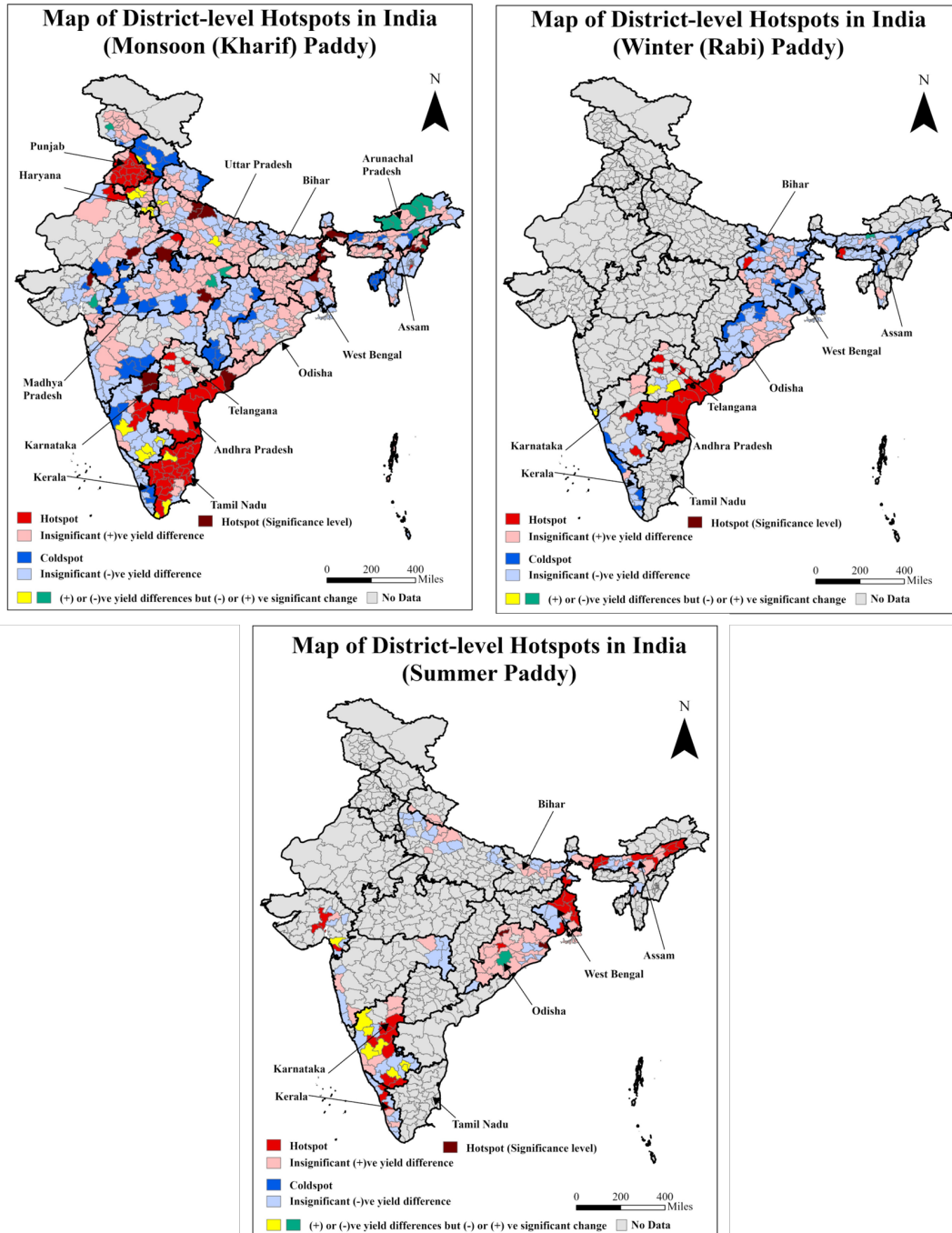


Online Appendix

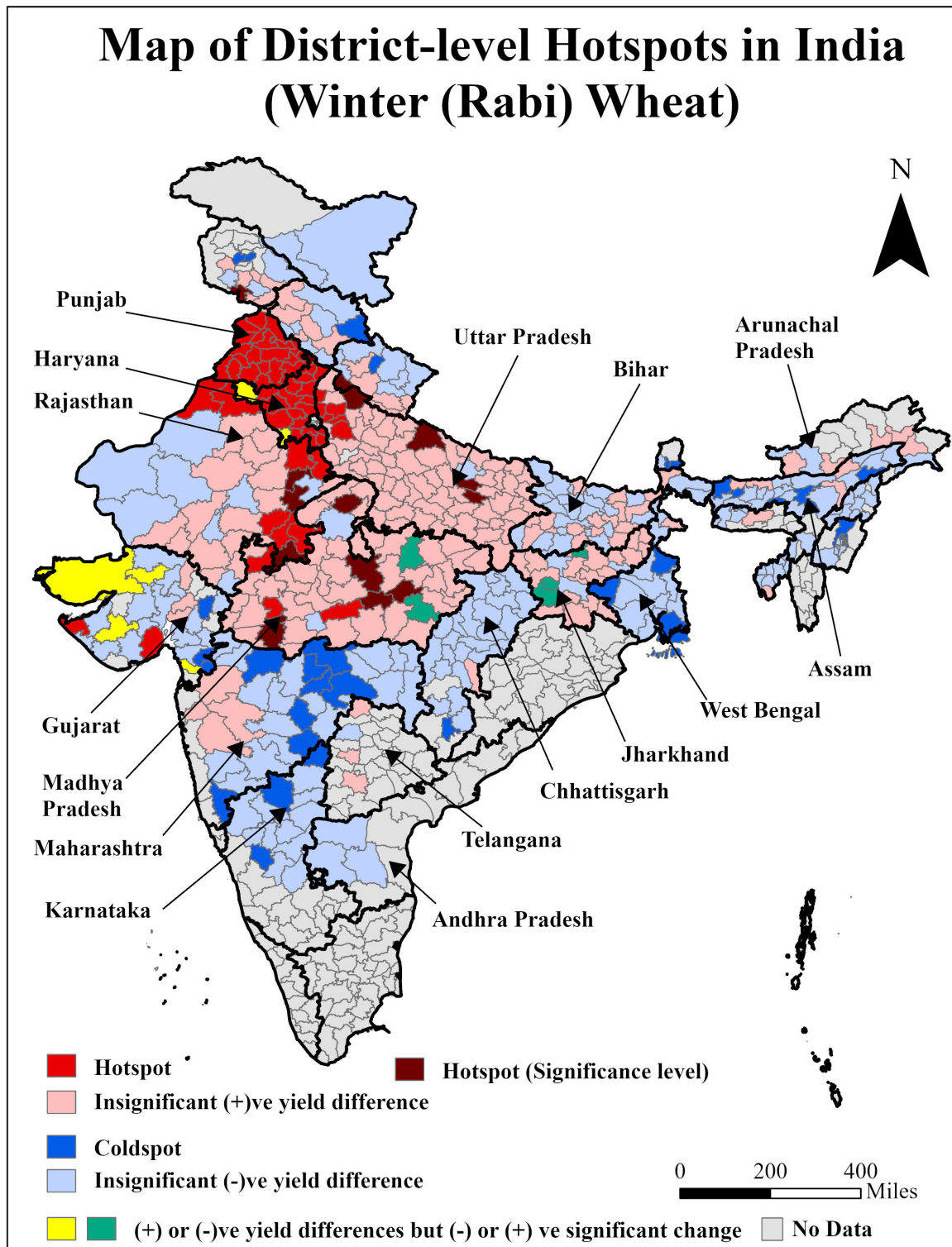
A Hotspot Analysis for Crop Yields (90 percentile rank)



Note: The third map presents the distribution of hotspot districts based on 90 percentile ranks in periods 1 and 2 and significant (+)ve yield difference between these periods. The coldspot districts are classified based on significant (-)ve yield differences between these periods. The average district-level yield of monsoon, winter, and summer paddy nationwide is 2.16, 2.31, and 2.62 t ha⁻¹. The average yields of monsoon, winter, and summer paddy for hotspot (≥ 90 percentile rank) districts are 3.62, 3.85, and 3.33 t ha⁻¹, respectively (Table 3).

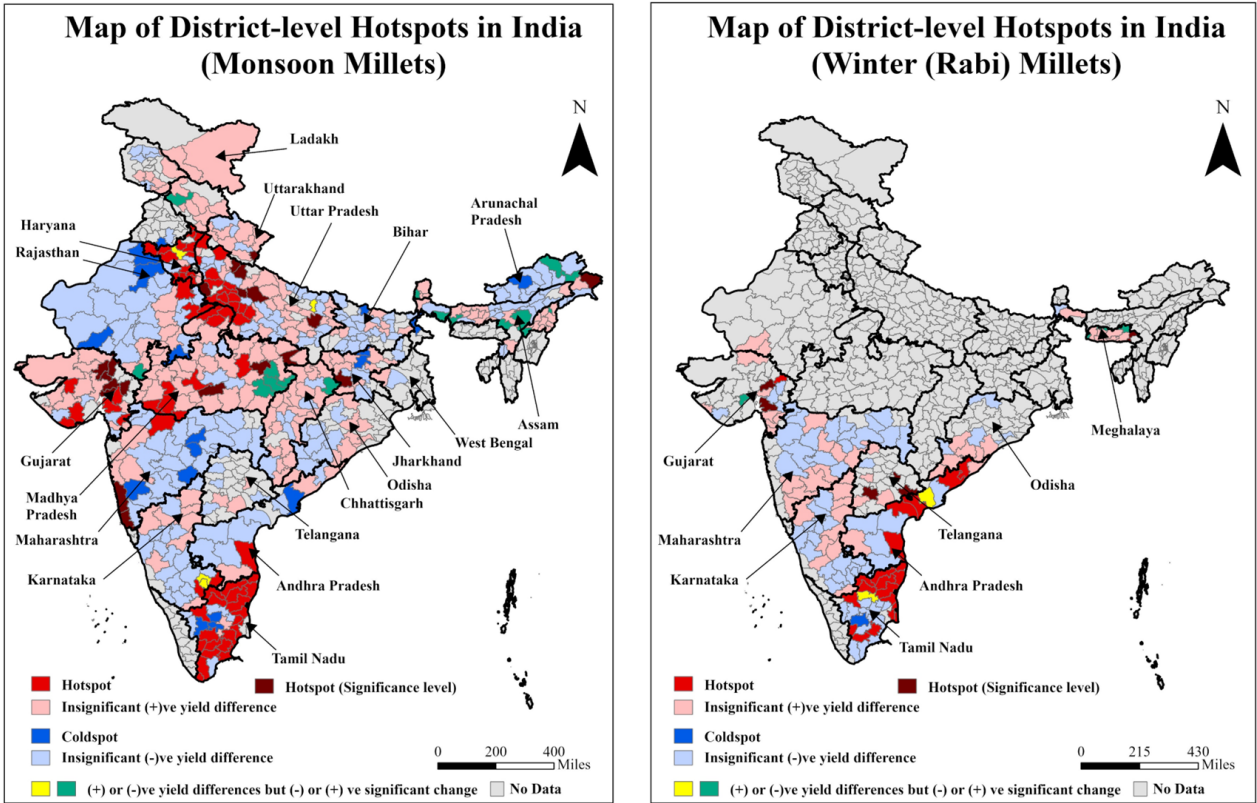
Figure A.1: Maps of hotspots for seasonal paddy yields (≥ 90 percentile rank) in India

Map of District-level Hotspots in India (Winter (Rabi) Wheat)



Note: The third map presents the distribution of hotspot districts based on 90 percentile ranks in periods 1 and 2 and significant (+)ve yield difference between these periods. The coldspot districts are classified based on significant (-)ve yield differences between these periods. The average district-level yield of winter wheat nationwide is 2.54 t ha^{-1} . The average yields of winter wheat for hotspot (≥ 90 percentile rank) districts is 4.25 t ha^{-1} (Table 3).

Figure A.2: Maps of hotspots for winter wheat yields (≥ 90 percentile rank) in India



Note: The third map presents the distribution of hotspot districts based on 90th percentile ranks in periods 1 and 2 and significant (+)ve yield difference between these periods. The coldspot districts are classified based on significant (-)ve yield differences between these periods. The average district-level yields of monsoon and winter millets nationwide are 1.15 and 1.36 t ha⁻¹. The average yields of monsoon and winter millets for hotspot (≥90 percentile rank) districts are 1.95 and 2.65 t ha⁻¹, respectively (Table 3).

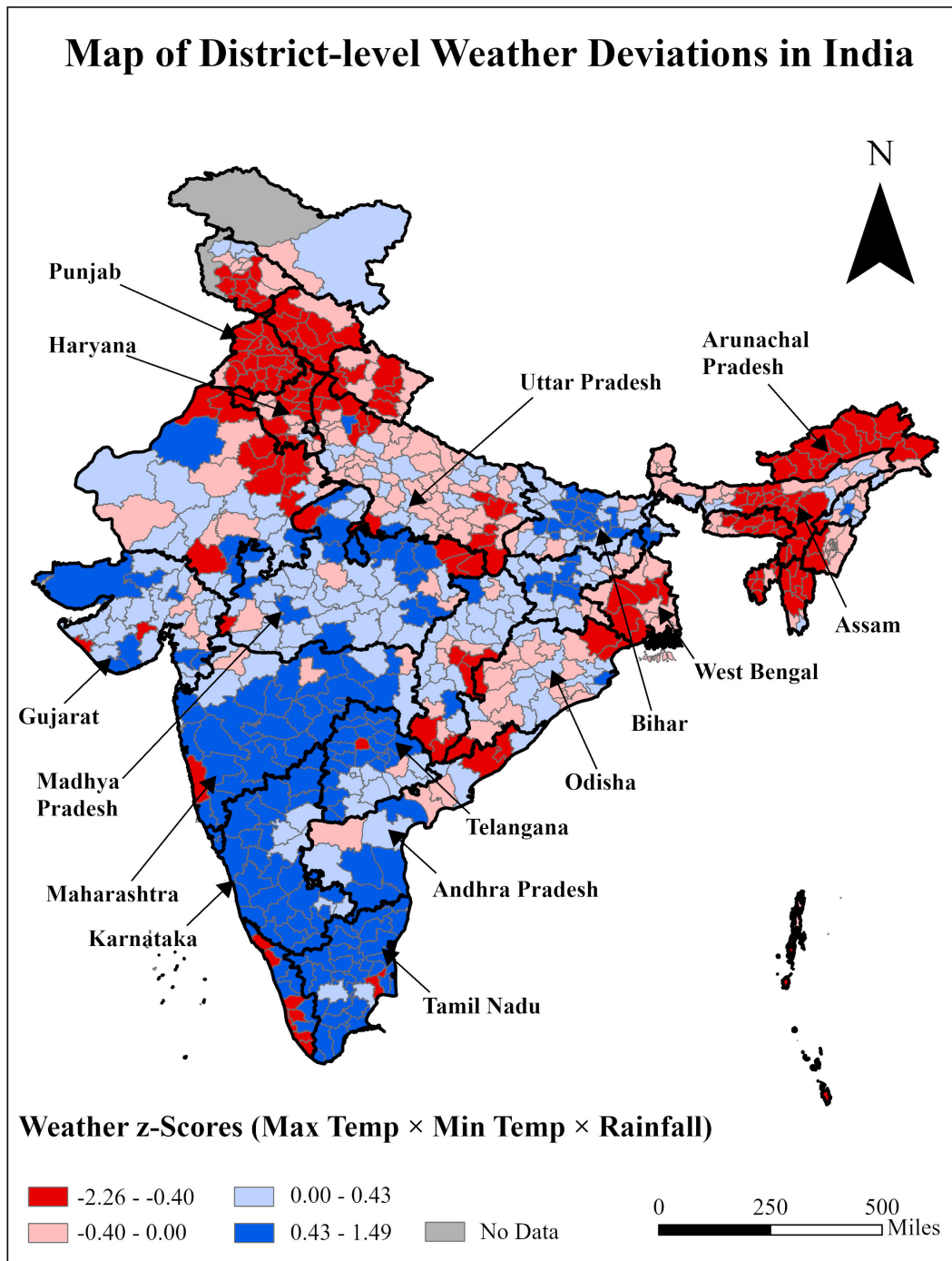
Figure A.3: Maps of hotspots for seasonal millets yields (≥90 percentile rank) in India

B Description and Hotspot Analysis for Independent Variables

Table B.1: Sample of farmers' queries at KCC

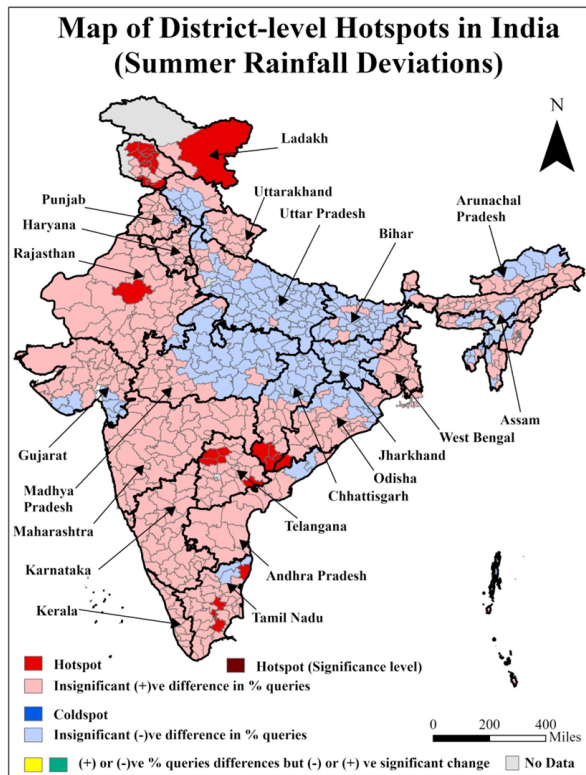
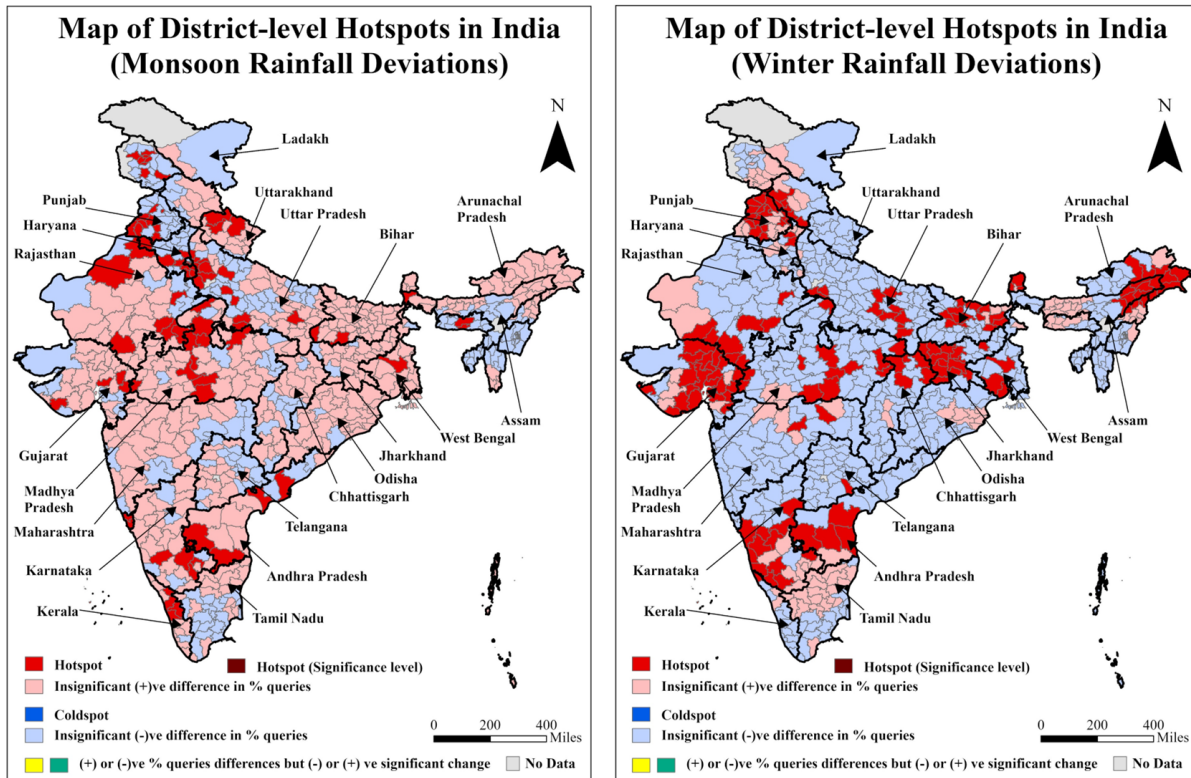
Season	Crop	QueryText	KccAns	StateName	DistrictName	BlockName	CreatedOn
Kharif	Millets	Weed manage- ment in jawar ?	Spray 2, 4- D 40 GM 20-25 days after sowing /15 liters of water	Maharashtra	Beed	Beed	11/19/2018 10:11
Kharif	Wheat	Improved vari- eties of wheat crop?	wh-711, pbw-343, wh-147, up-2338, raj-3765	Haryana	Bhiwani	Tosham	12/1/2012 6:09
Jayad	French Bean	Asking about the control measure of anthracnose in French Bean.	Suggested to spray carbendazim 50 wp @2gm/lt of water or mancozeb @ 2gm/lt of water at 8-10 days of inter- val.use disease free seeds and treatment of seed with carbendazim @ 2gm/kg of seed.	Nagaland	Dimapur	Dhansiripar	11/30/2014 11:30
Kharif	Paddy (Dhan)	SRI method	Detail POP explained	Odisha	Ganjam	Bhanjanagar	8/3/2018 18:14
Jayad	Paddy (Dhan)	Ask about seed of paddy	Prathika, Puja	West Bengal	Murshidabad	Kandi	6/13/2013 8:22

Source: Kisan Call Center database



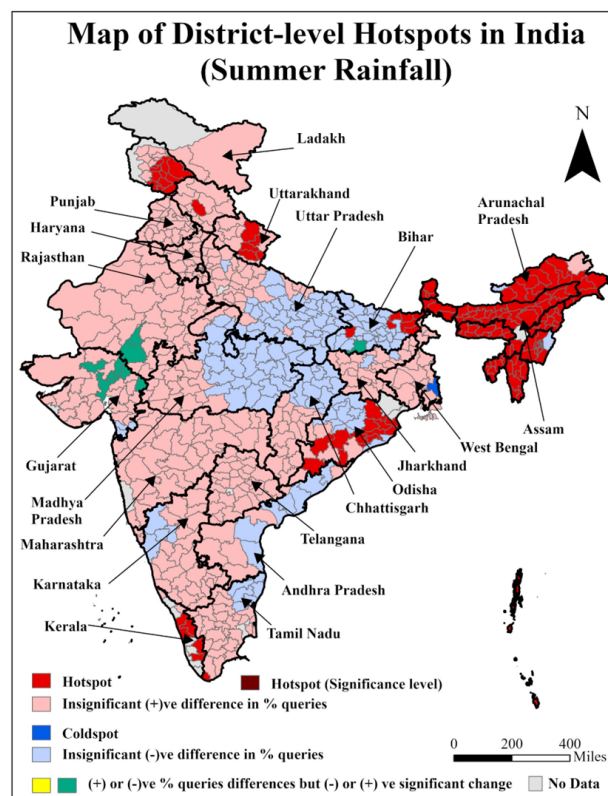
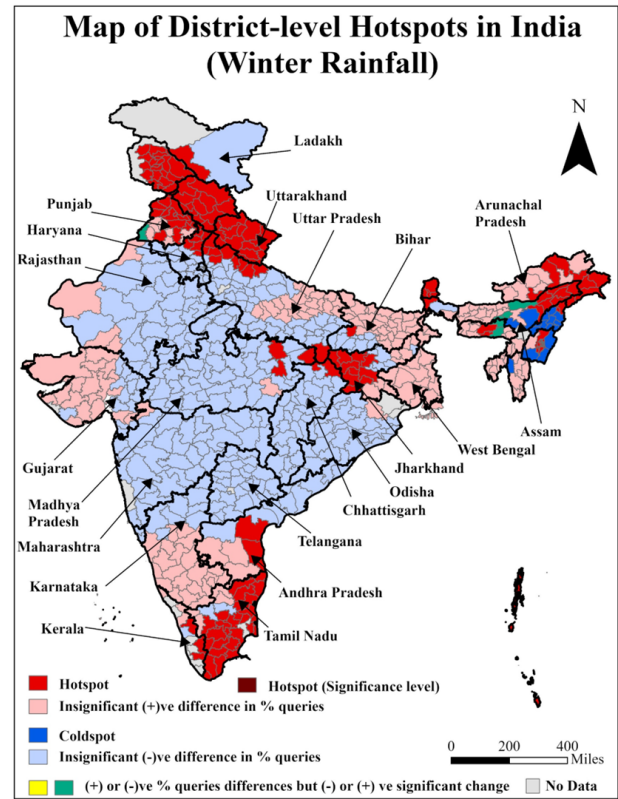
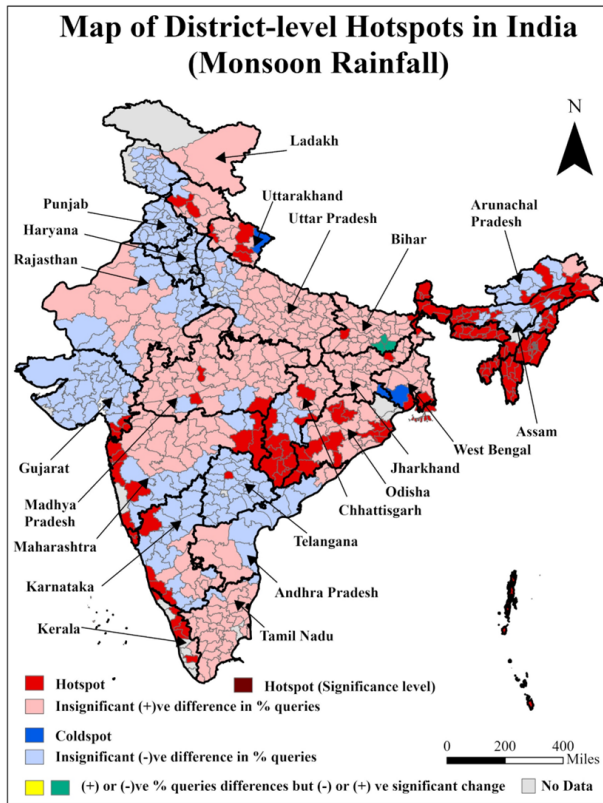
Note: The map illustrates the average z-scores associated with historical deviations in weather parameters, Maximum Temperature, Minimum Temperature, and Rainfall. Z-scores with positive values are indicative of deviations in weather conditions that exceed the average historical norms, while negative z-scores represent deviations that fall below these traditional averages. A z-score approaching zero indicates the weather deviations are nearing the historical average values, suggesting minimal variation from average conditions.

Figure B.1: Map of district-level weather deviations in India



Note: The hotspot maps present the distribution of hotspot districts based on 80 percentile ranks in periods 1 and 2 and significant (+)ve yield difference between these periods. The coldspot districts are classified based on significant (-)ve rainfall deviation differences between these periods. The average nationwide district-level rainfall deviations for monsoon, winter, and summer are 0.99, 0.74, and 0.89, respectively.

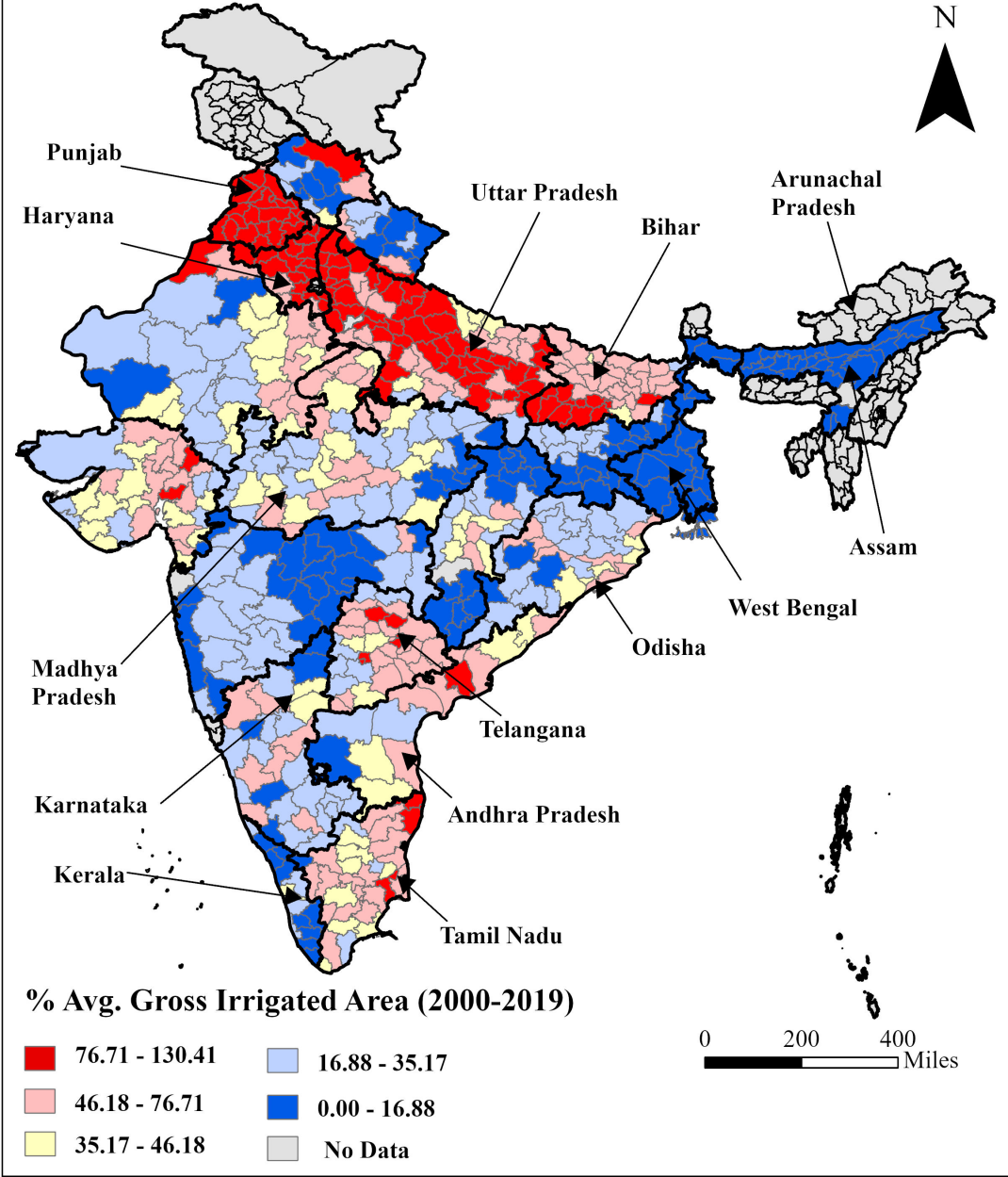
Figure B.2: Maps of hotspots for seasonal rainfall deviations in India



Note: The hotspot maps show the distribution of hotspot districts based on 80th percentile ranks in periods 1 and 2, and the significant (+)ve yield difference between these periods. The coldspot districts are classified based on significant (-)ve observed rainfall differences between these periods. The average district-level observed rainfall figures nationwide for monsoon, winter, and summer are 192.96, 12.99, and 69.72 mm.

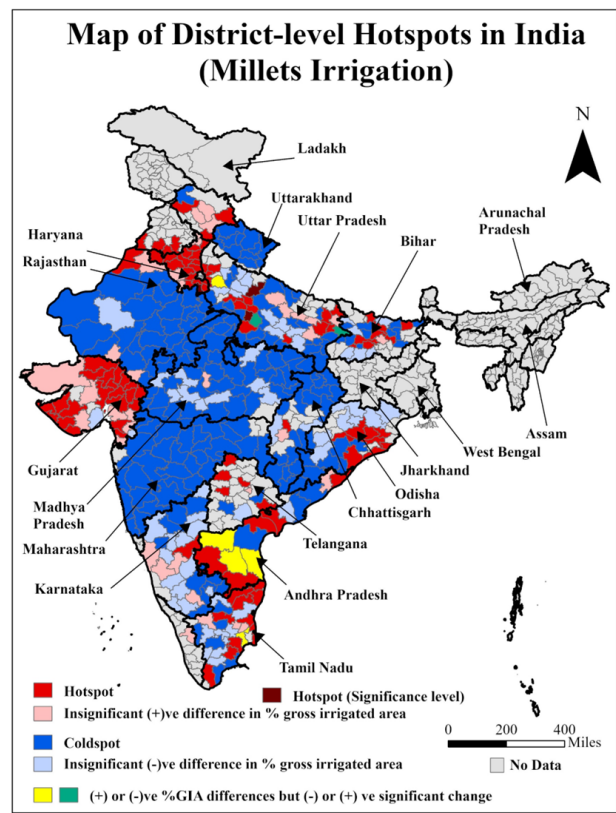
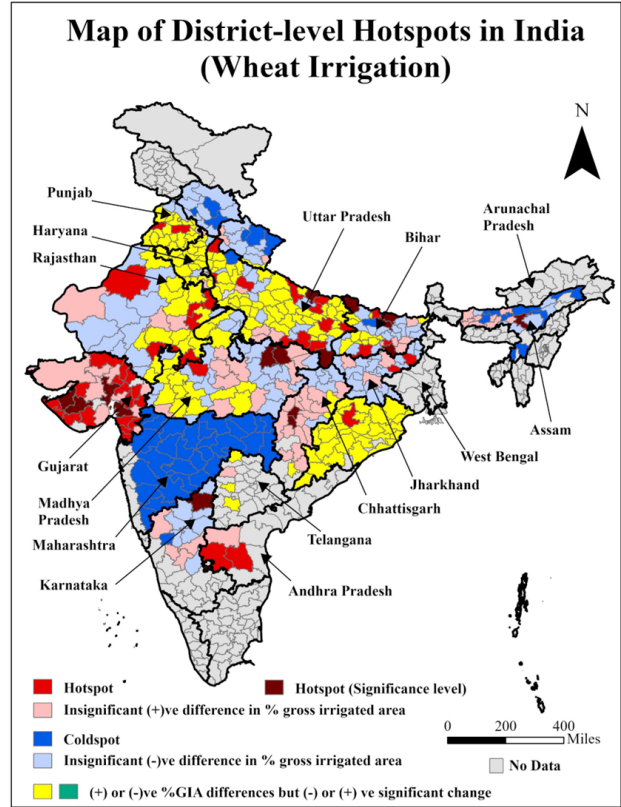
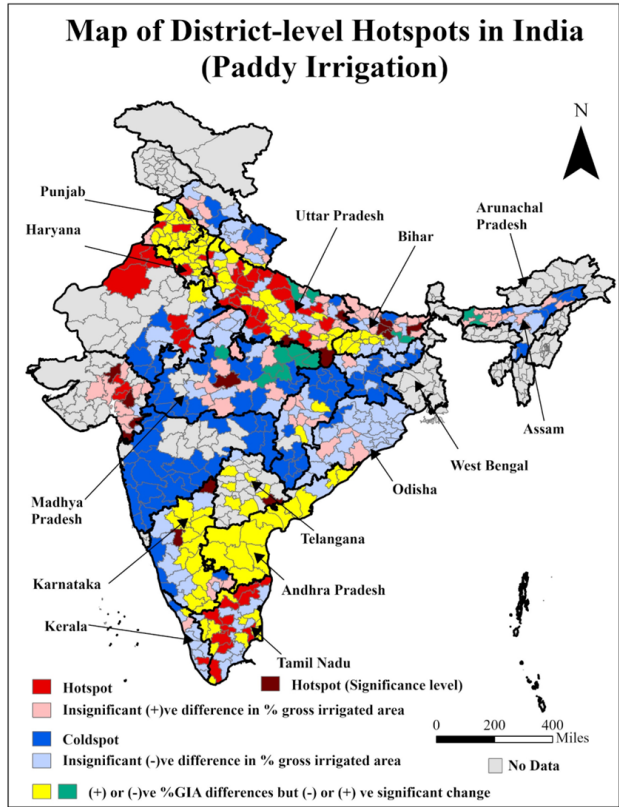
Figure B.3: Maps of hotspots for seasonal rainfall in India

Map of of Average Percentage Gross Irrigated Area in India



Note: This map presents district-level average gross irrigated area across all crops and seasons in India.

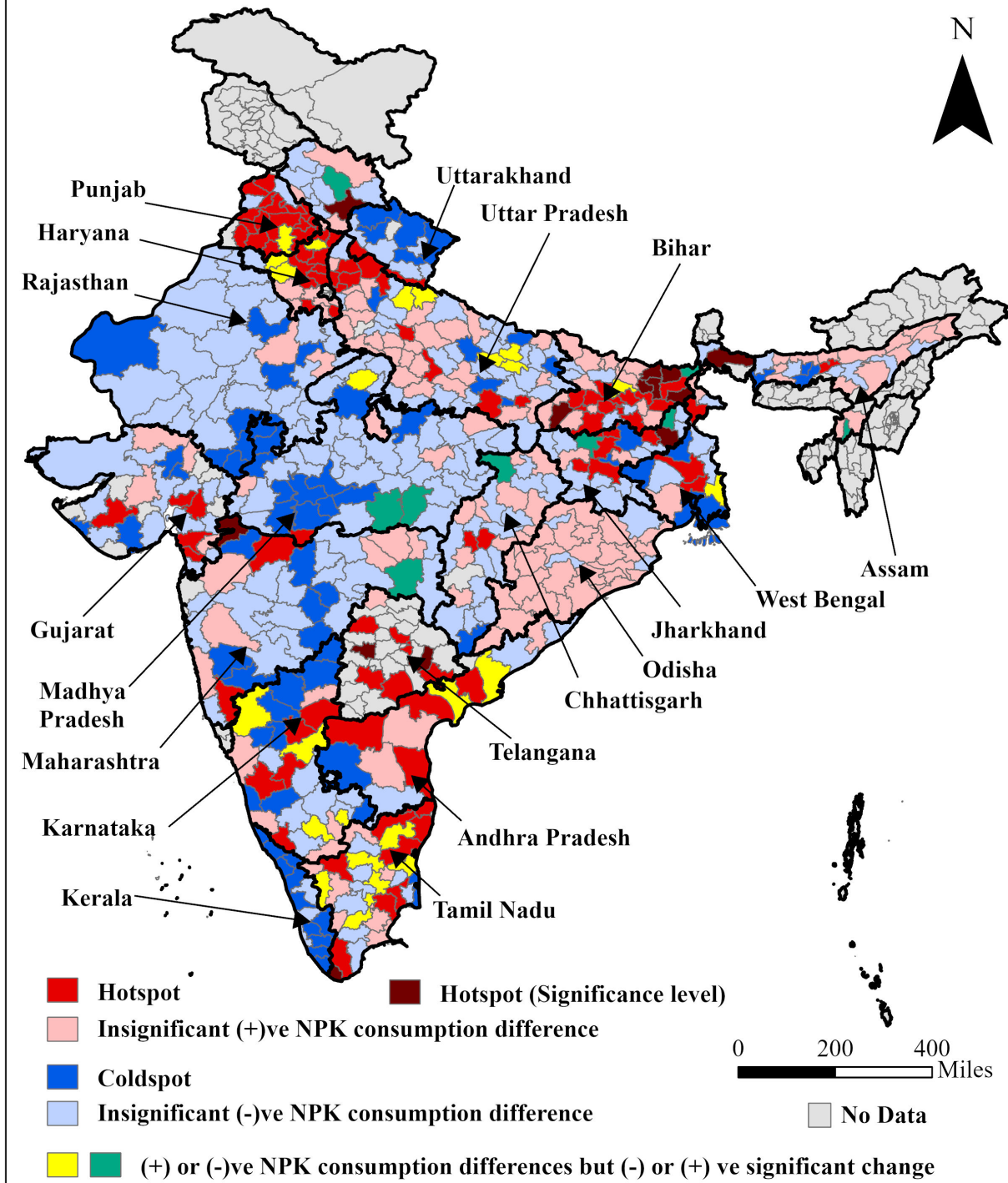
Figure B.4: Maps of district-level average percentage gross irrigated area in India



Note: The hotspot maps present the distribution of hotspot districts based on 80 percentile ranks in periods 1 and 2 and significant (+)ve percentage gross irrigated area difference between these periods. The coldspot districts are classified based on significant (-)ve percentage gross irrigated area differences between these periods. The average district-level percentage gross irrigated areas nationwide for paddy, wheat, and millets are 55.42, 75.27, and 18.38.

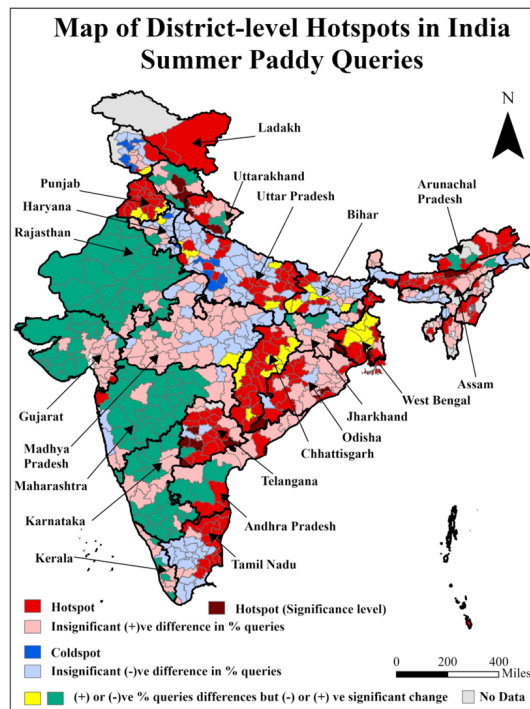
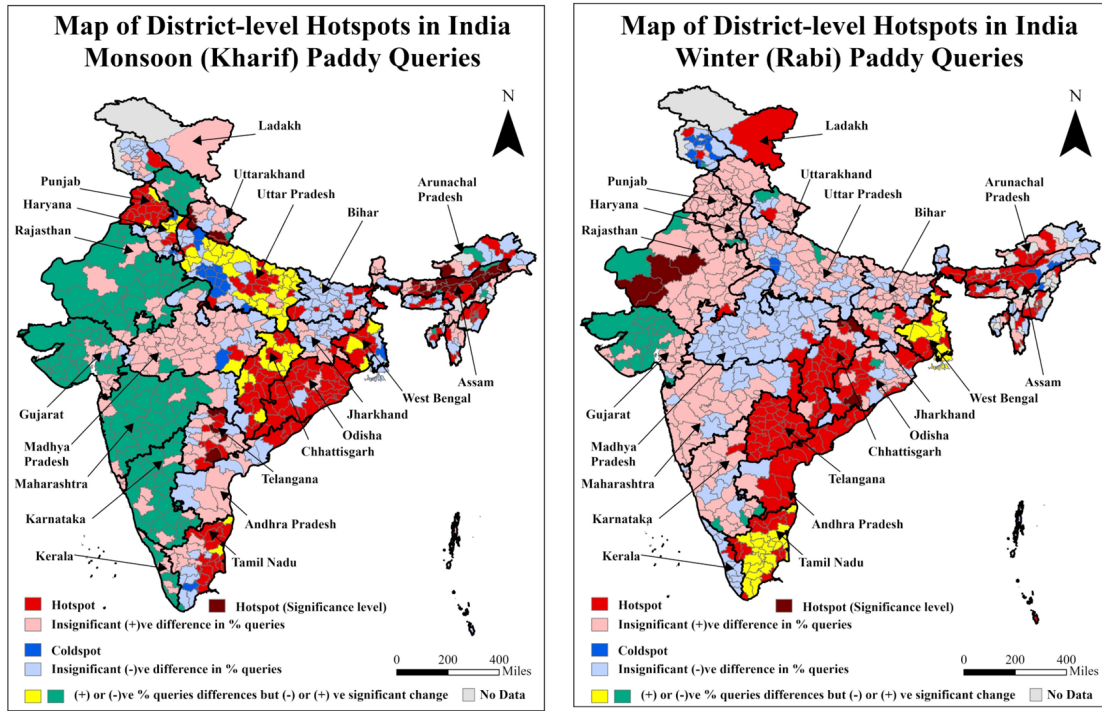
Figure B.5: Maps of hotspots for gross irrigated area based on crops in India

Map of District-level Hotspots in India (Fertilizer Consumption)



Note: The hotspot maps present the distribution of hotspot districts based on 80 percentile ranks in periods 1 and 2 and significant (+)ve fertilizer consumption per gross cropped area difference between these periods. The coldspot districts are classified based on significant (-)ve fertilizer consumption per gross cropped area differences between these periods. The average district-level fertilizer consumption per gross cropped area nationwide is 142.94 kg per hectare.

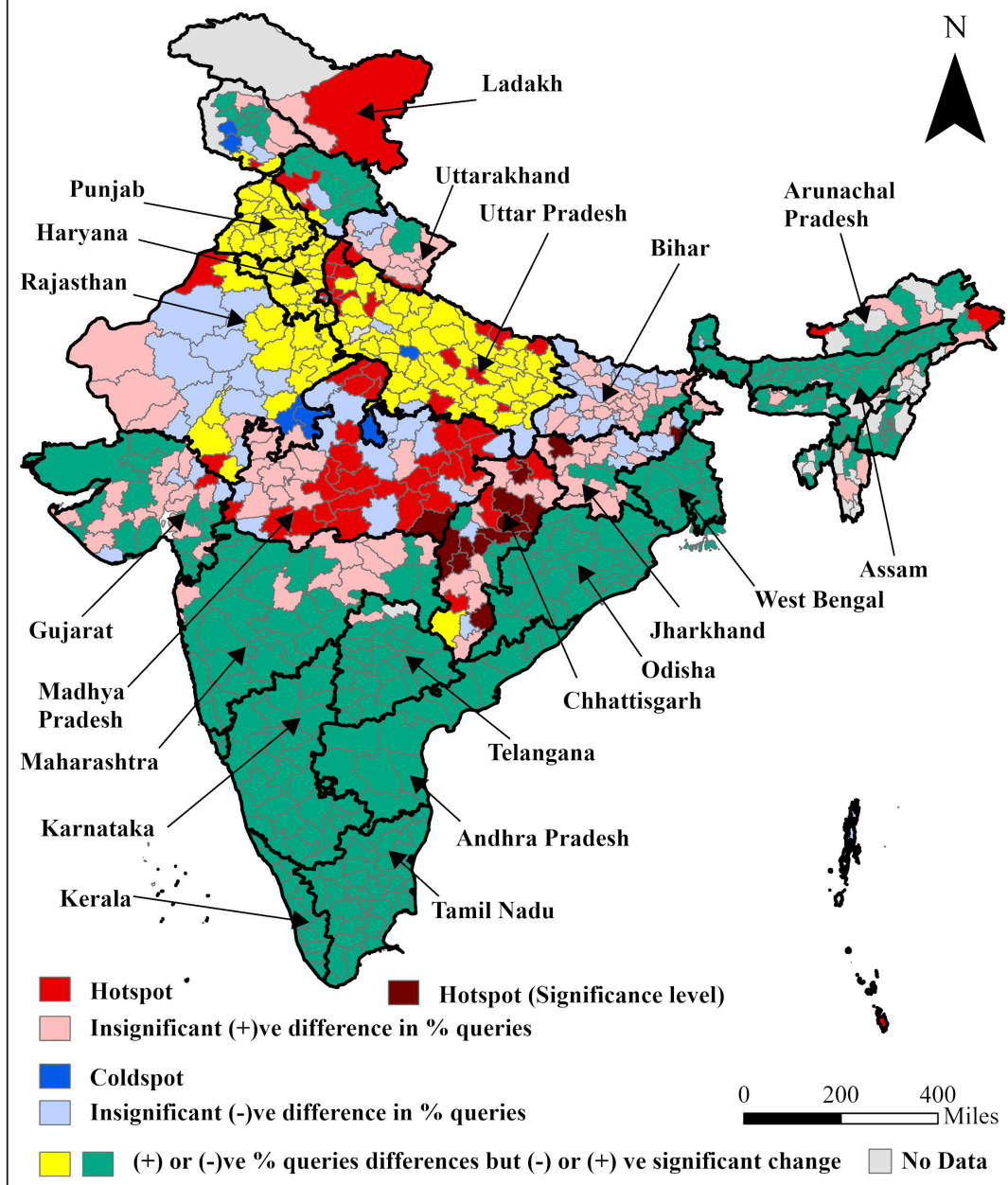
Figure B.6: Maps of hotspots for fertilizer consumption in India



Note: The hotspot maps present the distribution of hotspot districts based on 80 percentile ranks in periods 1 and 2 and significant (+)ve percentage queries difference between these periods. The coldspot districts are classified based on significant (-)ve percentage queries differences between these periods. The average district-level percentages of queries for monsoon, winter, and summer paddy nationwide are 14.74, 7.12, and 9.24. The average percentages of queries for monsoon, winter, and summer paddy for hotspot (≥ 80 percentile rank) districts are 17.07, 10.51, and 10.97, respectively (Table 3).

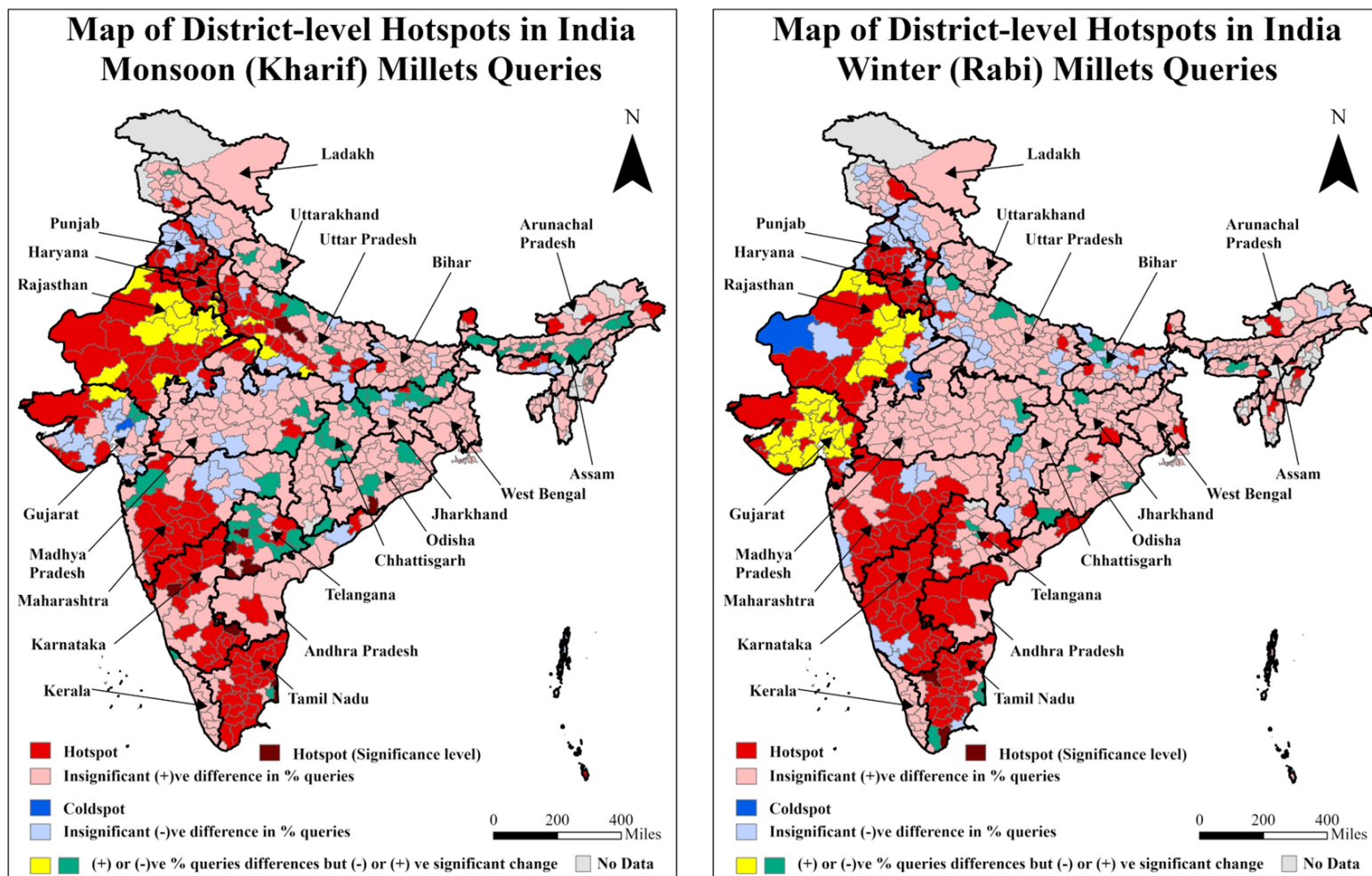
Figure B.7: Map of hotspots for paddy-related queries at KCC in India

Map of District-level Hotspots in India Winter (Rabi) Wheat Queries



Note: The hotspot maps present the distribution of hotspot districts based on 80 percentile ranks in periods 1 and 2 and significant (+)ve percentage queries difference between these periods. The coldspot districts are classified based on significant (-)ve percentage queries differences between these periods. The average district-level percentage of winter wheat queries nationwide is 11.56. The average percentages of queries of winter wheat for hotspot (≥ 80 percentile rank) districts are 24.09 (Table 3).

Figure B.8: Map of hotspots for wheat-related queries at KCC in India



Note: The hotspot maps present the distribution of hotspot districts based on 80 percentile ranks in periods 1 and 2 and significant (+)ve percentage queries difference between these periods. The coldspot districts are classified based on significant (-)ve percentage queries differences between these periods. The average district-level percentages of queries for monsoon and winter millets nationwide are 0.58 and 0.86. The average percentages of queries for monsoon and winter millets for hotspot (≥ 80 percentile rank) districts are 0.98 and 0.77, respectively (Table 3).

Figure B.9: Map of hotspots for millet-related queries at KCC in India

C Full Regression Results: Factors Associated with Crop yields in India

Table C.1: Relation between rainfall and irrigation coverage in India (full regression)

	<i>Dependent variable:</i>		
	Percentage Gross Irrigated Area _{(ds)cp}		
	(1)	(2)	(3)
Rainfall _{(ds)rp}	-0.009 (0.031)		-0.062 (0.038)
Rainfall Deviations _{(ds)rp}		1.579*** (0.449)	1.876*** (0.514)
Crop: Paddy _{(ds)rp}	39.139*** (0.940)	38.909*** (0.938)	39.139*** (0.940)
Crop: Wheat _{(ds)rp}	51.367*** (1.786)	51.671*** (1.760)	51.371*** (1.773)
Period 2 (2015-2019) _{(ds)r}	3.871*** (0.605)	3.874*** (0.583)	3.842*** (0.604)
Constant	42.881*** (8.894)	39.334*** (8.918)	42.261*** (9.187)
Region f.e.	✓	✓	✓
District × Season f.e.	✓	✓	✓
Observations	3,709	3,789	3,709
R ²	0.808	0.810	0.809

Note: All the regressions are based on data at the district-level for two periods (Period 1: 2010-2014 and Period 2: 2015-2019). Column (1) represents the regression results between the crop-specific average period-level percentages of gross irrigated area and average rainfall based on seasons and periods. Similarly, column (2) is the regression results between crop-specific irrigation coverage and rainfall deviations. Column (3) is the regression results when observed rainfall and rainfall deviations are regressed with crop-specific irrigation coverage. All regression equations include Region, district × season, Period, and Crop fixed effects. Since the study is at the India-level, we have a long list of districts (732) and regions (6: North, South, East, West, Central, and North-east). Thus, we indicate that the region and district × season fixed effects are included in these regressions. Standard errors are clustered at the district level and are reported in parentheses. d: District, s: State, c: Crop types (Paddy, Wheat, Millets), r: Season, p: Periods. Significance level: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table C.2: Factors associated with crop yields in India (full regression)

	Dependent variable: Yield Deviation _{(ds)crp} (t ha ⁻¹)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rainfall _{(ds)rp}	0.0001 (0.0005)		0.0004 (0.001)	0.002** (0.001)	0.002** (0.001)	0.002* (0.001)	0.001 (0.001)
Rainfall Deviation _{(ds)rp}		-0.009 (0.008)	-0.011 (0.009)	-0.032** (0.010)	-0.033** (0.011)	-0.025* (0.012)	
GIA _{(ds)cp}				0.008*** (0.001)	0.007*** (0.001)	0.007*** (0.001)	0.007*** (0.001)
NPK _{(ds)p}					0.001* (0.0002)	0.0005* (0.0002)	0.0005* (0.0002)
KCC Queries _{(ds)crp}					0.005* (0.002)	0.006* (0.002)	0.006* (0.002)
Maximum Temperature _{(ds)rp}						0.094** (0.030)	0.104*** (0.030)
Minimum Temperature _{(ds)rp}						-0.055 (0.037)	-0.070 (0.036)
Max Temp Deviation _{(ds)rp}						-0.009 (0.010)	-0.014 (0.010)
Min Temp Deviation _{(ds)rp}						-0.015 (0.012)	-0.011 (0.012)
Crop: Paddy _{(ds)rp}	-0.046** (0.018)	-0.043** (0.018)	-0.046** (0.018)	-0.344*** (0.026)	-0.402*** (0.029)	-0.411*** (0.029)	-0.409*** (0.036)
Crop: Wheat _{(ds)rp}	-0.286*** (0.037)	-0.280*** (0.037)	-0.286*** (0.037)	-0.617*** (0.044)	-0.654*** (0.044)	-0.657*** (0.044)	-0.655*** (0.054)
Period 2 (2015-2019) _{(ds)r}	-0.028** (0.012)	-0.032*** (0.012)	-0.028** (0.012)	-0.048*** (0.013)	-0.035** (0.014)	-0.028* (0.015)	-0.026 (0.019)
Constant	-0.414 (0.347)	-0.365 (0.288)	-0.510 (0.352)	-0.241 (0.195)	-0.290 (0.206)	-1.943* (0.991)	-1.915 (1.213)
Region f.e.	✓	✓	✓	✓	✓	✓	✓
District × Season f.e.	✓	✓	✓	✓	✓	✓	✓
Observations	4,452	4,532	4,452	3,709	3,652	3,652	3,652
R ²	0.786	0.786	0.786	0.816	0.820	0.820	0.820

Note: All the regressions are based on data at the district-level for two periods (Period 1: 2010-2014 and Period 2: 2015-2019). Columns (1) to (4) display the relation between seasonal crop yield deviations and rainfall, rainfall deviations, and crop-specific percentage gross irrigated area. In column (5), we include other input factors (fertilizer consumption and the percentage of KCC queries). Column (6) includes other weather variables as controls (maximum temperature, minimum temperature, and their average historical deviations). In column (7), we only exclude rainfall deviation as irrigation and rainfall deviation are significantly correlated (Table C.1). There is no significant change in estimates when comparing column (6) and column (7). All regression equations include district × season, Period, and Region fixed effects. Since the study is at the India-level, we have a long list of districts (732) and regions (6: North, South, East, West, Central, and North-east). Thus, we indicate that the region and district × season fixed effects are included in these regressions. Standard errors are clustered at the district level and are reported in parentheses. GIA: Gross Irrigated Area, NPK: Total Fertilizer consumption (GCA) per Gross Cropped Area (GCA), KCC: Farmers (*Kisan*) call center, d: District, s: State, c: Crop types (Paddy, Wheat, Millets), r: Season, p: Periods. Significance level: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.