Land Use/Cover Change from 2001 to 2010 and its Socioeconomic Determinants in Guangdong Province, A Rapid Urbanization Area of China

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ABSTRACT

Rapid economic and population growth exert profound effects on land use/cover change, especially in rapid economically developing areas, such as Guangdong Province-a pioneer of economic growth and urbanization in China. To elucidate the changes and mutual conversions of land-use types and their determinants in Guangdong Province, land-use maps of Guangdong Province from 2001 to 2010 were obtained from Moderate Resolution Imaging Spectroradiometer (MODIS) L1B images with 500 m resolution by using the supervised classification combined support vector machine (SVM) algorithm with a decision tree. The results indicate that during the studied time period, the area of urban land and orchards increased by 4186 km² and 3615.5 km², respectively, while the percentage of cropland decreased from 11.46% to 10.14%. Massive urbanization and cropland loss have occurred in the region. The conversion from wasteland to urban land, and the mutual transformation between wasteland and cropland were the most prevalent in Guangdong Province. This was especially obvious from 2007 to 2010, with an annual changing rate of 5.13% and -19.33%, respectively. Several socio-economic factors were also obtained to investigate their impacts on land-use changes in Guangdong Province. It is shown that marked increases in gross domestic product (GDP), total investment in fixed assets, total retail sales of consumer goods, and the increasing development of modern service industries have led to large-scale migration, and industrial structure adjustment and improvement; consequently dramatically rapid expansion of cities and cropland loss have occurred.

Keywords: Land use/cover change; MODIS; Change detection; Urbanization; Economic development

Çin'in Hızlı Bir Ekonomik Gelişim Alanı Olan Guangdong'da Arazi Kullanımı/Arazi Örtüsü Değişimleri ve Sosyo-Ekonomik Etkileri

ÖZET

Çin'in ekonomik gelişim ve kentleşme bakımından öncü bölgelerinden Guangdong'da, ekonomik gelişim ve nüfus artışına bağlı olarak arazi kullanım/arazi örtüsü hızla değişmektedir. Bölgede alan kullanım tiplerini ve arazi değişimlerini tespit edebilmek için 500 metre çözünürlükte Orta Çözünürlüklü Spektroradyometre Görüntüleme Sistemi (MODIS) L1B görüntüleri üzerinden destek vektör makineleri (SVM) algoritması kullanılarak 2001-2010 yıllarına ait alan kullanım haritaları elde edilmiştir. Harita analizleri sonucunda 2001-2010 yılları arasında kentsel alanların 4186 km² ve meyveliklerin 3615.5 km² artış gösterdiği, tarım alanlarının % 11.46 oranından % 10.14'e gerilediği görülmüştür. Bölgede hızlı kentleşmeye bağlı olarak tarım arazilerinin azaldığı belirlenmiştir. Boş arazilerin kentsel alana dönüşmesi yanında tarım alanları ile boş alanların yer değiştirmesi bölgede en çok görülen değişimlerdir. Bu değişimler özellikle 2007 ve 2010 yılları arasında % 5.13 ve % -19.33 değişim oranlarında görülmüştür. Bölgede alan kullanım değişimlerini etkileyen çeşitli sosyo-ekonomik faktörler belirlenmiştir. Gayrisafi yurtiçi hasıla ve sabit gelirin değişimi, perakende malların tüketimi ile çağdaş servis endüstrilerinin artışı ve yaygınlaşması sonucunda oluşan göçlerle endüstriyel yapı yaygınlaşmış; dolayısıyla kentler hızla büyüyerek tarım arazileri yok edilmiştir.

Anahtar Kelimeler: Arazi kullanımı/örtüsü değişimi: MODIS; Değişim belirleme; Kentleşme; Ekonomik gelişim

1. Introduction

Land use/cover change (LUCC) is regarded as a fundamental component of global environmental change because of its interactions with climates, ecosystems, biodiversity and human beings, and its crucial function in resource management and land planning (Meyer & Turner 1992; Bagarinao 2008; Sun et al 2012). Since the late 1980s, when remote sensing and GIS techonology were extensively applied to land research, the monitoring of regional land-use dynamic change has expanded globally, such as in the tropical rainforest areas of the Brazilian Amazon Basin (Skole & Tucker 1993), Africa (Tucker et al 1985), and South America (Townshend et al 1987). In 1995, the International Geoshpere Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) jointly developed a plan titled, "Land Use and Cover Change" (LUCC), which made land-use change an urgent international priority and focused on improving the ability to predict LUCC on different spatial scales (Thomson & Hardin 2000; Lo & Yang 2002; Gilani et al 2015). Masek et al (2000) utilized Landsat TM and MSS to detect urban growth in Washington D.C. based on a NDVI-differencing approach. Thenkabail et al (2005) mapped the irrigated areas in the Ganges and Indus River basins using near-continuous time-series, 500 m resolution

MODIS land data for 2001-2002. In addition, Kiage et al (2007) depicted the land degradation and land-use change in the Lake Baringo catchment by using the NDVI-differencing and post-classification comparison on TM classificaition results. Mertes et al (2014) also demonstrated a methodology for monitoring urban land expansion at continental to global scales through employing MODIS data.

A series of studies on LUCC at different spatial-temporal levels has also been conducted in China (Yu & Yang 2002; Liu et al 2003; Ye et al 2004; Wu et al 2006; Ding et al 2007; Chen et al 2011). For example, Wang et al (2001) applied mathematical methodology to study the spatial-temporal changes of land use and dynamic features in China. Okamoto et al (2005) classified the land cover in Heilongjiang Province, China by employing Landsat TM and ETM, and analyzed the conversions of paddy fields. Moreover, Xu et al (2007) described the development of the land-cover maps of the Yangtze River Delta. To accomplish this, they used 250 m MODIS data by utilizing DEM, EVI and reflectance data, and generating a compostitive classification matrix. Wang et al (2015) investigated the LUCC in the Kaidu-Kongqi River Basin during 1990-2010 based on the land-use classification data derived from Landsat images.

Nature, population, economy, and policy are considered to be the typical driving forces of land use/cover changes (Lambin et al 2003; Siciliano 2012). Lambin et al (2001) concluded that people's response to economic opportunities motivated land-cover changes, and global forces became the main determinant of LUCC. Yan et al (2006) studied the human dimensions affecting land-use change in one of China's mega-urban regions and revealed that the population factor, economic development level, urbanization, and industrialization were the major factors influencing LUCC in the Pearl River Delta. Wang et al (2012) indicated that land-use changes in China, especially regarding cultivated and developed land, were closely related to economic fluctuations and the enaction and implementation of land policies. In China, especially since the reform and opening-up periods, the population explosion and rapid urbanization have brought about a sharp increase in the demand for natural resources and produced remarkable land use/cover changes (Zhou & Jiang 2000; Lin & Ho 2003; Lichtenberg & Ding 2008), significantly affecting the sustainable development of China's economy, society, and ecology (Ge et al 2000; Liu et al 2010). Complex land-use structure and intensive utilization gradually created serious problems, such as land degradation and pollution, thus highlighting the necessity and significance of comprehensive study on LUCC and its determining factors (Shi et al 2000; Zhang et al 2008).

Guangdong Province, as China's richest province, has witnessed rapid economic development, fast population growth, and consequently tremendous changes in land use. These dramatic changes became obvious beginning in China's reform and opening-up periods, and have become especially pronounced in the past several years. Considering that many studies of LUCC have been conducted in the Pearl River Delta instead of Guangdong Province (Seto et al 2002; Weng 2002; Zhang et al 2007; Fan et al 2008; Dai et al 2010), this paper acquired the land-use maps of Guangdong Province from 2001 to 2010, a period when it experienced unprecedented development and expansion. The current study investigated land-use change and mutual conversions using remote sensing and geographic information system techniques, and then analyzed the driving factors behind the changes.

2. Material and Methods

2.1. Study area and data

Guangdong Province lies between 109.5° and 117.3° E longitude and 20.2° and 25.5° N latitude, and borders Fujian Province to the northeast, Jiangxi and Hunan Provinces to the north, and Guangxi Autonomous Region to the west (Figure 1). It exhibits diverse and complicated landscape types, including mountains, hills, plateaus and plains, constituting 33.7%, 24.9%, 14.2% and 21.7% of the whole province area, respectively. It has a humid subtropical climate, in which winters are short, mild and relatively dry, while summers are long, hot, and very wet. The annual average temperature ranges between 19-24 ᵒC, and the average yearly precipitation is between 1300-2500 mm.

Guangdong Province has a total population of 85.21 million and covers an area of 179800 km², accounting for only 1.87% of the entire country's land area. However, its gross domestic product (GDP) constitutes 11.17% of the country (Guangdong Statistical Bureau 2010) and it is known as the richest province in China. As the province's economy has developed rapidly in recent years, marked and intense land-cover changes have occurred in the region, and are closely correlated with human activity, resulting in greatly increased environmental pollution and damage. Therefore, it is of critical importance to analyze LUCC of Guangdong Province in recent years and further identify its determinants.

At present, MODIS has become a widely-used moderate resolution remote-sensing data sources. The unique design of MODIS instrument provides data (12 bit) in 36 spectral bands ranging in wavelength from 0.4 μm to 14.4 μm, and at varying spatial resolutions (two bands at 250 m, five bands at 500 m, and the remaining 29 bands at 1 km).
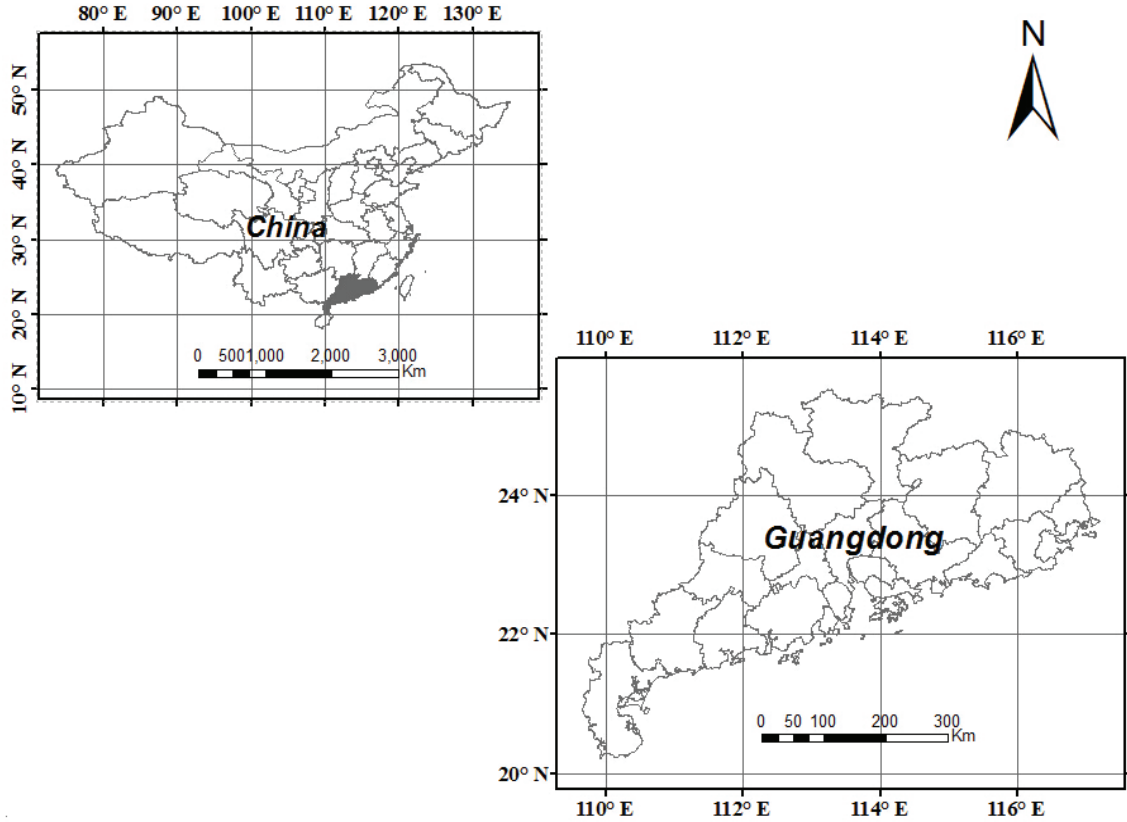
Figure 1- Location and administrative boundary of Guangdong Province, China (109.5°-117.3° E, 20.2°-25.5° N)

*Şekil 1- Guangdong bölgesinin konumu ve yönetim sınırları*

In addition, its ±55-degree scanning pattern at the EOS orbit could provide global coverage every one to two days. The moderate spectral, spatial, and temporal resolutions make it easy to obtain cloud-free images and facilitate land use and land cover classification on a large scale. The data involved in this paper mainly include: 1) MODIS 500 m resolution satellite images (L1B) in the last months from 2001 to 2010 (at URL http://lpdaac.usgs.gov/lpdaac/get_data), considering that the quality of images at that time is the best, and there is the least cloud coverage during that time of the year. The exact dates of the MODIS images used in the study are: November 25, 2001; October 8, 2002; October 23, 2003; December 7, 2004; December 21, 2005; December 21, 2006; December 1, 2007; December 9, 2008; October 10, 2009; and November 1, 2010. 2) The Digital Elevation Model (DEM) with a spatial resolution of 90 m. The data set is provided by the NASA Shuttle Radar Topographic Mission (SRTM) and downloaded from the International Scientific and Technical Data Mirror Site, Computer Network Information Center, Chinese Academy of Sciences (http://www.gscloud.cn). 3) Vector data of Guangdong Province administrative division boundary. 4) Several socioeconomic indexes

reflecting the development of the economy and population in Guangdong Province.

2.2. Methodology

The processing of remote-sensing images is the key to the entire study and the method, and thus the accuracy and the procedure may affect the final results greatly. Figure 2 is the entire image processing flow chart in this study.
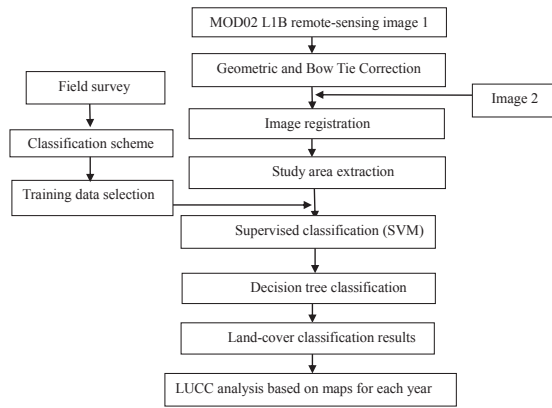
Figure 2- The image processing flow chart of remote-sensing images (including pre-processing and image interpretation)

Şekil 2- Uzaktan algılama görüntülerinin görüntü işleme akış diyagramı (ön değerlendirme ve yorumlama süreçleri dahil)

2.2.1. Pre-processing

MODIS LIB data reflect the calibrated and geo-located radiation values, and are saved as hierarchical data format (.HDF) through band hierarchical storage. Pre-processing tasks, such as reprojection and sub-setting, are crucial prerequisites for the study, and their accuracy has direct effects on classification and change detection.

Geo-referencing and Bow Tie Correction: The imaging characteristics of the MODIS detector result in geometric distortion of MODIS LIB images. This is especially the case between the scanning swathes where serious dislocation, i.e., bow tie, exists. Geometric and bow tie correction

are conducted through he MODIS processing module (Geo-reference MODIS) in ENVI software.

Image Registration: As MODIS images with the same coverage of each year are not identical and may have certain pixel offsets, we firstly subset the images with an area slightly bigger than Guangdong Province. Then, registration is performed to make all of the corresponding pixels locate in the same place by selecting over 50 control points, with a root mean square error (RMSE) below 0.5 pixels.

Image Sub-setting: Vector data of Guangdong Province boundary are needed to extract the study area from the corrected remote-sensing imagery.

### 2.2.2. Land-use classification scheme and approach

Before conducting Land-use classification, there are two aspects we should consider: 1) to develop a classification scheme suitable for the study area; and 2) to select an appropriate classification approach. Based on the prior knowledge of Guangdong Province obtained in recent years and a literature survey on previous research in this region, we developed a classification scheme comprising six classes, including water, wasteland, urban land, forest, orchards, and cropland. Moreover, wasteland includes waste grassland, saline-alkali land, sand, and undeveloped land.

The objective of image classification is to classify all of the pixels of the image into several categories or themes, and the cores of the classification algorithm are the discrimination function and the corresponding criterion. In this study, we firstly use a supervised classification with a support vector machine (SVM) algorithm (Burges 1998) to classify the MODIS image into water, vegetation, urban land, and wasteland with the aid of existing knowledge, experience and some auxiliary data, such as MODIS land use/cover products and Landsat TM images with higher spatial resolution. The auxiliary data in our study were used to help select regions of interest (ROIs) as training pixels for each class in the SVM and validate the classification results. TM images at similar times, covering parts

of Guangdong Province, were used because of their higher spatial resolution with 30 m, which provided clearer details of the objections. MODIS Land Cover Type Product supplies global maps of land cover at annual time steps. The primary results with IGBP global vegetation classification scheme identify 17 land-cover classes, and the overall accuracy of the product is about 75%. SVM is a classification system derived from statistical learning theory. Specifically, it separates the classes with a decision surface that maxmizes the margin between the classes. The surface is called the optimal hyperplane, and the data points closest to the hyperplane are support vectors. SVM classification output is the decision values of each pixel for each class, which are used for probability estimates, and then ENVI performs classification by selecting the highest probability. A decision tree (He 2007; Zhang et al 2008; Jia & Xu 2010) is then built by setting a series of thresholds to DEM data and Enhanced Vegetation Index (EVI) to further categorize vegetation into forest, orchard, and cropland (Figure 3). The decision tree performs multistage classifications by employing a series of binary decisions to place pixels into classes. Each decision divides the pixels in the images into two classes based on an expression, and the results of the decisions are classes. The rules of the decision tree include: 1) croplands are generally at low altitudes and have low Enhanced Vegetation Index (EVI); 2) orchards are at slightly higher altitudes and have much higher EVI values; and 3) forests are usually at the highest altitudes. Therefore, firstly a low value of elevation A is set to extract the cropland and orchards at low altitudes from the vegetation class, and then a threshold of EVI D is set to separate the cropland and orchards. For vegetation at altitudes greater than A, we further set a threshold for elevation B to extract the forests. For vegetation at altitudes between A and B, a value of EVI C is used to divide forests and orchards, since orchards have higher EVI values. Thresholds A, B, C and D vary in different years, and are defined according to existing knowledge, MODIS land use/ cover products, and Guangdong Province vegetation maps. The accuracy of classification was evaluated using the 30 m resolution TM images covering the

study areas. MODIS Land Cover Type products by the IGBP classification scheme were also utilized. Over 50 samples for each class were selected to calculate the kappa coefficient.
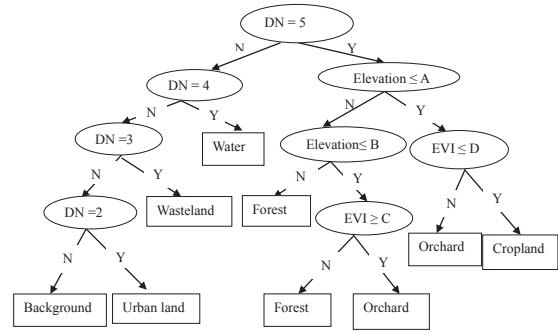
Figure 3- A decision tree developed for land-use classification in Guangdong Province (DN is the code of each type of initial classification result; A, B, C, and D are the thresholds of elevation and EVI for different years)

Şekil 3- Guangdong bölgesinde alan kullanım sınıflandırması için geliştirilen karar sıralaması (DN, sınıflandırma sonuçlarının kodlamasını ifade etmekte; A, B, C, ve D, farklı yıllara ait EVI ve yükseklik sınırlarını ifade etmektedir)

3. Results and Discussion

3.1. Land-use change detection from 2001 to 2010

The land use maps of each year from 2001 to 2010 were obtained through various image processing techniques and combined classification techniques (Figure 4). The overall accuracy of the results in 2008 and 2010 were calculated as 80.4% and 81.2% with kappa coefficient of about 0.79 and 0.776, respectively. These are mainly limited by the low spatial resolution of MODIS images, since a single pixel covers about 0.25 km^2 and there are many mixed pixels.

Table 1 shows that the water area changed very little from 2001 to 2010; the area of wasteland shrank in a large amount and proportion due to its low transformation cost; urban land expanded dramatically as a result of economic growth and

a great influx of population, so it is necessary to increase the built-up area to meet people's living demands; the forest area first shows a decrease, and then an increase, which implies that both human demand for forest resources and control over ecosystems have been increasing with the rapid development of society; the percentage of orchards demonstrates a significant rise during the period, since they produce much higher income due to market mechanisms. Moreover, because of superior geographical condition, the area of cropland decreased from 11.46% to 10.14% gradually in those years, identifying a dramatic expansion of urban area and a major loss of cropland during the years, which are closely related to the rapid growth of the economy and population in the region. As data acquision for the selected MODIS images in 2002, 2003 and 2009 took place in October when the harvest is not yet completed, an obscure variation trend of wasteland and forest resulted.

3.2. Analysis of the LUCC in Guangdong Province (2001-2010)

To perform further analysis, we selected the land-use maps of 2001, 2004, 2007, and 2010 to elucidate the mutual transformation of each land use/cover class. The change matrixes between each two years

are listed in Table 2, which reveals the unchanged area and the conversion area of land-cover type i in the initial stage to type j at the end of the period.

It can be concluded from the Table 2 that in the past 10 years, the conversion between land-cover types in Guangdong Province has been quite dramatic. Moreover, three major types of land-cover change can be identified: wasteland to urban land, wasteland to cropland, and cropland to orchards. The conversion from wasteland is the most notable, and the areas converted from wasteland to cropland account for 46.1%, 30.1% and 28.8% of the total changing area of wasteland in 2001-2004, 2004-2007 and 2007-2010, respectively. Urban land witnessed a great rise by 4186.25 km², exhibiting first an increasing trend and then a slowing trend. The areas transformed to urban land from wasteland are 2759.5 km², 2949.75 km² and 2973 km² during each of the above periods, respectively. In addition, a large amount of cropland was converted to orchards for the purpose of obtaining additional profits owing to the subsequent processes of agricultural restructuring and land encroachment. The conversion patterns are presented in Figure 5. The conversions between land cover types during 2007-2010 were the most profound and complicated.

Table 1- Percentage (%) of each land cover class in Guangdong Province (2001-2010)

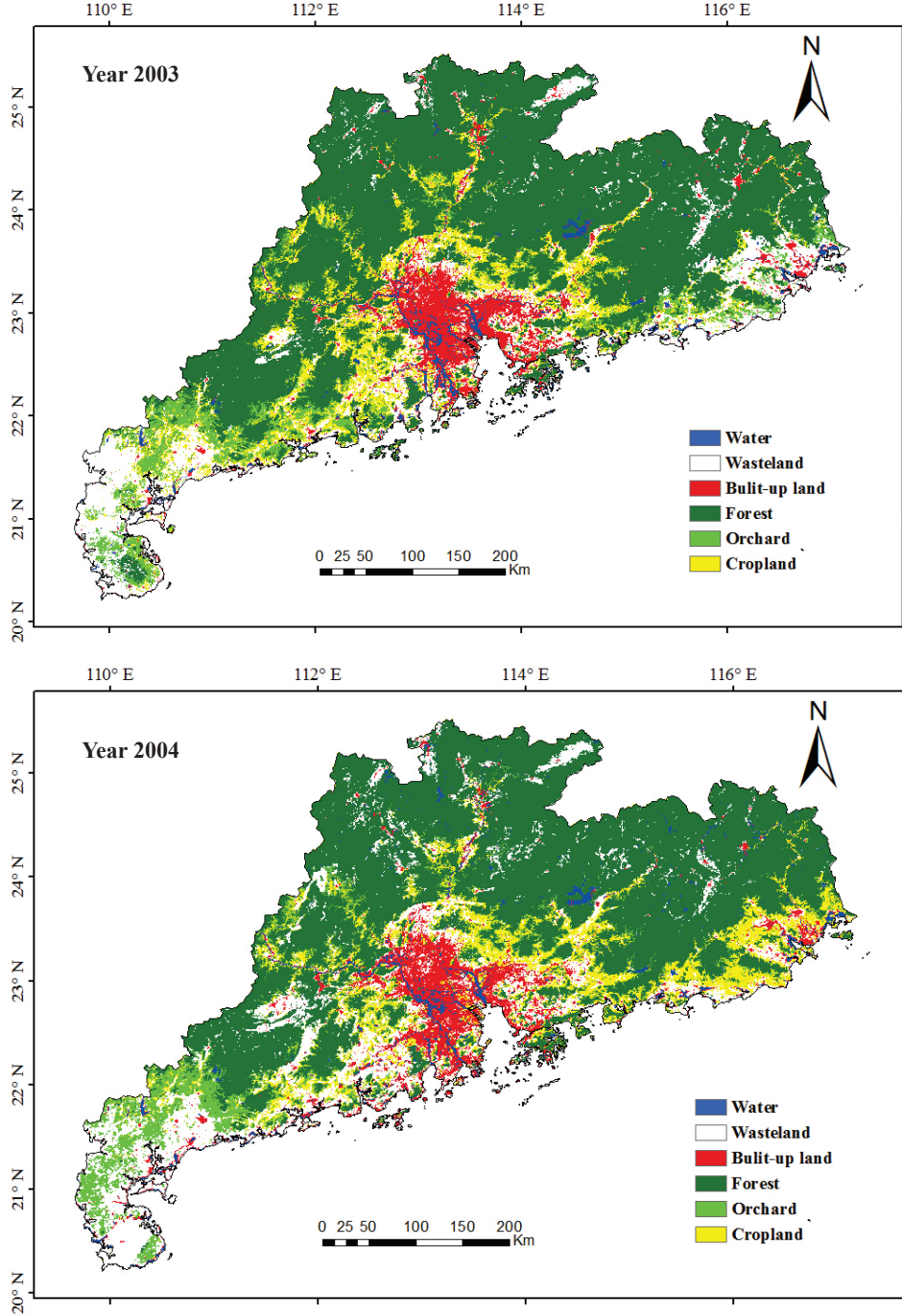*Çizelge 1- Guangdong bölgesinde herbir alan örtüsünün yüzdesi (%)*

Year \ LC	Water	Wasteland	Urban land	Forest	Orchard	Cropland
2001	2.95	17.78	6.21	54.83	6.76	11.46
2002	2.94	12.39	6.76	59.53	6.95	11.44
2003	2.63	15.08	7.03	56.69	7.20	11.35
2004	3.00	17.00	7.44	53.96	7.43	11.16
2005	2.76	14.01	7.58	57.03	7.68	10.94
2006	2.93	15.53	8.04	54.81	7.88	10.79
2007	2.85	15.50	8.19	54.83	8.02	10.59
2008	2.75	12.35	8.45	57.80	8.23	10.40
2009	2.59	5.86	8.58	64.27	8.43	10.25
2010	2.71	6.51	8.59	63.38	8.66	10.14
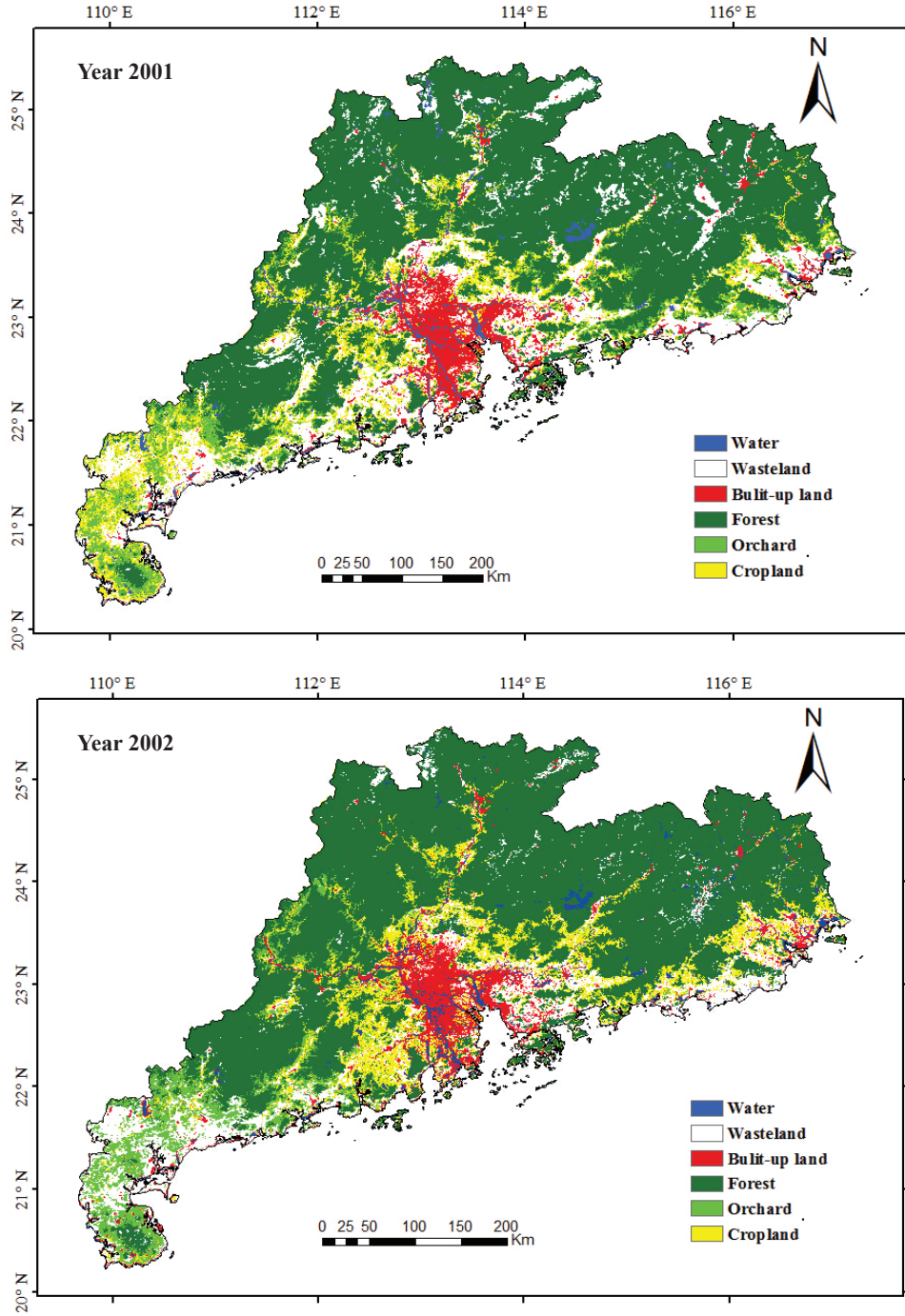
Figure 4- Land-use maps of each year in Guangdong Province from 2001 to 2010

Şekil 4- Guangdong bölgesinde 2001'den 2010 yılına kadar her yıla ait alan kullanım haritaları

Figure 4- (Continued) Land-use maps of each year in Guangdong Province from 2001 to 2010

Şekil 4- (Devam) Guangdong bölgesinde 2001'den 2010 yılına kadar her yıla ait alan kullanım haritaları

Figure 4- (Continued) Land-use maps of each year in Guangdong Province from 2001 to 2010

Şekil 4- (Devam) Guangdong bölgesinde 2001'den 2010 yılına kadar her yıla ait alan kullanım haritaları

Figure 4- (Continued) Land-use maps of each year in Guangdong Province from 2001 to 2010

Şekil 4- (Devam) Guangdong bölgesinde 2001'den 2010 yılına kadar her yıla ait alan kullanım haritaları

Figure 4- (Continued) Land-use maps of each year in Guangdong Province from 2001 to 2010

Şekil 4- (Devam) Guangdong bölgesinde 2001'den 2010 yılına kadar her yıla ait alan kullanım haritaları
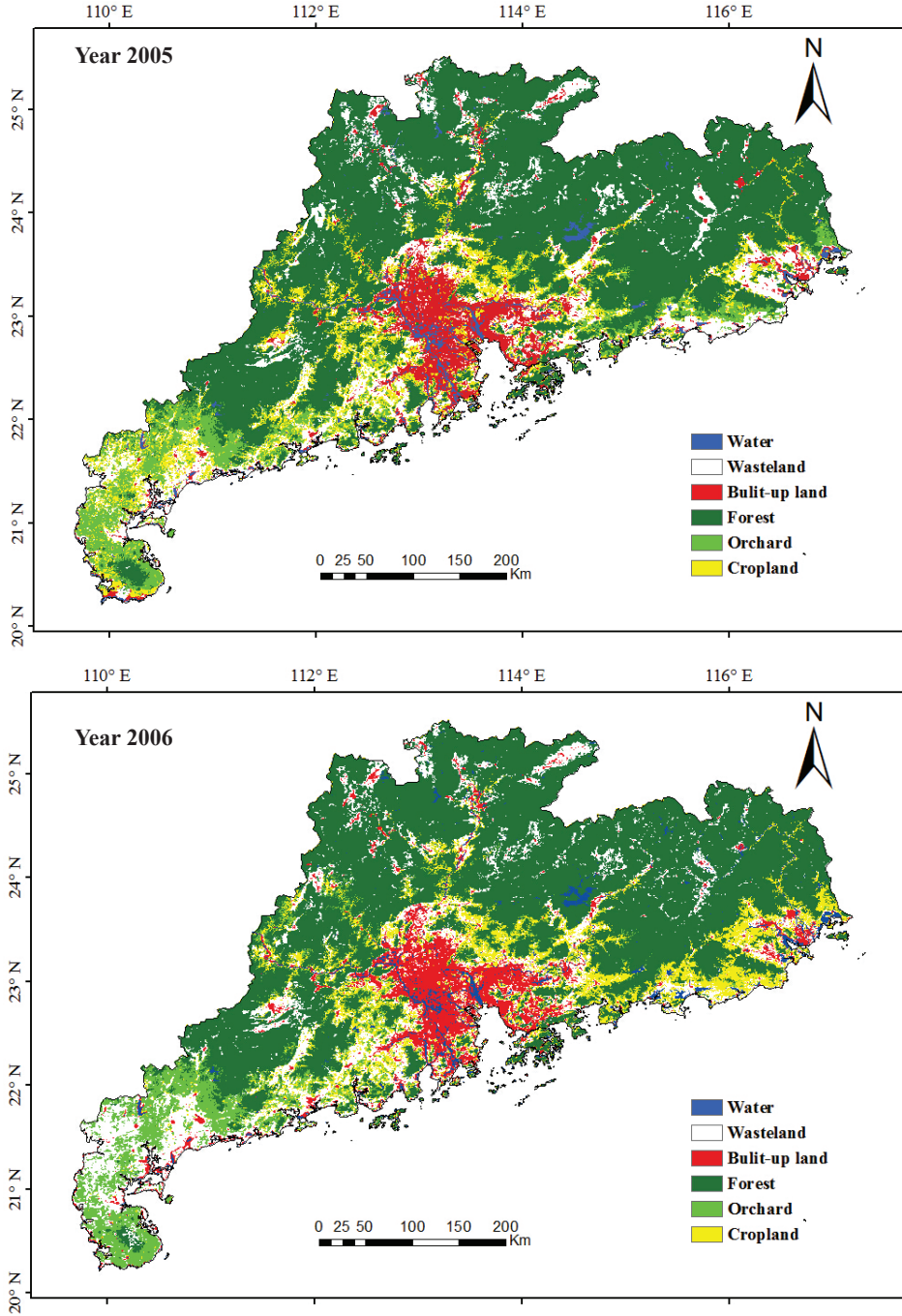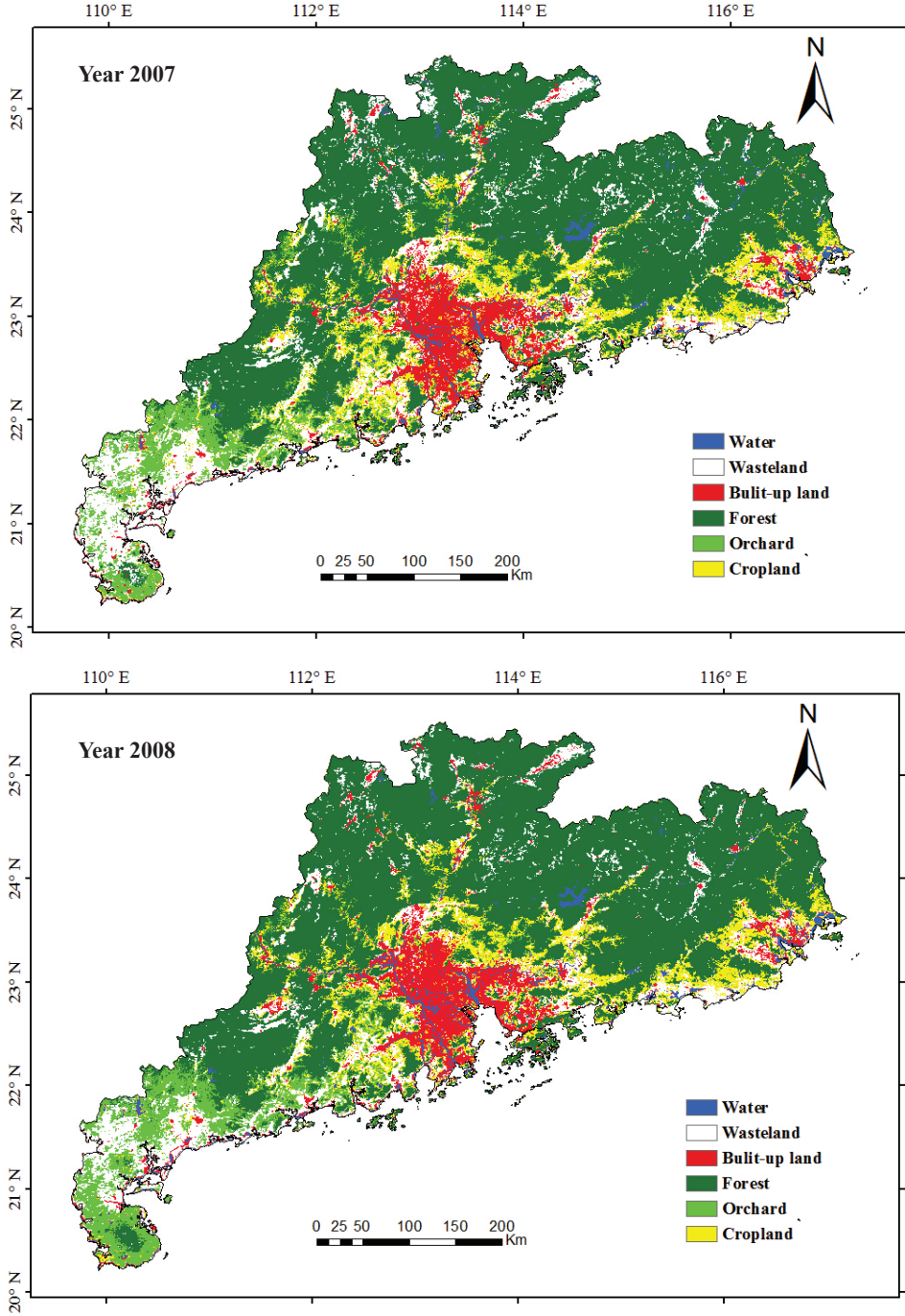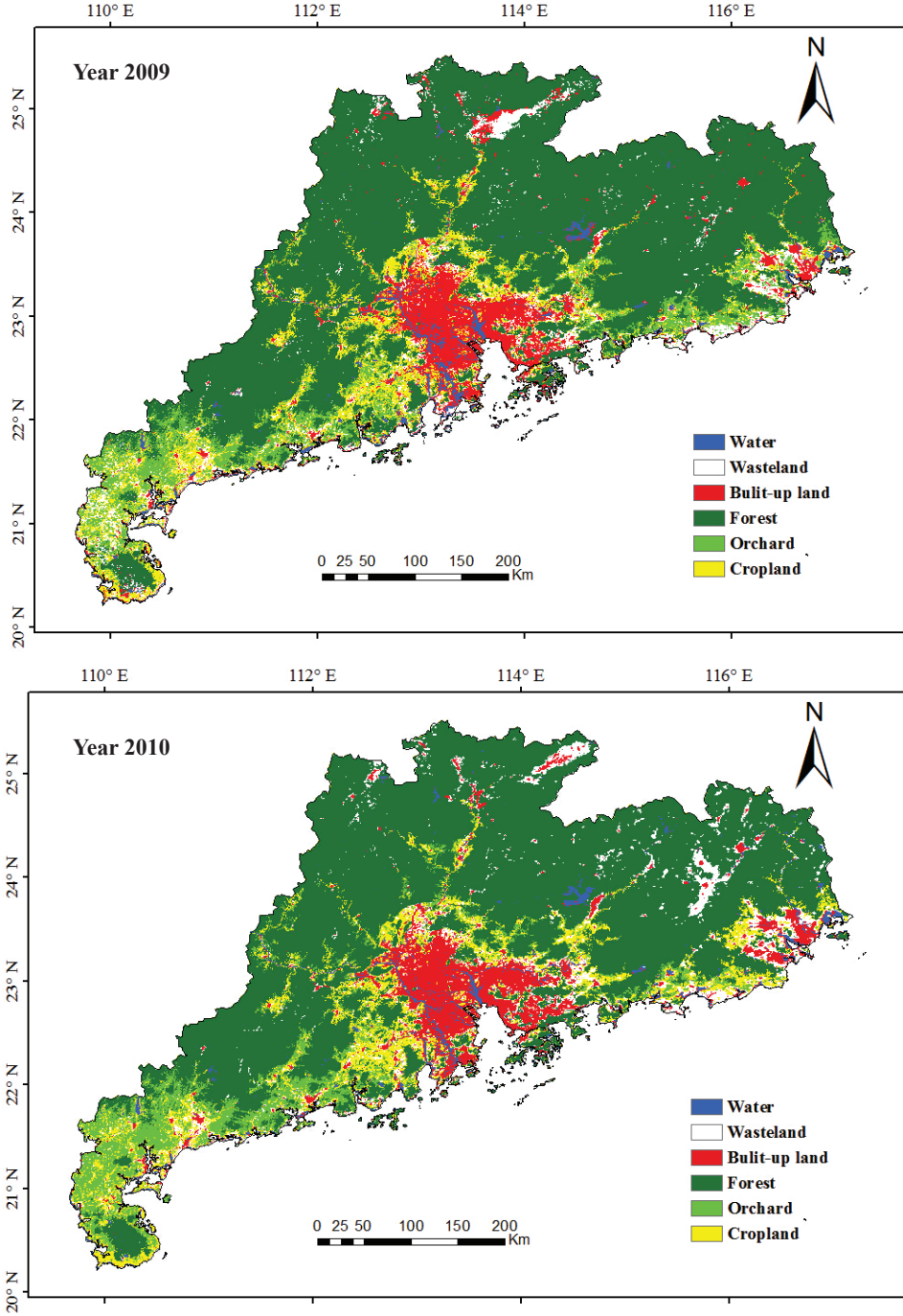
Table 2- Change matrixes of land-cover types during three different periods (km²)

Çizelge- 2- Üç farklı dönemde alan örtüsü tiplerinin değişim matrisleri (km²)

2001 / 2004	Water	Wasteland	Urban	Forest	Orchard	Cropland	Total
Water	2798	111.5	952.25	725.5	45	274.75	4907
Wasteland	395.75	20316.5	1050.75	2517.75	1388	4848	30516.75
Urban	1166.75	2759.5	8457.75	228.75	63.25	486.75	13162.75
Forest	308.5	2888	116.75	93076.25	319	403.25	97111.75
Orchard	15.5	513.25	3	2211	7456	3162	13360.75
Cropland	214.25	5354.75	426.25	0	2778.5	11232.75	20006.5
Total	4898.75	31943.5	11006.75	98759.25	12049.75	20407.5	179065.5

2004 / 2007	Water	Wasteland	Urban	Forest	Orchard	Cropland	Total
Water	2805.5	215.75	890.25	518.25	15.25	383.75	4828.75
Wasteland	117.5	19547.75	1263.75	3076.5	1514.25	2331.5	27851.25
Urban	1125.75	2949.75	9904.75	137.75	3.75	348	14469.75
Forest	604.5	2174.25	269.25	93154.75	2549	0	98751.75
Orchard	57.75	2325	97.25	224.5	8886.75	2712.75	14304
Cropland	196	3304.25	737.5	0	391.75	14230.5	18860
Total	4907	30516.75	13162.75	97111.75	13360.75	20006.5	179065.5

2007 / 2010	Water	Wasteland	Urban	Forest	Orchard	Cropland	Total
Water	2037	370	1335	199.75	35.25	378.25	4355.25
Wasteland	262.25	6428.25	1071	1662.25	150.25	2122.75	11696.75
Urban	1060	2973	10104.5	109.25	17	929.25	15193
Forest	874.25	6539	410	96780.5	6285.25	3071.25	113960.3
Orchard	18.75	5361.75	74.75	0	6274.5	3935.5	15665.25
Cropland	576.5	6179.25	1474.5	0	1541.75	8423	18195
Total	4828.75	27851.25	14469.75	98751.75	14304	18860	179065.5
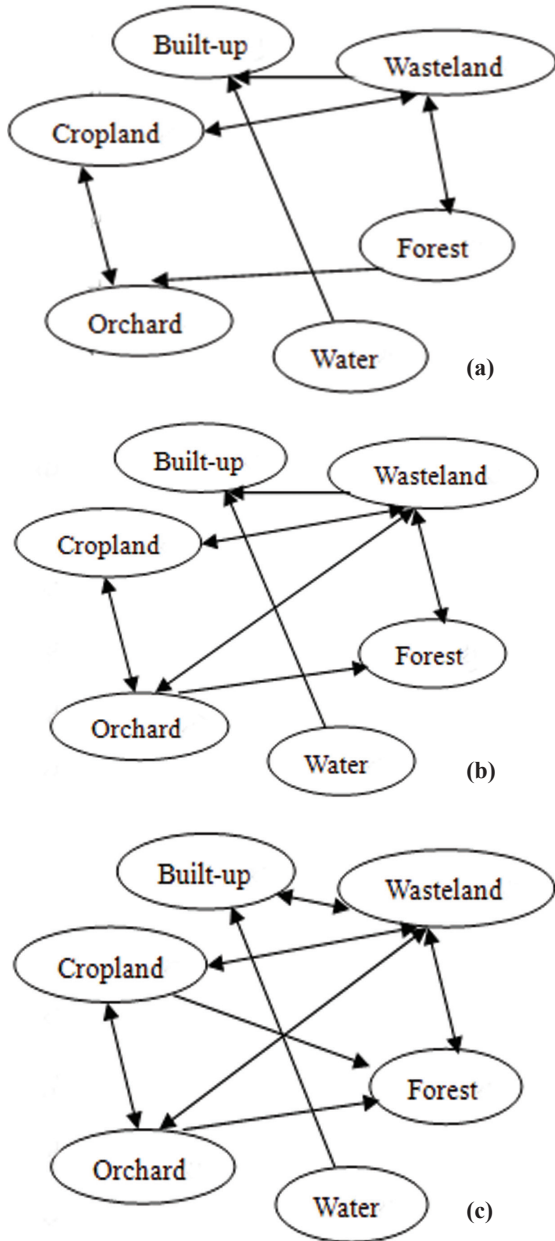
Figure 5- Land-use mutual conversion patterns during 2001-2004 (a), 2004-2007 (b), and 2007-2010 (c)

Şekil 5- 2001-2004 (a), 2004-2007 (b), ve 2007-2010 (c) yıllarında alan kullanım değişimlerini gösteren dokular

Here, two dynamic index proposed by Wang & Bao (1999) are used to quantify the yearly changing rate of land use types. The single land-use dynamic index is calculated with Equation 1.

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{t_2 - t_1} \times 100\% \tag{1}$$

Where; K is the dynamic degree of a land-use type in a certain period from t_1 to t_2; U_a represents the area of the type at the beginning of the period; and U_b is the area at the end of the period.

The comprehensive land-use dynamic index is used to describe the regional transforming rate of all land-use types during the study period, and quantitatively reflects the transformation rate and intensity of land use in the region. It can be expressed as Equation 2.

$$CR = \left[\frac{\sum_{i=1}^{r} \Delta LU_{i-j}}{2 \sum_{i=1}^{r} LU_i} \right] \times \frac{1}{t_2 - t_1} \times 100\% \tag{2}$$

Where; CR is the value of comprehensive land-use dynamic degree; LU_i is the area of land-use type i at the beginning of the period; and ΔLU_{i-j} is the conversion area from land-use type i to land-use type j.

The yearly changing rate and comprehensive land-use dynamic degrees during 2001-2004, 2004-2007, and 2007-2010 are obtained according to the above equations and are listed in Table 3. The results suggest that Guangdong Province has experienced striking and intense changes in land use, and the comprehensive land-use dynamic during 2001-2004, 2004-2007 and 2007-2010 was 3.32, 2.84 and 4.56, respectively. Wasteland shrank at an increasing rate, while the area of urban land witnessed a substantial expansion at a decreasing rate. The annual growth rate of orchards was rapid, while cropland suffered a moderate reduction from 2001 to 2010. It is inferred that agricultural restructuring, urbanization, and wasteland development are the direct causes of Guangdong Province's fast land-

cover change. Cities and towns spread rapidly into the countryside, creating strong development pressures on surrounding farmland and open spaces.

3.3. Analysis of the driving forces in Guangdong Province (2001-2010)

To further identify the socio-economic determinants of LUCC in Guangdong Province, several typical socio-economic factors during four years were collected from Guangdong's Statistical Bureau (Table 4).

Owing to the massive investment and rapid export growth made possible by the reform and opening-up policies, Guangdong Province's economy developed rapidly in the 1980s and early 1990s. Until 2001, the economy was large and the growth rate was moderate during 2001-2004; from 2004 to 2010, the economy advanced at a stable and fast speed, which can be reflected from marked increases in GDP, total investment in fixed assets, and total retail sales of consumer goods. Increases in wealth and income promoted increasing demands

Table 3- Single and comprehensive dynamic degree of land use/cover classes (from 2001 to 2010)

Çizelge 3- Alan kullanımı ve arazi örtüsünün tekli ve karmaşık derecesi

	Water	Wasteland	Urban	Forests	Orchards	Cropland
Single dynamic degree (%) (2001-2004)	0.056	-1.49	6.53	-0.56	3.63	-0.65
Comprehensive dynamic degree (%) (2001-2004)	3.32					
Single dynamic degree (%) (2004-2007)	-0.53	-2.91	3.31	0.56	2.35	-1.91
Comprehensive dynamic degree (%) (2004-2007)	2.84					
Single dynamic degree (%) (2007-2010)	-3.26	-19.33	1.67	5.13	3.17	-1.17
Comprehensive dynamic degree (%) (2007-2010)	4.56					

Table 4- Socio-economic indices in Guangdong Province

Çizelge 4- Guangdong bölgesinin sosyo-ekonomik indeksi

|	2001	2004	2007	2010
Gross Domestic Product (100 million Yuan)	10647.71	16039.46	31084.4	46013.06
Primary Industry	1004.35	1245.42	1695.57	2286.98
Secondary Industry	5341.61	8890.29	15939.1	23014.53
Tertiary Industry	4301.75	5903.75	13449.73	20711.55
Population (10000 people)	7565.33	7804.75	8156.05	8521.55
Government Revenue (100 million Yuan)	1160.51	1418.51	2785.8	4517.04
Total Investment in Fixed Assets (100 million Yuan)	3536.34	6025.53	9596.95	16113.19
Total Retail Sales of Consumer Goods (100 million Yuan)	4515.28	6370.42	10598.14	17414.66
Gross Agricultural Output Value (100 million Yuan)	1722.35	2154.79	2821.24	3754.86
Gross Industrial Output Value (100 million Yuan)	18909.91	26720.87	62759.92	85824.64

for urban land, since people desire more comfortable houses, more convenient transportation, and more beautiful living environments. Moreover, the rapid expansion of urban land occurred mainly because the economic output of urban land is generally much more than that of agricultural land. Since the agricultural land and wasteland in the urban fringe have the potential to be transformed into urban land, the rate of land cover change increased accordingly.

Guangdong Province's total investment in fixed assets soared to 16113.19 billion Yuan in 2010 from 3536.34 billion Yuan in 2001. The substantial increase in investment resulted in the rapid growth of infrastructure projects, simulated the low-density expansion of urban areas, and consequently the frequent conversion of wasteland and cropland into construction land.

The total retail sales of consumer goods in Guangdong Province has risen by over four times during the past 10 years, marking a great enhancement of buying power and demand for durable goods, including houses and cars. This consequently promoted the development of the

real estate, transportation, and service industries. Due to the above mentioned causes, along with the effects of developments in science and technology on economic development, Guangdong Province made significant progress in industrial structure adjustment and improvement. In fact, secondary and tertiary industries have increased at a fairly higher rate than primary industries, which led to a rising demand for labor, and consequently a large quantity of floating population. The population has been on the move, up to 852.15 million in 2010 from 756.53 million in 2001, and the population growth rate during 2001-2004, 2004-2007 and 2007-2010 was 3.16%, 4.5% and 4.48%, respectively. Furthermore, the population mainly gathered in urban centers and the outskirts surrounding them (mainly the Pearl River Delta), which is also a reason for urbanization and cropland loss.

To further confirm the influence of population and GDP on land-use change, we collected relevant data from 2001 to 2010. The change trend of GDP, and area of urban and cropland is shown in Figure 6. During the last 10 years, Guangdong
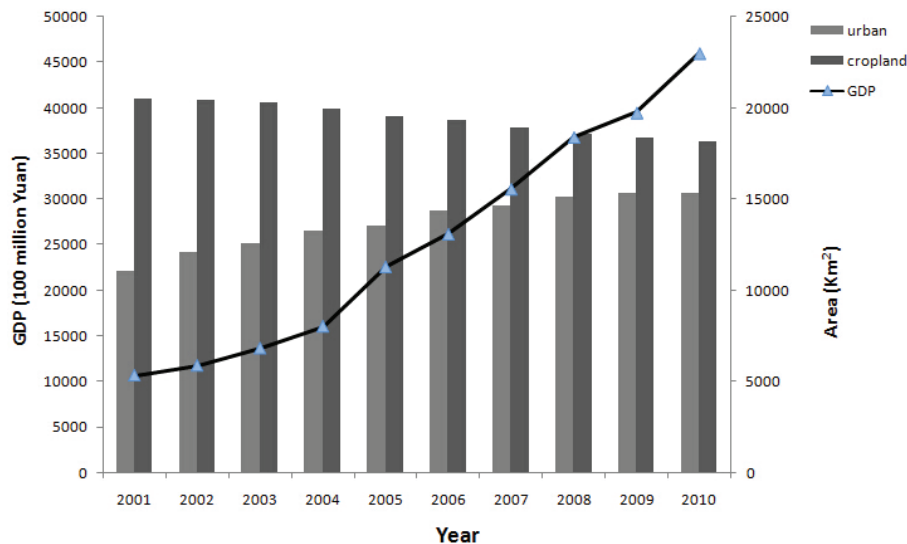
Figure 6- Change trend of GDP, and area of urban and croplands in Guangdong Province during 2001-2010

Şekil 6- Guangdong bölgesinde 2001-2010 yılları arasında GSYH ile kentsel ve tarım alanlarındaki değişim trendleri

Province has experienced a dramatic increase in GDP and corresponding gradual city expansion and cropland loss. Urbanization and economic growth are characterized by a close relationship and mutual promotion. Figure 7 indicates the correlation between population and area of urban and cropland, with the correlation coefficient of 0.923 and 0.987, respectively. In other words, the growing population has not only facilitated urbanization, but is also a major driving force behind reduction in farmland.
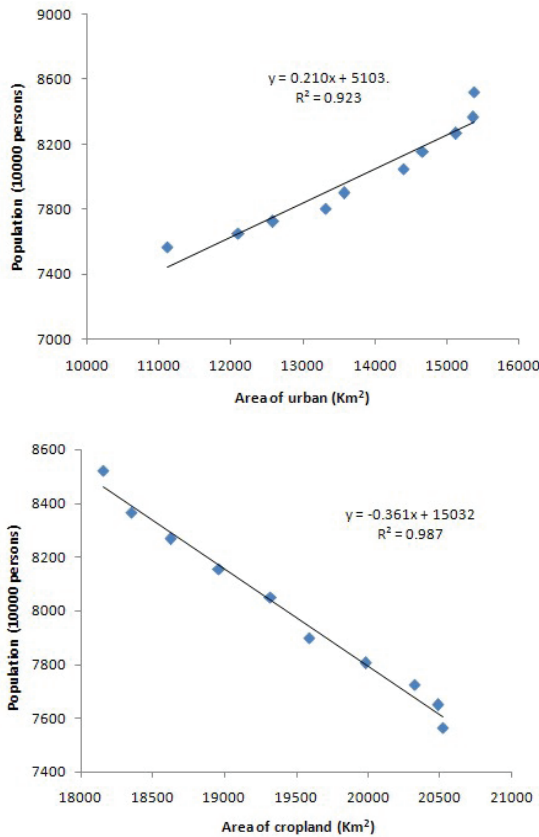
Figure 7- Correlation between population and area of urban (top) and cropland (bottom) in Guangdong Province during 2001-2010

Şekil 7- Guangdong bölgesinde 2001-2010 yılları arasında nüfus ile (üst) kentsel alan ve (alt) tarım alanları arasındaki korelasyon

4. Conclusions

Land use/cover change is recognized as an important factor in environmental change, especially in areas where enormous population and rapid economic growth exist. Our analysis indicates that in the last decade, Guangdong Province has witnessed dramatic land-use change, mainly manifested in urban land and cropland. The percentage of urban land and orchards increased by 2.38% and 1.9%, respectively; whereas, cropland shrank to 10.14% from 11.46%. This indicates that along with rapid economic development, massive urbanization (4186.25 km^2) and cropland loss (2212.5 km^2) have taken place in the region; meanwhile, the utilization of wasteland has been greatly increased, as shown by a decrease of area from 20407.5 km^2 to 18195 km^2. To some degree, the shrinkage of cropland and undeveloped land reflects an irreversible trend of growing industrialization, urbanization, and marketization. However, fertile cropland loss usually incurs substantial costs through diminishing the productivity of land and the capability of food grain production, as well as farmland diversity, which presents many challenges for farmers. Urban development could also cause environmental problems, such as air and water pollution, and an increase of carbon emissions.

The land-cover conversion mechanisms in Guangdong Province are mainly wasteland to urban land, and the mutual transformation between wasteland and cropland. The conversions from 2007 to 2010 were especially dramatic and complicated, which can also be inferred from the annual changing rate, with the most positive being 5.13%, the most negative -19.33%, and comprehensive land-use dynamic being 4.56%. The expansion rate of urban land and orchards was rapid, while wasteland and cropland suffered a sharp decline. The land-use changes could result in alterations in the physical and chemical soil parameters, thus giving rise to soil erosion, salinization, and desertification. Forestlands to built-up and wasteland conversions have been proven to produce an increase in soil erosion (Li et al 2014). Moreover, massive deforestation could change the atmospheric concentration of carbon

dioxide, i.e., the principal heat-trapping gas, and the local and regional climate by altering the vegetation cover on the surface. Therefore, there exists an urgent need for the government of Guangdong Province to plan and utilize the limited land resources more efficiently and effectively, and achieve a workable balance between the preservation of high-quality cropland and the need for urban growth.

The notable land-cover change in Guangdong Province is conclusively driven by its economic and population development. Marked increases in GDP (10647.71 billion Yuan to 46013.06 billion Yuan), total investment in fixed assets (3536.34 billion Yuan to 16113.19 billion Yuan), and total retail sales of consumer goods (4515.28 billion Yuan to 17414.66 billion Yuan) have led to fast expansion of cities and industrial structure adjustment and improvement. The rise of modern service industries has also created an opportunity for large-scale migration from rural to urban areas, together with rapid growth of the total population, thus accelerating the urbanization process and loss of farmland.

Acknowledgements

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