



Ecosystem Services Provisioning, Urban Growth and the Rural–Urban Interface: A Case Study from China

Haiying Feng ¹, Victor R. Squires ^{2,*} and Jingji Wu ³

¹ Qinzhou Development Research Institute, BeiBu Gulf University, Qinzhou 535011, China; fhy@bbgu.edu.cn

² School of Agriculture, Food and Wine, University of Adelaide, Adelaide 5000, Australia

³ School of Economics and Management, Beibu Gulf University, Qinzhou 535011, China; jingji_wu@bbgu.edu.cn

* Correspondence: dryland1812@internode.on.net

† The author is retired.

Abstract: The rural–urban (peri–urban) interface zones are important places that generate demands for ecosystem goods and services (EG & S). Urban regions face transitions in land use that affect ecosystem services (EG & S) and thus human wellbeing. Especially in urban areas with high population densities (as in most of China) and high demand for EG & S, the future availability of such services must be considered in order to promote effective and sustainable decision making and prevent further ecosystem degradation. The challenge for local government planners and land managers is to find tools that allow relevant data to be collected and analyzed. Ideally, such tools should be able to give a rapid assessment, and not involve large teams of highly trained personnel or incur high costs. The paper reports on the development and trial of such a tool. The paper has three main parts. First, we present a brief overview of the current and developing situation in China, in relation to urbanization, population shifts and the creation of peri–urban areas (PUAs). Next, we build on insights from the literature and from discussions with village heads and county- and prefecture-level officials to develop an understanding of their needs for tools to help planning and land management within the constraints of the national policy. Lastly, a “template” was derived from our multi-method approach that provided a new technical tool for the rapid assessment of the value of EG & S in each of five land use categories. The tool embodies a way to address trade-offs between environmental, social and economic values in the transition zone between rural and urban areas. The tool was trialed in QinBei District in Guangxi Autonomous Region in south China and judged to be useful and adaptable to other rural–urban regions.



Citation: Feng, H.; Squires, V.R.; Wu, J. Ecosystem Services Provisioning, Urban Growth and the Rural–Urban Interface: A Case Study from China. *Land* **2021**, *10*, 337. <https://doi.org/10.3390/land10040337>

Academic Editor: Zahra Kalantari

Received: 7 February 2021

Accepted: 22 March 2021

Published: 25 March 2021

Keywords: pollution; energy; water; food; waste management; degradation; arable land; non-market goods; society; planners; demographics; EG & S

Publisher’s Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction: Context and Setting

China is undergoing rapid urbanization [1–6] and according to the data from the national bureau of statistics, the rate increased from 10.64% in 1949 to 58.52% in 2017 and reached 60% in 2019. China’s urbanization progress will continue, with the urbanization ratio reaching 70 percent by 2035, according to a report published by the National Academy of Economic Strategy under the Chinese Academy of Social Sciences. Over the past 25 years or so, China has been experiencing arguably the most rapid, dramatic and far-reaching process of urbanization in human history. It therefore merits separate attention, despite both similarities to and differences from experiences elsewhere. The trend to greater urbanization is nationwide, but reflecting the distinctive national and regional political economies. According to a report in the “China Daily”, the structure and function of China’s “urban areas is expected to evolve from a metropolitan focus to urban agglomeration dominance in the next 15 years. It is projected that the pattern of urbanized population will be across the spectrum of urban agglomerations, with 25 percent

in small towns, 25 percent in small- and medium-sized cities, and 25 percent in central cities and metropolises, respectively. A metropolis will support functions of modern services [6], These include knowledge-concentrated industries, that is, those that need many talents to develop, and capital-concentrated industry, and small- and medium-sized cities will support industries from a metropolis, such as the manufacturing industry, in the future” (<https://www.china-daily.com.cn/a/201906/24/WS5d1089b0a3103dbf14329ea7.html>) (accessed on 3 November 2020).

Mobility of the workforce in China was first enhanced by the implementation of the household responsibility system (HRS), which, in 1982, dismantled the communes and gave rural households individual contracts to farm agricultural land [4,6–8]. A more efficient and productive use of resources-including labor-allowed for greater agricultural output and income, as markets for rural products thrived. The household became the main unit of production, at the same time that it acquired greater freedom of labor allocation as well as in migration decisions. Both household size and structure (the household development cycle) as well as land cultivation needs became important determinants of household surplus labor. In order to diversify the household income, surplus labor began to engage in off-farm work. However, the pull factor created by enterprise labor demand led many peasant workers to leave the countryside even when they were not surplus to agricultural production [4,6–8]. Mobility has further been ensured by a set of policies diminishing central state control over provincial and lower administrative units, which can now establish their own economic priorities. The new provincial and local economic strategies-especially in medium and larger urban areas-include bringing in cheap labor to work in construction, manufacturing and other service sectors. On the other side of the spectrum, decentralization policies in the rural areas have encouraged local governments to actively promote and facilitate out-migration in order to increase village living standards through migrant remittances. Increasing proportions of rural households and village income are indeed being derived from both migration and other non-agricultural activities. This spread of the availability of non-agricultural incomes and improved living standards means that villagers need not migrate to become better off, while reducing migration pressure. This is what Friedmann [6]) calls “in situ rural urbanization”. Better housing (electricity, indoor plumbing), access to the internet, more transport options (bus train, car), etc. make it possible to work from home and enjoy the comforts previously only found in urban areas. Following introduction of the HRS, rural urbanization and industrialization also commenced. Peri-urbanization has been occurring on a large scale, especially near larger cities and is seen as an industrially driven process [4–6]. Some peri-urban districts have become completely urbanized, absorbed by growing cities and sometimes even incorporated as urban administrative districts [5,7–10].

One consequence of urbanization has been the rise in importance of peri-urban areas (PUAs) and peri-rural areas (PRAs), which are the transitional areas between urban and rural landscapes; they exist at the intersection of rural and urban zones, often where infrastructure such as agriculture, shopping, roads and economic centers exist, just beyond the existing urban areas and the beginning of the rural areas proper. According to Christine FÜrst and her colleagues at Halle University, in Germany, “The peri-urbanization processes are affecting the sustainability of transitional peri-urban landscapes (PULs). The biodiversity of PULs is becoming endangered along with the provisioning of ecosystem goods and services due to the investments on infrastructure, communications, and services such as piped water, electrification and sewerage treatment works occurring in PULs”. At the same time, PULs are being characterized by a rising demand for various types of ecosystem services (ESs), while ES-providing areas in PULs are diminishing. This situation is causing ES and biodiversity trade-offs, thereby intensifying a gap between ES demand and provision. The degradation and loss of vital ecosystem functions and services have been an uncontested result of urbanization. An understanding of how ecosystem services are provided along rural–urban gradients is crucial in the task of conserving and enhancing vital services in urban environments, increasing the quality of life of urban dwellers, and

working towards a sustainable future. Focusing on nine ecosystem services—aesthetic, spiritual, recreation, water flow regulation, carbon sequestration, climate change adaptation, pollination, biodiversity potential and noise attenuation—regarded as important to urban areas, we can detail the changes in the values of these services along a gradient comprising four categories of urbanization: urban, suburban, peri-urban and rural.

The greatly accelerated economic and social development that accompanies rapid urbanization has also engendered numerous environmental problems, such as local climate alteration, changes in carbon storage, increased air and water pollution, increased energy demands [5,7–10], a major reduction in natural vegetation and decreased ecosystem service provision [10,11]. The increasing population density and demands of urban environments have exacerbated the pollution of air and water and affected water availability, leading to solid, liquid and gaseous waste disposal problems, and a high level of energy consumption (see below). The challenges of solid waste management include inadequate infrastructure, a paucity of policy and legal frameworks, poor environmental planning, budgetary and operational constraints, overpopulation and inadequate environmental education [6]. Urbanization is a growing issue and, therefore, so is the consequent waste generation and its management challenges. An aspect that has received some attention is the damage to soil quality through the disposal of saline wastewater or from contaminated industrial liquids that are discharged into waterways or onto the surface. Intensive livestock production facilities like poultry farms and piggeries or slaughterhouses and sewerage sludge solid waste and polluted effluent may also be problems in peri-urban areas. Managing these and other difficulties as the urban areas expand will require stronger planning guidelines and policies [8–10].

2. Environmental Degradation in the Peri-Urban Interface (PUI)

There is a downside to economic growth. It has come at the expense of natural resources and ecosystems. Many terrestrial ecosystems are being seriously degraded because land use decisions often fail to recognize non-economic ecosystem functions and biophysical limits to productivity [11–14]. Diverse urbanization and peri-urbanization processes have had unpredictable and complex human consequences (see Simon’s review paper [14]) but our focus here is on the environmental implications. These have generally been severe and are increasingly recognized officially as “unsustainable”. Attention to measures aimed at remediation and prevention is therefore urgent and essential. Levels of river and soil pollution and contamination from often toxic waste are high, resulting in health problems and severe agricultural contamination, such as the high levels of cadmium in rice. Nearly half the rice and rice products on sale in Guangzhou (a large and prosperous province in south China) contain too much cadmium, a toxin and carcinogen that can damage the kidneys (Available online: <https://www.scmp.com/news/china/article/1240198/guangzhou-food-safety-authorities-find-high-levels-cadmium-rice>, accessed on 11 November 2020).

In many urban areas of China, not just in large cities like Beijing, air quality is very poor and governments at all levels are taking action to remedy the situation. The Chinese government’s attitude to economic growth and industrialization at any cost has now changed and concerted efforts are being made to tackle both proximal and root causes. Pollution abatement measures and greenhouse gas emission reductions are now being introduced energetically. Prime agricultural land is being lost to urban activities in high-potential areas like the major river deltas—precisely where urbanization has been most rapid and extensive. Such loss cannot readily and sustainably be compensated for by bringing lower-potential land elsewhere into production or by intensifying existing production [5,7,12,13]. As we are reminded by David Simon [14] “environmental issues and problems have featured prominently in processes of peri-urbanization and the nature of PUIs almost everywhere. It is important to underscore that PUIs everywhere are not independent or isolated zones but are highly dynamic interfaces between urban and rural areas. Forces and pressures acting in the PUI are therefore not only local but national and

even international, in terms of human mobility, commodity and financial flows and their valuation, and claims on environmental resources”.

The increasing urbanization pressures on ecosystems and the threat to their potential for the provision of ecosystem goods and services (EG & S) have been highlighted in many studies. According to the World Bank [15], the PUI is a particularly vulnerable zone as cities expand and infrastructure is installed. In addition, the majority of the world’s poor, perhaps as many as 70%, live in these towns and small and medium cities and the rural areas more proximate to them. About 5.5 billion persons, three quarters of all of us on Earth, live in the increasingly diffuse and porous interface of rural and urban societies. Moreover, rates of poverty are also higher in small and medium cities than in large urban agglomerations [2,13].

The rural–urban fringe, also known as the outskirts, peri-urban area or the urban hinterland, can be described as the “landscape interface between town and country”, or also as the transition zone where urban and rural uses mix and often clash [8,11]. Alternatively, it can be viewed as a landscape type in its own right, one forged from an interaction of urban and rural land uses. The rural–urban interface or continuum extends from the rural areas to the towns and cities of China. It is quite variegated and is characterized by a complex nexus of sites, including primary and secondary sites in relationships of gain and loss, dominance and subordination, associated in different ways with rural-to-urban migration [8,10]. The UN Millennium Ecosystem Assessment [16] (2005) states that the degradation of environmental services is a significant barrier to achieving the Millennium Development Goals—and that this impediment could grow significantly worse over the next 50 years. The rural poor, who directly rely on ecosystem goods and services for their diet, health and livelihoods, are disproportionately affected [4,9,10,12,13].

The scope and character of the production and distribution systems have been restructured in the past few decades by what is now known as “globalization”. Peoples’ lives have been affected in profound cultural, ideological and economic ways. Globalization impinges on the provision of environmental goods and services (EG & S) in many different ways [12,14–18].

Seto et al. [3] say “As urbanisation proceeds, there is an increasing supply/demand ratio of food and water but a decreasing supply of energy”. As the population grows, per capita supply of farmland is increasingly in competition with accelerated urbanization [5,7,15,17–19]. Many studies are now examining the impact of ecosystem service conservation strategies on agricultural productivity [8,10,11,16]. The unprecedented scale of land use change has contributed significantly to changing local, regional and global climates. In the future, there is a high likelihood that the management will be geared to favor some ecosystem services (e.g., provisioning) over others (e.g., supporting). Urban regions face transitions in land use that affect ecosystem services (ESs) and thus human wellbeing. Especially in urban regions with high population densities and high demand for ESs, the future availability of such services must be considered to promote effective and sustainable decision making and prevent further ecosystem degradation. There are indications that the land use transitions that most significantly affect ES degradation or improvement are those from arable land to mainly non-residential uses—especially public and private services [8–11,13,19].

Although there is broad agreement on the importance of incorporating the concept of ecosystem services into policy strategies and decision making, the lack of a standardized approach and funding, to facilitate quantification of ecosystem services at the landscape scale, has hindered progress in this direction. In addition, the pattern of ecosystem demands shows a leveling of rural–urban gradients, reflecting profound modifications of traditional rural–urban relationships. The changes of ecosystem service supply gradients are determined more by land use intensity, such as the intensification of agricultural production, than by land cover changes such as urban sprawl. The comparison of supply/demand ratios and rural–urban patterns of ecosystem services can help decision makers involved in landscape management as they strive for a sustainable balance between resource supply

and demand. There is neither a typical rural–urban gradient in terms of urban ecosystem service provisioning nor a uniform urban spatial pattern of service provisioning that can serve as a generic model for cities [5,9,11,13,14].

3. Spatial and Environment Development Issues in the Rural–Urban Interface in Qinzhou Prefecture, Guangxi

In this paper, we try to develop a better understanding of the processes and forces at play and have endeavored to develop a “template” that allows local government planners and land managers to rapidly appraise the status and trend of EG & S provision. We use examples from the rural–urban fringe in Guangxi, China and trace the patterns that have emerged over the past decade and we attempt to project toward 2050, the end point of many of the UN Millennium Development Goals (MDGs). We focus on the dynamic developing coastal regions of Guangxi, China, along the shores of the South China Sea. Urbanization has been rapid and has created often wide and persistent transition zones that combine various rural and urban conditions. Moreover, their importance for the cities that they surround is increasingly appreciated. These impacts have been summarized by David Simon [14] as (i) absorbing urban migrants, as (ii) sources of food, water and other resources and as (iii) key areas for the disposal of urban wastes. They are also, typically, zones of mixed land use and livelihoods. On account of these characteristics, and the interactions between such areas and the cities, they have come to be known as peri-urban zones or interfaces (PUIs) and have become major research foci in their own right. PUIs comprise distinctive zones of mixed character beyond the suburbs [10]. Crucially, fringe or PUI areas should be treated as integral elements of urban systems (i.e., as extensions of cities) in both functional and planning terms, because they and their environments are integral to the growth and operation of growing cities, including being the source of vital ES & G.

There are many transitional zones (PUIs) between the distinctly urban and the unambiguously rural areas and these have special characteristics. Cities are dynamic human artifacts and they constantly undergo structural change, redevelopment, and growth [10,12,17–19]. Such processes also involve changes in urban relationships with the surrounding territory, most conspicuously on their outskirts. The importance of PUIs everywhere lies in their dynamic mix of functions and land uses; increasing population densities; growing significance as sources of urban food, construction materials and other resources; as urban waste disposal or treatment sites; and as recreational zones. However, primarily, we focus on their role in provisioning of ES & G. Although urban expansion rarely occurs neatly or uniformly, little attention has been devoted to the dynamics of, or implications for, the urban–rural fringe or transition zone. The spread of urban activities and land uses into rural areas create complex mosaics of juxtaposed activities previously regarded as incompatible, e.g., computer assembly workshops adjacent to rice paddy fields or sugar cane plantations, and urban activities and urban-oriented leisure activities, e.g., golf courses abutting rural villages [8].

4. Approach Adopted in Our Field Study and Notes on Methodology

4.1. Preamble

As peri-urban landscapes come under threat, there is a growing need to understand relationships between human livelihoods and environmental processes [18,19]. This often involves integrating multiple data sources capturing different scales of measurement. Participatory methods have emerged as a means to accomplish this, but are hampered by a wide range of challenges associated with data collection and translation. Often data are at different spatial and temporal scales than the activities of people in the landscape, and there are many challenges (i.e., matching levels of accuracy with other data sets, generalizing methods across different land cover types), especially when integrating remotely sensed data and data on human activities. In order to understand social–ecological systems dynamics, it is imperative that we overcome these challenges.

4.2. Scope and Purpose of Our Work

We were responding to a need expressed to us by local government officials (planners and land managers). The knowledge gap we addressed is the development of a “template” that allows a rapid “broad stroke” appraisal that can be useful to land use planners and those charged with the responsibility to move China toward an “ecological civilization” and ultimately achieve the “China Dream”. We focused on the development of a “tool box”, including the derivation of an ecosystem service index (An ecosystem service index (ESI) is a calculated weighting of many relevant attributes to derive a single number between 0 and 1, where 0 is the lowest. ESI scores were derived for geographical scales (from global to local) at which benefits accrue.) that would characterize the impact of change in land use and land cover (LULC) at local regional, national and global scales (see below). Our approach is something that can be achieved by a small team on a modest budget. The outcome is a broad-brush assessment—something that our university was asked by the prefecture government to provide.

4.3. Socio-Cultural Context for Qinbei Study

The population of towns within QinBei District have been increasing rapidly over recent years. This increase has been from natural growth and in-migration into the towns, mainly of government employees, alongside the engulfment of villages as urban centers. This increasing population does not sit well with the concomitant socio-economic infrastructure building program and poses a lot of planning challenges for the township administrators. For example:

- environmental degradation (soil erosion, water pollution, biodiversity loss) is localized and severe in areas of major development. There is need for remedial action and a prioritizing of where to start and what methodology to use;
- the spatial pattern of transport infrastructure development has placed markets close to roads and thereby concentrated traffic along these corridors. There are challenges for planners that will benefit from better knowledge of the environmental status and trends;
- products and services pass in and out of these few nodal points, creating localized environmental pressures (e.g., waste disposal, water quality);

Collectively, these challenges, unless overcome or mitigated, may ultimately undermine the environmental viability of these sites and the local population they serve [7–10,18,19].

The presence of expanding local government bureaus and private entrepreneurs in Qinzhou Prefecture provided avenues for employment, thus pulling people into the county towns, and even smaller urban centers. For example, the emerging towns in QinBei District have become urban, not only as a result of population growth but also as a result of political influence. Settlements that were once rural were later upgraded, for example, to house a local headquarters through government efforts to take administration closer to the people (decentralization). The rapid population growth has influenced changes in land cover. Until recent times, the urban space within QinBei District covered an approximate area of 124km², surrounded by open and gallery forests and grasslands, including savanna. A small percentage still comprises wasteland with barren rocky areas, degraded rocks, land with or without trees/shrubs and exposed rocks. Nowadays, agricultural land comprises about 28% of the area and the built-up area is a little more than 17%, while the peri-urban areas comprise 45%.

It is from these rural and peri-urban areas that most provisioning ES & G (food, water, timber, air purification, soil formation and pollination) flow. Of course, there is also a great contribution to the other three ESs (regulating, cultural and supporting services [10–14,18]). Another important group of ES & G are what are called supporting (also called regulatory) services. These are necessary for the production of other services. They include soil formation and conservation; nutrient cycling; primary production; water cycling; and cycling of atmospheric gas [9–13].

The regulating services relate to the quality of air and soil or minimize damage from flash flooding. Local climate and air quality are much influenced by changes in land use, whilst forests influence rainfall and water availability both locally and regionally and trees provide shade in urbanized areas, PUIs and in rural areas. Cultural services such as spiritual, recreational and cultural benefits are particularly important to the ethnic minority inhabitants such as, for example, the practice of preserving fengshui forests [20] and supporting services such as nutrient cycling that maintain the conditions for life on Earth that are vital to ecosystem functioning [10,13,16,19,21–24].

4.4. Procedures for Data Collection and Information Gathering

To collect and analyze the information and data, a mixed methods approach was used. A multi-methods approach (see Figure 1 and Box 1) compares ecosystem service provision and the factors behind the linked socio-ecological regeneration in local villages, seeking transferrable lessons for areas facing similar problems.

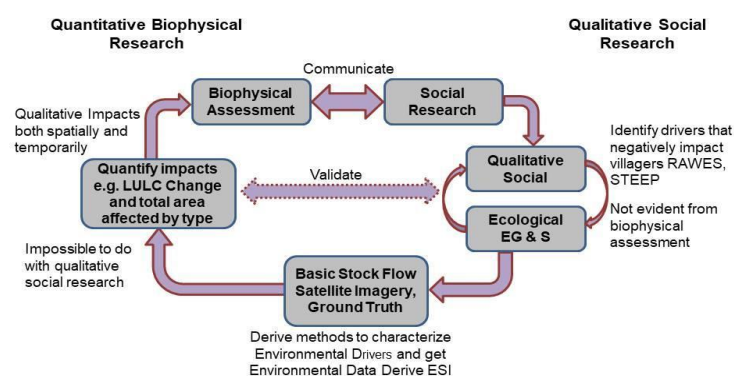


Figure 1. A flow chart to show the interdependencies in qualitative and quantitative research.

This multi-methods approach involves three disparate, and seemingly incompatible, analysis techniques [24], used to compare ecosystem service provision (see Box 1). The three mixed methods analyses involved (i) ecosystem service-based RAWES assessment including calculated ESIs; (ii) social, technological, environmental, economic, political (STEEP) analysis of systemic interactions across the socio-cultural system; and (iii) interpretation of satellite data to reveal differences in land use and condition and resultant societal benefit flows across sampled areas. It is for this reason that the STEEP framework was also used to stratify the information gathered and to explore systemic interdependencies between different components using key and contextual questions. This was combined with the quantitative data derived from analysis of satellite imagery and field-level studies (ground truthing) (see Figure 1).

4.5. Field Work and Image Interpretation

Guangxi is characterized by karst topography (Figure 2 with lots of prominent peaks interspersed by intensively cultivated flatlands and terraced fields on some slopes).

Our field work is ongoing and the following is to give readers a clearer picture of how we proceeded and the sort of analysis we are currently undertaking. A domain measuring 40 km × 40 km north of Qinzhou City was chosen and lying between highways G75 and G325 (see Figure 3: Map of Qinzhou Prefecture).

We used a 100 m horizontal resolution to assess variation in the terrain. A raster data set provided land cover data at a 1 km² resolution with 25 m × 25 m sub-grids and we settled on five different land cover classes. Each land cover class was allocated to the most appropriate land use class, retaining the sub-grid scale distribution. Two urban types are considered: “urban center”, with an average building height of 30 m and a high fraction of tall buildings, representing the city center, and “suburban”, with an average building height of 10 m, representing areas dominated by residential buildings of lower height. The

allocation of these types is based on the distinction of “continuous urban” and “suburban”. Figure 4 shows the percentage of each model grid cell covered by either continuous urban or suburban areas. The rural land use map was created by removing all the urban areas and replacing them with a combination of rural land use classes, in order to represent the land cover prior to any urbanization. The distribution of the rural land use at the sub-grid scale was created using combinations of the two rural land use classes (“grasslands” and “mixed forest”), so that the land use map represented a realistic rural state, rather than replacing all of the current urban land use with either of these two rural types.

Box 1. Explanation of the methodologies used in this study.

Social, technological, environmental, economic, political (**STEEP**) analysis of systemic interactions across the socio-cultural system. The STEEP framework was also used to stratify the information gathered and to explore systemic interdependencies between different components using key and contextual questions.

A rapid assessment of wetland ecosystem services (**RAWES**[#]) approach was used as a method that meets many needs. Its use enabled integration of different types of knowledge, both rapidly gathered statistical and non-statistical evidence, articulating in semi-statistical terms (ESIs) the tangible spatial and temporal differences in ecosystem service production in the village landscapes.

An ecosystem service index (ESI) is a calculated weighting of many relevant attributes to derive a single number between 0 and 1, where 0 is the lowest. ESI scores can be derived for geographical scales, varying from global to local, at which benefits accrue.

Satellite imagery analysis. A raster data set provided land cover data at a 1 km² resolution with 25 m × 25 m sub-grids and we settled on 5 different land cover classes.

[#] Although RAWES was originally developed for use in the assessment of wetlands, it has been successfully applied to other terrestrial ecosystems.



Figure 2. (Left) Guangxi is famous for its scenic beauty but arable land is in short supply and multi-layered terraces are common, as shown in the photo to the right. New urbanized clusters are now appearing in the countryside as cropland is consolidated.

4.6. Outcome of ESI Derivation

Land use patterns were analyzed and five distinct land uses were agreed upon. ESIs were derived using data from STEEP and RAWES models as well as field work (ground truthing). We took into account the significance, at local, catchment-wide, national and global levels. Figure 5 is a summary of our findings. The highest ESI component was local, while global was only evident in the areas of woodlands and forest. Guangxi has large areas of plantations (mainly *Eucalyptus* that are grown for pulping) but significant areas of natural forest and woodland can also be found. Catchment benefited a lot from good maintenance of terraces (Figure 2). Near-natural land uses, grazing land and woodland/forested land had significant ESIs for catchment while global benefited most from areas with tree and shrub cover, leading to a higher carbon sequestration rate and greater biodiversity.

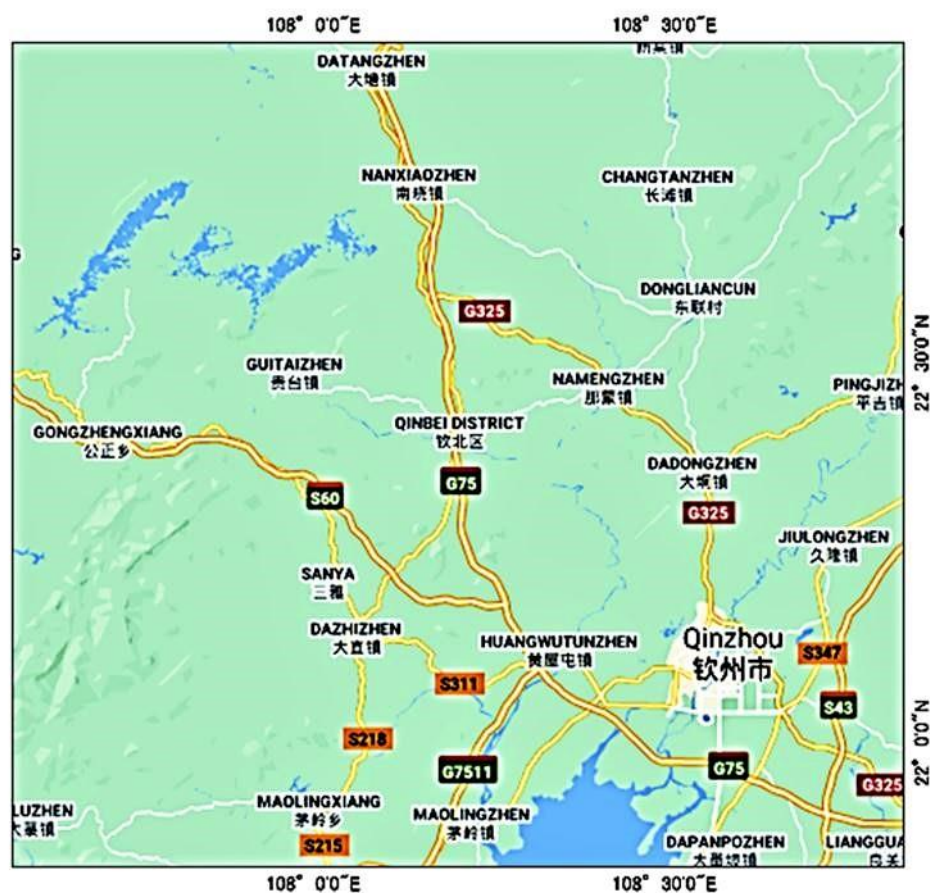


Figure 3. Map of Qinzhou Prefecture showing major district and county urban areas. The study site was Qinbei District north of the prefectural-level city of Qinzhou and in the area between highways G75 and G325.

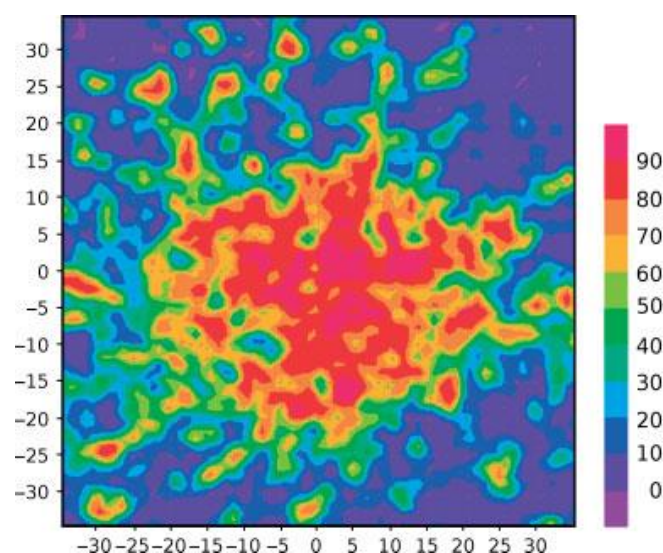


Figure 4. Image showing the percentage of land covered by either continuous urban (red) or continuous rural (blue) in the 40×40 km domain north of Qinzhou, Guangxi and lying between highways G75 and G325.

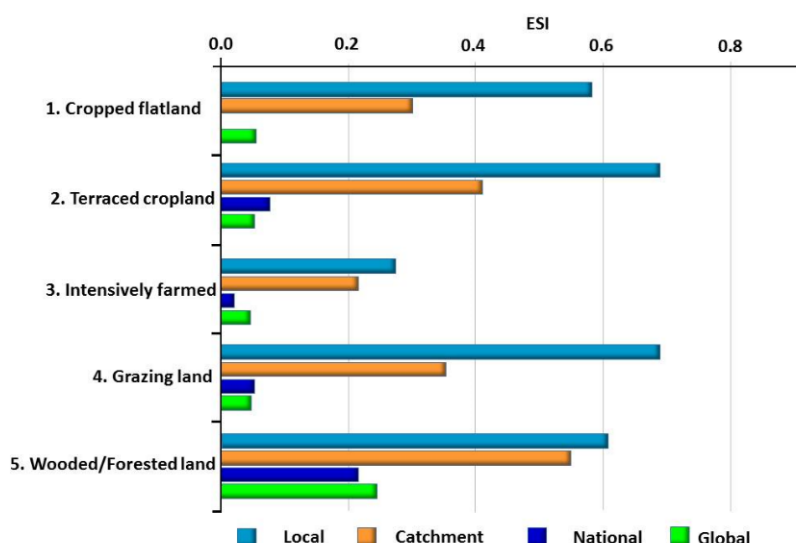


Figure 5. Ecosystem service index (ESI) for the five major land use types in rural and peri-urban areas, ranked according to the contribution at global, national, catchment and local levels.

4.7. Development of A “Template” That Allows A Rapid “Broad Stroke” Appraisal

The prefecture- and county-level governments are somewhat aware of the loss of EG & S but are also motivated to comply with the central government’s directive to accelerate major infrastructure projects and facilitate the national goal of moving 200 million people from rural to urban areas. Although there is broad agreement on the importance of incorporating the concept of ecosystem services into policy strategies and decision making, the lack of a standardized approach and funding to facilitate the quantification of ecosystem services at the landscape scale has hindered progress in this direction. The focus of our field work was on developing a rapid appraisal of the status and trend of the provisioning of EG & S. We are proceeding toward achieving a workable “template” that is useful to township, county and prefecture planners. We see the urgency of developing a means to gain a rapid appraisal of the situation surrounding fast-developing towns and county-level cities [19,21,22]. We worked within a modest budget appropriate to local planning. Therefore, what we present is a methodology (a toolbox) that can be applied along the rural–peri-urban–urban continuum that can help get a “first take” on how EG & S provisioning is going (up, down or stable).

5. Discussion

The population of towns within QinBei District have been increasing rapidly over recent years. This increase has been from natural growth and in-migration into the towns, mainly of government employees, alongside the engulfment of villages as urban centers. This increasing population does not sit well with the concomitant socio-economic infrastructure building program and poses a lot of planning challenges for the township administrators. The urban administrators need to further develop and exploit the database on land use changes to plan for the current and future land uses as a major thrust in urban and peri-urban space management. This land use planning must integrate economic, social and environmental considerations now and in the future for the sustainable management of the urban space that depends heavily on the EG & S from the surrounding rural land and in the peri-urban zones [21–27].

The presence of expanding local government bureaus and private entrepreneurs in Qinzhou Prefecture provided avenues for employment, thus pulling people into the county towns and even smaller urban fringes. For example, the emerging towns in QinBei District have become urban, not only as a result of population growth but also as a result of political influence. Settlements that were once rural were later upgraded, for example, to house a

local headquarters through government efforts to take administration closer to the people (decentralization). The rapid population growth has influenced changes in land cover. Until recent times, the urban space within QinBei District covered an approximate area of 124 km², surrounded by open and gallery forests and grasslands, including savanna and some pockets of farmland. A small percentage still comprises wasteland with barren rocky areas, degraded rocks, land with or without trees/shrubs and exposed rocks. Nowadays, agricultural land (terraced uplands, flat cropland and grazing land) comprises about 28% of the area and the built-up area is a little more than 17%, while the peri-urban areas comprise 45%. It is from these rural and peri-urban areas that most provisioning EG & S (food, water, timber, air purification, soil formation and pollination) flow. Of course, there is also a great contribution to the other three ESs (regulating, cultural and supporting services).

Rapid change in the urban space poses many challenges to town planning and future urban sustainability since the majority of these expanding sites are encroaching on marginal areas and agricultural productive land, including some that is quite marginal (because of slope, shallow soil depth and rockiness). A fundamental problem in land use and land cover changes in QinBei is how to preserve agricultural land. As the urban space keeps on growing, the unfortunate thing is that there is no piece of land actually reserved for agricultural use, although the urban dwellers need food. There has been engulfment of villages by urban space too (see new housing cluster in Figure 2). A major peri-urban challenge is how to protect the environment (especially ecosystem services) and human health while meeting the growing demand for water and development that is driven by population growth and affected by climate variability and land use change. The local government administrators need to further develop and exploit the database on land use changes to plan for the current and future land uses as a major thrust in urban and peri-urban space management. This land use planning must integrate economic, social and environmental considerations now and in the future for the sustainable management of the urban spaces that depend heavily on the EG & S from the surrounding rural land and in the peri-urban zones [26,27]. The steady economic and urban growth of towns over recent decades has brought with it a wide range of management concerns, demands and conflicts, and these are more complex than ever before. A major urban challenge is how to protect the environment (especially ecosystem services) and human health while meeting the growing demand for water and development that is driven by population growth and affected by climate variability and land use change [28]. Increasing demands for clean water, combined with changing land use practices and aging infrastructure (especially pipelines and canals), pose significant threats to the water resources [29].

6. Conclusions

Close interdependence between people and supportive ecosystems is further endorsed by our exploration of systemic linkages between the key social, technological, environmental, economic and political dimensions under the social, technological, environmental, economic, political (STEPP) model. Ecosystem–human interdependencies happen within complex socio-ecological systems, with highly interdependent governance arrangements, technology choices and economic considerations, hence our choice of the STEPP methodology. The STEPP framework was also used to stratify the information gathered and to explore systemic interdependencies between different components using key and contextual questions. RAWES enabled integration of different types of knowledge, both rapidly gathered statistical and non-statistical evidence, articulating in semi-statistical terms (ESIs) the tangible spatial and temporal differences in ecosystem service provision from the village landscapes.

This study offers a perspective of land use change in the peri-urban interface in rural Guangxi, which helps to explore the formation and change of rural land use and actual functions, as well as the mechanisms behind them. Our study could have some implications for improving rural development strategies, rural planning and governance in China. Tracking spatial restructuring in peri-urban areas in terms of their land use

changes and their underlying economic dynamics is a key perspective in the study of rural development in fast-developing China. The reform and opening policy, which took place in the 1980s (see above) has significantly transformed China's rural areas. A large amount of rural labor force has moved to and is working in cities due to the attraction of the lifestyle and the prosperity that cities can offer, resulting in many hollow villages [29–33]. In contrast, urbanization and industrialization have caused a dramatic change in the land use and natural landscape of rural areas, along with a significant loss of cultivated land, a spatial expansion of the surrounding cities and an increase in the construction of new rural settlements [30–33].

The template that we devised, based on the multi-methods approach, compared ecosystem service provision and identified the factors behind linked socio-ecological regeneration in local villages, seeking transferrable lessons for areas facing similar problems. As suggested by Pagella and Sinclair [34], a new and comprehensive typology of ES maps, developed by logical expansion of the basic stock–flow–receptor concept, could result in a set of map categories and interactions that embraces requirements for the management of ES provision from rural landscapes. We plan to incorporate this thinking into the next phase of the project. In this preliminary phase, we tried to produce a map at a scale and resolution that allows field-scale management options to be exercised. We learned that it is also necessary to incorporate stakeholder knowledge and perspectives in the generation and interpretation of maps and adopt more flexible approaches to local definition of ESs by stakeholders (land users and government officials) to facilitate their management at local scales. There are potential trade-offs (and some actually occurring now) between the people causing damage to EG & S and those who are providing off-setting EG & S and enhancing the local ecosystem [17,19,35–37].

The three mixed methods facilitated analysis of systemic interactions across the socio-cultural system and revealed differences in land use and condition and resultant societal benefit flows across sampled areas. Ecosystem–human interdependencies happen within complex socio-ecological systems, with highly interdependent governance arrangements, technology choices and economic considerations, hence our choice of the STEEP and RAWES methodology. We acknowledge the limitations and uncertainties inherent in this study, in which different forms of knowledge are integrated to seek understanding of, and transferrable principles from, the successes observed. Ideally, further research would replicate these surveys and analyses in many more villages to deepen understanding of sustainable ecosystem–community relationships. Nevertheless, although the findings of this study are subject to some unquantifiable uncertainty, they illustrate how different governance arrangements have profound impacts on whole socio-ecological systems and the sustainable accommodation between people and the natural systems that support them. This knowledge is transferrable to other situations in the rapidly developing regions in China and ASEAN countries and in many African countries where urbanization is accelerating and where peri-urban areas are extensive, noting of course that specific details relevant to the villages in the Qinzhou region require adaptation to other ecosystem types.

Author Contributions: Conceptualization, V.R.S. and H.F.; methodology, H.F. and J.W.; validation, H.F. and V.R.S.; investigation, H.F. and J.W.; resources, H.F. and J.W.; data curation, H.F. and J.W.; writing—original draft preparation, V.R.S.; writing—review and editing, V.R.S.; supervision, H.F.; project administration, H.F.; funding acquisition, H.F. and J.W. All authors have read and agreed to the published version of the manuscript.

Funding: H.F. and J.W. of BeiBu Gulf University worked on part of the research program Investigate demographic shifts and land use change along the rural-urban interface in Guangxi.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We are grateful to the many researchers, commentators and scholars whose work has inspired our own. We have drawn heavily on their wisdom, insights and writing to bring what we hope will be a synthesis. We are thankful for the support we received from government

officials and local leaders as well as the hospitality shown by villagers in QinBei and beyond. We are grateful to Mahesh K. Gaur for re-drawing and/or enhancing the figures.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chan, K.W. China's Urbanization 2020: A New Blueprint and Direction. *Eurasian Geogr. Econ.* **2014**, *55*, 1–9. [CrossRef]
2. Chen, J. Rapid urbanization in China: A real challenge to soil protection and food security. *Catena* **2007**, *69*, 1–15. [CrossRef]
3. Seto, K.C.; Güneralp, B.; Hutya, L.R. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 16083–16088. [CrossRef]
4. Feng, H.Y.; Squires, V.R. Integration of Rural and Urban Society in China and Implications for Urbanization, Infrastructure, Land and Labor in the New Era. *South Asian J. Soc. Stud. Econ.* **2018**, *2*, 1–13. [CrossRef]
5. Robinson, G.M.; Song, B. Transforming the Peri-Urban Fringe in China: The Example of Xi'an-Xianyang. *Sustainability* **2018**, *10*, 3932. [CrossRef]
6. Friedmann, J. *China's Urban Transition*; University of Minnesota Press: Minneapolis, MN, USA, 2005; p. 168.
7. Long, H.; Liu, Y.; Li, T. Agricultural production in China under globalization. In *Handbook on the Globalisation of Agriculture*; Robinson, G.M., Carson, D.A., Eds.; Edward Elgar: Cheltenham, UK, 2015; pp. 214–235.
8. Xu, W.; Tan, K. Impact of reform and economic restructuring on rural systems in China: A case study of Yuhang, Zhejiang. *J. Rural. Stud.* **2002**, *18*, 65–81. [CrossRef]
9. Güneralp, B.; Seto, K. Environmental impacts of urban growth from an integrated dynamic perspective: A case study of Shenzhen, South China. *Glob. Environ. Chang.* **2008**, *18*, 720–735. [CrossRef]
10. Tan, M.; Li, X. The changing settlements in rural areas under urban pressure in China: Patterns, driving forces and policy implications. *Landsc. Urban Plan.* **2013**, *120*, 170–177. [CrossRef]
11. Wang, Y. Environmental degradation and environmental threats in China. *Environ. Monit. Assess.* **2004**, *90*, 161–169. [CrossRef]
12. Zhang, D.; Huang, Q.; He, C.; Wu, J. Impacts of urban expansion on ecosystem services in the Beijing-Tianjin-Hebei urban agglomeration, China: A scenario analysis based on the Shared Socioeconomic Pathways. *Resour. Conserv. Recycl.* **2017**, *125*, 115–130. [CrossRef]
13. Kroll, F.; Muller, F.; Hasse, D.; Fohrer, N. Rural-urban gradient analysis of ecosystem services supply and demand dynamics 2012. *Land Use Policy* **2012**, *29*, 521–535. [CrossRef]
14. Simon, D. Urban Environments: Issues on the Peri-Urban Fringe. *Annu. Rev. Environ. Resour.* **2008**, *33*, 167–185. [CrossRef]
15. World Bank. 2016. Available online: <https://data.worldbank.org/indicator/SP.POP.GROW> (accessed on 12 January 2020).
16. Millennium Ecosystem Assessment. *UN Millennium Ecosystem Assessment Report 2005*; Island Press: Washington, DC, USA, 2005; ISBN 1597260401.
17. Lambin, E.F.; Meyfroidt, P. Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy* **2010**, *27*, 108–118. [CrossRef]
18. Qiu, B.; Li, H.; Zhou, M.; Lu, Z. Vulnerability of ecosystem services provisioning to urbanization: A case of China. *Ecol. Indic.* **2015**, *57*, 505–513. [CrossRef]
19. Long, H.; Li, T. The coupling characteristics and mechanism of farmland and rural housing land transition in China. *J. Geogr. Sci.* **2012**, *22*, 548–562. [CrossRef]
20. Yuan, J.W.; Liu, J.L. Fengshui forest management by the Buyi ethnic minority in China. *For. Ecol. Manag.* **2009**, *257*, 2002–2009. [CrossRef]
21. Lauf, S.; Haase, D.; Kleinschmidt, B. Linkages between ecosystem provisioning, urban growth and shrinkage—a modelling approach assessing ecosystem service trade-offs. *Ecol. Indic.* **2014**, *1809*, 22.
22. Fu, B.; Zhuang, X.-L.; Jiang, G.-B.; Shi, J.-B.; Lu, Y.-H. Environmental problems and challenges in China. *Environ. Sci. Technol.* **2007**, *41*, 7597–7602. [CrossRef] [PubMed]
23. Dale, V.H.; Polasky, S. Measures of the effects of agricultural practices on ecosystem services. *Ecol. Econ.* **2007**, *64*, 286–296. [CrossRef]
24. Liu, Y.; Fang, F.; Li, Y. Key issues of land use in China and implications for policy making. *Land Use Policy* **2014**, *40*, 6–12. [CrossRef]
25. Everard, M.; Waters, R.D. *Ecosystem Services Assessment: How to Do One in Practice*; Institution of Environmental Sciences: London, UK. Available online: https://www.the-ies.org/sites/default/files/reports/ecosystem_services.pdf (accessed on 24 April 2018).
26. Ahern, J. Urban landscape sustainability and resilience: The promise and challenges of integrating ecology with urban planning and design. *Landsc. Ecol.* **2013**, *28*, 1203–1212. [CrossRef]
27. He, J.; Huang, J.; Li, C. The evaluation for the impact of land use change on habitat quality: A joint contribution of cellular automata scenario simulation and habitat quality assessment model. *Ecol. Model.* **2017**, *366*, 58–67. [CrossRef]
28. Ho, S.P.S.; Lin, G.C.S. Converting Land to Nonagricultural Use in China's Coastal Provinces: Evidence from Jiangsu. *Mod. China* **2004**, *30*, 81–112. [CrossRef]
29. Gaur, M.K.; Squires, V.R. *Climate variability Impacts on Land Use and Livelihoods in Drylands*; Springer International AG: London, UK, 2018; p. 348.

-
30. Qiang, Y.; Lam, N.S. Modeling land use and land cover changes in a vulnerable coastal region using artificial neural networks and cellular automata. *Environ. Monit. Assess.* **2015**, *187*, 1–16. [[CrossRef](#)]
 31. Liu, Y.; Liu, Y.; Chen, Y.; Long, H. The process and driving forces of rural hollowing in China under rapid urbanization. *J. Geogr. Sci.* **2010**, *20*, 876–888. [[CrossRef](#)]
 32. Li, T.; Long, H.; Liu, Y.; Tu, S. Multi-scale analysis of rural housing land transition under China's rapid urbanization: The case of Bohai Rim. *Habitat Int.* **2015**, *48*, 227–238. [[CrossRef](#)]
 33. Zhu, J.; Guo, Y. Fragmented Peri-urbanisation Led by Autonomous Village Development under Informal Institution in High-density Regions: The Case of Nanhai, China. *Urban Stud.* **2013**, *51*, 1120–1145. [[CrossRef](#)]
 34. Xie, H.; He, Y.; Xie, X. Exploring the factors influencing ecological land change for China's Beijing-Tianjin-Hebei region using big data. *J. Clean. Prod.* **2017**, *142*, 677–687. [[CrossRef](#)]
 35. Pagella, T.F.; Sinclair, F.L. Development and use of a typology of mapping tools to assess their fitness for supporting management of ecosystem service provision. *Landsc. Ecol.* **2014**, *29*, 383–399. [[CrossRef](#)]
 36. Braat, L.C.; Groot, R. The ecosystem services agenda: Bridging the worlds of natural science economics, conservation and development, and public and private policy. *Ecosyst. Serv.* **2012**, *1*, 4–15. [[CrossRef](#)]
 37. Groot, R.S.; Wilson, M.A.; Boumans, J. A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. *Ecol. Econ.* **2002**, *41*, 393–408. [[CrossRef](#)]