

[10.1071/CP23110](https://doi.org/10.1071/CP23110)

Crop & Pasture Science

Supplementary Material

Should crop sequences in Western Australia include more lupins?

C. d'Abbadie^A, S. Kharel^A, R. Kingwell^{A,B,C,}, and A. Abadi Ghadim^A*

^ADepartment of Primary Industries and Regional Development, Perth, WA, Australia.

^BUniversity of Western Australia, Crawley, WA, Australia.

^CAustralian Export Grains Innovation Centre, South Perth, WA, Australia.

*Correspondence to: R. Kingwell Department of Primary Industries and Regional Development, Perth, WA, Australia Email: ross.kingwell@aegic.org.au

Appendix 1

Table A 1. Mean and standard deviation (values in brackets) of the Growing Season Rainfall (GSR) and yields, nitrogen (N) applied and green gas house emissions (GHG) for each crop within the 100% crop rotation for the high rainfall regions.

Location Code			NORn	MOO	YOR	KAT	KOJ	
AEZ			H1	H2	H3	H4	H5	
GSR		mm/yr	361 (93)	307 (69)	328 (73)	336 (67)	463 (80)	
100% Cropping	Wheat	Yield	t/ha	3.1 (1.0)	2.8 (0.9)	2.2 (0.6)	2.7 (0.5)	3.8 (0.7)
		N Applied	kg of N/ha	107 (42)	83 (33)	33 (22)	6 (9)	37 (20)
		GHG	kg of CO2e/ha	929 (314)	808 (267)	522 (143)	426 (92)	646 (164)
	Barley	Yield	t/ha	n.a.	2.6 (0.8)	2.3 (0.6)	2.7 (0.6)	3.9 (0.7)
		N Applied	kg of N/ha	n.a.	93 (32)	58 (25)	21 (16)	62 (21)
		GHG	kg of CO2e/ha	n.a.	824 (260)	607 (146)	477 (105)	722 (162)
	Canola	Yield	t/ha	2.0 (0.6)	1.7 (0.5)	1.5 (0.4)	1.7 (0.3)	2.3 (0.4)
		N Applied	kg of N/ha	146 (48)	129 (39)	84 (29)	47 (20)	97 (28)
		GHG	kg of CO2e/ha	1174 (329)	1067 (279)	803 (159)	682 (121)	973 (178)
100% Cropping - Including Lupins	Wheat	Yield	t/ha	3.2 (1.1)	2.8 (0.9)	2.2 (0.6)	2.8 (0.6)	3.9 (0.7)
		N Applied	kg of N/ha	69 (46)	38 (35)	18 (19)	2 (7)	17 (18)
		GHG	kg of CO2e/ha	761 (275)	621 (235)	459 (124)	418 (92)	563 (150)
	Barley	Yield	t/ha	n.a.	2.6 (0.8)	2.3 (0.6)	2.8 (0.6)	3.9 (0.7)
		N Applied	kg of N/ha	n.a.	69 (35)	43 (25)	12 (13)	40 (22)
		GHG	kg of CO2e/ha	n.a.	703 (218)	541 (131)	451 (106)	636 (149)
	Lupin	Yield	t/ha	3.0 (1.0)	2.6 (0.8)	1.5 (0.4)	1.8 (0.4)	2.3 (0.4)
		N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		GHG	kg of CO2e/ha	625 (224)	563 (187)	410 (99)	420 (86)	490 (118)

Table A 2. Mean and standard deviation (values in brackets) of the Growing Season Rainfall (GSR) and yields, nitrogen (N) applied and green gas house emissions (GHG) applied for each crop within the 75% crop rotation for the high rainfall regions.

Location Code			NORn	MOO	YOR	KAT	KOJ	
AEZ			H1	H2	H3	H4	H5	
GSR	mm/yr		361 (93)	307 (69)	328 (73)	336 (67)	463 (80)	
75% Cropping	Wheat	Yield	t/ha	3.2 (1.1)	2.8 (0.9)	2.2 (0.6)	2.7 (0.6)	3.8 (0.7)
		N Applied	kg of N/ha	90 (43)	62 (33)	25 (20)	3 (7)	27 (19)
		GHG	kg of CO2e/ha	823 (284)	672 (236)	458 (133)	385 (94)	551 (158)
	Barley	Yield	t/ha	n.a.	2.6 (0.8)	2.4 (0.6)	2.8 (0.6)	3.9 (0.7)
		N Applied	kg of N/ha	n.a.	82 (33)	48 (25)	15 (14)	49 (21)
		GHG	kg of CO2e/ha	n.a.	824 (260)	607 (146)	477 (105)	722 (162)
	Canola	Yield	t/ha	2.0 (0.6)	1.8 (0.5)	1.5 (0.4)	1.8 (0.3)	2.4 (0.3)
		N Applied	kg of N/ha	139 (48)	121 (38)	76 (29)	41 (18)	87 (27)
		GHG	kg of CO2e/ha	1174 (329)	1067 (279)	803 (159)	682 (121)	973 (178)
Legume Pasture	Yield	t DM/ha	6.0 (1.9)	5.0 (1.4)	4.4 (0.9)	4.7 (0.8)	6.3 (1.1)	
	N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	GHG	kg of CO2e/ha	1641 (229)	1602 (196)	1522 (111)	2632 (86)	2336 (131)	
75% Cropping - Including Lupins	Wheat	Yield	t/ha	3.2 (1.1)	2.8 (0.9)	2.2 (0.6)	2.7 (0.6)	3.9 (0.7)
		N Applied	kg of N/ha	69 (46)	37 (34)	14 (18)	1 (5)	13 (18)
		GHG	kg of CO2e/ha	740 (276)	575 (224)	415 (121)	385 (101)	502 (154)
	Barley	Yield	t/ha	n.a.	2.6 (0.8)	2.4 (0.6)	2.8 (0.6)	4.0 (0.7)
		N Applied	kg of N/ha	n.a.	70 (35)	41 (25)	11 (13)	37 (22)
		GHG	kg of CO2e/ha	n.a.	709 (222)	539 (136)	460 (117)	639 (160)
	Lupin	Yield	t/ha	3.1 (1.1)	2.6 (0.9)	1.6 (0.4)	1.8 (0.4)	2.4 (0.4)
		N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		GHG	kg of CO2e/ha	567 (219)	513 (183)	383 (103)	394 (97)	454 (129)
Legume Pasture	Yield	t DM/ha	5.2 (1.6)	4.4 (1.2)	3.8 (0.8)	4.1 (0.7)	5.4 (0.9)	
	N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	GHG	kg of CO2e/ha	1625 (210)	1587 (177)	1513 (101)	2637 (96)	2331 (127)	

Table A 3. Mean and standard deviation (values in brackets) of the Growing Season Rainfall (GSR) and yields, nitrogen (N) applied and green gas house emissions (GHG) for each crop within the 100% crop rotation for the medium rainfall regions.

Location Code			CAR	WON	CUN	COR	RAV		
AEZ			M1	M2	M3	M4	M5		
GSR		mm/yr	361 (93)	307 (69)	328 (73)	336 (67)	463 (80)		
100% Cropping	Wheat	Yield	t/ha	2.0 (0.8)	2.3 (0.7)	1.5 (0.4)	1.7 (0.5)	2.2 (0.7)	
		N Applied	kg of N/ha	52 (33)	63 (25)	9 (12)	3 (6)	2 (5)	
		GHG	kg of CO2e/ha	537 (184)	599 (195)	300 (70)	283 (60)	346 (67)	
100% Cropping	Barley	Yield	t/ha	n.a.	2.1 (0.7)	1.5 (0.4)	1.8 (0.6)	2.2 (0.7)	
		N Applied	kg of N/ha	n.a.	62 (23)	17 (14)	16 (14)	13 (12)	
		GHG	kg of CO2e/ha	n.a.	590 (190)	322 (76)	324 (75)	372 (77)	
100% Cropping	Canola	Yield	t/ha	1.3 (0.5)	1.5 (0.5)	1.1 (0.3)	1.2 (0.4)	1.4 (0.4)	
		N Applied	kg of N/ha	86 (38)	101 (29)	45 (21)	37 (19)	38 (17)	
		GHG	kg of CO2e/ha	717 (197)	798 (204)	482 (96)	464 (90)	540 (93)	
100% Cropping - Including Lupins	Wheat	Yield	t/ha	2.0 (0.8)	2.3 (0.7)	1.5 (0.4)	1.7 (0.6)	2.3 (0.8)	
		N Applied	kg of N/ha	28 (32)	24 (28)	3 (7)	1 (4)	1 (3)	
		GHG	kg of CO2e/ha	450 (162)	464 (170)	282 (60)	281 (59)	347 (71)	
	Barley	Yield	t/ha	n.a.	2.1 (0.7)	1.6 (0.4)	1.8 (0.6)	2.2 (0.7)	
			N Applied	kg of N/ha	n.a.	40 (26)	9 (12)	9 (11)	6 (9)
			GHG	kg of CO2e/ha	n.a.	500 (157)	298 (69)	305 (73)	359 (80)
	Lupin	Yield	t/ha	2.0 (0.8)	2.2 (0.8)	1.2 (0.4)	1.2 (0.4)	1.5 (0.5)	
			N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
			GHG	kg of CO2e/ha	440 (133)	464 (143)	295 (57)	298 (58)	368 (71)

Table A 4. Mean and standard deviation (values in brackets) of the Growing Season Rainfall (GSR) and yields, nitrogen (N) applied and green gas house emissions (GHG) for each crop within the 75% crop rotation for the medium rainfall regions.

Location Code			CAR	WON	CUN	COR	RAV	
AEZ			M1	M2	M3	M4	M5	
GSR		mm/yr	361 (93)	307 (69)	328 (73)	336 (67)	463 (80)	
75% Cropping	Wheat	Yield	t/ha	2.0 (0.8)	2.2 (0.7)	1.5 (0.4)	1.6 (0.6)	2.2 (0.7)
		N Applied	kg of N/ha	39 (34)	42 (26)	5 (8)	1 (4)	1 (3)
		GHG	kg of CO ₂ e/ha	476 (172)	498 (175)	274 (66)	265 (61)	323 (72)
	Barley	Yield	t/ha	n.a.	2.1 (0.7)	1.6 (0.4)	1.8 (0.6)	2.2 (0.7)
		N Applied	kg of N/ha	n.a.	53 (23)	12 (13)	11 (12)	9 (10)
		GHG	kg of CO ₂ e/ha	n.a.	590 (190)	322 (76)	324 (75)	372 (77)
	Canola	Yield	t/ha	1.3 (0.5)	1.5 (0.5)	1.1 (0.3)	1.2 (0.4)	1.5 (0.4)
		N Applied	kg of N/ha	79 (39)	94 (28)	39 (19)	33 (17)	31 (14)
		GHG	kg of CO ₂ e/ha	717 (197)	798 (204)	482 (96)	464 (90)	540 (93)
Legume Pasture	Yield	t DM/ha	4.1 (1.5)	4.4 (1.4)	3.4 (0.9)	3.4 (1.0)	4.0 (1.2)	
	N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	GHG	kg of CO ₂ e/ha	1188 (132)	1187 (151)	1107 (60)	1104 (57)	1350 (65)	
75% Cropping - Including Lupins	Wheat	Yield	t/ha	2.0 (0.8)	2.3 (0.7)	1.5 (0.5)	1.7 (0.6)	2.2 (0.8)
		N Applied	kg of N/ha	28 (32)	22 (26)	2 (6)	1 (3)	0 (2)
		GHG	kg of CO ₂ e/ha	442 (166)	436 (168)	269 (67)	269 (68)	329 (81)
	Barley	Yield	t/ha	n.a.	2.1 (0.7)	1.6 (0.5)	1.8 (0.6)	2.3 (0.7)
		N Applied	kg of N/ha	n.a.	40 (26)	9 (11)	8 (11)	6 (8)
		GHG	kg of CO ₂ e/ha	n.a.	508 (165)	305 (76)	311 (81)	366 (91)
	Lupin	Yield	t/ha	2.0 (0.8)	2.3 (0.8)	1.2 (0.4)	1.2 (0.4)	1.5 (0.5)
		N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		GHG	kg of CO ₂ e/ha	411 (134)	433 (146)	282 (65)	285 (67)	351 (80)
Legume Pasture	Yield	t DM/ha	3.6 (1.3)	3.9 (1.2)	3.0 (0.8)	3.0 (0.9)	3.5 (1.0)	
	N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
	GHG	kg of CO ₂ e/ha	1184 (127)	1179 (141)	1108 (63)	1107 (63)	1355 (75)	

Table A 5. Mean and standard deviation (values in brackets) of the Growing Season Rainfall (GSR) and yields, nitrogen (N) applied and green gas house emissions (GHG) for each crop within the 100% crop rotation for the low rainfall regions.

Location Code			MUL	KAL	MER	HYD	
AEZ			L1	L2	L3	L4	
GSR		mm/yr	361 (93)	307 (69)	328 (73)	336 (67)	
100% Cropping	Wheat	Yield	t/ha	1.7 (0.8)	1.4 (0.6)	1.5 (0.4)	1.5 (0.5)
		N Applied	kg of N/ha	46 (37)	24 (25)	7 (13)	4 (7)
		GHG	kg of CO2e/ha	467 (170)	368 (120)	296 (61)	293 (57)
100% Cropping	Barley	Yield	t/ha	n.a.	n.a.	1.4 (0.4)	1.6 (0.6)
		N Applied	kg of N/ha	n.a.	n.a.	13 (16)	18 (14)
		GHG	kg of CO2e/ha	n.a.	n.a.	307 (69)	333 (73)
100% Cropping	Canola	Yield	t/ha	1.1 (0.4)	0.9 (0.4)	1.0 (0.3)	1.1 (0.4)
		N Applied	kg of N/ha	73 (41)	52 (31)	37 (24)	40 (19)
		GHG	kg of CO2e/ha	611 (179)	517 (143)	454 (93)	475 (89)
100% Cropping - Including Lupins	Wheat	Yield	t/ha	1.7 (0.8)	1.4 (0.6)	1.5 (0.4)	1.6 (0.6)
		N Applied	kg of N/ha	27 (35)	12 (21)	2 (7)	1 (4)
		GHG	kg of CO2e/ha	398 (151)	331 (111)	286 (53)	289 (57)
	Barley	Yield	t/ha	n.a.	n.a.	1.5 (0.4)	1.6 (0.6)
		N Applied	kg of N/ha	n.a.	n.a.	7 (12)	10 (12)
		GHG	kg of CO2e/ha	n.a.	n.a.	292 (62)	311 (69)
	Lupin	Yield	t/ha	1.7 (0.8)	1.5 (0.7)	1.1 (0.4)	1.2 (0.4)
		N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)
		GHG	kg of CO2e/ha	383 (124)	350 (95)	300 (52)	306 (58)

Table A 6. Mean and standard deviation (values in brackets) of the Growing Season Rainfall (GSR) and yields, nitrogen (N) applied and green gas house emissions (GHG) for each crop within the 75% crop rotation for the low rainfall regions.

Location Code			MUL	KAL	MER	HYD	
AEZ			L1	L2	L3	L4	
GSR	mm/yr		361 (93)	307 (69)	328 (73)	336 (67)	
75% Cropping	Wheat	Yield	t/ha	1.7 (0.8)	1.4 (0.6)	1.5 (0.4)	1.5 (0.5)
		N Applied	kg of N/ha	34 (36)	16 (22)	3 (8)	1 (4)
		GHG	kg of CO ₂ e/ha	417 (160)	336 (113)	275 (60)	275 (62)
	Barley	Yield	t/ha	n.a.	n.a.	1.5 (0.4)	1.6 (0.6)
		N Applied	kg of N/ha	n.a.	n.a.	8 (13)	13 (13)
		GHG	kg of CO ₂ e/ha	n.a.	n.a.	307 (69)	333 (73)
	Canola	Yield	t/ha	1.1 (0.4)	0.9 (0.4)	1.0 (0.3)	1.1 (0.4)
		N Applied	kg of N/ha	67 (40)	46 (29)	32 (22)	34 (17)
		GHG	kg of CO ₂ e/ha	611 (179)	517 (143)	454 (93)	475 (89)
Legume Pasture	Yield	t DM/ha	3.7 (1.7)	3.0 (1.3)	3.2 (0.9)	3.4 (1.1)	
	N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	
	GHG	kg of CO ₂ e/ha	769 (120)	753 (85)	729 (54)	724 (57)	
75% Cropping - Including Lupins	Wheat	Yield	t/ha	1.7 (0.8)	1.4 (0.6)	1.5 (0.4)	1.6 (0.6)
		N Applied	kg of N/ha	25 (35)	11 (20)	2 (6)	1 (4)
		GHG	kg of CO ₂ e/ha	392 (157)	328 (115)	276 (62)	277 (67)
	Barley	Yield	t/ha	n.a.	n.a.	1.5 (0.4)	1.7 (0.6)
		N Applied	kg of N/ha	n.a.	n.a.	6 (12)	9 (12)
		GHG	kg of CO ₂ e/ha	n.a.	n.a.	301 (70)	319 (78)
	Lupin	Yield	t/ha	1.7 (0.8)	1.5 (0.7)	1.1 (0.3)	1.2 (0.5)
		N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)
		GHG	kg of CO ₂ e/ha	359 (126)	331 (99)	289 (62)	294 (67)
Legume Pasture	Yield	t DM/ha	3.3 (1.4)	2.7 (1.1)	2.9 (0.8)	3.0 (1.0)	
	N Applied	kg of N/ha	0 (0)	0 (0)	0 (0)	0 (0)	
	GHG	kg of CO ₂ e/ha	768 (119)	758 (93)	731 (59)	727 (62)	

Appendix 2

To validate the model, the predicted yields for the EVALUS model were compared to industry reported yields (Planfarm 2010 to 2022). Figure A1 compares the predicted and reported yields and shows the Pearson correlation coefficient for those comparisons (Freedman *et al.* 2007).

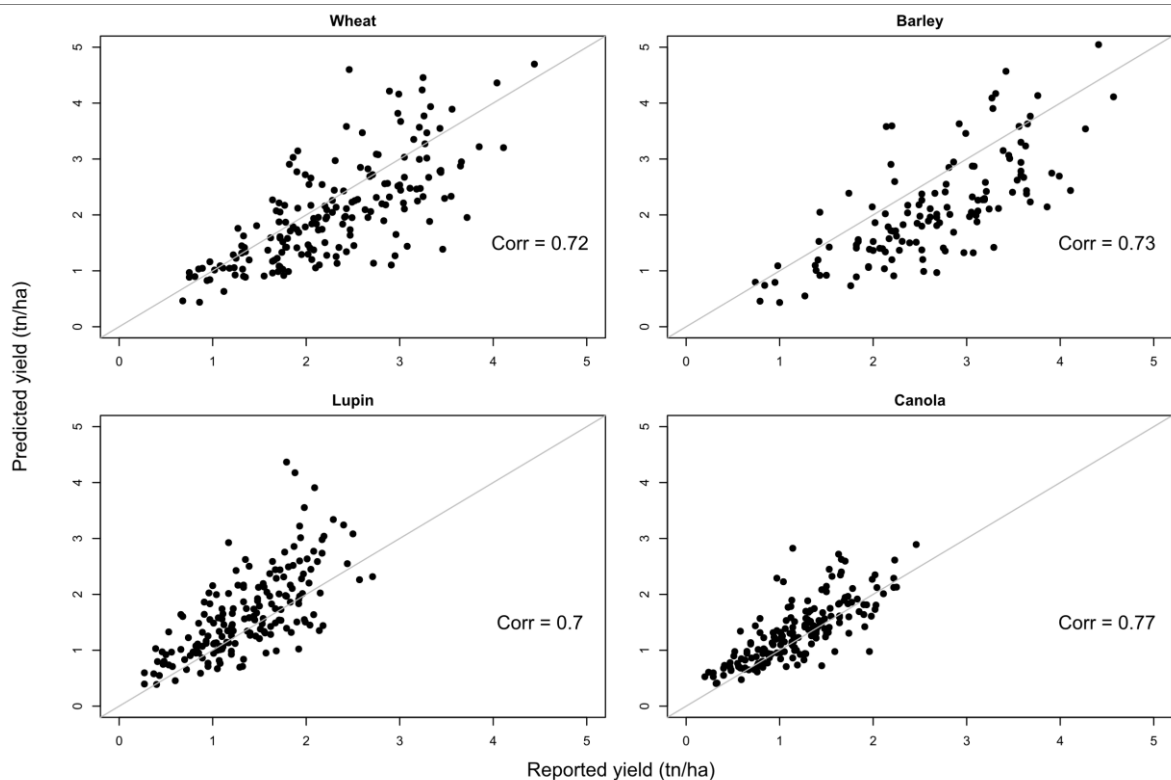


Figure A 1:

In general, the correlation coefficient varies between 0.7 to 0.77. It is important to note that there is an aggregation bias in the reported data. Each region has different soil types and weather varies across the regions. Additionally, the predicted value from EVALUS relies on a single location for each region. This implies there should not be perfect correlation.

References

Freedman D, Pisani R, Purves R. (2007) Statistics (international student edition). Pisani, R. Purves, 4th Edn. WW Norton & Company, New York.

Planfarm (2010) Planfarm Bankwest Benchmarks 2009-2010 season. Planfarm Pty Ltd, Wembley.

Planfarm (2011) Planfarm Bankwest Benchmarks 2010-2011 season. Planfarm Pty Ltd, Wembley.

Planfarm (2012) Planfarm Bankwest Benchmarks 2011-2012 season. Planfarm Pty Ltd, Wembley.

Planfarm (2013) Planfarm Bankwest Benchmarks 2012-2013 season. Planfarm Pty Ltd, Wembley.

Planfarm (2014) Planfarm Bankwest Benchmarks 2013-2014 season. Planfarm Pty Ltd, Wembley.

Planfarm (2015) Planfarm Bankwest Benchmarks 2014-2015 season. Planfarm Pty Ltd, Wembley.

Planfarm (2016) Planfarm Bankwest Benchmarks 2015-2016 season. Planfarm Pty Ltd, Wembley.

Planfarm (2017) Planfarm Bankwest Benchmarks 2016-2017 season. Planfarm Pty Ltd, Wembley.

Planfarm (2018) Planfarm Bankwest Benchmarks 2017-2018 season. Planfarm Pty Ltd, Wembley.

Planfarm (2019) Planfarm Benchmarks 2018-2019. Planfarm Pty Ltd, Wembley.

Planfarm (2020) Planfarm Benchmarks 2019 Season. Planfarm Pty Ltd, Wembley.

Planfarm (2021) Planfarm Benchmarks 2020 Season. Planfarm Pty Ltd, Wembley.

Planfarm (2022) Planfarm Benchmarks 2021 Season. Planfarm Pty Ltd, Wembley.