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Design Visioning: Interplay of Nature-based Solutions in a Sustainable Design Framework for Future Productive Landscape Community Planning and Design of Wuhan Peri-urban Region

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Abstract

The impact of Wuhan's urbanization leads to degradation of the natural peri-urban landscape where the shift from green and blue areas and farmlands to monocultural gated communities results in water management and food security issues. Sponge City initiatives are promoted to alleviate water quantity and quality challenges in urban environments; however, this approach is absent in peri-urban areas. Furthermore, the lack of a framework to support landscape planning and design to preserve local productive landscape communities in Wuhan peri-urban areas is a gap that urgently needs to be addressed. To overcome the limitations of Sponge City initiatives, this study introduces Nature-based Solutions (NbS) as an umbrella concept to encourage holistic approaches that could inform a new design framework for peri-urban development. The study aims to formulate a sustainable design framework for productive landscape community design in peri-urban regions. The framework categorizes NbS by types and its applications that are interconnected to the food system framework and the utilization of the landscapes. In conclusion, the interplay of NbS in the framework demonstrates the design solutions that apply theoretical insights into landscape design and planning. With the Research Through Design approach, a new construct of innovative future vision for Wuhan's peri-urban development is proposed.

Keywords

Nature-based Solutions; Peri-urban planning and landscape design; Productive landscape community; Sustainable design framework; Research Through Design

1. Introduction

"Wuhan, Different Every Day!" This famous slogan reflects the rapid urbanization of Wuhan, the capital of Hubei Province in the People's Republic of China. From the national goal to promote the rise of central China and the Yangtze River Economic Belt development campaign, Wuhan became an important economic and transportation hub in the middle reaches of the Yangtze River Agglomeration (Wang et al., 2022). With a population of approximately 11 million, the city continues its expansion to support economic growth. The development of the local economy is a focal point and has been promoted in the land use policies of Wuhan urban growth, however; the plan lacks action for ecosystem protection. The expansion of urban land use results in the increasing fragmentation of green areas which produces a reduction in ecosystem service value (Zhou et al., 2014). In the past two decades, several studies showed the impacts of Wuhan's urbanization with respect to the loss of blue and green spaces and productive landscapes to urban development (Wang et al., 2022; Zhou et al., 2014; Li et al., 2018; Wang et al., 2021).

The expansion of urban growth and the increasingly impervious landscape has caused flood and water-logging, not only in Wuhan's urban environments but also in the peri-urban areas. Wuhan's peri-urban areas witnessed a change of land use that transformed green and productive landscapes into urban built areas, with a particular emphasis on gated residential community development (Liu et al., 2023). In addition to water management issues, the reduction of productive landscapes underpinned food security challenges to many urban and peri-urban dwellers who faced the difficulty of fresh food accessibility during the pandemic lockdown in Wuhan (Frias, 2020).

In response to urbanization challenges, China's central government announced the Sponge City Programme (SCP) to cope with water management issues and selected Wuhan as one of the pilot cities. The brief of the National guideline stated that the "sponge city programme would enable urban areas and infrastructure, like parks, streets and buildings, to "act like sponges". The sponge city concept refers to a way of urban management that allows cities to naturally absorb, store, and purify rainwater to resolve water-logging issues, prevent urban flooding, improve water storage and discharge capacity, enhance water quality, and alleviate heat island effects through nature-based and grey solutions" (Peng & Reilly, 2021). Nature-based solutions include both green and natural infrastructure, in contrast to grey solutions. Traditionally, flood management was focused on grey solutions such as pipes, pumps, and concrete dikes. These days, it is recognized that grey solutions provide low sustainability while blue and green infrastructure offer complimentary advantages and cost-effectiveness (Alves et al., 2019). The study of Browder et al. (2019) mentioned the integration of green and grey infrastructure to provide low-cost and more resilient services. For example, grey solutions such as pipes and storm drains can complement green infrastructure such as bioswales and green roofs.

The comprehensive benefits of the SCP are not only enhancing urban water management but also providing social and environmental benefits such as improving biodiversity, air quality, and human health and well-being (Oates, 2020), However, SCP only targets urban area development. The implementation of SCP may not cover projects in peri-urban areas and lack of a framework to support landscape planning and design for specific land use type such as agricultural (productive) landscape is a gap that urgently needs to be addressed. To overcome the limitations of SCP, this study introduces Nature-based Solutions (NbS) as an umbrella concept to broaden and strengthen cost-effective and sustainable alternatives that cover wider perspectives in peri-urban development. In general, urbanization-related research has called for action on integrating ecological frameworks and environmental protection in proactive land use planning and landscape design (Zhou et al., 2014; Li et al., 2018; Wang et al., 2021; Du et al., 2010). The purpose of this research is to aid policy and decision-makers and planners in landscape planning and design for sustainable peri-urban development to balance future urban development while preserving productive lands and green spaces. Thus, the aim of this study is to integrate NbS in a sustainable design framework for productive landscape communities in peri-urban areas. By applying a Research Through Design approach, this new framework explores the visualization of NbS and answers the question what would an NbS-inspired landscape look like in spatial design? Ultimately, comparative spatial analysis is conducted as a preliminary assessment to test the applicability of this new framework in landscape planning and design.

This paper provides novel contributions in landscape planning and design in several areas. First, it addressed a gap in the SCP that does not include consideration of peri-urban areas and has a particular consideration for productive landscape communities in peri-urban development. Second, the study formulates a new design framework which represents a novel linkage of NbS in landscape planning and design to explore sustainable approaches in peri-urban development. Third, from the formation of the new design framework, the study demonstrates how to utilize this framework in landscape planning and design projects as a vision of the new peri-urban development by applying the Research Through Design approach, with a specific focus on Wuhan as a case study. Irvine et al. (2023) emphasized the success of implementing NbS in design for sustainable water management. Apart from providing effective functions, NbS must appear aesthetically pleasing to the communities. Hence, this study provides insight to utilization of the new framework in the design process and illustrates the aesthetic appeal of NbS in landscape design at different scales to enhance community health and well-being through preserved green spaces and local identity of place. This consideration is particularly important in the challenge of urban spread into peri-urban areas. Lastly, in order to apply the new framework to the design, comparative spatial analysis was used to assess the significance and success of utilizing this new framework in landscape planning and design.

The structure of the paper is organized as follows; Section 2 describes the research methodology which consists of mixed methods. First, the study reviews the literature and discusses Wuhan's peri-urban challenges, the needs of Nature-based Solutions and productive landscape community planning and design in peri-urban areas. Second, it explains the Research Through Design theoretical framework. Section 3 presents the results of a sustainable design framework for productive landscape communities that integrates Nature-based Solutions. The design visioning is provided to support evidence on how to apply this framework in landscape design projects under the Research Through Design approach. Comparative spatial analysis is conducted as a preliminary assessment to demonstrate the advantages of using the new framework in landscape planning and design. Lastly, the discussion and conclusion regarding the results of the study are presented in section 4. This section also identifies the shortcomings and opportunities related to this study and makes suggestions for future research in the landscape architecture field.

2. Methods

A mixed methods approach was utilized in this study. First, the study undertook a literature review to gain insight on design and NbS theory to support the formulation of the new design framework. The study applies the Research Through Design (RTD) approach and demonstrates how to utilize this new framework in landscape planning and design projects as a vision of the new peri-urban development, with a specific focus on Wuhan as a case study. Comparative spatial analysis was used as a preliminary assessment method to critically examine the potentials and constraints of the new framework utilization.

To set up the new framework an integrative literature review was conducted. The purposes of using an integrative literature review are to provide an overview of the knowledge base by combining perspectives and insights from the topic and to set up preliminary conceptualization for generating a new framework (Snyder, 2019). Key elements of the literature review and how they link to the overall study framework are summarized in Figure 1.

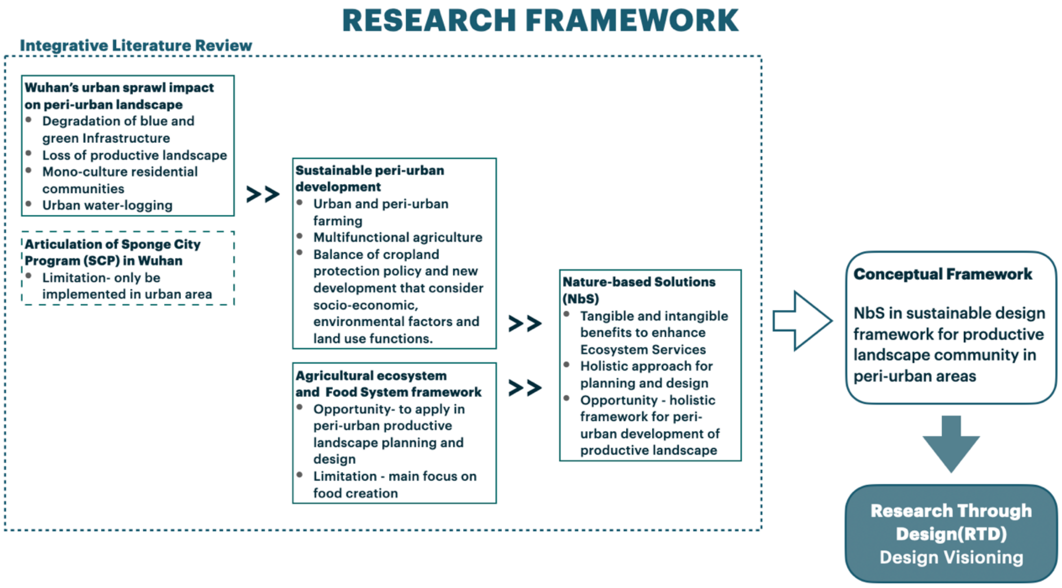

Figure 1. Research framework and study workflow

2.1 Integrative Literature Review

2.1.1. Wuhan Urbanization and Sponge City Programme

Socioeconomic, industrialization, and geography are driving factors in determining urban land expansion. In general, the current trend of urban growth in Wuhan occurs close to roads and the existing urban land and/or in flat plains (Li et al., 2018). Wuhan is located in the central China plain on the Yangtze River. The city is situated in the middle of the long navigable part of the Yangtze River and due to its advantageous location, Wuhan became the mainland transportation hub of the shipping industry and high-speed train (Song, 2023). Between 2010 and 2020, the Wuhan urban area increased by almost 150% from 611.46 sq.km to 1537.69 sq.km. (Wang et al., 2021). Currently, the "Greater Wuhan" new boundary is defined by the fifth ring road which covers an urban area that is 6.3 times greater than the urban area in 1980 (Wang et al., 2022). Ultimately, Wuhan is in China's top 10 largest cities with high-tech, education, and financial centers (Song, 2023).

Wuhan, as the city of a thousand lakes, has faced serious impact from rapid urbanization that has resulted in the loss of water storage areas along with the loss of green areas such as forestland, grassland, and farmland. Between 1995 and 2010, 35.94% of the lake area was lost (Zhaobiao & Mo, 2019). From 2000-2020, wetland areas were reduced from 133.33 sq.km. to 37.28 sq.km. In 1980-2020, 1,188.27 sq.km. of Wuhan farmland disappeared, meanwhile; the built-up areas increased by 823.99 sq.km. (Chen & Huang, 2021). The impact of urban development affects lakes, water bodies and their riparian zones by size reduction, land reclamation, and reducing its vegetation covers which lead to the reduction of ecological functions and degraded water quality (Du et al., 2010).

The loss of green and blue infrastructure together with increasing impervious landscape has caused water-logging and flooding in Wuhan urban areas. The central government announced the Sponge City Programme (SCP) and selected Wuhan as one of the pilot cities (Peng & Reilly, 2021). This program advocates for cities to embrace blue and green infrastructures which utilize natural environments such as water and vegetation, instead of relying on conventional grey and technology-based infrastructure. It is believed that the Sponge City Programme is cheaper than a conventional grey infrastructure approach to increase the city's resilience to flooding by reducing the extra costs of building, operating, and maintaining the city's drainage infrastructure. The further benefits of integrating green infrastructures are enhancement of community health and well-being by providing green public spaces, mitigating the effects of climate change such as urban heat island, and improving air quality (Oates et al., n.d.). Wuhan has demonstrated that adopting the SCP can enhance urban resilience to climate change in a cost-effective and efficient manner (Peng and Reilly, 2020).

However, criticisms of SCP include its inflexibility to consider the uniqueness of each city context and socioeconomic characteristics, the challenge of coordination between key stakeholders, and lack of a holistic approach to bring SCP into regional planning and design practices (Oates et al., 2020). Consequently, China has not yet enacted national law to govern SCP management, in part due to its diverse geographic complexity, with each province facing distinct environmental and socioeconomic considerations. Local governments only use the central guidelines to set up SCP constructions that are suitable for their contexts (Zeng et al., 2023). Moreover, it is common for local governments to prefer investing in transportation infrastructure such as building roads and bridges rather than investing in urban stormwater infrastructure because transportation can help stimulate economic development quickly. To better implement the Sponge City projects, the central government should help the local governments set goals related to funding and targets by consistently launching short- and long-term plans for Sponge City initiatives. In addition, local governments should involve residents in the Sponge City projects to achieve the success of SCP implementation (Zhang, 2022).

The Wuhan Sponge City Programme currently has the goal that 20% of the urban area should achieve Sponge City status by 2020 and reach 80% by 2030, with the ability to absorb 60%-85% of the annual rainfall (Peng & Reilly, 2021). Unfortunately, the Programme considers implementation only in urban areas and not in peri-urban areas.

2.1.2 Sustainable Peri-urban Planning of Productive Landscape Community

Peri-urban is also known as the rural-urban fringe, which Douglas (2006) defined as "The transition zone, where rural activities are juxtaposed with urban activities". Peri-urban is a unique area resulting from the process of scattered and dispersive urban growth that creates hybrid landscapes of fragmented and mixed urban and rural characteristics with dynamic spatial structure and diverse human culture (Ding & Chen, 2022). Su et al. (2014) monitored the dynamic changes of vegetation and identified the increasing fragmentation, irregularity, and diversity, together with decline in total area and connectivity of agricultural areas and forest as cities expand. The result of this urban expansion intensifies the vulnerability of agricultural landscapes (Ding & Chen, 2022). In the past decade, 17.70% (737.84 sq.km.) of Wuhan cropland has been transformed into urban areas (Wang et al., 2021).

The loss of productive landscape negatively impacted food accessibility and food security, in Wuhan, especially during the pandemic lockdown. On a global scale, food security in the 21st century has witnessed challenges derived from climate change, overpopulation, and natural resources degradation (Intergovernmental Panel on Climate Change [IPCC], 2022). To support agricultural sustainability, implementation of green practices such as urban and peri-urban farming have been suggested (Appolloni et al., 2021; O'Sullivan et al., 2019). Urban and peri-urban farming (UPF) is widely acknowledged for the potential to enhance food security and increase the resilience of food supply chains by reducing food miles and promoting local food systems (O'Sullivan et al., 2019). UPF can be categorized by environmental type, functionality, and purpose. Multifunctional UPF offers a variety of biological and social benefits, including reducing food scarcity in urban areas, promoting community participation and unity, and improving physical and mental health (Kumar & Yadav, 2023). Moreover, the concept of Multifunctional Agriculture has been employed by the Chinese government as a stimulus for rural revitalization strategies which provide rural prosperity, promote tourism, and increase landscape biodiversity, as compared to mono-functional commercial agriculture. With rapid urbanization, rural development campaigns are now concentrated in rural-urban fringe areas in most major Chinese cities (Song et al., 2023). For peri-urban development, we should not only consider the local context of social, economic, cultural, and political factors, but also place greater emphasis on the agricultural ecosystem. Furthermore, the impact of agriculture on land degradation and natural resources depletion should be considered as a step towards improving the ecological basis of agriculture and ecosystem services (Chen et al., 2023).

It is interesting to point out the relationship between protection policy and spatial change in peri-urban development. In China, the government has implemented cropland protection policies to regulate land use management to control urban expansion in peri-urban areas (Feng et al., 2015; Zhong et al.,2018). However, cropland conservation policies can reduce urban land use efficiency and the intensity of human activities as passive infilling expands. A policy that balances cropland preservation and urban development that considers the socioeconomic environment and land use functions to create social connections and enhance the vitality of the place is needed (Lu et al., 2023).

The study and investigation of peri-urban areas play an important role in promoting spatial planning and landscape design towards sustainable development (Wandl & Magoni, 2017). Tan et al. (2023) proposed a landscape-based framework for sustainable peri-urban planning. The landscape dimensions of unifying-the understanding of identity for natural landscape and place characters, morphogenetic-understanding of landscape structural relationships and process transformation, and socialized-valuing of community participation, are proposed as aspects to enhance our understanding of a certain place and its characteristics. By understanding the operation of the landscape and its development outcomes, we can characterize the structure of landscape transformation and consequently formulate a feasible solution towards its sustainability (Tan et al., 2023). Moreover, socioeconomic and environmental factors are important to create sustainable peri-urban planning.

Focusing on the productive landscape, greater attention should be placed on the role of agriculture ecosystems and the local food system. Van Berkum et al. (2018) defined a food system as "...all the processes associated with food production and food utilization: growing, harvesting, packing, processing, transporting, marketing, consuming and disposing of food remains. A food system operates in and is influenced by social, political, cultural, technological, economic and natural environments". The food system is an analytical framework used for understanding the integration of food-related activities within the system in socioeconomic and environmental terms. The food system framework acts as a guide for policy and design decision-making by providing a checklist that addresses the components and relationships of food-related activities and related stakeholders and helps enhance food security (Van Berkum et al., 2018). This paper complements the food system conceptual framework of Van Berkum et al. (2018), see Figure 2. By utilizing this system approach through the lens of planning and design, it can help to identify land use types and landscape programs that support the action and intervention for designing effective productive landscape communities.

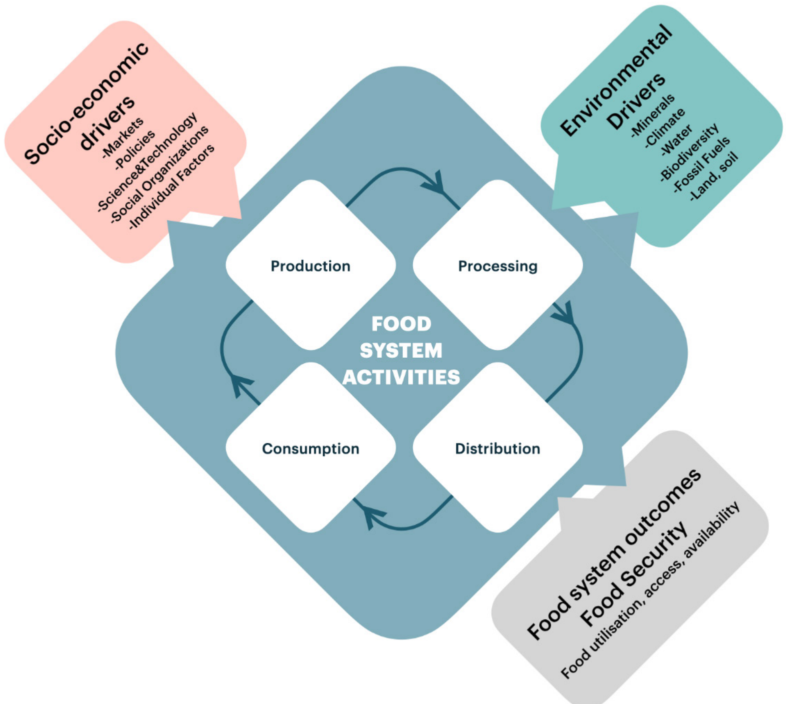

Figure 2. Food System activities adapted from the Food System Diagram of Van Berkum et al. (2018), by author

2.1.3 Nature-based Solutions in Peri-urban Productive Landscape Community Planning and Design.

NbS is considered an umbrella concept that covers a range of different approaches but shares a common focus on enhancing ecosystem services provisioning and aims to address societal challenges such as climate change, food security, or natural disasters (Cohen et al., 2016). The European Commission defined NbS as "solutions inspired and supported by nature, designed to address societal challenges which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience" (European Commission, 2013). NbS involves working with and enhancing nature to help address societal challenges. The concept is grounded in the knowledge that healthy natural and managed ecosystems produce a diverse range of services which support human well-being (Seddon et al., 2020). In comparison to many engineering approaches, researchers have shown that NbS can provide cost-effective solutions while offering multiple benefits to support biodiversity and people. NbS can synergize with grey infrastructure to form 'hybrid' solutions that strengthen the performance of nature (Seddon et al., 2020; Adelphi, 2021; World Bank Group, 2019).

Several approaches have evolved to help manage urban water, including LID (Low Impact Development), GI (Green Infrastructure), BGI (Blue-Green Infrastructure), WSUD (Water Sensitive Urban Design), SUDS (Sustainable Drainage System), ABC Waters (Active, Beautiful, Clean Waters), and SPC (Sponge City Programmes). They all share the same goal to reduce stormwater runoff and floods and improve water quality; however, their primary focus is different. For example, China's Sponge City Programme emphasizes stormwater runoff reduction and water quality improvement in urban environments, while BGI/GI approaches emphasize integration of additional benefits to increase biodiversity and recreational spaces (Brears, 2023a). LID, WSUD, SUDS and SCP show greater focus specifically on water management issues in urban development areas. There is a lack of specific approaches to tackle water management issues in peri-urban areas. To plan for sustainable peri-urban development, it is important to broaden the aims of holistic planning and design that address societal challenges, natural resources, and human well-being. This is why NbS should play an important role in driving the success of creating sustainable peri-urban planning and landscape design.

As mentioned by the International Union for Conservation of Nature (IUCN), implementing NbS will enhance Ecosystem Services (ES) that contribute to human well-being (Sarukhan & Whyte, 2005). IUCN (Sarukhan & Whyte, 2005) stated that Ecosystem Services are the benefits people obtain from ecosystems and are classified into four types: provisioning, regulating, cultural, and supporting services. The study of Almenar et al. (2021) explored the link between ES and NbS. For example, woodlands and horticultural gardens support the provisioning and regulating services of climate and nutrient cycling. Natural and constructed wetlands and ponds can be related to regulating and cultural services that promote aesthetic experience and education. Wu (2013) pointed out that ES depends on ecosystem structures and functions which are influenced by biodiversity. Biodiversity increases ecosystem functions and together both determine the flow of goods and services from nature to human societies. Irvine et al. (2024) quantified Ecosystem Services for different housing developments in a Bangkok peri-urban area. The study found housing with the Agrihood design vision, which provided community gardens, orchards, and constructed wetlands, would provide superior Ecosystem Service values related to Carbon sequestration, Urban cooling, Crop production, Habitat quality, Water yield, Water quality, and Aesthetics as compared to conventional monoculture housing development. NbS aredescribed as solutions capable of addressing multiple challenges and providing multiple benefits (Almenar et al., 2021). The benefits that ecosystems provide to humans as ES could be in the form of tangible or intangible benefits. Tangible benefits include food, fibre, fresh water and climate regulation (U.S. Department of Agriculture, 2022). Intangible benefits are provided by cultural services, and generally are more difficult to quantify, but hold importance related to intrinsic value, cultural and aesthetic values, spiritual or religious significance, and the rights and interests of future generations (Bruce, 2023). As stated by the Sarukhan and Whyte (2005), cultural services and values are at the heart of landscape planning and management. A better understanding of cultural services such as cultural heritage, aesthetics, or inspiration can help to shape decisions about sustainable development and optimize social and economic benefits for local communities (Mocior & Kruse, 2016; Blicharska et al., 2017) Implementing NbS in planning and design must consider its performances and suitability to the context but also its aesthetic appeal.

2.2 Research Through Design - Case Study

After formulating the new conceptual framework, the study applied the Research Through Design (RTD) approach to explore the integration of NbS in the sustainable design of a productive landscape community for a peri-urban area of Wuhan. The concept of RTD was comprehensively described by Lanzholzer et. al. (2013) and includes four epistemologies: (Post)positivist, Constructivist, Advocacy/participatory and Pragmatic. In this study, the Constructivist RTD, where the knowledge is shaped through social context, was used to explore and generate the new constructs, including possible forms of landscape and urban environments. In particular, landscape visualization and representations can help communicate the new ideas. Irvine et al. (2023) addressed the concept of NbS ‘guided seeing’ that articulates how NbS can be visioned in landscape planning and design projects. To achieve success. NbS, must appeal aesthetically to the audiences. This study complements the work of Irvine et al. (2023) and builds upon the concept of applying RTD to provide design visioning of NbS in sustainable design of a productive landscape community in peri-urban areas.

2.2.1 Study Area

The location of the study area is shown in Figure 3. The site is located in the Huangpi district of Wuhan, China. Shekou New Village has retained its characteristics of a traditional agricultural community next to the city urban areas. The site is in an important location for the next phase of urbanization which consists of Subway Station Line1 and the 3rd ring road express way. Surrounded by new expansion of the city and new gated residential communities, this site has strong potential to experience the change from agricultural landscape into the new urban development similar to the adjacent areas. The site is surrounded by the river with only one bridge connecting to the city in the south and it remains an agricultural landscape in the center of the island with informal settlements along the river, extending from the Transit Oriented Development (TOD) of the subway station. The local population is mostly farmers and more than 1,200 households are migrant rural residents with low incomes. With unorganized planning, the residential units were built in very dense conditions with no concern for public green spaces. In addition, the residential units are built on low lying land and are situated adjacent to the river, resulting in a greater risk from annual flooding.

With its unique landscape characteristics, the site still possesses a traditional agriculture landscape nearby the city, but we can predict that this site is in transition from peri-urban agricultural farmland to the new expansion of urban development. So, this site represents important potential as a pilot project to promote sustainable planning and landscape design in balancing the growth of the city and preservation of the fagricultural landscape and local communities. In this study, integrating NbS in sustainable planning and landscape design of a productive landscape community in a peri-urban area will help to maintain food security and preserve local identities and aesthetics of the site.

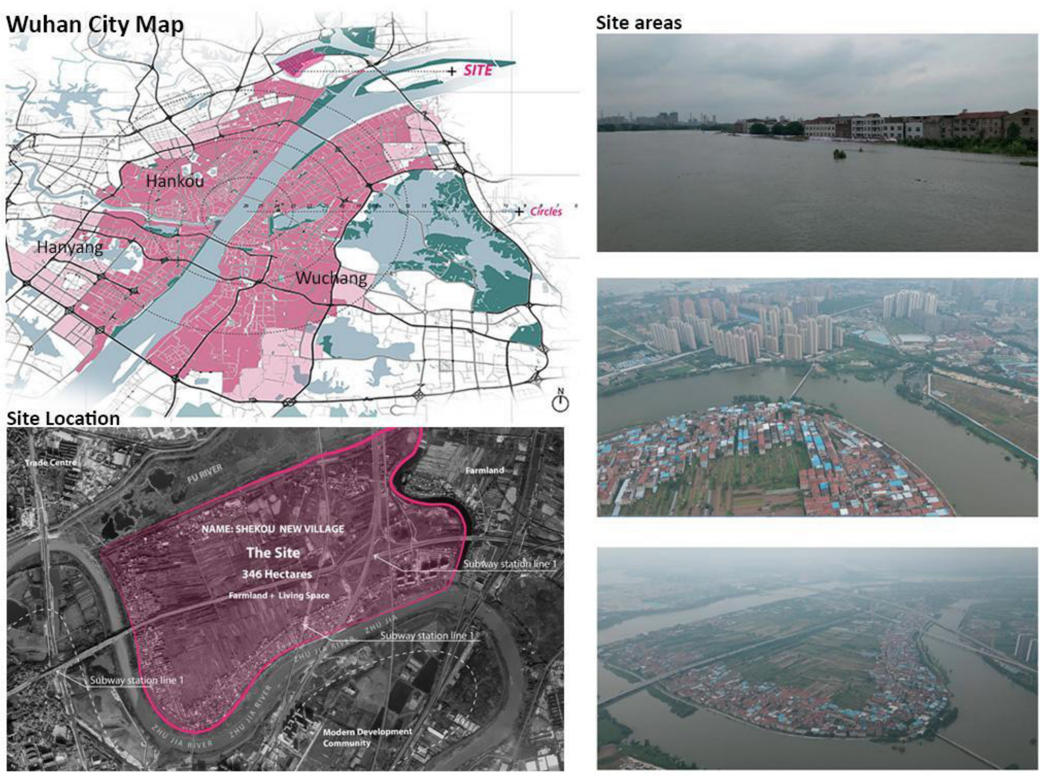

Figure 3. Site location: Shekou New Village, Huangpi district, Wuhan China (Graphic credits to Chenxin Xu, LAN 6108 Define and LAN 6107 Deliver modules of final graduation project, Final Year Project advisor-Sunantana Nuanla-or)

2.2.2 Comparative Spatial Analysis

To assess the utility of the new framework in landscape planning and design, the study conducted a spatial analysis to compare land use change between the existing site and the newly designed site. The existing site analysis used Google Earth Map for the year 2022 as a base map to calculate the spatial changes. The existing study area consists of five types of land use, including cropland, natural green area, building footprint area, industrial area, and transportation infrastructure area. These five land use attributes are used to compare with the land use change under the new NbS design. This comparative spatial analysis applied the AutoCAD version 2024 program as a tool to calculate land use change areas.

3. Results

3.1 Integrating NbS in a Sustainable Design Framework for Productive Landscape Community in Peri-urban Areas

The research framework for this paper is formulated to sustainably integrate NbS within a productive landscape community setting of a peri-urban area, see Figure 4. The framework consists of 3 sections: NbS type, NbS applications, and Food System framework activities. It is aimed to aid practitioners in design and planning to appropriately select NbS types and applications that will be suitable for landscape activities and programs of productive landscape planning and design in peri-urban settings.

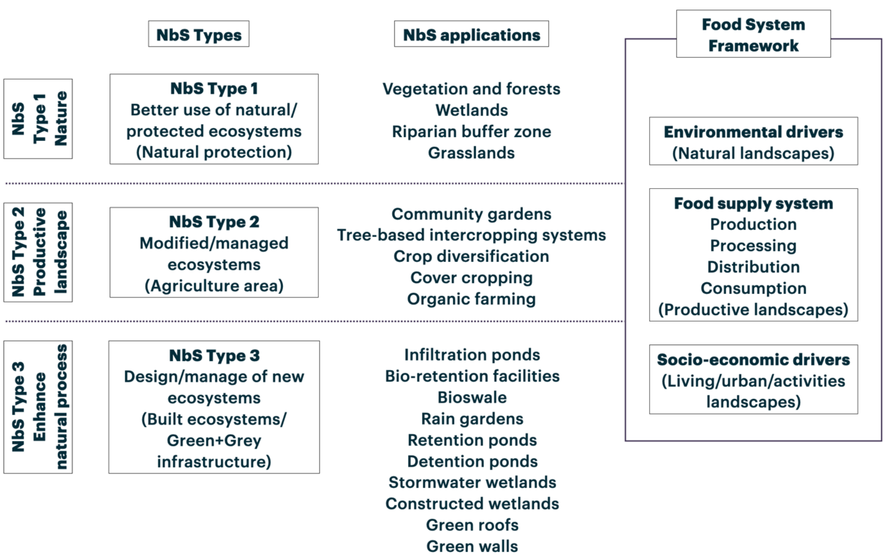

Figure 4. Integrating NbS in a sustainable design framework for productive landscape community in peri-urban areas.

3.1.1 NbS Types and Application in Productive Landscape

NbS has been promoted as a key approach for solving diverse environmental and societal problems. To efficiently use NbS, the understanding of a concept standard is needed. The core features that set standards of NbS were identified by Sowinska-Swierkosz & Garcia (2022) who reviewed several alternative definitions and concluded NbS is an intervention that "(1) is inspired and powered by nature; (2) addresses (societal) challenges or resolves problems; (3) provides multiple services/benefits, including biodiversity gain; and (4) is of high effectiveness and economic efficiency."

In order to integrate NbS into planning, it is essential to understand NbS types and their practical application. NbS typology was proposed by Eggermont et al. (2015) in which three types of NbS were identified: Type 1, better use of natural/ protected ecosystems; Type 2, modified and managed ecosystems; and Type 3, design and manage of new ecosystems. These types are organized based on their contribution to an increased supply of Ecosystem Services (ES) and the level of engineering to be applied to ecosystems to achieve this supply. NbS Type 3 requires the most engineering, while NbS type 1 requires the least. This NbS typology has been widely cited and helped set up a foundation for better understanding the NbS concept (Cohen et al., 2016; Almenar et al., 2021; Anderson & Gough, 2022; UNaLab, 2019.; UNEP-DHI Centre on Water and Environment, 2023).

IUCN suggested five broad categories of NbS, including Ecosystem restoration approaches, Issue-specific ecosystem-related approaches, Infrastructure-related approaches, Ecosystem-based management approaches, and Ecosystem protection approaches (Cohen et al., 2016). This paper will focus on the categories that relate to agricultural landscape which fall under Issue-specific ecosystem-related and infrastructure-related approaches. Anderson and Gough (2022) identified applications of NbS that support 'ecosystem-based adaptation' in Issue-Specific Ecosystem-related approaches including green roofs, community gardens, green walls, and tree-based intercropping systems. Infrastructure-Related approaches describe natural infrastructure and green infrastructure. Examples of 'natural infrastructure' include vegetation and forests, riparian buffer zones, and wetlands. Green infrastructure includes bioswales, engineered wetlands, green roofs, rain gardens, and riparian buffer zones (Anderson & Gough, 2022). Crop diversification, cover cropping, and organic farming are mentioned as examples of sustainable agricultural practices in NbS (Brears, 2023b).

In exploring the applications of NbS Type 3, the majority of the articles mentioned the definition but had a lack of explanation or examples of the applications. This paper conducted a literature search on the practical application of NbS Type 3 and organized categories for comprehensive implementation in planning and design (Table 1). The UNaLab project supported the implementation of NbS by providing a technical handbook factsheet for NbS Type 3, having the greatest amount of ecosystem intervention, which was divided into six categories: 1) Green space, 2) Trees and shrubs,3) Soil conservation and quality management, 4) Green built environment, 5) Natural and semi-natural water storage and 6) Infiltration, filtration and biofiltration structures. Within each category, the types of NbS application are provided with implementation information that is useful for practitioners (UNaLab, 2019). This paper utilizes this categorization approach to organize NbS applications found in the literature search.

Table 1. NbS Type 3 Applications

NbS Type 3 Categories	NbS Type 3 Applications	References
Green space	Residential park, Green corridor, Urban garden	(UNaLab, 2019)
Trees and shrubs	Single line street trees, Boulevards, Group of trees	(UNaLab, 2019)
Soil conservation and quality management	Living fascine, Revetment with cuttings, Planted embankment mat	(Anderson & Gough, 2022; UNaLab, 2019)
Green built environment	Extensive and intensive green roof, Constructed wet roof, Smart roof, Green facades, Free standing living wall, Mobile vertical greening, Moss wall	(Anderson & Gough, 2022; UNaLab, 2019; UNEP-DHI Centre on Water and Environment, 2023)
Natural and semi-natural water storage	Constructed wetland, Retention/detention pond, Daylighting, Underground water storage, Stormwater wetlands, Water harvesting	(Peng & Reilly, 2020; Anderson & Gough, 2022; UNaLab, 2019; UNEP-DHI Centre on Water and Environment, 2023;
Infiltration, filtration and biofiltration structures	Bioswale, Rain garden, Infiltration basin, Permeable paving system, Biofilter, Subsurface constructed wetland, Vegetation buffer zone, Buffer strips	(Peng & Reilly, 2020; Anderson & Gough, 2022; UNaLab, 2019; UNEP-DHI Centre on Water and Environment, 2023; Brears, 2023b)

3.1.2.NbS in Food System Framework

A simplified version of a Food System Framework is adopted from the work of Van Berkum et al. (2018) and demonstrated here with respect to application in landscape and planning practice. This simplified framework emphasizes characteristics of the food system activities that facilitate creation of spaces in landscape planning and design. The framework will be useful to aid the development of programs and activities and determine land use functions in spatial planning. This Food System Framework consists of three parts (Figure 4):

1. Environmental drivers (Natural landscapes)
2. Food system: production, processing, distribution and consumption (Productive landscapes)
3. Socioeconomic drivers (Living/urban/activities-Built environment landscapes)

Environmental drivers refer to natural resources; minerals, climate, water, bio-diversity, fossil fuels and land that provide materials and services to support the Food System (Van Berkum et al., 2018). These physical attributes can be found in the Natural landscapes. Natural landscape of Food System activities such as forest, wetlands, grasslands, riparian zones and natural water bodies are categorized as NbS application in NbS Type 1.

Socioeconomic drivers indicate social and economic factors in the Food System including; market, policy, science and technology, social organization, and individual factors (Van Berkum et al., 2018). These programs and activities can be integrated within different types of land use. In this study, landscape programs and land use activities that provide support for human uses appear in the type of living , urban and activities landscapes. As emphasized through human interventions, the new built environments fall under NbS Type 3 that design and manage new ecosystems. This new ecosystem constitutes NbS applications that enhance natural processes. These applications are demonstrated in Table 1 and Figure 4. Both Environmental and Socioeconomic drivers are interconnected and act as indicators that affect the function of the Food System. As basic ecological elements are different regionally, it is important to promote efficient use of natural resources which can be done through integrating socioeconomic incentives such as policy, science, and technology (Van Berkum et al., 2018).

Food System activities refers to a four-stage cycle; production, processing, distribution, and consumption, which form food creation. From fresh agricultural productions, the food goes through the stages of harvesting and processing, distribution and finally, sales to the consumer. Once the food has reached the consumption stage, ultimately it is composted back to the production (Concernusa, 2021). In considering integrated NbS in an agriculture landscape, it is placed into NbS Type 2, i.e. modified and managed ecosystems. Community gardens, Tree-based intercropping systems, Crop diversification, Cover cropping and Organic farming are examples of NbS Type 2 applications for agricultural landscape planning and design (Anderson & Gough, 2022; Brears,2023b).

Agricultural landscapes support Food System activities, especially in the food production stage. To promote sustainable productive landscape and reduce food miles, this study suggests the design of landscape spaces that facilitates all stages with concern for natural environments and socioeconomic factors of local communities in peri-urban areas. Ultimately, together with the integration of NbS performances, the success of sustainable productive landscape community design will be created.

3.2 RTD - NbS Design Visioning

This study engaged the RTD approach to vision the future design of integrating NbS in landscape planning and design of a peri-urban productive landscape community. The design visioning of this study was presented as part of the final year graduation projects in the Department of Landscape Architecture, BIFCA (Birmingham Institute of Fashion of Creative Arts), Wuhan Textile University, Wuhan, China. The final graduation project consists of two modules of major design courses; LAN6108 Define and LAN 6107 Deliver. The learning outcomes of both modules emphasize the theme of the United Nations (UN) Sustainable Development Goals (SDGs) which allow the students to explore and address global and national societal challenges and vision how landscape and planning design could help in solving those problems and enhance human health and well-being. To promote sustainable design for productive landscape in peri-urban areas, this project connects to SDG Goal 2- No hunger, SDG Goal 3-Good Health and Well-being and SDG Goal 11- Sustainable Cities and Communities (United Nations, 2018)

Prior to the conceptual design stage, the project started with preliminary research and site analysis. In Figure 5, after intensive analyze of the site, integration of NbS types and applications is taken into account in the initial stage of spatial planning to balance preservation, production, and urban development areas. By using the new sustainable framework, NbS in the conceptual masterplan phase identifies the NbS types that are suitable for the site context and proposed land use in each area. It is at this stage that NbS type and application are finalized; NbS Type 1: use of existing ecosystem where natural wetland, forest, riparian zone and flood plain will be preserved to help protect the site during annual floods, NbS Type 2: agricultural landscapes where NbS for productive landscape would be applied and NbS Type 3: new built ecosystems where NbS applications will be selected for suitable new built environment in urban and living areas, with the landscape programs supporting human activities.

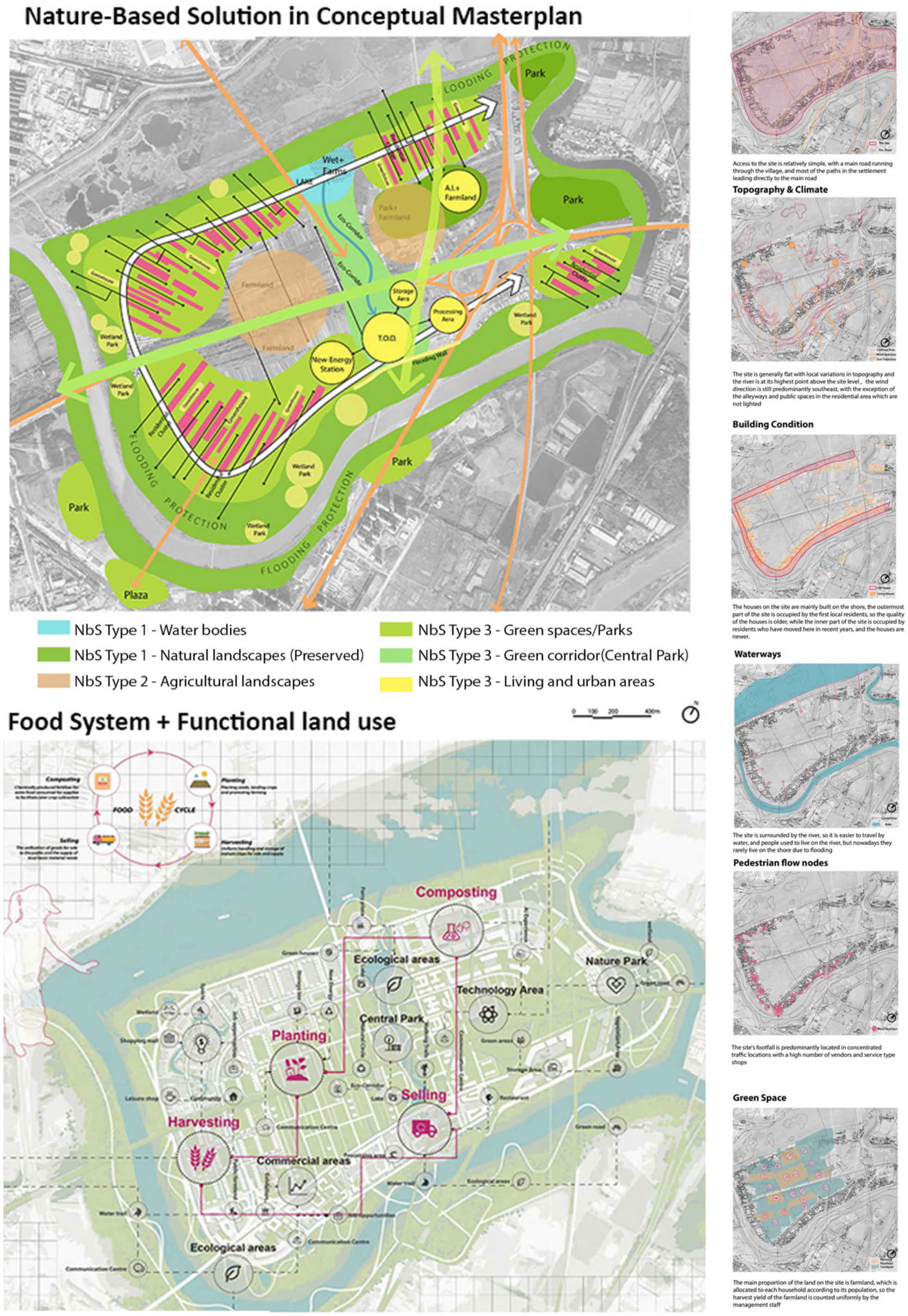

Figure 5. Site analysis and spatial planning using NbS integration framework (Graphic credits to Chenxin Xu, LAN 6108 Define and LAN 6107 Deliver modules of final graduation project, Final Year Project advisor-Sunantana Nuanla-or)

Referring to Figure 4, Food System Framework, Food System activities; production, processing, distribution and consumption are identified with respect to suitable locations to serve the best areas for enhancing food security. The location of existing agricultural landscape remains the same, while the residential units are re-organized with concern for water systems and public green spaces. Production and Harvesting areas are concentrated near farmland and communities. Distribution and selling activities are placed nearby the TOD area (next to the subway station). This will become a trading hub and central commercial area which is situated near the central park and important commercial landmarks. Composting activity is located in the technology areas which also promotes agricultural institutions and educational zones for local residents and government sectors. After several iterative rounds that considered design options for spatial planning, the master plan design was finalized, as shown in Figure 6.

Figure 6. Proposed new master plan for Shekou New Village - sustainable productive landscape community in Wuhan Peri-urban area. (Graphic credits to Chenxin Xu, LAN 6108 Define and LAN 6107 Deliver modules of final graduation project, Final Year Project advisor-Sunantana Nuanla-or)

In Figures 5 and 6, NbS applications are integrated into the planning scale design. Figure 7 shows the detailed design of Central Park, farmland and community garden that are interconnected by the water system. Water is an essential natural resource to support food security. The study integrates NbS to enhance the water system on the site. At the site, local communities face annual flooding during the rainy season, on the other hand they face severe drought in the dry season. To design the NbS for the water system, it is important to consider NbS functions to collect, store, and purify water. For the site water system, water flows from the river and collects in the Central Park. The Central Park acts as retention pond for rain harvesting in the rainy season and water storage during the dry season. From the Central Park, a ditch and dike system will help control erosion and flooding on site. Water connects by agricultural canal networks that will support food production. Bioswale and filter strips to filter urban run-off will be constructed alongside the road system. Each residential unit will share public community gardens to grow food for household consumption. In the community garden, the retention pond provides space for recreation and collects water to support the irrigation. Rain gardens are designed for recreational spaces. Moreover, green roofs will provide additional recreation and productive spaces for the residents.

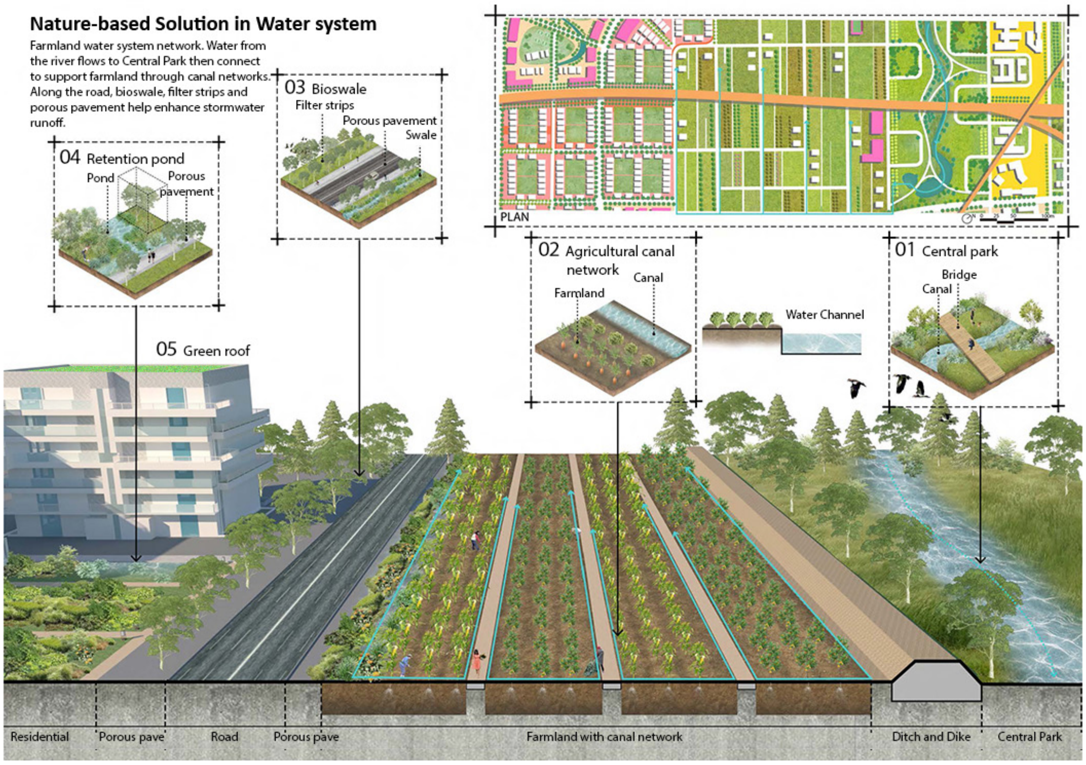

Figure 7. NbS applications in detailed design of the site water system in central park, farmland and community gardens areas. (Graphic credits to Chenxin Xu, LAN 6108 Define and LAN 6107 Deliver modules of final graduation project, Final Year Project advisor-Sunantana Nuanla-or)

In Figure 8, the project shows perspectives of main land use functions that represent sustainable development in landscape planning and design. Community gardens, as a productive landscape, provide public spaces for recreation and shared productive landscape for household consumption. NbS Type 2 will help enhance food security by providing fresh food access all year around. A community market hub, as living/ urban space, offers commercial and social opportunities to sell and buy local products in the adjacent transportation hubs of the subway and bus station. This area will concentrate on urban built environments with integration of NbS Type 3 to enhance the Ecosystem Services. Natural landscapes of waterfront, wetland, and forest park are preserved as NbS Type 1 to prevent annual floods and enrich biodiversity of natural environments. Overall, the vision projects sustainable living of local residents where they cherish natural landscapes, promotes socioeconomic opportunities, and preserves identity of community productive landscapes with the NbS approach. As seen from the visualizations, Constructivist-RTD knowledge claim are presented with authenticity and originality of the new spatial landscape design by integrating NbS concept to the site context. The new physical constructs of NbS in landscape design will aid local communities 'imagination of how NbS will look like and guide the sustainable future development of productive community in per-urban area.

Figure 8. Future vision of Shekou New Village - sustainable productive landscape community in Wuhan Peri-urban area. (Graphic credits to Chenxin Xu, LAN 6108 Define and LAN 6107 Deliver modules of final graduation project, Final Year Project advisor-Sunantana Nuanla-or)

3.3 Comparative Spatial Analysis

The comparative analysis of land use change between the existing site condition and the newly designed site is used as a preliminary assessment to evaluate the success of applying the new sustainable framework in landscape planning and design of productive landscape community in the peri-urban development. Overall, the analysis presents a clear increase of green spaces associated with the proposed new design that is supported by the additional new land use types including; public green spaces, green roof and community gardens (Figure 9; Table 2). In the NbS design site, total green areas include cropland (0.671 sq.km.), green roof (0.514 sq.km.), community garden (0.450 sq.km.), natural green area (0.491 sq.km), and public green spaces (0.680 sq.km.). Total green areas increased from 2.032 sq.km. for the exisiting site to 2.806 sq.km. for the proposed NbS design site, an increase of 38%. Natural green areas are preserved and increased by 18%, from 0.415 sq.km. for the existing site to 0.491 sq.km for the NbS design.

The area of building footprint and industrial land use decreased by 100% with the NbS design, as all new proposed buildings include a green roof to support productive landscape. Industrial areas are relocated out of the site and the land returned to a productive landscape. It is a remarkable achievement of preserving all the cropland areas while balancing the urbanization of peri-urban development. For the NbS design site, cropland is preserved, and there is even a slight increase of cropland at 1.11%, through the combination of NbS Type 2 agricultural landscape, community gardens, and NbS Type 3-green roof.

Figure 9. Existing site and the new NbS design site

Table 2. Area of different land use type (sq.km.), comparing existing site and new NbS design site

Land Use Type	Existing Site	NbS Design Site	Percentage Difference	Remarks
Cropland/Productive landscape	1.617	1.635	Increased 1.11%	Total NbS design productive landscape includes Cropland (0.671), Green roof (0.514) and Community garden (0.450) areas
Natural green area	0.415	0.491	Increased 18%	Vegetation and forests
Building footprint area	1.019	0	Decreased 100%	All new proposed buildings provide Green roof
Industrial area	0.830	0	Decreased 100%	Relocated
Transportation infrastructure	0.216	0.216	Remains	Highway, train
Additional Land Use Type from NbS Design	**Existing Site**	**NbS Design**	**Percentage Difference**	**Remarks**
Public green space	0	0.680	Increased 100%	Parks, gardens, green area
Green roof/Productive landscape	0	0.514	Increased 100%	Green roof on all new proposed buildings
Community garden/ Productive landscape	0	0.450	Increased 100%	

4. Discussion

In response to the growth of urbanization in the peri-urban landscape, this project aimed to integrate NbS in a sustainable design framework for productive landscape community planning and design in peri-urban areas. The purpose of sustainable peri-urban development is to balance future human intervention while preserving productive lands and green spaces. In this study, the new NbS framework was formulated with the Constructivist RTD approach to generate new insights and ideas for constructs of NbS visualization in landscape planning and design, taking Wuhan as a case study. The success of utilizing the new framework was tested and explored to confirm the utility of integrating NbS in landscape planning and design of peri-urban development.

Regarding to implementation of NbS in urban areas, NbS were used in combination with grey solutions under SCP's Sponge infrastructure to enhance urban water management in Wuhan's urban areas. The Wuhan SCP has achieved great success and showcases the ability to manage urban water issues with the potential of NbS to be more cost-effective as compared to conventional grey solution (Peng & Reilly, 2020). In particular, Peng and Reilly (2020) pointed out the key success of the Wuhan SCP included the integration of Sponge projects in comprehensive planning with the collaboration of city departments, the development of local strategies and technical standards suitable to the site context, and promotion of social participation for benefit-sharing. Currently, the success of SCP and NbS are only drawn from an urban water management perspective and there is a lack of both approaches in peri-urban development, especially in productive landscape communities planning. As mentioned, the success of NbS in urban areas has potential to be replicated in peri-urban development through the integration of NbS in landscape planning and design, developing suitable localized strategies and participation of the communities. Hence, this study was inspired by the success of SCP and NbS in urban areas to formulate the NbS framework for the peri-urban area development. The use of the RTD approach that integrated the NbS framework constructed visualizations to support landscape planning and design for productive landscape communities in peri-urban areas. It is hoped this framework can be utilized to aid policy and decision makers and planners to work on sustainable development in other peri-urban areas in China and elsewhere.

An important finding from the results of the comparative spatial analysis was that the combination of NbS type could advance effective planning. For the NbS design site, the combination of NbS Type 2- agricultural landscapes, community gardens and NbS Type 3-green roof helped to achieve the goal of not only preserving, but increasing productive landscape areas while balancing urban growth. Also, careful planning for NbS Type 1 at the early stage of the planning process will help preserve natural areas with potential to expand. With the utilization of the NbS design framework, additional land use for green spaces and communities' social interactions are proposed with public shared open spaces, public green spaces, community gardens, and community green roofs to support health and well-being. These considerations were absent in the existing site plan. In the RTD-case study, this project visualizes NbS in planning design in different scales including overall planning, zoning design, and detailed design of the water management system. This design visioning aims to aid the designers and planners as inspiration to utilize NbS in the design and support of the stakeholder 'imagination' of NbS in the peri-urban development.

5. Conclusion and Future Research

The impact of urbanization has affected our ecosystem functions and interrupted its Ecosystem Services. The consequences are found in the degradation of our environment which leads to societal challenges such as climate change, food security, and water management, especially in urban areas. Population is growing with attendant growth in resource demand, while concurrently we face a finite supply of natural resources. This situation has urged us to plan for our sustainable future. While the increase of interventions places greater attention on urban development, peri-urban areas -transition zones between rural and urban areas- have witnessed the impact of urban sprawl in which sooner or later they could become part of urban fabric, thereby losing identity and negatively impacting the ability to deliver Ecosystem Services.

This research takes Wuhan as a case study. Wuhan is one of the fast-growing cities in central China. From the theoretical background, Wuhan's peri-urban areas face the loss of green and productive landscapes to impervious surfaces of new city expansion. As a result, the peri-urban areas face similar problems as urban development, especially with respect to water management issues. Thanks to the Sponge City Programme (SCP), many SCP interventions were implemented in urban areas to mitigate water issues; however, lack of SCP implementation in the peri-urban areas remains an issue. Moreover, several urban expansion studies call for action on effective policy and planning management to balance the growth of the city and preservation of natural and productive landscapes (Zhou et al., 2014; Li et al., 2018; Wang et al., 2021; Du et al., 2010). A policy that promotes social connections through socioeconomic, environment, and land use functions is needed but such a policy also must enhance vitality and preserve identity of the places.

This study bridges the gap of peri-urban development by aiming to explore the role of NbS as an umbrella concept for sustainable development of productive landscape community planning and design in peri-urban areas. The study proposes a new NbS framework that integrates the field of planning and landscape design under which NbS types and their practical applications are elucidated to aid policy makers and designers in selecting suitable NbS features for the new land use and planning of productive landscapes in peri-urban areas with consideration of the local food system. The study also demonstrates how to apply this new framework via a Research Through Design approach that includes design visioning of new future sustainable development for the productive landscape community in a Wuhan peri-urban area. The design projects the contribution of NbS in planning and landscape design to promote food security, preserve local identity, and enhance vitality of community health and well-being.

The success of this framework in landscape planning and design is demonstrated by comparative spatial analysis that assesses land use change between the existing site and the proposed NbS design site. The results show the NbS design would increase productive landscape space and natural areas, while balancing the growth of urbanization in a peri-urban area. Furthermore, additional land use types such as public green spaces, green roof, and community gardens are offered for the communities to promote social interactions, health and well-being, and identity of the place. To conclude, the integration of NbS in the new framework for landscape planning and design can help achieve sustainable peri-urban development.

5.1 The Contribution of a New NbS Framework

This study responds to the growth of NbS in the planning and landscape design field. The framework proposes the integration of NbS in the planning and design of a productive landscape community in peri-urban areas. With a holistic approach, the implementation of NbS will provide a healthy ecosystem that optimizes delivery of Ecosystem Services.

To effectively utilize the new NbS framework, this study suggests planners and designers to initiate the integration of NbS at the beginning stage of the design as it paves the way for sustainable development on all scales. The new NbS framework acts as a guide to select proper NbS types and applications that interconnect to land use function of the food system activities and human activities. Thanks to the RTD approach, NbS in the design are visualized from site planning to detailed design features. The visualizations of integrating NbS in the design are presented in Figure 5, which show the process of how to bring NbS in the design to preserve natural green spaces and productive landscape while balancing urban developments at the site planning scale. Figure 6 shows the proposed masterplan with NbS integration and Figure 7 provides detailed design of NbS applications that enhance the function of food systems and water systems for the site. In Figure 8, the future visions provide examples of scenario design; or how NbS might look, which can support policy and decision making in the planning process and aid communities to imagine the future development of their sites.

5.2 Research Limitations and Further Research Plan

We acknowledge the shortcomings of the research which, in particular, was impacted by the pandemic situation. especially in Wuhan. With the travel restrictions, we faced difficulties in visiting the site and opportunities to fully engage with the communities. The study formulated the new NbS framework and visualized NbS in landscape planning and design with RTD approach. However, we faced difficulties to test the success of the framework with community participation. As a result, the spatial analysis method was chosen to provide a preliminary assessment tool, thereby confirming the applicability of the new NbS framework in landscape planning and design. After demonstrating the applicability of the new NbS framework in this study, the new landscape planning and design of this productive landscape community with integration of NbS is convincing. The preliminary assessment of spatial analysis results illustrates the sustainable design in a test peri-urban area that provided an increase of green spaces including; productive landscape, natural areas, and public green open spaces, while balancing the growth of urbanization.

5.3 Recommendation and Future Research

This paper explores NbS applications that link to the type of NbS; NbS Type 1, NbS Type 2, and NbS Type 3. Currently, the applications are provided within each type of NbS. In future research, the cross boundary of NbS or combination between three types should be explored. For example, combine NbS Type 1 with NbS Type 3 to strengthen the performance of ecosystem and natural processes. The verification of NbS cost-efficiency in construction and management is crucial to support decision-making in choosing the types of NbS to match local context and budget. Furthermore, cost comparison is useful between the types of NbS and between the use of grey-infrastructure to help find the most effective approaches for the new development.

There is more room to explore the potential of NbS in the planning and design realms. However, to conduct NbS in the Research Through Design (RTD) approach, it is important to consider the knowledge claims (Lenzholzer, 2013; Deming & Swaffield, 2011). The combination of RTD methods could add to the richness of research such as including the research design for RTD - Pragmatic approach. To generate new knowledge, the Pragmatic approach uses different knowledge claims and value both subjective and objective knowledge (Lenzholzer et al., 2013). Furthermore, Constructivist approaches combined with (Post)positivist methods to test the design with spatial simulation or modeling of societal challenges might be considered. Adding the Advocacy/participatory approach with the Constructivist approach will help in gaining insightful feedback from local community to improve the direction of the design. In the post-pandemic, we plan to generate detailed design of the master plan (Constructivist) and continue our research with the community participation (Advocacy/participatory) and analyze community preferences to support future development of the design and aim for this pilot project to get implemented by the government.

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Author Contributions

Conceptualization, Methodology, Writing-original draft preparation, Writing-review and editing, S.N.; Visualization, S.N.,C.X. All authors have read and agreed to the published version of the manuscript. The authors declare no conflict of interest.

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