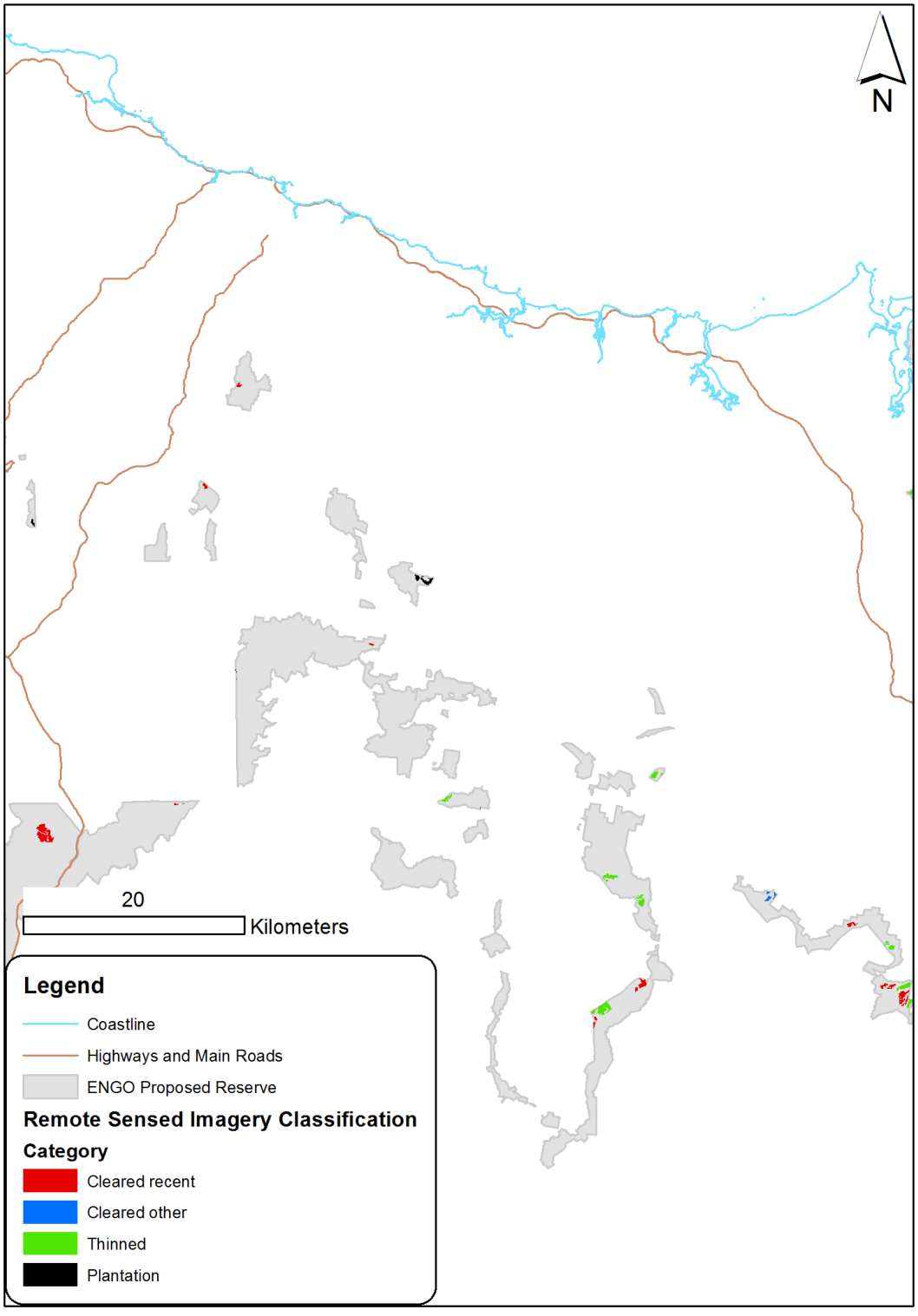
Central North West



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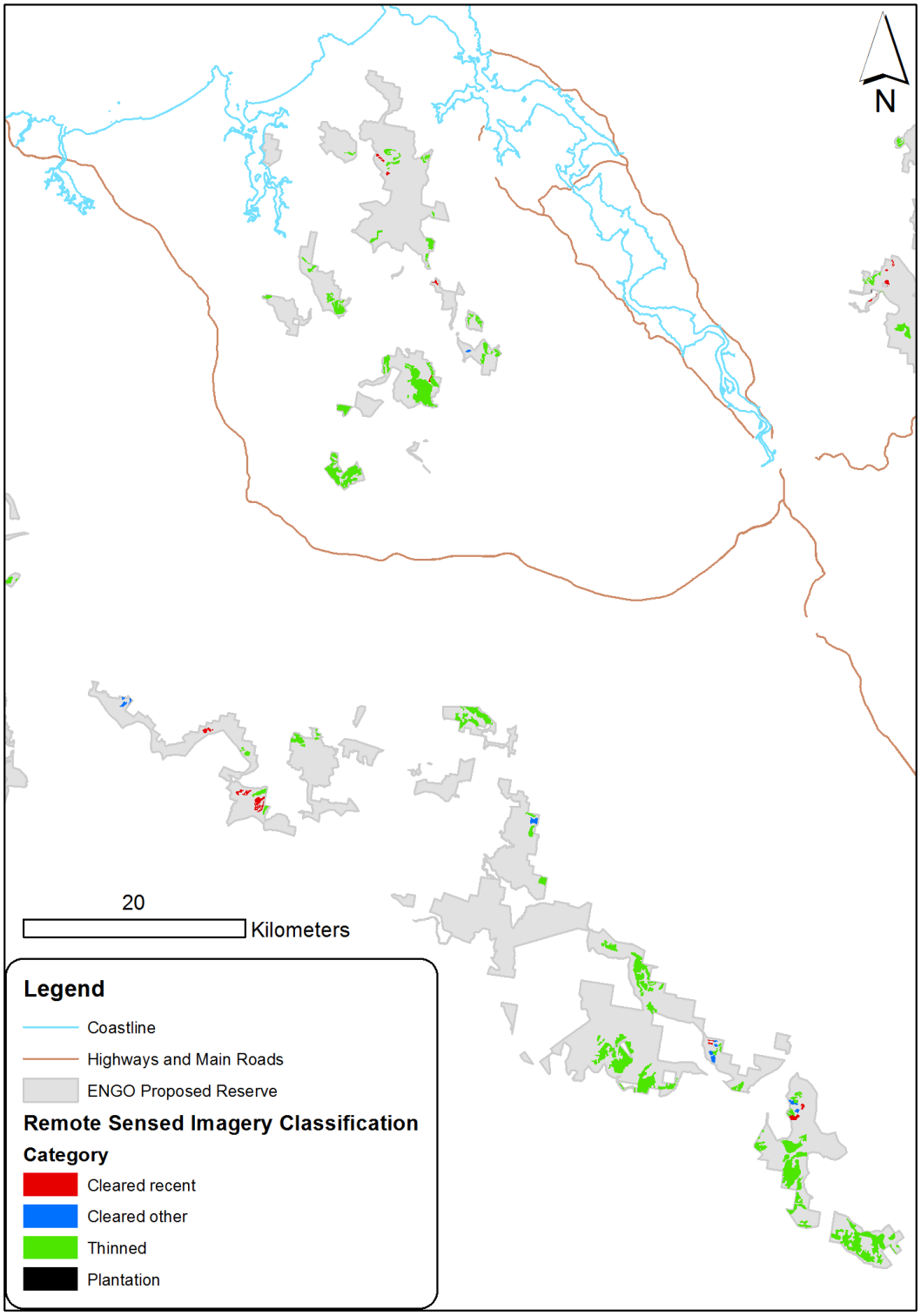

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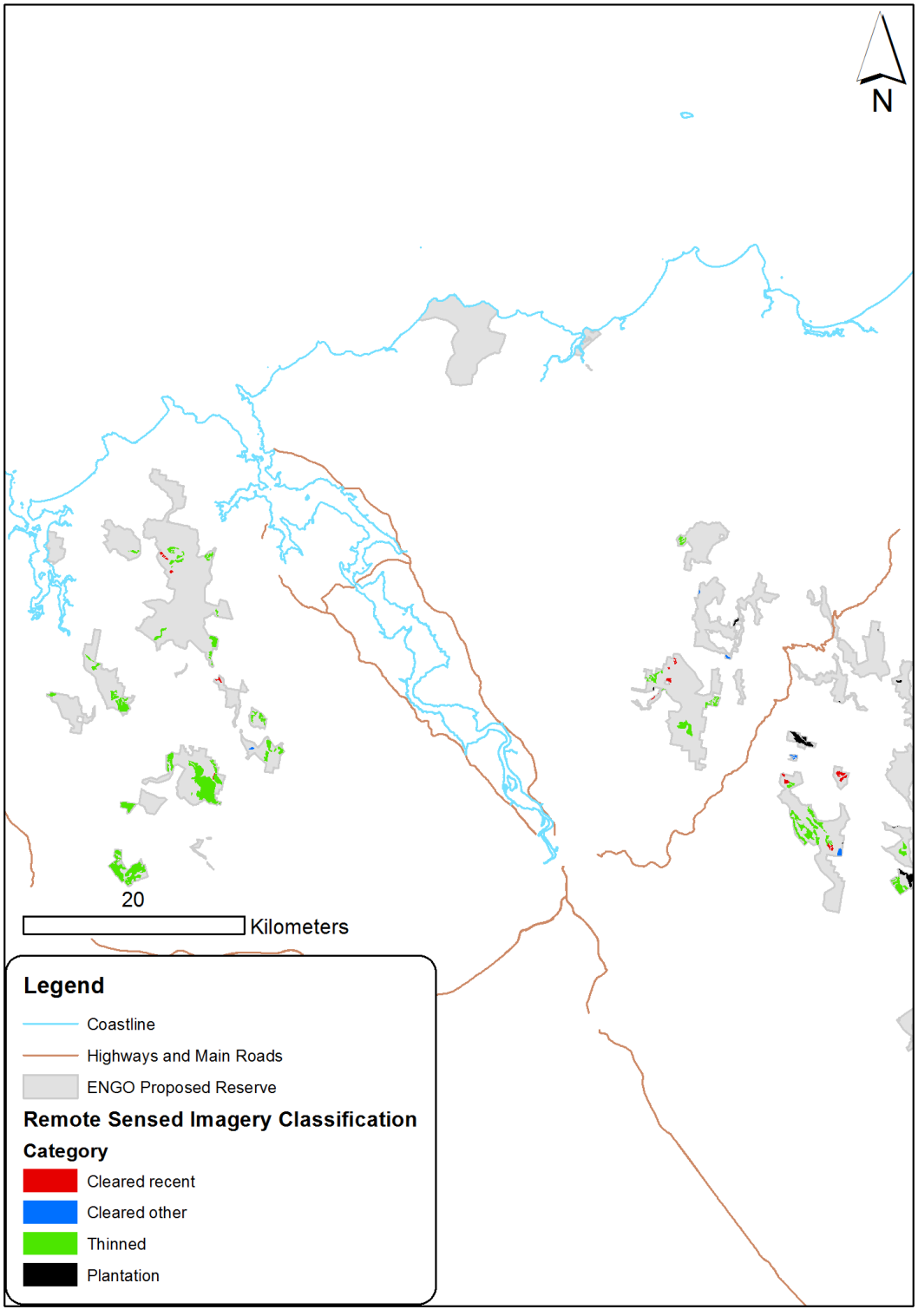
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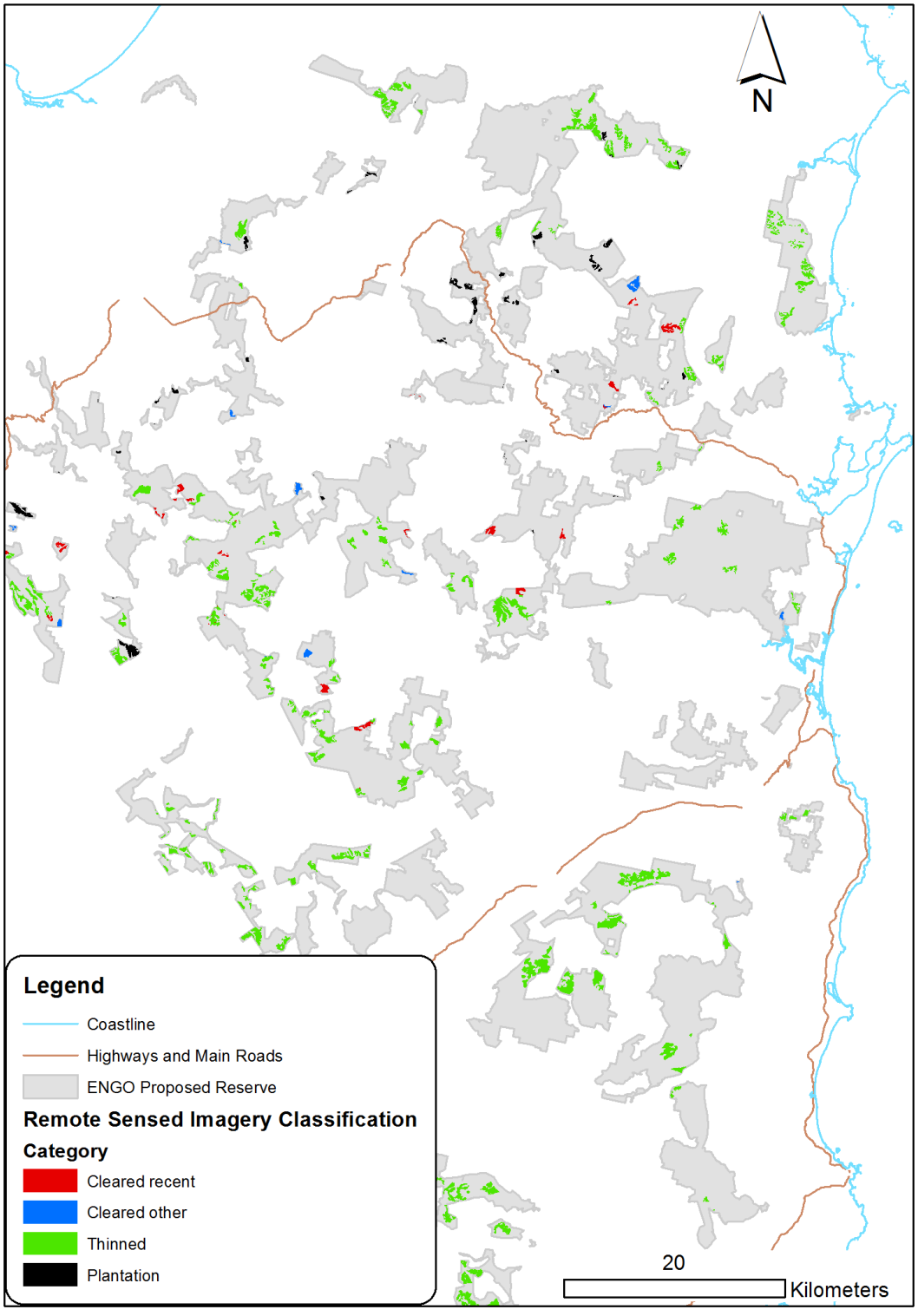
North East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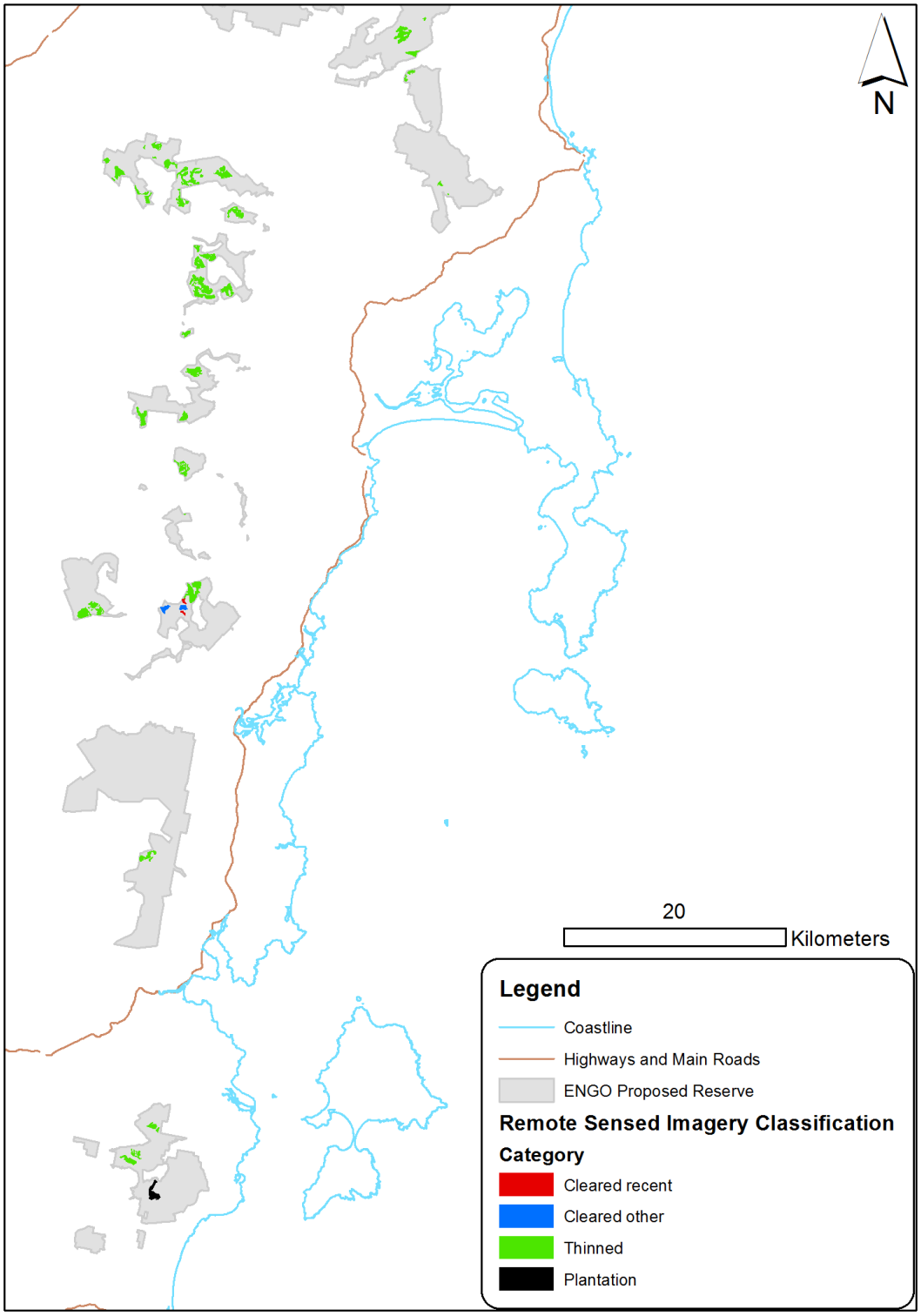
East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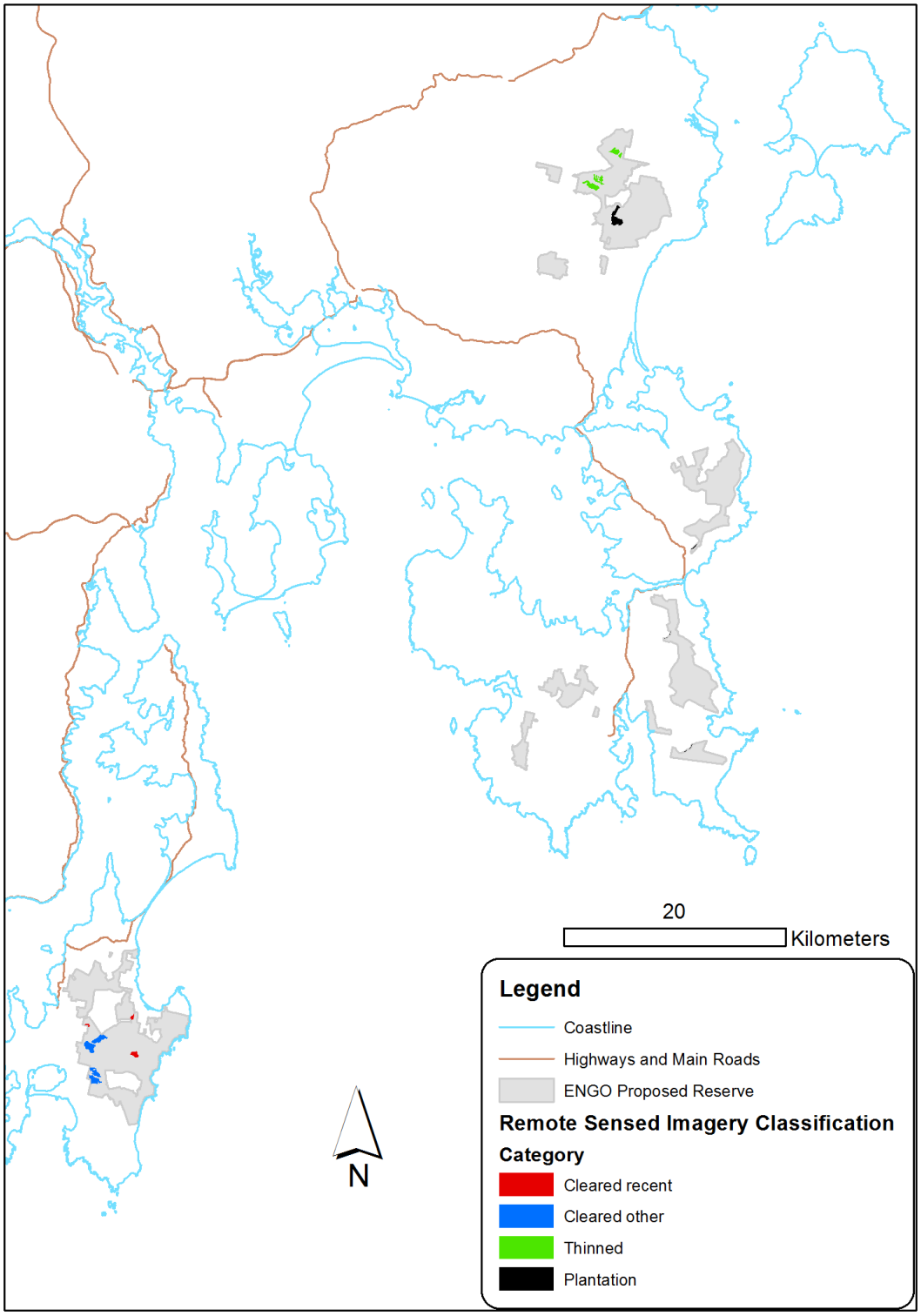
South East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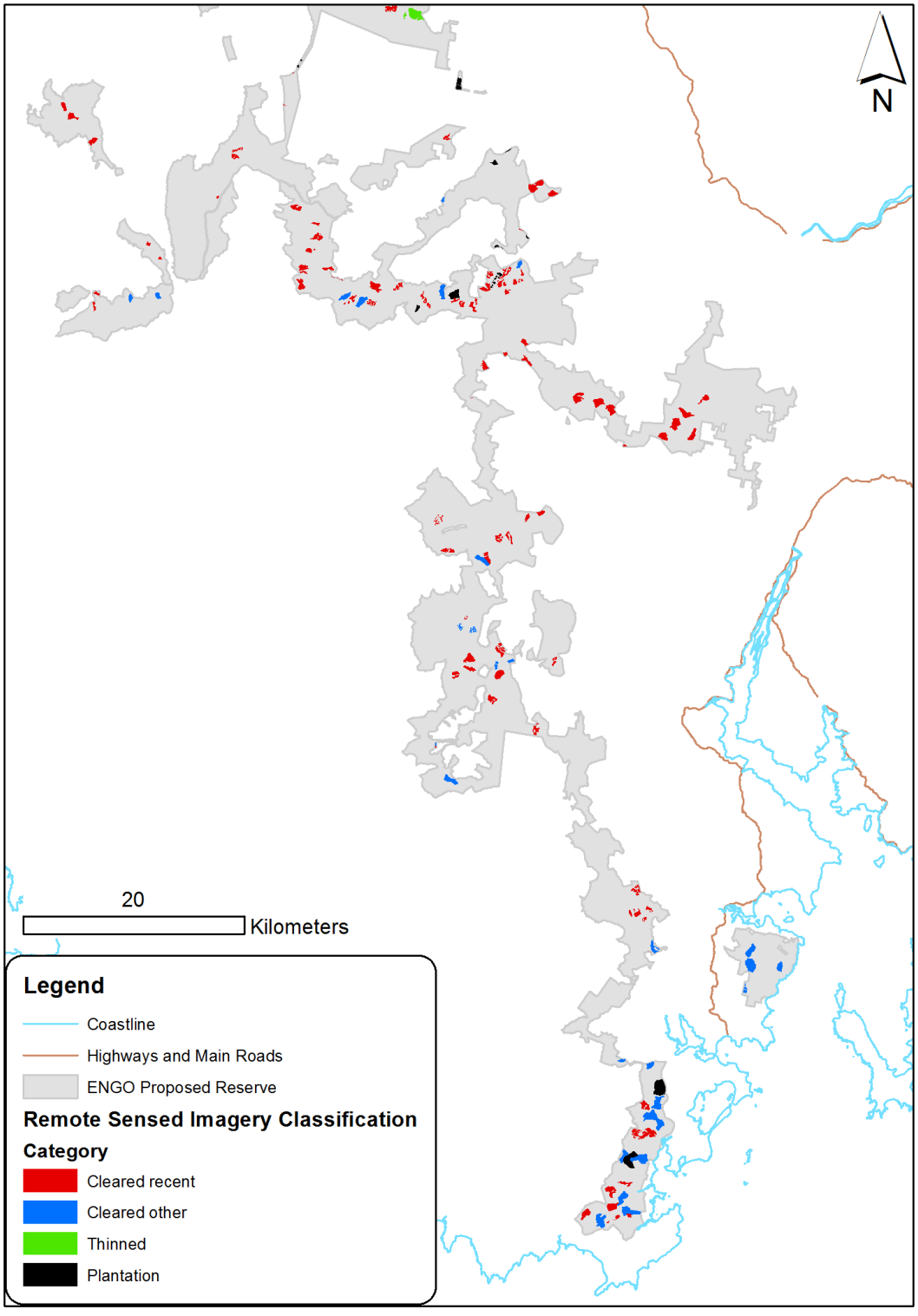
South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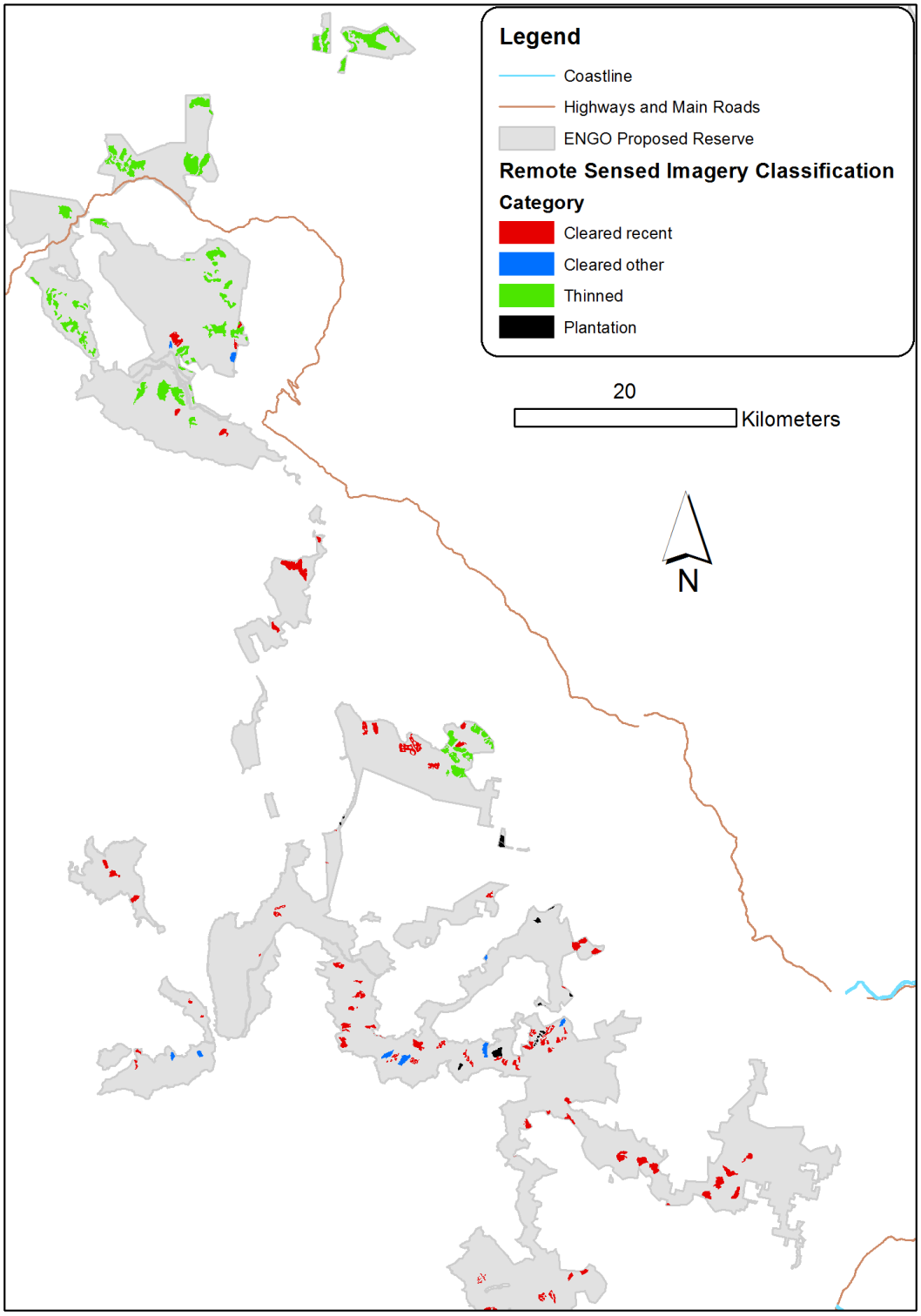
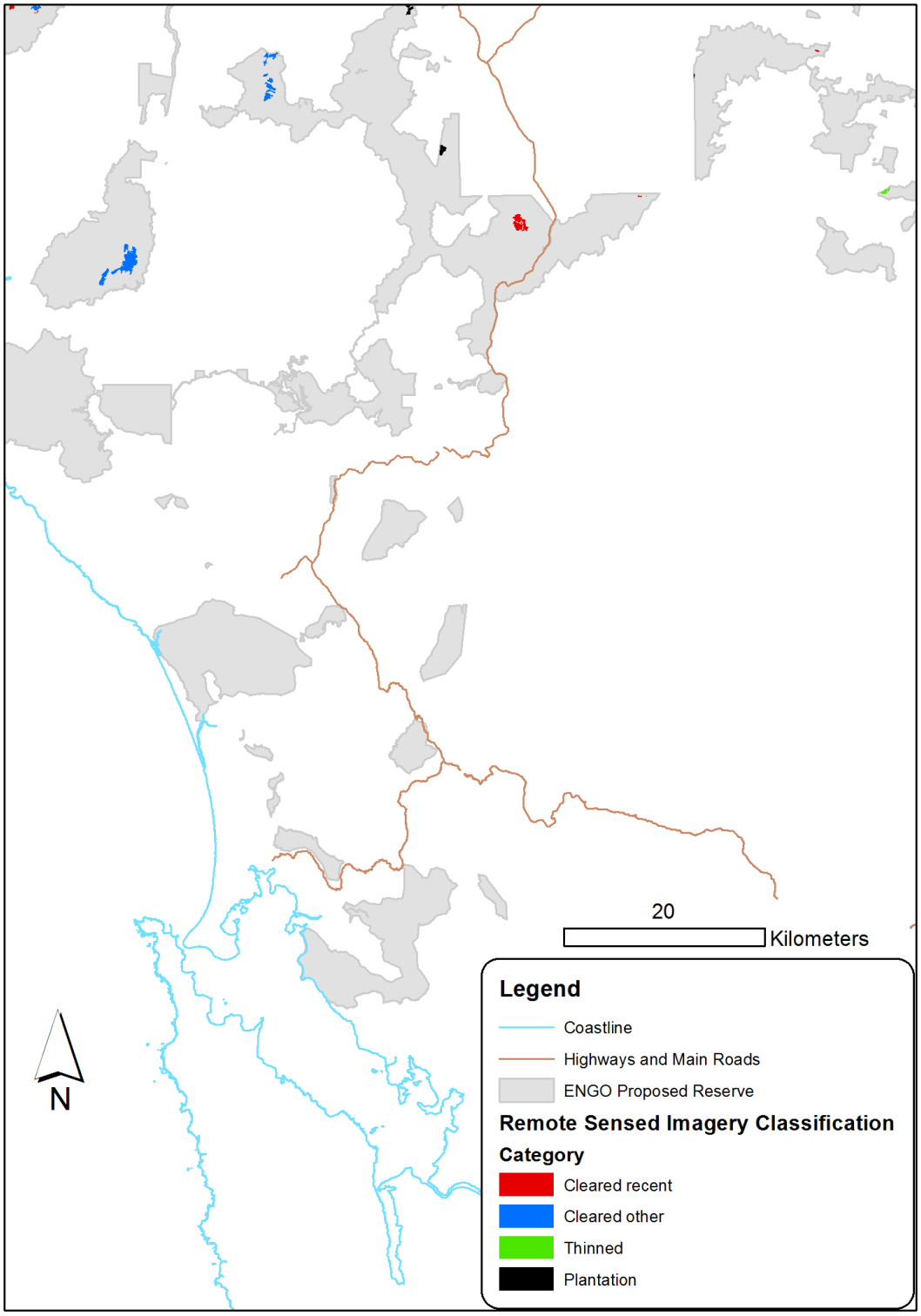
South Central



West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