Impact of spatial scale for phenological indices derived from remotely sensed data

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Abstract

Land surface phenology (LSP) characterizes the vegetated land surface and is practical to understand terrestrial environmentals at a global scale. Regularly observed remotely sensed data such as Landsat, MODIS, and AVHRR contributes to analyze LSP spatially. However, at least two main challenges should be addressed such that (i) the spatial resolution which attributes to the data source may significantly impact to LSP estimation, and (ii) the estimated LSP may not represent the vegetated land surface well due to the mixed land cover. Previous studies have shown that the estimation of LSP from different data is not consistent due to the spatial scale of data but yet fully linked with the mixed land cover problem. Thus, in this study, we attempt to analyze the impact of spatial scale issue to the estimated LSP in homogenous land cover areas. We use freely available remotely sensed data with different spatial resolution such as Landsat (30m), MODIS (250m, 500m, 1km), and GIMMS3g (8km) and estimate phenological indices for each. As land cover description differs among data products, land cover classes are aggregated into 12 classes globally from major global land cover producs (GLCC, GLC2000, and globcover), then spatially homogenuous land cover are only picked up. Phenological indices such as the magnitude and the peak of DOY are calculated by harmonic analysis to compare results among different spatial scales. The variability of phenological indices is explored according to the different spatial scale under the condition of homogenuous land cover. It is expected to model such variability to overcome the spatial scale impact and such characteristics depending on the spatial scale should be taken into account when considering LSP from satellite.

Impact of spatial scale on phenological indices derived from remotely sensed data

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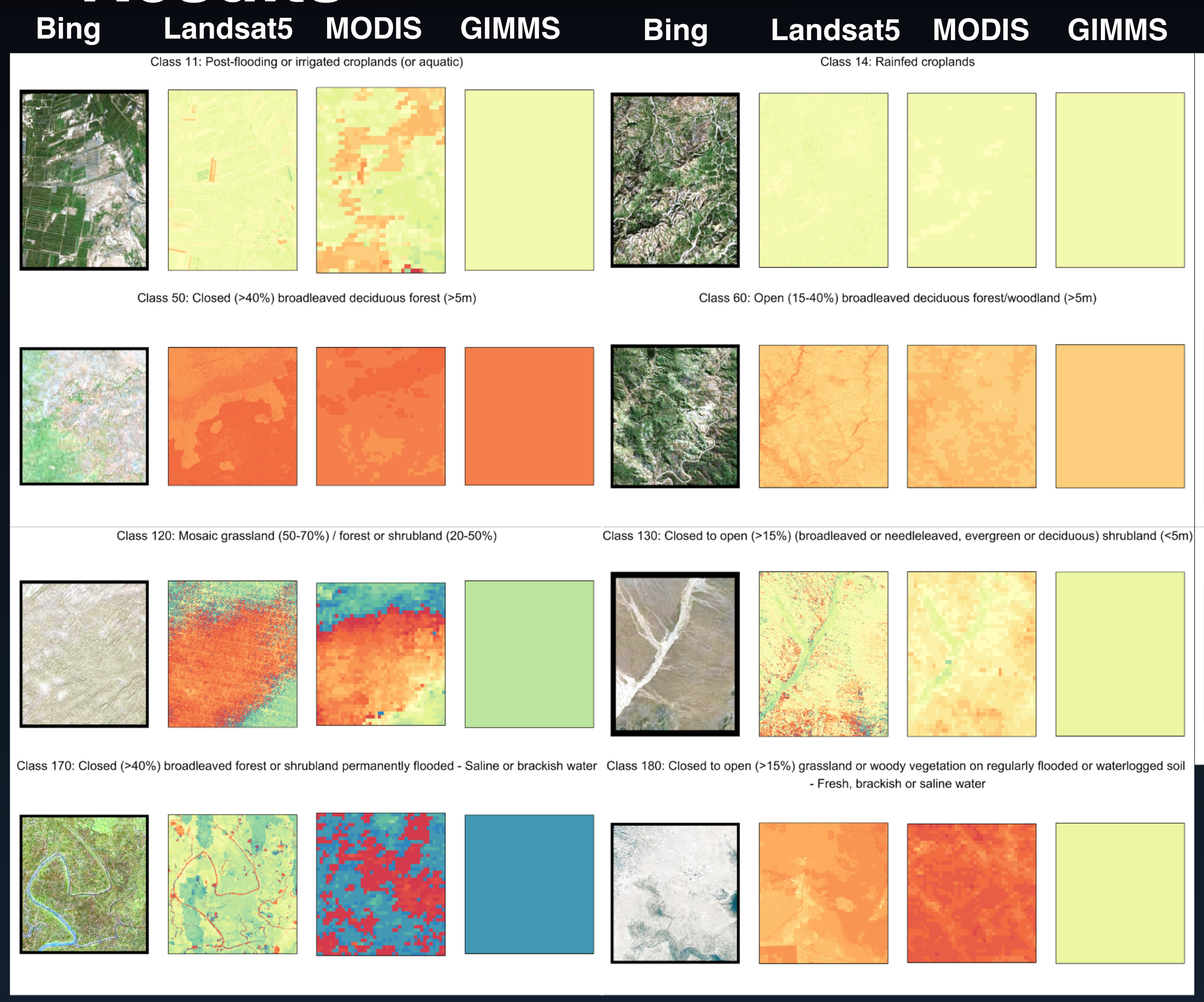
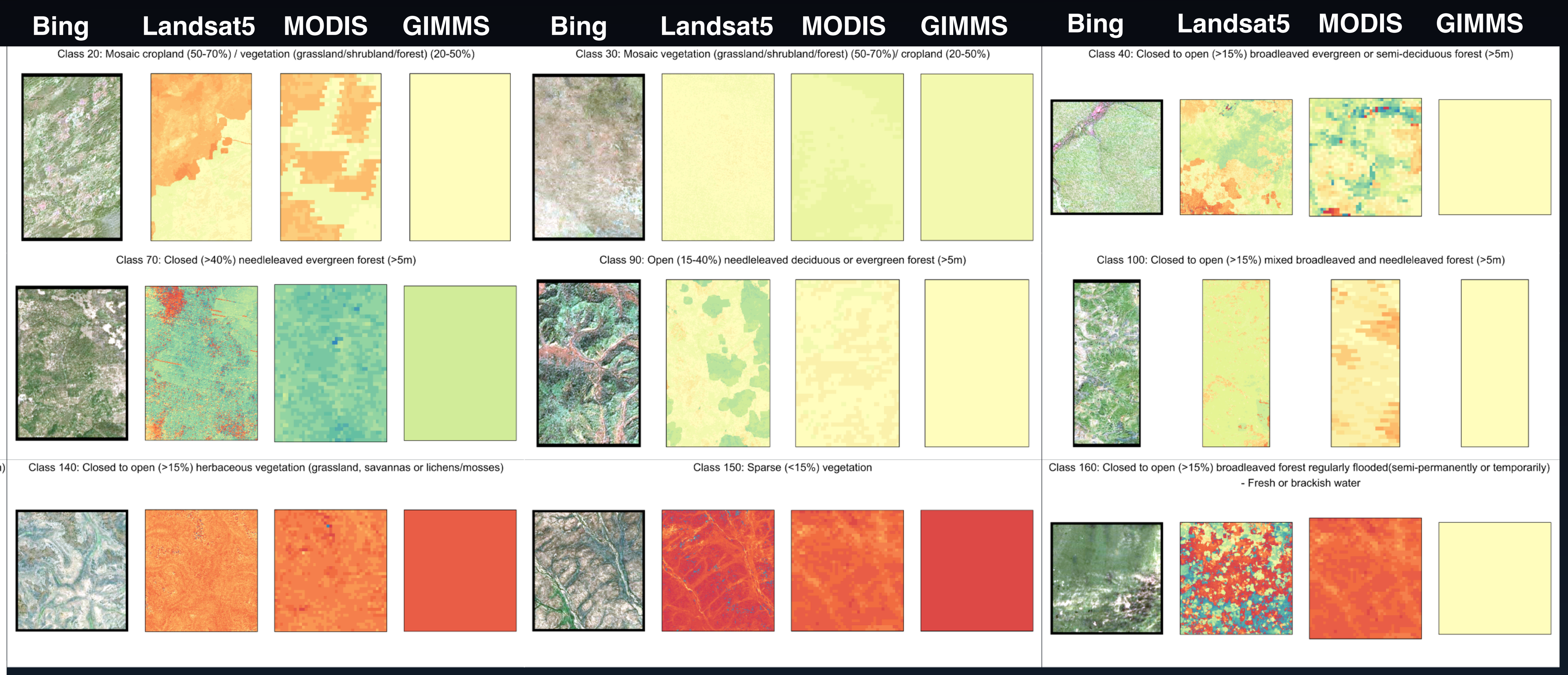
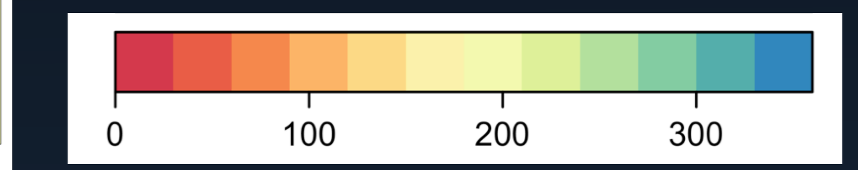
Introduction

Land surface phenology (LSP) characterizes the vegetated land surface and is important for understanding terrestrial environments at a global scale. Previous studies have shown that the estimation of LSP from different data is not consistent due to the spatial scale of data but yet fully linked with the land cover. In this context, issues would be that (i) the spatial resolution of the LSP data may significantly impact on LSP estimation and (ii) the estimated LSP may not represent the vegetated land surface well due to the mixed land cover. This study explores variations of LSP extracted from several sensors in homogenous land cover areas. While it is still difficult to obtain reliable data which represent global land cover well and vegetation conditions, this empirical study attempt to demonstrate how such impact can be addressed.

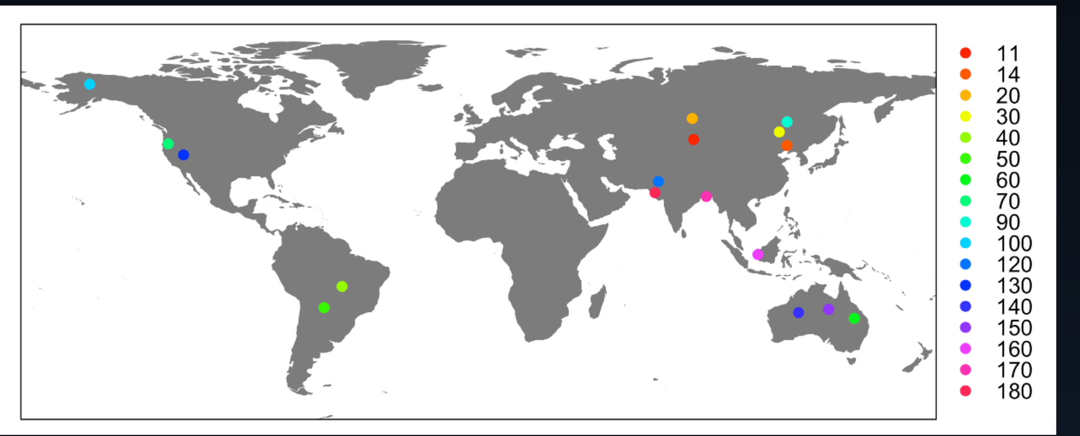
Results







Left: Bing image
Middle left: peakDOY of Landsat 5
Middle right: peakDOY of MODIS
Right: peakDOY of GIMMS



Spatial distribution of test site.

METHODOLOGY

The peak DOY of unimodal vegetation index curve is estimated from harmonic analysis by using Landsat, MODIS, and GIMMS time series data as a case study. To compare the impact on spatial scale, mean, median, standard deviation, and global Moran's I for Landsat and MODIS data are calculated. Additionally the cover rate which shows how much results from Landsat or MODIS corresponds the results with that from GIMMS (±9 days) in total is also calculated (e.g., higher rate suggests similar results to GIMMS-based analysis).

Materials

NDVI is calculated from Landsat 5 Surface Reflectance (30m), MODIS MOD13Q1 (250m), and GIMMS3g (0.083degree≒8km) for the year 2009. Temporal resolution of all datasets are 16 days and all missing values are interpolated using na.interp function of the forecast package on R software. Then harmonic analysis is applied for each product. The peakDOY of the unimodal wave which represents the main temporal profile of the original NDVI is calculated as a phenological parameter.
Homogeneous land covers are analyzed using by Globcover (version 2.3) which classify terrestrial surfaces into 23 classes with 300m spatial resolution at the global scale. These classes are spatially aggregated separately as the same pixel size as the GIMMS3g resolution. After omitting classes showing non-vegetation classes and non available satellite data, 17 class of them are used in this study. Sample locations are randomly allocated to meet the criteria which satisfies all satellite data are available for implementing harmonic analysis.

Summary of change

	Gimms	Mean (ls5)	Mean (modis)	SD (ls5)	SD (modis)	Median (ls5)	Median (modis)	Gmoran (ls5)	Gmoran (modis)	Cover rate (ls5)	Cover rate (modis)
class 11	207	204.00	185.25	13.96	46.37	206	206	0.83	0.65	0.71	0.26
class 14	201	204.32	201.23	6.10	3.95	205	202	0.74	0.73	0.86	0.98
class 20	186	152.94	157.36	38.84	38.43	151	126	0.97	0.70	0.30	0.16
class 30	200	190.74	209.63	5.84	4.09	191	209	0.51	0.81	0.51	0.50
class 40	185	197.32	213.33	53.63	55.79	208	208	0.86	0.52	0.09	0.16
class 50	65	66.12	66.73	11.25	7.17	63	68	0.92	0.92	0.47	0.79
class 60	134	124.66	119.75	12.28	7.73	126	121	0.80	0.71	0.55	0.26
class 70	250	253.79	299.50	88.32	12.22	286	300	0.32	0.41	0.03	0.00
class 90	191	213.89	184.01	33.40	7.21	200	184	0.92	0.56	0.41	0.60
class 100	191	218.66	163.14	31.61	21.30	230	171	0.68	0.56	0.01	0.08
class 120	270	133.86	150.73	111.04	111.94	80	100	0.57	0.82	0.04	0.00
class 130	212	185.61	169.74	57.35	23.90	191	169	0.36	0.75	0.16	0.06
class 140	45	83.07	70.23	22.21	12.33	82	71	0.19	0.17	0.04	0.04
class 150	23	37.28	49.94	57.39	11.37	25	48	0.23	0.65	0.45	0.03
class 160	184	165.94	49.94	133.77	11.37	147	48	0.67	0.65	0.01	0.00
class 170	358	243.21	206.44	56.74	171.14	250	345	0.55	0.46	0.01	0.45
class 180	224	97.81	49.94	15.33	11.37	96	48	0.92	0.65	0.00	0.00

DISCUSSIONS & CONCLUSIONS

Even spatially aggregated homogeneous pixels (8km) are picked up from Globcover (v2.3), bing map shows complex landscape. Sparse or mosaic land cover type represents inconsistent results among scales.

This study demonstrates how spatial scale attributed with satellite sensors affects calculations of phenology index as a case study. It addresses LSP highly depends on data itself, and differences among spatial scales as well as land covers need to be considered. This message would be helpful for understandings of macro-scale LSP analysis to inspect results, suggesting macro-scale results may not represent local conditions well.
Further analyses will be focused on the improvement of identifying homogeneous land cover, internal variations in a class, analyses for other phenological parameters, and continuous models for phenology beyond the effect of scales.

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References: Zhang et al. (2017) Exploration of scaling effects on coarse resolution land surface phenology, Remote Sensing of Environment 190, 318-330.

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