1 Introduction

1.1 The vulnerability of ecosystems and climate change

The study of the vulnerability of ecosystems and climate change has been a significant research direction in most ecological and environmental studies during the past several decades. The changes in ecological environment could threaten to shift vegetation, disrupt ecosystems, reduce biodiversity and even damage human well-being(Gonzalez et al., 2010).

The panel on Climate Change (IPCC) pointed out that global greenhouse gas emissions rose by 70 percent due to human activities in the context of climate change topic from 1970 to 2004(Programme, 2009). Many experts considered that with the rapid development of urbanization, the world may experience potentially dangerous in climate and environmental change. It could have a significant impact on our environment, economies, and societies(Graham, 2009).

1.2 Urban sprawl

At the same time, the phenomenon named “urban sprawl” has also emerged in many countries, which has become a major concern because of its detrimental [effects on a](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/effect-on-the-environment) series of ecological, economic and social issues(Brueckner et al., 2001)(Jaeger et al., 2010). Urban sprawl could be specified as the spilling over of urban-type buildings and constructed land into the suburban and farmland areas and the disorganized growth of settlements in farmland areas(Wackermann, 1968). It would result in encroaching excessively on farmland, leading to a loss of amenity benefits from open space as well as the depletion of farmland resources(Brueckner et al., 2001), which could also lead to air pollution due to the long commutes generated by urban expansion(Fenger, 1999). Therefore, the social ecological problem caused by urban sprawl should not be ignored by governments. With ecological space becoming scarcer at an alarming rate, much higher efforts are necessary to conserve and properly use land and soils resource(Haber, 2007).

According to Demographia World Urban Areas, 15 of the world's 20 largest cities are in developing countries(Demographia World, 2021). It means that developing countries have become the main deriving force of global urbanization and thus would be the areas with the most intense urban sprawl conflicts(Yue et al., 2013).

At the same time, Urban sprawl in China has also attracted general concern from scholars. There has been rapid and unprecedented urbanization in China, which also resulted in accelerating drastic urban sprawl over almost all of the last decade(Li and Li, 2019). However, due to the difference in urban form between China and other countries, there are relatively little research about the impact and future trends of urban sprawl in China compared with the rich literature on urban sprawl in developed countries(Wang et al., 2020). Therefore, it is necessary to research urban problems following a dynamic analysis of social, economic, and ecological aspects of sprawl.

1.3 Urban fringe area

The urban fringe area could refer to the outer zone of the urban built-up area, which has unique cross-over characteristics(Cui et al., 2020).

Generally, urban fringe area is facing urbanization-related social-ecological problems, especially in megacities in the background of urban sprawl (Peng et al., 2020). There would be a discussion about pro-growth or anti-growth interests in many urban fringe areas(Pacione, 1991). However, it is popular to decentralize the population by minimizing the growing development pressure of the metropolis emergence into urban fringe area(Howlader and Sarkar, 2020). With the growth of urban population and the expansion of industries, there is no doubt that the expansion of constructed land can maintain a continuous rise in the socio-economic status of the city. However, the development of constructed land represents a reduction in ecological space and farmland in the urban fringe area. At the same time, all energy and material resources are used to build and operate buildings would also cause the growth of greenhouse gas, impacting the supply of ecosystem services(Pedersen Zari, 2012). Therefore, there would be a trade-off relationship between urban growth and environmental change, and between urban growth and socio-economic growth.

Although the urban fringe area is challenged with social-ecological problems with the urbanization process, there is no standard principle for researching urban fringe area due to its complexity, dynamicity and fuzzification(Dong et al., 2022). Accurately identifying the urban fringe can significantly help to integrate urban-rural development planning in megacities(Peng et al., 2020).

1.4 Research objective and research questions

Besides, in order to find the balance in urbanization and ecological space, researching dynamic changes between socio-economic development and environmental outcome in urban fringe areas in megacities would provide a scientific reference to urban growth management in specific megacities. Apart from the identification and assessment, the study would also attempt to discuss social-ecological problems in depth from a policy perspective by combining ecological restoration and regional management approaches， which can also explore the special characteristic of proper intervention policies in developing countries, especially in China.

Therefore, the research question and framework could be shown below:

1. How to identify urban fringe area?

2. What are the changes between socio-economic development and environmental outcomes in urban fringe area in the past several years based on different cities?

3. Comparing results and existing urban fringe area management policies of different cities

4. What kinds of interventions (development priority or protection priority) should be taken in urban fringe area in different case cities?

2 Literature review

2.1 Sustainable Development

In 2015, the United Nations Development Program (UNDP) formed 17 global goals known as “[Sustainable Development Goals](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/sustainable-development-goals)” with 169 targets and 232 indicators for the protection of the planet for current and future generations(Pedersen Zari, 2012). According to SDGs, Sustainable Development Goal 15 (SDG15) would be aimed at protecting, restoring and promoting sustainable use of [terrestrial ecosystems](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/terrestrial-ecosystem)(UN, 2015). Therefore, when it comes to the urban fringe area development, it should be basically focused to cope up with social, economic, and environmental benefits in the present scenario. In order to achieve SDG15, it should be focused on three perspectives equally(Howlader and Sarkar, 2020). However, how to balance the social, economic, and environmental benefits of reservoir operation has become one of the most complicated problems facing governments worldwide.

2.2 Interventions to urban fringe area

Since there has been a fear that farmland would be swallowed up by urban sprawl with the growth of megacities, it is generally considered that it is necessary to think the need for possible physical intervention in the urban fringe area(Gallent and Andersson, 2007). Gallent (2006) also think that the intervention method should be built on a wider urban agenda concerned with growth and the management of growth.

By considering this, what form should interventions take to manage urban fringe areas has been generally discussed in different countries and megacities.

Green Belt policy was used as a universal solution to urban growth by thinking of urban fringe area(Gant et al., 2011). In London, intervention to urban fringe area would be fulfilling the function of fire break to protect the environment. The Green Belt has been a prime part of the land-use planning system for planners and could distinguish the area of urban and rural land use. Apart from the function of butter zone in ecological space, the Green Belt also provide opportunities for outdoor recreation near urban areas to citizens, retains and enhances attractive landscapes, and most importantly, secures nature conservation interest as well land in agricultural, and forestry uses(Ferguson and Munton, 1979).

The Green Belt policy successfully made urban containment in spatial distribution. However, Gant(2011) think that the intervention in the past has ignored the possibility that urban fringe area might have a varied character worthy of close attention. Although urban planners realized that they had made a mistake of seeing fringe area as buffers and tried to relax Green Belt retractions, the urban fringe area was still disconnected to nearby urban and rural areas. Therefore, Gallent(2011) hold his opinion that Green Belt policy should recognize the strategic needs of public service development and the importance of rural–urban fringes to view the urban fringe area in a wider subregional and regional context.

Besides, in the process of exploring sustainable development in urban fringe area, Netherland was treated as the success of current open space preservation policies. Green Heart planning was developed in the Hague Region, one of the most urbanized areas in the Netherland according to national spatial plan(Koomen and Dekkers, 2013). Apart from adopting a buffer zone policy, the government also assign the green infrastructure from urban fringe area to the status of a municipality or assign land ownership and stewardship to a community land trust(Aalbers et al., 2009). A unified system of management at a regional level provides greater clarity in the allocation of resources. Moreover, by developing glass and grass production and recreation area, it could successfully make market chains and urban-rural relationships compared with developing housing site in other cities. Therefore, urban fringe area in Netherland would be in a place where recreational facilities and natural areas were being developed by controlling its dynamic balance(Koomen and Dekkers, 2013).

It has been considered that urban fringe areas are a distinct entity because of their special characteristics and productive construction in each regions(Gallent, 2006). Many research indicated that sustainable intervention of urban fringe area in developing countries would be different. Howlader and Sarkar (2020) think it is hard to achieve the SDG in Indian scenario of urban fringe area in fast-growing megacities. With the rapid growth of population and environmental pressures in urban area, urban fringe area development is mainly focused on decreasing and decentralizing the pressure of the central area. Treated as a core sub-center in the future, Indian megacities are other priorities on hand compared with sustainable development. Therefore, they are more likely to form the Development Authorities (DA) to adopt and implement integrated policies and plans toward inclusion.

According to Liu (2018), megacities in China sprawled most from 2000 to 2010, and the rate of urban sprawl has decreased since 2010. The Land Administrative Law and the Regulations on the Protection of Basic Farmland are promulgated to implement open space preservation. Specifically, urban sprawl would show an obvious difference in megacities depending on region, population, and administrative hierarchy(Li and Li, 2019).

Different cities would consider the difference and formulate effective regulatory policies in the urban fringe area. In the context of rapid and large-scale city construction, scholars in China suggest local governments should enhance their control and propose local planning to serve the needs of growth(Tian et al., 2017). For example, according to the planning outline of ecological civilization construction in Guangzhou(2016-2020), important green corridors and nodes companied with two ‘green forest rings’ with a total area of 86 km2 are proposed by Guangzhou environmental protection bureau to mitigate environmental pollution from urban sprawl(Guangzhou environmental protection bureau, 2016) (Yu and Ng, 2007). Besides, according to Shanghai City Master Plan (1999–2020), Shanghai from a development strategy, “One City, Nine Towns”, to alleviate the city from the significant pressure of urbanization(Tian et al., 2017). With a projected population of 800,000 to one million in each new town, Shanghai also transferred local land revenues and land use from the municipality government to district governments to ensure the efficiency of environmental reservation(Wang et al., 2020). In conclusion, Although the intervention strategies have achieved some success in China, urban development strategies in fringe areas are still imperfect due to their late start and the dominant power for urbanization. Therefore, more research should be applied to quantify the impact of planning on urban fringe area and sustainable development planning could be explored in the future based on the result.

2.3 Research technique

**2.3.1 Identification of urban fringe area**

Traditionally, it would be common to identify urban fringe area by using statistical analysis methods(Beibei, 2012). By considering single or multiple indicators including density, population, economic level and land use, research might also use Multicriteria Analysis (MCA) to combine each indicator and finish the identification process(Yang et al., 2017). Due to the limitations such as not continuous statistical data and the difference of statistical standards, it would be difficult to obtain efficient and accurate results.

To minimize the uncertainty, a combination of multi-date Landsat Thematic Mapper (TM) with different years was used to detect urban detailed urban land use (Turker and Asik, 2005). However, accurate and timely urban data would be difficult to obtain since the long-time processing and interpretation of certain [remote sensing](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/remote-sensing) images (Li and Li, 2019). Nighttime stable light data (NSL) could be another selection from much research. For example, Feng et al.( 2020) has used DMSP/OLS nighttime light data to identify fringe area. By detecting weak near-infrared radiation, It could be a good way to search urban spatial patterns, and human activities and also recognize the ecological environment and other fields(Bennett and Smith, 2017). However, Zhang and Seto(2013) think only using nighttime data might accurately estimate spatial patterns in advanced countries but perform less accurate in developing economies. Considering this, spatial cluster analysis could be an improved method to identification. Comminating the K–means algorithm and nighttime light data, it would be more likely to find more details related to urban fringes when compared with the only indicator of nighttime data identification. Moreover, Peng et al. (2020a) also proposed a three-dimensional approach to integrating different analysis methods including nighttime data and land use data. By applying the cluster model of the Self-Organizing Feature Map (SOFM) urban fringe area of Beijing were accurately identified. Apart from this, many interesting identification methods including wavelet transform method(Jing et al., 2016) and deep learning method (Guo et al., 2019) were tested by scholars worldwide.

**2.3.2 Indicators of socio-economic development**

**2.3.3 Indicators of environmental outcome**

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