Wheat Yield Potential and Yield Gaps in South Africa

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INTRODUCTION AND OBJECTIVES

Wheat (*Triticum aestivum* L.) production in South Africa declined sharply over the past decade because of rising input costs, low global wheat prices and low relative profitability of the crop. In the present research, the possibility of improving wheat yields and farmer profits in production systems of South Africa was explored through analysing average farmer yields (*Ya*), yield potentials (*Yp* - or water limited yield potential in the case of dryland wheat) and yield gaps (*Yp* – *Ya*). The influence of geographic regions, tillage systems and planting dates on the yield gaps were also determined.

MATERIAL AND METHODS

The Western Cape (winter rainfall area) and the Free State Provinces (summer rainfall area) are the major dryland wheat production areas in South Africa (Figure 1). Irrigated wheat in the Free State, Mpumalanga, Northern Cape, North West, Limpopo and KwaZulu-Natal Provinces accounts for the rest of the production. The Agricultural Research Council-Small Grain Institute (ARC-SGI) conducts farmer representative wheat cultivar evaluation trials on farmers' fields annually across all the major production areas of South Africa. Long term data from yield trials such as these can be used to provide robust estimates of *Ya* and *Yp* for a given location under a specific set of management practices provided that the trials are replicated over many years (Cassman *et al.*, 2003). Under favourable, high *Yp* environments, 5 years' data is generally adequate but for low rainfall areas, longer intervals (15 - 20 years) of field experimentation are more ideal (Van Ittersum *et al.*, 2013). Summary statistics of the combined data are shown in Table 1. Upper (95th) percentile of the data sets provided reliable estimates of *Yp* (Van Ittersum *et al.*, 2013). The residual (or restricted) maximum likelihood (REML) model was used to test the significance of the fixed effects (geographic regions, planting dates, and tillage systems) and interaction effects on farmer yields (Table 2).

Table 1: Structure of the data used in analyses of average yields and yield gaps in South African wheat production systems

Data Period	Production areas and cultivars	Geographic regions	Tillage systems	Planting times	Number of farms (*n*)	Maximum yield (best farmer)	Yield potential (*Yp* - 95th percentile)	Average yield (*Ya*)	Yield gaps (*Yp* - *Ya*)	*Yg*:*Ya* ratio
15 years (2000 -2014)	Summer rainfall area (dryland) Cultivar: *Elands*	South Western Free State	Reduced tillage	Early	162	3.12	2.60	1.62	0.98	0.60
				Late	180	3.04	2.60	1.77	0.83	0.47
		Eastern Free State	Conventional tillage	Early	334	6.77	5.74	3.11	2.63	0.85
				Late	306	7.00	5.76	3.61	2.15	0.60
		North Western Free State	Reduced tillage	Early	124	5.71	5.05	3.20	1.85	0.58
				Late	107	8.17	5.52	3.19	2.33	0.73
		Central Free State	Conventional tillage	Early	176	4.78	3.71	2.09	1.62	0.78
				Late	191	4.62	4.03	2.36	1.67	0.71
5 years (2010 - 2014)	Winter rainfall area (dryland) Cultivar: *Tankwa*	Rûens	Reduced tillage	-	241	6.63	5.42	3.48	1.94	0.56
			Conventional tillage	-	78	5.42	5.28	3.85	1.43	0.37
		Swartland	Reduced tillage	-	212	6.67	5.91	3.69	2.22	0.60
			Conventional tillage	-	94	5.58	5.36	3.79	1.57	0.41
5 years (2010 - 2014)	Irrigated area Cultivar: *Buffels*	Cooler central region	Reduced tillage	-	426	13.67	11.45	8.32	3.13	0.38
		Warmer Northern region	Reduced tillage	-	176	11.1	8.84	6.59	2.25	0.34
		Highveld region	Conventional tillage	-	128	9.81	9.25	7.86	1.39	0.18
		KwaZulu-Natal	Reduced tillage	-	38	7.65	7.57	6.43	1.14	0.18

RESULTS AND DISCUSSION

Average yields for dryland wheat in the summer rainfall area (SRA) ranged from 1.62 ± 0.046 to 3.61 ± 0.068 t ha^{-1} (Table 1) and were significantly higher ($p<0.001$) for later plantings than early plantings (Table 2). For the winter rainfall area (WRA), *Ya* ranged from 3.48 ± 0.072 to 3.85 ± 0.15 t ha^{-1}, and it was significantly higher ($p<0.001$) for conventional tillage (3.79 t ha^{-1}) than reduced tillage (3.59 t ha^{-1}). However, the mean water limited *Yp* was higher for reduced tillage (5.67 t ha^{-1}) than conventional tillage (5.32 t ha^{-1}) (Table 1). Irrigated wheat *Ya* ranged from 6.43 ± 0.15 to 8.32 ± 0.10 t ha^{-1} and were highest in the cooler central irrigation region, where the majority of farmers practice precision farming. Yield gaps ranged from 0.83 – to 3.13 t ha^{-1}, and the *Yg*:*Ya* ratios were considerably higher for dryland production systems than irrigated production systems (Table 1). The exploitable yield gaps (based on 80 – 85% of *Yp*) were as follows: SRA (0.46 - 1.48 t ha^{-1}), WRA (0.38 - 1.04 t ha^{-1}) and irrigated area (0.44 - 1.41 t ha^{-1}).

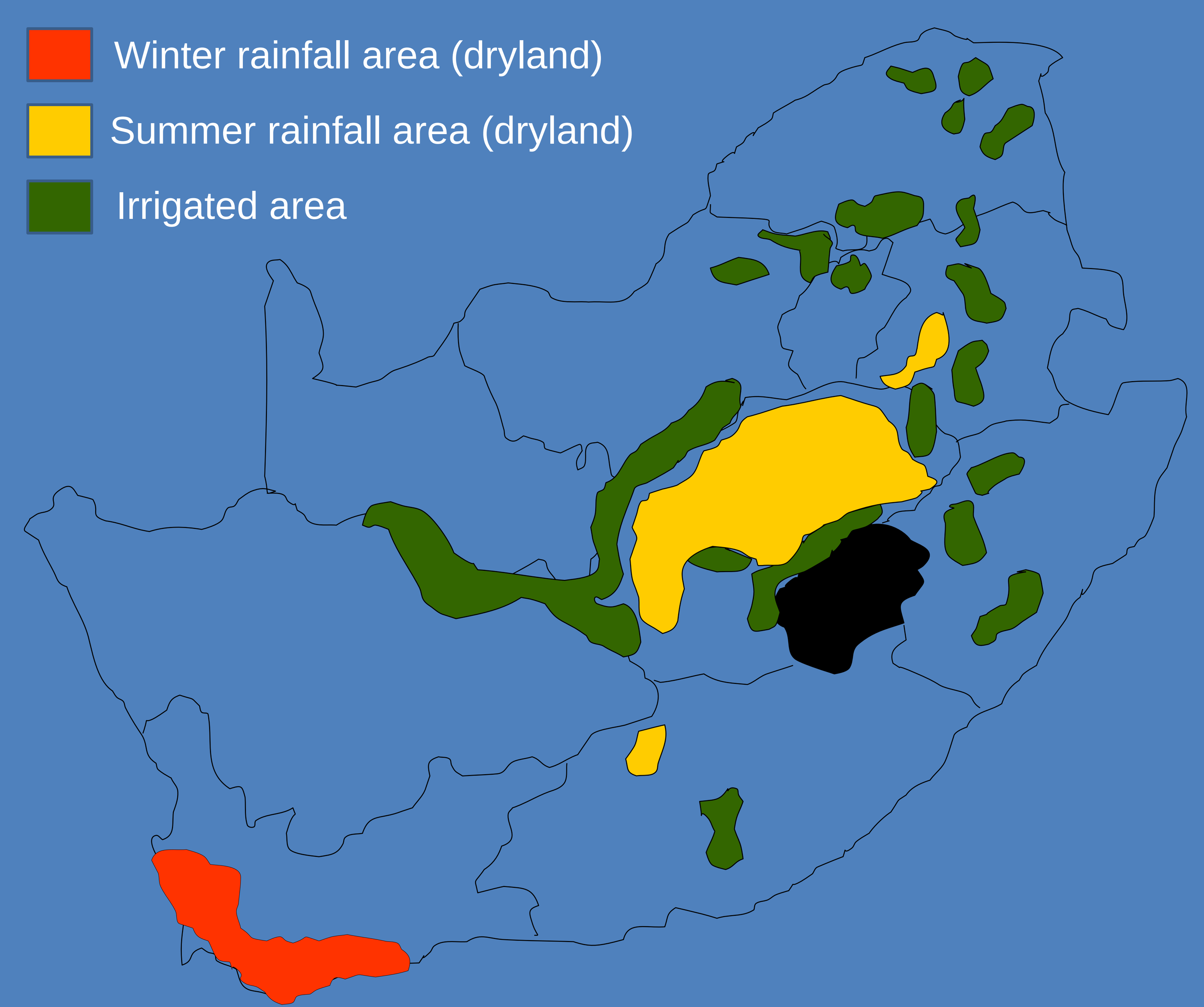

Figure 1: The various wheat production areas of South Africa

CONCLUSIONS

Dryland and irrigated wheat yields could be increased by 10 – 48% and 7 – 17% respectively through closing exploitable yield gaps in various production systems. Refinements in farmer planting date decision and tillage practices are important considerations for closing the wheat yield gaps in the winter rainfall area and summer rainfall area respectively. Additional research on other farmer crop management strategies in relation to wheat yields is required in order to provide a better understanding of the factors causing the large yield gaps in various wheat production systems of South Africa.

Table 2: Significance of the fixed effects tested by chi-squared F- statistic (Wald statistic/d.f) values in the overall REML analysis for wheat yield in production areas of South Africa

Production area	Source of variation	d.f	Wald statistic	F statistic	F pr.
Winter rainfall area	Geographic region	1	3.37	3.37	0.075
	Tillage system	1	22.34	22.34	<0.001
	Geog. region × tillage system	1	0.02	0.02	0.883
Summer rainfall area	Geographic region	3	113.01	37.67	<0.001
	Planting date	1	70.26	70.26	<0.001
	Geographic region × planting date	3	49.14	16.38	<0.001
Irrigated area	Geographic region	3	19.86	6.61	<0.001

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