OBJECT BASED CHANGE DETECTION OF DEGRADED POPULUS EUPHRATICA FLOODPLAIN FORESTS AT THE LOWER REACHES OF TARIM RIVER, CHINA

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ABSTRACT:

Desertification is one of the most serious current environmental challenges in the context of global change and China is among those countries that are most severely affected. One hotspot of desertification is in the lower reaches of the Tarim River where a narrow belt of floodplain forest, consisting of Euphrates poplars (*Populus euphratica*), prevent the Taklamakan and the Kum Tagh deserts from merging together. This forest has become highly degraded in recent decades as a result of dam constructions and withdrawal for irrigation. In 2000 the Chinese government launched the Ecological Water Conveyance Project (EWCP) with the goal to control the desertification and restore the degraded ecosystem in this region. The present research developed an object based image analysis change detection approach to investigate the effects of the 'ecological water' to the poplar trees. The analysis was performed on a QuickBird (2006) and a WorldView2 image (2011) using a bi-temporal change detection method. The analysis focused on a object based post classification comparison were tree crowns got independently classified, followed by an object to object comparison to detect changes. Changes are expressed in spatial modification and is evaluated in crown growth or shrinkage. Change detection analysis showed almost identical result between the field measured canopy areas of 2005 and QuickBird derived canopy areas. However the results for 2011 varied between image and field canopy area by 610 m^2 (49..6 %). The small off-nadir view angles from the QuickBird image can be the reason for high accurate canopy area estimate. The results of this study indicate that object based image analysis based on very high resolution remote sensing imagery can be used to tree crown identification and delineation as well as change detection of tree crown growth.

1. INTRODUCTION

Desertification is one of the most serious current environmental challenges in the context of global change and China is among those countries that are most severely affected (Chen and Tang 2005). One hotspot of desertification is in the Tarim River Basin in Xinjiang, Uyghur Autonomous Region. The Tarim River, with 1321 km the longest inland river in China, is running along the northern and eastern edges of the Taklamakan desert and ends in the Taitema Lake in southern Xinjiang. Ambitious agricultural development and land reclamation along the river have caused major environmental degradation and subsequently the advancement of desertification. Especially the area around the rivers lower reaches has been affected by dam constructions which disrupt the stream flow and successively decrease the groundwater level.

Riparian poplar forest grows in a narrow belt along the Tarim lower reaches. This forest type consists mainly of diversifolious poplar (*Populus euphratica*) which grows in dense clusters near the river course to sparse isolated trees towards the desert. *P. euphratica* is a phreatophytic tree that is completely dependent on groundwater supply (Rzepecki et al. 2010). The groundwater drop-off affected the poplars which have become highly degraded in recent decades (Westermann et al. 2008).

In 2000 the Chinese government granted approx. 107 x 10^8 Yuan to implement the Ecological Water Conveyance Project (EWCP) for conserving the natural vegetation, controlling the desertification and restoring the degraded ecosystem in the lower reaches of the Tarim River (Xu et al. 2007). The EWCP implementation is a so called 'controlled flooding' where the gates of the Bosten retaining lake are periodically opened and the water is deviated to the lower reaches of the Tarim.

Since the beginning of the EWCP, several studies were conducted to investigate the effects of the controlled flooding with respect to plant diversity, vegetation restoration and ecological benefits (Chen et al. 2010; Hao et al. 2010; Wu and Tang 2010; Yu et al. 2011). Remote sensing studies focused on Normalised Difference Vegetation Index (NDVI) changes over time by means of multi-temporal medium resolution data analysis (NIU et al. 2008; Sun et al. 2010; Tan et al. 2011).

However, the new generation of very high spatial resolution sensors like QuickBird or WorldView2 allow the recognition of tree clusters or individual trees (Blaschke et al. 2010). A variety of methods exists for the purpose of tree crown identification and delineation. One method focused on radiometric valleys of shadow between trees as a means of isolating crown boundaries (Gougeon 1995), another method estimated the location of tree crowns from radiometric maxima, and subsequently located the boundaries using the characteristic decrease in brightness from the centre of a crown to its edge (Culvenor 2002).

Often goes the analysis of single trees beyond the pixel level and more towards a tree object level. The so called object based image analysis (OBIA) approach combines groups of homogeneous pixels into image objects. Each image object is described by its spectral characteristics as well as spatial features such as shape, position, size, and the relationship to neighboring objects (Blaschke et al. 2008). Herrera et al. (2004) used the OBIA approach to classify trees outside forests, Bunting and Lucas (2006) delineated tree crowns within mixed-species forests of complex structure, Hay et al. (2005) used object-specific upscaling from individual tree crowns up to forest stands in a highly fragmented forest landscape and De Chant and Kelly (2009) used individual object change detection techniques to monitor the impact of a forest pathogen on a hardwood forest.

In this study we applied a bi-temporal change detection between two peak summer satellite images from QuickBird (08/10/2006) and WorldView2 (07/29/2011). The analysis focused on a

object based post classification comparison were tree crowns got independently classified, followed by a object to object comparison to detect changes. Changes are expressed in spatial modification and is evaluated in crown growth or shrinkage. The principle advantage of post classification lies in the fact that the two images are separately classified, thereby minimizng the problem of radiometrix calibration between dates and sensor types (Coppin et al. 2002).
The following research questions were addressed in this study:

- Did the canopy area of *P. euphratica* change between 2005 and 2011?
- Do changes in canopy area vary among different diameter classes?

2. METHODOLOGY

2.1 Study area

The research study area (see Figure 1) is located at the Arghan Forest Station at the lower reaches of the Tarim River (40° 8.72’ N, 88° 21.26’ E, at 830 m.a.s.l.). The terrain is a flat floodplain with a dry desert climate. In the surrounding of the station are 24 common plant species recorded. Among those is *Populus euphratica* the only tree species. Other common shrub species include *Tamarix hispida*, *Tamarix ramosissima, Elaeagnus angustifolia,* and *Karelina caspica* (Halik et al. 2006). These species have a high tolerance to salinity, dryness and heat and have a important ecological function in sand fixation (Lam et al. 2010).

Figure 1: Location of the study area within Xinjiang (China)

Within the study area (1 km²) were 26 sampling plots (each 0.125 ha) established. The plot selection was based on a double sampling for stratification designed by Lam et al. (2010). In August 2005 and 2011 were 93 trees within the sampling plots terrestrically measured. The measured tree parameters were tree height, diameter at breast height (dbh) and crown diameter. The diameter (d) of the tree crowns were measured by projecting the edges of the crown to the ground and averaging the length along two axis from edge to edge through the crown centre. The crowns of *Populus euphratica* are highly variable. Their general shape varies from relatively dense hemispherical shapes for young and healthy trees to wide open shapes for older trees. Despite the heterogeneity of the poplar crowns was the canopy area (Ca) calculated assuming homogeneous round crowns using the following equation (1):

$$\text{Ca} = \pi * (\tfrac{d}{2})^2 \tag{1}$$

2.2 Image Processing

The change detection analysis was based on two very high resolution satellite images from the QuickBird (QB) and WorldView2 (WV2) sensor (see Table 2). Both sensors are pushbroom imagers which construct an image one row at a time (Krause 2005; Updike and Comp 2010). QB acquires images with five spectral bands covering panchromatic, blue, green, red and near-infrared (NIR1) wavelengths while WV2 records data with nine spectral bands covering panchromatic, coastal, blue, green, yellow, red, rededge, NIR1, and NIR2. The purchased images were geometrically corrected and top of atmosphere reflectance values were calculated by means of sensor and band specific calibration factors (Krause 2005; Updike and Comp 2010). A new pan-sharpening algorithm called Hyperspherical Color Sharpening (HCS) (Padwick et al. 2010) was applied in order to fuse the multispectral (MS) and panchromatic (PAN) bands into one multispectral dataset with a spatial resolution of 0.6 m (QB) and 0.5 m (WV2).
Despite the sun angle differences is the major dissimilarity between the scenes the off nadir view angle. The view angle of the QB scene is close to nadir while the WV2 off nadir angle is about 16° higher.

	QuickBird	WorldView2
Recording date	08/10/2006	07/29/2011
Spatial resolution (m)	PAN: 0.6 MS: 2,4 Sharpened: 0.6	PAN: 0.5 MS: 2.0 Sharpened: 0.5
Spectral resolution (bands)	4 (blue, green, red, NIR1)	8 (coastal, blue, green, yellow, red, rededge, NIR1, NIR2)
Sun Elevation	63.1	65,4
Sun Azimuth	150.8	144.9
Off Nadir view angle	1.8	17.7

Table 2: QuickBird and WorldView2 sensor parameters

The red and NIR1 bands were used to derive the widely accepted NDVI as shown in equation (2).

$$NDVI = \frac{(\text{NIR1}-\text{red})}{(\text{NIR1}+\text{red})} \tag{2}$$

2.3 Tree identification and delineation

The object-based change detection analysis was performed using eCognition 8.7.1 from Definiens. A ruleset was developed which identifies and delineates *Populus euphratica* tree crowns from QB and WV2 imagery. The ruleset consists of several subroutines which are explained below and shown in Figure 3.

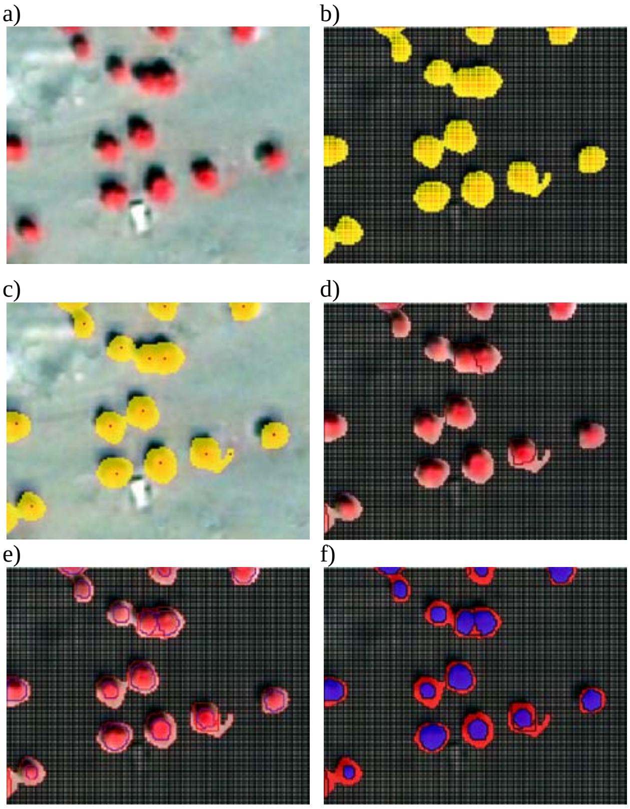

Figure 3: Object based image analysis procedure for single crown identification and delineation, a) QB scene (NIR1, red, green), b) chessboard segmentation, c) find local extrema, d) multiresolution segmentation region grow, e) contrast split segmentation, f) classification result

- **Chessboard Segmentation**

At first a chessboard segmentation with object size 1 was conducted. This segmentation method simply transformed each pixel into one image object. A NDVI threshold of 0.1 classified the newly created image objects into vegetation / non vegetation (see Figure 3 b).

- **Find local extrema**

At the whole-tree scale, the typically convex shape of a crown means that the crown peak is more likely to be directly illuminated at varying sun angles than the edge of a crown (Culvenor 2002). Therefore we used local NDVI maxima to define the position of likely crown peaks within the vegetation objects. The actual search process was realized with the 'find local extrema' algorithm. Because the maxima-derived objects are treated as starting points (seeds) in the crown delineation process (Culvenor 2002), the seed number and position has a high impact on the quantity and location of the tree crowns (see Figure 3 c).

- **Multiresolution segmentation region grow**

The crown delineation was processed with the multiresolution region grow algorithm. It is designed to aggregate objects adjacent to a seed pixel until predefined homogeneity criteria are reached. The process prevents that contiguous trees merge together or that objects belong to more than one tree crown. The previously set NDVI threshold (0.1) acted hereby as boundary restriction and determined the crown size (see Figure 3 d).

- **Contrast Split Segmentation**

The last process comprised the contrast split segmentation algorithm which divides crown objects into dark and bright regions. The contrast between dark (high NDVI) and bright (low NDVI) objects was calculated by means of the edge difference method (Definiens 2012). The algorithm evaluates the optimal threshold separately for each crown and split bright objects with the largest contrast (see Figure 3 e). The remaining dark objects were classified as trees.

- **Computing tree crown statistics**

Each tree crown got a unique tree identifier assigned and a series of crown-based feature parameters (see Table 4) were computed and exported for use in statistical analysis (see Figure 3 e). The derived image canopy area (ICa) was converted from pixel values to m^2; QB $(0.6\ m)^2$, WV2 $(0.5\ m)^2$. The final tree classification can be seen in Figure 3 f.

Parameter	Description
Tree ID	Unique tree identifier
Crown area (pxl)	Number of pixels per crown
Mean NDVI	Average Crown NDVI index value
River Distance	Distance from tree to Tarim River

Table 4: Statistics computed for each identified tree object

3. RESULTS AND DISCUSSION

The developed ruleset successfully recognised and delineated in both images the 91 *Populus euphratica* reference trees. Mean values for ICa of QB and WV2 were 16.20 m^2 and 13.51 m^2 with median values of 12.6 m^2 and 11.75 m^2, respectively. Figure 5 illustrates the density of ICa for 2006 and 2011.

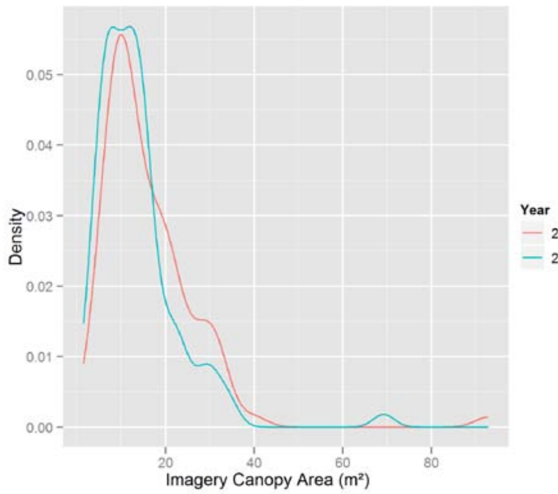

Figure 5: Kernel density estimation of imagery based canopy area (m^2)

The sum of ICa from the QB scene was estimated 1470 m^2 which is almost identical to the field measured Ca of 1450 m^2 (see Table 6). The estimated WV2 total sum ICa reached 1230 m^2, compared to the field measured Ca of 1840 m^2. The field measured crown canopy values between 2005 and 2011 show a Ca increase of 390 m^2 while the OBIA method illustrates a Ca decrease of 240 m^2.

Canopy area (m^2)	QB/2005	WV2/2011	Change
ICa	1470	1230	- 240 (16.3 %)
Ca	1450	1840	390 (26.8 %)
Difference	- 20 (1.3 %)	610 (49.6 %)	

Table 6: Total canopy area change (m^2) between 2005 and 2011

In order to compare the Ica and Ca results according diameter classes, we divided the dbh values into three dbh groups (1: 0-25 cm; 2: 26-34 cm; 3: 35–120 cm).. The number of trees within the dbh groups changed between the years. Trees dbh increased between the data collection years and move therefore from one group into the next higher (2005: 32, 30, 2;, 2011: 21, 26, 44). However the mean ICa decreased in dbh group 1 and group 3. The mean ICa for group 2 remained equal for both years (see Figure 7).

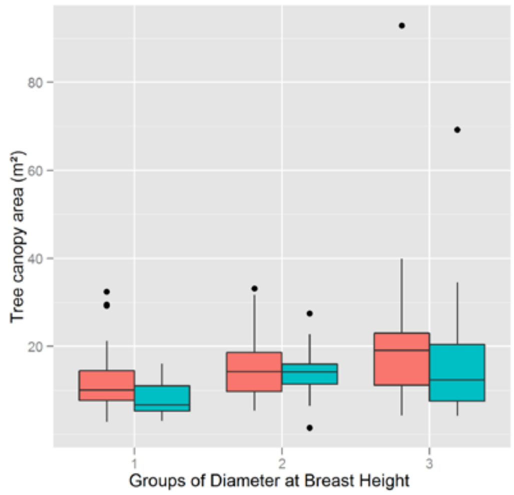

Figure 7: ICa plotted according to dbh groups for year 2005 and 2011

3.1 Median absolute deviation

We calculated the difference between ICa and Ca and computed the median absolute deviation (MAD) for each dbh group. The MAD is a robust measure of the variability of crown area differences minimizing bias from outliers. The MAD values of 2005 are bigger in all dbh groups compared to MAD values of 2011. The MAD values indicate that there is a bigger difference between ICa and Ca in 2005 than in 2011 (see Table 8).

dbh group	2005	2011
1	5.17	3.05
2	7.19	6.53
3	7.74	6.38

Table 8: Median absolute deviation of crown areas divided into three dbh groups

3.2 Pearson correlation

Calculations of the Pearson correlation, which defines the relationship between the Ica and Ca variables, indicate similar findings. A positive correlation is depicted between ICa and Ca for 2005 as well as 2011. However, there is a stronger correlation in 2011 (0.795) than in 2005 (0.662). One possible explanation can be the higher spatial resolution of WV2 compared to the spatial resolution of QB. The smaller pixel size of WV2 allows more detailed crown delineation then with QB.

3.3 Crown Change with Distance to River

It occurs that there is a higher concentration of *P. euphratica* individuals near the river than towards the desert. About 85 % of the reference trees grow within a corridor of 500 m from the Tarim. A corridor of 800 m contains 92 % of the reference trees (see Figure 9). Within the 500 m corridor occurred no clear trend on the increase or decrease of the canopy area. Beyond the 500 m corridor shrunk the ICa of about 85 % of the trees. It is assumed that the ground water supply is decreasing sharply beyond 500 m.

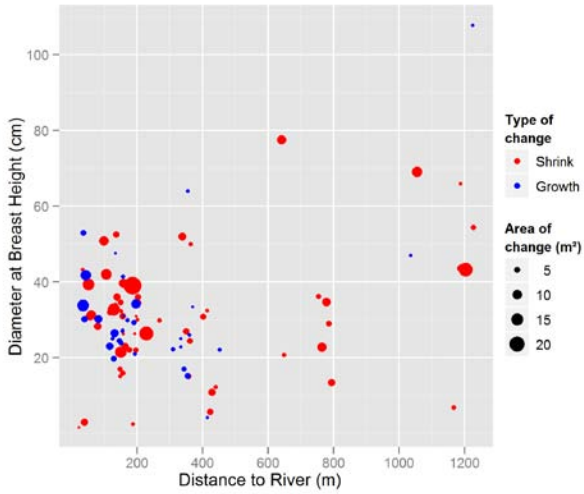

Figure 9: ICa change with respect to dbh and distance to the Tarim River

Possible reasons for the varying results between the image derived and field derived canopy areas are the differences in the spatial resolution of the imagery, the sun elevation and the sun azimuth. The biggest difference between the imagery is the off nadir satellite view angle. The QuickBird scene view angle is close to nadir while the WorldView2 view angle is at 17.7°. The small off nadir view angle from QB resulted in accurate canopy area estimates also (Culvenor 2000) showed that tree detection accuracy was best with small off-nadir view angles.
However, the sensor specific spectral response curves and gain settings influence the vegetation index and could also explain the differing analysis results (Updike and Comp 2010).
Phenological disparities between the imagery due to temperature variations and local precipitation may present real problems (Coppin et al. 2002) but can be neglected due to very low precipitation value of around 20-50 mm annually (Xu et al. 2007) and stable temperatures in summer months.

4. CONCLUSIONS

The results of this study show that QuickBird and WorldView2 imagery can be used to identify *Populus euphratica* and delineate their crowns successfully. Bi-temporal change detection analysis showed almost identical result between the field measured canopy areas of 2005 and QuickBird derived canopy areas. However the results for 2011 varied between ICa and Ca by 610 m^2 (49.6 %). The ICa between 2005 and 2011 shows a decrease of the canopy area by 240 m^2 (16.3 %) while the field measured area shows an increase in canopy area at about 390 m^2 (26.8 %). The small off-nadir view angles from the QuickBird image could be the reason for accurate canopy area estimate.

5. ACKNOWLEDGEMENT

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