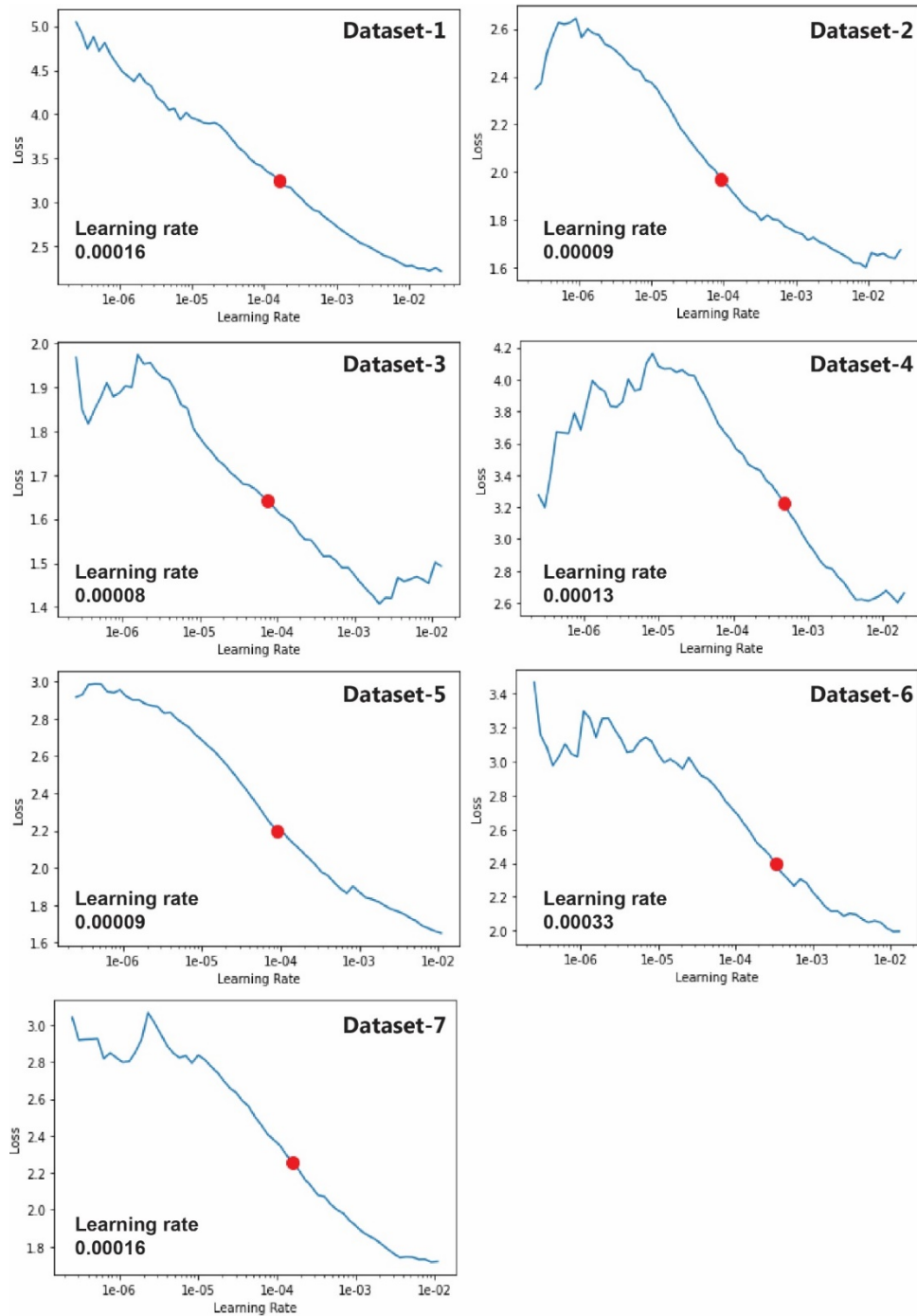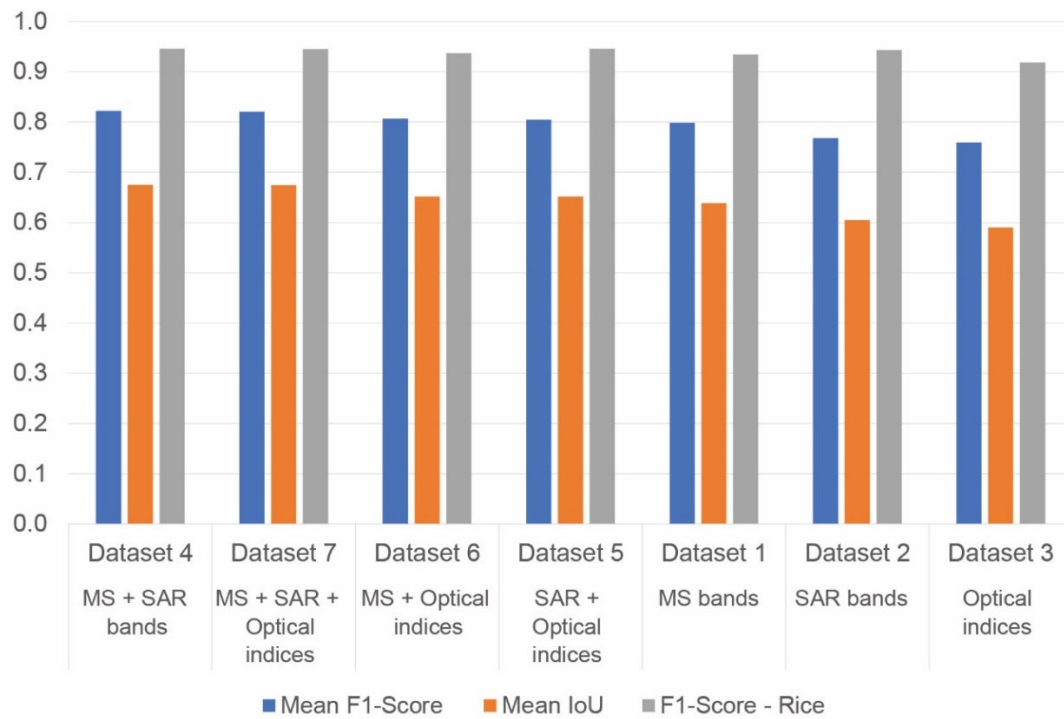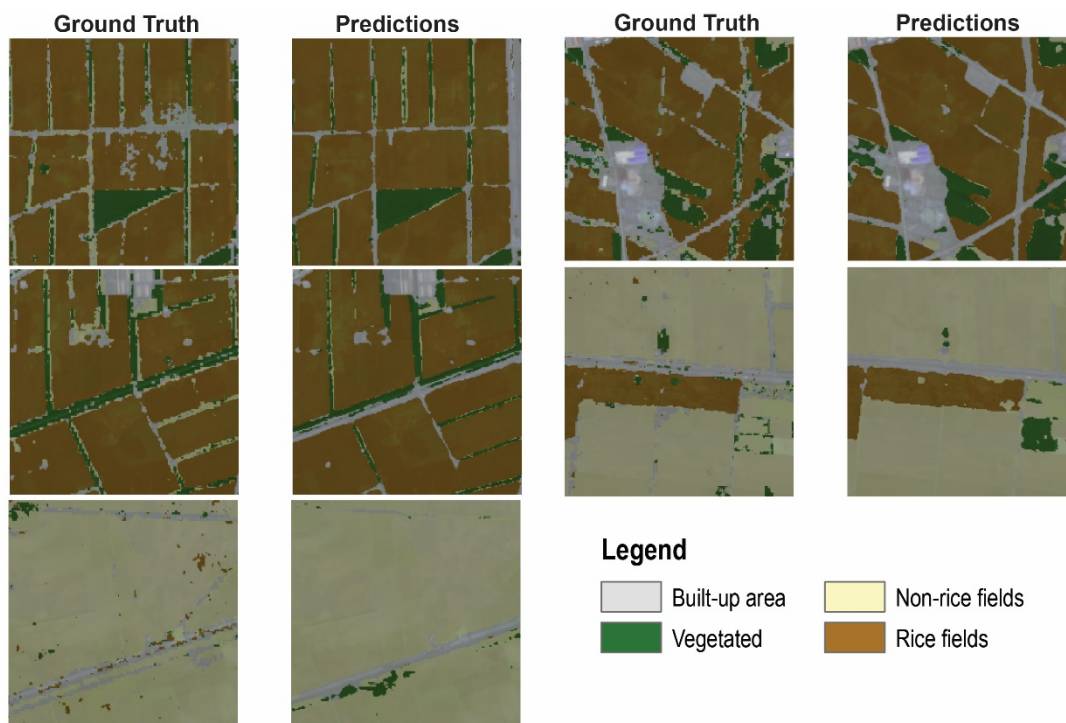*Supplementary Materials for "Deep ResU-Net Convolutional Neural Networks Segmentation for Smallholder Paddy Rice Mapping using Sentinel SAR and optical imagery."*

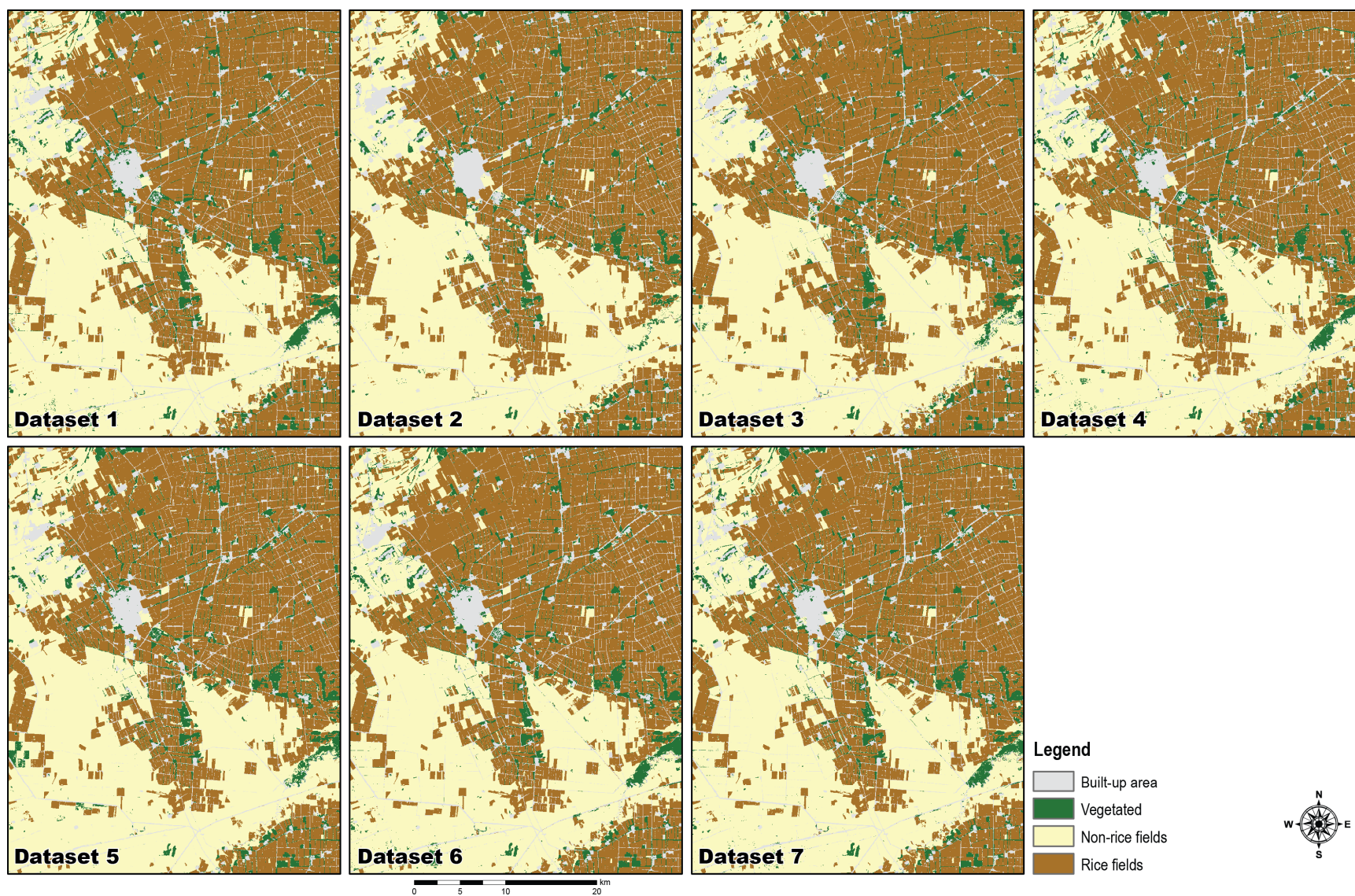**Figure S1**: Learning rates chart of U-Net segmentation models evaluated in the study.

Figure S2: Accuracy assessment of U-Net prediction experiments performed in the study.

Figure S3: Preview of ground truth and prediction chips for one of the optimal datasets from the U-Net DL experiments (Dataset 4).

Table S1: Accuracy assessment results of U-Net predictions to establish the optimal image combination.

Dataset 1 - Multispectral bands

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.77	0.71	0.88	0.91
Recall	0.67	0.62	0.89	0.96
F1 Score	0.72	0.66	0.88	0.93
Mean IoU	0.52	0.49	0.67	0.87

Dataset 2 - SAR bands

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.66	0.65	0.87	0.94
Recall	0.67	0.54	0.88	0.95
F1 Score	0.66	0.59	0.88	0.94
Mean IoU	0.46	0.41	0.66	0.89

Dataset 3 - Optical indices

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.72	0.64	0.88	0.89
Recall	0.69	0.47	0.86	0.95
F1 Score	0.70	0.54	0.87	0.92
Mean IoU	0.50	0.37	0.64	0.85

Dataset 4 - Multispectral + SAR bands

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.75	0.73	0.90	0.93
Recall	0.72	0.70	0.89	0.96
F1 Score	0.73	0.71	0.89	0.95
Mean IoU	0.54	0.56	0.70	0.89

Dataset 5 - SAR + Optical indices

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.74	0.68	0.88	0.94
Recall	0.71	0.65	0.89	0.95
F1 Score	0.72	0.66	0.88	0.95
Mean IoU	0.53	0.49	0.69	0.89

Dataset 6 - Multispectral + Optical indices

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.74	0.70	0.90	0.92
Recall	0.71	0.65	0.88	0.95
F1 Score	0.72	0.67	0.89	0.94
Mean IoU	0.53	0.51	0.69	0.88

Dataset 7 - Multispectral + SAR + Optical indices

Metrics	Built-up area	Vegetated	Non-rice fields	Rice fields
Precision	0.75	0.72	0.90	0.94
Recall	0.72	0.70	0.89	0.96
F1 Score	0.73	0.71	0.89	0.95
Mean IoU	0.54	0.55	0.71	0.89

Figure S4: U-Net prediction of paddy rice fields generated using datasets evaluated in the study.

Table S2: Error matrix and classification accuracy results of the Random Forest classification and optimal U-Net prediction.

### U-Net - Dataset 4 - Multispectral + SAR bands

Class Name	Other landuse	Rice fields	Total	Users' Accuracy
Other landuse	696	9	**705**	0.99
Rice fields	54	241	**295**	0.82
Total	**750**	**250**	**1000**	
Producers' Accuracy	0.93	0.96		
F1-Score	0.96	0.88		
Overall Kappa	0.84			
Overall Accuracy	0.94			
Mean F1-Score	0.92			

RF (250) - Dataset 4 - Multispectral + SAR bands

Class Name	Other landuse	Rice fields	Total	Users' Accuracy
Other landuse	691	29	**720**	0.96
Rice fields	59	221	**280**	0.79
Total	**750**	**250**	**1000**	
Producers' Accuracy	0.92	0.88		
F1-Score	0.94	0.83		
Overall Kappa	0.77			
Overall Accuracy	0.91			
Mean F1-Score	0.89			

RF (500) - Dataset 4 - Multispectral + SAR bands

Class Name	Other landuse	Rice fields	Total	Users' Accuracy
Other landuse	692	29	**721**	0.96
Rice fields	58	221	**279**	0.79
Total	**750**	**250**	**1000**	
Producers' Accuracy	0.92	0.88		
F1-Score	0.94	0.84		
Overall Kappa	0.78			
Overall Accuracy	0.91			
Mean F1-Score	0.89			
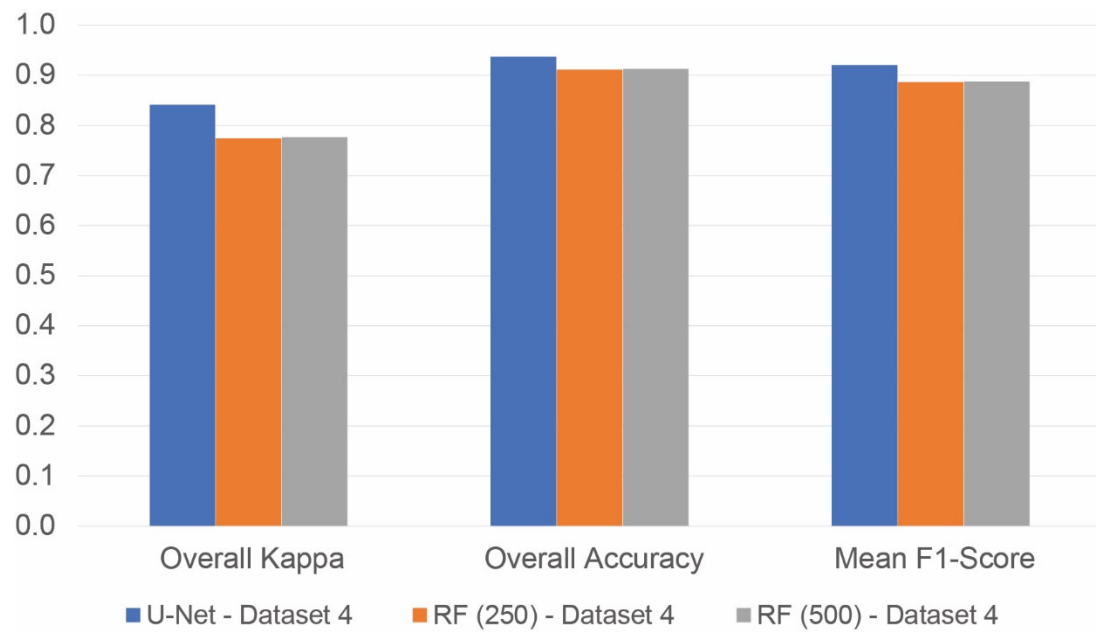
Figure S5: Accuracy assessment of U-Net prediction and Random Forest classification using optimal dataset.
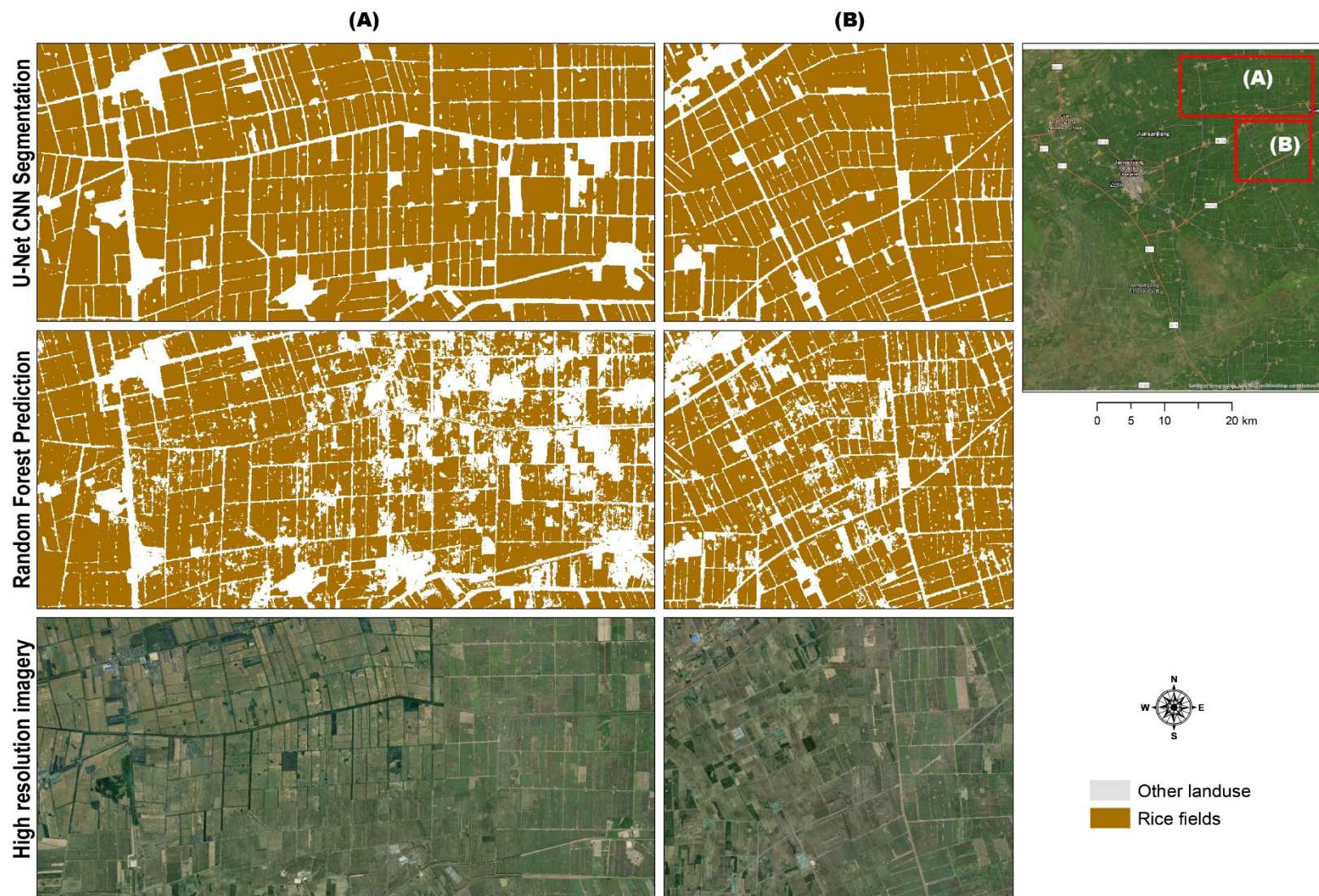
Figure S6: U-Net CNN segmentation paddy rice map produced from a combination of Sentinel 2 multispectral and Sentinel-1 dual polarization bands (Dataset 4).
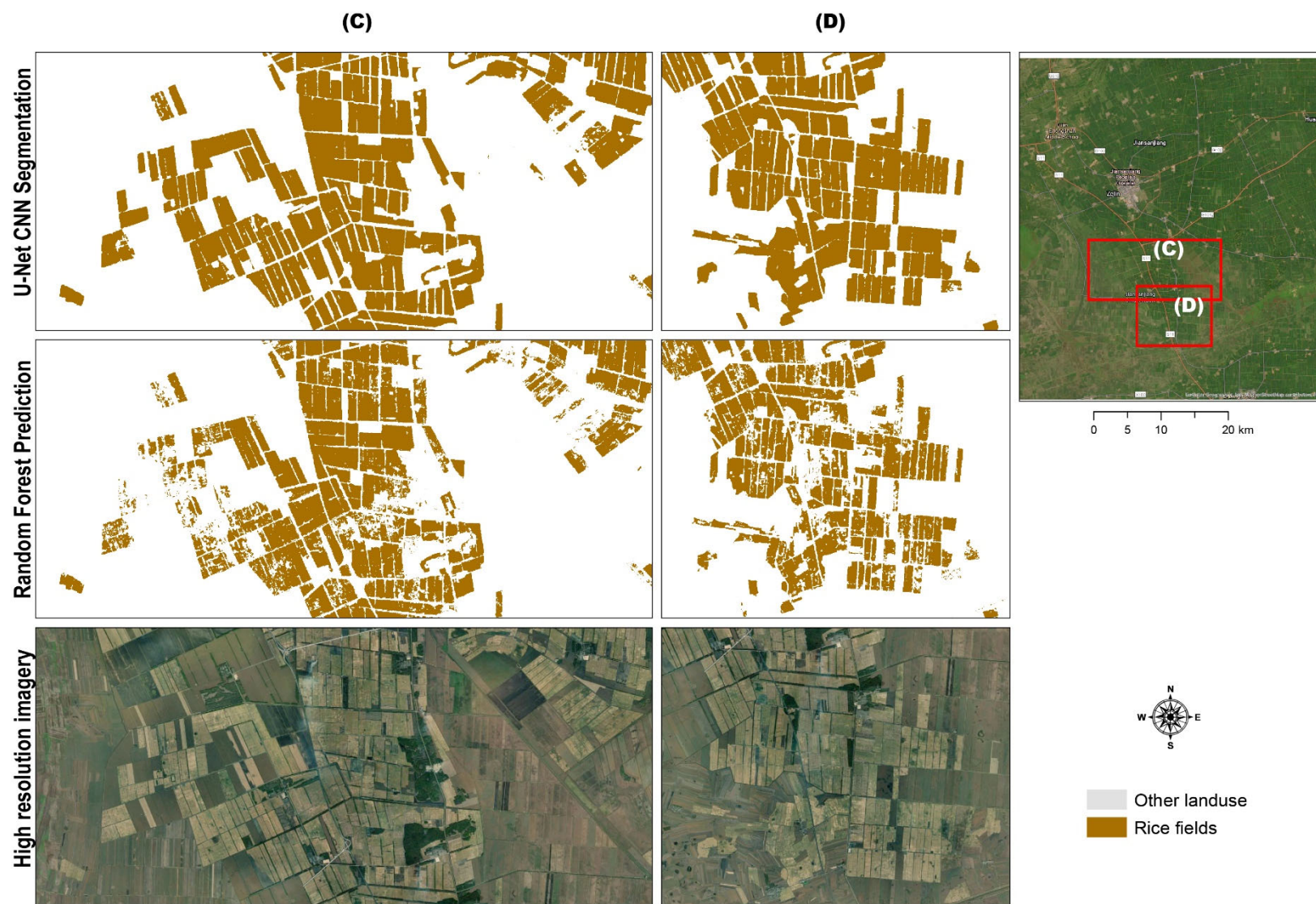
Figure S7: Random Forest (500 trees) paddy rice map produced from a combination of Sentinel 2 multispectral and Sentinel-1 dual polarization bands (Dataset 4).

Figure S8: Comparison of U-Net segmentation and Random Forest predictions using Dataset 4.

Figure S9: Comparison of U-Net segmentation and Random Forest predictions using Dataset 4 (contd.).

Table S3: Accuracy assessment results associated with the upscaled paddy rice mapping on the district scale for 2016, 2018, and 2020.

### U-Net - Dataset 4 - Multispectral + SAR bands (2016)

Class Name	Other land use	Rice fields	Total	User's Accuracy
Other landuse	701	8	**709**	0.99
Rice fields	49	242	**291**	0.83
Total	**750**	**250**	**1000**	
Producer's Accuracy	0.93	0.97		
F1-Score	0.96	0.89		
Overall Kappa	0.86			
Overall Accuracy	0.94			
Mean F1-Score	0.93			

U-Net - Dataset 4 - Multispectral + SAR bands (2018)

Class Name	Other land use	Rice fields	Total	User's Accuracy
Other landuse	695	43	**738**	0.94
Rice fields	55	207	**262**	0.79
Total	**750**	**250**	**1000**	
Producer's Accuracy	0.93	0.83		
F1-Score	0.93	0.81		
Overall Kappa	0.74			
Overall Accuracy	0.90			
Mean F1-Score	0.87			

U-Net - Dataset 4 - Multispectral + SAR bands (2020)

Class Name	Other land use	Rice fields	Total	User's Accuracy
Other landuse	683	37	**720**	0.95
Rice fields	67	213	**280**	0.76
Total	**750**	**250**	**1000**	
Producer's Accuracy	0.91	0.85		
F1-Score	0.93	0.80		
Overall Kappa	0.73			
Overall Accuracy	0.90			
Mean F1-Score	0.87			
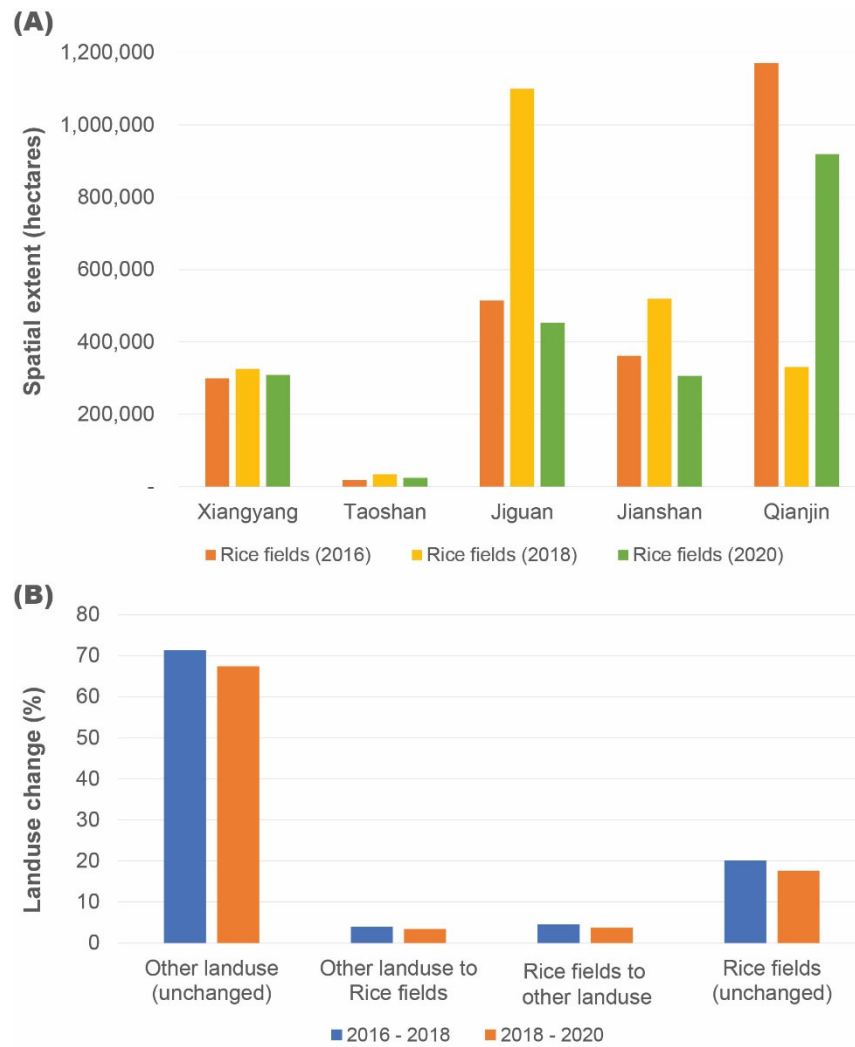
Figure S10: Graph showing (A) the spatial distribution of mapped paddy rice fields and (B) the percentages of landuse change relative to the total project area for 2016, 2018, and 2020 respectively.
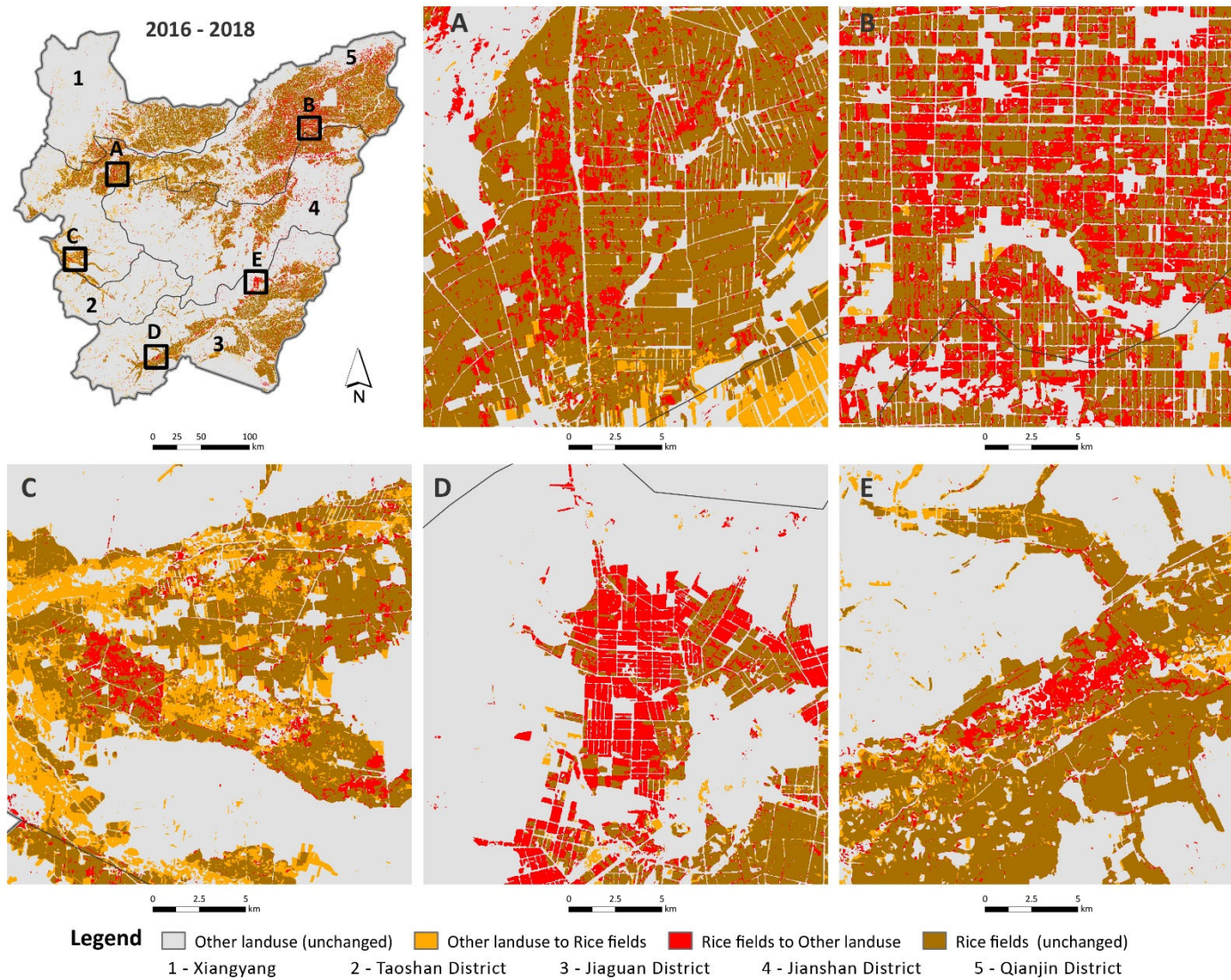
Figure S11: Change detection analysis results of selected sites between 2016 and 2018.

Legend
Other landuse (unchanged) — Other landuse to Rice fields — Rice fields to Other landuse — Rice fields (unchanged)
1 - Xiangyang   2 - Taoshan District   3 - Jiaguan District   4 - Jianshan District   5 - Qianjin District
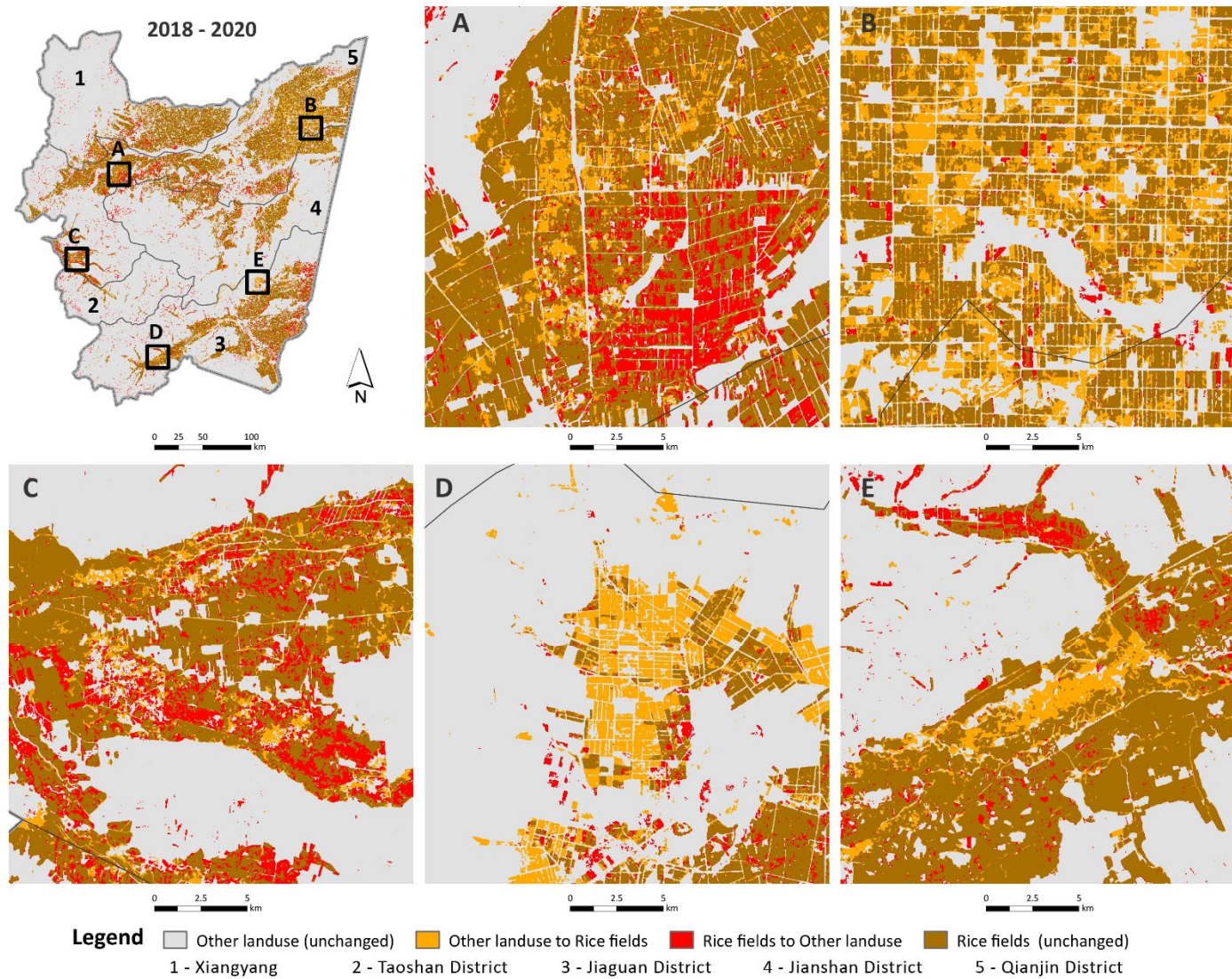
Figure S12: Change detection analysis results of selected sites between 2018 and 2020.
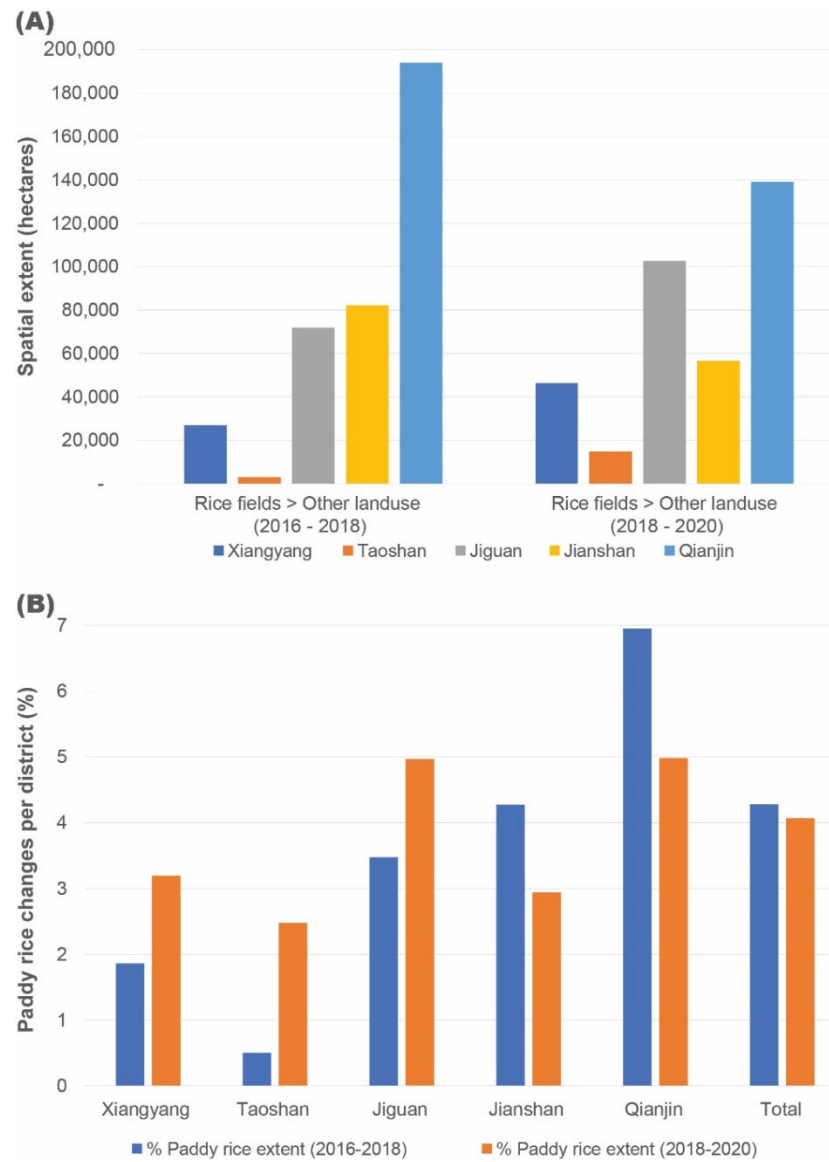
Figure S13: Graph showing (A): changes in paddy rice distribution and (B): the percentage of paddy rice loss for each district in the study area over two epochs (i.e., 2016 – 2018 and 2018 – 2020).

Table S4: Error matrix and classification accuracy results of U-Net predictions.

U-Net - Dataset 1 - Multispectral bands

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	155	23	6	7	191	0.81
Vegetated	19	170	2	0	191	0.89
Non-rice fields	41	45	227	2	315	0.72
Rice fields	35	12	15	241	303	0.80
Total	**250**	**250**	**250**	**250**	**1000**	
Producer's Accuracy	0.62	0.68	0.91	0.96		
F1-Score	0.70	0.77	0.80	0.87		
Overall Kappa	0.72					
Overall Accuracy	0.79					
Mean F1-Score	0.79					

U-Net - Dataset 2 - SAR bands

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	113	31	5	9	158	0.72
Vegetated	8	24	2	1	35	0.69
Non-rice fields	60	92	226	28	406	0.56
Rice fields	69	103	17	212	401	0.53
Total	**250**	**250**	**250**	**250**	**1000**	
Producer's Accuracy	0.45	0.10	0.90	0.85		
F1-Score	0.55	0.17	0.69	0.65		
Overall Kappa	0.43					
Overall Accuracy	0.58					
Mean F1-Score	0.52					

U-Net - Dataset 3 - Optical indices

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	153	37	6	8	204	0.75
Vegetated	23	130	3	1	157	0.83
Non-rice fields	37	64	224	2	327	0.69
Rice fields	37	19	17	239	312	0.77
Producer's Accuracy	**250**	**250**	**250**	**250**	**1000**	
F1-Score	0.61	0.52	0.90	0.96	0	
Overall Kappa	0.67	0.64	0.78	0.85		
Overall Accuracy	0.66					
Mean F1-Score	0.75					
Producer's Accuracy	0.73					

Table S4: Error matrix and classification accuracy results of U-Net predictions (contd.).

U-Net - Dataset 4 - Multispectral + SAR bands

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	159	27	8	6	200	0.80
Vegetated	14	168	4	1	187	0.90
Non-rice fields	38	46	228	2	314	0.73
Rice fields	39	9	10	241	299	0.81
Total	**250**	**250**	**250**	**250**	**1000**	
Producer's Accuracy	0.64	0.67	0.91	0.96		
F1-Score	0.71	0.77	0.81	0.88		
Overall Kappa	0.73					
Overall Accuracy	0.80					
Mean F1-Score	0.79					

U-Net - Dataset 5 - SAR + Multispectral bands

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	142	24	4	10	180	0.79
Vegetated	17	130	5	1	153	0.85
Non-rice fields	52	66	229	2	349	0.66
Rice fields	39	30	12	237	318	0.75
Total	**250**	**250**	**250**	**250**	**1000**	
Producer's Accuracy	0.57	0.52	0.92	0.95		
F1-Score	0.66	0.65	0.76	0.83		
Overall Kappa	0.65					
Overall Accuracy	0.74					
Mean F1-Score	0.73					

U-Net - Dataset 6 - Multispectral bands + optical indices

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	157	27	7	4	195	0.81
Vegetated	17	174	2	0	193	0.90
Non-rice fields	43	42	227	4	316	0.72
Rice fields	33	7	14	242	296	0.82
Total	**250**	**250**	**250**	**250**	**1000**	
Producer's Accuracy	0.63	0.70	0.91	0.97		
F1-Score	0.71	0.79	0.80	0.89		
Overall Kappa	0.73					
Overall Accuracy	0.80					
Mean F1-Score	0.79					

Table S4: Error matrix and classification accuracy results of U-Net predictions (contd.).

U-Net - Dataset 7 - Multispectral + SAR + optical indices

Class Name	Built-up area	Vegetated	Non-rice fields	Rice fields	Total	Users' Accuracy
Built-up area	159	36	8	7	210	0.76
Vegetated	17	158	3	0	178	0.89
Non-rice fields	41	45	226	2	314	0.72
Rice fields	33	11	13	241	298	0.81
Total	**250**	**250**	**250**	**250**	**1000**	
Producer's Accuracy	0.64	0.63	0.90	0.96		
F1-Score	0.69	0.74	0.80	0.88		
Overall Kappa	0.71					
Overall Accuracy	0.78					
Mean F1-Score	0.78					

Appendix S1: **Google Earth Engine Codes**

Sentinel-1 SAR data:

2016: https://code.earthengine.google.com/ccdce29bd42f21d23505bfd73652752d

2018: https://code.earthengine.google.com/c1d8f2a38a715d6b55ee7f1c9482d7d3

2020: https://code.earthengine.google.com/59b163e632aae630f733deba355b8ee9

Sentinel-2 multispectral data

2016: https://code.earthengine.google.com/c75475d18d8c2ea8ef0334bd3114d626

2018: https://code.earthengine.google.com/48c6c94ecc37ab7c6d28f0e60b790c7e

2020: https://code.earthengine.google.com/c3e5d095b6ceb6040693879d254a9cbe

Paddy Rice mapping app -
https://jolexy.maps.arcgis.com/apps/webappviewer/index.html?id=d4d061430bea480eb20ace85919861e5