Wheat yield gaps across smallholder farming systems in Ethiopia

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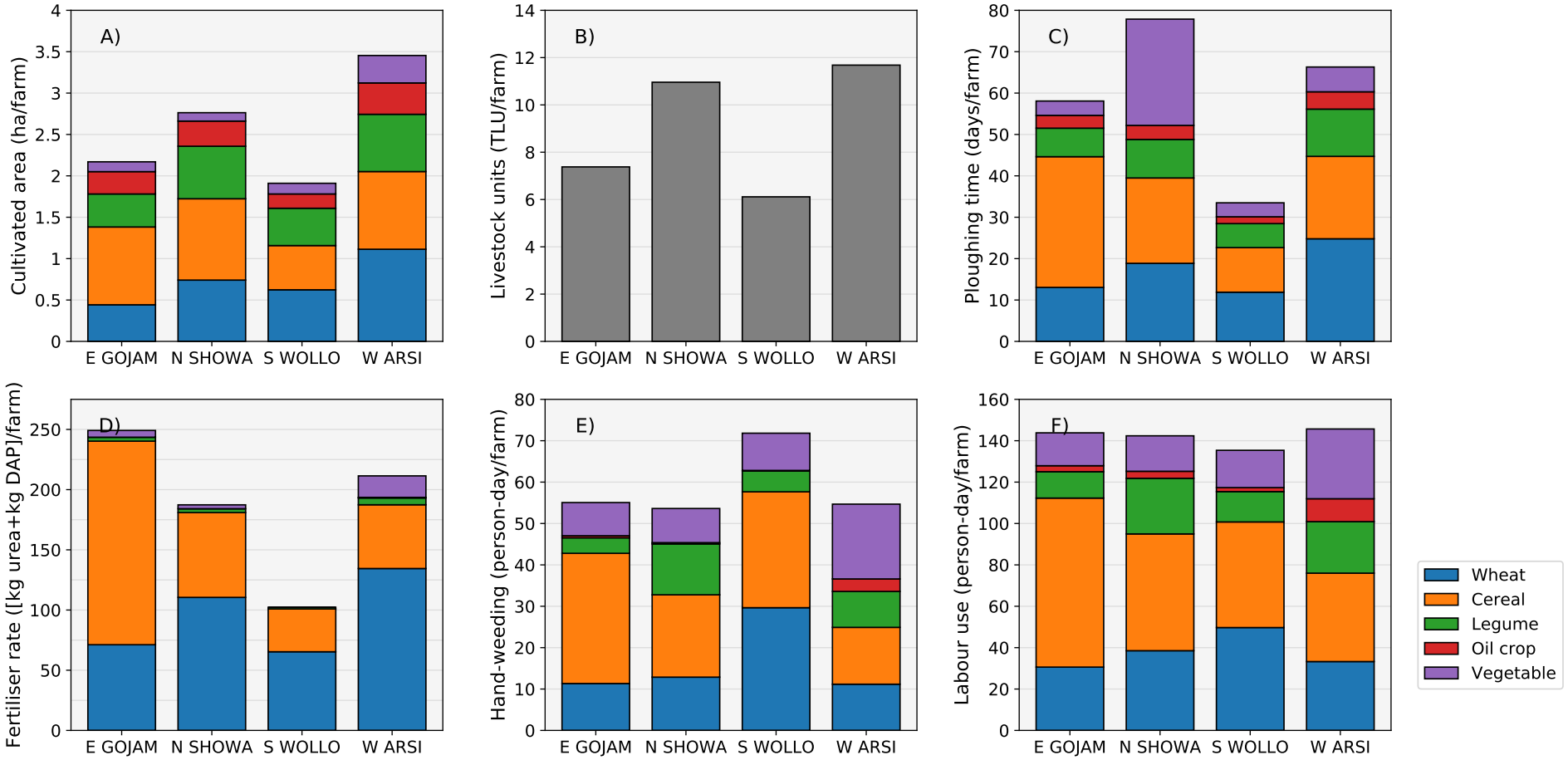

Figure S1: Descriptive statistics of selected farm characteristic and crop management practices for different crops in West Arsi, North Showa, East Gojam and South Wollo. Data refer to the Meher growing seasons of 2009 and 2013. Bars in B) are coloured grey because TLU can only be presented per farm and not per crop x farm as for the other indicators.

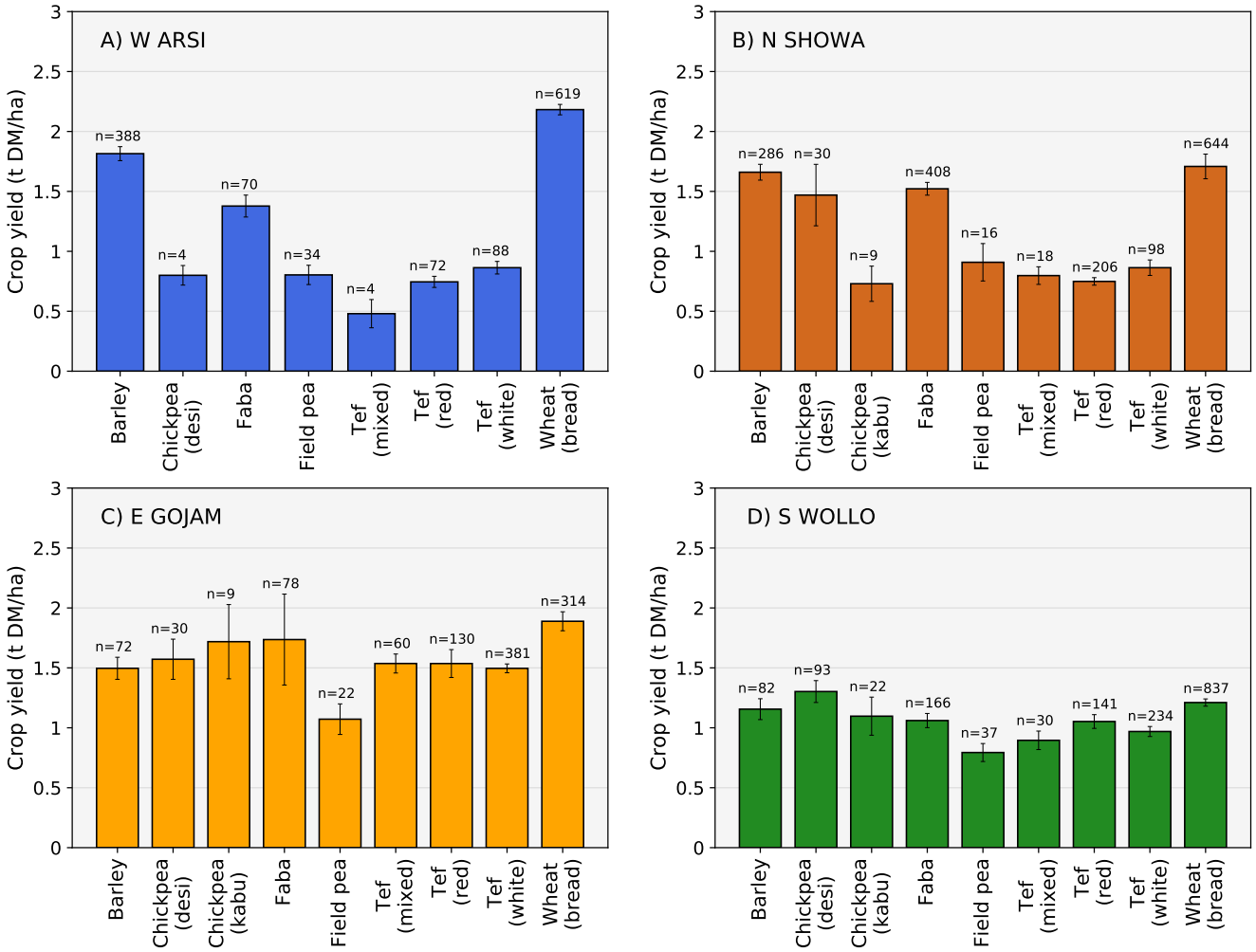

Figure S2: Descriptive statistics of crop yields in A) West Arsi, B) North Showa, C) East Gojam and D) South Wollo. Data refer to the 2009 and 2013 Meher growing seasons. Error bars show the standard error of the mean and sample sizes per crop per administrative zone are shown on top of each bar.

Table S1: Parameter estimates of the Cobb-Douglas (cf. Table 3) and translog stochastic frontier model estimated for wheat-based production systems in Ethiopia (Meher seasons of 2009 and 2013). Significance is indicated by the codes: '***' 0.1% '**' 1% '*' 5% '#' 10%. n.a. = not applicable.

Variables	**Cobb-Douglas model**	**Translog model**
Intercept	9.771 ***	198.809 ***
Meher_2013	-0.054 *	-0.062 *
Growing degrees day (GDD)	-0.584 ***	-30.256 ***
Growing degrees day^2	n.a.	2.384 *
Temperature seasonality (Tseas)	-0.325 ***	2.607
Temperature seasonality^2	n.a.	-0.599
Seed rate (kg/ha)	0.098 ***	-0.679
Seed rate^2	n.a.	0.047 ***
Variety_Improved	0.002	-0.007
Aridity index (AI)	-0.331 ***	-21.096 ***
Aridity index^2	n.a.	1.577 **
Soil available water (AvWater)	-0.008	17.527 *
Soil available water^2	n.a.	0.054
Soil depth_Medium	-0.074 ***	-0.069 **
Soil depth_Shallow	-0.081 **	-0.099 ***
Soil fertility_Medium	-0.057 **	-0.061 **
Soil fertility_Poor	-0.163 ***	-0.148 ***
Water logging_Yes	-0.347 ***	-0.344 ***
Drought_Yes	-0.447 ***	-0.463 ***
Water conservation_Yes	0.059 *	0.071 **
N applied (kg N/ha)	0.272 ***	2.736
N applied^2	n.a.	0.090 ***
Manure use_Yes	0.037	0.028
Crop residues_Yes	0.032	0.030
Previous crop_Legume	0.022	0.023
Previous crop_Other	0.123 ***	0.134 ***
Plough frequency_Three	-0.102 #	-0.100 #
Plough frequency_Four	-0.013	-0.021
Plough frequency_>Five	0.053	0.069
Herbicide use (L/ha)	0.013 ***	0.622
Herbicide use^2	n.a.	0.009 *
Hand-weeding (person-day/ha)	-0.004 #	0.081
Hand-weeding^2	n.a.	0.003
Weeding_YNYes	0.037	-0.094
Pesticide use_Yes	0.121 *	0.089 #
Disease occurence_Yes	-0.316 ***	-0.307 ***
Pest occurrence_Yes	-0.086	-0.082
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.598 ***	0.570 ***
$\gamma = \sigma_u^2 / \sigma^2$	0.742 ***	0.770 ***

Variables	Cobb-Douglas model	Translog model
GDD x Temperature seasonality	n.a.	0.231
GDD x Seed rate	n.a.	-0.225
GDD x Aridity index	n.a.	1.209 **
GDD x Soil available water	n.a.	-0.656
GDD x N applied	n.a.	-0.222 #
GDD x Herbicide use	n.a.	-0.048
GDD x Hand-weeding	n.a.	-0.019
Tseason x Seed rate	n.a.	0.380 **
Tseason x Aridity index	n.a.	-0.260
Tseason x Soil available water	n.a.	-0.420
Tseason x N applied	n.a.	0.140 *
Tseason x Herbicide use	n.a.	-0.008
Tseason x Hand-weeding	n.a.	0.019 *
Seed x Aridity index	n.a.	0.095
Seed x Soil available water	n.a.	-0.167
Seed x N applied	n.a.	-0.102 ***
Seed x Herbicide use	n.a.	0.009 #
Seed x Hand-weeding	n.a.	-0.005
AI x Soil available water	n.a.	-0.903 *
AI x N applied	n.a.	-0.147 #
AI x Herbicide use	n.a.	-0.025
AI x Hand-weeding	n.a.	-0.008
AvWater x N applied	n.a.	-0.012
AvWater x Herbicide use	n.a.	0.041 *
AvWater x Hand-weeding	n.a.	0.022
Napp x Herbicide use	n.a.	0.000
Napp x Hand-weeding	n.a.	0.002
Herb x Hand-weeding	n.a.	-0.001

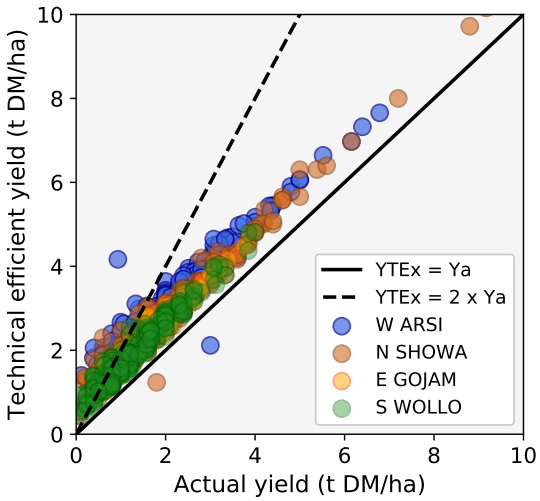

Figure S3: Actual (Ya) and technical efficient (Y_{TEx}) wheat yields for West Arsi, North Showa, East Gojam and South Wollo during the 2009 and 2013 Meher growing seasons. The solid line shows no efficiency yield gap and the dashed line shows an efficiency yield gap equal to 50% Y_{TEx}.

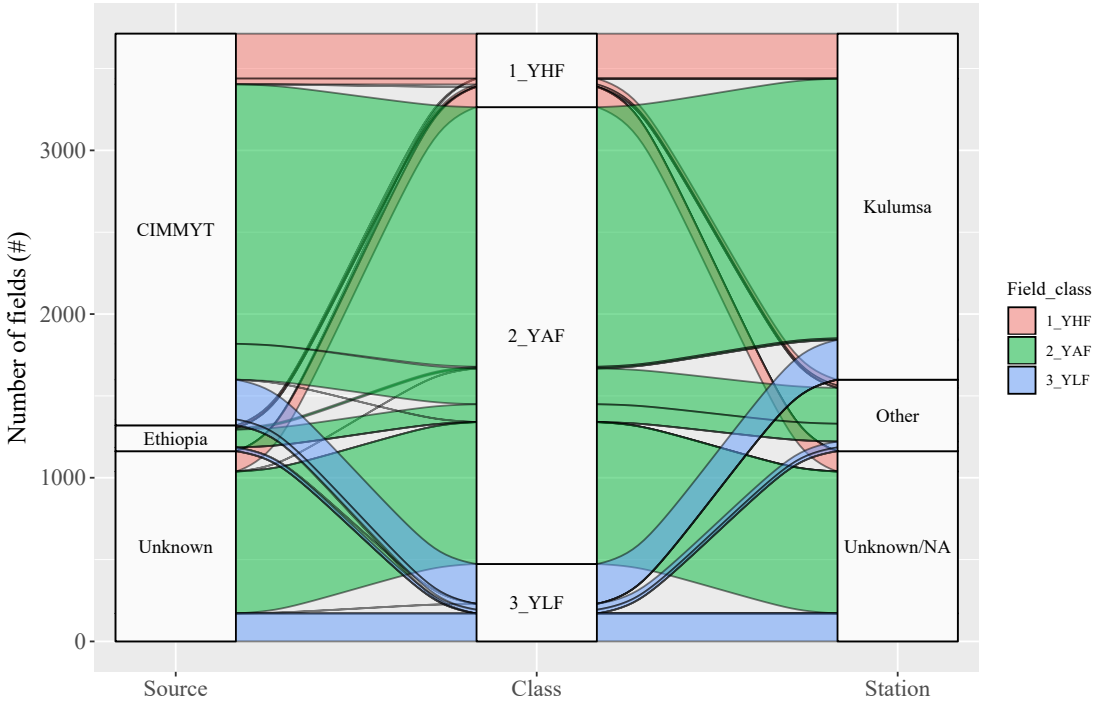

Figure S4: Source of the bread wheat varieties found across farmers' fields in Ethiopia. Data refer to the 2009 and 2013 Meher seasons. Codes: YHF = highest-yielding fields, YAF = average-yielding fields, YLF = lowest-yielding fields.

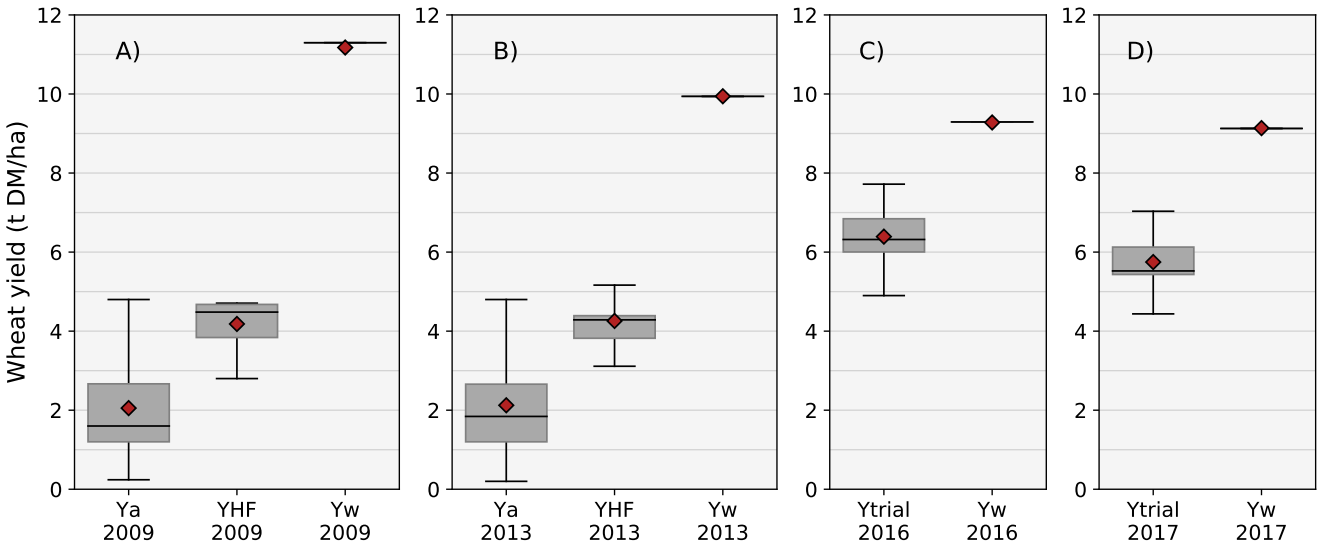

Figure S5: Magnitude and variation of wheat yields in Arsi as per A-B) the farm survey, Ya and Y_{HF}, and C-D) the variety trials conducted in Kulumsa and described in Bezabih et al. (2018), Ytrial. Simulated year-specific Yw are shown to assess differences in biophysical conditions (i.e., solar radiation, temperature and rainfall) between the different years.

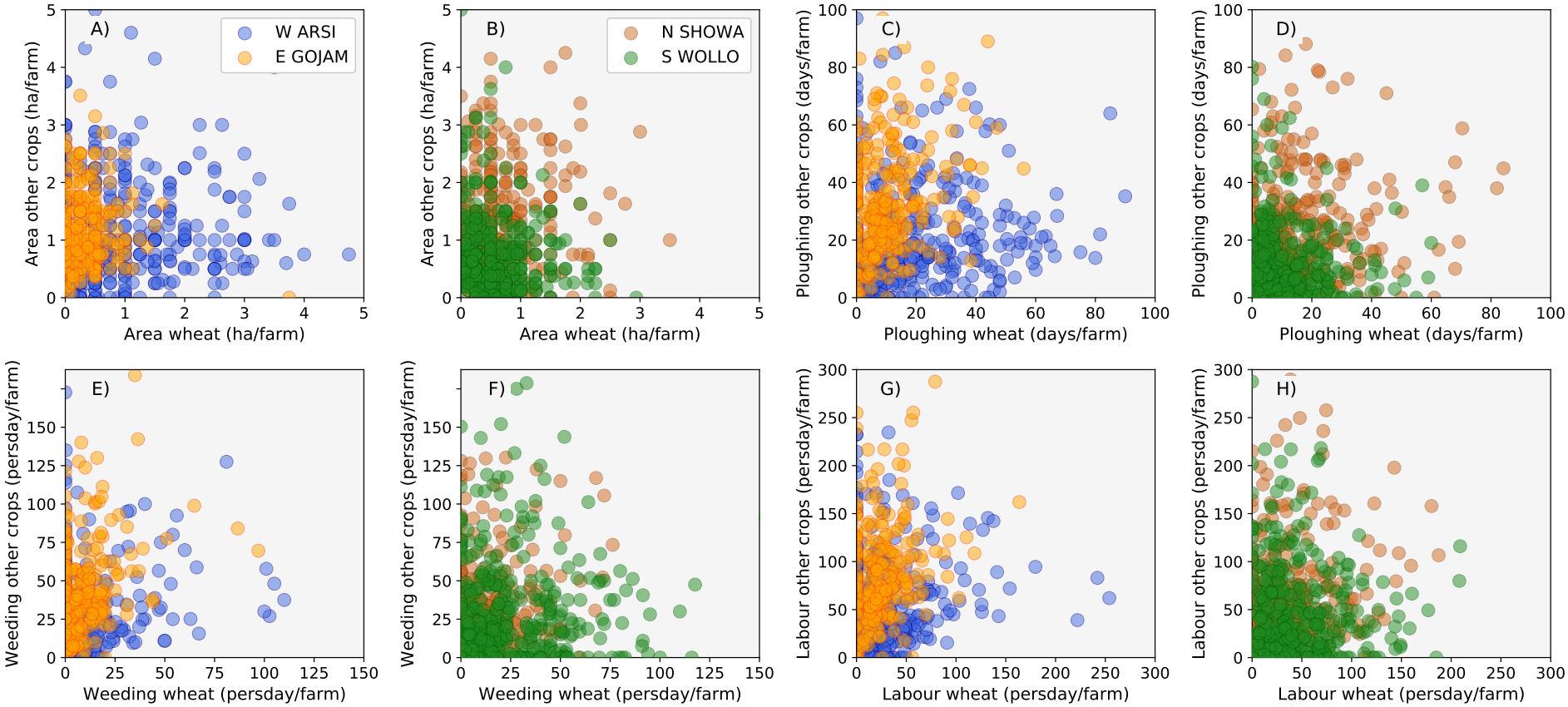

Figure S6: Land and labour allocation for wheat and other crops in West Arsi, North Showa, East Gojam and South Wollo. Each observations depict an individual household in the 2009 and 2013 Meher growing seasons.

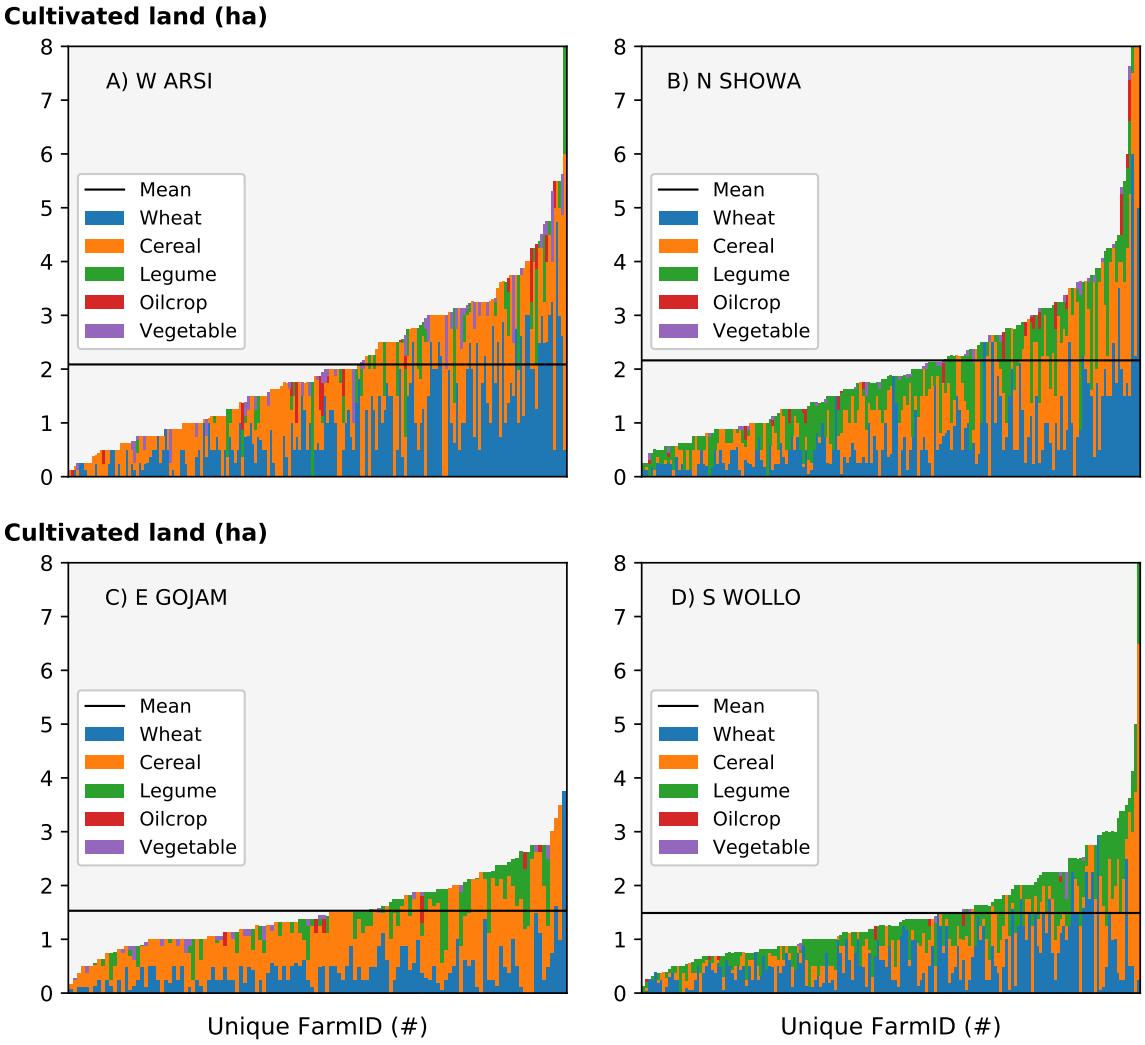

Figure S7: Cultivated land per household during the 2009 Meher seasons in selected administrative zones of Ethiopia: A) West Arsi, B) North Showa, C) East Gojam and D) South Wollo. Different colors depict different types of crops.

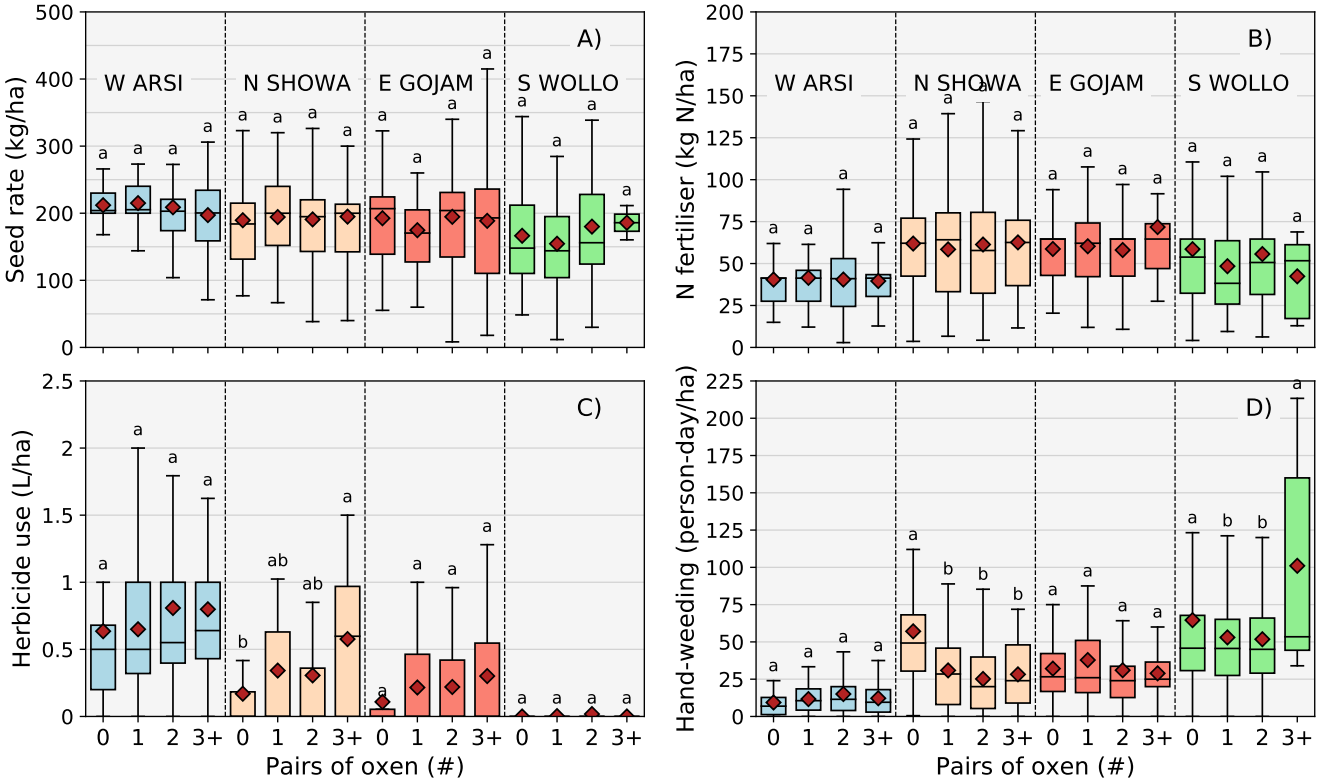

Figure S8: Relationship between number of pairs of oxen owned by households and A) seed rates, B) N fertiliser use, C) herbicide use and D) labour use for hand-weeding for West Arsi, North Showa, East Gojam and South Wollo. For each administrative zone, lower-case letters depict significant differences between groups at 5% significance level.