University of Exeter

TESS Lab

UKRI Engineering and Physical Sciences Research Council

The Relative Productivity Index: A breakthrough in assessing local impacts on rangeland condition

Andy Cunliffe, Guy Lomax, Tim Lenton, Tom Powell

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Oppenheimer Programme in African Landscape Systems (OPALS; opals-exeter.org)

Worldbuilding

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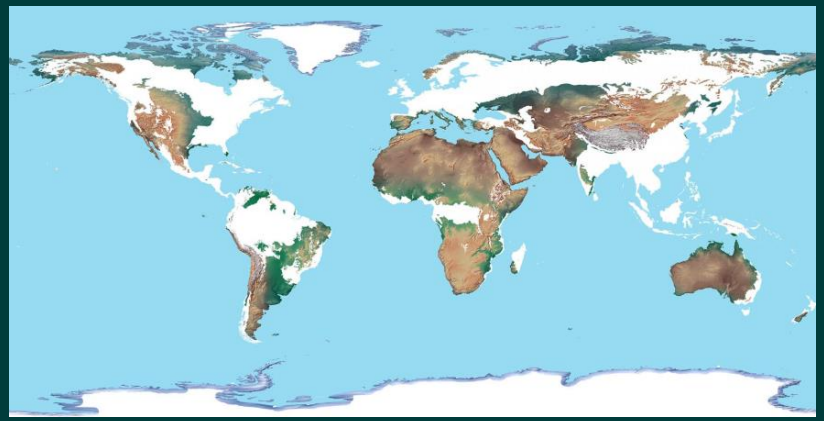


Rangelands Atlas' (imperfect) map of global rangelands

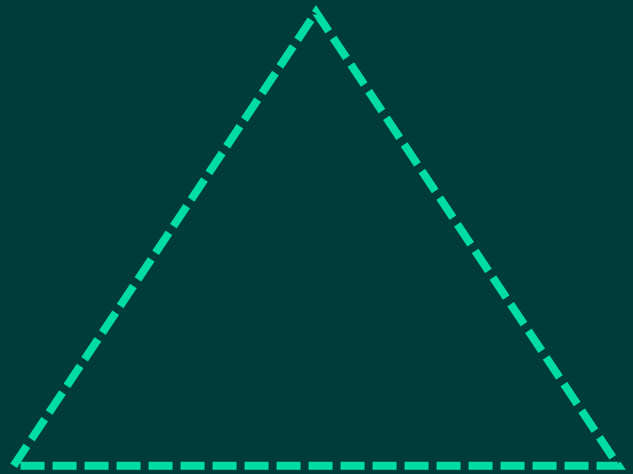
Worldbuilding

- Rangelands are natural open landscapes used for gazing wildlife/livestock
- Rangelands are big (~54% of terrestrial area)
- Rangelands resources support ca. 1-2 billion people

Worldbuilding

- **Rangelands are natural open landscapes used for gazing wildlife/livestock**
- **Rangelands are big (~54% of terrestrial area)**
- **Rangelands resources support ca. 1-2 billion people**
- **Rangeland condition matters** degradation/desertification processes – though narratives are complex and contested

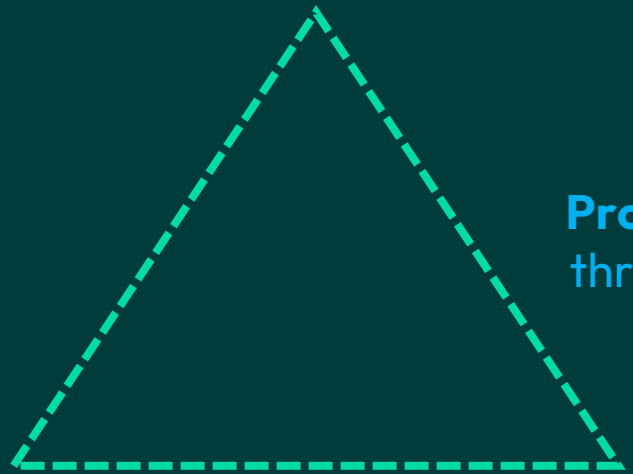
Remotely Sensed Attributes



Ecological ‘Intactness’ / Structure & Function

Ecosystem Service Provision
(e.g. forage)

Remotely Sensed Attributes



Productivity = carbon uptake through plant photosynthesis

Ecological ‘Intactness’ / Structure & Function

Ecosystem Service Provision
(e.g. forage)

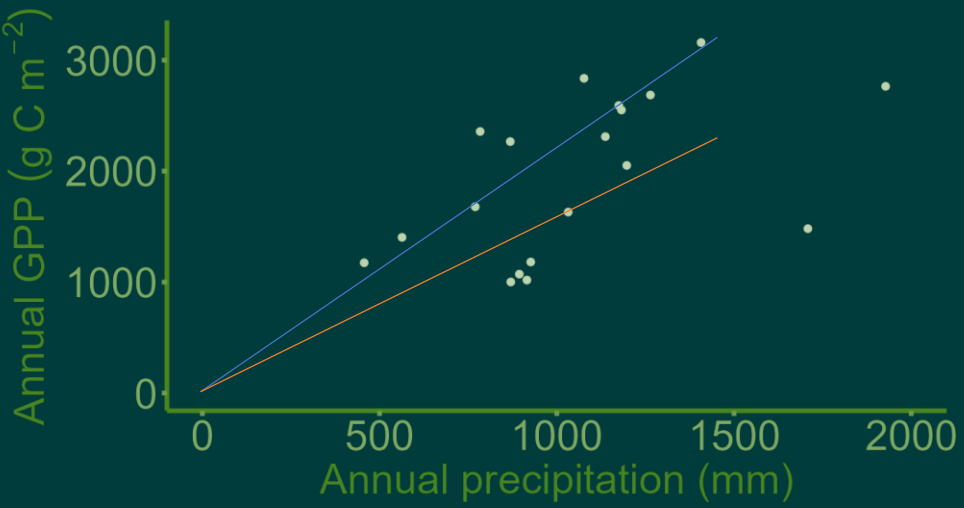
Jan 2020

Jan 2023

Temporal trends in productivity

1. Rain Use Efficiency (RUE)

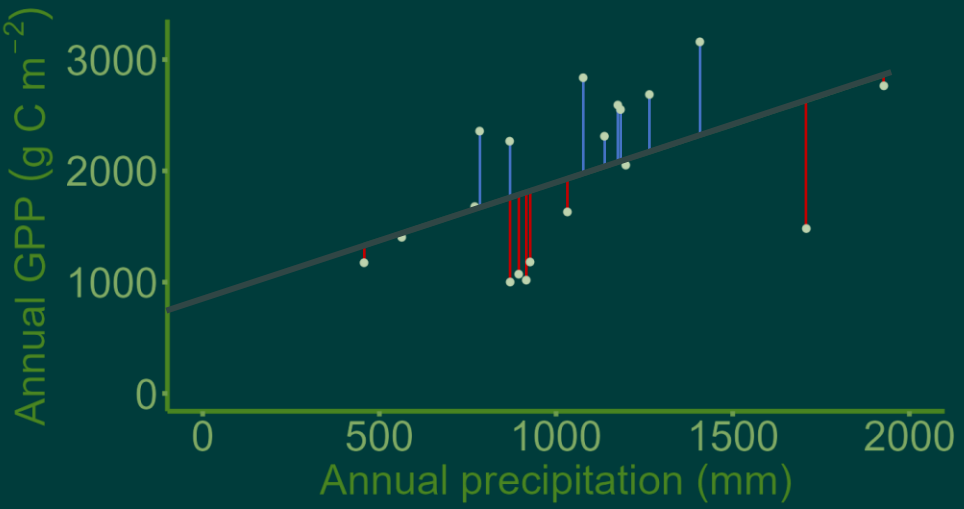
Ratio of productivity to rainfall



Temporal trends in productivity

2. Residual Trend Analysis (RESTREND)

Trends in residuals from vegetation-rainfall linear model.



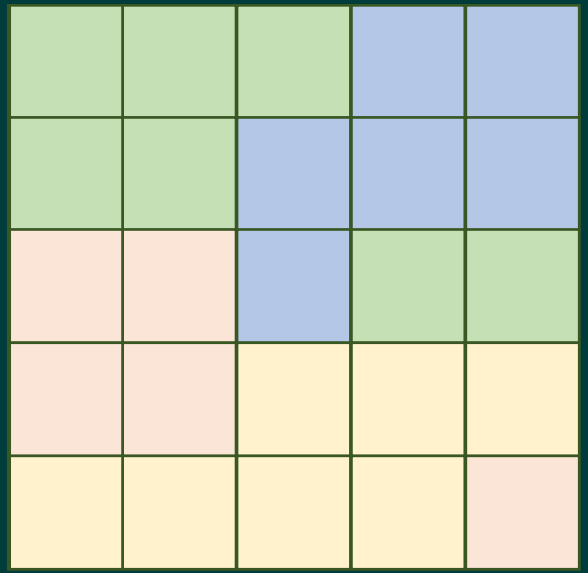
Temporal trends in productivity

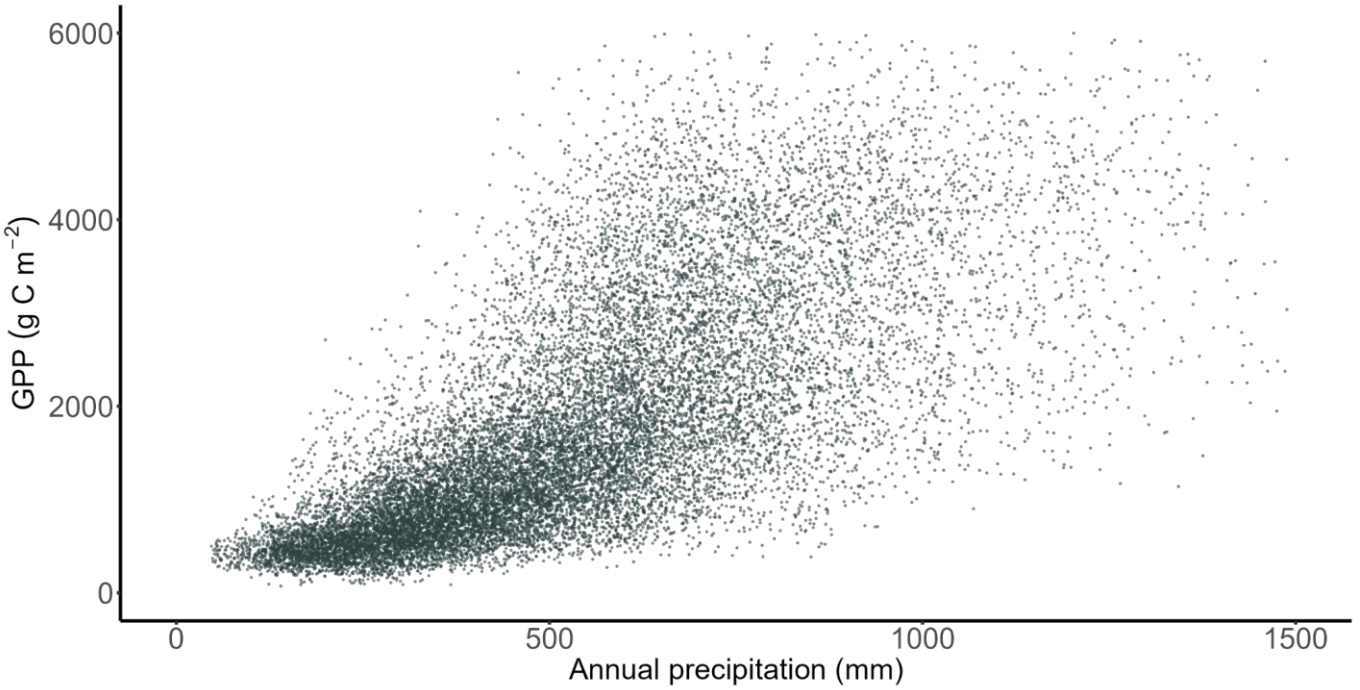
3. Local Gross Primary Productivity Scaling

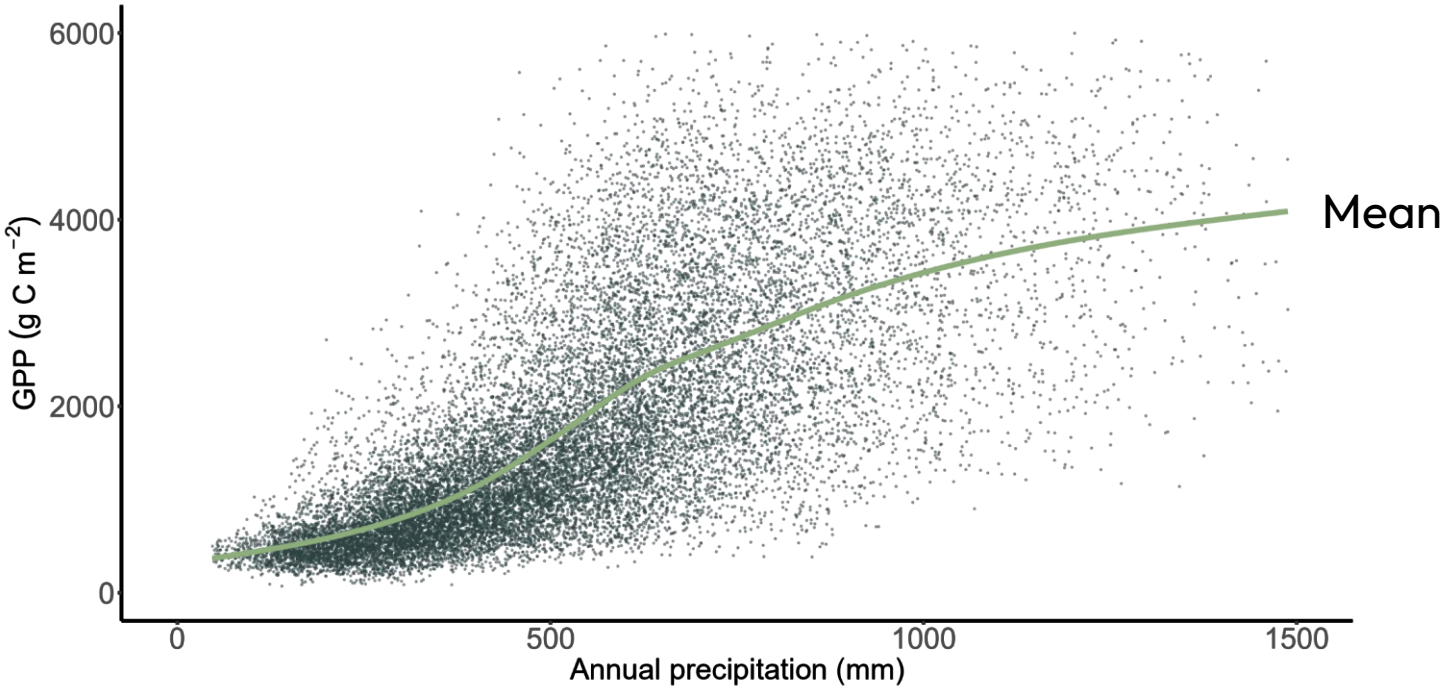
Divide all pixels in the landscape into “land capability classes”.

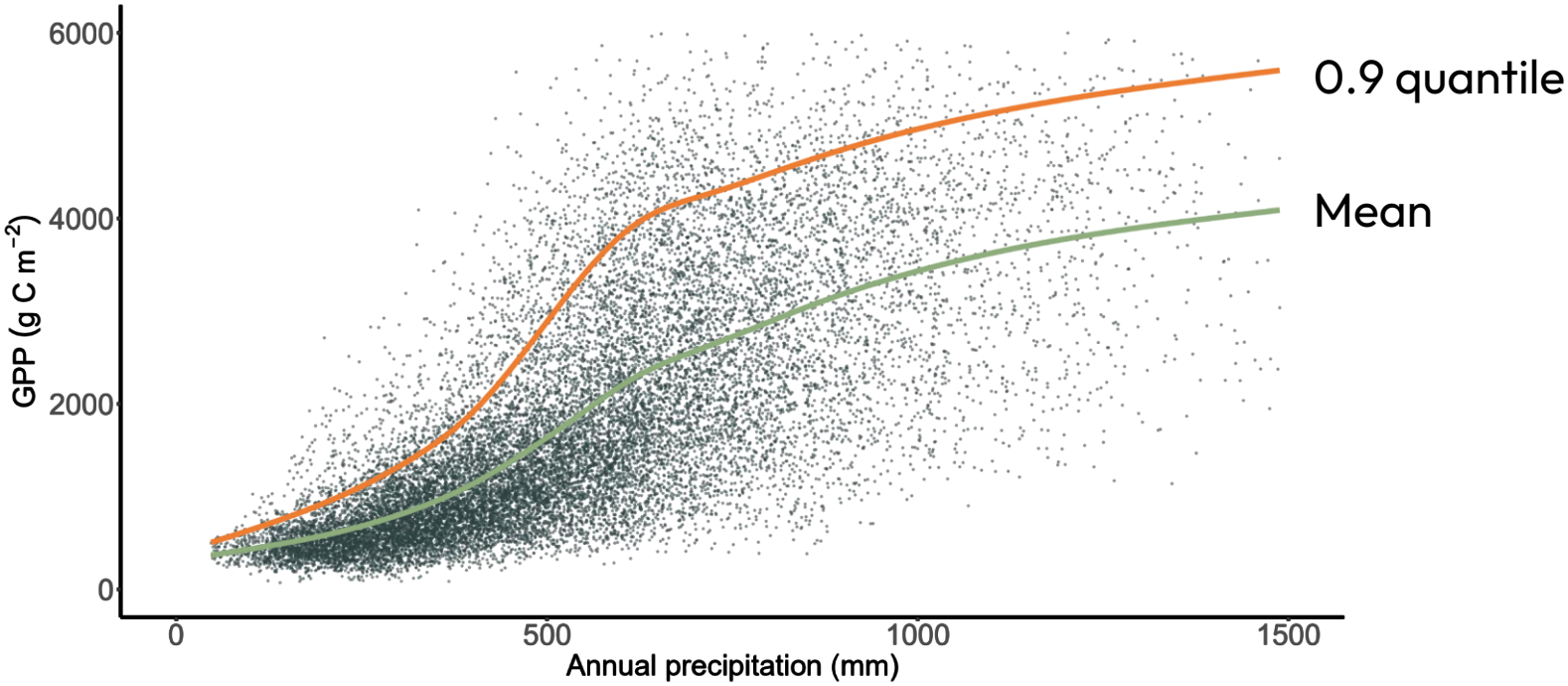
Estimate potential productivity of each LCC using 90th percentile of all pixels.

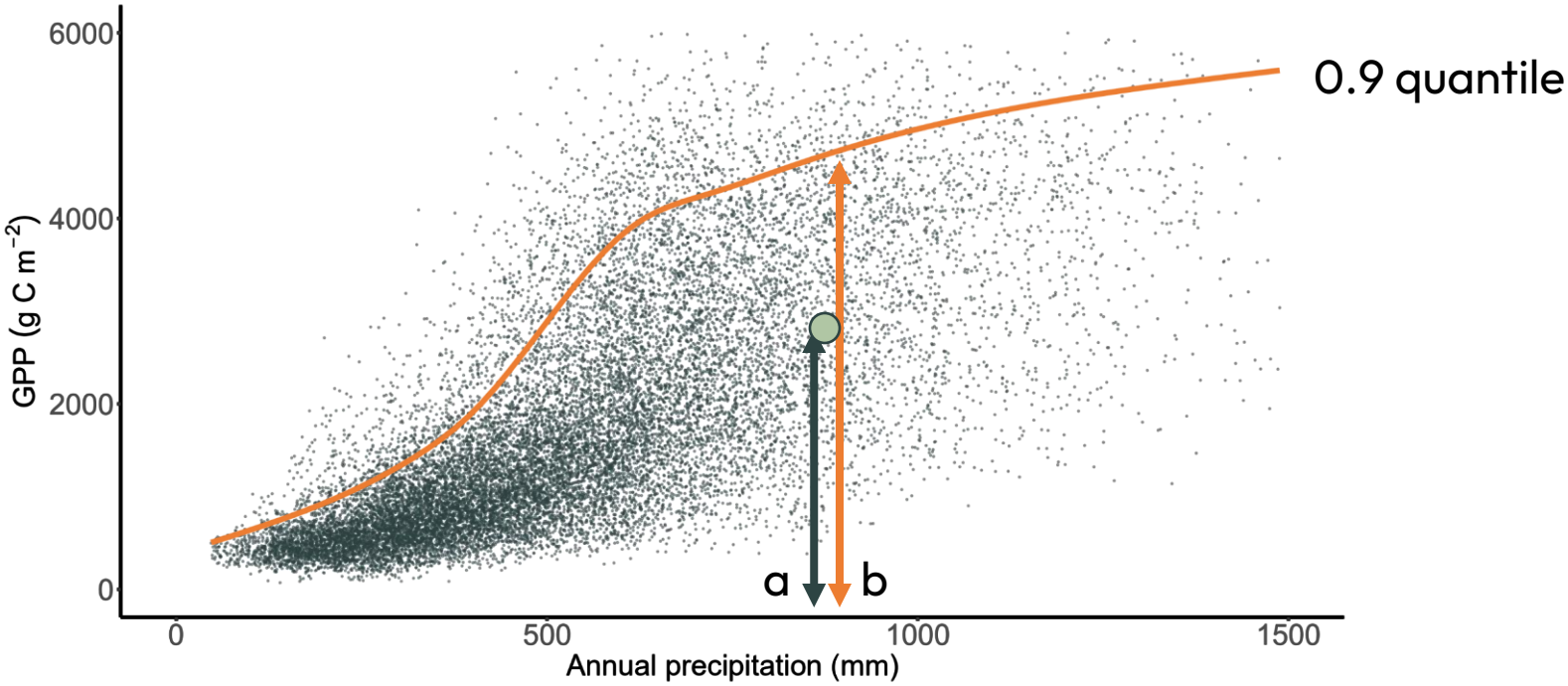
Calculate ratio of observed to potential productivity for each pixel.




6000
4000
2000
0
GPP (g C m^{-2})
0
500
1000
1500
Annual precipitation (mm)

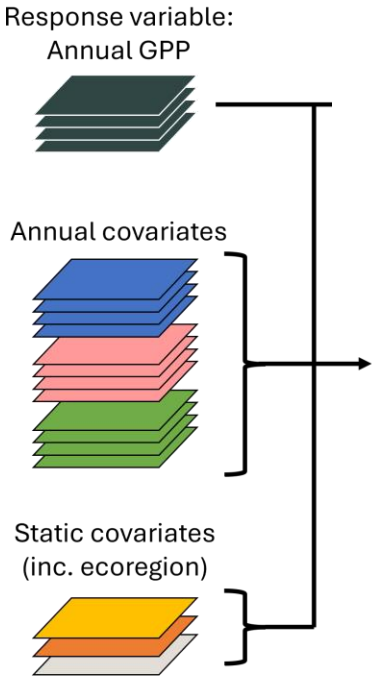

6000
4000
2000
0
GPP (g C m^{-2})
0
500
1000
1500
Annual precipitation (mm)
Mean


6000
4000
2000
0
GPP (g C m^{-2})
0
500
1000
1500
Annual precipitation (mm)
0.9 quantile
Mean


6000
4000
2000
0
GPP (g C m^{-2})
0
500
1000
1500
Annual precipitation (mm)
a
b
0.9 quantile

RPI = a / b

16 covariates



(Lomax et al., 2025; Lomax & Cunliffe et al., In Prep)

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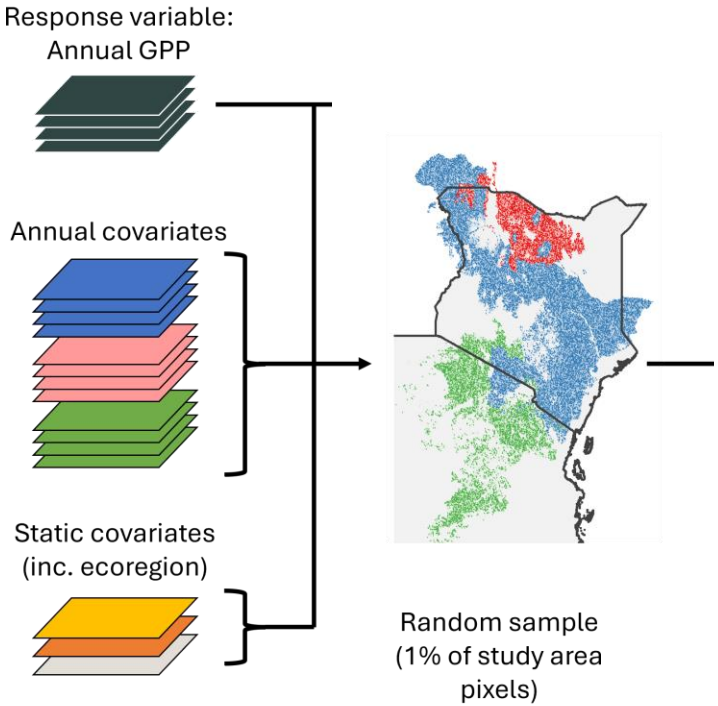

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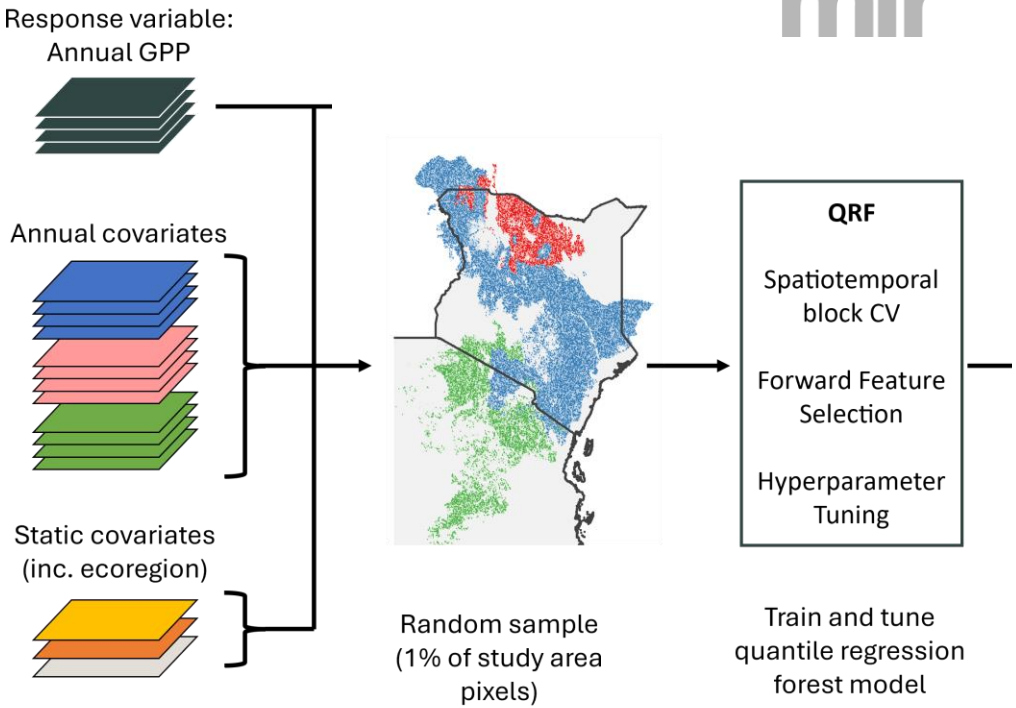

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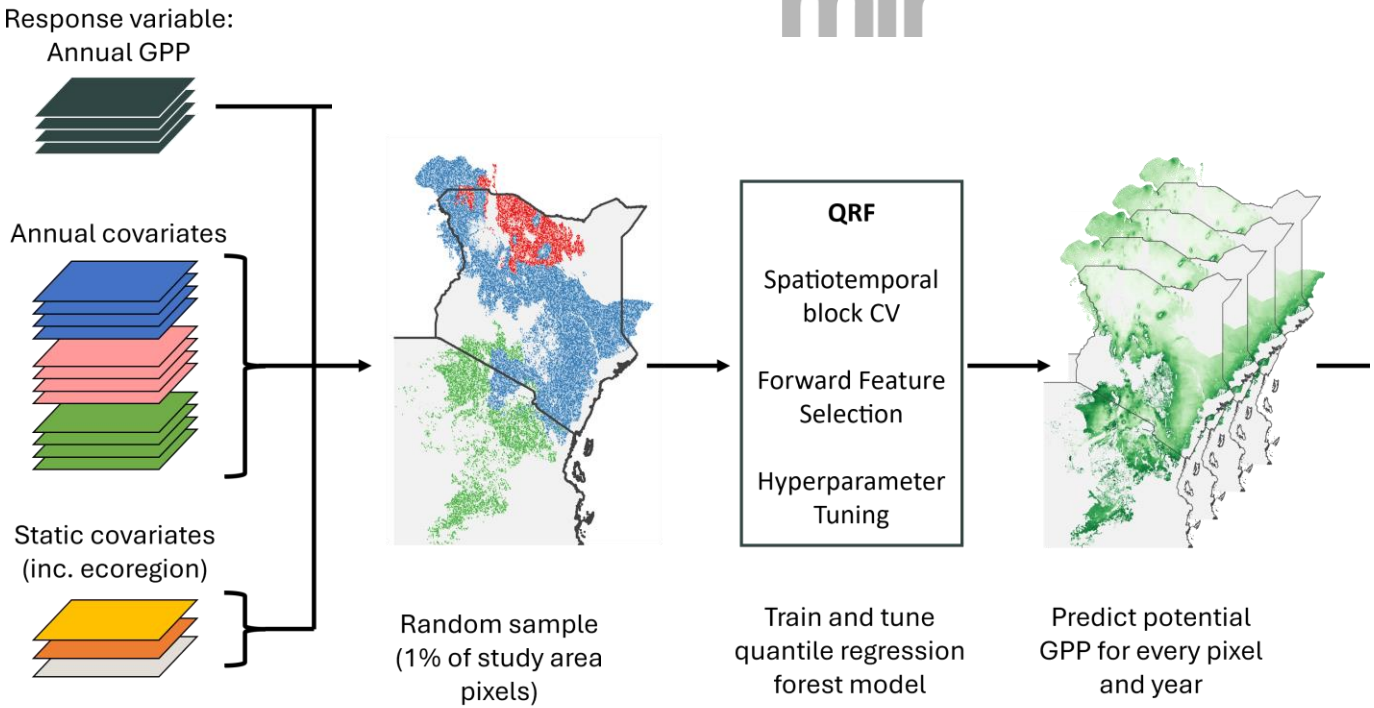

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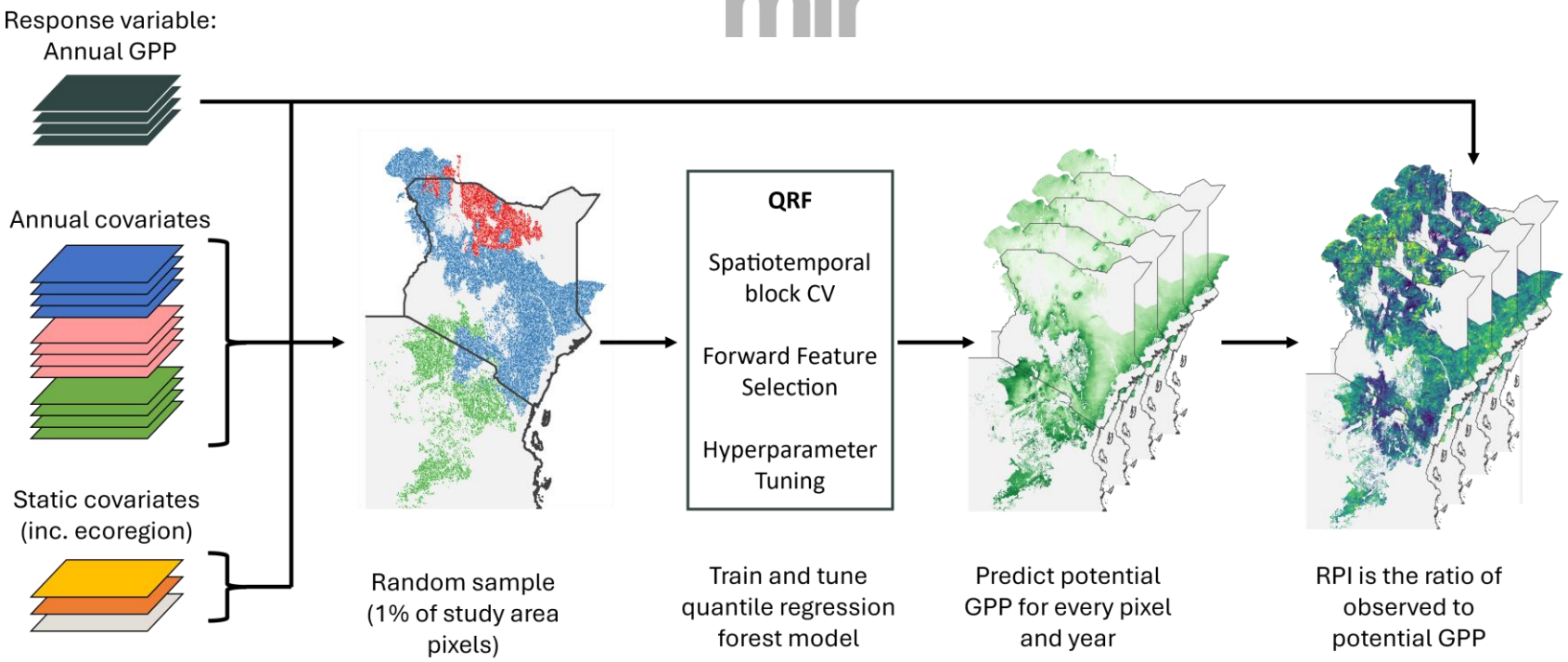

$$RPI = \frac{GPP_{Observed}}{GPP_{Potential}}$$

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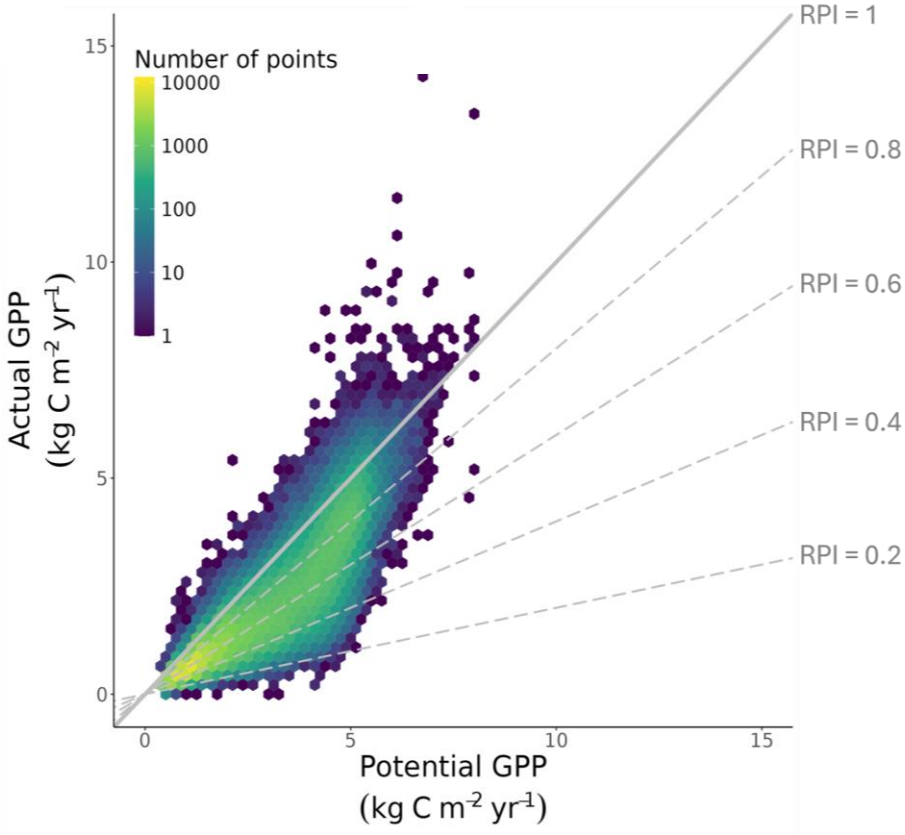
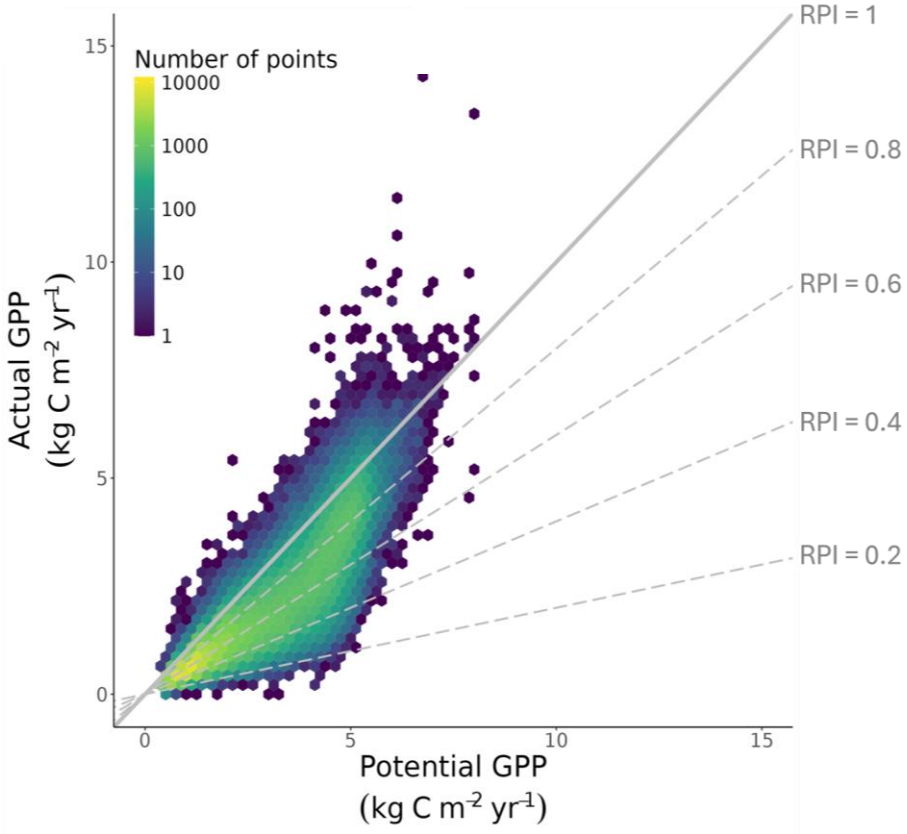

Number of points
10000
1000
100
10
1
RPI = 1
RPI = 0.8
RPI = 0.6
RPI = 0.4
RPI = 0.2
Actual GPP
(kg C m-2 yr-1)
Potential GPP
(kg C m-2 yr-1)
0
5
10
15



$R^2 = 0.81$ in cross validation

MAE = 0.53 kg C m^{-2} yr^{-1}

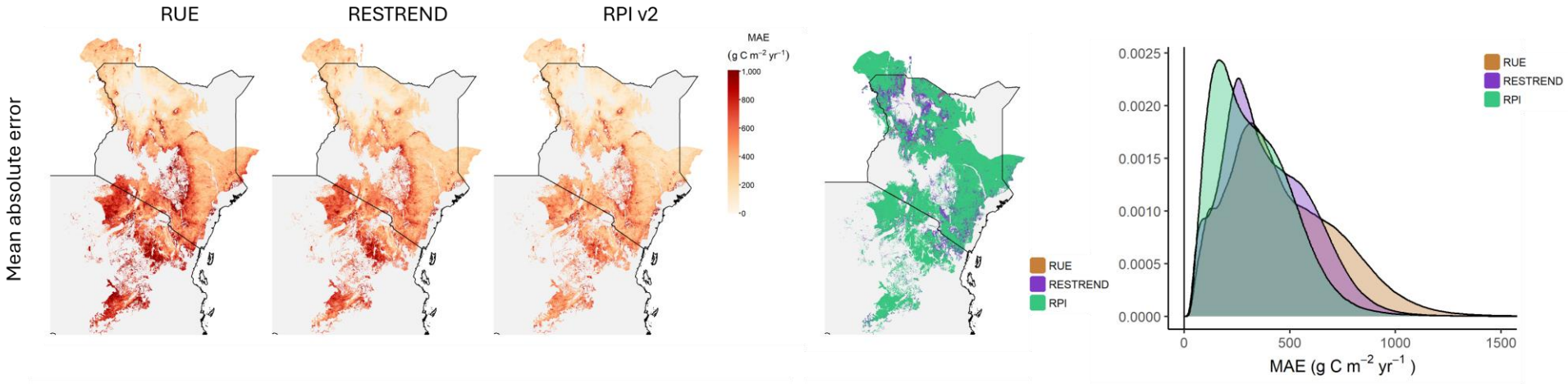
Model	Spatial variability		Temporal variability	
	MAE (g C m^{-2} y^{-1})	R^2	MAE (g C m^{-2} y^{-1})	R^2
RPI v1	318	0.85	378 ± 209	0.31 ± 0.21
RPI v2	**254**	**0.90**	**325 ± 188**	**0.48 ± 0.21**
RESTREND	-	-	384 ± 190	0.26 ± 0.15

Evaluating RPI: Temporal

(a) Method temporal performance by pixel

(b) Best method by pixel

(c) Distribution of pixel values



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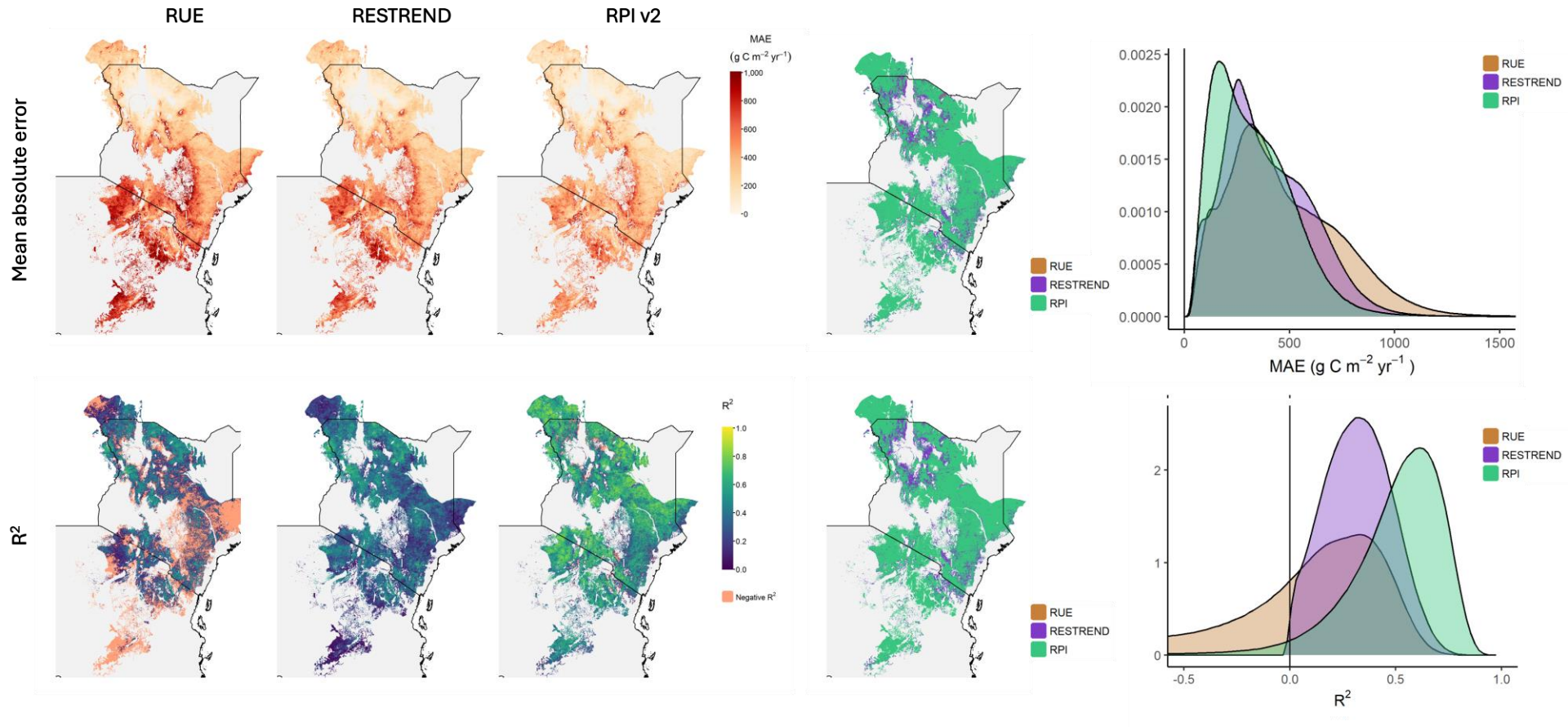
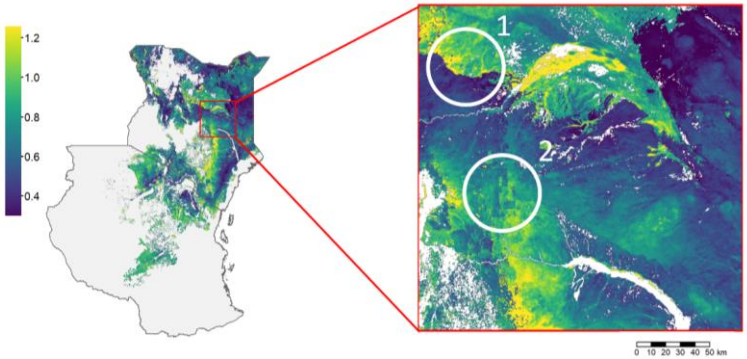


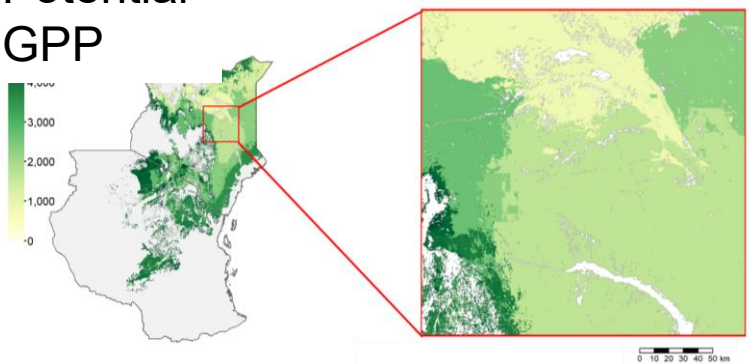
Evaluating RPI: Spatial

Local Productivity Scaling (k = 100)

Index



Potential GPP



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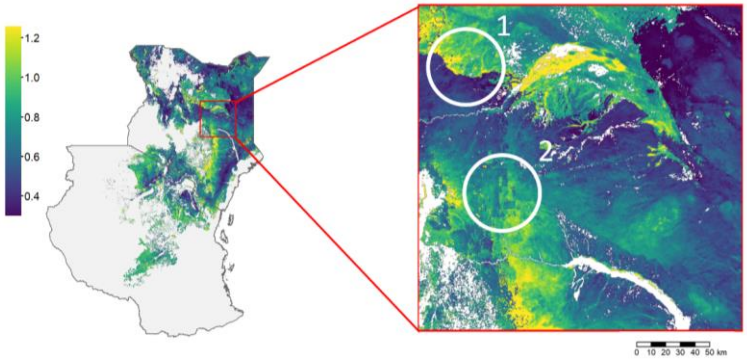
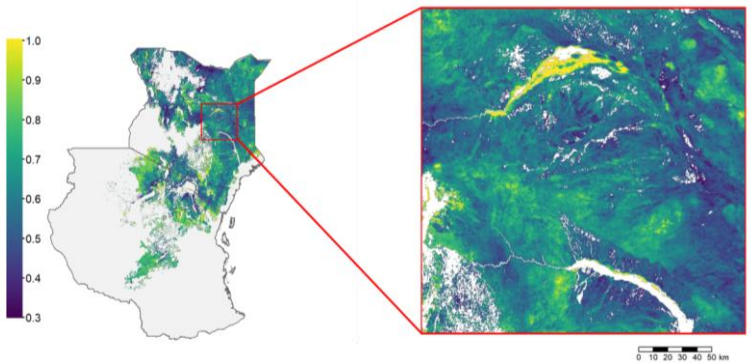


RPI



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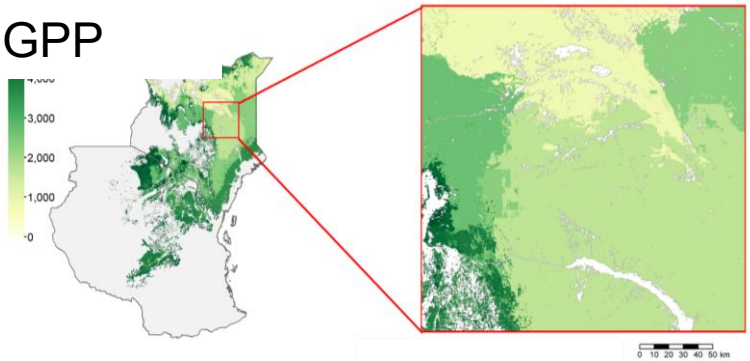
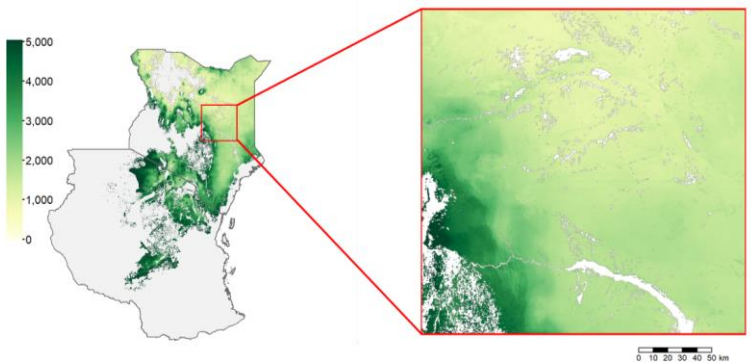
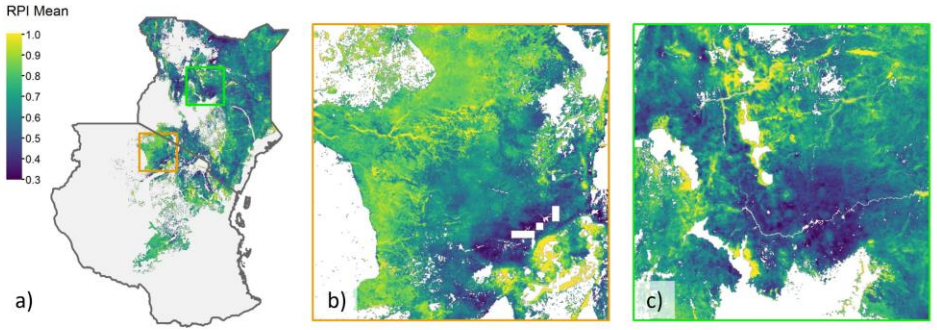
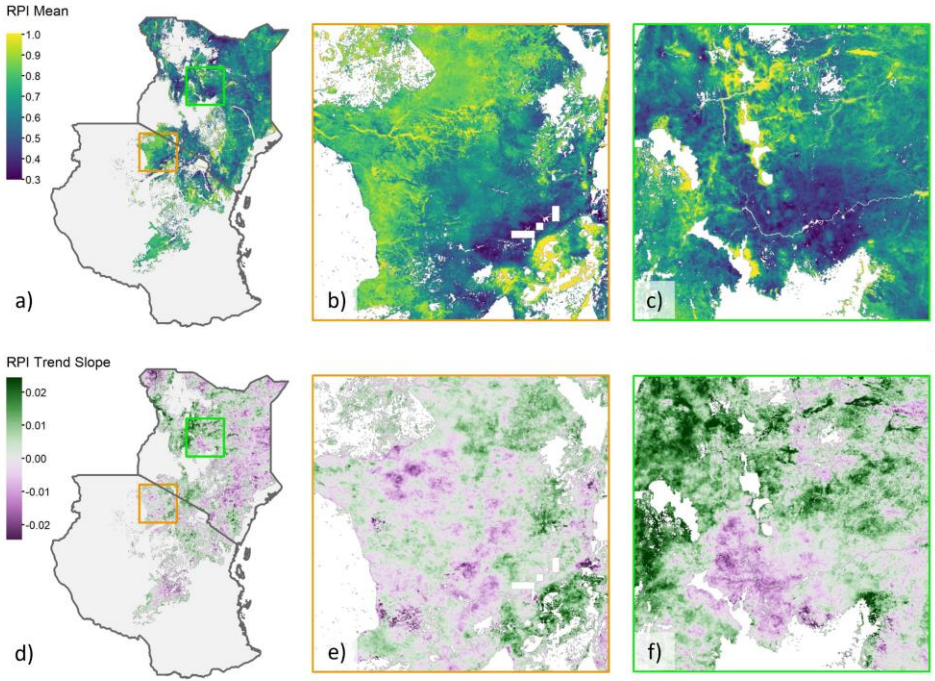
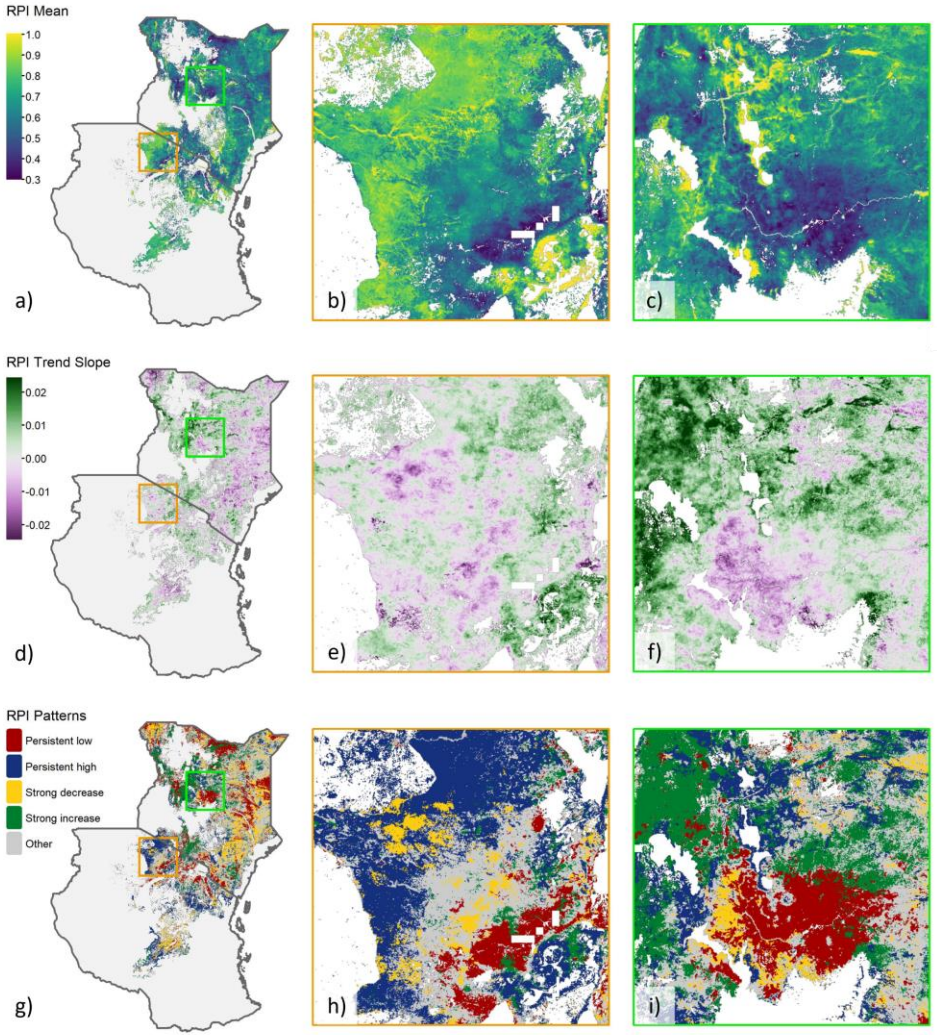





RPI Mean
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
a)
b)
c)


RPI Mean
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
a)
b)
c)
RPI Trend Slope
0.02
0.01
0.00
-0.01
-0.02
d)
e)
f)


RPI Mean
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
a)
b)
c)
RPI Trend Slope
0.02
0.01
0.00
-0.01
-0.02
d)
e)
f)
RPI Patterns
Persistent low
Persistent high
Strong decrease
Strong increase
Other
g)
h)
i)

Summary

- Relatively Productivity Index (RPI) works very well
  - Already outperforming widely used RESTREND and RUE
  - Very valuable for evaluating landscape management strategies ($$$!)
  - Quantile regression approaches have wider applicability

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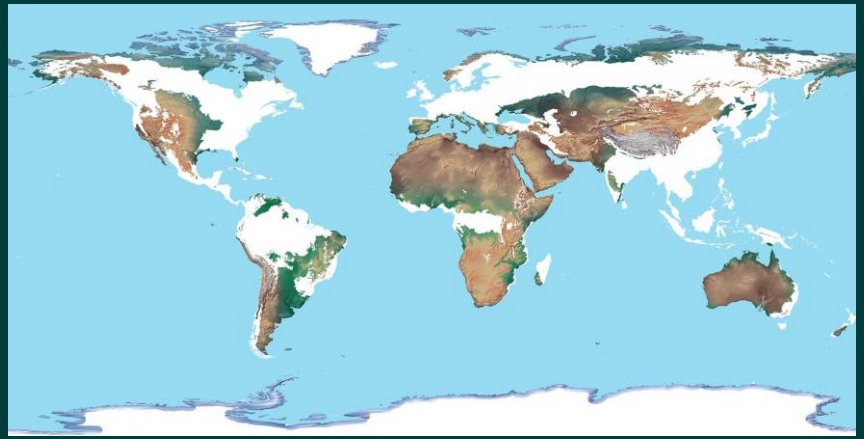
- Our future development pipeline
  - Larger scale products
    - Continental/Global extent
    - Disseminating RPI products



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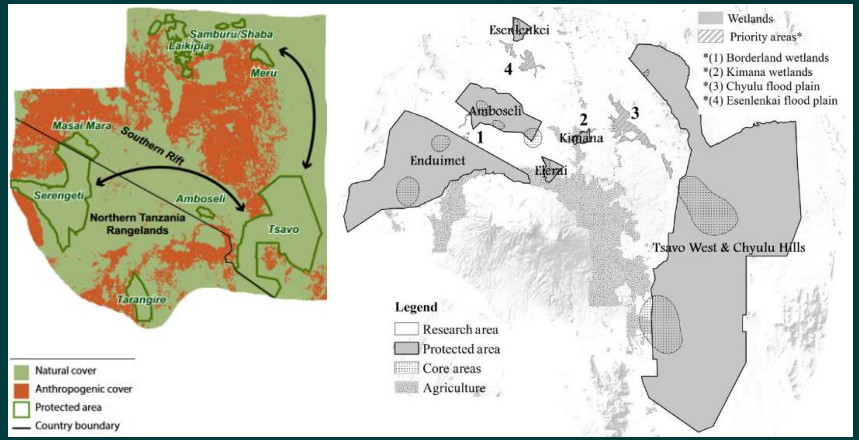
Greater Amboseli Ecosystem



Henschel et al., 2018; Osipova et al., 2018

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  - Guidelines for appropriate use
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  - More comprehensive evaluations
  - Improved modelling approach
    - (covariates and training strategies)

Lomax, Powell, Lenton, and **Cunliffe** (2025) The relative productivity index: mapping human impacts on rangeland vegetation productivity with quantile regression forests. *Ecological Indicators* DOI:10.1016/j.ecolind.2025.113208.

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