Ecological Indicators 80 (2017) 215–223

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

# Urbanization-induced site condition changes of peri-urban cultivated land in the black soil region of northeast China

Wenbo Li, Dongyan Wang*, Hong Li, Shuhan Liu

*College of Earth Sciences, Jilin University, Changchun 130061, China*

A R T I C L E  I N F O

*Keywords:*
Site assessment
Urbanization
Cultivated land
Peri-urban agriculture
Black soil region

A B S T R A C T

The site condition of cultivated land greatly influences the utilization and management of cultivated land resources and is an element that is disturbed tremendously by urbanization. Since the rejuvenation of the northeast old industrial base strategy in 2003, urbanization in northeast China has progressed rapidly. The excessive urban sprawl has profoundly changed land use structure in the peri-urban area of the black soil region, and the subsequent site condition changes will impede the full utilization of cultivated land resources. This study used the suburb of Changchun Kuancheng District as an empirical case, and employed a patch-scale site assessment system to analyze dynamic changes in cultivated land site conditions at a typical rural-urban interface of the black soil region from 2004 to 2014. Cultivated land loss and land use changes were prominent in the study area and the land conversion rate was shown to be accelerating. Most of the occupied cultivated land was converted to urban areas such as industrial land or urban settlements. However, a part of the occupied cultivated land was left unutilized, which indicates how the urban sprawl is jeopardizing benefits of both urban development and cultivated land protection. Besides direct occupation of cultivated land resources, urbanization has led to a loss of cultivated land with good site conditions and a deterioration of the site conditions of unconverted cultivated land in the peri-urban area. Urbanization has fragmented peri-urban cultivated land, increased farming distance and brought more frequent anthropogenic disturbances. On the other hand, it has also improved transportation conditions and the local ecological environment. As site condition is believed to be closely related to both cultivated land loss and cultivation abandonment, the deterioration will aggravate the loss of cultivated land resources in a disguised form.

## 1. Introduction

Over the past few decades, China has endured dramatic urbanization rates that have highlighted several land utilization issues, in particular, the urban sprawl rate continues to increase even though the population has a limited demand for urban space (Tan et al., 2016; Chen et al., 2015; Wei and Ye, 2014; Chen, 2007). The high urbanization rates have resulted in excessive conversion of cultivated land for construction purposes, and this phenomenon is especially significant in the black soil region of northeast China (Guo et al., 2015), which is one of core grain-producing areas in the country (Zhao et al., 2016; Liu et al., 2012). A direct effect of the urban sprawl has been the loss of high-quality cultivated land, and this has seriously threatened grain security (Kong, 2014; Song et al., 2015). The deterioration of cultivated land quality, which is an indirect effect of urbanization in China, poses another challenge to grain production.

Researchers generally agree that urbanization-induced deterioration of cultivated land, which can be noticed through changes such as soil degradation (Roy, 2012; Davies and Hall, 2010; Pouyat et al., 2008; Chen, 2007) and irrigation water pollution (Maheshwari and Bristow, 2016; Adhikary and Dash, 2012; Wittmer et al., 2010), will seriously damage cultivated land resources and lower the quality of agricultural products. Furthermore, fragmentation and changes in land use within the cultivated area are reported to be additional obstacles for profitable agricultural production, as they can potentially lead to cultivation abandonment (Janus et al., 2016; Qian et al., 2016; Falco et al., 2010; Niroula and Thapa, 2007). This indicates that landscape metrics and relative location, namely the major site conditions of each cultivated land patch, are crucial indicators that reflect the quality of cultivated land as well as elements that have been significantly disturbed by urbanization.

Site condition is a concept originally used in forestry that describes all of the external environment conditions that affect forest productivity (Matyssek et al., 2004; Pinard et al., 1996). However, the term, when applied to the field of agricultural land assessment, describes a collection of factors, except for natural quality factors, that influence

* Corresponding author.
*E-mail address:* wang_dy@jlu.edu.cn (D. Wang).

http://dx.doi.org/10.1016/j.ecolind.2017.05.038
Received 13 February 2017; Received in revised form 10 May 2017; Accepted 13 May 2017
Available online 20 May 2017

land quality, such as the distribution, location and coordination of land use (Qian et al., 2016). The American LESA (agricultural Land Evaluation and Site Assessment) system was proposed in 1980s as a way to emphasize the role of site conditions in agricultural land quality evaluations (Dung and Sugumaran, 2005; Tyler et al., 1987). On the basis of this evaluation model, some Chinese scholars have combined traditional cultivated land classification methods with site assessment and applied the evaluation results to the demarcation of prime farmland (Qian et al., 2016; Qian et al., 2015; Bian et al., 2015). There is a general consensus that good and stable site conditions are one of the representative characteristics of high-quality cultivated land. Moreover, cultivated land location and cultivated landscape are considered to be indispensable features of peri-urban cultivated land quality (Bian et al., 2015), and they are the site condition indexes discussed in this study.

Black soil is named according to the classification and codes for Chinese soil, and is defined as soils with evident humus accumulation process, similar to Mollisol in the American soil classification system (Li et al., 2017; Li et al., 2016). Characterized by cultivated soil rich in organic matter and superior tillage conditions, the black soil region of northeast China has always been an important area for the production of grain. However, since the rejuvenation of the northeast old industrial base in 2003, the urbanization rate in northeast China has increased (Zhang, 2013) and the need to protect black soil resources has become more apparent. There are noticeable changes in peri-urban land use within the black soil region (Sun et al., 2015; Yi et al., 2014), and the subsequent site condition changes may impede the optimal utilization of the cultivated land resources. The proper functioning of a strict cultivated land protection system requires patch-scale site assessments of peri-urban cultivated land, as well as measurements of spatiotemporal changes in site conditions. This study applies a patch-scale site assessment system for cultivated land to the Changchun Kuancheng District and then analyses dynamic changes in the cultivated land site conditions at a typical rural-urban interface of the black soil region from 2004 to 2014. This study aims to evaluate how urbanization-induced land use change affects the external utilization conditions of peri-urban cultivated land in order to contribute to the optimization of peri-urban land utilization structure and conservation of black soil resources.

## 2. Materials and methods

### 2.1. Description of the study area

A suburb of Kuancheng District (Fig. 1) was chosen as the study area for an analysis of the spatiotemporal changes in site conditions of a peri-urban cultivated land patch. The results from this study could then be extended to other peri-urban areas that are strongly influenced by urbanization. Kuancheng District is one of the major districts of Changchun City (124°18′E-127°05′E, 43°05′N-45°15′N), covering a total area of 23800 ha, and is located in the Jilin section of black soil region in northeast China. This region is characterized by high soil fertility and superior agricultural resources. However, Kuancheng District is one of the most developed areas in the black soil region, with the urban area expanding rapidly during the past decade. This has led to land use changes in areas along the urban-agricultural fringe. The selection of a suburb in Kuancheng District as the study area was motivated by the conflict between urban development and agricultural protection in this region, which is typical for urban-rural interfaces in the black soil region that are affected by urbanization. Therefore, the Kuancheng District case study provides evidence for how urbanization can impact cultivated land use in peri-urban areas of the black soil region.

### 2.2. Data processing

Land use information for the study area from 2004, 2009 and 2014 were interpreted using SPOT multispectral and panchromatic fused images with a spatial resolution of 10m, SPOT panchromatic images with a spatial resolution of 2.5 m and IKONOS multispectral and panchromatic fused images with a spatial resolution of 1m. In accordance with the study requirements, land use was classified into eight categories (Fig. 2): cultivated land (dry land, paddy land and agricultural greenhouses), rural settlement, urban settlement, industrial land (land for industrial manufacturing, storage and mining), transportation land (highways railways and major rural roads), ecological land (garden plot, grassland and forest land has been specified as a green area or wind shelter), water (river and irrigation reservoir) and unutilized land (bare land without vegetation cover or construction).

### 2.3. Modeling site condition for peri-urban cultivated land patches

According to a previous peri-urban cultivated land site assessment study (Bian et al., 2015), the site condition of an individual cultivated land patch in this study includes the landscape and relative location of the cultivated land, both of which are directly affected by land use pattern. Shape index, area index and contiguity index of cultivated land patch were selected as landscape features, while transportation convenience, irrigation availability, farming distance, urbanization risk and ecological environment of cultivated land patch were selected to represent the location features. This selection of indexes reflects land use changes that are typical for peri-urban cultivated land. Detailed descriptions of the indexes are shown in Table 1.

#### 2.3.1. Computational method for landscape indexes

All the presented methods for the computation of patch-scale landscape indexes are from a previous study (Li et al., 2000).

$$Frac = 2\log(P/4)/\log(A)$$
$$G = P/\sqrt{A}$$
$$SI = 4/(Frac^2 \times G) \quad (1)$$

Where $P$ is the perimeter of the cultivated land patch; $A$ is the area of the cultivated land patch; $Frac$ is the fractal dimension, and the theoretical range of $Frac$ is (1,2) when the cultivated land patch is compared to a square patch, with 1 representing a patch shape that is most similar to a square, and 2 representing the most complex shape under the same circumstances; $G$ is the growing index, and $G$ equals 4 when the patch shape is square; moreover, the higher $G$ is, the more elongated the patch will be; SI is the shape index, and the theoretical range of $SI$ is (0,1) when the cultivated land patch is compared to a square patch, with a higher SI indicating a more regular patch shape.

$$AI = (\log A_i\text{-}\log A_{min})/(\log A_{max}\text{-}\log A_{min}) \quad (2)$$

Where $A_i$ is the area of the cultivated land patch $i$; $A_{\min}$ and $A_{\max}$ are the minimum and the maximum areas, respectively, of all cultivated land patches during the three years; $AI$ is the area index, and represents the relative size of the patch. The range of $AI$ is [0,1], with a higher $AI$ indicating a relatively larger patch area.

$$CI = (\log A_i^{'}\text{-}\log A_{min}^{'})/(\log A_{max}^{'}\text{-}\log A_{min}^{'}) \quad (3)$$

All the cultivated land patches of each year were merged into one patch before the Contiguity Index was computed. Railways, highways, major rural roads, shelter belts and village boundaries were used as landscape corridors to segment the merged cultivated land into a new collection of patches. Where $A_i^{'}$ is the area of newly formed cultivated land patch $i$; $A_{\min}^{'}$ and $A_{\max}^{'}$ are the minimum and the maximum areas, respectively, of all newly formed cultivated land patches during the three years; $CI$ is the contiguity index, which represents relative size of a certain area, namely the relative contiguity of an area in which the cultivated land patch is located. The range of $CI$ is [0,1], with a higher $CI$ indicating relatively higher patch contiguity.