MAPPING FLOOD RECESSIONAL GRASSLANDS USED BY OVERWINTERING GEESE: A MULTI-TEMPORAL REMOTE SENSING APPLICATION

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Commission VII, WG 5 / TS 17

KEYWORDS: Phenology, multi-temporal analysis, MODIS, classification, grassland, wetland, migratory birds.

ABSTRACT:

Significant numbers of grass eating geese migrate in east Asia as far south as the Yangtze. Geese prefer young and high quality vegetation, a resource difficult to find in central China in autumn and winter when vegetation turns senescent. Cool season grasses and *Carices* develop in autumn in flood recessional grasslands along the Yangtze and geese forage in this biotope, attracted by the availability of young tissue of high quality in autumn and winter. Recently more insight became available on the distribution of geese species, following winter bird counts along the whole of the Yangtze organized by WWF China. In this study we explored the possibility using time series of MODIS images to localize the distribution of flood recessional grasslands along the Yangtze. The images were classified using PCA of a time series of NDVI and EVI images. We also developed a rule based system to classify vegetation based on NDVI, EVI and LSWI. Independent field data and TM imagery were used to assess the accuracy of the maps. Mapping accuracy was significantly higher for the rule based and the EVI based classification as compared to NDVI classification. The distribution of geese as recorded by the WWF winter bird counts matched well with the flood recessional grassland maps.

1. INTRODUCTION

Recent winter bird surveys along the Yangtze organized by WWF revealed large numbers of over-wintering geese (Barter *et al*., 2004). Significant proportions were reported of the populations of the globally endangered swan goose (*Anser cygnoides*) and lesser white-fronted goose (*Anser erythropus*) and three other species. WWF called for mapping their habitat, because the distribution and extent remained poorly explored.

Geese forage on the leaves and rhizomes of grasses and sedges (Zhang & Lu, 1999). They prefer easily digestible plant tissue low in fiber and high in nitrogen and/or carbohydrate content (Owens, 1997; Vickery & Gill, 1999). High quality is common to young tissue, but rapidly deteriorates in aging tissue. Also geese prefer vegetation of specific height (Allport, 1989; Vickery & Gill, 1999; Vickery *et al*., 1997). Shorter vegetation is avoided while foraging efficiency goes down with reduced bite size, while tall vegetation is avoided because of poor tissue quality (Riddington *et al.*, 1997; Summers & Critchley, 1990).

Where along the Yangtze do geese find such actively growing high quality vegetation? Active vegetation growth in terrestrial ecosystems along the Yangtze occurs in summer, following the onset of the monsoon. The geese arrive in autumn when rains have stopped and temperatures go down. The by then senescent terrestrial vegetation does not correspond to the forage geese prefer. Where upon then do geese feed from autumn to early spring? They are known to forage in grasslands developing upon the recession of the Yangtze waters. Submerged in summer they emerge and green up in autumn upon recession of the Yangtze floods thus providing the high quality forage for geese.

Not all of the vegetation in the floodplains might be suitable though, as grasslands show a zonation from high to low (Cai *et al*., 1997; Wu & Ji, 2002). Grasslands at higher elevations remaining green throughout summer are unsuitable for geese because they are tall and senescent in autumn. Shorter vegetation at low elevation greens up in autumn when the geese arrive provides the high quality forage they prefer. Hence, the vegetation along this elevation gradient displays a marked differences in phenology, which could be employed to map its distribution.

Multi-temporal remote sensing offers the possibility to monitor seasonal patterns of vegetation greenness and remote sensing derived multi-temporal information has been used to classify and map plant communities which differ in phenology (Davidson & Csillag, 2003; Tieszen *et al.*, 1997). We thus suggest that it would be possible to differentiate grassland communities based on their phenology, and for instance distinguish low from high elevation grasslands.

In this article we demonstrate that multi temporal MODIS imagery could be used to distinguish low and high elevation grasslands. We furthermore analyzed the relation between the distribution of geese and these grasslands.

2. MATERIAL AND METHODS

Study area

The research was executed at regional and local level. The regional study area included the lower Yangtze floodplain from Dongting Lake in the west to Poyang Lake and the lakes in Anhui province in the east (28° 12′- 31° 28′ N, 112° 18′- 117° 10′ E). The local study area was situated within Poyang Lake NR (29° 05′ - 29° 18′ N, 115° 53′- 116° 10′ E).

Local area mapping

At the end of November 2005 grassland vegetation was described for 208 sites of 30x30m randomly located along transects perpendicular to the shore of Bang, Sha, Dahu, Zhushi, Changhu and Xuzhou Lake. We classified the wetland vegetation in two classes; summer green grassland dominated by the tropical grass species *Miscanthus sacchriflorus Benth* and *Cynodon dactylon* and low elevation grassland dominated by *Carices (C. cinerascens*, *argyi* and *unisexualis)* and a number of cool season grasses**.** The first greens up in spring and remains green throughout summer, while the second has two separate periods of greening interrupted by a period when the vegetation submerges. Consequently the first is called early the second late greening grassland throughout this article. In addition we generated from topographic maps 46 sites for water and 52 for rice paddy fields and other vegetation not affected by the floods.

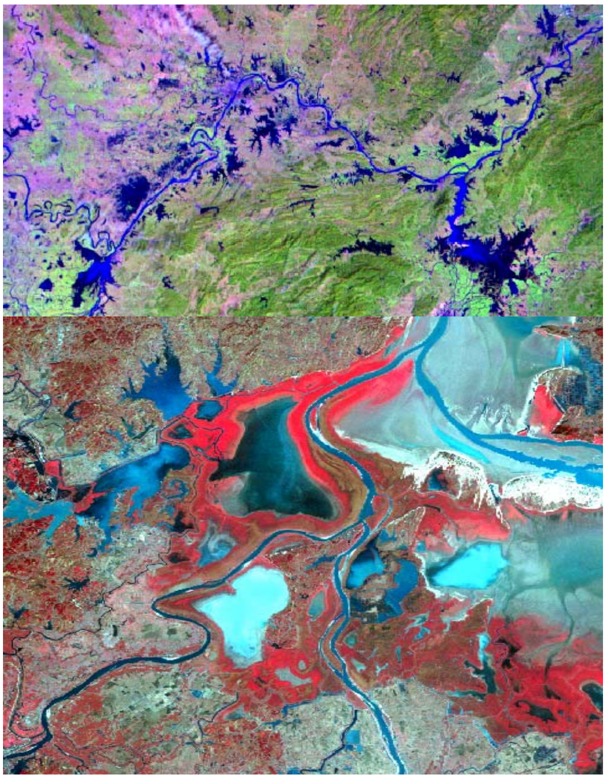

Figure 1. Top: MODIS image of the regional study area showing the lower Yangtze with its associated lakes including Dongting and Poyang. Bottom: Landsat TM false color composite of 29 November 2004 of the local study area showing the north west of Poyang lake. The bright red and the brownish colors fringing lakes and rivers correspond to late and early greening grasslands respectively.

We selected the Landsat 5 TM Image of 29th November 2004 in where the flood recessional grasslands where clearly distinguishable from open water and non flooded lands. We geometrically rectified the image using six ground control points from the topographic map of Poyang Lake NR. Maximum likelihood classification was used to classify the TM image using 70% of the field data for training.

Regional area mapping

For the regional area study one sample of 133 ground truth points of 250m size was collected in the field and from the TM classification for the flood recessional grasslands and another sample of 168 points was derived from the vegetation map of the Yangtze River (Lin *et al.*, 1999) to describe open water, paddy rice and other upland vegetation.

MODIS imagery of 23-7, 8-8, 16-9, 4-10, 7-11 and 5-12 2004 and 6-3 and 21-4 2005 was acquired from receiving stations at Wuhan University and Institute of Geographical Science and Natural Resource Research, CAS, Beijing. The image of 2004-08-08 was geometrically rectified using three control points. The other seven images were registered to this master image using seventeen control points. Bands 1 to 7 were atmosperically corrected using the histogram minimum value exclusion method (Mei *et al.,* 2003) and clouds were removed. Bands 3-7 were resampled to 250m and digital numbers were transformed into reflectance values. The normalized differential (NDVI) and the enhanced vegetation index (EVI) were calculated for all 8 images (Huete *et al*., 2002; Huete *et al.*, 1997; Xiao *et al*., 2005). The indices of the sequential images were highly correlated. Principal component analysis (PCA) was used to transform the eight dates into a number of uncorrelated components. Table 1 reveals that the first three principal components accounted for 93% of the variance in NDVI. PC 1 and 2 were related overall brightness while PC 3 was related to seasonal differences. Hence we retained PC 1, 2, 3 for further analysis. For EVI PC 6 related to seasonal differences and we retained PC 1, 2 and 6.

Vegetation index	PC1	PC2	PC3	PC4	PC5	PC6	PC7
NDVI	80.1	89.3	92.6	94.8	96.6	97.9	98.9
EVI	81.7	91.0	93.9	95.5	97.0	98.4	99.4

Table 1. Cumulative variance explained by the first seven principal components of the eight NDVI and EVI images respectively.

Next the retained principal components were subjected to unsupervised classification with 20 classes. These classes were assigned to four land cover classes (water, early and late up-greening grasslands and other vegetation) based on knowledge of the study area.

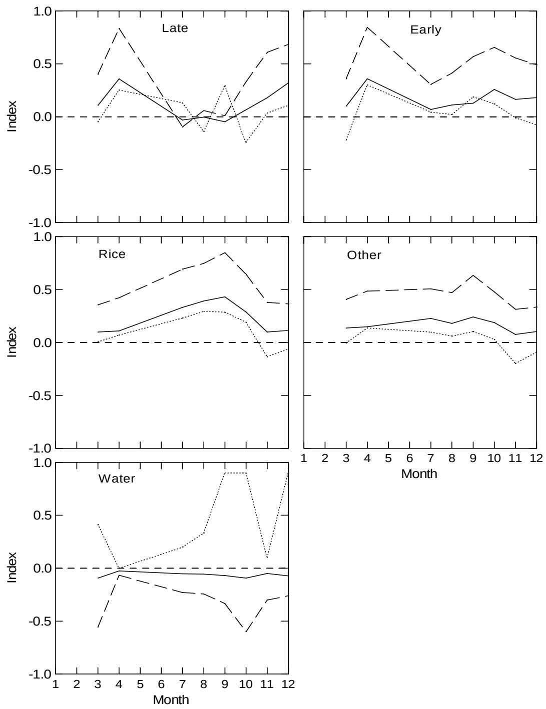

Figure 2. Seasonal development of NDVI (interrupted), EVI (continuous) and LSWI (dotted) derived from MODIS imagery for five ecosystems along the Yangtze.

Xiao *et al*. (2005) used time series of NDVI, EVI and LSWI (land surface water index) to classify rice paddy fields in southern China. Visual analysis of time series for rice was used to develop threshold values to classify lands as paddy or others. We used the same method to develop rules to distinguish four land cover types: water, early and late up-greening grasslands and upland vegetation including rice paddy. The seasonal patterns of NDVI, EVI and LSWI for five land cover categories are shown in figure 2. Interpretation of these curves combined with knowledge about phenology was used to develop the following rules. Water: EVI < 0.1 and EVI < LSWI in at least 5 out of 8 images. Upland vegetation: NDVI-9 > NDVI-4 or EVI-9 > EVI-4. Flooded land: EVI < LSWI or NDVI < LSWI. A further refining of the last category was done as follows. Early up-greening grasslands NDVI-10 > NDVI-7 and NDVI-10 > NDVI-12 or EVI-10 > EVI-7 and EVI-10 > EVI-12. Late upgreening grasslands: (NDVI-10 < NDVI-11 or NDVI-10 < NDVI-12) or (EVI-10 < EVI-11 or EVI-10 < EVI-12).

Accuracy assessment

Accuracy assessment of the various images was performed using overall accuracy and Kappa (Congalton 1992). The accuracy of the classified local scale TM image was assessed using a sample of 93 field observations. The accuracy of the classification of the regional scale MODIS imagery was assessed using a validation sample of 128 points. McNemar's test (de Leeuw *et al*., 2006) was used to assess whether the classification methods differed in accuracy.

Analysis of animal distribution

We next investigated how well goose distribution data were related to the maps produced. Regional scale observations on the presence and number five species of geese (Bean goose, swan goose, lesser and greater white fronted goose and greyleg goose) recorded in six provinces (Anhui, Hubei, Hunan, Jiangsu, Jiangxi and Shanghai) along the Yangtze in Jan – Feb 2004 data was acquired from World Wide Fund for Nature (WWF) in Wuhan (For further description, see Barter *et al.* 2004) . For Poyang Lake NR the distribution of greater white-fronted goose was acquired from sketch maps drawn by staff during a bird survey in November 2005. In addition we recorded in November 2005 the distribution of droppings of greater white-fronted goose. Droppings are cylindrical, 5.8cm in length and 0.9cm in diameter and grassy-green (Zhang & Lu, 1999).

3. RESULTS

Figure 2 shows the land cover map of Poyang lake nature reserve, based on the maximum likelihood classification of the Landsat TM image. The map shows that summer green grasslands were adjacent to the rivers, which is where levees occur. Late greening grasslands fringed the lakes, which correspond to sites at lower elevation. The quality of this map was excellent, since the validation data set revealed an overall accuracy of 90% and a Kappa of 86%. The map also shows the distributionn of greater white fronted goose which were recorded predominantly in late greening grasslands.

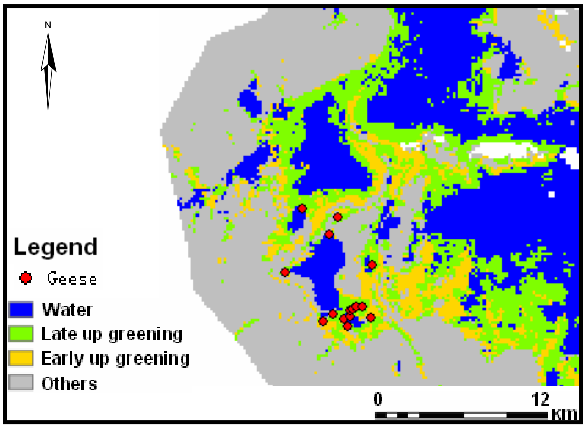

Figure 3. Maximum likelihood classification of land cover in Poyang Lake Nature Reserve, Landsat TM image of 29 November 2004. Red dots indicate observations of greater white fronted goose.

The predicted regional distribution of the four land cover classes is shown in figure 4. All three methods localize large areas of early and late greening grasslands in Dongting lake and Poyang lake, with scattered smaller sized patches of flood recessional elsewhere.

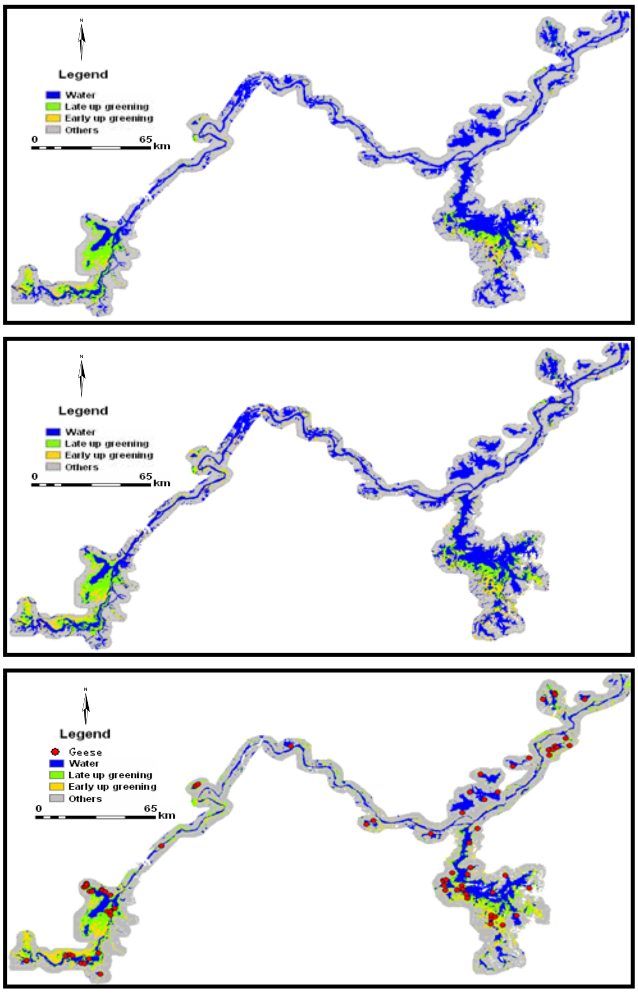

Figure 4. Distribution of flood recessional grasslands along Yangtze based on unsupervised classification of NDVI-PCA, EVI-PCA and a rule based system. Red dots represent greater white fronted goose according to the WWF survey of January 2004.

Table 2 show a confusion matrix for the three different classification methods. The overall accuracy of the three maps was 63.1, 76.7 and 79.9% for the unsupervised NDVI and EVI and rule based classification respectively. The poor accuracy of the NDVI based classification was to large degree due to late greening vegetation being classified as early greening. Both other classifiers performed much better in this respect.

Category	*Water*	*Late*	*Early*	*Other*	*Total*
Water	**85**	2	0	12	99
	86	*12*	*4*	*11*	*113*
	79	12	0	2	96
Late	1	**49**	2	1	53
	1	***92***	*14*	*1*	*108*
	3	**83**	4	6	96
Early	0	54	**24**	2	80
	0	*3*	***27***	*9*	*39*
	0	12	**39**	0	51
Other	1	3	33	**32**	69
	0	*1*	*14*	***26***	*41*
	5	1	16	**39**	61
Total	87	108	59	47	301

Table 2. Confusion matrix showing the results for classifications based on NDVI, EVI (*italics*) and rule based (underlined) classification.

Table 3 shows that the EVI and the rule based and classification were having a significantly higher accuracy than the map based on classification of NDVI images. There was no significant difference between the EVI and the rule based map.

	NDVI	*EVI*	*Rule based*
NDVI	-	19.32^{***}	27.78^{***}
EVI		-	$1.14^{n.s.}$
Rule based			-

Table 3. McNemar's statistic (χ^2) used to test for differences in classification accuracy. Significance levels: *** < 0.001, n.s. > 0.05.

The estimated area of flood recessional grassland differed between the three methods (Table 4). The NDVI classification gave the lowest estimate while the rule based map had the highest area predicted.

Method	*Early greening*	*Late greening*
NDVI	861	1760
EVI	1844	2155
Rule based	1790	2811

Table 4. Area (km^2) of early and late up-greening grasslands according to three image classification methods.

During the survey in January 2004 183,699 geese were recorded, among which were 60,886 swan goose, 79,744 bean goose, 25,241 greater and 16,937 lesser white fronted goose and 890 greylag goose. Figure 4 shows the distribution of the five geese species taken together. The figure shows a strong association between the distribution of the geese and the flood recessional grasslands.

4. DISCUSSION

Flood recessional grasslands are demanding ecosystems to be mapped. They are ephemeral and their boundaries keep changing with fluctuating water levels. The availability of multi temporal MODIS imagery allowed us to recognize classes with seasonal patterns which corresponded to particular ecosystems. This not only allowed us to discriminate two types of flood recessional grasslands but also to distinguish these from open water and rice paddy fields.

The advantage of the high temporal resolution of MODIS has the relatively low spatial resolution as a downside. This may have influenced our analysis, since the possibility to map these grasslands also depends on the size of individual grassland patches. In our case the diameter of many patches in Poyang and Dongting lake was in the order of one to several kilometres. This was sufficiently large to be picked up by the MODIS imagery. The Landsat image however revealed that there were even in these two lakes patches below this resolution. These will have gone unnoticed in the multi-temporal MODIS image analysis. It can not be excluded that numerous patches of flood recessional grasslands exist which have not be localized in our maps nor included in the estimated areal extent. The total area of these smaller patches probably only adds up to a few percent of the total area extent. A sub-pixel modelling approach could be considered to remove such bias from the area estimates.

WWF (Barter et al. 2004) was interested in the extent of the grasslands. This is particularly interesting when compared with the number of geese using the grasslands and considering whether there is sufficient foraging habitat to sustain these populations. The number of geese recorded in 2004 was around 180,000. So how do these numbers relate to the area of available flood recessional grassland? Before carrying out such analysis it should be considered that not all species depend on the flood recessional grasslands. Swan geese for instance also forage on submerged vegetation in lakes (Zhang and Lu, 1999) while the bean goose relies to a large extent on rice fields (Lei Gang, *pers. comm.*). Moreover, few geese will forage in the early greening grasslands as the vegetation is too tall and of poor quality. Even so the 1800 km^2 of late greening grassland estimated by the two more accurate methods implies that there would be approximately 1 ha of late greening grassland per head of goose, irrespective of species. This appears to be more than sufficient and we therefore conclude that it is absolutely unlikely that the size of the geese populations is limited by a shortage of suitable grasslands. Other factors though might have a negative influence on geese populations, such as intensive use by people and the associated disturbance and illegal hunting (*Pers. Comm*., Lei Gang).

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