

Estudo de caso

Primeira Etapa (2008 a 2012)

Author's personal copy

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Variable rate fertilization in citrus: a long term study

A. F. Colaço¹ · J. P. Molin¹ 

Objetivo

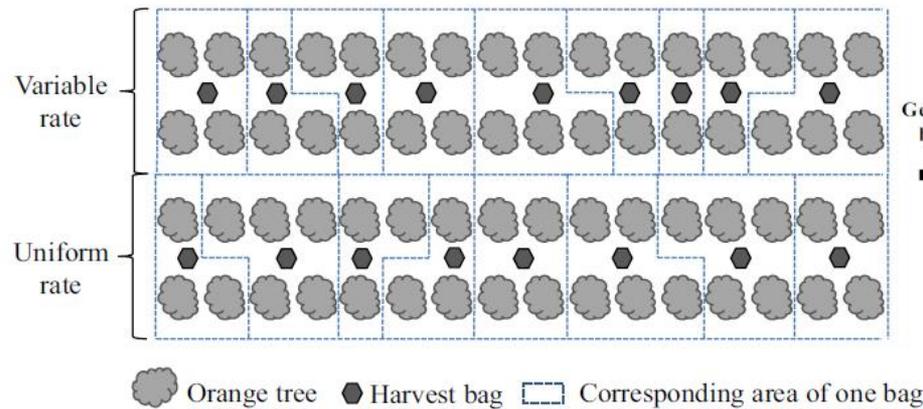
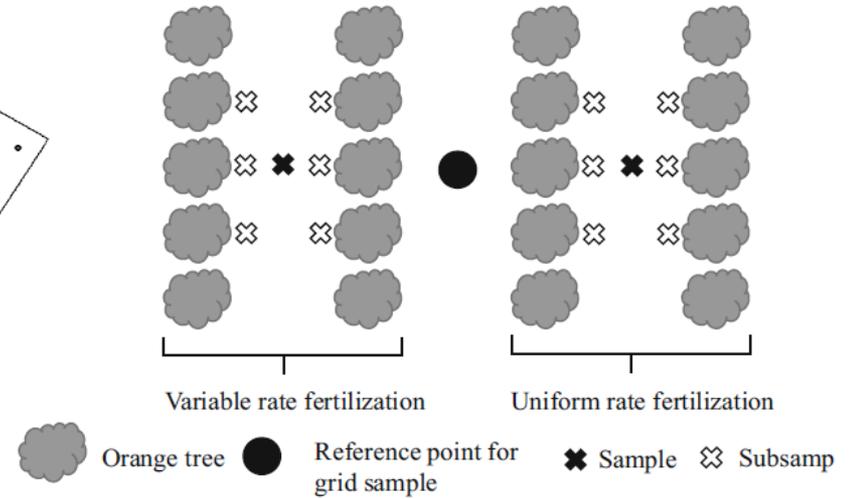
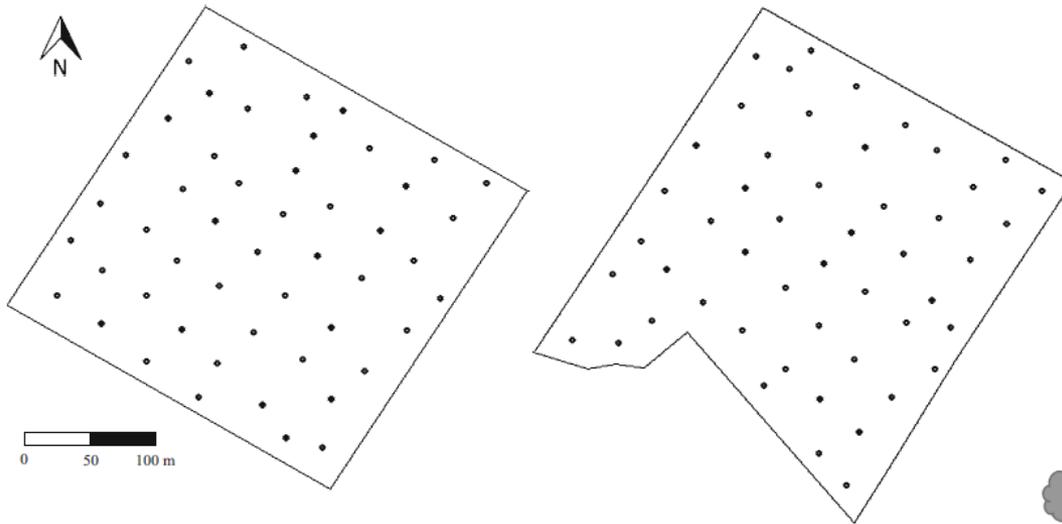
- ✓ Avaliar a aplicação em doses variadas de fertilizantes e corretivo na cultura da laranja ao longo de quatro safras e verificar seu efeito
 - no consumo dos insumos,
 - na produtividade,
 - na fertilidade do solo,
 - na nutrição das plantas e
 - na qualidade dos frutos e do suco.

Áreas experimentais

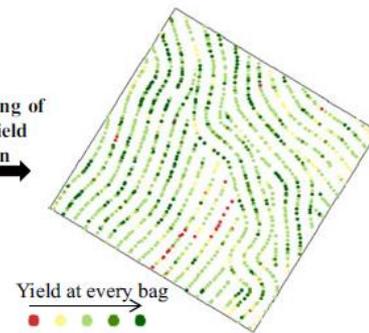
- Fazenda Quatrimas – Pratânia/Botucatu
- 2 pomares de 25,7 ha cada
- Variedade Rubi
- Plantio em 2003 e 2004
- Argiloso e arenoso



Procedimento

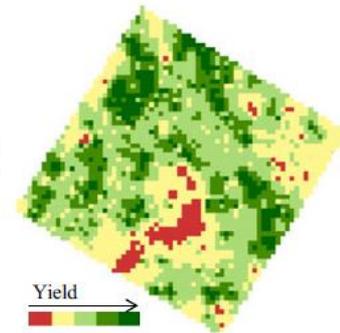


Georeferencing of bags and yield estimation



Yield points from one treatment

Interpolation



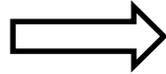
Yield map of one treatment

Tratamentos

– Implantados em 2008

– Dose variada (DV)

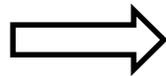
- N
- P
- K
- Calcário



- Mapas de recomendação
- Amostragem de solo em grade
- Amostragem de folhas em grade
- Mapeamento de produtividade

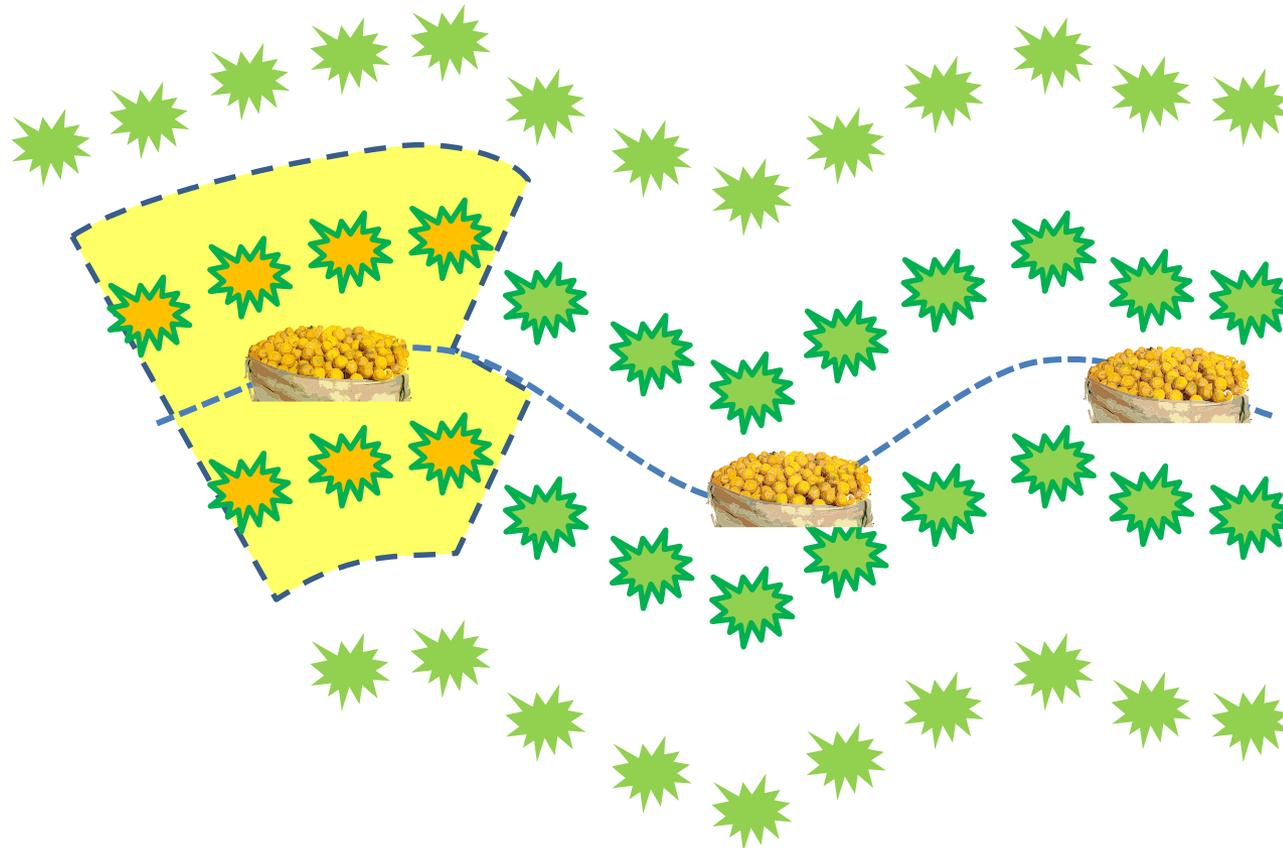
– Dose fixa (DF)

- N
- P
- K
- Calcário

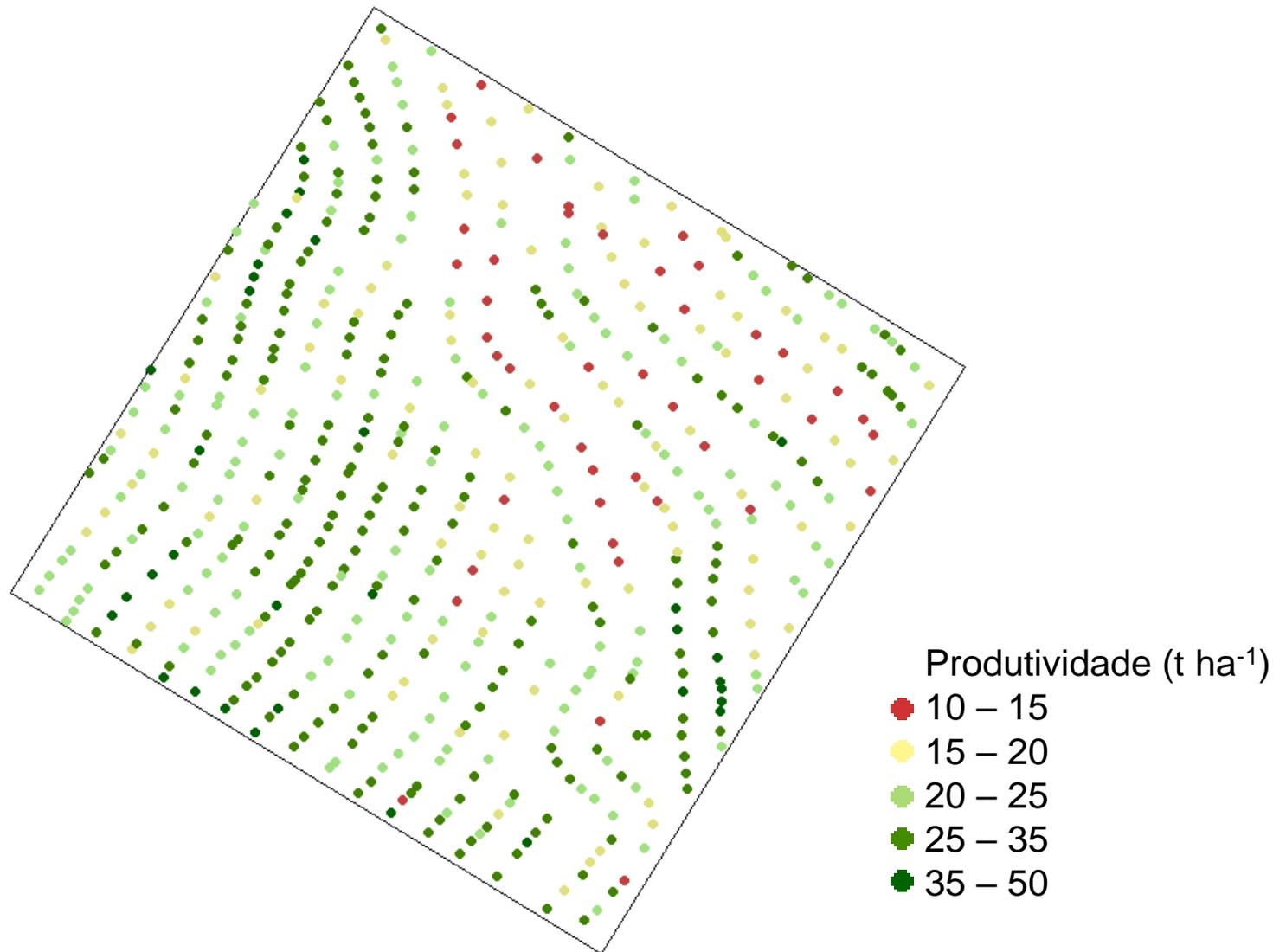


- Amostragem convencional
- Estimativa de produtividade

Colheita e mapeamento da produtividade



Colheita e mapeamento da produtividade



Adubação em taxa variável



Prescrição

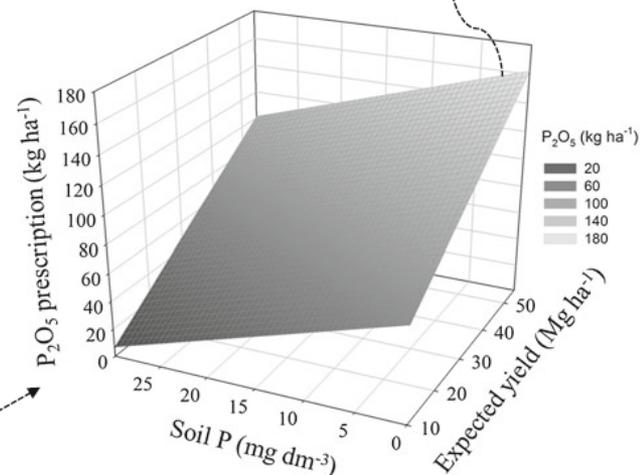
Fertilizer prescription chart based on expected yield and soil/leaf nutrient levels

Expected yield (Mg ha ⁻¹)	Leaf N (g kg ⁻¹)			Soil P (mg dm ⁻³)				Soil K (mmol _c dm ⁻³)			
	< 23	23 - 27	> 27	< 5	6 - 12	13 - 30	>30	< 0,7	0,8 - 1,5	1,6 - 3	> 3
	----- N (kg ha ⁻¹) -----			----- P ₂ O ₅ (kg ha ⁻¹) -----				----- K ₂ O (kg ha ⁻¹) -----			
< 20	120	80	70	80	60	40	0	80	60	40	0
21 - 30	140	120	90	100	80	60	0	120	100	60	0
31 - 40	200	160	130	120	100	80	0	140	120	80	40
41 - 50	220	200	160	140	120	100	0	180	140	100	50
>50	240	220	180	160	140	120	0	200	160	120	60

Adapted from Raij et al. (1997)

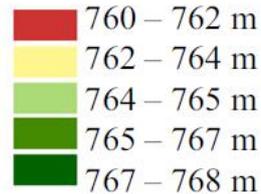
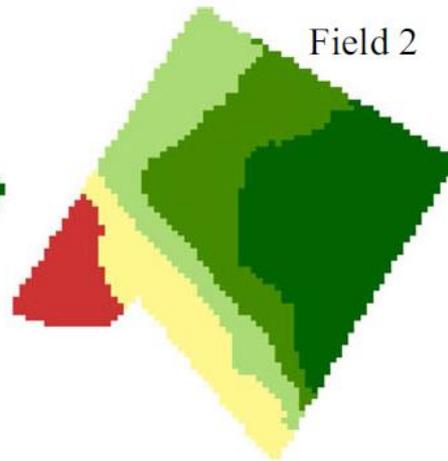
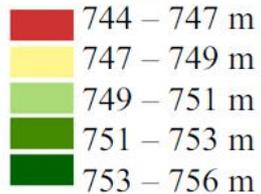
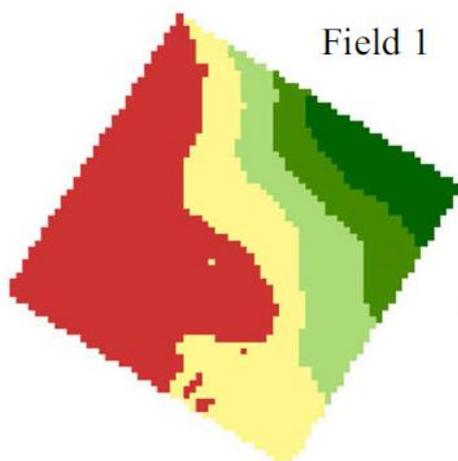
Bivariate linear regression

$$P_rate = 2.0994 \times Yield_exp - 2.0375 \times P_{soil} + 46.8327$$

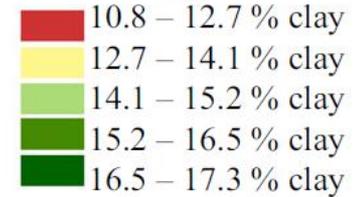
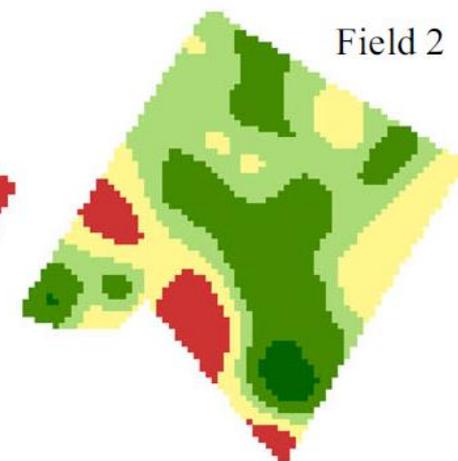
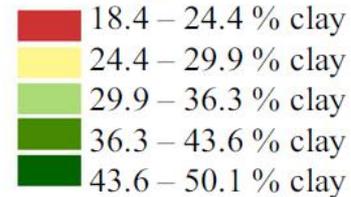
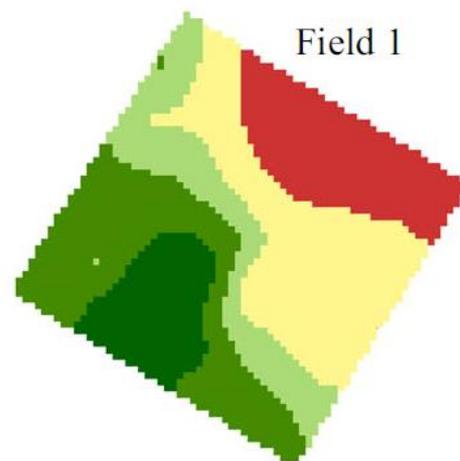


Dados complementares

Altitude



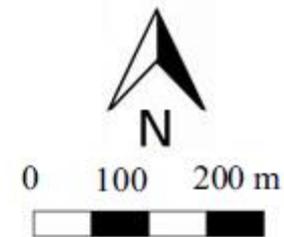
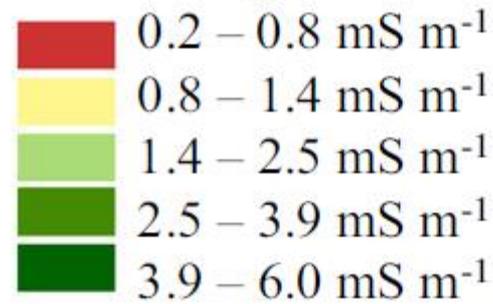
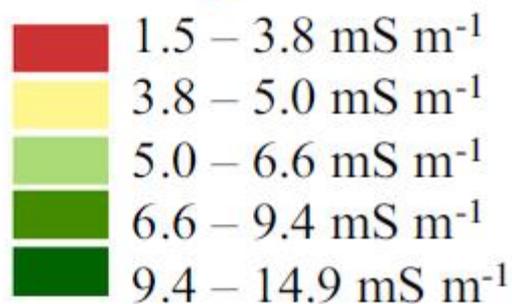
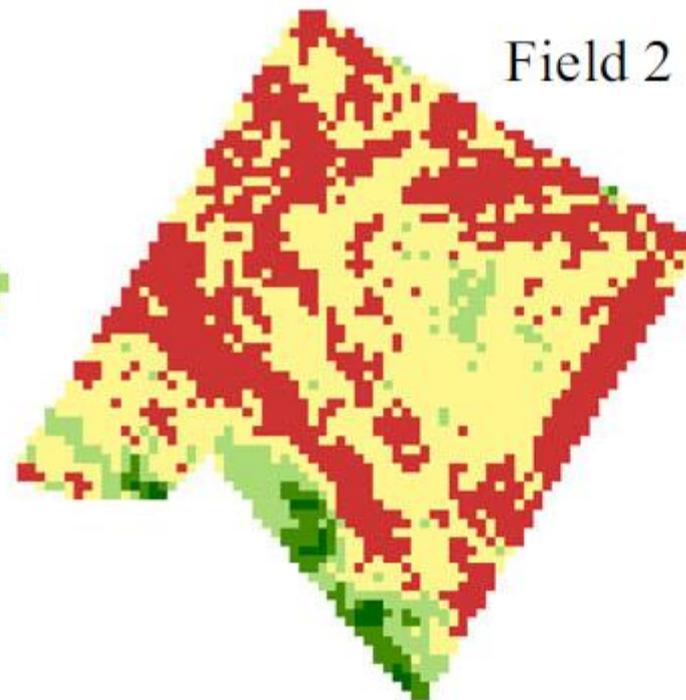
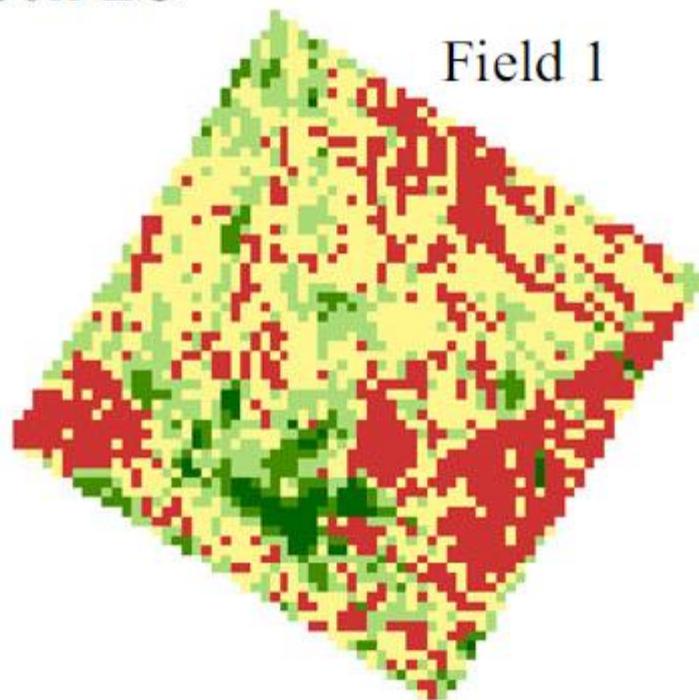
Clay content



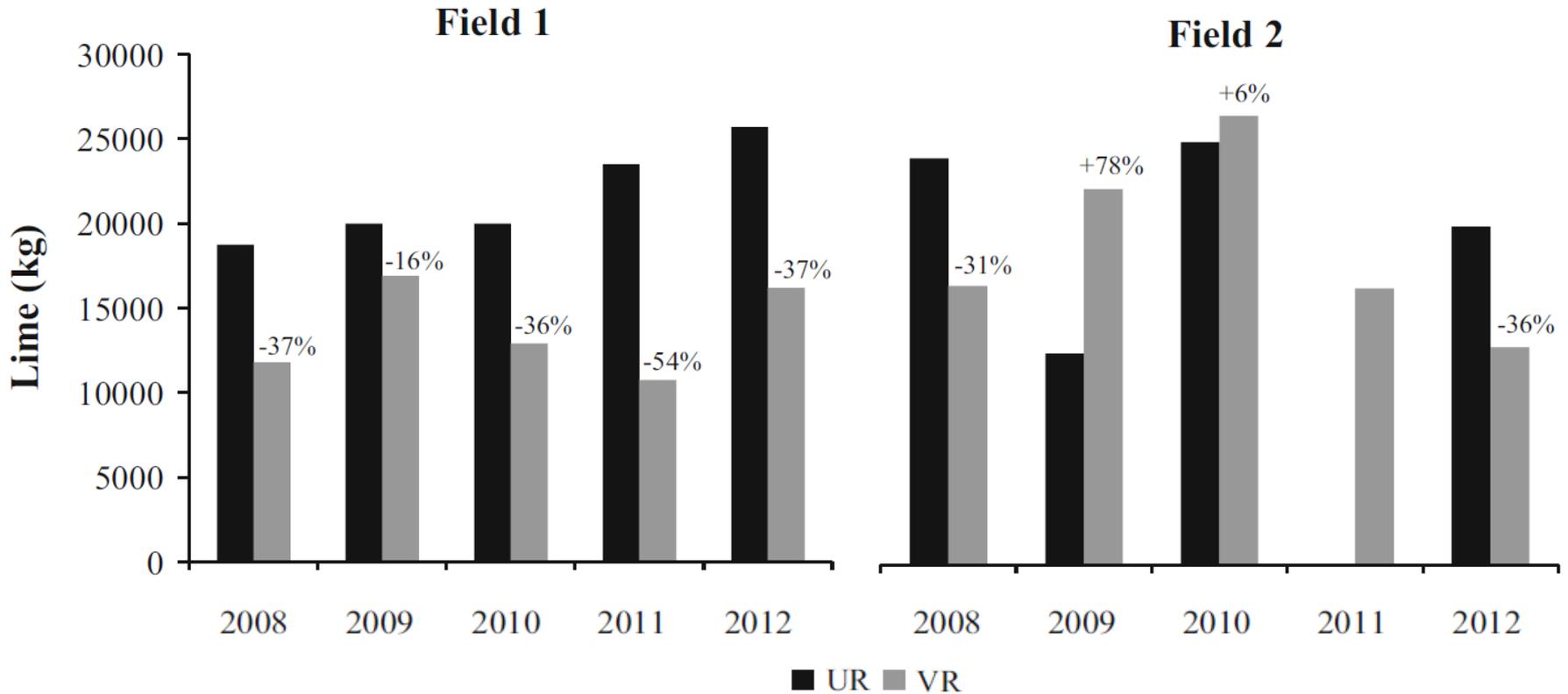
Soil EC

Field 1

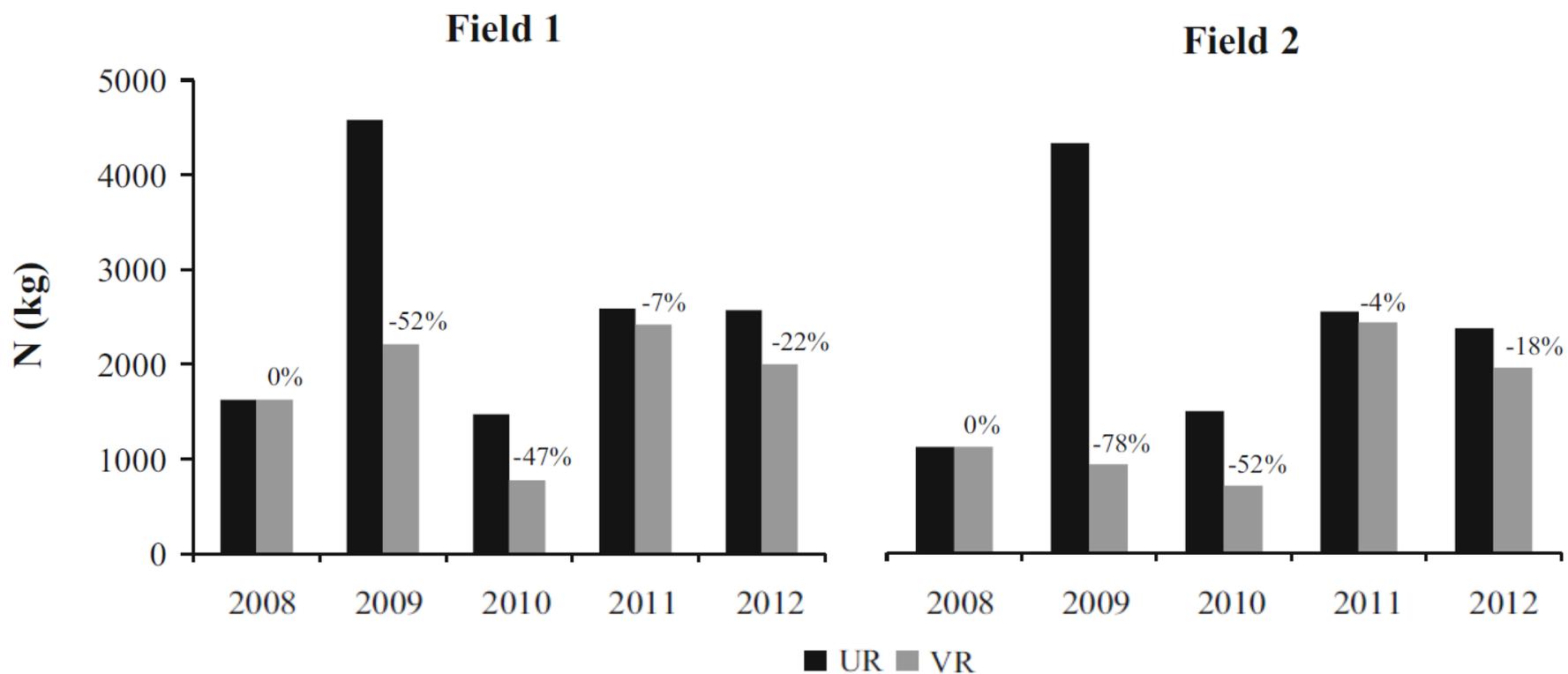
Field 2



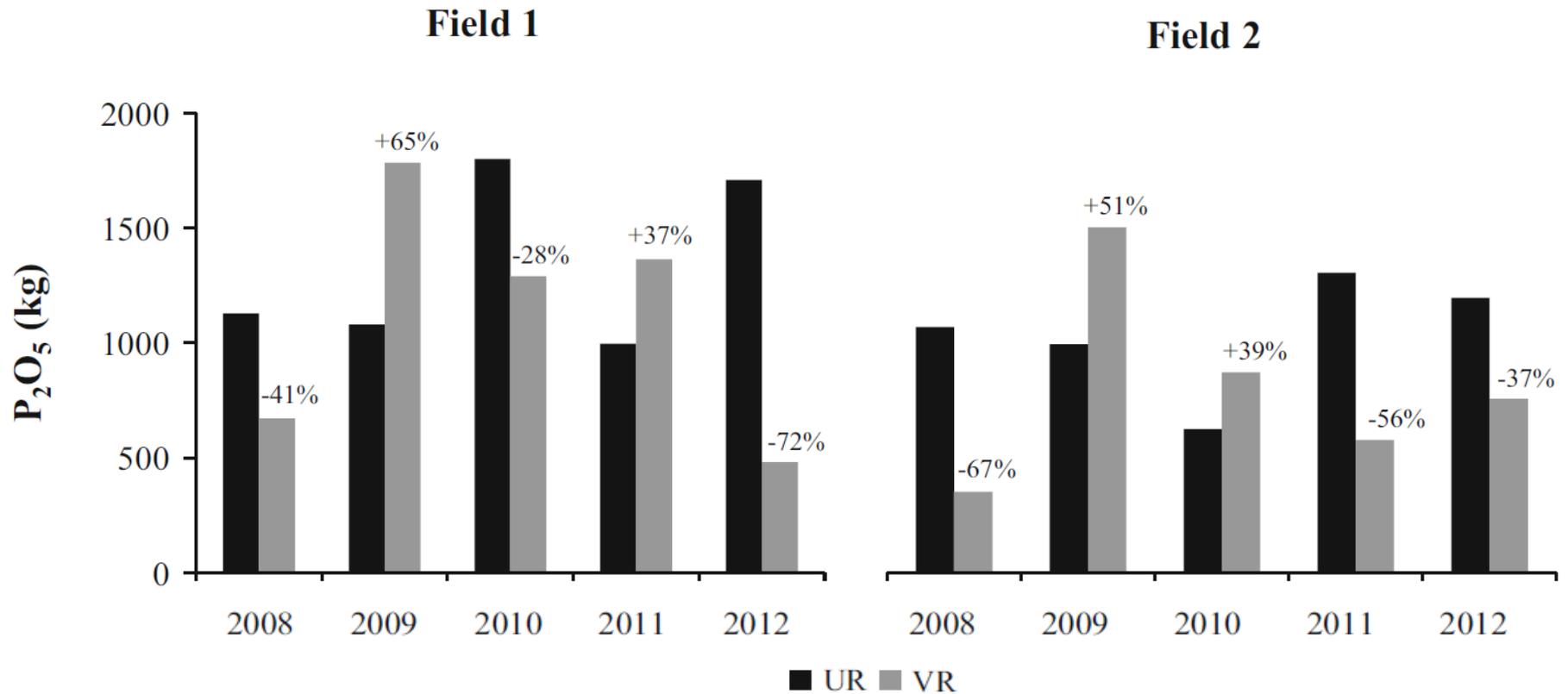
Quantidade de calcário



Quantidade de N



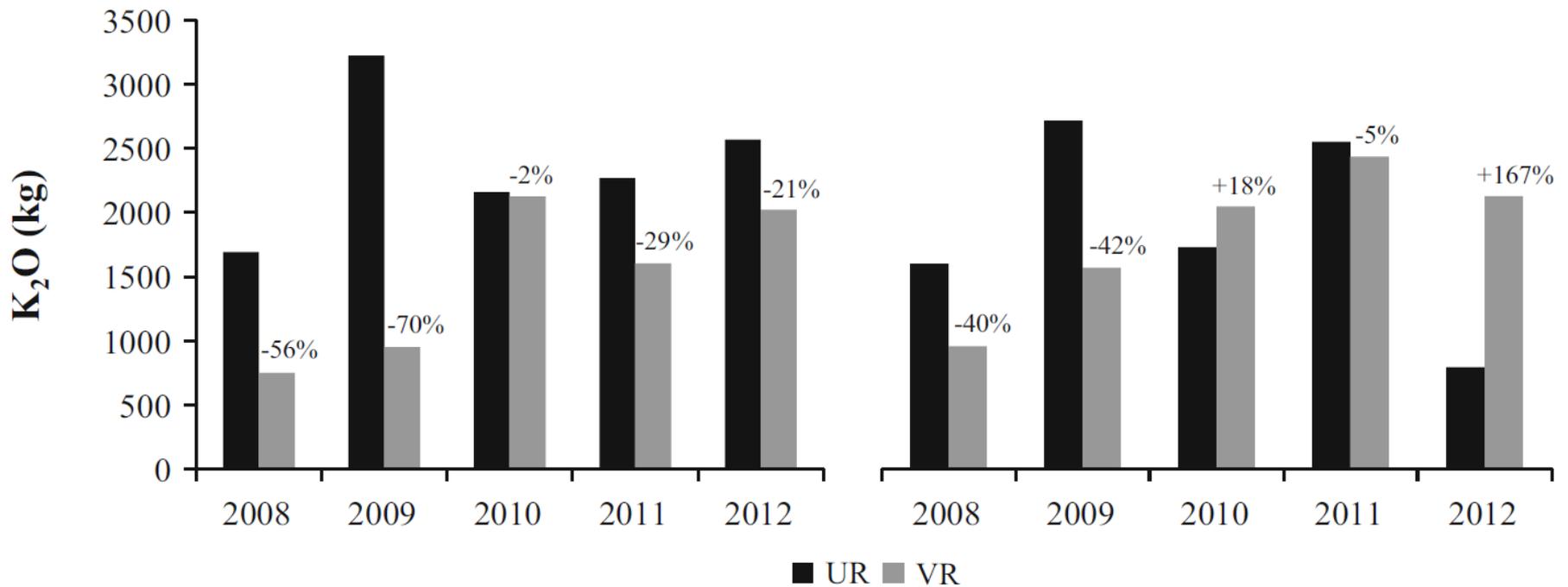
Quantidade de P



Quantidade de K

Field 1

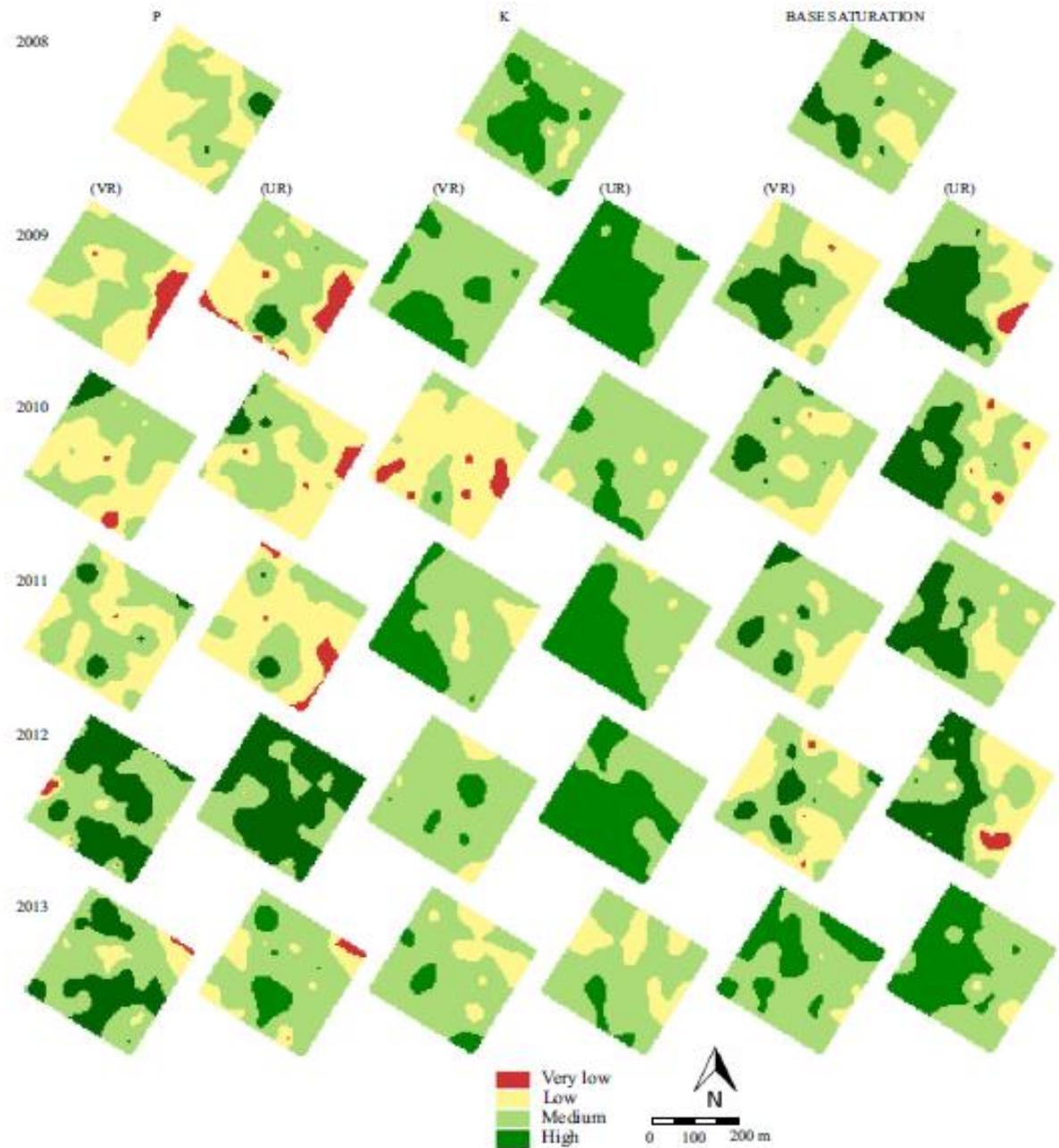
Field 2



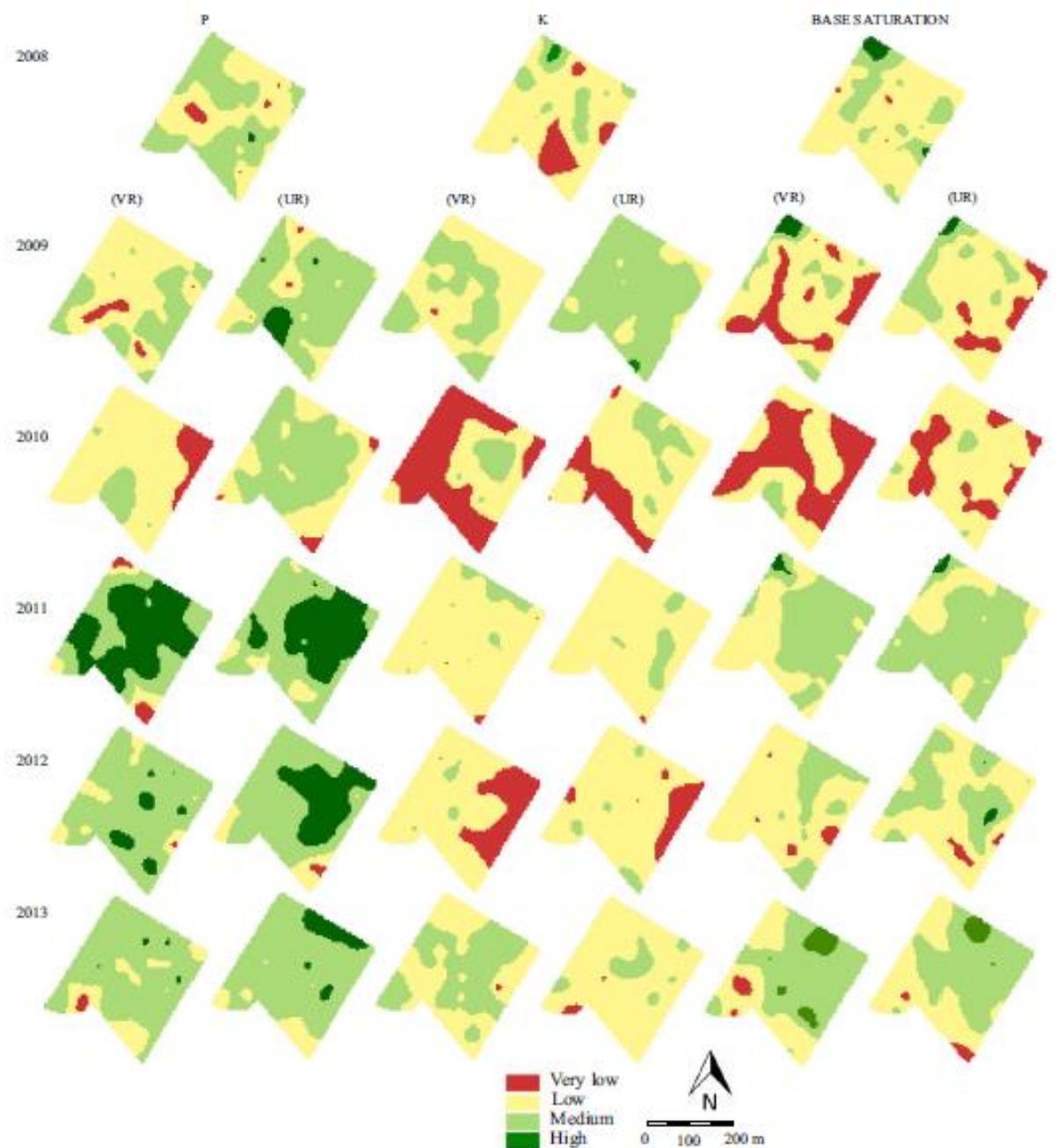
Consumo total de insumos nos tratamentos VR e UR ao final dos cinco anos

Field	Lime (%)	N (%)	P ₂ O ₅ (%)	K ₂ O (%)
1	-36.5	-29.6	-16.8	-37.4
2	15.8	-39.6	-21.8	-2.8

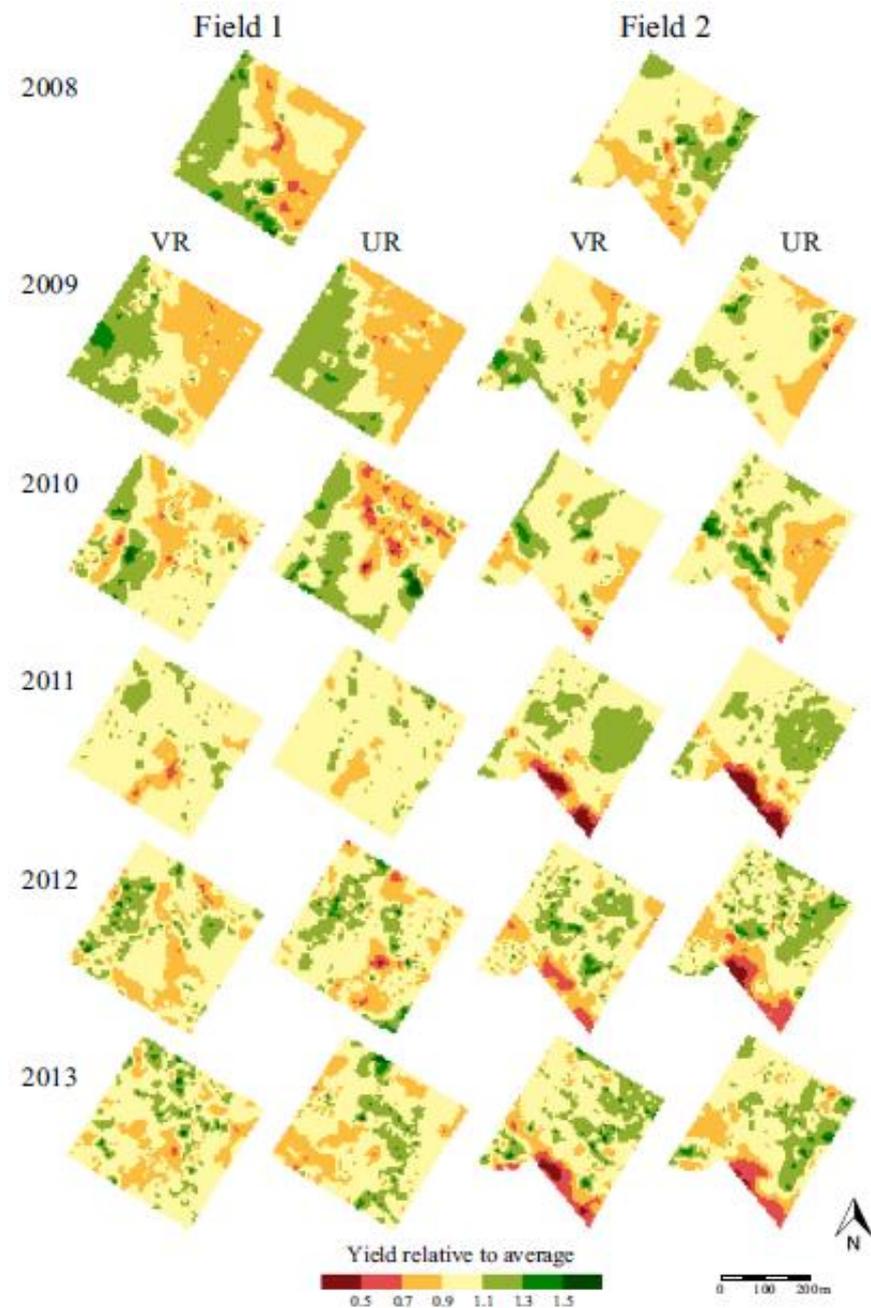
Valores de P, K e
V% para os
tratamentos VR e
UR ao longo dos
cinco anos
Talhão 1



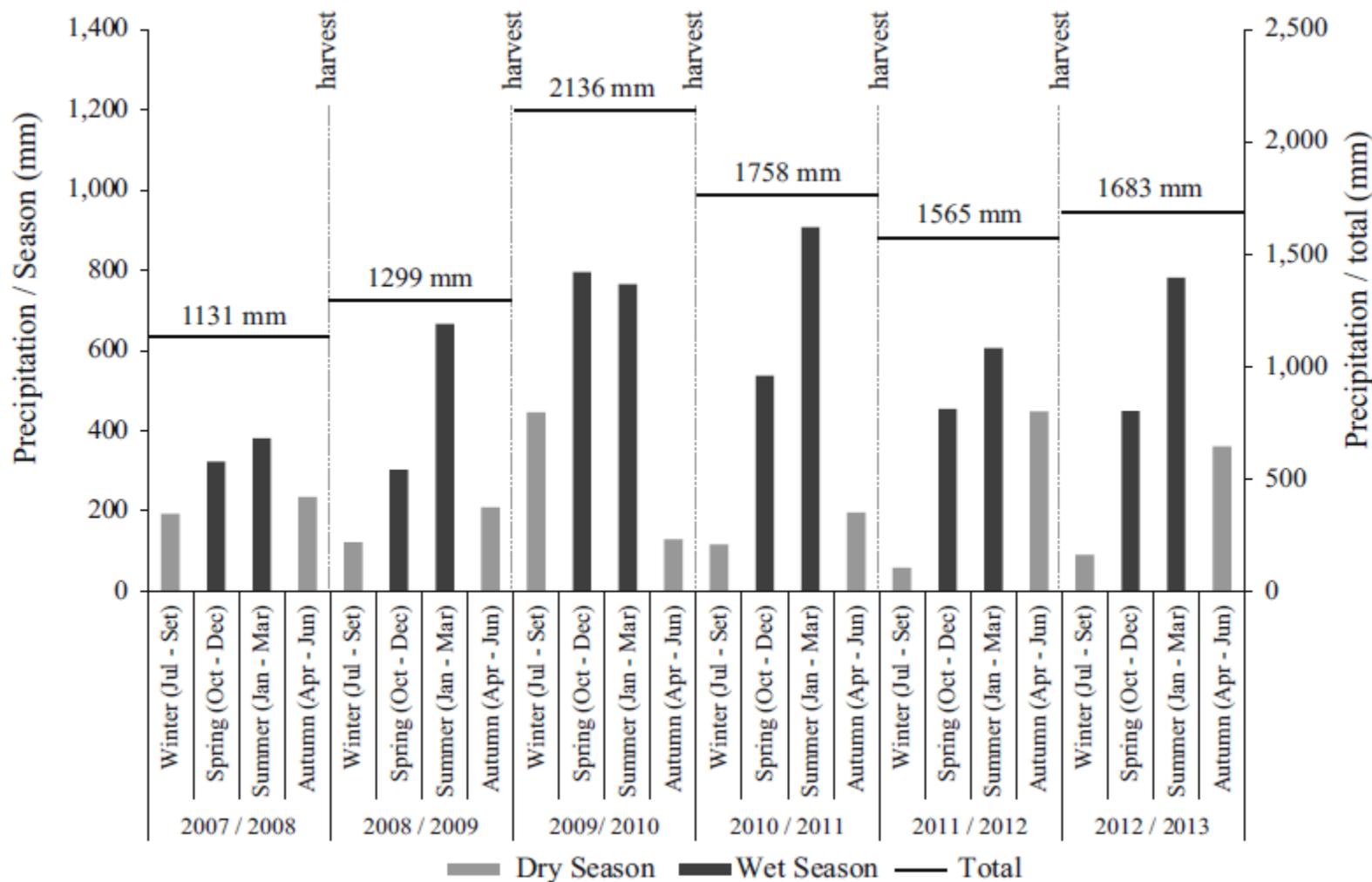
Valores de P, K e
V% para os
tratamentos VR e
UR ao longo dos
cinco anos
Talhão 2



Produtividades para os tratamentos VR e UR ao longo dos seis anos



Precipitações ao longo dos seis anos

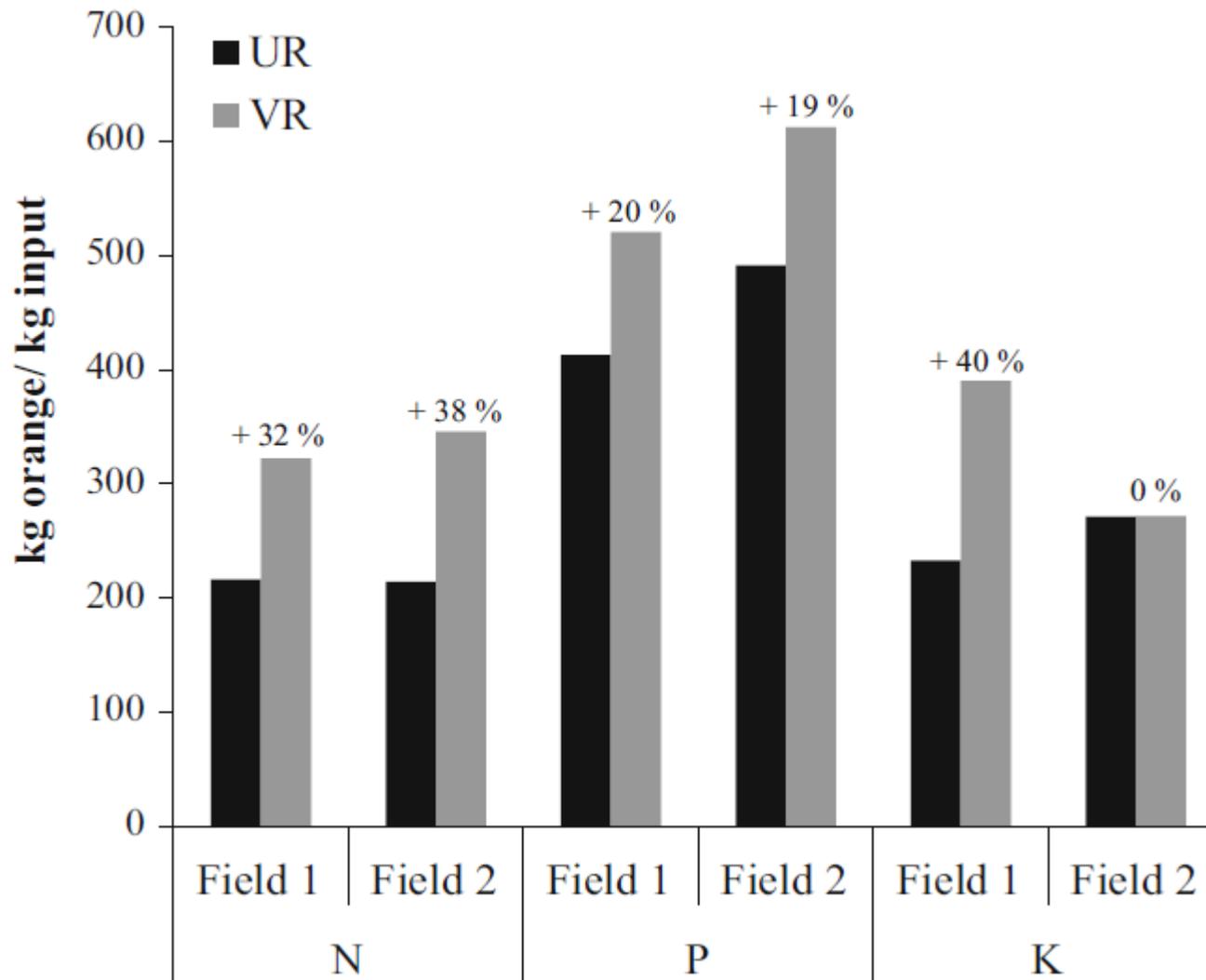


Estadística descriptiva e produção total

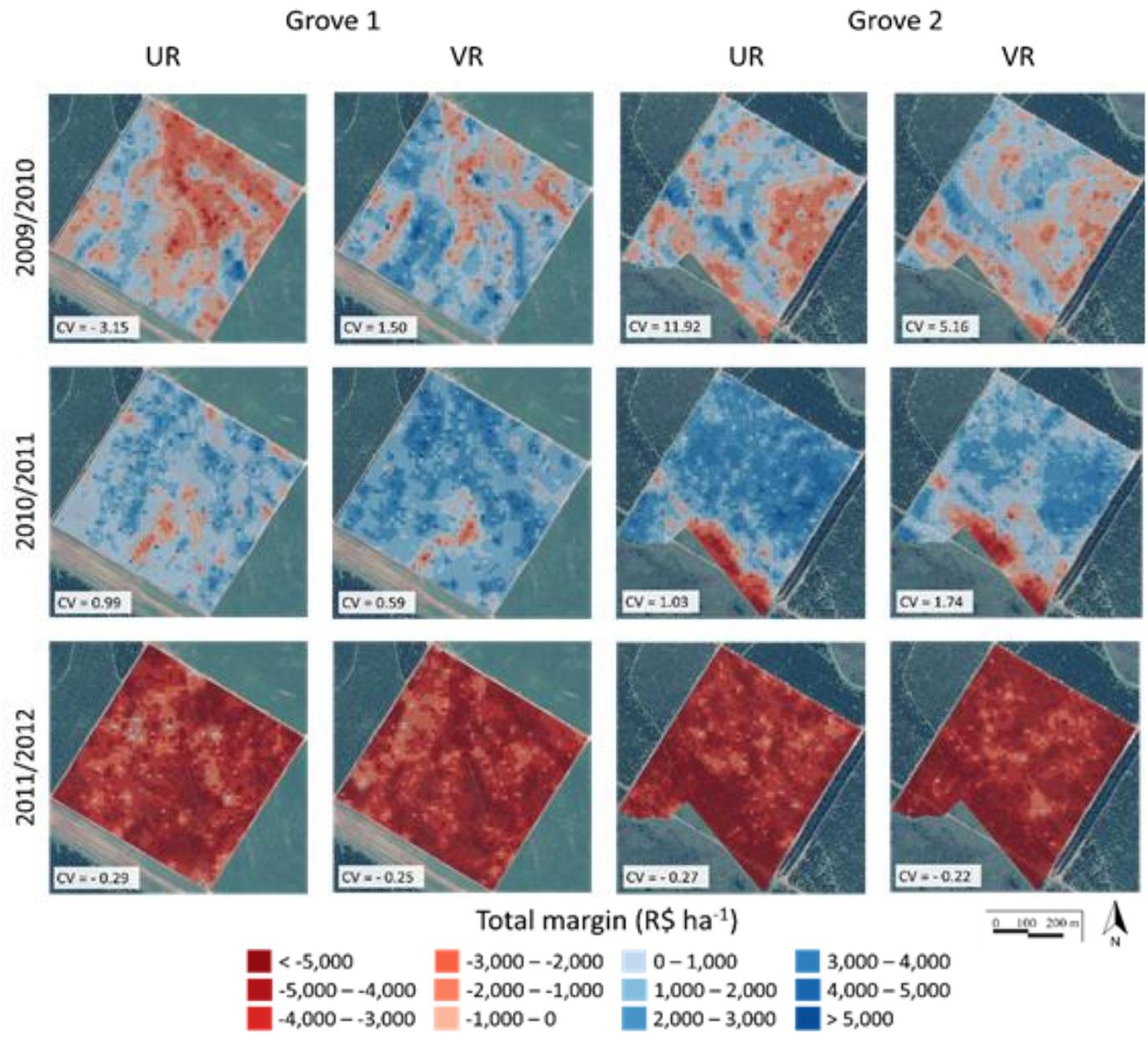
Field	Year	Treatment	Main harvest				Second harvest (Mg)	Total (Mg)	
			Average (Mg ha ⁻¹)	CV (%)	Min (Mg ha ⁻¹)	Max (Mg ha ⁻¹)			
1	2008	–	16.62	26.49	3.45	43.08	–	427.01	
	2009	Variable	36.52*	23.26	3.02	81.44	28.97	498.20	
		Uniform	34.22*	22.20	11.13	79.27	33.54	473.25	
	2010	Variable	23.45*	24.98	9.03	45.15	28.64	329.94	
		Uniform	20.72*	26.20	5.11	46.29	26.74	292.94	
	2011	Variable	49.46*	16.42	20.67	93.02	–	635.61	
		Uniform	45.73*	16.06	21.39	85.55	–	587.66	
	2012	Variable	64.53	26.22	32.47	120.58	–	829.22	
		Uniform	64.70	29.01	21.31	145.48	–	831.45	
	2013	Variable	50.71*	24.95	25.00	113.15	–	615.51	
		Uniform	48.11*	23.51	19.24	114.11	–	587.60	
	2	2008	–	12.45	20.93	3.24	25.95	–	320.04
		2009	Variable	20.97*	19.14	9.24	35.26	84.21	353.63
			Uniform	21.63*	19.24	8.88	35.51	94.33	372.31
2010		Variable	22.80	19.84	7.29	39.56	6.20	299.23	
		Uniform	23.54	23.72	8.51	51.08	4.98	307.44	
2011		Variable	45.27*	18.84	8.27	74.39	–	581.67	
		Uniform	49.04*	19.21	11.98	85.37	–	630.17	
2012		Variable	58.74	25.05	22.06	110.61	–	754.85	
		Uniform	58.16	30.37	17.24	129.23	–	747.40	
2013		Variable	40.80	24.57	13.48	84.11	–	491.48	
		Uniform	40.51	24.05	10.21	100.02	–	490.44	

* Different average yields between treatments (5 % significance)

Eficiência dos insumos



Mapas de rentabilidade para taxas variável (VR) e uniforme (UR)



Romanelli (2018) de Colaço et al. (em publicação)

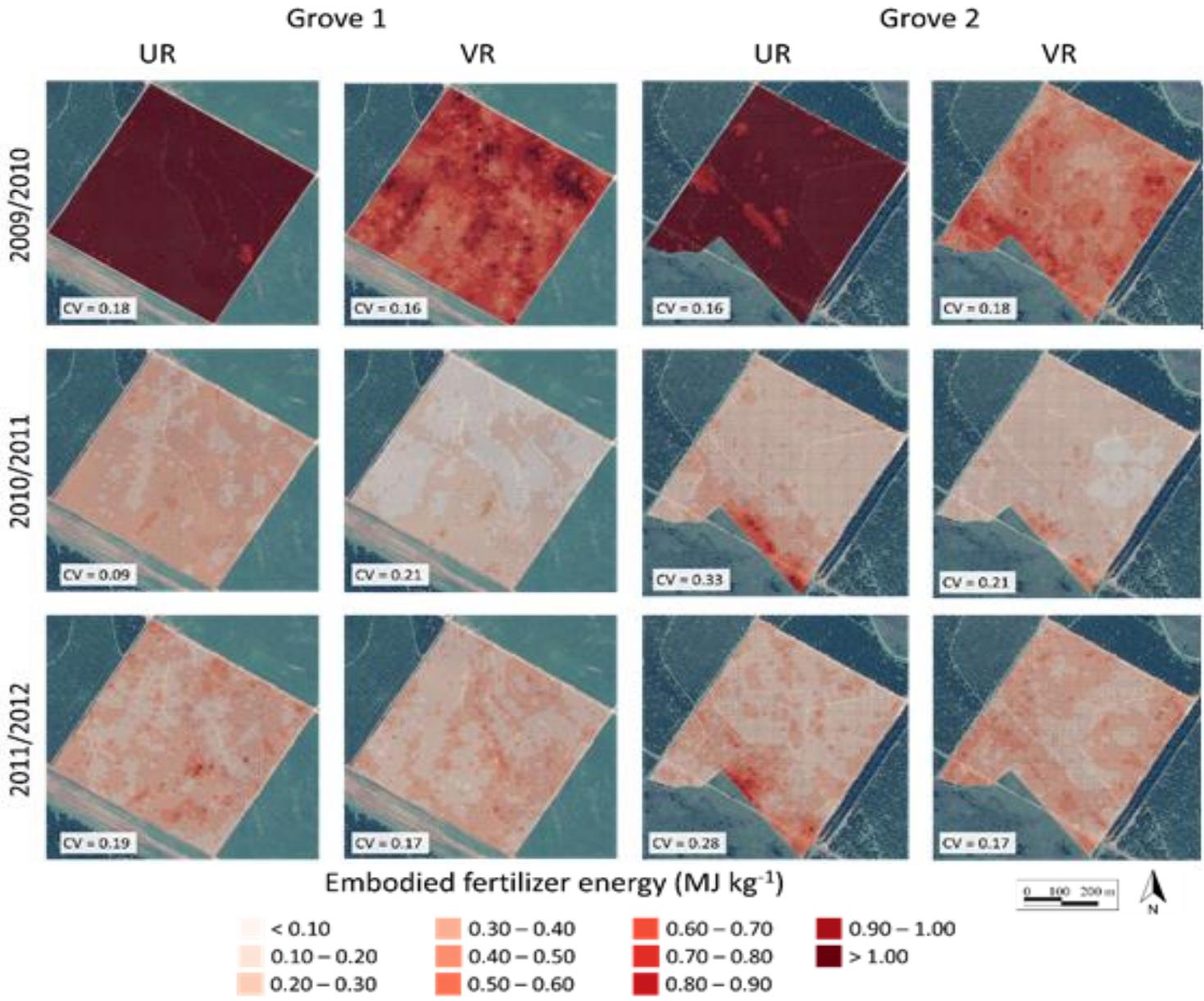
Rentabilidade

Custo adicional da informação e operação no VR - 162 US\$/ha ano

- Talhão 1: +24,8% em receita (373,6 US\$/ha ano)
- Talhão 2: -8,6% em receita (-126,0 US\$/ha ano)
Quando comparados ao convencional.
- TV reduziu fertilizante aplicado:
 - Aumentou produtividade no Talhão 1
 - Reduziu a produtividade no Talhão 2

Solo arenoso e baixa fertilidade do solo (talhão 2) são hipóteses para esse efeito.

Mapas de eficiência energética para taxas variável (VR) e uniforme (UR)



Romanelli (2018) de Colaço et al. (em publicação)

Eficiência energética

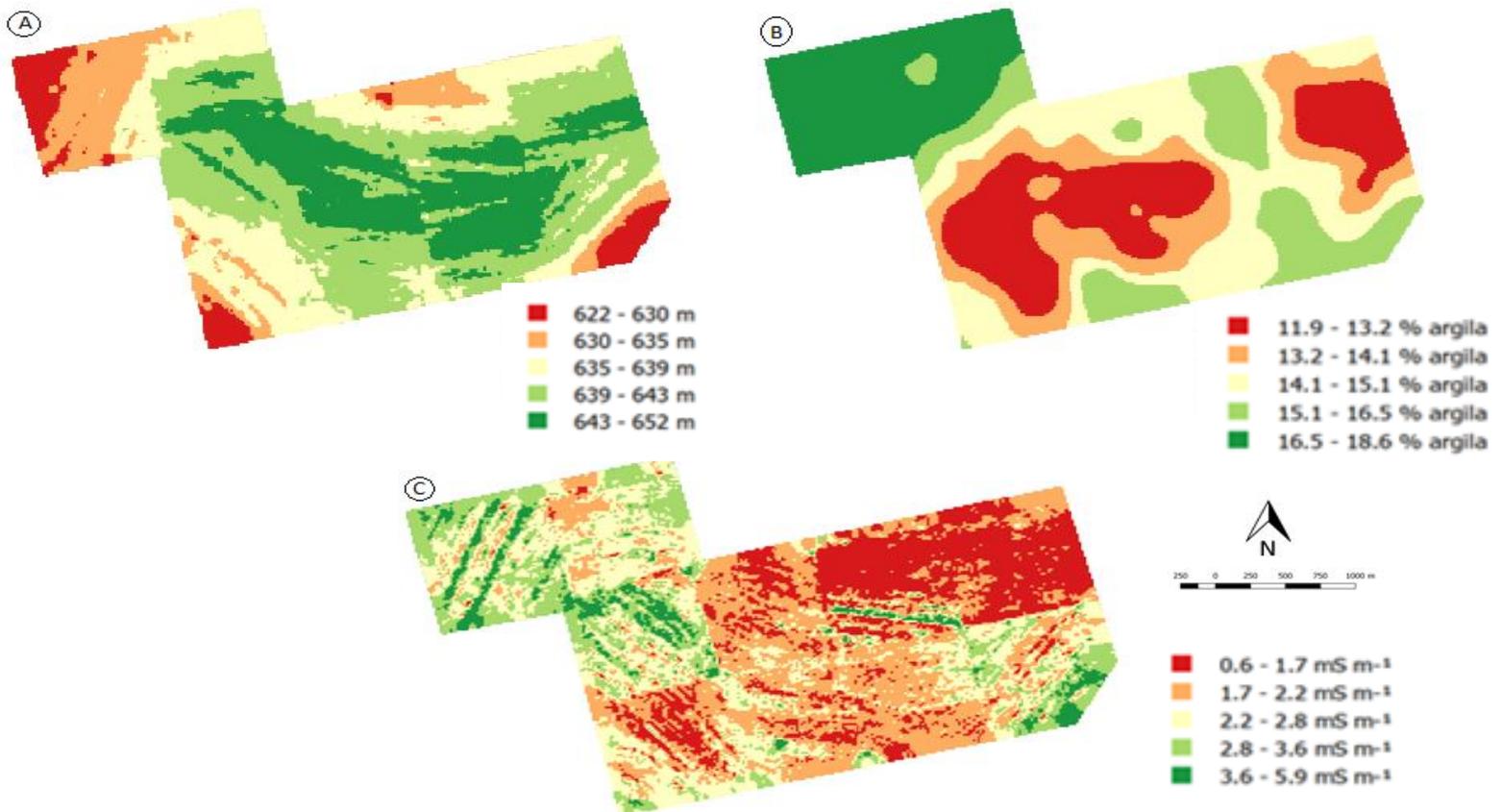
- Talhão 1: -34% em demanda (~ 0,20 MJ/kg)
- Talhão 2: -29% em demanda (~0,16 MJ/kg)
Quando comparados ao convencional.

- TV reduziu fertilizante aplicado:
 - Aumentou produtividade no Talhão 1
 - Reduziu a produtividade no Talhão 2



L G Mendes (2019)

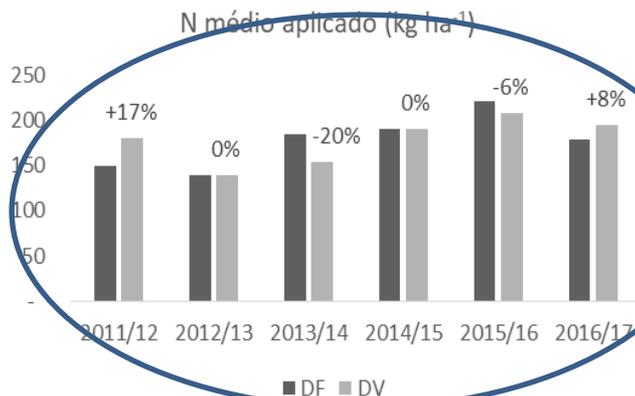
Mapa de altimetria (A), mapa de textura do solo (B) e condutividade elétrica aparente do solo na camada 0 - 0,3m (C)



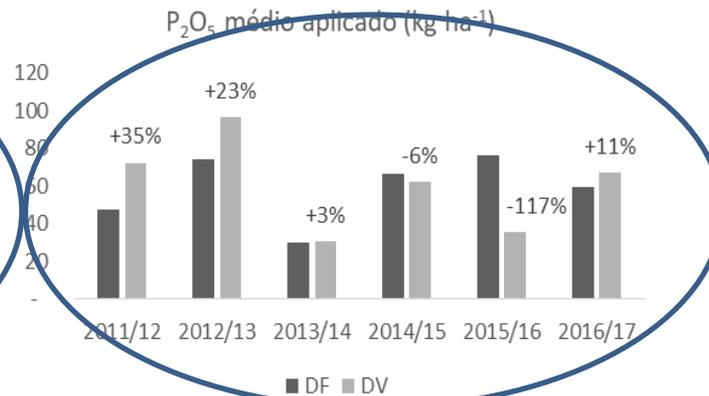
L G Mendes (2019)

Insumos aplicados

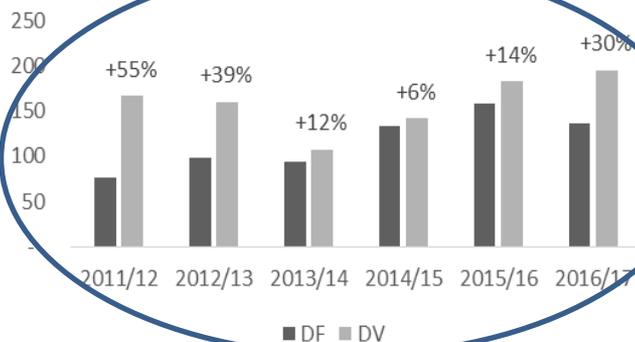
Nitrogenados: +0,4%



Fosfatados: +2,9%

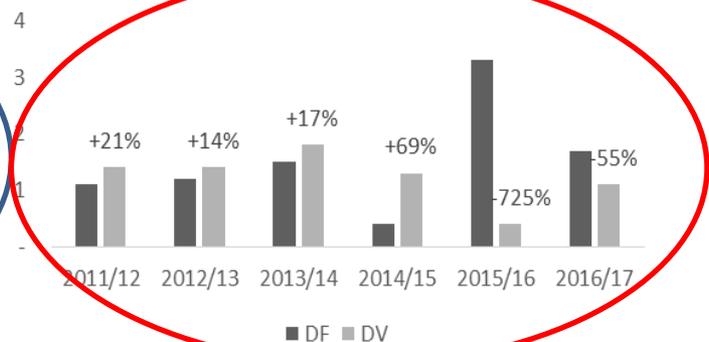


K₂O médio aplicado (kg ha⁻¹)



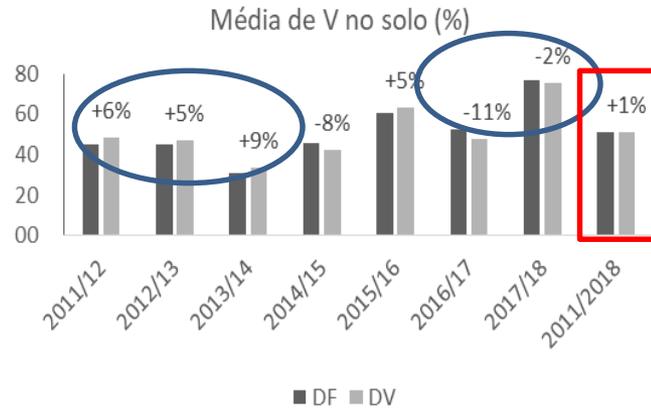
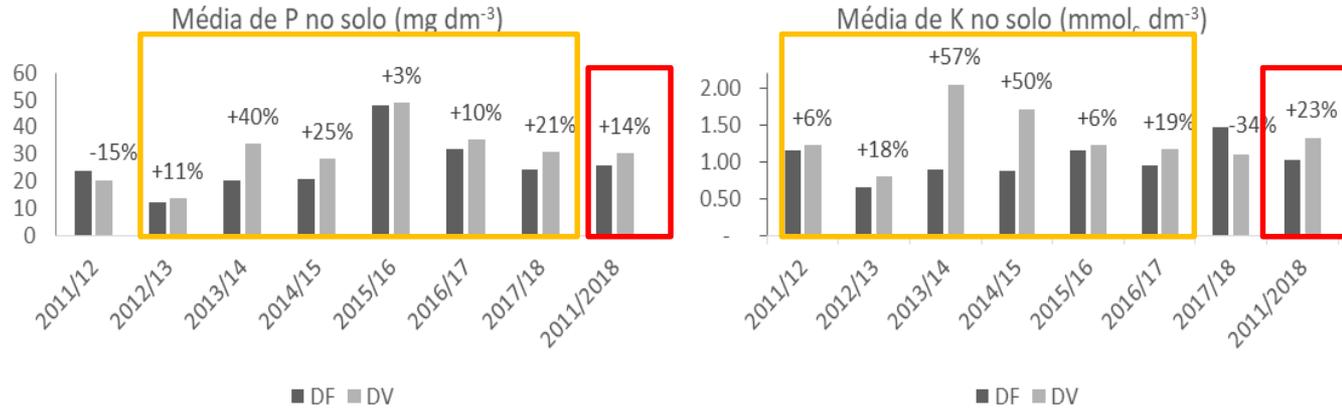
Potássicos: +27,2%

Calcário médio aplicado (t ha⁻¹)



Calcário: -24,3%

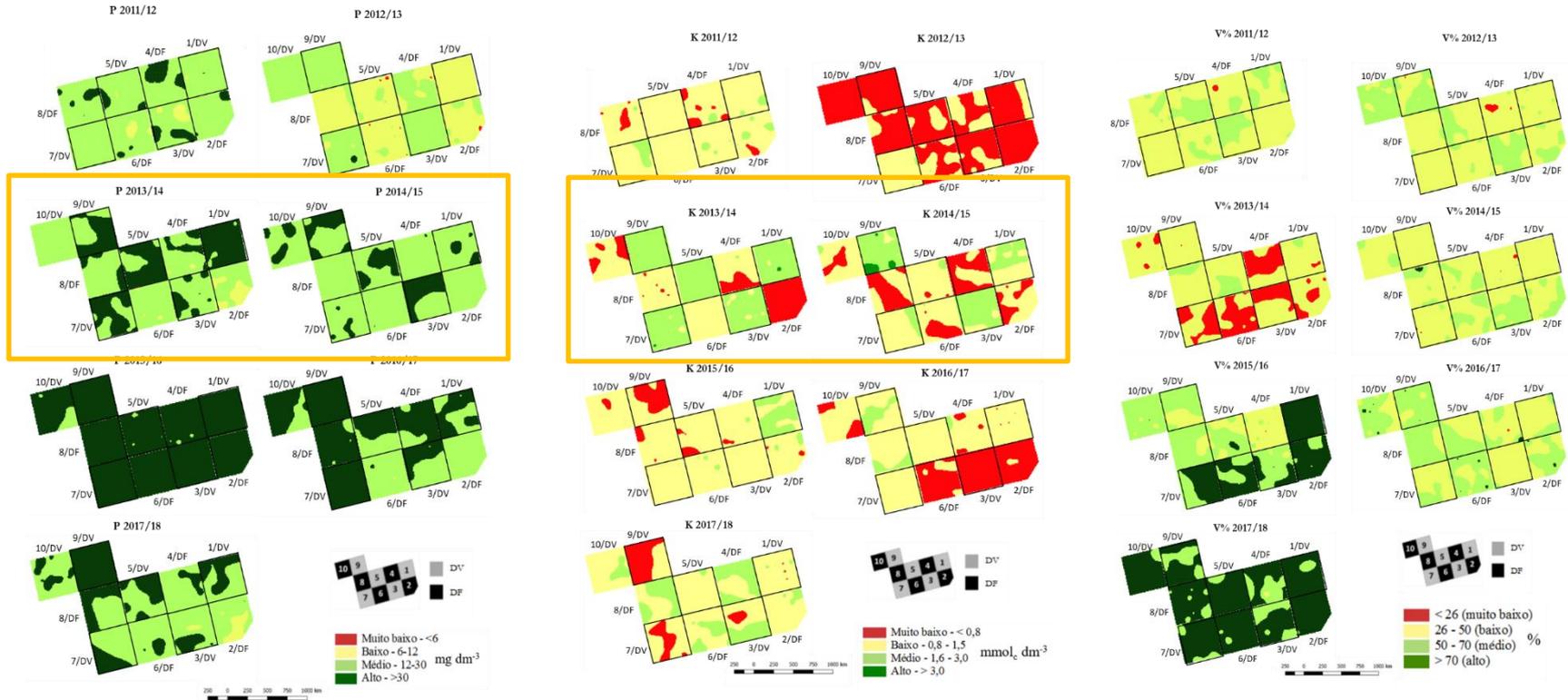
Teores no solo



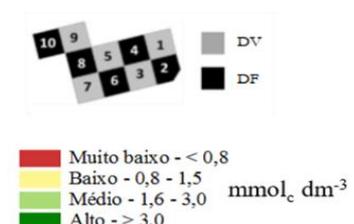
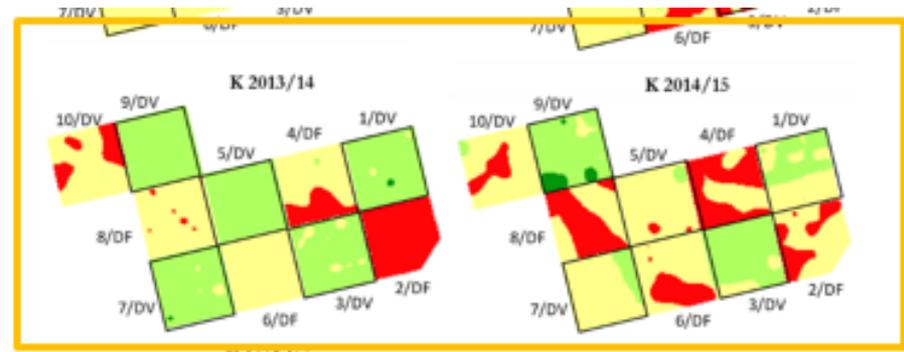
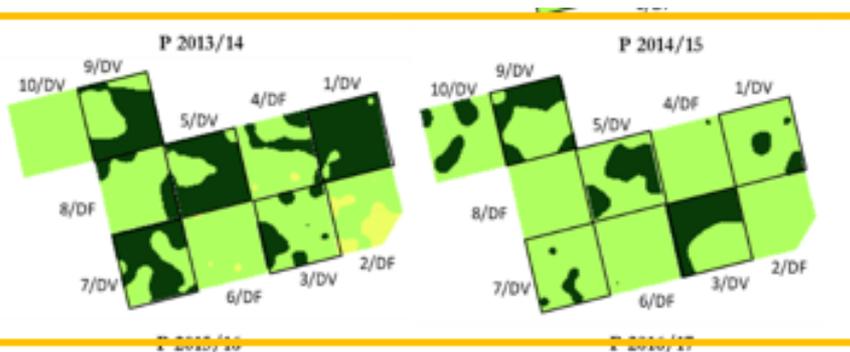
Teores no solo

- P e K no ano 2013/14 e 2014/15 diferenças significativas
- Decisão gerencial 2012 (reduzir a aplicação DF)
- Médias maiores no solo no DV
- Não foram encontrados padrões de fertilidade ao longo dos anos

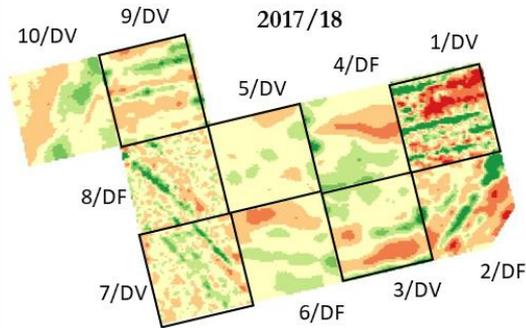
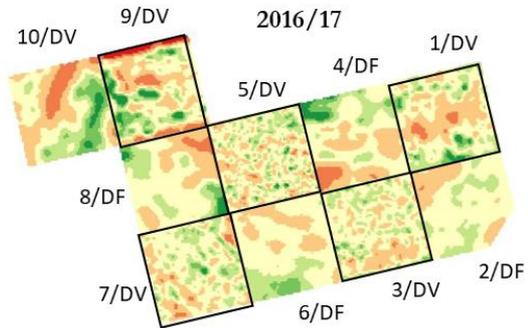
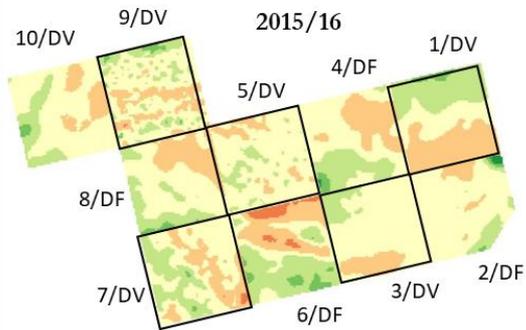
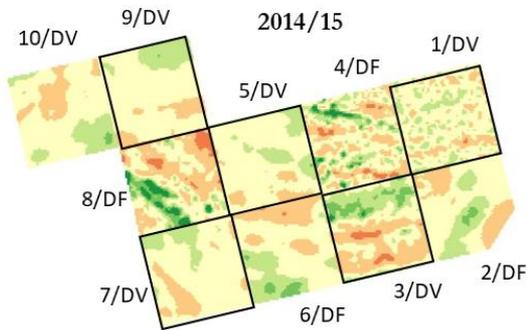
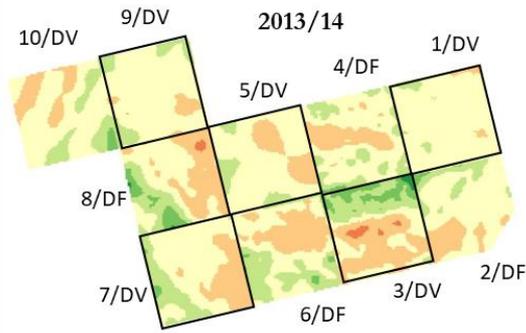
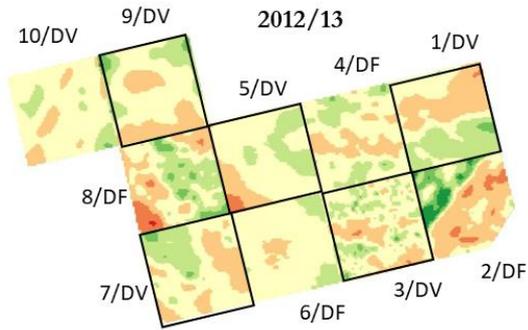
Teores no solo



Teores no solo



Produtividade

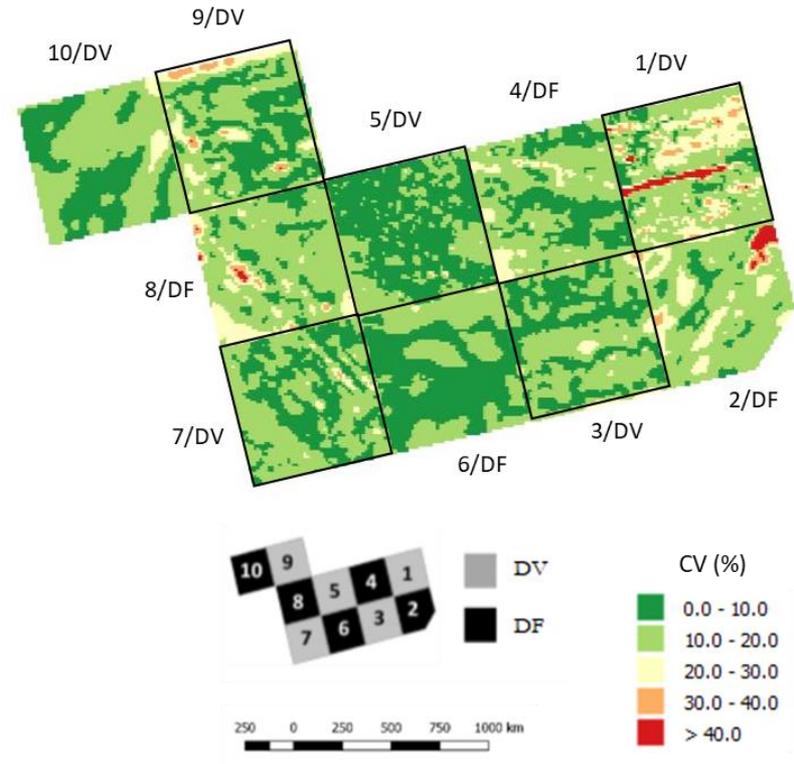
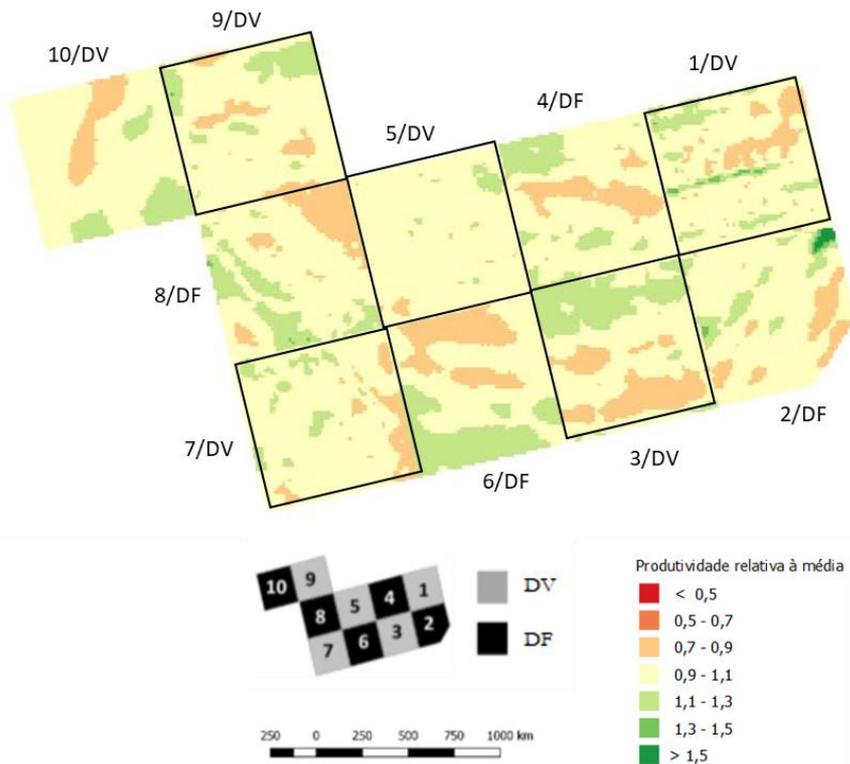


Produtividade relativa à média

- < 0,5
- 0,5 - 0,7
- 0,7 - 0,9
- 0,9 - 1,1
- 1,1 - 1,3
- 1,3 - 1,5
- > 1,5

L G Mendes (2019)

Produtividade

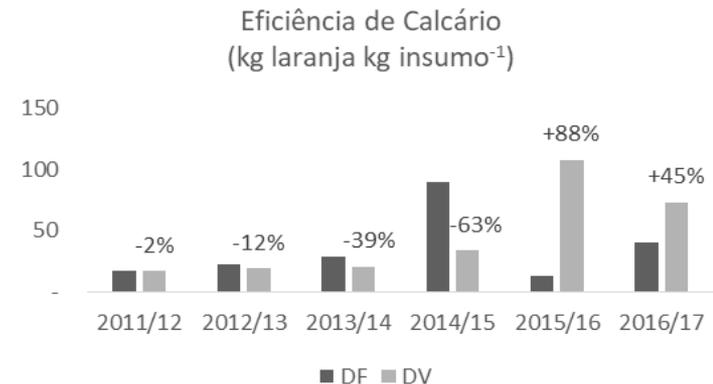
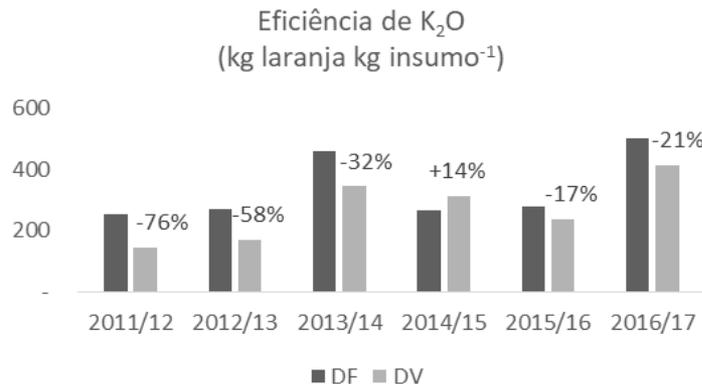
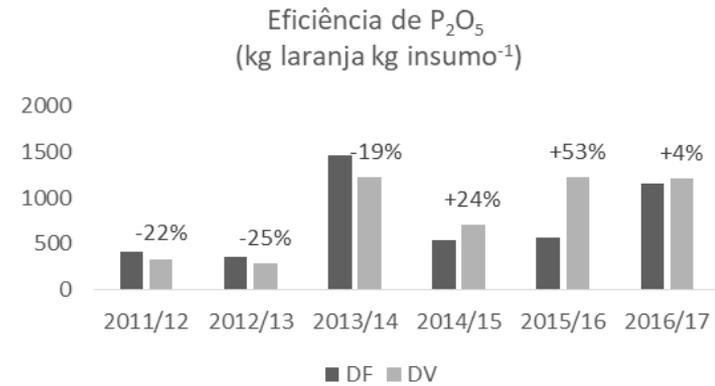
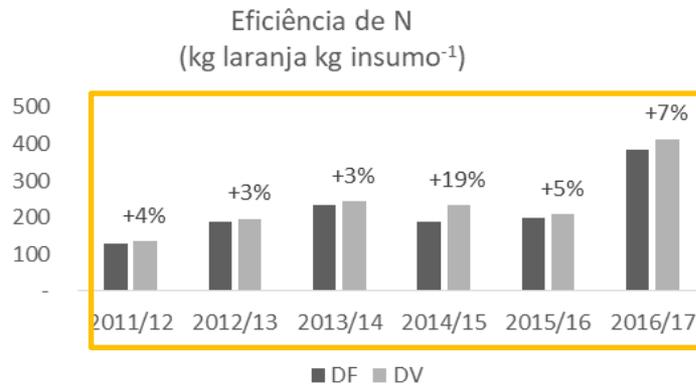


Produtividade

- Produtividades cresceram todos os anos
- Pomares em fase de crescimento (2011: 3 anos)
- DV apresentou menores CV
- 6 anos experimento
 - 4 anos DV (12/13 +26%; 13/14 +7%; 15/16 +16%; 17/18 +21%)
 - 2 anos DF (14/15 -15%; 16/17; -11%)
 - Acumulado DV +6,4%, cerca de 2,74 t ha⁻¹ ano

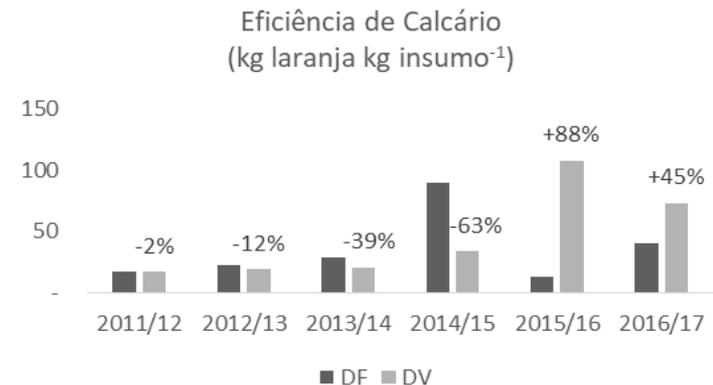
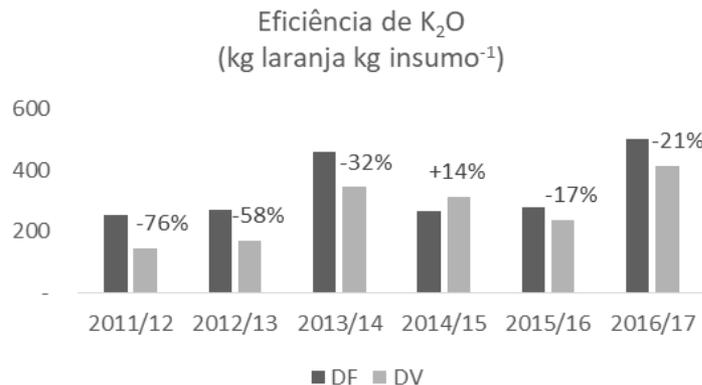
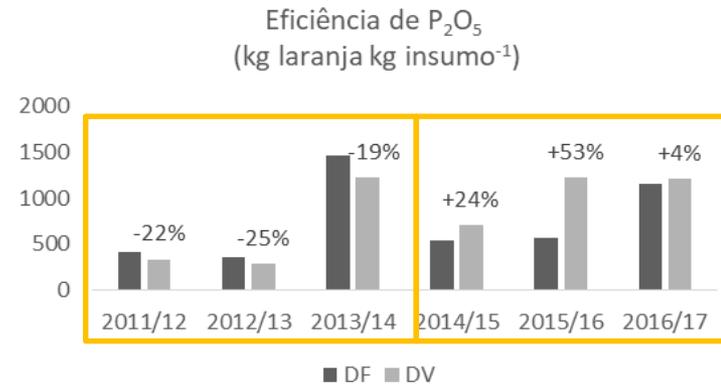
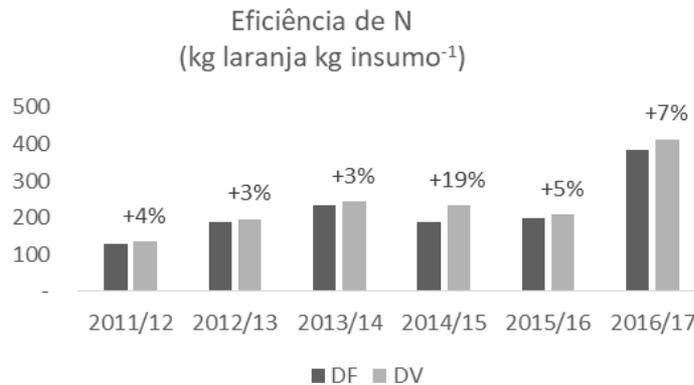
Eficiência dos insumos

N: todos os anos maiores no DV

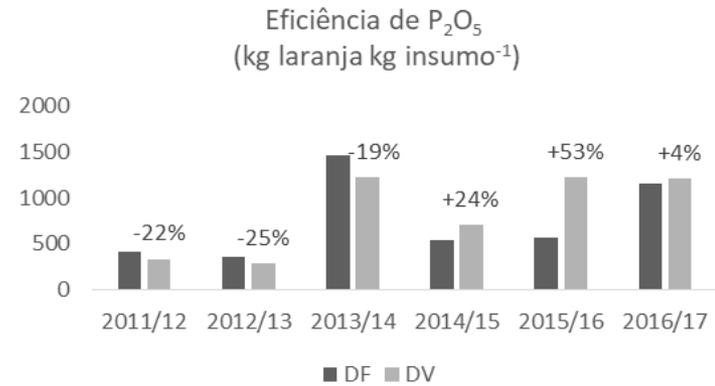
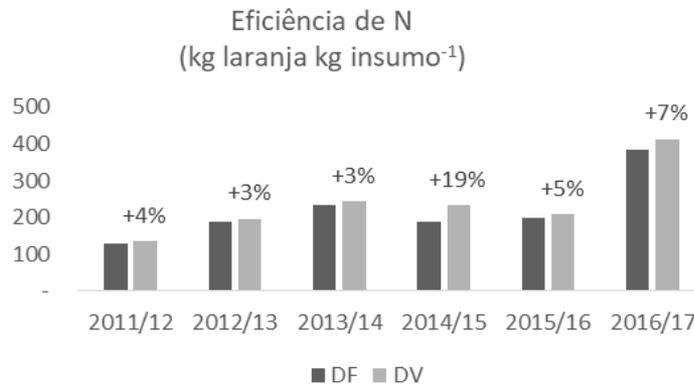


Eficiência dos insumos

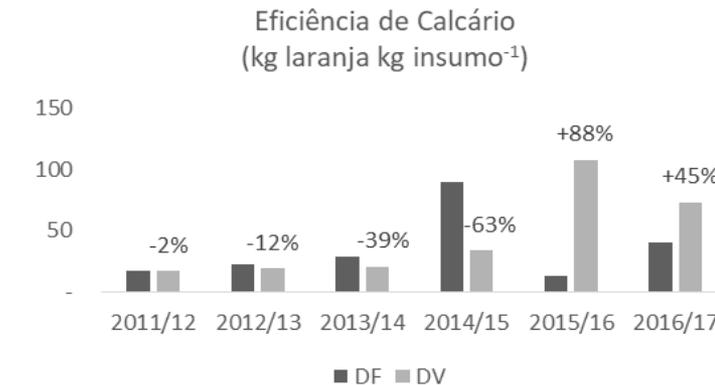
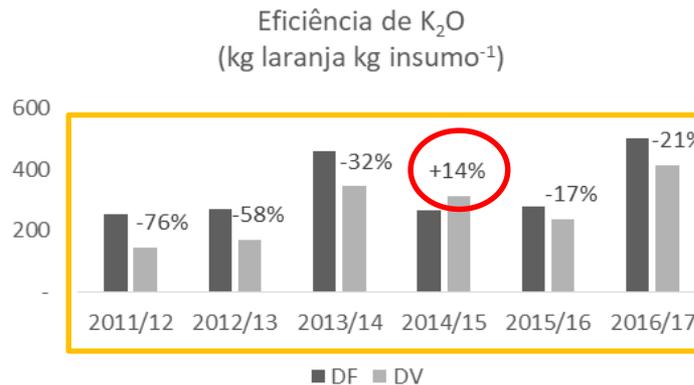
P: menores nos 3 primeiros anos e maiores nos 3 últimos



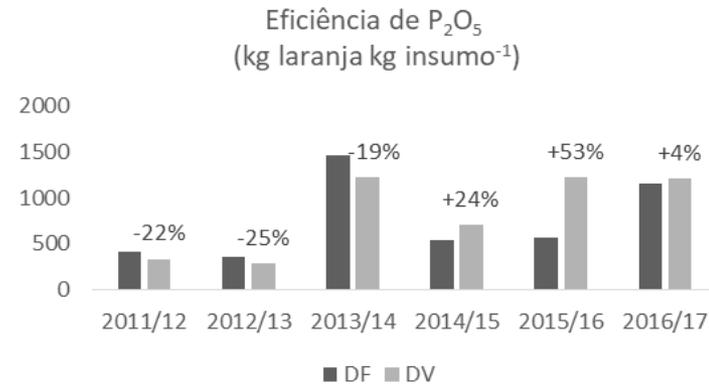
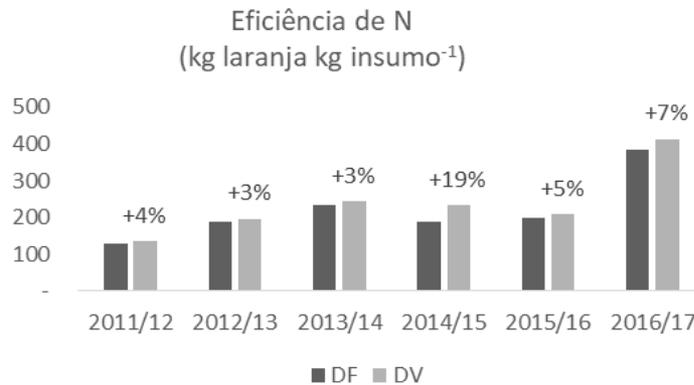
Eficiência dos insumos



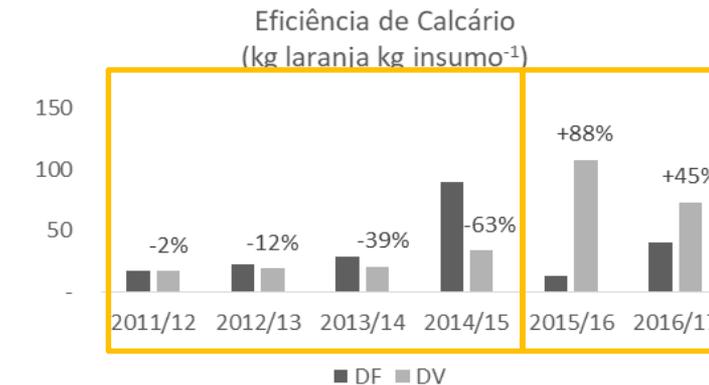
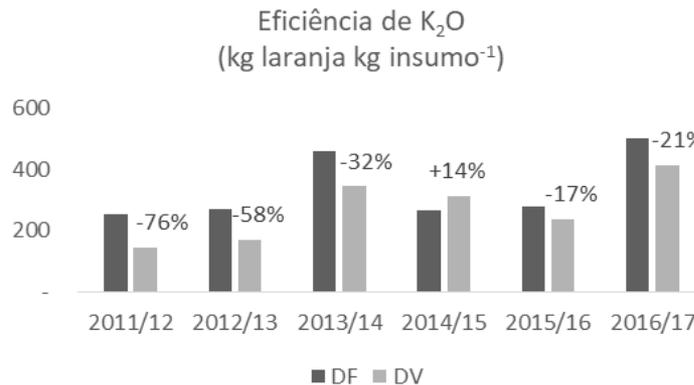
K: maiores para o DF em todos os anos, exceto 14/15



Eficiência dos insumos



Calcário: menores nos 4 primeiros anos e maiores nos 2 últimos



- As aplicações dos insumos P, K e N do tratamento DV não foram reduzidas quando comparadas às aplicações do tratamento DF
- As aplicações dos insumos P, N e calcário foram mais eficientes no DV
- Analisando os valores médios dos nutrientes nos solos, apenas P e K diferiram estatisticamente nos anos de 2013/14 e 2014/15, sendo que os maiores valores foram encontrados no tratamento DV.
- Nas comparações entre os anos, em quatro safras o tratamento DV apresentou maiores produtividades
- O tratamento DV produziu 26% mais frutas no ano de maior diferença entre os tratamentos, chegando a uma produção total média de 2,74 t ha⁻¹ ano maior durante os seis anos avaliados.

- DV 272,93 t \rightarrow 45,49 t ha⁻¹ ano⁻¹ 6,4%
- DF 256,54 t \rightarrow 42,75 t ha⁻¹ ano⁻¹
- 2,74 t ha⁻¹ ano⁻¹ x 1000 / 40,8 kg \rightarrow 67,16 caixas ha⁻¹ ano⁻¹
- X R\$22,00 \rightarrow R\$1.477,00 ha⁻¹ ano⁻¹
- X 125 ha x 6 anos \rightarrow R\$ 1.108.088,23 DV