



Revisiting fire-rainfall relationships in southern Africa

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Scholes, Brian van Wilgen

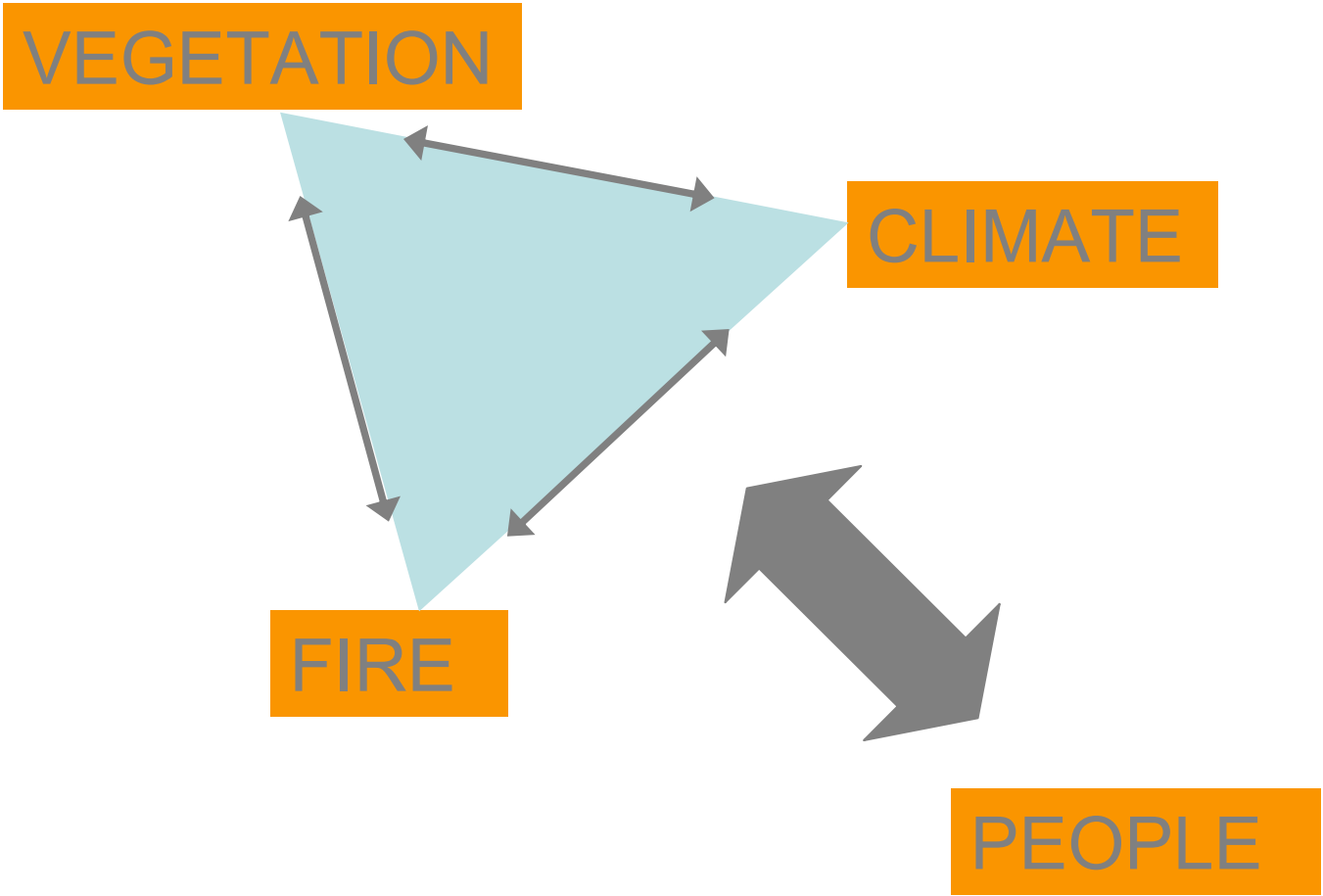


Thank you

- SanParks – Navashni Govender, Sandra Mac Fadyen
- Ezemvelo Wildlife – Sue Van Rensburg, Craig Mulqueeny
- North-West Parks Board – Bruce Brockett
- Etosha Ecological Institute – Johan Le Roux
- Hwange National Park – Peter Frost, Simon Chamaille
- Zimbabwe Department of National Parks and Wildlife Management – Patience Zisadza
- SA Weather Services – Colleen De Villiers
- CarboAfrica - Ulrich Weber, Veiko Lehsten
- Brian Van Wilgen - CSIR



What makes fire interesting?



What does this mean for management of savanna parks?...

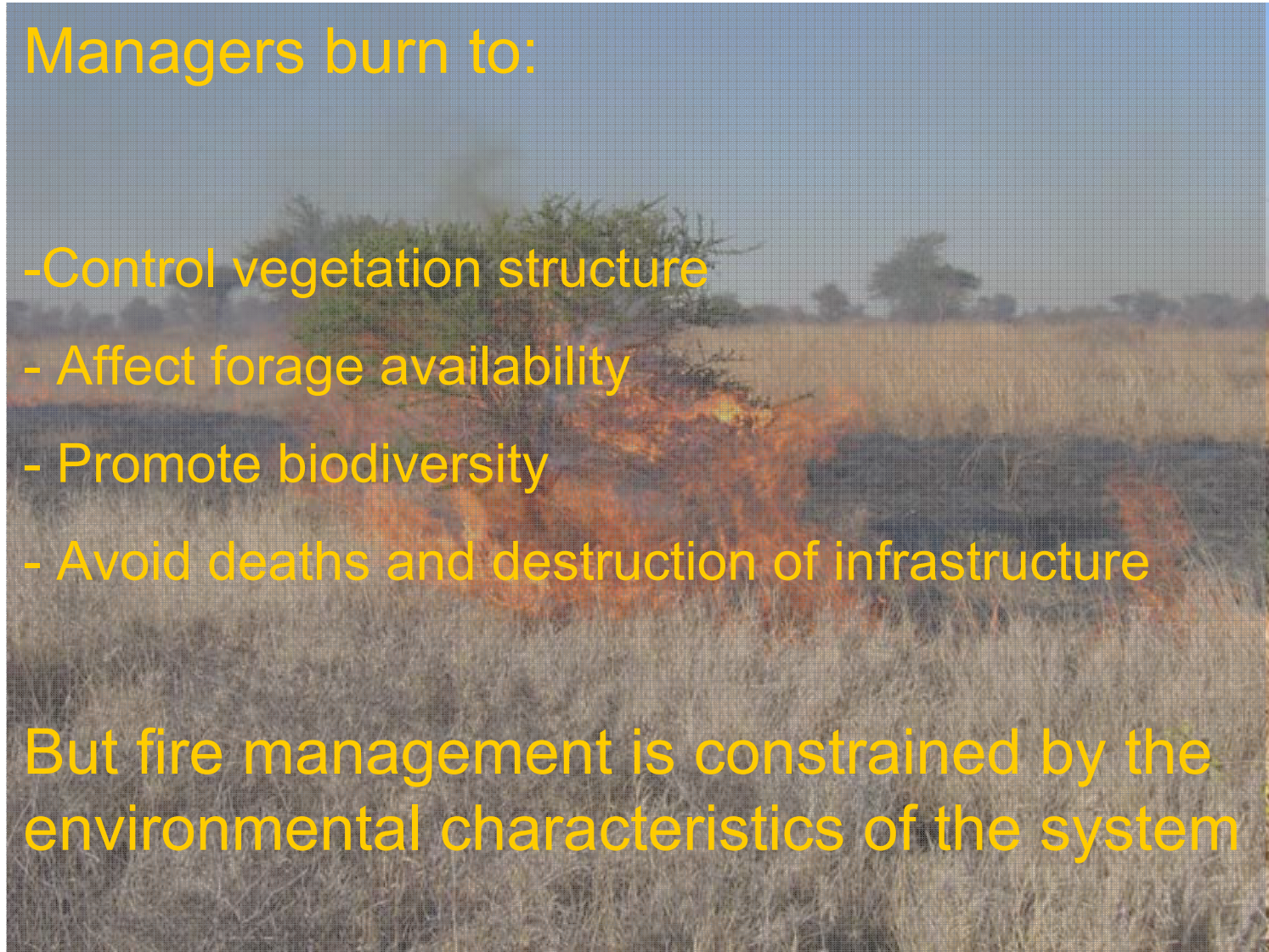


What does this mean for management of national parks?...

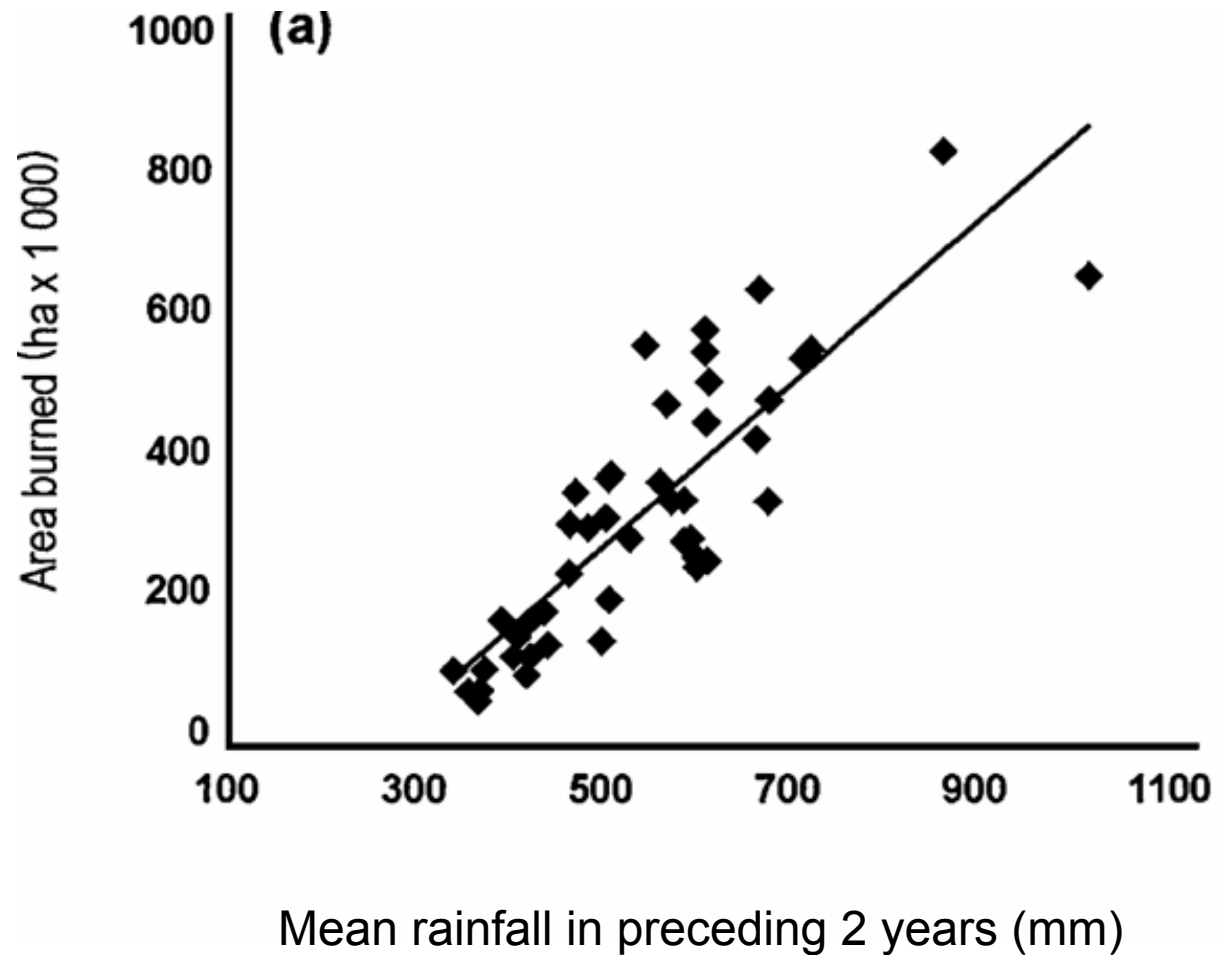
Managers burn to:

- Control vegetation structure
- Affect forage availability
- Promote biodiversity
- Avoid deaths and destruction of infrastructure

But fire management is constrained by the environmental characteristics of the system

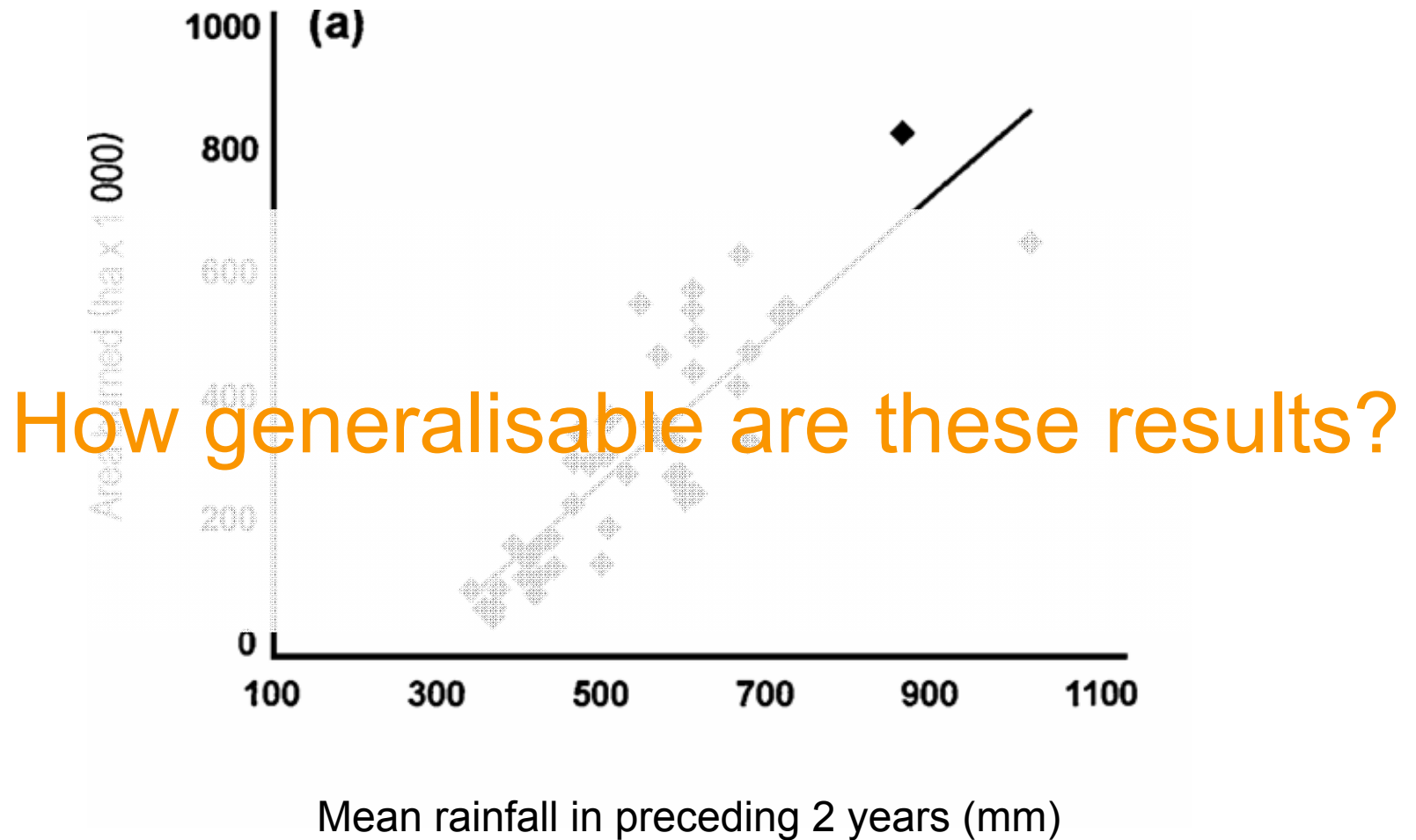


Inter-annual variability



Van Wilgen *et al* (2004) *Cons. Biol.*

Inter-annual variability



How generalisable are these results?

Inter-annual variability

Other potential drivers of variability in burnt area:

Rainfall	→	Rainfall	(FUEL LOADS)
Tree cover		Tree cover	
Seasonality	→	Seasonality	(FUEL MOISTURE)
Grazing		Grazing	
Population density		Population density	
Road density		Road density	
Land tenure		Land tenure	
Topography		Topography	
Lightning frequency		Lightning frequency	
Soil fertility		Soil fertility	
Weather	→	Fire Danger Index	(FIRE SIZE / INTENSITY)

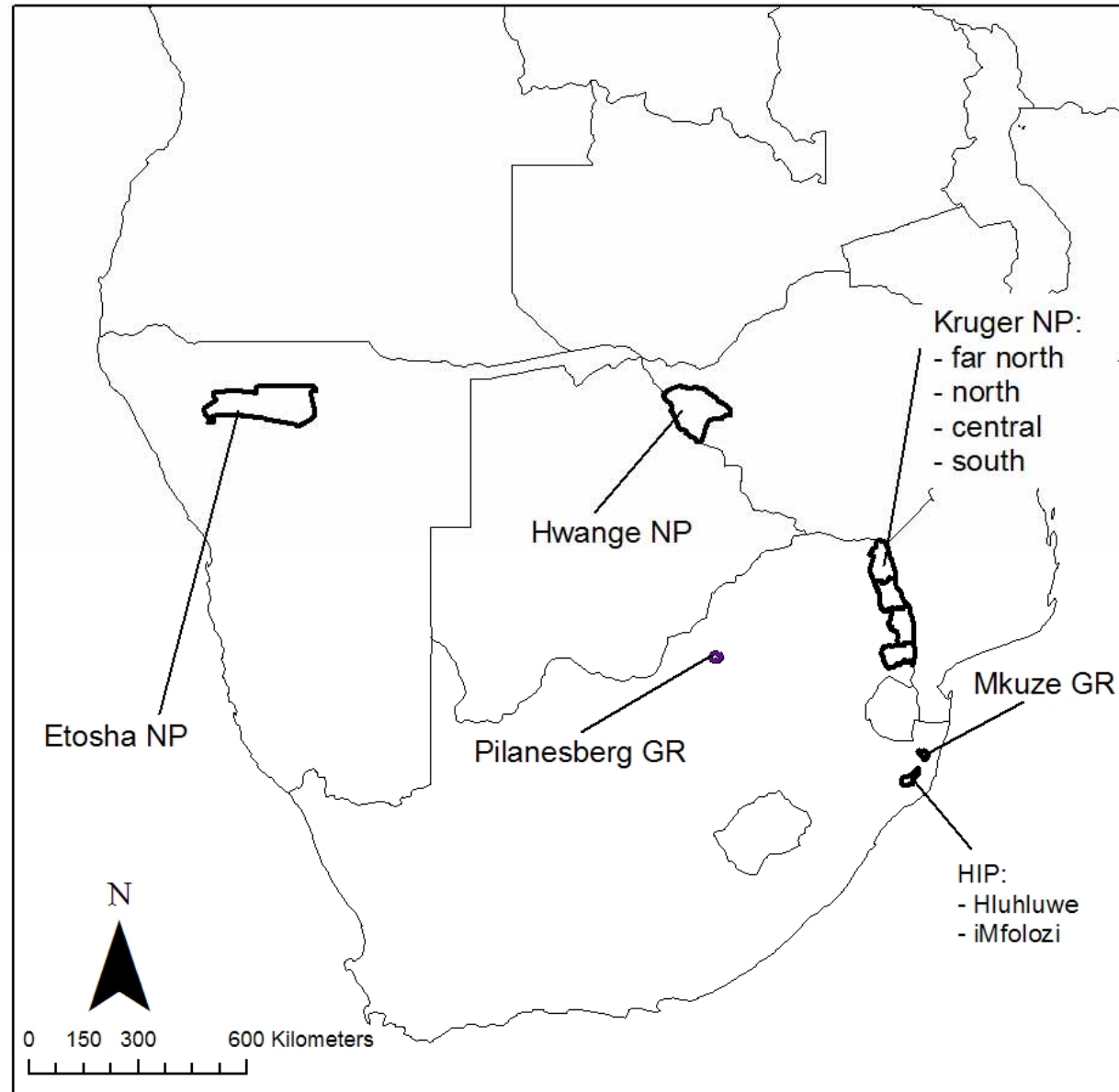


Questions

- Is the relationship between accumulated rainfall and burnt area consistent across parks in southern Africa?
- Can other factors which affect fire help to explain inter-annual variability in burnt area?
- Are similar relationships found outside national parks – at regional scales?
- Can we estimate which parts of Africa have more variable fire regimes? – start to predict future fire regimes?



Inter-annual variability





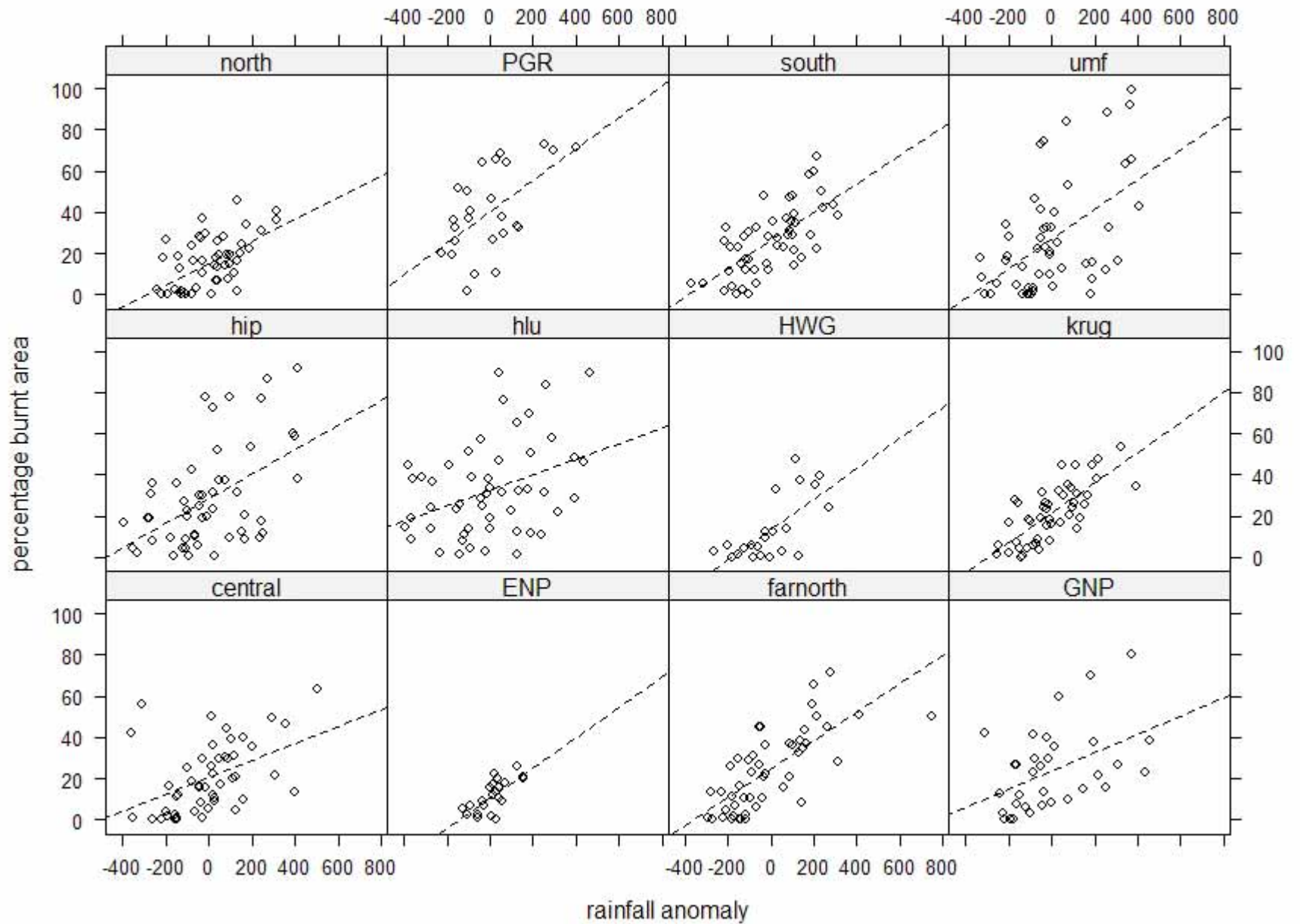
Inter-annual variability

park	n	accumulated rainfall			extent of dry season			FDI		
		R	conf.int	pval	R	conf.int	pval	R	conf.int	pval
KNP	49	0.75	(0.59, 0.85)	0.000*	0.18	(-0.10, 0.44)	0.205	-0.27	(-0.51, 0.01)	0.058
south	50	0.68	(0.50, 0.81)	0.000*	0.23	(-0.05, 0.48)	0.110	-0.19	(-0.44, 0.10)	0.191
central	49	0.45	(0.20, 0.65)	0.001*	0.06	(-0.22, 0.34)	0.669	-0.13	(-0.40, 0.15)	0.356
north	50	0.57	(0.35, 0.73)	0.000*	0.29	(0.01, 0.52)	0.043*	-0.32	(-0.55,-0.05)	0.022*
farnorth	49	0.74	(0.58, 0.84)	0.000*	0.15	(-0.14, 0.41)	0.303	-0.29	(-0.54, 0.00)	0.047*
HIP	51	0.50	(0.26, 0.68)	0.000*	0.24	(-0.04, 0.48)	0.090	-0.16	(-0.43, 0.14)	0.295
hlu	51	0.37	(0.10, 0.59)	0.008*	0.24	(-0.04, 0.48)	0.091	0.05	(-0.23, 0.32)	0.722
umf	51	0.52	(0.29, 0.70)	0.000*	0.21	(-0.07, 0.46)	0.147	-0.16	(-0.42, 0.12)	0.270
PGR	25	0.57	(0.23, 0.79)	0.003*	0.33	(-0.07, 0.64)	0.105	-0.25	(-0.59, 0.16)	0.232
MGR	38	0.54	(0.27, 0.73)	0.000*	0.25	(-0.08, 0.53)	0.132	-0.03	(-0.34, 0.30)	0.878
HWG	22	0.69	(0.38, 0.86)	0.000*	0.13	(-0.31, 0.52)	0.563	NA	(NA, NA)	NA
ENP	22	0.71	(0.41, 0.87)	0.000*	0.36	(-0.07, 0.68)	0.100	NA	(NA, NA)	NA

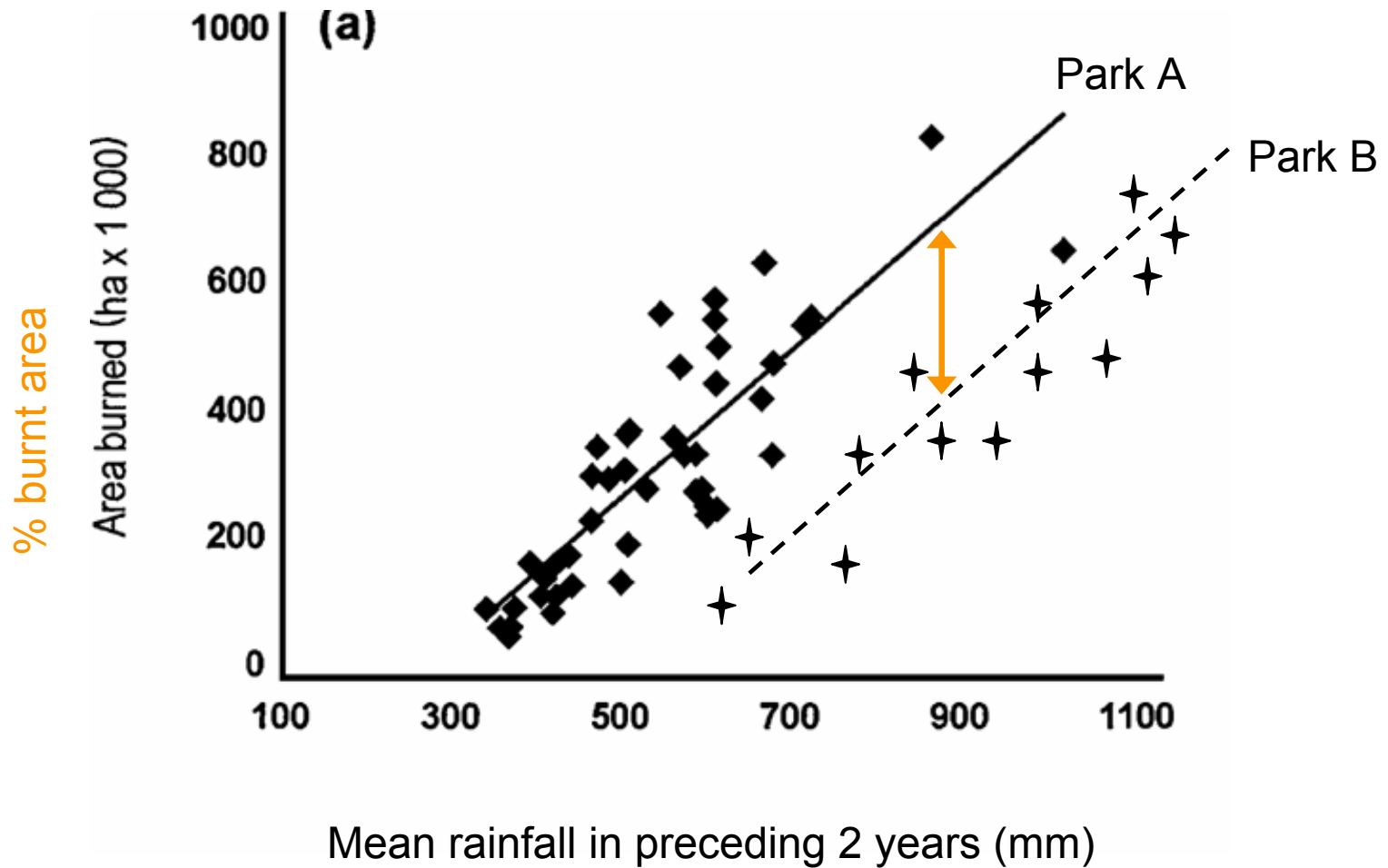


Variability in burnt area is most strongly correlated with accumulated rainfall (index of fuel loads)

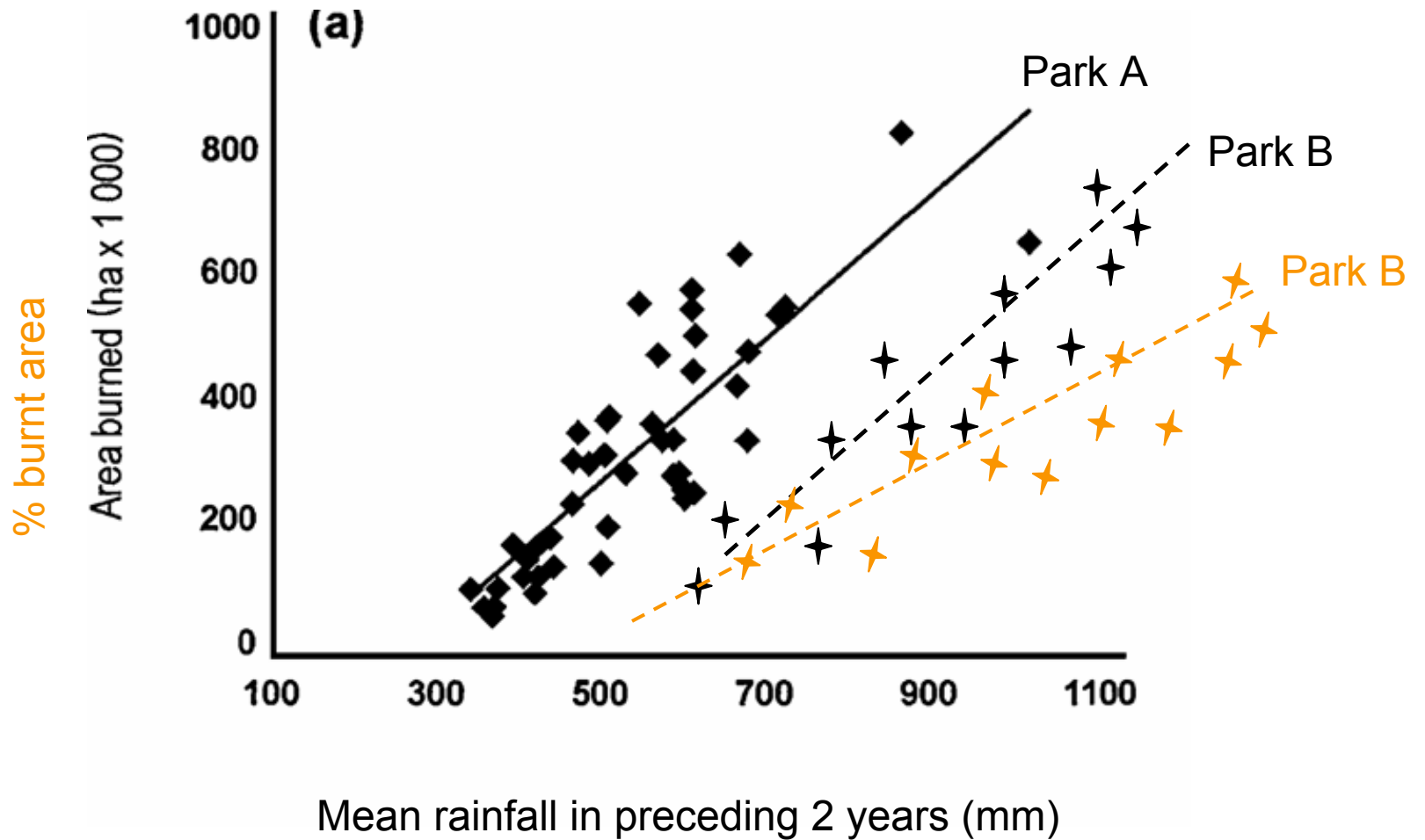
Inter-annual variability



Mixed effects analysis: by park



Mixed effects analysis: by park



Mixed effects analysis: by park

predictor	intercept	slope	Temporal autocorrelation (AR1)	Goodness of fit (AIC value)
rainfall	no	no	no	4635
rainfall	yes	no	no	4581
rainfall	yes	yes	no	4592
rainfall	yes	no	yes	4564



Mixed effects analysis: by park

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Equivalent to mean burnt area

$$\text{burnt}_{ij} = \underbrace{\beta_0 + b_i}_{0.68} + \beta_1 \text{rain}_{ij} + \varepsilon_{i,j} \text{ (with AR1)}$$

0.68

Error term

0.23: correlation between years



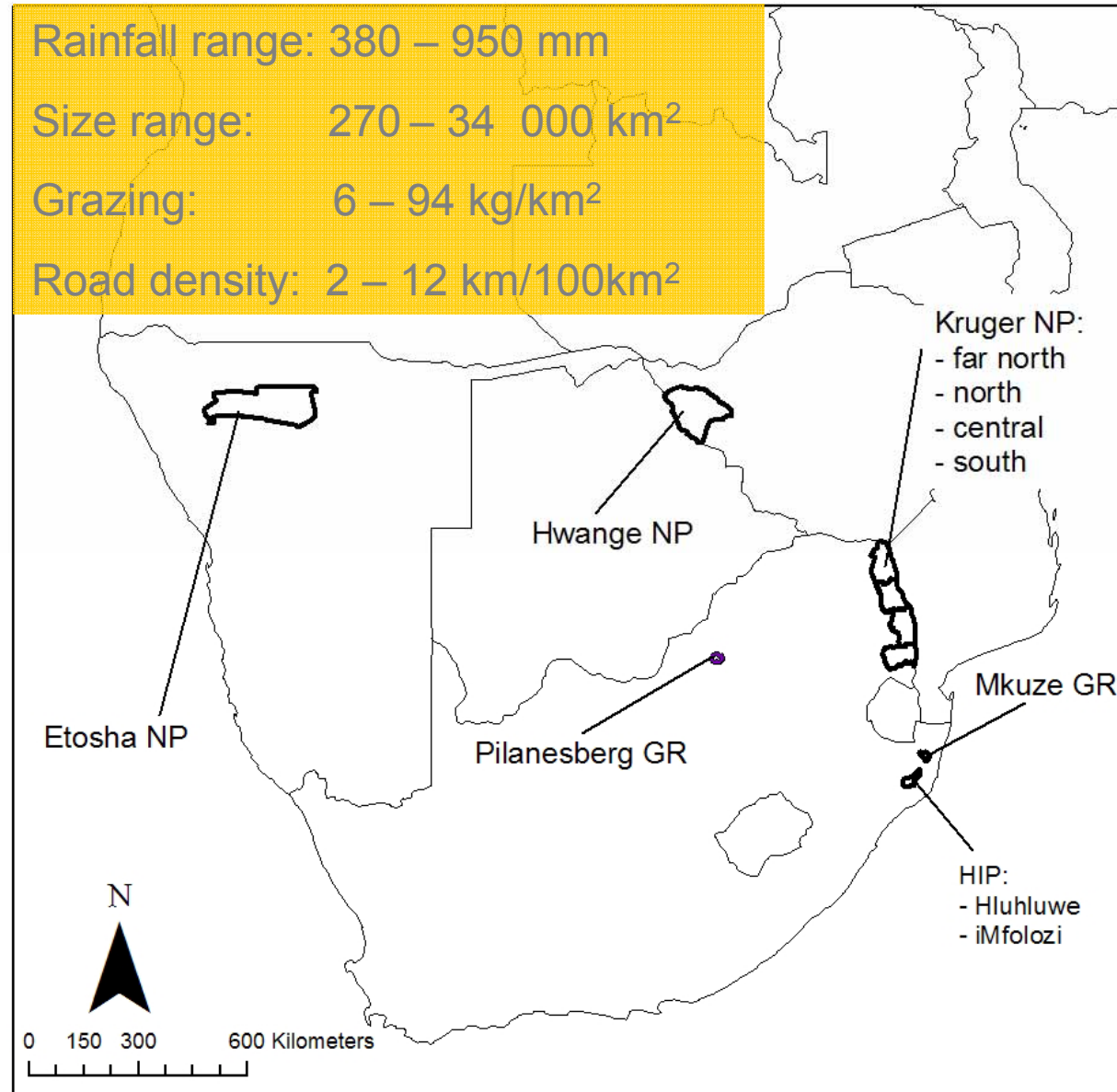
Mixed effects analysis: by park

Rainfall range: 380 – 950 mm

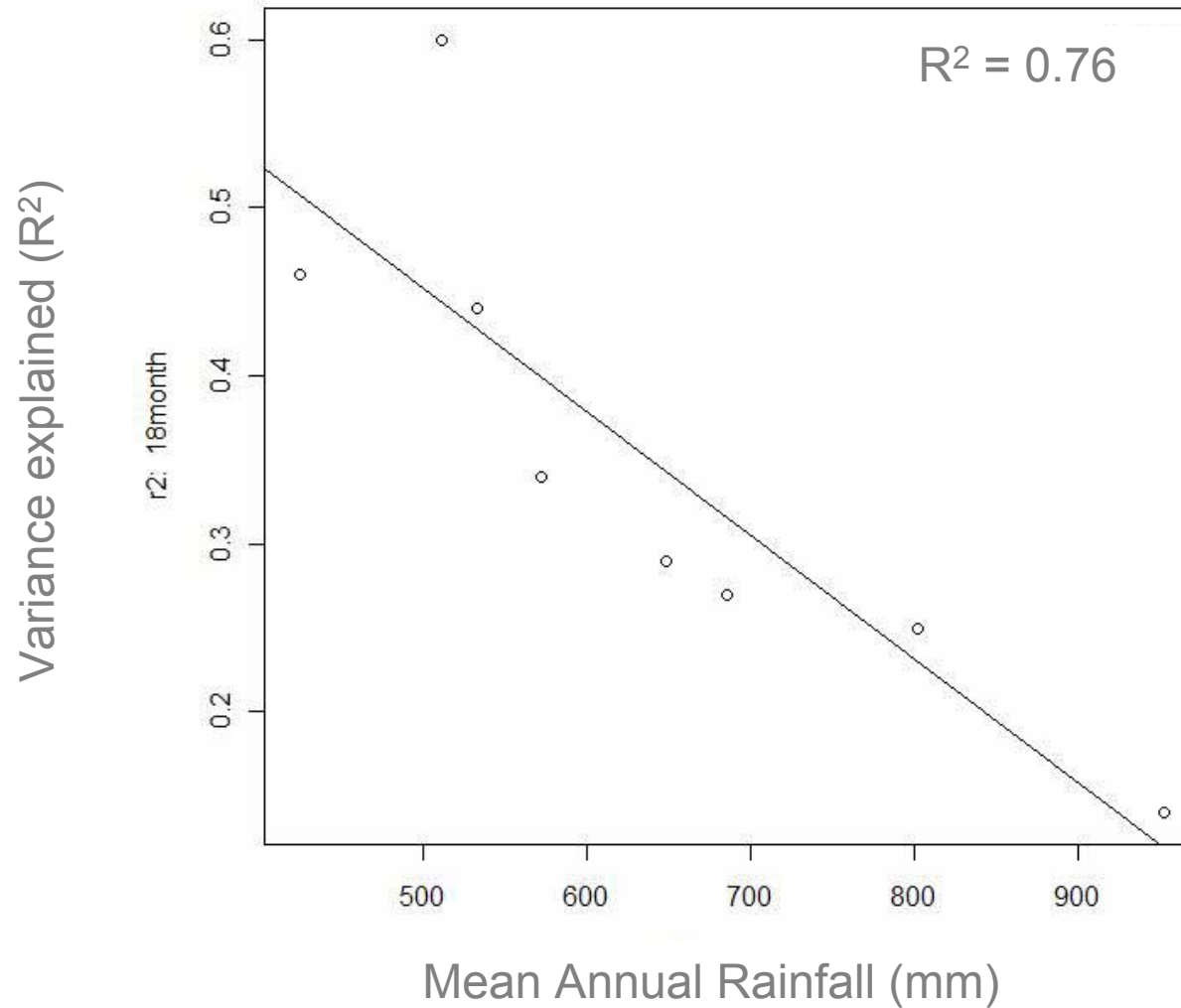
Size range: 270 – 34 000 km²

Grazing: 6 – 94 kg/km²

Road density: 2 – 12 km/100km²



Mixed effects analysis: by park



The amount of variance explained by the fire-rainfall relationship decreases for parks with high rainfalls - other climatic factors?



Mixed effects analysis: by park

predictor 1	predictor 2	intercept	slope	AR1	Goodness of fit (AIC value)
--	--	yes	no	yes	3999
Rainfall	--	yes	no	yes	3860
Seasonality	--	yes	no	yes	3990
Fire Danger	--	yes	no	yes	3995
Rainfall	Seasonality	yes	no	yes	3855
Rainfall	Fire danger	yes	no	yes	3869

Equivalent to mean burnt area

$$\text{burnt}_{ij} = \beta_0 + b_i + \beta_1 \text{rain}_{ij} + \beta_2 \text{season}_{ij} + \varepsilon_{i,j} \text{ (with AR1)...}$$

0.68

0.21

0.23

correlation between years





Summary: rainfall-fire relationships

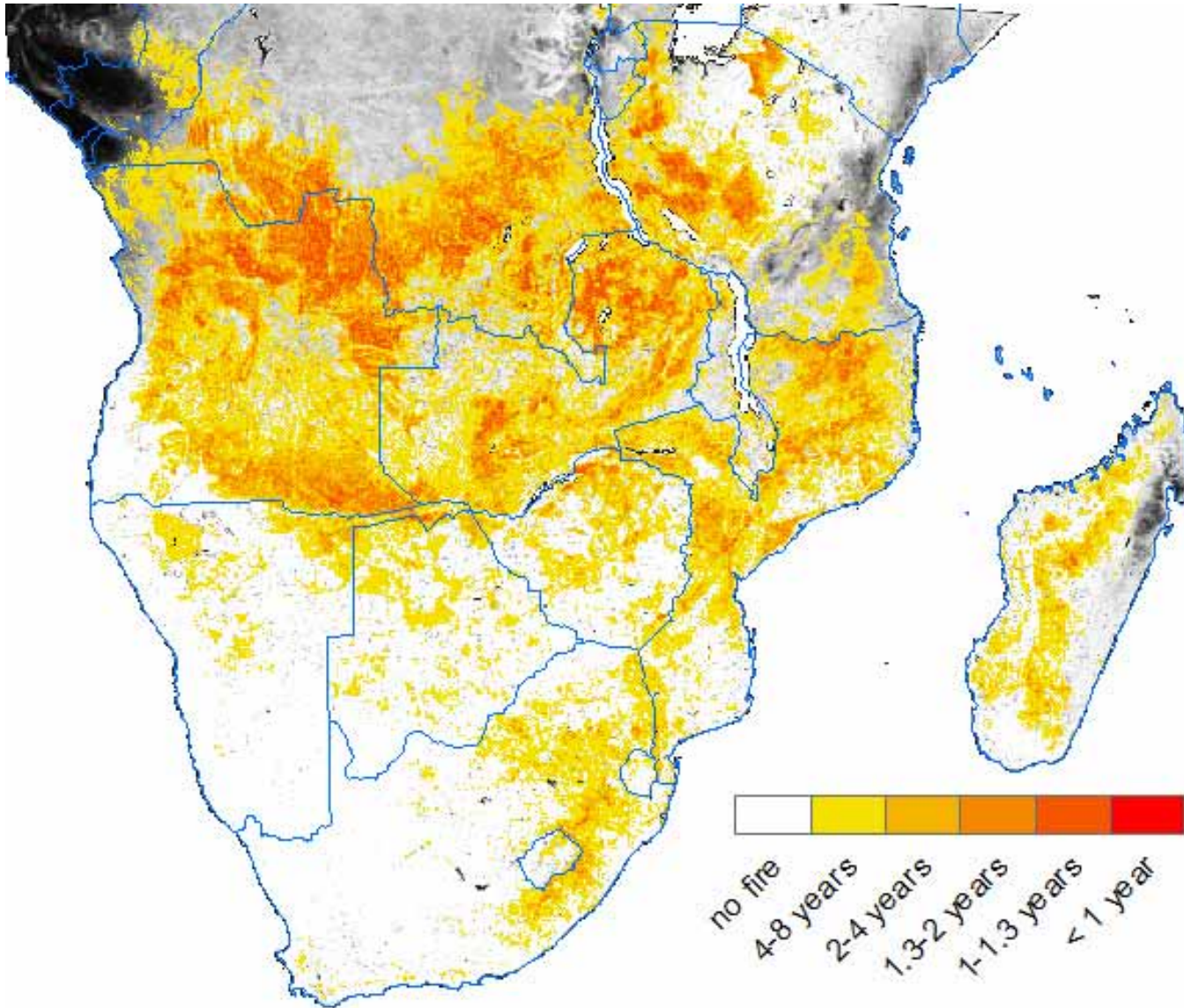
- All parks in southern Africa show the same relationship with rainfall:
 - Managers can use simple models to plan annual burn targets
- The amount of variation explained by rainfall varies, however:
 - Dry parks have stronger relationships with rainfall.
 - Other factors, like length of the dry season, are also important



Summary: rainfall-fire relationships

- All parks in southern Africa show the same relationship with rainfall:
 - Managers can use simple models to plan annual burn targets
- The amount of variation explained by rainfall varies, however:
 - Dry parks have stronger relationships with rainfall.
 - Other factors, like length of the dry season, are also important
- Are the same relationships found outside national parks – at regional scales?
 - Can we estimate which parts of Africa have more variable fire regimes?

Regional patterns

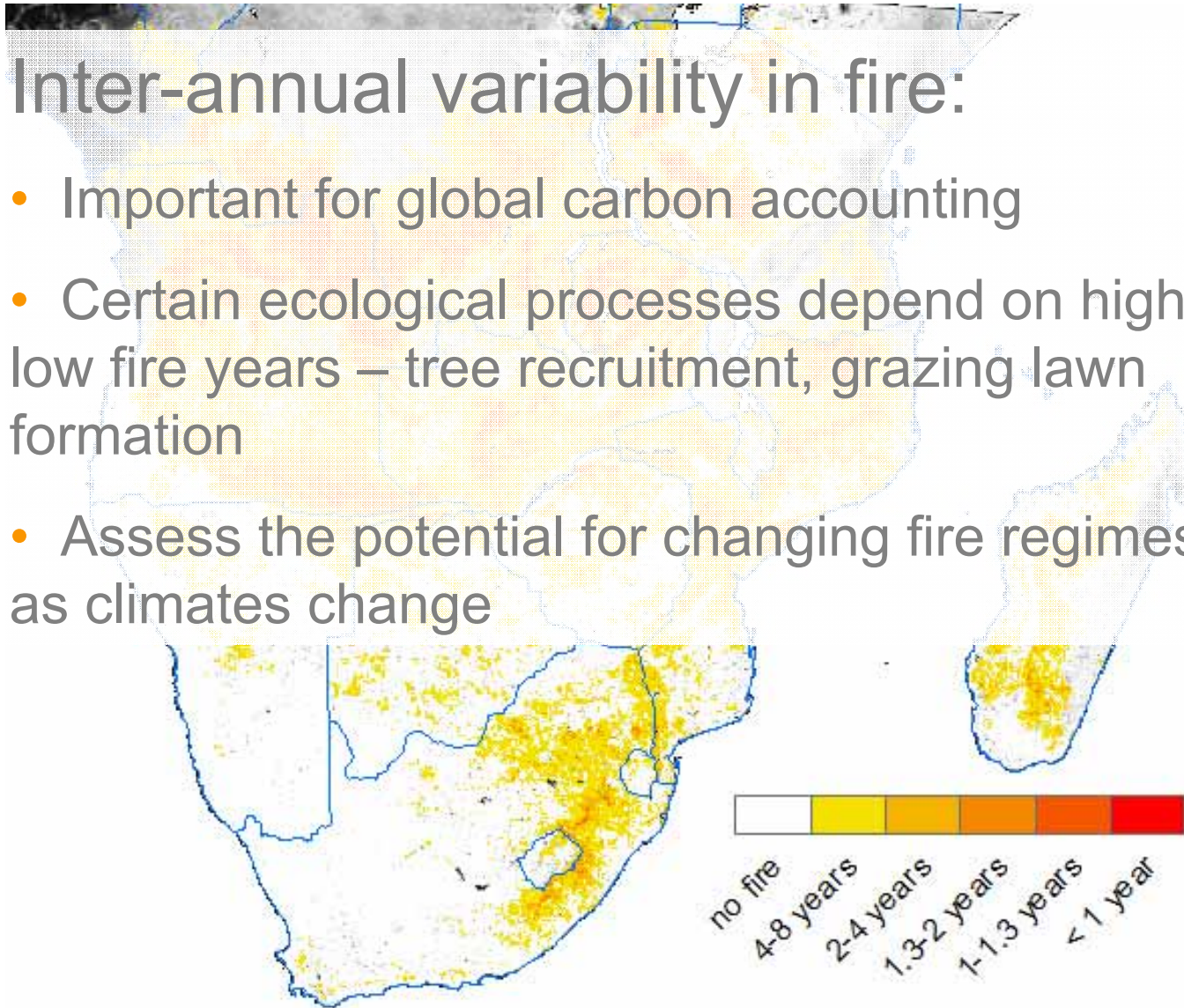


Fire return period in Southern Africa

Regional patterns

Inter-annual variability in fire:

- Important for global carbon accounting
- Certain ecological processes depend on high or low fire years – tree recruitment, grazing lawn formation
- Assess the potential for changing fire regimes as climates change



Fire return period in Southern Africa



Regional patterns

rainfall range: southern Africa

90 mm

2650 mm

rainfall range: regions that burn

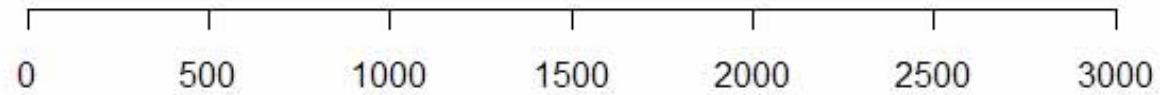
430 mm

1700 mm

rainfall range: parks in the analysis

380 mm

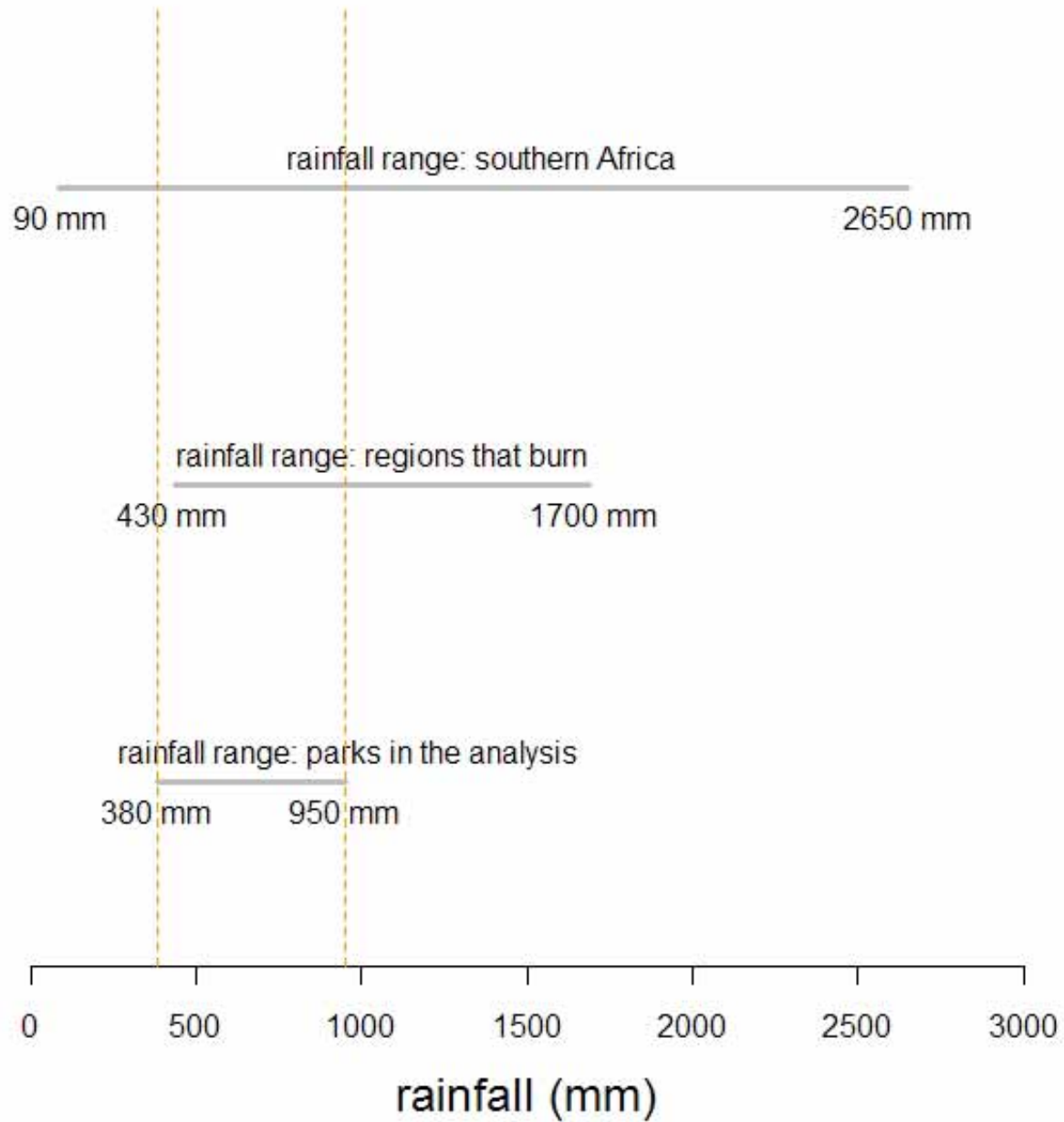
950 mm



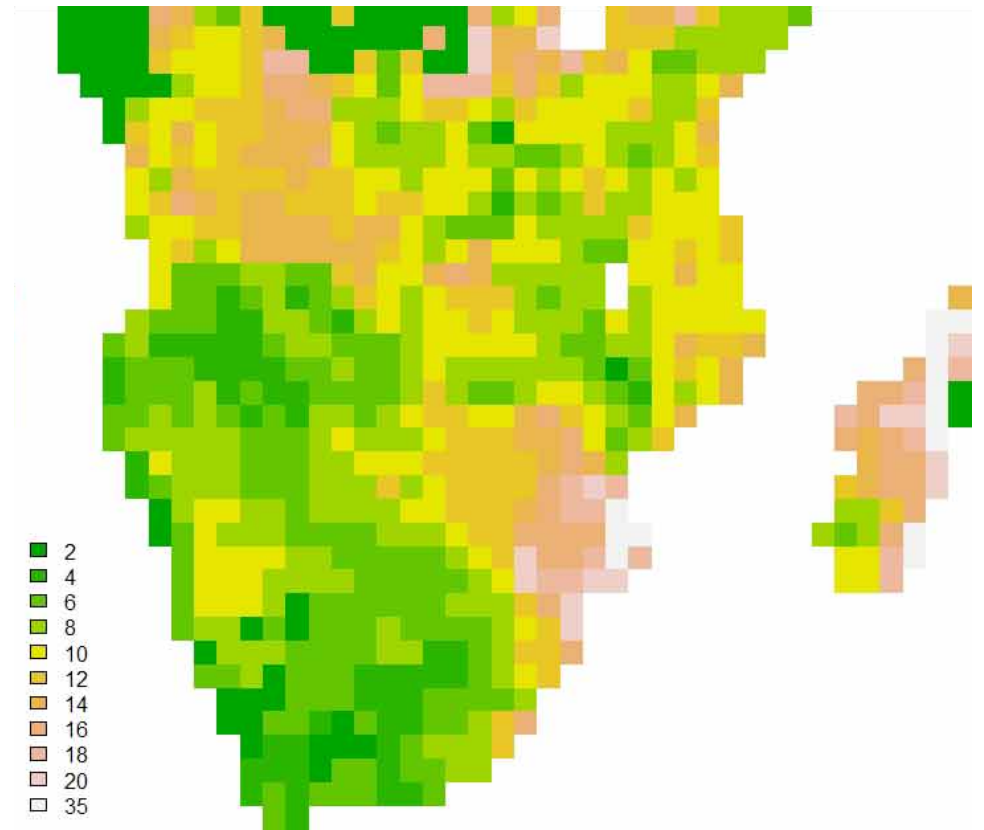
rainfall (mm)



Regional patterns

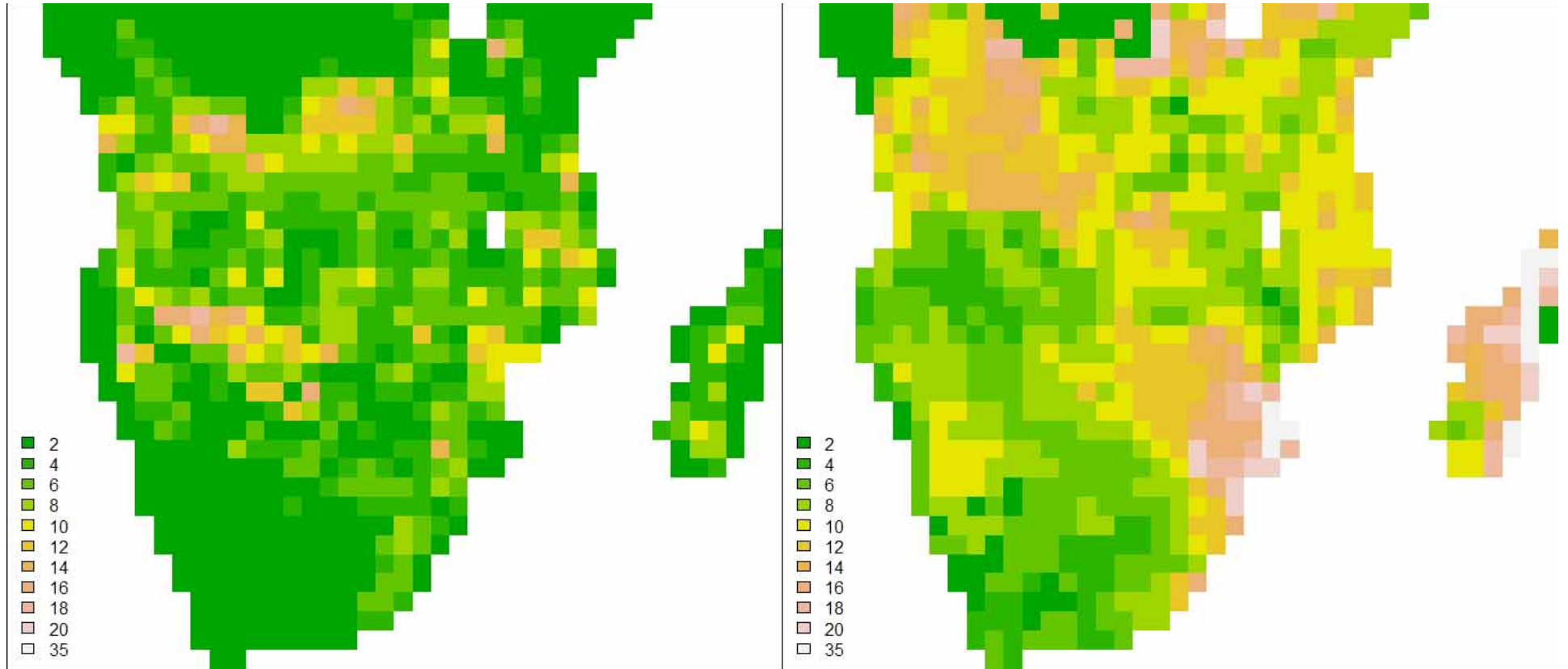


Regional patterns



Predicted variability (sd) in
% burnt

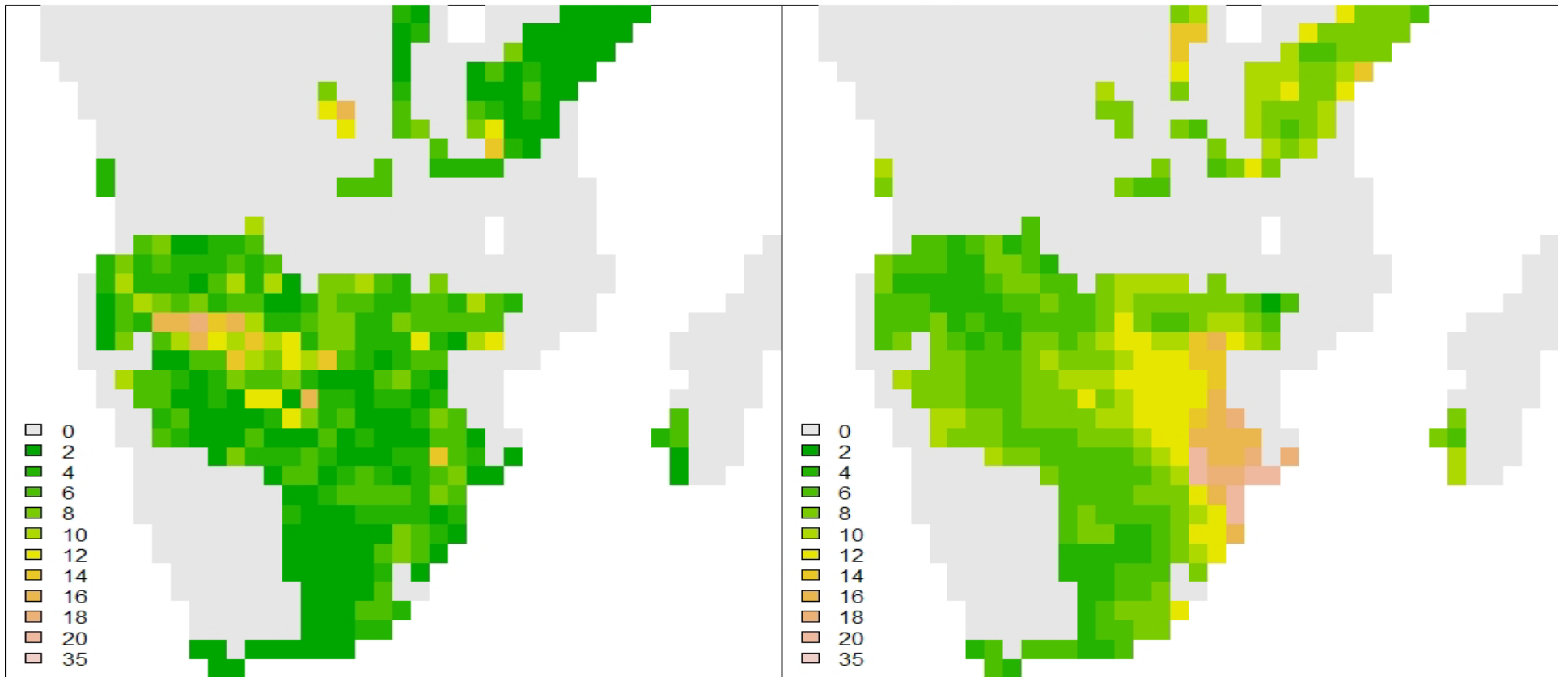
Regional patterns



Observed variability (sd) in
% burnt

Predicted variability (sd) in
% burnt

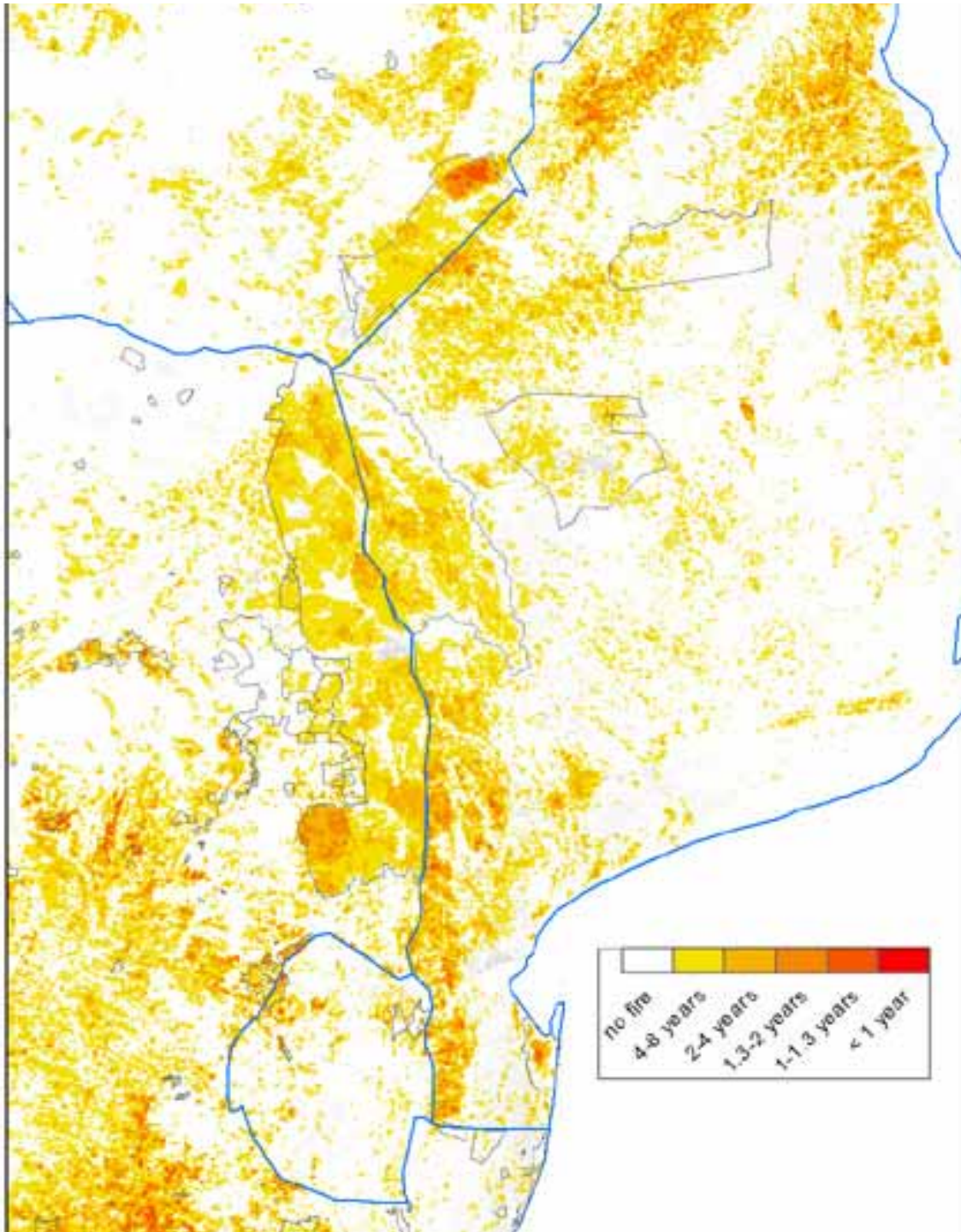
Regional patterns



Observed variability (sd) in
% burnt

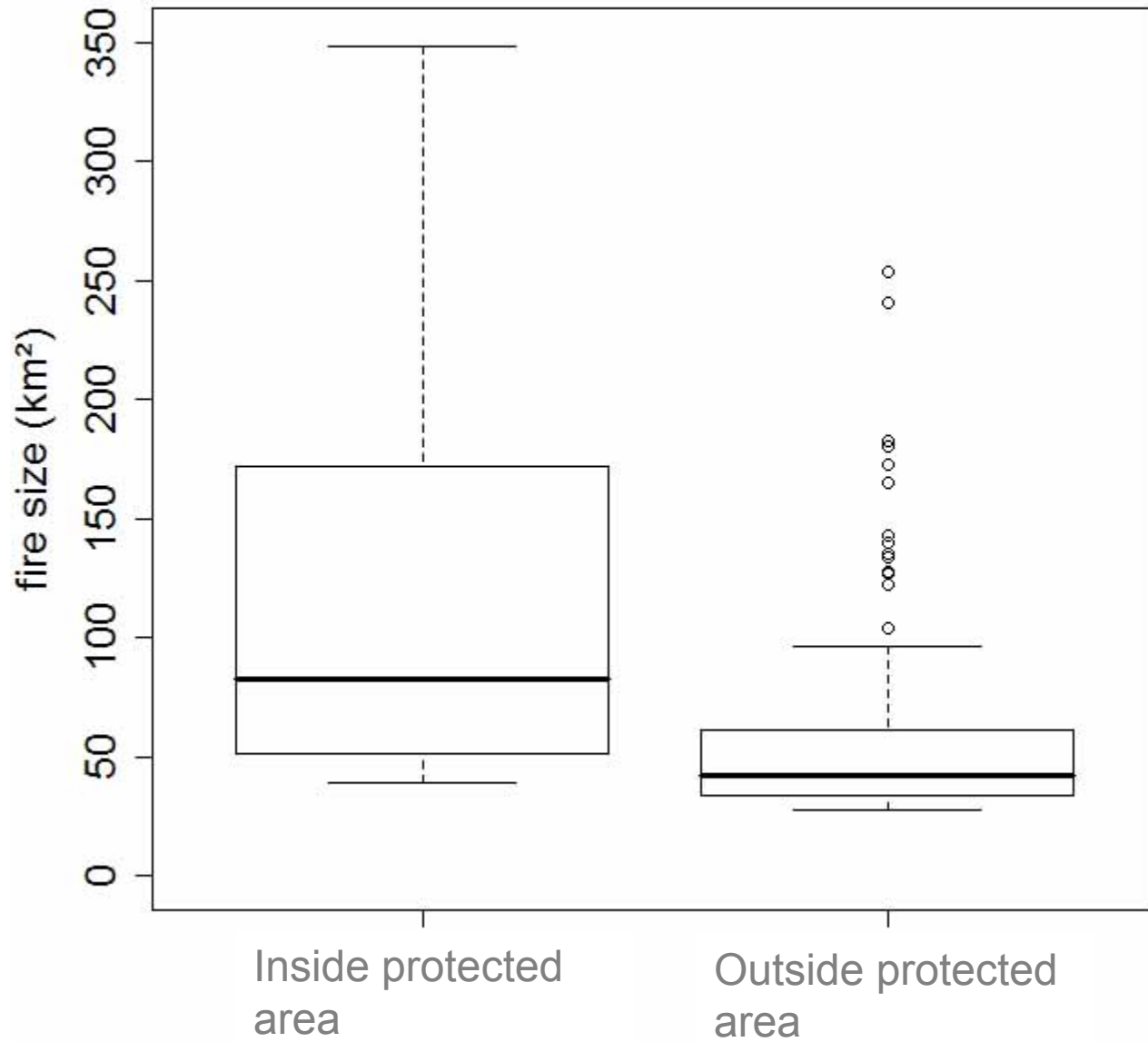
Predicted variability (sd) in
% burnt

Regional patterns



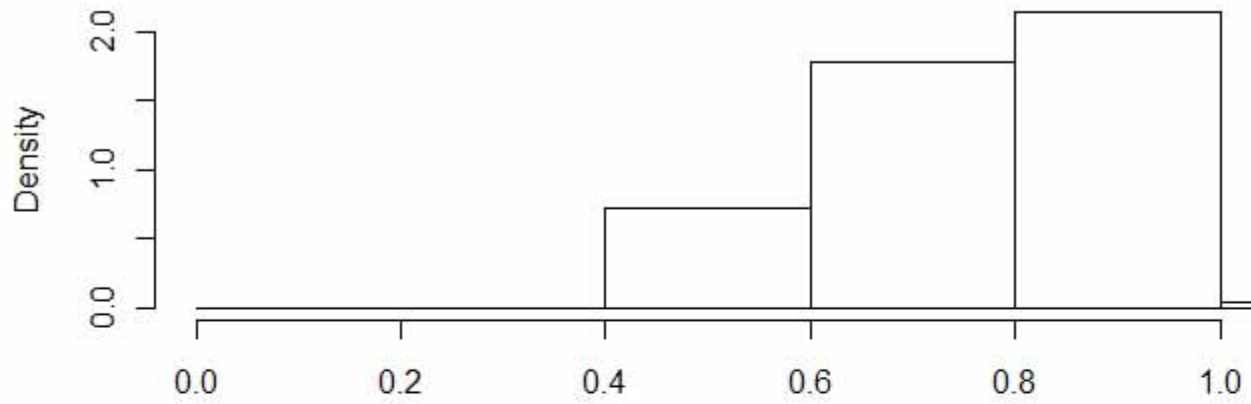
Fire return period
inside and outside the
Kruger National Park

Regional patterns

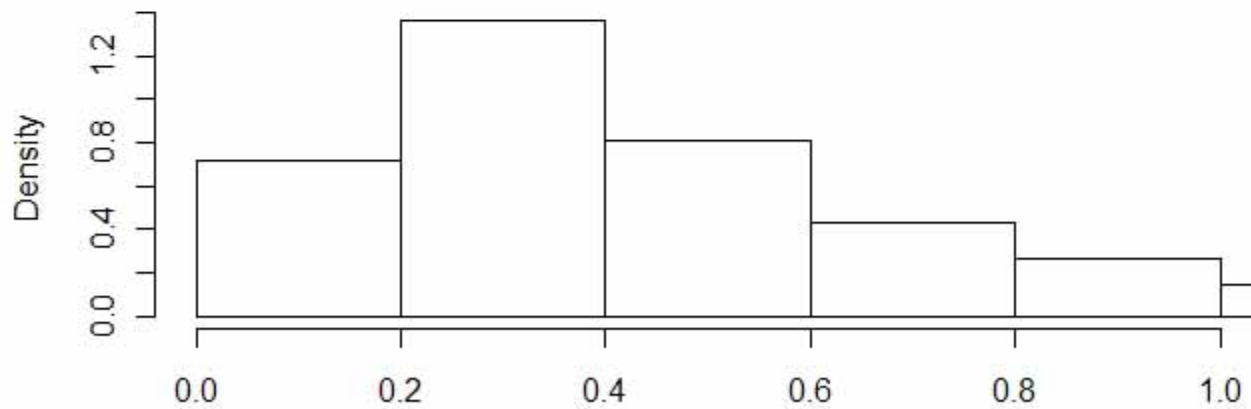




Regional patterns

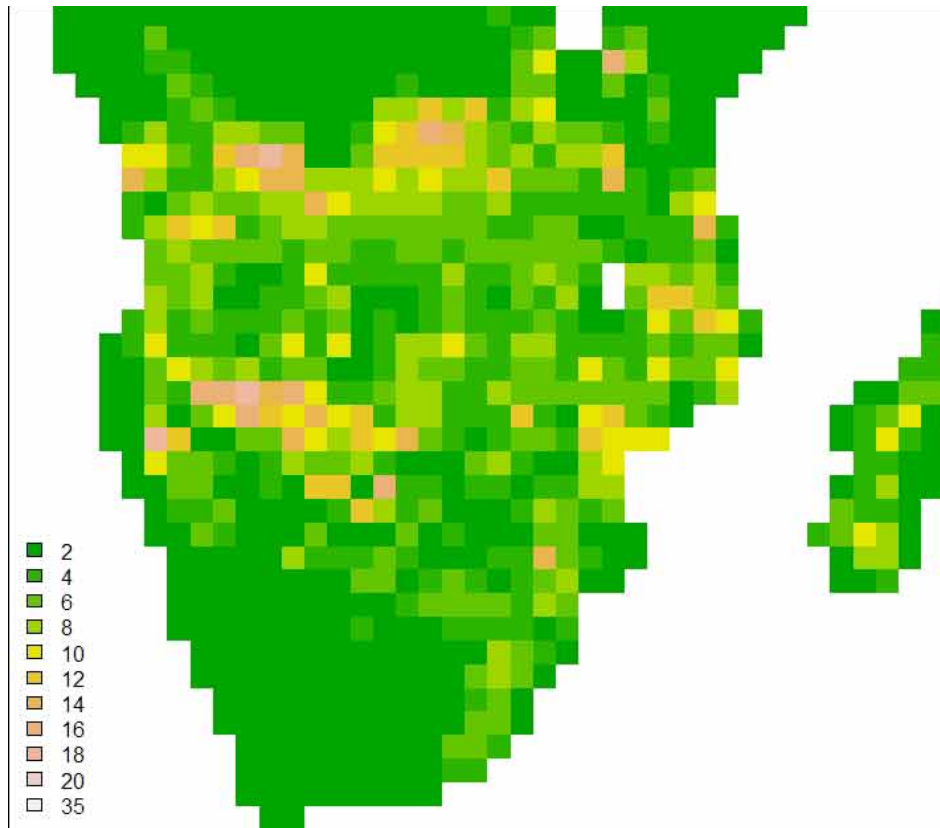


Coefficient of variation (CV) in burnt area inside protected areas



Coefficient of variation (CV) in burnt area outside protected areas

Regional patterns



Observed variability (sd) in
% burnt

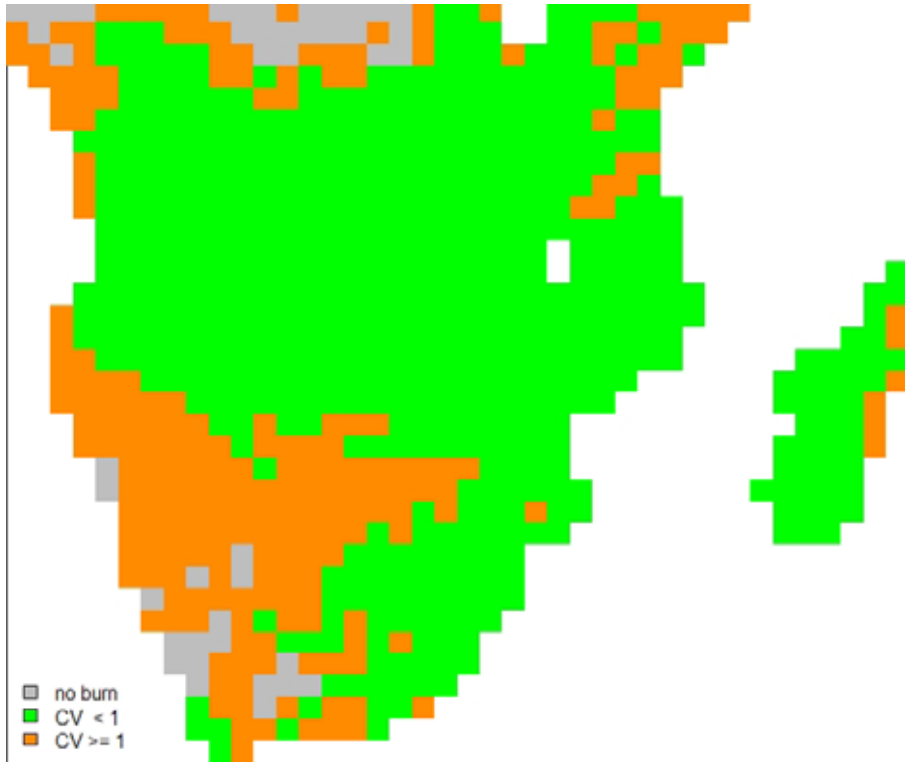
If not climate, then what
controls inter-annual
variability?

Hypotheses: interaction of climate and
humans

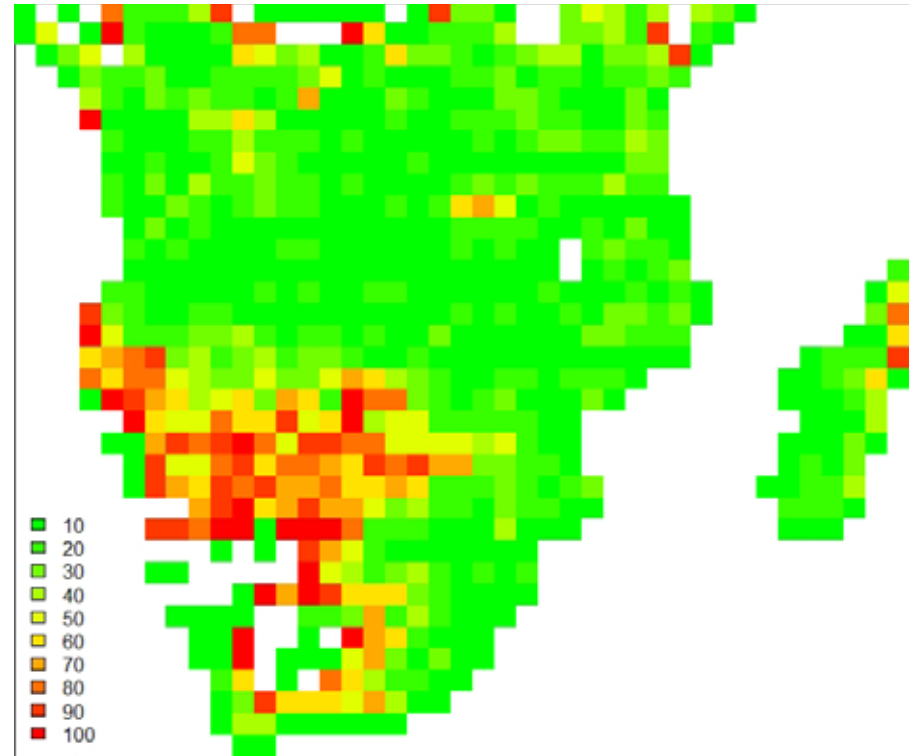
1: Can only get large fires where there
are few people.

2: Can only get variability in burnt area
where there are large fires

Regional patterns

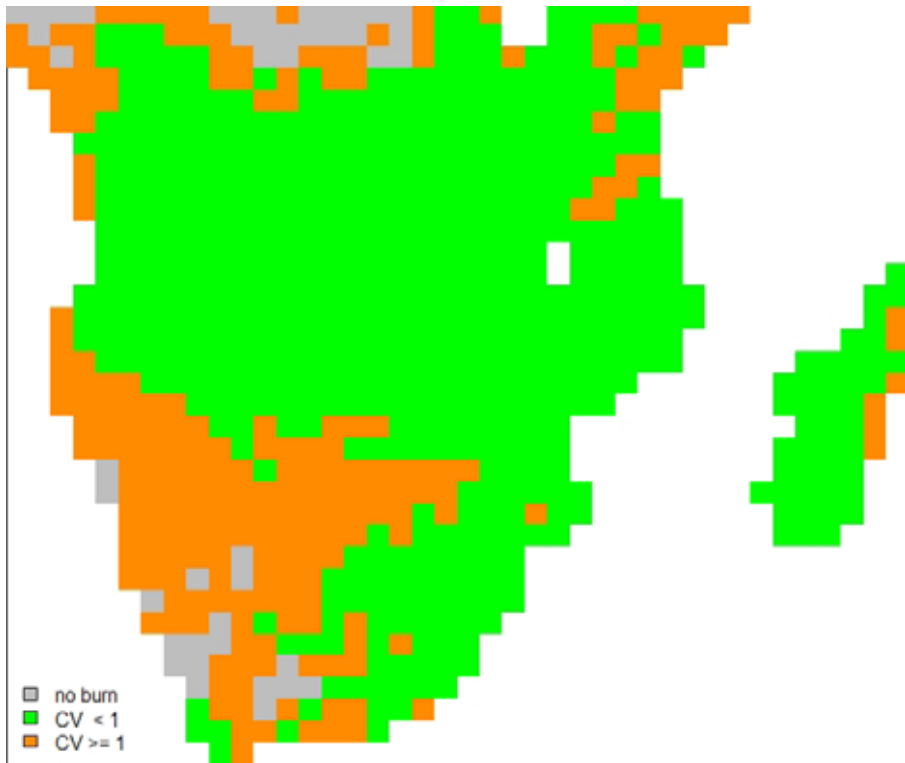


Variance in burnt area (CV)

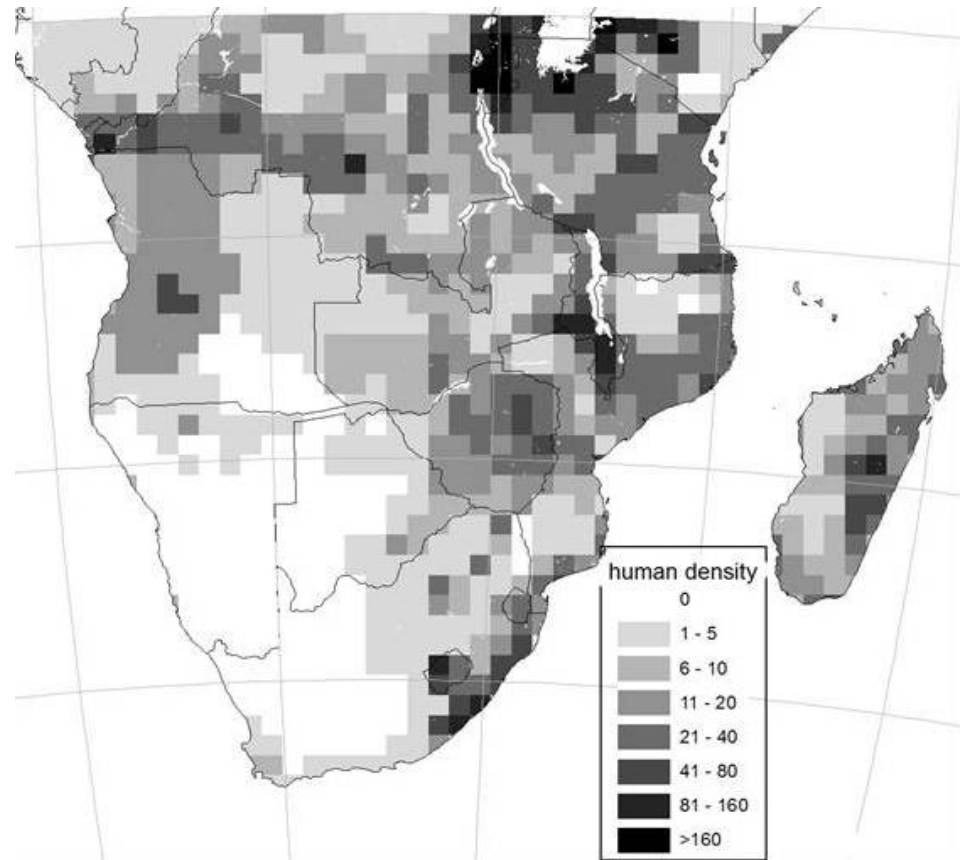


% total area burnt by 5 largest fires

Regional patterns



Variance in burnt area (CV)



Human population densities

Where does that leave us?

- In protected areas:
 - Rainfall and length of the dry season can be used to predict burnt area across a range of parks in southern Africa
- At a regional scale:
 - These climatic determinants can not reproduce patterns of fire variability
- To test:
 - Inter-annual variability is higher in areas with the potential for large fires
 - Humans – by affecting fire size, are restricting variability in burnt area
- When linking fire and climate in global models one must also explicitly consider human impacts



Thank you

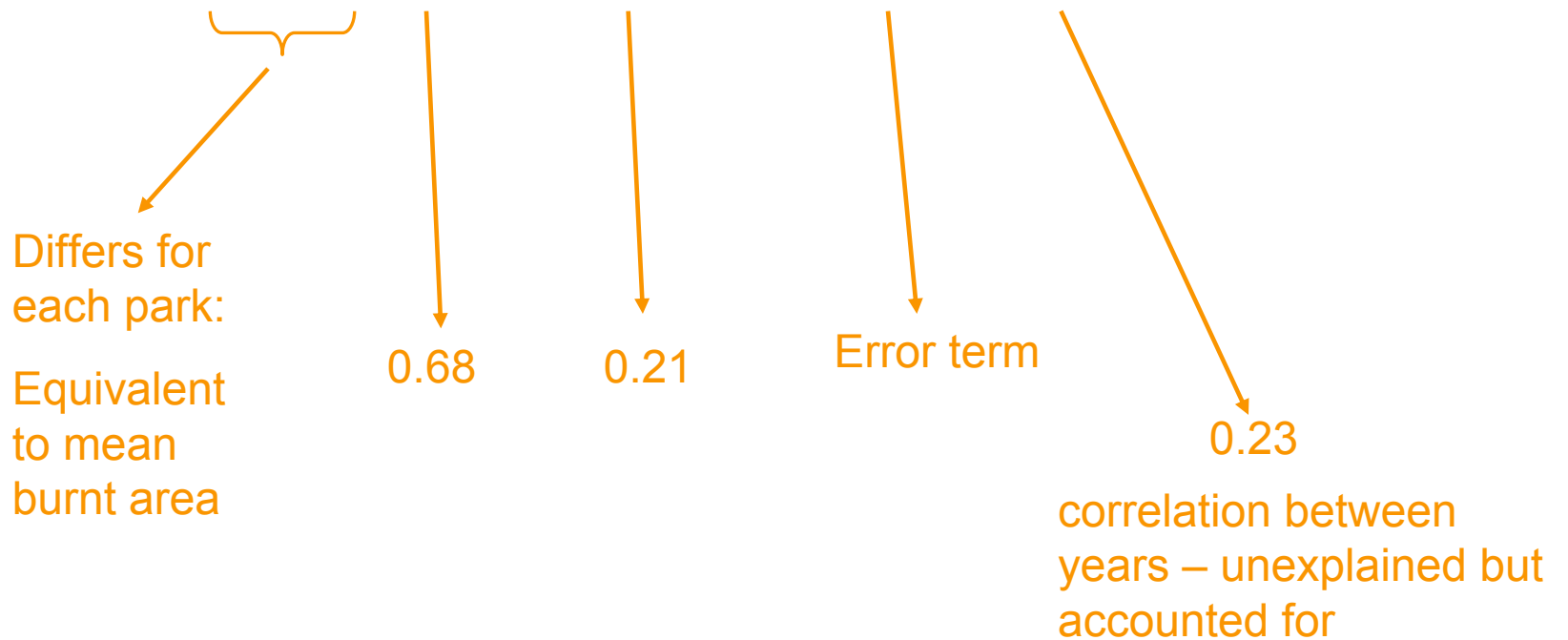


Photo: Mendelsohn (2002)

Inter-annual variability

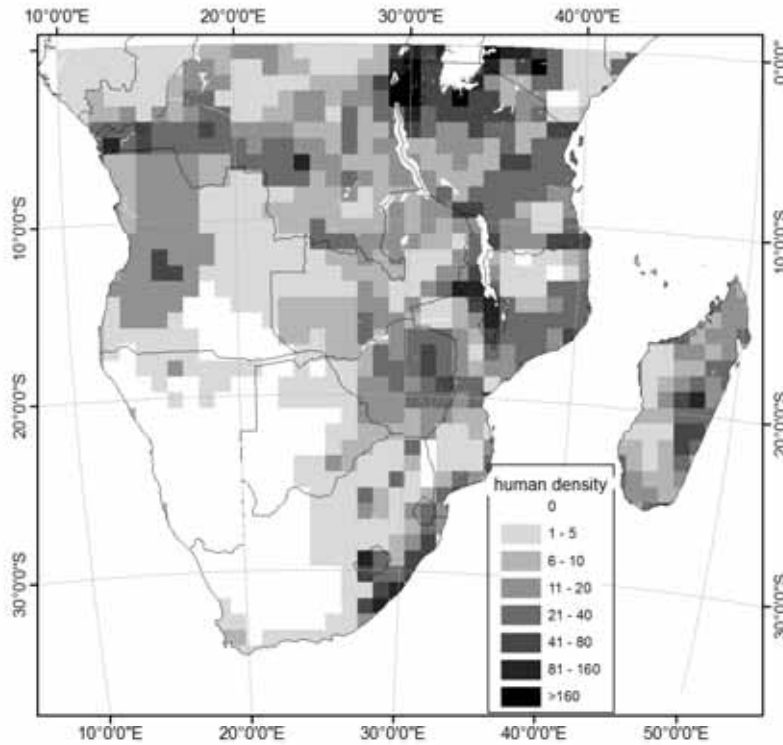
Linear mixed effects models:

$$\text{burnt}_{ij} = \beta_0 + b_i + \beta_1 \text{rain}_{ij} + \beta_2 \text{season}_{ij} + \varepsilon_{i,j} \text{ (with AR1)} \dots \text{BIC} = 3855$$

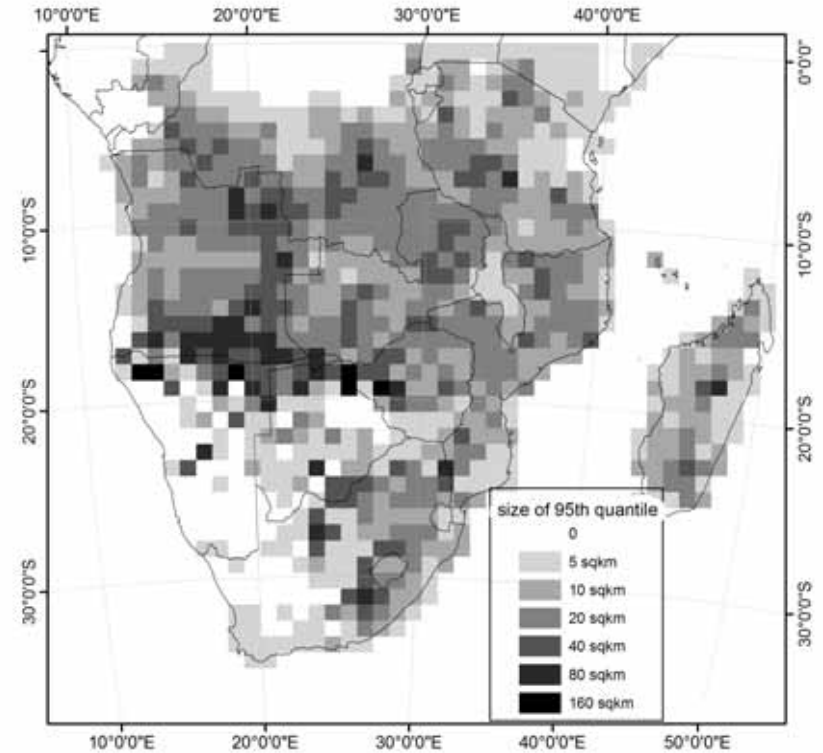


Effect of people

Human densities



Fire size



What does this imply?

Altering fire regimes by altering ignitions is going to be ineffectual?



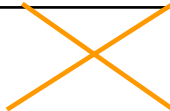


Thank you



- David Roy – South Dakota State University
- Bob Scholes – CSIR
- Alecia Kirton – CSIR
- William Bond – University of Cape Town
- Brian van Wilgen – CSIR
- Simon Levin – Princeton University
- The Andrew Mellon Foundation
- The CSIR young researchers' establishment fund
- South African National Parks (SanParks)

Mixed effects analysis: regional



predictor 1	predictor 2	intercept	slope	AR1	Goodness of fit (AIC value)
--	--	yes	no	yes	21201
Rainfall	--	yes	no	yes	21209 
Seasonality	--	yes	no	yes	21194 
Fire Danger	--	yes	no	yes	21216 

Inter-annual variability

Linear mixed effects models:

$\text{burnt}_{ij} = \beta_0 + b_i + \varepsilon_{ij}$ (with AR1).....	BIC = 3999	0
$\text{burnt}_{ij} = \beta_0 + b_i + \beta_1 \text{rain}_{ij} + \varepsilon_{i,j}$ (with AR1).....	BIC = 3860	-139
$\text{burnt}_{ij} = \beta_0 + b_i + \beta_1 \text{season}_{ij} + \varepsilon_{i,j}$ (with AR1).....	BIC = 3990	-9
$\text{burnt}_{ij} = \beta_0 + b_i + \beta_1 \text{FDI}_{ij} + \varepsilon_{i,j}$ (with AR1).....	BIC = 3995	-4
<p>The perception that rainfall is the most important variable is confirmed but seasonality can add information</p>		
$\text{burnt}_{ij} = \beta_0 + b_i + \beta_1 \text{rain}_{ij} + \beta_1 \text{season}_{ij} + \varepsilon_{i,j}$ (with AR1).....	BIC = 3855	-144

