

## Interannual county-level climate–yield relationships for winter wheat on the Columbia Plateau, USA

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**Table S1.** Winter wheat phenological stages and corresponding growing degree days (GDD, base 0°C; *Ritchie 1991*)

Phenological stages	Germination	Emergence	Tillering	Booting	Flowering	Grain filling	Maturity
<b>Cumulative GDD</b>	70	400	685	875	1075	1575	1825

**Table S2.** Average number of days to finish various phenostages from 1979-2014. Days listed are relative to Oct 1, which we use as the universal sowing date in the study area.

No.	State	County	Germination	Emergence	Tillering	Booting	Flowering	Grain Filling	Maturity
1	ID	BENEWAH	8	138	205	225	242	277	291
2	ID	CLEARWATER	7	114	194	216	233	268	282
3	ID	IDAHO	7	104	190	213	230	266	279
4	ID	KOOTENAI	8	134	203	223	240	274	288
5	ID	LATAH	7	90	183	207	226	261	276
6	ID	LEWIS	8	126	201	222	239	274	288
7	ID	NEZ PERCE	7	117	193	215	232	267	281
8	OR	GILLIAM	6	61	162	191	213	252	267
9	OR	MORROW	6	44	134	169	192	232	248
10	OR	SHERMAN	6	62	164	194	215	254	269
11	OR	UMATILLA	6	48	141	175	199	238	254
12	OR	UNION	8	111	197	218	236	271	285
13	OR	WASCO	6	58	160	189	211	250	265
14	WA	ADAMS	6	58	160	186	206	243	257
15	WA	ASOTIN	8	117	202	223	241	275	289
16	WA	BENTON	6	43	139	171	193	231	247
17	WA	COLUMBIA	6	56	153	183	206	244	260
18	WA	DOUGLAS	7	132	198	217	232	264	277
19	WA	FRANKLIN	6	42	136	169	192	230	246
20	WA	GARFIELD	7	69	171	200	220	258	273
21	WA	GRANT	6	77	176	198	216	250	264
22	WA	KLICKITAT	6	47	144	176	199	238	254
23	WA	LINCOLN	7	111	189	211	228	262	276
24	WA	SPOKANE	7	117	193	215	232	267	281
25	WA	WALLA WALLA	7	111	189	211	228	262	276
26	WA	WHITMAN	7	65	165	192	213	250	266
27	WA	YAKIMA	6	62	165	191	212	248	263

**Table S3.** The growing degree days (GDD) and crop coefficients of winter wheat growth stages in FAO-56 model. (Saadi et al. 2015)

Stages	Initial	Crop development	Mid-season	Late season
GDD (°C·day)	0-400	400-1250	1250-1900	1900-2150
Crop Coefficient	0.7	0.7-1.15	1.15	1.15-0.3

**Table S4:** Summary table of county-level stepwise linear regression models. The units of yields ( $\Delta Y$ ) are kg/ha; °C for mean temperature ( $\Delta T_{gm}$ ); °C·day for heat degree days ( $\Delta HDD$ ); mm for precipitation ( $\Delta P_{bm}$ ), actual evapotranspiration ( $\Delta AET_{gm}$ ), and water deficit ( $\Delta DEF$ ). Model fit is reported as the coefficient of determination ( $R^2$ ), and adjusted  $R^2$ . The pooled model explanatory power ( $R^2_{pooled}$ ) at each county is also reported. The second column lists the state abbreviation, ID: Idaho, OR: Oregon, WA: Washington. The far-right column shows the percent of total harvested area for winter wheat that was irrigated in 2012 (NASS, 2014b)

No.	State	County	Equation	R <sup>2</sup>	Adj R <sup>2</sup>	R <sup>2</sup> <sub>pooled</sub>	Irr. Rate (%)
1	ID	BENEWAH	$\Delta Y = -164 + 18.6 \Delta AET_{gm} + 0.258 \Delta AET_{gm}^2$	0.46	0.43	0.32	0
2	ID	CLEARWATER	$\Delta Y = -119 + 14.4 \Delta AET_{gm} + 54.2 \Delta T_{gm}^2$	0.37	0.32	0.21	0
3	ID	IDAHO	$\Delta Y = 34.9 + 14.5 \Delta AET_{gm}$	0.26	0.24	0.22	0
4	ID	KOOTENAI	$\Delta Y = -199 - 408 \Delta T_{gm} + 0.0754 \Delta P_{bm}^2$	0.40	0.35	0.13	0
5	ID	LATAH	$\Delta Y = 18.9 - 7.64 \Delta DEF$	0.29	0.26	0.25	0
6	ID	LEWIS	$\Delta Y = 30.8 + 19.9 \Delta AET_{gm}$	0.53	0.52	0.46	0
7	ID	NEZ PERCE	$\Delta Y = 51.0 - 14.3 \Delta DEF$	0.35	0.33	0.27	0
8	OR	GILLIAM	$\Delta Y = -3.76 + 15.9 \Delta AET_{gm}$	0.42	0.40	0.45	0
9	OR	MORROW	$\Delta Y = -30.8 - 5.81 \Delta DEF - 3.89 \Delta HDD$	0.33	0.29	0.29	3.4
10	OR	SHERMAN	$\Delta Y = 140 + 12.6 \Delta AET_{gm} - 0.0293 \Delta DEF^2$	0.47	0.44	0.39	0
11	OR	UMATILLA	$\Delta Y = -32.0 - 11.1 \Delta DEF$	0.37	0.35	0.34	9.3
12	OR	UNION	no model	0	0	0.08	31.5
13	OR	WASCO	$\Delta Y = -12.6 + 15.3 \Delta AET_{gm}$	0.36	0.34	0.38	6.5
14	WA	ADAMS	$\Delta Y = -25.1 + 11.3 \Delta AET_{gm}$	0.28	0.26	0.27	10.7
15	WA	ASOTIN	$\Delta Y = -135 - 210 \Delta T_{gm} - 11.5 \Delta DEF + 0.057 \Delta P_{bm}^2$	0.67	0.64	0.49	0
16	WA	BENTON	$\Delta Y = 179 + 12.8 \Delta AET_{gm} - 3.86 \Delta HDD$	0.28	0.23	0.20	0
17	WA	COLUMBIA	$\Delta Y = -174 - 19.7 \Delta DEF + 0.0593 \Delta HDD^2$	0.55	0.52	0.41	0
18	WA	DOUGLAS	$\Delta Y = -19.5 + 9.03 \Delta AET_{gm}$	0.22	0.20	0.19	0
19	WA	FRANKLIN	$\Delta Y = -40.7 + 143 \Delta T_{gm} - 7.43 \Delta DEF - 3.92 \Delta HDD$	0.52	0.48	0.31	21.2
20	WA	GARFIELD	$\Delta Y = -124 + 3.64 \Delta P_{bm} - 14.2 \Delta DEF + 0.094 \Delta HDD^2$	0.77	0.75	0.64	0
21	WA	GRANT	$\Delta Y = -53.5 - 5.12 \Delta DEF$	0.23	0.20	0.24	0
22	WA	KLICKITAT	$\Delta Y = -24.9 - 3.37 \Delta HDD$	0.22	0.20	0.21	6.5
23	WA	LINCOLN	$\Delta Y = 30.5 + 14.7 \Delta P_{bm}$	0.37	0.35	0.37	5.7
24	WA	SPOKANE	$\Delta Y = 6.06 + 9.51 \Delta P_{bm}$	0.44	0.42	0.41	1.1
25	WA	WALLA WALLA	$\Delta Y = 27.2 + 23.1 \Delta AET_{gm}$	0.46	0.44	0.53	10.8
26	WA	WHITMAN	$\Delta Y = 23.1 + 15.7 \Delta AET_{gm}$	0.33	0.31	0.38	0
27	WA	YAKIMA	no model	0	0	5.2E-03	78.6

**Table S5.** Summary table of the pooled stepwise model for Columbia Plateau. The units of yields ( $\Delta Y$ ) are kg/ha; °C·day for heat degree days ( $\Delta HDD$ ); and mm for precipitation ( $\Delta P_{bm}$ ), actual evapotranspiration ( $\Delta AET_{gm}$ ), and water deficit ( $\Delta DEF$ ). The explained variance of the pooled model was 0.273 and adjusted  $R^2$  was 0.270.

	Estimate	p-value
(Intercept)	11.771	0.600
$\Delta P_{bm}$	1.846	<0.01
$\Delta AET_{gm}$	8.433	<0.001
$\Delta DEF$	-1.833	<0.05
$\Delta HDD$	-1.589	<0.001