Waikato Regional Council Technical Report 2022/08

Using the Kahikatea Green Wheel to guide management of kahikatea fragments in the Waikato region: a technical guide to spatial analyses

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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April 2022

Document #: 16540746

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Using the kahikatea Green Wheel to guide management of Kahikatea fragments in the Waikato Region: a technical guide to spatial analyses

Prepared for: Waikato Regional Council

February 2022

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Contract Report: LC5018

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Contents

Summary

Background

- Kahikatea (*Dacrycarpus dacrydioides*) forest in the Waikato Region has been reduced to c. 1% of its pre-human area.
- Almost all the remaining habitat fragments occur on private land, and are highly vulnerable to weed invasion, mammalian herbivores, and species loss due to the small size and isolation.
- Consequently, Waikato Regional Council has produced an assessment tool – the Kahikatea Green Wheel (KGW) - designed to help private landowners monitor the condition of kahikatea fragments on their land.
- Designing the management interventions needed to enhance fragment resilience and connectivity to neighbouring woody habitat requires geospatial analyses, beyond the capacity of most landowners.

Objectives

- To quantify the potential benefits to local resilience for kahikatea fragments across the Waikato Region of buffer plantings which fill the minimum bounding convex hull of existing fragments.
- To quantify the benefits to connectivity for kahikatea fragments in the Waitoa catchment from planting riparian buffers (see Figures 7-9 for illustrations and an example).

Conclusions

- Resilience of over 95% of kahikatea fragments in the Waikato Region is currently at risk due to their small area and small percentage of core habitat. Fencing and buffer planting to achieve minimum bounding convex hulls will not markedly increase total habitat area of individual fragments but could considerably improve the amount of core habitat in many fragments.
- Most kahikatea fragments in the Waikato Region currently have a compact shape (low shape index). However, buffer plantings and fencing to achieve minimum bounding convex hulls could result in 95% of fragments achieving the maximum possible rank for shape.
- There is relatively little (<25%) indigenous habitat in the immediate neighbourhood of most kahikatea fragments in the Waikato Region. However, most fragments are reasonably close to (within 2000m of) large patches of indigenous habitat.
- Riparian buffer planting widths of at least 25 m in the Waitoa catchment would greatly enhance connectivity, but would not markedly improve indigenous habitat in the immediate neighbourhoods of most kahikatea fragments.

Recommendations

- Buffer plantings and fencing to achieve minimum bounding convex hulls should be encouraged. These efforts should be prioritised in fragments with the greatest potential gains in core habitat area and shape index.
- A long-term goal of implementing 25-m riparian buffer plantings along the Waitoa River from Waharoa northward and along the small tributary immediately east of Waharoa should be promoted to enhance connectivity of kahikatea fragments in the Waitoa catchment.
- Potential benefits of riparian buffer plantings for connectivity should be examined in other catchments or sub-catchments in the Waikato Region containing large numbers of kahikatea fragments.

1 Introduction

This report is provided as additional documentation to accompany spatial analyses examining the impact of potential restoration scenarios and the resilience and connectivity of kahikatea forest fragments in the Waikato Region.

2 Background

The Regional Policy Statement (RPS) for the Waikato Region prioritises: "the re-creation and restoration of habitats and connectivity between habitats (section11.1 Maintain or enhance indigenous biodiversity); particularly for, (in Table 11-1) "…indigenous vegetation or habitat type that is under-represented (20% or less of its known or likely original extent remaining) in an Ecological District, or Ecological Region, or nationally".[1] Further, the Waikato Regional Council (WRC) is responsible for monitoring forest fragmentation under the 2021–2031 Long Term Plan.[2]

Kahikatea forest in the Waikato Region has been reduced to c. 1% of its pre-human area (Fig. 1). Almost all the remaining fragments occur on private land, and are highly vulnerable to weed invasion, mammalian herbivores and species loss due to their small size. Consequently, Waikato Regional Council has produced an assessment tool – the Kahikatea Green Wheel (KGW) - designed to help private landowners monitor the condition of kahikatea fragments on their land and choosing management interventions to improve condition (Denyer & Deng 2019). A description on of the tool and various background materials are now publicly available on the Waikato Regional Council website[3].

For certain attributes (i.e. occurrence and abundance of invasive plants, impacts of livestock), choosing appropriate management interventions is relatively straightforward. For other attributes (i.e. edge effects and connectivity to neighbouring woody habitat), appropriate management interventions are less obvious.

Waikato Regional Council is supporting "Connecting the Waitoa" project, a community-led initiative aimed at linking indigenous ecosystems and communities within the Waitoa River catchment. This catchment contains one of the highest densities of kahikatea forest remnants in the Waikato. Further, Leathwick (2016)[4] identified several high-value remnants in the Waitoa catchment as high priority for restoration efforts. Thus, Connecting the

[1] Waikato Regional Policy Statement (RPS)

[2] Waikato Regional Council Long Term Plan, and https://waikatoregion.govt.nz/assets/WRC/2021-2031-LTP.pdf

[3] Kahikatea Green Wheel | Waikato Regional Council

[4] Leathwick J 2016. Notes on indigenous forest remnants on the alluvial floodplains of the Waihou-Piako zone, Waikato.

Waitoa provides an excellent opportunity to apply the KWG in a real-world landscape-scale ecological restoration project.

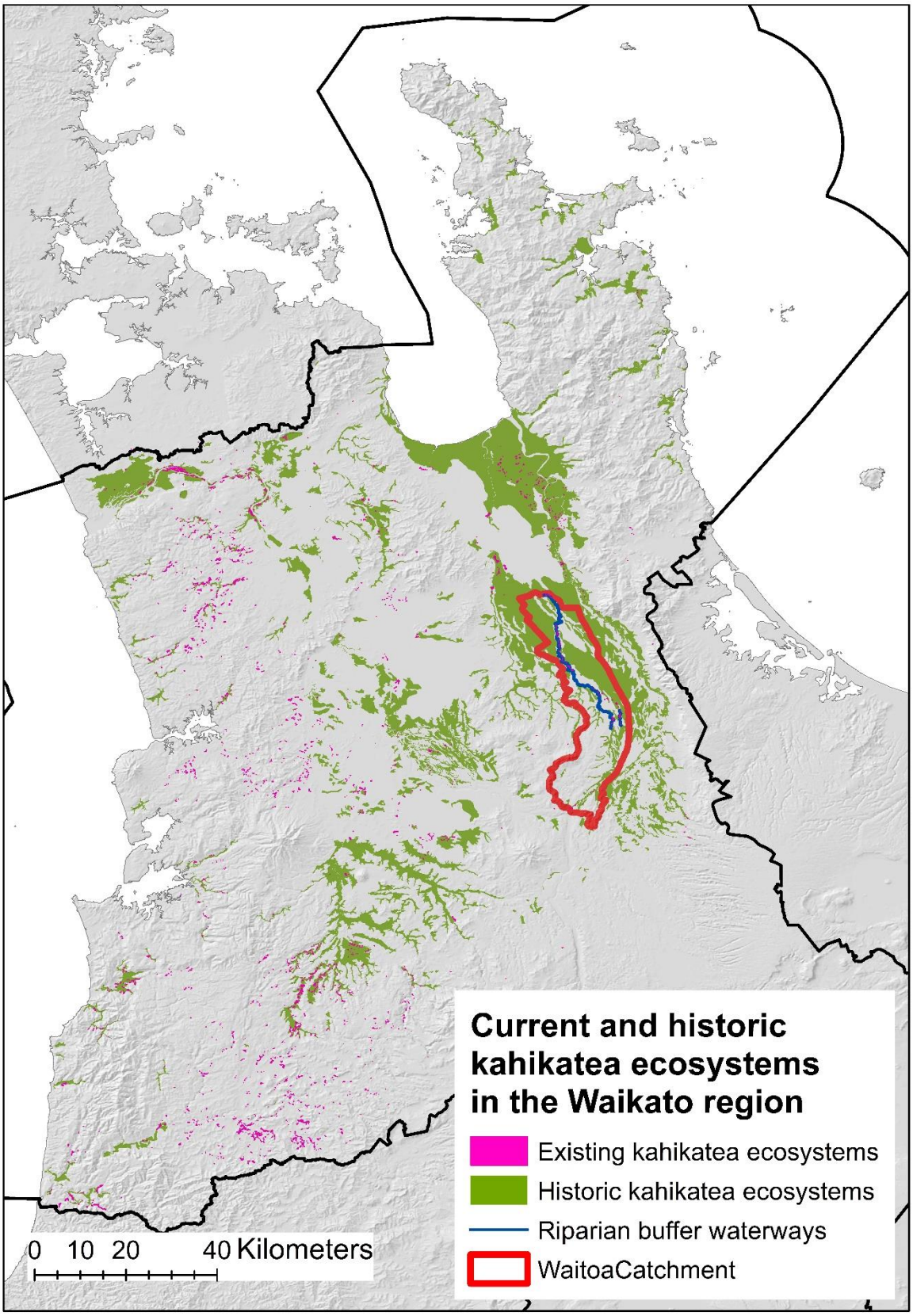

Figure 1. Existing and historic distribution of kahikatea-dominated ecosystems in the Waikato Region.

Forest fragment area, amount of core habitat, and perimeter to area ratio are key determinants of edge effects. Edge effects can compromise the resilience of forest fragments by altering microclimatic conditions and increasing their vulnerability to invasive species. The KGW contains three attributes related to local resilience:

1 fragment area "GW_12_SIZE_RANK"

2 proportion of fragment area more than 60m from the edge "GW_14_INTERIOR_RANK"

3 a "shape index" which expresses the actual perimeter of forest fragments as a ratio of the minimum possible perimeter for a fragment of equal area "GW_13_SHAPE_RANK" (Table 1).

Connections to nearby indigenous-dominated ecosystems in the landscape are considered important for the long-term viability of native(?) animal and plant populations withing fragments. The KGW contains two attributes related to connectivity:

1 percentage of indigenous forest or scrub landcover within a 1km radius "GW_24_LANDSCAPE_RANK"

2 Distance to indigenous-dominated habitats greater than 25 hectares in area "GW_25_HABITAT_LINKS_RANK" (Table 1).

Table 1. Kahikatea Green Wheel attributes examined in this study

GW_12_SIZE_RANK	Green Wheel size rank value	Possible values: (1) The kahikatea forest area is < 1 ha; (2) The kahikatea forest area is 1 to <5 ha; (3) The kahikatea forest area is 5 to <10 ha; (4) The kahikatea forest area is 10 to <20 ha; (5) The kahikatea forest area is 20 ha or more
GW_13_SHAPE_RANK	Green Wheel shape index rank	Possible values: (1) Shape index is 3 or more (very convoluted or narrow); (2) Shape index is 2.5 to <3 (somewhat convoluted); (3) Shape index is 2 to <2.5 (blocky but stretched out); (4) Shape index is 1.5 to <2 (oval or round with some slight protrusions); (5) Shape index is less than 1.5 (very round or square)
GW_14_INTERIOR_RANK	Green Wheel forest interior rank	Possible values: (1) None of the kahikatea vegetation is more than 60 m from a native forest edge; (2) Less than 10% of the kahikatea vegetation is more than 60 m from a native forest edge; (3) From 10 up to 25% of the kahikatea vegetation is more than 60 m from a native forest edge; (4) From 25 up to 30% of the kahikatea vegetation is more than 60 m from a native forest edge; (5) 30% or more of the kahikatea vegetation is more than 60 m from a native forest edge.

GW_24_LANDSCAPE_RANK	Green Wheel landscape matrix rank	Possible values: (1) There is no indigenous forest or scrub within a 1-km radius of the site; (2) Less than 25% of the land within a 1-km radius of the site is in indigenous forest or scrub; (3) From 25 up to 50% of the land within a 1-km radius of the site is in indigenous forest or scrub (4) From 50 up to 75% of the land within a 1-km radius of the site is in indigenous forest or scrub; (5) 75% or more of the land within a 1 km radius of the site is in indigenous forest or scrub.
GW_25_HABITAT_LINKS_RANK	Green Wheel habitat links – terrestrial	Possible values: (1) Site is 4 km or more from another patch of indigenous forest and/or scrub > 25 hectares; (2) Site is from 2 up to 4 km of another patch of indigenous forest and/or scrub > 25 hectares; (3) Site is from 500 m up to 2 km from another patch of indigenous forest and/or scrub > 25 hectares; (4) Site is from 100 up to 500 m of another patch of indigenous forest and/or scrub > 25 hectares; (5) Site is < 100 m from another patch of indigenous forest > 25 hectares.

3 Objectives

- To quantify the potential benefits to local resilience for kahikatea fragments across the Waikato Region of buffer plantings filling the minimum bounding convex hull of existing fragments (see Fig. 3 for an example).
- To quantify the benefits to connectivity for kahikatea fragments in the Waitoa catchment from planting riparian buffers (see Figures 7-9 for illustrations and an example)

4 Methods

Below we outline the main components of the proposal and the potential methodology for each of them. Figure 2 outlines the proposed workflow.

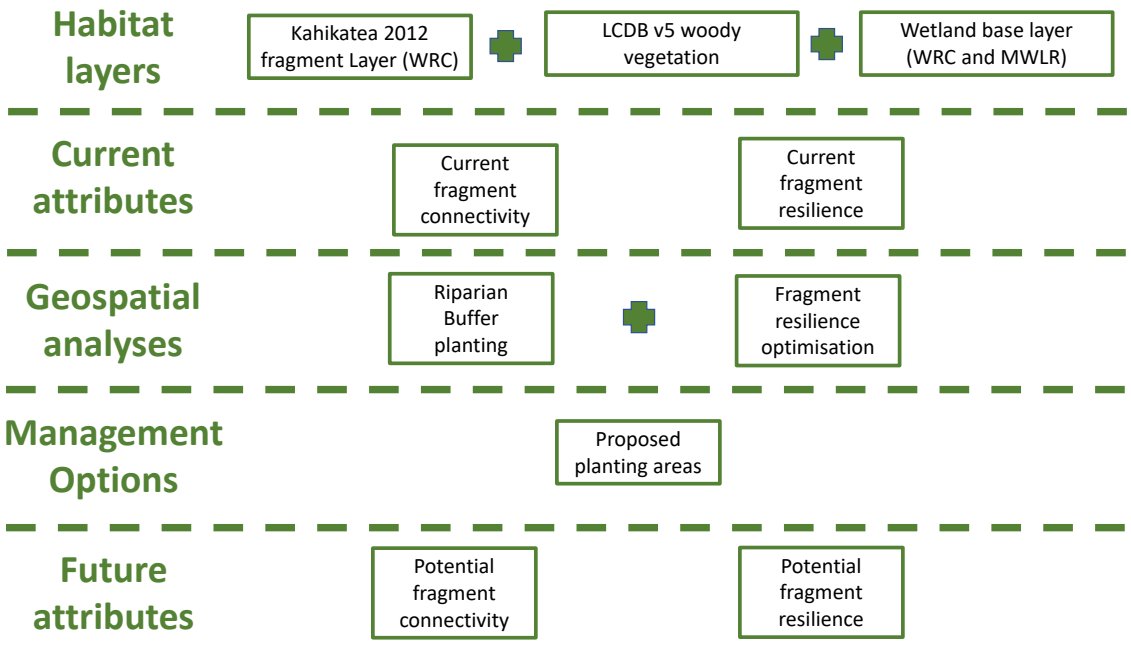

Figure 2. Schematic workflow for proposed analyses.

We begin by combining the kahikatea fragment base layer (2012 version) with woody vegetation polygons in the recently-updated LCDB v5 and the digitised wetland layer (produced by Manaaki Whenua – Landcare Research for WRC) into a single vegetation layer, from which we calculate the current connectivity and resilience values for each kahikatea fragment. We then perform geospatial analyses to alter the combined vegetation layer according to restoration planting scenarios. Finally, we calculate new resilience and connectivity values for the altered vegetation layer.

The three habitat base layers were combined using the 'Merge' and 'Dissolve' tools. LCDB v5[5] classes dominated by indigenous woody species were included in defining 'existing habitat'. All spatial analyses were performed using Model Builder in ARC GIS Desktop 10.5. All models have been provided to the Waikato Regional Council as an ARC GIS Toolbox", so that the analyses performed in this study may be repeated in future.

[5] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

4.1 Optimising kahikatea fragment resilience

We generated a spatially-explicit solution for all woody habitat areas containing kahikatea-dominated forests (as defined by the WRC kahikatea fragment layer) in the Waikato Region. This used the 'minimum bounding geometry' tool in ARC GIS Desktop 10.5 to generate convex hulls (see Fig. 3) linking points at the extremities to eliminate any 'negative space' between them. We recorded current and potential values for KGW attributes related to resilience (GW 12-14).

Fragment area and perimeter for existing habitat and convex hulls were estimated using the "Add Geometry Attributes" tool. The percentage of core habitat was calculated by creating a 60m internal buffer using the "Buffer" tool with a buffer distance of 60m and selecting the "outside only" option. Core habitat area was estimated by subtracting the area of this internal buffer from the total fragment area.

The minimum possible perimeter length was calculated as the circumference of a circle with an area equal to that of the fragment, using the following expression:

$$Perimeter_{min} = 2\pi \left[Area \frac{10000}{\pi} \right]^{0.5}$$

where Area is expressed in hectares and perimeter in metres. Shape index was then estimated as the ratio of actual to minimum possible perimeter.

4.2 Improving the connectivity of kahikatea fragments in the Waitoa catchment

We explored the benefits for kahikatea fragment area and connectivity to larger areas of woody habitat (as quantified in the KWG) of planted riparian buffers of different widths (5 m to 100 m). This is a sensible option as it is both conceptually and computationally quite simple and much of the remnant kahikatea forest in the Waitoa catchment occurs along, or near, these two waterways. We performed these analyses assuming that management to enhance fragment shape (i.e. fencing and planting to achieve convex hulls generated in 4.1) was undertaken We recorded current and potential values for KGW attributes related to connectivity (GW 24 and 25).

Riparian buffer planting scenarios were simulated by generating buffers for selected river and stream reaches in the Waitoa catchment using the 'Buffer' tool (see Figs 7 and 8). We generated buffers of 5, 10, 15, 20, 25, 30, 40, 50, 75, and 100 metres. New habitat layers were generated for each scenario by combining riparian buffers with the existing habitat layer via the 'Merge' and 'Dissolve' tools.

Percentage habitat within a 1-km radius (GW 24) of each fragment was estimated by generating a 1-km buffer around the convex hull. This buffer was then intersected with the habitat layer for each riparian buffer planting scenario (using the 'Intersect' tool) to obtain the amount of habitat within the 1-km buffer. This area was then divided by the buffer area (which varied according to fragment size and shape) to obtain the percentage of habitat within the buffer.

Distance to nearest habitat patch greater than 25 ha in area was estimated using the 'Near' tool. To achieve this, we removed all habitat patches ≤25 hectares in area from the habitat layer for each riparian buffer planting scenario. We then applied the 'Simplify Polygons' tool to the resulting habitat layers to reduce the number of vertices for each polygon (with 5-m simplification tolerance), since applying the Near tool to large numbers of complex polygons is not computationally feasible. We used the Near tool to calculate the distance from each fragment to the nearest habitat polygon.

5 Results

5.1 Resilience and connectivity of kahikatea fragments in the Waikato region

Figure 3 provides an example of the effectiveness of buffer plantings in achieving the minimum bounding convex hull on resilience-related Green Wheel attributes. In this example, buffer planting does not alter the area rank (GW 12), but does shift the shape rank (GW 13) from 3 to 5 and the interior rank (GW 14) from 2 to 5.

Less than 4% of kahikatea fragments in the Waikato Region were greater than 5 hectares in area (had an area – GW 12 – rank of 3 or more, Fig. 4). Buffer plantings to achieve the minimum bounding convex hull had very little impact on fragment area or area rank. 5% of fragments had an interior – GW 14 - rank of 3 or more and buffer plantings increased this to 12%. 62% of fragments had a shape rank – GW 13 – of 5 and buffer planting increased this to 96% (Fig. 5). 23% of fragments had a landscape matrix rank – GW 24 – of 3 or more, while 64% of fragments had a habitat links rank – GW 25 – of 3 or more (Fig. 6).

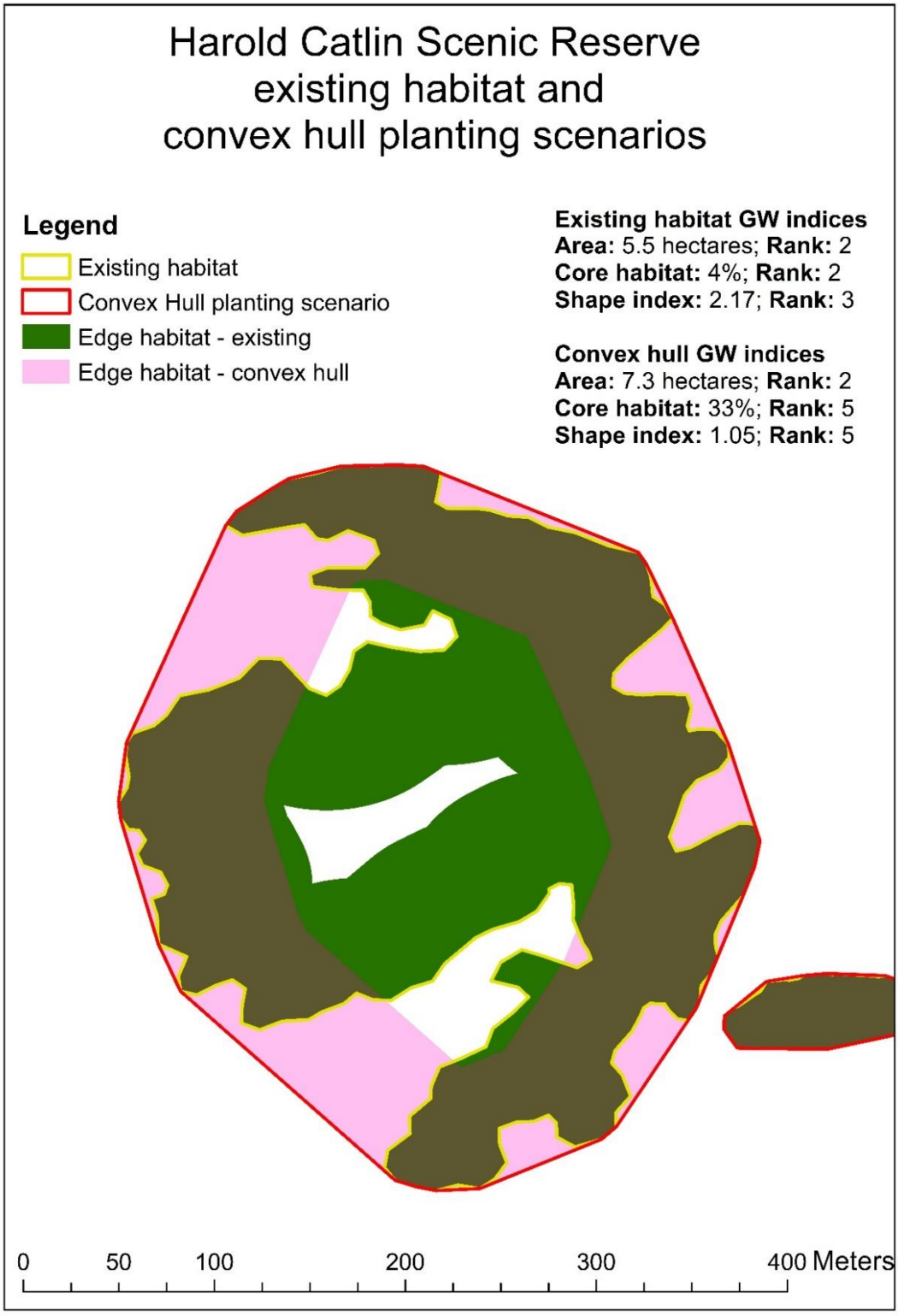

Figure 3. An example of benefits to resilience-related KGW attributes – area (GW 12), core habitat area percentage (GW 14) and the shape index (GW 13) – from buffer plantings to achieve the minimum bounding convex hull for existing kahikatea fragments.

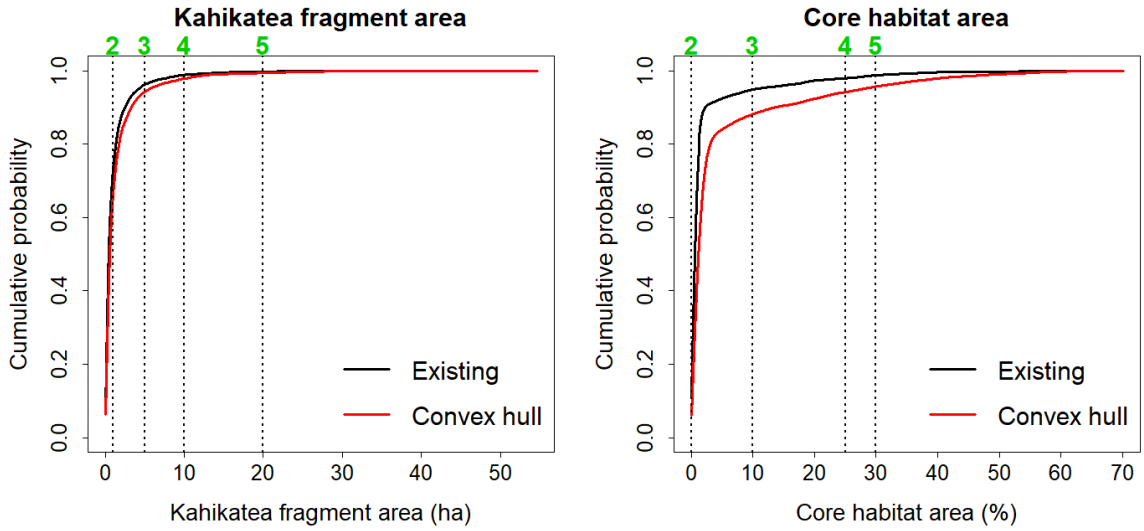

Figure 4. Cumulative probability functions for fragment area (GW 12) and core habitat area percentage (GW 14) for existing kahikatea fragments and with buffer plantings to achieve the minimum bounding convex hull. Green numbers and black dotted lines indicate boundary values for Green Wheel ranks.

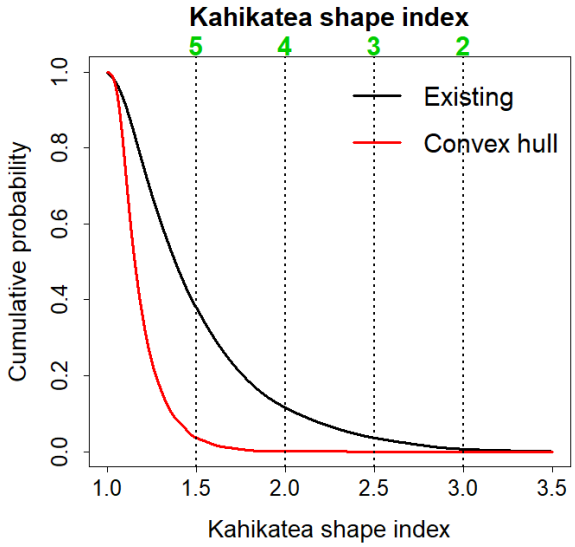

Figure 5. Cumulative probability functions for shape index (GW 13) for existing kahikatea fragments and with buffer plantings to achieve the minimum bounding convex hull. Green numbers and black dotted lines indicate boundary values for Green Wheel ranks.

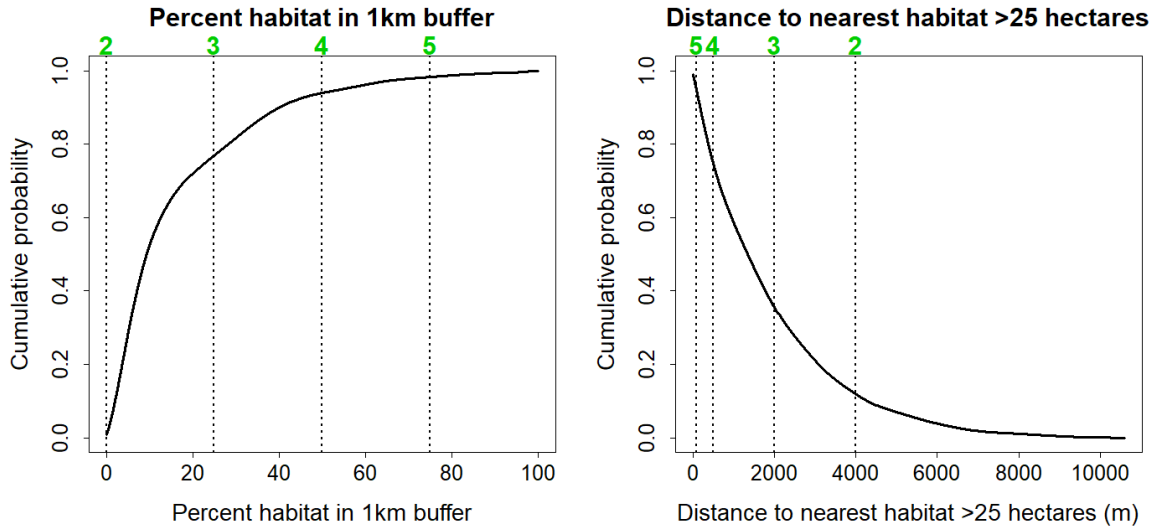

Figure 6. Cumulative probability functions for percent indigenous woody habitat within a 1-km buffer (GW 24) and distance to nearest habitat patch greater than 25 hectares in area (GW 25) for existing kahikatea fragments across the entire Waikato Region. Green numbers and black dotted lines indicate boundary values for Green Wheel ranks.

5.2 Riparian buffer planting and connectivity of kahikatea fragments in the Waitoa catchment

Figure 7 shows that the vast majority of kahikatea fragments in the Waitoa catchment occur in areas where kahikatea ecosystems are believed to have occurred in pre-human times. It also shows that most fragments occur in close proximity either to the main stem of the Waitoa River or the small un-named stream east of Waharoa. Figure 8 illustrates how a riparian buffer planting strategy would increase connectivity between fragments, using the fragments near Waharoa as an example. Figure 9 provides an example of how riparian buffer planting affects ranking for Green Wheel attributes linked to connectivity (GW 24 and GW 25).

The median value of percentage of habitat within a 1-km radius of each fragment increased linearly with riparian buffer planting width (Fig. 10). However, with riparian buffer planting widths of <100 metres, 95% of fragments in the Waitoa had a landscape matrix (GW 24) rank of 2 or less. With existing habitat, most fragments in the Waitoa were more than 4,000 m from the nearest habitat patch >25 hectares in area (i.e. had a GW 25 rank of 1). With a riparian buffer planting width of ≥5 metres, most fragments had a GW 25 rank of 5. With a riparian buffer width of ≥25 metres, 95% of fragments in the Waitoa catchment had a GW 25 rank of 3 or more.

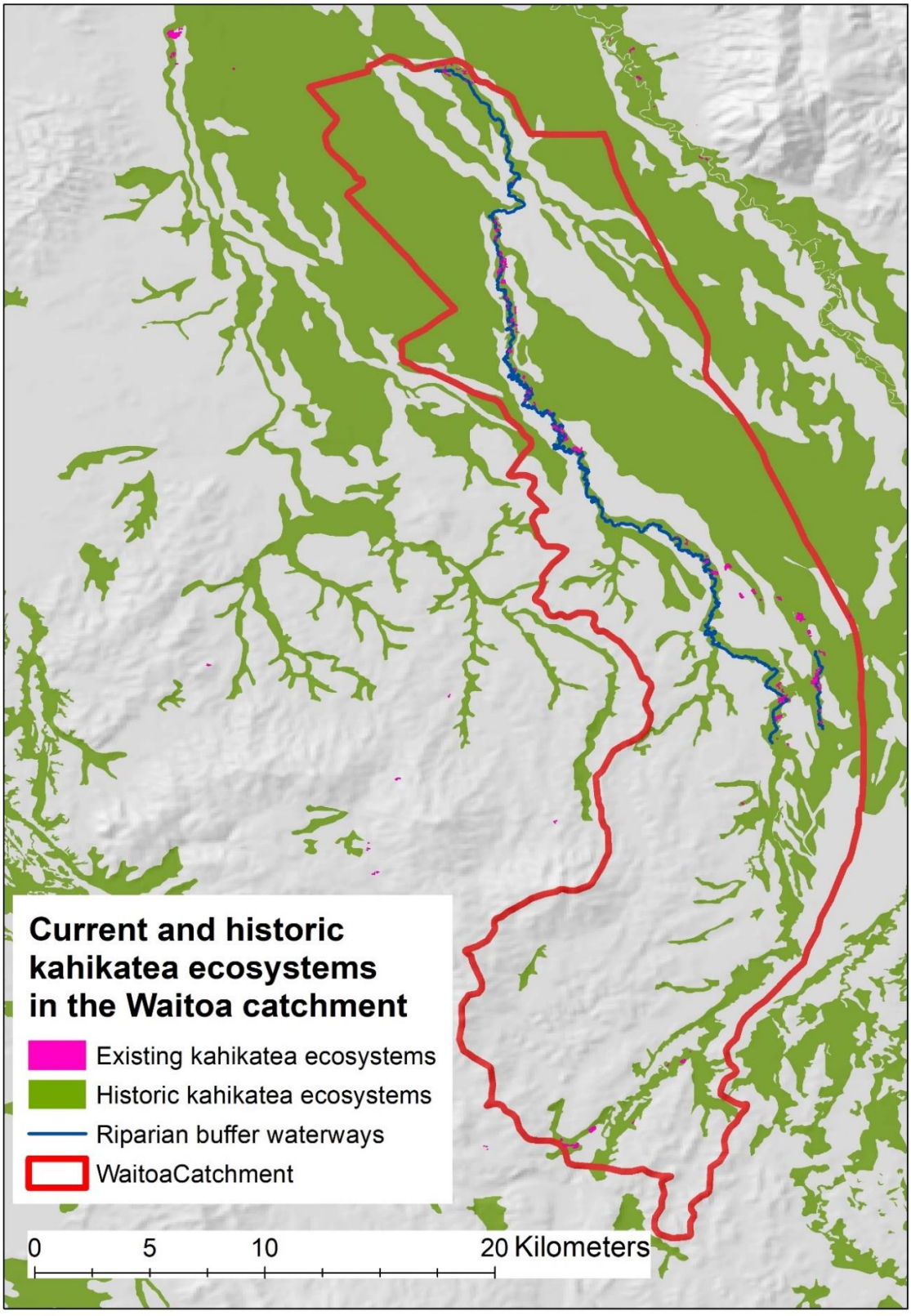

Figure 7. Existing and historic kahikatea ecosystems in the Waitoa catchment.

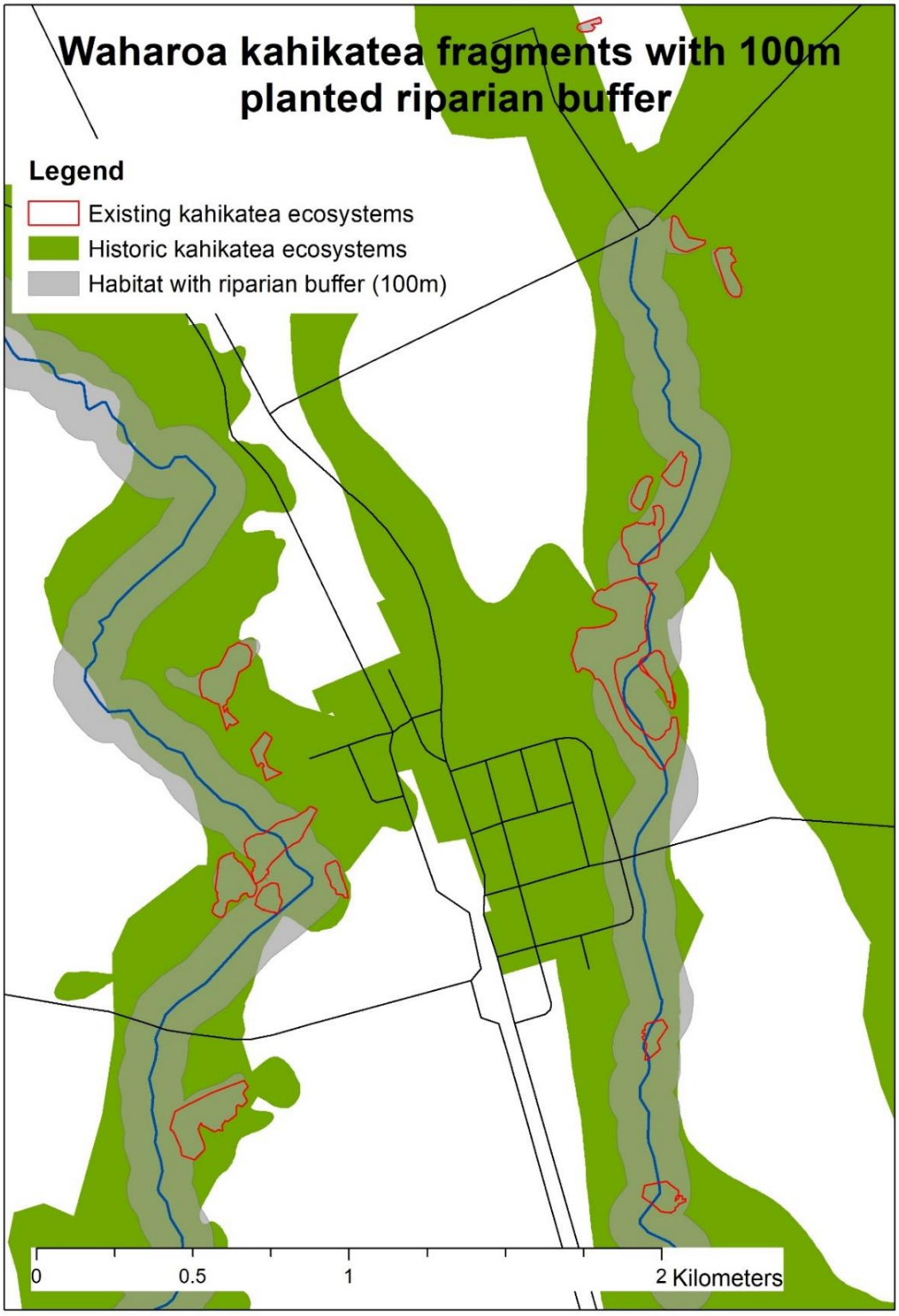

Figure 8. Existing and historic kahikatea ecosystems and potential indigenous woody habitat with a riparian buffer planting width of 100 m.

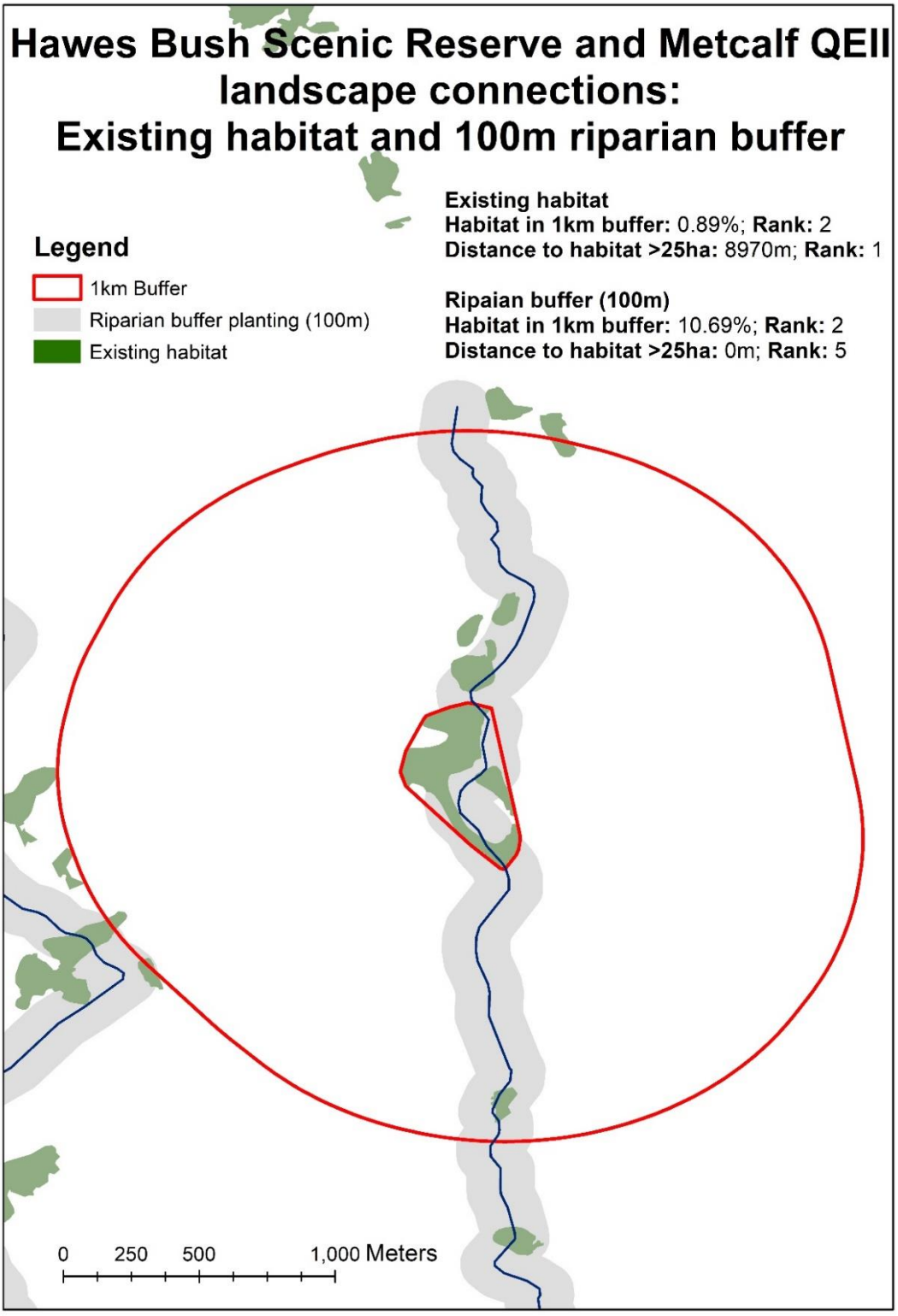

Figure 9. Example of riparian buffer planting effects on Green Wheel attributes linked to connectivity.

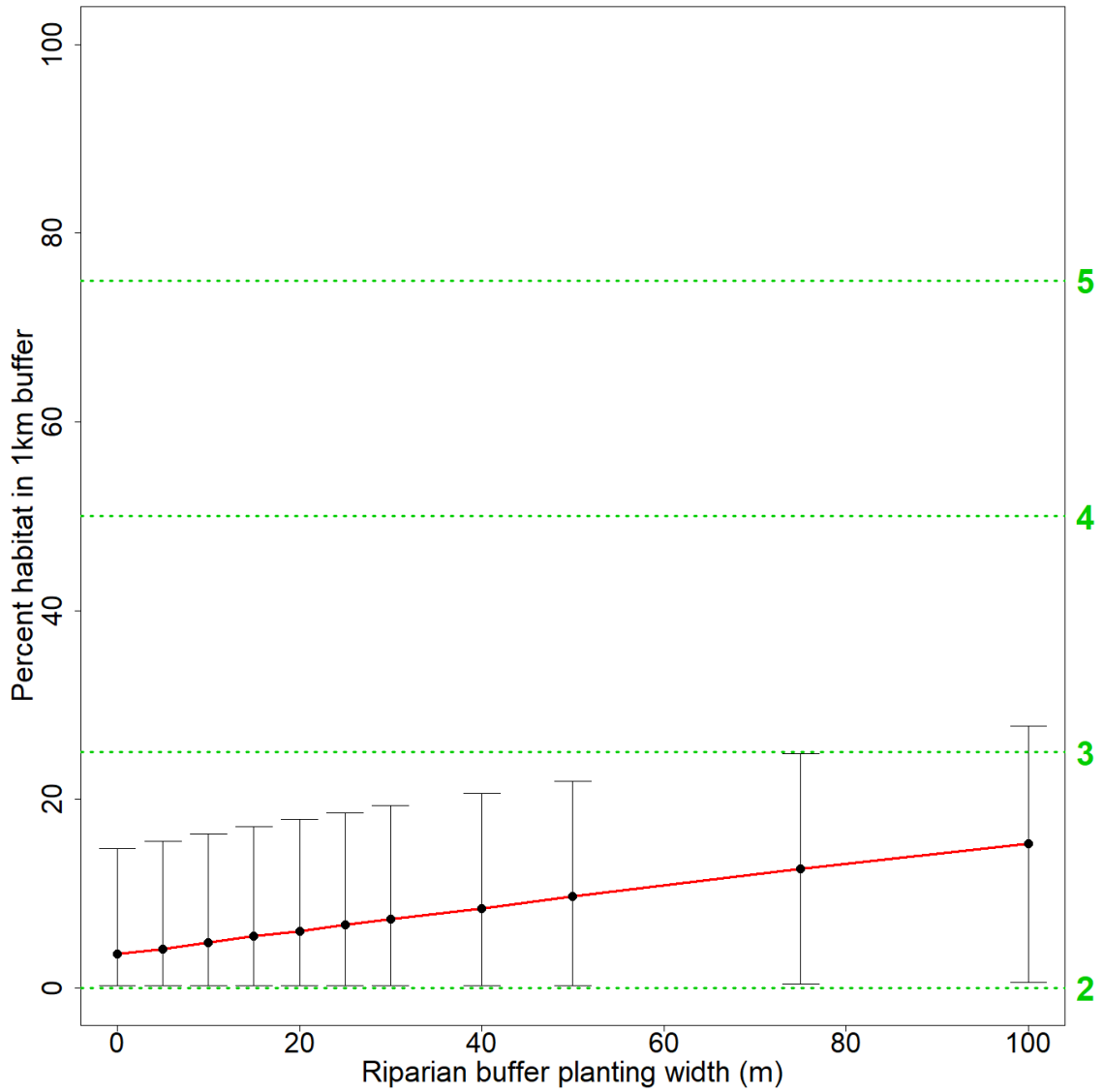

Figure 10. Median and 95% confidence bounds for percent indigenous woody habitat within a 1-km buffer (GW 24) for kahikatea fragments in the Waitoa catchment with different riparian buffer planting widths. Green numbers and dotted lines indicate boundary values for Green Wheel ranks.

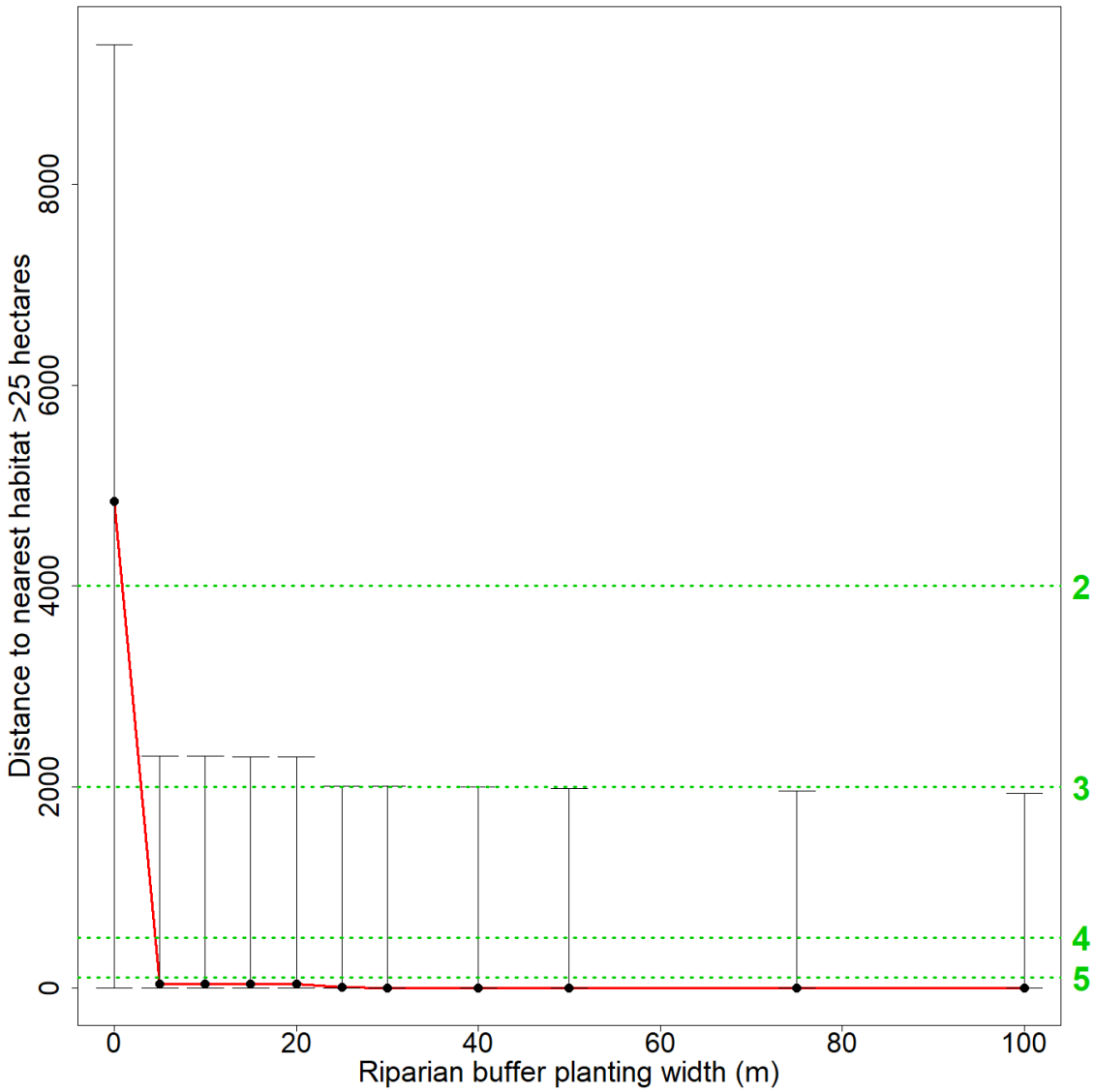

Figure 11. Median and 95% confidence bounds for distance to nearest indigenous habitat patch greater than 25 hectares in area (GW 25) for kahikatea fragments in the Waitoa catchment with different riparian buffer planting widths. Green numbers and dotted lines indicate boundary values for Green Wheel ranks.

6 Conclusions

- Resilience of over 95% of kahikatea fragments in the Waikato Region is currently at risk due to their small area and small percentage of core habitat. Fencing and buffer planting to achieve minimum bounding convex hulls will not markedly increase total habitat area of individual fragments but could considerably improve the amount of core habitat in many fragments.
- Most kahikatea fragments in the Waikato Region currently have a compact shape (low shape index). However, buffer plantings and fencing to achieve minimum bounding convex hulls could result in 95% of fragments achieving the maximum possible rank for shape (GW 13).
- There is relatively little (<25%) indigenous habitat in the immediate neighbourhood of most kahikatea fragments in the Waikato Region. However, most fragments are reasonably close to (within 2000 m of) large patches of indigenous habitat
- Riparian buffer planting scenarios in the Waitoa catchment greatly enhanced connectivity, but did not markedly improve indigenous habitat in the immediate neighbourhoods of most kahikatea fragments.

7 Recommendations

- Buffer plantings and fencing to achieve minimum bounding convex hulls should be encouraged. These efforts should be prioritised in fragments with the greatest potential gains in core habitat area and shape index.
- A long-term goal of implementing 25-m riparian buffer plantings along the Waitoa River from Waharoa northward and along the small tributary immediately east of Waharoa should be promoted to enhance connectivity of kahikatea fragments in the Waitoa catchment.
- Potential benefits of riparian buffer plantings for connectivity should be examined in other catchments or sub-catchments in the Waikato Region containing large numbers of kahikatea fragments.

8 Acknowledgements

Yanbin Deng (Waikato Regional Council) facilitated the contract to undertake this work and Daniel Tait (Waikato Regional Council) provided feedback on spatial analyses.

9 References

Denyer K, Deng Y 2019. Kahikatea Forest Green Wheel – developing a tool to assess ecosystem recovery of Kahikatea remnants in the Waikato region. Waikato Regional Council Technical Report 2019/01.