IMPACT OF CLIMATE CHANGE ON RICE PRODUCTION IN THAILAND

By John Felkner, Kamilya Tazhibayeva and Robert Townsend

Appendix

Table 1 uses the 100 weather realizations generated by WGEN for each climate scenario to compare high and low emission climate scenarios to the neutral scenario. Panel A of table 1 compares amounts of daily precipitation and panel B compares average temperature during daylight hours. In each panel, second column contains mean daily values for each month under neutral climate. The next three columns address shift from neutral to high-emissions climate. Column three shows the corresponding change in mean daily values, column four expresses this change in percent, and column five shows the probability value of the test on the equality of daily precipitation under neutral and high-emissions climates. In the same manner, columns six through eight address shift from neutral to low emissions climate, and columns nine through 11 address shift from low emissions climate to high emissions climate.

Table 2 provides aggregate yield comparisons across the three climate scenarios. Panel A of table 2 shows DSSAT results and panel B shows model results. In each panel, row one shows mean yield change, measured in kilograms per acre, and row two expresses this change as percent of aggregate mean yield under initial climate scenario. Row three shows p-value for the test of equality of means under initial and final climate scenarios.

Table 3 provides plot-level analysis of DSSAT predictions. First three rows of table 3 compare predicted yields, measured in kilograms per acre, when shifting from neutral to high emissions climate. For each plot in our sample of 100 plots, we test the equality of mean yields under neutral and high emissions climates. We then compute the percent of plots that have statistically significant change in yields. These numbers are reported in the first row of table 3,

separately for increases and decreases in yields, for 1, 5 and 10% significance levels. The second row of table 3 reports the actual size of mean yields change over plots conditioned on the change being statistically significant. To give the idea of the scope of yield changes, third row expresses mean yields change of row two in percent. In the same manner, rows four to six compare predicted yields when shifting from neutral to low emissions climate, and rows seven to nine compare yields when shifting from low to high emissions climate.

Table 4 provides plot-level analysis of model predictions and is constructed in the same manner as table 3. Rows one to three compare predicted yields, measured in kilograms per acre, when shifting from neutral to high emissions climate, rows four to six compare predicted yields when shifting from neutral to low emissions climate, and rows seven to nine compare yields when shifting from low to high emissions climate.

Table 5 examines the connection between yield changes and per capita income in farmer's household. Panel A contains results for yield changes significant at 1% level, panel B contains results for yield changes significant at 5% level, and panel C contains results for yield changes significant at 10% level. Row one shows the probability of a household's per capita income being below the median given that the household experienced statistically significant increase (decrease) in yields. Row two shows the difference in soil pH between plots with and without yield increase (decrease), expressed in percent. We test for equality of mean pH values between plots with and without yield increase (decrease) and report the resulting probabilities in row three. In the same manner, rows four and five compare cation exchange capacity (CEC) between plots with and without yield increase (decrease).

We next examine significance of DSSAT as a measure of intermediate output. Intermediate output is an explanatory variable in demand equations for stage 2 and stage 3

inputs.[1] Overall, four different operations were performed in stage 2: weeding and thinning, spraying, fertilizing, and water control. Weeding and thinning, and water control, required only labor input. Spraying operation required both labor and herbicide inputs. Fertilizing operation required both labor and chemical fertilizer inputs. Four different operations were performed in stage 3: harvesting, collection for threshing, threshing, and transport to storage. All stage 3 operations used only labor input.

Our data include households from four villages. Farmers in two of these villages do not perform spraying and water control operations, while farmers in the other two villages do perform these operations. As a measure of intermediate output DSSAT is statistically significant within each of these two groups of villages, but its importance averages out when data are pooled over all four villages. These results are presented in table 6, which shows DSSAT coefficients DSSAT in input demand equations. Panel A shows results for stage 2 input demands, and panel B shows results for stage 3 input demands. Each column corresponds to the input used in a given stage.

[1] We treat equipment inputs (tractors, machines used for spraying, harvesting and so on) as predetermined because most households use equipment which they already own at the start of production cycle.

Table 1 – Comparison of Neutral to Alternative High and Low Emissions Climates

Panel A: Daily Amount of Precipitation, in mm

	Neutral	Neutral to high emissions shift			Neutral to low emissions shift			Low to high emissions shift		
Month	Mean	Mean change	Percent	P-value	Mean change	Percent	P-value	Mean change	Percent	P-value
1	0.123	0.003	2.285	0.01	0.005	4.413	0.01	-0.003	-2.038	0.01
2	0.226	0.003	1.342	0.00	0.007	3.252	0.00	-0.004	-1.850	0.00
3	1.119	0.035	3.157	0.00	0.034	3.062	0.00	0.001	0.092	0.00
4	3.329	0.102	3.053	0.00	0.102	3.053	0.00	0.000	0.000	0.00
5	4.882	0.152	3.111	0.00	0.150	3.066	0.00	0.002	0.044	0.00
6	6.402	-0.059	-0.914	0.00	0.024	0.375	0.00	-0.083	-1.285	0.00
7	5.068	-0.001	-0.021	0.01	0.050	0.984	0.00	-0.051	-0.995	0.00
8	5.691	0.030	0.522	0.00	0.055	0.967	0.00	-0.025	-0.441	0.00
9	8.127	-0.082	-1.013	0.00	0.080	0.990	0.00	-0.163	-1.983	0.00
10	4.391	-0.042	-0.967	0.00	0.042	0.967	0.00	-0.085	-1.915	0.00
11	1.160	-0.014	-1.210	0.00	0.007	0.629	0.00	-0.021	-1.827	0.00
12	0.023	-0.001	-3.467	0.00	0.001	5.270	0.00	-0.002	-8.300	0.00

Panel B: Average Daily Temperature during Daylight Hours, in degrees Centigrade

	Neutral	Neutral to high emissions shift			Neutral to low emissions shift			Low to high emissions shift		
Month	Mean	Mean change	Percent	P-value	Mean change	Percent	P-value	Mean change	Percent	P-value
1	26.697	2.300	8.615	0.00	1.300	4.869	0.00	1.000	3.572	0.00
2	29.083	2.300	7.909	0.00	1.300	4.470	0.00	1.000	3.291	0.00
3	31.391	2.300	7.327	0.00	1.300	4.141	0.00	1.000	3.059	0.00
4	32.357	2.300	7.108	0.00	1.300	4.018	0.00	1.000	2.971	0.00
5	31.339	2.327	7.426	0.00	1.300	4.148	0.00	1.027	3.147	0.00
6	30.464	2.078	6.821	0.00	1.300	4.267	0.00	0.778	2.449	0.00
7	29.894	2.100	7.024	0.00	1.300	4.349	0.00	0.800	2.563	0.00
8	29.414	2.199	7.478	0.00	1.300	4.420	0.00	0.899	2.928	0.00
9	30.350	1.205	3.971	0.00	1.300	4.283	0.00	-0.095	-0.300	0.00
10	28.434	1.298	4.567	0.00	1.300	4.572	0.00	-0.002	-0.005	0.00
11	27.191	1.172	4.311	0.00	1.300	4.781	0.00	-0.128	-0.449	0.00
12	25.733	2.420	9.405	0.00	1.300	5.052	0.00	1.120	4.144	0.00

Table 2 – Aggregate Yield Changes across Climate Scenarios

Panel A: DSSAT Predictions

	Neutral to high emissions	Neutral to low emissions	Low emissions to high emissions
Yield change	-53.521	-209.154	155.633
Percent change	-3.53	-13.79	11.91
P-value[a]	2.683E-02	1.030E-12	2.390E-09

[a] Corresponds to one-sided test in the direction indicated by sign of yield change in the first row: H_a is decrease in yields for columns one and two and H_a is increase in yields for column three.

Panel B: Model Predictions

	Neutral to high emissions	Neutral to low emissions	Low emissions to high emissions
Yield change	-71.152	-79.230	7.981
Percent change	-10.81	-12.04	1.40
P-value[a]	0.000E+00	0.000E+00	1.170E-13

[a] Corresponds to one-sided test in the direction indicated by sign of yield change in the first row: H_a is decrease in yields for columns one and two and H_a is increase in yields for column three.

Table 3 – DSSAT Predictions of Yield Changes

		1 percent significance		5 percent significance		10 percent significance	
Climate shift	Variable	Increase	Decrease	Increase	Decrease	Increase	Decrease
Neutral	Percent of sample	4.21	20.00	10.53	26.32	13.68	36.84
to	Yield change	306.308	-272.687	325.976	-220.047	286.748	-260.302
High emissions	Percent change	102.50	-49.25	49.26	-33.98	38.51	-27.97
Neutral	Percent of sample	3.16	29.47	5.26	35.79	12.63	36.84
to	Yield change	119.723	-581.584	221.085	-605.151	206.053	-591.514
Low emissions	Percent change	123.43	-50.27	78.77	-43.57	36.42	-42.76
Low	Percent of sample	5.26	1.05	9.47	5.26	20.00	10.53
to	Yield change	2301.83	-61.71	1322.69	-75.67	690.29	-117.94
High emissions	Percent change	36.83	-100.00	21.45	-8.60	21.30	-7.68

Table 4 – Economic Model Predictions of Yield Changes

		1 percent significance		5 percent significance		10 percent significance	
Climate shift	Variable	Increase	Decrease	Increase	Decrease	Increase	Decrease
Neutral	Percent of sample	15.85	62.20	15.85	68.29	17.07	69.51
to	Yield change	2.427	-114.872	2.427	-104.719	2.396	-102.973
High emissions	Percent change	0.42	-14.08	0.42	-12.84	0.43	-12.62
Neutral	Percent of sample	79.27	12.20	81.71	12.20	81.71	12.20
to	Yield change	3.840	-675.937	3.898	-675.937	3.898	-675.937
Low emissions	Percent change	0.55	-98.20	0.55	-98.20	0.55	-98.20
Low	Percent of sample	4.82	84.34	4.82	85.54	4.82	85.54
to	Yield change	313.04	-8.32	313.04	-8.29	313.04	-8.29
High emissions	Percent change	0.83	-0.99	0.83	-0.98	0.83	-0.98

Table 5 – Soil Quality and Household Income in Yield Changes

Panel A: Yield Changes Significant at 1% Level

		DSSAT predictions			Model predictions		
Yield change	Variable	Neutral to high emissions	Neutral to low emissions	Low to high emissions	Neutral to high emissions	Neutral to low emissions	Low to high emissions
Increase	Below median per capita income	50.00	0.00	40.00	53.85	47.69	50.00
	pH mean change, in percent	-3.03	3.20	0.92	-4.94	2.98	-10.33
	pH mean change, P-value	0.665	0.691	0.884	0.223	0.333	0.136
	CEC mean change, in percent	73.56	-4.38	16.95	31.07	-7.71	41.63
	CEC mean change, P-value	0.186	0.903	0.620	0.199	0.577	0.363
Decrease	Below median per capita income	68.42	60.71	0.00	49.02	70.00	47.14
	pH mean change, in percent	-4.38	-0.74	0.00	2.32	-6.25	4.40
	pH mean change, P-value	0.207	0.810	0.000	0.416	0.168	0.181
	CEC mean change, in percent	16.14	7.22	0.00	-9.12	23.20	-11.24
	CEC mean change, P-value	0.385	0.634	0.000	0.470	0.370	0.438

Panel B: Yield Changes Significant at 5% Level

		DSSAT predictions			Model predictions		
Yield change	Variable	Neutral to high emissions	Neutral to low emissions	Low to high emissions	Neutral to high emissions	Neutral to low emissions	Low to high emissions
Increase	Below median per capita income	50.00	40.00	33.33	53.85	46.27	50.00
	pH mean change, in percent	-3.53	-2.05	4.30	-4.94	3.68	-10.33
	pH mean change, P-value	0.439	0.745	0.372	0.223	0.243	0.136
	CEC mean change, in percent	23.60	23.78	-8.33	31.07	-6.09	41.63
	CEC mean change, P-value	0.363	0.510	0.689	0.199	0.668	0.363
Decrease	Below median per capita income	60.00	55.88	60.00	50.00	70.00	46.48
	pH mean change, in percent	-3.93	-0.54	-2.42	3.46	-6.25	4.22
	pH mean change, P-value	0.212	0.853	0.701	0.235	0.168	0.205
	CEC mean change, in percent	8.62	8.74	23.91	-14.57	23.20	-9.07
	CEC mean change, P-value	0.588	0.547	0.508	0.246	0.370	0.540

Panel C: Yield Changes Significant at 10% Level

		DSSAT predictions			Model predictions		
Yield change	Variable	Neutral to high emissions	Neutral to low emissions	Low to high emissions	Neutral to high emissions	Neutral to low emissions	Low to high emissions
Increase	Below median per capita income	46.15	50.00	52.63	50.00	46.27	50.00
	pH mean change, in percent	-4.94	-2.32	8.20	-5.07	3.68	-10.33
	pH mean change, P-value	0.223	0.583	0.020	0.197	0.243	0.136
	CEC mean change, in percent	20.65	17.03	-11.07	33.12	-6.09	41.63
	CEC mean change, P-value	0.360	0.454	0.460	0.163	0.668	0.363
Decrease	Below median per capita income	60.00	54.29	70.00	49.12	70.00	46.48
	pH mean change, in percent	-2.03	-1.00	-3.34	3.65	-6.25	4.22
	pH mean change, P-value	0.483	0.730	0.465	0.211	0.168	0.205
	CEC mean change, in percent	-5.25	9.85	15.80	-14.08	23.20	-9.07
	CEC mean change, P-value	0.691	0.497	0.519	0.266	0.370	0.540

Table 6 – DSSAT as a Measure of Intermediate Output[a]

Panel A: Stage 2 Labor and Input Demand Equations

			Labor inputs (hours/acre)			Non-labor inputs (kg/acre)	
	DSSAT	Weeding /				Chemical	
	End of stage 1 value	Thinning	Spraying	Fertilizing	Water control	Fertilizer	Herbicide
Villages 1 and 10	Leaf weight (kg/ha)	-0.1509***		-0.0711***		0.1047***	
	Root weight (kg/ha)	0.3120***		0.1104*		-0.1656**	
Villages 6 and 9	Leaf weight (kg/ha)	0.0552***	-0.0160**	0.0235***	-0.0035	-0.0315***	0.0047
	Root weight (kg/ha)	-0.2053***	0.0770***	-0.1212***	0.0216	0.1519***	-0.0249
All villages	Leaf weight (kg/ha)	-0.0015	-0.0019	-0.0024	-0.0063	0.0067	0.0015
	Root weight (kg/ha)	-0.0289	0.0112	-0.0292	0.0259*	0.0329	-0.0058

Panel B: Stage 3 Labor Demand Equations

	DSSAT	Labor inputs (hours/acre)			
	End of stage 2 value	Harvesting	Collection for threshing	Threshing	Transport to storage
Villages 1 and 10	Leaf weight (kg/ha)	0.0006	-0.0017	-0.0011**	-0.0001
	Root weight (kg/ha)	0.0006	0.0077	0.0010	-0.0024
	Stem weight (kg/ha)	-0.0006***	-0.0001	0.0007***	0.0004*
Villages 6 and 9	Leaf weight (kg/ha)	-0.0014***	0.0015***	-0.0006	0.0031**
	Root weight (kg/ha)	0.0057**	-0.0059**	0.0050	-0.0172**
	Stem weight (kg/ha)	0.0002	-0.0002	-0.0003	0.0005
All villages	Leaf weight (kg/ha)	-0.0004	-0.0001	-0.0002	0.0007
	Root weight (kg/ha)	0.0019	0.0033	-0.0007	-0.0060
	Stem weight (kg/ha)	0.00002	-0.0007*	0.0003	0.0005

[a] ***, **, and * indicate statistical significance at 1, 5, and 10% respectively.