Too wet to burn?

High-resolution predictions of forest temperature and near-surface soil moisture in complex terrain.

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THE UNIVERSITY OF MELBOURNE

EMV EMERGENCY MANAGEMENT VICTORIA

Natural Disaster Resilience Grant Scheme (NDRGS)

VICTORIA State Government | Environment, Land, Water and Planning

Overview

Objectives & Rationale

Study area & measurements

Predictive models

Prescribed burn case study

Objectives

To examine the fine-scale spatial patterns of **near-surface soil moisture** in complex terrain.

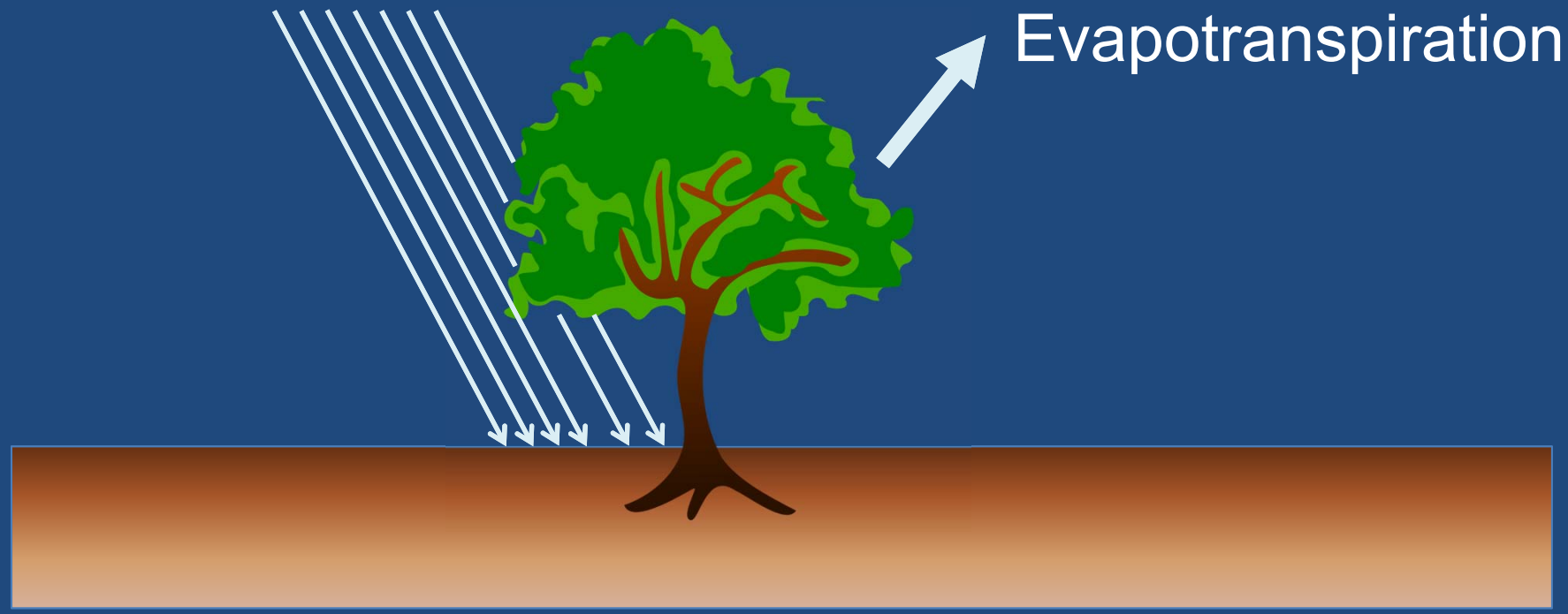
To test whether simple microclimate models of **forest air and litter temperature** can help in the prediction of near-surface soil moisture.

Rationale

Near-surface soil moisture affects the moisture of critical surface fuels (Hatton *et al.* 1998)

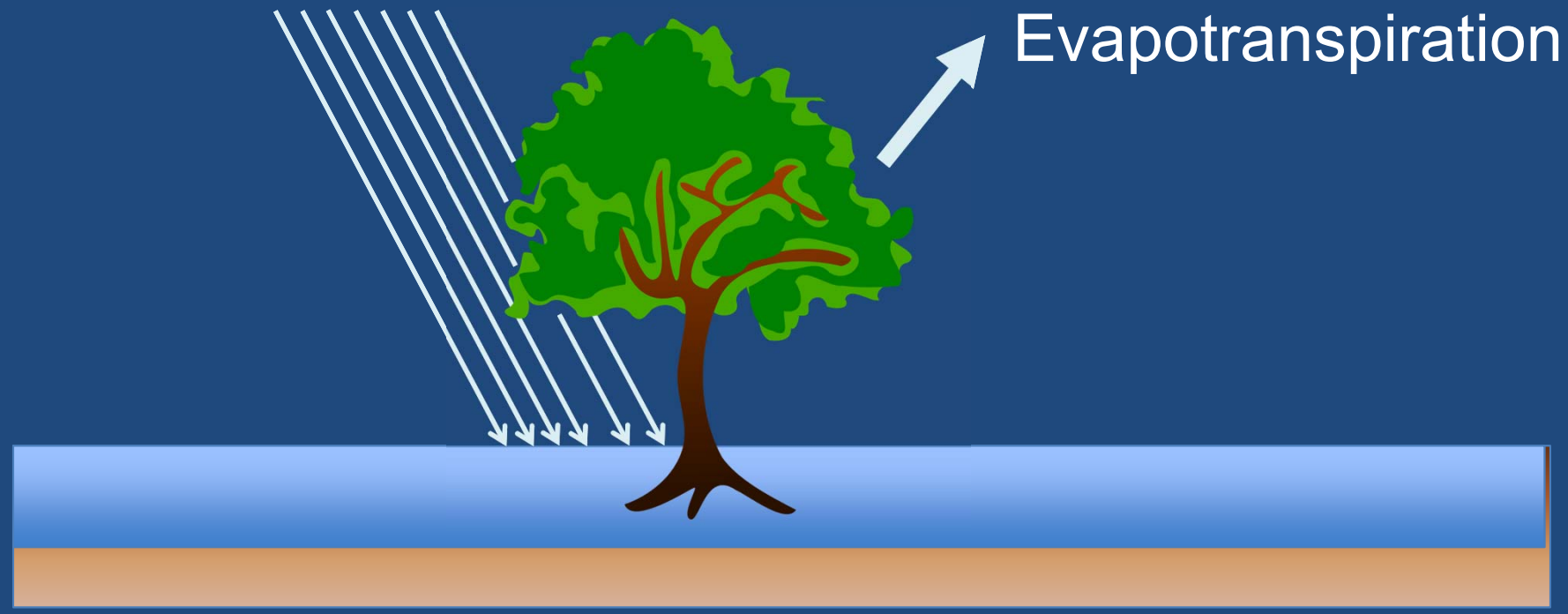
Rationale

Operational predictions of soil moisture deficit involve an overall water budget, with water loss dominated by tree transpiration…



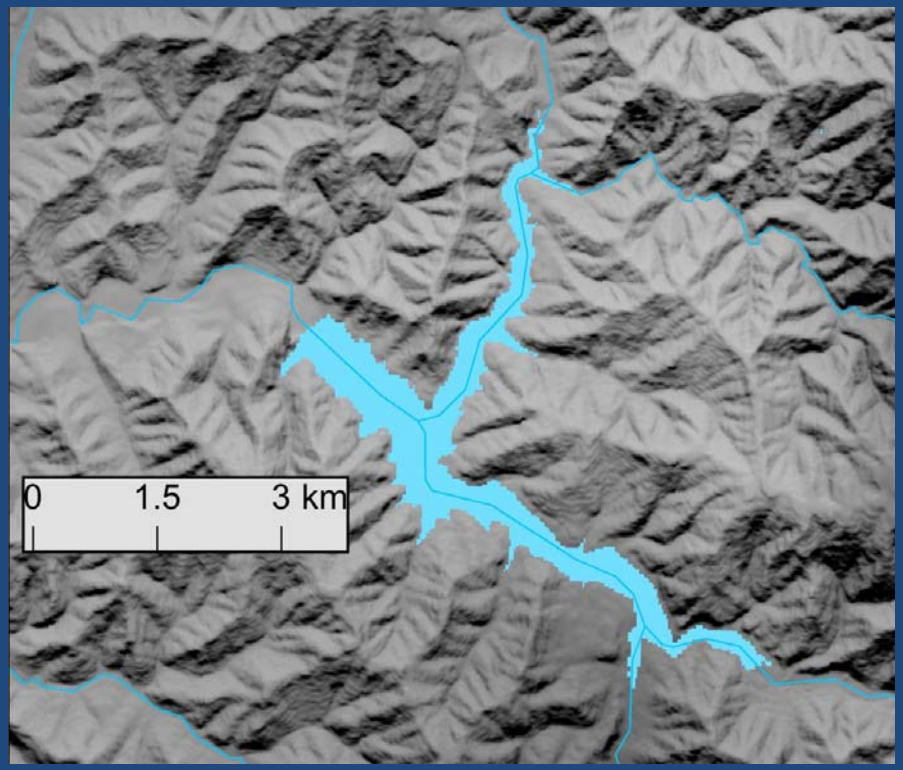
Rationale

… essentially giving a measure of tree root-zone moisture … not forest floor moisture.



Rationale

Also, spatial resolution is very coarse … if complex terrain affects soil moisture, it won't be captured.



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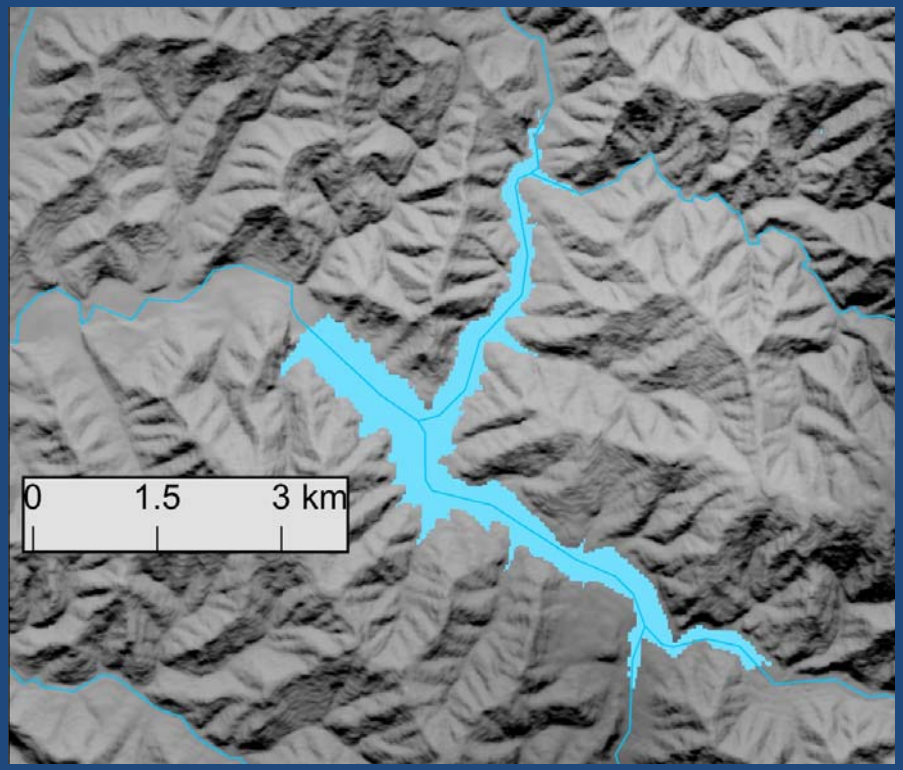
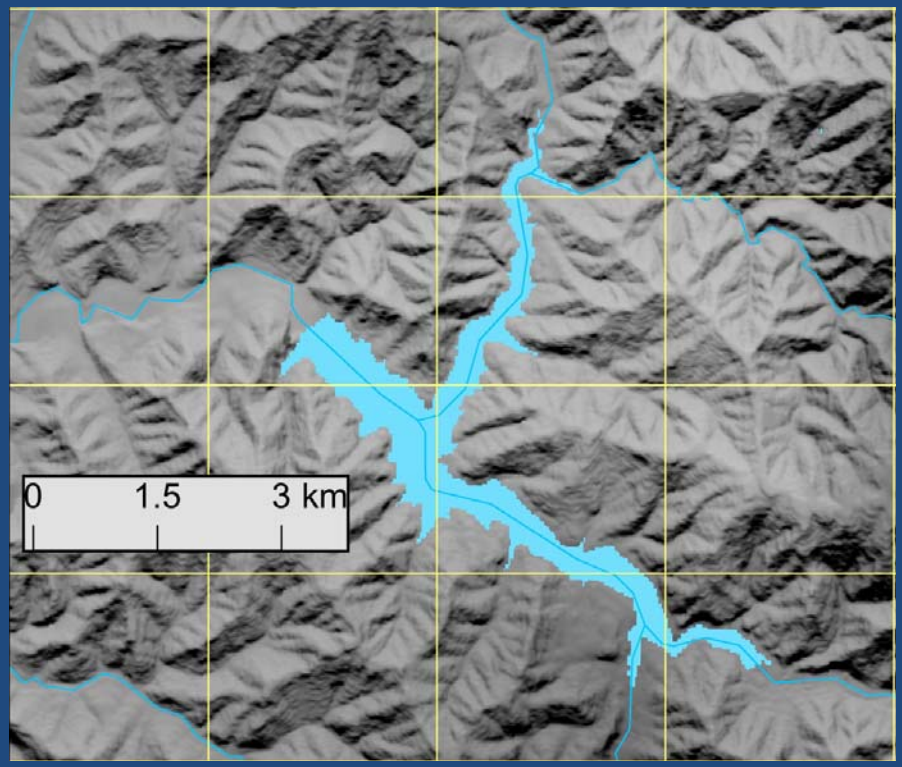
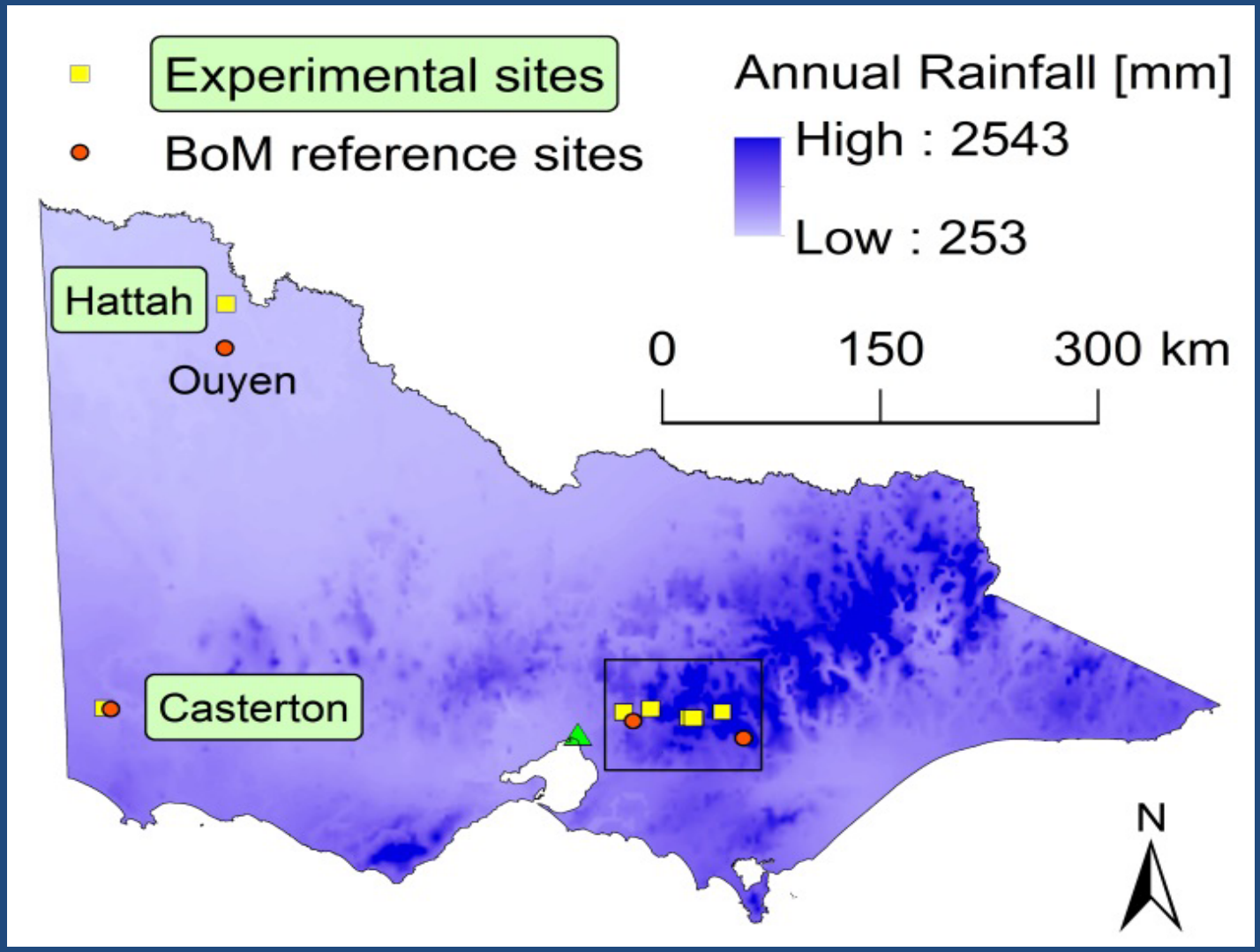




Study area and measurements



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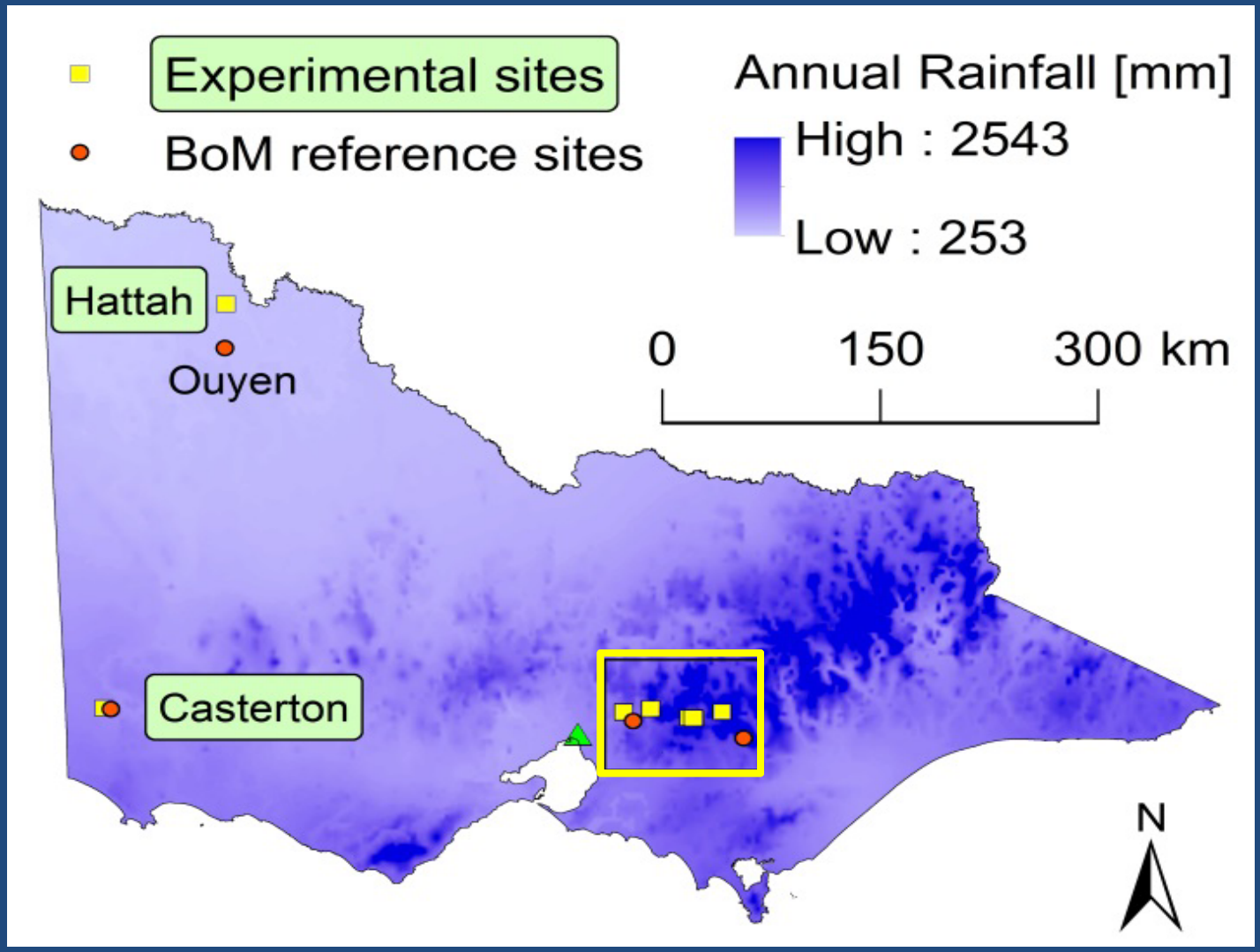

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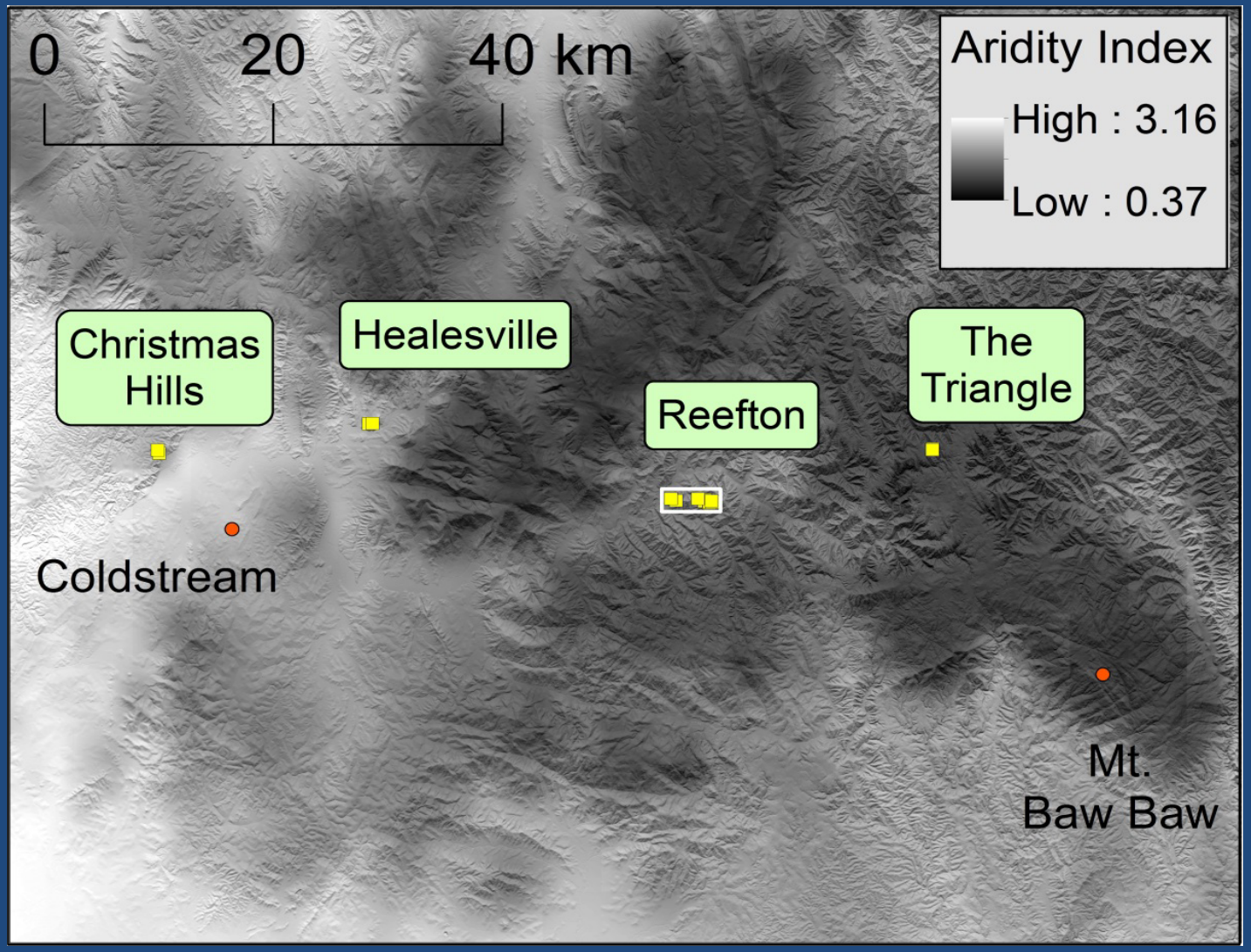

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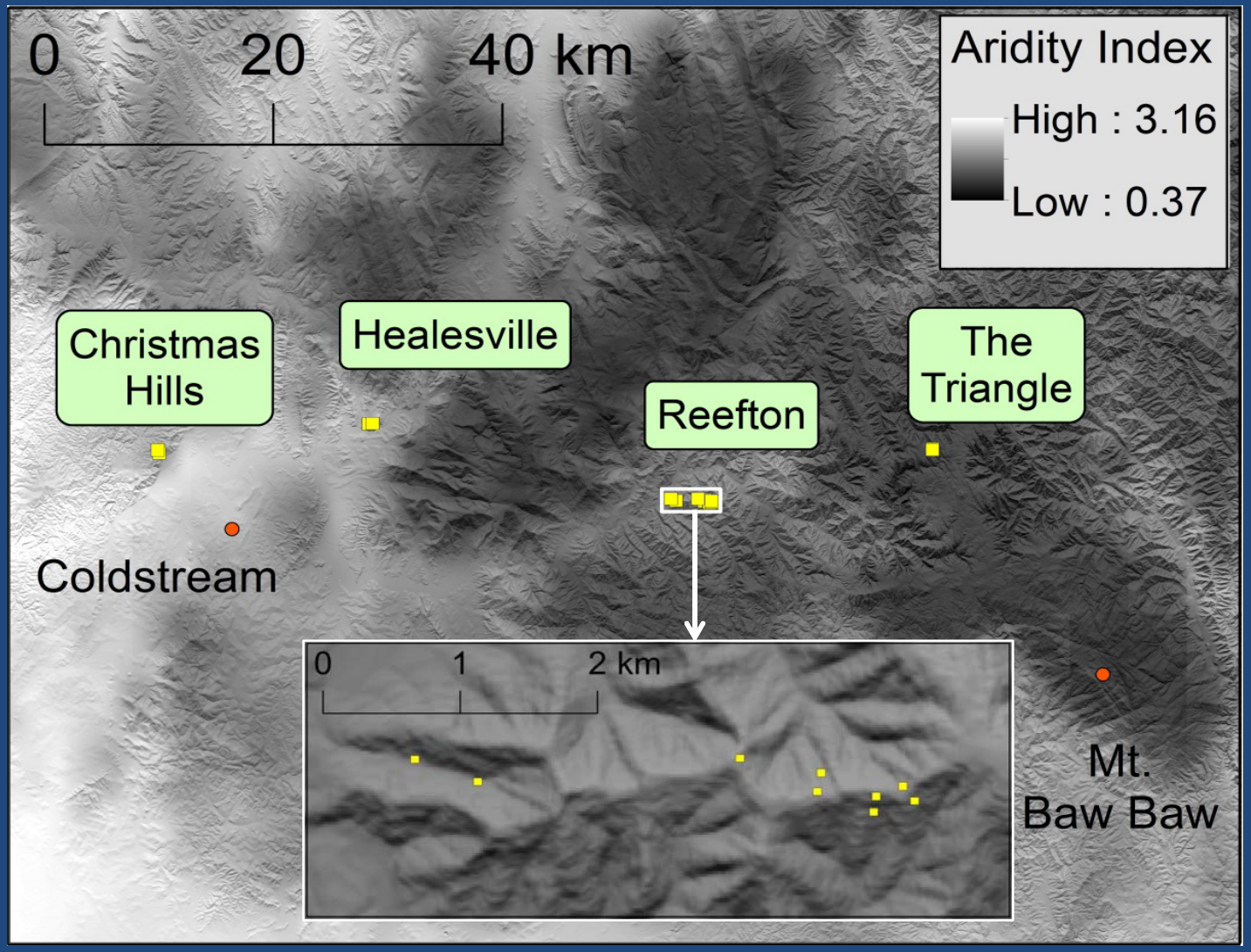


Study area and measurements

Time series measurements include:

- Screen-level air temperature (1.5 m)
- Litter layer temperature
- Near-surface soil moisture (10 cm depth)

Site hemispherical photos → Plant Area Index (PAI)

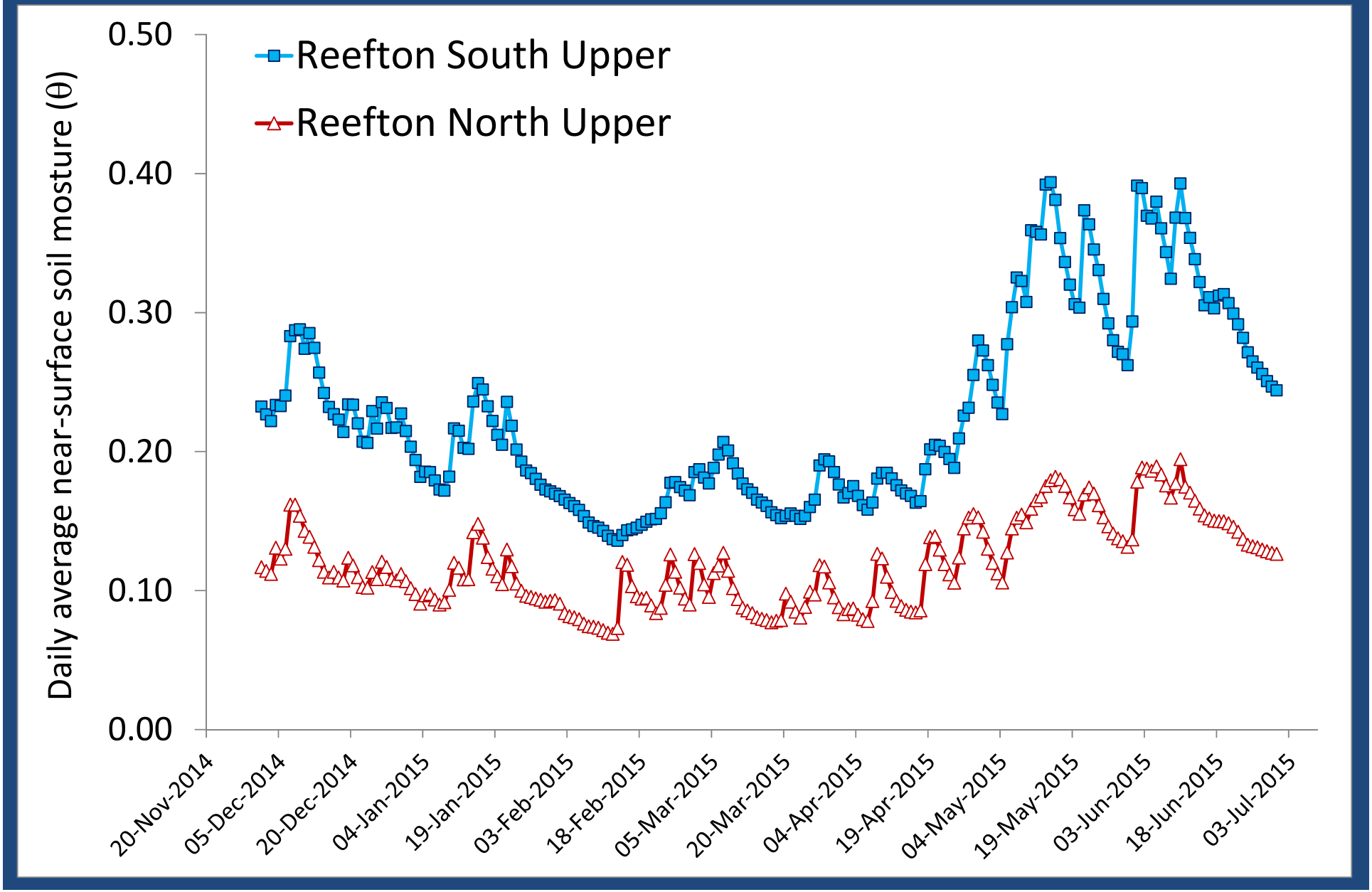
Study area and measurements

GIS layers (20 m resolution)

- **Z** = Elevation
- **S** = Shortwave Radiation Ratio

North-facing hillslopes	S > 1
Flat terrain	S = 1
South-facing hillslopes	S < 1

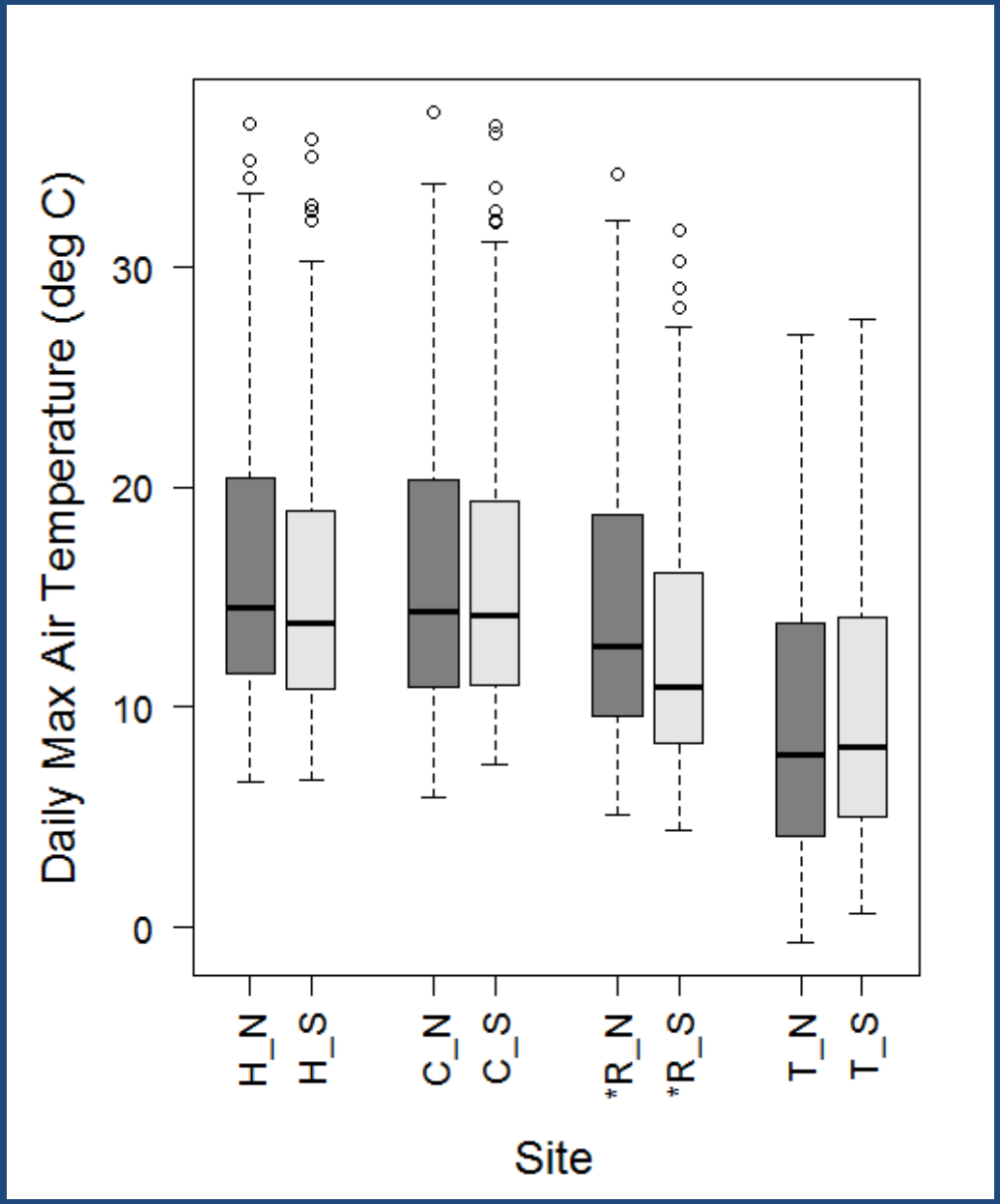
Near-surface soil moisture



Daily max air temperature

North-facing

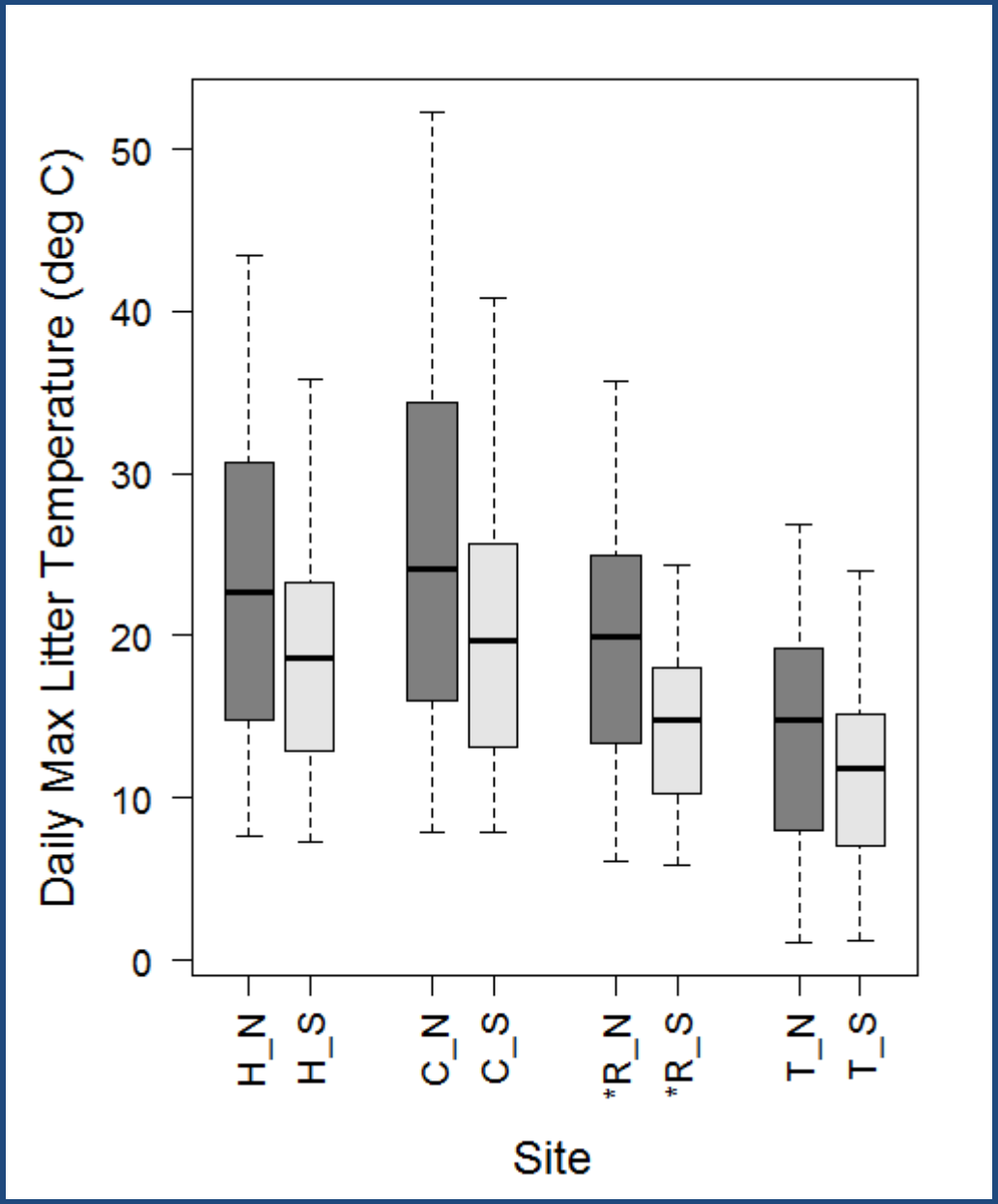
South-facing



Daily max litter temperature

North-facing

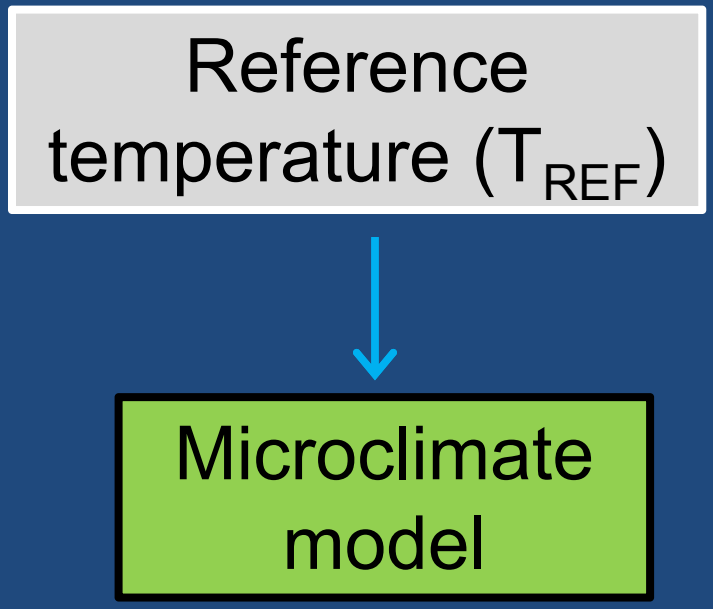
South-facing



Predictive models - Temperature

Reference temperature (T_{REF})

Predictive models - Temperature



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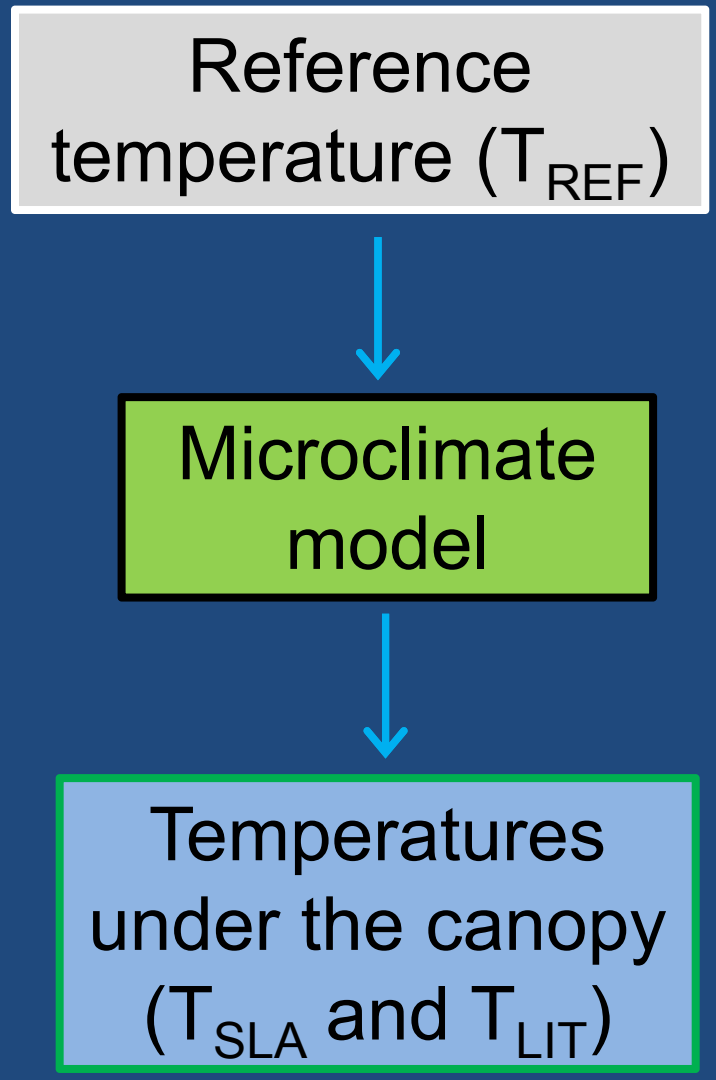
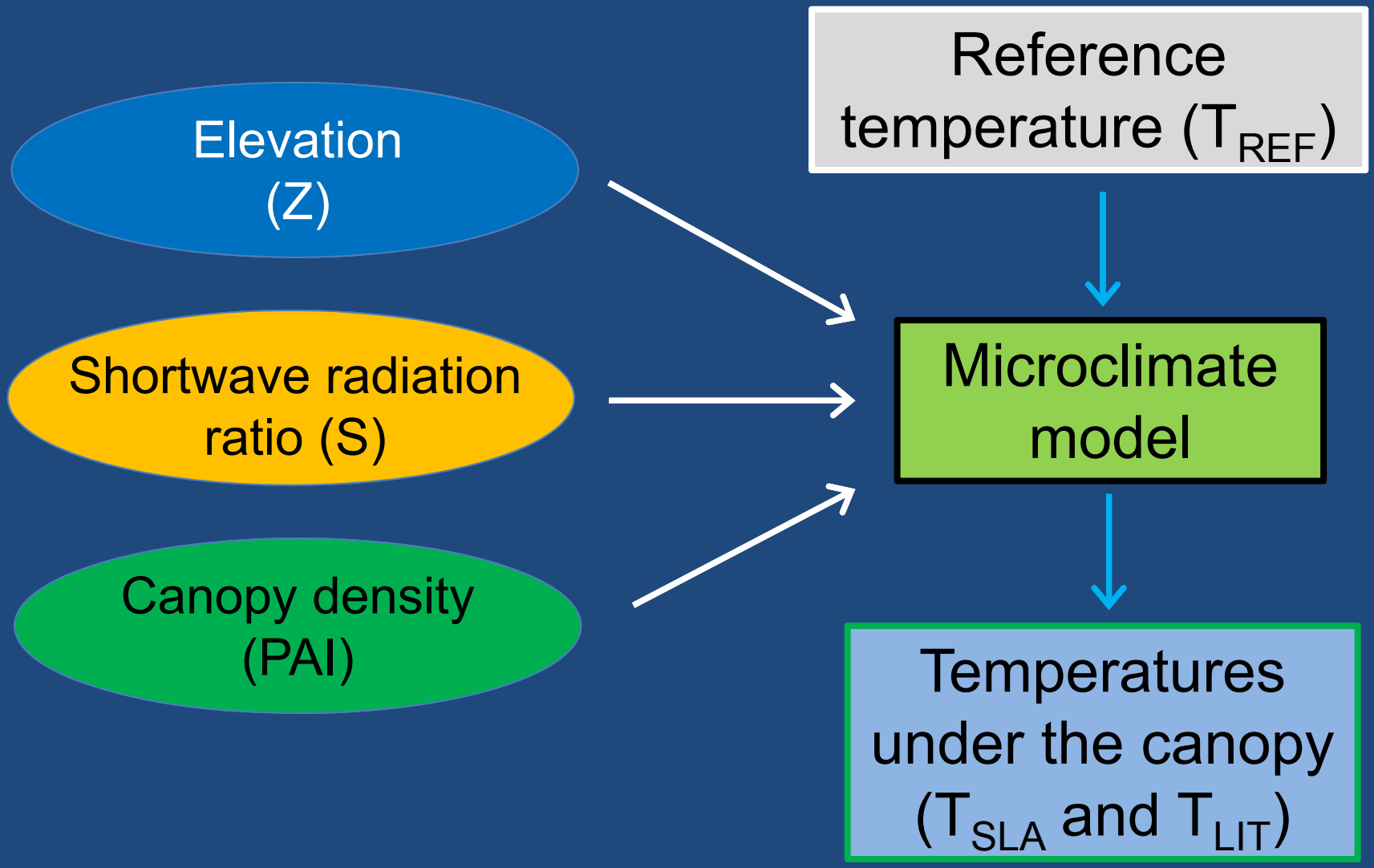


Predictive models - Temperature



Predictive models - Temperature

$$T_{LOC}(t) = T_{REF}(t) - \Delta\bar{T}$$

$$T(t) = f(T_{LOC}(t), S, PAI)$$

Predictive models - Temperature

$$T_{LOC}(t) = T_{REF}(t) - \Delta\bar{T}$$

$\Delta\bar{T}$ = Difference in elevation x lapse rate

$$T(t) = f(\, T_{LOC}(t), S, PAI \,)$$

Predictive models - Temperature

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Adjustment for incoming radiation (slope & aspect)

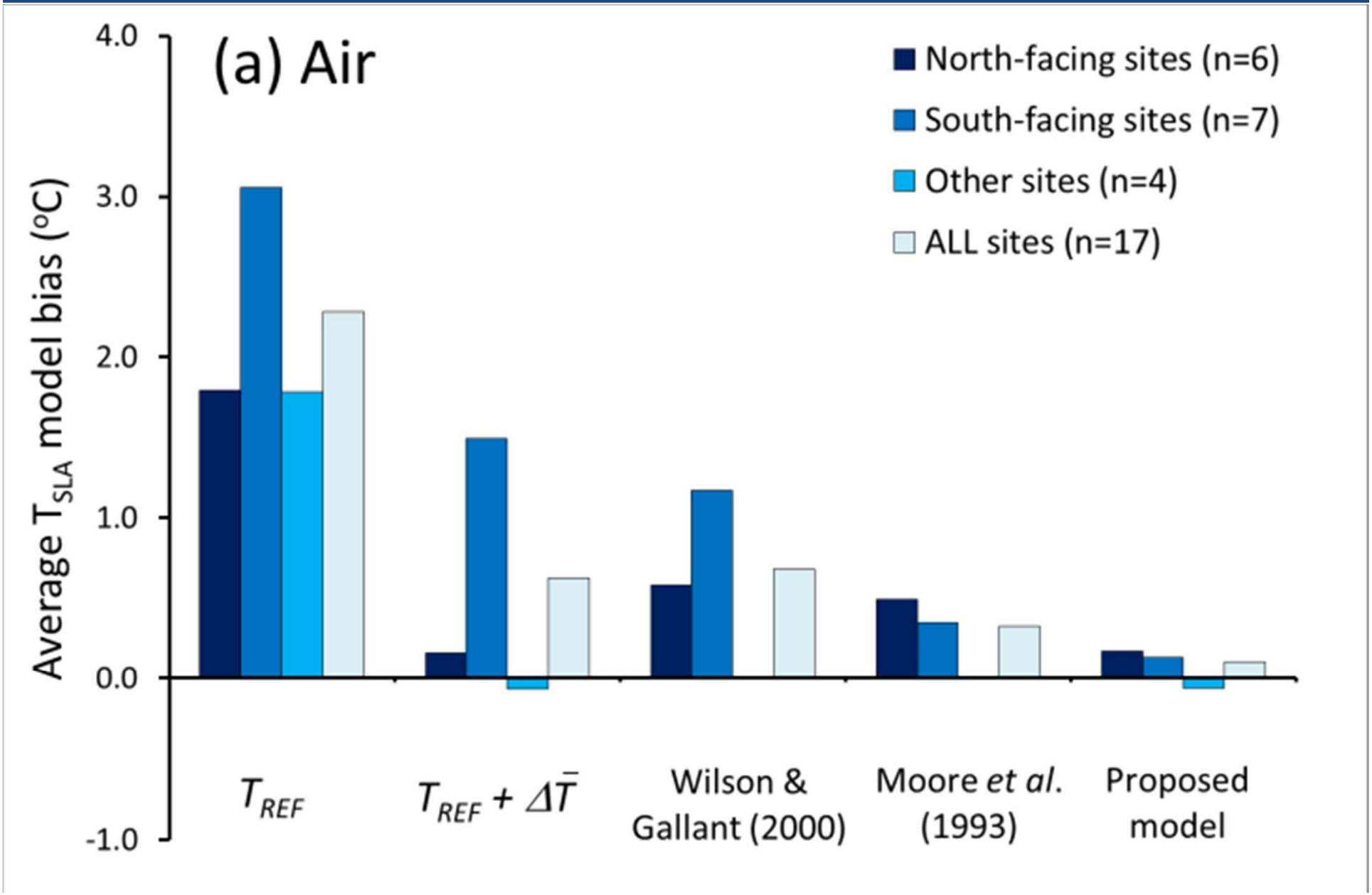
Predictive models - Temperature

$$T_{LOC}(t) = T_{REF}(t) - \Delta\bar{T}$$

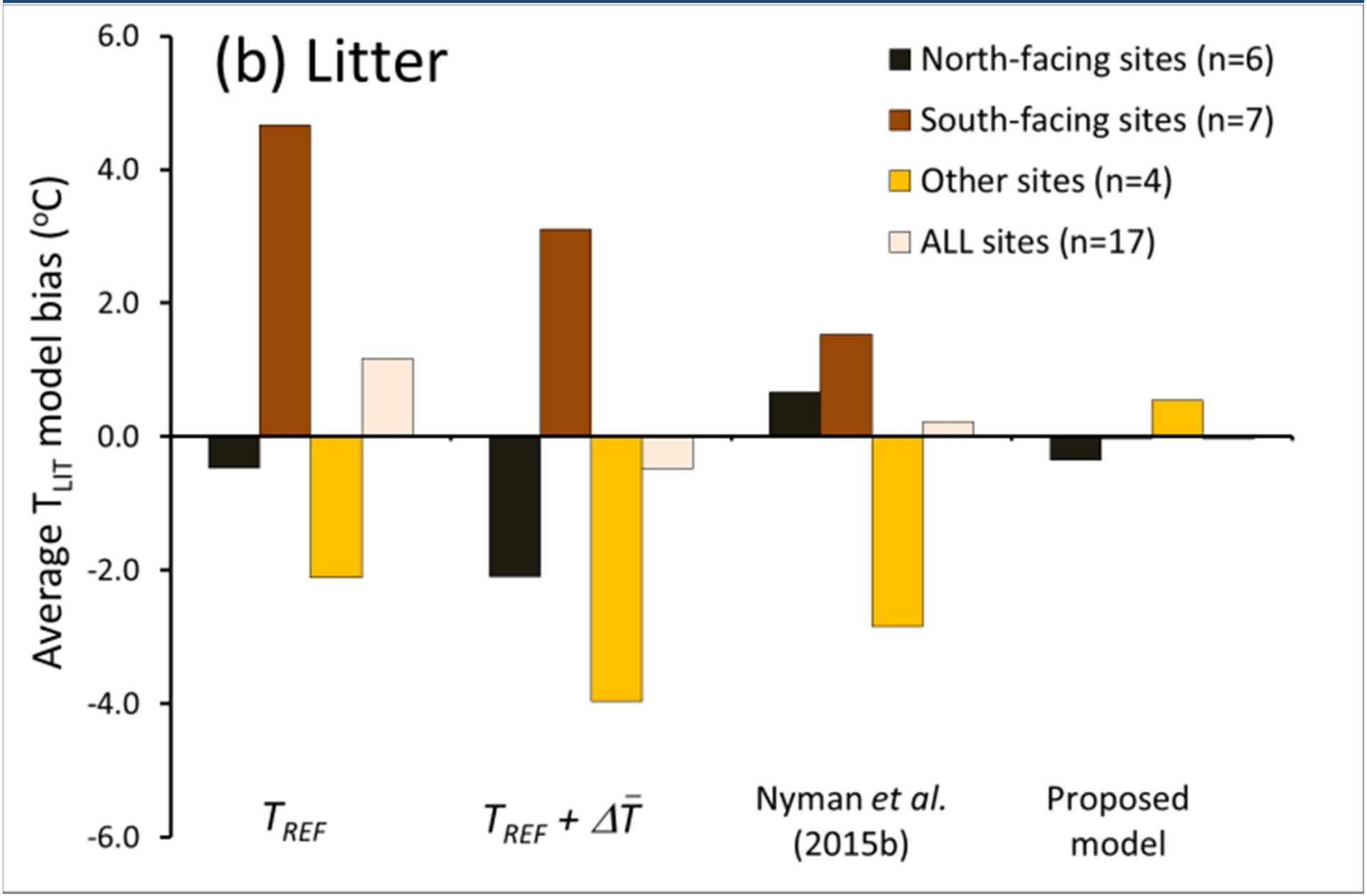
$$T(t) = f(\, T_{LOC}(t), S, PAI \,)$$

Adjustment for radiation absorbed by the canopy

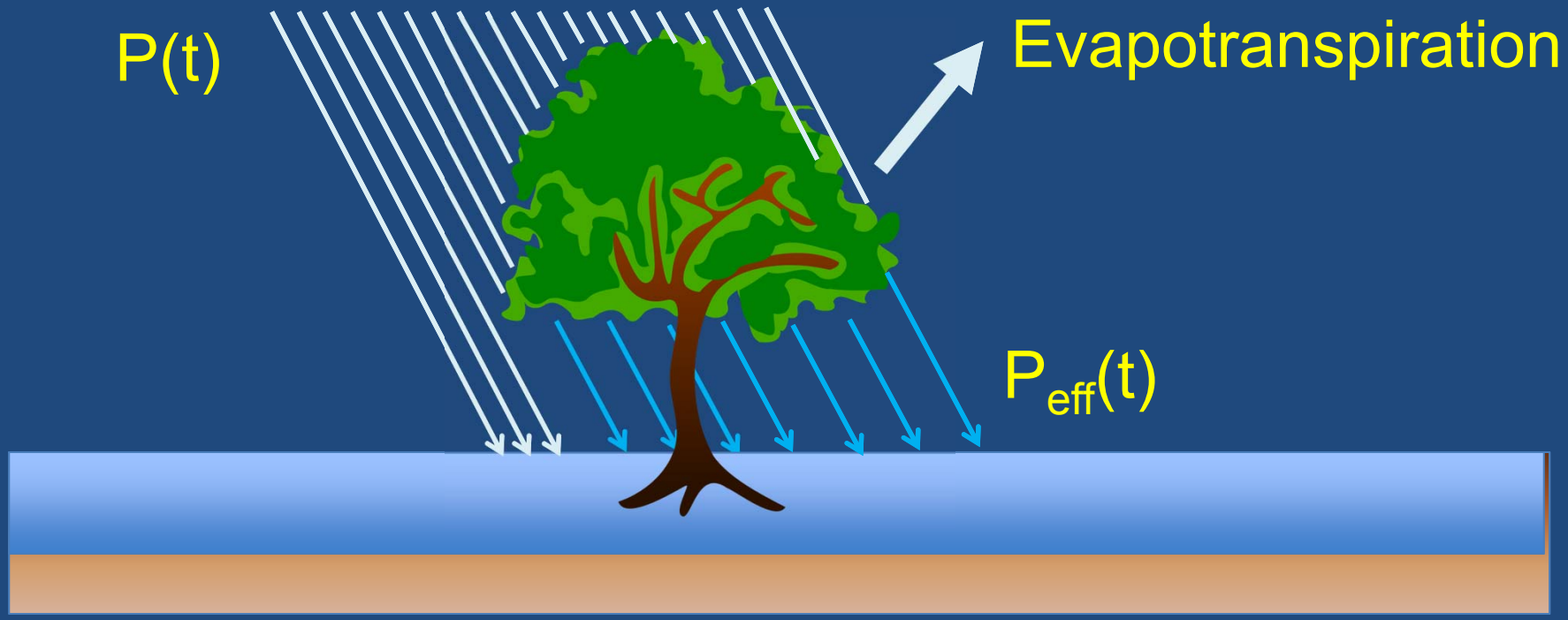
Screen-level air temperature bias



Litter temperature bias



Predictive models – Soil Moisture Deficit



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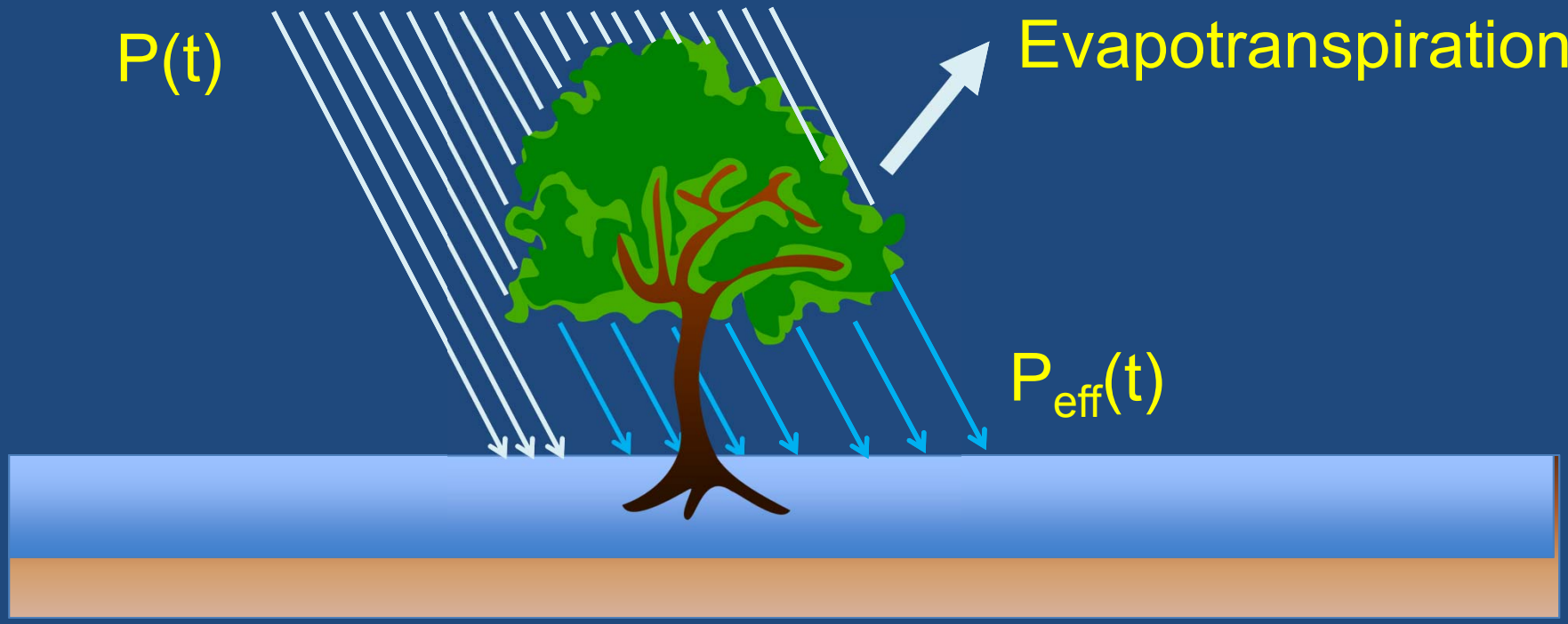


KBDI – Keetch-Byram Drought Index

Forest temperature and near-surface soil moisture in complex terrain

Predictive models – Soil Moisture Deficit

Annual Rainfall

↓

Evapotranspiration

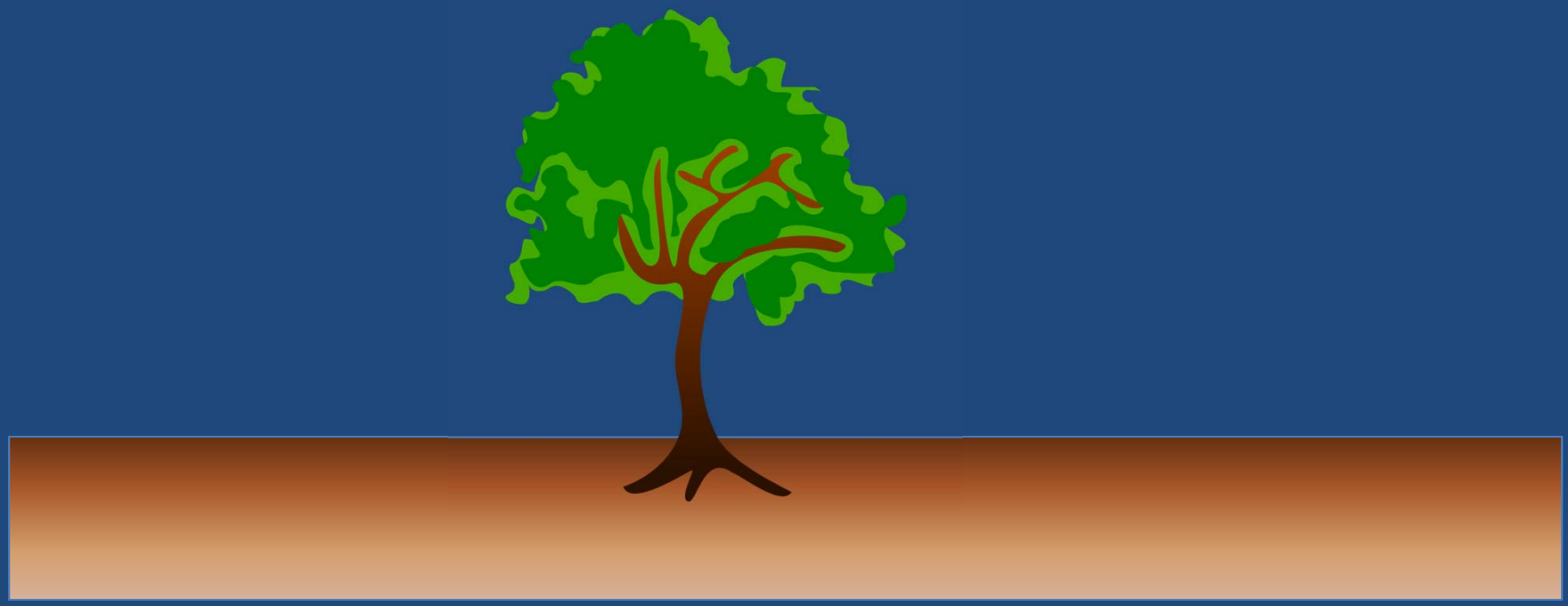
↑

Daily Max Temperature

KBDI – Keetch-Byram Drought Index

Predictive models – Soil Moisture Deficit

Predictive models – Soil Moisture Deficit

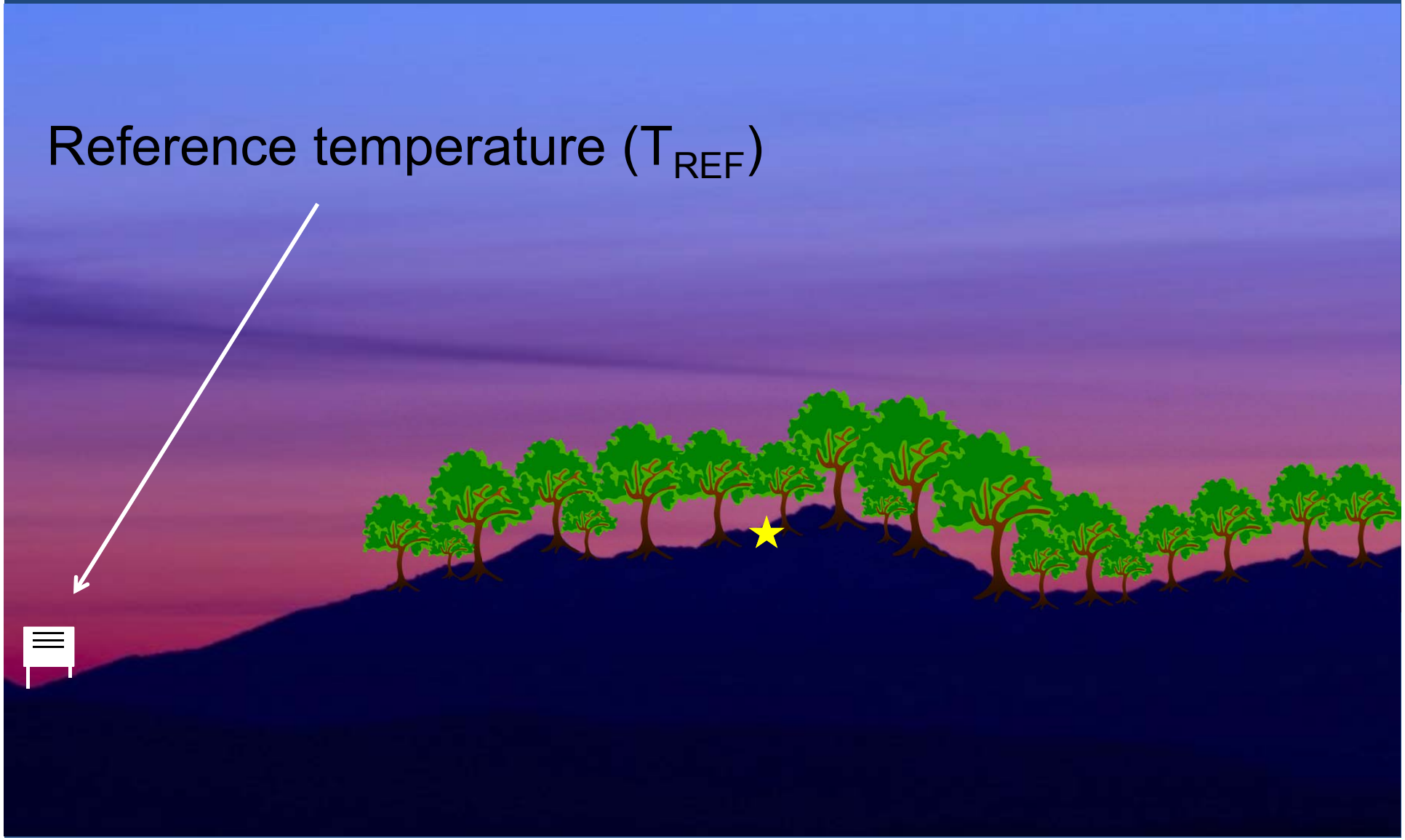


"Normalised" value (K) = KBDI / $KBDI_{MAX}$

Predictive models – Soil Moisture Deficit

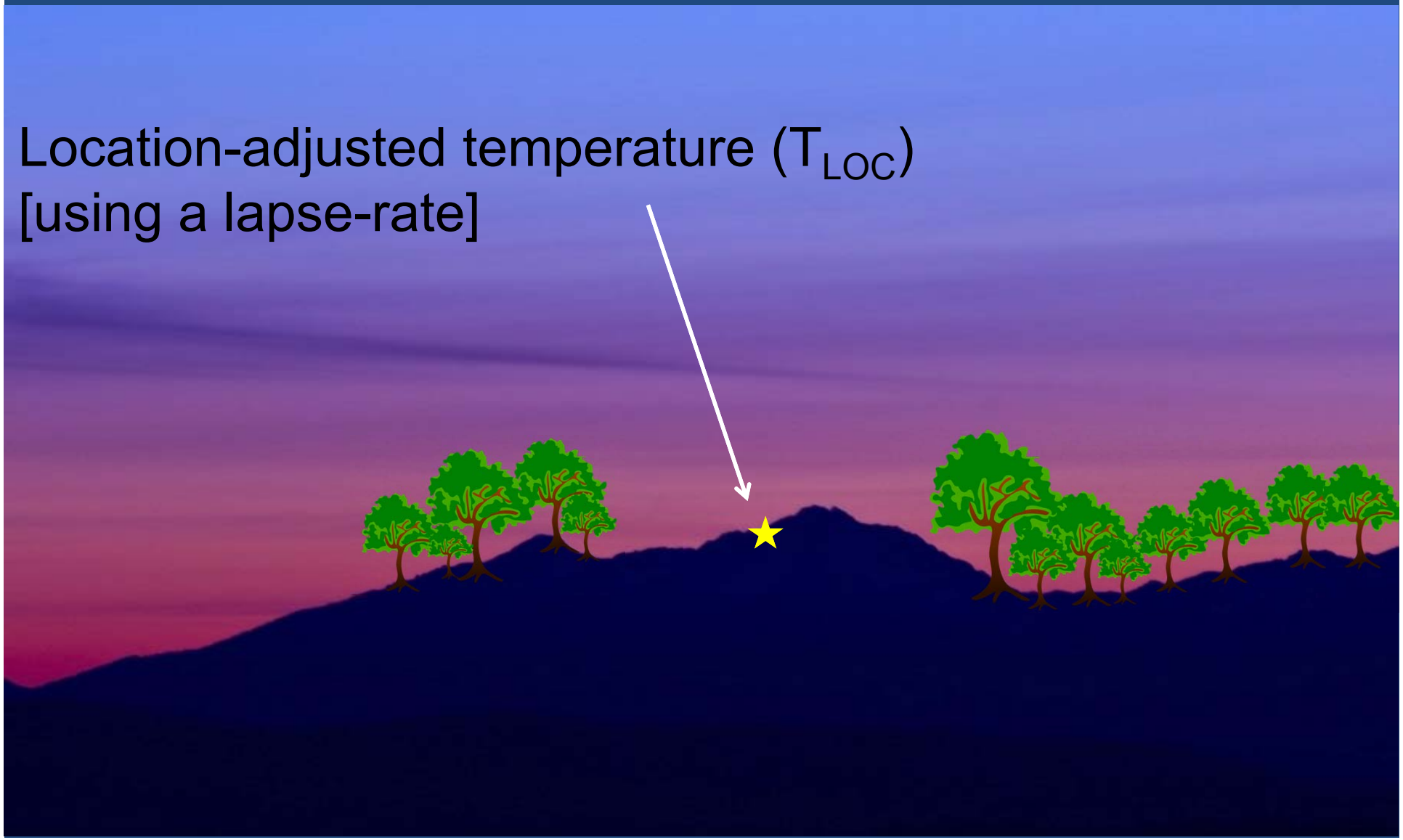
Where do we measure temperature for purposes of the KBDI calculation?

Predictive models – Soil Moisture Deficit



Predictive models – Soil Moisture Deficit

Location-adjusted temperature (T_{LOC})
[using a lapse-rate]



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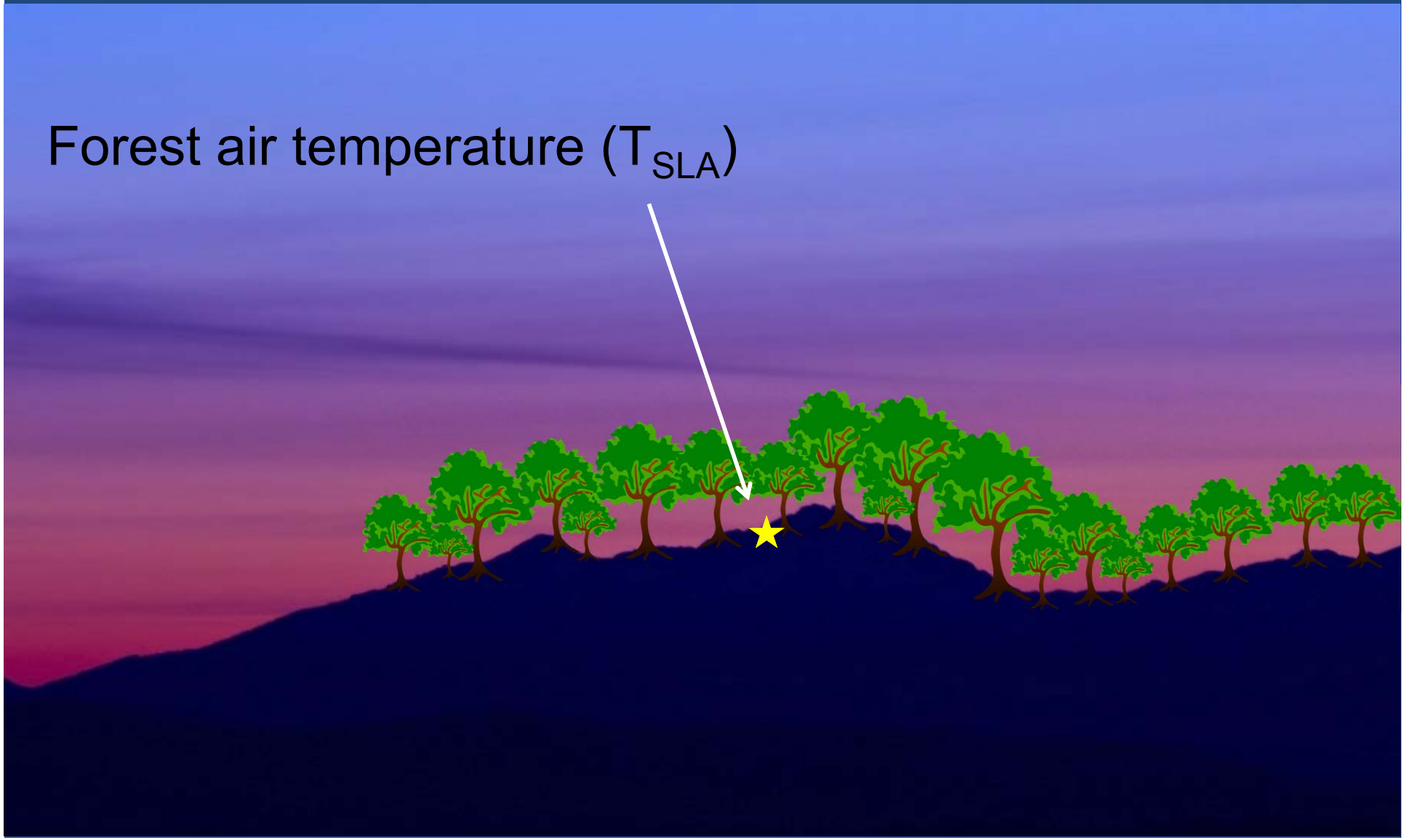

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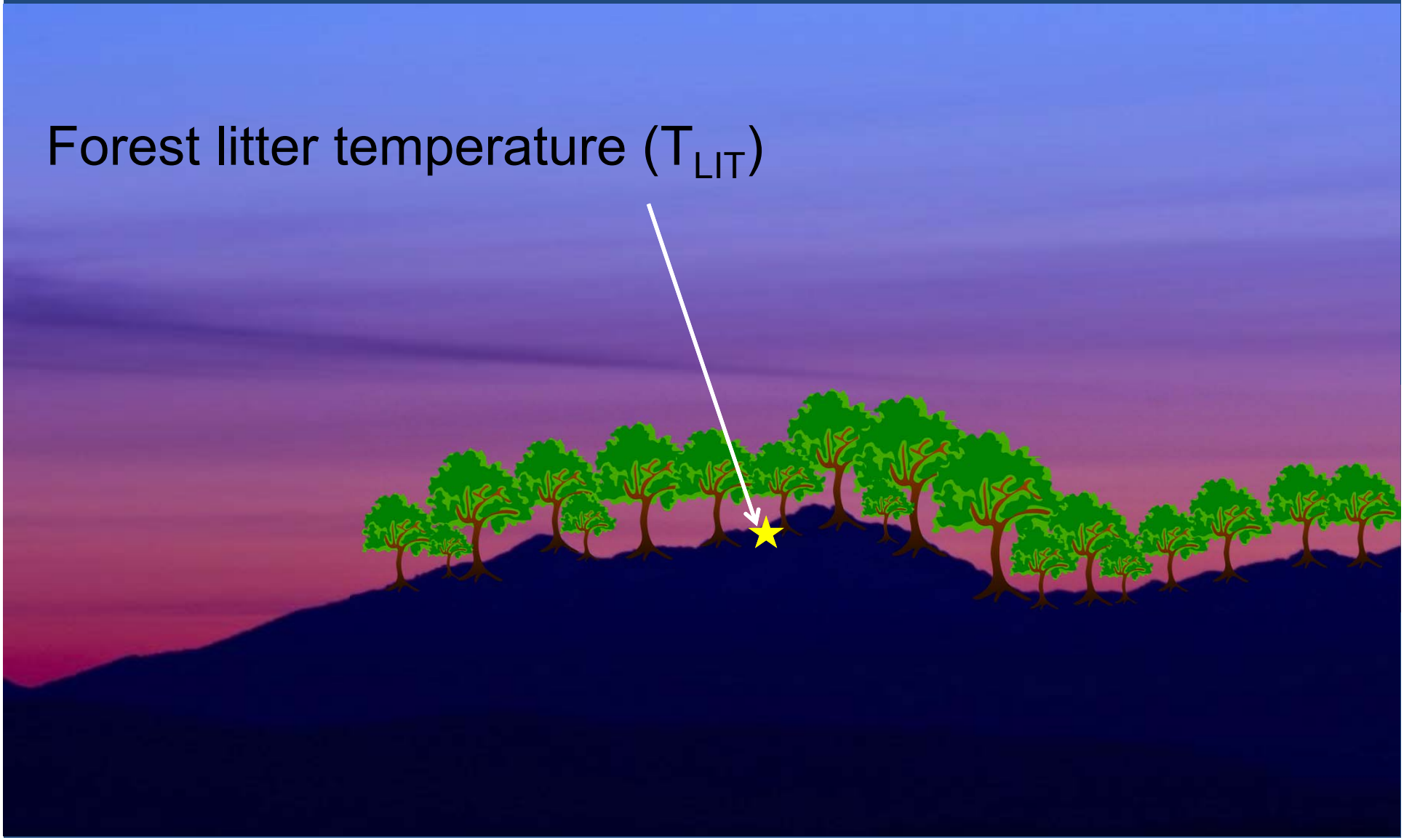

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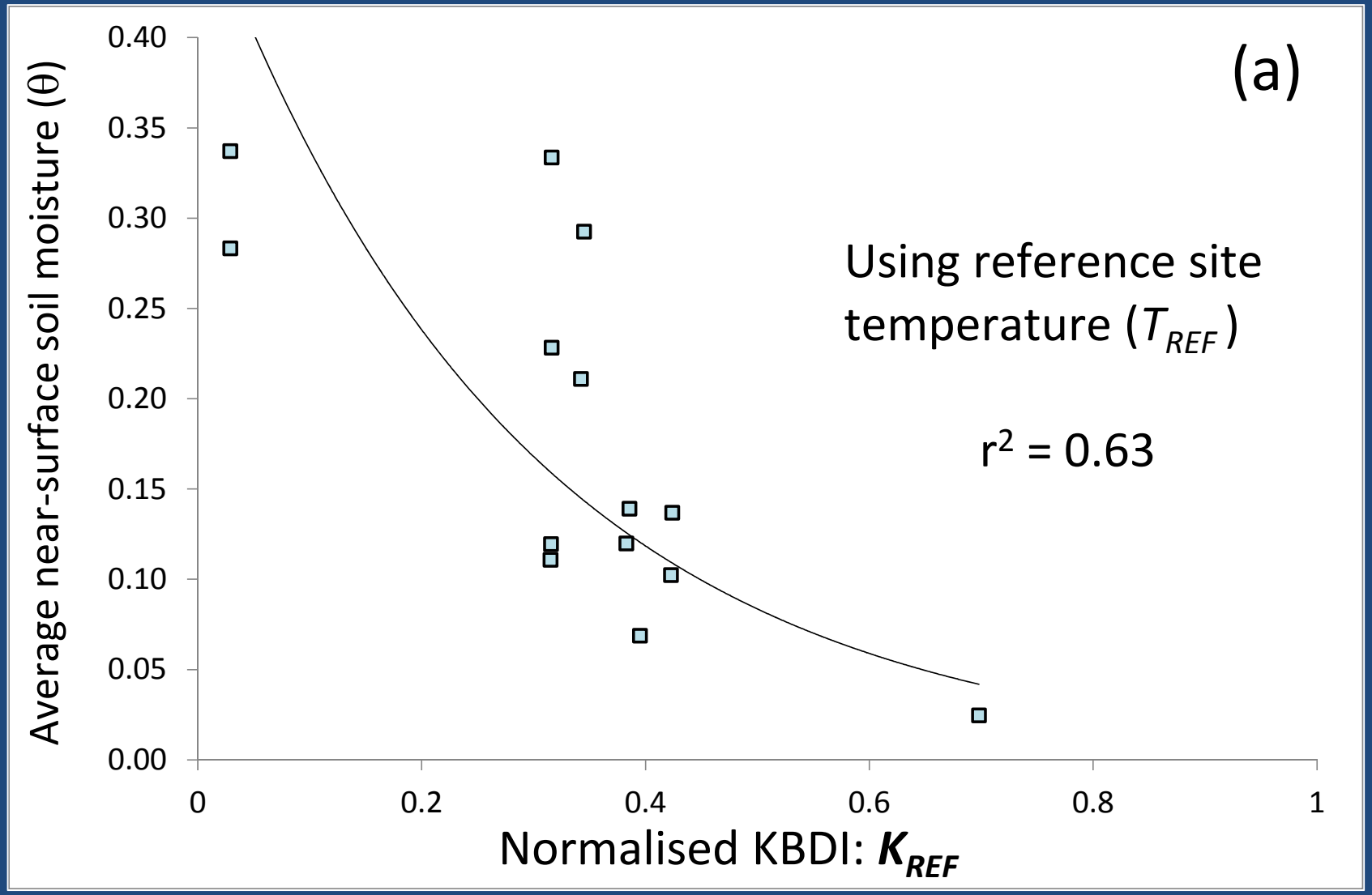

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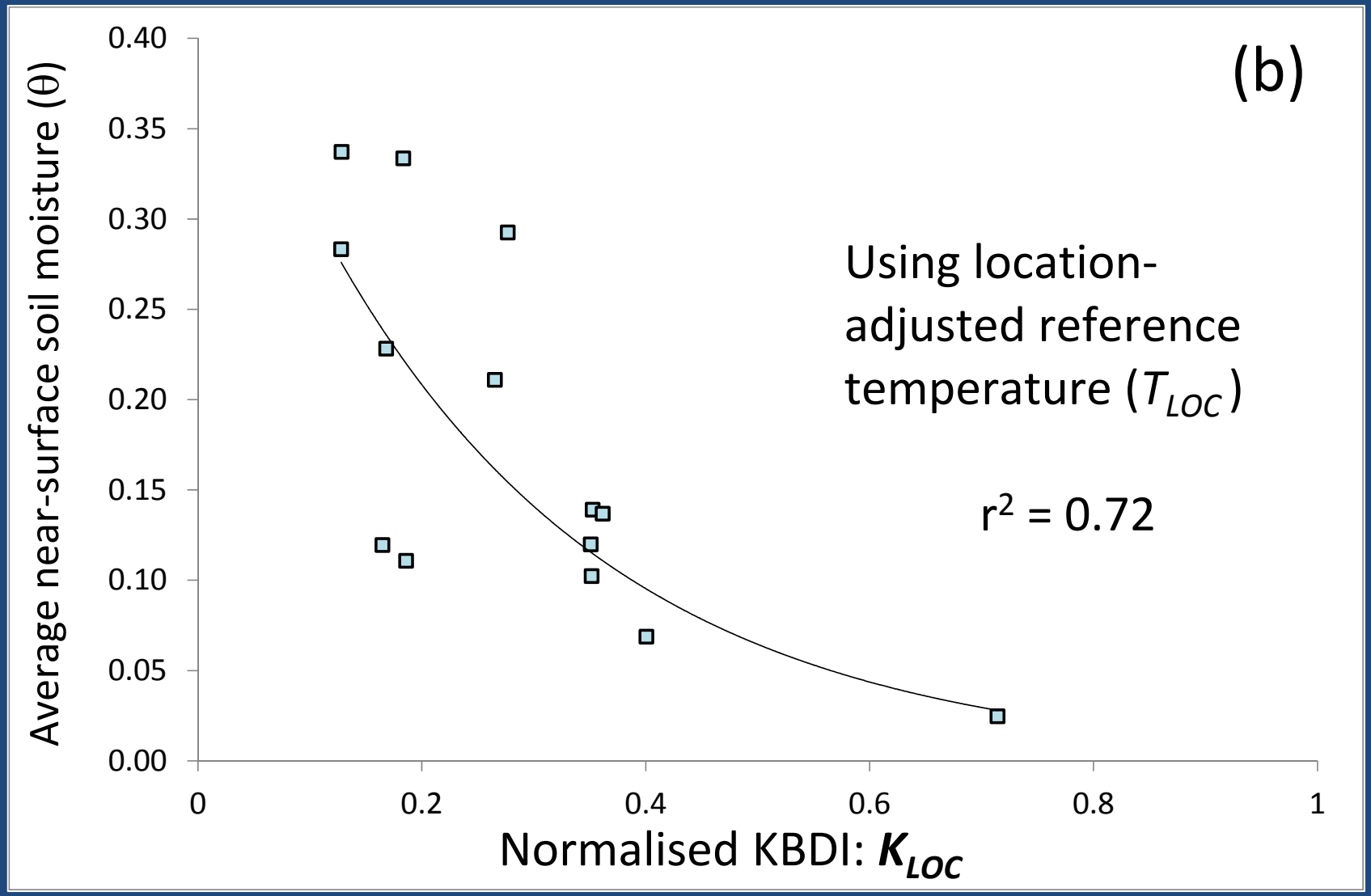

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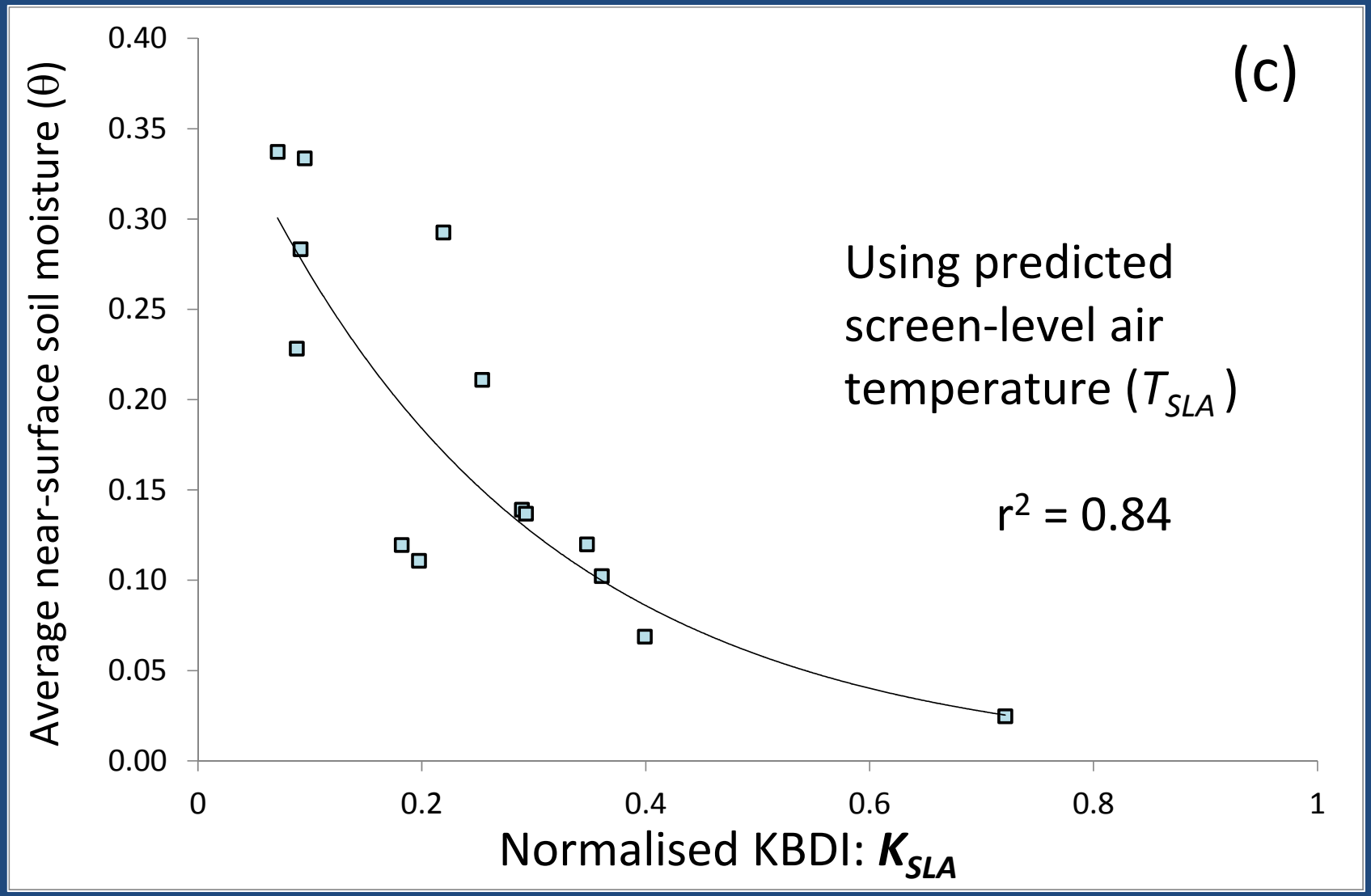

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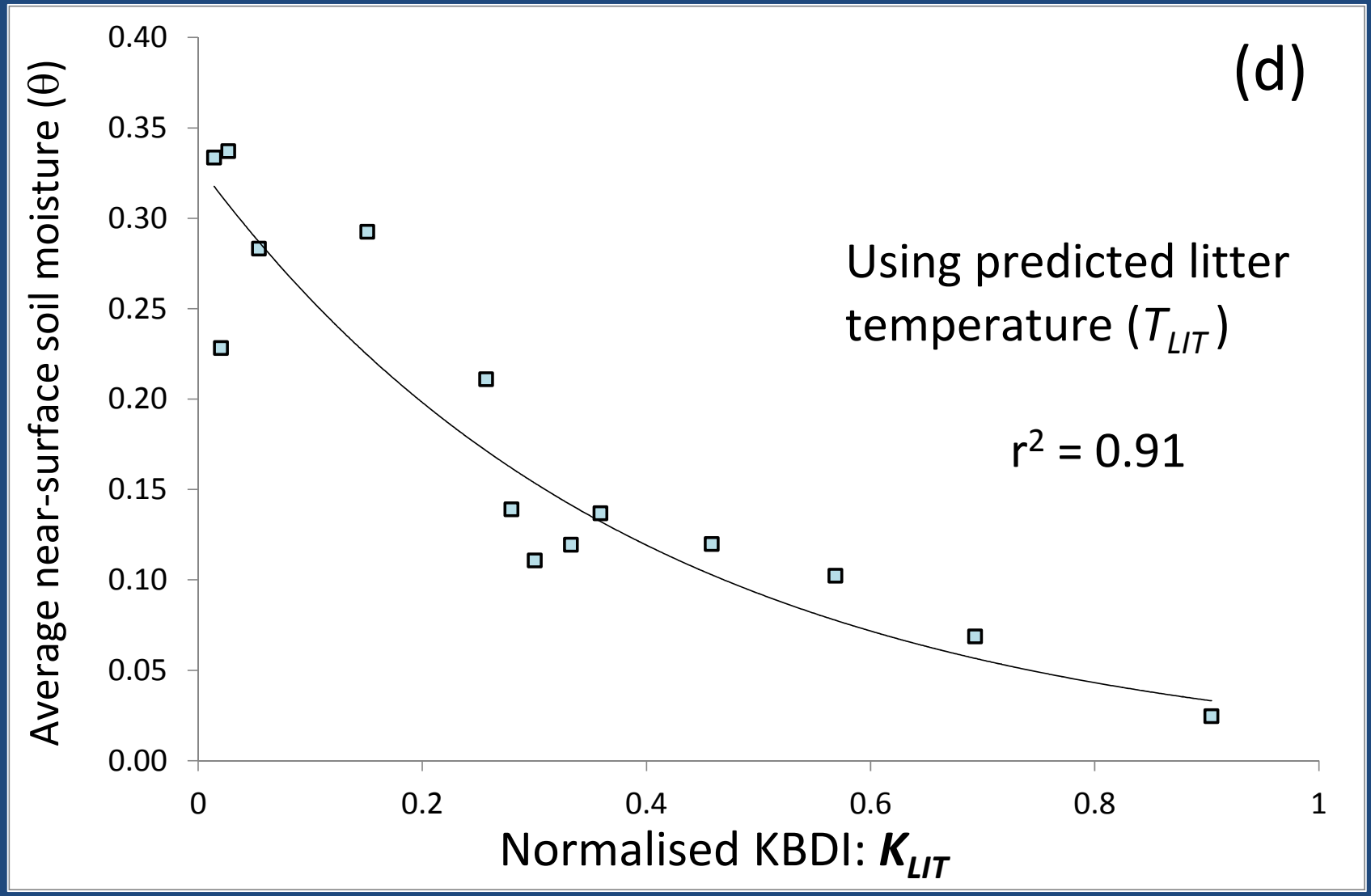
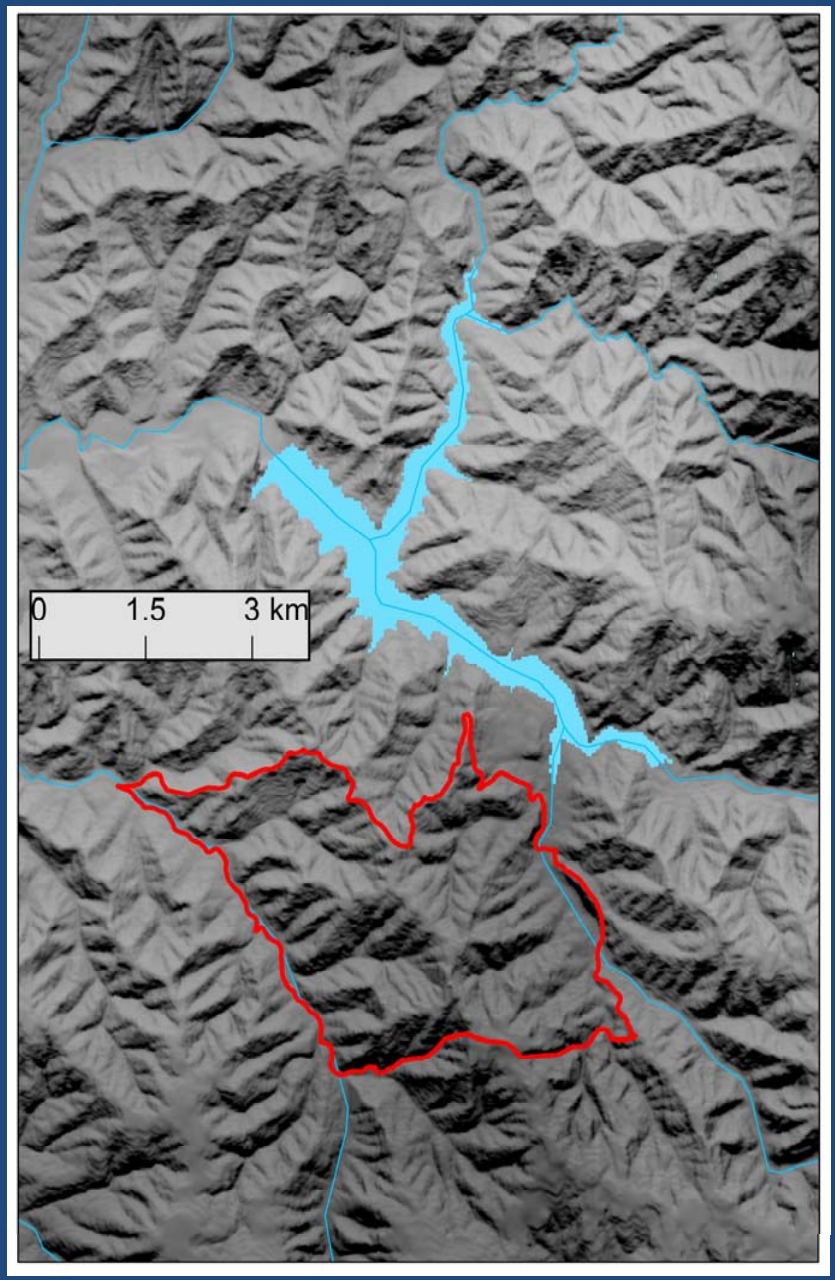
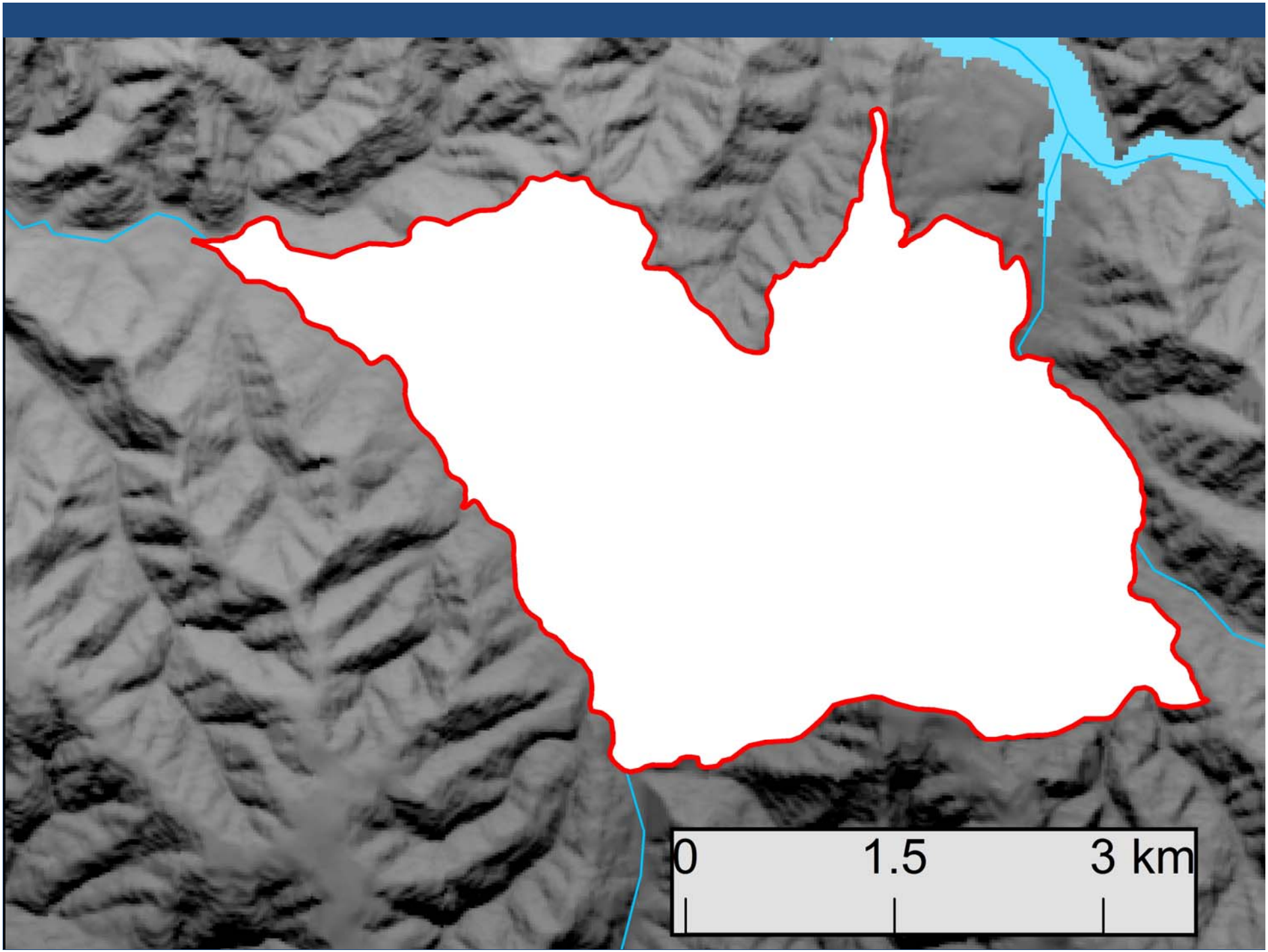


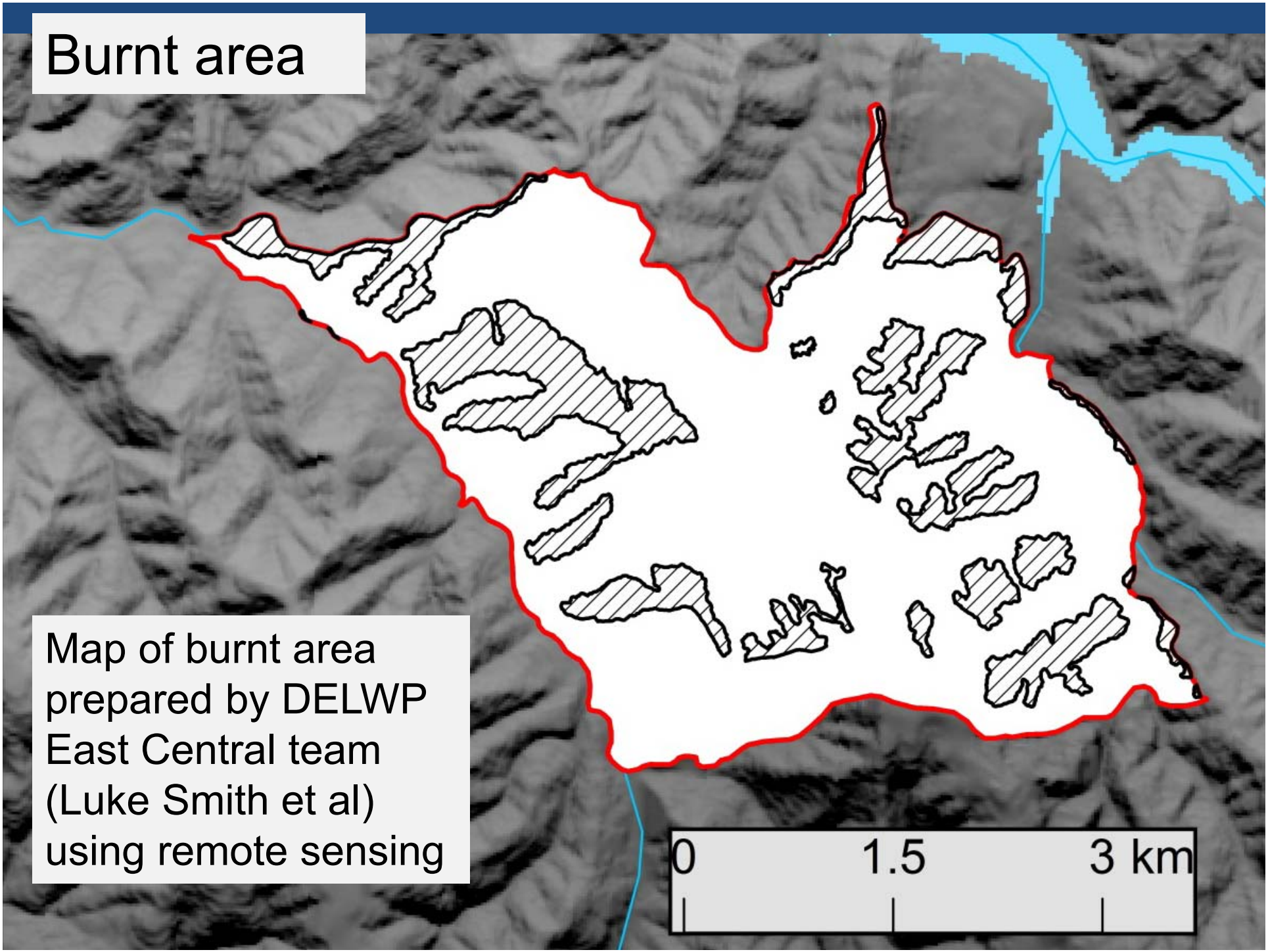
Does this model have any relevance for fire management ?

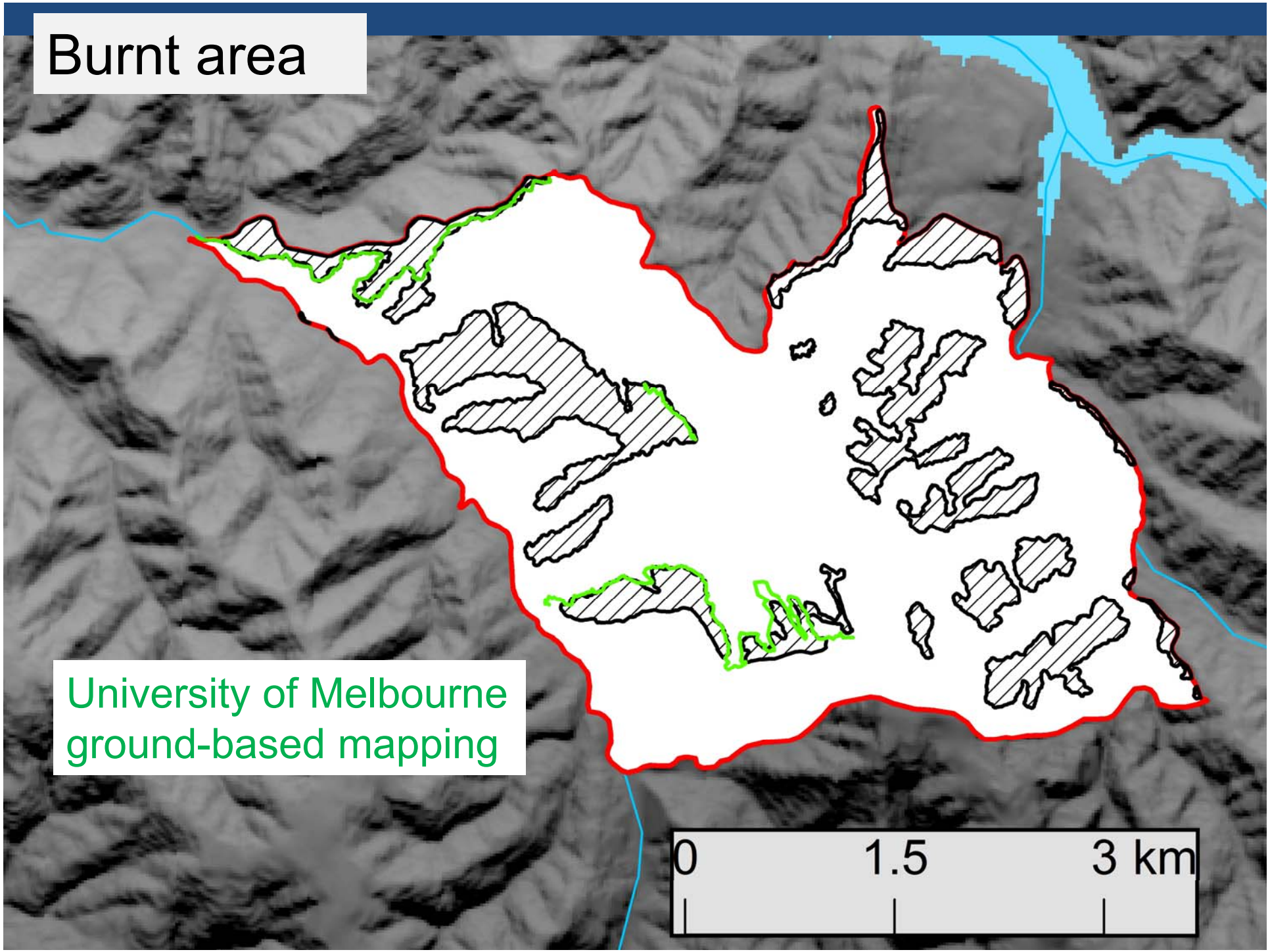
Case study

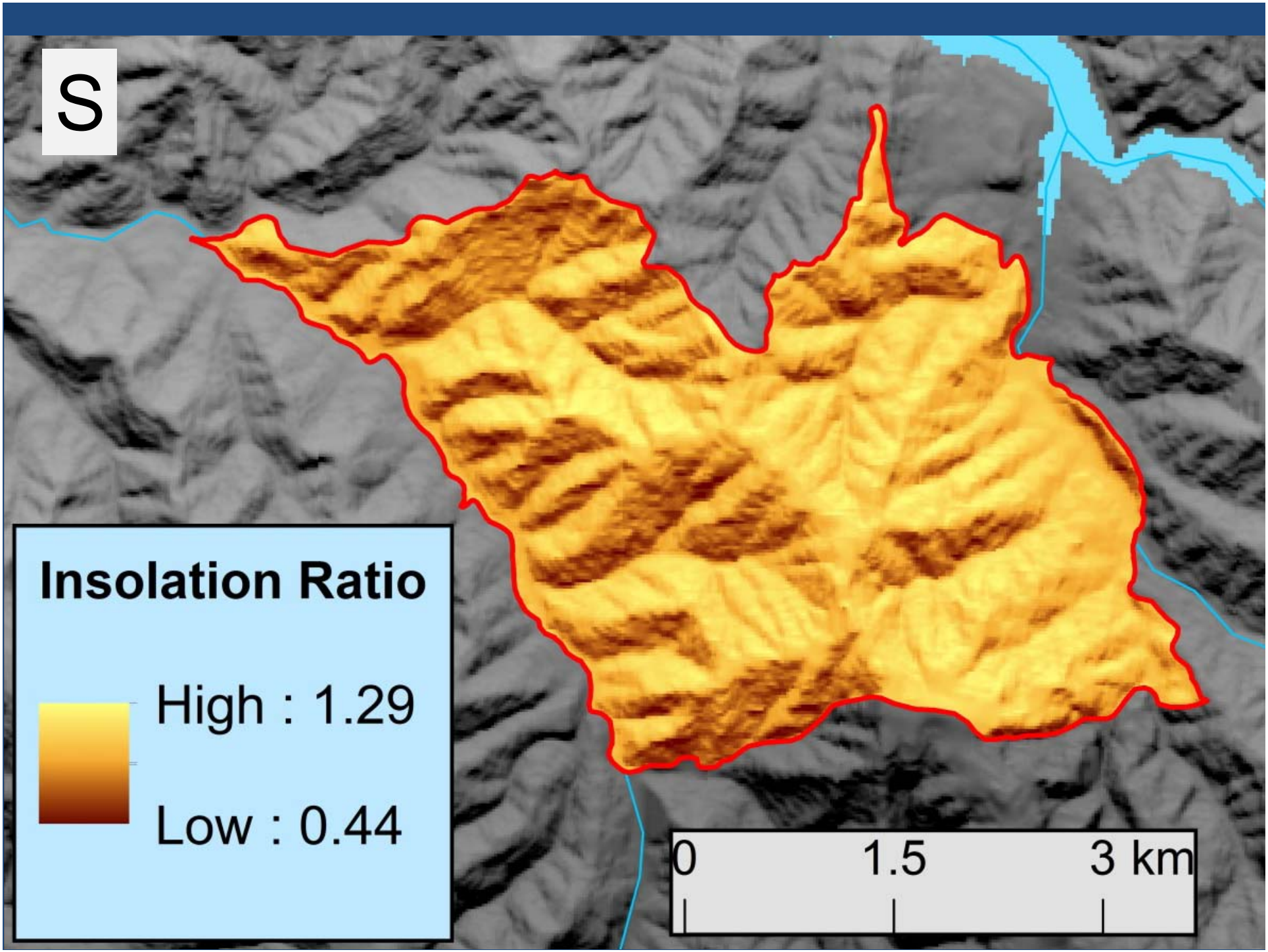
Prescribed burn conducted east of Melbourne on 13th-14th March 2015.

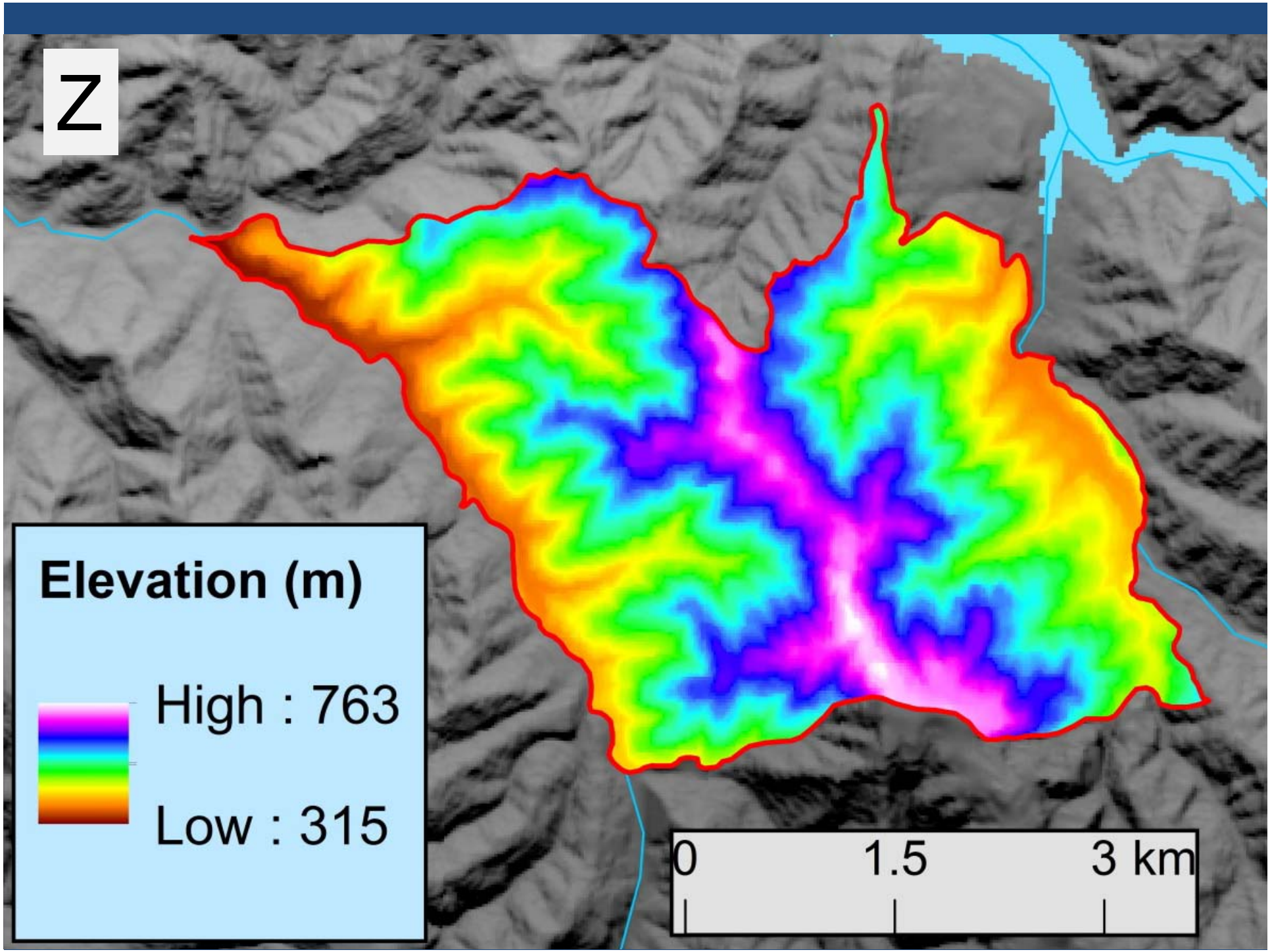


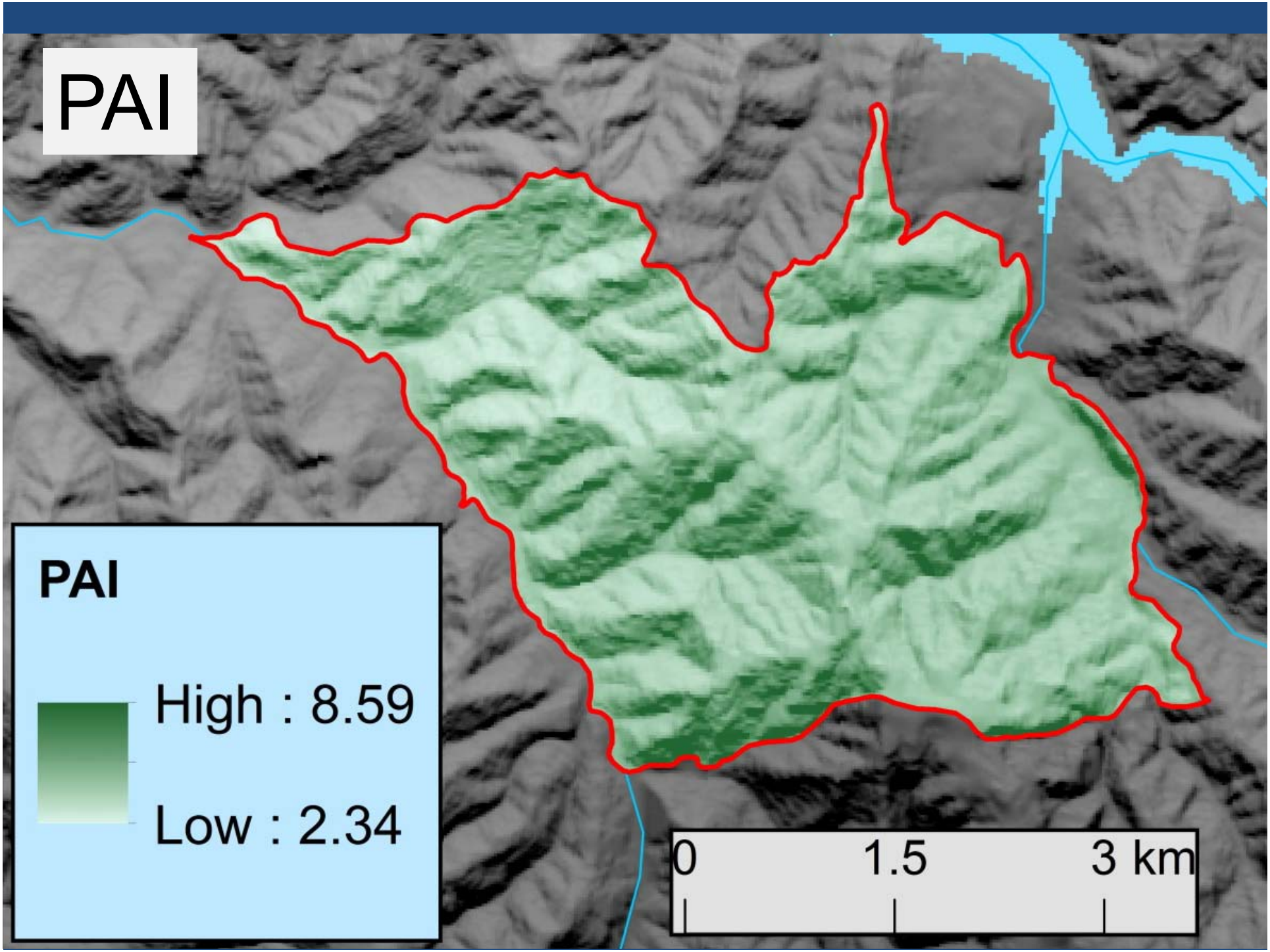

0
1.5
3 km


Burnt area
Map of burnt area prepared by DELWP East Central team (Luke Smith et al) using remote sensing
0
1.5
3 km

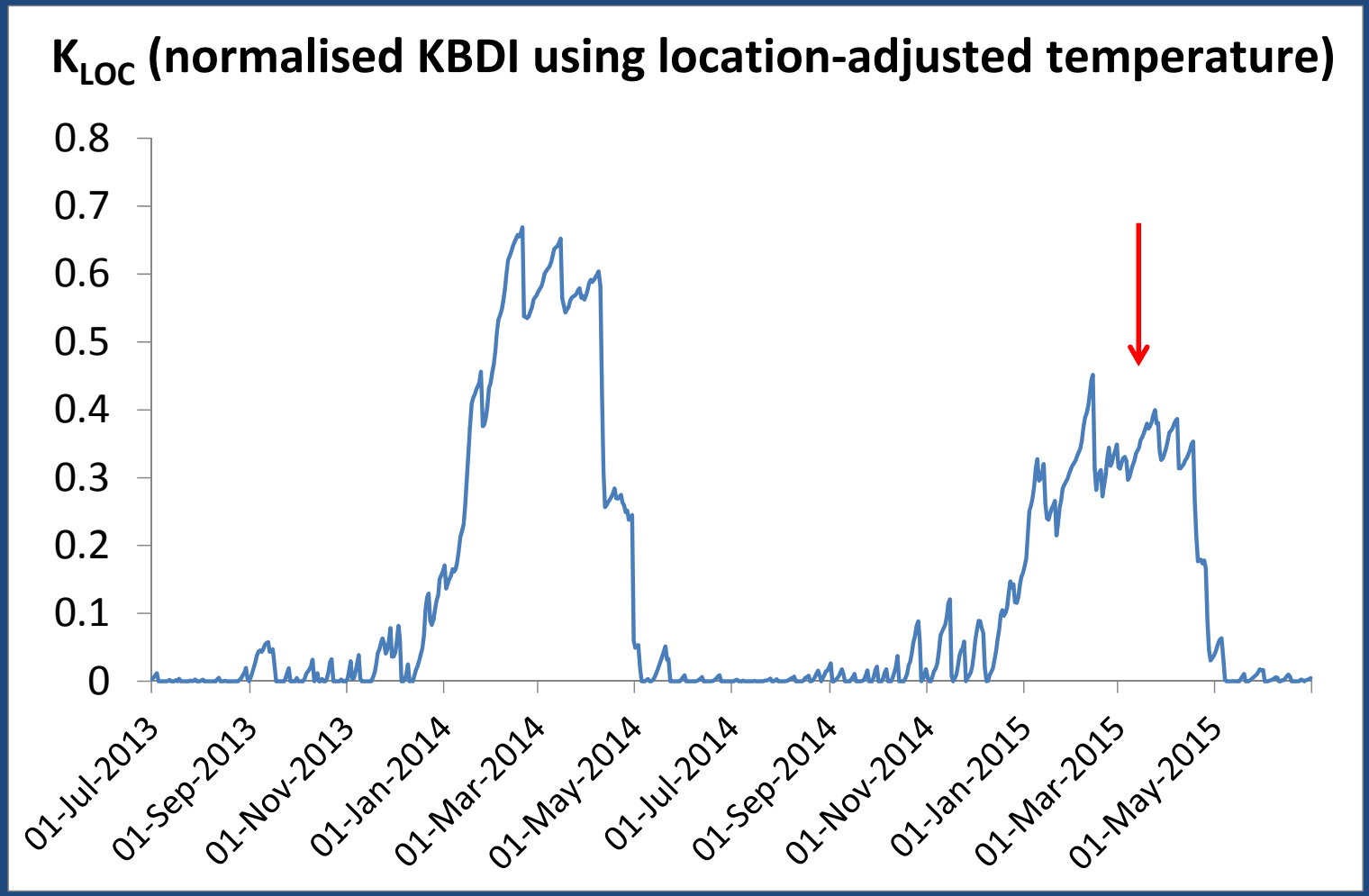

Burnt area
University of Melbourne
ground-based mapping
0
1.5
3 km


S
Insolation Ratio
High : 1.29
Low : 0.44
0
1.5
3 km

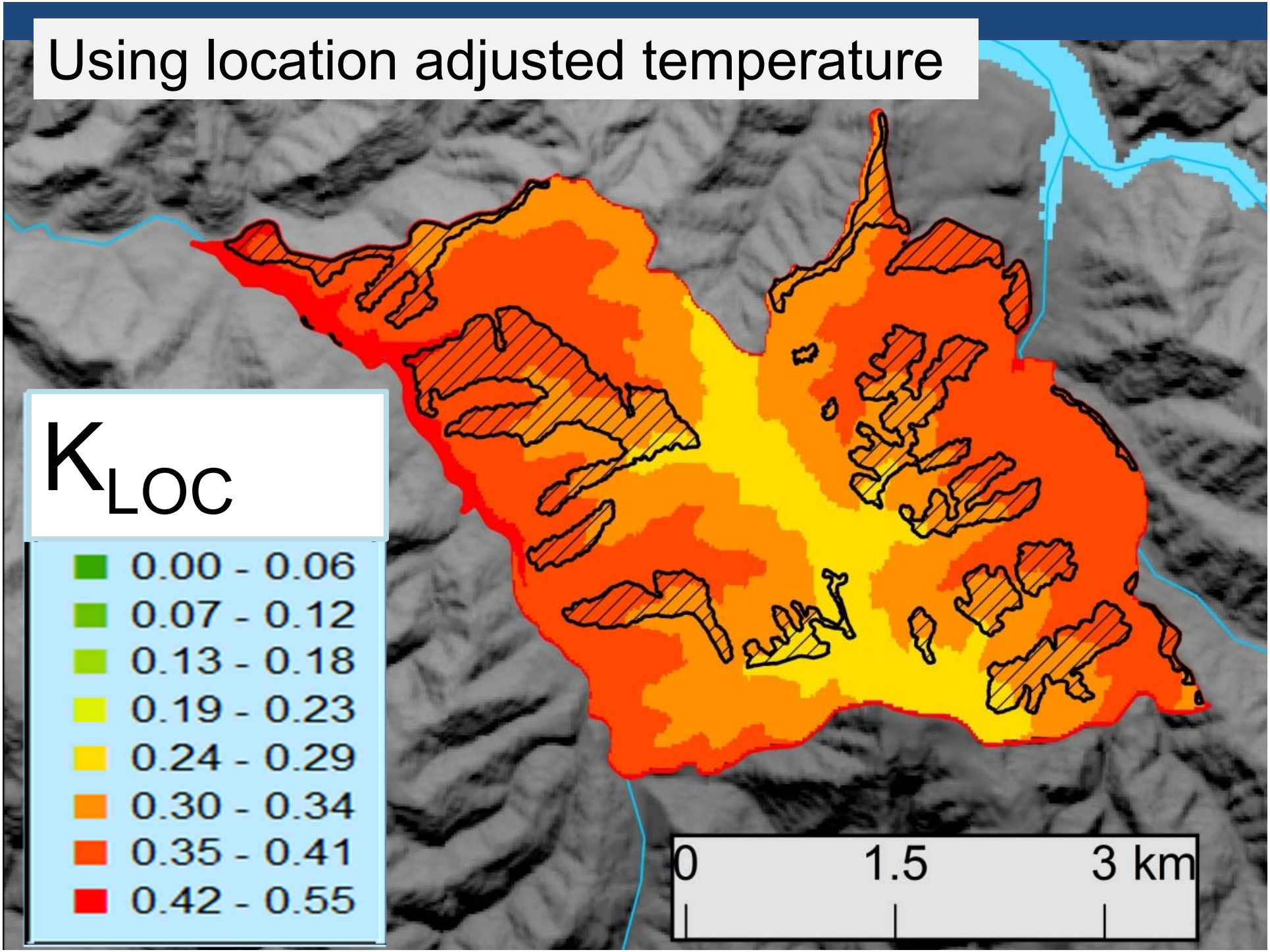

Z
Elevation (m)
High : 763
Low : 315
0
1.5
3 km


PAI
PAI
High : 8.59
Low : 2.34
0
1.5
3 km

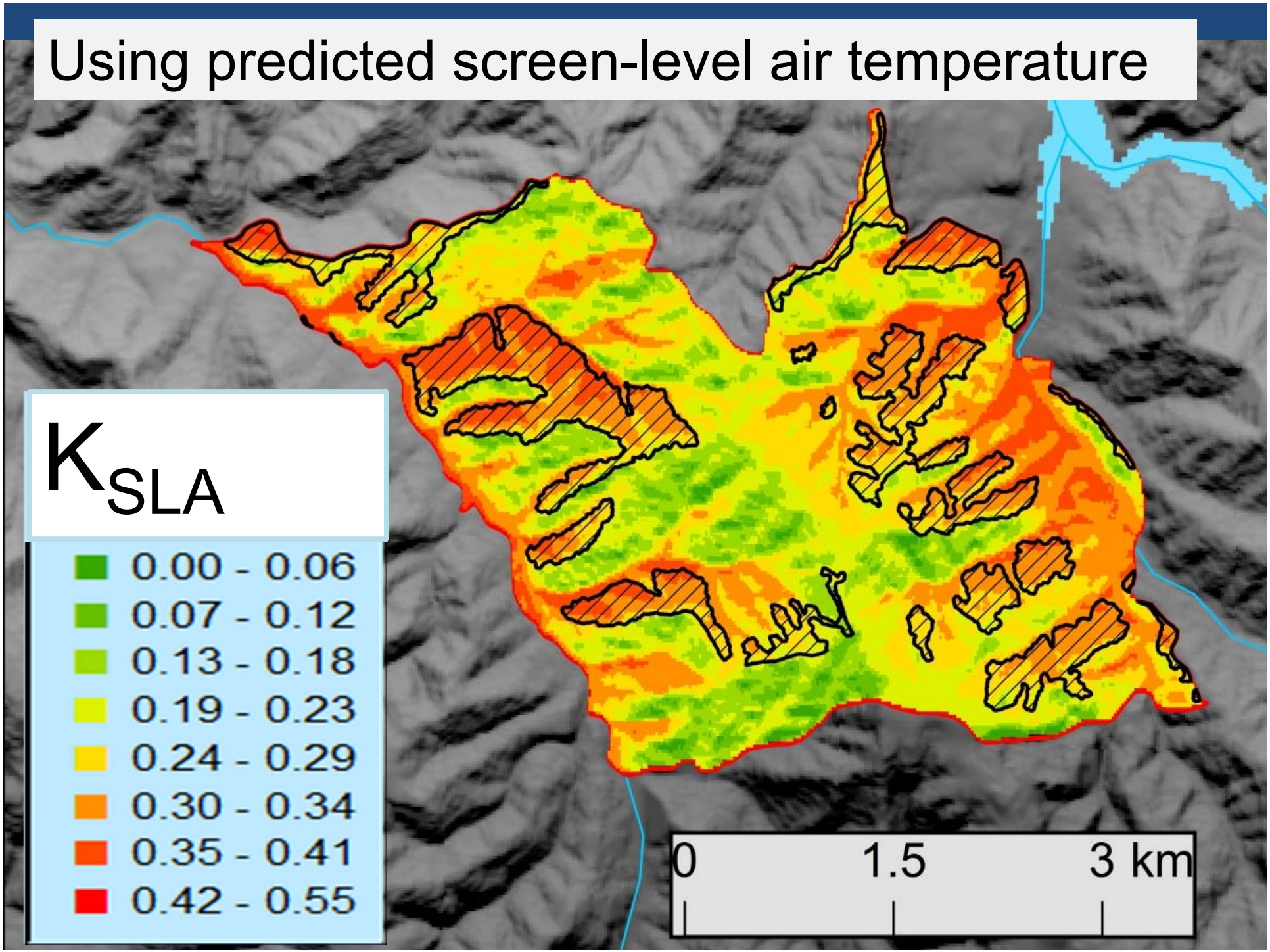
Normalised KBDI metrics were calculated over a two-year period, for every pixel (20 m resolution).

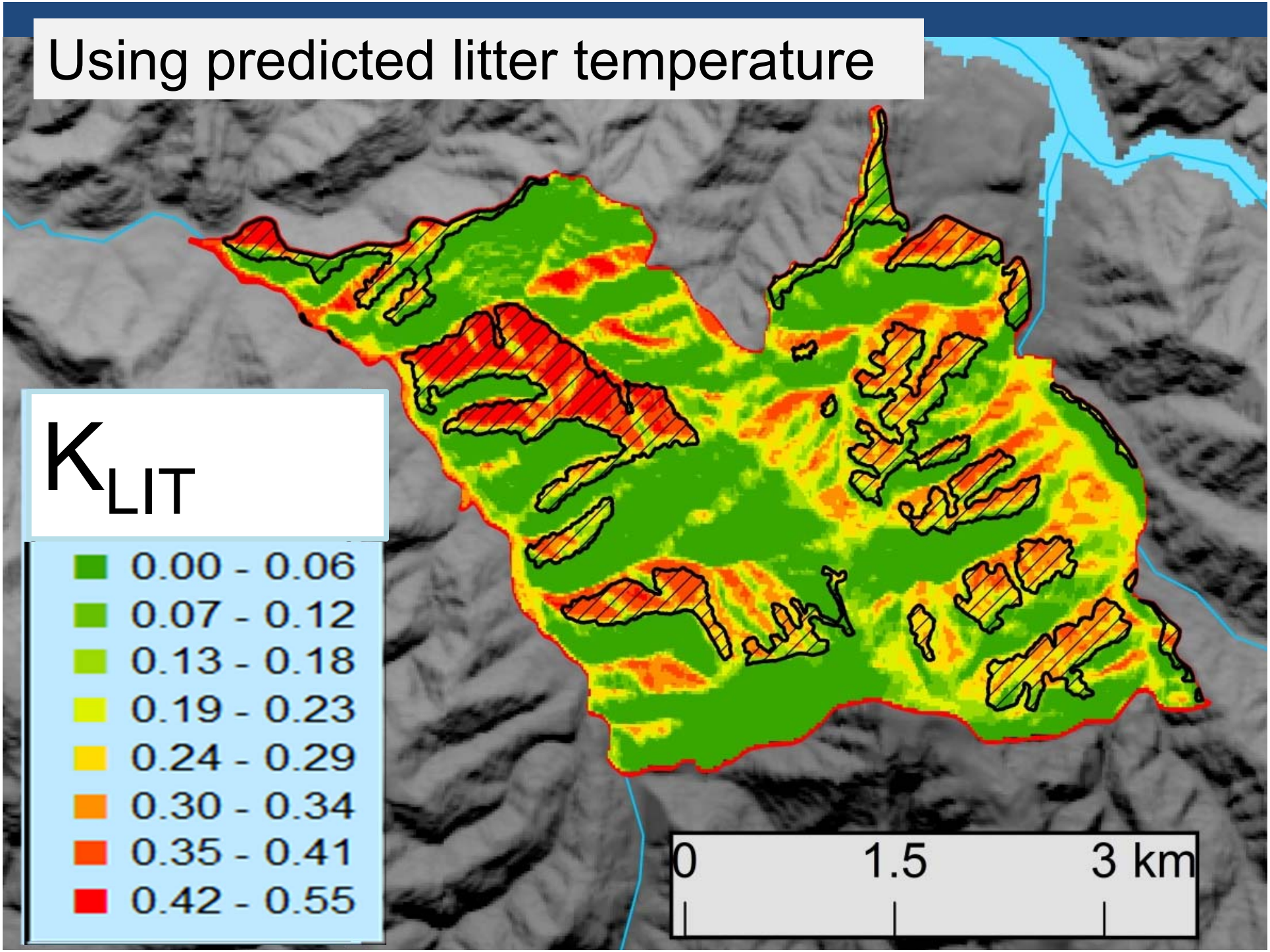


Using location adjusted temperature



Using predicted screen-level air temperature




Using predicted litter temperature
K_{LIT}
0.00 - 0.06
0.07 - 0.12
0.13 - 0.18
0.19 - 0.23
0.24 - 0.29
0.30 - 0.34
0.35 - 0.41
0.42 - 0.55
0
1.5
3 km

Conclusions

Near-surface soil moisture is important for fuels such as litter and surface vegetation.

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QUESTIONS & DISCUSSION

Aridity Index

(Budyko Radiative Index
of Dryness)