

## Supplementary Material :

# Analyzing Spatial Dependence of Rice Production in Northeast Thailand for Sustainable Agriculture: An Optimal Copula Function Approach

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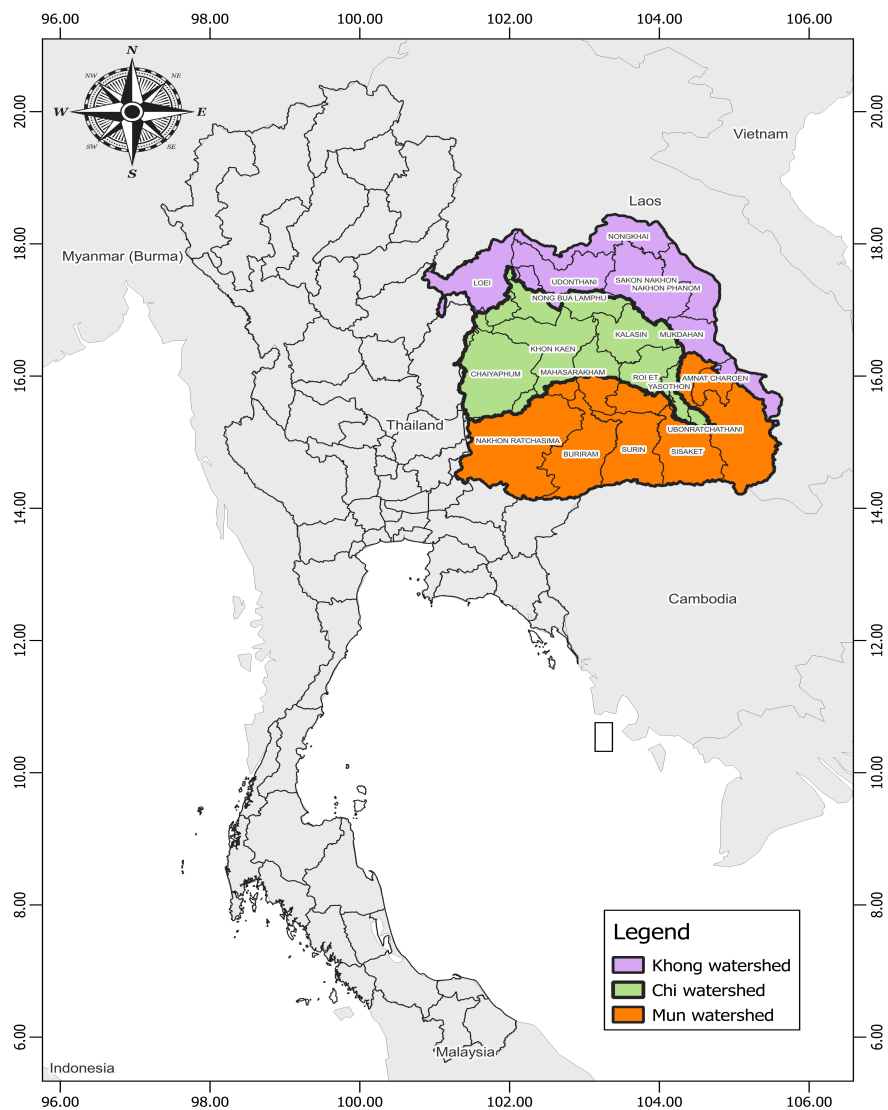
## 1. Area Summary

Northeast Thailand encompasses the flat to undulating lands of the Khorat Plateau between the Phetchabun Range in the west and the Mekong River in the east. These lands are conventionally classified into high, middle, and low terraces, with different susceptibilities to drought and flood and hence different suitabilities for rice and field crops. Most of the arable soils in the Plateau are sandy, acidic, and infertile, comprising mainly quartz and kaolinite from highly weathered parent materials. Originally covered with monsoonal dipterocarp forests, progressive clearing for farming has led to a decline in soil organic matter and mineral nutrients and an increase in soil acidity. Much of the arable land is also salt-affected to varying degrees—strongly in the hilly to undulating regions in the west and weakly in the flat low-lying areas along the Mun and Chi Rivers.

There are twenty provinces in the Northeast, Thailand. They belong to three watersheds or main rivers, Khong, Chi and Mun. Their details are as in Table S1 and Figure S1.

**Table S 1** Provinces in the Northeast regions which belong to main watershed.

Watershed Name	Province
Khong	Loei
	Nong Bua Lamphu
	Udon Thani
	Nong Khai
	Beung Kan
	Sakon Nakhon
	Nakhon Phanom
	Mukdahan
Chi	Amnat Charoen
	Khon Kaen
	Maha Sarakham
	Roi Et
	Kalasin
Mun	Yasothon
	Chaiyaphum
	Nakhon Ratchasima
	Buriram
	Surin
	Sisaket
	Ubon Ratchathani



**Figure S 1** The map of provinces in the Northeast regions which belong to main watershed.

## 2. Data Summary

The summary of crops data, cultivated area (ha), harvested area (ha), productivities (ton) and yield(kg) per ha, in the Northeast regions during 1991-2021 are shown in Table S2 - S5, respectively.

**Table S 2** Summary of cultivated area (ha) in the Northeast regions in selected years.

Province	Min	Average	Max	skewness	kurtosis
Kalasin	537,796	1,263,580	1,604,208	-0.97	5.41
Khon Kaen	1,491,156	2,107,690	2,704,124	-0.21	2.05
Chaiyaphum	562,899	1,346,462	1,835,990	-0.24	3.19
Nakhon Phanom	778,199	1,106,682	1,479,789	0.47	2
Nakhon Ratchasima	1,879,743	3,119,621	3,889,701	-0.82	3.79
Beung Kan	480,528	500,391	561,850	1.6	3.69
Buriram	1,839,593	2,734,872	3,217,615	-1.3	7.52
Maha Sarakham	1,148,559	1,794,322	2,253,259	-0.33	2.53
Mukdahan	228,429	385,658	492,320	0.2	2.08
Yasothon	710,426	1,117,988	1,367,528	0.15	2.9
Roi Et	2,061,733	2,668,835	3,222,284	0.06	2.08
Loei	265,016	393,926	455,577	-1.18	3.67
Sisaket	1,786,767	2,492,575	3,201,512	0.4	1.8
Sakon Nakhon	1,024,110	1,785,697	2,236,939	-0.4	3.52
Surin	1,497,532	2,783,108	3,301,794	-1.59	6.35
Nong Khai	465,700	933,689	1,276,298	-0.68	1.93
Nong Bua Lamphu	647,685	823,122	953,324	-0.35	1.65
Amnat Charoen	853,534	958,035	1,074,427	0.23	2.24
Udon Thani	1,682,081	2,147,493	3,033,845	0.89	2.46
Ubon Ratchathani	2,891,807	3,544,253	4,314,831	0.14	2.01

**Table S 3** Summary of harvested area (ha) in the Northeast regions in selected years.

Province	Min	Average	Max	skewness	kurtosis
Kalasin	526,968	1,191,222	1,516,504	-0.75	5.08
Khon Kaen	1,206,504	1,886,594	2,470,815	-0.44	2.60
Chaiyaphum	504,535	1,179,523	1,718,665	-0.11	3.52
Nakhon Phanom	557,410	1,010,922	1,473,189	0.34	2.56
Nakhon Ratchasima	1,730,854	2,792,024	3,448,251	-0.8	3.16
Beung Kan	407,529	455,976	485,152	-0.48	2.20
Buriram	1,786,980	2,553,609	2,987,172	-0.93	4.36
Maha Sarakham	1,069,139	1,635,388	2,095,471	-0.18	2.41
Mukdahan	178,753	366,835	485,382	-0.03	2.70
Yasothon	679,849	1,043,662	1,300,388	0.04	3.54
Roi Et	2,009,837	2,441,921	2,985,251	0.32	2.14
Loei	228,743	371,510	439,606	-0.96	3.31
Sisaket	1,602,726	2,378,476	3,071,352	0.29	1.90
Sakon Nakhon	823,003	1,668,439	2,210,028	-0.38	3.91
Surin	1,428,146	2,633,325	3,106,496	-1.62	6.50
Nong Khai	449,279	848,730	1,200,984	-0.54	1.89
Nong Bua Lamphu	621,582	763,880	903,048	0.08	1.53
Amnat Charoen	842,106	916,653	1,067,209	0.85	3.01
Udon Thani	1,551,505	2,023,943	3,017,958	1.02	2.90
Ubon Ratchathani	2,588,008	3,385,282	4,163,693	0.09	1.91

**Table S 4** Summary of productivities(ton) in the Northeast regions in selected years.

Province	Min	Average	Max	skewness	kurtosis
Kalasin	132,987	403,758	572,702	-0.22	2.45
Khon Kaen	308,047	574,822	830,166	-0.26	1.94
Chaiyaphum	101,656	381,358	646,020	0.15	2.61
Nakhon Phanom	123,636	305,629	524,374	0.56	2.01
Nakhon Ratchasima	338,263	851,798	1,431,024	-0.10	2.79
Beung Kan	123,844	144,782	165,157	-0.06	2.48
Buriram	382,635	806,889	1,187,300	-0.22	2.59
Maha Sarakham	225,808	514,926	777,572	-0.15	1.87
Mukdahan	47,585	119,826	185,931	0.42	2.07
Yasothon	114,509	312,005	482,904	0.32	2.21
Roi Et	323,293	758,475	1,118,021	-0.07	2.08
Loei	74,106	145,701	198,299	-0.57	4.33
Sisaket	341,492	769,446	1,229,381	0.14	1.88
Sakon Nakhon	206,334	498,748	756,201	-0.05	2.14
Surin	336,945	860,704	1,214,083	-0.2	1.89
Nong Khai	166,023	254,835	401,837	0.29	2.17
Nong Bua Lamphu	194,148	245,059	348,114	0.76	3.15
Amnat Charoen	211,013	290,514	383,946	0.19	2.37
Udon Thani	156,796	594,182	793,994	-1.18	6.62
Ubon Ratchathani	485,860	959,868	1,436,095	0.37	1.99

**Table S 5** Summary of yield (kg) per ha in the Northeast regions in selected years.

Province	Min	Average	Max	skewness	kurtosis
Kalasin	235	335	395	-0.50	2.05
Khon Kaen	185	301	380	-0.55	2.86
Chaiyaphum	201	317	394	-0.28	1.98
Nakhon Phanom	190	294	397	-0.07	2.06
Nakhon Ratchasima	192	300	415	-0.18	2.21
Beung Kan	288	318	382	1.88	6.41
Buriram	214	314	421	-0.22	1.96
Maha Sarakham	186	308	392	-0.48	1.83
Mukdahan	186	320	405	-0.22	2.19
Yasothon	168	294	407	-0.09	1.96
Roi Et	154	307	389	-0.53	2.10
Loei	322	394	543	0.99	4.19
Sisaket	171	318	401	-0.45	2.26
Sakon Nakhon	131	295	372	-0.98	4.24
Surin	217	324	409	-0.30	1.52
Nong Khai	220	308	379	-0.07	1.81
Nong Bua Lamphu	266	321	385	0.21	2.49
Amnat Charoen	241	316	361	-0.82	2.43
Udon Thani	52	302	395	-1.35	6.58
Ubon Ratchathani	158	281	363	-0.39	2.08