INT. J. REMOTE SENSING, 2003, VOL. 24, NO. 5, 1165–1170

# The perimeter/area ratio as an index of misregistration bias in land cover change estimates

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(*Received 24 January 2002; in final form 14 August 2002*)

**Abstract.** Two Thematic Mapper (TM) scenes were used to analyse the amount and pattern of land cover change in China's Pearl River delta. From 1988 to 1996 net cropland area decreased by 13.5%, net vegetated land cover decreased by 11.5%, and built-up land increased by over 272%. A perimeter/area (*P*/*A*) ratio analysis was performed on the size and shape of the cropland parcels that were lost between 1988–1996. Cropland was lost primarily due to conversion to vegetated (forest, orchard, etc.) or built-up land. The changes from cropland to vegetated land had a large percentage of area changed in smaller clumps with high *P*/*A* ratios, indicating potential linear changes that could be attributed to misregistration. The changes to built-up land cover had a large percentage of area changed in larger clumps with smaller *P*/*A* ratios. The *P*/*A* ratio appears to be an easily derived method for determining potential areas of linear 'false change' caused by misregistration in change detection analyses.

## 1. Introduction

Co-registration errors have been recognized as a potentially significant source of land cover change overestimation (Townshend *et al.* 1992, Stow 1999). Land cover change may be overestimated due to positional error in multitemporal images, even with sub-pixel co-registration rms errors (Verbyla and Boles 2000). Dozens of metrics have been developed to quantify landscape spatial patterns with fragmentation analysis (Brown *et al.* 2000). Landsat data have been used for fragmentation analysis in several different landscapes (Chuvieco 1999, Brown *et al.* 2000). We propose a method by which a simple fragmentation index, the perimeter/area (*P*/*A*) ratio, can be used to quantify the amount of false changes that are potentially attributed to co-registration errors between satellite sensor images.

The Pearl River (Zhujiang) delta, Guangdong Province, China, has had rapid urban and population growth for the last 25 years (Weng 2001). Satellite remote sensing has been used to estimate rapid land cover changes in this region (Li and Yeh 1998, Weng 2001, Seto *et al.* 2002). Our study area consisted of 11 counties

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*International Journal of Remote Sensing*
ISSN 0143-1161 print/ISSN: 1475-9942 online 
http://www.tandf.co.uk/journals
DOI: 10.1080/0143116021000044841

(approximately. 10 600 $km^2$) in the Pearl River delta. Using Landsat Thematic Mapper (TM) data, we explored the utility of using the *P/A* ratio to quantify potential false land cover changes caused by misregistration between 1988 and 1996.

## 2. Methods

### 2.1. *Image pre-processing and change detection analysis*

Landsat TM data (path 122, row 44) imaged on 10 December 1988 and 3 March 1996 were used in this study. Images were co-registered to a 1990 reference image with nearest neighbour resampling (28.5 m spatial resolution), with rms errors of less than 0.5 pixels. We employed the post-classification comparison method of change detection, where classified images of different dates are compared. An unsupervised ISODATA clustering algorithm was used to classify the data, using all bands except band 6 as input. Classes were assigned based on a field survey of the study site in September 1996, on the inherent spectral properties of the clusters, and from the use of ancillary data sources (Wu 1990). Spectral clusters were assigned to one of the following classes: cropland and aquaculture, other vegetated land, other waterbodies, built-up land and cloud. Clusters containing mixed classes were reclassified in order further to extract individual classes, as recommended by Jensen (1996). If clusters remained mixed after being reclassified, they were manually assigned (using digitizing tools) to one of the classes. Generalized classes were used to help minimize post-classification errors due to edge effects, misregistration and seasonal image differences (e.g. crop and fallow lands in the same class). Conversion matrices were used to determine both the amount and the nature (e.g. cropland to built-up) of the changes. Cloudy areas in either date ($<1\%$ of the study area) were masked. A minimum mapping unit of four pixels (0.36 ha) was assigned to reduce the effects of image noise.

### 2.2. *Analysis of land-cover change parcels*

We performed a clump analysis on the two types of change that involve losses of cropland (to both built-up and vegetated land). Clumping groups of contiguous pixels that experienced the same land cover change, using neighbours from all eight directions, allows for analysis of the size of the areas changed. Individual clump *P/A* ratios provide an indication of the shape of the changed area. Higher *P/A* values represent change areas with a shape closer to linear. False changes due to co-registration errors are likely to have a near-linear shape.

The theoretical limit of the *P/A* ratio for single pixel offsets was calculated (figure 1). For purely diagonal single pixel offsets the *P/A* ratio $=4/x$ [figure 1(*b*)], regardless of the size of the diagonal strip, with $x$ being the spatial resolution of the sensor. This is the upper limit of *P/A* ratios for all single pixel offsets; for 28.5 m spatial resolution TM data this value is $0.14\,m^{-1}$. For single pixel offsets in either the row or column directions [figure 1(*a*)] the *P/A* ratio $=2/x(1+1/n)$, where $n$ is the number of pixels along the offset edge. This is the lower limit of *P/A* ratios for all single pixel offsets; for 28.5 m TM data this value approaches $0.07\,m^{-1}$ for large values of $n$. The *P/A* ratios of the clumps were compared with the theoretical limits in order to estimate potential errors due to misregistration. As a simple test of our method, the 1996 classification was manually offset by one pixel and the change

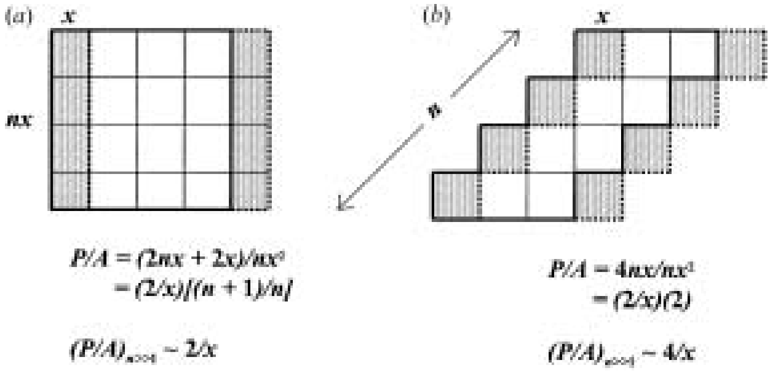


Figure 1. Potential scenarios of single-pixel misregistration and the calculation of the perimeter/area (*P*/*A*) ratio, where *x* represents the spatial resolution of the sensor, and *n* represents the number of pixels along the offset edge. Shaded areas indicate regions of false land cover change. (*a*) Row/column offset; the minimum possible *P*/*A* ratio, as all but the top and bottom pixels share two edges with neighbours. (*b*) Offset for a diagonal boundary; the maximum possible *P*/*A* ratio, as no pixel shares an edge with a neighbour.

detection analysis was re-performed. Results were compared with the initial analysis so that the effect of a forced one-pixel offset could be determined.

## 3. Results and discussion

From 1988 to 1996 there was a net cropland loss of over 68 000 ha in the study area (13.5% of the 1988 cropland estimate) and the vegetated area decreased by about 51 000 ha (11.5% of the 1988 vegetated land estimate). The amount of built-up land increased by over 135 000 ha (274% of the 1988 built-up land estimate). The changes from cropland to vegetated land had markedly different clump size distributions and *P*/*A* ratio allocations than the changes from cropland to built-up (figure 2). More than 65% of the area that changed from cropland to vegetated land occurred in smaller clumps ($<10$ ha) [figure 2(*a*)]. Over 20% of this area had *P*/*A* ratios over $0.07\,m^{-1}$, indicating potential linear changes that could be attributed to misregistration. More than 65% of the area that changed from cropland to built-up land occurred in larger clumps ($>10$ ha) [figure 2(*b*)]. Less than 10% of this area had *P*/*A* ratios over $0.07\,m^{-1}$, indicating that most were nonlinear and more likely to represent true land cover change.

By comparing the *P*/*A* ratio for the changed areas with their theoretical limits, we see that almost 10% of the total change from cropland to vegetated land could be due to single pixel misregistration [figure 3(*a*)], but less than 4.5% of the area that changed from cropland to built-up could result from this type of error [figure 3(b)]. With a forced one-pixel offset applied to the 1996 classification, the amount of change that could be due to misregistration increases to almost 15% for the cropland to vegetated areas and over 7.3% for the cropland to built-up areas.

## 4. Conclusions

Remote sensing analyses of land cover change are subject to a variety of error sources that can lead to falsely increased or decreased estimates of land cover

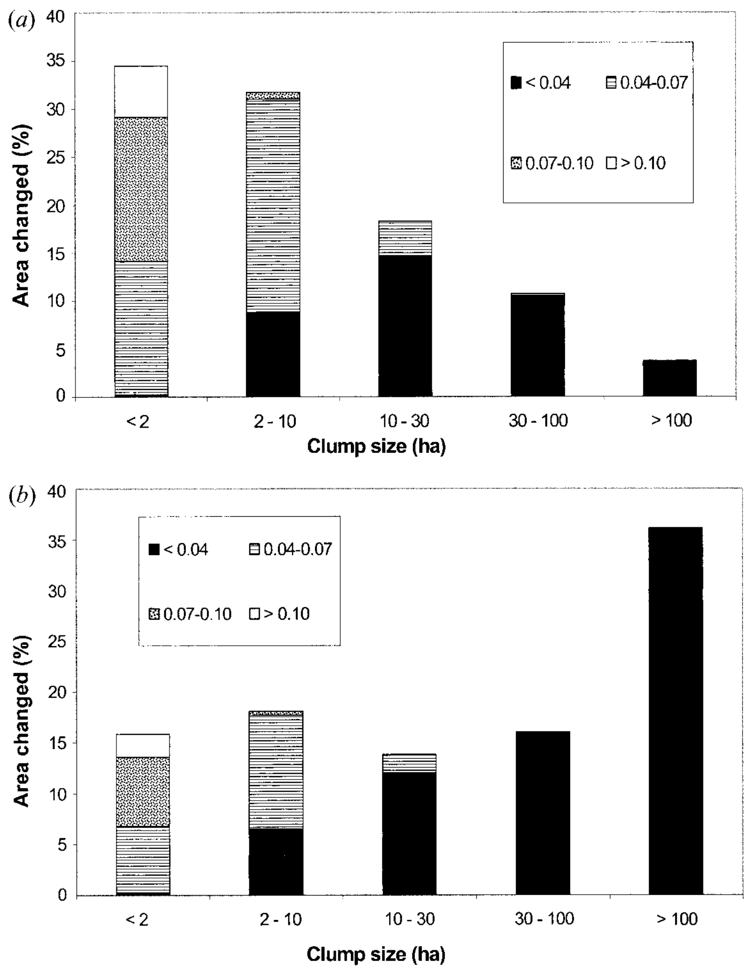


Figure 2. Relationship between clump size, percentage of changed area and perimeter/area (*P*/*A*) ratio for changes of (*a*) cropland to vegetated land, and (*b*) cropland to built-up land. Clumps are groups of contiguous pixels with the same land cover/land use patterns between 1988–1996. The vertical axis represents the percentage of all land area within that change class. Clump size groupings are disaggregated according to *P*/*A* ratio, as indicated by the legend inset.

change. Co-registration errors can result in false areas of change with near-linear shapes, even if low rms errors are achieved. While some linear shapes will be actual changes (e.g. building of roads), it is important to have some estimate of the degree of these potential false changes. Our analysis of land cover change in a rapidly developing area of southern China suggests that the *P*/*A* ratio can be used to provide estimates of the amount of false change due to misregistration.

**Acknowledgments**

This work was supported by a grant from the Terrestrial Ecology (TECO) programme, jointly supported by NASA, NSF, EPA, DOE and the USDA. The

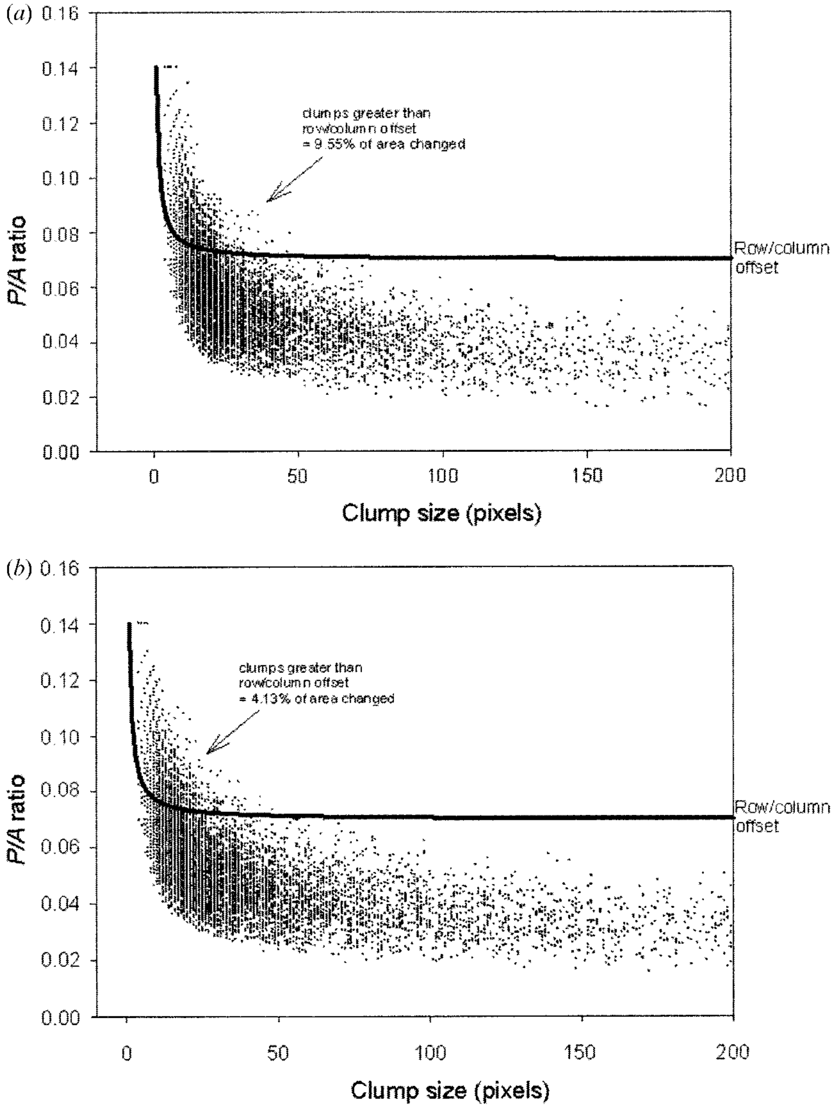


Figure 3. Perimeter/area ($P/A$) ratio by clump size for all areas that changed from (*a*) cropland to vegetated land, and (*b*) cropland to built-up. The thick black line is the theoretical lower limit for $P/A$ ratio for a misregistration clump generated by a single pixel offset. On an area-weighted basis, the upper limit of potential changes due to single pixel misregistration is 9.55% and 4.13% of the total change area for cropland to vegetated land and built-up land, respectively.

authors thank David Justice, Dave Skole, Michael Routhier and Stanley Glidden for their assistance.

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