# Cool Country Koala Project (South)

## Final Project Report and Koala Management Plan – Armidale/Uralla, Walcha and Nowendoc

Stringybark Ecological

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## Abbreviations

| | |
|---|---|
| ALA | Atlas of Living Australia |
| BRG CMA | Border Rivers-Gwydir Catchment Management Authority |
| CWD | Coarse Woody Debris |
| FPC | Foliage Projected Cover |
| GIS | Geographic Information System |
| KHE | Koala Habitat Envelope |
| NR CMA | Northern Rivers Catchment Management Authority |
| NT LLS | Northern Tablelands Local Land Services |
| NW LLS | North West Local Land Services |
| OEH | Office of Environment and Heritage |
| PCT | Plant Community Type |
| RGB | Red Green Blue |
| SED | Small end diameter |

## Acknowledgements

We acknowledge and thank all of the land owners who allowed us access to their land to carry out surveys. Northern Tablelands Local Land Services, in addition to managing the project, provided access to Travelling Stock Routes and Reserves; contacted landholders; and provided mapping data. We also wish to thank staff of National Parks and Wildlife Services and the Forestry Corporation of NSW for facilitating access to their reserves. University of New England and Walcha Council provided venues for our community workshops. We also wish to thank the staff and students of Nowendoc Public School, Walcha Central School, St Patrick's Catholic Primary School (Walcha), Uralla Central School, Black Mountain Public School and Thalgarrah Environmental Education Centre. Southern New England Landcare and Armidale Tree Group helped us to contact landholders through their newsletters.

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## Summary

- Field surveys were carried out at 139 sites in the Armidale-Uralla, Walcha and Nowendoc areas of the Northern Tablelands of New South Wales. At each site an area within a one metre radius of each of 30 trees was searched for koala scats. The number, size and age of the scats was recorded and the species of each tree. Vegetation surveys were carried out at 74 sites.
- Of the 3910 trees surveyed, 266 had scats present and 3644 had no scats (6.8% occurrence). 49% of plots (30 trees) had scats present. Scats were detected in each of the 3 study areas.
- In the scat surveys, 51 species of trees were surveyed. Scats were found under 24 species (only 20 species for those with more than 10 individuals).
- Koalas were observed in Nowendoc and west of Uralla. Many recent sightings of koalas were reported to the project team by landholders and the community. All the koalas we saw were healthy.
- The data from the scat surveys and the reports of koala sightings indicate that koalas are spread throughout most of the areas we surveyed, but with a few exceptions, occur as low-density populations. The exceptions include low to mid-slope Snow Gum (*Eucalyptus pauciflora*) vegetation communities near Nowendoc and upper slope stringybark (*E. youmanii* and *E. laevopinea*) communities between Armidale and Guyra.
- Koalas were detected in some Plant Community Types (PCTs) more than others. The preferred PCTs were: 541, 507, 565, 510, 567, 554, 1341, 568 and 741 (see Table 7).
- We identified the following core populations based on our observations and existing Atlas records:
    - North of Armidale to Guyra, between Boorolong Rd in the west and Rockvale Rd in the east.
    - West of Uralla to Kingstown, north to Invergowrie and including the Yarrowyck-Torryburn area.
    - The Nowendoc River Valley around Nowendoc and Riamukka.
- We identified the following areas for revegetation to improve connectivity for koalas based on our data, existing Atlas records and state-wide 3C modelling (Drielsma et. al., 2014):
    - East of Uralla to Enmore, Mihi and Dangars Falls, including Gostwyck.
    - Improving east-west linkages between ridges running north-south between Guyra and Armidale.
    - Between Black Mountain and Invergowrie west of Boorolong Rd.
    - West of Uralla between Uralla and Balala and north to Invergowrie.
    - North-east of Walcha to the Blue Mountain area connecting existing large remnants.
    - South-west of Walcha towards Aberbaldie.
    - At a local scale, connectivity between remnants in the Nowendoc Valley could be improved.

- The project has been unable to detect obvious threats to koalas in this region. Koalas were not detected in many areas of seemingly suitable habitat we surveyed. There was no correlation with threats that we looked for (grazing, tiger pear, weeds, dieback, wild or domestic dogs). During the survey two koalas were reported to us as having been hit by cars on the New England Highway north of Armidale.
- The project was limited in the number of sites and the variation in the landscape that could be surveyed, so all recommendations must be considered in this light. However, from the combination of new survey results, new sighting records and existing records of koala sightings, a clearer picture of the areas where koalas occur and are likely to move through is emerging.

## Recommendations

- Northern Tablelands Local Land Services, with its partners, should work to protect core populations of koalas identified in this report in the Armidale-Uralla and Nowendoc priority areas. This may include initiating stewardship agreements or covenants and improving the condition of existing vegetation through revegetation, weed control, predator control or other actions identified in the Saving Our Species Action Toolbox (OEH, 2016).
- NT LLS should encourage and facilitate revegetation works in the identified corridor areas, using the PCTs identified in this report as reference ecosystems. Within the identified corridor areas use the mapped PCT and FPC distributions to prioritise revegetation work.
- NT LLS should facilitate further investigation into koala populations in the three priority areas:
    a. Update the Koala Habitat Envelope Mapping using results from this project and recent Armidale Regional Council records.
    b. Running a community engagement program encouraging landholders in the whole LLS area to report all koala sightings over a defined period (3-6 months). Follow up reports with rapid site assessments by contractors using the vegetation and scat survey methods developed for this project. This will build a better picture of the distribution and population size of koalas in the region.
    c. Finer-scale, targetted spotlight surveys in core habitat areas identified in this project.
    d. A radio-collar or GPS tracking project to increase knowledge of koala home ranges in the region. The 'Newholme' – Black Mountain area would be a good candidate for this research.
    e. Newly identified Koala hotspots within the Armidale and Nowendoc focus areas could be further defined and explored with the aid of high resolution remote sensing products such as ADS40/80 aerial photography and airborne lidar. In particular the Black Mountain population lies within a spatially data-rich zone. A baseline database of high resolution data and analysis products could be generated to support KHE v3 and future tracking-collar studies. Regional hotspot locations can also be placed on

Department of Land and Property Information priority acquisition programmes for lidar and ADS.

- We recommend caution in using the currently available PCT mapping for the region. Further on-ground assessment of mapping is required to improve the accuracy of the product.

## Introduction

### Project Description

Northern Tablelands Local Lands Service (NT LLS) has recently commissioned a number of studies into threatened species and communities on the Northern Tablelands of NSW (Fig. 1). NTLLS has focused on koalas (*Phascolarctos cinereus*) because of a lack of knowledge about koala populations in the area. Initially, a Northern Tablelands Koala Recovery Strategy [the Strategy] was developed by The Envirofactor (Hawes et. al., 2016).

The Strategy identified 14 koala populations on the Northern Tablelands. A project Reference Committee identified three of these as priority areas for the project to focus survey effort. From June 2016 to May 2017 the "Cool Country Koala Project (South) 2016" conducted systematic field based surveys in priority areas and worked with members of the community to identify areas where koalas occur. The three priority areas were: Armidale/Uralla (3543 $km^2$); Walcha (1850 $km^2$) and Nowendoc (1419 $km^2$). These are a subset of areas identified in the Strategy.  The extent of the three areas are shown in Figures 2 to 4. A complementary project was run in the Ashford and Delungra area by a separate project team.

The aims of the project are:

- To address data deficiencies through systematic field based surveys in priority areas as identified in the Northern Tablelands Koala Recovery Strategy,
- To inform future investment in koala habitat restoration and revegetation, and
- To build a platform of community engagement to initiate community monitoring programs for threatened species and communities, via private/public landholders where surveys are undertaken as part of this project.

To achieve these aims, the project implemented a community engagement program to encourage the community to participate in the project, and conducted a systematic field survey in three priority areas. This final report documents the outcomes of the field surveys and community engagement activities in regard to:

- The presence or absence of koalas in each area and the estimated population density,
- The species of preferred koala food trees and the ecosystems these trees occur in,
- Threats to koalas and associated management actions to mitigate these threats,
- Recommendations of priority areas for restoration, enhancement and connectivity of koala habitat and identification of reference ecosystems for these actions, and
- Recommendations for continued community engagement.

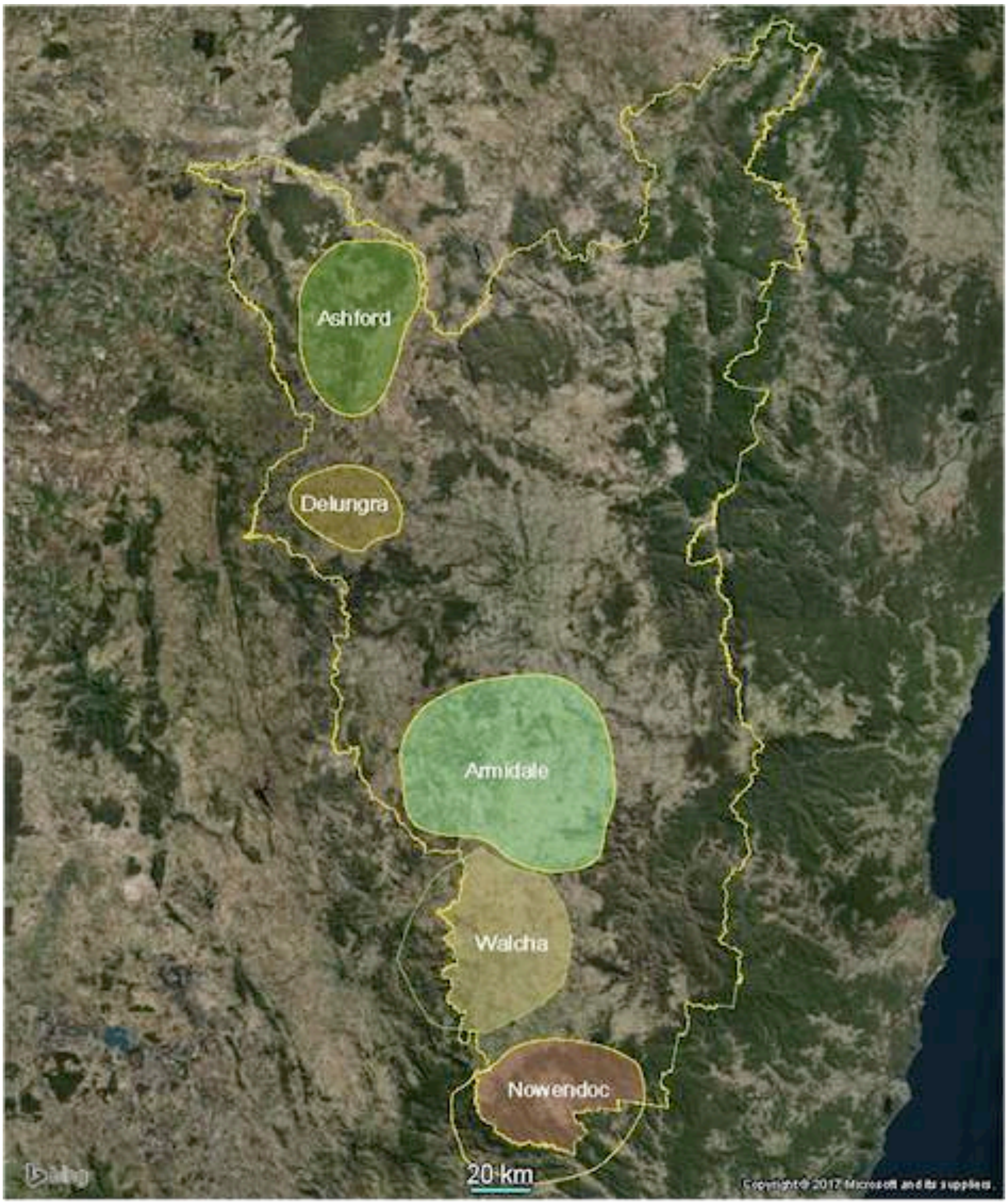


**Figure 1: Boundary (in yellow) of the Northern Tablelands Local Land Services area and the relative location of the three priority areas for this project and two priority areas of an associated northern project.**

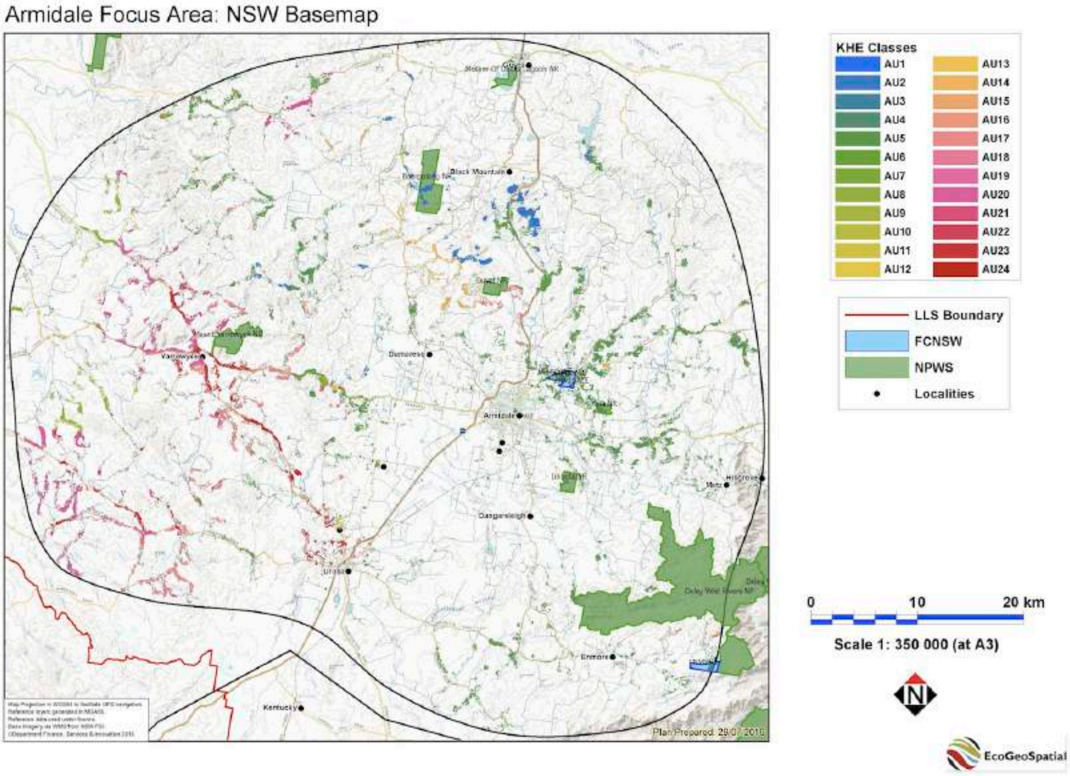


**Figure 2: Boundary of the Armidale-Uralla Koala Priority Study Area. Blue dots indicate previous records of koala occurrence from NSW Wildlife Atlas. See Appendix 2 for explanation of KHE classes.**

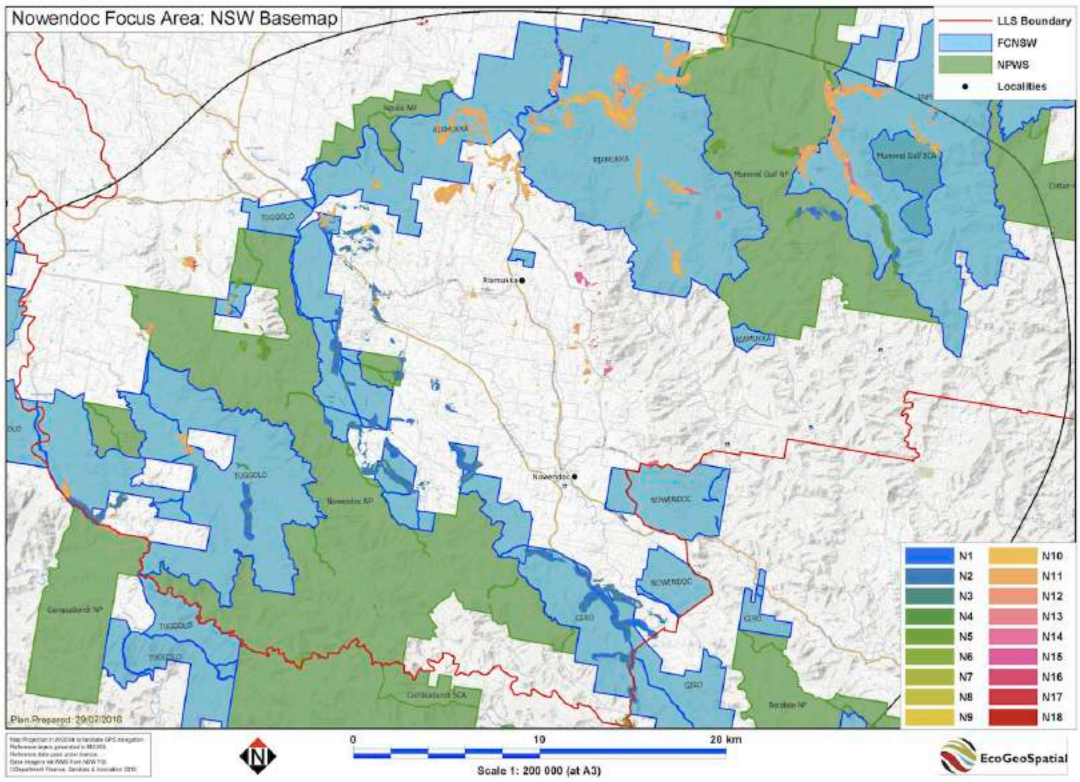


**Figure 3: Boundary of the Nowendoc Koala Priority Study Area. Blue dots indicate previous records of koala occurrence from NSW Wildlife Atlas. See Appendix 2 for explanation of KHE classes.**

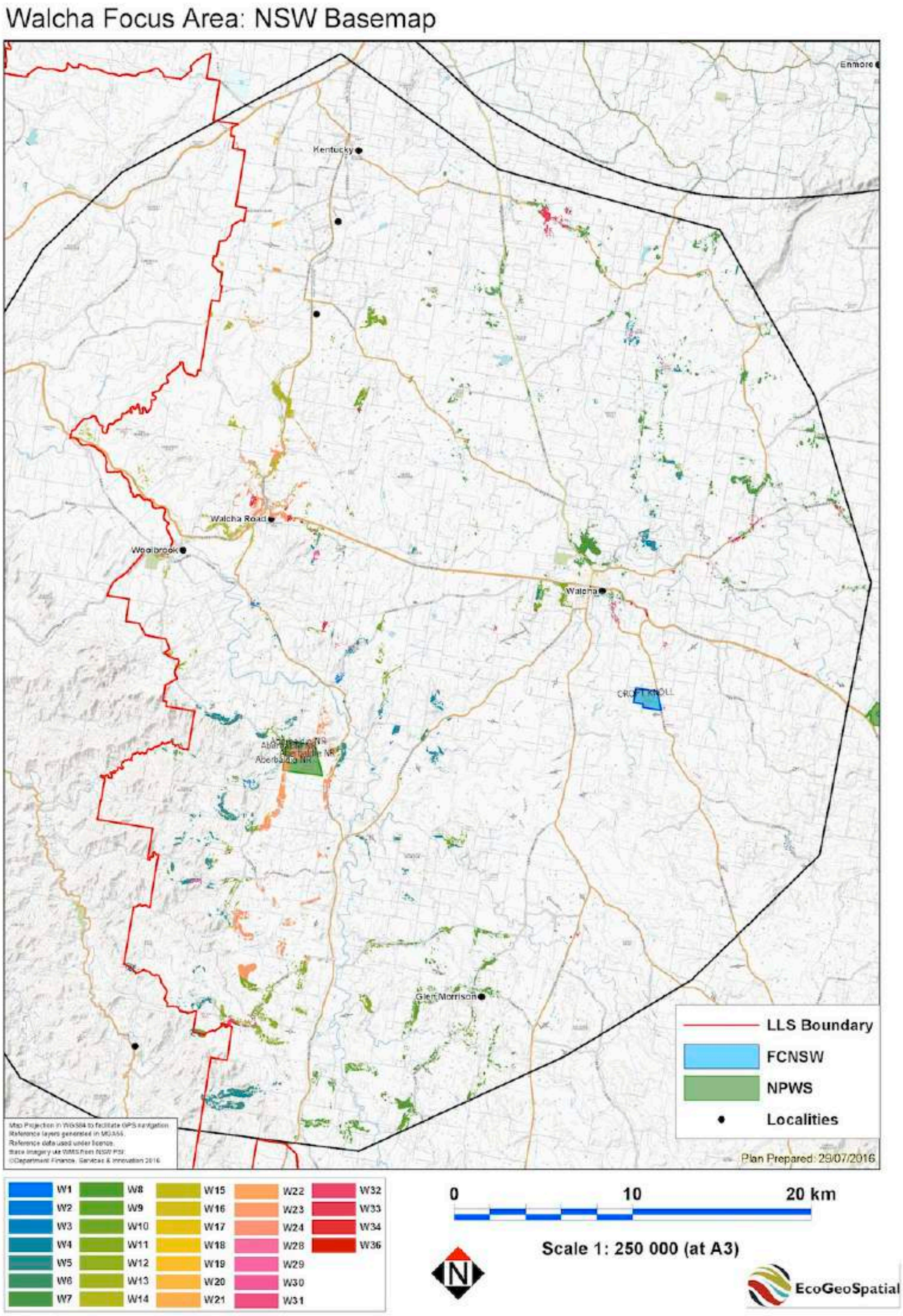


**Figure 4: Boundary of the Walcha Koala Priority Study Area. Blue dots indicate previous records of koala occurrence from NSW Wildlife Atlas. See Appendix 2 for explanation of KHE classes.**

## Methods

The consultants who developed the Strategy had intended to model habitats on the Northern Tablelands preferred by koalas, based on existing koala records and mapped topographic, climatic and vegetation information. Unfortunately, the number of records and the spatial and temporal bias of these records meant that meaningful models could not be developed. The Strategy recommended a number of actions to improve baseline data about regional koala populations and allow future modelling to have a greater degree of accuracy. The priorities for future koala surveys (in decreasing order) were identified as:

1. Areas with old koala records (pre-2001) and few if any recent records,
2. Under-surveyed areas,
3. Areas with known populations and numerous koala records over time.

### GIS analysis

The aim of the GIS analysis process was to identify parts of the landscape in the priority areas that had similar environmental attributes to those locations where koalas had previously been recorded, in line with the first and second survey priorities in the Strategy. This approach was discussed and adopted by the Reference Committee for both the south and north Cool Country Koala projects. The details of the desktop GIS analysis method can be found in Appendix 1.

In summary, the method used existing NSW Wildlife Atlas records (Office of Environment and Heritage, 2016) in the NT LLS area and compared these to a range of environmental attributes to see if there were any associations between these attributes and past koala records. There were not enough records to use regression analysis (as the authors of the Strategy found), so we used frequency histograms to see which 'class' of each attribute had the most records. Table 1 shows the four attributes that were most indicative of koala presence. We then used these attributes to map combinations of all classes of these four variables.

**Table 1: Koala Habitat Envelope for existing koala records (attributes and ranges used)**

| | Ashford | Delungra | Armidale | Walcha | Nowendoc |
|---|---|---|---|---|---|
| Geology (1) | Clastic sediment, felsic intrusive | Mafic extrusive | Clastic sediment, felsic intrusive | Mafic extrusive, Clastic sediment, felsic intrusive | Mafic extrusive, Clastic sediment |
| PCT (2) | 578, 594, 595, 596, 368, 516, 78, 84 | 84, 590, 599 | 510, 538, 565, 567 | 501, 565, 567, 568 | 526, 554, 608 |
| Slope Relief (3) | 22, 32, 33, 43 | 21, 22, 32, 33 | 32, 33, 44, 45 | 32, 33, 43, 44 | 43,44,54,55 |
| FPC (4) | 30 – 50% | All woody | 30-100% | All woody | 50-80% |

(1) 1:250,000 scale Surface Geology of NSW:c.2003 – Department of Industry
(2) BRGN v2 and LLS extension PCTs, OEH

(3) Terrain data from Soil and Landscape Grid of Australia (various agencies: inc. Geoscience Australia)
(4) FPC 5m SPOT-5 2008-2012, and also 5m woody/non-woody binary mask. OEH

For each priority areas, the stratification was combined into distinct classes of combinations of geology, PCT and slope position (from Slope and Relief). Many combinations of stratifying factors did not occur naturally. The remaining classes were mapped to guide field work, with priority given to sites in lower slope positions. In the analysis of the datasets, some were more strongly associated with koala records than others. We weighted the combined classes to reflect this association. This further enabled us to reduce the target area for searches. After feedback from NT LLS we further clipped the KHE to sites within 200m of a road or track to ensure we could easily access survey sites. The final classifications used are shown in Appendix 2.

The final reduced KHE was provided to all field staff as geo-referenced PDF files for use in the field on a tablet computer using *AvenzaPDFMaps.

## Community Engagement

An important aim of the project was to engage the community in observing koalas, reporting their presence and taking appropriate management actions to protect koalas. The methods used to engage landholders to allow scat surveys is described below.

With NTLLS, we developed a small fridge magnet and had 1500 printed. The fridge magnets directed people to report koala sightings to a LLS 133 phone number or to the Atlas of Living Australia. Seven hundred magnets were supplied to the northern team for distribution. We distributed the remaining magnets at workshops, at other events (such as Frog Dreaming), to LLS, Landcare and Armidale Tree Group and to Council offices in Armidale, Guyra, Uralla and Walcha.

We engaged the broader community through the use of conventional and social media and through a series of workshops and school visits. Table 2 lists the workshops and visits and the number of attendees. We found that social media was the most effective means of getting people to come to events or express interest, followed by word-of-mouth and direct invitation.

Table 2:Community engagement activities conducted by the Cool Country (south) Koala project

| Event | Location | Number attending | Outcomes |
|---|---|---|---|
| Armidale workshop | Newholme field studies centre | 10 | 2 volunteers helping with field surveys. 3 others adding records to ARC database. |
| Walcha workshop | Walcha Council chambers | 1 | Journalist who then wrote an article for Walcha paper. |
| Nowendoc workshop | Nowendoc Public school | 15 (including 9 students) | Workshop led to us being given access to 5 properties in the Nowendoc area. |
| Walcha Council staff breakfast briefing | Walcha Council depot | 35 | Alerted WC staff to koala habitat requirements and gave supervisors numbers for reporting sightings. Alerted to 3 new population areas. |
| Black Mountain School | Black Mountain Primary School | 30 students, 2 teachers. | Awareness raising and distribute magnets. |
| Walcha Central School | Walcha Central School | 120 students, 6 teachers | Awareness raising and distribute magnets. Alerted to 2 new sites. 80% of students had seen a koala locally. |
| St Mary's Catholic School, Walcha | St Mary's Catholic School, Walcha | 100 students, 5 teachers | Awareness raising and distribute magnets. 80% of students had seen a koala locally. |
| Uralla Central School | Uralla Central School | 150 students, 15 teachers | Addressed assembly then ran workshop for 30 students. |
| Nowendoc Primary School | Nowendoc Primary School | 9 students, 3 teachers | John responded to a call from school saying they had mother and baby on grounds. Spent day with kids talking about koalas. |
| Snow Gums Schools (small schools north and east of Armidale) | Thalgarrah Environmental Education Centre | 30 students and 6 teachers | Awareness raising and distribute magnets. |

Figure 5: Participants in the Armidale workshop looking for koala scats.

## Field methods

### *Site selection*

The priority areas identified in the Strategy total approximately 7000 km$^2$, so the first priority for the project team was to narrow the search area down to an achievable scale.

Using the reduced KHE as a guide, we attempted to select sites that would give a representative coverage of as many of the combination classes as possible. At the direction of NT LLS, sites were prioritised according to:

1. Private land,
2. Travelling Stock Routes and Reserves and other Crown Land,
3. National Parks and State Forests.

We used a number of methods to access suitable sites:

- NTLLS staff contacted landholders with property in the reduced KHE area by phone. This proved both time-consuming and frustrating as many landholders were suspicious of the aims of the project and the implications for their management of finding koalas on their property.
- Requests for people to get involved in the project were made through the media (media releases from NTLLS, interviews on local and regional radio, television interviews), through the Stringybark Ecological website, through social media and through the newsletters and social media pages of Southern New England Landcare and Armidale Tree Group.
- Requests from the project team to landholders and clients they had previously worked with and through friends and family.
- Public workshops held in Armidale, Walcha and Nowendoc (see Community Engagement methods).

### *Scat surveys*

Once land owners or managers had agreed to allow us to conduct surveys on their property, we selected suitable areas from the KHE maps. We encouraged private landholders to accompany us while we conducted surveys to show them what we were doing, show them how to identify koala scats and to discuss koala sightings on their properties. All of the landholders we worked with were enthusiastic about identifying and conserving koala populations. In some cases, landholders took us to areas of their properties where koalas had previously been observed. We conducted our surveys in these areas even if they were not part of the KHE.

Once at a site, we used a random number table to select a compass bearing and number of paces to walk to guide us to our plot location.

Scat surveys are commonly used to detect koalas in the wild as they are better at detecting presence of koalas than looking for live animals. Scats remain in situ for several weeks or months (Sullivan, 2004), while live animals may only be at a site for a few minutes at a time.This was seen as the most efficient way to address the aim of overcoming data deficiencies in realtion to koala presence.

Field methods for scat surveys were based on the method of Woosnam-Merchez *et. al*. (2012). At each site an area within a one metre radius of each of 30 trees was searched for koala scats. The number, size and age of the scats and the species of each tree was recorded. If no scats were found in the first 30-tree plot, a second plot was established nearby at the same site using the random number method, within the same KHE.

The age of all scats was noted, but for analysis the range was recorded as the freshest scat present. Similarly, the range of scat sizes were recorded but analysis was done using the largest size present.

The average time taken to search each tree was 2 minutes. The surveyor would walk around the outside of the trunk observing and recording any scats on the surface. Then the surveyor would begin gently raking away any surface litter and bark as well as looking among leaves on any plants in this area. Finally they would look on the trunk, particularly any protruding bark, tree forks or branches.

In the few cases where fresh scats were found or koalas were observed, we made additional observations. We collected samples of fresh scats using gloves and sterile tubes. These scats were sent to Romane Cristecu at University of Sunshine Coast for DNA analysis (results not reported here). If we observed koalas, we recorded the tree species, the coordinates of the tree, the presence of a joey and where possible, the sex, age and health of the koala. We took photos of koalas whenever we saw them.

At eight sites we carried out casual surveys. In these surveys we searched the base of 1 to 10 trees for scats, recording the same information for each tree as in the full scat survey. Casual surveys were conducted opportunistically where koalas had been observed or where the habitat present was deemed likely to be used by koalas.

We also looked for other signs of koala presence including: koalas at the site (alive or dead), reports from landholders of recent koala observations, signs of browsing in the canopy, presence of scats outside the 1m radius around the trunk, and scratches on the trunk. We classified direct koala observations into three classes: Class 1 observations are those where a landholder or another person reported to us that they had seen a koala within 500m of the site within the previous year; Class 2 observations are where the project team saw a koala; and class 3 observations are where both the landholder and the project team saw a koala.

### *Vegetation surveys*

At each site a rapid assessment of vegetation was also conducted. Vegetation surveys were only conducted for the first scat survey plot, unless the vegetation in subsequent plots was significantly different. The vegetation survey approximately followed the OEH VIS survey methodology (Oliver et. al., 2010). The survey used a 20 x 20m quadrat with one corner being the randomly selected point from the scat survey. In all sites the vegetation plot overlapped the scat survey plot.

The vegetation surveys recorded: all tree species including number of adults and seedlings; number of trees >50cm dbh; crown cover (%); bare ground cover (%); coarse woody debris (m of CWD >10cm s.e.d); 3 most common shrubs; 3 most common grasses; 3 most common sub-shrubs or other ground plants; all weed species; slope; aspect; elevation (m); soil lithology; soil texture; and soil colour.

Photographs were taken of all vegetation plots. Vegetation surveys were conducted in 74 sites. These were not repeated for every scat survey plot as second scat plots were always in the same vegetation type.

One aim of surveying the vegetation at each site was to determine the Plant Community Type (PCT) (Benson *et. al.,* 2010) and see if koalas were associated with some in preference to others. The mapping of PCTs at the state scale is not always accurate so the project offered a chance to ground-truth the mapping data. The association of koalas with particular PCTs was analysed to determine reference ecosystems for future revegetation work associated with koala conservation.

As part of each vegetation survey, we also recorded threats to koalas. The threats were deemed to apply across all scat survey plots at each site unless there were obvious differences between plots. The following threat classes and levels were noted:

- Grazing frequency: none, Old (>3yr), Not Recent (1-3 yrs ), Recent (<1yr),
- Grazing intensity: none, light, severe,
- Tiger Pear: none, light, severe,
- Weeds preventing overstorey regeneration: none, light, severe,
- Dieback: none, light, severe,
- Other threats such as presence of dog scats, proximity to busy roads etc.

## Data analysis

Data collected in the field was transferred to a spreadsheet.

Where scats were located, we noted the number of scats per tree. A frequency histogram of scats/tree was developed across the three priority areas.

We also recorded the total number of trees with scats for each species and calculated a percentage of trees of each species with positive records out of the total number of trees of that species surveyed. This was used to indicate species preference across all priority areas.

We recorded the number of scats found in three scat size classes (<15mm, 15-20mm and >20mm) across all priority areas. We also calculated the percentage of scats found in each of three age classes: fresh, medium and old (Woosnam-Merchez et. al., 2012).

Plot summaries were generated for:

- Total scats/plot,
- Percentage of trees with scats/plot.

Within each priority are, we calculated the number of plots with different numbers of scats present. Within each priority area we mapped the location of plots with and without scats, for both systematic and casual surveys. We also plotted the location of trees with scats and the number of scats at each tree.

Threats were analysed by site across all priority areas. We converted threat levels to numerical values so higher numbers reflected a greater threat level as follows:

- Grazing frequency: none (0), >3yr (1), 1-3 yrs (2), <1yr (3),
- Grazing intensity: none (0), light (1), severe (2),
- Weeds preventing overstorey regeneration: none (0), light (1), severe (2),
- Dieback: none (0), light (1), severe (2).

We then correlated threat levels against the presence of koala scats for each site, calculating a correlation coefficient $r^2$. As the correlation for each threat variable was very weak, we did not carry out further regression analysis.

### *Connectivity analysis*

We used the data from this survey about koala association with particular PCTs to examine areas where connectivity would be of most benefit to koalas. We looked at where these PCTs occur (using current mapping layers) and where they intersect with FPC data. The PCTs are intersected with the FPC data from 0% to 20% for all PCTs except 0 and 1. The aim of this analysis is to find areas of the landscape where the vegetation cover is low enough to warrant revegetation. For PCTs 0 and 1 we used FPC >10% and <20%. This made sure all the segments with a few % FPC on average, but no trees, were eliminated. Otherwise all the cleared country would be included. The intersection of preferred PCTs (separately and as a group) and these FPC classes were mapped for each priority area.

We used state-wide metapopulation links analysis (Drielsma *et. al*., 2014) for each priority area. This is a relative benefit layer showing the areas where investment in corridors and linkages will give the greatest benefit at a state-wide scale for a selected suite of animals (not just koalas).

We also overlaid the PCT/FPC analysis results against the state-wide 3C layer to determine where most benefit would accrue from revegetation and other works and to see if the state-wide priorities matched our recommendations for koalas.

In this analysis three management recommendations are indicated:

- Manage (Red) – take actions to manage threats to existing vegetation and improve condition and extent.
- Connectivity (Blue) – take actions to protect existing corridors and linkages.
- Revegetate (green) – undertake revegetation to connect existing patches and remnants.

3C mapping by Drielsma *et. al.,* (2014) is a composite of 3 Climate models (CAN, MIR, MPI) and two RCPs (45 and 85) for two time periods (2020 and 2050). CAN model is hotter and drier than the MIR model, and the MPI model is the most extreme. 3C mapping utilised up to 12 climate-model results to produce single 2050 surfaces for each of three factors: Revegetate/Restore, Conserve/Manage, and Connect/link.

**Manage:** Manage Benefits are based on the principal of maximising the representation of pre-clearing native vegetation communities by conserving existing vegetation. This layer combines locations that are suitable for depleted communities now with locations that will become increasingly important in the future as important communities need to shift to meet a changing climate. The calculations give equal weight to 1990 data ('now') and the future scenarios because management needs to start now and continue to 2050.

**Revegetation:** Revegetation benefits are based on the principle of maximising representation of pre-clearing native vegetation communities through revegetation in areas that are expected to become suitable for target communities by 2050. Rates of loss used to weight the importance of communities are based on past clearing, degradation and fragmentation, as well as future contractions, expansions and shifts of bioclimatic envelopes due to climate change. Calculations of revegetation benefits only consider the 2050 benefits, giving no weighting to the 1990 values; they "…reasoned that all revegetation efforts should aim towards meeting future climates (spatially and compositionally) due to the lag time involved in new planting reaching maturity."

**Connecting:** This 3CLINKS dataset is derived from MPI-8.5 scenario so is not directly comparable to the products listed above, but is close enough. 3CLINKS benefits are derived by combining the outputs of three analysis: · A multi-scale habitat links analysis based on 1990 climate; · A multi-scale habitat links analysis (based on MPI-8.5 only) where currently extant bioclimatic envelopes are linked through extant vegetation to areas expected to support compositionally similar communities by 2050; New colonisations from any class predicted from a 3CMP model (based on MPI-8.5 only) where each colonisation is weighted by the 2050 estimate of conservation significance for the relevant community (from the BFT assessment).

**Combined Benefits Mapping:** 3C subsequently plotted these three (climate-model-composite) factors as RGB in a colour space to generate a single colour map of "Priorities", with each pixel being a combination of the three themes: Manage (Red), Revegetation (Green), Connecting (Blue).

## Results

### Scat surveys

Scat surveys were carried out in 131 systematic plots (30 trees) and 8 casual plots (<30 trees). 73 surveys were in the Armidale-Uralla area, 37 in the Nowendoc area and 29 in the Walcha area.

Of the 3910 trees surveyed, 266 had scats present and 3644 had no scats (6.8% occurrence). 49% of plots (30 trees) had scats present. Scats were detected in each of the 3 study areas (Figure 6).

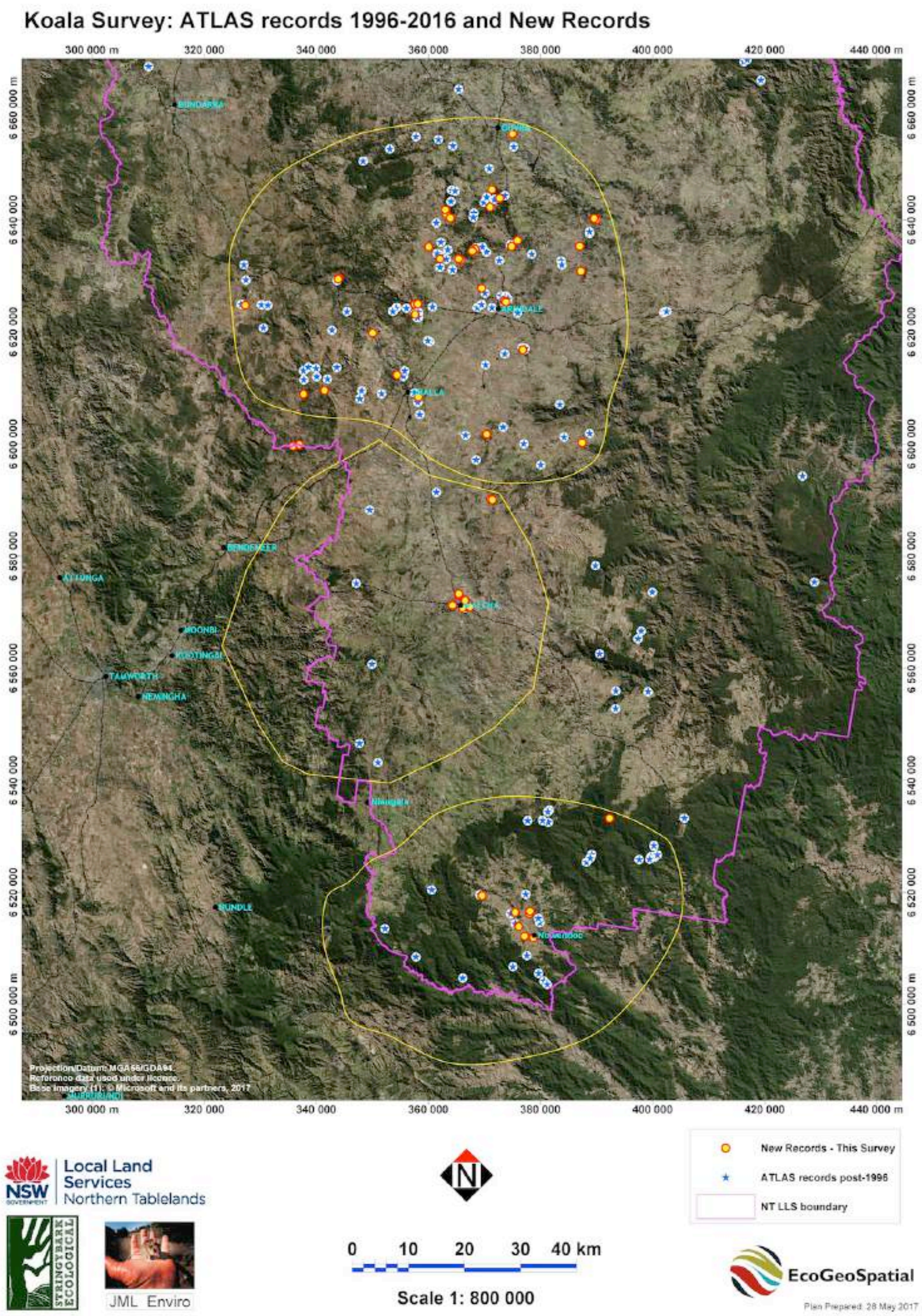


Figure 6: Recent Atlas koala records and sites where scats were detected by this project.

The number of scats around each tree was usually low (Figure 7). Of the 266 trees where scats were found, 90 (34%) had only one scat present.

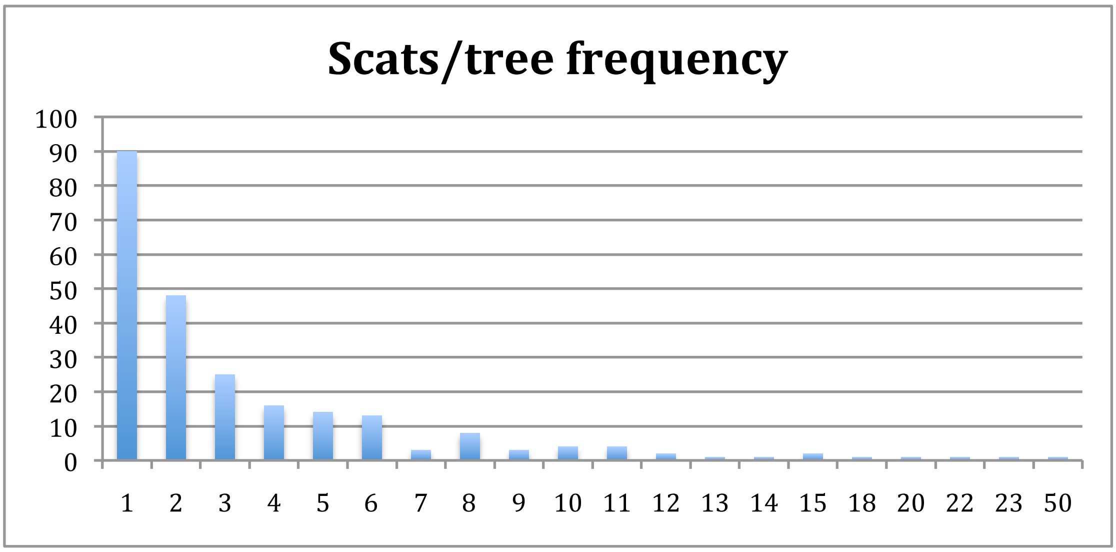


**Figure 7: Frequency distribution of scats per tree across all sites.**

Across all sites, 2% of scats were fresh (age class 1), 25% were medium fresh (age class 2)and 75% were old (age class 3).

Scat size ranged from 10 to 28mm. At some sites scats of two or three different sizes were found. 13% of scats were smaller than 15mm, 56% were smaller than 20mm but larger than 15mm and 31% were smaller than 25mm but larger than 20mm.

### *Armidale-Uralla*

Within the Armidale-Uralla area 63% of plots had scats present around the base of at least one tree. Figure 8 shows the distribution of the survey plots. Note that some surveys were carried out outside the boundaries of the region at the request of willing landholders.

Fig 9 shows the percentage of trees in each plot that had scats. Table 3 summarises the spread of plots with trees with scats. In the majority of plots where scats were found, the scats were found next to only 1 or 2 trees.

**Table 3: Number of trees with scats in plots in the Armidale-Uralla priority area.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Number trees with scats** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 12 | 15 | 17 | 20 |
| **Number of plots** | 28 | 13 | 11 | 4 | 1 | 2 | 2 | 1 | 2 | 0 | 1 | 0 | 2 | 0 |

Figure 10 shows the distribution and number of scats found around individual trees.

Figure 11 shows the number and location of live koalas recorded. Only one koala was observed by the project team in the Armidale-Uralla area by the project team. A student at UNE reported 16 koalas seen or heard at Mt Duval as a result of transect spotlighting two weeks prior to our scat survey.

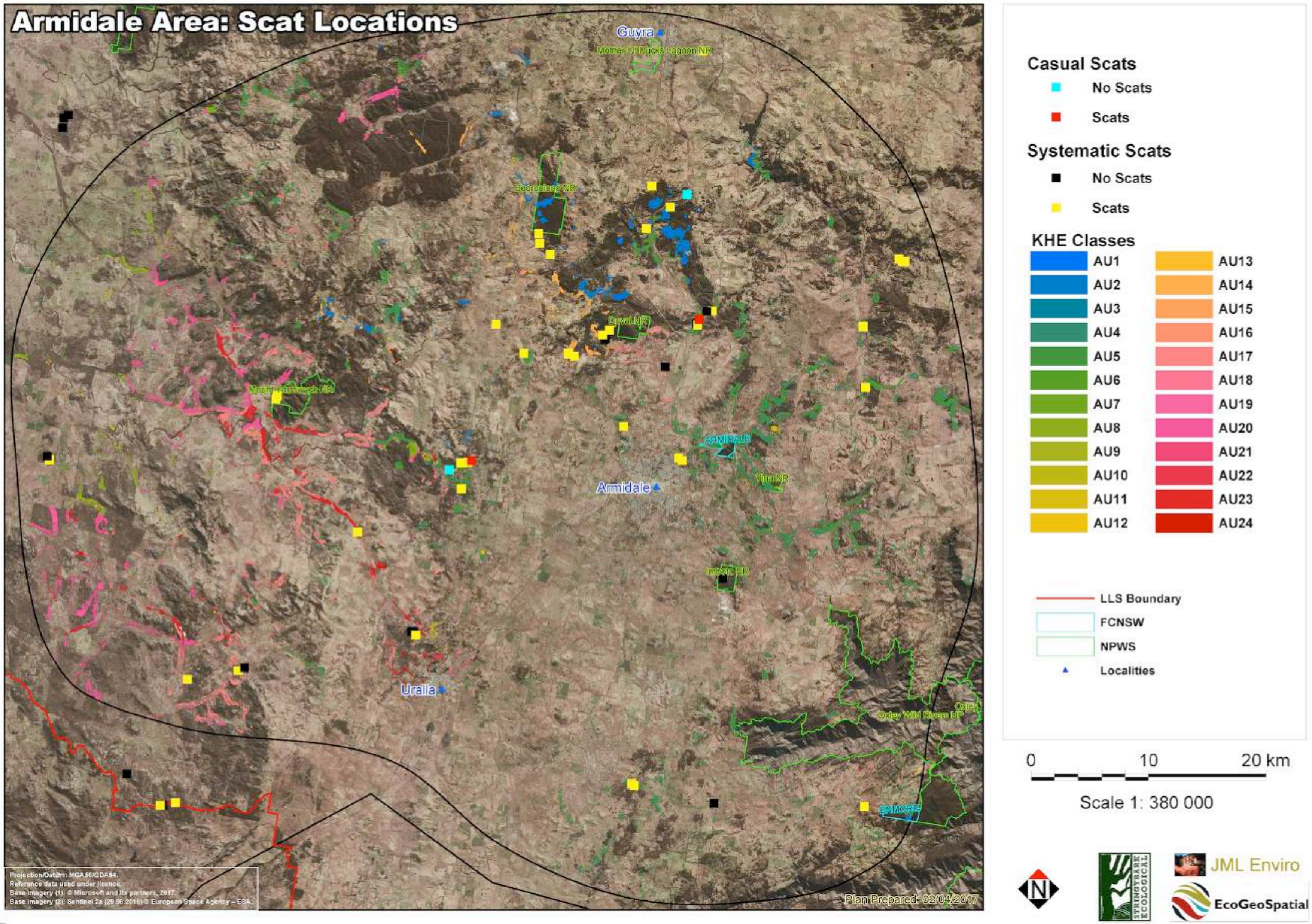


**Figure 8: Location of koala survey sites in the Armidale-Uralla area and presence or absence of scats**

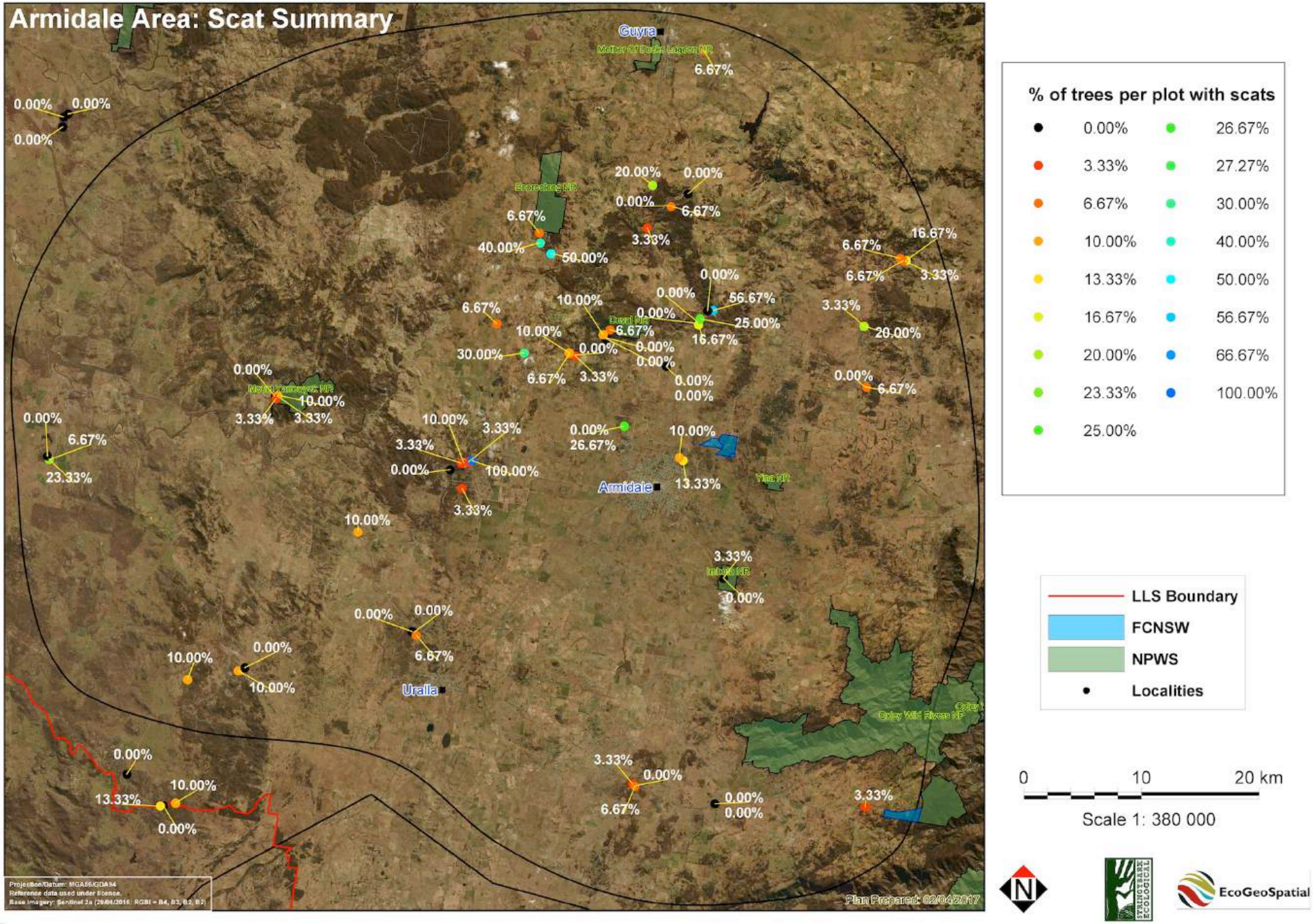


Figure 9: Location of plots surveyed in the Armidale-Uralla area showing % of trees per plot with scats.

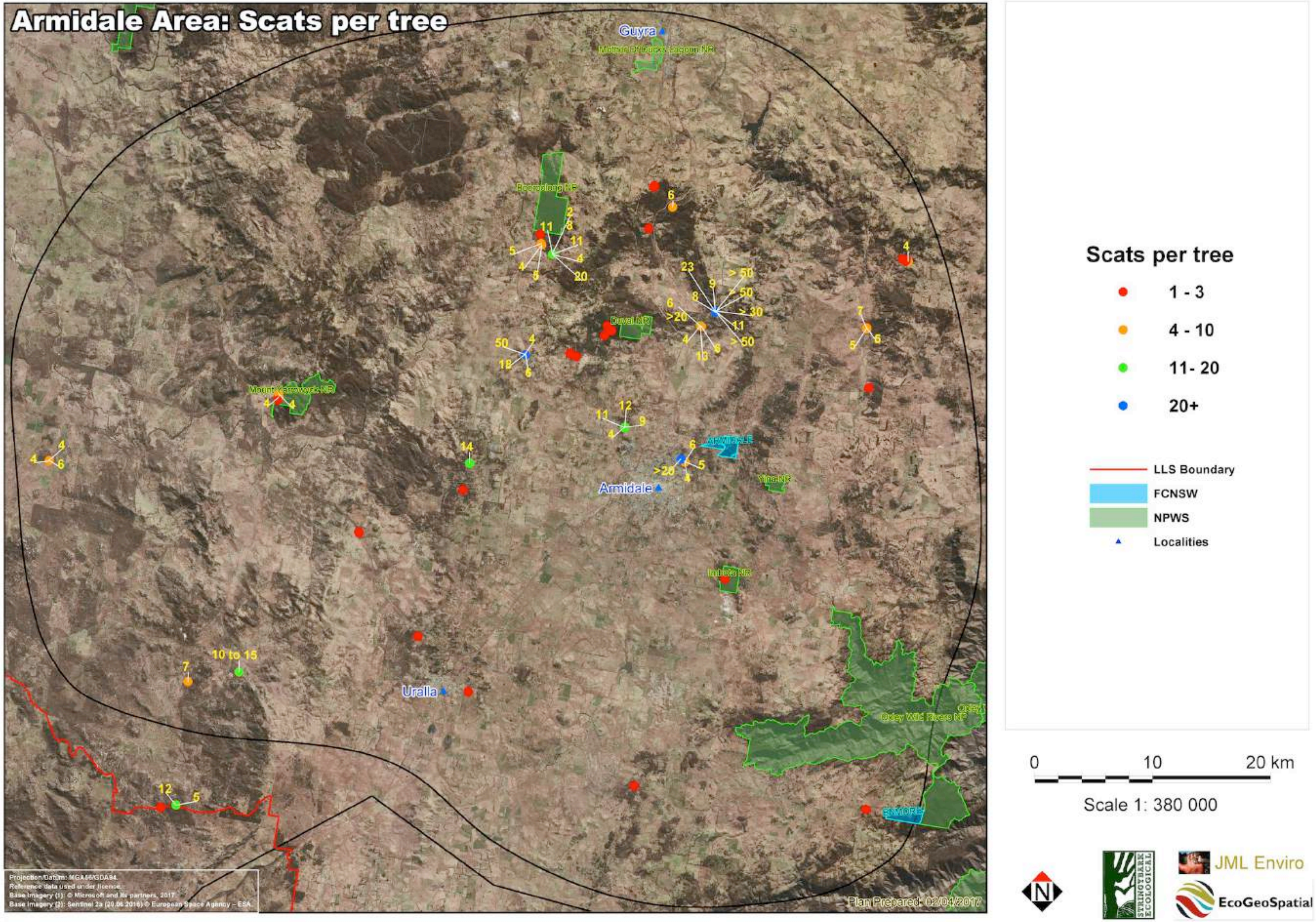


Figure 10: The number of scats per tree for individual trees at sites in the Armidale-Uralla area.

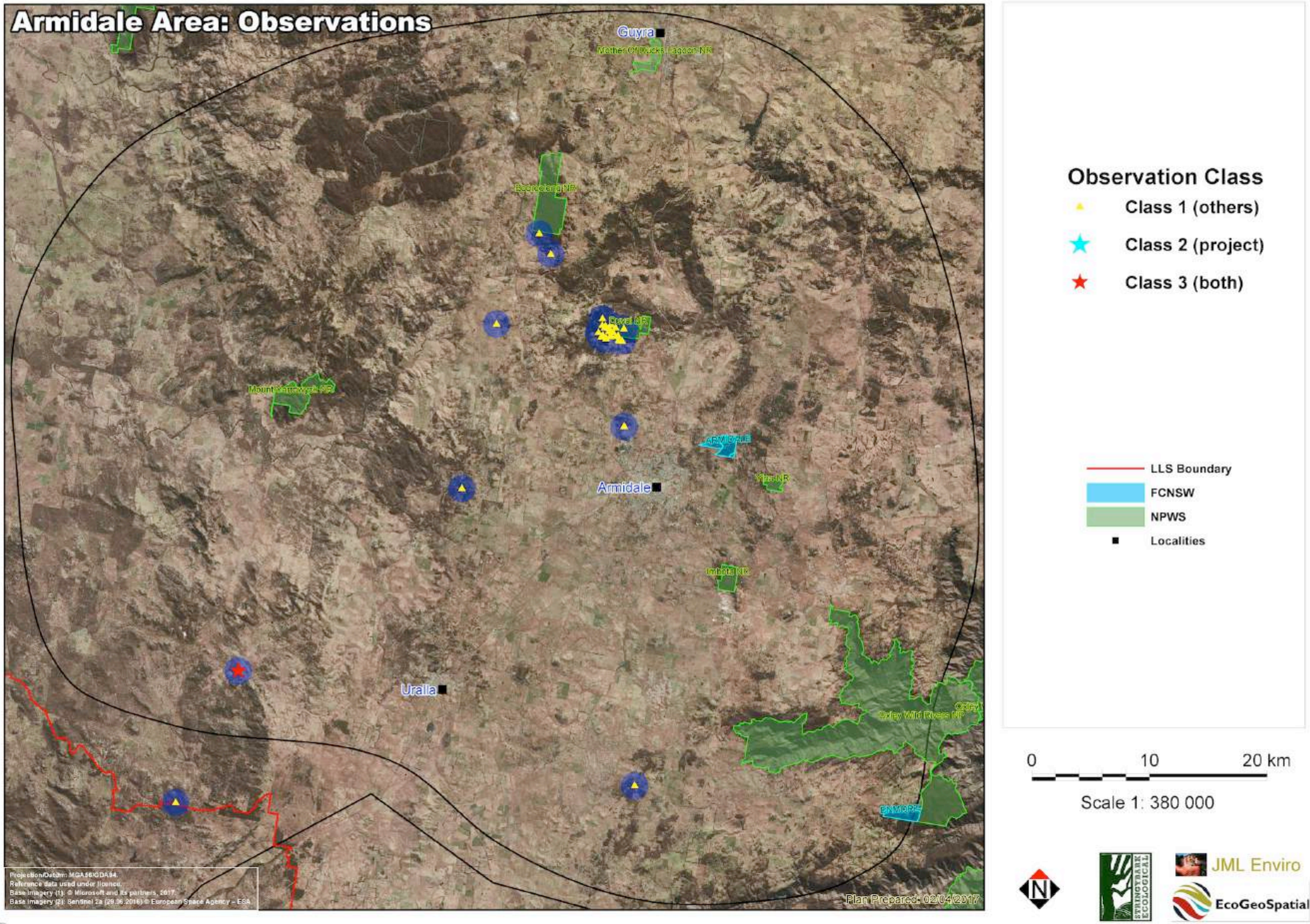


**Figure 11: Actual observations of koalas made by the project team (class 2), landholders or others (class 1) or both (class 3).**

Figure 12 shows the intersection of the selected FPC classes and the PCTs preferred by koalas in the Armidale Uralla priority area., while Figure 13 shows the same analysis with individual PCTs highlighted.

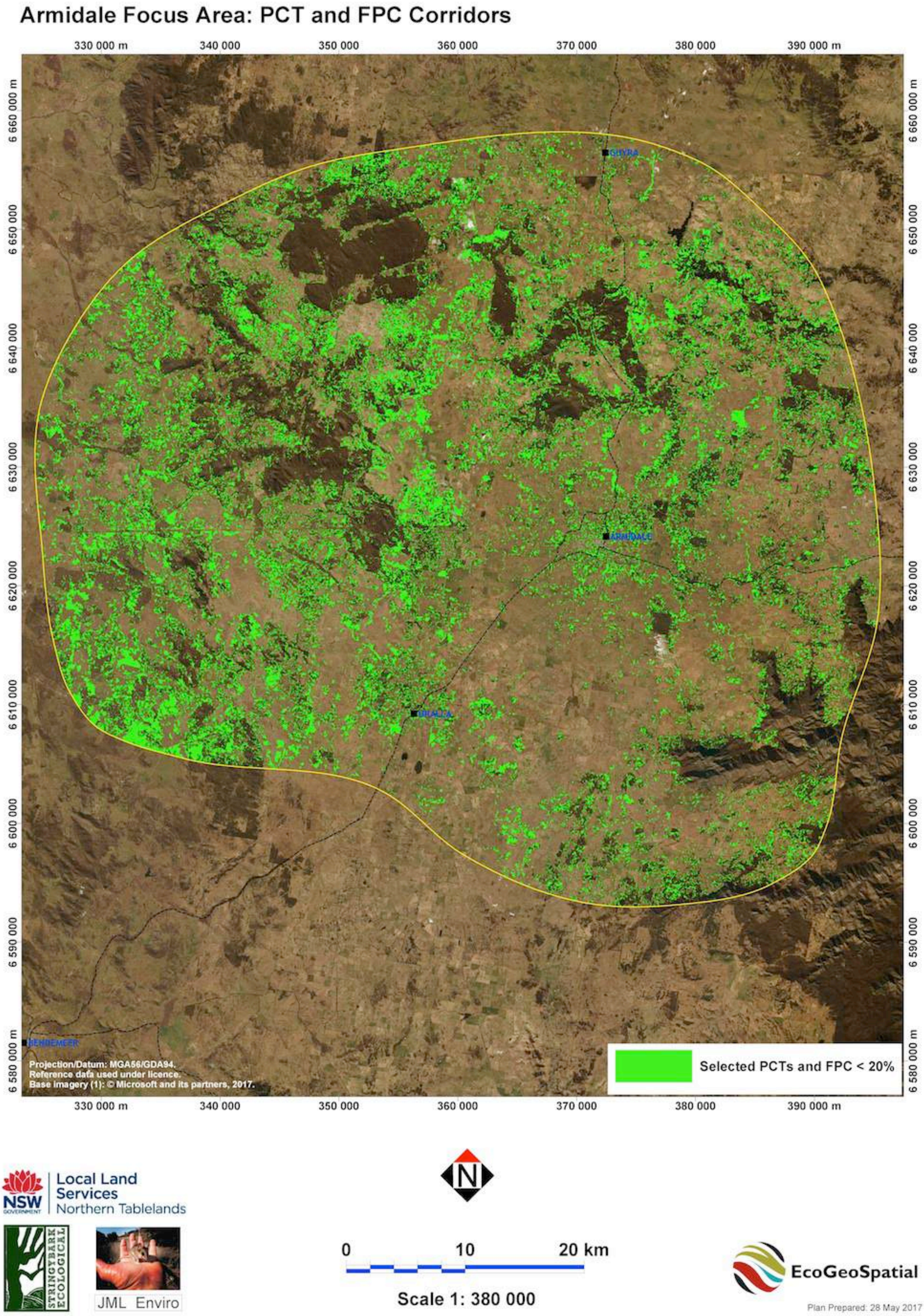


**Figure 12: Armidale-Uralla priority area suggested koala revegetation areas. Individual PCTs are not defined.**

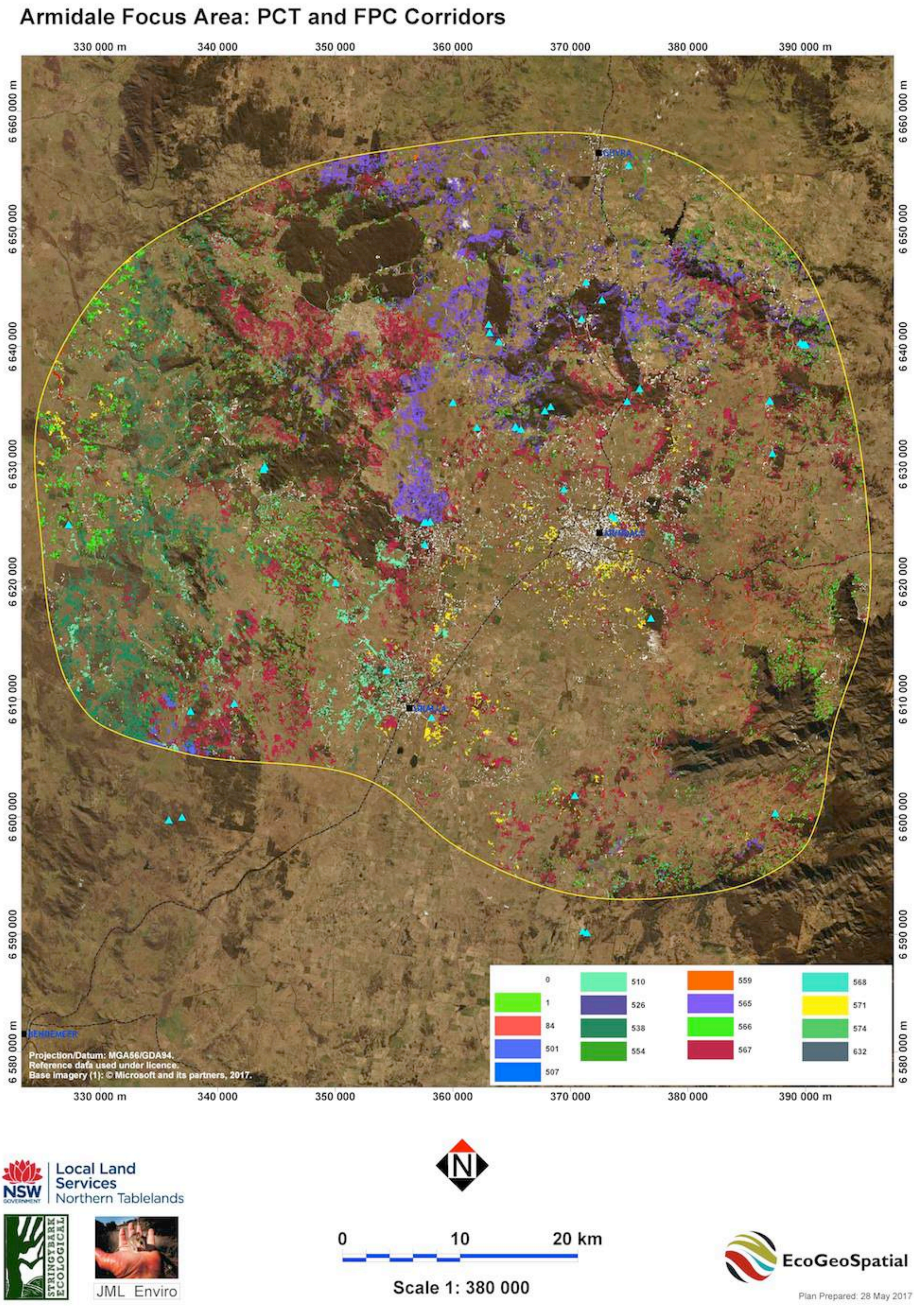


**Figure 13: Armidale-Uralla priority area suggested koala revegetation areas. Individual PCTs are individually defined.**

Figure 14 shows the state-wide metapopulation links analysis of Drielsma et. al. (2014) for the Armidale-Uralla area.

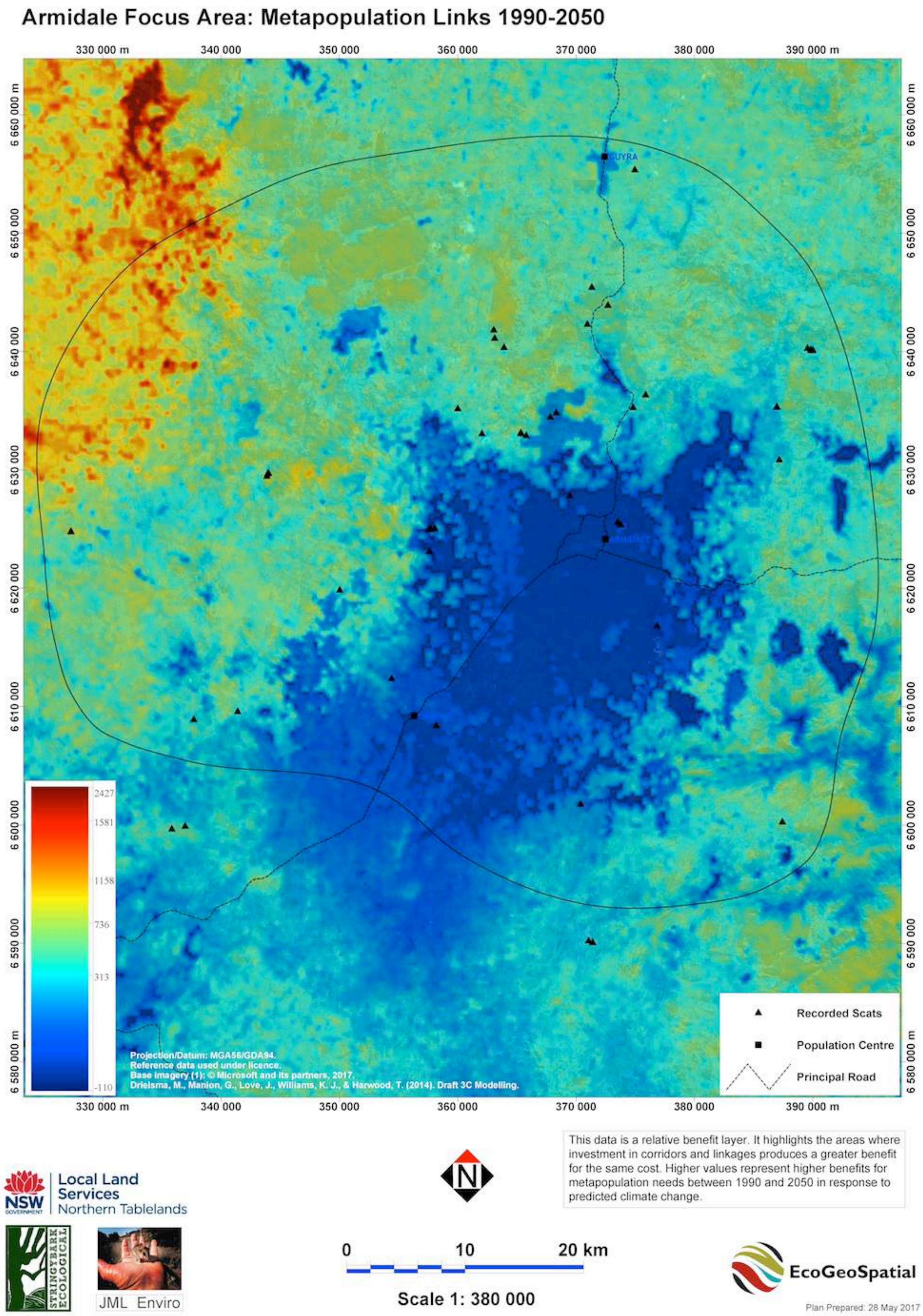


**Figure 14: State-wide metapopulation analysis of relative benefits of corridors and linkages for the Armidale-Uralla priority area (Drielsma et. al., 2014).**

Figure 15 shows the recommended PCT and FPC classes overlaid against the state-wide 3C modelling (Drielsma et. al. (2014).

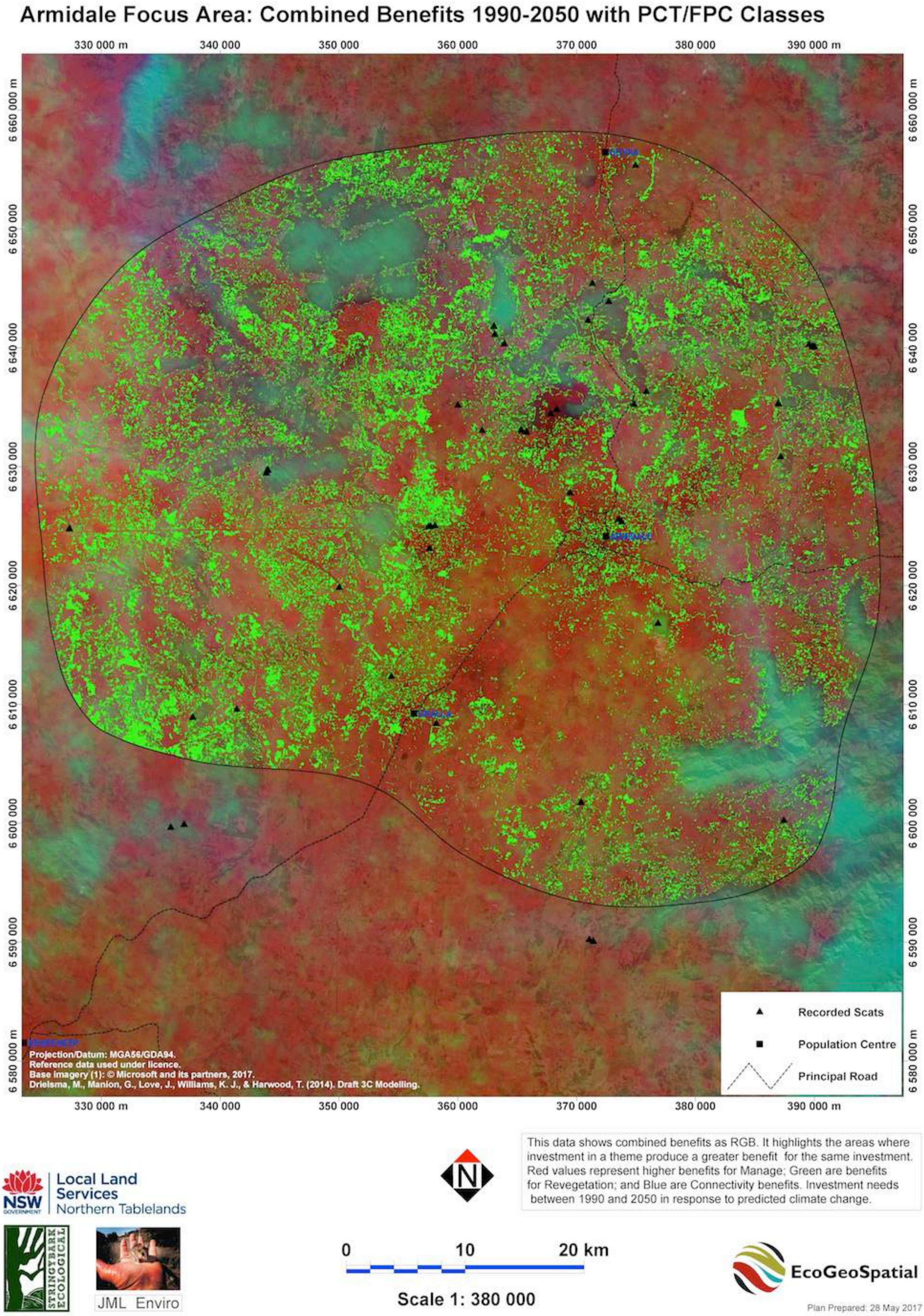


**Figure 15: Recommended koala revegetation areas (light green) over state-wide 3C modelling for the Armidale-Uralla priority area.**

### *Walcha*

Figure 16 shows the location of survey plots in the Walcha area and the presence or absence of koala scats in each. Of the 29 plots surveyed in the Walcha priority area, nine (31%) had scats present. Only three localities in the Walcha area were surveyed: around Walcha township, Aberbaldie Nature Reserve and district, and a property in the north east of the area. While no scats were detected at Aberbaldie Nature Reserve, the ranger responsible for the area recorded a koala on a camera trap two years earlier.

Figure 17 shows the percentage of trees in each plot that had scats. Table 4 summarises the spread of plots with trees with scats. In the majority of plots where scats were found, the scats were found next to only 1 or 2 trees.

**Table 4: Number of trees with scats in plots in the Walcha priority area.**

| **Number of trees with scats** | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| **Number of plots** | 18 | 4 | 2 | 1 | 2 | 1 |

Figure 18 shows the distribution and number of scats found around individual trees.

Figure 19 shows the number and location of live koalas recorded. No koalas were observed by the project team in the Walcha area but one recent sighting was reported to us.

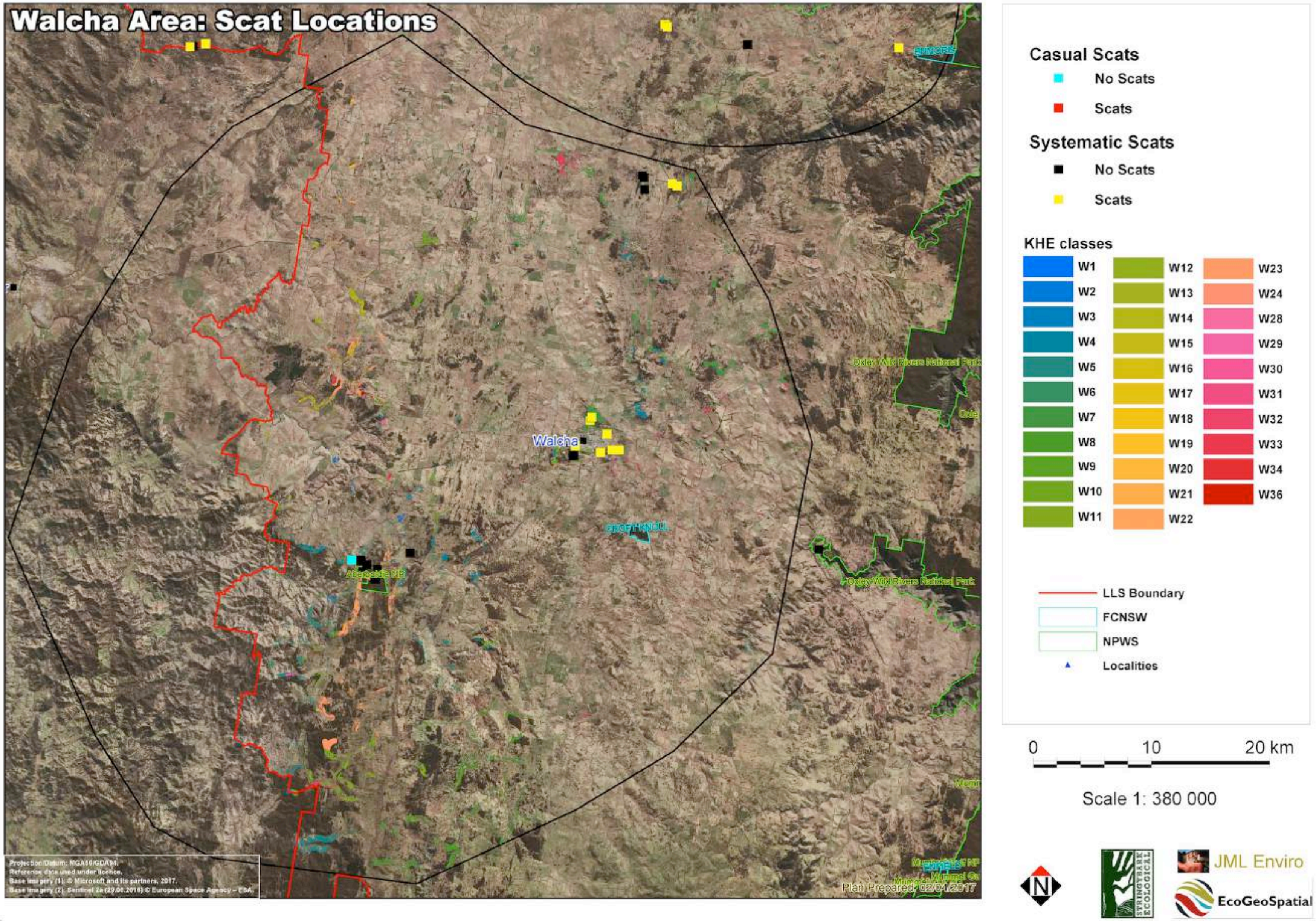


Figure 16 :Location of koala survey sites in the Walcha area and presence or absence of scats.

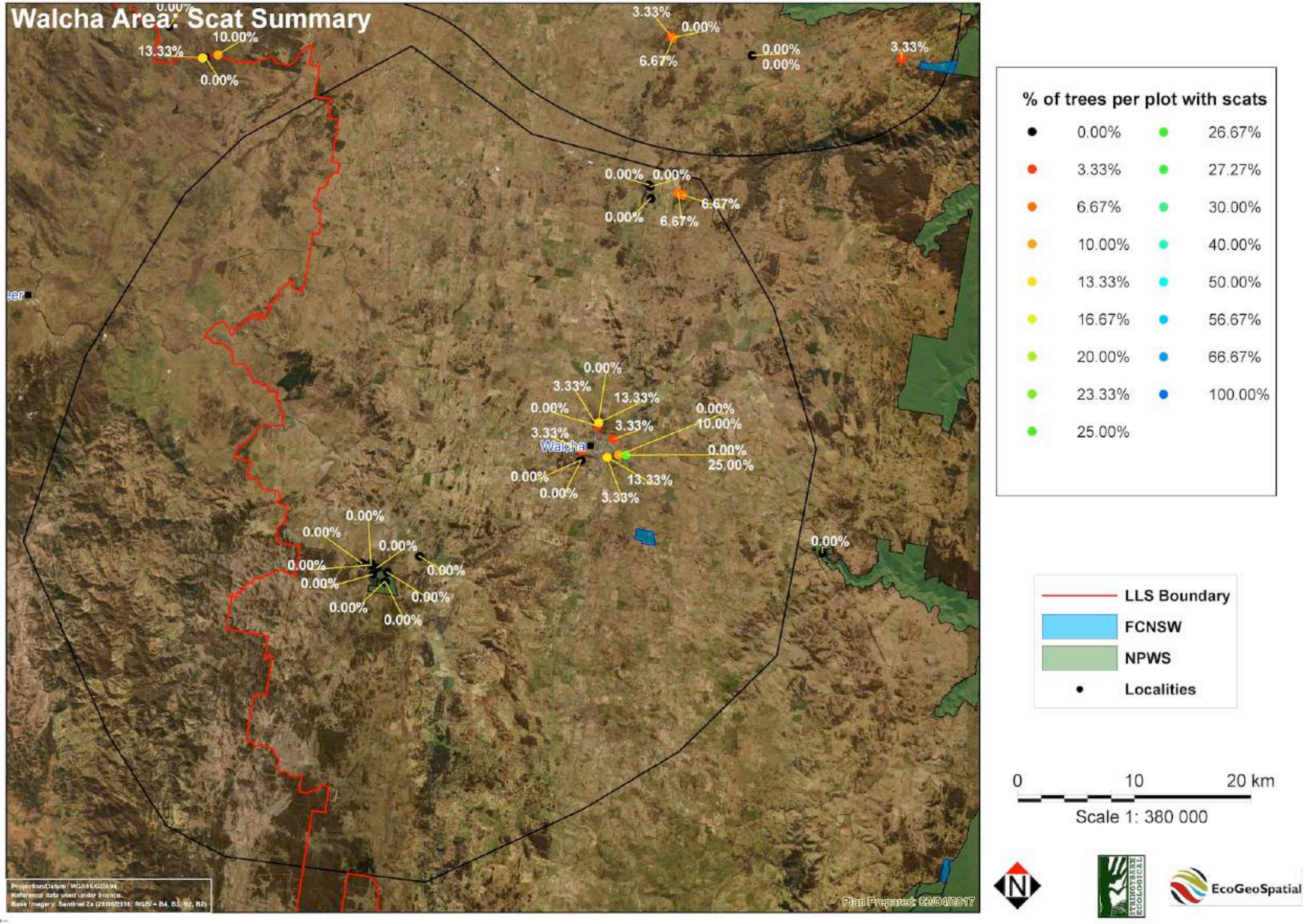


**Figure 17 :Location of plots surveyed in the Walcha area showing % of trees per plot with scats.**

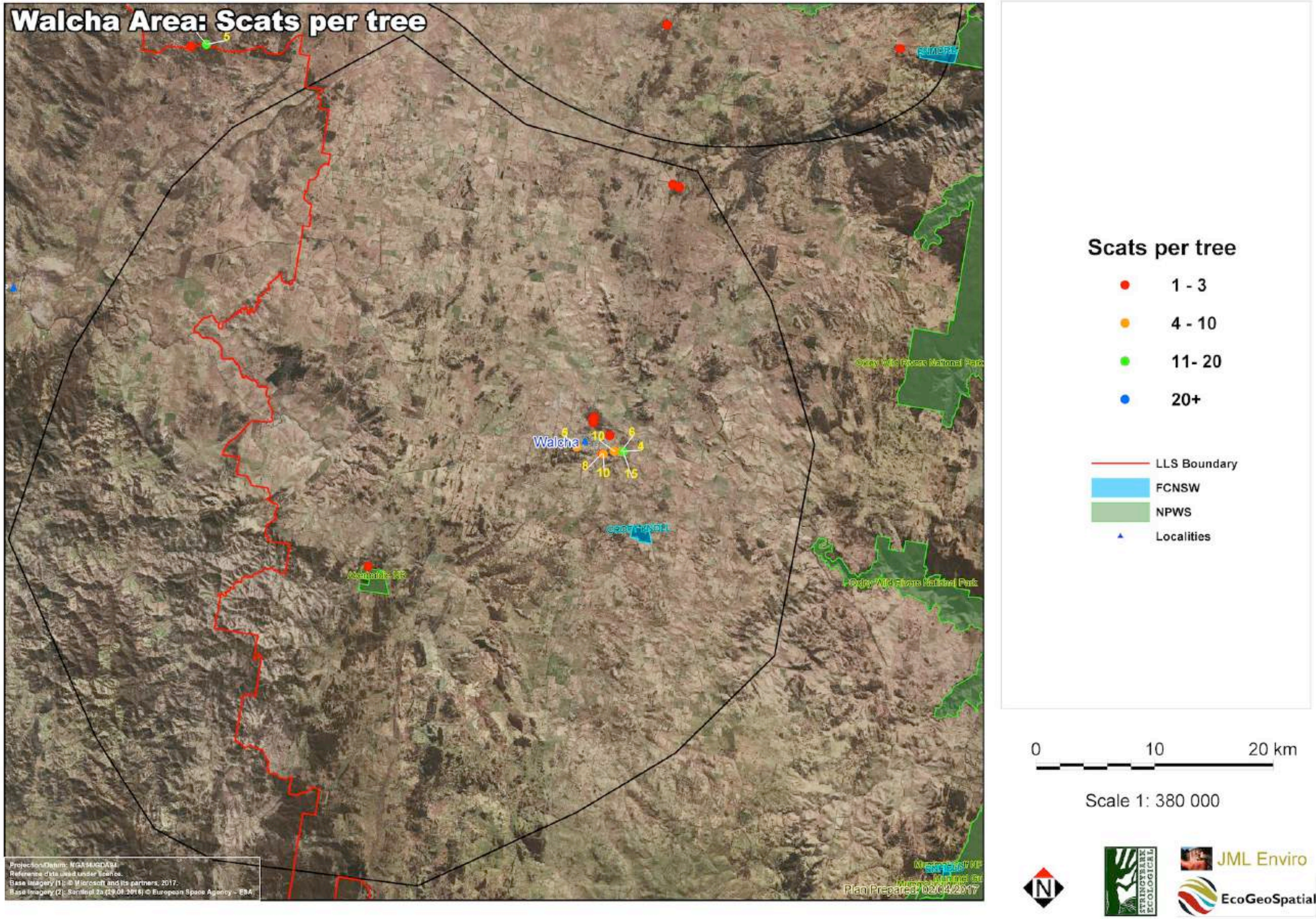


**Figure 18: The number of scats per tree for individual trees at sites in the Walcha area.**

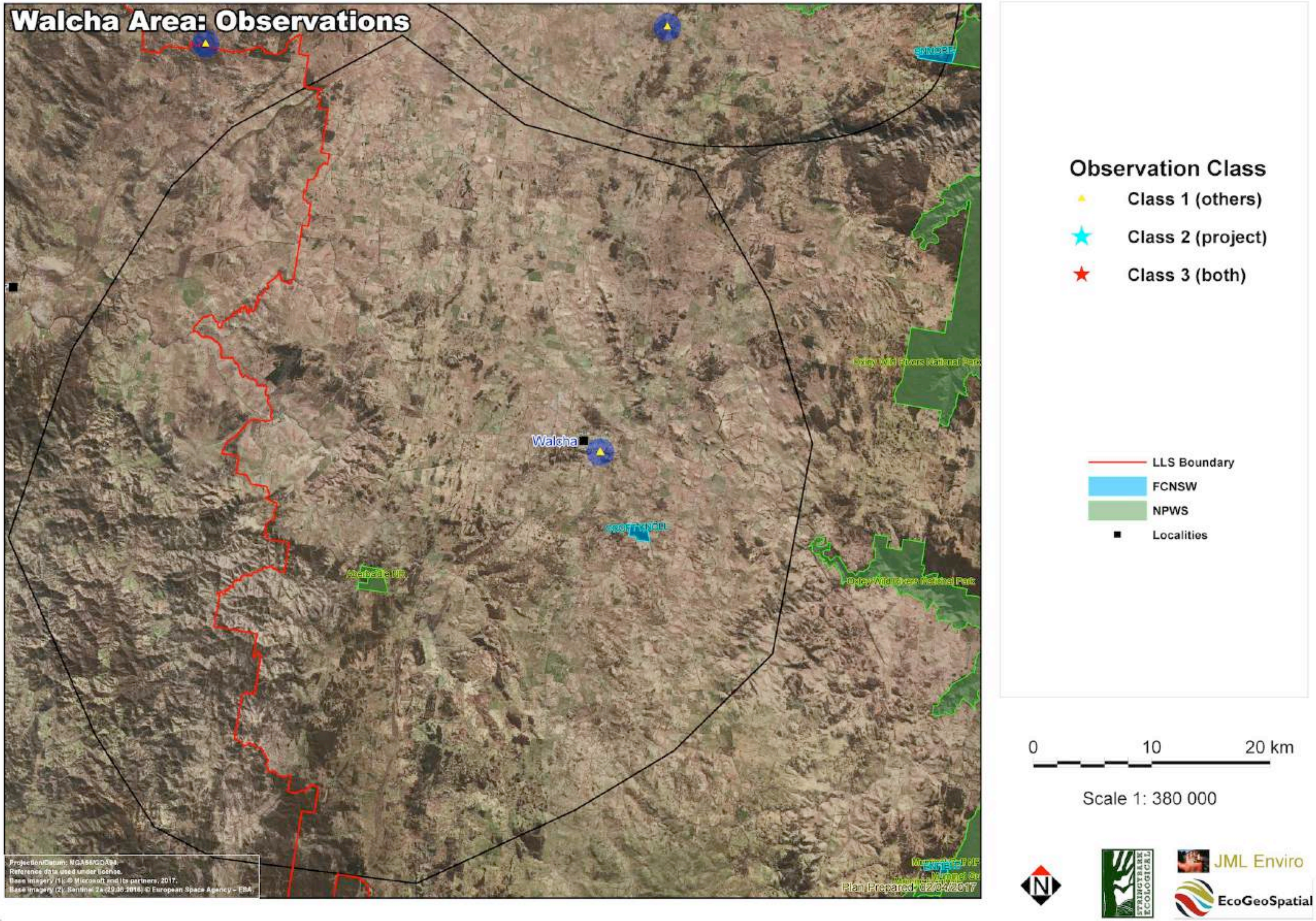


Figure 19:Actual observations of koalas made in Walcha by the project team (class 2), landholders or others (class 1) or both (class 3)

Figure 20 shows the intersection of the selected FPC classes and the PCTs preferred by koalas in the Walcha priority area, while Figure 21 shows the same analysis with individual PCTs highlighted.

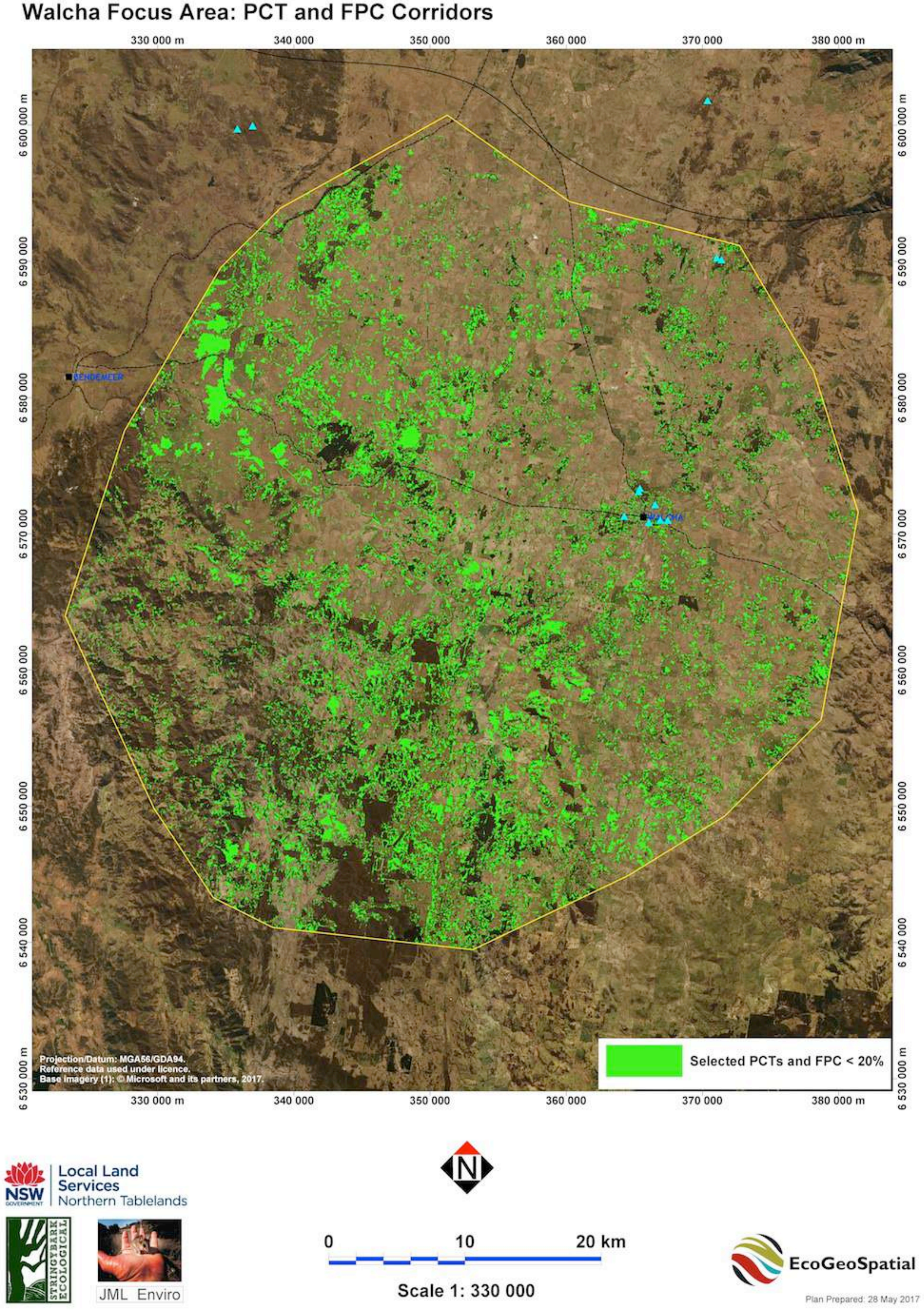


**Figure 20: Walcha priority area suggested koala revegetation areas. Individual PCTs are not defined.**

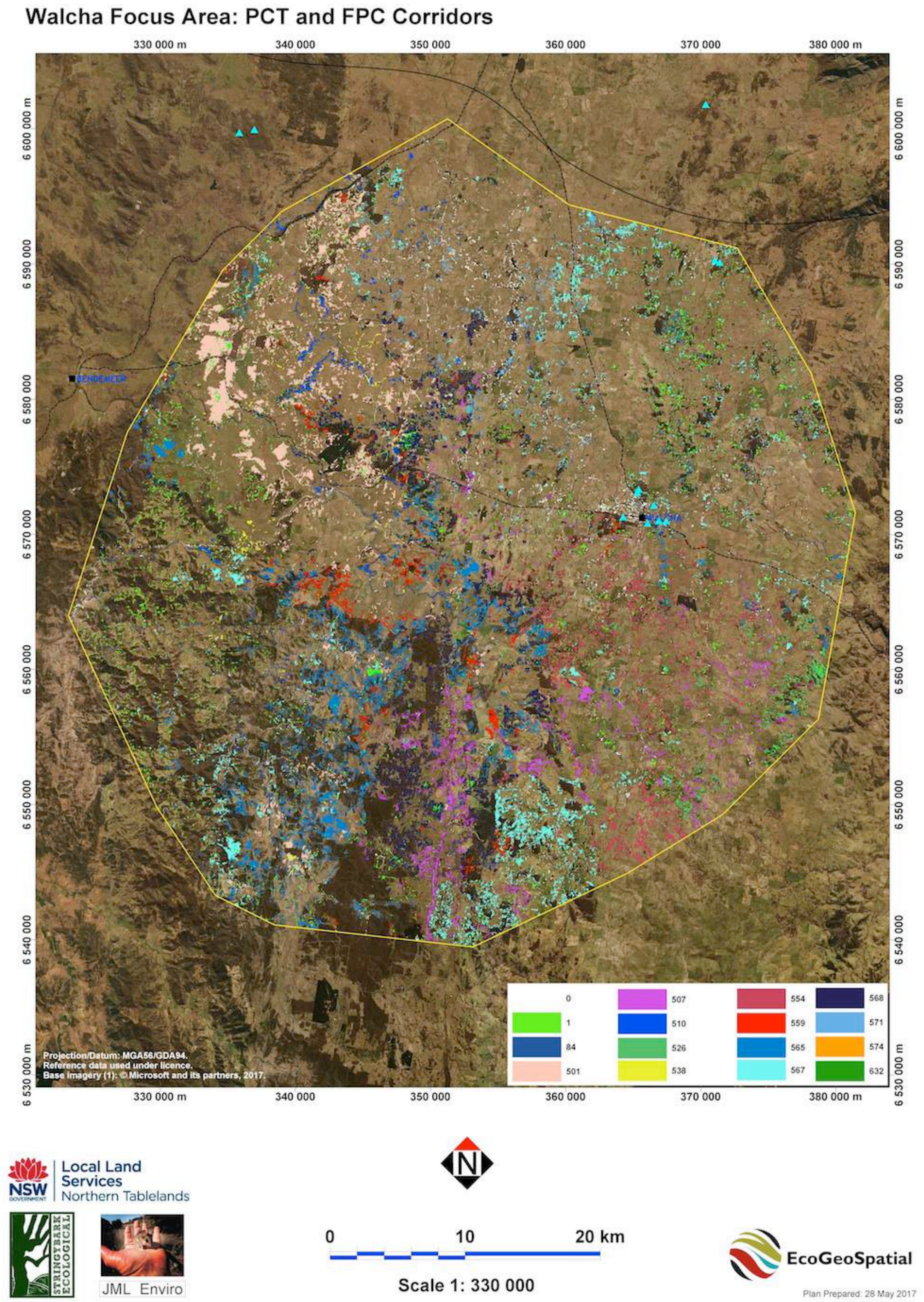


**Figure 21: Walcha priority area suggested koala revegetation areas. Individual PCTs are individually defined.**

Figure 22 shows the state-wide metapopulation links analysis of Drielsma et. al. (2014) for the Walcha area.

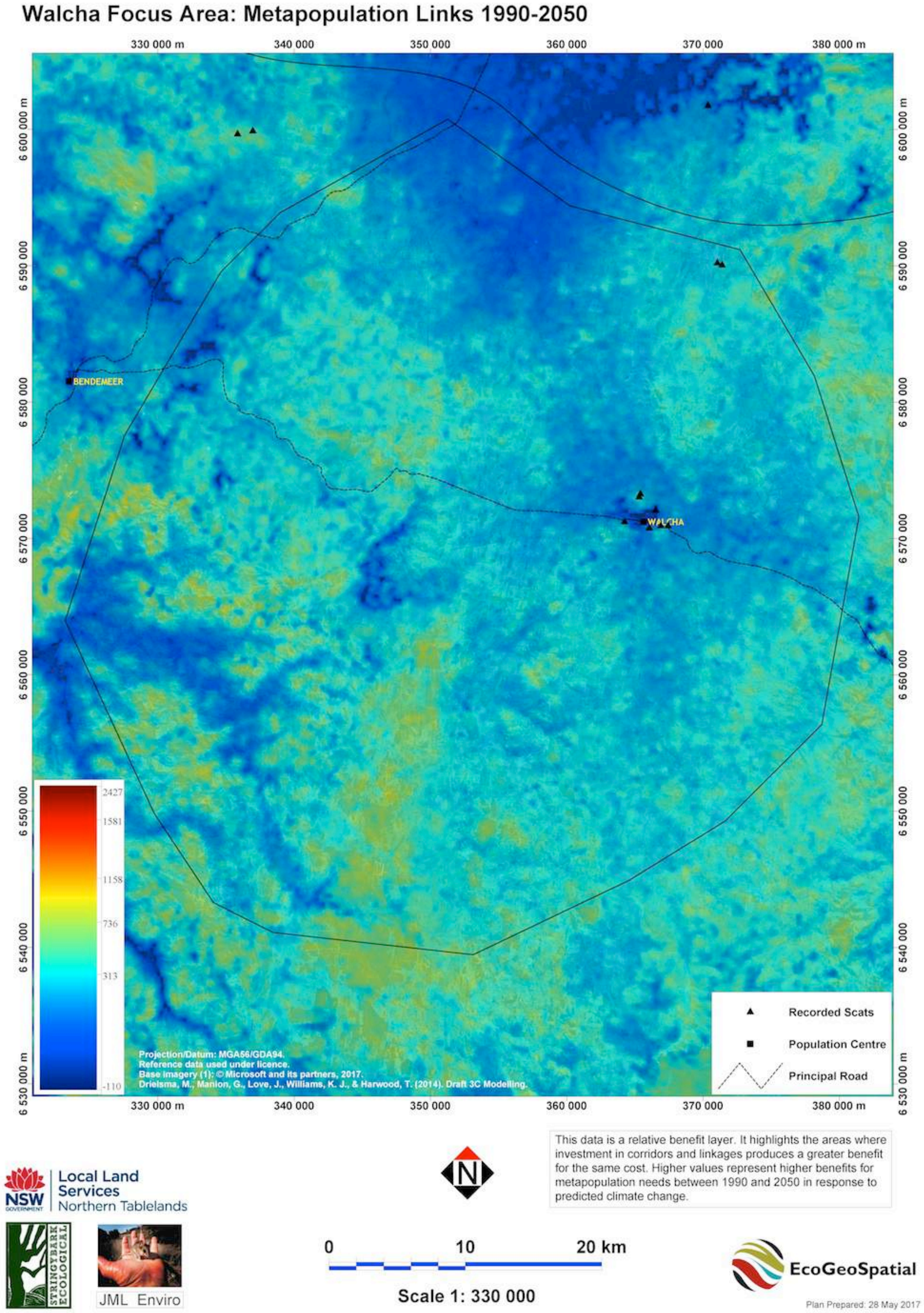


**Figure 22: State-wide metapopulation analysis of relative benefits of corridors and linkages for the Walcha priority area (Drielsma et. al., 2014).**

Figure 23 shows the recommended PCT and FPC classes overlaid against the state-wide 3C modelling (Drielsma et. al. (2014).

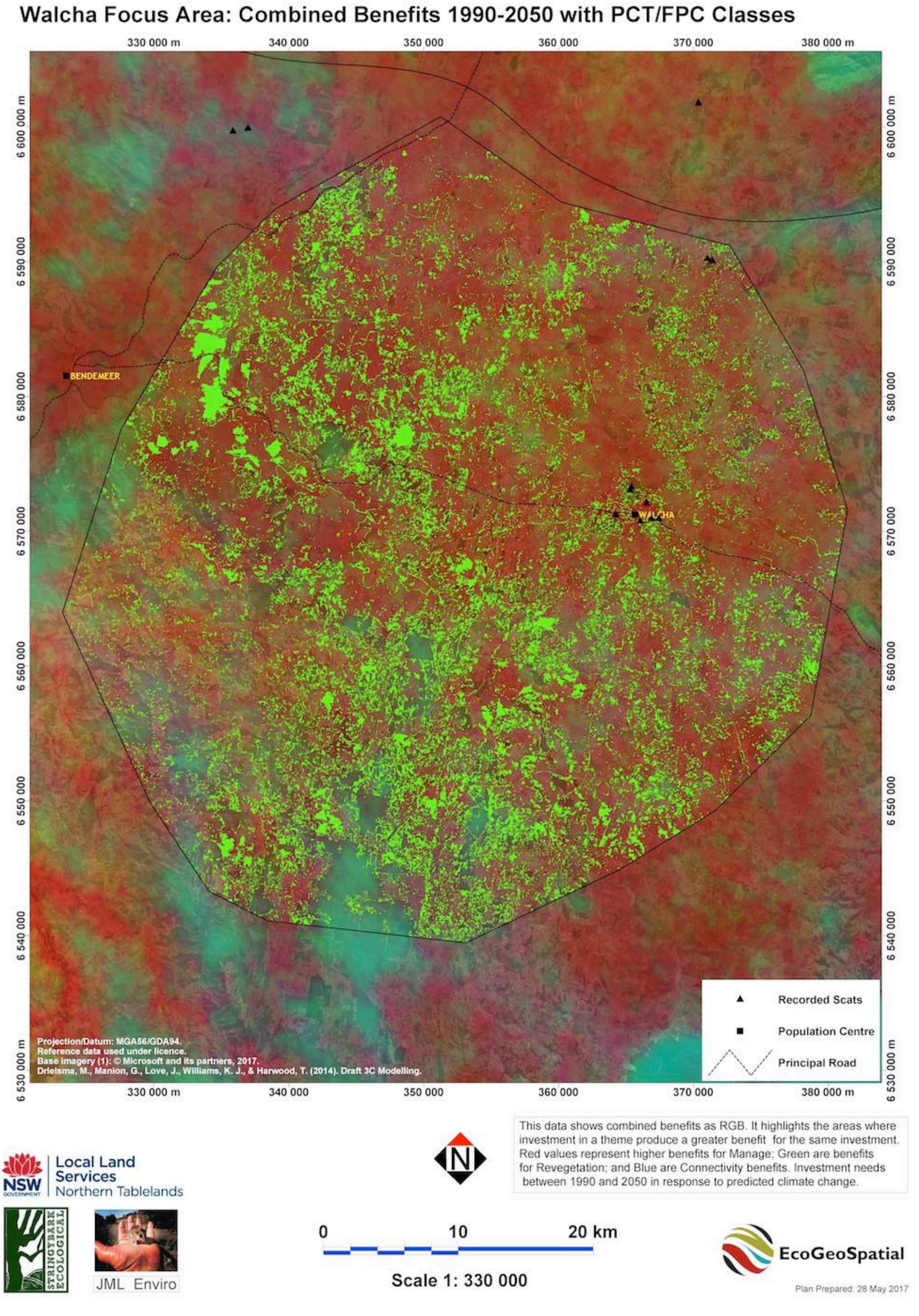


**Figure 23: Recommended koala revegetation areas (light green) over state-wide 3C modelling for the Walcha priority area.**

### *Nowendoc*

Figure 24 shows the location of survey plots in the Nowendoc area and the presence or absence of koala scats in each. Of the 37 plots surveyed in the Nowendoc priority area, 13 (35%) had scats present. Most of the plots with trees with scats were close to Nowendoc, with few of the forest plots having scats.

Figure 25 shows the percentage of trees in each plot that had scats. Table 5summarises the spread of plots with trees with scats. In the majority of plots where scats were found, the scats were found next to only 1 tree.

**Table 5: Number of trees with scats in plots in the Nowendoc priority area.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Number of trees with scats** | 0 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 17 | 20 |
| **Number of plots** | 23 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 |

Figure 26 shows the distribution and number of scats found around individual trees.

Figure 27 shows the number and location of live koalas recorded. The project team saw many koalas in the Nowendoc area and local people reported regular sightings in the vicinity of the town of Nowendoc. Koalas are regular visitors to the school and all the students were very familiar with them.

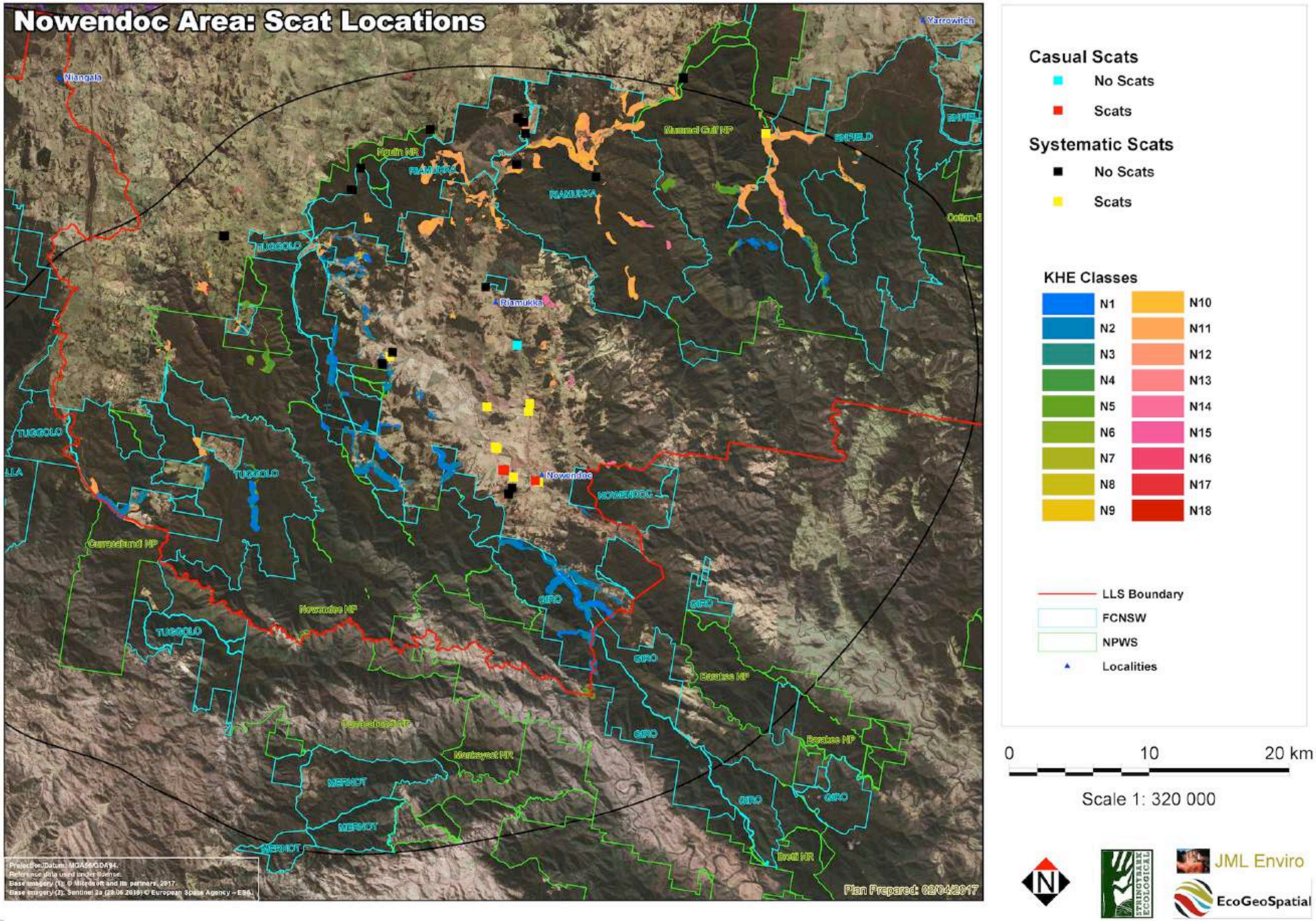


**Figure 24:Location of koala survey sites in the Nowendoc area and presence or absence of scats.**

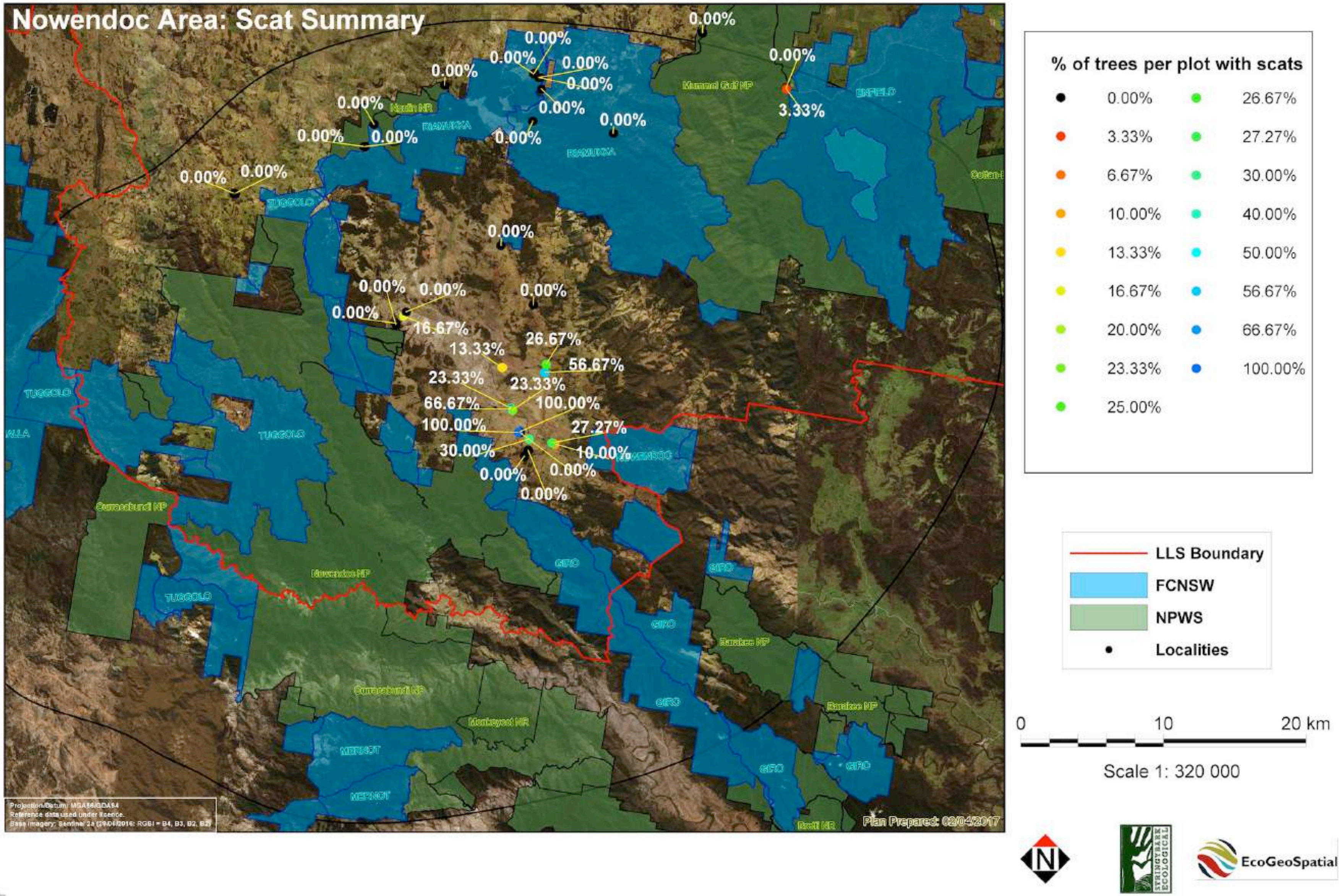


**Figure 25: Location of plots surveyed in the Nowendoc area showing % of trees per plot with scats.**

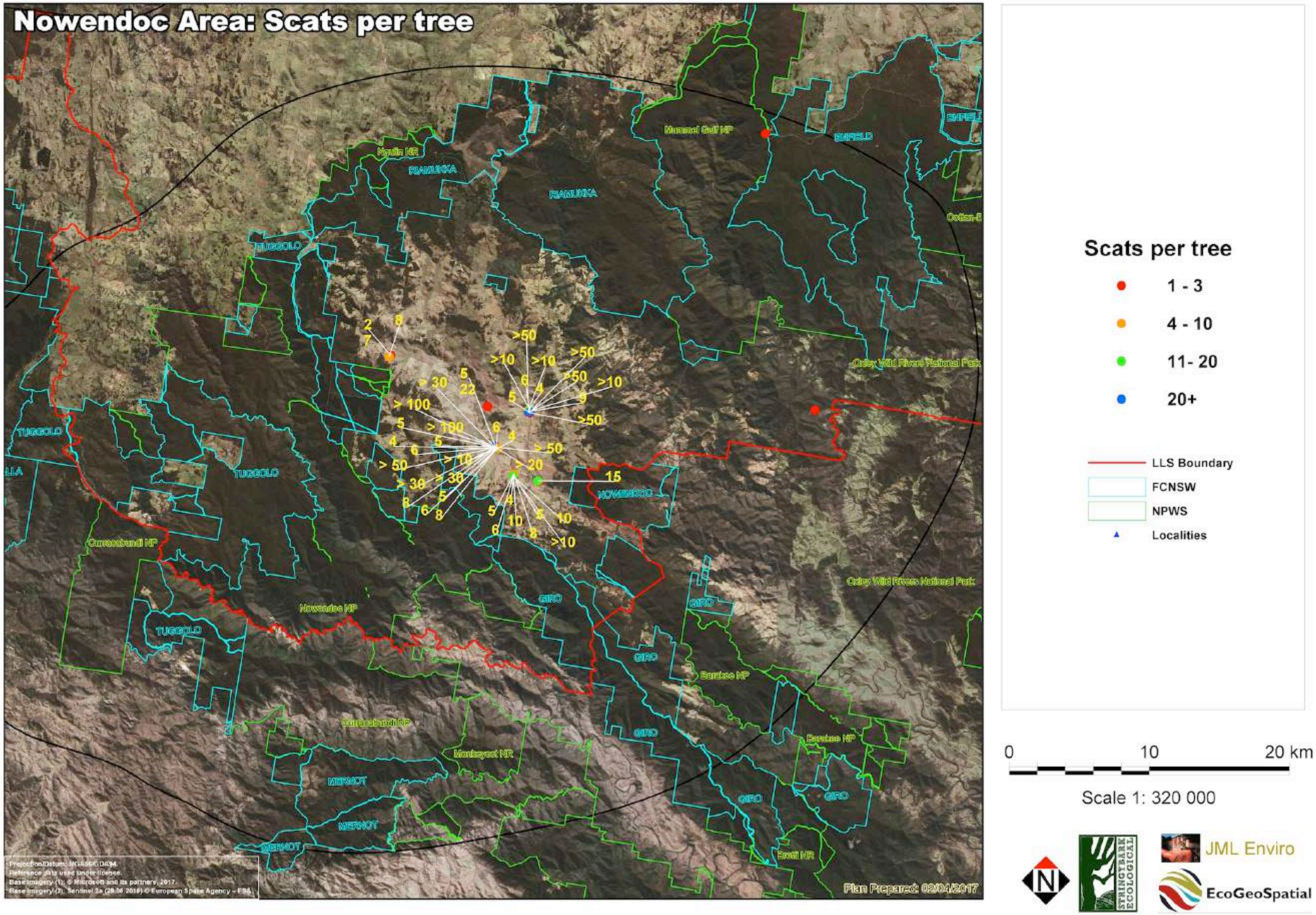


**Figure 26: The number of scats per tree for individual trees at sites in the Nowendoc area.**

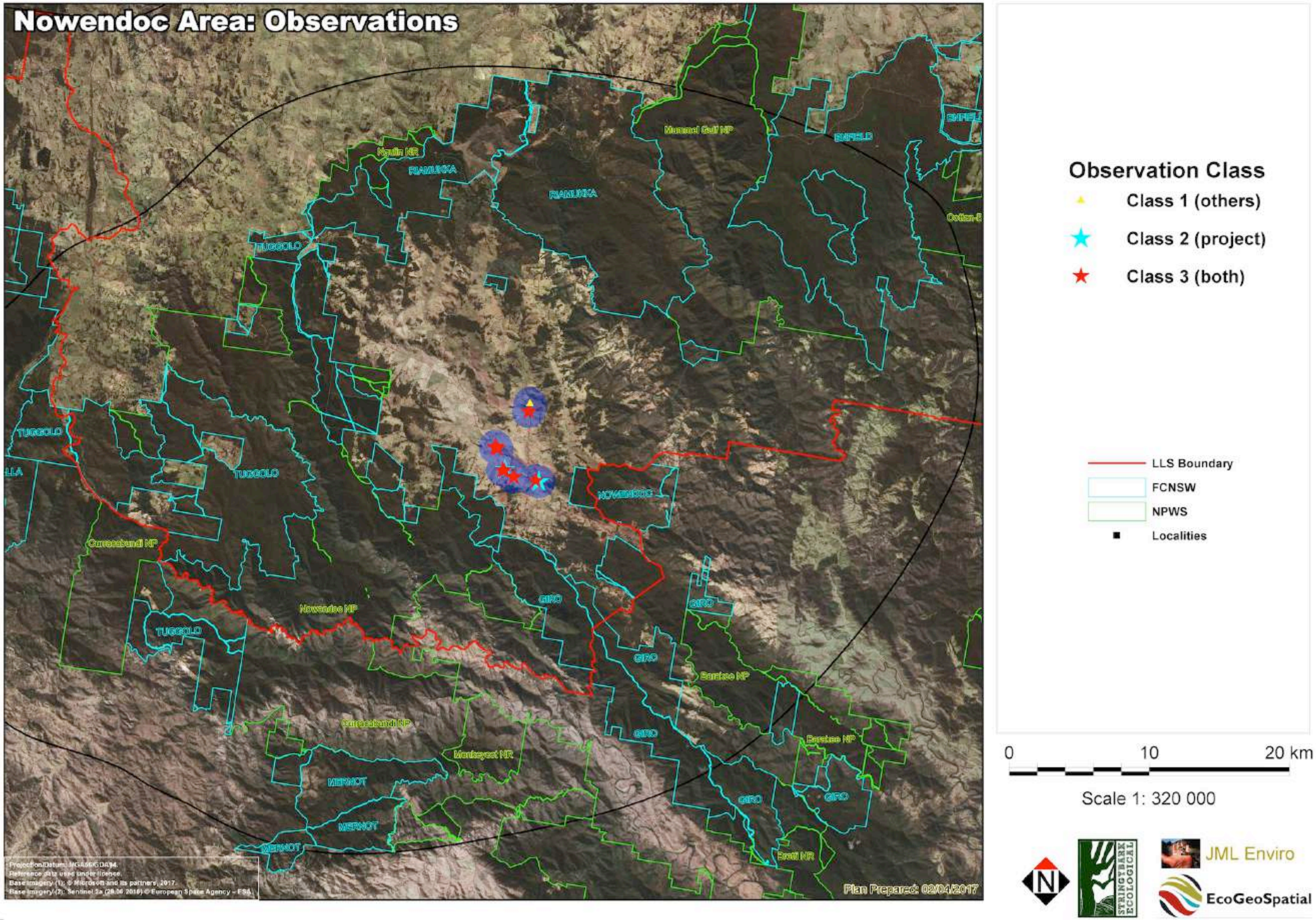


**Figure 27: Actual observations of koalas made in Nowendoc by the project team (class 2), landholders or others (class 1) or both (class 3)**

Figure 28 shows the intersection of the selected FPC classes and the PCTs preferred by koalas in the Nowendoc priority area, while Figure 29 shows the same analysis with individual PCTs highlighted. Note that in the Nowendoc River Valley much of the *E. pauciflora* habitat favoured by koalas does not show up as a PCT because of its sparse nature.

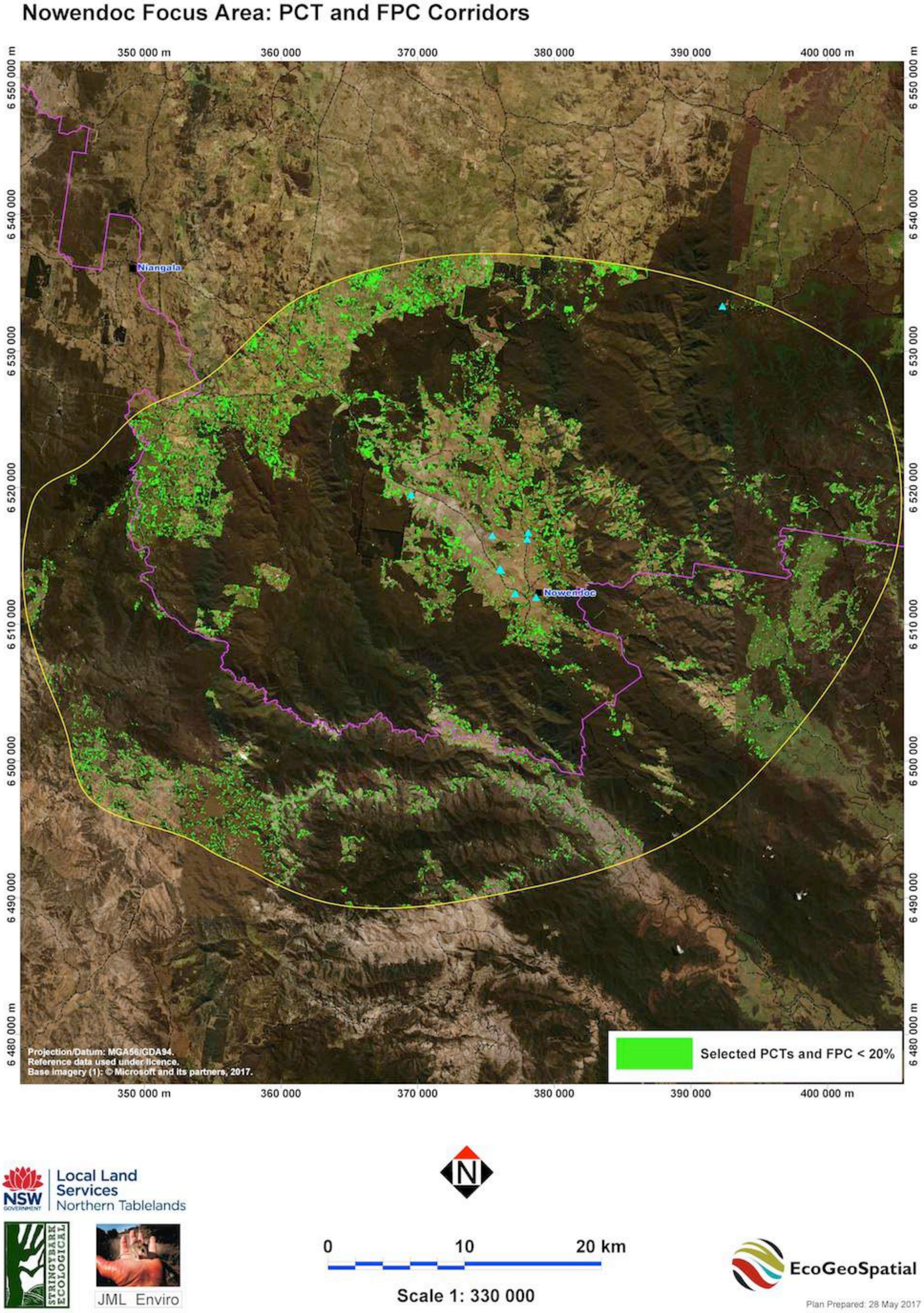


**Figure 28: Nowendoc priority area suggested koala revegetation areas. Individual PCTs are not defined.**

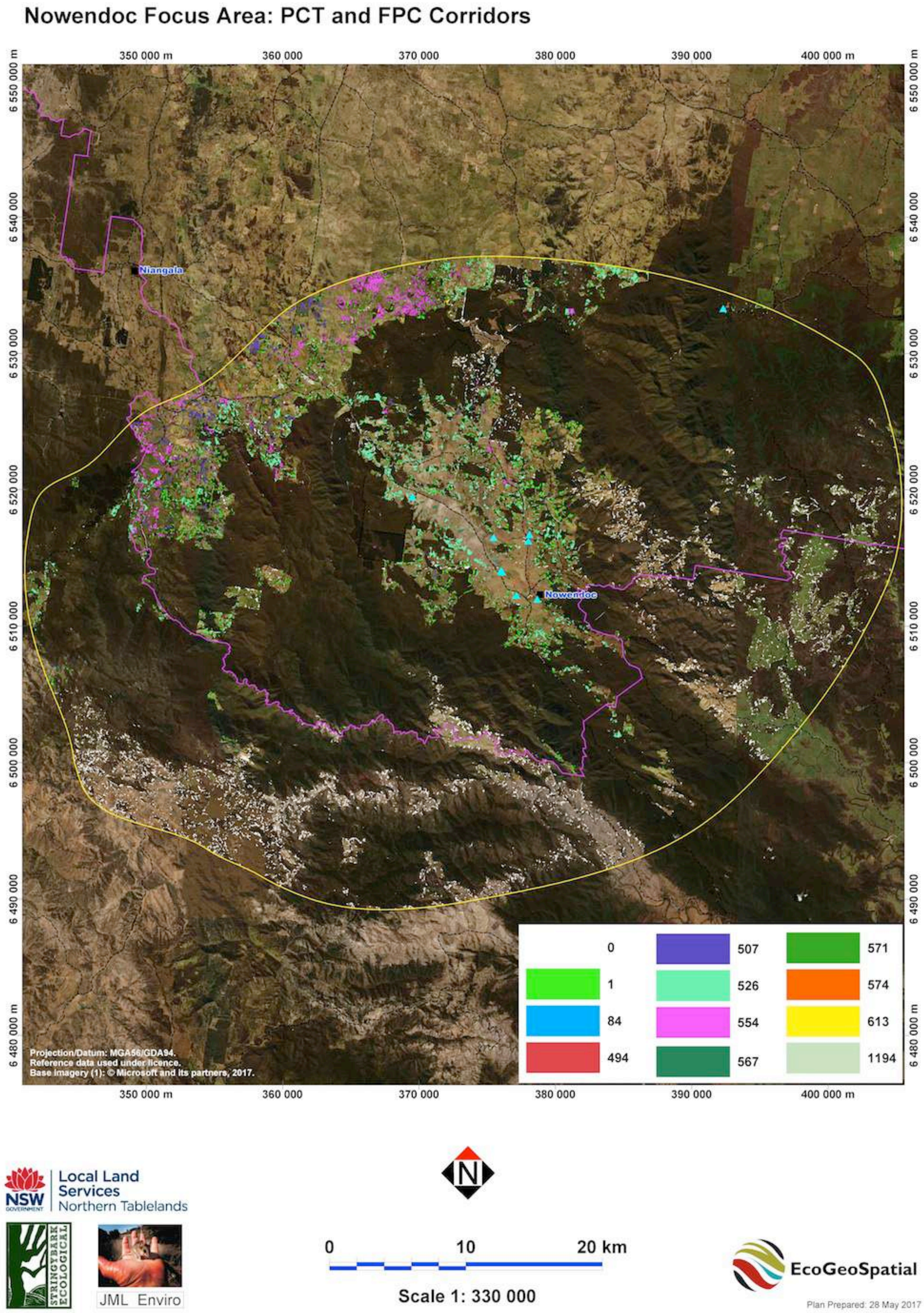


**Figure 29: Nowendoc priority area suggested koala revegetation areas. Individual PCTs are individually defined.**

Figure 35 shows the state-wide metapopulation links analysis of Drielsma *et. al.*,(2014) for the Nowendoc area.

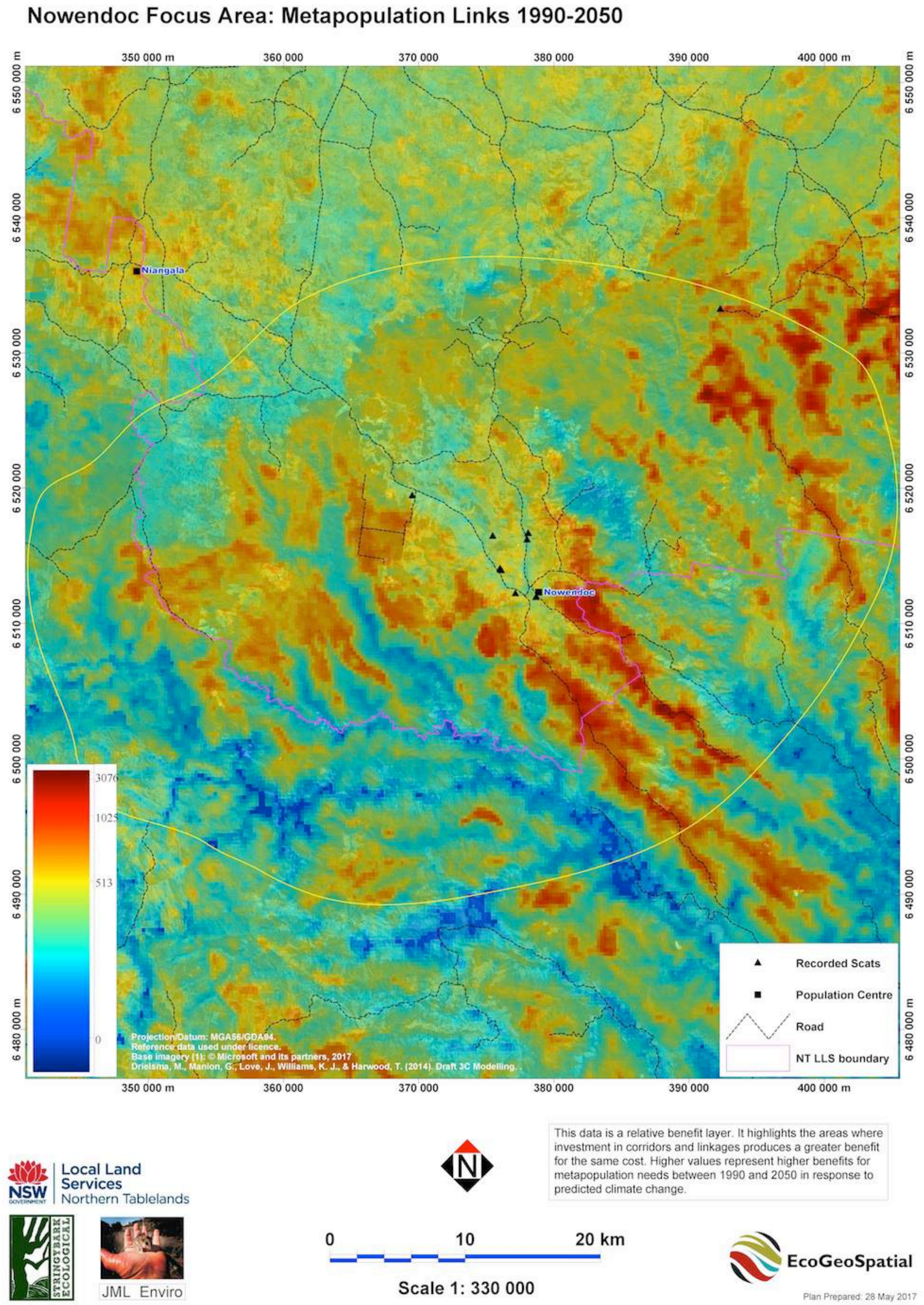


**Figure 30: State-wide metapopulation analysis of relative benefits of corridors and linkages for the Nowendoc priority area (Drielsma et. al., 2014).**

Figure 31 shows the recommended PCT and FPC classes overlaid against the state-wide 3C modelling (Drielsma et. al. (2014)

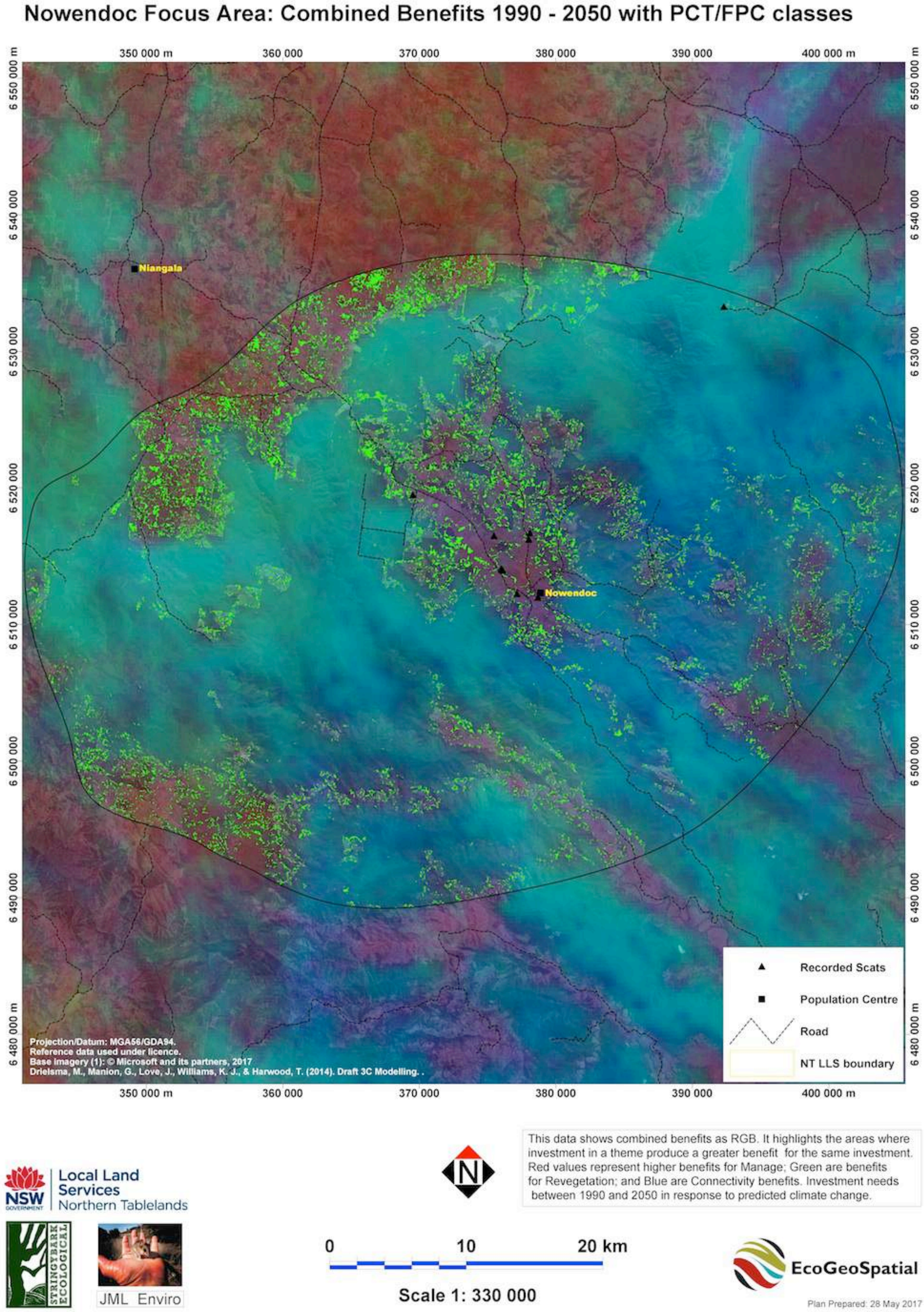


**Figure 31: Recommended koala revegetation areas (light green) over state-wide 3C modelling for the Nowendoc priority area.**

## Results across three priority areas

We have looked at vegetation data and threats across all three priority areas together as there is not enough data available at the area scale alone.

### *Species use by koalas*

We have taken the presence of scats within a one metre radius of a tree to indicate that a koala is using that tree. We are unable to detect (except in a few cases) that 'use' indicates feeding. In a few areas in Nowendoc, we could also see that koalas had been browsing on particular tree species because of the level and type of defoliation present. Table 5 shows the use of all species surveyed in systematic survey plots. Some species could not be identified in the time available due to lack of low branches in dense forest and are indicated as *Eucalyptus sp.* Most of these species were stringybarks.

Figure 20 shows the results for those species where at least 10 trees of the species were surveyed.

**Table 6: Tree species use by koalas across the three priority areas.**

| Species | Absent | Present | Total | % used | Notes |
|---|---|---|---|---|---|
| *Eucalyptus laevopinea* | 534 | 35 | 569 | 6.15 | |
| *Eucalyptus pauciflora* | 394 | 50 | 444 | 11.26 | |
| *Eucalyptus caliginosa* | 378 | 28 | 406 | 6.90 | |
| *Eucalyptus melliodora* | 353 | 15 | 368 | 4.08 | |
| *Eucalyptus dalrympleana ssp. heptantha* | 310 | 10 | 320 | 3.13 | |
| *Eucalyptus viminalis* | 269 | 13 | 282 | 4.61 | |
| *Eucalyptus blakelyi* | 240 | 19 | 259 | 7.34 | |
| *Eucalyptus fastigata* | 145 | 0 | 145 | 0.00 | |
| *Angophora floribunda* | 121 | 13 | 134 | 9.70 | |
| *Eucalyptus nova-anglica* | 125 | 5 | 130 | 3.85 | |
| *Eucalyptus obliqua* | 125 | 2 | 127 | 1.57 | |
| *Eucalyptus youmanii* | 61 | 18 | 79 | 22.78 | |
| *Eucalyptus radiata* | 59 | 14 | 73 | 19.18 | |
| *Eucalyptus bridgesiana* | 67 | 5 | 72 | 6.94 | |
| *Eucalyptus microcorys* | 57 | 0 | 57 | 0.00 | |
| *Eucalyptus macrorhyncha* | 48 | 7 | 55 | 12.73 | |
| *Eucalyptus acaciiformis* | 41 | 7 | 48 | 14.58 | |
| *Eucalyptus stellulata* | 37 | 6 | 43 | 13.95 | |

| | | | | | |
|---|---|---|---|---|---|
| *Eucalyptus nicholii* | 37 | 5 | 42 | 11.90 | |
| *Eucalyptus andrewsii* | 38 | 0 | 38 | 0.00 | |
| *Eucalyptus nobilis* | 37 | 0 | 37 | 0.00 | |
| *Acacia falciformis* | 25 | 0 | 25 | 0.00 | |
| *Eucalyptus albens* | 24 | 0 | 24 | 0.00 | |
| *Eucalyptus saligna* | 23 | 0 | 23 | 0.00 | |
| *Pinus radiata* | 12 | 7 | 19 | 36.84 | Gardens and cemeteries |
| *Acacia dealbata* | 12 | 0 | 12 | 0.00 | |
| *Angophora subvelutina* | 9 | 1 | 10 | 10.00 | |
| *Eucalyptus sp.* | 8 | 2 | 10 | 20.00 | Mostly stringybarks |
| *Acacia sp.* | 7 | 0 | 7 | 0.00 | |
| *Acacia implexa* | 6 | 0 | 6 | 0.00 | |
| *Eucalyptus cameronii* | 7 | 0 | 7 | 0.00 | |
| *Allocasuarina littoralis* | 4 | 1 | 5 | 20.00 | |
| *Acacia melanoxylon* | 4 | 0 | 4 | 0.00 | |
| *Acacia decurrens* | 3 | 0 | 3 | 0.00 | |
| *Acacia filicifolia* | 3 | 0 | 3 | 0.00 | |
| *Eucalyptus rubida ssp barbigerorum* | 3 | 0 | 3 | 0.00 | |
| *Acacia neriifolia* | 2 | 0 | 2 | 0.00 | |
| *Callistemon salignus* | 2 | 0 | 2 | 0.00 | |
| *Eucalyptus amplifolia* | 2 | 0 | 2 | 0.00 | |
| *Eucalyptus banksii* | 2 | 0 | 2 | 0.00 | |
| *Thuja sp* | 1 | 1 | 2 | 50.00 | Gardens and cemeteries |
| *Quercus robur* | 2 | 0 | 2 | 0.00 | Gardens and cemeteries |
| *Acacia floribunda* | 1 | 0 | 1 | 0.00 | Gardens and cemeteries |
| *Acacia irrorata* | 1 | 0 | 1 | 0.00 | |
| *Acacia rubida* | 1 | 0 | 1 | 0.00 | Gardens and cemeteries |

| | | | | | |
|---|---|---|---|---|---|
| *Acer palmatum* | 1 | 0 | 1 | 0.00 | Gardens and cemeteries |
| *Banksia integrifolia* | 1 | 0 | 1 | 0.00 | |
| *Eucalyptus mckieana* | 1 | 0 | 1 | 0.00 | |
| *Eucalyptus moluccana* | 1 | 0 | 1 | 0.00 | |
| *Eucalyptus cinerea* | 0 | 1 | 1 | 100.00 | Gardens and cemeteries |
| *Eucalyptus scoparia* | 0 | 1 | 1 | 100.00 | Gardens and cemeteries |
| **Grand Total** | **3644** | **266** | **3910** | **6.80** | |

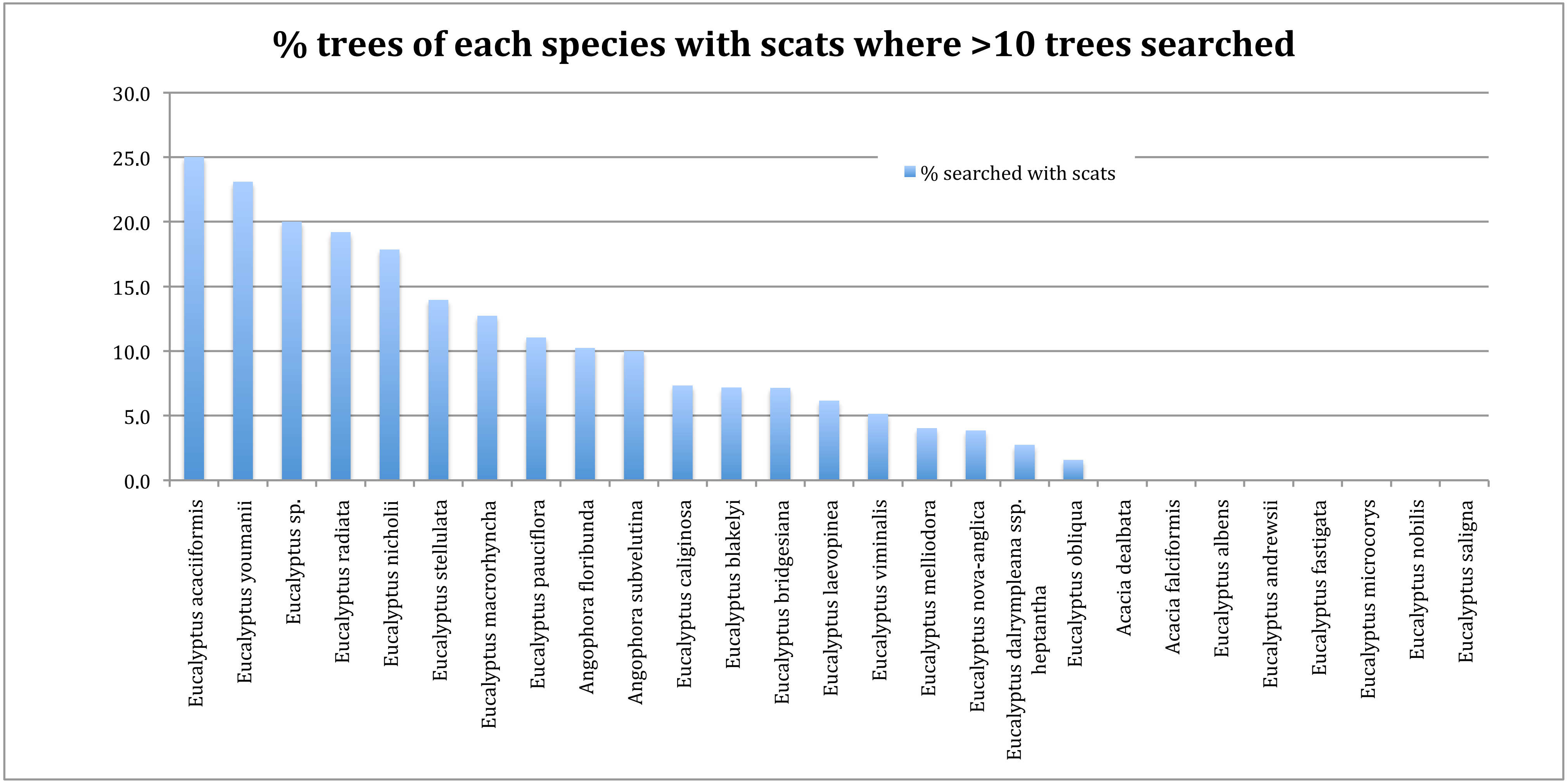


**Figure 32: The percentage of trees surveyed that had scats present, where at least 10 trees of that species were surveyed.**

### *Vegetation results*

The vegetation surveys at each site enabled us to determine the Plant Community Types (PCT) at each site. We compared these to mapped PCTs (NSW OEH, 2017) for the site. There was a low correlation (c=0.13) between the mapped and actual PCTs.

Scats were found in 19 of the 29 different PCTs identified. Figure 21 shows the PCTs where scats were found and the % of plots where scats were found in each. These results are for PCTs where at least 3 plots were surveyed in a PCT. Table 6 shows the figures for these and the number of plots of each PCT surveyed.

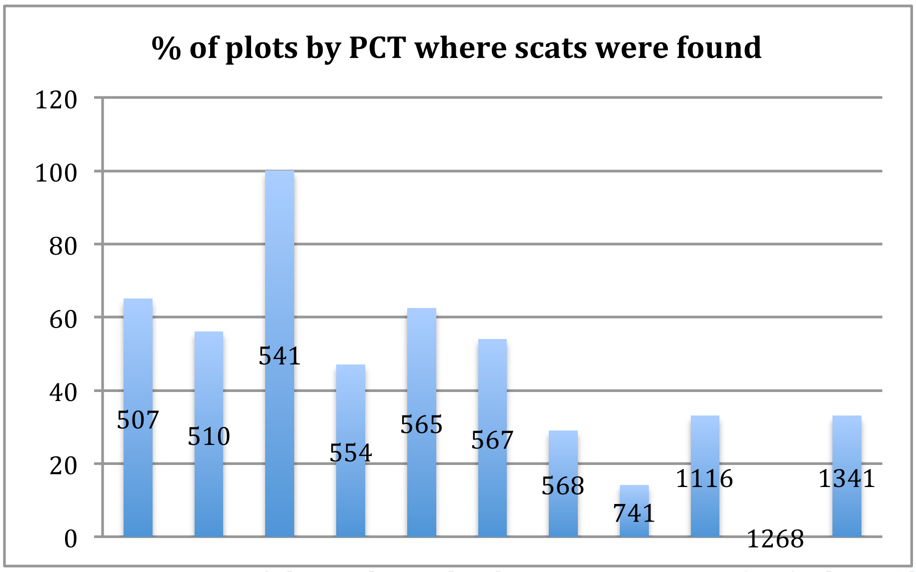


**Figure 33: Percentage of plots with scats by Plant Community Type (PCT) where at least 3 plots were surveyed for each PCT. See Table 7 for PCT descriptions..**

**Table 7: Percentage of plots with scats by PCT where n>2.**

| PCT | Plots with scats (%) | PCT common name | n |
|---|---|---|---|
| 541* | 67 | Silvertop Stringybark - Rough-barked Apple grassy open forest of southern Nandewar Bioregion, southern New England Tableland Bioregion and NSW North Coast Bioregion | 6 |
| 507 | 65 | Black Sallee - Snow Gum grassy woodland of the New England Tableland Bioregion | 14 |
| 565 | 62.5 | Silvertop Stringybark - Mountain Gum grassy open forest of the New England Tableland Bioregion | 16 |
| 510 | 56 | Blakely’s Red Gum - Yellow Box grassy woodland of the New England Tableland Bioregion | 18 |

| | | | |
|---|---|---|---|
| 567 | 54 | Broad-leaved Stringybark - Yellow Box shrub/grass open forest of the New England Tableland Bioregion | 13 |
| 554 | 47 | Ribbon Gum - Mountain Gum - Snow Gum grassy open forest or woodland of the New England Tableland Bioregion | 17 |
| 1341 | 33 | Youman's Stringybark - New England Blackbutt - Narrow-leaved Black Peppermint - Eucalyptus subtilior open forest of the New England Tableland Bioregion | 3 |
| 568 | 29 | Broad-leaved Stringybark shrub/grass open forest of the New England Tableland Bioregion | 7 |
| 741 | 14 | Brown Barrel - gum moist open forest of the escarpment ranges of NSW North Coast Bioregion and New England Tableland Bioregion | 7 |
| 1268 | 0 | Tallowwood open forest of the coastal ranges of the NSW North Coast Bioregion. | 3 |

*includes three plots of the very similar PCT #1116 (see Figure 21).

### *Threats*

There was no obvious relationship between koala presence and absence and any of the threat factors we recorded. We found no occurrence of Tiger Pear at any sites.

**Table 8: Relationships between koala presence and absence and threats.**

| | Grazing freq. | Grazing intensity | Weeds preventing regrowth | Dieback |
|---|---|---|---|---|
| $r^2$ | 0.0322 | 0.0129 | 0.0036 | 0.0012 |

### *Koala sightings*

We saw ten live and one dead koalas in the Nowendoc area, all within 250m of the river in lower slope positions and in either open Snow Gum (*E. pauciflora*) woodland or riparian Snow Gum – Wattle-leaved Peppermint woodland.

We saw one live koala in the Armidale-Uralla priority area, at Balala.

## Discussion

### Community Engagement

The community engagement component of the project demonstrated that a section of the community in this region cares about koalas and is willing to participate in projects to ensure their survival.

The workshops held in Armidale and Walcha did not attract many landholders. We believe that the focus was too broad and landholders did not see the relevance to them. We discussed the poor attendance by landholders with landholders we worked with during scat surveys. Their feedback indicated that they would be more likely to attend a workshop in their local area aimed at a specific locality. We concluded that in areas with a high incidence of koalas, workshops to show landholders how to look for koala signs and report sightings, would be better attended and of more value to landholders.

The school workshops allowed us to reach a very wide audience within a number of communities. In Walcha and Uralla, we asked school students how many of them had seen koalas locally and at least 75% had seen a koala. At least 50% had seen one in the last 12 months. At Nowendoc, all of the students had seen koalas in the last few days and regularly saw koalas at school or at home. We distributed fridge magnets to all school students and asked them to talk to their parents about koalas and report any sightings.

During the project we distributed nearly 900 fridge magnets. We do not know if this resulted in any calls to NT LLS or if any sightings have been contributed to the Atlas of Living Australia. Magnets are long-lived tools and it is possible that they will be referred to in the future to report infrequent koala sightings by towns people and landholders where they were received.

Direct cold-calling of landholders in areas identified through the Koala Habitat Envelope analysis yielded very few positive responses. Many landholders were suspicious of the motives of Local Land Services in calling out of the blue. The project was run while changes to native vegetation clearing laws were under development in NSW. This is likely to have made some landholders more wary of allowing government employees (or their agents in this case) onto their properties.

The other methods used to contact landholders to gain access to survey sites were more successful than cold-calling. Of these methods, the most responses were generated through the Stringybark Ecological website and Facebook page and the personal contacts of the project team. This is in line with current understanding of effective extension practice (Clarke, 2007) where people will more readily engage with someone they trust rather than an unknown person or organisation.

Most of the landholders who allowed us to conduct surveys on their properties were very protective of their koala populations and keen to find out more about how to ensure their survival. A koala visit to someone's property was seen as a rare event and landholders had memories of specific instances going back many years.

Landholders are one of the most important stakeholder groups in koala conservation in this region. Not only are they responsible for maintaining koala habitat, they are in the best position to record infrequent visits by koalas to their properties and add to knowledge of koala distribution and population size.

We believe that landholders are in the best position to record sightings of koalas so a better picture of regional koala distribution can be formed. A well-resourced public information campaign calling for sightings to be reported, along with a central location for collecting sighting records, would rapidly build up a new set of location records. Such a campaign would need to be supported and promoted by a network of local, trusted people such as Landcare, local government and LLS staff, consultants and researchers. Sightings could be followed up with visits to landholders by ecologists to carry out scat and habitat surveys; collections of koala DNA; and to provide management information.  More sighting records and more information about genetics, habitat and tree preference and koala population density would enable better habitat modelling and targeting of connectivity and conservation programs.

There are a number of different methods for recording koala numbers including the Atlas of Living Australia, the NSW Wildlife Atlas, mail-out surveys (Predavec et. al., 2015), phone-based applications such as Feral Scan (Guy Ballard, pers. comm.) or web-based reporting mechanisms (Armidale Regional Council).

We believe that the project has achieved one of its aims, of building a platform for community engagement in threatened species management, particularly for koalas. The landholders and managers who assisted us will receive a copy of the survey results for their properties and will be encouraged to participate in similar future projects and to take up incentive funding when offered, for conservation works.

### Presence and absence of koalas as indicated by scats

Across all three priority areas, the presence of scats was sparse, with a few exceptions. When scats were detected they were found near a small percentage of the trees sampled and there were usually only one or two scats found near any tree. Nevertheless, scats were detected in 49% of the plots we surveyed and near 6.8% of trees.  Scats were detected in each of the three priority areas.

The scat data indicates that koalas are present throughout the area, although it appears that they are sparse, except for areas around Nowendoc and north of Armidale. Most of the scats we found were old. Koalas produce on average 80 (Archer *et. al.,* 1987) to 150 (Sullivan *et. al.,* 2004) scats per day. The low numbers we found indicate that while koalas are present, they are not staying in any one site long enough to produce large numbers of scats.  Based on the expected scat production, the sites we surveyed had been used by koalas in transit, rather than by resident animals, except in a few situations.

We used a finite number of plot surveys at one point in time to intercept koalas moving through or using the landscape. We only found two areas where koalas are regular inhabitants – the Nowendoc River Valley and the area around Sunnyside Rd and TSR north east of Armidale. In these areas we found high numbers of scats, more fresh scats and more trees with scats. In Nowendoc we regularly saw koalas and all local people we met reported that koalas were common and regularly seen. In the Armidale area, Armidale Regional Council has set up a reporting system for koala sightings (ARC website; accessed 26th May, 2016) and there are many records from the last few years indicating a high koala population in this area.

It is likely that the method we used is not appropriate for the scale of the three areas we covered. It would work well (and has in the past) in smaller areas of contiguous habitat. In smaller areas, there is a much higher chance of intercepting koalas or of locating areas that are more intensively used. While the results of the survey indicate that koalas are found throughout the three priority areas, we have no indication of population sizes or home ranges.

The low number of scats and the high percentage of plots with scats indicates that koalas are located throughout the areas but we did not find areas of high or recent occupation. These areas no doubt exist, as indicated by the sites indicated above and the results from spotlighting surveys at Mt Duval by UNE (Luke Emerson, unpublished Honours project). Mt Duval is part of the University of New England's 'Newholme' property and has been used for ecosystem management research for many years. This research has included several koala studies (Heinz, 1999; Carney, 1995). The area is known to support a resident koala population. We conducted four plots surveys on the southern slopes of Mt Duval, but found no koala scats. During the Armidale community workshop we surveyed 100 trees of a range of species, but found no scats. We went to two sites where student Luke Emerson (pers. comm.) had observed koalas by spotlighting two weeks prior to our survey and only found a single scat.

In Nowendoc, we observed koalas sitting in trees, but on two such occasions we could not find koala scats within a 1m radius of the trunk as per the method we were using.

It appears that scat surveys are effective means of detecting koalas when used with a high-sampling intensity over smaller areas than those we surveyed (Woosnam-Merchez *et. al*., 2012). The chances of intercepting a mobile koala population over large areas of contiguous habitat are low when a limited number of plot surveys are used. A higher density of plot-based scat surveys would have a higher chance of intercepting koalas.

It appears that there is more suitable habitat available throughout the three areas than is currently used by koalas. The species and PCTs they prefer (see below) are widely distributed throughout the region but seem to be understocked. From our data, and previous observations recorded in the NSW Bionet Atlas or reported to us, koalas are located throughout the region. We found no obvious threats to koalas from grazing, dieback or weeds.

While this project has not revealed any obvious threats to koalas it is likely that longer-term or intermittent threats may be keeping koala numbers relatively low in this region. It is possible that fires, drought and lack of connectivity may be limiting koala numbers. Elsewhere it has been reported that car strike and dog attacks are significant causes of koala deaths. We had two car strike deaths reported to us but no accounts of dog attack.

Fires occur infrequently in this region and are usually confined to large bushland areas such as steep country, National Parks or State Forests. It is likely that these are important refuges for larger populations of koalas. Many of these large remnants are isolated from other remnants because of fragmentation in the agricultural landscapes. This may prevent koalas being able to easily move to other habitats in the event of fire or other catastrophic events such as droughts or storms. What connectivity there is usually has sparse tree cover, many fences, roads and exposure to attacks from dogs or cattle. Several landholders involved in the project reported seeing koalas again for the first time up to 30 years after catastrophic fires in the area. Many reported seeing koalas on, or crossing, roads, near cattleyards or around farm dwellings.

As fire can be a significant threat to local koala populations, land managers should consider koalas when planning hazard reduction burns.

We cannot attribute any specific losses of habitat to climate change, but it is likely to lead to more severe climatic events such as fires and droughts which will force koalas to move through the fragmented landscape, exposing them to more threats (Lunney et. al., 2015).

We believe that the most effective recovery action for koalas in the southern parts of the Northern Tablelands is to increase connectivity in key areas where they are known to occur and move. This is explored further in the connectivity discussion below.

### Species used by koalas

The results of the surveys supported the common understanding about many of the species known to be used by koalas (such as those identified in the Strategy). There were a number of disparities with the strategy.

As Figure 18 shows, *Eucalyptus acaciiformis* was a preferred species. This was supported by the fact that wherever we saw this species, particularly in the Nowendoc area, some of the trees would be well used by koalas. In Nowendoc, some trees of this species had been browsed to death and we saw signs of heavy use of other trees. Similarly, *E. pauciflora* seemed to be a preferred species around Nowendoc. Within a stand of trees of this species though, we would often see some trees heavily browsed while others were untouched.

Other peppermint species, *E. radiata subsp sejuncta* and *E. nicholii* were also well used by koalas. *E. nicholii* was particularly favoured west of Guyra, where individual trees had been heavily browsed. *E. radiata* was not identified in the Strategy as a preferred or occasional food tree.

Species that are locally regarded as the most important koala food trees ranked very low in this survey. *Eucalyptus viminalis, E. nova-anglica, E. dalrympleana subsp heptantha* and *E. melliodora* are all listed as preferred species in the strategy, but we found scats under less than 6% of trees of these species that we surveyed. As this is a very limited survey, we do not believe that it indicates that these species are not regularly used. It may be that they are preferred at certain times of the year or during certain environmental conditions.

Species such as *E. microcorys, E. obliqua* and *E. fastigata* are indicated in the Strategy as being preferred food trees. These species are more commonly associated with wetter forests on the eastern and southern parts of the Tablelands. In our survey the use of these species by koalas was very low or non-existent. These species are common in the higher elevation forests around Nowendoc where we found very few signs of koalas, despite the Nowendoc Valley having very high numbers of koalas and scats. It may be that the forests are so vast and our methods were not suitable for detecting koalas. Alternatively, it may be that these species are not preferred by koalas in these region, despite them being referred in the escarpment and coastal forests. Carney (1995) found that *E. obliqua* was one of the trees least utilised by koalas, while Heinz found this species was very rarely used by koalas.

Koalas were also commonly found using stringybarks, particularly *E. youmanii* with some use of *E. laevopinea* and *E. caliginosa. E. youmanii* and *E. caliginosa* are only recorded in the Strategy as occasional species. *E. laevopinea* is mentioned as a preferred species at 'Newholme' north of Armidale with *E. caliginosa* used to a lesser extent (Heinz, 1999).

### Plant Community Types

We found a very strong association between koala occurrence and particular PCTs. Stringybark communities (PCTs 541, 565, 567, 1341) and Snow Gum communities (507, 554) were most strongly associated with the presence of koalas. These communities have a relatively high proportion and diversity of preferred food species. It is likely that while koalas may prefer one species over another at a particular location or time, they will require a diversity of species associated with particular communities. Blakely's Red Gum- Yellow Box Grassy Woodland (part of the critically endangered Box Gum Grassy Woodland community) was also strongly associated with koala presence.

We believe that PCTs will be a better indicator of koala habitat preference than the location of individual species. PCTs could be used to indicate areas for habitat protection or connectivity work, particularly where this aligns with conservation priorities. The Chief Scientist of NSW recommends the use of habitat mapping as a tool to inform and guide the management of koala populations at regional and state scales. Based on our results PCTs are a key indicator of habitat.

The difficulty however, will be in detecting PCTs at a regional scale. We compared the PCTs we found from the vegetation surveys, with the PCTs that are mapped as part of the state-wide mapping layer (NSW OEH, 2017) and found that there was only a 13% match. The mapping is highly inaccurate in many areas. This may be because most of our plots occurred in the part of the Tablelands that falls outside the old Border Rivers-Gwydir CMA boundary and has not been properly mapped yet. However, none of the plots in the old BRG CMA area were mapped as the same PCT as we found from ground surveys.

If the vegetation mapping could be improved to be more accurate then PCTs could be used as a good indicator of likely koala habitat.

## Connectivity

We can only speculate, that in the absence of any other obvious threat, that habitat fragmentation is one of the main threats to koalas in the New England Tableland bioregion. While koalas are capable of crossing open farmland (Archer et. al., 1987); doing so exposes them to other threats such as vehicles, dogs and cattle. Increasing connectivity between existing habitat patches will be an effective means of addressing fragmentation. Connectivity for koalas is different to that required by small birds (Doerr *et. al.*, 2010). Lunney (2016) recommends planting food and shade trees used by koalas to link existing remnants. He recommends prioritising planting in lower parts of the landscape where the trees will get more moisture and be of greater benefit to koalas.

The comparison of the preferred PCT envelope with the low FPC class shows that there are parts of each priority area where revegetation could be carried out to increase connectivity between existing vegetation. Based on our observations, we have recommended areas within each priority area where connectivity would link existing koala habitats. In these areas, we recommend that revegetation be based on the PCTs found in this study to be more used by koalas than others. The maps for each priority area show that there are many areas that would benefit from revegetation for koalas, while the maps with individual PCTs can be used to prioritise according to the PCTs shown to be preferred by koalas (Table 6).

The maps for Nowendoc (Figs 28 and 29) are an exception, because the PCT preferred by koalas in that area is so sparse as to not readily show up on state-wide mapping. In this case PCT 507 (Black Sallee - Snow Gum grassy woodland of the New England Tableland Bioregion) in the valleys around Nowendoc and Riamukka should be targeted for revegetation works to increase extent and condition of this community.

At the state-wide scale, OEH has modelled benefits to be gained from investment in biodiversity conservation (Drielsma *et. al.,* 2014). For the Armidale-Uralla (Fig 14) and Walcha (Fig 22) areas, most of the landscape is classified as low priority for investment. However, there are parts of these landscapes identified as higher investment priorities. In Nowendoc (Fig 30), there are many high priority investment areas, mainly on ridge tops that connect the New England Tablelands to the Manning River tributaries. Each of these figures highlights the need to protect existing vegetation and improve or maintain its condition. Revegetation is a more costly option than those that seek to improve or maintain condition.

In the 3C modelling (Drielsma, 2014), the three options of Manage, Connectivity and Revegetate (in the context of climate change predictions to 2050) are considered together as a colour index. In Figure 15, the options for the Armidale-Uralla area can be seen. There are areas recommended for maintaining existing connectivity in the well vegetated areas north of Armidale and in the National Parks estate. The fragmented and relictual landscapes of the flatter pastoral areas are indicated as best managed to increase extent and condition of existing vegetation, while bare areas close to existing vegetation are identified as suitable for revegetation. A similar picture emerges in Walcha (Fig 23), with denser vegetation on the western escarpment of the Tablelands recommended for maintaining connectivity; open grazing country for managing and increasing the extent of existing vegetation; and revegetation for connectivity in areas close to larger remnants.

In both the Armidale-Uralla the state-wide biodiversity benefits and 3C modelling supports the areas we recommend for revegetation and maintenance of condition, with the revegetation 'envelope' overlain on the 3C maps. This reinforces our belief that investing in revegetation for conservation in the highlighted areas, will have benefits for a range of biodiversity attributes at the state scale.

In Nowendoc, the picture is less clear from the state-wide mapping and the PCT mapping. We can confidently say from our data and observations, that there is a core population located in the valley floor vegetation around Nowendoc and Riamukka. We can also confidently say that these vegetation communities are in declining condition and would significantly benefit from investment in revegetation to expand remnant size, connect remnants, increase species diversity and to improve condition. Condition improvements could be gained by fencing some remnants to manage grazing and controlling weeds.

The 3C modelling (Fig 31) does support our recommendation for investing in revegetation on the mid-slopes of the Nowendoc valleys to increase connectivity between the lower slope Snow Gum community and the denser, taller forests of the ridges.

Overall, the identification of PCTs preferred by koalas and the identification of important areas of koala habitat in each priority area, have enabled us to refine the corridor recommendations in the Strategy and to recommend actions for protecting core populations of koalas. We are confident that these recommendations align with state-wide priorities for investment in biodiversity conservation and with predicted climate change.

Specific recommendations for each priority area are contained in the individual koala management plans below. At a regional scale (the southern half of the New England Tablelands bioregion), the following actions are recommended:

- Preservation of extent and condition of koala habitat in identified core areas. This could be achieved by conservation covenants, stewardship agreements, incentive funding for appropriate conservation works, land acquisition for the Reserve system. While private land is most important for koala conservation, public land (TSRs, State Forests and National Parks) should also be managed to ensure koala survival.
- While there appears to be plenty of suitable habitat for koalas, it is likely that connectivity between habitats is a factor limiting their numbers. Climate change will increase the incidence of severe weather events including fire, drought and storms. A well-connected landscape is critical for animals to be able to survive these events. We recommend that connectivity be increased in key areas to increase the chances of koala populations dispersing through the landscape over time.
- Further investigation to determine the distribution of koalas and the location of core populations in the New England Tableland bioregion. Current koala numbers are based on limited sightings data and estimates

based on expert knowledge (Adams-Hosking et. al., 2016). This project has shown there is a sparse widespread distribution of koalas in may parts of the priority areas, with few core areas. The project may, by chance, have missed surveying other core areas. We know that koalas are affected by different threats in different parts of their distribution and that they respond to these threats in different ways (McAlpine et. al., 2015). In order to understand whether koalas in the New England Tableland bioregion are increasing or declining and the size, demographics and health of the regional population, we need more information. Better community engagement through some form of bioregion-wide community survey may address this issue. This project has shown that the community are willing to engage in koala conservation projects. Local Land Services would be well placed to run a short term "report-a-koala" project across the New England Tablelands bioregion, perhaps in conjunction with local governments. Recent sightings could be followed up by quick site visits from an ecologist to do a scat survey using the methods used in this project and a rapid vegetation assessment.

The information required for this increased understanding depends on the scale. At a bioregional scale, we need to better understand where koalas are located and where core populations occur. This project has made some contribution to this knowledge gap. At a population scale, we need to understand how many koalas occur in a particular population, the population demographics, the incidence of disease (such as Chlamydia), the genetic diversity of the population and the ability of the population to move through the landscape. Further local scale surveys using scat detection, spotlighting, camera trapping and use of thermal imaging may address some of this knowledge gap.

At the sub-population scale, we need to better understand the home ranges of koalas in different areas. It appears from this study that koalas may have different-sized home ranges north of Armidale to those around Nowendoc. Radio or GPS tracking of individual koalas within core population areas will address some of this need.

- As sighting records increase (such as from this project), improve current modelling of koala habitat as a tool for predicting habitat occupancy. Use simpler models based on occupancy rates within 10 x 10km grid squares such as proposed by Predavec *et. al.,* (2015b). Contribute data to state-wide koala mapping projects. Newly identified Koala hotspots within the Armidale and Nowendoc focus areas could be further defined and explored with the aid of high resolution remote sensing products such as ADS40/80 aerial photography and airborne lidar. In particular the Black Mountain population lies within a spatially data-rich zone. A baseline database of high resolution data and analysis products could be generated to support KHE v3 and future tracking-collar studies. Regional hotspot locations can also be placed on Department of Land and Property Information priority acquisition programmes for lidar and ADS.

The Saving Our Species program (Office of Environment and Heritage, 2016) has identified a number of key actions to address threats to koalas in NSW. The following table (9) reviews these threats and, where possible, proposes actions for koalas on the Northern Tablelands.

**Table 9: Actions to address threats to koalas on the Northern Tablelands based on action framework of the Saving Our Species program**

| Threat | Actions relevant to the Northern Tablelands | Arm-Ura | Wal | Now |
|---|---|---|---|---|
| Loss, modification and fragmentation of habitat | • Revegetation in specific areas will benefit koalas in each of the 3 priority areas. | Y | Y | Y |
| | • Protection of existing koala populations by stewardship agreements or covenants is likely to be important in the Armidale-Uralla and Nowendoc Area. | Y | N | Y |
| | • Koala habitat studies will be important for the core populations in Armidale-Uralla and Nowendoc. | Y | N | Y |
| Vehicle strike | No direct evidence but discussions with RMS and local Councils likely to be important on the New England Hwy north of Armidale and on Thunderbolts Way and Brackendale Rd between Nowendoc and Riamukka. | Y | ? | Y |
| Predation by roaming or domestic dogs | No direct observations or anecdotal reports. | ? | ? | ? |
| Intense prescribed burns or wildfires that reach canopy | NTLLS should liaise with RFS and NPWS to ensure the core koala populations are identified as assets for protection in wildfire and hazard reduction management. | Y | N | Y |
| Koala disease | Few direct observations and anecdotal reports. Carers would have better information. | ? | ? | ? |
| Heat stress through drought or heat waves | Not obviously relevant to this region but reconsider during drought | N | `N | N |
| Human-induced climate change | • This report considers likely climate change to 2050 in recommending revegetation and connectivity actions.<br>• Modelling of changes to habitat would be beneficial | Y | Y | Y |
| Inadequate support for fauna rehabilitation | No direct observations or anecdotal reports. Not covered by this project. | ? | ? | ? |

| | | | | |
|---|---|---|---|---|
| Lack of knowledge (trauma and mortality) | No direct observations or anecdotal reports. | ? | ? | ? |
| Lack of knowledge (population distribution and trend) | Continue to use scat surveys at a more intensive scale in identified areas. | Y | Y | Y |
| | Carry out spotlighting or thermal imaging surveys in identified core population areas. | Y | N | Y |
| Lack of knowledge (animal movements and habitat use) | Investigate options for radio-tracking koala movements in the three priority areas to see how far koalas are moving. | Y | Y | Y |
| Community engagement | This project has shown that the community, including landholders, are willing to engage in koala conservation. We recommend this as the most effective means of increasing understanding of where koalas are. | Y | Y | Y |

The area between Armidale and Guyra and between Boorolong Rd and Rockvale Rd, supports a core population of koalas (Fig 34). This area still has large areas of intact and connected vegetation, including many species preferred by koalas and many of the PCTs that are strongly associated with koalas. The ridges that have not been cleared in this area mostly run north-south.

In this area, there is scope to improve connectivity to enable koalas to move through the landscape more easily without being exposed to threats (Fig 34). Connectivity could be improved by linking the north-south ridges or by improving vegetation cover in gaps along the edge of the Guyra Plateau running west from Black Mountain and to the west of Boorolong Rd running north-south from Toms Gully Rd to Invergowrie.

The main threat to koalas in this area is fragmentation and subsequent inability to escape from drought, fire or storm damage. Increasing fragmentation as a result of the new Biodiversity Act is likely to have a major impact on koala populations in this area. It is highly likely that road fatalities on the New England Highway between Tilbuster Rd and Sunnyside Rd and on the Devil's Pinch south of Black Mountain kill a significant number of koalas. A major bushfire in the Mt Duval area would have a significant impact on koala populations.

There are many records for koalas in the area west of Armidale extending from Uralla to Kingstown and taking in Invergowrie, Yarrowyck, Kingstown, Balala. We also received many reports of koalas from landholders in this area. We believe that this area also supports a core population of koalas, although it is more sparse due to the higher level of fragmentation of the vegetation. There are still large areas of intact bushland in this area and good connectivity, particularly along the Rocky (Gwydir) River.

Connectivity could be improved to allow koalas to move more easily through the landscape in this area. The areas between Uralla and Balala and Uralla and Invergowrie particularly need better connectivity.

There are sparse records of koalas in the area east of Uralla including Mihi and Gostwyck. The vegetation includes some large patches of open woodland and sparse paddock trees, fragmented by very large areas of mostly cleared farmland. New England Dieback had a big impact in this area in the 1970's and 80's resulting in the loss of many thousands of trees. We believe that koalas use this area to move between very large remnants in the Macleay River valleys and the area west of Uralla, so is an important area for improving connectivity for koalas.

Our analysis of the spatial distribution of Atlas records and observations during our surveys, shows that koalas seem to prefer woodland or open woodland to forest in this area. We found signs of them in very open country and many observations have been made in areas with only sparse paddock trees. This is partly due to the ease of observing koalas in these areas, but indicates that they will use vegetation of different densities.

In the Armidale-Uralla area we recommend the following species be included in revegetation programs in order to assist koalas. These species should be matched to the appropriate ecosystems in the area.

- **Stringybarks** – *E. youmanii, E. laevopinea, E. caliginosa, E. macrorhyncha* (in the west).
- **Peppermints** – *E. radiata subsp sejuncta, E. nicholii, E. acaciiformis* (in the east), *E. nova-anglica.*
- **Gums –** *E.pauciflora, E. stellulata, E. blakelyi, E. viminalis, E. dalrympleana subsp heptantha.*
- **Boxes –** *E. melliodora, E. bridgesiana*
- **Other –** *Angophora floribunda.*

**Core populations:**

1. North of Armidale to Guyra, between Boorolong Rd in the west and Rockvale Rd in the east.
2. West of Uralla to Kingstown, north to Invergowrie and including the Yarrowyck-Torryburn area.

**Priority connectivity areas**

1. East of Uralla to Enmore, Mihi and Dangars Falls, including Gostwyck.
2. Improving east-west linkages between ridges running north-south between Guyra and Armidale.
3. Between Black Mountain and Invergowrie west of Boorolong Rd.
4. West of Uralla between Uralla and Balala and north to Invergowrie.

**Further investigation**

1. Scat surveys in Kingstown area.
2. Spotlighting or capture/release and radio tracking surveys between Armidale and Guyra, particularly Sunnyside – Black Mountain area and west of Black Mountain.
3. Spotlight and more scat surveys in Balala to Uralla area.
4. Continue to encourage the community to report koala sightings to NT LLS or ALA.

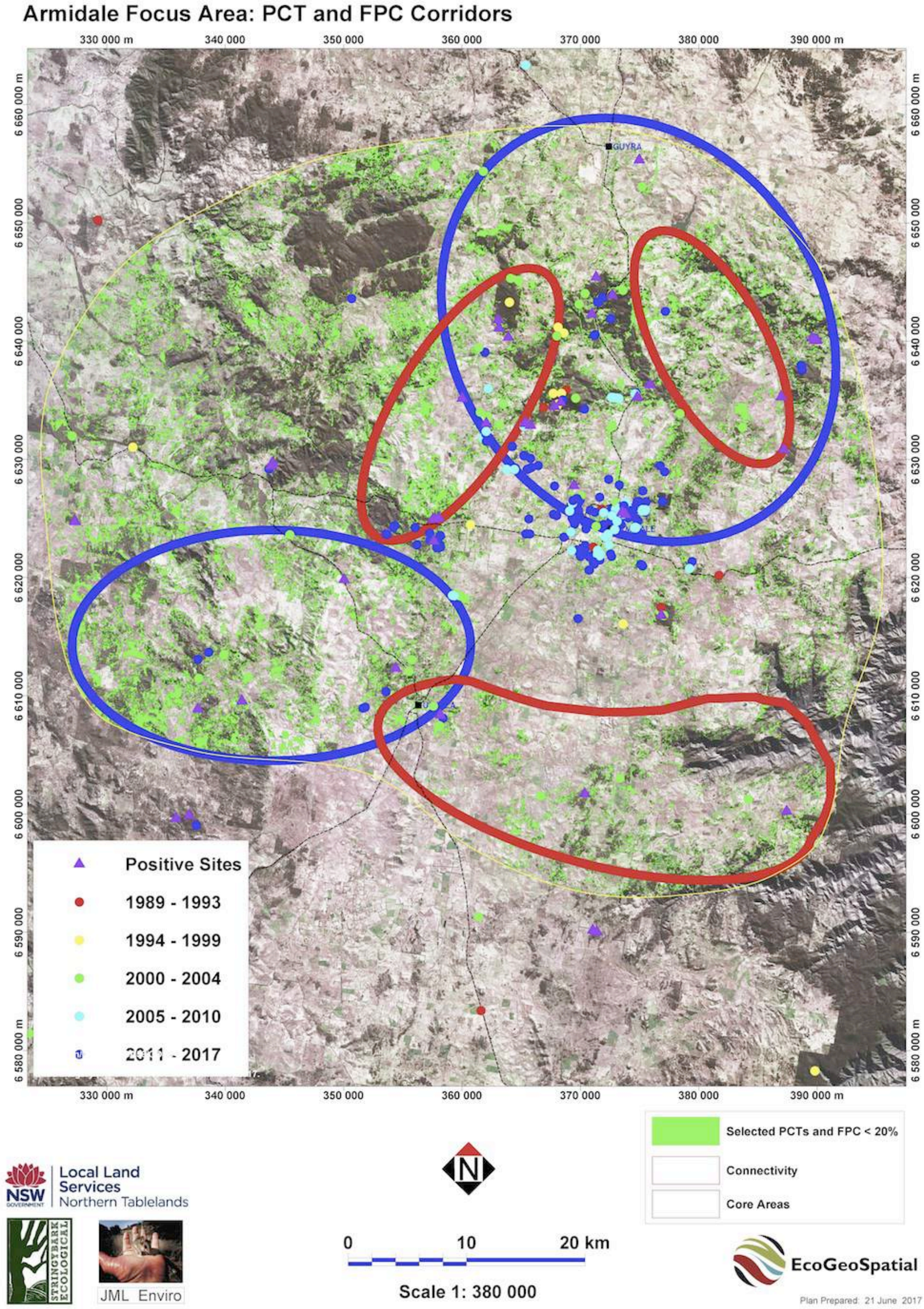


**Figure 34: Core populations and recommended areas for revegetation in the Armidale-Uralla priority area. The blue circle indicates a core population and a red ellipse indicates an approximate boundary for a connectivity area. The light green shading is the intersection of the preferred PCTs and the <20% FPC layers.**

In both Walcha and the property 'Eastlake' near Blue Mountain, scats were most commonly found in association with *E. pauciflora, E. stellulata, E. radiata, E. caliginosa* and *E. viminalis.*

There are very few Atlas records. It is likely that the population around Walcha is small as there is very low vegetation cover and connectivity in the area. Nevertheless, local people including school children were very familiar with koalas and said they were seen often. The vegetation in TSRs, Council land and the common around Walcha are very important habitat for koalas, although the proximity to town likely increases the risk of dog attack.

There are some vegetated areas to the south of Walcha between Thunderbolts Way and Brackendale Rd, but the vegetation is very sparse and open here. There is some connectivity between Walcha and Aberbaldie and between Walcha and Blue Mountain in the north east, but vegetation is sparse and fragmented due to past clearing and dieback. We recommend improving connectivity through revegetation in these areas (Fig 35).

It is likely that there is some movement of koalas between Walcha and Apsley Falls area but we saw no evidence of koalas in this area other than one anonymous landholder report. It is also likely that there are koalas in the area between Woolbrook, Walcha Road and Wollun but we did not have time to survey this area.

Based on our evidence from this survey we believe that Walcha is not a core area for koalas, but supports a small and sparse population. There are areas around Walcha where connectivity for koalas could be improved through revegetation.

In the Walcha area we recommend the following species be included in revegetation programs in order to assist koalas. These species should be matched to the appropriate ecosystems in the area.

- **Peppermints** – *E. nova-anglica, E. radiata subsp sejuncta, E. nicholii, E. acaciiformis* (in the east).
- **Gums –** *E. pauciflora, E. stellulata, E. blakelyi, E. viminalis, E. dalrympleana subsp heptantha.*
- **Boxes –** *E. melliodora.*
- **Stringybarks** – *E. youmanii, E. laevopinea, E. caliginosa.*
- **Other –** *Angophora floribunda.*

## Priority Connectivity Areas

1. North-east of Walcha to the Blue Mountain area connecting existing large remnants.
2. South-west of Walcha towards Aberbaldie.

**Further investigation**

1. Scat surveys or spotlighting in the Walcha Rd area between Woolbrook and Wollun.
2. Scat surveys or spotlighting in the Apsley River corridor to Apsley Falls.
3. Continue to encourage the community to report koala sightings to NT LLS or ALA.

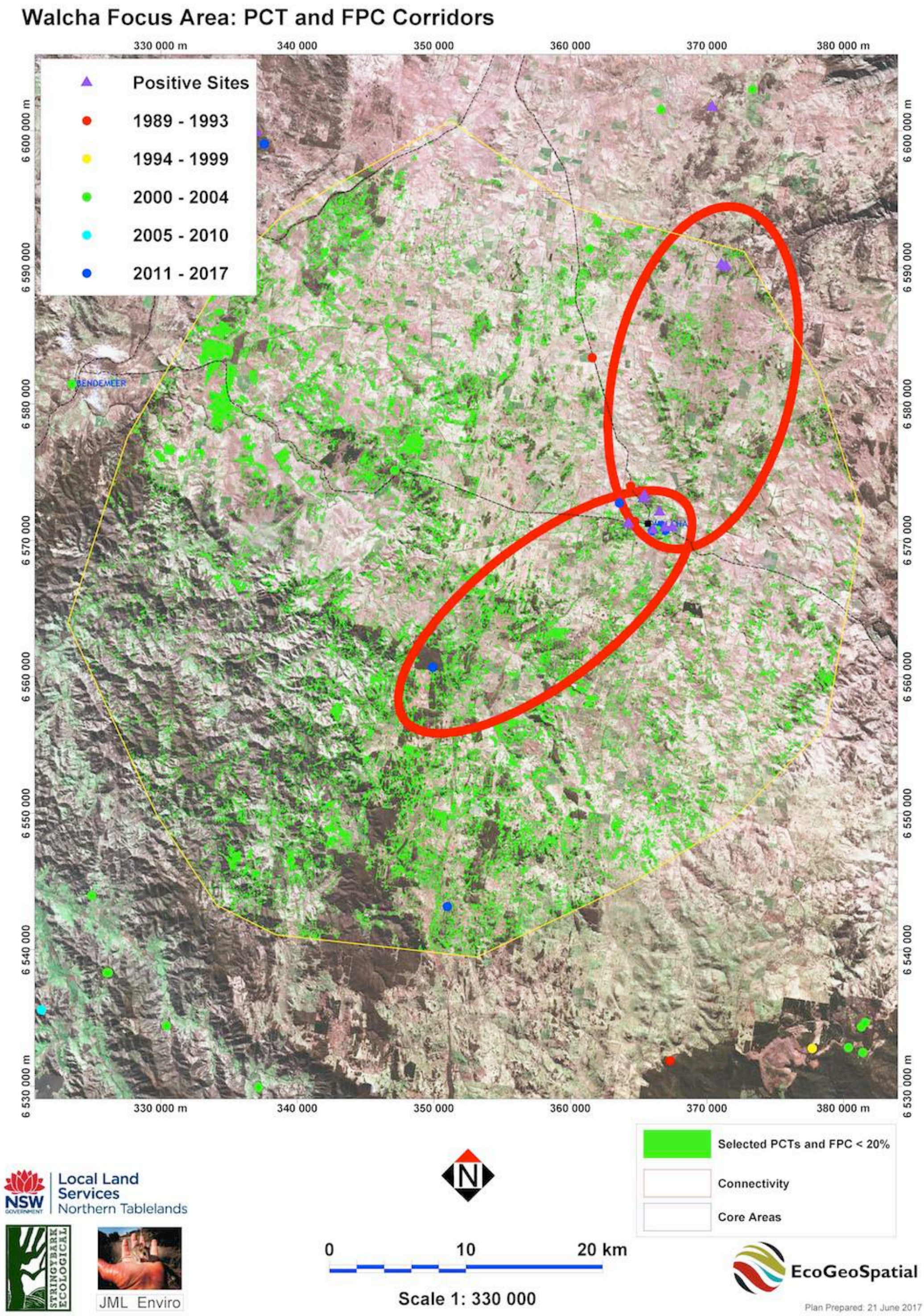


**Figure 35: Recommended areas for revegetation in the Walcha priority area (red ellipses). The light green shading is the intersection of the preferred PCTs and the <20% FPC layers.**

## Koala Management Plan - Nowendoc

The Nowendoc area is a significant regional location for koalas. In the valley of the Nowendoc River near the town of Nowendoc there are many koalas.

From the surveys, it appears that koalas in this area have a strong preference for the open Snow Gum Woodland on the lower valley slopes. There are many small to medium patches of this community in the valley but they are highly fragmented by open grazing land. We saw no evidence that koalas use the *E. microcorys* or *E. obliqua* forest on the mid to upper slopes. However, the method we used did not have enough plots to properly estimate koala numbers.

The main threats in this area are likely to be bushfires and local fragmentation. We saw no evidence of koalas killed on the Thunderbolts Way, but locals reported that they occasionally see dead koalas by the side of the road. Thunderbolts Way has seen a significant increase in traffic since it was sealed and upgraded and it runs right through the core koala habitat in the area. Given the importance of the koala population measures should be implemented to reduce road fatalities (possible signage and koala overpass bridges).

We believe that the area around Nowendoc and Riamukka is a core koala habitat for a large population (Fig 36). More intensive surveys in surrounding forests are required to get a better estimate of koala numbers. This should include spotlighting in selected locations.

Connectivity could be improved on a local scale by revegetating areas on the lower slope with *E. pauciflora* and *E. acaciiformis* to connect smaller patches (Fig 36), and connecting lower slope remnants to mid and upper slope forests..

In the Nowendoc area we recommend the following species be included in revegetation programs in order to assist koalas. These species should be matched to the appropriate ecosystems in the area.

- **Peppermints** –*E. radiata subsp sejuncta, E. acaciiformis*
- **Gums –** *E.pauciflora, E. stellulata, E. dalrympleana subsp heptantha.*
- **Boxes –** *E. melliodora.*
- **Other –** *Angophora floribunda, A. subvelutina.*
- *E. microcorys* and *E. obliqua* are common and widespread in the area and are recorded as koala food trees in other areas, but we saw no evidence of koalas using them in the Nowendoc area.

### Core population areas

- The Nowendoc River Valley around Nowendoc and Riamukka.

### Priority connectivity areas

- At a local scale, connectivity between remnants in the Nowendoc Valley could be improved.

**Further investigation required**

1. More detailed surveys, including spotlighting, in the mid to upper slope forests around the Nowendoc River Valley and in Nowendoc State Forest.
2. More intensive scat surveys in State Forests and National Parks at higher elevations north of Riamukka.
3. More intensive scat surveys between Niangala and Nundle, including Tuggolo State Forest (in cooperation with North West LLS).
4. Continue to encourage the community to report koala sightings to NT LLS or ALA.

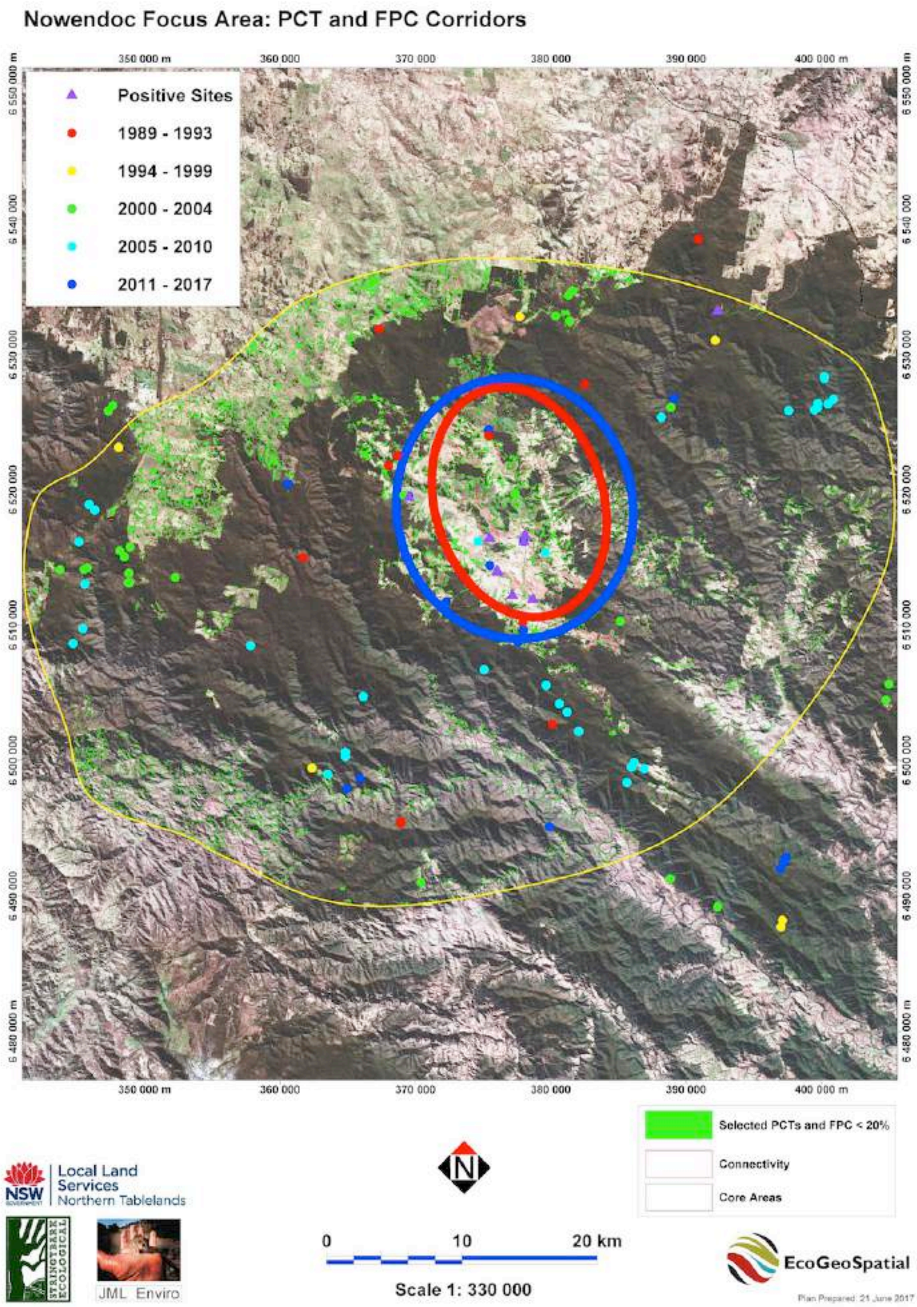


**Figure 36: Core population and recommended area for revegetation in the Nowendoc priority area. The blue circle indicates a core population and the red ellipse indicates an approximate boundary for a connectivity area. The light green shading is the intersection of the preferred PCTs and the <20% FPC layers.**

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## Appendix 1: GIS analysis for generating "Koala Habitat Envelopes"

1. Download and import NSW Koala records from the online BioNet site maintained by OEH. http://www.bionet.nsw.gov.au/
2. Clip koala records to Northern Tablelands LLS boundary.
3. Assemble relevant reference datasets following discussion with D Carr.
4. Approximately 50 reference datasets were reviewed in four broad themes:
    a. climate,
    b. soil and geology,
    c. vegetation,
    d. Topography/terrain.

Nominating study area boundaries was an iterative process and the original 14 nominated populations were reduced to 5 for final analysis and mapping. Factors considered were: the location of the population in the landscape in relation to current or future corridors; number of records; age of records; proximity to communities and landowners.

5. Transfer values from the reference data to the regional koala point locations. In some instances there are multiple records for a single site location. These were treated as a single site.
6. Export the point attributes data to excel and generate a pivot table. Where necessary, divide the continuous attribute data (i.e. FPC, slope, elevation ranges) into a series of bins or classes to allow analysis of the results.
7. Query the pivot table to generate simple histograms of the reference data occurrences as they relate to each nominated koala population study area.
8. Based on the histogram results, expert knowledge (DBC) and an interactive desktop GIS review and analysis (AW and DBC) we identified 4 datasets that cluster the current koala records within relatively restricted ranges. In this case Rock type, plant community type (PCT), slope and relief class, and foliar projective coverage (FPC) were identified as the most diagnostic with respect to existing records. The following table provides details.

| | Ashford | Delungra | Armidale | Walcha | Nowendoc |
|---|---|---|---|---|---|
| Geology [1] | Clastic sediment, felsic intrusive | Mafic extrusive | Clastic sediment, felsic intrusive | Mafic extrusive, Clastic sediment, felsic intrusive | Mafic extrusive, Clastic sediment |
| PCT [2] | 578, 594, 595, 596, 368, 516, 78, 84 | 84, 590, 599 | 510, 538, 565, 567 | 501, 565, 567, 568 | 526, 554, 608 |

| | | | | | |
|---|---|---|---|---|---|
| Slope Relief (3) | 22, 32, 33, 43 | 21, 22, 32, 33 | 32, 33, 44, 45 | 32, 33, 43, 44 | 43,44,54,55 |
| FPC (4) | 30 – 50% | All woody | 30-100% | All woody | 50-80% |

(5) 1:250,000 scale Surface Geology of NSW:c.2003 – Department of Industry
(6) BRGN v2 and LLS extension PCTs, OEH
(7) Terrain data from Soil and Landscape Grid of Australia (various agencies: inc. Geoscience Australia)
(8) FPC 5m SPOT-5 2008-2012, and also 5m woody/non-woody binary mask. OEH

Note however that the number of koala records was low in all cases (20 to 138) so it is likely that koalas occur in other areas not identified by our analysis. However we can only work with the available data, and this analysis is a repeatable and objective process for mapping the KHE for each of the nominated population study areas.

Once the attribute ranges were identified, subsets of the reference datasets were created for each study area and the data was combined to generate the overlap of the four individual subsets. There are vector datasets (points, lines, polygons) and raster data (images, surfaces, continuous data) that need to be combined.

9. For the Geology and PCT data, the selected values (subsets) within the study area(s) were copied into new vectors.
10. For the slope and relief class layer, this was converted to a vector, and then the relevant subset values were copied into a new vector.

The FPC data is a 5m raster containing much more detail than the slope relief class layer so it was impractical to convert the FPC data into a vector format. Instead the three vector layers were combined then converted into a raster for subsequent raster processing combinations.

11. Merge the three vectors using an AND operation: this generates a new vector where all the chosen attributes are valid.
12. EDIT the vector to remove polygons that are included within the AND result but that have attributes that are not wanted (i.e. if a small patch of one rock type is enclosed by another larger polygon of another rock type, this unwanted polygon is included in the AND result). These extras need to be deleted as they don't match the criteria nominated, or assigned a null/zero value.
13. Combine the vector attribute tables for each dataset (geology, slope/relief, PCT) into a single table. Edit the values for each attribute so they fit within the numerical range of 0-255 (8 bit dataset). This makes subsequent data handling more efficient.
14. Convert the vector into a raster. We do this in order to be able to mask the vector results using the FPC (raster) data ranges nominated. FPC data is very dense (5m pixel) so converting it into a vector is computationally intensive. Converting the combined AND vector to a raster is much quicker.

15. Convert the vector to three rasters, one for each attribute, and nominate the cell size of the rasters to be 5m x 5m. This ensures they can be combined with the 5m FPC data. The output type is 8-bit unsigned.
16. These 3 rasters need to be reprojected and resized to match the FPC dataset extents in order to be combined using raster algebraic combinations. Reproject the data selecting *match reference* for the extents, *nearest neighbour* for the resampling method (the only valid method for categorical data) then nominate the relevant FPC binary layer to match.
17. The FPC binary layer for each study area has been generated using the raster/classify/reassign cell values process. In this process the FPC values (0-255) are reassigned based on the koala envelope category for each study area. In the case of Nowendoc, the FPC range is 50-80%. This represents digital numbers 151 -180. These values are reassigned to 1, and the rest are set to null (or zero). This binary layer can then be combined with other raster data using raster combinations and arithmetic/indices processes.
18. The three rasters are then individually combined with the FPC binary data to generate three new product layers process. The operation selected is 'multiply' where 0 values = no output, 1 values= transfer the data).

These Product layers are the final Koala Habitat Envelope (KHE) extents for each of the three nominated reference datasets (Rock type, PCT, Slope and relief) within the nominated FPC range. In two cases (Delungra and Walcha) the FPC range was *not* identified as a relevant descriptor so this last step was modified to use the woody vegetation mask. This is already a binary mask for woody vegetation (i.e. all FPC values).

19. The individual rasters are exported as a 3-band tiff which can be displayed as an RGB raster. In this case the different classes are mapped as different colours. The individual layers can also be viewed in isolation. For instance the Rock type raster for Nowendoc will display the entire Koala habitat envelope in only 2 colours, one for mafic extrusive rocks (i.e. basalt) and one for clastic sediments. The PCT raster will have three colours, and the slope/relief raster will have 4 colours.
20. The individual (final) rasters are then converted into three individual vectors and merged into a single vector with a final attribute table. This result is exported as a shapefile.
21. Map production can occur using the rasters or the shapefile. In any GIS software (ArcGIS, QGIS, TNTGIS, MapInfo etc.) other reference datasets can be overlain to inform decision making and to further refine fieldwork priorities (community engagement, local landowners).

## Appendix 2: KHE Classification

Koala habitat envelope classes were defined using combinations of priority area, rock type, PCT and Slope position (Appendix 1). PCTs were weighted according to the number of recorded koala observations associated with them. Slope position was weighted towards lower slope sites. The 'Priority' column is the additive value of PCT and slope columns. The higher the value, the higher the priority in selecting sites for koala surveys.

| Priority Landscape | Code | Rock type | PCT | Slope Posn | PCT priority | Slope posn priority | Priority |
|---|---|---|---|---|---|---|---|
| **Armidale-Uralla** | AU1 | Clastic sediments | 565 | U | 2 | 0 | 2 |
| | AU2 | Clastic sediments | 565 | M | 2 | 2 | 4 |
| | AU3 | Clastic sediments | 565 | L | 2 | 4 | 6 |
| | AU4 | Clastic sediments | 567 | U | 0 | 0 | 0 |
| | AU5 | Clastic sediments | 567 | M | 0 | 2 | 2 |
| | AU6 | Clastic sediments | 567 | L | 0 | 4 | 4 |
| | AU7 | Clastic sediments | 538 | U | 0 | 0 | 0 |
| | AU8 | Clastic sediments | 538 | M | 0 | 2 | 2 |
| | AU9 | Clastic sediments | 538 | L | 0 | 4 | 4 |
| | AU10 | Clastic sediments | 510 | U | 0 | 0 | 0 |
| | AU11 | Clastic sediments | 510 | M | 0 | 2 | 2 |
| | AU12 | Clastic sediments | 510 | L | 0 | 4 | 4 |
| | AU13 | Felsic intrusive | 565 | U | 2 | 0 | 2 |
| | AU14 | Felsic intrusive | 565 | M | 2 | 2 | 4 |
| | AU15 | Felsic intrusive | 565 | L | 2 | 4 | 6 |
| | AU16 | Felsic intrusive | 567 | U | 0 | 0 | 0 |
| | AU17 | Felsic intrusive | 567 | M | 0 | 2 | 2 |
| | AU18 | Felsic intrusive | 567 | L | 0 | 4 | 4 |
| | AU19 | Felsic intrusive | 538 | U | 0 | 0 | 0 |
| | AU20 | Felsic intrusive | 538 | M | 0 | 2 | 2 |
| | AU21 | Felsic intrusive | 538 | L | 0 | 4 | 4 |
| | AU22 | Felsic intrusive | 510 | U | 0 | 0 | 0 |
| | AU23 | Felsic intrusive | 510 | M | 0 | 2 | 2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | AU24 | Felsic intrusive | 510 | L | 0 | 4 | 4 |
| | | | | | | | |
| **Walcha** | W1 | Clastic sediments | 501 | U | 0 | 0 | 0 |
| | W2 | Clastic sediments | 501 | M | 0 | 2 | 2 |
| | W3 | Clastic sediments | 501 | L | 0 | 4 | 4 |
| | W4 | Clastic sediments | 656 | U | 0 | 0 | 0 |
| | W5 | Clastic sediments | 656 | M | 0 | 2 | 2 |
| | W6 | Clastic sediments | 656 | L | 0 | 4 | 4 |
| | W7 | Clastic sediments | 567 | U | 0 | 0 | 0 |
| | W8 | Clastic sediments | 567 | M | 0 | 2 | 2 |
| | W9 | Clastic sediments | 567 | L | 0 | 4 | 4 |
| | W10 | Clastic sediments | 568 | U | 0 | 0 | 0 |
| | W11 | Clastic sediments | 568 | M | 0 | 2 | 2 |
| | W12 | Clastic sediments | 568 | L | 0 | 4 | 4 |
| | W13 | Felsic intrusive | 501 | U | 0 | 0 | 0 |
| | W14 | Felsic intrusive | 501 | M | 0 | 2 | 2 |
| | W15 | Felsic intrusive | 501 | L | 0 | 4 | 4 |
| | W16 | Felsic intrusive | 656 | U | 0 | 0 | 0 |
| | W17 | Felsic intrusive | 656 | M | 0 | 2 | 2 |
| | W18 | Felsic intrusive | 656 | L | 0 | 4 | 4 |
| | W19 | Felsic intrusive | 567 | U | 0 | 0 | 0 |
| | W20 | Felsic intrusive | 567 | M | 0 | 2 | 2 |
| | W21 | Felsic intrusive | 567 | L | 0 | 4 | 4 |
| | W22 | Felsic intrusive | 568 | U | 0 | 0 | 0 |
| | W23 | Felsic intrusive | 568 | M | 0 | 2 | 2 |
| | W24 | Felsic intrusive | 568 | L | 0 | 4 | 4 |
| | W25 | Mafic Extrusive | 501 | U | 0 | 0 | 0 |
| | W26 | Mafic Extrusive | 501 | M | 0 | 2 | 2 |
| | W27 | Mafic Extrusive | 501 | L | 0 | 4 | 4 |
| | W28 | Mafic Extrusive | 656 | U | 0 | 0 | 0 |
| | W29 | Mafic Extrusive | 656 | M | 0 | 2 | 2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | W30 | Mafic Extrusive | 656 | L | 0 | 4 | 4 |
| | W31 | Mafic Extrusive | 567 | U | 0 | 0 | 0 |
| | W32 | Mafic Extrusive | 567 | M | 0 | 2 | 2 |
| | W33 | Mafic Extrusive | 567 | L | 0 | 4 | 4 |
| | W34 | Mafic Extrusive | 568 | U | 0 | 0 | 0 |
| | W35 | Mafic Extrusive | 568 | M | 0 | 2 | 2 |
| | W36 | Mafic Extrusive | 568 | L | 0 | 4 | 4 |
| **Nowendoc** | N1 | Clastic sediments | 526 | U | 2 | 0 | 2 |
| | N2 | Clastic sediments | 526 | M | 2 | 2 | 4 |
| | N3 | Clastic sediments | 526 | L | 2 | 4 | 6 |
| | N4 | Clastic sediments | 608 | U | 0 | 0 | 0 |
| | N5 | Clastic sediments | 608 | M | 0 | 2 | 2 |
| | N6 | Clastic sediments | 608 | L | 0 | 4 | 4 |
| | N7 | Clastic sediments | 554 | U | 0 | 0 | 0 |
| | N8 | Clastic sediments | 554 | M | 0 | 2 | 2 |
| | N9 | Clastic sediments | 554 | L | 0 | 4 | 4 |
| | N10 | Mafic Extrusive | 526 | U | 2 | 0 | 2 |
| | N11 | Mafic Extrusive | 526 | M | 2 | 2 | 4 |
| | N12 | Mafic Extrusive | 526 | L | 2 | 4 | 6 |
| | N13 | Mafic Extrusive | 608 | U | 0 | 0 | 0 |
| | N14 | Mafic Extrusive | 608 | M | 0 | 2 | 2 |
| | N15 | Mafic Extrusive | 608 | L | 0 | 4 | 4 |
| | N16 | Mafic Extrusive | 554 | U | 0 | 0 | 0 |
| | N17 | Mafic Extrusive | 554 | M | 0 | 2 | 2 |
| | N18 | Mafic Extrusive | 554 | L | 0 | 4 | 4 |