

Article

Annual Cropland Mapping Using Reference Landsat Time Series—A Case Study in Central Asia

Pengyu Hao ^{1,*}, Fabian Löw ^{2,*} and Chandrashekhar Biradar ³

¹ Key Laboratory of Agricultural Remote Sensing, Ministry of Agriculture, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

² MapTailor Geospatial Consulting, 53113 Bonn, Germany

³ International Centre for Agricultural Research in Dry Areas (ICARDA), Cairo 11431, Egypt; C.Biradar@cgiar.org

* Correspondence: haopy8296@163.com (P.H.); fabian.loew@maptailor.net (F.L.); Tel.: +86-131-1866-8296 (P.H.)

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Abstract: Mapping the spatial and temporal dynamics of cropland is an important prerequisite for regular crop condition monitoring, management of land and water resources, or tracing and understanding the environmental impacts of agriculture. Analyzing archives of satellite earth observations is a proven means to accurately identify and map croplands. However, existing maps of the annual cropland extent either have a low spatial resolution (e.g., 250–1000 m from Advanced Very High Resolution Radiometer (AVHRR) to Moderate-resolution Imaging Spectroradiometer (MODIS)); and existing high-resolution maps (such as 30 m from Landsat) are not provided frequently (for example, on a regular, annual basis) because of the lack of in situ reference data, irregular timing of the Landsat and Sentinel-2 image time series, the huge amount of data for processing, and the need to have a regionally or globally consistent methodology. Against this backdrop, we propose a reference time-series-based mapping method (RBM), and create binary cropland vs. non-cropland maps using irregular Landsat time series and RBM. As a test case, we created and evaluated annual cropland maps at 30 m in seven distinct agricultural landscapes in Xinjiang, China, and the Aral Sea Basin. The results revealed that RBM could accurately identify cropland annually, with producer's accuracies (PA) and user's accuracies (UA) higher than 85% between 2006 and 2016. In addition, cropland maps by RBM were significantly more accurate than the two existing products, namely GlobaLand30 and Finer Resolution Observation and Monitoring of Global Land Cover (FROM-GLC).

Keywords: Central Asia; Xinjiang; Aral Sea Basin; cropland mapping; Google Earth Engine; Landsat; reference time series

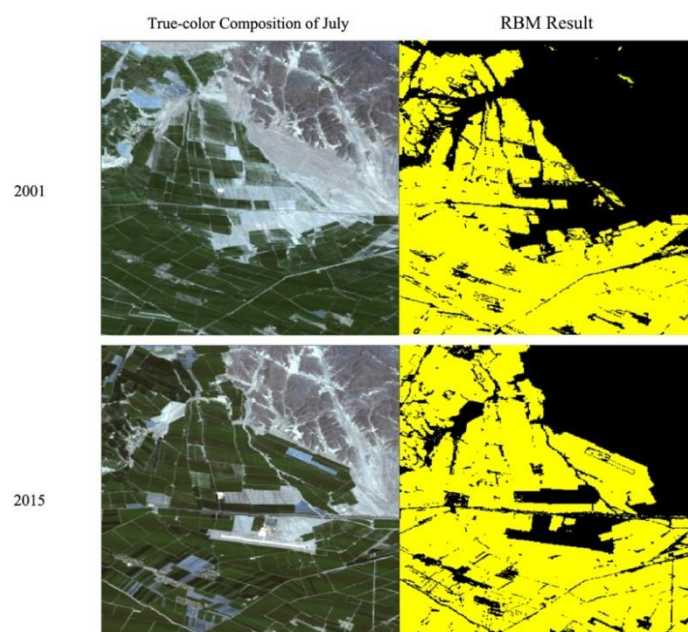


Figure. S1 Cropland distributions of two sub-regions in Bole (BL).

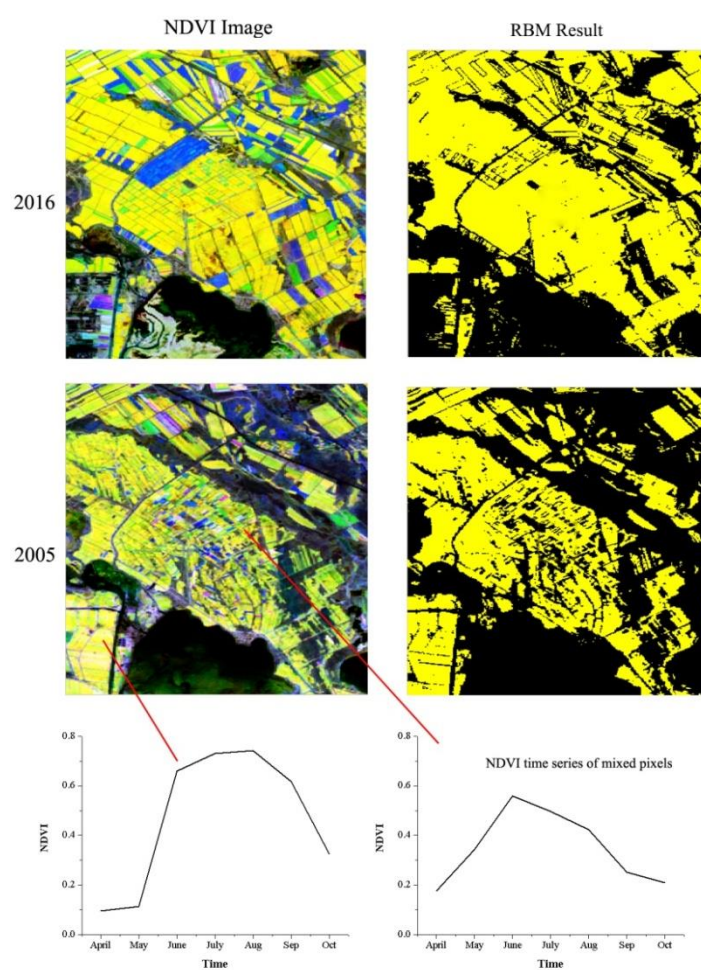


Figure. S2 Cropland distributions of sub-regions in Manas (MNS). Note: The NDVI images were composed by R, NDVI in September, G: NDVI in July, B: NDVI in May.

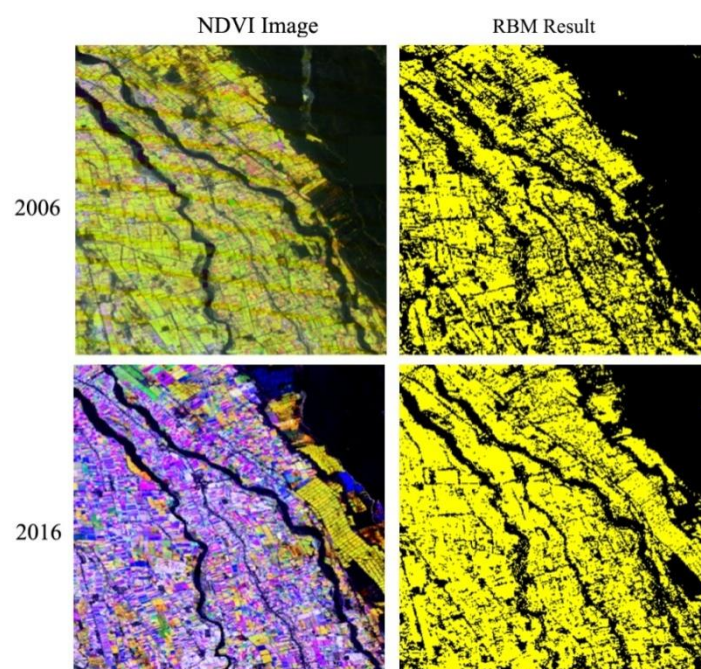


Figure. S3 Cropland distributions of sub-regions in Luntai (LT). **Note.** The NDVI images were composed by R, NDVI in September, G: NDVI in July, B: NDVI in May.

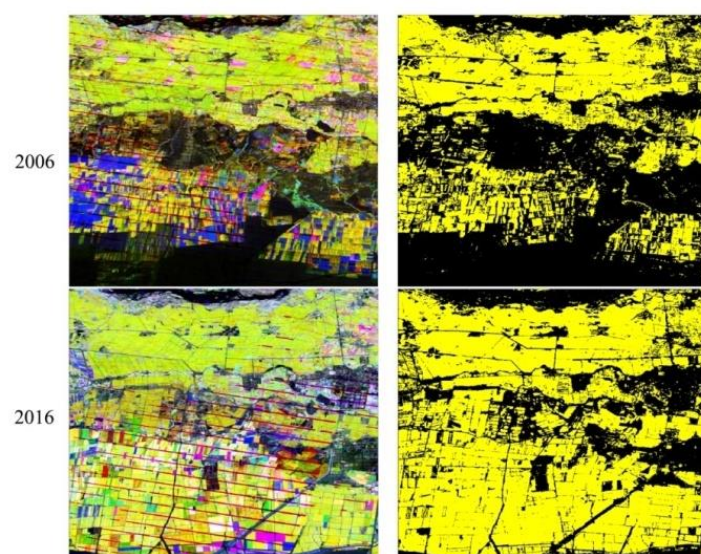


Figure. S4 Cropland distributions of sub-regions in Yining (YN). **Note:** The NDVI images were composed by R, NDVI in September, G: NDVI in July, B: NDVI in May.

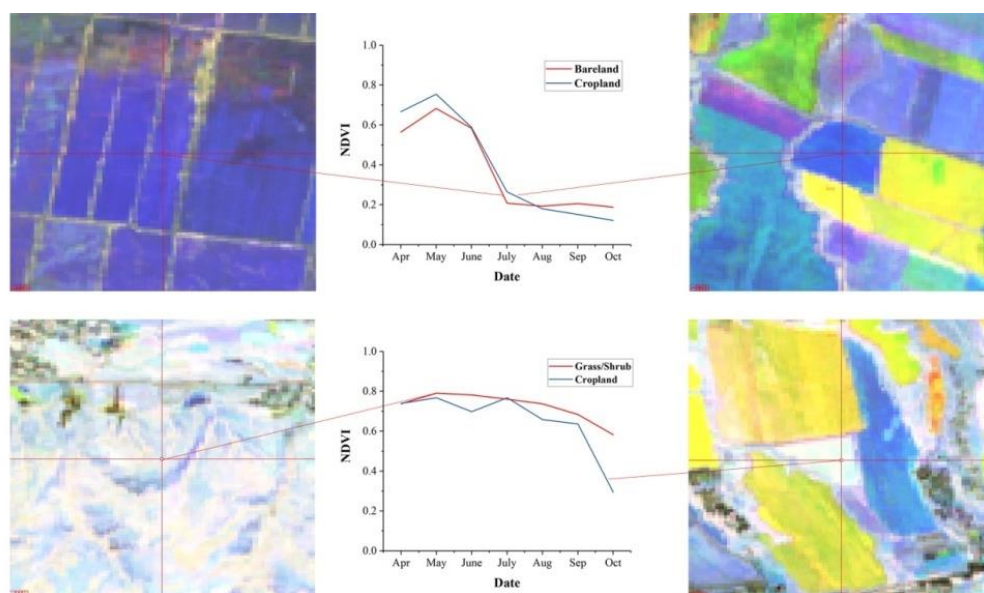


Figure.S5 Some of Cropland, Bareland and Grass & Shrub NDVI time series. Note: The NDVI images were composed by R, NDVI in September, G: NDVI in July, B: NDVI in May.

Table S1 Gini Importance score for different time phases and features (BL).

	Time	Blue	Green	Red	NIR	SWIR1	SWIR2	NDVI	NBR	NDMI	VIG	NDWFI	Sum
Cropland /Bareland	Apr	7.26	6.9	14.28	1.82	12.34	6.94	25.55	2.96	1.69	1.54	1.08	82.36
	May	14.86	26.4	17.65	28.72	1.9	9.19	25.13	22.63	15.14	19.15	19.59	200.36
	June	18.47	11.97	10.14	157.62	6.39	24	229.87	252.81	127.89	82.79	0.29	922.24
	July	23.1	17.13	16.94	101.75	1	5.06	307.61	32.9	13.72	22.2	1.03	542.44
	Aug	21.83	16.04	21.71	111.41	1.34	14.64	170.03	80.41	60.12	41.29	1.58	540.4
	Sep	19.08	7.48	6.4	71.3	1.8	1.82	149.65	18.27	9.59	10.95	6.26	302.6
	Oct	3.57	4.21	6.35	1.15	0.6	0.42	54.92	1.98	0.54	6.16	0.44	80.34
	Sum	108.17	90.13	93.47	473.77	25.37	62.07	962.76	411.96	228.69	184.08	30.27	
Cropland /Artificial surface	Apr	2.44	3.52	6.95	3.37	8.34	3.11	4.56	2.58	2.33	5.43	16.45	59.08
	May	14.33	15.21	15.46	9.79	4.89	18.1	9.46	13.6	11.46	11.47	9.75	133.52
	June	19.77	13.34	5.15	96.83	4.74	22.76	54.02	120.55	82.55	53.96	2.87	476.54
	July	22.46	4.43	11.4	46.08	3.4	4.66	24.92	26.54	12.13	10.38	14.05	180.45
	Aug	35.27	2.52	6	56.83	4.63	9.32	76.44	62.62	28.89	42.18	6.73	331.43
	Sep	9.74	2.68	7.46	123.54	11.08	6.58	36.93	19.43	14.02	9.79	4.06	245.31
	Oct	1.07	0.94	1.29	8.92	4.78	1.51	6.89	4.57	1.5	1.28	3.27	36.02
	Sum	105.08	42.64	53.71	345.36	41.86	66.04	213.22	249.89	152.88	134.49	57.18	
Cropland /Grass& Shrub	Apr	21.9	24.97	10.95	3.24	9.06	13.3	17.06	1.15	2.55	2.95	21.26	128.39
	May	43.32	21.02	16.6	4.39	2.05	7.58	11.77	6.38	5.79	5.59	5.6	130.09
	June	24.39	8.02	15.1	9.82	3.01	2.49	7.45	7.93	10.77	2.78	112.81	204.57
	July	14.48	13.66	7.07	4.22	2.62	8.56	5.41	3.97	3.85	5.51	12.29	81.64
	Aug	37.3	3.1	4.11	3.3	4.36	5.79	5.57	7.06	9.97	2.57	4.58	87.71
	Sep	57.1	9.13	5.16	10.71	2.81	2.31	4.16	6.84	7.01	2.71	2.68	110.62
	Oct	121.91	134.68	174.59	44.51	23.1	3.39	12.71	31.62	110.75	13.88	4.8	675.94
	Sum	320.4	214.58	233.58	80.19	47.01	43.42	64.13	64.95	150.69	35.99	164.02	
Cropland /Water	Apr	0	0	0	63.23	72.98	53.07	67.95	0	0	0	0	257.23
	May	0	0	0	68.08	92.04	102.58	102.72	0	0	0	0	365.42
	June	0	0	0	82.4	78.15	101.93	48.94	0	0	0	0.01	311.43
	July	0	0	0.02	102	73.17	72.7	4.87	0	4.82	0	0	257.58
	Aug	0	0	0	58.23	97.41	82.8	0	0	4.8	0	0	243.24
	Sep	0	0	0	78.45	87.86	97.24	4.87	0	0	3.07	0	271.49
	Oct	0	0	0	0	0	4.86	59.14	0	0	0	0	64
	Sum	0	0	0.02	452.39	501.61	515.18	288.49	0	9.62	3.07	0.01	

Table S2 Gini Importance score for different time phases and features (MNS).

	Time	Blue	Green	Red	NIR	SWIR 1	SWIR 2	NDVI	NBR	NDM I	VIG	NDW FI	Sum
Cropland /Bareland	Apr	1.61	0.27	1.65	0.49	2.04	2.55	2.12	2.75	3.51	0.92	0.43	18.34
	May	9.83	16.6	23.44	1.16	6.24	19.18	30.44	19.07	6.08	15.57	7.47	155.08
	June	6.88	14.04	14.88	4.99	11.01	13.35	140.45	91.52	82.09	88.7	1.82	469.73
	July	116.06	57.69	30.59	11.91	6.57	31.59	45.66	44.93	12.79	13.99	4.38	376.16
	Aug	37.05	14.91	25.15	14.99	2.61	10.52	50.74	32.8	23.7	25.95	5.8	244.22
	Sep	1.12	0.81	0.63	6.36	0.26	1.35	8.54	3.33	4.93	2.1	1.34	30.77
	Oct	0.73	0.43	0.49	4.59	0.37	0.45	3.9	0.26	0.93	0.18	0.22	12.55
	Sum	173.28	104.75	96.83	44.49	29.1	78.99	281.85	194.66	134.03	147.41	21.46	
Cropland /Artificial surface	Apr	1.01	0.82	1.26	3.59	5.97	2.99	1.2	2.42	3.1	1.85	2.34	26.55
	May	2.44	5.01	6.19	23.59	4.14	6.94	6.34	3.83	6.42	2.83	3.71	71.44
	June	11.73	2.93	3.84	62.2	2.35	3.61	61.29	47.4	26.12	23.84	1.64	246.95
	July	50.37	9.84	3.79	23.45	1.73	1.91	37.23	10.13	9.12	4.54	1.65	153.76
	Aug	11.64	2.02	3.01	34.42	2.26	0.63	22.19	19.15	10.43	7.58	1.22	114.55
	Sep	1.75	0.53	0.7	58.68	15.35	1.4	4.63	3.43	0.91	0.48	4.43	92.29
	Oct	0.84	0.25	0.71	21.11	19.89	1.72	3.9	0.55	0.87	1.16	2.08	53.08
	Sum	79.78	21.4	19.5	227.04	51.69	19.2	136.78	86.91	56.97	42.28	17.07	
Cropland /Grass & Shrub	Apr	4.01	8.38	3.9	70.68	30.74	7.64	21.69	4.06	4.01	12.18	5.04	172.33
	May	11.08	6.93	9.52	44.31	14.52	10.67	20.35	13.41	10.91	14.72	8.21	164.63
	June	4.96	5.52	5.01	7.72	12.32	6.57	15.49	12.21	10.63	4.57	21.51	106.51
	July	2.2	3.53	3.81	27.61	32.76	7.27	9.62	6.68	8.15	4.52	6.7	112.85
	Aug	4.2	3.3	7.16	34.01	7.76	3.52	14.02	5.18	7.54	3.38	4.21	94.28
	Sep	8.99	5.02	3.58	21.6	8.39	5.66	11.79	4.65	4.7	3.41	13.01	90.8
	Oct	37.16	12.16	7.13	2.04	2.21	7.92	11.22	3.43	2.48	3.1	2.82	91.67
	Sum	72.6	44.84	40.11	207.97	108.7	49.25	104.18	49.62	48.42	45.88	61.5	
Cropland /Water	Apr	0	0	0.08	42.27	66.74	59.47	40.38	0	0.02	0.03	1.51	210.5
	May	0.01	0	0	55.62	38.67	52.84	42.14	0	0	0	0	189.28
	June	0	0	0	52.35	40.53	57.58	9.89	0.13	2.96	0	0	163.44
	July	0	0	0	49.67	15.72	6.61	13.69	0	0.04	0	0	85.73
	Aug	0	0	0	20.82	5.13	3.32	5.02	0.02	0	0.01	0	34.32
	Sep	0	0	0	3.11	3.12	4.43	1.66	0	0	0	0	12.32
	Oct	0	0.03	0	1.45	1.67	0.02	0	0	0	0	0	3.17
	Sum	0.01	0.03	0.08	225.29	171.58	184.27	112.78	0.15	3.02	0.04	1.51	

Table S3 Gini Importance score for different time phases and features (LT).

	Time	Blue	Green	Red	NIR	SWIR1	SWIR2	NDVI	NBR	NDMI	VIG	NDWFI	Sum
Cropland /Bareland	Apr	5.76	6.28	6.23	0.22	5.9	3.37	9.73	8.35	3.1	1.66	3.18	53.78
	May	0.76	1.43	4.15	0.73	1.88	1.94	25.3	6.66	12.25	4.14	4.14	63.38
	June	3.35	3.73	2.62	2.46	0.16	2.64	129.43	42.91	42.22	74.87	0.35	304.74
	July	84.36	75.88	79.65	4	4.55	84.53	177.98	50.58	32.68	3.15	0.79	598.15
	Aug	2.68	7.24	17.24	5.39	0.52	5.04	179.75	34.69	49.9	26.32	0.54	329.31
	Sep	18.03	5.68	7.59	0.32	0.75	1.87	81.48	8.15	4.9	3.91	1.37	134.05
	Oct	76.5	23.83	18.9	0.23	0.48	0.34	23.99	20.33	6.08	0.52	0.92	172.12
	Sum	191.44	124.07	136.38	13.35	14.24	99.73	627.66	171.67	151.13	114.57	11.29	
Cropland /Artificial surface	Apr	2.92	1.49	1.85	0.47	0.62	1.72	2.69	2.25	3.56	1.56	2.01	21.14
	May	8.39	8.87	14.15	5.9	3.17	11.87	20.39	28.04	21.48	13.28	7.99	143.53
	June	5.47	5.6	4.87	6.12	2.06	7.17	9.89	24.45	22.64	15.04	0.77	104.08
	July	22.71	1.88	3.28	17.56	1.36	4.57	22.6	25.66	14.81	10.97	1.28	126.68
	Aug	2.08	1.64	2.29	65.89	3.3	3.87	34.66	18.76	8.74	20.37	2.94	164.54
	Sep	4.09	2.77	3.87	24.81	5.66	3.05	17.56	15.17	10.8	6.69	3.27	97.74
	Oct	3.11	1.28	1.43	12.13	1.22	1.06	11.52	13.44	12.36	2.89	2.03	62.47
	Sum	48.77	23.53	31.74	132.88	17.39	33.31	119.31	127.77	94.39	70.8	20.29	
Cropland /Grass& Shrub	Apr	9.7	15.04	11.15	14.49	6.85	9.23	23.5	3.04	10.43	14.41	3.98	121.82
	May	36.83	20.94	7.85	130.55	13.39	18.06	48.46	20.95	39.54	32.47	23.07	392.11
	June	29.04	17.14	12.03	58.45	8.84	10.89	43.55	94.65	120.19	27.07	5.94	427.79
	July	16.62	20.19	37.88	170.9	30.44	16.36	136.38	14.51	15.22	15.18	23.42	497.1
	Aug	5.89	4.61	5.43	298.01	11.81	3.65	55.12	18.85	29.06	8.46	6.45	447.34
	Sep	21.05	25.24	32.81	257.15	141.91	37.95	27.96	30.37	33.16	17.38	42.66	667.64
	Oct	11.84	13.51	15.79	190.89	27.68	24.79	28.03	39.26	86.52	5.86	41.09	485.26
	Sum	130.97	116.67	122.94	1120.44	240.92	120.93	363	221.63	334.12	120.83	146.61	
Cropland /Water	Apr	1.58	3.48	3.84	0.44	2.64	1.16	3.71	0.29	0.11	0.14	0.54	17.93
	May	0.59	1.34	0.38	0.53	0.37	1.39	16.41	0.27	0.35	0.11	1.65	23.39
	June	1.18	2.8	2.83	0.17	2.61	7.15	32.72	22.2	15.3	3.71	1.53	92.2
	July	2.83	11.45	11.38	19.75	1.15	7.13	69.43	4.47	4.54	1.83	1.45	135.41
	Aug	2.93	3.77	4.57	27.49	36.76	0.38	94.5	1.02	1.54	1.19	0.41	174.56
	Sep	6.98	9.35	4.45	112.13	58.56	49.5	78.93	65.36	150.49	1.08	3.42	540.25
	Oct	2.07	1.37	2.98	19.12	1.33	0.18	64.14	0.4	3.09	1.07	2.82	98.57
	Sum	18.16	33.56	30.43	179.63	103.42	66.89	359.84	94.01	175.42	9.13	11.82	

Table S4 Gini Importance score for different time phases and features (YN).

	Time	Blue	Green	Red	NIR	SWIR1	SWIR2	NDVI	NBR	NDMI	VIG	NDWI	Sum
Cropland /Bareland	Apr	0.45	0.73	0.73	1.96	0.64	0.98	1	0.94	1.13	0.98	1.83	11.37
	May	4.83	3.43	5.58	0.53	2.81	3.33	11.76	4.15	12.43	7.34	2.33	58.52
	June	47.8	42.64	23.83	0.86	12.08	44.95	87.42	77.07	80.33	26.7	0.16	443.84
	July	1.95	0.84	0.8	1.14	0.88	3.39	8.91	5.74	5.01	1.71	0.26	30.63
	Aug	5.53	3.18	5.71	6.18	1.02	9.52	24.28	41.54	23.98	10.43	0.86	132.23
	Sep	0.93	0.64	1.05	1.53	0.73	0.5	3.13	3.08	2.01	0.8	0.87	15.27
	Oct	0.19	0.01	0.08	0.1	0.11	0.02	1.02	0.37	1.09	0.08	0.15	3.22
	Sum	61.68	51.47	37.78	12.3	18.27	62.69	137.52	132.89	125.98	48.04	6.46	
Cropland /Artificial surface	Apr	2.1	6.12	6.72	10.48	1.22	2.75	4.31	3.22	3.47	1.32	1.27	42.98
	May	12.68	6.71	11.75	9.71	6.45	15.65	28.11	26.03	23.27	12.57	3.01	155.94
	June	23.4	3.43	0.57	3.76	0.47	7.91	28.92	67.99	44.9	8.79	0.82	190.96
	July	3.77	1.01	2.7	7.66	0.51	4.87	7.41	9.3	8.44	5.99	2.28	53.94
	Aug	8.17	1.07	11.28	15.96	0.89	7.13	29.8	38.92	29.05	26.66	1.33	170.26
	Sep	2.85	4.67	8.93	10.73	3.43	3.47	5.62	1.76	2.52	2.15	1.96	48.09
	Oct	0.27	1.15	1.89	1.19	2.72	1.35	2.5	0.38	0.37	0.75	14.98	27.55
	Sum	53.24	24.16	43.84	59.49	15.69	43.13	106.67	147.6	112.02	58.23	25.65	
Cropland /Grass& Shrub	Apr	2.55	2.73	3.91	0.73	0.97	1.25	6.47	2.49	2.13	1.66	2.06	26.95
	May	2.69	3.08	2.89	0.58	6.91	2.58	4.05	7.94	7.68	2.39	2.32	43.11
	June	6.45	5.49	1.77	0.09	16.32	17.42	4.61	33.36	39.47	1.18	1.26	127.42
	July	0.26	1.71	0.56	0.76	1.46	1.94	1.57	6.11	9.9	0.75	0.9	25.92
	Aug	0.31	3.12	1.54	0.37	1.46	4.15	2.18	9.65	8.15	0.56	1.41	32.9
	Sep	0.9	0.83	1.16	0.35	1.83	2.78	4.93	3.8	5.47	1.31	0.38	23.74
	Oct	14.89	18.19	11.38	11.85	0.53	0.66	0.25	81.9	61.81	0.52	0.19	202.17
	Sum	28.05	35.15	23.21	14.73	29.48	30.78	24.06	145.25	134.61	8.37	8.52	
Cropland /Water	Apr	0.01	0.01	0.01	3.48	6.1	0.43	5.71	0.02	0.03	0	0.01	15.81
	May	0.01	0.02	0	0.01	0.01	0.01	0.74	0.01	0.47	0	0.04	1.32
	June	1.53	0.92	1.07	27.49	20.46	6.14	46.59	0.09	0.91	0.05	0.03	105.28
	July	0.82	0.9	0.83	28.84	25.53	8.67	17.2	0.04	4.6	0.01	0.01	87.45
	Aug	0.14	0.38	0.32	12.5	8.68	2.08	33.33	1.64	4.02	0.2	0.07	63.36
	Sep	0.48	0.53	0.03	6.46	0.53	1.24	22.01	0.02	0.11	0	0.03	31.44
	Oct	0.06	0.03	0	1.58	0.29	0.06	3.1	0	0	0.08	0	5.2
	Sum	3.05	2.79	2.26	80.36	61.6	18.63	128.68	1.82	10.14	0.34	0.19	

Table S5 Gini Importance score for different time phases and features (KYZ).

	Time	Blue	Green	Red	NIR	SWIR1	SWIR2	NDVI	NBR	NDMI	VIG	NDWFI	Sum
Cropland /Bareland	Apr	1.00	2.00	3.00	4.00	1.78	2.91	0.93	0.90	0.79	0.86	0.64	94.87
	May	1.23	1.36	0.88	1.66	1.24	1.21	3.28	1.76	0.13	0.84	0.99	40.1
	June	3.08	2.53	3.95	1.00	1.28	2.54	8.09	6.20	0.4	3.96	1.57	14.68
	July	11.04	9.74	7.49	1.11	0.7	0.6	10.15	3.66	0.23	1.38	0.53	13.6
	Aug	4.96	3.10	1.50	0.61	0.47	0.63	6.78	10.10	3.66	2.27	0.91	17.62
	Sep	3.87	1.38	1.48	1.17	6.89	16.34	4.33	1.52	0.64	0.66	0.71	59.99
	Oct	3.17	1.94	0.98	0.52	10.03	45.78	2.18	2.53	5.77	0.10	0.25	127.1
	Sum	3.05	1.49	0.77	0.42	22.39	70.01	35.76	26.66	11.62	10.07	5.61	
Cropland /Artificial surface	Apr	0.36	0.32	0.43	1.47	0.41	6.20	5.32	0.33	0.73	0.81	0.31	6.5
	May	0.28	0.16	0.42	2.86	8.74	10.63	4.57	24.66	2.35	2.91	0.42	76.66
	June	1.47	1.36	0.41	1.08	6.44	8.22	5.05	1.41	0.11	0.37	0.3	27.13
	July	3.39	1.97	20.86	1.07	9.5	8.82	14.41	7.88	2.5	14.8	10.65	86.86
	Aug	1.32	3.71	7.01	7.52	0.68	5.59	14.70	1.67	1.73	7.74	8.21	46.94
	Sep	0.32	1.04	2.27	2.16	0.21	4.17	10.96	0.15	0.65	0.18	7.88	16.06
	Oct	0.62	0.27	0.64	1.7	1.11	7.66	7.48	0.45	1.11	0.07	2.25	9.46
	Sum	7.76	8.83	32.04	17.86	27.09	51.29	62.49	36.55	9.18	26.88	30.02	
Cropland /Grass& Shrub	Apr	0.03	0	0	0	0	6.30	0	0.01	4.82	0	0	0.24
	May	0.64	0.62	1.9	0	8.02	6.73	0.03	0.61	4.15	0	1.12	20.3
	June	30.87	22.4	19	0	30.41	9.63	17.85	7.39	4.26	6.52	1.23	179.28
	July	2.1	1.41	0.11	0	2.55	4.75	30.73	2.63	3.95	0	0.18	63.89
	Aug	4.65	0.01	0.01	0.04	0.6	4.56	16.22	24.6	9.15	0.04	0.04	91.21
	Sep	0.8	0.01	0	0	0	13.24	5.21	0	6.14	0	0	12.82
	Oct	1.97	0	0.02	0	0.04	21.33	0.2	0.16	7.54	0	0	9.36
	Sum	41.06	24.45	21.04	0.04	41.62	66.55	70.24	35.4	40.00	6.56	2.57	
Cropland /Water	Apr	0.03	0.01	0	0.03	0.09	2.29	0.04	0.01	0.07	0	0.03	0.5
	May	0.28	0.5	0.21	0.04	0.26	4.27	0	0.05	0.17	0.01	0.2	2.33
	June	1.54	1.14	0.78	0	0.64	3.51	8.38	0.06	0	0.04	0.2	12.98
	July	0.17	0.02	0.06	3.65	2.57	3.89	19.38	0.32	0.24	0.3	0.1	28.55
	Aug	0	0.01	0.12	14.61	16.55	8.16	11.06	0	1.65	0.01	0.1	53.44
	Sep	0.07	0.13	0.24	7.88	8.91	6.23	12.76	0.17	2.02	0.45	1.41	39.43
	Oct	0.08	0.01	0	0.16	0.02	3.06	5.98	0.02	0.34	0.12	0.06	7.23
	Sum	2.17	1.82	1.41	26.37	29.04	31.41	57.6	0.63	4.49	0.93	2.1	

Table S6 Gini Importance score for different time phases and features (KKP).

	Time	Blue	Green	Red	NIR	SWIR1	SWIR2	NDVI	NBR	NDMI	VIG	NDWFI	Sum
Cropland /Bareland	Apr	1.62	5.54	1.39	0.2	2.62	4.48	0.47	1.72	1.63	0.13	0.79	20.59
	May	3.38	3.47	3.52	1.85	4.23	3.57	4.31	5.11	5.57	2.7	1.24	38.95
	June	12.66	5.58	0.86	0.07	3.18	21.64	0.43	79.54	49.56	0.49	0.71	174.72
	July	14.01	3.78	1.58	0.13	0.67	1.94	0.17	27.67	1.8	0.46	0.61	52.82
	Aug	30.59	23.76	19.9	0.24	7.68	15.48	0.53	56.42	40.28	11.66	0.58	207.12
	Sep	27.89	23.37	7.36	0.29	5.14	16.02	0.32	9.67	5	0.76	0.22	96.04
	Oct	0.08	0.95	0.53	0.14	1.43	8.32	0.3	4.55	1.77	0.31	0.11	18.49
	Sum	90.23	66.45	35.14	2.92	24.95	71.45	6.53	184.68	105.61	16.51	4.26	
Cropland /Artificial surface	Apr	10.14	4.84	9.03	0.08	12.59	15.45	1.59	7.08	7.34	6.25	4.8	79.19
	May	10.02	10.7	8.16	0.05	8.97	17.08	10.46	19.62	17.32	15.83	3.22	121.43
	June	32.72	15.86	10.58	0.44	4.22	23.95	0.15	1.63	19.08	0.52	0.4	109.55
	July	6.92	4.61	4.13	0.45	1.24	5.33	1.07	3.87	3.02	0.79	2.61	34.04
	Aug	39.2	21.76	14.39	1.26	28.23	30.17	3.67	78.39	56.18	15.27	0.96	289.48
	Sep	2.54	5.64	1.39	2.45	2.04	0.28	2.24	4.1	3.77	0.86	0.63	25.94
	Oct	0.42	0.33	0.73	0.44	0.34	0.33	0.67	1.37	0.23	0.25	0.72	5.83
	Sum	101.96	63.74	48.41	5.17	57.63	92.59	19.85	116.06	106.94	39.77	13.34	
Cropland /Grass& Shrub	Apr	4.18	10.94	3.81	15.89	6.05	2.21	1.89	1.49	1.81	0.25	0.75	49.27
	May	5.13	3.86	8.64	0.96	0.48	1.42	54.38	0.49	1.01	4.21	6.06	86.64
	June	11.87	20.21	41.54	8.86	5.44	7.54	106.51	2.04	0.93	50.01	100.69	355.64
	July	4.65	3.38	3.96	0.99	6.92	10.13	7.06	4.5	3.83	12.84	11.51	69.77
	Aug	7.39	1.02	5.51	0.75	1.01	2.61	1.13	39.34	76.3	8.49	9.67	153.22
	Sep	5.99	1.95	4.24	0.69	0.73	0.97	2.32	0.26	1.52	1.77	7.64	28.08
	Oct	17.33	39.64	23.35	0.22	1.98	19	22.85	3.78	1.95	0.59	5.24	135.93
	Sum	56.54	81	91.05	28.36	22.61	43.88	196.14	51.9	87.35	78.16	141.56	
Cropland /Water	Apr	0.98	0.58	0.81	24.08	18.67	5.19	69.34	0.18	2.24	0.21	1.09	123.37
	May	1.68	3.53	1.42	0.65	0.13	0.15	59.87	0.2	0.62	0.13	0.56	68.94
	June	3.99	3.95	0.9	0.67	0.04	1.41	35.84	25.61	14.8	0.14	0.46	87.81
	July	4.49	0.72	0.18	2.13	0.09	0.09	59.28	0.97	0.32	1.21	0.53	70.01
	Aug	11.21	20.37	6.03	3.72	0.15	1.03	68.65	8.32	3.59	1.48	1.19	125.74
	Sep	8.33	8.87	2.39	6.23	3.1	3.63	93.23	2.85	1.41	0.23	1.04	131.31
	Oct	0.31	0.53	0.02	23.26	14.53	8.11	101.36	0.77	0.45	1.04	2.14	152.52
	Sum	30.99	38.55	11.75	60.74	36.71	19.61	487.57	38.9	23.43	4.44	7.01	

Table S7 Gini Importance score for different time phases and features (ALM).

	Time	Blue	Green	Red	NIR	SWIR1	SWIR2	NDVI	NBR	NDMI	VIG	NDWFI	Sum
Cropland /Bareland	Apr	0.2	0.45	0.2	0.26	0.75	0.18	0.36	0.43	0.31	0.12	0.39	3.65
	May	1.69	1.01	5.89	3.63	9.05	9.39	9.38	7.56	13.74	7.53	5.84	74.71
	June	1.3	1.02	0.94	16.23	2.37	2.34	8.62	8.67	22.06	4.58	0.3	68.43
	July	1.03	0.8	2.71	24.62	2.05	9.27	9.61	14.49	13.93	0.97	0.39	79.87
	Aug	0.78	0.33	1.28	47.94	1.65	2.46	27.29	23.26	16.83	3.91	2.14	127.87
	Sep	2.38	2.44	3.49	21.42	0.7	1.57	5.46	11.98	16.64	0.71	5.07	71.86
	Oct	0.38	1.46	1.43	1.21	0.21	0.69	0.55	0.53	10.77	0.22	2.84	20.29
	Sum	7.76	7.51	15.94	115.31	16.78	25.9	61.27	66.92	94.28	18.04	16.97	
Cropland /Artificial surface	Apr	0.5	0.42	0.49	9.36	18.28	1.48	1.9	0.83	1.12	0.88	3.72	38.98
	May	2.56	0.64	1.41	6.75	1.95	1.68	4.14	3.59	3.44	4.98	4.26	35.4
	June	2.42	0.67	0.66	6.85	2.47	0.86	3.89	7.64	2.64	5.19	5.98	39.27
	July	11.93	0.97	1	14.18	0.91	0.67	2.08	3.06	2.07	1.69	1.65	40.21
	Aug	3.18	0.8	1.13	30.71	1.65	1.11	7.61	4.51	5.83	2.29	0.96	59.78
	Sep	0.87	0.78	1.11	32.83	12.67	2.4	3.15	6.18	8.74	2.14	9.27	80.14
	Oct	1.06	0.94	0.89	1.88	34.21	2.4	1.26	1.54	6.2	3.37	16.44	70.19
	Sum	22.52	5.22	6.69	102.56	72.14	10.6	24.03	27.35	30.04	20.54	42.28	
Cropland /Grass& Shrub	Apr	3.18	4.81	1.02	4.14	2.72	1.05	2.49	2.03	2.78	2.5	1.18	27.9
	May	4.23	6.97	6.67	0.82	2.08	1.38	16.93	4.78	6.29	3.06	1.53	54.74
	June	2.03	6.55	29.21	1.08	2.49	8.86	63.02	1.98	1.32	4.19	37.78	158.51
	July	1.48	0.61	1.16	0.76	2.04	3.01	4.3	2.52	1.38	0.67	3.21	21.14
	Aug	1.33	6.07	0.54	0.9	1.04	1.43	20.12	1.43	1.18	0.73	5.75	40.52
	Sep	1.13	23.94	3.34	1.73	0.86	1.9	68.17	1.32	1.51	1	0.98	105.88
	Oct	4.32	6	1.55	0.41	1.26	1.41	23.83	3.82	0.69	0.44	0.55	44.28
	Sum	17.7	54.95	43.49	9.84	12.49	19.04	198.86	17.88	15.15	12.59	50.98	
Cropland /Water	Apr	0	0	0	5.54	8.49	6.3	12.51	0	9.53	0	0	42.37
	May	0	0	0	4.8	7.71	13.37	14.24	0	0	0	0	40.12
	June	0	0	0	11.13	7.58	11.05	6.87	0	0	0	0	36.63
	July	0	0	0	11.75	10.39	5.35	11.13	0	0	0	0	38.62
	Aug	0	0	0	6.19	10.4	11.23	4.18	0	0	0	0	32
	Sep	0	0	9.6	8.47	4.9	9.76	13.68	0	0	7.31	7.91	61.63
	Oct	0	0	0	8.21	8.26	5.59	9.31	0	0	0	0	31.37
	Sum	0	0	9.6	56.09	57.73	62.65	71.92	0	9.53	7.31	7.91	



