Manaaki Whenua
Landcare Research

Geospatial landslide modelling for targeted erosion control

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Hugh Smith

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In this talk …

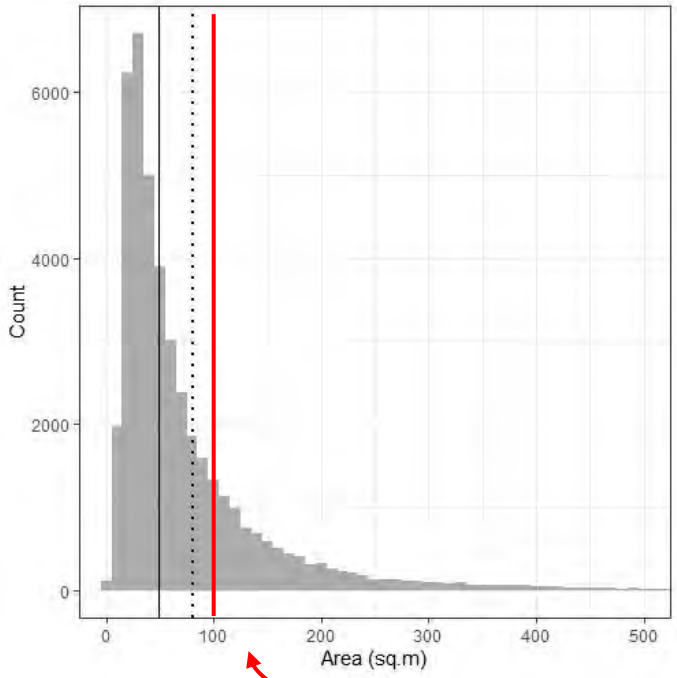
1. Motivation
2. Landslide data acquisition
3. Landslide susceptibility modelling
   - *From regional to tree scale*
4. Decision support for land management
5. Key messages

From remote sensing to decision support

- **WHY:** To support the design and implementation of cost-effective, targeted erosion control measures to meet national water quality targets.
- **HOW:** Acquire data and develop models to:
  - Quantify links between erosion sources and sediment-related water quality
  - Determine the performance of erosion control measures across multiple spatial scales

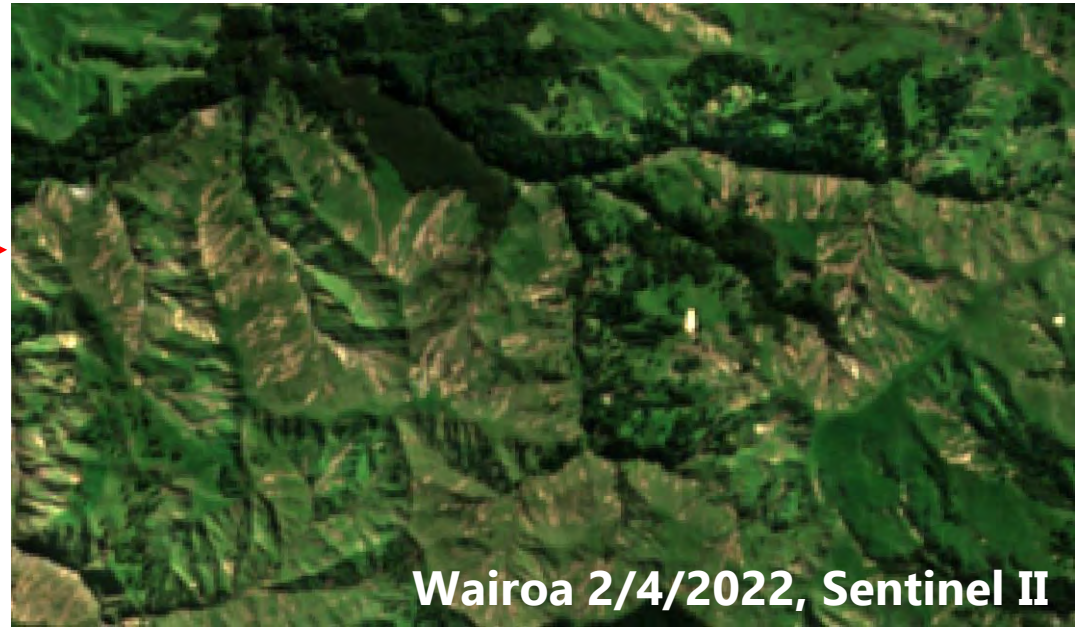
Shallow landslide mapping

- Scale of imagery determined by geomorphic process



Typical distribution of scar size in soft rock hill country

WV2 – 0.5 m GSD
1 pixel = 0.25 m^2



Sentinel II – 10 m GSD
1 pixel = 100 m^2

Landslide mapping

- Build landslide inventories by mapping from high-resolution imagery (< 1 m)
- Compare data sources:
    a) manual vs. semi-automated mapping
    b) event vs. historic records

Geomorphology 381 (2021) 107660

Contents lists available at ScienceDirect

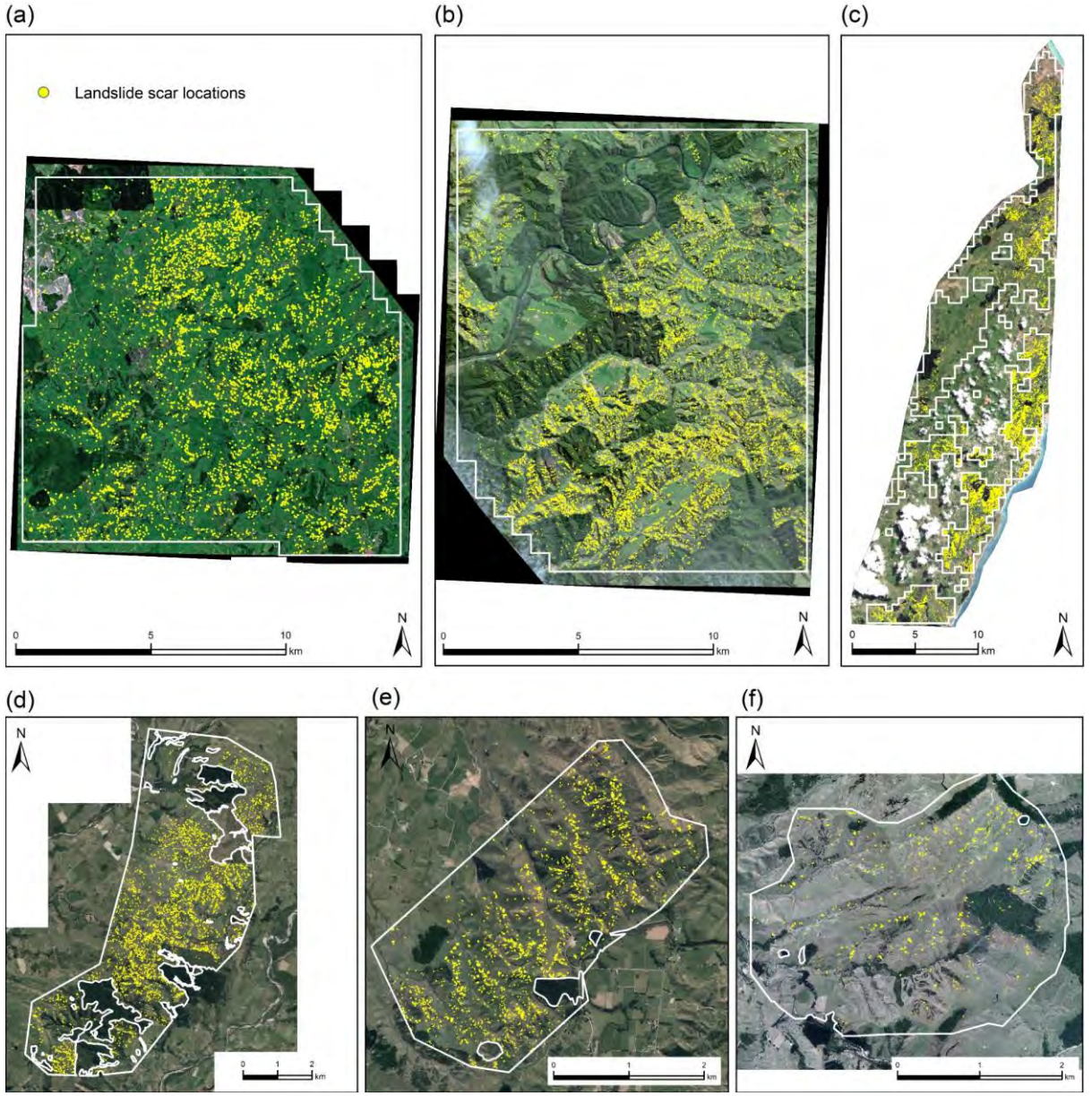
Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Comparing methods of landslide data acquisition and susceptibility modelling: Examples from New Zealand

Hugh G. Smith *, Raphael Spiekermann, Harley Betts, Andrew J. Neverman

Manaaki Whenua – Landcare Research, Palmerston North, New Zealand



Object-based image analysis (OBIA) for rapid landslide mapping

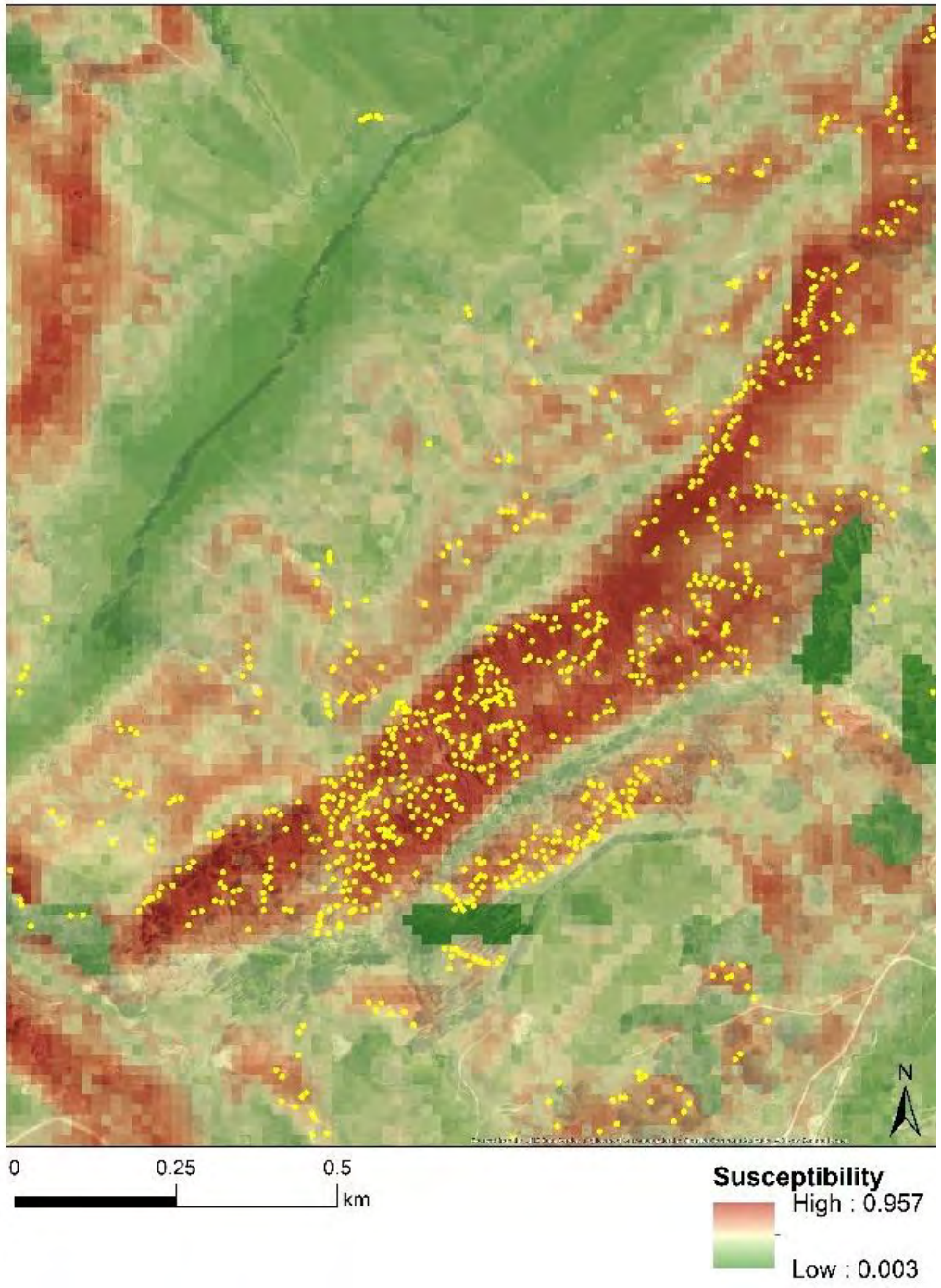
Landslide susceptibility

Shallow landslide susceptibility

- The likelihood of future landslide occurrence for a given areal unit given local environmental conditions.
- Focus on rainfall-triggered shallow landslides.

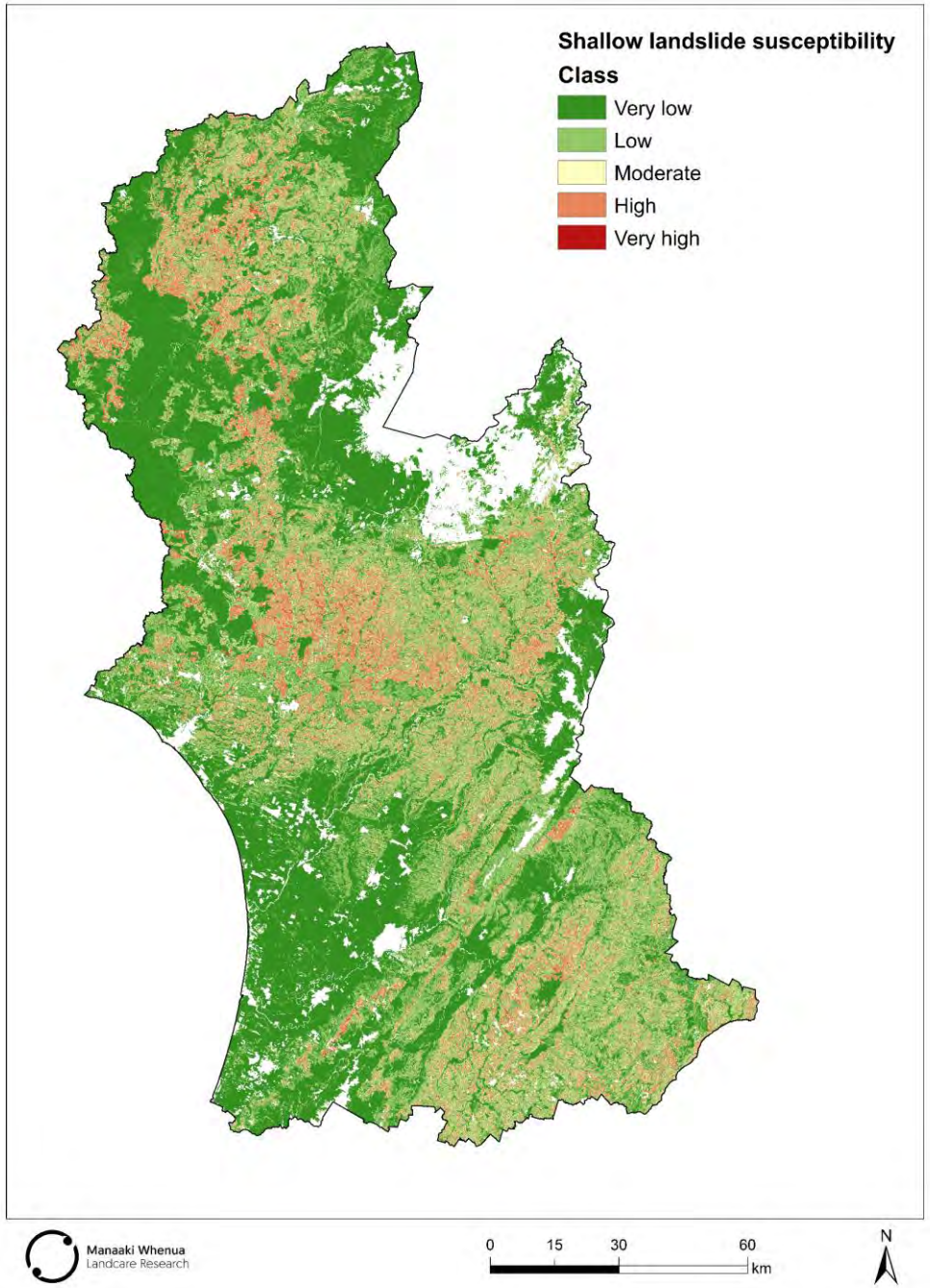
Method

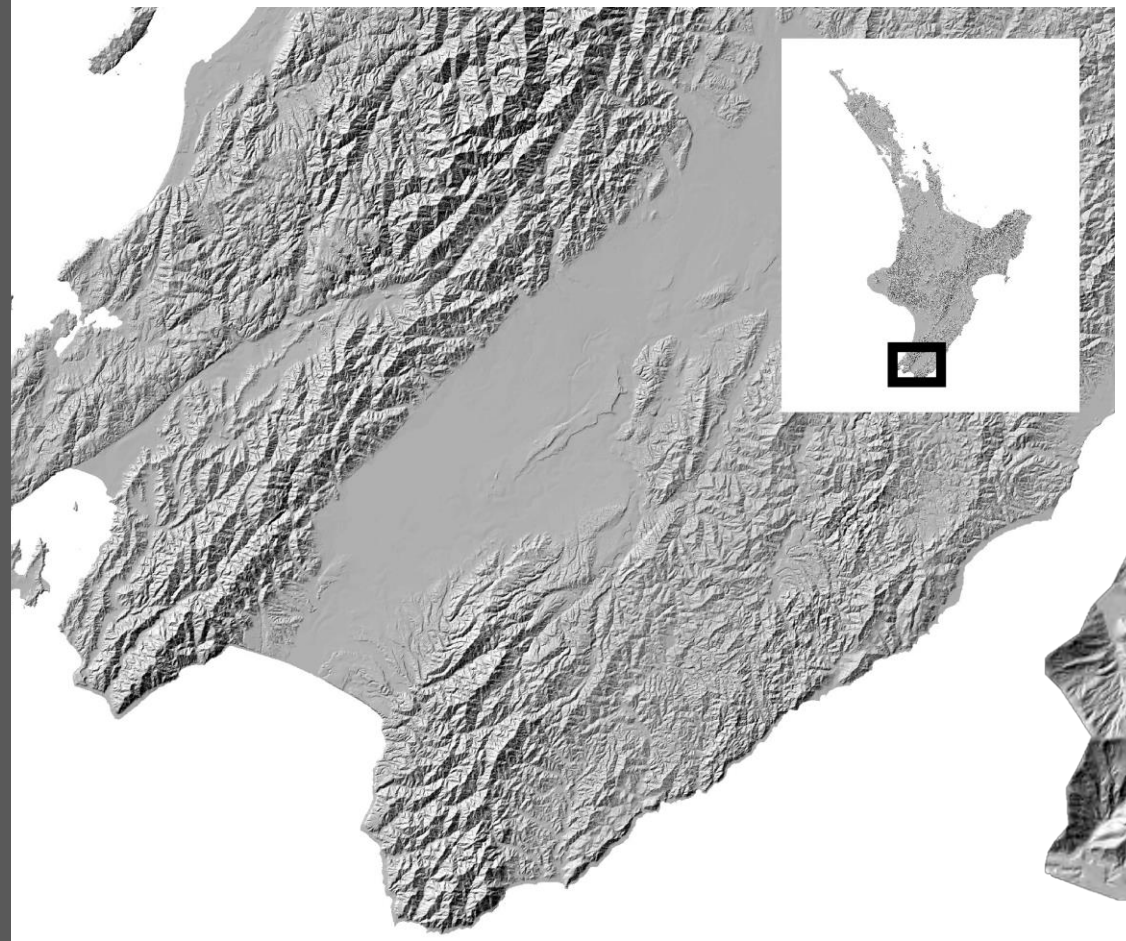
- Extract spatial data for **landslide** and **non-landslide** locations (e.g. slope, aspect, land cover).
- Train model to predict likelihood of landslide occurrence for each grid cell.
- Model output is a probability (0 – 1) that can be given a class (e.g. ‘high’).
- Model predicts **where** and not **when** landslides may occur.

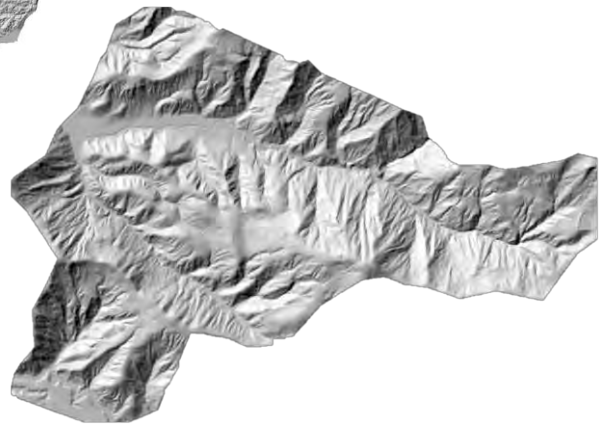


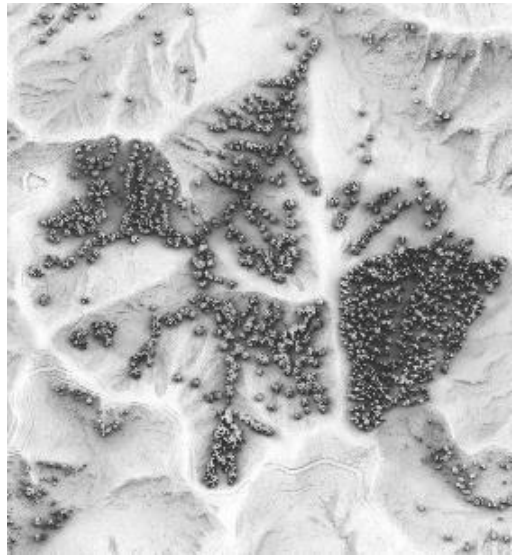
National / regional scale

- MWLR has developed models to predict spatial patterns in susceptibility to rainfall-initiated shallow landslides
- Draws on database of >100,000 shallow landslides









NATIONAL/REGIONAL: 15m national DEM / 5m LiDAR DEM derivatives, LCDB

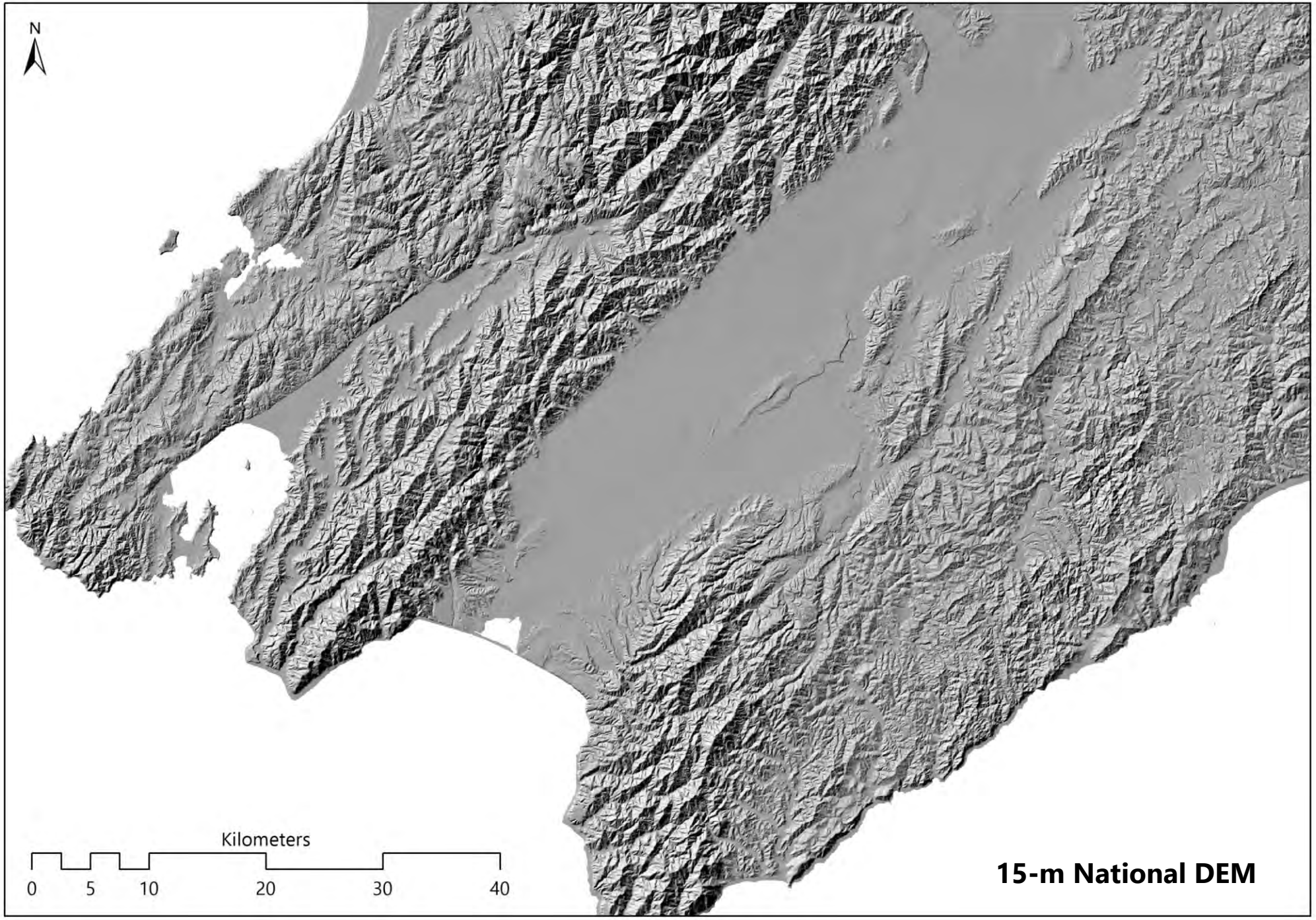
CATCHMENT/FARM: 5m LiDAR DEM derivatives, LCDB

FARM/TREE: 1m LiDAR DEM derivatives, individual trees

Scale

National

- **Regional**
  - **Farm**
    - **Slope**
      - **Tree**



Scale

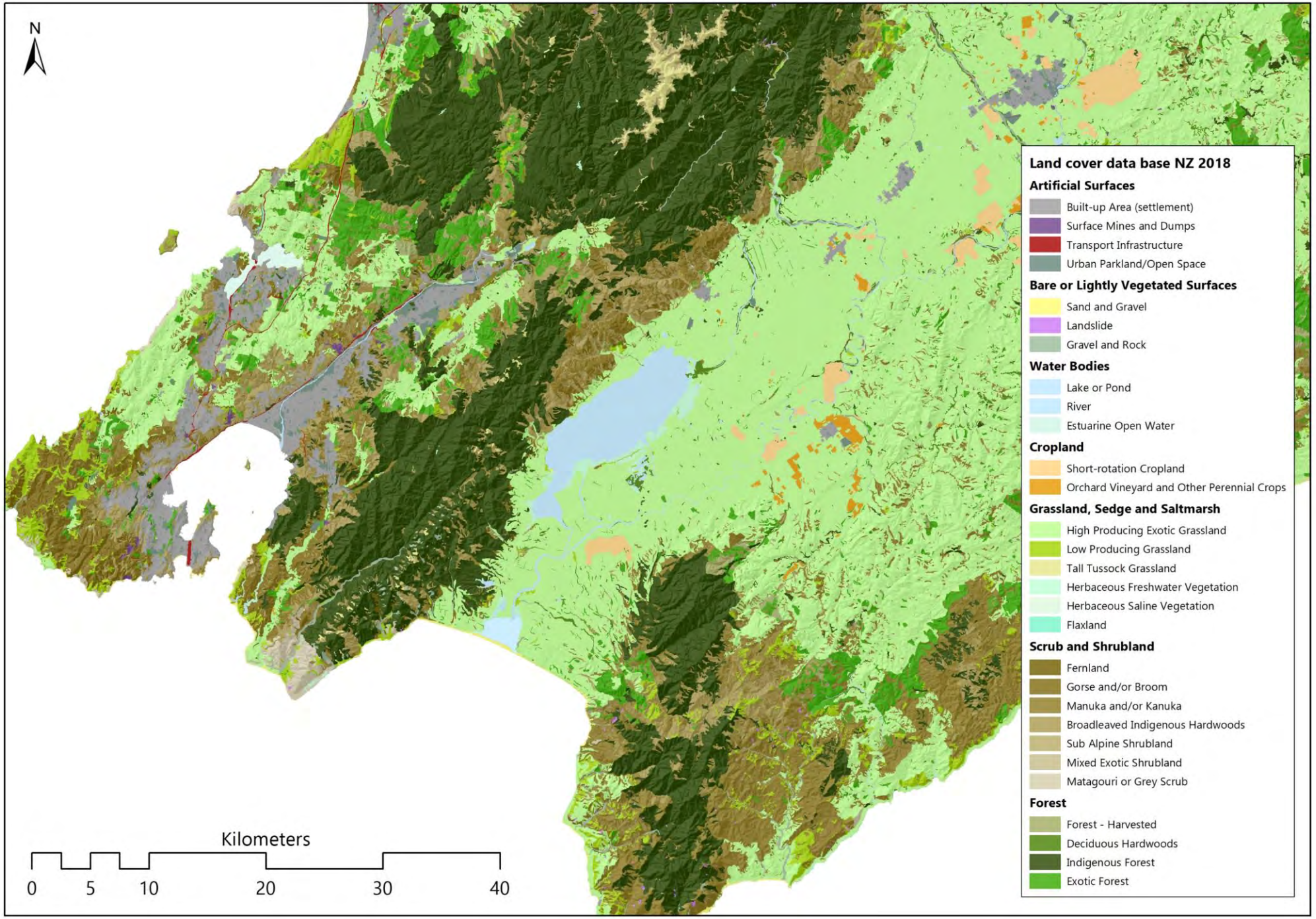
National

↳ **Regional**

↳ **Farm**

↳ **Slope**

↳ **Tree**



Scale

National

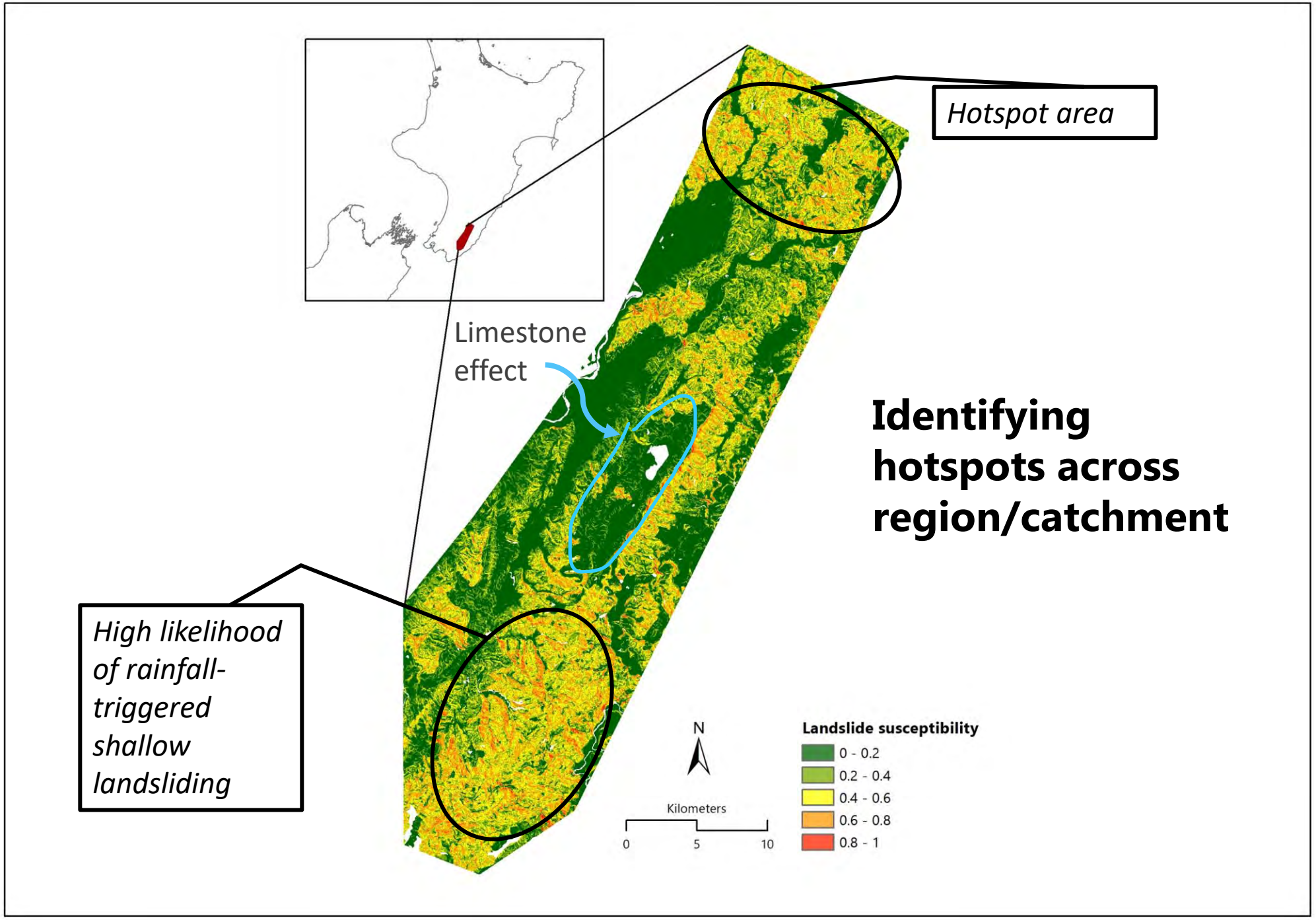
↳ **Regional**

↳ **Farm**

↳ **Slope**

↳ **Tree**

Model using 15-m DEM, LCDB, NZLRI rock type



Identifying hotspots across region/catchment

Scale

National

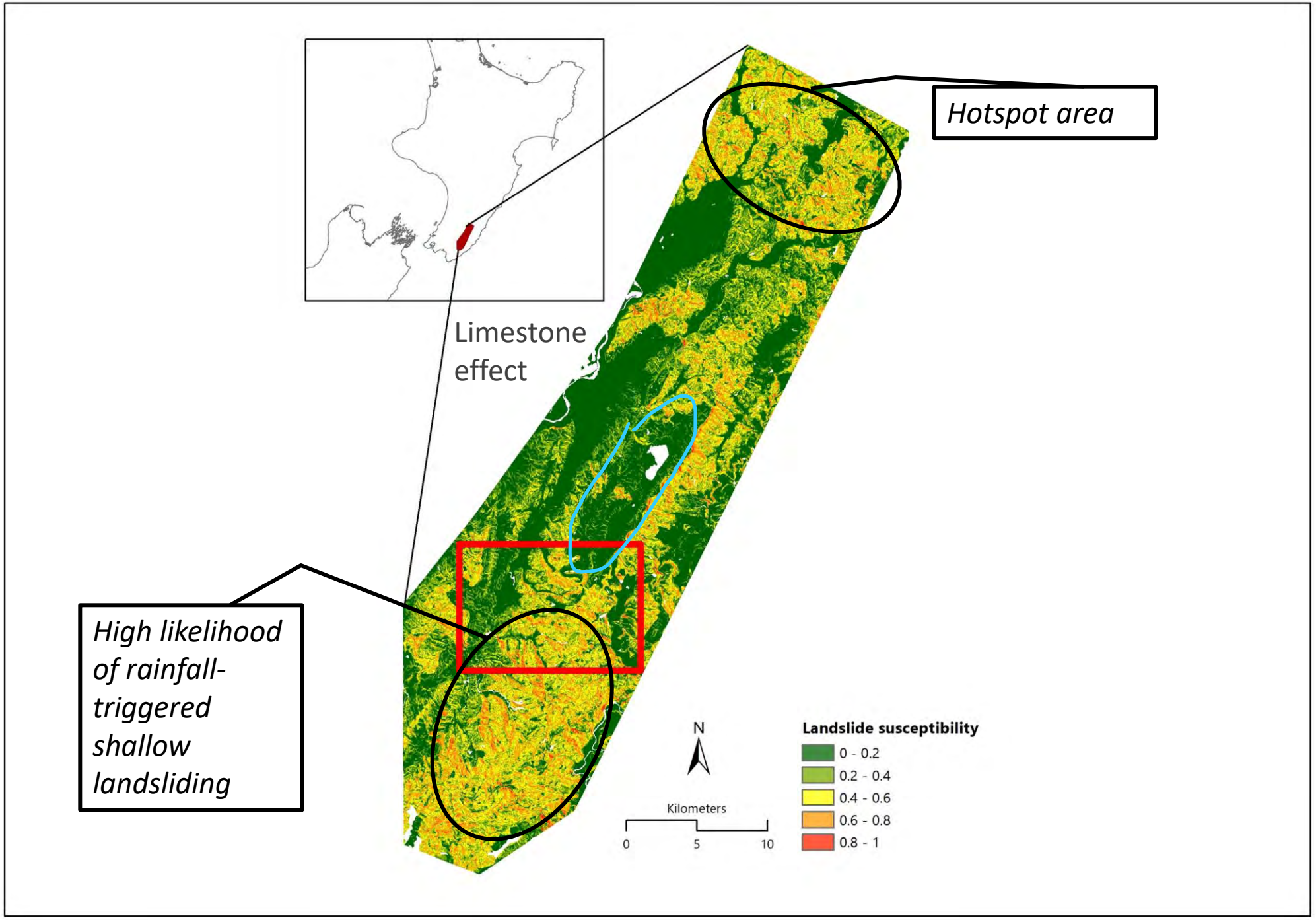
↳ **Regional**

↳ **Farm**

↳ **Slope**

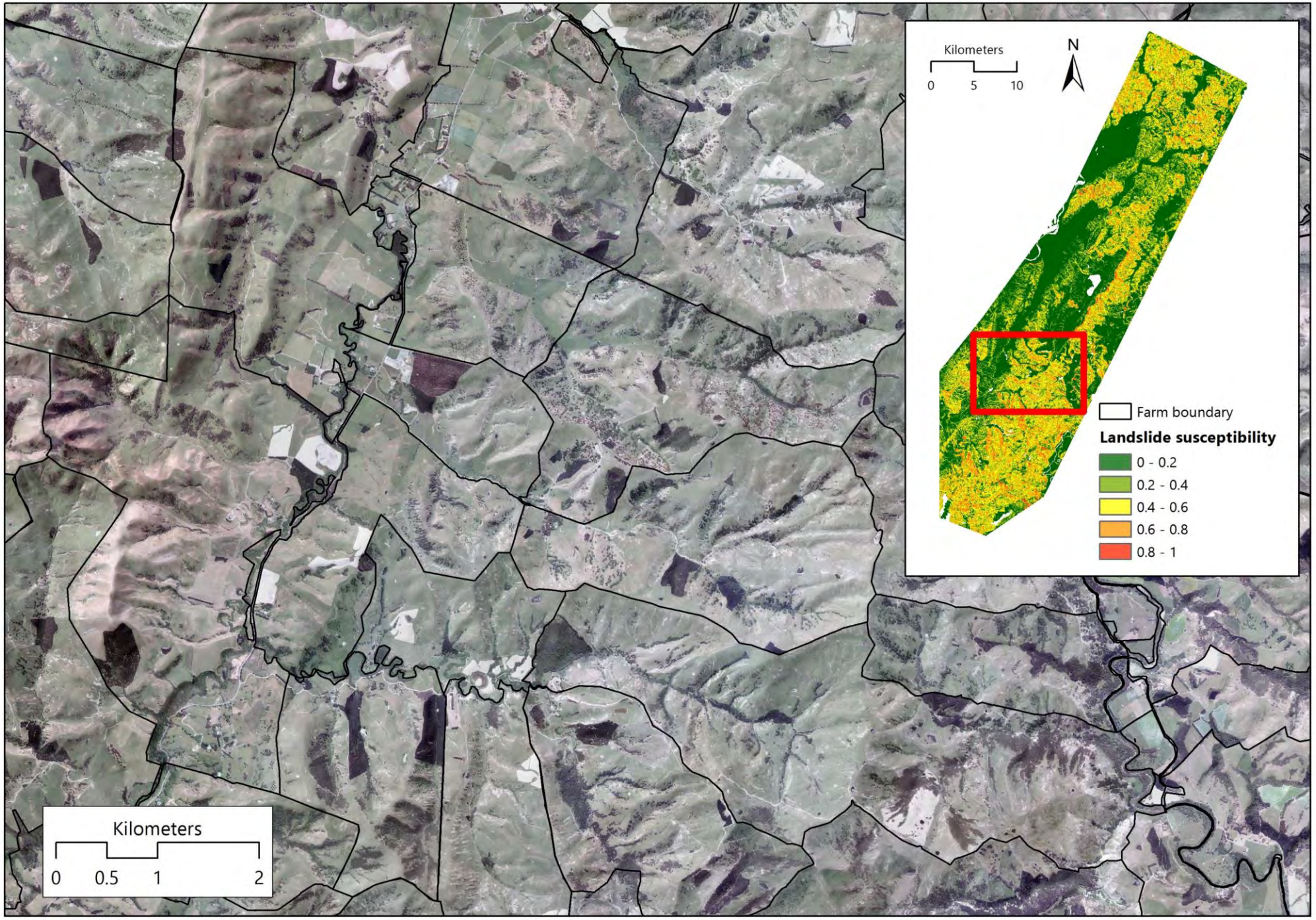
↳ **Tree**

Model using 15-m DEM, LCDB, NZLRI rock type



Scale

- National
  - **Regional**
    - **Farm**
      - Slope
        - Tree

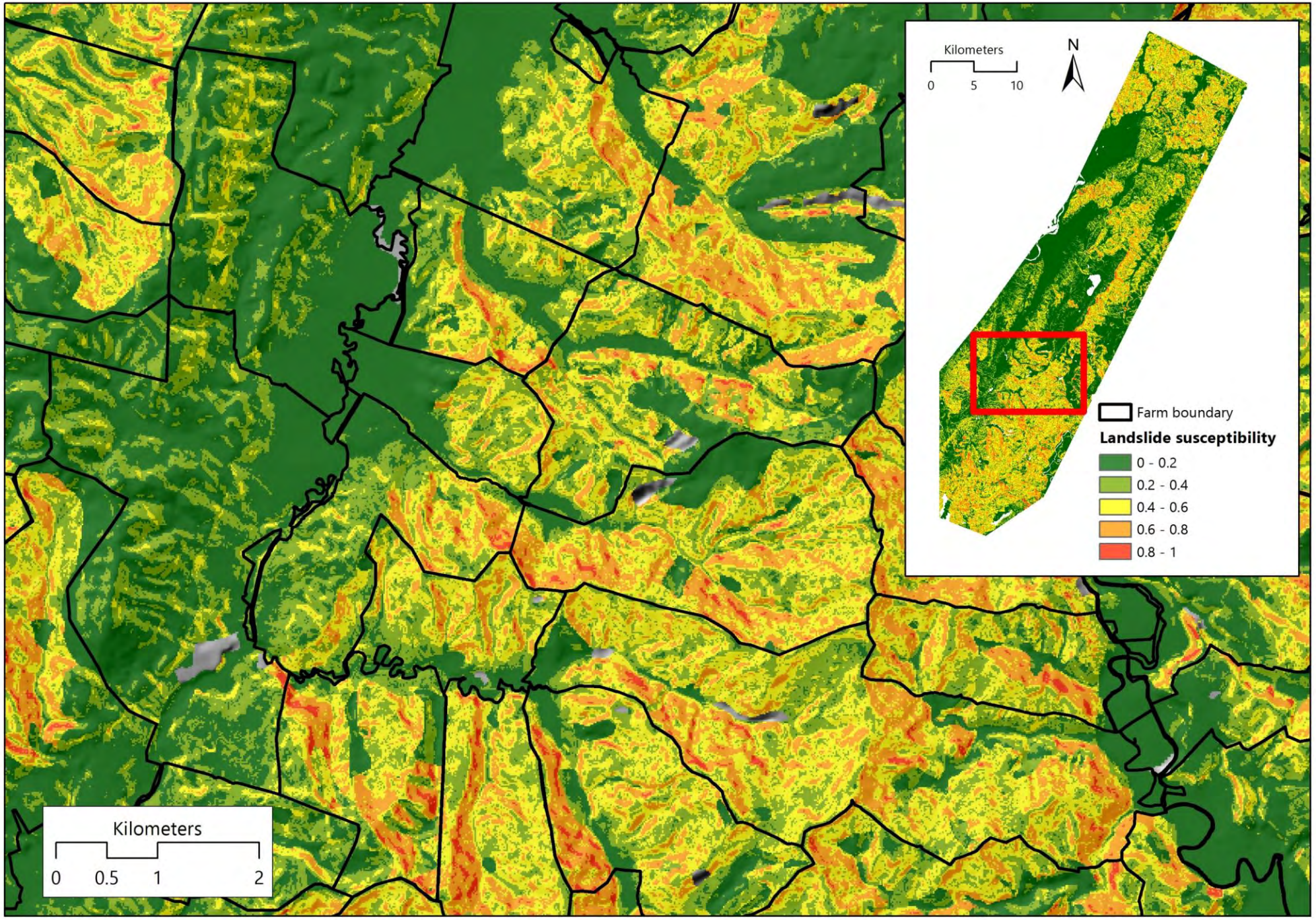


Scale

National

- Regional
  - Farm
    - Slope
      - Tree

Model using 15-m DEM and LCDB

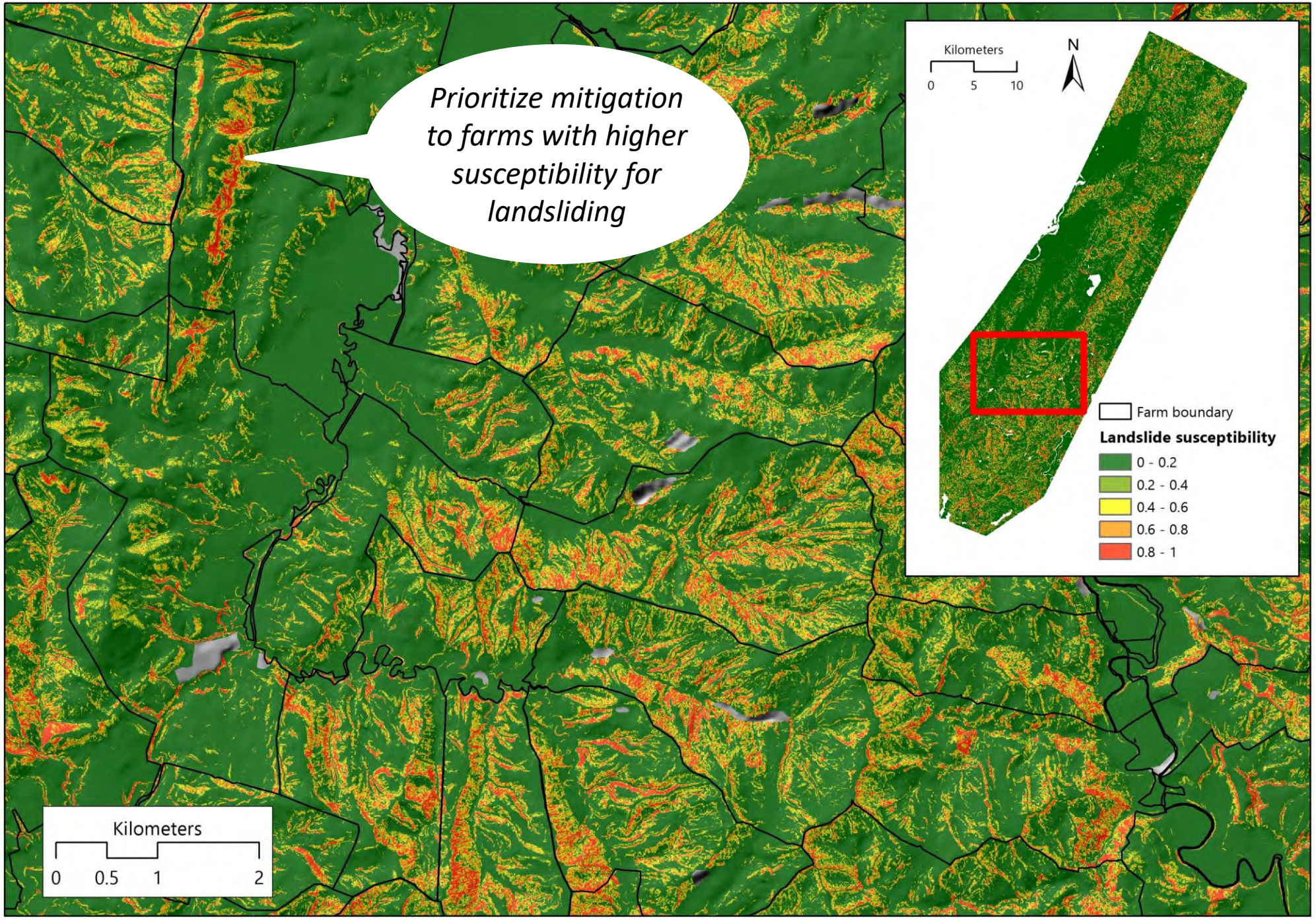


Scale

National

- **Regional**
  - **Farm**
    - **Slope**
      - **Tree**

Model using 5-m LiDAR DEM and LCDB

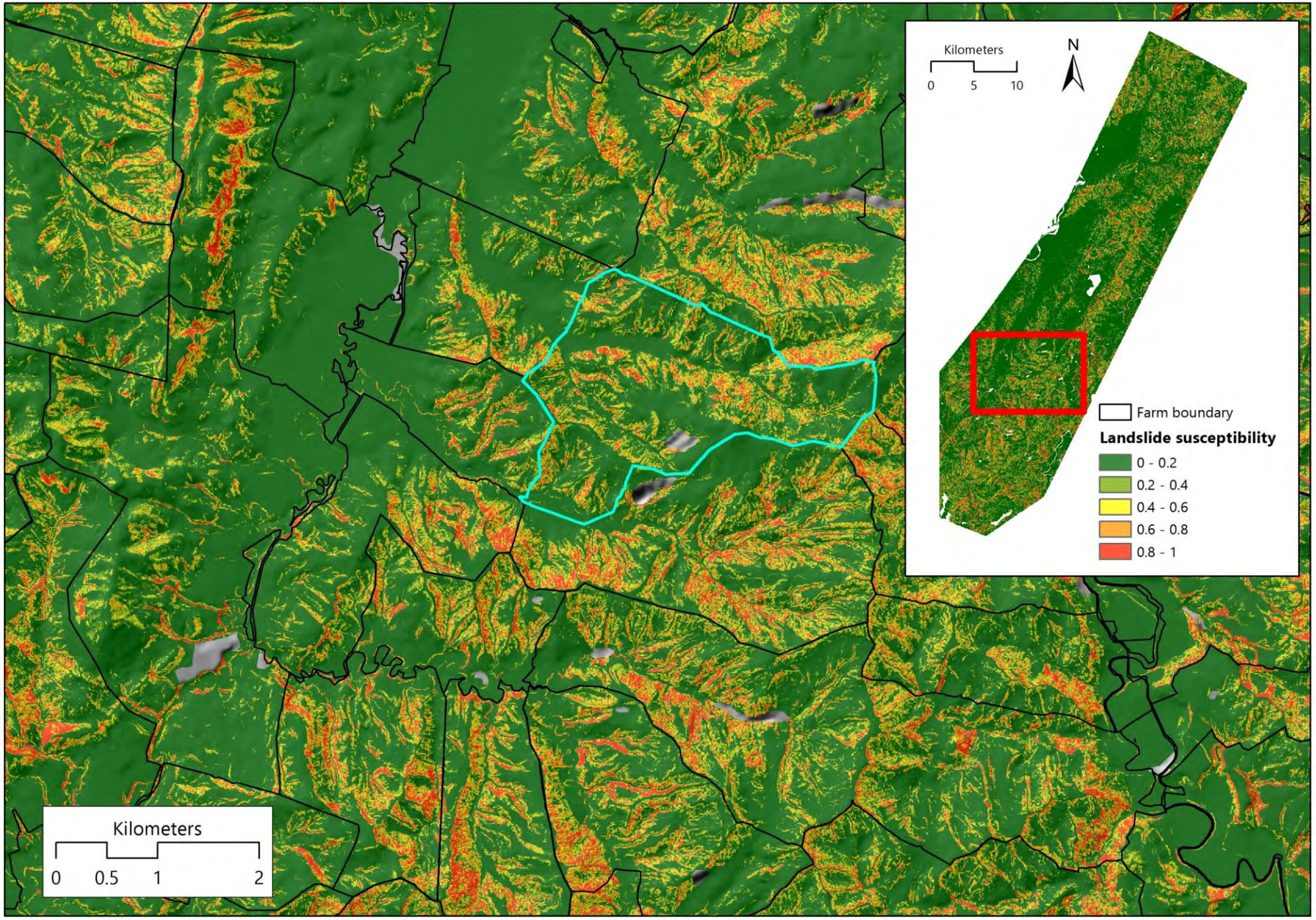


Scale

National

- Regional
  - Farm
    - Slope
      - Tree

Model using 5-m LiDAR DEM and LCDB



Scale

National

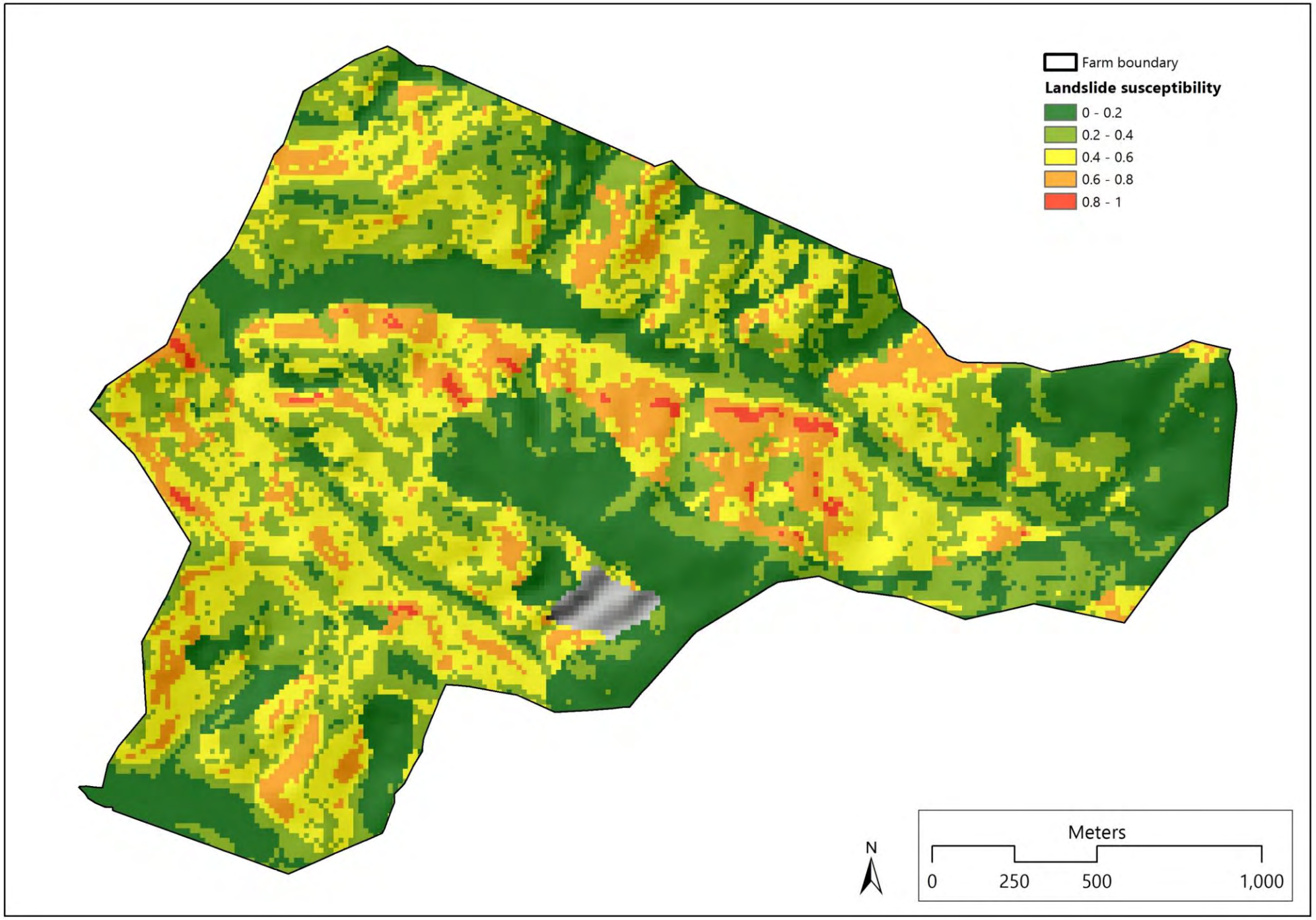
↳ **Regional**

↳ **Farm**

↳ **Slope**

↳ **Tree**

Model using 15-m DEM and LCDB

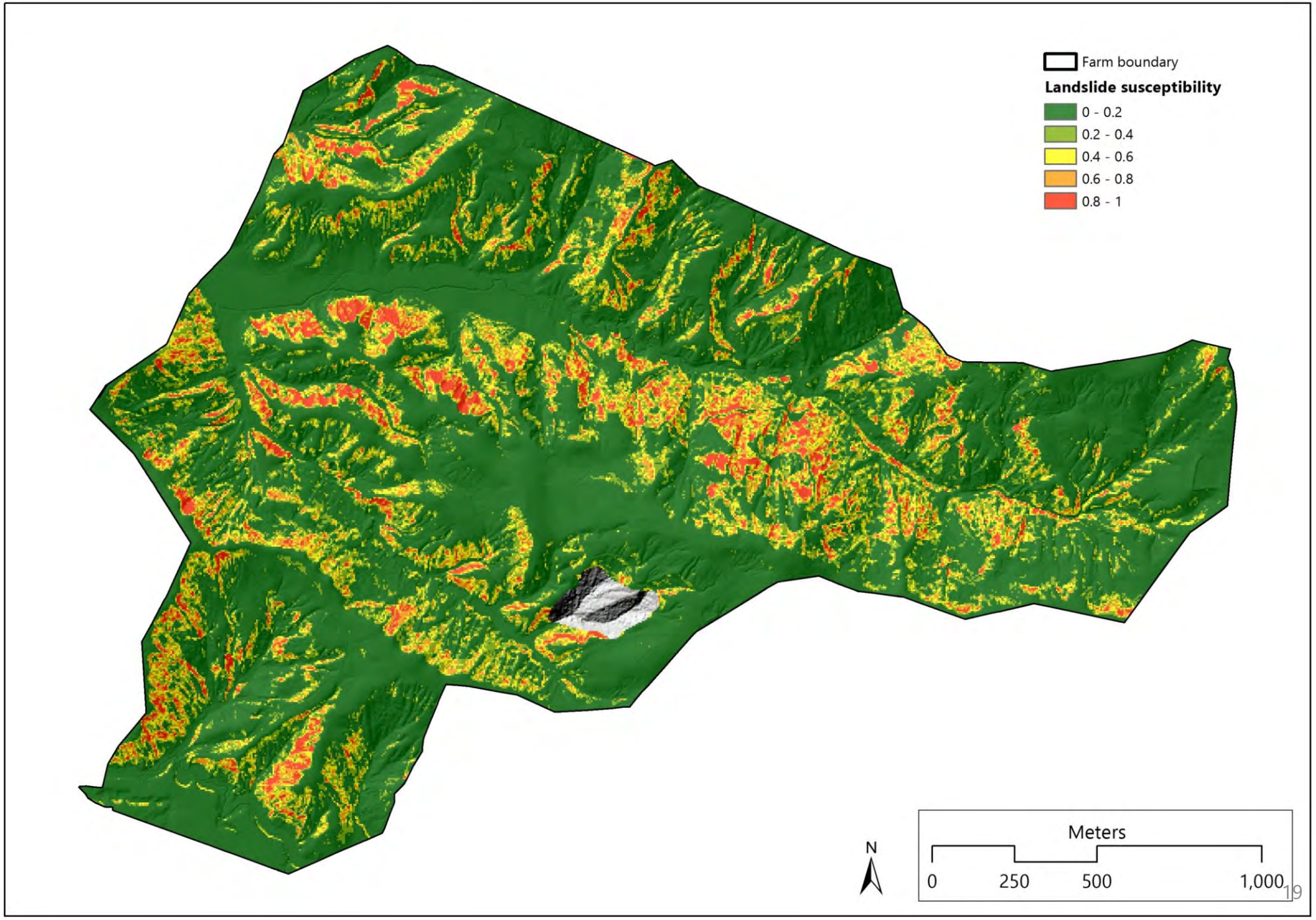


Scale

National

- Regional
  - Farm
    - Slope
      - Tree

Model using 5-m LiDAR DEM and LCDB



Scale

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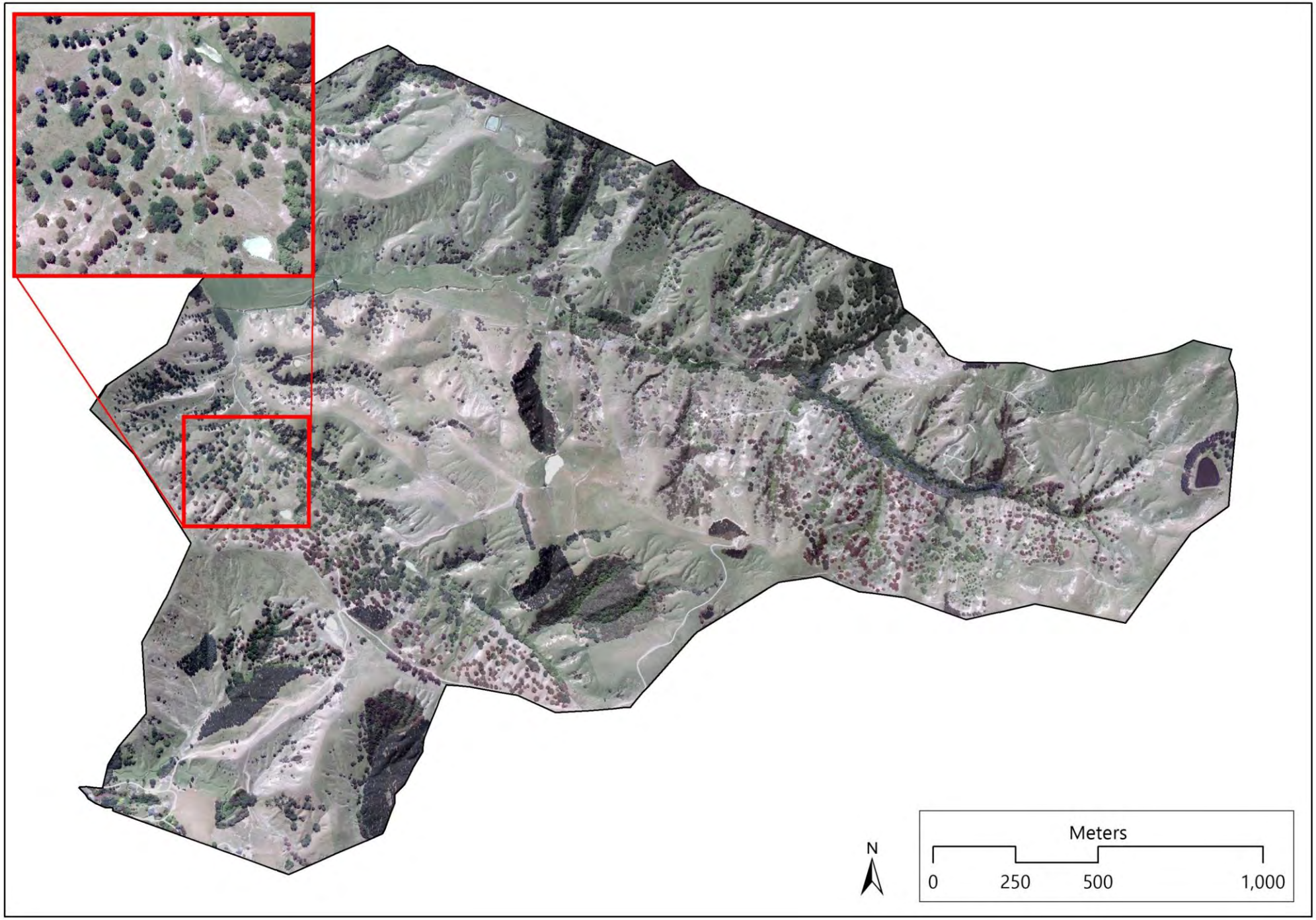

Scale

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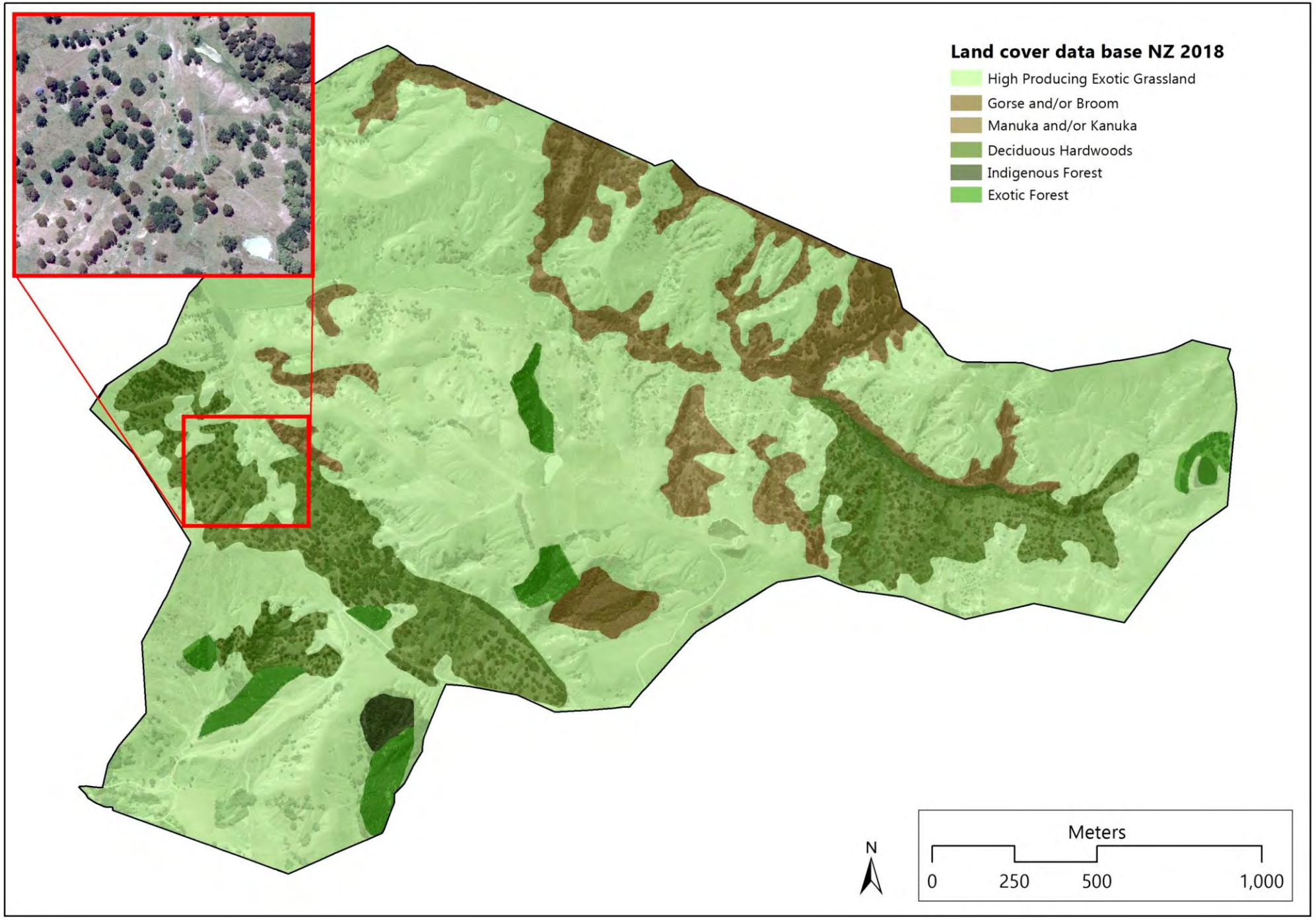


Scale

National

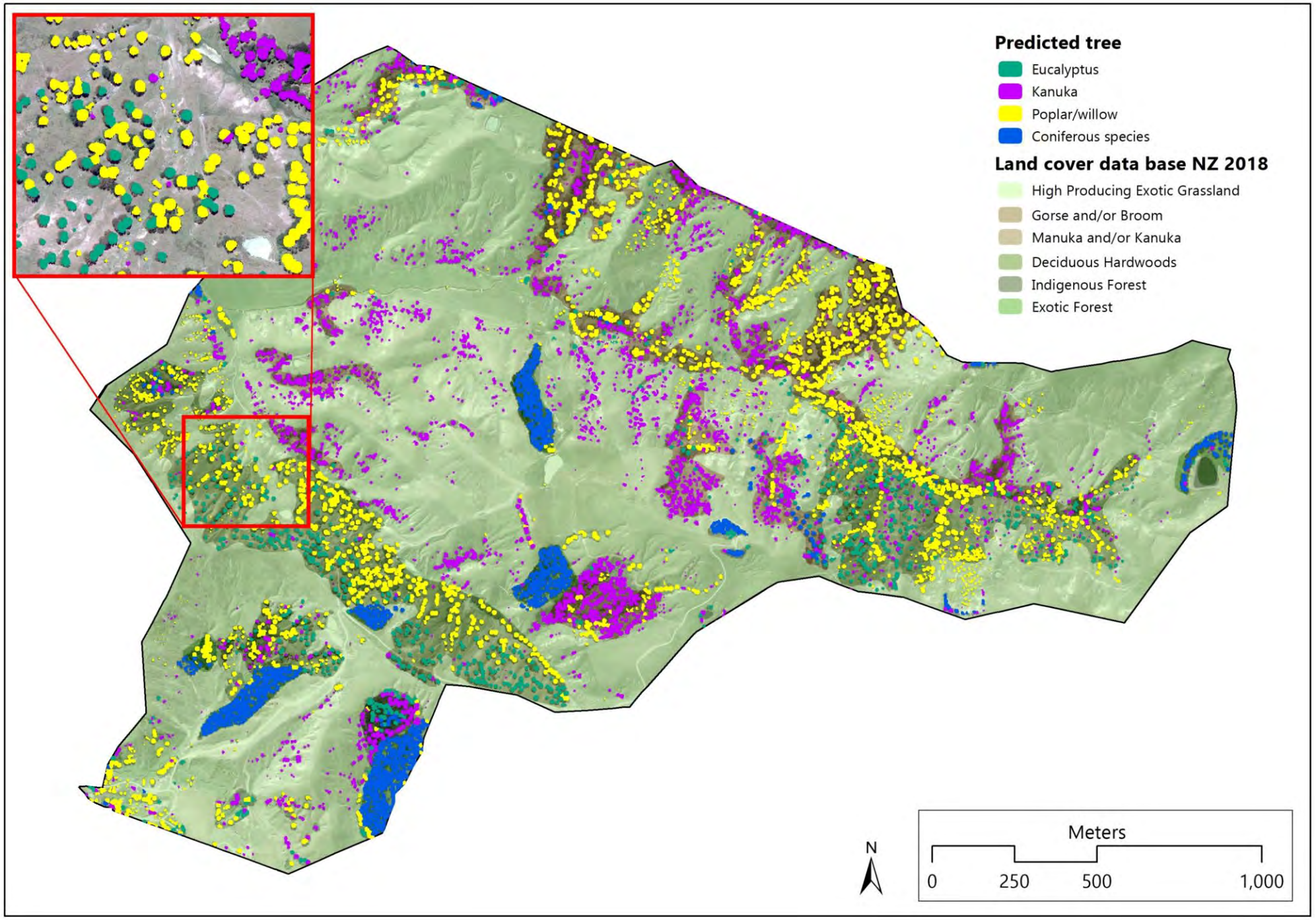
↳ **Regional**

↳ **Farm**

↳ **Slope**

↳ **Tree**

1-m LiDAR canopy height model (CHM)



Scale

National

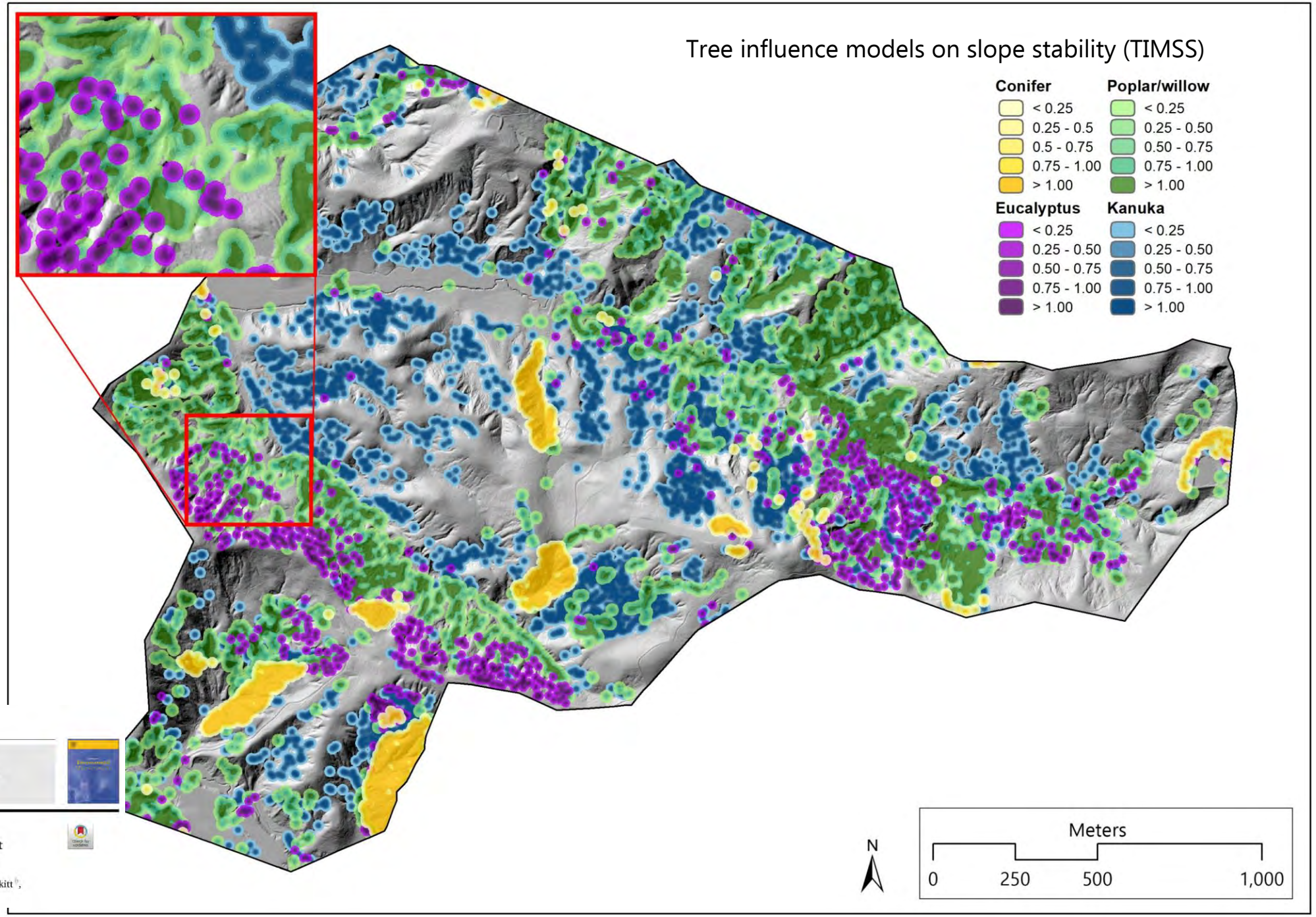
↳ **Regional**

↳ **Farm**

↳ **Slope**

↳ **Tree**

1-m pixel scale



Journal of Environmental Management 286 (2021) 112194

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: http://www.elsevier.com/locate/jenvman

Quantifying the influence of individual trees on slope stability at landscape scale

Raphael I. Spiekermann [a,b,*], Sam McColl [b], Ian Fuller [b], John Dymond [a], Lucy Burkitt [b], Hugh G. Smith [a]

Scale

National

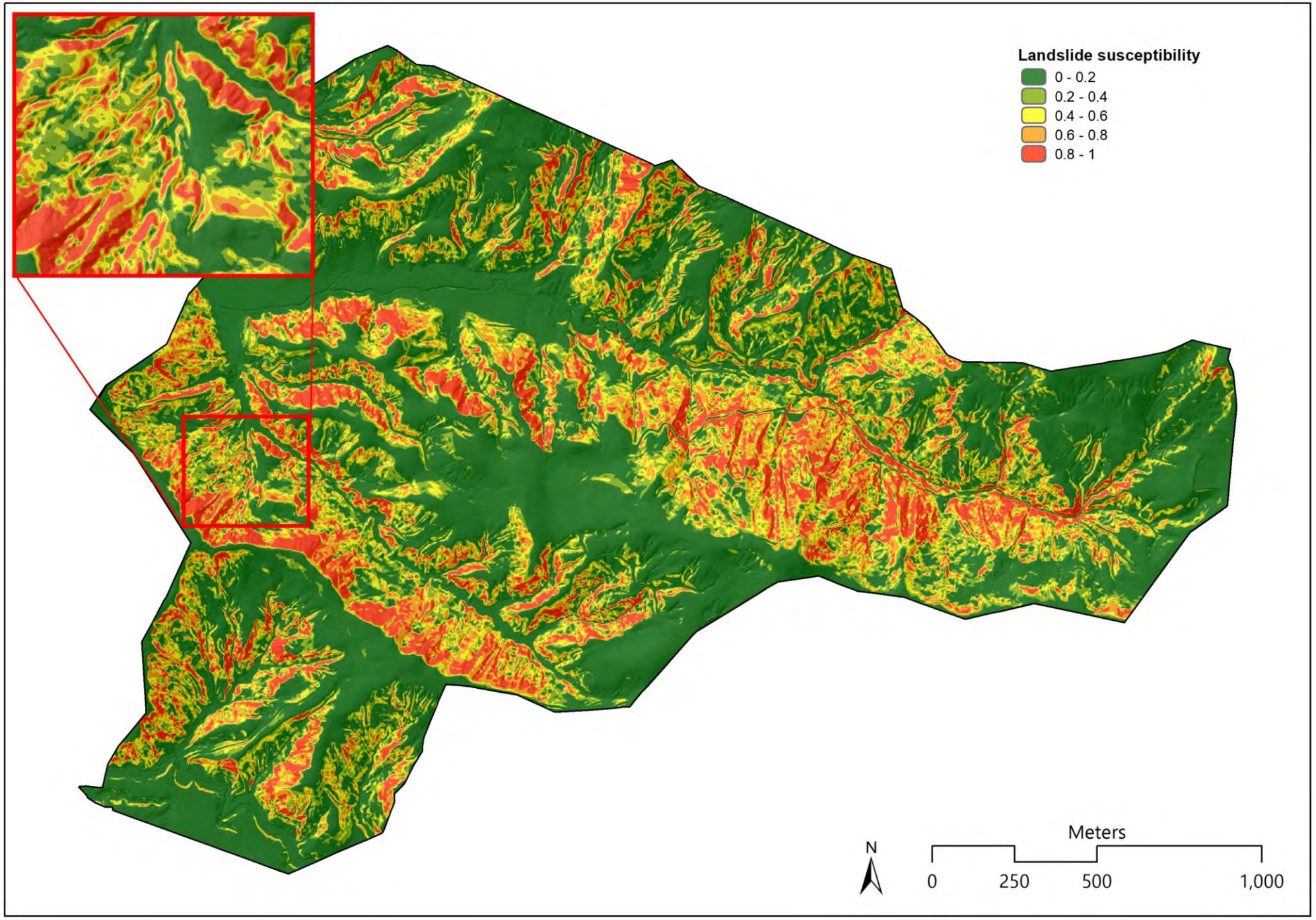
↳ **Regional**

↳ **Farm**

↳ **Slope**

↳ **Tree**

Treeless baseline LS model using 1-m LiDAR DEM



Scale

National

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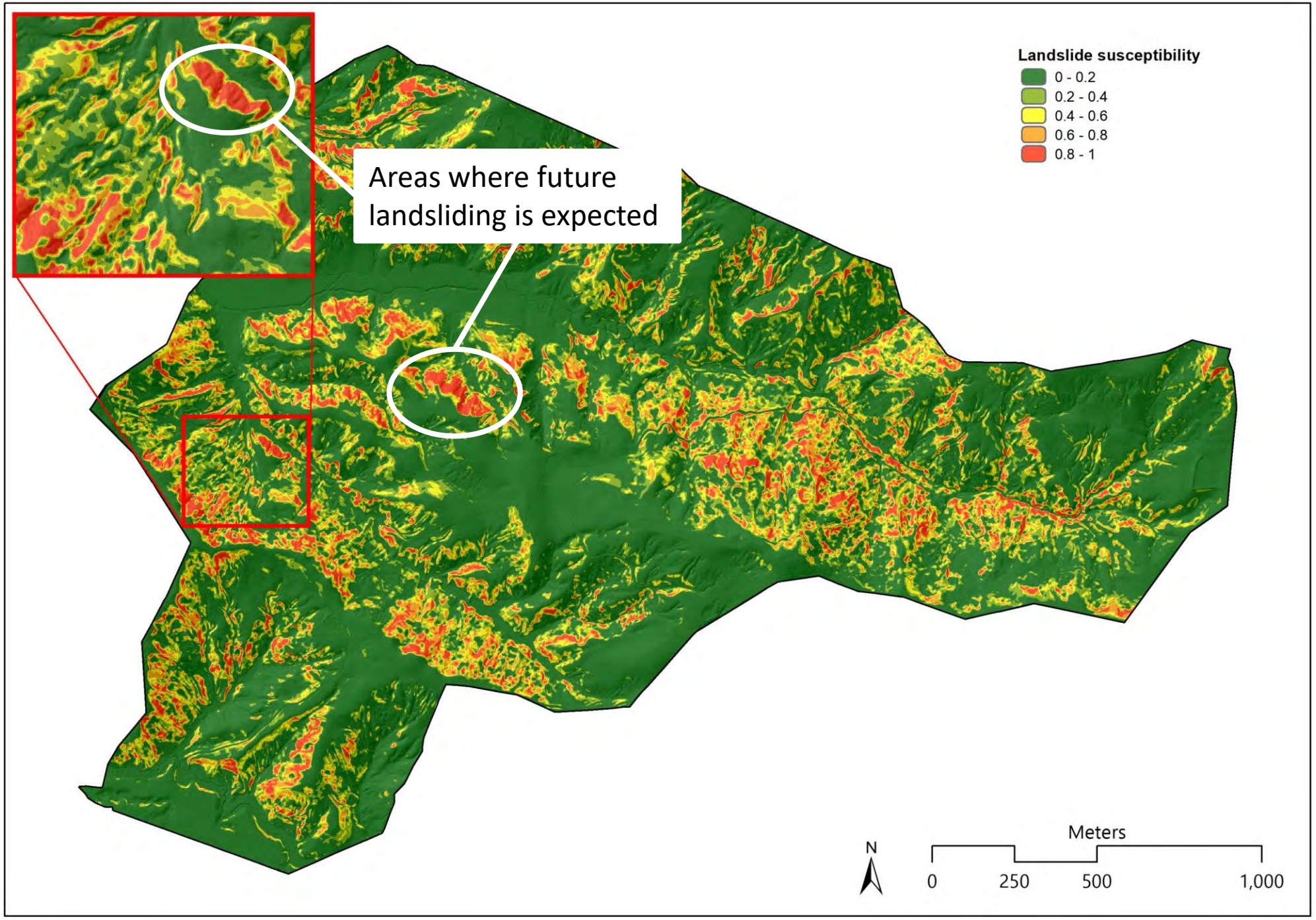
  - **Farm**
    - **Slope**
      - **Tree**

Actual trees LS model using 1-m LiDAR DEM and TIMSS



Scale

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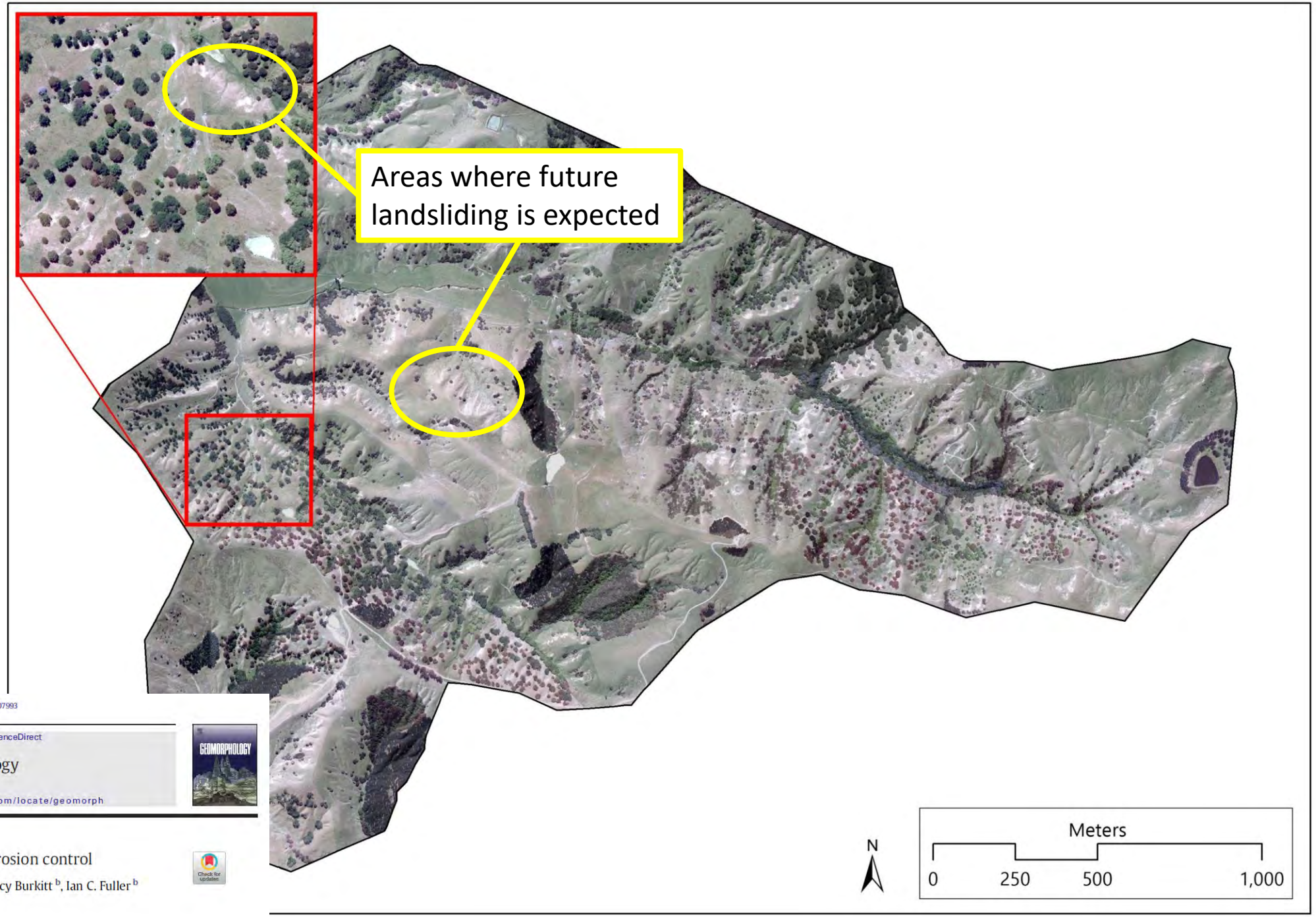


Geomorphology 396 (2022) 107993

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Quantifying effectiveness of trees for landslide erosion control

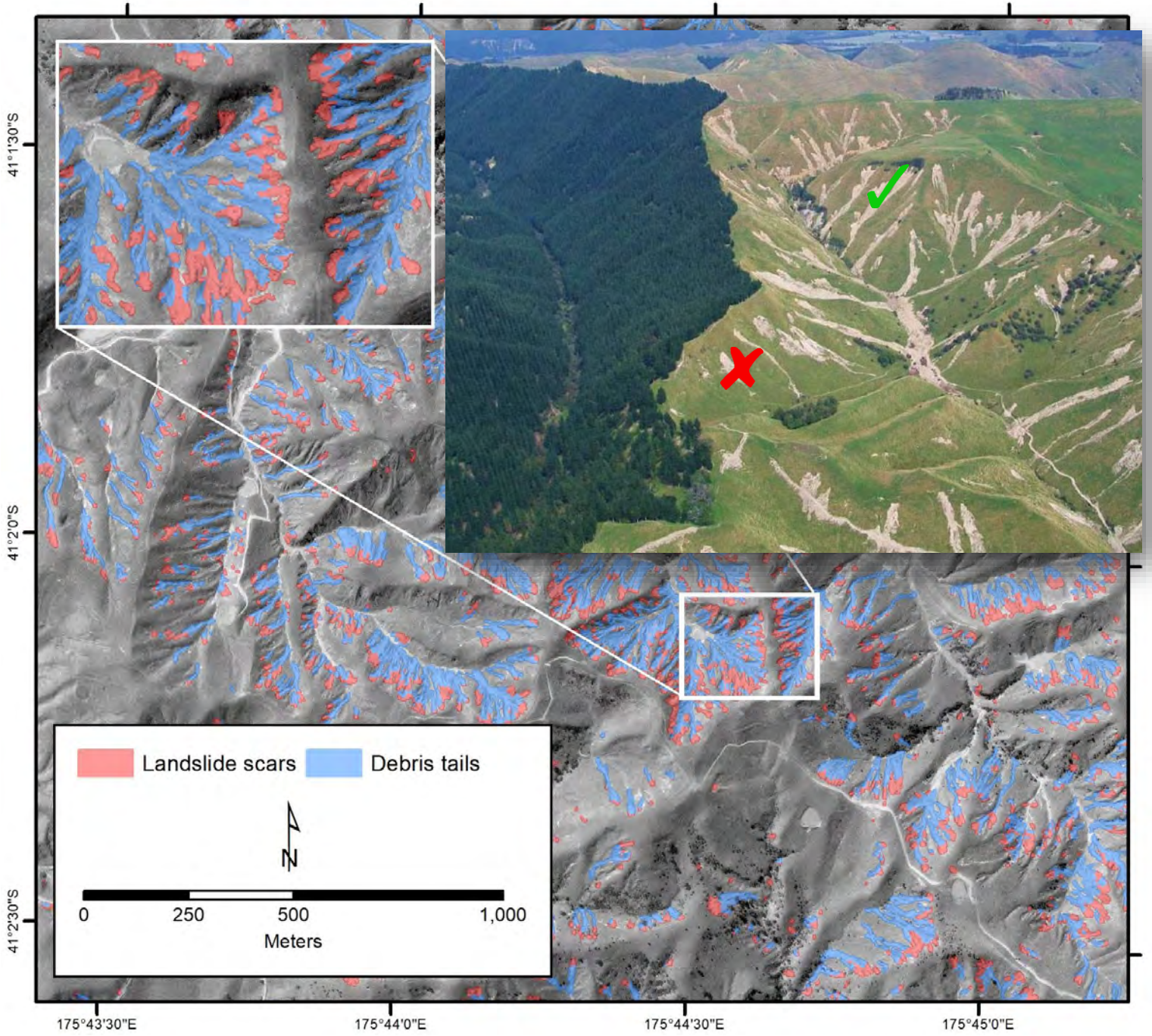
Raphael I. Spiekermann [a,b,*], Hugh G. Smith [a], Sam McColl [b], Lucy Burkitt [b], Ian C. Fuller [b]

[a] Manaaki Whenua – Landcare Research, Palmerston North, New Zealand
[b] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand

Landslide-derived sediment delivery

- Landslide scar and debris tail mapping
- Wairarapa 1977 rainfall event
- Landslide inventory used to develop a connectivity model

➢ Assess potential sediment delivery to streams



Scale

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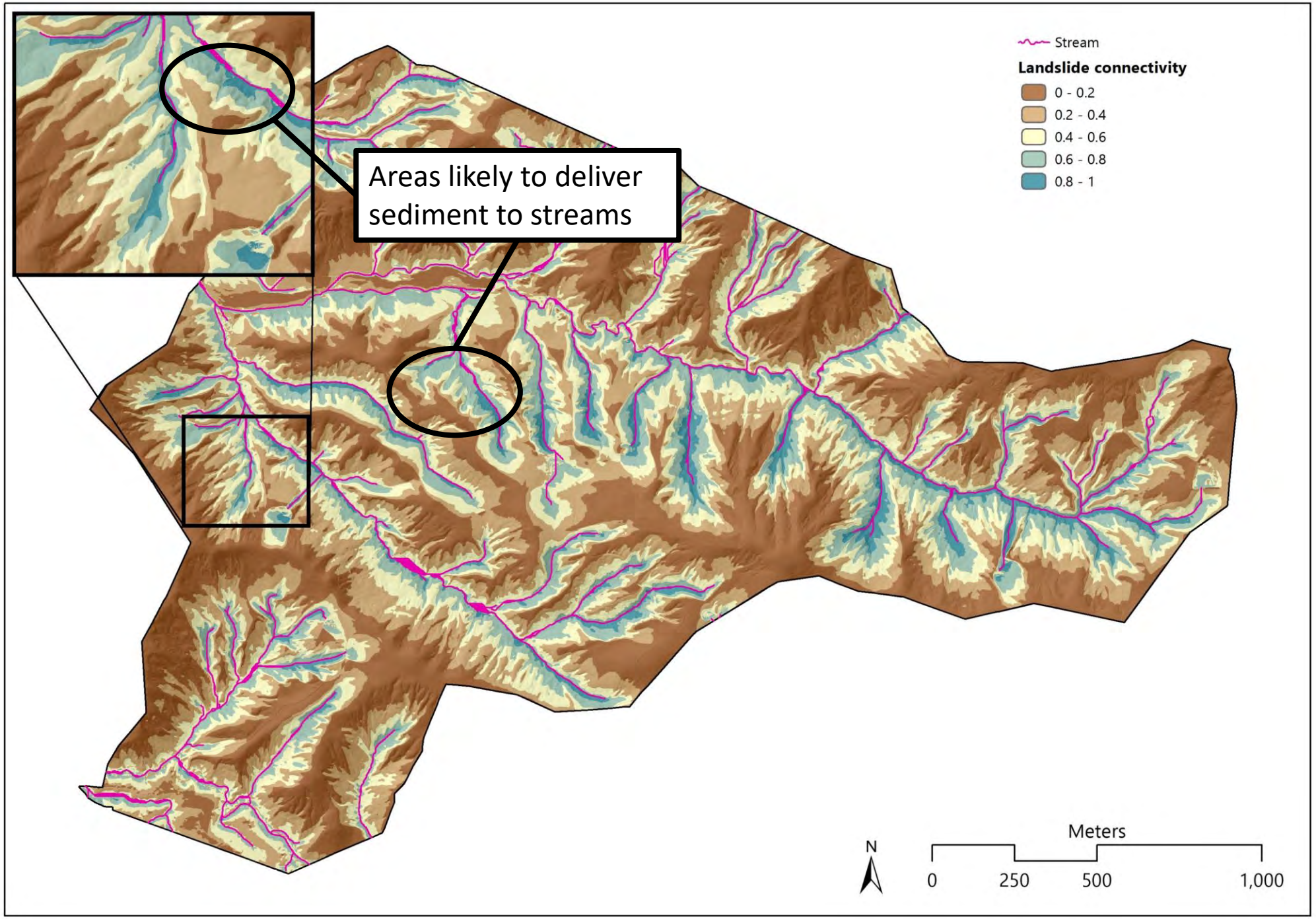
↳ **Slope**

↳ **Tree**

Landslide connectivity model using 1-m LiDAR DEM



Scale

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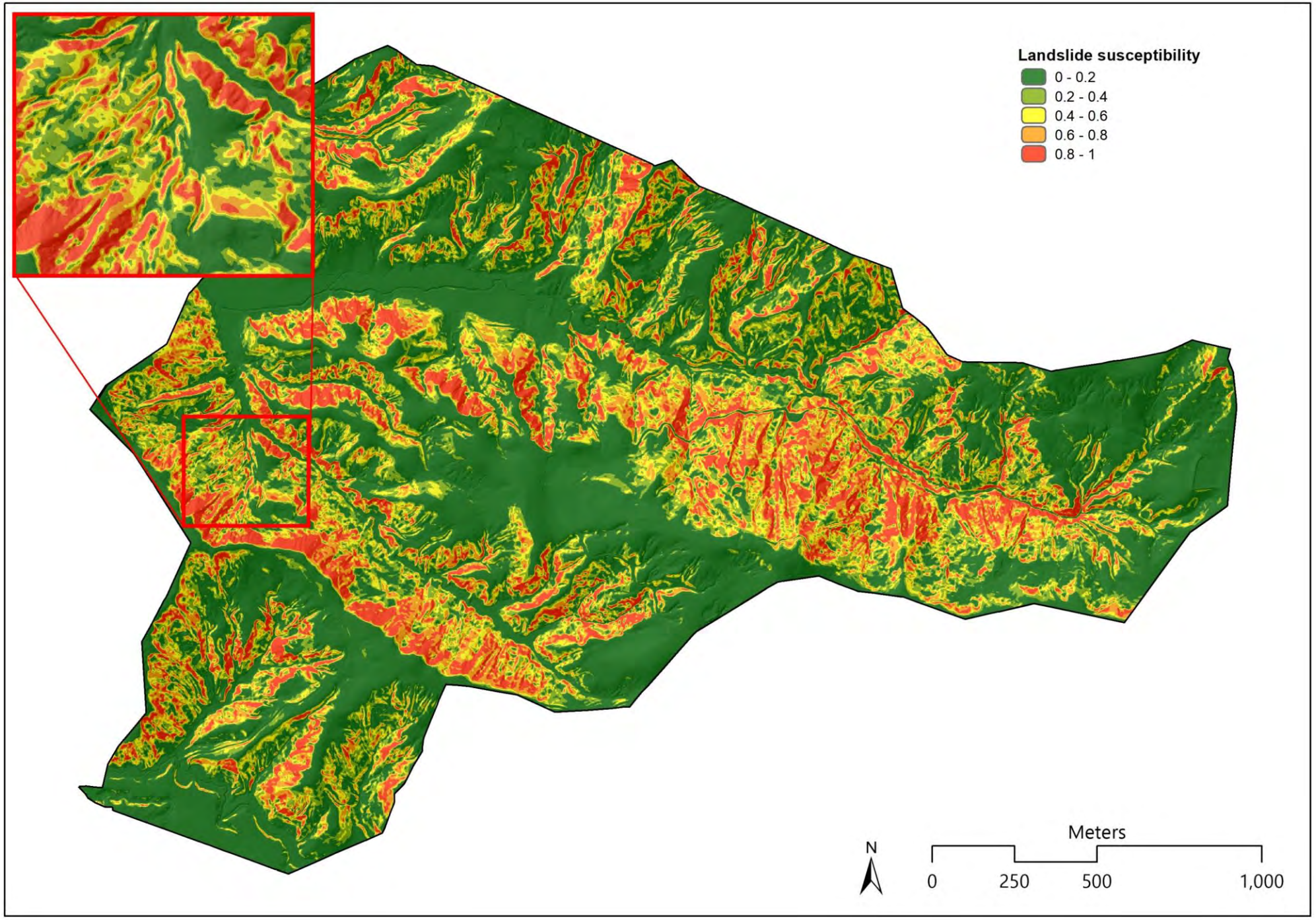
      - **Tree**

Treeless baseline LS model using 1-m LiDAR DEM

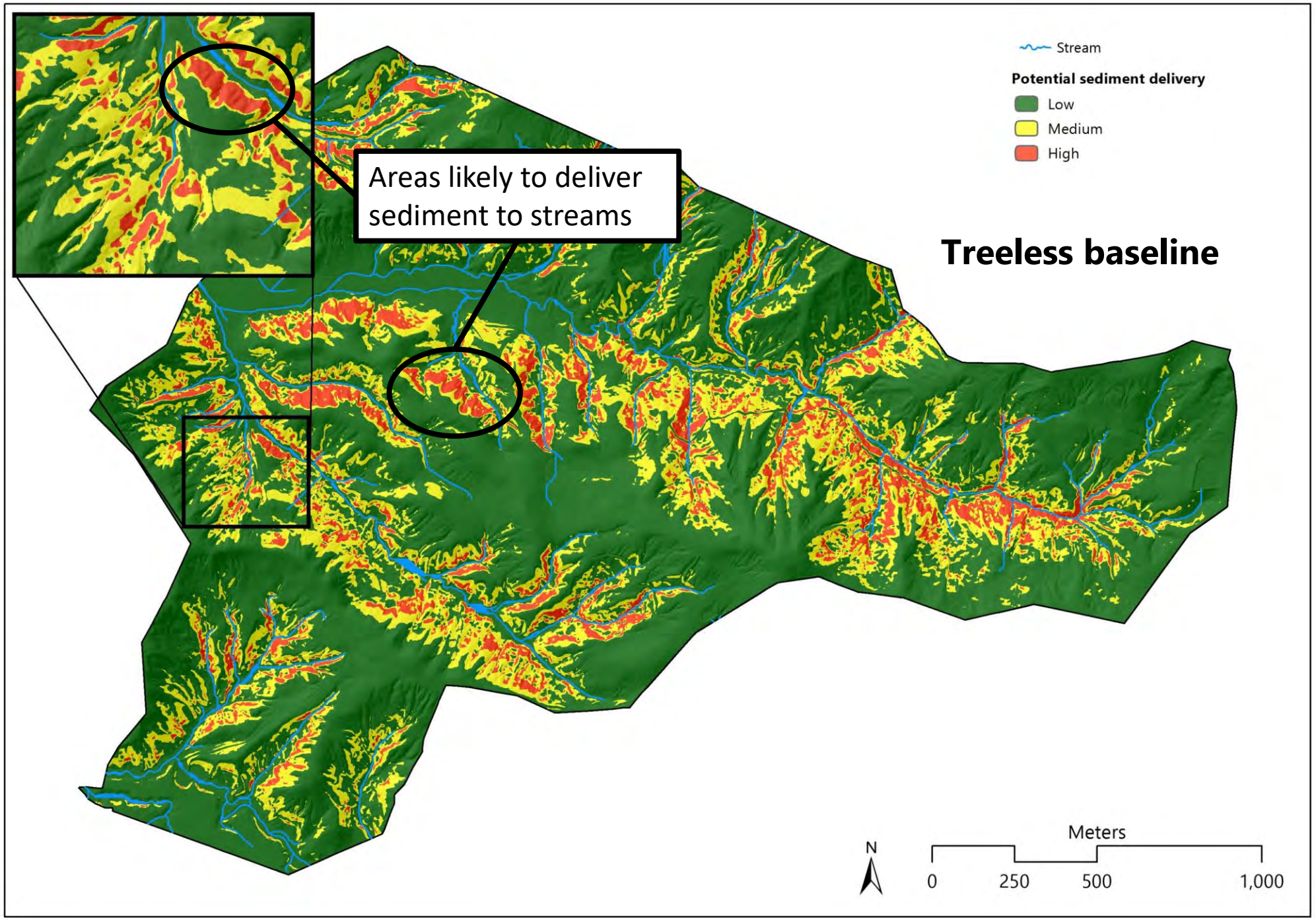


Scale

National

- **Regional**
  - **Farm**
    - **Slope**
      - **Tree**

Integrated LS and connectivity models based on 1-m LiDAR DEM



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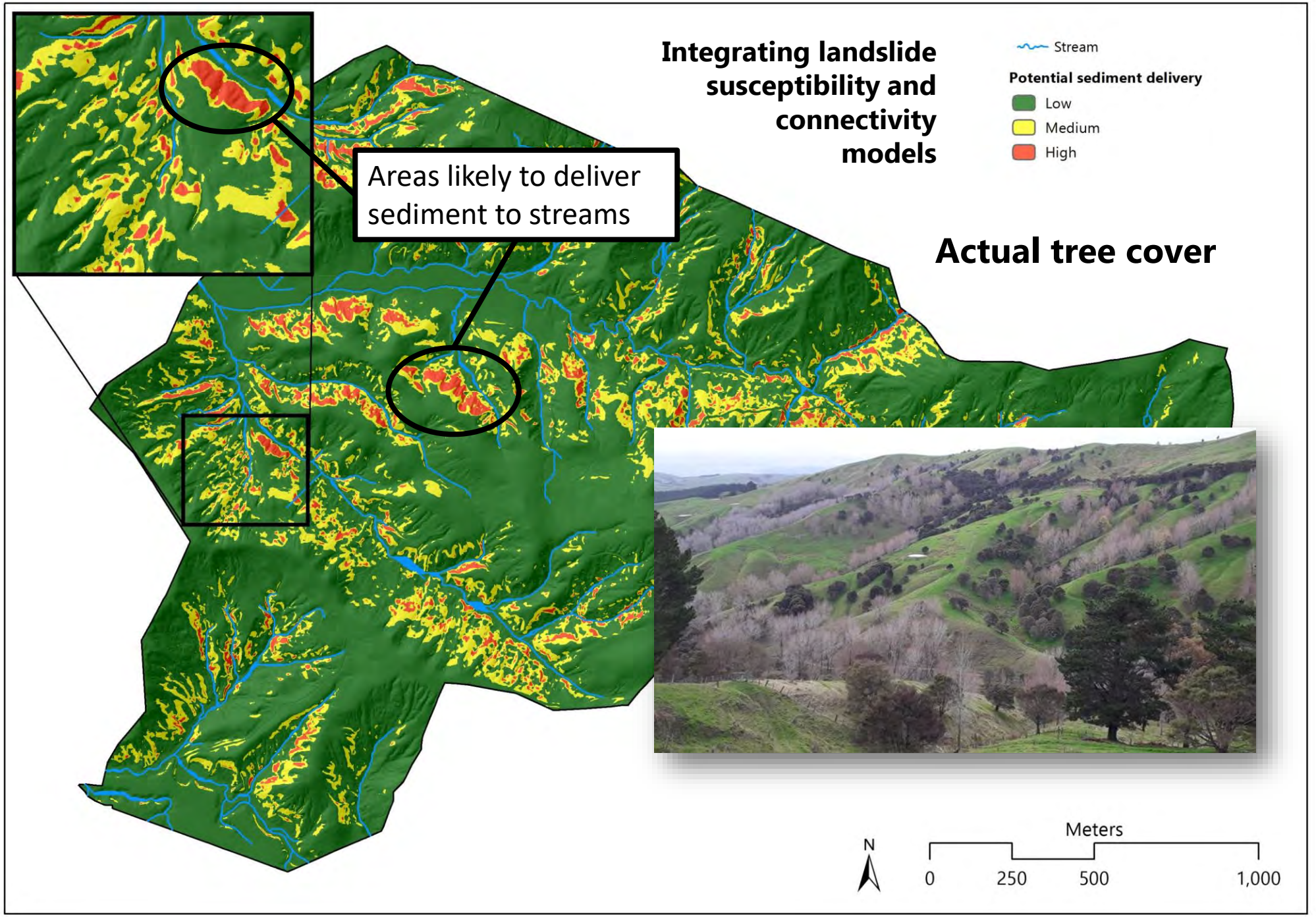
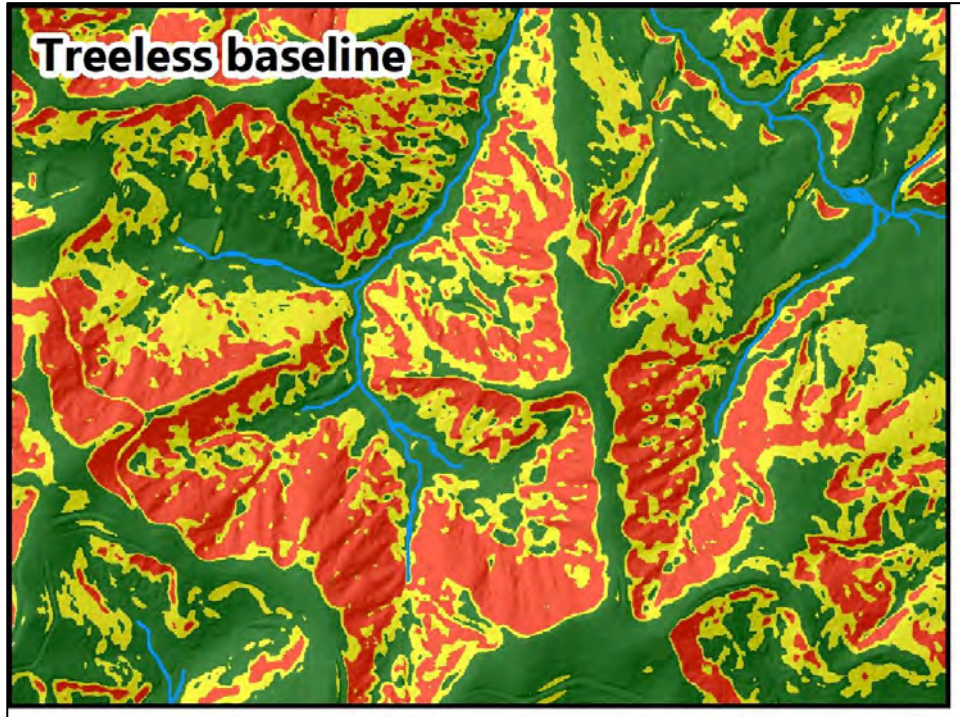
Integrated LS and connectivity models based on 1-m LiDAR DEM

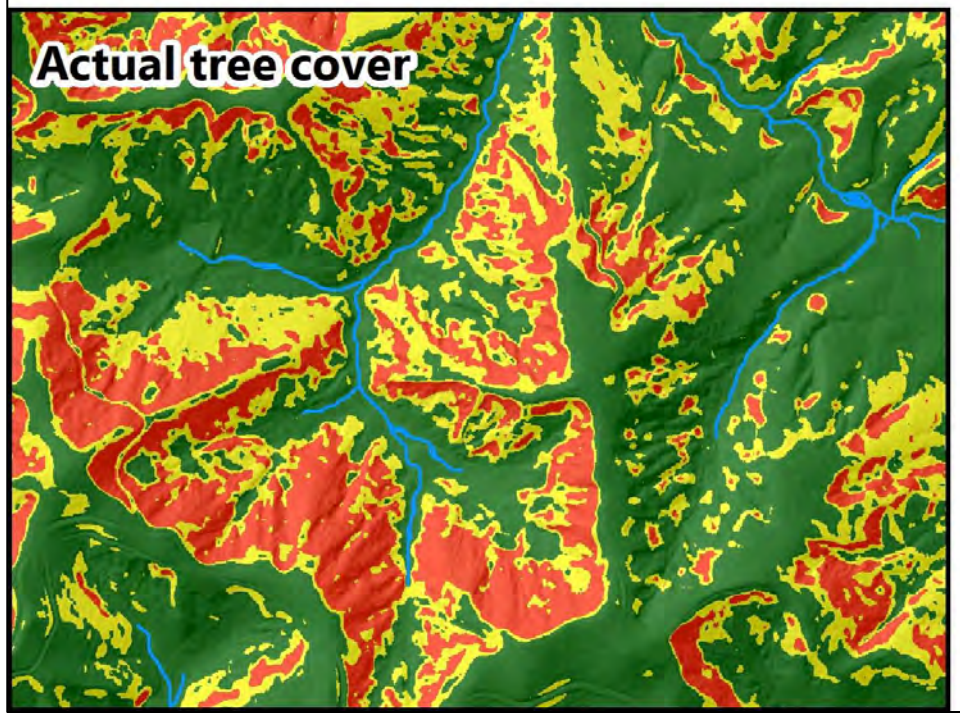


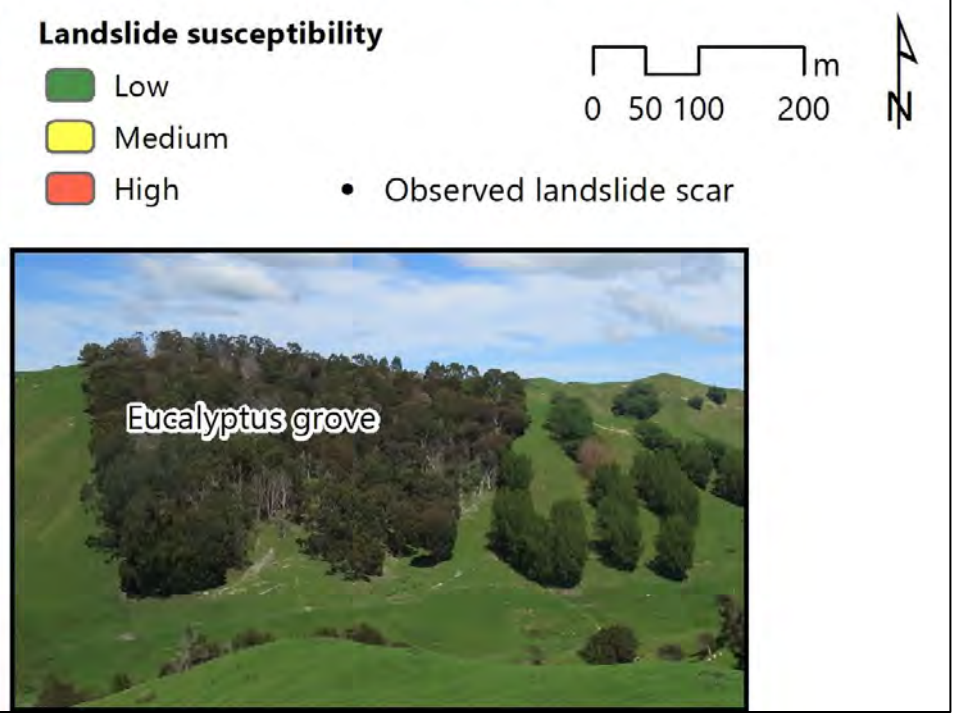
Scale

National
- Regional
  - **Farm**
    - **Slope**
      - **Tree**

LS model using 1-m LiDAR DEM and TIMSS







Scale

National
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  - Farm
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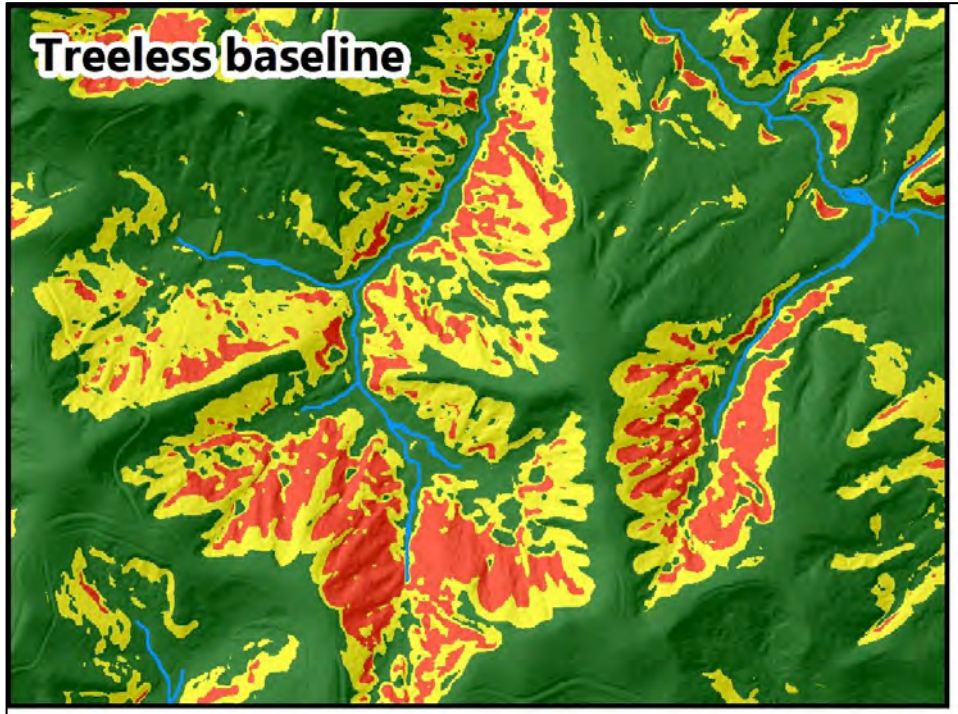
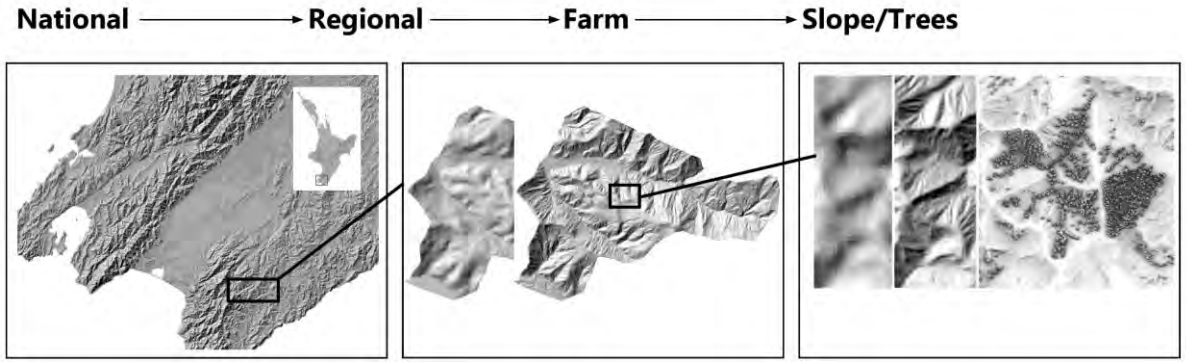
Integrated LS and connectivity models based on 1-m LiDAR DEM



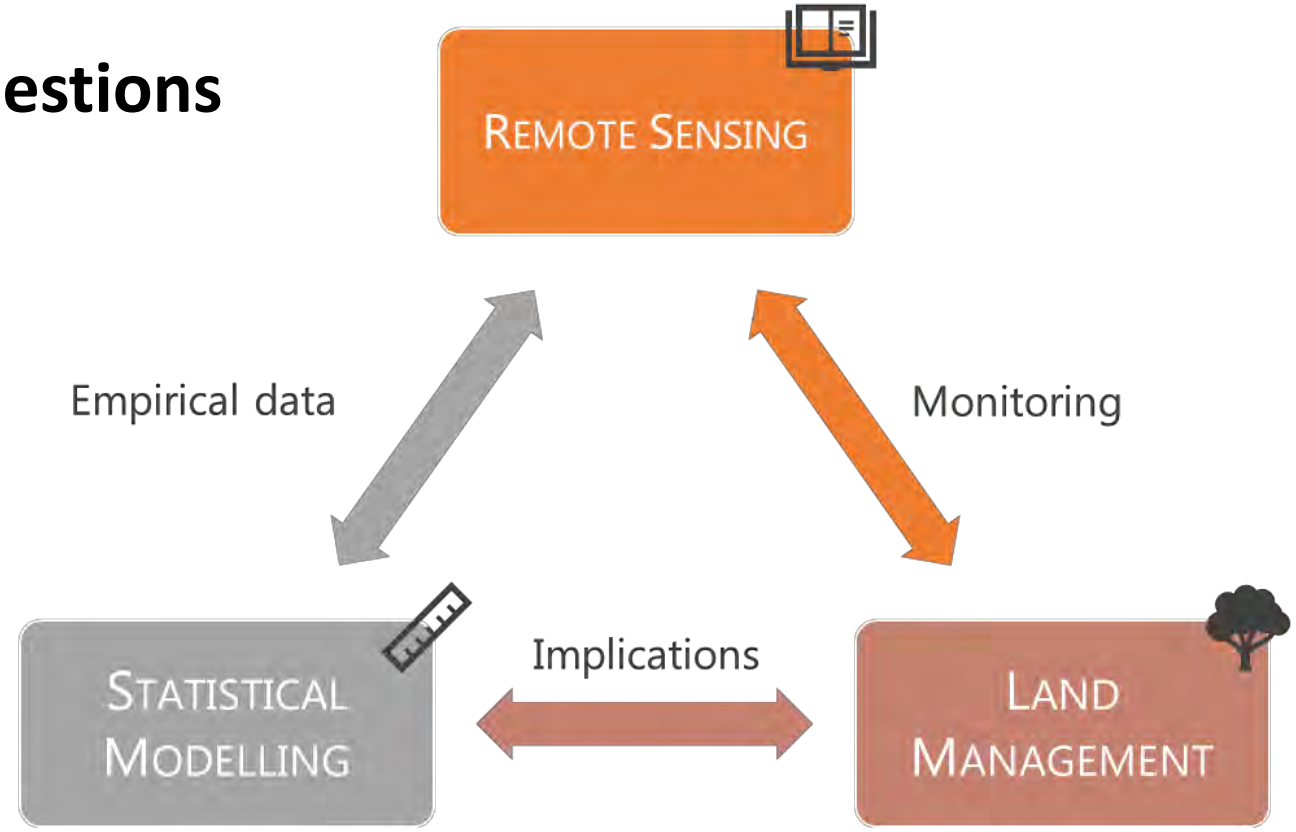
Contents lists available at ScienceDirect
Ecological Engineering
journal homepage: www.elsevier.com/locate/ecoleng
ELSEVIER

Development of a morphometric connectivity model to mitigate sediment derived from storm-driven shallow landslides

Raphael I. Spiekermann [a, b, *], Hugh G. Smith [a], Sam McColl [b], Lucy Burkitt [b], Ian C. Fuller [b]
[a] Manaaki Whenua – Landcare Research, Palmerston North, New Zealand
[b] School of Agriculture and Environment, Massey University, Palmerston North, New Zealand



Different data <> Different questions



Key Messages:

- Remote sensing techniques facilitate rapid acquisition of large quantities of landslide data for modelling.
- Statistical landslide susceptibility modelling provides a data-driven approach to better target erosion control from region to paddock scale.
- LiDAR enables new higher-resolution data collection and analysis, including individual trees.
- Mitigation can be targeted to sediment source locations with the connectivity model.
- Scenario modelling indicates targeted mitigation results in a 10-fold increase in cost-effectiveness of measures.

This research was supported by the MBIE research program "Smarter Targeting of Erosion Control (STEC)"