



Are There Sufficient Landsat Observations for Retrospective and Continuous Monitoring of Land Cover Changes in China?

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Introduction

The supplementary material includes the following contents: (1) The yearly and monthly numbers of Landsat imagery in China from 1984 to 2017; (2) the yearly and monthly average numbers of total and valid Landsat observations in China from 1984 to 2017; (3) spatial distributions of total and valid Landsat observations in China in different months; (4) spatial distributions of total and valid Landsat observations in China in terms of different sensors; (5) Google Earth Engine codes for the investigations of Landsat data availability in China.

Text S1. Yearly and Monthly Numbers of Landsat Imagery in China

Figure S1 shows the yearly and monthly amounts of L5/7/8 surface reflectance images in China during 1984–2017. The yearly and monthly amounts of Landsat images generally show an increasing trend over time, with two sharp increases during 1999–2000 and 2013–2014 (Figures S1a and S1b). The yearly amounts of Landsat images increased from ~5000 images/year before 1999 to ~10,000 images/year during 2000–2011, then they decreased in 2012, followed by a dramatic increase to ~15,000 images/year since 2013 (Figure S2a). In terms of the three sensors, the yearly amount of images of L8 were the most (7047–10,005), followed by those from L7 (1731–8871) and L5 (576–8318). The monthly amounts of Landsat images increased from ~500 images/month before 1999 to ~1000 images/month during 2000–2011, then they decreased in 2012, followed by a dramatic increase to ~1500 images/month since 2013 (Figure S1b).

Figure S2 shows the monthly amounts of L5, 7, and 8 images in China from 1984 to 2017, respectively. For L5, the yearly amount of images gradually increased since 1984, and has kept relatively stable since 1991 (Figure S2a). Significant variations exist in monthly L5 image numbers among different months, ranging from 0 to 856. For L7, the monthly amounts of images have gradually increased since July 1999, and kept relatively stable since 2000 (Figure S2b). The numbers of L7 images also vary among different months, ranging from 0 to 865. It was obvious in the color intensity map that the monthly amounts of L7 images during 2014–2017 were significantly more than those in the previous years (Figure S2b). For L8, the differences in monthly amounts of images were smaller compared to L5 and L7, ranging from 143 to 914 (Figure S2c). In terms of the comparisons among the three sensors, the monthly amounts of images from L8 were the highest (ranging from 143 to 914), followed by L7 (0 to 865), and L5 (0 to 856) (Figure S2a–S2c).

Text S2. Yearly Average Numbers of Total and Valid Landsat Observations in China

Figure S3 shows the yearly average number of total and valid observations of the three Landsat sensors in China from 1984 to 2017. As can be seen, the annual average number of total (valid) observations of the three Landsat sensors within China varied from 1.63 to 60.25/1.13 to 31.72 during 1984–2017 (Figures S3a and S3b). Specifically, the annual average number of total (valid) Landsat observations gradually increased after the launch of L5 in March 1984, and kept relatively stable to ~20 (~10) from 1991 (Figures S3a and S3b). Then, the numbers increased from 1999, and reached ~40 (~20) since 2000, double of what they were during 1991–1999 (Figures S3a and S3b). Due to the failure of L5 in capturing images since November 2011, the annual average numbers of total (valid) observations decreased to ~20 (~10) in 2012. With the launch of L8 in February 2013, the numbers dramatically increased from 2013, and have kept relatively stable to ~60 (~30) since 2014 (Figures S3a and S3b). In terms of the three sensors, the annual average numbers of total (valid) observations within China from L8 were the most, ranging from 22.75 to 32.67 (13.38 to 18.77), followed by L7 (5.31 to 27.63/3.52 to 13.37), and L5 (1.63 to 25.73/1.13 to 15.50).

Text S3. Spatial Distributions of Total Landsat Observations in China in Different Months

Figure S4 shows the spatial distributions of total Landsat observations within China in different months. Generally, total Landsat observations in China in January-April showed similar spatial patterns, namely: The central, southern, and western parts of China had relatively less observations with numbers less than 100, while there were more observations with numbers more than 100 in the northern and southwestern parts of China (Figure S4). Then, the total observation numbers in Southwestern China began to decrease in May, and only Northern and Northeastern China had relatively more observations with numbers more than 100 in June (Figure S4). From July, the observation numbers in the eastern parts of China began to increase, and Landsat observations across the entirety of China showed similar spatial patterns in July and August, namely: Northern and Eastern China had relatively more observations with numbers more than 100, while Western and Southwestern China had less observations with numbers less than 100 (Figure S4). After that, the total observation numbers in the southwestern parts of China began to increase from September (Figure S4), and the spatial patterns of Landsat observations in China were similar in October-December, namely: Southern China had relatively less observations, as well as the western parts of the Xinjiang Autonomous Region and the northern parts of the Tibet Autonomous Region; while Northern, Northeastern, Eastern, and Southwestern China had more observations (Figure S4).

To reveal the spatial patterns of Landsat observations along with latitudes (15 N°–50 N°), we also calculated the average number of total observations in each one-degree latitude interval within China. Generally, the average numbers of total observations in each one-degree latitude interval within China increased along with the latitudes, though it showed a decreasing trend along with the latitudes in high latitudes (>45 N°) in December and January (Figure S4).

Text S4. Spatial Distributions of Valid Landsat Observations in China in Different Months

Figure S5 shows the spatial distributions of valid Landsat observations within China in different months. Generally, valid Landsat observations in China in January–April showed similar spatial patterns, namely: The central, southern, and western parts of China had relatively less valid observations with numbers less than 80, while there were more valid observations with numbers more than 80 in the northern and southwestern parts of China. Then, the valid observation numbers in Southwestern China began to decrease in May, and only Northern and Northeastern China had relatively more valid observations with numbers more than 80 in June. From July, the valid observation numbers in the eastern parts of China began to increase, and valid Landsat observations across the entirety of China showed similar spatial patterns in July and August, namely: Northern and Eastern China had relatively more valid observations with numbers with numbers more than 80, while Western and Southwestern China had less valid observations with numbers for the southwestern china had relatively more valid observations with numbers more than 80, while Western and Southwestern China had less valid observations with numbers less than 80. After that, the valid observation numbers in the southwestern parts of China began to increase from September, and the

spatial patterns of valid Landsat observations in China were similar in October–December, namely: Southern China had relatively less valid observations, as well as the western parts of the Xinjiang Autonomous Region and the northern parts of the Tibet Autonomous Region; while Northern, Northeastern, Eastern, and Southwestern China had more valid observations.

Given the variations of cloud covers, cloud shadows, and terrain shadows in different regions, we investigated the spatial patterns of valid Landsat observations within China along with the latitudes (15 N° – 50 N°) by calculating the average number of valid observations in each one-degree latitude interval. Generally, the average number of valid observations in each one-degree latitude interval within China increased along with the latitudes, though it showed a decreasing trend along with the latitudes in high latitudes (> 45 N°) in December and January (Figure S5).

Text S5. Spatial Distributions of Landsat Observations in China in Terms of Different Sensors

Figure S6 shows the spatial distributions of total and valid Landsat observations of L5, 7, and 8 within China from 1984 to 2017, respectively. Total and valid observations of different sensors showed different spatial patterns. For L5, Northern and Northeastern China had relatively more total (valid) observations with numbers more than 300 (240), while Southern and Western China (Western Xinjiang and Northern Tibet) had less. For L7, there were relatively more total (valid) observations in the Northern, Northeastern, and Western China with numbers more than 240 (140), while less in Southern China. For L8, only Western China had relatively more total observations with numbers more than 100. The spatial patterns of valid observations were different from that of total observations, namely: There were small differences in the spatial patterns of valid observations, except that the southern parts of China had relatively less valid observations with numbers less than 80.

By investigating the trends of total and valid observations along with the latitudes, we found that the average number of total and valid observations of the three sensors in each one-degree latitude interval within China increased along with the latitudes (Figure S6). It is notable that the average number of total and valid observations along with the latitudes kept relatively stable in latitudes higher than 35° N (Figure S7).



Figure S1. Yearly (**a**) and monthly (**b**) amounts of L5, 7, and 8 surface reflectance images in China from 1984 to 2017.

Dec.	57	44	345	464	524	643	576	656	713	608	627	488	587	508	613	678	658	524	344	608	636	0	660	0	326	450	733	0
Nov.	77	90	403	450	567	610	460	700	735	516	679	622	469	633	578	509	596	537	476	463	698	602	652	0	419	779	672	191
Oct.	47	79	217	381	494	608	357	600	613	413	570	432	676	645	564	438	633	545	534	491	726	625	800	125	683	856	692	397
Sep.	71	57	74	415	442	437	244	585	504	442	622	423	683	563	655	465	635	545	505	484	562	557	715	674	571	707	554	564
Aug.	68	89	176	193	276	514	425	539	529	499	537	429	591	577	489	481	538	582	503	487	555	422	655	645	550	720	601	688
Jul.	66	64	281	270	239	270	346	477	539	460	528	424	450	485	388	486	505	604	528	496	501	520	534	620	630	685	536	491
Jun.	46	75	319	287	458	440	477	493	582	501	420	407	482	502	426	395	513	500	412	461	580	526	503	501	623	691	514	596
May	105	71	86	426	371	557	593	532	638	665	556	533	618	528	531	483	548	571	242	448	634	582	599	692	707	782	487	647
Apr.	39	96	135	371	414	344	556	574	650	633	553	649	585	576	557	464	535	608	37	426	618	587	591	633	629	706	683	690
Mar.	0	70	80	434	391	494	581	568	683	677	699	699	619	668	515	282	577	679	492	502	582	640	326	609	656	773	476	632
Feb.	0	40	117	343	390	502	492	540	665	639	621	507	567	633	545	626	553	589	562	512	604	464	591	614	413	682	675	557
Jan.	0	63	73	375	520	477	565	638	654	682	617	615	329	685	610	497	526	613	516	528	558	558	151	597	11	487	482	668
2	7	35	90	22	8	6	0	1	32	33	4	95	90	76	8	66	0	5	2	33	4	5	90	17	8	6(0	Ξ
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Figure S2. Monthly amounts of L5 (**a**), 7 (**b**), and 8 (**c**) surface reflectance images in China from 1984 to 2017.



Figure S3. Yearly average number of total (**a**) and valid (**b**) observations of L5, 7, and 8 in China from 1984 to 2017.



Figure S4. Spatial distributions of total Landsat observations in January–December. For each subfigure, the left part was the spatial distributions of total observations of L5, 7, and 8 in China in the specific month during 1984–2017, while the right part was the number of Landsat observations along with the latitudes.



Figure S5. Spatial distributions of valid Landsat observations in January–December. For each subfigure, the left part was the spatial distributions of valid observations of L5, 7, and 8 in China in the specific month during 1984–2017, while the right part was the number of valid Landsat observations along with the latitudes.





Figure S6. Spatial distributions of total (the first row) and valid (the second row) observations of L5, 7, and 8 in China from 1984 to 2017. For each subfigure, the left part was the spatial distributions of total (valid) observations in China during 1984–2017, while the right part was the total (valid) observation numbers along with the latitudes.

Google Earth Engine Code of This Study

// get the bites of data quality assessment band

function getQABits (image, start, end, newName) {

// Compute the bits we need to extract.

```
var pattern = 0;
```

```
for (var i = start; i <= end; i++) {
```

```
pattern += Math.pow(2, i);
```

}

// Return a single band image of the extracted QA bits, giving the band a new name.

return image.select([0], [newName])

.bitwiseAnd(pattern)

.rightShift(start);

}

//remove bad observations (clouds, cloud shadows), for more info pls contact Corresponding author

```
function filterBadObs(img){
```

// selection of Quality Assessment band

var cfmask = img.select(['pixel_qa']);

// mask of cloud

var cloud_mask = getQABits(img.select('pixel_qa'),5,5,'cloud');

// mask of cloud shadow

var cloudShadow_mask = getQABits(img.select('pixel_qa'),3,3,'cloudShadow');

```
var
                                           mask
ee.Image(0).where(cloud_mask.eq(0).bitwiseAnd(cloudShadow_mask.eq(0)),1);
 return mask
 }
function clipImage(image){
 return image.clip(region)
}
function count2Mean(year){
 //from Jun.1 to Oct.1
 var dataRange = ee.DateRange(ee.Date(year),ee.Date(year).advance(4,'month'))
 // surface reflectance image collection of Landsat 5/7/8
 var ImageCollectionL5 = ee.ImageCollection('LANDSAT/LT05/C01/T1_SR')
                   .filterBounds(region)
                   .filterDate(dataRange)
                   .sort('system:time_start')
                   .select(['B1','pixel_qa']);
 var ImageCollectionL7 = ee.ImageCollection('LANDSAT/LE07/C01/T1_SR')
                   .filterBounds(region)
```

.filterDate(dataRange)

.sort('system:time_start')

.select(['B1','pixel_qa']);

var ImageCollectionL8 = ee.ImageCollection('LANDSAT/LC08/C01/T1_SR')

=

.filterBounds(region)

.filterDate(dataRange)

.sort('system:time_start')

.select(['B2','pixel_qa'],['B1','pixel_qa']);

var

ImageCollection=ee.ImageCollection(ImageCollectionL5.merge(ImageCollectionL7).merg e(ImageCollectionL8)) // Calculation of yearly percentages of Landsat pixels with at least one valid observation

// Removing invalid pixels

var GoodObsers = ImageCollection.map(filterBadObs).select(0)

// Calculating valid pixel numbers

var validNum=GoodObsers.sum().select(0);

var validExistOrNot = validNum.gt(0)

// Total numbers of Landsat pixels with at least one valid observation in China

var areaProportion = validExistOrNot.reduceRegion({

reducer: ee.Reducer.mean(),

geometry: region,

scale: 30,

maxPixels:1e13,

bestEffort:true,

tileScale:16

});

var dict = {Area_Percentage: areaProportion};

return ee.Feature(null,dict);

}

//Define region

var chinaBoundary = ee.FeatureCollection("users/2271832363/Subregion_IGSNRR");

var region = chinaBoundary.filter(ee.Filter.eq('Name','XJ'));

//Definition of year, from 1984 to 2017

```
var list = ee.List.sequence(0,33,1);
```

```
var list2Date = function (num){
```

return ee.Date('1984-06-01').advance(num,'year'); // from 1984 to 2017

}

```
var year = list.map(list2Date);
```

print(year)

//Final Results

var fc = ee.FeatureCollection(year.map(count2Mean));

//Exporting the final results to csv file

Export.table.toDrive({

collection:fc,

description: 'XJ_1984_2017',

fileFormat: 'CSV',

folder:'Subregion'

//Exporting the spatial figure

// Export.image.toDrive({

- // crs: 'EPSG:4326',
- // image: result.clip(region),
- // description: "XJ_One_year",
- // scale: 30,
- // region: region,
- // folder:"Subregion",
- // maxPixels: 1.0E13
- // })



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