Habitat International xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Habitat International

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

Toward improved land elements for urban–rural integration: A cell concept of an urban–rural mixed community

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ARTICLE INFO

Keywords:
Land elements
Mixed community
Urban–rural integration
Urban–rural cell
Internal structure
Tangjialing
Erbozi

ABSTRACT

As the frontier of urban expansion against rural reservations, the urban–rural fringe faces both urban and rural land use problems that result in traffic jams, environmental pollution, and low quality of life. The urban–rural fringe refers to a transitional region characterized by a combination of urban and rural elements. However, the optimum composition of land elements for urban–rural integration remains unknown. Therefore, to effectively express the micro dynamic development of urban–rural fringe areas and guide land use, we formulate essential elements that can be used to enhance urban–rural integration from the perspective of an urban–rural mixed community. This study establishes a theoretical framework to analyze the formation of the urban–rural mixed community and finds that the community is similar to a cell with urban and rural elements. Unlike other studies that consider the entire cell as a grid unit representing a particular land use type, this study aims to investigate intracellular elements based on the general internal structure of a biological cell. Thus, the elements between the urban–rural and biological cells are compared to illustrate the potential optimized path of inner land elements. A comparative case study of the Tangjialing and Erbozi areas in Beijing is conducted to demonstrate the empirical implementation of an urban–rural cell. Our analysis shows that the urban–rural mixed community can be regarded as a micro-unit in achieving urban–rural integration. The inner elements of an urban–rural cell can help provide a suitable concept and design for analyzing the formation and composition of the urban–rural mixed community and propose an applicable way to determine the law for effective land element optimization and urban–rural integration.

1. Introduction

Land use patterns in urban–rural fringes have been profoundly reshaped as a result of rapid urbanization in China (Cao, Bai & Sun, 2017; He, Chen, Mao, & Zhou, 2016; He, Han, Veris, Wang, & Zhao, 2017). As the frontier of urban expansion against rural reservations, the urban–-rural fringe faces both urban and rural land use problems (Conzen, 2009; Yan, Xia, & Bao, 2015), such as excess industrial areas, insufficient residential spaces, uneven land distribution for public services, and landscape fragmentation, which result in traffic jams, environmental pollution, and low quality of life (Chen, Tang, Wan, & Chen, 2017; Wang, Liu, Li& Li, 2016; Wang, Zhang, Wu, & Skitmore, 2015; Xie, Wang, Yang, & Choi, 2016; Zhang, Uwasu, Hara, & Yabar, 2011). The urban–rural fringe has attracted numerous studies on spatial planning (Bedini & Bronzini, 2016), livelihood vulnerability (Huang, Huang, He, & Yang, 2017), conflict (Shan, Yu, & Wu, 2017; Zhao, 2017), and land use change because of its special combination of urban and rural characteristics (Bittnera & Soferb, 2013; Vizzari & Sigura, 2015). However, few studies have illustrated the optimal internal structures and functions of such a fringe; thus, its elements and functions remain undefined. The ideal composition of urban–rural integration, particularly the land elements of the transitional region, is still obscure (Piloyan & Konečný, 2017; Schmidt & Hewitt, 2004).

Considering that the "poor might be bad for each other" and "the poor are systematically disadvantaged by living in areas with poor resources and weak comparative advantage" (DCLG, 2010), the idea of a mixed community is highly recommended and applied in modern community construction. A mixed community encourages a sense of unity, supports family networks, improves safety, creates job opportunities, and boosts local economies (Hachem, 2015; Kearns & Mason, 2007; ODPM, 2003). Researchers have studied various components of a mixed community such as mixed household type, mixed ethnicity, mixed income, and mixed housing tenure (Baum, Arthurson, & Rickson, 2010; Livingstone, Bailey, & Kearns, 2010; Tunstall, 2003). However, the type of urban–rural mixed community that may benefit from integration, residential and employment stability, and environmental

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https://doi.org/10.1016/j.habitatint.2018.01.007
Received 10 December 2017; Received in revised form 10 January 2018; Accepted 30 January 2018

harmony (Lang, Chen, & Li, 2016) is largely ignored in the existing literature. Moreover, the literature fails to answer what elements or functions are important, how urban and rural elements can mix effectively, how to determine the optimal size of the mixed community, and where to locate these functional units. Among these crucial questions, the top priority is to identify what land elements are needed by considering the urban–rural mixed community as a long-standing space.

As regions that reflect the transition from rural to urban areas, urban–rural fringe areas are dynamic systems that can evolve and basic units that can nurture new cities in a manner similar to biological functions. The concept of cities as a biosystem is not a new idea. Early efforts can be traced back to Perry (1929), who described the neighborhood unit as a core cell of a residential area. Saarinen (1958) was inspired by the growth of trees and proposed an organic evacuation theory to create a good city form under an organic order of moderate dispersion and local concentration. Jacobs (1961) also proposed the mixed community as one of the means to promote organic urban vibrancy. Several researchers correlated the idea of living organisms with urban planning; for example, the urban cell is regarded as a tool for sustainable urban development because of its size and function (Bindzárová, 2016). Wu, Chang, and Chen (2012) regarded each cell as the center of a local area and highly correlative neighboring cells as bundled elements to propose a new location management scheme with lower location management cost. The concept of a cell is also widely accepted as a grid in the cellular automata model to simulate and predict future land use (Aburas, Ho, Ramli, & Ash'Aari, 2016; Wang et al., 2013; White, Engelen, & Uljee, 2008). By estimating the combined probabilities of all the land use types in each specific grid cell, researchers can allocate the dominant land use type to this grid cell during cellular automata iteration (Hewitt & Díaz-Pacheco, 2017). However, these studies usually regard the entire cell as a grid unit representing a particular land use type (Liu et al., 2017), and the cell–cell interaction or external network is emphasized more than the intracellular elements or structure. The real biological cell has extremely delicate internal elements and structures that cannot be generalized as one land use type. Thus, existing studies have failed to examine why an area is likened to a cell or other living things from the perspective of formation and structure.

In this study, we attempt to address the issue of what land elements are needed for urban–rural integration from a microcellular structural perspective of the urban–rural mixed community. We initially establish a theoretical framework that involves the formation and development of an urban–rural mixed community as an urban–rural cell. We then compare two cases, namely, the Tangjialing and Erbozi areas of Beijing, to demonstrate the empirical implementation of such a cell. Our analysis shows that an urban–rural cell can be considered a micro-unit to achieve integration, which can help us understand the necessary land elements of a dynamic urban–rural fringe.

The rest of this paper is structured as follows. Section 2 discusses the formation of an urban–rural community and compares an urban–rural and biological cell as a potential optimized path of land elements. Section 3 presents a comparative case study of Tangjialing and Erbozi. Section 4 provides discussions and conclusions.

2. Theoretical framework: formation and development of an urban–rural cell

2.1. A box that defines an urban–rural mixed community

Many studies have discussed the formation mechanism and impact factors of an urban–rural fringe (Peng, Zhao, Liu, & Tian, 2016). However, most studies have conducted a descriptive statistical analysis of the development phenomenon, whereas few have constructed abstract models of the urban–rural fringe as a whole to describe how it forms, expands, and maintains balance during a certain period. Thus, this section constructs a relatively concise quantitative model from the perspective of an urban–rural mixed community to explore the mechanism of formation, expansion, and balance as an urban–rural cell.

On the basis of the assumption that the population and economic activity are distributed on the same line (Fujita & Krugman, 2003; Krugman, 1996, pp. 75–97), the city center is located at $r = 0$ point and f is the urban boundary. B is the rural boundary with homogeneous land settling in plain areas. Only industrial and agricultural sectors exist in the economic system. The former can select its location freely and provide various industrial products. The latter is evenly distributed on a straight line and offers single and homogeneous agricultural products. Suppose that the agricultural population is evenly distributed, and each person's consumption is fixed at 1. Manufacturers can select the location of factories. The fixed cost of constructing one more factory is F, whereas the transportation cost of one unit product under one unit distance is τ. Each unit of agricultural product requires 1 unit of land and c^A units of labor, whereas each unit of an industrial product only needs c^M units of labor. Using the concept of iceberg cost (Samuelson, 1952), we suppose that only an amount of $\exp(-\tau^A d)$ or $\exp(-\tau^M d)$ can arrive if one unit of industrial/agricultural product is transported for a distance d. As the city provides industrial products for its surrounding rural areas, these rural areas also provide agricultural products at a price p^A simultaneously. If we regard $p^A \equiv p^A(0)$ as the price of agricultural products in the city center, then we can assume that $p^A(r) = p^A e^{-\tau^A|r|}$. In the model of bidding land rent (Alonso, 1964), farmland rent $R^A(f)$ is equal to industrial land rent $R^M(f)$ in the urban–rural mixed community. Let land rent in point f be M, and $\omega^A(f)$ can be defined as $\frac{p^A e^{-\tau^A f} - M}{c^A}$.

If we consider the urban–rural mixed community as point f, then industrial products can be provided internally because the manufacturing industries are distributed evenly in the city, whereas agricultural products should be imported externally. The price index $G(r)$ stated by Krugman (1991) is virtually the same as the urban and rural people at point f. Therefore, the condition of spatial equilibrium can be regarded as the market clearing of agricultural products and the same real wages between workers and farmers at the boundary point.

Equation (1) shows the market clearing of agricultural products, namely, balance between the supply and demand of agricultural products. D^A stands for the food consumption of the city, L^M is the number of manufacturing workers distributed evenly with the same wage of w^M, and $1 - \mu$ part of which is spent on agricultural products. Suppose the agricultural area also spends $1 - \mu$ part of its income on agricultural products, and the rest is supplied to the city. If the agricultural area is r away from the city center, then only $e^{-\tau^A|r|}$ part of per unit agricultural products can arrive at the city center and another $e^{-\tau^A|r-s|}$ part can arrive at the area that is s away from the center. Thus, the total food supply of the city can be seen as S^A, which should be equal to D^A.

$$\begin{cases} D^A = 2\int_0^f \frac{(1-\mu)w^M L^M}{p^A e^{-\tau^A|r|}} dr \\ S^A = 2\mu \int_0^f \left(\int_f^B e^{-\tau^A|r-s|} dr \right) ds \\ D^A = S^A \end{cases} \quad (1)$$

As shown in Equation (2), the second condition involves the same real wages between workers and farmers at the boundary point. $w_r^A(f)$ represents the real wage of farmers at the boundary point, and we assume $1 - \mu$ part of the nominal wage is used to buy agricultural products and the rest is for industrial products. $w_r^M(f)$ indicates the real wage of workers at the boundary point.

$$\begin{cases} w_r^A(f) = \omega^A(f) G(f)^{-\mu} p^A(f)^{1-\mu} \\ w_r^M(f) = \omega^M G(f)^{-\mu} p^A(f)^{1-\mu} \\ w_r^A(f) = w_r^M(f) \end{cases} . \quad (2)$$

From Equations (1) and (2), we can deduce f as