Mapping landowner values and objectives in Walter Hill Range, Queensland: Optimising the management of rainforest connectivity

Thesis submitted by

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I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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Abstract

This thesis provides a novel method for optimising the management of rainforest connectivity in a diverse landscape, by combining social and ecological data. The project takes place in eastern Walter Hill Range – a habitat corridor within Queensland's Wet Tropics which is at risk of fragmentation. The project is in collaboration with natural resource management organisation Terrain Natural Resource Management (Terrain NRM). The overall purpose is to identify the values, objectives and capacity of private landowners within Walter Hill Range to maintain or improve rainforest connectivity - this information may assist Terrain NRM in developing future management schemes. To determine which properties may have the most potential for management, we rank each property in terms of its suitability for social criteria, and its ecological importance.

To identify landowner values and objectives, face-to-face surveys are conducted with landowners who own land within the Walter Hill Range study area. From the surveys, we determine three main groupings of management activities taking place – incidental management activities (retaining existing rainforest, weed management and pest management), revegetation and nature refuge agreements. Each landowner is ranked according to their management potential for each grouping. The ecological rankings are then determined by ranking each property in terms of its importance as habitat for the southern cassowary.

Properties are then mapped in ArcGIS according to their social rankings and ecological rankings. To determine target regions for connectivity management, a circular polygon is drawn around the top three most suitable properties for each management grouping, and the top three most ecologically important properties. The

socially suitable and ecologically important regions are then overlaid to determine areas of overlap. Overall, there is significant overlap between regions which are highly suitable for management and also ecologically important within the study area. This suggests that there is good potential for optimising rainforest connectivity management on the surveyed properties within Walter Hill Range.

Additionally, we identified two groups of landowners within Walter Hill Range – a group interested in incidental management activities; and a group interested in both incidental management and conservation-orientated activities (revegetation and creating nature refuges). The difference between the management objectives of these groups highlights the need for management which will support the needs of diverse private landowners.

Overall, it is recommended that future connectivity management be focused in the north of the study area, which was both ecologically important and socially suitable. This research may improve the economic feasibility and success of connectivity management for the diverse landscape in Walter Hill Range. However, future research will further our practical and theoretical knowledge on how social-ecological data can be combined to achieve practical outcomes for a range of management objectives.

Introduction

This project has both applied and theoretical objectives. The theoretical objective is to produce a novel methodology for joining spatially explicit social and ecological data by combining derived spatial data layers. The applied objective is to provide the collaborating organisation, Terrain Natural Resource Management (Terrain NRM), with information and recommendations for future planning and management schemes in East Walter Hill Range – a habitat corridor within Queensland's Wet Tropics World Heritage Area which is at risk of fragmentation. Terrain NRM manage Queensland's Wet Tropics, and are currently focusing on improving rainforest health and connectivity within East Walter Hill Range.

To address these objectives, I have structured my thesis as follows. First, the current knowledge, gaps and need for management which incorporates spatially-explicit social and ecological data is summarised. The methodology then describes how the data was collected, analysed, and combined in a final overlay. Summary statistics from the social surveys and the characteristics of the social, ecological and combined layers are then presented and discussed to highlight the implications for connectivity management: both practically within the study area, and theoretically for future management across diverse landscapes. Finally, a summary of the paper is presented, including the key management implications for Terrain NRM and recommendations for future research.

Ecological importance of landscape connectivity

As it pertains to ecology, connectivity is the degree to which a landscape facilitates or impedes movement (Taylor et al, 1993). Connectivity across landscapes is facilitated by the continuity of "resource patches"; areas in which a plant or animals' resources are located. When resources patches become fragmented, organisms cannot access resources which are necessary for survival. The loss of connectivity compromises biological diversity across landscapes, and therefore establishing and maintaining landscape connectivity is important for maintaining healthy ecological systems (Taylor et al, 1993).

The degree of connectivity in a landscape has significant implications for ecological processes: it facilitates gene flow between populations, movement of animals, migration, access to refugia, dispersal of offspring/propagules, and allows organisms to access a wide range of food and habitat resources (Bennett, 1999; Metcalfe & Lawson, 2015; Tucker, 2000). Because different species have different ecological requirements and different scales of movement, some are more sensitive to changes in landscape connectivity than others (Henle et al., 2004).

Species which can move large distances through the landscape are less sensitive to small scale fragmentation, as they can reach more distant habitat patches. For example, adult southern cassowaries *(Casuaurius casaurius johnsonii)* may travel distances of over 5km, and have an estimated home range size of approximately 2.13km (Wescott et al, 2007; Moore, 2007). This means that they can reach distant patches, if there are no barriers to their movement. However, cassowaries are highly susceptible to anthropogenic threats – particularly from cars when they are forced to cross roads, and dogs in rural-residential areas. Feeding of cassowaries by humans also encourages their presence in anthropogenic environments (Kofron & Chapman, 2006). These factors contribute significantly to cassowary mortality, and are prime examples of why it is important to maintain landscape connectivity despite increasing urbanisation from rural residences, agriculture and recreation (Bohnet & Smith, 2007; Kotru et al., 2014).

Critical threshold theory has been used to describe the effect which increased urbanisation has on landscape connectivity (With, 1991; With et al., 1997; Fahrig, 1998). Critical thresholds describe the abrupt change in a landscape from one of predominant continuity to one of significant fragmentation, i.e. the gradation from intact rainforest to an urban setting. The effects of critical thresholds on species loss are non-linear - with minimal fragmentation, species mortality is subtle. However as fragmentation increases towards the critical threshold, species loss can increase rapidly. Andren (1994) estimated that the critical threshold for some bird and mammal species across a range of habitats is between 10% and 30%; when only 10-30% of habitat remains, the resulting decrease in population size is greater than what would be expected from habitat loss alone. It is therefore important to maintain connectivity throughout the habitat of the cassowary (Monkkonen & Reuanen, 1999).

How is connectivity currently managed?

Maintaining landscape connectivity in natural environments is becoming more difficult as human use of natural landscapes increases (Laurence, 2014; Bohnet & Smith, 2007). Currently, there is no general overarching principle to guide connectivity management. There is a need for practical management which is based on meta-analysis as opposed to species or case-specific approaches (Lindenmeyer et al, 2008). To develop sustainable connectivity management schemes, both social and ecological data must be combined.

From an ecological perspective, researchers have identified some major themes which should be considered when managing connectivity. (Lindenmeyer et al, 2008). These include recognising the importance of landscape mosaics and the relationship between vegetation cover vs. configuration, as well as how these change over different landscape scales. Lindenmeyer et al (2008) developed a conceptual model which seeks to quantify the relationships between six major themes in landscape management. However, management cannot focus solely on ecological factors for a number of reasons - purely ecological knowledge does not often transfer to management actions, it is impossible to study all species and landscapes in detail, and finally, human use of natural landscapes is increasing, which means there is an increasing need to include social dimensions in management (Lindenmeyer et al, 2008). In recent years, managing natural landscapes has often involved managing the users of those landscapes (Stork et al., 2014). Consequently, government ownership and legislature have been employed in management.

In Australia, governments typically manage connectivity via legislature (Worboys & Pulsford, 2011). National parks and protected areas manage natural features which have outstanding conservation value - but the areas in between these provide important corridors between habitats, and these also require protection. The Queensland vegetation management prevents the unnecessary clearing of areas of important vegetation which are not included in national parks and reserve networks; however there are exemptions in the act for some types of development (Queensland Government, 2016). Additionally, landowners are able to apply to the government to obtain clearing permits for their property (Department of Environment and Resource Management, 2011). However, there is often a disconnect between those who manage the land daily and those who manage is from a legislative perspective – this makes the work of natural resource management (NRM) organisations such as Terrain NRM critical.

For privately owned areas of land in particular, NRM organisations provide information, labour, materials and financial support to landowners and community groups to encourage good land management practices (Terrain NRM, 2016). Supporting landowners is critical, because not all landowners have the information and/or resources to act – despite having good intentions. Additionally, the good will that comes from supporting landowners is a motivation for them to continue using good management practices (Cocklin et al., 2007). NRM organisations can also help manage properties to achieve landowners' objectives, whilst still contributing to ecological connectivity.

To maintain connectivity, managers require information on both social factors (such as values and objectives) and ecological factors which affect landscapes (Lindenmeyer et al, 2008). This will ensure management is ecologically valuable, socially feasible and sustainable. Whilst this information is attainable, there is a lack of theoretical and applied knowledge on how it can be incorporated into methodologies and applied for management (Lindenmeyer et al, 2008).

What are the challenges of maintaining connectivity?

There are multiple factors which challenge the maintenance of connectivity across landscapes – many of these stem from human habitation. Firstly, studies which consider the management of landscape connectivity either focus on the social or ecological factors, rather than both; secondly, ecologically important land often competes with agriculturally important land, and finally, an increasing population size means that humans require more land to survive. In landscapes with diverse land uses, it is critical that ecological and social factors are considered equally so that management is effective and sustainable.

Maintaining landscape connectivity is becoming increasingly challenging in a time where human use of the landscape is increasing at an alarming rate (Laurence, 2014). The human population is increasing exponentially, and so is the demand for land, be it for agricultural, residential, cultural or recreational uses (Heimlich & Anderson, 2001; Kotru et al., 2014). Additionally, interest in rural areas is increasing as landowners seek to expand away from busy urban centres (Bohnet & Smith, 2007). This has negative implications for connectivity – urbanisation splits land into smaller parcels, clearing begins, and road networks fragment vegetation into increasingly disjointed blocks.

Additionally, increased land use may increase the overlap between ecologically important and agriculturally important land. These land uses have a relationship which is somewhat competitive, and one often excludes the other (Bohnet & Pert, 2010). For example in tropical Australia, agricultural development favours flat, highly fertile land; yet this land also is also ecologically important for threatened lowland rainforests (Metcalf & Lawson, 2015). As more land is cleared for agriculture, the incidence of these remnant lowland rainforest pockets decreases.

Another major challenge for managing rainforest connectivity is a lack of practical knowledge on how to combine social and ecological data for management across diverse landscapes (Lindenmeyer et al., 2008). Social science and ecology have developed as separate disciplines, and thus combining them is difficult (Norgaard, 2008). Despite the significant and increasing threats to landscape connectivity, it is hoped that recent advances in the knowledge and application of social and ecological data for management will provide more comprehensive solutions for managing connectivity in diverse landscapes.

What types of information may be useful for improving connectivity management?

Successful connectivity management requires both social and ecological data. For example, analysing ecological landscape attributes from a social perspective can build relationships with stakeholders, assist with social learning and deconstruct complex agro-ecological issues (Toderi, 2007; Bohnet & Smith, 2007). To achieve comprehensive management, there is a need to collect information which will reflect the range of social values across a landscape (Endter – Wada, 1998). For private landowners, this information may include values associated with the landscape, objectives for management, current land management practices, how long the land will be managed/owned by the current owner, current and future land uses and tenure (Brown, 2005; Emtage & Herbohn, 2012b).

Additionally, determining the ecological attributes of an area can ensure that management is both practical and relevant, and can help to identify key management areas. Ecological variables which may be important for connectivity management are species ecology and presence, vegetation type, elevation, and the value of individual land parcels to overall connectivity (Beier & Noss, 1998; Lin, 2008). The ecological variables used in management dependent on the management objectives.

How could connectivity management be co-ordinated across landscapes with multiple stakeholders/land uses?

In recent years, there have been a number of studies which seek to combine social and ecological data to manage connectivity in diverse landscapes. Diverse social values can be difficult to reflect in management schemes, and thus complex socio-ecological problems are often simplified for practicality. This means that connectivity management may not actually achieve the intended objectives across diverse landscapes. Spatially quantifying the diversity of landowners across landscapes can ensure that connectivity management is suitable for the needs of stakeholders.

Geographic information systems (GIS), such as ArcGIS, are mapping programs used for compiling, mapping and analysing geographic information (ESRI, 2004). ArcGIS provides users with opportunities to manage diverse landscapes because it allows social data, as well as multiple types of ecological information, to be mapped in a qualitative spatial context. Spatially explicit social science data has been used to plan new conservation areas, to manage tourism and recreation, and finally to review protected area management (Jacobs et al., 2015; Brown, 2005; Stork et al, 2014; Molina, Silva & Herrera, 2016).

Brown (2005) developed a framework for incorporating social values and spatial measures into planning - this was then used to review protected area management in Alaska. Brown developed the framework after undertaking five separate surveys of the Alaskan public. He aimed to better integrate human perceptions with biophysical landscape information by developing a "typology" - a set of variables used to represent social landscape values - and then interviewing the public to spatially locate these values on maps of the study area. "Hotspot" analyses were then used to identify socially valuable areas and gap analyses were used to locate areas which are currently not included in protected areas but which perhaps should be. Finally, he conducted suitability spatial analyses to determine whether the identified areas were suitable for inclusion in protected areas. This work bridged the gap between the ecology of ecosystems and their management by recognising people as part of the ecosystem (Brown, 2005).

Additionally Brown (2005) found that spatially identifying social values and determining the motivation for these was useful in land use planning, which requires knowledge of human values to ensure there is agreement between users. Each of Brown's (2005) surveys used a typology consisting of numerous landscape values, which respondents could use to describe an area. He also allowed respondents to identify "special places" to provide a more open-ended measure of attachment.

Spatially representing this information was useful for managers in reviewing the terrestrial and marine management plans for protected areas in Alaska (Brown, 2005). It allowed them to identify the most ecologically & socially suitable areas for protection based upon multiple criteria.

Additionally, Brown provided an example of how overlaying single criteria data layers allowed social and ecological data to be displayed on single maps. By overlaying "socially defined landscape features" such as ownership boundaries or management areas with biophysical features, he ensured that areas identified as "important" satisfied a number of critical criteria. A system to rank "potential" protected areas with spatially-explicit social landscape values was derived from this methodology, and used to develop a forest management plan which was ecologically suitable and more consistent with public values (Brown, 2005). Brown's (2005) methodology could be useful in the management of rainforest connectivity, particularly to identify if there is consistency between areas which are protected and which provide critical connectivity, and those which are deemed important for connectivity but perhaps are not recognised in management plans.

Similar to Brown (2005), Emtage & Herbohn (2012) created a "typology" of landowners based upon their attitudes to environmental health and their adoption of current best practice management. The typology included concerned but unengaged, multiple objectives, production orientated, disconnected and conservative, and well-connected and progressive. This approach is known as "prime prospects analysis", and is often used in social marketing to identify target groups (Emtage & Herbohn, 2012). Each group requires different management strategies to adopt best-practice management on their property, and so developing profiles of each is important for managers/regulators.

Spatially explicit social data could also be used to quantify the value of protected areas and identify priority conservation areas in diverse landscapes (Molina et al., 2016). Molina et al. (2016) developed a tool which incorporated economic, social and ecological factors relevant to environmental management. This was based on human valuation and the Contingent Valuation Method (CVM) – a method of estimating the economic value of environmental services. The tool was used to measure the value of protected areas and the increasing human demand on forests in the Mediterranean Basin. The study identified priority areas for management and conservation, as well as areas where conflict could arise, and then provided alternative planning solutions.

This method could be used to manage connectivity across landscapes and determine priority conservation areas in diverse agricultural regions. Specifically it could help to identify priority properties for management and those which may be less suitable based upon the ecological importance, social values and economic viability. Used in this way, tools such as the CVM could allow managers to optimise the allocation of resources for managing connectivity (Molina et al., 2016).

What are the landscape characteristics and challenges for connectivity management in the Wet Tropics World Heritage Area – particularly Walter Hill Range?

The Wet Tropics World Heritage Area - and particularly Walter Hill Range - has some landscape characteristics which make managing connectivity difficult. Firstly, most of the land within Walter Hill Range is privately owned – and this can make it difficult to quantify the variability in the landscape without fine-scale data collection techniques. Secondly, the Walter Hill Range could become more fragmented – there have been investigations for a potential highway upgrade which would widen the dissection between the eastern and western extents of the range (T. O'Malley, personal communication, 2016). Finally, some land within the Walter Hill Range, and more broadly the Wet Tropics, is highly valuable for agriculture. This can sometimes result in conflict between ecological and agricultural objectives.

The land surrounding Walter Hill Range is relatively low-lying, topographically consistent and consists of alluvial soils – it is therefore important for agriculture (Metcalf & Lawson, 2015; Terrain NRM, 2012). However, it is also highly important from an ecological perspective – it contains complex and species diverse lowland rainforests, and is especially important as habitat for the endangered southern cassowary (Metcalf & Lawson, 2015; Moore, 2007). It is therefore important to maintain connectivity between low-lying rainforest patches, especially in Queensland's Wet Tropics where low land rainforest is threatened (Metcalf & Lawson, 2015). Walter Hill Range itself contributes significantly to the surrounding landscape. Following rainfall events, it distributes water to low land water points which are important for wildlife.

Another factor affecting connectivity management within Walter Hill Range is the potential construction of a highway upgrade which would create an additional two over-taking lanes through Smith's Gap (T. O'Malley, personal communication, 2016). This would not only exacerbate fragmentation, but would increase the speed of road users and my increase wildlife fatalities (Goosem, 2004). Management must therefore consider how connectivity could be maintained despite development – for example, the use of under or over road tunnels, wildlife swings, or creating bridges to preserve creek connectivity between the eastern and western extents of the range (Goosem, 2004).

Finally, one of the most challenging aspects of connectivity management within Walter Hill Range is the fact that land is predominantly privately owned. This means that land management typically falls upon the landowner, and for this reason, it is particularly important to understand the social values and objectives which landowners have for the management of their land. Private ownership means that there are also likely to be a variety of competing land uses. Stork et al. (2014) stated that in Australia's Wet Tropics, environmental management can no longer be considered a tenure-based process - with tenures having only a single use –instead, it must consider multiple uses across multiple tenures at a landscape scale. Ecological and social factors naturally become paramount to the successful management of such landscapes; given that environmental variation is a certainty and the diverse values attached to such multifunctional landscapes are also likely to vary. Stork et al. (2014) also explained that there is a new era of "multifunctionality" emerging in response to the need for management of concurrent multiple values (Stork et al., 2014). There is therefore a need for comprehensive and thorough management which will consider not only the ecological functionality, but also the social feasibility of management in diverse rural locations in order to maintain the integrity of rainforest connectivity.

Aims

The purpose of this project was to identify the values, objectives and capacity of landowners within Walter Hill Range to maintain or improve rainforest connectivity. This information will assist Terrain NRM in developing future management schemes. Broadly, the project aimed to gain an understanding of the diversity of land users, their attitude to natural resource management and relative contribution to the connectivity of rainforest within Walter Hill Range. To achieve this, three specific aims were addressed:

1. To identify land-use values and objectives, socioeconomic data, and participation and interest in management activities from land users.
2. To determine the suitability of individual properties for management through ranking schemes of social and ecological data.
3. To identify priority areas for management by combining the social and ecological data in GIS.

Methodology

To identify landowner values and objectives, 21 face-to-face surveys were conducted with landowners who own land within the Walter Hill Range study area. All potential landowners were invited to participate via phone call. Surveys contained a range of questions, covering landowner values, current and future management objectives, interest in management activities and perceived importance, as well as wildlife, with a particular focus on cassowary movement and distribution. This information was used to allocate social and ecological rankings for each property. These were mapped in GIS, and combined to locate the most suitable properties for management overall. The most ecologically important and socially suitable properties were selected from the study area, and these areas could be targeted by Terrain NRM for management in the future.

The study area: Eastern Walter Hill Range, QLD Wet Tropics

The study area for my project, Walter Hill Range, is situated within the extent of Queensland's Wet Tropics World Heritage Area (figure 1). The Wet Tropics World Heritage Area is located on the state's north-east coast, and stretches 450km from north of Townsville to south of Cooktown (Department of Environment and Heritage Protection, 2016; UNESCO, 2016). The Wet Tropics covers 894, 420ha, most of which is comprised of tropical rainforest (Mackney et al, 1989). Queensland's Wet

Tropics WHA is known for its intrinsic natural beauty, rugged topography, mountains, creeks and waterfalls. It also contains the only locations in Australia where the rainforest meets the Great Barrier Reef - this type of coastline is rarely seen anywhere else in the world. The Wet Tropics' cultural values, along with its role as habitat for numerous rare plants and animals, evolutionary significance and high biodiversity of both flora and fauna necessitate the need for its protection (Department of Environment and Heritage Protection, 2016; UNESCO, 2016).

Walter Hill Range is located to the west of Mission Beach, approximately halfway along the wet tropics coastline. It is part of the longest and widest east-west highlands-lowlands rainforest corridor in Australia, which extends west to the southern Atherton tablelands (figure 1). I focused explicitly on east Walter Hill Range, which is bordered by World Heritage with Djiru and Mt Mackay National Parks on the eastern side and Japoon and Tully Gorge National Parks to the west (figure 2). East Walter Hill Range has been identified by Terrain NRM as a "bottleneck"; it is the thinnest section of rainforest within the Walter Hill corridor. Further, this area is not part of the World Heritage area itself, which means that management provided by stakeholders and natural resource management groups is paramount to maintaining its natural integrity.

The study area encompasses the localities of Smith's Gap, the eastern extent of East Feluga, Djarawong, Friday Pocket, Maadi and Granadilla (figure 2). In total it is 4296.27ha in size and contains a diverse range of land uses; predominantly consisting of conservation/natural areas, productive areas (fruits, horticulture, cropping, sugar and grazing), intensive use area (residences, services or waste disposal/treatment) and a dam/reservoir area (figure 3). The protected areas within Walter Hill Range include the Warrabullen and Walter Hill conservation parks;

however there are significant areas of natural vegetation, most notably the area adjacent to Djiru national park, which contains Granadilla Ridge and Maccabe's Gap (figure 3).

Most vegetated areas within Walter Hill range exist above the 80m contour, which is largely a product of slope and unsuitability for production or development purposes in these areas. Lowland areas have greater amounts of clearing as they provide prime land for production and agriculture (Metcalf & Lawson, 2015). Additionally, the low-lying passage through Smith's Gap provides a route for the Bruce Highway, which dissects the rainforest on either side. This is the site of a potential highway upgrade, which could add two overtaking lanes through this section. Clearings on properties adjacent to the highway also contribute to the lack of connectivity in Smith's Gap. The Smith's Gap area will therefore form a focus area for this project, as maintaining the connectivity between the Eastern lowland rainforests and their upland counterparts to the west are important for the movement of species.

The diverse nature of the private land uses and users within Walter Hill Range means that active management is required to maintain the natural and social values in the area. Further, land management typically falls upon the landowner; thus, understanding landowners' values and objectives for management is critical for determining how the management of rainforest connectivity can be optimised.

Walter Hill Range is important both socially and ecologically. From a social perspective, it provides people with homes, areas for production, agriculture and recreation, it provides significant scenic amenity and is highly important for culture and heritage. There are 26 Aboriginal tribal groups which live in and around the Wet Tropics, including the Djiru people who are traditional owners of the Walter Hill

Ranges. Aboriginal people have inhabited the area since ancient times (WTMA, 2004). Rainforest plants and animals, especially the Southern Cassowary, play important roles in Aboriginal culture, customs and values. Effective management is therefore critical for maintaining these connections between people and country.

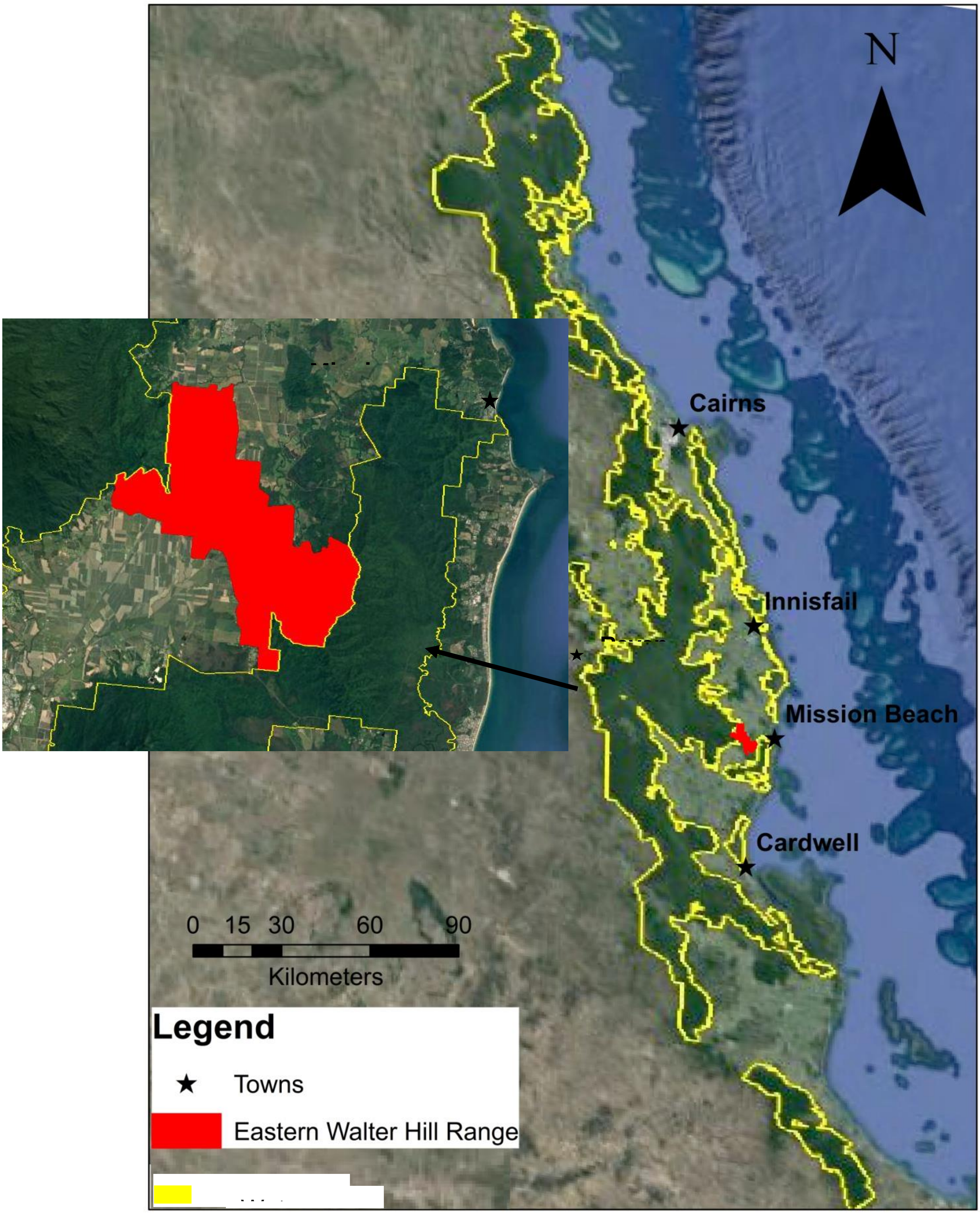


Figure 1: Location of eastern Walter Hill Range in relation to Queensland's Wet Tropics World Heritage Area

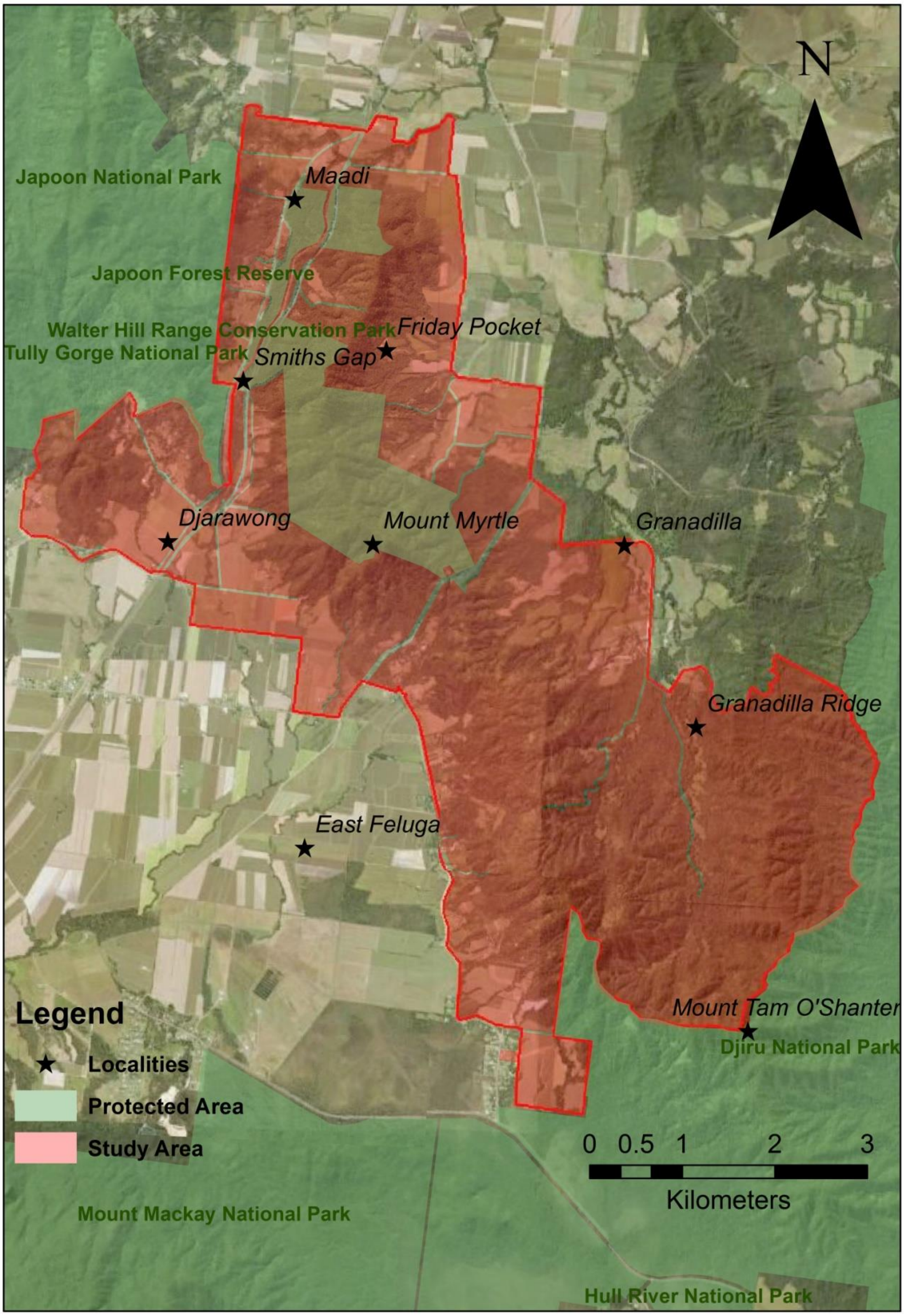


Figure 2: Map of the study area, showing protected areas and localities. The extent of vegetation can be seen underneath the respective layers.

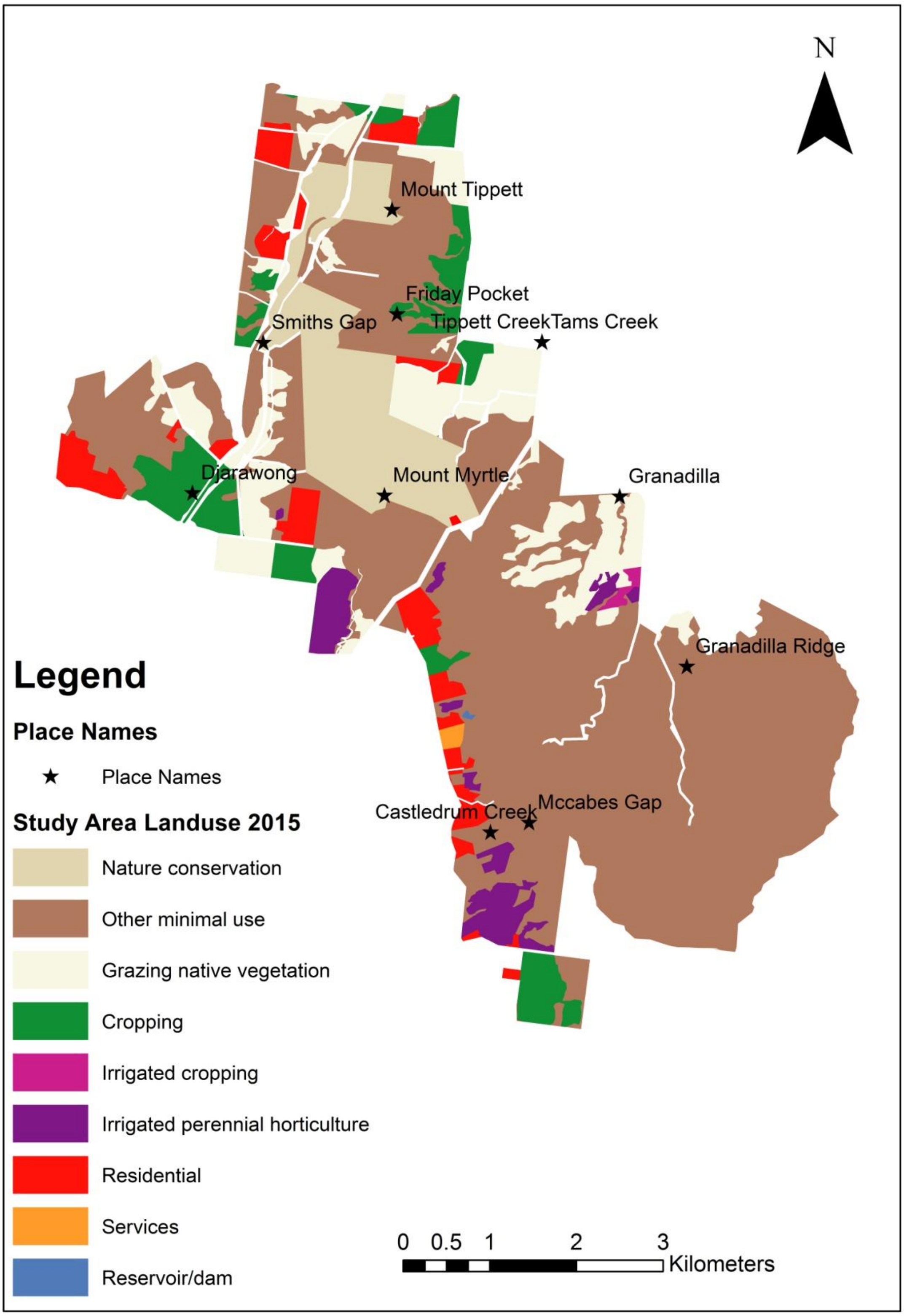


Figure 3: Spread of land uses within the study area. Note the large areas of "minimal use" around Granadilla Ridge and Mccabes Gap

Land within Walter Hill Range is also important for residential living. The majority of the blocks of land within the study area are classed as rural residential lots, and as the demand for rural living increases, people are increasingly seeking large blocks in undeveloped areas. The lowland areas surrounding Walter Hill range are agriculturally important, with approximately 1427.96ha of the study area being class A agricultural land: crop land suitable for a wide range of potential crops (Department of Agriculture, Forestry and Fisheries, 2016). The study area is also situated in the wettest region in Australia, with approximately 3200-3600mm of rain falling on the Walter Hill range annually (Terrain NRM, 2007). This makes it an ideal location for both crops and grazing.

The extent of the range, from Mission Beach to Ravenshoe in the southern Atherton Tablelands, also makes it a potential major corridor for species moving in response to changes in climate and resources. The entire Mission Beach area, including Walter Hill Range, contains important habitat for the Southern Cassowary (*Casaurius casaurius johnsonii*), and houses the largest known population in Queensland (Bradford et al., 2008). The corridor itself provides approximately 3075.10ha of cassowary habitat, and the creeks which flow down from the range act as fine-scale corridors which allow cassowaries to move through the rainforest (Department of Environmental and Heritage Protection, 2014).

There are a number of factors which affect connectivity within Walter Hill Range. Some of these include weeds, pests such as wild pigs, and the potential for future clearing. These factors contribute to patchiness in the landscape to varying degrees; however their effects can be reduced by employing strategic management. Because there are likely to be a wide variety of views, beliefs and practices for management; strategically it would be ideal to focus on privately owned properties where natural resource management is ecologically beneficial, where landowners are interested in doing management, and where the management may also benefit the overall landscape. Smith's Gap is a critical area of the corridor which has become increasingly populated with private residences. Additionally, it is an area in which management would be both ecologically beneficial and benefit the wider corridor by providing a movement pathway for the endangered southern cassowary. It will therefore be a focus location for this project.

Data collection methods

Designing and trialling the survey

We conducted face-to-face interviews to identify landowner values and objectives within Walter Hill Range. Face-to-face interviews have many benefits, particularly an increased level of respondent –interviewer engagement, a decreased level of uncertainty with respondent answers, and they create an atmosphere which is conducive to discussion (Queensland Government Statisticians' Office, 2015).

A map of the study area on Google maps was used to gain an understanding of the landscape and how the study area itself fits in with its surrounds. The QLD Globe dataset was also used to explore properties and tenures. We then consulted Terrain NRM to identify information to collect during interviews which may assist them with future planning and management in the area, and also discussed the types of questions which the study should address from a scientific perspective. Specifically, we addressed issues such as how to compromise between the scientific requirements of the study, the need for practicality and the need for information to support real management needs. Several series of draft questions were circulated between Terrain NRM and my supervisors, before a final copy was established (appendix 1).

After the survey was finalised, we contacted Terrain to arrange trial surveys with local landowners just outside the study area, who might have a range of opinions and provide feedback. Four trial interviews were organised. The project supervisor and the collaborating partner from Terrain were present to provide feedback on the trial interviews and the aptness of the survey. Aspects considered during the trial surveys were survey length, flow, mutual understanding of the questions and interview style.

After the trial interviews, the survey was edited to ensure it maintained flow, was relevant, was understandable for respondents, and was encouraging the types of responses we had envisaged. A final copy of the survey was then written up and circulated between the project supervisor and the collaborating partner at Terrain.

Characteristics of the finalised survey

The final survey was approximately 1-hr long and contained 63 questions, as well as a range of questions types: open ended, categorical, ordinal scaled response and participatory mapping (table 1). A range of question types were used to gain a thorough understanding of respondents' values, attitudes and beliefs; and also to collect information with differing levels of complexity for use in different analysis applications. Questions addressed general attitudes and perceived importance of the Walter Hill Range, demographics, cassowaries/wildlife, current/future land use, and current/future participation in activities which may be beneficial to rainforest within the corridor.

Table 1: Key variables included in the survey and their scale of measurement

Variable	***Scale***
Landowner roles and responsibilities to NRM	Coded response
Current/future land use	Coded response
Important natural features	Coded response, spatial

Importance of Walter Hill Range and property	Ordinal scale
Previous engagement in management activity	Coded response, spatial
Success of previous management activity	Ordinal scale
Interest in future management activity	Ordinal scale, spatial
Information sources, barriers, incentives/support, reasons for interest	Coded response
Participation/interest in other activities	Coded response, spatial
Main land use	Categorical
Time period which land has been managed, owned, owned in family	Coded response
Planned future ownership	Closed
Occupation	Coded response
Land contribution to income	Ordinal-scale
Wildlife Presence	Coded response
Cassowary sightings	Coded response, spatial
Cassowary population fluctuations	Closed

Sampling scheme

I aimed to sample as many landowners as possible, with the sample stratified for the Smith's Gap area. Lot plan, ID number, size and address information was collected for all properties within the study area using Google Earth, and recorded in an excel database. Overall, there were 174 properties and 138 landowners – some landowners owned multiple properties. 46 properties were located in Smith's Gap. Landowner information and phone numbers were then collected using the publicly-available property search program PDS Live. Phone numbers were found for 79 landowners, and 20 of these were for landowners within Smith's Gap. The number of phone numbers available did limit the sample size both overall and within Smith's gap, and so I elected to call all available numbers.

All phone numbers were called until every landowner had been spoken to, or a maximum of 6 unanswered calls was reached. A standardised script was used to explain the project and invite landowners to participate in the survey. For each uninterested landowner, a note was made of why they weren't interested. For those who were interested, a face-to-face interview was planned and a survey information sheet and project flyer was e-mailed to them.

Conducting the survey

2 Two separate trips to the study location were organised to undertake interviews – the first from the 14th June – 1st July, and the second from the 4th-8th August to meet with interested respondents who could not make the previous interview period. In total, the time spent in the field conducting interviews with landowners was 23 days. Almost all interviews took place at the landowners' property. Interviews were also recorded on agreement by the respondent. Generally, interviews were completed within an hour –the shortest was 31 minutes, while the longest was an hour and 50 minutes.

Characteristics of the total and sample populations

Overall, 21 landowners and 36 properties were sampled. The sampled properties were quite evenly spread – from Friday Pocket, East Feluga, Granadilla, Djarawong, Maadi and Smith's Gap. A multi-distance spatial cluster analysis (Ripley's K function) performed in GIS confirmed this – the spread of the sampled properties remained almost entirely within the calculated confidence envelopes, indicating that overall, the spread was not significantly dispersed or clustered. However, at very small distances (<50m), there was some dispersal, and at very large distances (≈2450m) there was some clustering (figure 4). Of the 79 potential respondents, 21 participated in interviews, 28 said they were not interested, and all others did not answer the phone, did not attend arranged interviews or had disconnected/wrong numbers. This means approximately 27% of the target population was sampled. The characteristics of the sample and total populations did have some variation; however there were also a number of similarities (table 2).

Firstly, the sizes of properties in the sample and total population differed. The minimum property area sampled was comparatively larger than the minimum property area in the total study area. Similarly, the largest property sampled was less than half the size of the largest property within the study area. T-tests also revealed that the non-sampled properties were significantly larger than those that were sampled. Chi-square tests revealed that there were no significant differences in the number of properties which had more than 50% of land cleared, or which were lower than 80m in elevation. However, t-tests showed that non-sampled properties had significantly more remnant vegetation. The most common land use (by area) was conservation/natural environments for both the sample and total population (figure 2).

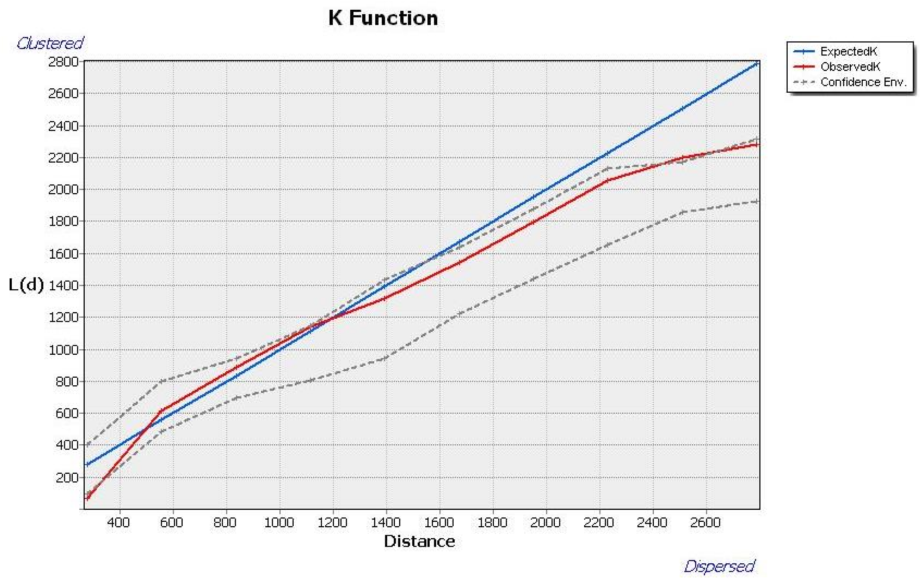


Figure 4: A multi-distance spatial cluster analysis based on Ripley's K function.

Table 2: Comparison of total and sample populations		
Variable	***Total Population***	***Sample Population***
Total number of landowners	138	21 (15%)
Number of landowners with phone numbers	79	21 (27%)
Total number of properties	174	36 (20%)
Number of properties with phone numbers	91	36 (40%)
Minimum property area	1350m2	2015m2
Maximum property area	1,944,715m2	676,502m2
Mean property area[1]	M = 206769.605 SD = 324458.688	M = 111955.165304 SD = 137512.805
Mode land use type	Conservation/natural environments	Conservation/natural environments
Number of properties with >50% land cleared	49 (35%) Clear = 49 Veg = 125	9 (43%) Clear = 9 Veg = 27
Number of properties with elevation <80m	109 =low 65=high	20 =low 16=high
Remnant Veg (ha)[2]	24389951m2 M = 150555m2	2780051m2 M = 64652m2

Data analysis methods

Inputting the data

The first step in analysing the data was to listen to the recorded interviews, read the survey response sheets and verify the respondents' answers to ensure there was no ambiguity in interpretation. The raw data from the verified survey response sheets was then manually entered into a "Raw Data" Microsoft excel file.

The open-ended questions were then coded into general themes emerging from the raw data. For example, the question "why are you interested in retaining existing

[1] N=155; t= 2.9608; $p < 0.05$

[2] N=261; t = 2.9265; $p < 0.05$

rainforest" resulted in responses such as; "to look after wildlife", "so cassowaries have food", and "for wildlife habitat." The emerging theme in this instance could be simplified as "wildlife", and particularly "protecting wildlife". Thus, each of these responses would be re-classified as "protect wildlife."

Exploring the data

The next step in the analysis was to explore the data using summary statistics and correlations. Due to the relatively small sample size, bar charts were applied in Microsoft excel to explore frequencies and key trends in the data. Spearman's rank correlations were also used to assess the strength and nature of relationships between some of the quantitative variables. These results will be presented in the following results chapter.

Ranking the properties

To determine which properties have the most potential for management, each property was ranked in terms of its suitability for social criteria, and its ecological importance.

Social criteria

In order to conduct the social ranking, I focused on landowner participation and interest in management activities, total property area, size of management areas and amount of vegetation within management areas. These variables were then combined to calculate an overall "management potential" value for each property, for each of the five management activities – weed management, pest management, retaining existing rainforest, conducting revegetation and creating a nature refuge. A description of individual variables and the formulas used to calculate potential values are presented in table 3.

"Management potential" was considered a more effective means of determining management suitability than landowner interest alone - it provides a measure of how much a landowner is willing to do in relation to how much has already been achieved, factoring in the size of the property. It provides a relative measure of the potential contribution of their property to rainforest connectivity.

Table 3: Calculations for potential values			
Parameter	***Scale***	***Definition***	***How was it calculated?***
Potential - weed management	Ordinal	Potential for landowners to conduct weed management which is beneficial for rainforest	***weighted potential = (interest * future accomplishment) * weighting factor*** WHERE: *Interest* = level of landowner interest in weed management *Future Accomplishment* = Total area of intended weed management – area of weed management already accomplished *Weighting factor* = area of intended weed management within vegetated areas
Potential - revegetation	Ordinal	Potential for landowners to conduct revegetation	***weighted potential = (interest * future accomplishment) * weighting factor*** WHERE: *Interest* = level of landowner interest in revegetation *Future Accomplishment* = Total area of intended revegetation – area of revegetation already accomplished *Weighting factor* = area of intended revegetation
Potential - nature refuge	Ordinal	Potential for landowners to create a viable nature refuge	***weighted potential = interest * area landowners would create nature refuge on***

Potential - retaining rainforest	Ordinal	Potential for landowners to retain existing rainforest	***weighted potential = interest * area of existing rainforest which landowners want to retain***
Potential - pest management	Ordinal	Potential for landowners to conduct high-quality pest management	***weighted potential = (interest * future accomplishment) *weighted factor*** WHERE: *Interest* = level of landowner interest in pest management *Future Accomplishment* = Total area of intended pest management – area of pest management already accomplished *Weighting factor* = area of intended pest management within vegetated areas

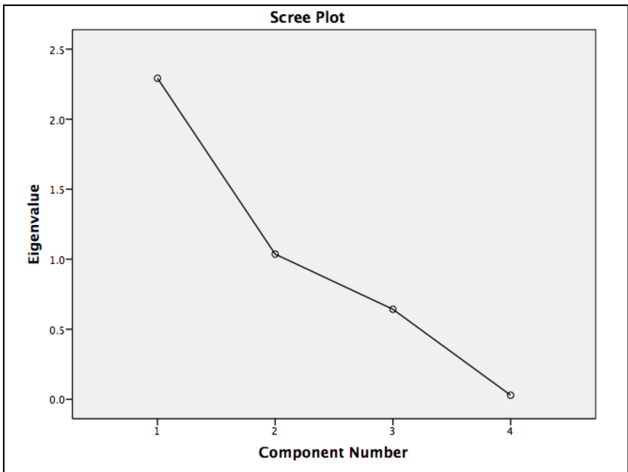
A Principal Component Analysis (PCA) with Varimax and a Kaiser Normalisation was conducted using SPSS software to explore the relationship among the potential values for four management activities: weed management, pest management, retaining existing rainforest and revegetation. The nature refuge potential variable was left out of the PCA because its calculated values were very different to those of the other four variables: it contained multiple zeroes and few scores. From a conceptual perspective, nature refuges are also inherently different from the other activities – they involve an agreement between the landowner and the government, and additionally an agreement that the land will be protected in perpetuity (Department of Environment and Heritage Protection., 2016).They therefore require a different management approach than the other activities, and would require a different motivation for participation.

The Kaiser-Meyer-Olkin measure of sampling adequacy for the PCA was 0.307, which reflected the small sample size (n=17). However, Bartlett's test of Sphericity returned a statistically significant result (<0.001) indicating that at least some of the variables are correlated.

The scree plot for the PCA suggested that principal components one and two account for most of the total variance in the data, whereas components three and four account for increasingly less (figure 5). The eignenvalues of the PCA confirmed this; 57% of the variance within the data was explained by the first principal component and approximately 26% was explained by the second. A Varimax-rotated component matrix with Kaiser normalisation showed that the potential values for weed management, retaining rainforest and pest management were grouped in component one, whereas revegetation made up component two (table 4).

Logically, these groupings make sense. The first component consists of incidental management activities which landowners who manage their land for business, production, or as a residence may already do regularly – weed management, pest management and retaining existing rainforest (especially if the rainforest is retained on areas which otherwise can't be used). The second component, revegetation, reflects a separate group – landowners who manage their land and have a pure conservation interest. Based on the results of the PCA, I elected to include three layers of social rankings in our analysis: individual potential scores for nature refuges, factor scores for revegetation (component 2), and factor scores for incidental management activities (component 1). These were standardised on a 1-10 ordinal scale to facilitate overlays with the ecological data. Based upon the management potential scores, each property was then ranked from least potential to greatest potential for each of the three social ranking layers.

The potential of each property for each of the three management types was mapped using GIS. The first three properties with the highest ranking potential scores were selected for each management type. A circular polygon was drawn around the perimeter of the three most important properties, starting at the central point between the three and extending outwards such that only the outermost edge was included (figure 6). A Getis-Ord General G clustering analysis was then conducted to determine if the properties which received high potential management scores significantly grouped together or were dispersed throughout the study area.



ROTATED COMPONENT MATRIX		
	Component	
	1	**2**
POTENTIAL weed management	**.864**	-.107
POTENTIAL revegetation	-.015	**.924**
POTENTIAL retaining rainforest	**.969**	.190
POTENTIAL pest management	**.649**	.566

Figure 5: Scree plot showing the calculated eigenvalues for each principal component; and the rotated component matrix for the potential management activities

Ecological criteria

Areas which are considered ecologically important for management are largely dependent on specific management objectives. For this project, the management objective was to optimise rainforest connectivity. Underpinning the overall objective of connectivity is the need to sustain suitable habitat for species, and particularly in the Wet Tropics, the endangered southern cassowary. Thus, the ecological importance of individual properties was based on variables that also represent suitable ecological conditions for the cassowary. Incorporating cassowary conservation into the ecological rankings has a number of benefits. It is a highly mobile keystone species, and therefore by protecting its habitat it may act as an umbrella species and ensure that critical ecological processes acting at finer scales can continue (Moore, 2007). Additionally, from a practical perspective, it may act as a model organism and allow the ranking to be tailored for future studies which may have different management objectives.

Because some of the ecological parameters for cassowary range and habitat are not well known, for example home range size and elevation, broader variables which reflect current best knowledge of cassowary ecology were used. Using broader variables also means that there is less of a chance that areas which are highly suitable for cassowaries will be excluded. The variables used to determine the ecological suitability of individual properties include creek length, area of cassowary-suitable vegetation, slope and cassowary-compatible land use (table 5). Values for the variables were obtained using data from the Watercourse lines north-east coast drainage division data layer, Queensland regional ecosystems data layer and Regional Ecosystem Description Database, Wet Tropics Digital Elevation Model 25m raster layer, and Queensland Current Land Use 2015 layer.

Table 5: Variables use to determine ecological importance		
Variable	***Description***	***Calculations***
Creek Length (m)	Total length of all creeks on the property	
Area of cassowary-suitable vegetation (ha)	Summed area of ranked cassowary habitat on the property *The area of each habitat type was measured for each property. The habitat areas were weighted according to the suitability rankings, and summed together*	Ranked habitat = $\left(\frac{\text{area of class 1}}{1}\right) + \left(\frac{\text{area of class 2}}{2}\right) + \left(\frac{\text{area of class 3}}{3}\right) + \left(\frac{\text{area of class 4}}{4}\right)$

Slope	Sum of the areas on the property which have gradients suitable for cassowaries *Gradients between 0° and 10° were considered suitable for cassowaries*	
Area of cassowary-suitable land use (ha)	Summed area of land uses on the property which lie outside remnant vegetation *The area of each land use type outside remnant vegetation was measured for each property. The land use areas were weighted according to the suitability rankings, and summed together*	Ranked land use = $\left(\frac{\text{area of class 1}}{1}\right) + \left(\frac{\text{area of class 2}}{2}\right) + \left(\frac{\text{area of class 3}}{3}\right) + \left(\frac{\text{area of class 4}}{4}\right)$

Area of cassowary-suitable vegetation was calculated by assessing a map of regional ecosystems (RE's) in GIS and using the attribute table to calculate the total area of each RE in each property. Then, a ranking schema was applied to all RE types present within the study area. The ranking schema was based upon how suitable the various RES' are for cassowaries, following the descriptions listed in the regional ecosystem description database (table 6). To determine how important a particular RE may be for cassowaries, I considered whether or not it contained cassowary food plants, the level of disturbance and the floristic composition. RE's which were most suitable were composed of relatively undisturbed rainforest with cassowary food plants (Department of Environment and Heritage Protection, 2016; J. Moloney, personal communication, 2016; Campbell et al., 2012).

Table 6: Suitability ranking of habitat for the southern cassowary

Regional Ecosystem Classification Code	***Description***	***Suitability Ranking***
7.12.1	Simple-complex mesophyll to notophyll vine forest on moderately to poorly-drained granites and rhyolites of moderate fertility of	1

	the moist and wet lowlands, foothills and uplands	
7.3.10	Simple-complex mesophyll to notophyll vine forest on moderately to poorly-drained alluvial plains of moderate fertility	2
7.11.1	Simple-complex mesophyll to notophyll vine forest on moderately to poorly drained metamorphics (excluding amphibolites) of moderate fertility of the moist and wet lowlands, foothills and uplands	2
7.3.7	Eucalyptus pellita and Corymbia intermedia open forest to woodland (or vine forest with emergent E. pellita and C. intermedia), on poorly drained alluvial plains	3
7.3.8	Melaleuca viridiflora +/- Eucalyptus spp. +/- Lophostemon suaveolens open forest to open woodland on poorly drained alluvial plains	3
7.3.20	Corymbia intermedia and Syncarpia glomulifera, or C. intermedia and Eucalyptus pellita, or S. glomulifera and Allocasuarina spp., or E. cloeziana, or C. torelliana open forest (or vine forest with these emergents) on alluvial fans at the base of ranges	3
7.11.5	Eucalyptus pellita +/- Corymbia intermedia open forest (or vine forest with E. pellita and C. intermedia emergents) on lowlands and foothills on metamorphics	3
7.11.24	Closed vine land of wind-disturbed vine forest of metamorphic slopes, often steep and exposed	3
nonrem	Assemblage which is not native, remnant vegetation. Includes regrowth and disturbed vegetation.	4
plant	Plantation (native or exotic)	4

The same methodology was used to determine the area of suitable land use for cassowaries on each property. The Queensland Current Land Use (2015) layer was sourced from the Queensland spatial database and was used to calculate the area of each land use. Knowledge of cassowary movement and threats was then used to calculate the suitability of each individual land use. For example, locations in which there was minimal disturbance were considered most suitable, followed by cropping areas which are not fenced and are still mostly vegetated, and finally residential areas – because they may include fences or have dogs. Locations which were fenced, and therefore inaccessible to cassowaries, were classed as most unsuitable (J. Moloney, personal communication, 2016). Generally, the rankings for suitability of land use are from most accessible (1 – conservation/minimal use) to least accessible (4 – cattle farming) (table 7).

Table 7: Suitability rankings of land use for the southern cassowary

Land Use	***Description***	***Suitability Ranking***
Conservation/ minimal use	Includes national parks, protected natural features, conserved areas, area of minimal use, or areas of residual native cover. All these areas are predominantly natural.	1
Crops/ horticulture/ fallow land	Includes sugar cane and irrigated cropping, horticulture and fruit trees. These areas area significantly disturbed but do not prevent cassowary movement or pose as a direct threat.	2
Residential	Includes rural living or rural residential areas. These areas are typically unsuitable for cassowaries due to interference from humans and domestic animals such as dogs.	3
Grazing native vegetation	Includes areas where grazing occurs in mostly native environments. These areas are least suitable for cassowaries due to fencing.	4

To rank properties according to their ecological importance, the variables were standardised on a 1-10 ordinal scale. An average “ecological importance” score was then calculated for each property, treating all of the variables as equal. Based upon this score, the properties were ranked from most ecologically important to least ecologically important. The ecological importance of each property was mapped using GIS, and the first three properties with the highest ranking ecological scores were selected. A circular polygon was drawn around the perimeter of the three most important properties, starting at the central point between the three and extending outwards such that only the outermost edge was included (figure 6).

Combining the social and ecological rankings

To determine which regions were most critical for management in different contexts (incidental management, revegetation and nature refuge agreements) each of the target region layers for each management type was individually overlaid with the single ecological importance layer using ArcGIS.

This identified contiguous target regions and unsuitable regions for management – similar to a suitability analysis in which the appropriateness of a particular area for a particular use is identified. Finally, to calculate an overall score of ecological and social suitability for each type of management on each property, the potential management scores and the ecological ranking scores were added together.

Results

Summary Statistics

Overall, there was significant variability within the data. This section will highlight the main trends and most common responses from landowners.

Phone call response data

There was a range of responses received when registering interest for interviews with landowners (figure 7). Of the 79 potential landowners, most indicated that they were not interested in being interviewed (33%), and interviews were organised with twenty-nine percent - however three percent of these interviews were either missed or cancelled. Some landowners could not be interviewed for other reasons – they lived elsewhere, had disconnected phone lines, or wrong numbers (8%). All other landowners could have potentially been interested – however they could not be reached by phone, did not call back, or were busy at the time of the phone call and could not be reached again (figure 7).

Of the landowners who were not interested in interviews, there were a range of reasons given (figure 8). Besides those who did not give a reason (44%), the most common reasons were already being busy (15%), illness (11%) and being away at the time of interviews (11%). Collecting this information is useful for determining how to better engage with landowners in the future, and this will be discussed in the following discussion section.

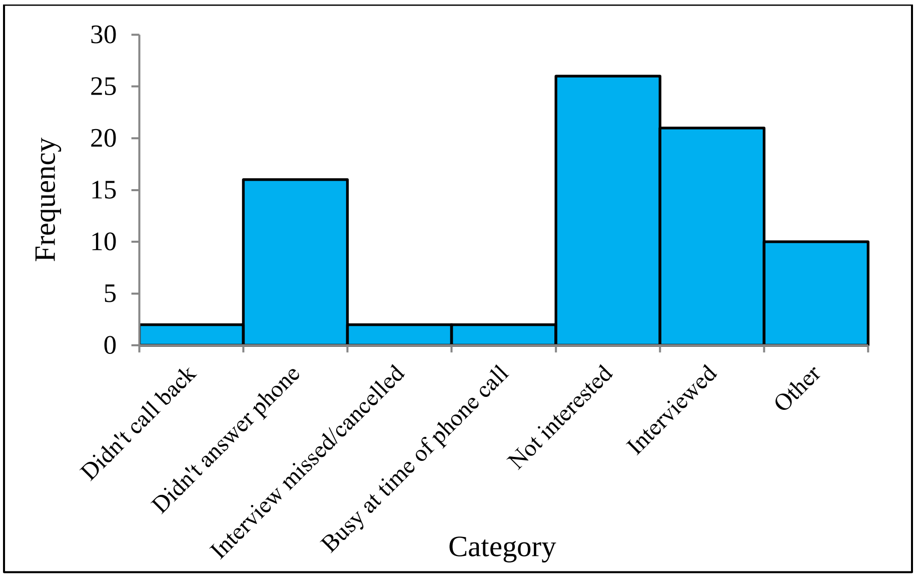


Figure 7: Frequency of phone call interactions

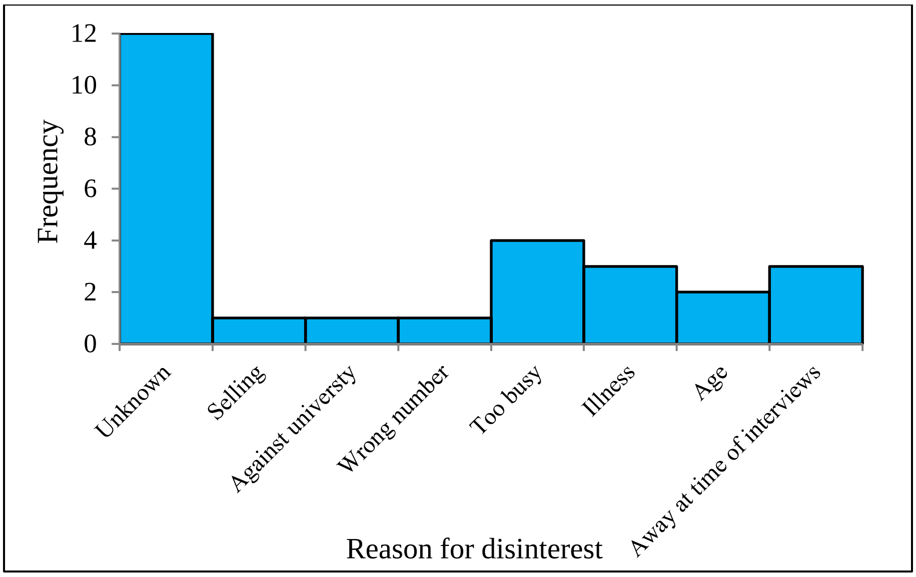


Figure 8: Frequency of responses for disinterested landowners

General trends and demographics

Landowners most commonly used their land as a residence, and many also said their land was rainforest, and/or they ran a business from it (figure 9). 29% of landowners' said that their property contributed somewhat to their income, with 19% of these saying their land contributed fully to their income. 71% of respondents said that their land did not contribute at all. The landowners who earned all of their income from their property either ran cattle or grew sugar cane, fruits or horticulture production. Not needing to pay rent on land (n=1) and leasing land (n=1) also were sources of income from properties.

Overall, the number of landowners who had owned and managed their land in the family were similar across all periods of time (figure 10). This indicates that the survey had sampled a range of respondents who had lived in the area for varying amounts of time. 76% of landowners wanted their land to continue in its current ownership; however 19% were hoping to sell. 57% of landowners interviewed were hoping to pass their land on to family, 29% were unlikely to pass their land onto family and all others were unsure.

Most landowners (70%) did not want to change the way they use their land in the future, however those that did wanted to create a nursery, plant small crops, create walking tracks, or create small-scale accommodation for tourism use. The majority of landowners believed that the natural features on their properties most important for wildlife were watercourses (45%) and vegetation (43%). Most landowners believed their roles and responsibilities were to maintain rainforest (30%), protect rainforest and wildlife (22%), or to let the land manage itself (22%).

Additionally, the majority of landowners who knew about their property being a part of Walter Hill Range said that they obtained this information through Terrain NRM (35%), their local government/council (25%), or through local knowledge (25%). Almost all landowners (91%) believed the Walter Hill Range was important - that is, they rated it better than a five (neutral) (figure 11), and this was mainly attributed to wildlife (34%), its contribution to rainforest connectivity (20%) and its aesthetic value (15%). Seventy-eight percent of landowners also believed their property was important to the Walter Hill Range corridor (figure 12). Most landowners believed their land was important because it provided connectivity to other tracts of rainforest (44%), and also housed wildlife (22%). The landowner's who didn't believe their land was important to Walter Hill Range said this was because of the amount/condition of vegetation (n=5), lack of wildlife (n=1) or lack of connectivity to other areas of rainforest (n=1).

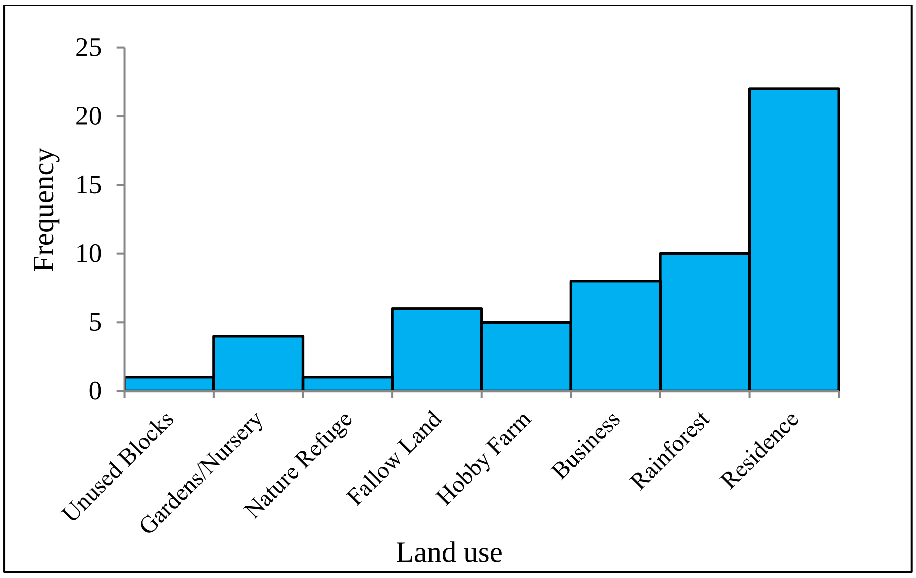


Figure 9: Frequency of land use on properties

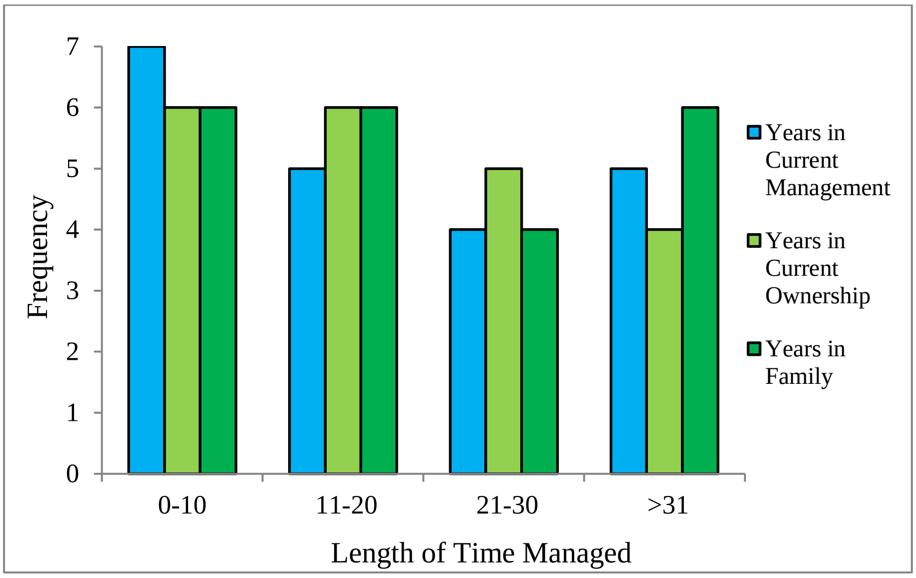


Figure 10: Length of current management period

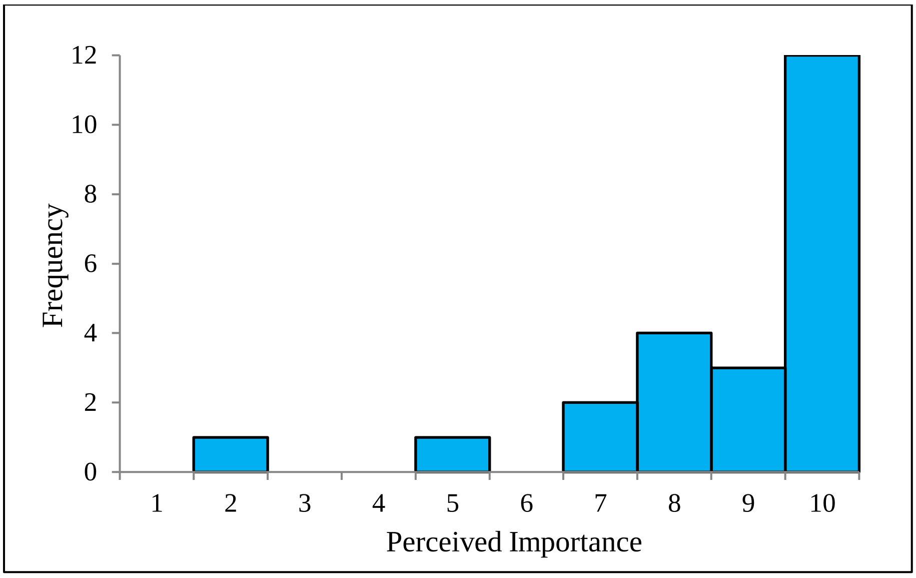


Figure 11: Landowner's perceived importance of Walter Hill Range

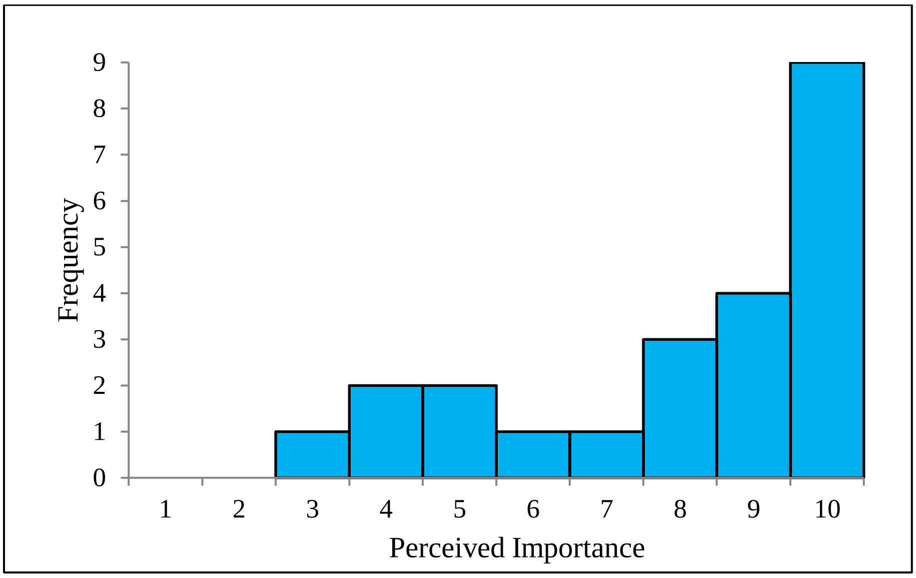


Figure 12: Landowner's perceived importance of their property to Walter Hall Range

Interest in Management Activities

There were varying levels of interest in each of the five management activities (figure 13). Most landowners were interested in retaining rainforest (95%), doing weed management (70%) and pest management (68%). Landowners were least interested in revegetation (30%) and nature refuge agreements (14%). In this case, I've interpreted interest as a landowner giving a score of 6 or better for their level of interest in an activity.

When considering all interest levels and activities together, the most commonly occurring categories were "extremely interested" in retaining rainforest, and "extremely uninterested" in creating a nature refuge (figure 13). The interest scores were bimodal (ks = 0.3472, p-value = <0.05), with landowners most likely to give a score of either one or ten (24% and 33% respectively).

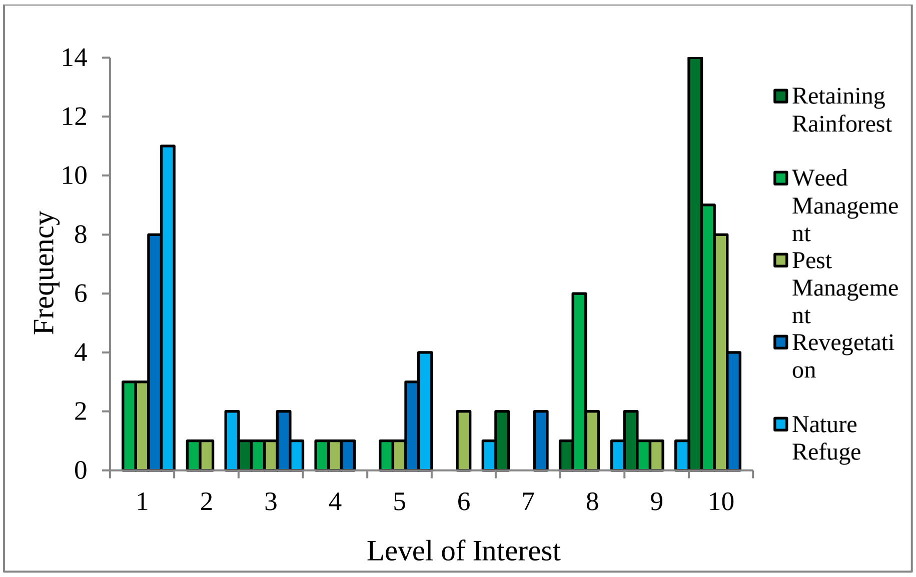


Figure 13: Level of interest in management activities

Motivations, methods and success for management activities

Retaining existing rainforest

Sixty-eight percent of landowners who were interested in retaining rainforest said they wanted to retain all rainforest on their property. The most common reasons for retaining rainforest were the health of environment (29%), because they simply did not want to remove it (23%) and because it held aesthetic value (19%). Those landowners who were not interested in retaining rainforest on their land said this was because they may choose to remove it in the future (n=2), the rainforest is regrowth and not virgin rainforest (n=1), and finally the rainforest is small in size and extent (n=1).

Weed management

Forty percent of landowners said they were interested in doing weed management to look after animals and the environment, and twenty-seven percent said they simply wanted to control weeds. Those who were not interested mainly said this was because they already had their weed management under control (n=5). Most landowners said their motivation for doing weed management was to control and limit spread (45%), to assist animals and the environment (31%) and to keep their property tidy (14%).

Fifty percent of landowners conducted weed management in natural areas, including either in the rainforest, on the forest edge, or in creeks. The other fifty percent wanted to do weed management in gardens, crops, paddocks or fallow land. The most commonly managed weeds were wild raspberry (19%), Singapore daisy (13%) and siam weed (9%). Manual removal (40%) and spraying (40%) were the most commonly used management techniques; however some landowners also used ground cover (10%), for example using native species to shade out weeds.

Eighty percent of landowners said that management had been successful, and that this was mostly due to due to persistence (38%), or using correct methods of management (24%). Most landowners gained knowledge on weed management from local knowledge, experience and observation (31%), and many also gained knowledge through their occupation (29%).

Pest management

Pest management was mostly done to prevent environmental damage (41%) and to prevent damage to crops, property or wildlife (29%). The most commonly managed pest species were pigs (59%) and dogs (23%), and the methods used were predominantly trapping (42%) and shooting (38%). Seventy percent of landowners said that the management they had done was successful, with the average level of success being 7/10. Success was predominantly achieved by using correct materials and methods (n=4). Most information on pest management was gained through local knowledge, previous experience or observation (41%); or from the media, reading, the internet or radio (24%).

Most landowners were interested in doing pest management in the future (65%), and this was predominantly because they wanted to reduce pests (55%).Those that were uninterested said this was because they did not have any pest problems (67%). Most landowners said they would do pest management anywhere (40%), or in rainforest areas (40%).

Revegetation

Seventy-one percent of landowners had done some form of revegetation in the past, and the most common motivations for doing revegetation were to improve aesthetics (16%), benefit wildlife (16%) or prevent erosion (16%). Ninety percent of landowners who had done previous revegetation said it had been quite successful. Only twenty-nine percent were interested in doing any additional revegetation in the future, and the motivations for this were either to improve connectivity (44%) or revegetate damaged areas of rainforest (22%). The seventy-one percent who were not interested said this was because they either had no room (46%), or had already revegetated all areas they wanted vegetated (46%).

Nature Refuge

Very few landowners were interest in creating nature refuges (14%); with approximately half saying they were extremely uninterested - that is, an interest level of 1 (52%). One landowner already had a nature refuge on their property. Landowners did not want to create a nature refuge because they already conserve the land (22%), because they don't want to be restricted in what they can do on their land (22%), and because of a potential drop in resale value (14%) and lack of information (11%). Those who were interested said it was because nature refuges are a great idea (n=3), and also because they are perpetual (n=1).

Barriers to conducting management activities

There were a wide range of barriers that affected landowners' participation in management activities, and these were specific to each activity. In regards to retaining rainforest on properties, sixty-seven percent of landowners said there were no barriers. However, some landowners mentioned that the potential to remove rainforest in the future, erosion, cyclones, wanting to remove damaged vegetation and revegetate with native plants, future landowners, neighbours, wanting to build a house, power line maintenance and requiring essential assets were barriers that affected their ability to retain rainforest. For weed management, the biggest barriers were accessibility (25%), time (21%) and labour (12%). Landowners also said that age/health, co-operation from neighbours, weather, cost, materials and having other priorities to attend also negatively affected their participation in weed management.

For pest management, cost (29%) and lack of materials/personnel (21%) were the biggest barriers affecting landowners' ability to do pest management, with twenty-one percent saying they experienced no barriers. The biggest barriers for revegetation were cost (29%) and time (5%). For creating a nature refuge, twenty-eight percent of respondents said that resale value was a major barrier, along with a lack of information (17%) and the fact that the agreement is perpetual (17%).

Across all of the activities, the most commonly stated barriers to management were time (17%), cost (14%), accessibility (10%), needing land for another use (6%) and none (6%).

Support and incentives for management

Landowner interest in various forms of support also differed for each management activity. Fifty-four percent of landowners said that they required no additional incentives or support to retain rainforest on their land; however twenty-one percent also mentioned that monetary support would be beneficial (Figure 14). For weed management, the most useful forms of support were labour (23%), materials (particularly chemical sprays, 21%) and monetary support (especially to buy chemical sprays, 17%) (Figure 14). The most helpful forms of support for pest management were labour (33%), followed by materials (20%), and monetary support (20%). Twenty percent of landowners also said they didn't require any support (Figure 14).

Materials (45%) and monetary support (25%) were the most commonly sought forms of support for conducting revegetation (Figure 14). Finally, Twenty-two percent of landowners suggested that monetary support might be a good incentive to create a refuge, for example a reduction in rates for properties which enter refuge agreements. Information (13%), materials (13%) and labour (13%) would also be beneficial (Figure 14). Twenty-one percent of landowners also said the program should be changed in some way, for example, making it commercially viable, making it non-perpetual, making it something that doesn't require constant management, and preventing devaluation of the property – these alterations would make the program more appealing.

Across all activities, the most common forms of incentives and support were monetary support, followed by materials, and no support (Figure 15). It must be noted that monetary support was a popular form of support across all of the activities, and materials was popular for all activities bar retaining rainforest. The popularity of no support overall was largely attributed to its high score for retaining rainforest – it was also the single most high scoring category (figure 16).

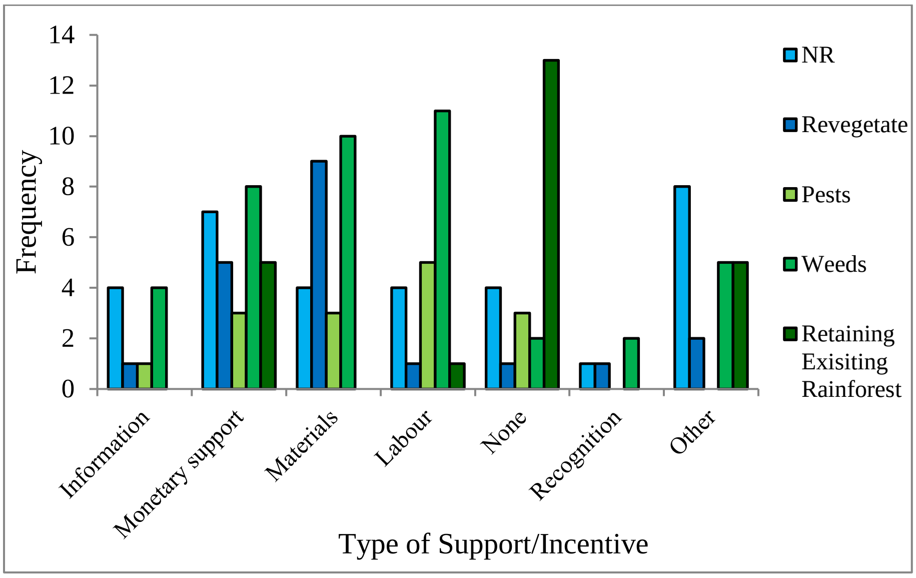


Figure 15: Main types of support/incentives mentioned by landowners for each management activity

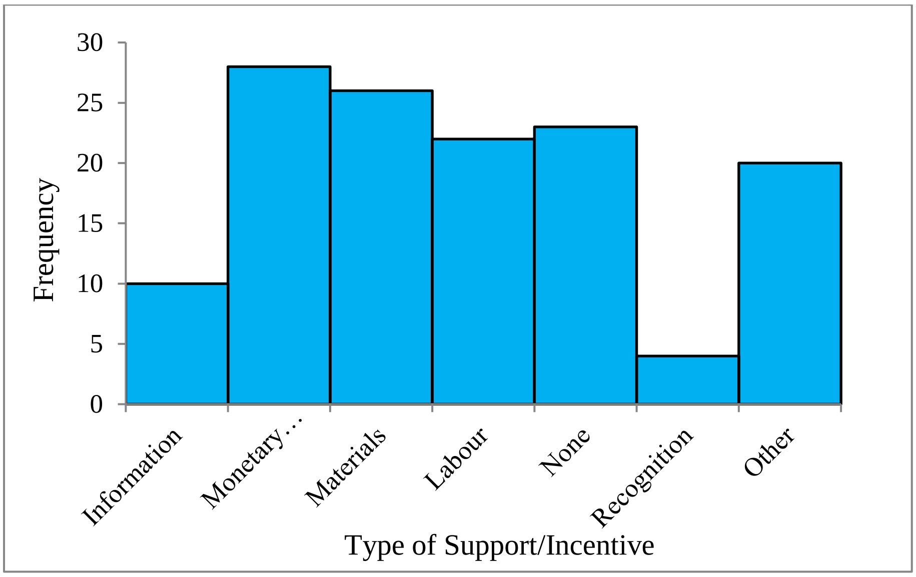


Figure 16: Overall frequency of support/incentives

Wildlife

Overall, there were approximately 46 different wildlife species groups seen on properties. Each property had varying levels of biodiversity, with the smallest number of species viewed being zero, and the greatest being 14 (figure 17). On average, most landowners viewed 6 different species on their property. The most commonly viewed class was birds, with fifty-four percent of all wildlife sightings being bird sightings (figure 18). This was followed by mammals (27%) and reptiles (11%).

Southern cassowaries were present on 15 properties, with at least 27 individuals sighted. Most of these sightings were adults (46%) and chicks (35%). Forty-one percent of landowners believed that the cassowary population in their area was increasing (figure 19). Some mentioned that this could be because people are feeding them, there is more awareness of cassowary protection and there has been improved pig and dog management. In the previous year, the number of cassowary sightings was quite variable (figure 20). Fifty percent of landowners did not see a cassowary at all, and thirty percent saw them less than once a week. However, ten percent of landowners said they saw cassowaries at least daily (figure 20).

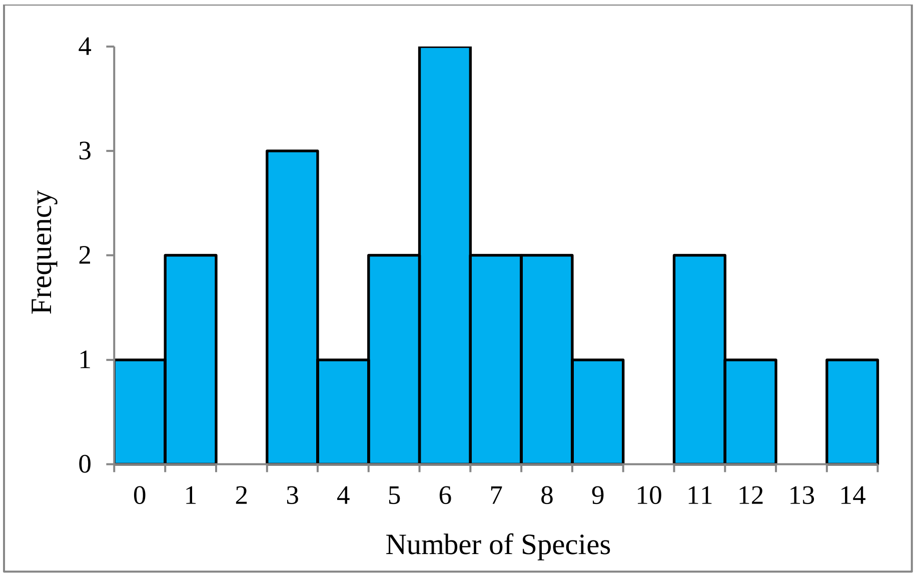


Figure 17: Frequency of observed biodiversity on properties

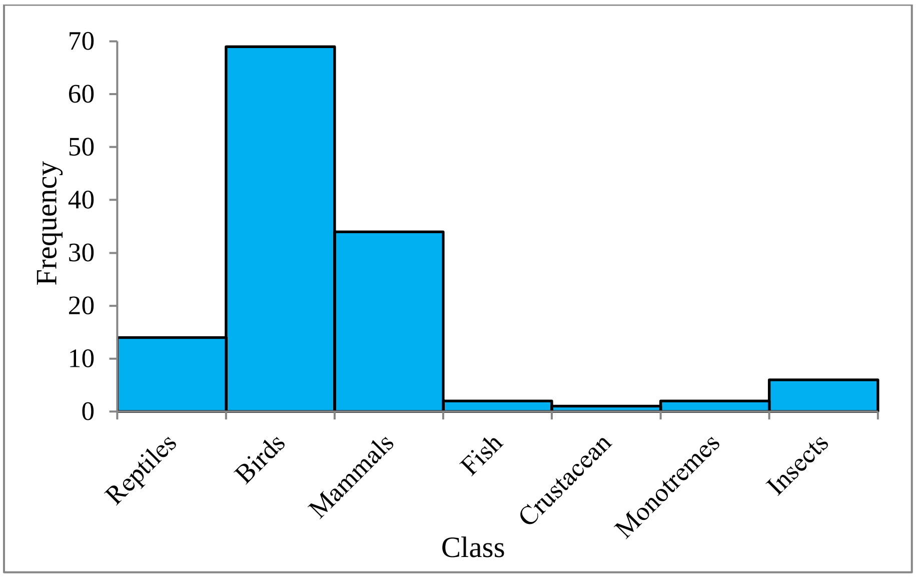


Figure 18: Overall number of signtings for each class

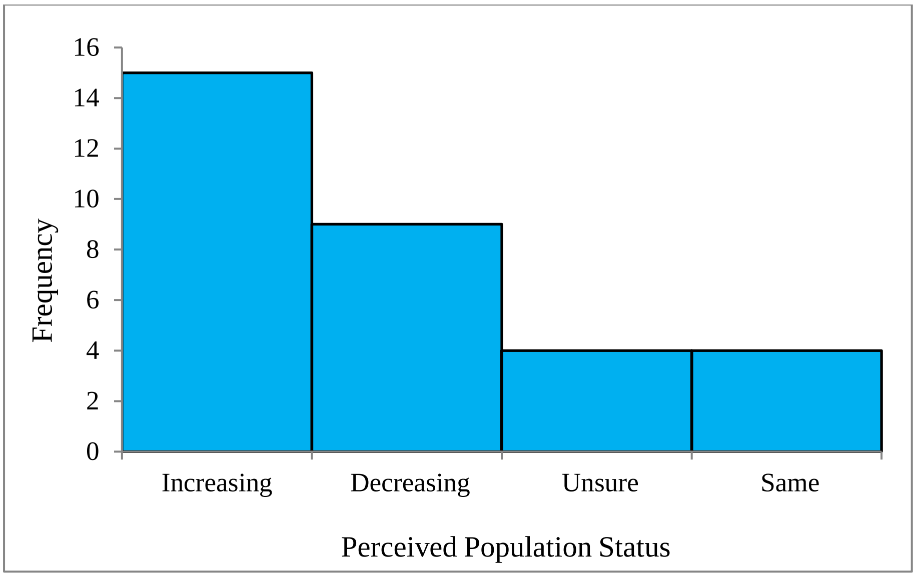


Figure 19: Perceived population fluctuations for the Southern Cassowary

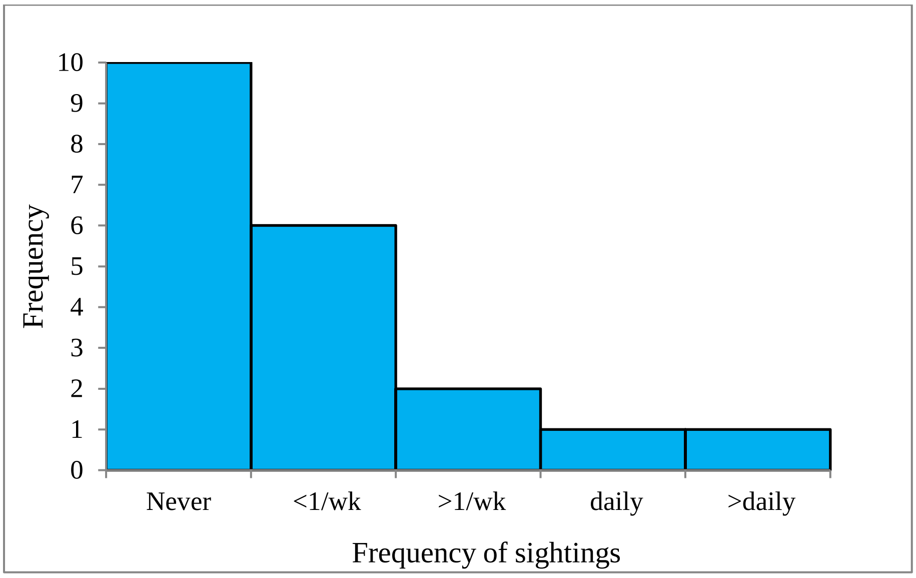


Figure 20: Frequency of cassowary sightings in the last year

Correlations for summary statistics

Spearman's rank order correlations revealed a number of significant correlations within the summary statistics data (table 8). The significant interactions (R) are in bold and are starred according to their significance level.

TABLE 8: SPEARMAN'S RANK CORRELATIONS FOR VARIABLES																			
Property Importance	Area to Retain Rainforest	Interest in Weed Management	Success of Weed Management	Area for Weed Management	Interest in Pest Management	Success of Pest Management	Area for Pest Management	Interest in Revegetation	Success of Revegetation	Area for Revegetation	Interest in Nature Refuge	Area for Nature Refuge	Time Managed	Income	Biodiversity	Cassowary Sightings	Property Area	Approximate Vegetation	
.534**	-.239	.349	-.130	-.078	-.267	-.206	-.739**	-.153	.529	-.217	.298	.235	-.244	-.271	.414	-.080	-.305	-.382	Walter Hill Range Importance
	.009	.434*	-.190	.075	.062	-.010	-.192	-.336	.719*	-.422	.133	.174	.053	-.077	.129	.192	-.046	-.031	Property Importance
		.444*	-.538*	.739**	.441	-.177	.571*	-.074	.146	-.025	.308	.293	.129	.247	-.476*	.470*	.914**	.982**	Area to Retain Rainforest
			-.378	.712**	.311	-.516	-.076	.123	.775**	.051	.340	.204	-.142	-.165	-.016	.285	.409	.404	Interest in Weed Management
				-.392	-.320	.252	.073	.316	-.051	.375	-.353	-.093	.022	.084	.274	-.431	-.467*	-.437	Success of Weed Management
					.339	-.325	.231	-.060	.395	.005	.116	.043	.105	.044	-.222	.327	.665**	.708**	Area for Weed Management
						-.193	.500	.149	.023	.158	.088	.214	.382	.355	-.188	.513*	.613**	.605**	Interest in Pest Management
							.794	-.675*	-.305	-.196	-.838**	-.406	.712*	.466	.145	-.427	-.018	-.086	Success of Pest Management
								.068	-.894	.031	-.322	-.309	.365	.723**	-.413	.236	.698**	.654*	Area for Pest Management
									.098	.846**	.510*	.544*	-.271	-.243	.099	.181	-.079	-.035	Interest in Revegetation
										-.386	.041	-.047	-.022	-.027	.448	.411	-.216	-.095	Success in Revegetation
											.321	.417	-.088	-.152	-.041	.045	.064	.041	Area for Revegetation
												.757**	-.517*	-.294	-.084	.474*	.211	.249	Interest in Nature Refuge
													-.107	-.301	-.162	.245	.188	.235	Area for Nature Refuge
														.477*	-.003	.071	.092	.145	Time Managed
															.023	.286	.347	.304	Income
																-.069	-.456*	-.499*	Biodiversity
																	.338	.410	Cassowary Sightings
																		.959**	Property Area

***. Correlation is significant at the 0.01 level (2tailed).*

**. Correlation is significant at the 0.05 level (2-tailed).*

Social rankings

Spread of potential scores

There were 15 properties included in the social ranking, as only 15 answered all questions pertaining to each potential management type, and therefore factor scores could only be obtained for these 15 properties. Each of these was assigned three "potential management" scores reflecting their potential for incidental management, revegetation and the establishment of a nature refuge (figures 21A-F). All three potential management components were skewed to the left – there was a higher frequency of smaller potential scores (Figure 21A-F).

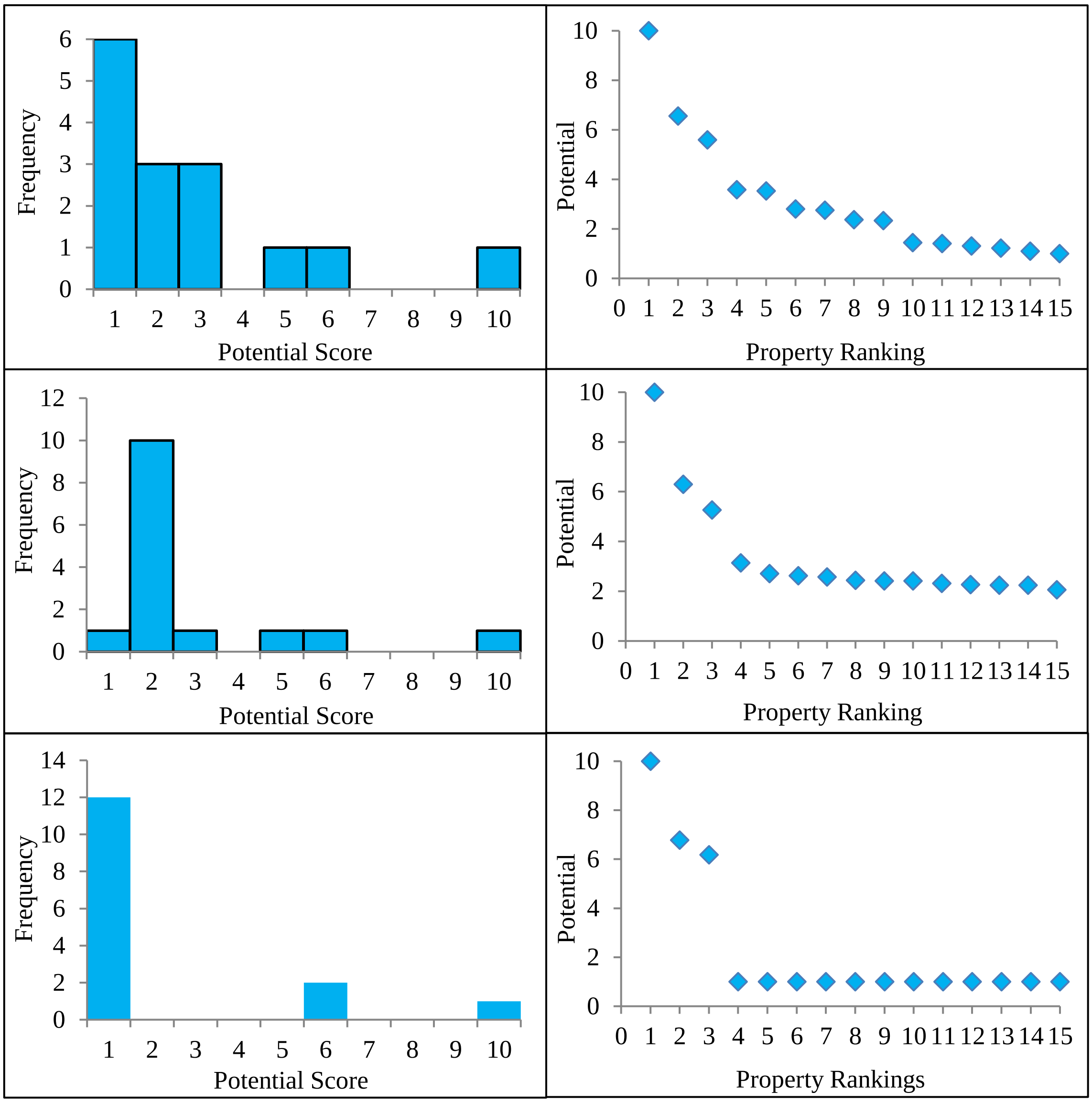


Figure 21: Frequency and spread of potential scores for A & B: Incidental management; C & D: Revegetation; and E & F: Nature refuge.

Target regions for management

The regions containing properties most important for each management component are displayed below. One target region was identified for incidental management and nature refuges, whilst two separate regions were identified for revegetation. There was significant overlap between the incidental management and revegetation regions, and the nature refuge and revegetation regions – but not between the incidental management and nature refuge regions (Figure 22A-D).

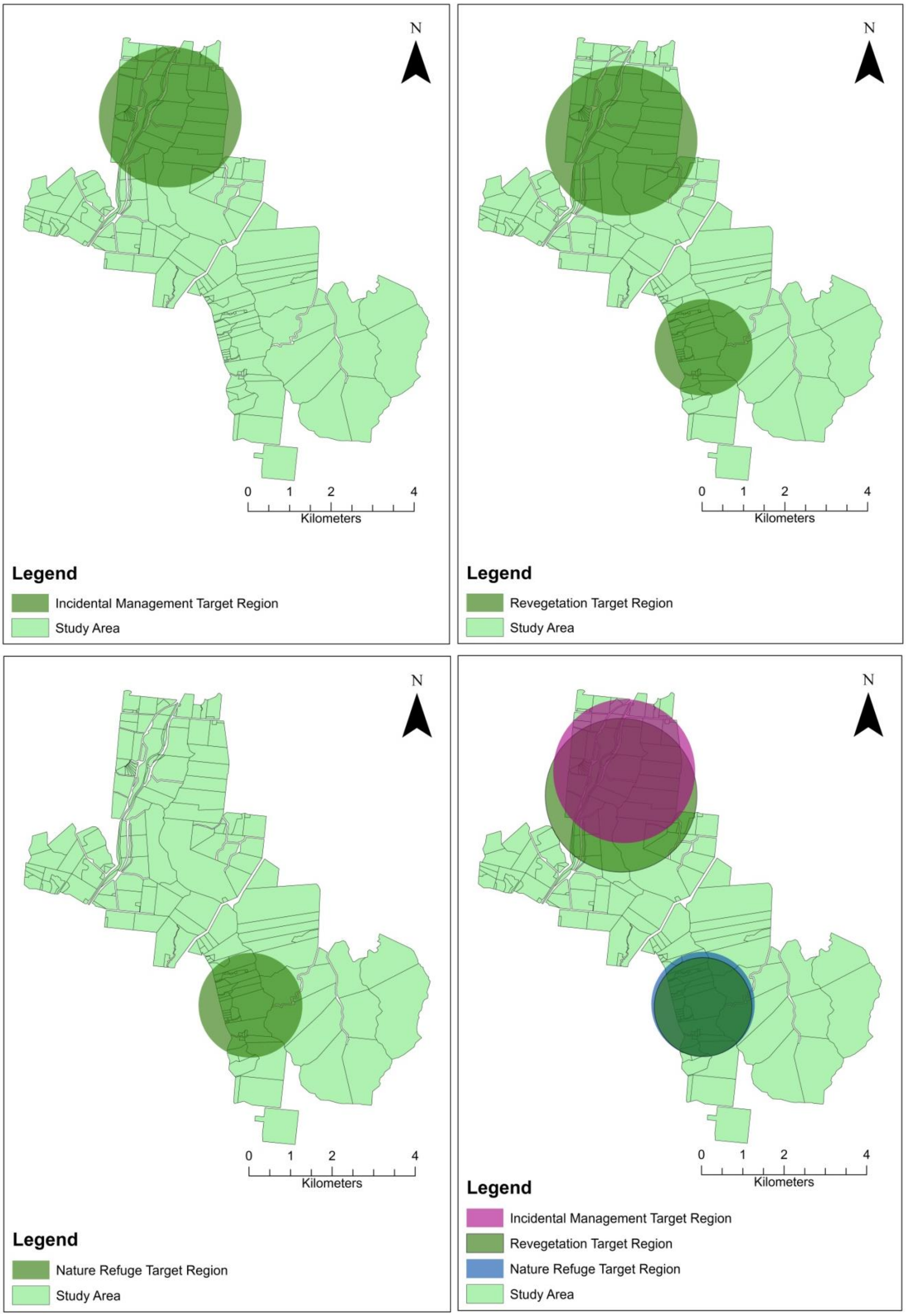


Figure 22 A-D: Target regions for incidental management (A), revegetation (B), and incidental management (C) and for all three management activities combined (D). Figure 22D shows the separation of the incidental management (purple) and nature refuge (blue) target regions.

Ecological rankings

Spread of potential scores

Similarly to the potential management scores, the ecological scores for properties were skewed to the left – there was a higher frequency of low-scoring properties (figure 23).

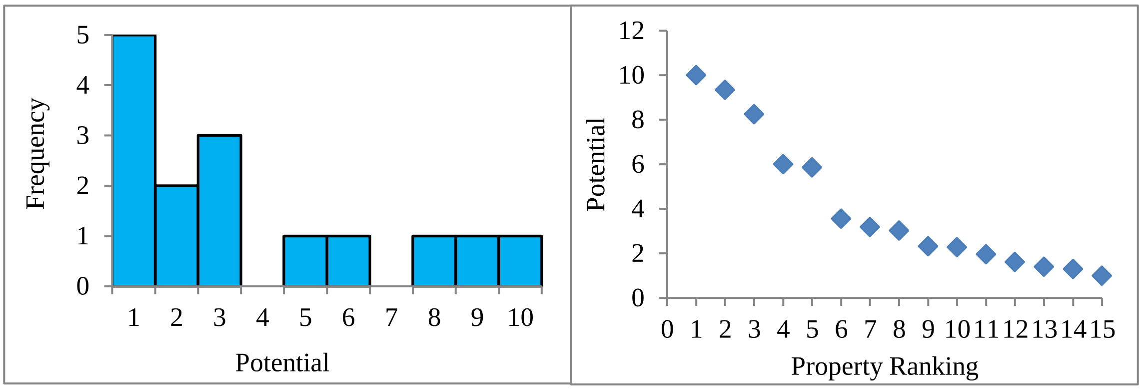


Figure 23: Frequency and spread of scores for ecologically important properties.

Ecologically important management region

The most ecologically important properties were located in the north east of the study area. All of those properties which scored a value of five or above for ecological important were clustered in the north of the study area (Figure 25A).

Combined social and ecological rankings

The region which was most suitable for incidental management and the most ecologically important region within the study area overlapped (figure 25B), as did the larger region considered most suitable for revegetation (figure 25C). There was no overlap between the region which was considered most suitable for nature refuge agreements and the most ecologically important region, however (figure 25D).

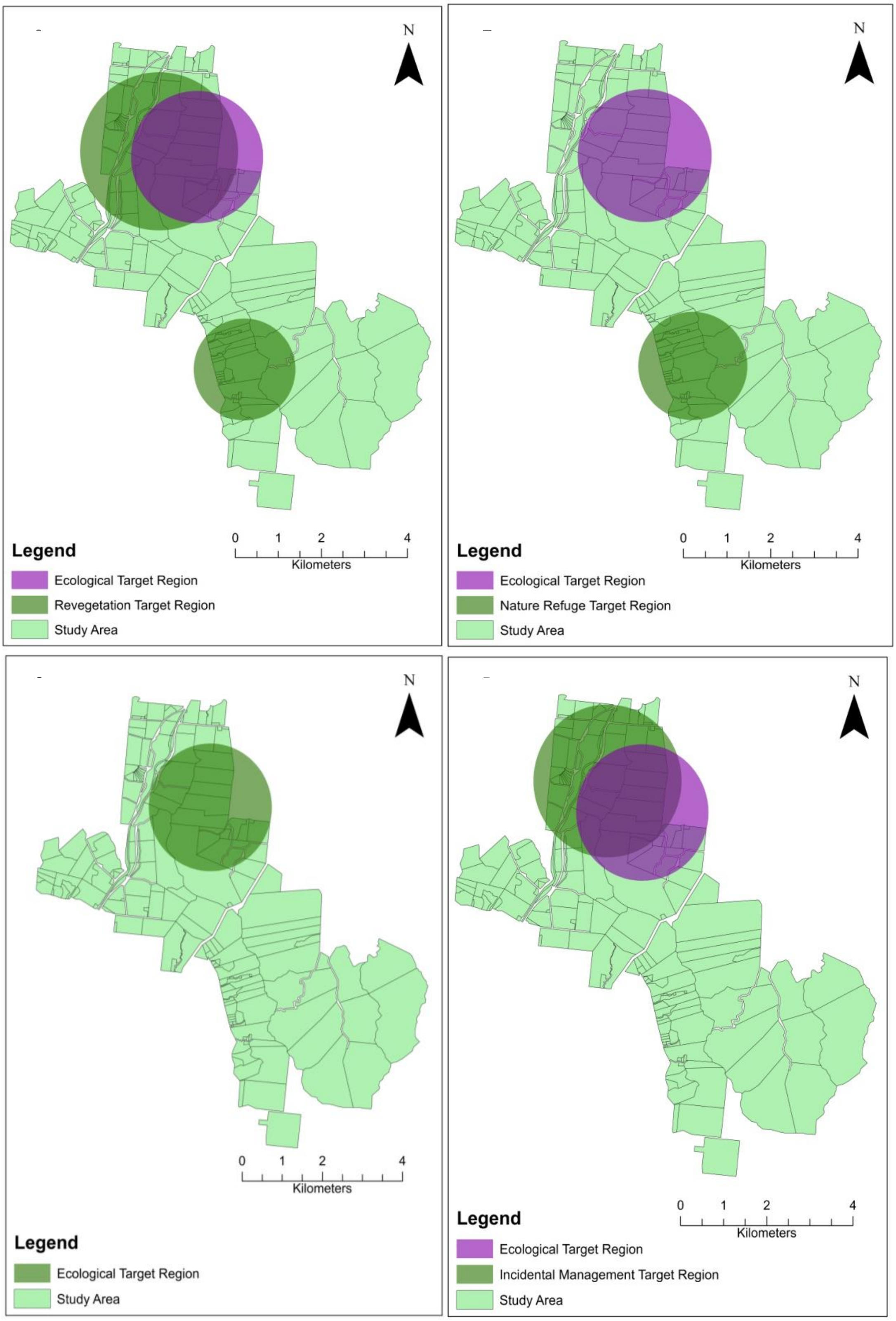


Figure 25A-D: Area of highest ecological importance based on the ecological importance values given to individual properties (A, top left), areas of overlap between B - ecologically important and incidental management regions (top right), C - ecologically important and revegetation target regions (bottom left), and D – ecologically important and nature refuge target regions.

Discussion

There was significant overlap between regions which were highly suitable for management and the ecologically important region within the study area. Particularly, the ecologically important properties and those most suitable for incidental management and revegetation overlapped in the north of the study area; while the properties suitable for creating nature refuges and doing revegetation overlapped in the south of the study area. This suggests that there is good potential for optimising rainforest connectivity management on the surveyed properties within Walter Hill Range.

The three management groupings seemed to represent two broader groups of landowners with different management objectives. The first, smaller group was conservation-orientated; they were interested in or had already conducted incidental management as well as intensive conservation activities such as revegetation and creating nature refuges. This group generally consisted of residents who did not use their land for production. The second, larger group was only interested in incidental management activities, and they tended to use their land for production. The difference between the management objectives of these groups highlights the need for management which will support the needs of diverse private landowners.

Deconstruction of the survey responses

General trends and demographics

Almost all landowners used their land as a residence, some used it for business, many simply kept rainforest on their land and one landowner leased their land to tenants. Most landowners wanted to hold onto their land or pass it on to family members, and most did not want to change the way their land was used in the future

– this is promising for future management schemes. Continuity in ownership and land use is important for management: if a landowner sells their land to somebody with different objectives, time and resources that have been spent improving the ecological health of a property could be wasted.

Another feature shared by landowners was a sense of duty and care for the local environment. Landowners believed their property's location and role as part of the Walter Hill Range corridor was important. They also believed that connectivity was important for ecological health. Landowners' knowledge and appreciation of rainforest connectivity is likely to be a result of Terrain NRM's community engagement efforts in the region, and also the Walter Hill Range's location within the range of Queensland's Wet Tropics World Heritage Area – an area of renowned environmental significance. The fact that landowners valued rainforest connectivity verifies the importance of community engagement and knowledge-sharing for managing connectivity within Walter Hill Range.

Interest in management activities

There were distinct trends for level of interest in each of the five management activities. Landowners were very interested in retaining rainforest, and doing weed and pest management; however they were very uninterested in creating nature refuges and conducting revegetation. These trends support the differentiation between the incidental-management landowners and those who are conservation-orientated. It also implies that landowners have strong views about their interest and participation in management activities. This is also reflected by the two highest scoring categories for level of interest– "extremely interested" for retaining rainforest and "extremely uninterested" for creating a nature refuge.

Retaining rainforest is something that landowners are probably already committed to doing, given it is still present on their land. They would therefore be comfortable with the idea of retaining rainforest, and have established opinions and beliefs regarding their participation in this activity. This is an example of construal level theory - the more closely related an idea or activity is to a respondent, the more likely they are to have "concrete" opinions about it (Van Lange, Kruglanski & Higgins, 2012). Therefore, it is not surprising that "extremely interested" for retaining rainforest scored highly, because it is an example of a concrete opinion.

Secondly, nature refuges were rated as the least popular management activity by almost all landowners. Nature refuge agreements involve the landowner signing a perpetual agreement with the state government which states that they will continue to manage their land sustainably, and according to the terms written in the agreement, in perpetuity (Department of Environment and Heritage Protection, 2016). Many landowners were least interested in nature refuges due to this formal agreement, which makes logical sense. Perpetual agreements often have "time-inconsistency" problems – if a landowners' management objectives change down the track, their interest in having a nature refuge may also change (Hogan, Sturzenegger & Tai, 2010). The fact that nature refuge agreements are government-run may also implicate a landowners' decision. According to the stereotype content model, we divide people according to two dimensions – warmth (e.g. friend vs. foe) and competence (divides by status) (Fiske, 2012). Governments are powerful and have high status, and can be quite ambivalent in their views – this leads to distrust from society, and may be one reason why landowners are less inclined to enter into nature refuge agreements (Palmer et al., 2009).

What is the management potential for individual management activities based on the survey responses?

Retaining Rainforest

The motivations for retaining large areas of rainforest reflect the two different kinds of landowners - those who are conservation-orientated and want to maintain the health of the environment, and those who are incidental-management orientated and simply have no other use for the land. Retaining rainforest to maintain environmental health is a mindset which is reflective of conservation-orientated landowners, who likely bought their land for its natural values. Additionally, landowners who received more income from their land and had larger properties were more likely to retain rainforest – this is representative of the incidental management group which use their land primarily for production. Conservation may be a secondary objective–if the land cannot be used for production, it may be retained it because it is too costly to remove or there are regulations preventing removal.

Landowners who wanted to retain rainforest also saw cassowaries more frequently. This may have affected interest and motivation in retaining rainforest - landowners may want to retain rainforest because they see more cassowaries. However, this relationship could also be causative - the fact that these landowners already have areas of suitable cassowary habitat on their land may mean they see more cassowaries anyway.

Landowners were disinterested in retaining rainforest if it was low quality (regrowth or a small patch), or if they might want to remove it in the future. Regrowth rainforest can be ecologically important if it is left to grow past a young age - this is especially so in Queensland's wet tropics, which have faced extensive clearing in the past (Kanowski, 2003). Landowners wanting to remove regrowth or small areas of rainforest tended to lack conservation prerogatives, and therefore were more consistent with the incidental management group. One landowner also discussed that retaining rainforest was not a matter of motivation or interest, but of legislation. Remnant vegetation can't be altered without government permission, regardless of landowner objectives (Department of Environment and Resource Management, 2011). Finally, landowners required no resources to retain rainforest, and this is ideal for management - it means there are less resources required to manage these areas.

Weed management

Motivations for weed management again reflected the two different groups of landowners. The conservation-orientated landowners wanted to remove weeds to look after animals and the environment, whereas the incidental management group simply wanted to remove the weeds. Eighty percent of landowners said that weed management had been successful in the past, which shows potential for future management – with support; weed management success could continue. Fifty percent of landowners had conducted weed management in natural areas, which is important as it shows landowners understand the role that weeding can play in improving rainforests.

Despite this, landowners who retained larger areas of rainforest had less success in weed management. Weeds are fast growing and tolerant which makes them capable of growing across large areas, making management difficult (Csurhes & Edwards, 1998). It may be beneficial to optimise management for critical areas, such as edges, because weeds tend to be excluded from rainforests due to competition for resources with established rainforest plants (Csurhes & Edwards, 1998). Focusing on edges may promote rainforest regrowth and limit the spread of weeds into disturbed rainforest (Queensland Government, 2014; Grice & Setter, 2002).

Finally, there was a need for weed management to be done at certain times and in certain areas to achieve the greatest success (Grice & Setter 2002). The frequency and forms of support required by landowners was dependent on the type of weed problems and barriers which they experienced. Those who had trouble accessing isolated patches of weeds in the rainforest required labour for one significant weed removal and revegetation event, and possibly spray for follow-up maintenance. However once revegetated rainforest plants grow, they are likely to outcompete weeds, leading to minimal future management (Grice & Setter, 2002). Those with a clustered weed problem outside rainforest required materials and/or labour. And those who had significant, widely distributed and recurring weed problems, for example, maintaining weeds on rainforest edges or along creeks, typically required ongoing materials or monetary support to ensure weed incidence is kept to a low level.

Pest management

Motivations for pest management revealed that landowners were either conservation-orientated or incidental management-orientated, and this was largely a product of their land use. Conservation-orientated landowners wanted to prevent environmental damage from pests, whereas incidental land managers wanted to prevent damage to crops, property or animals (e.g. cattle), predominantly from pigs or dogs. Although landowners had been successful with pest management, there was still significant interest. This is because pests are highly mobile – a new population could easily move back into an area following removal (Hone, 2002). Pest management is therefore an on-going task which requires consistent management to ensure pest incidence is kept consistently low (McGaw & Mitchell, 1996).

Given the methods of pest control for pigs and dogs are trapping and shooting, identifying priority areas where they occur regularly is likely to achieve management success. For example, cassowary-friendly traps can be set up semi-permanently in priority locations, and managed by nearby landowners. One of the biggest barriers to this is cost – traps are expensive, and the purchase of crack corn for pig traps is also costly long-term. Lack of personnel is also a barrier– landowners cannot always dedicate time to checking traps, and this can be problematic if animals are left in traps for too long. Despite this, the pay-offs for pest management are significant, and it is therefore an area worth investing in.

Landowners who had pest problems had lower biodiversity on their properties. This was expected - pigs and dogs tend exclude native species, either directly by predation or indirectly by damaging habitat or competition (Taylor, 2011; Kofron & Chapman, 2006; Glen et al., 2011). Pigs consume cassowary eggs, deteriorate creeks, and prevent seedling growth, while dogs attack threatened species and are now hybridising with dingoes, threatening their genetic lineage. Pests also damage landowners' assets –pigs consume or root around crops, and dogs attack cattle and are a threat to humans and pets (Pavlov et al, 1992; Hone, 2002; Fleming et al, 2000).

Landowners who managed their property for longer had more success with pest management – these landowners likely had thorough local knowledge. Further, landowners who had high levels of interest in pest management also experienced high levels of success in previous pest management activities. According to the theory of planned behaviour and social cognitive theory, those who have had success in an activity in the past are likely to be interested in doing it again in the future because they have developed a belief in its success and also have greater motivation (Ajzen, 2011). There is therefore good scope for landowners and managers to work together to achieve positive outcomes for pest management.

Revegetation

Many landowners had done revegetation in the past, and consequently very few were interested in doing revegetation in the future. Those that were interested wanted to improve connectivity or revegetate damaged areas of rainforest – concepts which reflect the interest of those in the conservation-orientated group. Landowners who had high levels of interest in doing revegetation also wanted to revegetate larger areas of their properties.

Following on from this, interest in revegetation and creating a nature refuge were correlated, which was unsurprising given they are both strongly conservation-orientated activities. Landowners who had done successful revegetation wanted to do weed management, which suggests they want to maintain the area after revegetation efforts. Those who had done successful revegetation also thought their property was important – this may have been a cause for doing the revegetation, or an effect of completing successful revegetation.

Overall, there is significant opportunity for management assistance in doing revegetation, but there are few landowners who are interested, and the ecological benefit which revegetation would provide the landowners should be considered individually first.

Nature refuge

Landowners were very uninterested in creating nature refuges. Interestingly, the reasons for disinterest suggest that both conservation-orientated and incidental management orientated landowners were uninterested –this is because many already conserve their land. Resale value, lack of information and the fact that nature refuge agreements are perpetual were the biggest barriers, and these are related to the time-inconsistency theory – landowners could change their minds later on, and this prevents them from entering an agreement. Monetary support such as a reduction in rates was mentioned as being a beneficial incentive– this was not surprising. Nature refuge agreements are essentially government - protected areas in which management is done by the landowner, and so many landowners believed this was fair compensation for their dedication to conservation. A number of landowners wanted to see the program changed to make it commercially viable, non-perpetual, to prevent devaluation of the property and to decrease the management required. Landowners who were interested in having nature refuges also saw cassowaries more frequently. This could be explained by the fact that these landowners also had significantly more vegetation on their land, which means more cassowary habitat. Alternatively, landowners may want to turn their land into a refuge because they know that cassowaries are present.

Wildlife Sightings

There was a wide variety of wildlife sighted on properties; including cassowaries which were seen on over seventy percent of properties. This suggests that the Walter Hill Range area is important habitat for many species. However, these trends are likely to be a product of how often the landowners spend outside, their knowledge and interest in wildlife. A number of landowners believed that the cassowary population in their area was increasing due to a greater awareness of cassowary conservation, improved pig and dog management and the fact that people are feeding them. This has a number of implications for current and future management. Firstly, the fact that people perceive that there is greater public knowledge of cassowary conservation and improved pig and dog management highlights the success of current management. However, it also suggests that there may be high incidence of cassowary feeding by humans, and knowledge-sharing should be increased to discuss the threats of cassowary feeding when wild food sources are readily available.

There was a negative relationship between level of biodiversity on properties and the area of vegetation, which was unexpected. However, this could be a product of landowners spending minimal time outside. It could also be because their land is predominantly rainforest and is inaccessible in places – most houses were build in cleared, lowland areas while the steeper, less accessible rainforest slopes were untouched.

Social rankings

The three main groups identified for the social ranking were potential for incidental management (including retaining rainforest, weed management and pest management), revegetation, and creating a nature refuge. Broadly, these groups can be classed together as management activities which landowners already engage in without conservation purpose (incidental) and conservation-orientated management (revegetation and nature refuge) in which the landowner goes above and beyond the general maintenance of their property. The distribution of properties which received high potential scores for the three management groups was similar - approximately 20% of the properties surveyed achieved potential scores which were greater than five. There was also some overlap between the areas which were found to be suitable for the three management activities, and these represent a number of different relationships.

Firstly, the same properties were often important for different activities. Some landowners who achieved high incidental management potential scores also achieved high revegetation potential scores. This makes sense, because the highest scoring landowners for incidental management are also likely to be more conservation-orientated than those who achieved lower scores. Thus, it is logical that they might also achieve high scores for revegetation. Further, potential scores were a product of landowners' interest and the size of the intended management area. Thus, size of the property, and consequently management area, skewed the results towards larger properties - a result which is obvious when observing properties which achieved the highest scores in each of the management groups.

Additionally, the overlap between the revegetation and nature refuge focus areas is largely a result of one property which had unique attributes that made it ideal for both revegetation and as a nature refuge. It contained a significant vegetated area which the landowner cannot and does not want to use for other purposes, and which they want retain in its natural state. This is an attribute which is ideal for a nature refuge. Secondly, it also contained a considerable area which the landowner was very interested in revegetating. Consequently, it scored highly in both of these management activities, and this made it unique in comparison to the other properties.

The distribution and overlap of the target management areas is also important from a management perspective. It reinforces the importance of the identified areas for management, and it also provides managers with neighbouring properties that could be target for management. From a connectivity perspective, identifying regions for management in which landowners of adjacent properties share similar values and objectives for the management of rainforest connectivity is likely to be more beneficial for managing connectivity across landscapes than selecting mutually exclusive individual properties where neighbouring parcels may have opposing views. This is similar to the idea that managing adjacent neighbouring parcels of rainforest is more ecologically beneficial for rainforest connectivity than attempting to protect smaller, more disjointed patches (Fahrig, 1998; Taylor et al 1993). Whilst the scale of connectivity management would obviously vary depending on the ecological requirements of the landscape or species in questions, when managing the connectivity of corridors especially for the southern cassowary, it is important to ensure there is continuity between the management objectives of landowners. There are a number of reasons for this.

First, cassowaries are significantly affected by the presence of pest species, especially pigs and wild dogs. Pigs tend to cause the most disturbances in wet sclerophyll forests, which are also the habitat of choice for cassowaries (Laurence & Harrington, 1997). Pigs root around in the soil and raid cassowary nests to consume the eggs, and this poses a threat to their survival (Crome & Moore, 1990). Additionally, dog attacks on cassowaries are a major source of mortality (Kofron & Chapman, 2006). Thus, ensuring that management is focused on regions where landowners may be most willing to adopt pest management practices is important for the cassowary.

Secondly, focusing time and management efforts on a cluster of properties rather than those which are disconnected is also beneficial for maximising the use of resources. Once a focus area has been identified and the target landowners are engaged, it is likely more cost and time efficient to employ a “snowballing” technique and aim to spread the management area outwards, as opposed to starting again separately in a different location.

Properties which ranked highly for incidental management potential also had significantly more vegetation and were larger than less important properties. This indicates that they contribute significantly to Walter Hill Range, and confirms their importance for management. The distribution of important properties also indicates that there is good potential for management within Walter Hill Range. For most management groups, important properties were located nearby each other. This confirms the important of these regions for management, and exemplifies how social factors can be used in a spatial sense to achieve management goals across landscapes (Chazal et al., 2008).

Ecological rankings

The ecological ranking revealed that surveyed properties in the northern part of the study area were most ecologically important for management. Property size was likely to have played a significant factor in the determination of ecologically important properties, just as it did for those which were most important for management activities – the most ecologically important properties were larger in size than those which were less important. This trend may be explained by a number of phenomena.

Firstly, the ranking of ecological importance was dependent on the area or length of each of the individual variables – length of creeks, area of habitat, land use and slope. Properties which had more of these variables were more important. Obviously, larger properties will contain more of each feature, and so tended to be more important for management. Weighting property importance by area, as opposed to proportion of vegetation, was one of the most important aspects of the methodology, and this will be discussed further along in the methodological implications section.

Although the ecological rankings used were simplified, with more research and fully-developed analyses in the future, this ranking could be adapted to suit a range of applications. This study and its management objectives focused on the adjacency of rainforest patches and land parcels - however, it must be noted that connectivity within the landscape can also be facilitated by the distribution of “stepping stones”; patches of rainforest which are not adjacent but which allow mobile organisms to “hop” between them and thus access larger and more suitable patches (Fahrig, 1998). Better defining the level of connectivity of the landscape by including a “connectivity” value in the ecological ranking is one way in which this may be quantified - I will discuss this further in the methodological implications.

Combining social and ecological suitability rankings

There was a high level of overlap between socially suitable and ecologically important management regions – from a social-ecological perspective, management in these areas would be ideal. Most surprisingly, the nature refuge target management region was the only region that did not overlap with the area of ecological importance. The criteria for creating nature refuges states that there needs to be sufficient conservation values of a significant size – and this may be one reason why the regions did not overlap (Department of Environment and Heritage Protection, 2016). The properties which were most ecologically important were much larger in size than those which were considered most suitable for nature refuges in the social ranking. However, because interest in nature refuges trended towards either extremely disinterested or extremely interested, it is likely that this drove the strong pattern of distribution. Additionally, smaller properties are more likely to have residential land uses, and it is these landowners are more likely to enter in nature refuge agreements than landowners with larger properties who earn a living from their land.

Methodological significance and implications

This analysis is a first, broad glance at a way in which social and ecological data could be combined to achieve management outcomes. There is only so much time within a year, and for this reason this analysis has only focused on a small area in what is fundamentally a hugely diverse area of research. However; when it comes down to management practicality – sometimes it is better to have focused on small-scale research, especially in diverse areas which are under significant threat. In Walter Hill Range, simply assuming all landowners have similar values, objectives, attitudes and beliefs towards management would be a highly unsuccessful management strategy. And yet this is often the way we conduct management, because it is quick and cost-effective. Using only social data to determine focus areas for management is not ideal, because it gives no indication of ecological contribution - how can we know that it is worth investing time and resources here, even though the area appears socially suitable? It is necessary to include ecological variables to determine the properties which are most likely to optimise management

The methodology used in this study is one of its most innovative aspects. Although there are many studies which focus on social or ecological factors (Lynch et al., 2015; Kendal et al., 2015; Brown, 2005; Tambosi, Martensen, Ribeiro & Metzger, 2013; Endter – Wada, Blahna, Krannich & Brunson, 1998; Brown, 2005; Hausmann, Slotow, Burns, & Di Minin, 2016; Ianni & Geneletti, 2010), the major problem in natural resource management is that ecological studies rarely consider social factors, and vice versa (Endter – Wada et al., 1998). A major limiting factor to this has been the concept of spatially identifying social data for overlay with ecological data layers (Brown, 2005). This study is therefore, to the best of our knowledge, unique in that it provides a conceptual methodology for combining these critical factors to allow the identification of socially viable and ecologically important locations for management of rainforest connectivity.

Overall, the methods used in this study achieved the intended purpose – we identified priority properties and regions in which management efforts may be focused. However, this study was limited by time and resources, and thus there are some aspects of the methodology which require further study and have stimulated reflections for future learning in this area. First, the variables used to determine the property rankings were broad – incorporating additional variables could be useful in achieving more specific management objectives. Secondly, the data collection for some social variables was open to ambiguity, and this meant interpreting the results with caution. Third, the calculation of the "potential management" scores was conceptually innovative, and had significant bearing on the results. Fourth, respondent confidentiality affected and in some ways limited how the results could be displayed and interpreted. And finally, the characteristics of the sample population and the non-response rate provide learning for future work in the applied natural resource management field.

Ecological variables for future consideration

Future natural resource management studies could consider incorporating additional variables to address more specific management needs. For example, the inclusion of a connectivity value into the ecological ranking scheme of this study would have allowed us to quantify the contribution of individual properties to the connectivity of the corridor – and this would have helped prioritise for connectivity more explicitly.

A methodology for calculating connectivity values was described by Lin (2008) in which a proximity index metric tool was used to calculate the contribution of individual land parcels to functional connectivity within a landscape. The tool used a formula to calculate a connectivity score for each land parcel within a specified dispersal distance of the focal parcel according to the number of patches it was connected to, the habitat value of the patch, the habitat value of the neighbouring patch, and the least cost edge-to-edge distance between the patch and its neighbour. This formula could be applied to properties within management areas to determine those which are most important to the connectivity of habitat for species. It could also be used to analyse the distribution of land uses which are most suitable for species, or to determine path of least-cost for species depending on elevation or slope. As with all models, this formula is only as good as the estimated variables, and therefore it will only provide robust estimates of connectivity values for well-studied species. Unfortunately, the cassowary is not well-studied– we do not yet have estimates which are robust enough to include in such analyses. However, incorporating a functional connectivity variable for a well-studied species in the ecological rankings of future studies would be interesting and should be considered – it may provide better estimates for the connectivity contribution of patches, and may lead to more ecologically beneficial management outcomes.

Another component not addressed in the ecological rankings was temporal scale. Temporal scale may have been a useful variable for determining the change in ecological value of properties through time. Specifically, temporal scale could be useful in property rankings to identify the current ecological value of properties, and what their future ecological value is if management was improved. From a social perspective, temporal scale could also be used to determine management effort and history. For example, two landowners may have been doing weed management in equally sized areas, but landowner A has been doing it for 10 years whereas landowner B started 4 months ago. Even though the area of management is the same, landowner A has put in more management effort and has a more consistent management history. This could be an important factor for managers when deciding where to allocate resources to ensure the effects are maximised.

Interpretation of results

Interpretation of the results was affected by ambiguity in the social survey responses and participatory mapping components. Particularly, the results for ordinal-scaled responses were taken with care. Because each number is relative, landowners may have interpreted these differently. For example, one landowner might say their interest level is7 and that they are interested, whereas another might also say they are interested and give their interest level a 9. For this reason, it is important to note that the social data informs general as opposed to precise trends in the data. If the data is interpreted in this way, lack of precision is not a severe limiting factor.

Ambiguity in responses was also prevalent within the participatory mapping component of the survey. The prompt for the participatory mapping questions was "draw", which is vague and open to interpretation by landowners –therefore lines, dots and polygons were all used by landowners during participatory mapping. This caused complications when digitising the data into GIS for analysis. For example, some landowners used dots to indicate patches of weeds, whereas some circled the patches. Some landowners drew a line to represent the row of trees they had revegetated, or the edge of the rainforest on which they had done weed management, while other circled these features. Because one intention of the participatory mapping questions was to define the total area on which a landowner was doing an activity, not just the location, this leads to some uncertainty in results. However, error was significantly reduced by having a second interviewer who made notes about the participatory mapping component of the survey whilst the landowner was drawing. Additionally, having recorded the surveys proved invaluable when interpreting this information at a later date. For future studies, using prompts which are more explicit, such as "circle" when trying to determine area, and "place a dot" when trying to determine a location, would be highly beneficial and would help to reduce both interviewer and respondent ambiguity (Brown, 2005).

Calculating potential scores

A strong point in this study was using property area and area of vegetation as a weighting factor, as opposed to simply interest or proportion of vegetation. The benefit to scaling potential values with property size, in the context of this study, is that interest alone is not a good enough measure to determine how best to optimise management. Although a landowner may be extremely interested, if their property is small, it does not necessarily contribute as highly to management as a landowner with a larger property and similar interest.

We used interest and area of interest as variables in the potential calculations because these indicate a landowners' willingness to do land management, as well as their motivation for doing the activity. For example, a landowner wanting to do weed management in rainforest areas is more likely to have rainforest conservation imperatives than a landowner doing weed management in crops. Additionally, weed management in rainforest areas is more likely to be ecologically beneficial for rainforest health than management done in crops or gardens. Perceived importance of the Walter Hill Range and land use were omitted from the ranking because these variables were reflected by the overall "potential" values – potential proved to be a clear indicator of whether landowners interest in management was production or conservation driven.

Confidentiality of Landowners

Unfortunately, the need to maintain landowner confidentiality did somewhat limit the presentation of results in this thesis. Because this is a spatial study, it was difficult not to be able to present maps of the surveyed properties. Particularly, the social, ecological and combined ranking sections would have benefitted from the inclusion of maps. Brown (2005) previously used hotspot analyses to identify regions in which landowners had identified important natural features - and this inspired a solution to the confidentiality limitation. Instead of mapping the importance of individual properties, we decided to map socially and ecologically important “regions” of properties – that is, areas where important properties may be clustered. This form of analysis and presentation also has practical benefits – it provides Terrain NRM with focus areas for management. Terrain NRM may focus community engagement and management efforts in these areas in order to optimise management success. It must be noted that when providing Terrain with results, explicit maps and landowner information will be supplied for those respondents who agreed to grant Terrain NRM this access. In this way, it is ensured that they may contact these critical properties.

Non-response rate

Of the 79 potential landowners who were invited via telephone to participate in the project, most were not interested. The first point of contact between a researcher and the respondent is considered to be most critical to ensuring co-operation, and as a first point of contact, phone calls are not an ideal method (Blom, A. G., & Blohm, M.; reference). Firstly, phone calls make it difficult for researchers to get information across and secondly it is more difficult to legitimise the survey. Caller ID also likely affected non-response rate- social perceptions surrounding phone calls from unknown callers also make it more difficult to gain a respondents trust, and calls from unrecognised numbers are often not answered. Given the time and resources available for the project, phone calls were a necessary first contact point. They also allowed multiple contact attempts, which was critical in an area where landowners were likely to have highly variable work hours. Although the survey sample of 21 respondents does achieve the practical aims of this study, it would be more beneficial to utilise letters as a first point of contact, and to advise landowners they might expect a phone call. This also provides the landowner with the opportunity to read about the project prior to making a decision, and allows them to contact the researcher if they would like additional information.

It must be mentioned that working with Terrain NRM provided some familiarity to respondents, and my prior attendance at a Terrain NRM field day allowed me to meet some respondents prior to phone calls. This was clearly an important factor when arranging interviews – almost all respondents who were familiar with Terrain NRM, or who I had previous contact with, were interested in participating in interviews.

Sample population

Walter Hill Range area has not been extensively studied from a demographic perspective. It is also likely that the project was biased towards those with an interest in the rainforest and in natural resource management. Because the study was applied, the sampling bias was not a severe limiting factor. Firstly, the sample wasn't used to make generalisations about the broader population. Further, the project aimed to identify interested landowners in order to achieve its practical aims, and so from a practical perspective it was not necessary to sample the total population. Finally, those landowners who were uninterested in natural resource management were unlikely to be helpful in achieving the study's practical aims.

Finally, although the small number of respondents did not limit the applicability of results, it did limit how we could spatially analyse the data. Hot-spot and Getis-Ord Gi* analyses could not be completed because they are not reliable when there are <30 features in a layer (ESRI, 2016). Future studies should aim for a sample size of at least 30 landowners in order to conduct statistical spatial analyses.

Future potential and applications

In its entirety, this project presents a first glance at a highly adaptable methodology for optimising management. For the purpose of presenting this methodology, we focused on the Walter Hill Range and broadly on the Southern Cassowary for the ecological analysis. However, with greater information on parameters and more specific management objectives, this methodology could be applied to species management, natural resource management, or used for certain vegetation assemblages/habitats. For example, how can we manage for a species which requires large, connected patches based on the social characteristics of the landscape? What about a species one that needs creeks to travel through? These are important management questions that could be addressed in future research using this method of analysis.

From a practical perspective, the next step for this study is to test the feasibility of the management priorities which have been determined for the Walter Hill Range in this study. This will help to determine if there is good scope for future applications to management, as well as how the methodology may be adapted for future studies. Theoretically, future research based upon the methodological implications and significance identified in this work is required to further develop the theoretical and practical knowledge on combining social and ecological data in GIS. Some potential future areas of research include incorporating better defined variables, such as landscape connectivity to achieve explicit management objectives, reducing ambiguity in results and increasing statistical power so that more robust spatial analyses can be conducted.

Conclusions and Recommendations

Connectivity is important because it facilitates gene flow between populations, movement of animals, migration, access to refugia, dispersal of offspring/propagules, and allows organisms to access a wide range of food and habitat resources (Metcalfe & Lawson, 2015; Tucker, 2000). This study provided a novel method for determining areas for optimised management of connectivity given social suitability and ecological important of properties. Overall, the study was successful in achieving its aims, and the overlap of important properties reinforces this.

There was significant overlap between regions which were highly suitable for management and the ecologically important region within the study area. This suggests that there is good potential for optimising rainforest connectivity management on the surveyed properties within Walter Hill Range. The different interests, values and objectives of the conservation-orientated and incidental management-orientated groups highlight the need for management which will support the needs of diverse private landowners. It is recommended that future management for connectivity of Walter Hill Range be focused in the northern target region, which was both ecologically important and socially suitable for the most popular form of management – incidental management.

There is good potential for future research into combining social-ecological data for a variety of management objectives, including connectivity. Some areas for future research might include incorporating connectivity values into ecological rankings, determining how more robust spatial analyses can be used to quantify target regions for management, and trialling a similar methodology for different management objectives. Overall, this research has the potential to improve the economic feasibility and success of landscape management over diverse areas. Future research is recommended to support the optimisation of landscape management for a variety of objectives.

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Appendix

Appendix 1: Survey

This survey is fully confidential, the information will only be used in an aggregated form and it won't be traceable to you. Feel free to stop the interview at any time. Also, so that I can listen to your answers again later when I'm writing the project report, would it be okay if I record this interview?

The interview today is for my project with James Cook Uni and Terrain NRM. Terrain work with the community on natural resource management in the region. The study area we are looking at is here *SHOW MAP*, which is part of the Walter Hill Range.

Terrain is working with JCU to meet landholders in this area so that we can gain an insight into your values and objectives, and also gain a better understanding of what resources you might require if you would like to conserve any rainforest, habitat or wildlife on your property through activities such as weed management or revegetation.

GENERAL FEATURES OF LAND: Firstly I'm going to talk with you about some of the general features of your land and your role in managing these.

1. What do you believe are your roles and responsibilities in regards to managing natural resources on your land?
2. What are the current land uses on your land? Can you please draw and label these on MAP 1 provided?
3. Do you want to significantly change your land use plans in the next 5 years? Could you please draw your intended land use plans on MAP 2?
4. What are the natural features on your land that you believe are most important for wildlife? Could you please draw these natural features onto MAP 3 provided? *prompt for additional features*

1-
2-
3-

AWARENESS OF RAINFOREST AND HABITAT CORRIDORS: Next I'm going to ask you a few questions about rainforest and habitat corridors.

5. Before we gave you any information about this project, were you aware that your property was part of an important rainforest and habitat corridor? *IF NO, SKIP NEXT QUESTION*
6. How did you find out about your property being a part of this rainforest and habitat corridor?

I've already given you some information about Walter Hill Range, however before I go onto the next questions I'll talk a bit about the significance of the corridor and provide a definition of rainforest corridors to use for the purpose of this interview.

Walter Hill Range is part of the longest and widest lowlands-highlands rainforest corridor in Australia, running from Mission Beach to the Southern Atherton Tablelands. The rainforest in the corridor is important for the habitat and movement of many rainforest plants and animals.

For the purpose of this interview, by "rainforest and habitat corridors" we mean areas of vegetation that include native rainforest plants and that allow rainforest animals to move through the area. Now I'm going to ask you just a few more questions about the Walter Hill Range corridor.

7. On a scale of 1-10, how important do you think it is to maintain the Walter Hill Range corridor? 1 is not important and 10 is extremely important.
8. Why do you think it is important/isn't important?

1-
2-
3-

9. On a scale of 1-10, how important do you think your land is for maintaining the Walter Hill Range corridor? 1 is not important and 10 is extremely important.
10. Why do you believe your land is important/isn't important?

1-
2-
3-

ACTIVITIES TO MAINTAIN/IMPROVE RAINFOREST AND HABITAT CORRIDORS: I'm now going to talk with you about activities that you've done on your land that may have had (or intended to have) positive outcomes for rainforest corridors, and then ask about your interest in doing any of these in the future. The activities are weed management, pest management, retaining existing rainforest and habitat corridors, doing revegetation and creating a nature refuge.

WEED MANAGEMENT: I'll start with weed management.

11. In the last 10 years, have you ever done any weed management activities on your land that have had positive outcomes for rainforest or habitat?
12. What activities did you do? Can you please draw and label these on MAP 4 in Blue Pen provided? *Prompt for what the weed was, what method they used, and how much time they spent on the activity*
13. What was the purpose of doing the activity? *prompt for each activity*
14. On a scale of 1 to 10 what was the outcome of doing this activity? 1 indicates that there was no change in the weeds, and 10 indicates that weeds were significantly removed. *prompt for each activity*
15. Why do you think the activity worked/didn't work? *prompt for each activity*
16. Do you currently have a formal weed management plan?
17. How did you find out about weeds and doing weed control?
18. If you had all the resources, on a scale of 1 to 10, how interested would you be in doing weed management activities on your land, to improve rainforest corridors? 1 is not interested and 10 is extremely interested. *IF NOT INTERESTED, SKIP 20 & 21, & GO TO 22*
19. Why are you interested or not interested?
20. Where on your land would you be willing to do weed management if you had all the resources? Please draw on MAP 4 in red pen provided.
21. Are there any barriers that limit your interest in doing weed management activities?
22. What types of incentives or support might you require to do weed management activities on your land? It could be anything from materials, information, recognition and monetary support to labour. *prompt for what info*

PEST MANAGEMENT: Next I'm going to ask you a few questions about pest management.

23. In the last 10 years, have you ever done any pest management activities on your land that have had positive outcomes for rainforest and habitat corridors?
24. What activities did you do? Can you please draw and label these on MAP 5 in blue pen provided? *Prompt for what the pest was, what method they used, and how much time they spent on the activity*
25. What was the purpose of doing the activity? *prompt for each activity*
26. On a scale of 1 to 10 what was the outcome of doing this activity? 1 indicates that there was no change in pests, 10 indicates that pests were significantly reduced. *prompt for each activity*
27. Why did the activity work/not work? *prompt for each activity*
28. Do you currently have a formal pest management plan?
29. How did you find out about pests and pest control?

30. If you had all resources, on a scale of 1 to 10, how interested would you be in doing pest management activities on your land to improve rainforest corridors? 1 is not interested and 10 is extremely interested. *IF NOT INTERESTED, SKIP 32 & 33, & GO TO 34*
31. Why are you interested or not interested?
32. Where on your property would you be willing to do pest management if you had the resources? Please draw on MAP 5 in red pen provided.
33. What barriers may limit your interest in doing pest management activities?
34. What types of incentives or support might you require to do pest management activities on your property? By incentives and support I mean anything from materials, information, recognition and monetary support to labour. *prompt for what info*

RETAINING EXISITNG RAINFOREST AND HABITAT CORRIDORS: Next I will talk with you about retaining existing rainforest and habitat corridors on your land.

35. Assuming all the resources are available, on a scale of 1 to 10, how comfortable would you be in keeping the existing rainforest and habitat corridors on your land? 1 is not comfortable and 10 is extremely comfortable. *not maintaining, just not removing**IF NOT INTERESTED, SKIP 37 & 38, & GO TO 39*
36. Why are you not interested?
37. Where on your land would you be willing to keep rainforest and habitat corridors? Please draw on MAP 6 in red pen provided.
38. What barriers may limit your interest in keeping rainforest and habitat corridors?
39. What types of incentives and support might you require to keep rainforest and habitat corridors on your land? It can be anything from materials, information, recognition and monetary support to labour. *prompt for what info*

REVEGETATION: Next I'm going to talk with you about expanding habitat and corridors on your property by doing revegetation.

40. In the last 10 years, have you ever done any revegetation on your land which has had positive outcomes for rainforest corridors?
41. What area did you revegetate? Can you please draw and label where you did revegetation on MAP 7 in blue pen provided? *Prompt for what plants were revegetated and how much time they spent on revegetation*
42. What was the purpose of doing the revegetation? *prompt for each area*
43. On a scale of 1 to 10 what was the outcome of doing revegetation? 1 indicates that the revegetation was unsuccessful (i.e. trees did not survive), 10 indicates that the revegetation was extremely successful (trees survived and more habitat was created). *prompt for each area*

44. Why did the activity work/not work? *prompt for each area*
45. Assuming you have all the resources you need, on a scale of 1 to 10, how interested would you be in revegetating to expand rainforest and habitat corridors on your land? 1 is not interested and 10 is extremely interested. *IF NOT INTERESTED, SKIP 47 & 48, & GO TO 49*
46. Why are you interested or not interested?
47. If all the necessary resources were available, which areas of your land would you be willing to revegetate? Please draw on MAP 7 in red pen provided.
48. What barriers may limit your interest in doing any revegetation?
49. What types of incentives and support might you require to do any revegetation? By incentives and support I mean anything from materials, information, recognition and monetary support to labour. *prompt for what info*

NATURE REFUGE: Next I'm going to talk with you about protecting rainforest and habitat corridors on your property in a nature refuge.

50. Have you ever heard of nature refuges?

A nature refuge is a voluntary agreement that a landowner can make with the state government if their land qualifies as having outstanding conservation significance. A nature refuge agreement means that the current landowner and all subsequent owners of the land agree to protect a certain part of the property like a private national park, while allowing compatible and sustainable land uses to continue. Landholders with a nature refuge continue to own and manage their land for enjoyment and /or to generate an income.

51. On a scale of 1 to 10, how comfortable would you be in considering a nature refuge on part of your land, if you had all the resources you needed? 1 is not interested and 10 is extremely interested. *IF NOT INTERESTED, SKIP 53 & 54, & GO TO 55*
52. Why are you interested or not interested?
53. Which part, if any, of your land would you consider creating a nature refuge on? Please draw on MAP 8 in red pen provided.
54. What barriers may limit your interest in creating a nature refuge?
55. What types of incentives and support might you require to create a nature refuge on part of your land? It can be anything from materials, information, recognition and monetary support to labour. This might also include a one-off or ongoing payment. *prompt for what info*

OTHER ACTIVITIES:

56. Are there any other activities that I haven't mentioned that you are doing on your property that may be beneficial for rainforest and habitat corridors? Please draw on MAP 9 in red pen provided

57. Are there any other activities or resources that might assist you in maintaining or improving rainforest on your property?

DEMOGRAPHIC FACTORS: I'm now going to talk with you about some demographic factors such as economics, your occupation and your property's tenure.

58. What is the main use of your land?
    - ☐ Residence
    - ☐ Business (Family)
    - ☐ Business (Other)
    - ☐ Other (Please specify)
59. How long have you managed this land?
60. How many years has the land been in the...
    a) Current ownership?
    b) Family ownership?
    c) Do you wish for the land to continue in its current ownership?
    d) Do you intend to pass your land on to family?
61. What is the occupation from which your household receives its primary income?
62. On a scale of 1 to 10, how much does this property contribute to your income? 1 indicates it does not contribute at all, 5 indicates it contributes approximately half, 10 indicates it contributes fully to your household income.
    a) What land use does the majority of this income come from?

CASSOWARY QUESTIONS: Now I'm going to ask some brief questions about cassowaries in your area. This information will contribute to our understanding of cassowary connectivity and distribution and is not intended to target cassowary presence on specific properties. The information will be kept fully confidential.

63. What significant wildlife species have you seen on or near your property in the last 5 years? *If they don't list cassowaries, prompt*
64. Where did you see the cassowary/cassowaries? Please draw on MAP 10.
65. Please place a line on MAP 10 showing the cassowary's movement pathway.
66. Were the cassowaries juveniles (or chicks), adolescents, or mature individuals?
67. If possible, what time of day and time of year did you see the cassowaries/each cassowary?
68. How many times have you seen cassowaries on your property in the last year?
69. Can you tell the difference between individual cassowaries? If so, how many different cassowaries have you seen on your property?
70. Do you think the cassowary population is increasing or decreasing in your area? Why is it increasing or decreasing?

FINAL QUESTIONS: Thanks for your time today and for helping me with my project, it's been great having a chat with you. I've just got a few more questions to finalise the survey.

71. Would you be interested in having any more discussions at a later date about land management and wildlife?
72. Would you be willing to be contacted by Terrain in regards to follow-up research for this project?
    a) If yes, I'd need to share your answers to the survey with Terrain – would that be okay?
73. Would you be willing to be contacted by James Cook University in regards to follow up research for this project?
74. When completed, would you like to receive a copy of the project report? *If yes, get e-mail*