Studies on ecosystem service valuation and human-nature interactions in urban areas

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Studies on ecosystem service valuation and human-nature interactions in urban areas

都市における生態系サービス評価及び人間と自然との相互作用の研究

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Doctoral Dissertation

Studies on ecosystem service valuation and human-nature interactions in urban areas

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SUMMARY

Urban ecosystems are the foundation of people's lives and improve their well-being, but their well-designed conservation and management are not easy. It is desirable to manage ecosystems to improve the well-being of residents and realize a sustainable society. However, the benefits that urban ecosystems provide to residents and society are not always traded through the market, making it difficult to recognize their value and sometimes preventing them from resisting development pressures in the market economy. The conservation and management of ecosystems must be considered by public policies, not left to market mechanisms. The valuation of urban ecosystems can provide critical information for making appropriate decisions about the costs and benefits of policies and priorities based on conservation needs, but traditional environmental economic approach has not completely addressed the valuation of urban ecosystems. Pioneered by the Millennium Ecosystem Assessment, an economic valuation effort mainly led by ecologists in 2005, worldwide research projects of international organizations such as IPBES have been working on ecosystem valuation. Still now, however, many challenges and limitations remain, and ecosystem degradation continues. Especially, human-nature relationship has been an important research topic. The reduced interaction of urban residents with nature accelerates the destruction of urban ecosystems. A feedback loop has been identified as a problem, in which the destruction of urban ecosystems reduces opportunities for urban residents to interact with nature, which in turn accelerates the destruction of ecosystems. By accumulating research that focuses not only on the proper valuation of ecosystems, but also on human-nature interactions, it is necessary to consider a framework for conservation management.

Therefore, this dissertation discusses the following four issues.

(1) The extent to which urban ecosystems enhance the well-being of urban residents.

(2) Factors that determine residents' valuation of urban ecosystems.

(3) Heterogeneous preferences of urban residents for ecosystems.

(4) Proposing a new valuation method with psychological factors and policy recommendations.

By exploring these four issues, this dissertation aims to deepen the understanding of urban residents' interactions with nature and to develop urban ecosystem valuation studies.

In the first study (CHAPTER II), the Hanshin region, which is one of megacities in Japan, was used as the study area to analyze what kind of urban ecosystem services increase the life satisfaction of urban residents. The results showed that an increase in the area of urban green spaces increases life satisfaction, and that green spaces in the same area have different impacts on life satisfaction depending on their quality. In addition, the Life Satisfaction Approach (LSA) was used to estimate the monetary value per unit increase in urban green space. While traditional environmental valuation methods are based on utility theory and cannot value the benefits that residents unconsciously receive

from the environment, the LSA was developed with the aim of valuing such benefits. As a result of this study, the monetary value per unit increase in urban green space estimated by the LSA tended to be higher than the value estimated by the traditional environmental valuation method. One of the reasons for the difference in value is considered to be that the traditional valuation method can only estimate the value perceived by the residents, while the LSA can also estimate the value received unconsciously.

In the second study (CHAPTER III), using Singapore as the study area, the factors that determine an individual's willingness to pay (WTP) for environmental policy were analyzed. Two factors in the formation of WTP were given special attention: the frequency of contact with nature in childhood and the sense of "connectedness to nature". As a result, it became clear that the higher the frequency of contact with nature, the stronger the sense of "connectedness to nature", and the stronger the sense, the higher the WTP. The results also showed that those with a stronger sense of "connectedness to nature" placed more importance on "providing recreational and educational opportunities" among the functions of urban green spaces. This finding suggests that those who had more frequent contact with nature in their childhood tend to want the next generation to have frequent contact with nature as well. On the other hand, less frequent contact with nature is also likely to be passed on to the next generation.

The third study (CHAPTER IV) analyzed the effects of less frequent contact with nature on the relationship between residents and urban rivers flowing through the Hanshin region. A decrease in the frequency of contact with nature may lead to the degradation of the natural environment. Therefore, this study compared groups with high and low frequency of contact with nature and analyzed whether there is a difference in the relationship between the level of biodiversity and subjective satisfaction in the neighborhood waterfront. A unique feature of this study is the use of the environmental DNA method to quantitatively approximate the level of biodiversity. The results indicated that urban residents with less frequent contact with nature in their childhood had lower subjective satisfaction with the waterfront as the level of biodiversity increased. If biodiversity enrichment does not improve the subjective satisfaction of urban residents, it will be difficult to implement environmental policies that enrich biodiversity. Policymakers need not only to create urban ecosystems rich in biodiversity, but also to understand exactly what kind of rivers urban residents want and make efforts to reflect their preferences in their policies.

The fourth study (CHAPTER V) extended the first study (CHAPTER II), which analyzed the impact of green spaces on life satisfaction, and focused on residents' subjective perception of the size of green spaces. The results showed that residents' perception of the size of green spaces varies with the quality of the green space, even when the same area of green space is used. Furthermore, LSA based on the two-stage least squares method was used to focus not only on the physical area of green spaces, but also on residents' subjective perception of the extent of green spaces. In the first step, the effect of physical green area on subjective green area was estimated, and in the second step, the effect of subjective green area on life satisfaction was estimated. The results indicate that the impact of physical green space on life satisfaction is estimated to be small when passing through the filter of subjectively perceived green space. This is consistent with the suggestion made in the first and third studies (CHAPTERS II and IV) that urban residents unconsciously benefit from urban ecosystems. Consideration of these subjective measures is essential when designing environmental policies aimed at improving the subjective well-being of residents.

This dissertation has shown that in order to maximize the well-being of residents, it is important to value ecosystems based on well-being rather than only on traditional environmental economic valuations based on utility theory. This is because traditional valuation methods that use residents' utilities for environmental goods sometimes fail to account for environmental values that are not reflected in residents' utilities. In other words, policymakers may be better able to enhance residents' well-being if they are not overly constrained by the utility extrapolated from residents' preferences. On the other hand, this dissertation has also shown that it is important to consider the subjective preferences of residents when designing and managing urban areas with the objective of promoting residents' interactions with nature. The reason for the apparent discrepancy between these proposals is that satisfying preferences does not always maximize residents' well-being, which is less associated with short-term pleasure and has a more long-term and sustainable life perspective.

In particular, there are two factors that lead to discrepancies. One is that residents may not have preferences for conservation policies that maximize their own well-being, for example, if they unconsciously benefit from the ecosystem. Another is that residents' preferences are heterogeneous, so that minority preferences are ignored when policy decisions are made based on majority preferences. In order to address these issues, policy makers should not be too constrained by residents' preferences, but sometimes it is necessary to implement paternalistic policies aimed at maximizing residents' well-being. Future research is needed on how to guide urban residents to make choices that maximize their own well-being, and how to make reasonably paternalistic policies without being overly constrained by residents' preferences. The identification of issues that need to be addressed in the future is an important outcome of this dissertation.

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LIST OF ABBREVIATIONS

2SLS	:	Two-Stage Least-Squared
ABINC	:	Association for Business Innovation in harmony with Nature and Community
CASBEE	:	Comprehensive Assessment System for Built Environment Efficiency
CBA	:	Cost-Benefit Analysis
CBD	:	Convention on Biological Diversity
CE	:	Choice Experiment
CNS	:	Connectedness to Nature Scale
COP	:	Conference of the Parties
COVID-19	:	Coronavirus Disease 2019
CVM	:	Contingent Valuation Methods
DID	:	Densely Inhabited District
DNA	:	Deoxyribonucleic acid
ESG	:	Environmental, Social, and Governance
GEP	:	Gross National Ecosystem Productivity
GIS	:	Geographic Information System
GLM	:	Generalized Linear Model
GSIA	:	Global Sustainable Investment Alliance
IIDEV	:	Independently and Identically Distributed Extreme Value
IPBES	:	Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
IVs	:	Instrumental Variables
JHEP	:	Japan Habitat Evaluation and Certification Program
JPY	:	Japanese Yen
K6	:	Kessler 6 scale
LEED	:	Leadership in Energy and Environmental Design
LPI	:	Living Planet Index
LSA	:	Life Satisfaction Approach
MEA	:	Millennium Ecosystem Assessment
MWTP	:	Marginal Willingness to Pay
NCP	:	Nature's Contribution to People
NDVI	:	Normalized Difference Vegetation Index
NEP	:	New Ecological Paradigm
OECD	:	Organisation for Economic Co-operation and Development
PCR	:	Polymerase Chain Reaction

LIST OF ABBREVIATIONS

SBMIAC	:	Statistics Bureau of Ministry of Internal Affairs and Communications
SD	:	Standard Deviation
SEEA-EEA	:	System of Environmental and Economic Accounting Experimental Ecosystem Account
SEGES	:	Social and Environmental Green Evaluation System
SEM	:	Structural Equation Model
SGD	:	Singapore dollars
TEEB	:	The Economics of Ecosystem and Biodiversity
UN	:	United Nations
UNCED	:	United Nations Conference on Environment and Development
USA	:	United States of America
USD	:	United States dollar
WCED	:	World Commission on Environment and Development
WHO	:	World Health Organization
WTP	:	Willingness to Pay
WWF	:	World Wide Fund for Nature
eDNA	:	environmental DNA

LIST OF PUBLICATIONS

CHAPTER II	Aoshima, I., Uchida, K., Ushimaru, A., & Sato, M. (2017). Economic valuation of the urban green spaces using life satisfaction data. *Environmental Science, 30*(4), 238-249. (in Japanese).
CHAPTER III	Sato, M., Aoshima, I., & Chang, Y. (2021). Connectedness to nature and the conservation of the urban ecosystem: Perspectives from the valuation of urban forests. *Forest Policy and Economics, 125*, 102396.
CHAPTER IV	Aoshima, I., Nakao, R., Minamoto, T., Ushimaru, A., & Sato, M. (2023). Heterogeneous preference for biodiversity in Japanese urban blue spaces based on people's nature experiences: Analysis using eDNA and satisfaction data. *City and Environment Interactions, 18*, 100101.
CHAPTER V	Aoshima, I., Uchida, K., Ushimaru, A., & Sato, M. (2018). The influence of subjective perceptions on the valuation of green spaces in Japanese urban areas. *Urban Forestry & Urban Greening, 34*, 166-174.

CHAPTER I

Introduction

1.1. Preface

Since the dawn of humanity, we have drawn various benefits from ecosystems and developed society through their use. As the world's population exploded after the Industrial Revolution, people formed urban areas in search of a more comfortable lifestyle. In general, urban areas are human-oriented places created for people to engage in social and economic activities. In urban areas, not only man-made structures such as roads and buildings, but also natural features such as trees and grasslands are formed according to human preferences and convenience. However, even in man-made urban areas, urban residents derive various benefits from these ecosystems, and their lives are supported by these benefits. Even in urban areas, ecosystems are indispensable to people. However, the explosive growth of urban populations is putting urban areas under intense development pressure. Despite the importance of urban ecosystems, green spaces are shrinking in many cities around the world (Güneralp et al., 2020).

In addition, the decline in urban residents' interactions with nature has contributed to the loss and degradation of urban ecosystems. Pyle (1993) called this decline in human interactions with nature the "extinction of experience" and warned that it is a factor that makes it difficult to properly conserve ecosystems. The extinction of experience is particularly pronounced in urban areas, where urban residents' interactions with nature are rapidly disappearing. The loss of urban experience not only leads to the loss and degradation of urban ecosystems. The proportion of the world's urban population, which was 55% in 2018, is still growing rapidly (UN, 2018), and the impact of urban residents' lives on natural ecosystems outside urban areas is also increasing. If urban residents lose interest in ecosystem conservation, ecosystems around the world will suffer serious damage. Leakey (1996) warned of the loss of biodiversity due to the emergence of humanity, calling it the "sixth extinction," but the urban area's extinction of experience could accelerate the sixth extinction.

Residents of urban areas derive tremendous physical and psychological benefits from ecosystems, and therefore the dilution of their interactions with nature leads to a decline in their well-being. In order to promote urban residents' interactions with nature, it is necessary for the government to take the lead in properly conserving urban ecosystems that are under development pressure. When the government implements a policy, it may involve the injection of public money and restrictions on the rights of some residents. The role of government is to implement environmental policies that enhance the well-being of residents. In recent decades, the various benefits that people derive from ecosystems have been recognized as ecosystem services, and the need to conserve urban ecosystems has been widely acknowledged. However, ecosystem services have not been sufficiently valued in environmental economics and, partly because of this, ecosystems have continued to be degraded. Since MEA (2005) highlighted the importance of ecosystem services, research on the economic valuation of ecosystem services has finally begun to accumulate. As representative examples, international projects such as TEEB (Kumar, 2010) and international organizations such as IPBES (Diaz et al., 2015) have attempted to value ecosystem services. However, convincing valuations remain a challenge. This is mainly because ecosystem services have not only market values, but also non-market values that do not manifest as market values.

The purpose of this dissertation is to deepen our understanding of the interactions between urban residents and nature, to examine appropriate valuation methods for urban areas, and to derive policy implications. Through the four case studies in CHAPTERS II-V, the objectives of this dissertation are achieved. The following four points are discussed in each of the four case studies. CHAPTER II discusses the extent to which urban ecosystems enhance the well-being of residents, which is crucial when dealing with human-nature interactions. The following CHAPTER III discusses which factors determine the valuation of ecosystems by residents. In making environmental policy decisions, it is also important to build consensus among residents, and CHAPTER III provides useful suggestions from this perspective. The following CHAPTER IV discusses the environmental preferences of urban residents. Previous studies have confirmed that some urban residents tend not to favor rich biodiversity (Soga et al., 2016), and a detailed analysis of this aspect is essential for understanding human-nature interactions. CHAPTER V, which presents the final case study, introduces a new valuation methodology that considers psychological factors in order to derive policy suggestions. Each case study provides a new perspective that deepens our understanding of human-nature interactions.

The main study area is the Hanshin region (Kobe, Ashiya, Nishinomiya and Amagasaki cities), which is part of the Kansai metropolitan area in Japan. The Hanshin region is an urban area in close proximity to the rich natural environment of Mt. Rokko (designated as a national park) and the Seto Inland Sea. By targeting the Hanshin region, it is possible to address both peri-urban forests and green spaces scattered throughout urban areas. Furthermore, since there are many urban rivers in the Hanshin region that flow from Mt. Rokko to the Seto Inland Sea, it is also possible to focus on the relationship between these rivers and urban residents. This dissertation takes advantage of the characteristics of the Hanshin region to analyze the impact of peri-urban forests, urban green spaces, and rivers on the well-being of urban residents. This dissertation also includes a case study of Singapore, focusing on the process of promoting environmental awareness. Singapore is a region that has successfully implemented a national greening policy, and its success can be attributed to the high level of environmental awareness among its citizens. By focusing on such a model region, important suggestions for raising environmental awareness are obtained.

The remainder of this dissertation is organized as follows: before introducing the four case studies, a review of previous studies is given in 1.2. After clarifying the purpose of this dissertation and the objectives of the four case studies in 1.3., the four case studies are introduced in CHAPTER II through CHAPTER V. The CHAPTER VI, develops the discussion through all the case studies.

1.2. The Theory and Practice of Economic Valuation of Urban Ecosystem Services: A Literature Review

1.2.1. The Human-Ecosystem Relationships in Urban Areas

1.2.1.1. Practical Definition of Urban Area and the Targeted Areas in this Dissertation

When focusing on urban ecosystems, it is important to clearly define the urban area. However, it is difficult to strictly define urban areas. The definition may vary from country to country. In Japan, a densely inhabited district (DID) is sometimes used as a standard. The DID basically uses townships as the unit of aggregation, and its criteria are a population of at least 5,000 and a population density of at least 4,000 persons/km^2. Based on the DID definition, the percentage of Japan's population living in urban areas was 70.0% in 2021, up 1.6% from 68.4% in 2015 (Statistics Bureau of the Ministry of Internal Affairs and Communications, 2021). However, the results change when Japan's urban population ratio is measured by the standards of other countries. For example, the United States (US) defines an urban area as having a population of 2,500 or more and a population density of 386 persons/km^2 or more (Tsuchiya, 2009). Although the tabulation is based on population statistics as of 2005, the figure would be 92% if the US definition is adopted and 100% if the UK definition is adopted (Tsuchiya, 2009). The level of certification for urban areas in Japan is set high. The United Nations report, 2018 revision of the World Urbanization Prospect, also does not provide an absolute definition of urban areas (UN, 2018). The cultural and geographical context of each region is likely to have an impact on how urban areas are defined. In Japan, for example, the threshold for defining an urban area is likely to be set high due to the country's history of densely populated settlements based on its rice-growing culture before urbanization. While there is no uniformity in the definition of urban areas across countries, most definitions are based on population size or population density.

According to the UN (2018), the world's urban population, which was about 30% in 1950, surpassed the rural population for the first time in history in 2007 and has been growing ever since. The percentage of the world's urban population was 55% in 2018 and is expected to increase to 68% by 2050. The world's urban population, which was 7.7 billion in 2018, is projected to grow by 2.5 billion by 2050, with about 90% of this population growth occurring in Asia and Africa (UN, 2018). Among cities, urban areas with a population of 10 million or more are called megacities (UN, 2004). As of 2018, there were 33 megacities in 20 countries (UN, 2018). China has the most megacities, with a total of six. Japan has two megacities: the Tokyo metropolitan area and the Kansai metropolitan area. The Tokyo metropolitan area is the largest urban area in the world, with a population of 37 million, followed by Delhi, India, with 29 million (UN, 2018). As of 2018, approximately one in eight of the world's population lives in a megacity. By 2030, 43 megacities are expected to be occurred, most of them in developing countries. The UN report "World Population Prospects 2022" (UN, 2022) predicts that the world's population will peak in the 2080s at about 10.4 billion people, and that the world's urban population will continue to grow until then.

According to the Statistics Bureau of the Ministry of Internal Affairs and Communications (SBMIAC) (2022), Japan's total population has been declining steadily from 2008 to 2022. Along with the decline in the total population, the population of the three metropolitan areas (Tokyo, Kansai, and Nagoya) has also declined to varying degrees. For the Tokyo metropolitan area, the population declined from 2021 to 2022, the first decline since statistics began in 1975 (SBMIAC, 2022). While the urban population share is expected to continue to increase in Japan (UN, 2018), a new problem of urban shrinkage is beginning to emerge as the total population is declining at a faster rate than urban population growth (UN, 2018). Urban shrinkage is a problem that many developed countries will have to deal with in the future (UN, 2022), as countries with low fertility rates, such as Japan and South Korea, face similar problems.

The Hanshin region, which is part of the Kansai metropolitan area, is the main study area for this dissertation. This dissertation focuses on the cities of Kobe, Ashiya, Nishinomiya, and Amagasaki as the Hanshin region. The region covers an area of 726 km^2 and has a population of 2.56 million (SBMIAC, 2020). In 1950, there were 1.21 million people living in the region (SBMIAC, 1950), and it has been growing continuously since then, but the growth almost stopped around 2010. The population density in 2020 is 3,531 persons/km^2, but since this population density was measured including forested areas, it would be even higher if the population density were measured for the DID. Population densities in the DID (persons/km^2) are 8,800 for Kobe City, 10,000 for Ashiya City, 11,000 for Nishinomiya City, and 9,100 for Amagasaki City (SBMIAC, 2022). Despite being a densely populated area, the region is characterized by the rich natural environment of Mt. Rokko, which has been designated as a national park. Mt. Rokko is a lush green mountain range that stretches about 30 km from east to west and rises very close to the urban area. By selecting this area as the subject of the study, it is possible to address both peri-urban forests and green spaces scattered within urban areas. In addition, since the Hanshin region is a sloping land between Mt. Rokko and the Seto Inland Sea, water from Mt. Rokko flows to the Seto Inland Sea through rivers.

Of the four case studies presented in this dissertation, three focus on the Hanshin region and one focuses on Singapore. Singapore has an area of 720 km^2, almost the same as the Hanshin region, but its population is 5.69 million in 2020 (Ministry of Foreign Affairs, 2021), more than twice that of the Hanshin region. Between 1987 and 2007, the population increased from 2.7 million to 4.6 million, while the green area increased from 35.7% to 46.5% (National Parks, 2019). This is attributed to the "Garden City" plan initiated in the 1960s, and the country is doing relatively well in terms of conservation and nature management. By focusing on a country that has had some success in environmental conservation in recent decades as a case study, it is possible to analyze what factors have contributed to the success of environmental conservation. To take advantage of this, the second case study in this dissertation is conducted on Singapore.

Since the population density of the Hanshin region DID and Singapore is approximately 8,000-11,000 persons/km^2, this dissertation deals with areas with this level of population density as urban areas. According to population data from Demographia World Urban Areas (2022), more than 250 of the world's urban areas have a population density of more than 8,000 persons/km^2. Most are located in Asia, Africa, and South America, but there are also areas in the Western world. The number of such areas is expected to continue to grow. It is in these extremely densely populated areas that the suggestions of this dissertation will be particularly relevant. For the green area in the DID, 33% for Kobe (Kobe City, 2011), 25% for Ashiya (Ashiya City, 2021), 18% for Nishinomiya (Nishinomiya City, 2020), 23% for Amagasaki (Amagasaki City, 2014). The suggestions of this dissertation could be applied to commercial and industrial areas that are not densely populated but have a green cover of about 20-30%.

1.2.1.2. Practical Definition of Well-Being

The rationale for conserving urban ecosystems is to enhance the well-being of urban residents. However, there is no clear definition of well-being and it is used in a variety of contexts. In general, happiness is often associated with short-term pleasure, whereas well-being has a more long-term and sustainable life perspective. According to Ryan and Deci (2001), it is preferable to use the term well-being rather than happiness when discussing what makes life good for an individual. Famous examples of the use of the term well-being can be found in the Constitution of the World Health Organization (WHO) (1948), where "health" is defined, and in one of the goals of the SDGs (UN, 2015). Both statements are about long-term visions for life, and more specifically, they also take into account the lives of future generations. In this dissertation, the term well-being is used instead of happiness or pleasure, because the focus is on how urban ecosystems can improve the lives of urban residents in the long term.

The case study presented in this dissertation deals with quantified well-being, but it is not easy to objectively quantify an individual's well-being. This is because the criteria for what constitutes a better life differ from person to person. For this reason, subjectively answered well-being items are often used to index well-being (Kahneman and Krueger, 2006; Diener and Ryan, 2009). If 10 is the best life you can imagine and 0 is the worst life you can imagine, where do you feel you are currently between 0 and 10? This question, called the Cantril ladder, is a typical question used to measure subjective well-being. The Cantril ladder is also used to measure well-being in this dissertation.

Traditional economics treated well-being as a utility that can be observed in market behavior. It then defined the subject acting in the market as a rational being who succeeds in maximizing utility at any given time. However, behavioral economics in recent decades has shown that the actual human being is an entity that frequently fails to maximize utility and well-being (Kahneman et al., 1982; Chetty, 2015). Although there are many reasons for this failure, one reason is that people are so focused on short-term pleasure that they lose sight of the long-term well-being of their lives as a whole. Another major cause is the lack of information available to individuals. These problems not only affect individuals, but can lead society as a whole in unfavorable directions that reduce the well-being of each individual (Sunstein and Ullmann-Margalit, 1999). One way to address these problems is to have well-informed experts and elites guide policy in a paternalistic manner (Sunstein and Thaler, 2003).

Uzawa (2005) called social common capital the social equipment that enables people to live a comfortable economic life and maintain a stable and humane society. Social common capital includes natural capital, social infrastructure, and institutional capital, which should be maintained and managed not by the market or bureaucrats, but by a group of experts who are knowledgeable in each area. This is because if left to ordinary people or bureaucrats who do not have sufficient knowledge and information, the foundation of society will collapse and people's well-being will deteriorate. In this dissertation, the key concern is whether urban residents are aware of the quantitative and qualitative levels of urban ecosystems that maximize their own well-being. If urban residents misperceive the level of ecosystems that maximize their own well-being, then it is not enough to manage urban ecosystems according to the intentions of urban residents. Therefore, studies are needed to estimate the value that residents unconsciously receive, which is not valuated through utility theory. How to achieve the optimal level of urban ecosystems will be discussed through case studies.

1.2.1.3. The Establishment of the Concept of Urban Ecosystems

In general, an ecosystem is a system created by a biological community interacting with the abiotic environment, such as the atmosphere and soil. For example, a tropical rainforest ecosystem is a system maintained by biological communities, such as plant and animal populations, in a hot and humid climate zone. On the other hand, urban areas are places of high population size and density, which became the recipients of the population explosion following the Industrial Revolution, and where people have gathered to live a social life. Although urban areas and ecosystems may seem to be two separate concepts, in reality all urban life is connected to ecosystems in material ways, such as food, and in non-material ways, such as the experience of nature. "Natural ecosystems" are found in natural environments that are relatively untouched by humans, while "urban ecosystems" are artificially formed in urban areas.

The increased interest in urban ecosystems is driven by the explosive growth of the urban population and the deterioration of the global environment associated with changes in people's lifestyles. Lifestyles of mass consumption, which are particularly prevalent in urban areas, are directly and indirectly linked to several global environmental problems. Climate change and biodiversity loss are examples. A sense of urgency about these issues was shared worldwide, and the Brundtland Report (UN, 1987) issued by the United Nations World Commission on Environment and Development (WCED) in 1987 stimulated interest in sustainable development. In 1992, the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, adopted the Rio Declaration on Environment and Development (Weiss, 1992). In the same year, at the initiative of the UNCED, many countries ratified the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity, and the Conferences of the Parties (COPs) based on these conventions are still held regularly today.

Whereas the Washington Convention and the Ramsar Convention, which entered into force in 1975, focused on specific actions and specific habitats, the Convention on Biological Diversity emphasizes the comprehensive conservation of the diversity of life on the planet. Behind the establishment of these conventions was the recognition that the loss of biodiversity would be catastrophic if left unaddressed. The loss of biodiversity due to the emergence of humankind is so severe that it has been called "the sixth extinction" (Leakey, 1996). The Living Planet Index (LPI), regularly published by the World Wide Fund for Nature (WWF) as an indicator of the state of biodiversity and calculated on the basis of vertebrate populations, has declined by 69% between 1970 and 2018 (WWF, 2022). In addition, according to IPBES (2019), the current rate of extinction of organisms is several hundred times faster than in the past 10 million years, and approximately 25% of all existing species globally are threatened with extinction.

P. J. Crutzen, the 1995 Nobel laureate in chemistry, stated that the earth is now entering a new geological epoch, the Anthropocene (Crutzen, 2006), and that there is no ecosystem on earth that has not been affected by humans. Understanding the relationship between humans and ecosystems is critical to promoting biodiversity conservation on a global scale. Urban areas are an important arena for understanding the relationship between the two. In recent years, it has become clear that wildlife of conservation importance (e.g., threatened species and local endemics) are more abundant in and around urban areas than previously thought (Luck, 2007; Ives et al., 2016). Urban ecosystems are attracting increasing attention because the conservation of rich urban ecosystems has the potential to make a significant contribution to global biodiversity conservation.

The emergence of the concept of "ecosystem services" at the end of the 20th century also contributed to the establishment of the concept of urban ecosystems. Costanza et al. (1997) defined ecosystem services as "the benefits human population derives, directly or indirectly, from ecosystem functions." The emergence of the concept of ecosystem services provided an opportunity to examine the benefits that ecosystems provide to humans from multiple perspectives. Some ecosystem services are provided indirectly to urban residents, who normally have little direct contact with nature. As more and more studies focus on ecosystem services in urban areas, the concept of urban ecosystems has become widely recognized. This dissertation also focuses on the benefits that urban ecosystems provide to urban residents.

1.2.1.4. Ecosystems Services and Nature's Contribution to People

The concept of Nature's Contributions to People (NCP) is relatively new and first appeared at IPBES at the plenary meeting of the fifth session of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services in 2017 (IPBES, 2017). According to the Global Assessment Report on Biodiversity and Ecosystem Services (IPBES, 2019), the NCP is defined as " Nature's contributions to people (NCP) are all the contributions, both positive and negative, of living nature (i.e. all organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life". The NCP was not proposed as a replacement for the concept of ecosystem services, but as a broad concept that includes ecosystem services.

One difference between ecosystem services and NCP is that NCP can explicitly include negative impacts from ecosystems in their conceptual framework (Díaz et al., 2018). In addition, while ecosystem services is a concept proposed mainly by ecology and economics, NCP has the attitude to consider values that cannot be captured by ecology and economics, such as different traditional and cultural elements in different regions (Pascual et al., 2017). In this sense, the NCP is proposed to overcome the limitations of the conceptual framework of ecosystem services. As IPBES emphasizes the preservation and transmission of traditional knowledge in each region, the NCP, which also focuses on context-dependent values, is highly compatible with the IPBES stance.

However, some criticisms of the NCP can also be found: criticisms such as that the NCP does not go beyond the limits of the ecosystem services concept, both alternatively and complementarily (Braat, 2018; Kenter, 2018), and that the importance of nature in urban areas is not easily remembered (Peterson et al., 2018). There is also criticism that although the NCP was intended to push the boundaries of the ecosystem services concept, it actually inherited an anthropocentric and utilitarian paradigm and rather contributed to perpetuating the conceptual framework of ecosystem services (Muradian and Gómez-Baggethun, 2021). Some researchers believe that these debates on NCP and ecosystem services are meaningful in themselves (Martinez-Harms et al., 2018). Although NCP is a controversial concept, it is a useful concept for examining the human-ecosystem relationship in a context-dependent manner, taking into account different cultural factors in different regions.

This dissertation, however, aims to provide a broadly general analysis and discussion of the human-ecosystem relationship, rather than a context-specific analysis and discussion. This dissertation consists of four case studies, all of which aim to draw general considerations from the results of their analyses. Nevertheless, it is essential to consider the characteristics of the study area of each case study in order to link them to highly general discussions. In this sense, this dissertation also takes into account the different cultural elements of each study area, but not in order to make a region-specific, context-dependent discussion. Therefore, this dissertation uses the term "ecosystem services" throughout, considering that there is little need to use the concept of NCP.

1.2.1.5. Ecosystem Services in Urban Areas

There are two main sources of urban ecosystem services: urban green spaces and urban blue spaces. Urban green spaces can be found in managed areas such as parks, riverbanks, schools, shrines, etc., but they can also be found in abandoned areas that have become desolate and overgrown. Urban blue spaces include rivers, lakes, ponds, seashores, etc. Urban green spaces have been the subject of research as a source of urban ecosystems for a relatively long time, and recently there has been increasing interest in urban blue spaces (Ampatzidis and Kershaw, 2020; Veerkamp et al., 2021). Although some studies have focused on the relationship between these natural environments and human well-being without using the term "ecosystem services," this dissertation intentionally uses the term "ecosystem services" to clarify the subject of the studies.

MEA (2005) classified ecosystem services into four categories: supporting services, provisioning services, regulating services, and cultural services. Supporting services provide the foundation for the other three services, such as soil formation, plant photosynthesis, and nutrient cycling. The three services, excluding supporting services, are described below.

Provisioning Services

The prime example of a provisioning service in an urban area is the food supply provided by urban agriculture. Water supplied by urban areas is an example of a provisioning service, just as water drawn from urban rivers sometimes supports urban agriculture. Urban agriculture takes place not only in typical farms, but also in community farms, rooftop gardens, and other places that increase the food productivity of urban areas. The need for urban agriculture is being reevaluated in terms of food security in an era of global urban population growth, which is causing food shortages in urban areas (Orsini, 2013). It should be noted that urban agriculture provides not only provisioning services, but also regulating services such as mitigating the heat island effect, water quality regulation, flood mitigation, and pollinators, as well as cultural services by providing opportunities for urban residents to engage with the natural environment (Aerts et al., 2016). From this perspective, some studies suggest that urban agriculture is key to creating a sustainable society (Mougeot, 2006; Pearson et al., 2010). Especially in developed countries facing urban shrinkage, it is necessary to find ways to transform vacant land into farms (LaCroix, 2010).

Regulating Services

Regulating services support urban areas in many ways. From mitigating flooding and the heat island effect to regulating air and water quality and even pollinators, regulating services play a very important role in urban areas. The following are recent research trends on typical regulating services in urban areas.

Floods are one of the disasters that have increased in severity around the world in recent years. The risk of flooding is reported to be increasing due to global warming (Schiermeier, 2011). In urban areas, the risk of flooding is particularly high because the heat island effect makes torrential rains more likely and the large area of paved ground makes it difficult for rain to soak into the ground (Jha et al., 2012). Urban ecosystems are expected to reduce the risk of flooding. Barth and Döll (2016) used a geographic information system (GIS) to analyze the relationship between flood hazard maps and urban ecosystems in an urban area in Germany. They found that riparian forests are useful for flood risk reduction in an economic sense. In addition, case studies have been accumulated for flood-prone areas in Bangladesh, Indonesia, and China (Afriyanie, 2020; Abdullah, 2022). In China, the accumulation of research on sponge cities, which aim to increase natural areas in urban areas to enhance stormwater storage and infiltration, is particularly noteworthy (Li et al., 2017; Nguyen et al., 2019).

The heat island phenomenon is another typical urban environmental problem. The main causes of urban heat islands are the accumulation and re-radiation of solar heat by urban structures and the large amount of heat generated by anthropogenic heat sources (Rizwan et al., 2008). Urban ecosystems also serve to mitigate the heat island effect; Bowler et al. (2010a) conducted a meta-analysis of several case studies focusing on heat island mitigation and found that parks with more trees had lower daytime temperatures. Recent meta-analyses have also shown that the cooling effect varies depending on the type and quality of vegetation and the arrangement of green spaces (Aram et al., 2019). Numerous studies have also shown the effectiveness of green roofs and walls (Santamouris, 2014), as well as the effectiveness of urban blue spaces (Gunawardena et al., 2017; Yu et al., 2020).

Water quality in urban blue spaces is often degraded compared to water quality in rural environments. The main causes of water quality degradation include pollution from domestic and industrial wastewater (McGrane, 2016), the influx of surface pollutants from rainfall (Herngren et al., 2005), and the effects of agricultural activities (Carey et al., 2012). The degradation of water quality in urban blue spaces has a significant impact on the survival of the organisms that inhabit them (Lawrence et al., 2013). Artificial nutrient resources, often found in domestic and agricultural wastewater, are a perturbing factor for ecosystems and threaten to degrade biodiversity in urban areas (Miserendino et al., 2011). As mentioned above, human activities in urban areas tend to negatively affect urban blue spaces, but urban ecosystems work to clean polluted water quality (Livesley et al., 2016). The richer the vegetation and the higher the biodiversity, the greater the effect on water purification (Oral et al., 2020).

Cultural Services

Among urban ecosystem services, cultural services have received particular attention in recent years. Cultural services are generally defined as intangible, non-material benefits such as spiritual enrichment, recreation, aesthetics, and educational experiences. More recently, the health benefits of engaging with nature have received attention from a preventive medicine perspective (Pröbstl-Haider, 2015). It has been suggested that under the COVID-19 pandemic, people spend more time at home and have fewer opportunities to communicate with others, increasing the importance of urban ecosystems for the physical and mental health of urban residents (Grima et al., 2020; Venter et al., 2020; Jo et al., 2022). The following section outlines research trends by dividing health benefits into four categories: mental health, physical health, social health, and cognitive function.

Numerous studies have shown that exposure to nature in daily life is important for the mental health of modern people living in urban areas full of information, stimulation, and stress (Bratman, 2019; Collins et al., 2020). Ulrich (1984) documented the recovery process of people who had surgery in the same hospital, dividing them into two groups: those who could see green spaces from their windows and those who could not, and found that those who could see green spaces were discharged after a shorter hospital stay. In Auckland, New Zealand, Nutford and colleagues (2013) found that the greater the amount of green space around one's home, the lower the number of anxiety/mood disorder treatments. There is a large amount of research examining the relationship between urban ecosystems and mental health. In recent years, the mechanisms of this relationship have also been elucidated. In analyzing the relationship between nature experiences and brain activity, Bratman et al. (2015) focused on the prefrontal cortex, which has been linked to depression. They found that the brains of people who spent a certain amount of time in a forest showed reduced activity in the prefrontal cortex, compared to the brains of people who spent time in an urban area.

The physical health of urban residents is also closely linked to urban ecosystems. Daily interactions with nature have been shown to reduce the incidence of obesity, hypertension, diabetes, and cardiovascular disease (Lee and Maheswaran, 2011). Shanahan et al. (2016) conducted a study among residents of Brisbane, Australia, and reported that those who visited green spaces for 30 minutes or more per week had a 7% lower incidence of depressive symptoms and a 9% lower incidence of hypertension. Soga et al. (2017) reviewed previous studies focused on the relationship between urban gardening and health and found that gardening was beneficial for mental health, as well as reducing obesity. Gascon et al. (2016) reviewed previous studies focusing on the relationship between urban green spaces and mortality, highlighting that larger green spaces around homes reduce the risk of death from cardiovascular disease. Grima et al. (2020) surveyed more than 400 urban residents of Burlington, Vermont, USA, and found that about 70% of them visited urban green spaces more often than before the COVID-19 pandemic. This suggests that urban green spaces play an important role in mental and physical health, even during a pandemic.

Urban ecosystems contribute not only to physical and mental health, but also to social cohesion. Urban green spaces and parks serve as meeting places for local people, resulting in increased social cohesion in local communities (Peters et al., 2010; Shanahan et al., 2016; Jennings and Bamkole, 2019). Maas et al. (2009) found that Dutch urban residents with smaller green spaces around their homes were more likely to experience loneliness and lack of social support, and concluded that green spaces promote social contact. Some studies have found that urban green spaces reduce crime rates (Kuo and Sullivan, 2001; Weinstein et al., 2015). While urban green spaces themselves have also been shown to evoke fear of crime (Sreetheran and Van Den Bosch, 2014), many studies have confirmed that well-managed urban green spaces reduce crime rates. Troy et al. (2012) analyzed the relationship between crime rates and tree canopy for the city of Baltimore, Maryland, USA, and reported that a 10% increase in tree canopy reduced crime by approximately 12%.

Numerous studies have shown that urban ecosystems also have positive effects on cognitive function (e.g., intellectual abilities such as memory, reasoning, and calculation) (Stevenson et al., 2018; Oswald et al., 2020). According to the Attention Restoration Theory proposed by Kaplan and Kaplan (1989), being in nature helps to relax directed or voluntary attention that is overused in daily life, leading to improved cognitive function. Berman et al. (2012) compared a group that walked in nature with a group that walked in an urban area and found that the group that walked in nature had better short-term memory. Dadvand et al. (2017) conducted a large cohort study in Barcelona, Spain to examine the cognitive development of children and found that the abundance of nature in childhood had a positive effect on cognitive development.

1.2.1.6. Human–Nature Interactions in Urban Areas

As shown in the previous section, urban residents can enjoy ecosystem services through contact with nature around them, and there is a growing body of research emphasizing the importance of contact with nature (Bowler et al., 2010b; Jimenez et al., 2021). At the same time, recent evidence suggests that urban residents' interactions with nature are rapidly disappearing (Miller, 2005; Soga and Gaston, 2016). Pyle (1993) referred to the decline in human interactions with nature as the "extinction of experience," and the extinction of experience is underway in many developed countries. According to Soga and Gaston (2016), interactions with nature are influenced by two main factors: opportunities and orientation. Opportunity refers to places and creatures that are targets for engagement with nature, such as nearby green spaces and wildlife. People who live in areas with more of these opportunities will have more frequent interactions with nature in their daily lives (Soga et al., 2016). However, some people who are fortunate enough to have opportunities rarely interact with nature, while others live in urban areas with fewer opportunities but still interact with nature on a daily basis (Soga et al., 2018a). These differences are largely due to differences in the extent of positive attitudes toward nature (nature orientation) (Soga and Gaston, 2016). In this section, recent research trends in human-nature interactions are outlined.

It has been shown that nature orientation is strongly related to the amount of nature exposure in childhood (Chawla, 2020). A number of studies have shown that those with more nature exposure in childhood have more nature exposure in adulthood (Pensini et al., 2016; Rosa et al., 2018; Wood and Smyth, 2020). In a survey of Canadian university students, Windhorst and Williams (2015) found that students with a strong orientation toward nature were more likely to have grown up in accessible and spacious natural environments and to have grown up in families that valued nature experiences. Numerous studies have found that more nature experiences in childhood tend to lead to more pro-environmental behaviors in adulthood (Sato et al., 2017; Rosa et al., 2018; Whitburn et al., 2020). Guiney and Oberhauser (2009) conducted a survey of conservation volunteers in Minnesota, USA, and reported that their childhood experiences with nature motivated them to volunteer as adults.

Interacting with nature increases knowledge about the environment, and knowledge further increases orientation toward nature (Bögeholz, 2006; Duerden and Witt, 2010). With increased knowledge comes increased awareness of environmental protection (Gifford and Nilsson, 2014). It has also been shown that environmental education for children deepens the environmental knowledge of their parents (Damerell et al., 2013), making environmental education by educational institutions highly important. However, in order to improve society's orientation toward nature, it is necessary to promote awareness among the population. It has also been observed that the more affectionate parents are toward nature, the more likely they are to encourage their children to interact with nature (Soga et al., 2018b). An effective way to promote awareness among adults would be to demonstrate the importance of daily nature experiences, for example, through the Internet and events. Urban green commons have attracted attention as a place to share social-ecological knowledge accumulated within communities (Colding and Barthel, 2013). Through shared management, accumulated knowledge can be shared.

Given that knowledge of the environment is passed down from one generation to the next, there is a risk that the loss of experience will also be passed down from one generation to the next. In recent years, it has been pointed out that there is a risk of falling into a negative feedback loop in which, as the willingness to interact with nature decreases, awareness of the need to preserve the natural environment decreases, urban green spaces decrease, and orientation toward nature diminishes even further (Soga and Gaston, 2016). Soga and Gaston (2018) identify the shifting baseline syndrome as a factor that accelerates this negative feedback loop. This refers to a socio-psychological phenomenon in which newer generations, with less information and experience of the past, perceive the environment in which they grew up as normal. In other words, the new generation, which has no memory of the rich natural environment that surrounded their residential areas, perceives this as normal and does not feel a sense of unease or crisis about the current situation.

In order to break the negative feedback loop, it is important to foster an orientation toward nature through environmental education, but it is also necessary to increase the amount of available urban ecosystems through urban restructuring. In recent years, the amount of vacant land in urban areas has increased and urban shrinkage has been reported in developed countries (Wiechmann and Yahagi, 2016; Haase et al., 2017). Urban residents can benefit in many ways from the conversion of these vacant lands to nature-rich land uses (Nassauer and Raskin, 2014; Németh and Langhorst, 2014; Anderson and Minor, 2017). When vacant lots are converted to urban green spaces that can be used for community and recreational activities, urban residents have more opportunities to interact with nature (McPhearson et al., 2013; Kremer et al., 2013). The conversion of vacant land into natural environments is also receiving attention in terms of improving biodiversity in urban areas (Harrison and Davies, 2002, Muratet et al., 2007). Scattered natural environments in urban areas can improve biodiversity by providing a foothold for small mammals, birds, and insects to move between larger natural ecosystems (Herbst and Herbst, 2006; Angold et al., 2006).

1.2.2. Conservation Policies for Urban Ecosystems

1.2.2.1. The Institutional Aim of Conserving Urban Ecosystems

There are a variety of institutions related to urban green spaces. International organizations such as IPBES make broad agreements such as the percentage of protected areas that a country or region should achieve, but in order for a country or region to actually achieve such goals, a specific institution is needed. Especially in urban areas, the natural environment tends to be under strong development pressure if left to the market. Therefore, in order to preserve green spaces, it is necessary for the government to deliberately manage and create green spaces by establishing institutions. Institutions for conserving urban green spaces include systems that preserve existing green spaces through land-use regulations and systems that require a certain area of green space to be set aside within the premises of buildings. When these institutions are applied to private land, they generally impose restrictions on property rights, such as expropriation and land-use regulations, on green space owners and developers. To compensate for these restrictions, it is necessary to adjust interests through subsidies and tax breaks, which are financed through taxes. Similarly, taxes are used for greening of publicly owned land. As mentioned earlier, urban green spaces are in many cases public goods, so it makes sense for taxpayers to pay for urban greening. Valuing urban green spaces can help determine how much money should be invested in such policies.

Figure 1 shows the relationship between the three stakeholders: urban residents, the government, and landowners. First, urban residents delegate economic value judgments related to urban planning to the government, and after receiving the delegation, the government makes value judgments and designs institutions related to urban planning, and manages green spaces based on these plans. At this time, compensation and subsidies for green spaces are provided to landowners as necessary. The cost of this is covered by the taxes of the urban residents who will benefit from the green spaces. As a result, the benefits and burdens of landowners are ideally balanced, as are the benefits and tax burdens of urban residents. This structure allows for the coordination of economic interests among stakeholders through the intermediary of government.

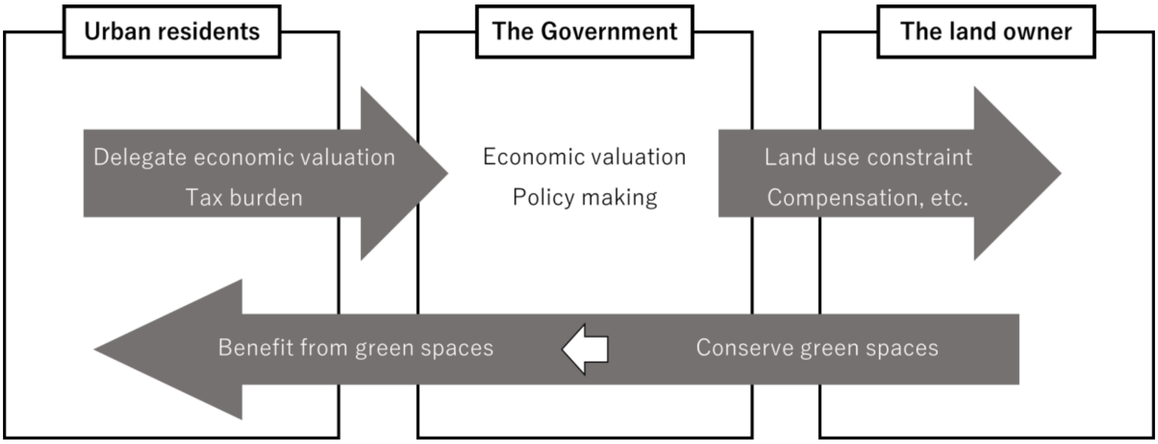

Figure 1: Relationships among stakeholders involved in green space policy.

1.2.2.2. History of Policies for Conserving Urban Green Spaces in Japan

In Japan, green space protection institutions have been established to meet the needs of the times. The following is an overview of the transition of the system in Japan as an example of how the system for conserving green spaces in urban areas was established (as summarized in Table 1). In Japan, the "Old City Planning Act" was enacted in 1919, establishing a common urban planning system for the first time in the country. The Old City Planning Act used concepts such as urban parks and scenic districts (Oshio, 1981). Globally during this period, the establishment of green belts around the perimeter of urban areas to control the expansion of large cities was recommended at the International Conference on Urban Planning held in Amsterdam in 1924 (Akimoto, 2020). Against this backdrop, awareness of the need to consider the urban environment also took root in Japan. In 1933, the then Ministry of the Interior announced standards for urban area planning, stating that in districts meeting certain conditions, at least 3% of the district's area should be set aside as parks (Ishikawa, 2001). This became the legal basis for park development nationwide. However, in the confusion during and after the war, many parks were gradually converted into industrial, commercial, and residential areas. Therefore, the "Urban Parks Act" was enacted in 1956 to unify the management of urban parks. The Urban Parks Act included definitions of urban areas, planning standards, and provisions for government subsidies for the development of urban parks.

In the 1960s and 1970s, the need to control urban expansion and preserve the environment increased in response to rapid urbanization and the resulting environmental problems (Funabiki, 2014).

Under these circumstances, the " Act on the Conservation of Suburban Green Zones" was enacted in the Tokyo and Kansai metropolitan areas after 1966, establishing strong regulations to preserve the natural environment in urban areas, as well as a framework for land expropriation and compensation for losses. The "New City Planning Act" of 1968 also emphasized the importance of preserving the natural environment in urban areas by distinguishing between urbanization zones and urbanization control zones. In 1973, the " Act on the Conservation of Urban Green Zones" was enacted, and strict regulations freezing the status quo for the preservation of the natural environment and a system of land expropriation and compensation for losses were applied nationwide. The "Factory Location Act," revised in 1973, mandated that a certain area of green space be set aside on factory sites, and the "Productive Green Space Act," enacted in 1974, promoted the systematic preservation of agricultural land in urban areas. The "Green Master Plan," institutionalized between 1977 and 1981, became the basis for urban green space planning, and a basic set of greening systems was established based on it.

After the 1980s, the rate of urban sprawl slowed and the demand for high-quality urban environments increased (Funabiki, 2014). In 1985, urban greening promotion plans were institutionalized, with each municipality taking the initiative. These plans described specific goals and implementation measures for urban greening at the municipal level. In 1994, the " Act on the Conservation of Urban Green Zones" was amended to create the "Green Basic Plan". These plans recognized that green areas on construction sites, which are private property, have certain public benefits and are subject to public planning. In 1993, the "Urban Parks Act" was revised, raising the standard for the per capita area of urban parks in municipalities. After 2000, as global environmental problems became more serious and government budgets became tighter, there was a policy shift toward measures to preserve green spaces efficiently with less cost (Funabiki, 2014). With the revision of the City Planning Act in 2000 and the Act on the Conservation of Urban Green Zones in 2001, the emphasis has shifted from preserving green space as public property to preserving green space as private property. Specifically, the system has been revised to efficiently conserve green spaces with less cost, such as reducing the cost of urban land acquisition and strengthening the obligation to conserve green spaces (Funabiki, 2014). Today, there is still a need for more efficient greening policies.

In 2017, the Urban Green Space Conservation Act was revised. This revision of the Act marks the beginning of the recognition of urban agricultural land, which was originally seen as something to be converted into residential land, as something to be conserved. This revision amends the Productive Green Land Law, which provides a reduced tax rate for urban agricultural land with a fixed term, and allows landowners to extend the term repeatedly if they wish. In addition, under the previous Productive Green Land Law, the reduced tax rate could not be applied to urban agricultural land that is not farmed by the landowner, but under the revised law, the reduced tax rate can now be applied to agricultural land for rent. This means that even those who rent out their own agricultural land as an allotment garden can receive a reduced tax rate. This revision of the Act is expected to play an important role in maintaining green spaces in urban areas. In mature Japanese urban areas, such as the Hanshin region, there is a need to focus on the greening of private property, as the greening of public property has reached its limits, and the law encourages the greening of private property. In addition, the conversion of existing urban agricultural land into allotments will help strengthen social ties. Since green spaces are expected to improve well-being by strengthening social ties, these legislative changes will move society in a desirable direction. However, the results of these legal revisions will only become apparent in the coming years, so it will be necessary to monitor the development carefully.

Table 1: History of Policies Related to Green Space and Parks in Japan.

Year	Policy (in Japanese)	Contents
1919	Old City Planning Act (旧都市計画法)	Establish a common urban area planning system for the first time in the country.
1933	Urban Area Planning Standards (都市計画標準)	Stipulating that in districts fulfilling certain conditions, at least 3% of the area of the district must being set aside as parks.
1956	Urban Parks Act (都市公園法)	Including definitions of urban areas, planning standards, and government subsidy provisions for the development of urban parks.
1966	Act on the Conservation of Suburban Green Zones (近郊緑地保全法)	Establishing strong regulations to preserve the natural environment in urban areas, as well as a framework for expropriation of land and compensation for losses.
1968	New City Planning Act (新都市計画法)	Emphasizing the importance of preserving the natural environment in urban areas by distinguishing between urbanization zones and urbanization control zones.
1973	Act on the Conservation of Urban Green Zones (都市緑地保全法)	Appling nationwide strict regulations freezing the status quo for the preservation of the natural environment and a system of expropriation of land and compensation for losses.
1973	Factory Location Act (工場立地法)	Mandating that a certain area of green space be set aside on factory sites.
1974	Productive Green Space Act (生産緑地法)	Promoting the systematic preservation of agricultural land in urban areas.
1993	Revison of Urban Parks Act (改正都市公園法)	Raising the standard for the area of urban parks per capita in municipalities.
2001	Revision of Act on the Conservation of Urban Green Zones (改正都市緑地保全法)	Reducing the cost of acquiring urban land and strengthening mandates for green space conservation.
2017	Revision of Urban Green Space Conservation Act (改正都市緑地法)	Allowing landowners to extend the time limits for the temporary reduced rates on urban agricultural land if they wish.

1.2.2.3. Current Conservation Policies and Challenges

As a result of the continuous creation of urban parks since the enactment of the " City Planning Act" in 1919, the total area of urban parks in Japan has increased from 14,388 ha in 1960 to 122,839 ha in 2014 (Ministry of Land, Infrastructure and Transport, 2022). In addition to urban parks, each municipality continues to create and preserve the nature-rich environment based on the "Green Basic

Plan". In light of the "National Spatial Planning Act" formulated by the government in 2015, which explicitly states that the creation of green infrastructure should be promoted, an increasing number of municipalities have included the promotion of green infrastructure in their "Green Basic Plan" (City Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, 2021). Green infrastructure does not aim to conserve ecosystems per se, but rather to integrate ecosystem conservation into existing socioeconomic systems (Pauleit et al., 2017). Expectations for green infrastructure are growing, especially in Japan, where traditional gray infrastructure is expected to become increasingly difficult to maintain as the population declines. It is important to state the promotion of green infrastructure not only in the green basic plan, but also in the transportation plan, water supply and sewerage plan, and disaster prevention plan (Iwasa and Nishida, 2017).

In recent years, there has been a growing recognition that not only governments but also companies have a social responsibility to care for the environment. According to a report by the Global Sustainable Investment Alliance (GSIA), the share of global ESG investments increased by 8% over the four-year period 2016-2020, from 28% to 36% (GSIA, 2020). In Japan, ESG investments have also grown rapidly, from $47.4 billion in 2016 to $287.4 billion in 2020 (GSIA, 2020). Against this trend, a growing number of companies are using third-party environmental certification systems to publicize their environmental performance. One certification system used worldwide is LEED (Leadership in Energy and Environmental Design), which was created in the United States in 1998. LEED is an environmental performance rating system for the built and urban environment, and the number of certifications in Japan has increased from 3 in 2009 to 197 in 2021 (Dodge, 2021). Japan's own certification systems include "CASBEE" (Comprehensive Assessment System for Built Environment Efficiency), developed in 2001 under the initiative of the Ministry of Land, Infrastructure, Transport and Tourism; "SEGES" (Social and Environmental Green Evaluation System), developed in 2005 by the Organization for Landscape and Urban Green Infrastructure; "ABINC certification", developed by the Association for Business Innovation in harmony with Nature and Community; and "JHEP" (Japan Habitat Evaluation and Certification Program), developed by the Ecosystem Conservation Society. All of these are useful in objectively evaluating and certifying the greening and biodiversity conservation that companies voluntarily undertake, and in promoting their achievements. The SEGES and ABINC certifications will also be evaluated for their environmental education and other public awareness activities, and are expected to have the effect of curbing the extinction of experience.

An example of a company's active greening efforts is the Otemachi Forest in Chiyoda Ward, Tokyo, which was completed in 2014. Based on the concept of "regenerating nature along with regenerating the city," the East Japan Railway Company and the government worked together to plant trees in the urban area. After careful consideration of the density and balance of tree species, trees were planted in a plot in Chiba over a period of three years, and then the forest was moved directly to Otemachi (Kitawaki et al., 2015). In addition to providing a place for urban residents to relax, it has become the center of an urban ecosystem network, and many birds have been observed flying in (Uchiike et al., 2014). Although there are examples of high quality green spaces being created in urban areas, there are also examples of attempts to develop high quality green spaces and place buildings in them, which have led to protests from urban residents. Recently, an attempt to develop the Meiji Jingu Gaien in Shinjuku Ward, Tokyo, met with opposition from local residents. In order to reach a consensus among residents, it is important to make information about studies and discussions by experts available to the public. In particular, public disclosure of environmental assessments is essential. Public disclosure of assessments helps residents better evaluate the pros and cons of development and greening policies. Japan is expected to experience a steady decline in tax revenues due to a shrinking population. However, an overemphasis on policies that cost less should not lead to an undervaluation of urban ecosystems. Proper valuation of urban ecosystems is necessary for more effective policies.

1.2.3. Theoretical Foundations and New Approaches for Economic Valuation

1.2.3.1. The Necessity of Environmental Economic Valuation

As mentioned above, urban ecosystems are essential for urban residents to lead affluent lives, but they are not always properly managed and are often neglected. Appropriate management requires not only an understanding of the importance of ecosystems, but also a multifaceted approach to management from the perspectives of economics, sociology, politics, and other disciplines. However, with the development of advanced capitalism, the influence of the market has increased to an extreme degree, and ecosystems that do not have "prices" tend to be ignored or neglected. The purpose of this dissertation is to discuss the appropriate management of urban ecosystems from an economic perspective. This section outlines the need for economic valuation of urban ecosystems.

Market Failure

From the economic perspective, markets create value through the voluntary exchange of goods and services. Markets use prices to exchange the supplies and demands of a society in order to distribute finite goods and services efficiently. As Adam Smith expressed with “the invisible hand,” we can achieve what is best for society as a whole by depending on market systems (Smith, 1776). He pointed out that self-interest is the driving power and competition is the regulator of that power. Combining self-interest and competition, markets work to improve the quality of life of people.

However, markets sometimes fail. Market failure arises when resources do not attain their highest social value. It can be caused by several factors, such as externalities, and public goods (Hanley et al., 2013). Externalities are the major causes of market failure. An externality can arise when the market price or cost of production excludes its social cost or benefit. For example, urban green spaces create numerous externalities. Urban green spaces alleviate the effects of heat islands, reduce noise, increase carbon storage, and improve the mental and physical health of residents. Social benefits would be underestimated and externalities can arise when markets treat these urban green spaces without considering the aforementioned benefits (Boyle and Kiel, 2001; Picazo-Tadeo and Prior, 2009).

The feature as public goods can also promote a market failure (Cornes and Sandler, 1996). A public good is defined by two features: non-excludability and non-rival consumption. Non-excludability is regarded as the situation in which no one can be excluded from its benefits or cost. Non-rival consumption is regarded as the situation whereby one person's consumption of the good does not reduce its availability for anyone else. These two features separate a public good from a private good. An ecosystem is one example of a public good (Costanza et al., 1997). No person can be excluded from the public benefits created by ecosystems. If people derive value from the existence of a species, exclusion is basically impossible, which constitutes non-excludability. If an endangered species is protected, the number of people affected does not reduce the benefits each person obtains, which is non-rivalry. Urban green spaces are also a public good insofar as all visitors can enjoy its availability at the same rate.

Regarding the management of a public good, the important point is whether people pay enough to create the socially optimal level of the public good (Groves and Ledyard, 1977). If people pay enough, public goods can be successfully allocated by the market. On the other hand, if people do not pay enough, the market can fail. The optimal level of public goods is the level that maximizes the net benefits to society. Marginal social benefits reflect how society values each extra unit of the public good. The public good should be provided up to the point that the aggregated marginal social benefits of each person equal the marginal social cost of providing one more unit of the good (Hanley et al., 2013). This criteria is called the Samuelson condition and the optimal level is known as the Lindahl equilibrium.

In actuality, the realization of optimal levels of public goods is not easy because it is hard to allow everyone to contribute enough. Since the driving power of market is people's egoistic self-interests, some people have indicated that markets should not undertake the management of public goods. For example, Uzawa (2005) argued that social common capital, such as the natural environment, social infrastructure and institutional capital, should be treated not by markets but by experts. Certainly, this attitude is one of the strategies for managing public goods. However, in reality, a lot of public goods are managed by market since it is also hard to maintain an optimal level of public goods even for experts. Therefore, it is necessary to consider how to manage public goods in markets properly. To realize the optimal level of public goods, governments or experts need to modify the capitalist model at least to some extent, not depending only on market. This system is called modified capitalism and to modify appropriately, the valuation of public goods is indispensable.

Based on these findings, international initiatives have also emphasized the importance of economic valuation of environmental goods. Originally, along with increasing concern about worldwide environmental issues (e.g. global warming and biodiversity loss), the United Nations Conference on Environment and Development (UNCED) (Weiss, 1992), which is generally called the Earth Summit, was held in Rio de Janeiro in 1992. At this conference, many countries signed some important conventions. One of the representative conventions was the Convention on Biological Diversity (CBD). The countries ratifying CBD have convened every two years and held the Conference of Parties (COP), aiming to develop national strategies for the conservation and sustainable use of biological diversity (Balmford et al., 2005). At the 10th CBD/COP held in Nagoya in 2010, the Nagoya Protocol and the Aichi Targets were adopted. Simultaneously, the synthesis report of The Economics of Ecosystems and Biodiversity (TEEB) which is a global initiative focused on "making nature's values visible" was launched at CBD/COP-10 (Kumar, 2010). TEEB emphasized the importance of assessing the value of ecosystem services from the perspective of economics.

The Aim of Valuing the Environment

In economics, the value of something depends on what we are willing to give up to have it. For example, if people can sacrifice their income to improve the quality of environmental goods, environmental goods are regarded as having some value. According to Hanley et al. (2013), an important point is that a change in environmental quality is being valued, not the total environment. Willingness to pay (WTP) is one of the tools used to measure the benefits people obtain from changes in environmental quality. For instance, taking the case of a hypothetical increase in one unit of green spaces, the WTP is the maximum income that an individual can give up in order to have the increase in one unit of green spaces. Therefore, the environment can have economic value, even if it has no market value or price.

Using not only market prices, but also estimating the economic value of changes in environmental goods is necessary to measure their value appropriately. Adequate estimations of these values are helpful in many contexts. One of the main context is cost-benefit analysis (CBA). CBA developed from welfare economics as a democratic and practical application of a decision-making rule (Cullen, 1994). It could be used to decide between different policy options or projects in terms of their net contribution to social well-being (Layard, 1994). CBA identifies the impacts of a project or policy by valuing these effects on social well-being, and then comparing the positive effects (benefits) with the negative effects (costs). Measuring costs and benefits in monetary terms enables comparison of them. CBA is based on the Kaldor-Hicks compensation test. This test asks, "Could the gainers (those who benefit from a project) compensate the losers, and still be better off?" (Hanley et al., 2013). Since CBA focuses on utility impacts, it is not necessary to restrict attention to market-valued impacts. In other words, if the changes of non-market goods affect people's utility, these impacts are also relevant. CBA has helped the system of modified capitalism function better.

Most ecosystem services are non-market goods. The aforementioned regulating and cultural services provide benefits to people without being traded in the market. If development is undertaken without considering these non-market values of ecosystems, people's utility can be reduced by it. For example, if the development of urban ecosystems results in the loss of flood control functions that were previously provided free of charge, flood control measures may have to be taken by creating artificial reservoirs and other measures, which could increase the financial burden. To avoid such a situation, it is important to conduct economic valuation of ecosystems, including non-market values. In addition, by conducting an economic valuation that includes non-market values, it is possible to convey to people that ecosystem services that are provided for free are in fact important and how much economic loss would result from their loss. Appropriate recognition of the value of ecosystem services can stimulate people's conservation awareness. When budgets for conservation are limited, the economic value of multiple ecosystems can be compared through CBA to prioritize conservation and make more effective conservation policies. It is important to properly value environmental goods such as ecosystems in order to lead to policies that further enhance people's well-being.

International organizations are also making efforts to link the economic valuation of environmental goods to policy, but their efforts are still insufficient. For example, TEEB project and the IPBES (Diaz et al., 2015) have been working on the conservation of ecosystems and biodiversity. However, according to a report published by the CBD Secretariat in 2020, none of the 20 targets set out in the Aichi Targets to be achieved by 2020 to halt biodiversity loss have been fully achieved (SCBD, 2020). To address this problem, it has become urgently necessary to reflect the value of ecosystem services and biodiversity into sustainability indicators related to policy planning and evaluation. Some global frameworks for ecosystem accounting, such as the System of Environmental and Economic Accounting Experimental Ecosystem Account (SEEA-EEA) and the Gross National Ecosystem Productivity (GEP), have already been suggested. SEEA-EEA aims to facilitate the mainstreaming of environmental information in economic development and planning discussions through structuring the framework of ecosystem accounting (Weber, 2014).

1.2.3.2. Methodology for environmental economic valuation

Traditional Valuation Methods based on Utility Theory

To date, numerous methods have been developed to estimate economic values of non-market environmental goods. Most of the methods are based on utility theory, which means they focus on impacts of the environment on utility. These methods, which aim to measure the people's WTP for changes in the natural environment, can be classified into two: stated- and revealed-preference method. Stated-preference methods include contingent valuation methods (CVM) and choice experiments.

These methods have the common feature that they are all based on direct surveys about WTP for hypothetical changes in environmental quality. The representative revealed-preference methods are hedonic pricing and travel cost method. These methods use people's actual behavior in markets of related goods to infer the value people place on environmental goods. A major difference between revealed- and stated-preference methods is that revealed methods use people's actual behavior, rather than their statements.

Although stated- and revealed-preference methods have widely contributed to economic valuation for environmental goods they have not escaped criticism. For example, stated-preference methods ask respondents directly what they would be willing to pay for a change in an environmental good, which is often an unfamiliar situation and gives opportunities for strategic responses (Frey et al., 2010). Therefore, the credibility, validity, and reliability of results based on the CVM are a major controversy in economics (Kahneman and Knetsch, 1992). Regarding revealed-preference methods, the main problem arises from dependence on strict assumptions. For instance, the assumption of hedonic pricing is met only if there is a sufficiently wide variety of houses, if prices adjust rapidly, if households have full information, and if transaction and moving costs are zero (Rosen, 1974; Roback, 1982). These conditions are often violated, and consequently WTP estimates are biased.

Significantly, further problems seem to lie in the fact that both stated- and revealed-preference methods rely on the basic concept of utility. The utility concept assumes that the choices made by individuals provide all the information required to infer people's well-being. Traditional methods stated above underlay this assumption. However, some researchers have indicated that utility prediction of individuals is often mistaken in both hypothetical and real markets, thus methods relying on utility theory are likely to yield biased results (Kahneman and Thaler, 2006; Frey and Stutzer, 2010). Sen (1995) also pointed out that the gap between utility and well-being is too large to ignore when evaluating non-market goods based on utility.

The Life Satisfaction Approach

To avoid the bias that traditional methods cannot escape, the life satisfaction approach (LSA) was established as a new non-market valuation technique (Welsch, 2007; Frey et al., 2010). In this method, individuals are not asked to value the environmental good directly, but to evaluate their general life satisfaction. This is presumed to be a cognitively less demanding task, and there is no reason to expect strategic behavior. Furthermore, the approach does not rely on an equilibrium assumption. Therefore, the LSA avoids some of the difficulties in previous valuation approaches. In this method, the increase (decrease) in income that would be necessary to compensate an individual for a given decrement (increment) in environmental conditions is calculated (Frey et al., 2010). Empirically, the marginal value of environmental goods is calculated in monetary terms by using the substitution rate between the marginal effects of respondents' income and the marginal effects of environmental goods on life satisfaction. This estimated marginal value is used as WTP.

Importantly, the LSA does not rely on utility theory, which postulates that utility represents human well-being, even though traditional valuation methods rely on this theory. In other words, the LSA is considered an essential method because it focuses on people's subjective well-being. In addition, methods relying on utility theory cannot calculate the value of non-market goods unless people consciously notice the influence they receive from them, but LSA can take it into account, even if people do not consciously recognize it. This is one of the major advantages of the LSA (Frey et al., 2010). As a result of these advantages, studies using LSA have increased considerably recently, including, for example, studies on the monetary worth of air quality (Welsch, 2006; Luechinger, 2009; Barrington-Leigh and Behzadnejad, 2017; Mendoza et al., 2019), nuclear power plant externalities (Welsch and Biermann, 2016) , extreme weather events (von Möllendorff and Hirschfeld, 2016) , flood disasters (Luechinger and Raschky, 2009; Fernandez et al., 2019) , and ecosystem diversity (Ambrey and Fleming, 2014a). In these studies, the values of non-market goods, which influence people's well-being directly without going through the market system, have been calculated in monetary terms.

Although the LSA avoids some of the difficulties of previous valuation approaches, it depends on its own preconditions for a successful application. In particular, the validity of measures of subjective well-being are important. The LSA builds on the recent development of subjective well-being research in economics. A common understanding in this field is that subjective well-being can serve as an empirical approximation to individual welfare (Frey et al., 2010). If this interpretation of subjective well-being measures is accepted, the LSA works adequately. However, there is concern that measures of subjective well-being include a lot of noise. Some specific evidence showing the validity of subjective well-being measures are presented here. According to Di Tella and MacCulloch (2006), life satisfaction scores correlate with other variables that can be plausibly claimed to be associated with true individual well-being. Respondents who are satisfied with their lives are likely to satisfy their family members and friends (Sandvik et al. 1993). Those who have high levels of satisfaction tend to be mentally healthy (Stenhangen et al., 2014; Grevenstein and Bluemke, 2015). Those who have low levels of reported life satisfaction are more likely to be diseased (Koivumaa-Honkanen et al. 2000), and suicidal (Koivumaa-Honkanen et al. 2001).

1.3. The Targeted Problems and Objectives of the Study

As mentioned in the previous section, the dilution of human-nature interactions makes proper management of urban ecosystems difficult. The purpose of this dissertation is to discuss appropriate valuation methods for urban ecosystems and to explore better ways to encourage urban residents to interact with nature. The four case studies presented in CHAPTERS II-V were conducted to achieve this purpose.

Multiple environmental valuation methods have been developed to value urban ecosystem services in monetary terms. However, traditional valuation methods are based on utility theory and may not fully consider the well-being of urban residents. Therefore, in CHAPTER II, an economic valuation of urban green spaces is conducted using LSA. Although there have been studies in the past that valued urban green spaces using LSA, they all focused on the physical area of urban green spaces as the target of valuation. However, in order to create opportunities for urban residents to interact with nature, it is important to focus not only on the quantitative increase of green spaces, but also on the qualitative improvement of green spaces. CHAPTER II focuses on the quantity and quality of green spaces, analyzes which ecosystem services increase residents' life satisfaction, and uses LSA to conduct a monetary valuation of them. By taking the Hanshin region as the target area, both the green spaces scattered in the urban area and the peri-urban forests are covered. Understanding the characteristics of ecosystem services that enhance the well-being of residents and estimating their value is useful in designing environmental policies. The use of numerical indicators that measure not only life satisfaction but also mental health is also a unique feature of the study presented in this chapter.

In order to break the negative feedback loop that leads to the dilution of interactions with nature, it is important to increase the opportunities for urban residents to interact with nature through environmental policies, as well as to cultivate their orientation toward nature. Even if there is a good natural environment around one's home, it will not lead to actual contact with nature if there is no orientation toward nature. If they have the orientation, they will want to visit the natural environment, and they will want a good natural environment to exist in their neighborhood. The orientation toward nature emerges as a conservation awareness. From the perspective of environmental economics, this conservation awareness can be measured in monetary terms as WTP. CHAPTER III focuses on the process by which orientation is promoted by analyzing which individuals have a high WTP. CHAPTER III is characterized by the adoption of the concept of "connectedness to nature". This is based on the fact that numerous previous studies have shown a strong link between environmental awareness and connectedness to nature (Dutcher et al., 2007; Barbaro and Pickett, 2016). Connectedness to nature is a respondent's subjective sense of connection to the natural world (Mayer et al., 2009). Previous research has confirmed that contact with nature increases connectedness to nature and that connectedness to nature increases environmental awareness (Mayer et al., 2009). However, none of these studies have examined the relationship between environmental awareness, measured in monetary terms, and connectedness to nature. Therefore, CHAPTER III analyzes the relationship between environmental awareness measured in monetary terms and feeling of connectedness to nature. Another feature of this study is to focus on the influence of the frequency of childhood contact with nature on the relationship. Singapore was chosen as the research site for CHAPTER III. Although Singapore is an extremely densely populated urban area, it is also a country with a strong environmental awareness, as its green cover has increased over the past few decades due to systematic greening.

If it is true that orientation toward nature increases contact with nature, then conversely, without orientation, contact with nature may be lost. Previous research suggests that extinction of experiences is underway in urban areas (Soga and Gaston, 2016). On the other hand, few studies have focused on the impact of reduced contact with nature on urban ecosystems. The negative feedback loop that accelerates the diminishing orientation to nature assumes that the diminishing orientation to nature leads to the degradation of the natural environment. However, few studies have focused on the relationship between orientation toward nature and the degradation of the natural environment. Degradation of the urban natural environment can be categorized as either quantitative or qualitative, and CHAPTER IV focuses on riverine biodiversity as one indicator of the quality of urban ecosystems. Specifically, whether the relationship between the level of biodiversity and subjective satisfaction in nearby nature changes in dependence on the frequency of contact with nature was analyzed. If more contact with nature tends to lead to a desire for a richer natural environment, less contact with nature may lead to a deterioration of the natural environment. CHAPTER IV differs from similar studies in that it uses the recently developed environmental DNA (eDNA) method to identify biodiversity as an objective numerical indicator. CHAPTER IV, like CHAPTER II, takes the Hanshin region as its study area. This area, located between Mt. Rokko and the Seto Inland Sea, is an appropriate place to focus on the relationship between urban residents and rivers.

If rich biodiversity does not improve the satisfaction of urban residents, it is difficult to implement environmental policies to enrich biodiversity. As many previous studies have shown, biodiversity enrichment has many positive effects on people. However, if urban residents do not seek biodiversity enrichment, it may be partly because they do not properly value the benefits they receive from ecosystem services. It is possible that modern urban residents, whose contact with nature has diminished, have a dampened orientation toward nature and no longer desire a rich natural environment in their neighborhoods. The key is to form natural environments that encourage urban residents to interact with nature. In particular, it is necessary to form natural environments that urban residents, whose orientation toward nature has already been dampened, will want to visit.

By focusing not only on objective numerical indicators, such as the number of species and the area of green spaces, but also on subjective indicators, different strategies for improving well-being can be identified. CHAPTER V focuses on residents' subjective perceptions of the extent of green spaces. Specifically, the study analyzes whether residents' perceptions of the same area of green spaces change when the quality of the green spaces changes. Furthermore, the study analyzes whether the impact on urban residents' life satisfaction differs between objectively measured green spaces and subjectively perceived green spaces. CHAPTER V is an extension of CHAPTER II, which deals only with physical green spaces. Analyzing the relationship between subjective indicators and residents' well-being, rather than objective indicators alone, has the potential to lead to environmental policy proposals that are more in line with residents' intentions. In particular, it is important to consider urban residents' subjective perceptions of the natural environment in order to create greener environments in which urban residents, whose orientation toward nature tends to be weakened, will want to connect with nature. In order to break the negative feedback loop, it is essential to study how residents perceive the natural environment. CHAPTER V provides new insights in this regard.

Through the four case studies above, this dissertation explores ways to break the negative feedback loop that leads to the dilution of nature interactions and transform it into a positive feedback loop that strengthens nature interactions. As the feedback loop that enhances interactions with nature progresses, well-being should improve in response. However, it is not easy to strengthen interactions with nature when a negative feedback loop is already underway. Based on the findings of CHAPTERS II-V, the appropriate management of urban ecosystems is discussed in CHAPTER VI.

CHAPTER II[1]

Economic Valuation of Urban Green Spaces using Life Satisfaction Approach

2.1. Introduction

Among ecosystems services, cultural services are particularly important in urban areas (Chan et al., 2012). Cultural services include contribution to spiritual fulfillment, provision of recreational opportunities, and services that serve as the foundation of religion and society. Many of these cultural services can be benefited by contact with nature. It has been pointed out that cultural services have a difficult-to-quantify function of healing the hearts and minds of urban residents, and it is difficult to properly value them using traditional economic methods based on utility theory (Frey and Stutzer, 2010). As described in the CHAPTER I, LSA was proposed as a method that goes beyond the limitations of traditional environmental valuation methods. The discomfort and satisfaction that people unconsciously perceive from environmental goods could not be valued within the framework of traditional utility theory because they do not affect the increase or decrease of utility. On the other hand, LSA can also take into account discomfort and satisfaction, of which the source cannot be identified by the residents. In this respect, LSA differs significantly from traditional valuation methods based on utility theory. Since the benefits of urban green spaces are not always recognized by people, LSA is an appropriate method for valuing urban green areas.

This study analyzes the impact of green spaces on the mental health as well as the life satisfaction of urban residents. At this stage, it cannot be said that there is a fixed method for measuring these indices, but in this study, for the life satisfaction index, the index used in the Better Life Index of the OECD (2013) will be adopted, and for mental health, the K6 index recommended by Kessler et al. (2002) and WHO. The impact of urban green spaces on mental health is analyzed and compared with LSA. In order to focus on the quality of urban green spaces, this study classified urban green areas into four categories: school's, park's, shrine's, and other green spaces, when constructing geographic data with a GIS. Then, an analysis using the LSA and K6 indicators is performed to show that the valuation can differ depending on the type of green spaces.

The remainder of this chapter is organized as follows. Section 2 describes the LSA employed in this study, introducing similar previous studies. Section 3 describes the study area, the data set, and the estimation model. Section 4 presents and discusses the results of the analyses using life satisfaction and the K6 index, respectively. Then, Section 5 discusses and Section 6 summarizes the study.

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[1] This chapter is written based on Aoshima et al. (2017).

2.2. Methods

The LSA applied in this study estimates the value of environmental goods through regression analysis using the life satisfaction obtained from the questionnaire as the dependent variable. By including income as an in independent variable, it is possible to estimate the value of the environmental goods in monetary terms using the substitution rate between the marginal effects of environmental goods and income. In other words, it is possible to calculate the level of income needed to maintain the level of life satisfaction before the environment deteriorated, and conversely, the level of income needed to maintain the level of life satisfaction before the environment improved. For such an analysis, we assume a function of the form (1) and specify and estimate a regression equation. Regarding the equation (1), *LS* is the level of life satisfaction obtained through the questionnaire, *x* is the non-market good to be valued (in this study, green spaces), *y* is income, and *z* is other factors affecting life satisfaction.

$$LS=f(x,y,z) \tag{1}$$

Similar to this study, Ambrey and Fleming (2014a), Tsurumi and Managi (2015), and Tsurumi et al. (2015) can be cited as studies that applied LSA to urban green spaces for valuation. Ambrey and Fleming (2014a) used GIS to calculate the green coverage of urban areas in Australia and determined the marginal value of an increase in green coverage around residential areas. As a result of the analysis, the marginal WTP for a 1% increase in green spaces (143 m^2) is estimated to be $467 per capita per year. The study, however, treated parks, community parks, cemeteries, stadiums, national parks, and nature reserves as green spaces, and thus classified sites without green vegetation as green spaces, which remains an issue. Tsurumi and Managi (2015) conduct an analysis for the Tokyo and Kansai metropolitan area of Japan and present the following two results. First, the higher the green coverage around the residence, the lower the WTP for a marginal increase in green spaces, and second, the marginal WTP is affected by attachment to green spaces, knowledge of green spaces, satisfaction with green spaces, the amount of contact with green spaces, and distance to green spaces. However, one issue that remains in this study is that forests, rice paddies, fields, parks, and shrine forests are treated together as one indicator, without distinguishing between them.

In contrast, Tsurumi et al. (2015) used satellite images to construct green spaces data for Tokyo and extracted vegetation using an index called the Normalized Difference Vegetation Index (NDVI). This method is particularly novel in terms of the construction of green spaces data, as it is described as being capable of identifying individual trees. In addition, green spaces were subdivided into private land, roads, parks and playgrounds, agricultural land, waterfront, educational facilities, cultural facilities, temples and shrines, and churches, and their marginal monetary values were calculated separately. In addition to the LSA using life satisfaction, the study is very advanced in that it calculates the impact of green coverage on the Cantril ladder, dominant emotions (yesterday and in the past week), positive emotions, mental health (GHQ12), and depression (MHI-5), respectively.

However, Tsurumi et al. (2015) evaluated only the central area of Tokyo, and there are no forests or mountain within the areas subject to valuation. However, the Hanshin region, the target area of this study, is a region where urban areas and forests are closely connected. By taking advantage of this regional characteristic, it is possible to separately calculate and compare the impact of forests on urban residents and the impact of urban green spaces on urban residents. In the field of ecology, as clearly stated by MA (2005) and Chan et al. (2012), the functions of forests and those of urban green spaces are considered to be very different, so it is significant to calculate their marginal values separately in LSA and compare them. The main objective of this study is to value forests and urban green spaces by LSA based on the differences in their functions. In addition, the impact of green spaces on mental health is also analyzed separately for forests and urban green spaces to examine the impact of each.

In this study, the residence of the survey respondents was ascertained at the zip code level. Therefore, there is some error in the calculation of the percentage of green cover around the residential area due to the fact that the residential area of the survey respondents is not accurately known. In light of this, it is not necessary to identify individual trees in this study, and it is thought that the construction of green spaces data using aerial photographs of green spaces with multiple trees provides data suitable for the purpose of the study.

2.3. Data and Estimation Model

Geographic Characteristics of the Study Area

As Fig. 1 shows, the study area comprised four cities in Hyogo Prefecture in Japan: Kobe, Ashiya, Nishinomiya, and Amagasaki. This area is highly urbanized and populated, with up to 2.6 million people inhabiting an area of 72,100 ha. It forms part of the Kansai region, which is Japan's second largest metropolitan area. Mt. Rokko, a transverse mountain range that extends over a distance of about 30 km, is located in this area and has been designated as a national park in recognition of its biodiversity rich natural environment. This mountain range is home to more than 100 bird species and 1,700 plant species, including many endangered and endemic species (Museum of Nature and Human Activities, Hyogo, 2001). Mt. Rokko's ecosystem services include the provision of biodiversity, water provision and purification, recreational use, sightseeing, and landscaping opportunities (Kobe City, 2016). Despite its close proximity to the city, a place with such a rich natural and ecological environment is rare in the whole country (Tsuge, 2001). Its selection as the study area enabled a simultaneous focus on the dispersed green spaces within an urban area and an adjacent peri-urban forest.

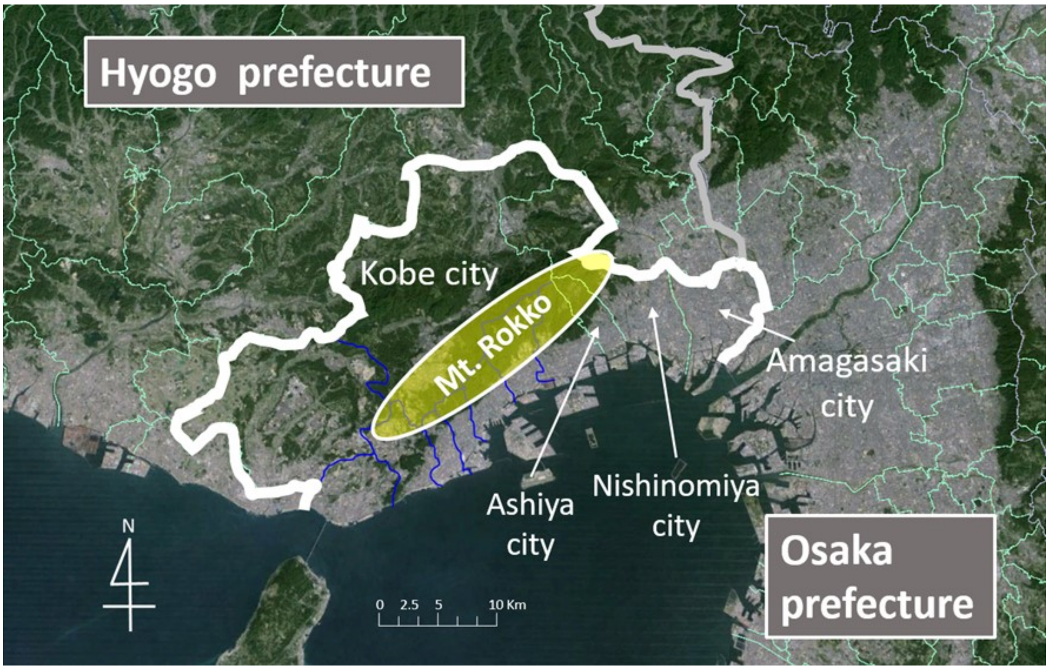

Figure 2: Location of the study area.

Data on Green Spaces

Previous studies measuring forest values in Japan include Marushige and Yasuda (2009), Tsuge (2001), and Urade et al. (1992). Studies that estimated the value of urban green spaces but did not apply LSA include Yoshida et al. (2010), Fujimoto et al. (2006), and Elmqvist et al. (2004). Studies focusing on urban green spaces can be divided into those that focus on specific green spaces and those that treat green spaces scattered throughout the urban area from a broad viewpoint, the latter of which involves difficulties due to the complexity of data construction. In this study, the data was constructed originally by using GIS. The urban green spaces used as an independent variable is the percentage of green spaces in the neighborhoods where the respondents of the social survey live.

The method of constructing data on green coverage is as follows. First, land use patterns are depicted in GIS based on aerial photographs provided by the Geospatial Information Authority of Japan. In this regard, since the aerial photographs used in this study were taken between 1994 and 2007, there is a possibility that the land use patterns at the time the photographs were taken and the current land use patterns have changed. Therefore, after producing a map of land use patterns using aerial photographs, the map was compared with Google map, and the information on points where land use has changed significantly was revised sequentially. The geographic data constructed in GIS is shown in Figure 3. Five types of land use patterns related to green spaces are distinguished: forests, school's green spaces, shrine's green spaces, park's green spaces, and other green spaces. The remaining four types, excluding forests, are used as urban green spaces. Only urban green spaces with a perimeter of 150 m or more are included in the analysis. For example, parks that are parks but do not have clusters of trees are not treated as "park's green spaces. In this study, therefore, only clusters of trees are defined as green spaces, and the effects of clusters of trees on human well-being are analyzed. The definition of each green spaces is summarized in Table 2.

The addresses of the social survey respondents are plotted at the zip code level, the physical center of gravity of each zip code block is determined, a circle with a radius of 1 km is drawn around the point, and the occupancy rate of green spaces within that area is defined as the green coverage rate of each survey respondent. The distance of 1 km is set here because it is a distance that an average adult can walk for about 10 to 15 minutes, and therefore, it can be considered as a walking distance, which is considered to be an appropriate distance as a living area.[2] The average occupancy of urban green spaces in a circle with a radius of 1 km in the entire sample of this study was 2.4%.

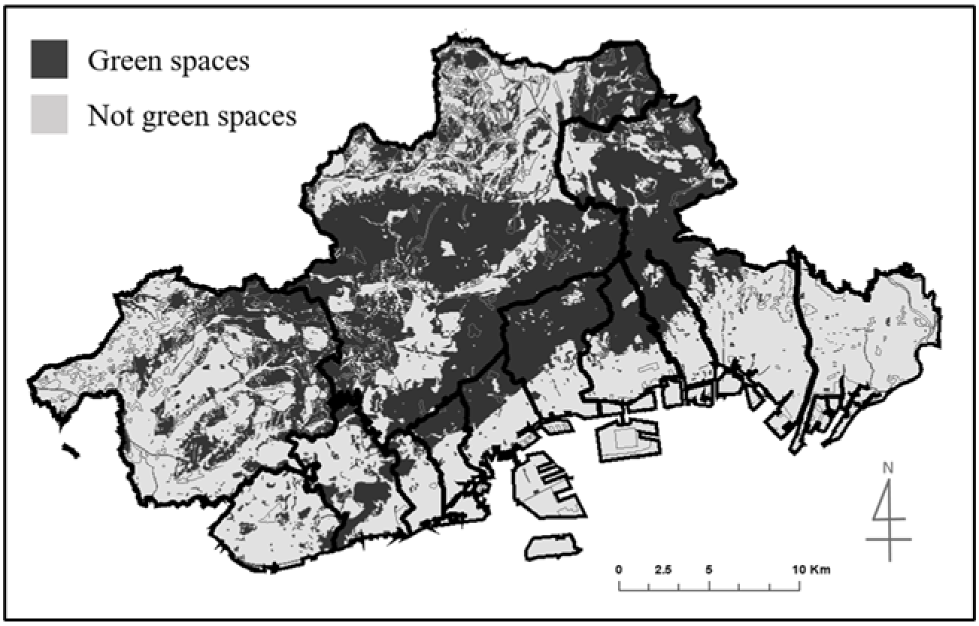

Figure 3: Physical data on green spaces obtained using GIS in the study area.

[2] Tsurumi and Managi (2015) found that green spaces 100m to 500m from the residence significantly increase life satisfaction, while Tsurumi et al. (2015) used the green coverage rate within 1500m from the residence as an independent variable in their analysis. It can be said that the distance setting is still in the exploratory stage.

Table 2: Definitions of green spaces in CHAPTER II.

<table>
<tr><td></td><td colspan="2"></td><td>Definition</td></tr>
<tr><td rowspan="7">Physical size
of green spaces

(calculated using
a circle with an
1km radius
from the centroids
of addresses)</td><td colspan="2">Forest</td><td>Physical size of peri-urban forests located next to a highly urbanized area (ha)</td></tr>
<tr><td colspan="2">Urban green spaces</td><td>Physical size of green spaces scattered in an urban area (ha)</td></tr>
<tr><td rowspan="4"></td><td>School's green spaces</td><td>Physical size of green spaces on the grounds of schools (ha)</td></tr>
<tr><td>Park's green spaces</td><td>Physical size of green spaces on the grounds of maintained parks (ha)</td></tr>
<tr><td>Shrine's green spaces</td><td>Physical size of green spaces on the grounds of shrines or temples (ha)</td></tr>
<tr><td>Other green spaces</td><td>Physical size of green spaces on grounds other than listed above, such as riverside green and derelict green (ha)</td></tr>
</table>

Data on Social Survey

Some of the data used in this study were obtained by conducting an Internet-based social survey. The response period for this survey was six days, from November 27 to December 2, 2014, and the target population was residents of Kobe, Nishinomiya, Ashiya, and Amagasaki cities, aged 20 to 69. The subjects were randomly selected for the survey, paying attention to the demographic population ratio, sex ratio, and age group ratio of each city. The sample size was 1092, of which 930 were valid responses. Table 3 shows the number of responses and their ratios by sex, age, and place of residence for each city block.

Table 3: Demographic statistics for survey respondents.

		Obs.	Ratio (%)
Sex	Male	425	45.7
	Female	505	54.3
Age	20s	118	12.7
	30s	205	22.0
	40s	275	29.6
	50s	213	22.9
	60s	119	12.8
Address	Kobe city	595	64.0
	Ashiya city	46	4.9
	Nishinomiya city	123	13.2
	Amagasaki city	166	17.8

The level of life satisfaction is a subjective rating scale based on the answers to the question, "on the whole, how satisfied do you normally feel?" on an 11-point scale from 0 (extremely unsatisfied) to 10 (extremely satisfied). Other questions on personal attributes include income, sex, age, place of residence, marital status, last level of education, occupation, number of family members, importance of leisure time compared to work, and the amount of leisure time available on weekends and holidays.

In addition, a number of recent literatures have pointed out the positive impact of urban green spaces on the mental health of neighborhood residents. For example, many studies have shown that urban green spaces enhance subjective well-being (Stigsdotter et al., 2010; Stigsdotter and Grahn, 2011; Grahn and Stigsdotter, 2010; Morita et al., 2007; Carrus et al., 2015). Medical and immunological studies have shown that visiting urban green spaces has positive effects on blood pressure, cortisol levels, pulse rate, sympathetic nervous system, etc. (Lee et al., 2011; Park et al., 2010; Gidlow et al., 2016; Li and Sullivan, 2016). In particular, Tyrväinen et al. (2014) and Tsunetsugu et al. (2013) have clearly shown that green spaces have a positive impact on people's mental health even if they spend less time visiting green spaces, and this effect can also be expected for urban green areas.

Based on these previous studies, this study analyzes the impact of green spaces on mental health by including questions measure not only life satisfaction but also the mental health of the respondents to the questionnaire. Although many measures of mental health have been developed since the end of World War II, none of them has proven to be influential. In this context, Kessler et al. (2002) developed the K6 index with the aim of measuring mental health more accurately with fewer questions. This index was developed by statistically scrutinizing previously developed mental health scales, and the questions were narrowed down to the following six items.

・About how often during the past 30 days did you feel nervous?
・During the past 30 days, about how often did you feel hopeless?
・During the past 30 days, about how often did you feel restless or fidgety?
・How often did you feel so depressed that nothing could cheer you up?
・During the past 30 days, about how often did you feel that everything was an effort?
・During the past 30 days, about how often did you feel worthless?

The respondents were asked to answer each of these questions on a 5-point scale, with the higher the total score, the more serious the mental problem. The K6 has been widely used in health surveys in various countries, including the World Mental Health Survey conducted by the WHO. In this study, in addition to the analysis using the LSA, the mental health measured by the K6 was used as the dependent variable, and these analyses were compared and discussed.

The Estimation Model

In order to analyze the collected data, a regression model is specified based on equation (1). In this study, the analysis will be based on the following model, which includes variables related to the green spaces to be focused on, in addition to various factors that affect life satisfaction.

$$Y_i = \alpha + \sum_{k=1}^{n} \beta_k X_{ki} + \varepsilon_i \tag{2}$$

Y is the dependent variable and represents the degree of life satisfaction and mental health of each survey respondent, X_k is the socioeconomic factor or location factor that explains Y. i is the individual being surveyed, ε is the error term, and α and β are the parameters to be estimated by the regression analysis. The X_k to be added to the regression model is summarized in Table 4, including the expected signs, with reference to previous studies. Since the dependent variables in regression equation (2) are ordinal scale variables, the Generalized Linear Model (GLM), which applies the maximum likelihood method, is applied for all estimation. Model selection was performed using the Akaike Information Criterion (AIC) to derive the best estimating equation.

For urban green spaces, four types of green spaces are used as independent variables: "school's green spaces," "shrine's green spaces," "park's green spaces," and "other green spaces." In addition, the total of these four types of green spaces is also included as one variable as "aggregated urban green spaces." Therefore, there are a total of five variables related to urban green spaces, but in order to avoid the problems of multicollinearity and endogeneity, these variables are included in the model separately.

Table 4: Data summary.

Variable		Definition	Sign
Life satisfaction	*LS*	0 (extremely unsatisfied) to 10 (extremely satisfied)	
Mental health	*K6*	0 (low depression level) to 24 (high depression level)	
Income	*Income*	the closest income among 100, 300, 500, 700 900, and 1100 ten-thousand JPY	+
Female dummy	*Sex*	female = 1, man = 0	+
Age	*Age*	20＝20s, 30＝30s, 40＝40s, 50＝50s, 60＝60s	U-shaped
Marriage dummy	*Marriage*	married = 1, other = 0	+
Number of family members	*Family*	Number of family members other than him/herrself living with him/her	-
Educational background	*Education*	1=junior high school, 2=high school, 3=technical school, 4=two-year college or technical college, 5=college, 6=master's course, 7=doctoral course	+
Satisfaction with residential neighborhoods	*Surrounding*	0 (extremely unsatisfied) to 10 (extremely satisfied)	+
Childhood nature experiences	*Nature_exp*	4 (rich nature experiences) to 23 (poor nature experiences)	+/-
Sociabillity	*Sociability*	11 (high sociabillity) to 44 (low sociabillity)	+
Student dummy	*Student*	student = 1	+
Housekeeper dummy	*Housekeeper*	housekeeper = 1	+
Leisure time on holidays	*Leisure_time*	1 (short leisure time) to 48 (long leisure time)	+
Work-leisure balance	*Work_or_leisure*	0 (emphasis on work) to 10 (emphasis on leisure)	+/-
Coast dummy	*Coast*	1 = there is an ocean within a radius of 1km	+/-
Amagasaki dummy	*Amagasaki*	1 = living in Amagasaki city	+/-
Tarumi-Suma dummy	*Tarumi_suma*	1 = living in Tarumi or Suma city	+/-
Number of stations within a 1km radius	*Station*	number of stations within a 1km radius	+/-
Occupancy of "forests" within a 1km radius	*Forest*	as above	+
Occupancy of "school's green spaces" within a 1km radius	*School_green*	as above	+
Occupancy of "shrine's green spaces" within a 1km radius	*Shrine_green*	as above	+
Occupancy of "park's green spaces" within a 1km radius	*Park_green*	as above	+
Occupancy of "other green spaces" within a 1km radius	*Other_green*	as above	+
Occupancy of "aggregated urban green spaces" within a 1km radius	*Urban_green*	as above	+

2.4. Result and Discussion

2.4.1. Analysis using Life Satisfaction

Table 5 shows the results of estimating equation (2) with life satisfaction as the dependent variable. The estimation results are divided into model1 to model5. Model1 includes "School_green" to equation (2), model2 includes "Shrine_green", model3 includes "Park_green", model4 includes

"Other_green", and model 5 includes “Urban_green,” which is the total of these four types of urban green spaces.

The results of the estimation show the following. First, for income, statistically significant positive signs are obtained for all the models in Table 5, indicating that income increases life satisfaction. As for the control variables, results consistent with previous studies are obtained for all variables except age. A positive sign was obtained for the importance of leisure compared to work at the 1% significance level for all models, indicating that people who value leisure more than work generally tend to have higher life satisfaction. No significant results were obtained for the number of stations included in the model as a variable representing convenience. One possible reason for this is that, given that convenient residential areas tend to have high housing prices and rents, the satisfaction derived from high convenience is offset by the dissatisfaction associated with paying high housing prices and rents. With respect to green spaces, "other green spaces" in model 4 and "aggregated urban green spaces" in model 5 were significantly estimated. In addition, a significant positive sign was obtained for "forest" in both models. One of the reasons why significant results could not be obtained for "school’s green spaces," "shrine’s green spaces," and "park’s green spaces" is that these green spaces were observed in smaller numbers than the "other green spaces.

The analysis of this study showed that the presence of urban green spaces and forests within a radius of 1 km from the place of residence improves the level of life satisfaction. Comparing the coefficients for "aggregated urban green spaces" and "forest" obtained in Model 5, the coefficient value for "aggregated urban green spaces" is about 6 times larger than that for "forest," indicating that an increase of 1 unit of "aggregated urban green spaces" contributes to life satisfaction about 6 times higher than an increase of 1 unit of “forest” within a radius of 1 km. This result suggests that forests and urban green spaces should be incorporated separately into the regression when applying LSA. The reason why forests and urban green spaces contribute differently to life satisfaction is considered to be that forests and urban green spaces fulfill different functions, as described in Section 2.

Based on these results, the marginal value of green spaces is 98,550 yen per person per year for an increase of 1 ha of "aggregated urban green spaces" within a radius of 1 km, and 16,970 yen per person per year for an increase of 1 ha of "forest". This means that the average person living in the study area can maintain his/her life satisfaction even if his/her annual income decreases by about 98,550 yen when the urban green spaces near his/her residence increase by 1 ha. When a similar analysis was conducted by selecting only people living with children under 15 years old, the marginal value of urban green spaces was estimated to be higher than in the analysis using the entire sample. In other words, it is clear that urban green spaces contribute particularly to the life satisfaction of those with children under 15 years old. It can be expected that the presence of green spaces near residential areas increases children's satisfaction, and that the increase in children's satisfaction increases the life satisfaction of the parents.[3]

[3] Although not shown in the table, a similar analysis was conducted by selecting only survey respondents living with children under 15 years old, and a significantly positive sign was obtained for "aggregated urban green spaces." The marginal value of "aggregated urban green spaces" is 209,600 yen per capita per year for an increase of 1 ha within a radius of 1 km, which is about twice the marginal value of 98,550 yen per capita per year in the case of Table 5.

Table 5: Estimation results when the dependent variable is life satisfaction.

specification	model1	model2	model3	model4	model5
Income	0.001452***	0.001446***	0.001447***	0.001447***	0.001444***
	(5.40)	(5.39)	(5.39)	(5.40)	(5.39)
Sex	0.680843***	0.672942***	0.675228***	0.669532***	0.666169***
	(4.09)	(4.06)	(4.07)	(4.05)	(4.03)
(Age) ^{2}	0.000076	0.000075	0.000076	0.000075	0.000076
	(1.05)	(1.04)	(1.05)	(1.05)	(1.05)
Marriage	0.433008**	0.427110**	0.427379**	0.441186***	0.430397**
	(2.55)	(2.52)	(2.52)	(2.61)	(2.54)
Family	-0.145174**	-0.146224**	-0.147323**	-0.153892**	-0.155990**
	(-2.13)	(-2.14)	(-2.15)	(-2.25)	(-2.28)
Education	0.141311***	0.139185***	0.139981***	0.143243***	0.140841***
	(2.78)	(2.73)	(2.76)	(2.82)	(2.78)
Surrounding	0.270384***	0.271279***	0.271757***	0.267668***	0.270914***
	(7.14)	(7.16)	(7.18)	(7.08)	(7.17)
Nature_exp	0.047260**	0.046726**	0.047062**	0.045797**	0.045898**
	(2.52)	(2.49)	(2.51)	(2.45)	(2.45)
Sociability	0.053755***	0.053325***	0.053296***	0.053883***	0.052849***
	(3.88)	(3.83)	(3.84)	(3.90)	(3.82)
Student	1.619319***	1.601542***	1.611810***	1.617578***	1.616413***
	(3.64)	(3.61)	(3.63)	(3.65)	(3.65)
Housekeeper	0.422796**	0.426657**	0.426195**	0.432082**	0.437154**
	(2.24)	(2.25)	(2.25)	(2.29)	(2.31)
Leisure_time	0.036807***	0.036697***	0.036659***	0.037336***	0.036944***
	(4.57)	(4.55)	(4.55)	(4.64)	(4.59)
Work or leisure	0.111924***	0.111415***	0.111395***	0.113669***	0.112550***
	(3.91)	(3.89)	(3.89)	(3.98)	(3.94)
Coast	0.171361	0.184766	0.188235	0.251304*	0.257408*
	(1.14)	(1.23)	(1.26)	(1.65)	(1.67)
Amagasaki	0.415501**	0.426704**	0.431183**	0.475059**	0.483965**
	(2.09)	(2.15)	(2.18)	(2.39)	(2.42)
Tarumi_suma	-0.102720	-0.088435	-0.092289	-0.344188	-0.256500
	(-0.57)	(-0.49)	(-0.52)	(-1.59)	(-1.28)
Station	0.008003	0.008829	0.003883	0.021265	0.006033
	(0.18)	(0.20)	(0.08)	(0.48)	(0.14)
Forest	0.005895	0.006135	0.006278	0.007284*	0.007694*
	(1.40)	(1.44)	(1.49)	(1.72)	(1.79)
School_green	-0.048460				
	(-0.49)				
Shrine_green		0.033871			
		(0.13)			
Park_green			0.021693		
			(0.50)		
Other_green				0.063463**	
				(2.06)	
Urban_green					0.044685*
					(1.82)
constant	-2.264547***	-2.243710***	-2.266305***	-2.366267***	-2.346642***
	(-3.53)	(-3.50)	(-3.53)	(-3.69)	(-3.66)
Log likelihood	-1894.9473	-1895.061589	-1894.942366	-1892.911342	-1893.387946
AIC	4.118166	4.118412	4.118156	4.113788	4.114813
observation	930	930	930	930	930

* p<0.1, ** p<0.05, *** p<0.01 Note: Figures in parentheses are Z-values.

2.4.2. Analysis using K6 Index

Next, in order to examine the possibility that green spaces affect mental health, an analysis is conducted using mental health (the K6 indicator) as the dependent variable. Table 6 shows only the results related to green spaces among the estimation results. Significant negative signs were obtained for all models from model 1 to model 5 for income, marriage, education, satisfaction with one's surroundings, sociability, housewife/househusband dummy, and leisure time on holidays, indicating that these variables affect mental health. An inverse U-shaped relationship was obtained for age.

Significantly negative estimates were obtained for model 2, model 4, and model 5 for green spaces. These results indicate that urban green spaces not only increase the level of life satisfaction of urban residents, but also have a positive impact on their mental health. Although significant estimates could not be obtained for "shrine’s green spaces" in the analysis in which the dependent variable was life satisfaction, its impact on mental health was estimated to be significant. This suggests that shrine’s green spaces have a particularly pronounced impact on the mental health of neighborhood residents. Many of the shrine and temple green spaces have been protected and managed for many years for religious reasons, and thus can be said to be places where the original natural vegetation and biodiversity of the area that was lost due to urbanization is still present (Manabe et al., 2007). From this perspective, shrine and temple green spaces have a slightly different character than other urban green areas. It is also possible that the sense of sacredness of the shrine or temple itself has a healing effect on the residents of the neighborhood.[4] Note that significant results were obtained for "aggregated urban green spaces," but not for "forest." These results indicate that the impact of urban green spaces is more significant than the impact of forest on people's mental health.

Table 6: Estimation results when the dependent variable is K6 index.

specification	model1	model2	model3	model4	model5
Forest	0.000761	-0.004399	-0.000690	-0.003267	-0.004748
	(0.06)	(-0.36)	(-0.06)	(-0.27)	(-0.39)
School_green	0.231004				
	(0.82)				
Shrine_green		-1.424136*			
		(-1.94)			
Park_green			-0.071135		
			(-0.58)		
Other_green				-0.171640*	
				(-1.95)	
Urban_green					-0.130852*
					(-1.87)
constant	18.568160***	18.283512***	18.550321***	18.810546***	18.779385***
	(10.16)	(10.01)	(10.14)	(10.28)	(10.27)
Log likelihood	-2869.306781	-2867.728259	-2869.481548	-2867.709383	-2867.876704
AIC	6.213563	6.210168	6.213939	6.210128	6.210488
observation	930	930	930	930	930

4 Even if shrine and temple green spaces have special benefits, it is difficult to create new ones as a practical matter. Nakamura et al. (2002) and Hattori et al. (2003) discuss the possibility of creating highly naturalistic forests that resemble shrine and temple green spaces. Valuation of such attempts will be necessary in the future.

2.5. Discussion

The value of green spaces estimated in this study is compared to similar valuation studies conducted on green spaces in Japan. Although there are very few previous studies that have conducted valuations per hectare of green spaces on an individual or household basis, there are several studies that have attempted to apply CVM to value them. Sato et al. (2019) applied CVM and conducted a valuation of the marginal value of an increase of 1 ha for forests in Japan on a household basis and found the national average to be 2,447 yen per year. Kuriyama et al. (2000) conducted a valuation using CVM for a forest on Yakushima Island, Kagoshima Prefecture, which is a World Heritage site, and obtained an annual value of 1,500 yen per hectare increase for each household. Managi and Institute for Global Environmental Strategies (2011) conducted CVM on Kabukurinuma, Miyagi Prefecture, and obtained a valuation of 917 yen per hectare increase per year for each household. In this study, the marginal value for an increase of 1 ha of urban green spaces was evaluated at 98,550 yen per capita per year, and the marginal value for an increase of 1 ha of forest was evaluated at 16,970 yen per capita per year, showing a large deviation from the valuations in these previous studies.

There are two main reasons for this deviation. The first is due to the distance between the valuator and the green spaces. In this study, the value was estimated for green spaces within a radius of 1 km from the home of each valuator. On the other hand, in the previous studies mentioned above that applied CVM, each valuer estimated the value of green spaces in their municipality. This difference in distance is considered to be a factor in the deviation, because people generally value green spaces that are closer to their homes more highly. Second, there is a difference in valuation methods. While this study applied LSA, the previous studies mentioned above used CVM. CVM is based on utility theory, which means that values that do not appear as utility cannot be valued. Discomfort and satisfaction that people unconsciously perceive from environmental goods cannot be valued within the framework of traditional utility theory because they do not affect the increase or decrease of utility. In contrast, LSA can also theoretically value discomfort and satisfaction, the sources of which cannot be identified by the valuator. It can be inferred that urban residents unconsciously benefit from urban green spaces, resulting in a deviation in the valuation. Since both of the above two factors are speculative, additional research is required to elucidate them in the future.

2.6. Conclusion

This chapter quantitatively shows that urban green spaces and forests increase people's life satisfaction and contribute to their mental health, using the LSA framework. In particular, this study focused on the type of urban green spaces and analyzed the magnitude of their impact on life satisfaction and mental health. The results of this study provide the following findings on the function and importance of urban green spaces. First, unlike forests in natural areas, urban green spaces have a high value in terms of cultural services, and it is essential to value them from the perspective of subjective well-being. This suggests that urban green spaces contribute to human well-being in a different way than forests in natural areas. On the contrary, LSA may underestimate the valuation of the provisioning and regulating functions of forests, such as food supply and climate control. Second, the study suggested that urban green spaces also contribute to the mental health of residents and may have value that cannot be grasped by traditional utility theory-based valuations. This suggests that when conducting urban development, it is essential to consider the potential value of urban green spaces, which may not be grasped within the framework of traditional utility theory. There is a need for careful consideration of the meaning of urban green spaces to neighborhood residents, and this study presents one way to do so.

The following points need to be addressed in the future. First is the refinement of green spaces data. In the analysis of this study, the significance of the impact of variables related to urban green spaces on life satisfaction was not so large. If the density of vegetation, types of trees, and whether green spaces are available for public use can be quantified using GIS, more detailed analysis of the quality of green spaces will be possible. Second is the improvement of LSA. While LSA can value a wide range of non-market goods, it is difficult to value services that do not contribute directly to life satisfaction. In the future, it is necessary to seek a highly valid environmental valuation method by devising other method, such as a combination of LSA and traditional valuation methods.

It should also be noted that while LSA allows for intrinsic environmental valuation based on life satisfaction, the estimated value is not the WTP that residents are willing to pay for environmental policies. As mentioned in the Discussion, the valuations estimated in the LSA tend to be larger than the marginal values of green spaces estimated using methods based on traditional utility theory. This is considered to be because the LSA can estimate even values that are not recognized by the residents. However, when the cost of investing in environmental policies is calculated based on valuations that include values that residents do not recognize, residents may feel that the cost is greater than the benefits from it. Several problems exist here, but one solution is to raise residents' awareness of environmental conservation and help them understand environmental policies. CHAPTER III examines how to get residents to have a high WTP for environmental policy.

CHAPTER III[5]

Nature Experiences, Connectedness to Nature, and WTP for Environmental Policy

3.1. Introduction

While CHAPTER II revealed that urban ecosystem services improve the well-being of residents, the residents' willingness to conserve is important for the proper management of urban ecosystems. It has been pointed out that urban residents who have little interaction with nature have a low environmental awareness (Sato et al., 2017), and thus, it is important to strengthen residents' interactions with nature. Under these circumstances, "connectedness to nature" is attracting attention as a key concept for analyzing the interactions between urban residents and nature.

Restall and Conrad (2015) posited that "connectedness to nature" can be used to understand how individuals personally identify with the natural environment and the relationships they form with nature. Previous studies have shown that individuals' contact with nature fosters and enhances their connectedness to nature (Mayer et al., 2009; Frantz and Mayer, 2014). In turn, this connectedness to nature increases their environmental awareness and prompts pro-environmental behaviors (Dutcher et al., 2007; Gosling and Williams, 2010; Cheng and Monroe, 2012; Barbaro and Pickett, 2016). Therefore, extinction of experience results in a decline in individuals' connectedness to nature, which, in turn, appears to constrain environmental management. Consequently, connectedness to nature has been used as a bridging concept between contact with nature and environmental management and policy.

Although researchers have confirmed and analyzed the positive relation between connectedness to nature and environmental awareness, few studies have examined how connectedness to nature affects acceptance of environmental policies. The findings of a meta-analysis of connectedness to nature indicated that only 13% of the 90 included studies focused on the implications of connectedness to nature for environmental conservation (Restall and Conrad, 2015). Moreover, the economic implications of connectedness to nature in relation to conservation have not been ascertained. However, economic valuation is needed when a conservation policy can be justified from the perspective of accountability. In other words, monetary costs and benefits are non-negligible issues in environmental management (Costanza et al., 2016). In conducting a social cost-benefit analysis of environmental conservation policy, the economic valuation of environmental impact plays an important role and is related to people's acceptance of policy implementation.

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[5] This chapter is written based on Sato et al. (2021).

Therefore, a detailed investigation of people's willingness to pay (WTP) for environmental conservation is important, especially in highly urbanized areas where people's varying characteristics and lifestyle diversity create heterogeneous subjective recognition of the natural environment. In considering people's cognitive diversity in relation to policy and management evaluation, it is important to assess the determinants of WTP for environmental benefits, such as the management of forests and green spaces. However, researchers have criticized WTP, such as Faccioli et al. (2020) who argued that while WTP is typically valued by environmental economic techniques, such as stated preference method, it often ignores the role of complex psychological and sociological factors. Thus, to better understand the determinants of WTP for urban forests and green spaces, an analysis of the impact of connectedness to nature on economic valuations is needed.

This paper presents an analysis aimed toward demonstrating how connectedness to nature enhances individuals' WTP for environmental conservation. Specifically, we analyzed the connection between connectedness to nature and WTP using a structural equation model (SEM). We measured connectedness to nature using the Connectedness to Nature Scale (CNS; Mayer and Frantz, 2004) and conducted a choice experiment (CE), a method which has been widely used to calculate the value of environmental goods (Hanemann, 1994; Christie et al., 2007; Vecchiato and Tempesta, 2013) when assessing respondents' WTP for environmental policies. Focusing on the relationship between the CNS and WTP enabled us to assess whether fostering connectedness to nature can effectively increase individuals' willingness to make financial sacrifices to facilitate the implementation of environmental policies.

Furthermore, this study focused on ecosystem services in an urban area where human–nature relationships are important. In particular, the study highlighted the effects of residents' characteristics on the value they place on urban ecosystem services and related conservation policy. To achieve this aim, the survey area needed to have both natural and urban environments in close proximity. If the study area had too much forest area, there may be little perceived need for afforestation policies, whereas in an urban environment with little forest area, it would be difficult to explore the effects of residents' characteristics, such as their experiences with nature. Thus, we chose Singapore, which is highly urbanized and can therefore be an appropriate for studying how different people perceive the different value of urban forests.

The remainder of the paper is organized as follows. The Section 3.2. presents a literature review on how the concept of connectedness to nature has been previously applied. The Section 3.3. describes the survey method, study area, and dataset, while also elaborating on the measurement scales' construction and quantification. In the Section 3.4., we present the result on obtained score of connectedness to nature. The Section 3.5. and 3.6. provide the results of and discussion on the CE and SEM analysis, respectively. In the Section 3.7., we offer conclusions derived from the study's findings.

3.2. Literature Review

Connectedness to Nature and Environmental Concerns

The feeling of being connected to nature is inherently psychological. Roszak (1995) stated that people would care about natural world if the self were expanded to include it. In recent decades, human-nature relationships have begun to be investigated in this context and become regarded as a key component of fostering environmental awareness (e.g., Dunlap et al., 2000; Mayer and Frantz, 2004). Moreover, without opportunities to experience the natural environment individuals do not develop a strong sense of connectedness to nature (Mayer et al., 2009), and such opportunities have recently declined, especially for urban residents (Soga and Gaston, 2016). To address this problem, numerous studies have applied the concept of connectedness to nature to explore ways to conserving the natural environment. For example, Dutcher et al. (2007) conducted regression analyses using data on Pennsylvanian landowners, which indicated that respondents with a high level of connectedness to nature retained a significant and positive relationship with their self-reported environmental awareness and pro-environmental behaviors. Connectedness to nature also appears to encourage pro-environmental behaviors among farmers in relation to native vegetation management (Gosling and Williams, 2010). Moreover, Barbaro and Pickett (2016) posited that an association exists between connectedness to nature and self-reported engagement in 17 daily expressed pro-environmental behaviors.

Some concepts and indicators related to connectedness to nature have been applied within the literature, such as the CNS (Mayer and Frantz, 2004), Environmental Connectivity Scale (ECS; Dutcher et al., 2007), New Ecological Paradigm (NEP; Dunlap et al., 2000), and Nature Relatedness scale (NR; Nisbet et al., 2009). An empirical examination to assess the extent to which these indicators overlap revealed a strong correlation, indicating that they can be considered to measure the same factor (Tam, 2013). In light of this finding, Restall and Conrad (2015) applied “connectedness to nature” as an umbrella term that encompasses all of the above terms. Among these related concepts, Olivos et al. (2011) investigated the validity and reliability of the CNS as a measure of connectedness to nature and concluded that it is useful for investigations in social psychology. As a result, the CNS has been established and widely used (Kleespies and Dierkes, 2020). Considering the aim of this research (i.e., to analyze the effect of connectedness to nature on the valuation of ecosystem services), a basic measure would be preferable. Therefore, after reviewing previous discussions on measures, we chose the established CNS for use in this study.

Willingness to Pay and Connectedness to Nature

This study aimed to determine whether connectedness to nature can promote forest conservation policies in urban areas. The intangible benefits of urban forests are relatively more important than their tangible benefits for urban residents because the benefits that they derive from visiting urban forests are mostly psychological (Lee and Maheswaran, 2011). Researchers have therefore applied WTP rather than market values to estimate these benefits (Tyrväinen and Väänänen, 1998; Tyrväinen, 2001; Lo and Jim, 2010, 2015; Majumdar et al., 2011; Sato et al., 2017). These estimates of residents' WTP are especially important for evaluating the effectiveness of environmental policies on urban forests. Moreover, governments need to ensure that the environmental policies they formulate will be met with public acceptance, which can be measured using an indicator such as WTP (Horowitz and McConnell, 2002). In other words, WTP is a monetary criterion that is essential in policy evaluation. Therefore, in this study, we used WTP to measure public environmental concerns. Stern et al. (1995) suggested that there is a correlation between the NEP, which measures individuals' cognitive beliefs toward nature, and WTP for forest preservation. However, based on findings from their empirical study, Mayer and Frantz (2004) argued that, while the CNS and NEP are related to some extent, they are distinct in that the CNS is more strongly related to ecological behavior than the NEP. Accordingly, it is important to analyze the relationship between the CNS and WTP and validate the CNS as a suitable predictor of WTP.

We conducted a CE to estimate participants' WTP for forest conservation. The value of a forest comprises several attributes, such as provision of timber, food, and recreational opportunities and mitigation of the effects of global warming (De Groot et al., 2010). CE is an appropriate method because it can be applied to value the multi-attribute structure of an evaluation target. This method has been previously used to value the multi-attributes of forest (Giergiczny et al., 2015; Filyushkina et al., 2017; Diafas et al., 2017; Tait et al., 2017). In WTP estimates, it is necessary to consider different forest attributes, as the relationship between connectedness to nature and WTP is expected to vary according to these attributes. Therefore, we incorporated multiple forests attributes into our analyses of the CNS and WTP.

Dynamics to Improve the Quality of Natural Environment

Our study included the dynamics associated with four positive feedback processes (see Figure 4). In the first process, an increase in opportunities for establishing contact with nature leads to an increase in the level of connectedness to nature. In the second process, increased connectedness to nature leads to a higher WTP. In the third process, an increase in WTP for an environmental policy leads to improvement in the quality of the natural environment. In the final process, an improvement in the quality of the natural environment leads to a further increase in opportunities to experience contact with nature. Furthermore, due to their strong positive correlation (Cervinka et al., 2012; Kamitsis and Francis, 2013; Zelenski and Nisbet, 2014; Capaldi et al., 2014), human well-being is likely to continuously increase along with connectedness to nature, provided that the above loop continues to have a positive impact. However, reversing the cycle is likely to lead to a decrease in human well-being, as a decline in opportunities to experience contact with nature would presumably result in deterioration in the quality of the natural environment, which could subsequently prompt a decline in human well-being.

As our primary concern was connectedness to nature, we tested the validity of the first and second processes using questionnaire data and applying an SEM. Researchers (e.g., Dutcher et al., 2007) have confirmed that a positive association exists between connectedness to nature and environmental awareness (the second process); however few studies have examined the economic role of connectedness to nature through estimates of WTP.

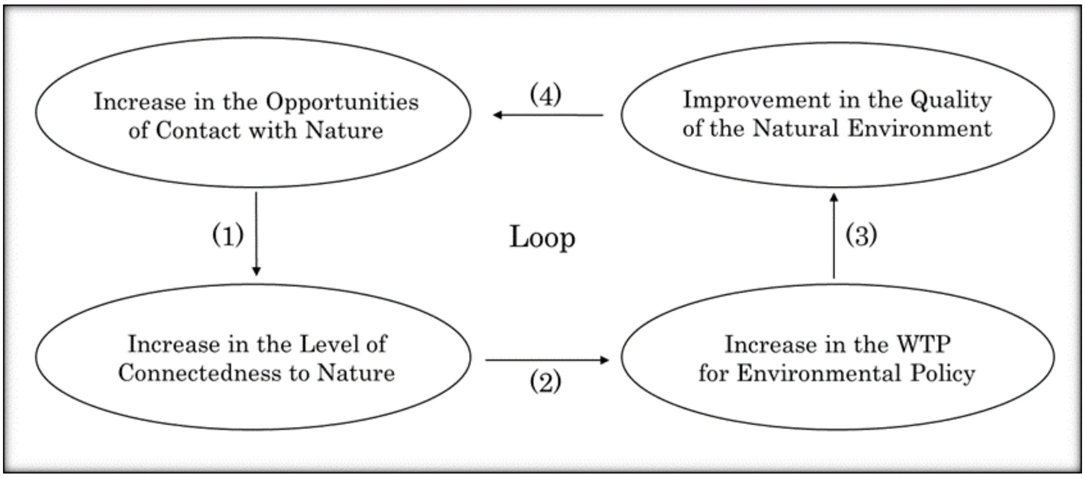

Figure 4: The dynamics entailed in contact with nature and the quality of the natural environment (authors' formulation).

3.3. Methods and data applied in our case study of Singapore

We used three types of data within an empirical analysis relating to the first and second processes: data on respondents' contact with nature, connectedness to nature, and WTP for environmental policies. The data were collected from residents of Singapore through an online survey. The indicators used to measure respondents' connectedness to nature and contact with nature are described in Section 3.3.1. A brief explanation of the CE used to estimate respondents' WTP is subsequently provided in Section 3.3.2.1, followed by a description of the SEM in Section 3.3.2.2.

3.3.1. Measurement scales

Connectedness to nature was measured using the CNS (Mayer and Frantz, 2004), which is widely used to measure the strength of respondents' traits that promote feelings of being emotionally connected to the natural world (e.g., Frantz et al., 2005; Mayer et al., 2009; Howell et al., 2011; Kamitsis and Francis, 2013). The CNS comprises 14 questions, such as "I often feel a sense of oneness with the natural world around me" and "I recognize and appreciate the intelligence of other living organisms," which assess the sense of oneness with the natural world. These questions are rated using a five-point response scale, ranging from 1 (strongly disagree) to 5 (strongly agree). An overall score is calculated based on the mean of the responses to all questions, with higher scores reflecting greater connectedness to nature. Participants' CNS scores are provided in detail in Section 3.4.

Regarding contact with nature, some scholars have argued that childhood contact is much more important than contact in adulthood for instilling environmental consciousness (Wells and Lekies, 2006; Sato et al., 2017). Thus, as one of our objectives was to explore whether contact with nature fostered respondents' feelings of connectedness to nature, childhood contact with nature needed to be measured in detail. Accordingly, we categorized individuals' contact with nature into past (prior to junior high school) and present contact to assess the influence of age on connectedness to nature. To measure past contact, we used the indicator "nature experience in the past," comprising six questions. Past environmental education (Ernst and Theimer, 2011; Cheng and Monroe, 2012) and direct contact with nature (Liefländer et al., 2013; Braun and Dierkes, 2017) are important determinants of connectedness to nature. In light of the findings of earlier studies, respondents were asked to recall their experiences relating to nature prior to attending junior high school; for example, "How often did you experience picking, breeding, or raising animals and plants?" Participants responded to these questions using a scale ranging from 1 (not at all) to 4 (often). Table 7 shows all of the components of "nature experiences in the past" along with details on how this variable was constructed. A four-point response scale was used for all of the questions, with the exception of Q4. To synthesize the responses, we converted the four-point response scale used for the above questions to a two-point scale by replacing the response options 1 and 2 with 0 and the remaining response options with 1. The participants who responded to Q4 were divided into two groups: those who chose the "no, there are no nature-loving persons" options and those who selected other options. The former group rated 0 and the latter group rated 1 for Q4. Then, these adjusted values were added up in order to make the variable relating "nature experience in the past." Cronbach's alpha for this variable was 0.7794.

The status of respondents' present contact with nature was ascertained through questions relating to the following variable: "frequency of visits to nature." In response to the question, "How often do you visit green spaces or forests on average (including wooded local parks, gardens, etc.)," participants answered according to a scale ranging from 1 (never) to 7 (every day). The seven-point response scale adopted in this study was also used by Kaźmierczak (2013).

Table 7: The components of "nature experiences in the past."

Question	Choice
(1) In your childhood (before junior high school), how often did you experience picking, breeding, or raising animals and plants?	1: not at all 2: seldom 3: sometimes 4: often
(2) In your childhood (before junior high school), how often did you experience playing in mountains, rivers, or the ocean?	1: not at all 2: seldom 3: sometimes 4: often
(3) In your childhood (before junior high school), how often did you experience visiting the countryside, with natural environments?	1: not at all 2: seldom 3: sometimes 4: often
(4) In your childhood (before junior high school), were there any nature-loving individuals around you? Please choose all of the applicable options. (Multiple answer)	- parent - grandparent - brother or sister - teacher - neighbor - no, there were no nature-loving persons
(5) Before junior high school age, how many nature environments were there in the neighborhood?	1: very little 2: relatively little 3: much 4: very much
(6) In your childhood (before junior high school), how often did you have environmental and ecological education programs on awareness and perception of nature?	1: not at all 2: seldom 3: sometimes 4: often

3.3.2. Willingness to pay

3.3.2.1. Choice experiment

We applied a classical approach based on utility theory for the economic valuation, which entailed measuring participants' WTP (Hanemann, 1984). Among the various methods used for measuring WTP, the CE is widely applied for determining non-market values related to the environment (Adamowicz et al., 1998; Hoyos, 2010). We chose to conduct a CE because it enables respondents' WTP to be estimated for each forest attribute.

At the start of the CE, participants were presented with a hypothetical scenario. The assumption adopted in this scenario was that the government planned to terminate all existing forest-related projects and initiate a new project aimed toward effectively regulating Singapore's forests. Participants were then provided with five independent and sequential choice sets. The number of choice sets was determined by the result of the orthogonal planning. Although a CE requires a large number of items, respondents may feel demotivated and provide answers that do not reflect serious thought if they are asked too many questions. Therefore, we adopted an orthogonal planning method and designed efficient choice sets based on Louviere et al. (2000). Although an orthogonal arrangement sometimes leads to unrealistic choice sets, it enables efficient estimates of coefficients in the CE, avoiding the effects of multicollinearity that occurs when choice sets are constructed in such a way that correlations among attributes yield a value of zero. However, if the choice set includes unrealistic alternatives, it can lead to a less informative answer and sometimes reduce respondents' interest and involvement with the questionnaire (Kruijshaar, et al. 2009), potentially leading to a provided response of "no choice."

As a result of applying the orthogonal planning method, we obtained 25 choice sets, which were divided into five groups of five choice sets each. All participants answered the repetitive choice questions in the choice set randomly selected from among the five groups. As alternatives were created using orthogonal planning, each choice set included three alternative environmental management plans (Alts. 1–3) and two no-choice options (Alts. 4 and 5). Each of the environmental management plans (Alts. 1–3) comprised six attributes: five emphasized forest ecosystem services and one entailed a burden charge.

There has been some controversy over what format should be used to present each attribute level. One idea for this is to show the quantity itself; however, within the literature on urban green spaces, Kim et al. (2020) suggested that presenting a percentage is better for respondents when indicating their choices. As this study was not focused directly on the monetary valuation of ecosystem services, but on examining the cognitive factors which affect this valuation, we adopted the presentation by percentage method with consideration to the difficulty of the responses. Thus, we could estimate the weight on each variable that the respondents expect to enforce with reference to the current situation. The weight of each ecosystem service could then be applied in the following analysis using psychological factors defined as CNS. These attributes and their levels are summarized in Table 8.

After considering the different features of each hypothetical plan, participants selected the one that appealed to them the most. Table 9 provides an example of a choice set from the CE questionnaire.

After analyzing the responses to the choice questions, we calculated the parameters of the utility function and participants' WTP to improve the quality of each forest ecosystem service by 1%.

We focused on forest ecosystem services, defined as the benefits for human beings derived from ecosystem services (Costanza et al., 1997). The Millennium Ecosystem Assessment (2003) identified four categories of ecosystem services: provisioning, regulating, supporting, and providing cultural services. In this research, forest ecosystem services were divided into the following five categories: (1) provision of timber and food (provisioning service); (2) moderating extreme events, such as landslides, drought, and floods (regulation service); (3) preventing global warming by CO_2 absorption (regulation service); (4) providing habitats for species and preserving ecosystems (supporting service); and (5) providing opportunities for recreation and education (cultural service). Given that ecosystem services provide extensive benefits related to their well-being (Bolund and Hunhammar, 1999), an investigation of urban residents' attitudes toward these ecosystem services would contribute to the enhancement of their life quality.

The levels of each forest ecosystem service in each alternative were determined based on a previous study conducted for the forest in Shiga prefecture, Japan. We referred to this study for the following reasons. First, it estimated values for forest ecosystem services using a CE (Sato et al., 2019). The estimated values were considered valid and reasonable, and the Shiga prefecture referenced them when discussing forest management policy (Shiga Pref., 2016). Second, we needed a starting point for the survey design; however, there was no direct study which estimated values for forest ecosystem services using a CE in Singapore. Thus, as Shiga prefecture also has a mixture of natural and urban areas with a high population density, we based our questionnaire on the one used there. Finally, we conducted a pretest before the actual survey and confirmed that we could estimate the value of forest ecosystem services using these CE settings in Singapore.

The level of burden charge was determined in reference to Barrio and Loureiro (2010), who conducted a meta-analysis of 35 studies applying stated preference method for valuing a variety of forest-related goods and services. In their study, a mean annual WTP value of US$ 34.81 per household was obtained.[6] In our study, we incorporated this value as a reference point within a range of values using the following levels of burden charge in Singapore dollars (SGD): 10, 20, 50, 100, or 200 per household annual.

Stated preference methods, such as CE, often entail biases (Murphy et al., 2005). In the choice questions of this study, percentages from current attribute levels of ecosystem services were shown. This means respondents were required to compare the hypothetical improvement with current situation.

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[6] To enable the information obtained from the 35 studies to be compared, Barrio and Loureiro (2010) standardized the values reported in these studies in relation to the US dollar value in 2008 using purchasing power parity rates. Because the mean WTP in this study was expressed as a logarithm, we converted it to an antilogarithm. In March 2017, the exchange rate was 1.40 SDG/USD.

Regarding anchoring bias (Ladenburg and Olsen, 2006), the anchor of this study is considered as the status quo. Thus, when a conservation policy is suggested, people generally estimate the value of the environmental change from the status quo according to cost and benefit. If there is a strong anchoring bias, the proposed change has less value, and the policy evaluation tends to be conservative. Despite other potential biases, such as strategic bias (Meginnis et al., 2018) and hypothetical bias (Hensher, 2010), CE is useful as a stated preference method (OECD, 2018). The effect of bias on valuation results is important to. However, note the focus of this study was not on the absolute values of individuals' WTP, but on the difference in relative values among different people.

Table 8: Attributes and associated levels applied in the Choice Experiment.

Attribute	Level
Forest ecosystem services	75% (down by 25%)
	100% (status quo)
	125% (up by 25%)
	150% (up by 50%)
Burden charge (per year per household)	SGD 10
	SGD 20
	SGD 50
	SGD 100
	SGD 200

Table 9: An example of a choice set used in the Choice Experiment questionnaire.

	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Function 1: provisioning timber and food	Down by 25%	As status quo	Down by 25%	No adequate plan	No need to implement project itself
Function 2: moderating extreme events, such as landslides, drought, and floods	As status quo	Up by 50%	Up by 25%		
Function 3: preventing global warming by CO_2 absorption	Down by 25%	Up by 50%	Down by 25%		
Function 4: providing habitats for species and preserving ecosystems	As status quo	Down by 25%	Up by 25%		
Function 5: providing opportunities of recreation and education	Up by 25%	Up by 50%	Up by 25%		
Burden Charge (per year per household)	SGD 20	SGD 50	SGD 100		
Choice one					

As participants' reasons for selecting a no-choice option could differ, each choice set included two no-choice options: "(there is) no adequate plan" (Alt. 4) and "(there is) no need to implement the project itself" (Alt. 5). Whereas Alt. 4 implied the absence of a desirable plan within the choice set, Alt. 5 implied that the participant considered an additional forest-related project to be unnecessary. This response was considered to be a protest of the policy itself and omitted from the analysis. Contrastingly, participants who selected Alt. 4 were included because they favored some other environmental policy, thus indicating their preferences and WTP.

Accordingly, out of the total number of observations (442), 33 respondents selected Alt. 5 in all of choice sets, and were considered to be against implementing any policy. In addition, 100 respondents selected Alt. 5 in some of the choice sets. Their answers were considered to be inconsistent, because if they thought the policy itself was not needed, then they should have selected Alt. 5 in all choice sets. The analysis in this study retained only consistent answers. As a result, the CE included 309 people who did not select Alt. 5 for any choice set.

3.3.2.2. Model for Estimating WTP

The analytical CE model was based on random utility theory. Accordingly, we assumed that the utility function could be expressed as the numerical sum of the observable portion of utility function V, and the independently and identically distributed extreme value (IIDEV) error term, ε. The utility function U relating to the choice of alternative i in choice set t by respondent n was expressed as:

$$U_{nit} = V_{nit} + \varepsilon_{nit}. \quad (1)$$

A widespread assumption regarding an IIDEV type 1 (IIDEV1) error term ε that is applied to derive a conditional logit model can be found within the literature (McFadden, 1973). In this study, we also assumed that ε is an IIDEV1, and that the observable portion of the utility function, V, is a linear combination of the attributes, as expressed in Eq. (2), using the parameter vectors α and β:

$$V_{nit} = \alpha_n + \beta_{1n} \times Function1_{nit} + \beta_{2n} \times Function2_{nit} + \beta_{3n} \times Function3_{nit} + \beta_{4n} \times Function4_{nit} + \beta_{5n} \times Function5_{nit} + \beta_{6n} \times Burden\ Charge_{nit}. \quad (2)$$

The property of independency from the irrelevant alternatives derived from the IID assumption of the conditional logit model was strict, and individual evaluation of the forest value was disallowed. A mixed logit model that accommodates the variance of random components was developed to overcome such limitations. Mixed logit models allow for random taste variations, unrestricted substitution patterns, and the correlation of random terms over time (McFadden and Train, 2000; Train, 2009). They are also rather flexible in addressing the limitations of conditional logit models. We chose a mixed logit model to estimate WTP at the individual level, as this model enabled us to ascertain the variety of parameters at this level. It was necessary to estimate individuals' WTP because the SEM, which was subsequently used to analyze the relationship between CNS and WTP, required individual data. Differing from a standard logit model in which parameter vectors are estimated using point estimation, the model applied in the present study estimated the distribution forms of the density function, because random parameters are assumed to be distributed with density function $f(\beta)$ in mixed logit models. In our model, parameters α_n, denoting the alternative-specific constant term for the option "no adequate plan," and β_6 were considered non-random parameters, and β_{1n}, β_{2n},..., β_{5n} were assumed to be normally distributed random parameters. The WTP of individual n for the improvement of attribute j (WTP_{jn}) was defined as the marginal utility of each forest coefficient (β_{2n}, β_{3n}, β_{4n}, and β_{5n}) divided by the burden charge coefficient (β_6), as expressed in Eq. (3). In the process, we assume the denominator as non-random parameter to calculate WTP of each respondent (Revelt and Train, 1998).

$$WTP_{jn} = \frac{coefficient\ of\ forest\ function\ (\beta jn,\ \ j{=}2,3,4,5)}{coefficient\ of\ Burden\ charge\ (\beta 6)}. \quad (3)$$

We estimated each distribution form, then used Bayes' theorem to calculate the estimator of the conditional mean of random parameters in relation to each participant, as expressed in Eq. (4), which was determined by the individual-specific choice profile y_n (Revelt and Train, 1998):

$$\mathrm{h}(\beta|y_n) = \frac{P(y_n|\beta)f(\beta)}{\int P(y_n|\beta)f(\beta)d\beta}. \quad (4)$$

The signs of parameters β_{1n}, $\beta_{2n,\ldots}$, β_{5n} were expected to be positive, whereas the sign of β_6 was expected to be negative. We applied this result in the second stage of the SEM analysis.

3.3.3. Target area and survey data

This study focused on urban forests and green spaces in Singapore. The forested area in Singapore is roughly 20 km,[2] accounting for 3% of the total land area of 719 km^2 (Food and Agriculture Organization of the United Nations, 2010). The entire forested area is classified as primary forest. Furthermore, there are a lot of managed green spaces throughout the city. The National Parks Board, which was subsequently established as a statutory board, has contributed to the development and enhancement of the city's greenery. For example, the Board manages four nature reserves covering about 33.26 km^2, with the specific aim of conserving endemic species (National Parks Board Singapore, 2010). However, despite Singapore's rich biodiversity, much of its flora and fauna are on the verge of extinction. Owing to their nonviable populations, many extant plant species in Singapore are threatened with extinction (Turner et al., 1994). Further, 67% of the city's bird species disappeared between 1932 and 2000, along with more than 90% of the forest cover, and some bird species continue to face the threat of extinction (Castelletta et al., 2000). Thus, an investigation of potential processes to improve the quality of the natural environment is essential for preserving the remaining flora and fauna.

To collect data, we used the services of Nikkei Research, Inc., one of the largest companies in Japan that provides reliable research data for academic use, to initiate a web survey in March 2017. Cash vouchers were awarded to respondents to motivate their participation in the survey. The respondents were selected at random for the survey according to prefectural demographics, such as population, gender, and age ratios. A total of 442 responses were collected. Table 10 presents the study's descriptive statistics.

The sample comprised 219 women and 223 men aged between 21 and 69 years (mean = 44.2; SD = 13.7). The respondents' ethnic backgrounds were as follows: 372 Chinese (84.16%), 36 Indian (8.14%), 22 Malay (4.98%), and the remaining 12 respondents (2.71%) chose the "other" category. The average annual household income of the respondents was SGD 88,867 (SD = SGD 63,018), which did not differ significantly from the per capita GDP of SGD 79,697 in 2017 (Government of Singapore, 2018). Among the respondents, 230 (52.04%) were full-time workers, 31 (8.14%) were part-time workers, and, 25 (5.66%) were unemployed and job-seeking. The respondents' geographical distribution was determined based on the 29 constituencies into which Singapore is divided, with respondents selected from each constituency according to population size. Thus, the sample is representative of the residents of Singapore to some extent, although not perfectly, from the perspectives of age, gender, and residential area.

Table 10: Descriptive statistics of the study.

	Obs.	Mean	Std. dev.	Min	Max
CNS	442	3.52	0.42	2.14	5
"Nature experience in the past"	442	3.01	2.01	0	6
"Frequency of visits to nature"	442	3.21	1.47	1	7

3.4. Connectedness to Nature Scare

Mean CNS scores are shown in Table 11, as calculated based on the 442 participants who were considered to have provided consistent answers. To calculate CNS, we follow the procedure of Mayer and Frantz (2004) to reverse the scored of three items (4, 12, and 14). As a result, the mean CNS score was 3.52 (SD = 0.44). These values did not differ widely from those found by Mayer and Frantz (2004), who reported a mean CNS score of 3.65 (SD = 0.64). Cronbach's alpha was 0.849 in the present study, which confirmed the reliability of the initial scale.

Table 11: The mean score of Connectedness to Nature Scare.

	Item	Score
1	I often feel a sense of oneness with the natural world around me.	3.602
2	I think of the natural world as a community to which I belong.	3.708
3	I recognize and appreciate the intelligence of other living organisms.	3.944
4	I often feel disconnected from nature.	2.813
5	When I think of my life, I imagine myself to be part of a larger cyclical process of living.	3.699
6	I often feel a kinship with animals and plants.	3.599
7	I feel as though I belong to the Earth as equally as it belongs to me.	3.705
8	I have a deep understanding of how my actions affect the natural world.	3.886
9	I often feel part of the web of life.	3.626
10	I feel that all inhabitants of Earth, human and nonhuman, share a common 'life force'.	3.772
11	Like a tree can be part of a forest, I feel embedded within the broader natural world.	3.661
12	When I think of my place on Earth, I consider myself to be a top member of the hierarchy that exists in nature.	3.304
13	I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.	3.503
14	My personal welfare is independent of the welfare of the natural world.	3.272

3.5. Choice Experiment Results and Discussion

Choice Experiment Results

A total of 1,545 observations were obtained from 309 respondents addressing five choice sets each. McFadden's Pseudo R2 value was 0.2478, which indicated further analysis can be performed. The results shown in Table 12 include both the means and standard deviations for five random parameters. These values had to be significant to enable WTP to be determined from the calculated means. The positive values of β2n to β5n that we calculated were statistically significant at the 1% level. However, β1n, which is a parameter of ecosystem service 1 (provision of timber and food), was not significant, given that forests in Singapore do not provide either timber or food. Moreover, β6, which was a parameter of the burden charge, was statistically significant at the 1% level and had a negative coefficient, as expected. The coefficient of the "no adequate plan" option was statistically significant and positive. Some respondents were reluctant to pay for proposed alternatives, but favored another forest policy.

As shown by equation (2), the estimated coefficient represents respondents' marginal WTP to improve the quality of each forest ecosystem service by 1%. WTP values were defined as the mean of the four forest coefficients (β2n, β3n, β4n, and β5n) divided by the mean burden charge coefficient (β6), yielding a negative value, as shown in Table 13. The results revealed that respondents' WTP was highest for ecosystem service 4 ("providing habitats for species and preserving ecosystems"), and lowest for ecosystem service 2 ("moderating extreme events such as landslides, drought, and floods"), as Singapore currently experiences almost no landslides, droughts, or floods. We obtained correlations among the WTPs, as they were estimated at the individual level. As shown in Table 14, the variables were highly correlated. The highest correlation was obtained between ecosystem services 4 and 5. This result was consistent with the finding of Sato et al. (2017), in that the opportunity to experience contact with nature was shown to enhance one's environmental awareness.

Additionally, we investigated the correlations between income and WTP.[7] Carson et al. (2001) identified the effect of income on WTP in a stated preference approach, and previous empirical studies suggested income level has a significantly positive effect on WTP (Jacobsen et al. 2013). In the present study, we found the correlations between income and WTP for each service were 0.020, 0.121, 0.036, and 0.099 for forest ecosystem services 2−5, respectively. These small correlations indicated that annual income did not impact their WTP.

We calculated the averages of four significantly estimated WTP values based on respondents' ethnic backgrounds, and found no notable differences in the values (1.50 SGD for Chinese, 1.44 SGD for Indian, and 1.36 SGD for Malay).

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[7] Although other variables, such as gender and age, might influence on WTP, this has not always been observable (see Glenk et al., 2019). Thus, other variables should be investigated in future research.

Table 12: The results of the random parameter logit model.

			Coefficient	S.E.
Random parameter	**Forest Ecosystem service 1**: provisioning timber and food	Mean	-0.0009	0.0018
		S.D.	0.0179**	0.0021
	Forest Ecosystem service 2: moderating extreme events: landslides, drought, and floods	Mean	0.0066**	0.0015
		S.D.	0.0100**	0.0022
	Forest Ecosystem service 3: preventing global warming by CO_2 absorption	Mean	0.0106**	0.0014
		S.D.	0.0027	0.0035
	Forest Ecosystem service 4: providing habitats for species and preserving ecosystems	Mean	0.0116**	0.0013
		S.D.	0.0040	0.0031
	Forest Ecosystem service 5: providing opportunities for recreation and education	Mean	0.0076**	0.0016
		S.D.	0.0128**	0.0024
Non-random parameter	**Burden charge**		-0.0061**	0.0007
	"No adequate plan" option		2.4831**	0.1696
No. of observations				309*5
Log likelihood function				-1,870.48
McFadden's Pseudo R-squared				0.2478

Note: ** and * denote significance levels of 1%, and 5% levels, respectively.

Table 13: Marginal values of forest ecosystem services (mean value per household per annum).

Forest Ecosystem service 2: moderating extreme events such as landslides, drought, and floods	SGD 1.09
Forest Ecosystem service 3: preventing global warming by CO_2 absorption	SGD 1.75
Forest Ecosystem service 4: providing habitats for species and preserving ecosystems	SGD 1.91
Forest Ecosystem service 5: providing opportunities for recreation and education	SGD 1.24

Table 14: The correlations among the WTPs.

	WTP on Fn. 2	WTP on Fn. 3	WTP on Fn. 4
WTP on Ecosystem service 2 (Moderating extreme events)	-	-	-
WTP on Ecosystem service 3 (Preventing global warming)	0.403	-	-
WTP on Ecosystem service 4 (Preserving ecosystems)	0.408	0.304	-
WTP on Ecosystem service 5 (Recreation and education)	0.460	0.419	0.515

Choice Experiment Discussion

The results suggest that Singaporean residents would be relatively supportive of implementing new policies meant to preserve biodiversity and ecosystems. The Ministry of the Environment and Water Resources (MEWR) released the "Singapore Green Plan 2012", which aimed to promote environmental consciousness among Singaporeans and strengthening the conservation of Singapore's wealth of biodiversity and natural resources (MEWR, 2012). However, the government has not collected taxes earmarked for biodiversity preservation. Accordingly, these results suggest that residents may accept further taxes if they are collected for the purpose of biodiversity preservation.

Although existing studies assessing forest ecosystem service by using stated preference methods have largely focused on recreational values (Christie et al., 2007; Giergiczny et al., 2015; Agimass et al., 2017; Filyushkina et al., 2017), few studies have compared functional forest values, as their incongruity makes it difficult to assess them using the same metric (Kant and Lee, 2004; Vatn and Bromley, 1995). However, in the present study, we considered not only forests' recreational services but also their ecological and environmental functions, confirming that urban residents also appreciate the latter. Respondents ranked the functions of “preventing global warming” and “providing habitats for species and preserving ecosystems” higher than recreational function, indicating that Singapore’s urban forests may already satisfy residents’ demands for recreation to some extent.

Notably, correlations between household income and each calculated WTP values were unremarkable, indicating that WTP is not a significant function of wealth. The marginal WTP that we calculated enabled us to assess the value of a hypothetical forest policy. For example, respondents may agree to pay up to SGD 149.8 for a forest policy that promises improvements of 25% for each of the four significant forest ecosystem services. This value, which amounts to 0.17% of the average household income of the respondents (SGD 88,867), was non-negligible.

Although the WTP values were estimated, there were 100 people who selected Alt. 5 in some of the repeated choice sets. We assumed that they should have consistently selected Alt. 5 in all choice sets if it was their preferred option. However, we acknowledge that it may have been somewhat difficult for respondents to understand the difference between Alt. 4 and 5. Further research should take steps to simplify the “no choice” option. For example, if the CE questionnaire was not be given to respondents who did not feel the need to implement the project itself, this would refine the CE. In addition, a future study should seek a better way to compare multiple forest ecosystem services. Although this study introduced a percent scale for comparison, percent changes of forest ecosystem services may be difficult for respondents to understand.

3.6. Structural Equation Model Results and Discussion

Structural Equation Model Results

We conducted SEM analysis to test the relationships between CNS and WTP and between “contact with nature” and CNS (Kline, 1998). The WTP of forest ecosystem service 1 was not significant in the CE, and was therefore was omitted from the SEM. Figure 5 depicts the model applied to test the relationship between CNS and WTP, and Table 15 shows the statistical values of this relationship. As the analysis was conducted using standardized data, Figure 5 and Table 15 depict standardized coefficients as β. The covariance matrix among error terms for the WTP of each forest ecosystem service was considered in the SEM, as there were non-negligible correlations among them. Each covariance is shown in Table 15.

The results showed that having more nature experience in the past and a higher frequency of visits to nature were significantly linked to higher levels of CNS, indicating that respondents who frequently experienced contact with nature tended to demonstrate high levels of CNS. The use of variables relating not only to present contact with nature but also to past contact enabled a comparison of their relationships with CNS. Evidently, the relationships between past contact and CNS was stronger than that between present contact and CNS. However, it is noteworthy that the methods for constructing indices differed for past and present contacts. Moreover, to examine whether those respondents who had experienced more contact with nature during their childhood also visited natural settings more frequently as adults, we assessed the link between "nature experiences in the past" and "the frequency of visits to nature," which we found to be significant and positive.

Importantly, the main objective of the study was achieved, as the results confirmed that CNS and WTP were interlinked. We tested these relationships with respect to the WTP of participants in the CE for each forest ecosystem service and found significant links between CNS and the participants' WTP for all of the forest ecosystem services. This finding indicates that those with higher CNS levels also demonstrated higher levels of WTP for environmental policies.

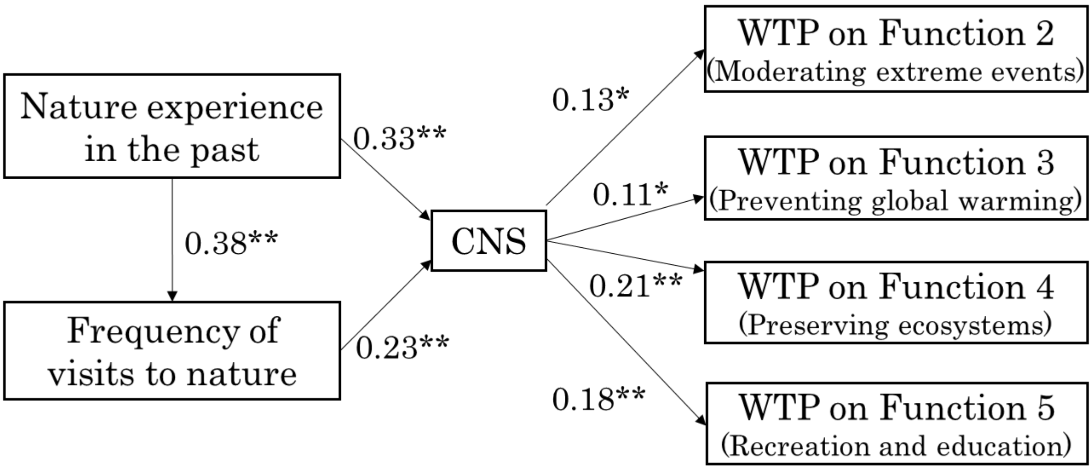

Figure 5: The results of the SEM analysis.

Note: ** and * denote significance levels of 1%, and 5% levels, respectively.

Table 15: Detailed SEM results.

			Coef.	Std. err.	z-value
Nature experience in the past	→	Frequency of visits to nature	0.3777**	0.0470	8.04
Nature experience in the past	→	CNS	0.3346**	0.0504	6.64
Frequency of visits to nature	→	CNS	0.2342**	0.0529	4.43
CNS	→	WTP on Forest Ecosystem service 2	0.1304*	0.0559	2.33
CNS	→	WTP on Forest Ecosystem service 3	0.1118*	0.0562	1.99
CNS	→	WTP on Forest Ecosystem service 4	0.2068**	0.0544	3.80
CNS	→	WTP on Forest Ecosystem service 5	0.1769**	0.0551	3.21
(Covariance)					
WTP on Forest Ecosystem service 2	⇄	WTP on Forest Ecosystem service 3	0.3946***	0.0480	8.22
WTP on Forest Ecosystem service 2	⇄	WTP on Forest Ecosystem service 4	0.3931***	0.0481	8.17
WTP on Forest Ecosystem service 2	⇄	WTP on Forest Ecosystem service 5	0.4473***	0.0455	9.83
WTP on Forest Ecosystem service 3	⇄	WTP on Forest Ecosystem service 4	0.2888***	0.0521	5.54
WTP on Forest Ecosystem service 3	⇄	WTP on Forest Ecosystem service 5	0.4076***	0.0474	8.59
WTP on Forest Ecosystem service 4	⇄	WTP on Forest Ecosystem service 5	0.4965***	0.0429	11.58

Structural Equation Model Discussion

The results of the present study support previous findings on a positive relationship between connectedness to nature and environmental awareness (e.g., Dutcher et al. 2007). However, our study differed from earlier studies in that we conducted a monetary assessment of respondents' environmental awareness, thereby confirming that connectedness to nature plays a non-negligible role from an economic perspective. The strongest link between CNS and WTP was found for ecosystem service 4 ("providing habitats for species and preserving ecosystems"). According to Mayer and Frantz (2004), the CNS measures individuals' sense of oneness with the natural world, sense of affinity with animals and plants, and sense of equality between the self and nature. In light of this concept, the findings of our SEM analysis suggest that the service of preserving ecosystems is most strongly linked to CNS, as those with high CNS scores can be reasonably expected to have a strong affinity with other species and greater willingness to conserve ecosystems and biodiversity.

The second strongest link between CNS and WTP was found for ecosystem service 5 ("providing opportunities for recreation and education"). As suggested by the findings of the present and previous studies, connectedness to nature is partly fostered by childhood contact with nature (e.g., Mayer et al., 2009) and environmental education (e.g., Cheng and Monroe, 2012). Therefore, it seems reasonable to conclude that individuals who had frequent opportunities for contact with nature during childhood are likely to attach relatively more importance to the forest ecosystem service of providing opportunities for recreation and education in adulthood. It is also worth noting that nature experiences in adulthood are significantly linked to CNS. Even if childhood experiences of nature are low, more nature experiences in adulthood are associated with a higher CNS and a more positive attitude towards environmental conservation.

Although the moderation of extreme events (ecosystem service 2) and mitigation of global warming (ecosystem service 3) are also linked to conservation of the natural environment, respondents showed little recognition of the potential benefits that may be obtained from enhancing either of these ecosystem services.

3.7. Conclusion

This study supports the existence of a positive relationship between connectedness to nature and environmental awareness relating to urban ecosystem services from an economic perspective. Connectedness to nature was broadly defined as respondents' subjective sense of connection to the natural world and measured using the CNS, while environmental awareness was narrowly defined in monetary terms as their WTP for forest preservation services and measured through a CE. The results of the SEM revealed a positive relationship between CNS scores and calculated WTP values. Thus, among the respondents, high levels of connectedness to nature tended to correspond with higher levels of WTP for improvements to the quality of forests in Singapore.

The findings of previous studies suggested that individuals' environmental awareness and pro-environmental behaviors are fostered by how they perceive their connectedness to nature. Our study's support for the economic role of connectedness to nature through monetary estimates of WTP further contributes to this literature. However, it should be noted that WTP cannot completely reflect environmental awareness but CE provide us information of forest ecosystem services. Participants with higher CNS scores tended to place more emphasis on the forest ecosystem services of "providing habitats for species and preserving ecosystems" and "providing opportunities for recreation and education." Another important finding of this study is the positive link between CNS and both past and present contact with nature. Thus, we posit that individuals' connectedness to nature can be nurtured in association with their contact with nature, thereby prompting them to endorse the future implementation of environmental policies. Most of all, environmental management methods and policy should set a goal of providing opportunities for residents to experience the natural environment in their neighborhood.

CHAPTER IV[8]

Heterogeneous Preference for Biodiversity based on People's Nature Experiences

4.1. Introduction

This study focuses on the impact of the decline in nature experiences on residents' perceptions of the environment. Previous studies have confirmed that the extinction of experience is progressing in urban areas (Soga and Gaston, 2016). On the other hand, there is a lack of studies focusing on the effects of reduced contact with nature on urban ecosystems. In particular, few studies have focused on how urban residents' perceptions of nearby ecosystems change depending on how much nature experience they have had. In order to design environmental policies that take into account urban residents who have little experience with nature, it is meaningful to understand their perceptions of urban ecosystems.

In cities, ecosystem disservices are more easily recognized by residents than positive ecosystem services (Gómez-Baggethun et al., 2013). This is also because of the heterogeneity of people's preferences in the city. What may be a positive ecosystem service for one person may be viewed as a disservice by another (Agbenyega et al., 2009). Soga et al. (2016) surveyed elementary school students in Tokyo and found that children who visited riverbeds and green spaces less frequently had lower affinities for familiar creatures. These studies indicate that urban residents with reduced nature experiences may no longer desire a natural environment around their homes. However, most previous studies, including Soga et al. (2016), have investigated urban residents' preferences for natural environments and organisms by asking the question, "Do you like organisms?" and other direct questions. In this study, a more objective analysis will be conducted by using biodiversity levels measured in the field, rather than direct questions.

The natural environment can be broadly divided into green and blue spaces, both of which are also present in urban areas. Although the number of papers on green space is larger than that on blue spaces, scholars have started evaluating the ecological resources present in urban blue spaces in recent years. For example, urban residents have reported that walking beside rivers and lakes can provide spiritual healing and enhance their sense of well-being through recreational activities, such as fishing and camping (Dou et al., 2017; Jo et al., 2022). Blue spaces are increasingly recognized as an important factor in improving urban residents' quality of life (Labib et al., 2020; Smith et al., 2021). Urban planners have the potential to improve the residents' quality of life by creating blue spaces in the urban

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[8] This chapter is written based on Aoshima et al. (2023).

area.

Studies have shown that the richer the biodiversity surrounding them, the more positive impacts urban ecosystems have on humans (Díaz et al., 2015; Knight et al., 2022; Pires et al., 2018). Carrus et al. (2015) evaluated biodiversity in Italian urban greens space by establishing a panel of 15 independent experts from the urban forestry sector and found that the richer the biodiversity, the better the self-reported well-being of the residents. Dennis and James (2016) evaluated differences in vegetation in urban green spaces in England through careful field surveys and found a high degree of synergy between site use and biodiversity. However, the lack of research on urban biodiversity, especially in blue spaces, can be attributed to the difficulty in quantifying it (Thomsen and Willerslev, 2015). Observing and ascertaining the number of species inhabiting a field is a time-consuming process. In recent years, however, the eDNA metabarcoding method has emerged as an innovative method to easily determine the biodiversity in blue spaces broadly (Deiner et al. 2017). Together with conventional social assessments, this method has also enabled scholars to analyze people's attitudes and reactions to blue-space biodiversity, which have been difficult to examine in the past.

Therefore, this study investigated how urban residents perceive the biodiversity of these blue spaces. Specifically, this study tests the hypothesis that the more extensive someone's nature experience is, the more positive is the relationship between satisfaction with the urban waterfront area and river biodiversity. Quantitative data measured by the eDNA method is used as an indicator of river biodiversity, and residents' satisfaction with the neighborhood waterfront is measured by questionnaire. However, this study used quantitative biodiversity data for each river, measured by the eDNA method, to analyze its impact on residents' satisfaction with the neighborhood waterfront area. By asking about their satisfaction levels rather than whether they like organisms, enables researchers to analyze whether urban residents would be open to having more biodiversity around their homes. This is because, some people may like living organisms but may not want to actually have a highly biodiverse environment near their residence. Therefore, choosing areas with rivers around the participants' homes as a research setting is of tremendous significance.

Fisher et al. (2021) found that the degree to which waterways contribute to the residents' subjective well-being is greater when waterways are perceived as more natural than artificial. However, this study was conducted in Georgetown, the capital of Guyana, which is surrounded by a lush nature and not in a large city. Contrary Fisher et al.'s (2021) findings, urban residents with reduced nature experience may prefer artificial rather than natural elements around them. Thus, considering existing research and its gaps, this study analyzes whether the impact of biodiversity on residents' satisfaction with waterfront areas varies depending on the extent of their experiences with nature. Given rapid global urbanization, clarifying how urban residents perceive the natural environment as a source of ecosystem services is extremely meaningful for planning the future of our cities.

4.2. Study area

This study focuses on 20 rivers flowing through Kobe, Ashiya, and Nishinomiya cities in Hyogo Prefecture, Japan. CHAPTER II included the Amagasaki City as a target area, but this study does not include the city. As an overview of the area is given in CHAPTER II, this section describes what is known about the rivers in the area. To the north of the study area lies Mt. Rokko, which stretches approximately 30 km from the east to the west. Its highest point is 931 m above sea level, and the ridges running east to west are approximately 700–900 m high. The water flowing out of this mountain drains through rivers in the urban area to the Seto Inland Sea in the south. The distance from the ridgeline to the coast was the shortest in Tarumi Ward, Kobe City, the westernmost part of the target area, at approximately 4 km, and the longest in Nishinomiya City, the easternmost part of the target area, at approximately 10 km (Ministry of Land, Infrastructure, Transport, and Tourism, 2009). The area between the ridge to the sea has almost no flat land and steep slope.

As mentioned in CHAPTER II, Mt. Rokko was designated as a national park in 1956 because of its rich nature and recreational functions, and is a valuable place with a rich natural ecosystem despite its proximity to the city. The rivers in this study, which run along the southern slope of Mt. Rokko, used to serve as a recreational area for urban residents to get in touch with nature. However, after the Great Hanshin-Awaji Earthquake (magnitude of 7.3 ML) occurred in January 1995, many rivers were damaged. After the disaster, revetment work using masonry and concrete retaining walls was conducted, and based on the lessons learned from the disaster, rivers were made disaster-resistant. Meanwhile, in some places, trees were planted along rivers and parks were established (Hyogo Prefectural Kobe Civil Engineering Office, 1997). Considering this background, different rivers have different levels of biodiversity, making this an appropriate area for analyzing the impact of biodiversity on the residents' valuation of rivers.

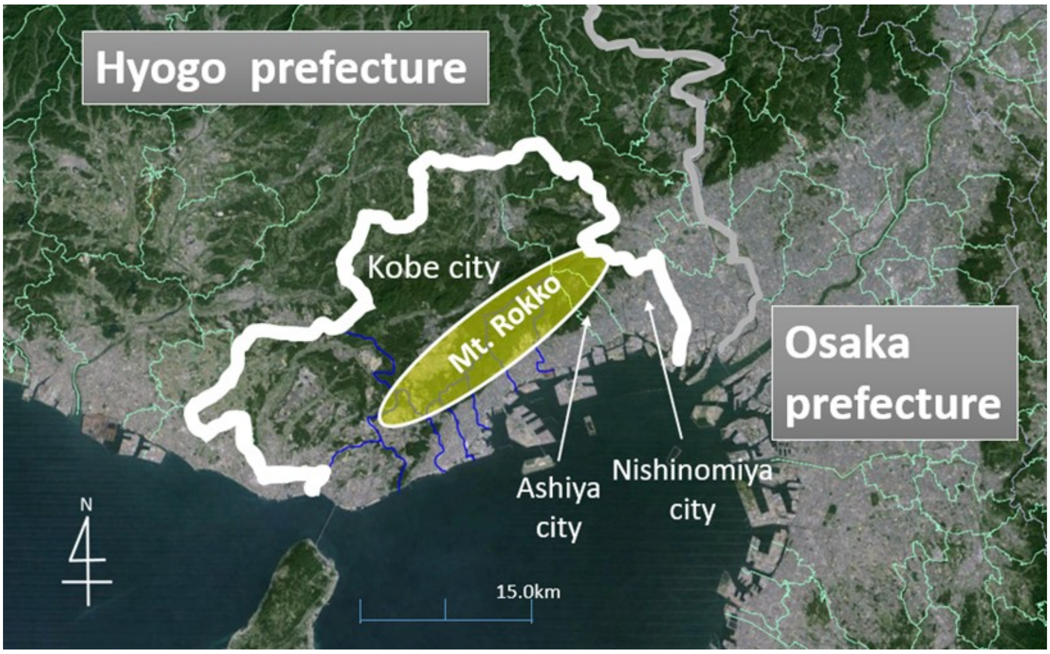

Figure 6: Location of the study area.

4.3. Methodology

4.3.1. Data on eDNA

This study analyzes the relationship between 20 rivers and urban residents living in catchment areas surrounding these rivers. The 20 catchments shown in Figure 7 are identified based on the GIS data published by the Ministry of Land, Infrastructure, Transport, and Tourism (2009). As this study aims to analyze the impact of river biodiversity on people's satisfaction with waterfront areas surrounding these 20 rivers, it is preferable that conditions other than biodiversity do not differ significantly when comparing the 20 rivers. In this respect, the study area is appropriate both geographically, with a similar topography from east to west, and socially, with an insignificant variation in population density and resident demographics. The 20 rivers used as case studies in this study are all classified as "second class rivers" by Japanese standards, and do not differ greatly in size (Hyogo Prefecture, 2022). Most of these rivers are 3–15 m wide, are familiar to residents, and blend into their living space. The river length data in Table 16 were obtained from the Hyogo Prefecture (2021) and the Hyogo Prefectural Land Development Department (2004).

The biodiversity of the rivers were ascertained using eDNA metabarcoding, which is an exhaustive method to detect the taxa of a species such as fish or mammals (Deiner et al., 2017). To perform eDNA metabarcoding on fish, first, the eDNA collected from an environment such as river water is amplified by polymerase chain reaction (PCR). The DNA sequence can then be determined using an instrument called a next-generation sequencer to estimate the species of fish inhabiting the study area. Determining the DNA sequence enables us to determine which fish species live in the rivers simply by collecting approximately 1 L of environmental water at the study site, without using fishing gear, such as hand nets or cast nets, as is done in conventional capture surveys. Studies on biodiversity monitoring using eDNA metabarcoding have been conducted worldwide, focusing on rivers, lakes, coastal areas, and open oceans (Bista et al., 2017; Miya et al., 2015; Port et al., 2016). In addition, although this study focuses on fish, the river water includes various targeted taxonomic groups, including amphibians, mammals, birds, and crustaceans (Komai et al., 2019; Sakata et al., 2022; Ushio et al., 2017, 2018). The focus on fish is significant because previous studies have shown that fish diversity is an important indicator of diversity around a river (Schiemer and Spindler, 1989; Schiemer, 2000).

This study used our eDNA data, measured at 90 sites in 20 rivers flowing through the study area, between October and November 2016. At each study site, 1 L of river water was collected using a polyethylene bucket, which was brought back to the laboratory. After filtering the water samples, the filter papers were kept frozen. DNA was then purified from the filter paper and the resulting DNA sample was used for eDNA metabarcoding. As this study targets fish, a primer set called MiFish (Miya et al., 2015) was used to comprehensively amplify the eDNA of the fish in the DNA samples. The DNA sequences of the fish in each sample were determined using a next-generation sequencer (MiSeq). Dedicated analysis software (MiFish pipeline, Miya et al., 2020) was used to identify the fish species corresponding to the DNA sequences in each sample, which helped estimate the number of fish species present at each study site.

For each river, measurements were taken at three or more points: upstream, midstream, and downstream. However, because this study is focused on the relationship between rivers and neighborhoods, measurements were not taken in upstream areas where few people live. Consequently, the mean and median values of fish species for each river measurement site were both 4.5. As shown in Table 16, the 312 survey respondents resided across 20 river catchments, with a mean (median) value of 15.6 (15.5) participants residing in each catchment.

Biodiversity was quantified in terms of the average number of species at several measurement points along each river. For example, if eDNA is measured at three sites, the biodiversity level of that river was calculated as the total number of species identified at each site divided by three. Using the average values measured at multiple sites, rather than only at one site, allows us to capture trends in biodiversity across the river, rather than using local values. In addition, as this study focuses on biodiversity, we do not focus on the number of individuals per species, but only on the number of species.

Table 16 shows the biodiversity points in each river obtained from the eDNA measurements. Each river has an average of 8.4 fish species living in it. The most abundant species were freshwater fishes such as *Rhinogobius flumineus*, found in 70 of the 90 sites, followed by *Nipponocypris temminckii* and *Cyprinus carpio,* found at 64 and 49 sites, respectively. The *Thunnus albacares* was the most commonly found saltwater fish species (18 sites). As expected, pristine rivers had the higher biodiversity (Images 1 and 2), than artificial rivers paved with concrete (Images 3 and 4).

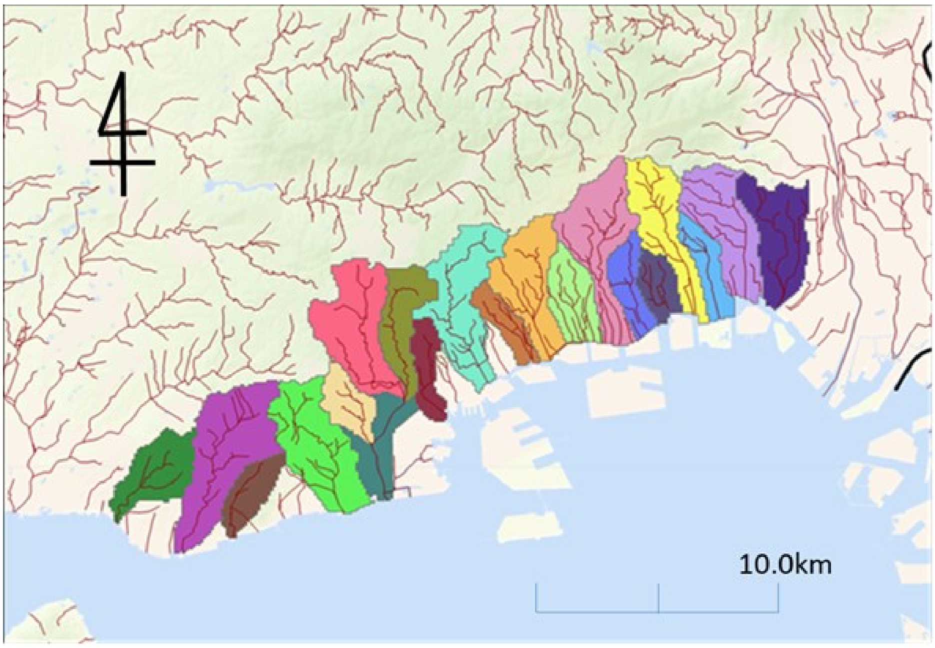

Figure 7: Location of the 20 catchment areas.

Images of the rivers

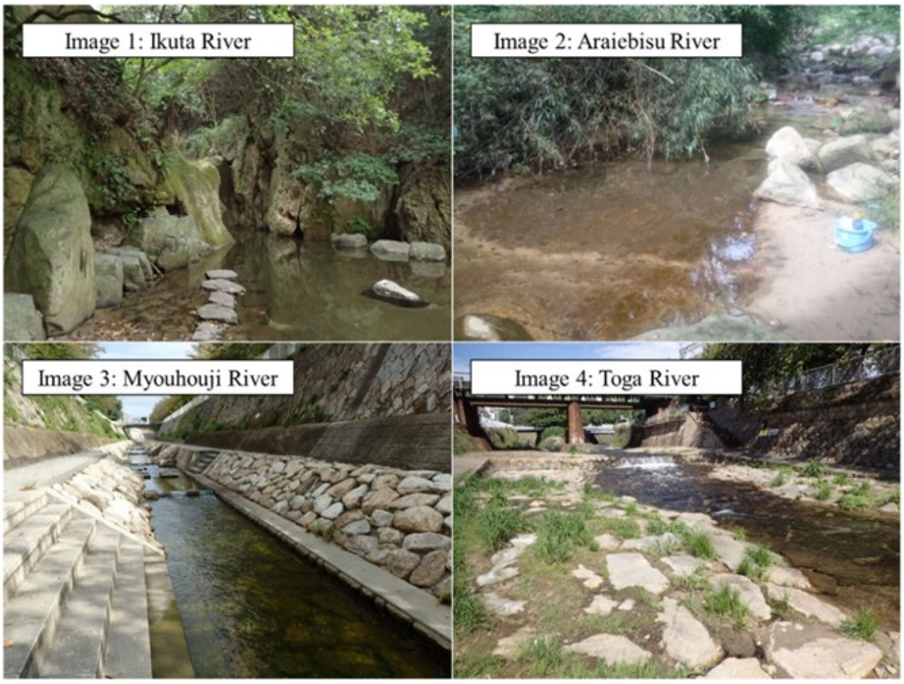

Table 16: Biodiversity points in each river.

River	Length (km)	Analyzed residents of each watershed	Biodiversity point
Higashi River	5.29	35	11.5
Araiebisu River	1.86	31	9.0
Miya River	3.07	15	10.7
Ashiya River	4.54	9	11.4
Takahashi River	1.41	16	10.7
Tenjou River	2.51	10	5.8
Sumiyoshi River	3.60	17	9.2
Tenjin River	2.88	31	6.7
Toga River	1.79	19	5.2
Saigou River	2.32	12	6.0
Ikuta River	1.79	16	14.6
Uji River	2.27	3	9.8
Shinminato River	4.70	17	15.8
Karumo River	0.44	3	6.5
Ishii River	2.20	11	4.0
Tennoudani River	4.12	3	4.5
Myouhouji River	6.98	19	4.3
Shioyadani River	3.46	11	7.5
Hukuda River	7.41	21	7.0
Yamada River	3.84	13	7.7
Median	2.98	15.5	7.6
Averege	3.32	15.6	8.4
Total	66.48	312	167.7

4.3.2. Data on Social Survey

To analyze the relationship between the biodiversity in the neighborhood river and urban residents' satisfaction, we utilized data from a social survey to determine urban residents' perceptions of and satisfaction with the natural environment. The data were extracted from an Internet-based survey targeting residents in December 2016. All the content of the surveys was prepared by the authors, and Nikkei Research prepared the response format, distributed it to the respondents, and compiled the data. Nikkei Research conducted the survey based on its own ethical standards, and in addition, the survey was ethically reviewed by the Research Ethics Review Committee of Kobe University, to which the authors belong (Review No. 132), to ensure that there were no ethical issues with the survey content and methods. To prevent a sampling bias, prefectural demographics such as population, sex, and age ratios were considered during the survey. Of the original 1,013 responses received for this survey, 465 were used for subsequent analyses after excluding respondents who did not provide their addresses and did not live in the 20 catchment areas. After excluding those who did not respond to the indicators that served as control variables, a total of 312 responses were included in the analysis. Table 17 shows the number and ratio of respondents classified by sex, age, and address. The respondents' addresses were identified at the Zip-code level. The 312 final respondents resided in 208 zip codes.

Table 17: Demographic statistics for survey respondents.

			Obs.	Ratio (%)
sex		Male	180	58%
		Female	132	42%
age		20s	27	9%
		30s	58	19%
		40s	83	27%
		50s	78	25%
		60s	49	16%
		70s	11	4%
		80s	6	2%
Address	Kobe city	Higasinada ward	61	20%
		Nada ward	44	14%
		Hyogo ward	10	3%
		Tyuo ward	19	6%
		Nagata ward	14	4%
		Suma ward	24	8%
		Tarumi ward	37	12%
		Kita ward	13	4%
	Ashiya city		26	8%
	Nishinomiya city		64	21%

4.3.3. Model for Estimation

Using the eDNA and social data introduced in the previous sections, the extent to which biodiversity contributes to people's satisfaction with waterfront areas is statistically analyzed. Descriptive statistics for each variable, including the control variables, are presented in Table 18. The dependent variable is the respondents' satisfaction with their neighborhood waterfront area, which was captured using the question, “Are you satisfied with the waterfront area within a 10-minute walk from your home where you can go and play?” The participants responded on a scale ranging from 0 (extremely unsatisfied) to 10 (extremely satisfied). The subjective measures of satisfaction have been used in numerous previous studies as dependent variables when conducting a regression analysis (Diener 2009; Frey and Stutzer, 2010).

The main independent variables in this study are "river biodiversity" and "nature experiences." River biodiversity data were obtained using the procedure described in Section 4.3.1. The respondents' level of nature experiences was ascertained through the social survey. Using responses obtained from the social survey, a dummy variable was created using the procedure described below. Respondents were asked to recall their experiences relating to nature prior to attending junior high school, “How often did you experience picking, breeding, or raising animals and plants?” “How often did you experience playing in mountainous, river, or ocean environments?” “How often did you experience visiting relatives or friends in the countryside with natural environments?” “How often did you experience seasonal events such as *Setsubun*, *Higan*, and *Sekku* at home?” They responded to these four questions on a scale ranging from 1 (not at all) to 4 (often). Those who responded positively (3 or 4) to all four questions were scored 1, and all others were scored 0. For this dummy variable, 161 respondents scored 1, while 151 scored 0. Similar indicators have been used in previous studies as factors that can influence people's perceptions of and attitudes toward the environment (Sato et al., 2017).

In addition, the impact of "nature experiences" on the relationship between "satisfaction with the neighborhood waterfront area" and "river biodiversity," was analyzed by incorporating a cross term between "river biodiversity" and "nature experiences" into the model. Prior research suggests that the richer a person's experiences with nature in their childhood, the more they will love nature as an adult (Soga et al., 2016). Accordingly, we assume that the more extensive someone's nature experience is, the more positive is the relationship between satisfaction with the waterfront area and river biodiversity.

We use the following control variables in this study. First, as we expect the respondents' satisfaction with blue spaces to increase with the increase in the frequency of their visit to such spaces, we use a four-point scale of frequency as an independent variable. Next, as the distance to blue spaces is another important factor, the GIS-measured values of the linear distance from the residence to the river and to the sea are also included in the regression analysis. Knowledge of the river can also influence river satisfaction. Therefore, we prepared six questions regarding river functions and obtained the index level of knowledge of river functions by simply summing the five levels (5: deep knowledge, 1: lack of knowledge) of subjective knowledge on each function. Diener (2009) reported that factors such as gender, age, and income can influence satisfaction indices. Hence, these indices are also employed as independent variables in this study. Gender is a dummy variable with 1 for females and 0 for males.

The estimation model is shown in equation (1). As this indicator is an ordinal scaled variable, we apply the ordinal probit model for the estimation. X_k is an independent variable, which is the quantified biodiversity of a river as ascertained by eDNA methods, as well as the control variables, such as socioeconomic characteristics of the survey respondents. i is the individual to be surveyed, ε is the error term, and α and β are the parameters to be estimated by regression analysis.

$$Y_i = \alpha + \sum_{k=1}^{n} \beta_k X_{ki} + \varepsilon_i \tag{1}$$

Table 18: Descriptive statistics.

Variable	Unit	Mean	Std. Dev.	Min.	Max.
Stisfaction with waterfront area	Index	5.41	2.22	0	10
Female dummy	-	0.423	0.495	0	1
Age	Year	48.3	13.7	20	87
Income	10,000-Yen	379	343	100	1750
Distance to the river	Meter	219	166	2.32	898
Distance to the sea	Meter	1941	1300	186	6490
Frequency of visits (to blue spaces)	Index	1.55	0.772	1	4
Knowledge of the river	Index	20.6	5.17	6	30
Nature experience in the past	Index	0.516	0.501	0	1
Biodiversity point of river	Species	8.74	3.20	4.0	15.8

4.4. Results

Before estimating equation 1, the correlations for each variable are shown in Table 19. Except for the cross term, the correlations between any variables do not exceed an absolute value of 0.5. Therefore, the problem of multicollinearity is negligible. There seems to be a high correlation between nature experience in the past and frequency of visits to blue spaces, but the absolute value is less than 0.1. Some previous studies have shown that people with more past nature experiences have more current contact with nature (Sato et al., 2021), but the correlation analysis do not show such a trend in this study. This may be partly due to the fact that urban blue spaces are surveyed in this study, but additional research is needed on this topic in the future.

The results of estimating equation (1) are presented in Table 20. The estimated model was an ordinal probit with 312 observations. The estimated model's pseudo R-squared is 0.0435, which is acceptable for a regression analysis with subjective indicators as dependent variables. All independent variables are significant except for age, income, and the distance from home to the sea. The coefficient for the female dummy variable was positive, indicating that women were more satisfied with the neighborhood waterfront area. General happiness and life satisfaction are also higher for women, which is consistent with Diener's (2009) finding. The coefficient of the distance from home to the river was estimated to be negative, indicating that as expected, the greater the distance to the river, the lower the respondents' satisfaction with their neighborhood waterfront area. The coefficient for the frequency of visits to blue spaces was positive. This result was expected, because we assumed that those who are satisfied with blue spaces are likely to visit them more often. The coefficient for knowledge about the river was also positive.

As the model includes a cross term between river biodiversity and nature experiences, the coefficients of the three terms must be interpreted in a composite manner, which allows us to check whether the impact of biodiversity on satisfaction varies depending on the amount of nature experiences. As shown in Figure 8, this study focuses on the sum of the coefficients of nature experiences, river biodiversity, and the cross term of the two. As nature experience is a dummy variable, Figure 8 distinguishes between the trends for those with rich and poor childhood nature experiences. The coefficient for river biodiversity is negative, suggesting that the higher the biodiversity, the lower the satisfaction with the waterfront area for those with poor natural experiences. However, the coefficient of the interaction between nature experiences and biodiversity is positive, and its absolute value is greater than the absolute value of the coefficient of river biodiversity. Thus, for those with rich nature experiences, the higher the biodiversity, the higher their satisfaction with the waterfront area. The coefficient of nature experiences is negative, and in Figure 8, the vertical axis intercept for those with rich nature experiences is also negative.

As shown in Figure 8, the sum of the coefficients of the above three variables (nature experience, river biodiversity, and their interaction term) are negative in almost all ranges. Negative values indicate that the combination of biodiversity and nature experiences negatively impact satisfaction. Theoretically, the horizontal axis intercept for those with rich nature experiences is 50.7. It indicates that the combination of biodiversity and nature experiences positively impacts satisfaction only when the biodiversity point exceeds 50.7. Note that the biodiversity point of 50.7 is not a realistic value, because even the river with the highest biodiversity measured in this study had a biodiversity point of 15.8, as shown in Table 16. Figure 8 also shows the intersection of people with rich and poor childhood nature experiences when the biodiversity of the river was 9.18. This indicates that theoretically, people with poorer childhood nature experiences are more satisfied with the river when the river biodiversity is less than 9.18, whereas people with more childhood nature experiences are more satisfied with the river when its biodiversity is greater than 9.18. As the median biodiversity of the river in this study is 7.6, 9.18 is slightly above the median, as shown in Table 18.

Table 19: Correlation coefficients of variables.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Female dummy	1								
2. Age	-0.131	1							
3. Income	-0.470	0.132	1						
4. Distance to the river	0.004	-0.002	-0.047	1					
5. Distance to the sea	-0.054	-0.000	0.047	0.087	1				
6. Frequency of visits (to blue spaces)	-0.040	0.125	0.079	-0.065	-0.047	1			
7. Knowledge of the river	-0.077	0.176	0.117	-0.082	0.020	0.145	1		
8. Nature experience in the past	0.012	0.079	0.030	0.008	0.075	0.069	0.123	1	
9. River biodiversity (eDNA)	0.071	-0.020	0.003	0.020	-0.238	-0.071	-0.096	0.003	1
10. Cross term (eDNA X Nature experience)	0.015	0.065	0.032	-0.006	-0.026	0.067	0.087	0.883	0.343

Table 20: Results of the regression analysis.

Variable	Coef.	Std. Err.	t-value
Female dummy	0.301033 **	0.133967	2.25
Age	-0.000035	0.004331	-0.01
Income	0.000049	0.000193	0.25
Distance to the river	-0.000638 *	0.000354	-1.80
Distance to the sea	-0.000021	0.000046	-0.45
Frequency of visits (to blue spaces)	0.449328 ***	0.079093	5.68
Knowledge of the river	0.023706 **	0.011687	2.03
Nature experience in the past	-0.729700 **	0.340873	-2.14
River biodiversity (eDNA)	-0.065072 **	0.027126	-2.40
Cross term (eDNA X Nature experience)	0.079457 **	0.036609	2.17

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

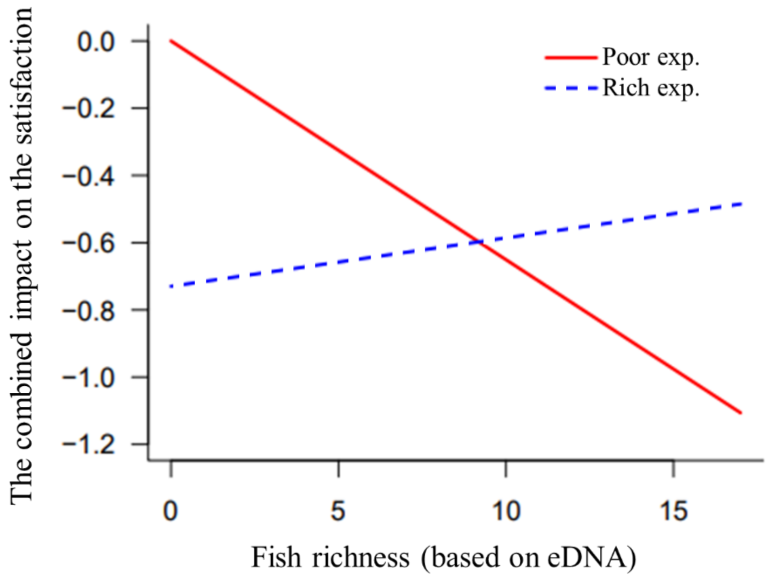

Figure 8: The combined impact of the three variables (nature experiences, river biodiversity, and their cross term) on satisfaction with waterfront area.

The vertical axis in Figure 8 is the sum of the three coefficients, in other words, the combined impact of the three variables on satisfaction with waterfront area. The horizontal axis, fish richness, refers to river biodiversity as determined by the eDNA method. As childhood nature experience is a dummy variable, the two straight lines reflect two trends for those with rich and poor childhood nature experiences.

4.5. Discussion

First, the results suggest different effects of river biodiversity on satisfaction between people with rich and poor nature experiences. As presented in the hypothesis, the study found that people with fewer childhood experiences with nature tended to prefer rivers with lower biodiversity. Therefore, even if a river with high biodiversity is created in a residential area, it may result in lower satisfaction for those with limited childhood experiences with nature. For many residents living in large cities, blue spaces are used for feeling mentally refreshed (Labib et al., 2020; Smith et al., 2021) and are valued more for their convenience and recreation opportunities rather than for their biodiversity. Prior studies have shown that those with more nature experiences in childhood are more nature loving as adults (Sato et al., 2021). Our results also suggest that childhood experiences with nature are important as a factor in forming preferences for nature in adulthood.

As shown in Figure 8, people with rich nature experiences are not satisfied with the current biodiversity levels. Even when considering the rivers with the highest biodiversity in this study (at 15.8 points), the impact of river biodiversity on satisfaction with the waterfront area is negative. The number of fish species would have to be approximately triple for the river biodiversity to have a positive impact on satisfaction. Someone with a rich experience of nature will find it difficult to derive satisfaction from the biodiversity in their neighborhood's urban river. This could be due to two factors. The first is that the rivers in the area covered by this study are rivers with low biodiversity when compared to typical rivers in Japan. The second is that people with more experience of nature are likely to demand a higher level of natural environment, and therefore cannot get a positive impact from the current biodiversity. However, this does not mean that the biodiversity of urban rivers should be neglected; creating and preserving a rich natural environment is important because urban rivers are one of the few places where urban residents can interact with nature.

The target area of the study is a part of the megacities in Japan, and most of the rivers analyzed are paved with concrete, except in the upper reaches. While previous studies have shown that rivers rich in nature contribute to people's well-being in rural areas (Fisher et al., 2021), this study focused on highly populated urban areas. Some rivers are paved with concrete but have walking paths and other facilities that allow neighborhood residents to engage in recreational activities, whereas others are overgrown with grass and sediment on top of the concrete, leaving no room for residents to enter. Rivers with bare concrete tended to have low biodiversity, whereas rivers with thick grass tended to have high biodiversity. Therefore, well-maintained rivers with high recreational capacity seemed to have lower biodiversity than wild rivers with low recreational capacity.

Previous studies have shown that creating biodiversity-rich natural environments in urban areas can greatly increase residents' life satisfaction (Elmqvist et al., 2015). However, this study suggests that rich biodiversity does not necessarily increase neighborhood residents' satisfaction. Depending on their experiences with nature, some residents might value a river more for its recreational capacity rather than its rich biodiversity. If this is the case, then it is desirable for rivers to have both rich biodiversity and recreational capacity. However, these two characteristics are often in a trade-off relationship. To preserve urban biodiversity, residents' understanding of biodiversity should be deepened through recreational activities on rivers. However, presently biodiversity conservation appears to be neglected in rivers that emphasize recreational capacity. One recommendation is to intentionally create both types of rivers separately so that residents can use the rivers according to their intended use. Further research is required to explore the ways in which the rivers' recreational capacity and biodiversity can be balanced by analyzing the relationship between these aspects.

4.6. Conclusion

This study found that the relationship between the biodiversity of blue spaces and neighborhood residents' satisfaction with waterfront areas varies significantly depending on the extent of their childhood nature experiences. Previous studies have shown that the decline in urban residents' nature experiences is a critical issue for the conservation of urban ecosystems, and this study reinforces the results of previous studies. However, many of these studies have analyzed the impact of reduced nature experiences on people’s emotional affinity toward nature, not on their perceptions and feelings toward biodiversity. In this regard, this study focused on biodiversity measured quantitatively using the eDNA method. The model output shows that the relationship between biodiversity and satisfaction with neighborhood rivers is influenced by childhood nature experiences. This analysis shows that the decrease in nature experience lowers not only people’s subjective emotional affinity toward nature, but also their objectively measured appreciation of biodiversity.

The dilemma facing policymakers and conservation experts is that while biodiversity positively impacts people's well-being and mental health, urban residents who have had little experience with nature in their childhood may not want a highly biodiverse natural environment around their homes. In the long run, this dilemma can be resolved by expanding urban residents’ nature experiences and fostering an emotional affinity toward nature. However, encouraging residents to experience nature in urban areas is difficult, and given this decline in people’s nature experiences has been happening for some time already. For instance, parents who have had little experience with nature are not likely to promote positive nature experiences for their children (Soga and Gaston, 2016). Thus, policymakers should strive to form natural environments that those who derive low satisfaction from high biodiversity would want to visit with their children. However, as discussed in the Discussion section, too much emphasis on recreational capacity to attract people may lead to neglect of the natural environment’s biodiversity. Thus, understanding how to strike a balance between these two aspects requires further research on the relationship between the urban biodiversity and urban residents.

It is important to note, however, that the results of this study do not provide definitive information on why rivers with lower biodiversity are satisfying for some residents. As mentioned above, there may be a trade-off between biodiversity and recreational capacity. A more detailed discussion of this issue would require quantification of recreational capacity, and analysis of its relationship with waterfront satisfaction. As the rivers in this study are overall low biodiversity rivers, a similar case study in a river with richer biodiversity would provide other meaningful insights. Given that the level of demand for the natural environment increases with increasing experience of nature, it would also be useful to examine the impact on satisfaction of the growing gap between expected and current levels of biodiversity. Although this study focused only on underwater biodiversity, it would also be useful to investigate biodiversity such as vegetation. If it becomes clear what factors contribute to the level of waterfront satisfaction, it will be possible to make more concrete policy recommendations regarding the creation of urban rivers.

CHAPTER V[9]

The Influence of Subjective Perceptions on the Valuation of Urban Green Spaces

5.1. Introduction

In CHAPTER II, the marginal value of a 1 ha increase in green spaces around one's home was estimated by LSA. Other previous studies that have applied LSA to estimate the value of urban green spaces have also used the physical area of green spaces (Ambrey and Fleming, 2014a; Krekel et al., 2016). However, as suggested in CHAPTER IV, it is important to take into account residents' subjective perceptions of urban ecosystems when valuing urban areas. The importance of taking into account the perceptions of residents increases, especially in the context of the urgent need to encourage urban residents to have more contact with nature, which is on the decline (Soga and Gaston, 2016). Against this background, this chapter focuses not only on the physically measured green space area, but also on urban residents' subjective perception of the extent of green spaces.

The extent of green spaces that is self-reported by residents is one of the key criteria determining requirements for new greening projects. However, few studies have focused on determinants of the self-reported extent of green spaces. This is partly because policymakers implicitly assume that residents share a common recognition of same-sized green spaces, irrespective of their individual features. Nevertheless, there is a possibility that the self-reported extent of green spaces may fluctuate (Leslie et al., 2010). Jiang et al. (2017) found an evident difference in the tree cover densities measured by remote sensing and perceived by residents at eye-level. Kothencz and Blaschke (2017) found a discrepancy between respondents' subjective evaluations of urban parks and objective environmental indicators. They consequently argued that both should be considered by land planners. An exploration of the determinants of the self-reported extent of green spaces is important for effective decision making on greening projects or policies.

Thus, the first objective of this study was to analyze the influence of different features of green spaces on the extent of neighborhood green spaces self-reported by residents. This required identification of the features of physical green spaces. A geographical information system (GIS) map was developed, with information about physical green coverage provided through aerial photographs. Land utilization of urban green spaces is a salient feature of green spaces. For example, the benefits of green spaces located around shrines for residents in the neighborhood are relatively substantial because these spaces usually have old trees and rich biodiversity, especially in Japan (Ishii and Iwasaki,

[9] This chapter is written based on Aoshima et al. (2018).

2008; Ishii et al., 2010). The characteristics of green spaces are presumed to differ, depending on their land use classification. Land utilization is also a criterion for decision making regarding greening projects. Thus, each type of green space within a land-use database, such as those in shrines, parks, and schools, is identified individually in terms of its land-use category. These data can be used to analyze whether residents' self-reporting of green spaces fluctuate according to the type of green space.

Importantly, the discrepancy between physically measured data and self-reported data is a topic of considerable controversy in the context of environmental valuation (Adamowicz et al., 1997; Van Praag and Baarsma, 2005; Armbrecht, 2014). This issue also applies to the use of the life satisfaction approach (LSA), which is a method of environmental valuation (Welsch, 2007; Frey et al., 2010). In the LSA, the values of targets are calculated based on their influence on self-reported life satisfaction. Physically measured data are used to calculate the values of urban green spaces (Ambrey and Fleming, 2014a; Tsurumi and Managi, 2015; Krekel et al., 2016). However, Hur et al. (2010) found that the self-reported attributes of green spaces were associated more strongly with residents' satisfaction than their physically measured attributes. This finding implies that the physical areas of green spaces are subjectively filtered through residents' perceptions. Consequently, the values of green spaces estimated using the LSA may potentially fluctuate depending on whether they are based on objectively measured or subjectively reported data. Because political decision-making is often based on people's subjective statements, assessing the influence of self-reported attributes of green spaces on their life satisfaction is critical for estimating the values of green spaces.

Therefore, a second objective of this study was to apply the LSA to explore differences in estimated monetary values between a physically measured area of green space and the self-reported extent of this area. It is noteworthy that the units of the two datasets in this study differed. A Likert scale was used for self-reported data, whereas a hectare-based scale was used for physical data. A two-stage least-squared (2SLS) analysis was used to compare these two datasets. Accordingly, the self-reported extent of green spaces was used as an intermediate variable between physical green spaces and life satisfaction. The results of this analysis indicated the extent to which self-reported data filtered the effect of physical data on life satisfaction.

In sum, two questions were investigated in this study. In Study V-1, the extent to which the features of green spaces influenced their self-reported extent was assessed. In Study V-2, differences in values estimated using the LSA for the two analyses were obtained. On the one hand, self-reported green spaces were used as an intermediate variable between physical green spaces and life satisfaction, while on the other hand, this intermediate variable was absent.

The remainder of the paper is organized as follows. In the Section 2, the survey area and data on green spaces and respondents are described. Subsequently, Study V-1 and V-2 are outlined in the Section 3 and 4, respectively. In each section, the methods, results, and discussions are presented. The conclusions of the study, presented in the Section 5 of the paper, highlight some of the political implications of the above analyses and discussions for urban planners. In particular, the importance of considering people's perceptions in the valuation of urban green spaces within planning to promote effective use of spaces is emphasized.

5.2. Data

5.2.1. Respondents in the Social Survey

As shown in the Figure 2 (reprint), the study area is same as CHAPTER II and comprised four cities in Hyogo Prefecture in Japan: Kobe, Ashiya, Nishinomiya, and Amagasaki cities. Its selection as the study area enabled a simultaneous focus on the dispersed green spaces within an urban area and an adjacent peri-urban forest. It was assumed that residents' perceptions of these urban green spaces and peri-urban forest would differ given substantial differences in their ecological and recreational roles. Generally, urban residents visit dispersed urban green spaces more frequently than they do peri-urban forests because the former are more accessible. A focus on this site enabled an investigation of whether people's perceptions of the extent of urban green spaces and peri-urban forests differ, even in relation to green spaces of the same size.

Data extracted from the results of an Internet-based survey targeting residents in the study area, conducted by Nikkei Research Inc. in November and December 2015, were used for the study. To prevent sampling bias, prefectural demographics, such as population, sex, and age ratios were considered in the survey. Of the original 1,240 responses received for this survey, 1,189 were considered valid for the subsequent analyses after excluding respondents who did not provide their addresses. Respondents' addresses were identified at the Zip-code level. The 1,189 respondents were distributed across areas covered by 562 Zip codes, each of which was 41.2 ha on average, with a median area of 19.0 ha. Table 21 shows the numbers and ratios of respondents classified by sex, age, and address. It also presents the actual demographic statistics for the area to ensure the similarity of demographics between respondents and the actual population distribution.

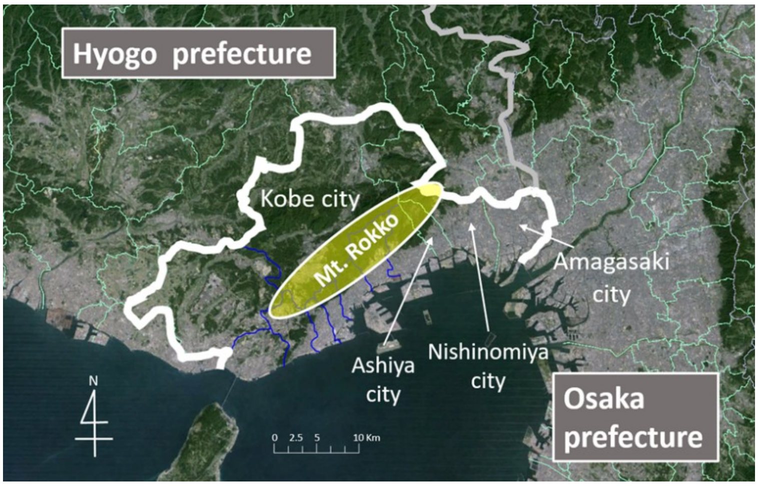

Figure 2 (reprint): Location of the study area.

Table 21: Demographic statistics for survey respondents.

			Demographic statistics of respondents		Actual demographic statistics	
			Obs.	Ratio (%)	Pop. (thou.)	Ratio (%)
Sex		Male	609	51.35	1217	47.31
		Female	577	48.65	1355	52.69
Age		20s	185	15.60	248	15.36
		30s	216	18.21	309	19.15
		40s	277	23.36	389	24.12
		50s	245	20.66	309	19.19
		60s	263	22.18	358	22.18
Address	Kobe City	Higashinada Ward	126	10.62	214	8.32
		Nada Ward	62	5.23	136	5.29
		Hyogo Ward	47	3.96	107	4.16
		Tyuo Ward	55	4.64	135	5.25
		Nagata Ward	40	3.37	98	3.81
		Suma Ward	73	6.16	162	6.30
		Tarumi Ward	91	7.67	219	8.52
		Kita Ward	79	6.66	220	8.56
		Nishi Ward	110	9.27	246	9.57
	Ashiya City		69	5.82	95	3.70
	Nishinomiya City		261	22.01	487	18.94
	Amagasaki City		173	14.59	452	17.58

Note: These demographic statistics are based on data derived from the national population census conducted in 2015.

Source: Ministry of Internal Affairs and Communications Statistics Bureau (2017).

5.2.2. Data on Green Spaces

As shown in Table 22, two types of data on green spaces were used in the study: self-reported data and physical data. Self-reported data were obtained as responses to one of the questions in the abovementioned survey. Respondents were asked to respond to the question, "How many green spaces are there within a 10-minute walk from your house?" based on a Likert scale ranging from 1 (very few) to 10 (a lot). This question is in line with questions used by Hur et al. (2010), in that respondents were asked to provide their perceptions regarding the extent of neighborhood vegetation using a Likert scale.

Following the approach adopted in studies that examined the relationship between the neighborhood green coverage rate and human well-being (Ambrey and Fleming, 2014a; Tsurumi and Managi, 2015; Krekel et al., 2016), GIS-derived physical data were obtained as follows. First, a GIS-based green coverage map was developed with reference to aerial photos taken in the period 1994–2007 and made public by the Geospatial Information Authority of Japan (2010). By superimposing aerial photos on to the GIS-based map, we were able to identify each green space by tracing its outline manually. This method has the advantage of producing accurate outlines of green spaces. It should be noted that "green spaces" were defined as densely wooded areas in this study. This meant that anything resembling a park without wooded space, or only comprising a lawn area, was excluded from the study. Although use of the latest available aerial photos was desirable, these images did not cover all of the study locations. Consequently, older photos were used. To address the problem of possible changes in the classification of land use since the time of taking the aerial photos, areas where the classification of land use had clearly changed were determined individually, and land use information was updated with reference to Google Maps. For example, green spaces that were subsequently developed as residential areas after aerial photos had been taken were modified based on data provided in Google Maps. Next, and again referring to land use data provided in Google Maps, every single green space was manually classified into one of two categories: a dispersed green space within an urban area, and a peri-urban forest adjacent to a highly urbanized area. Moreover, dispersed green spaces in urban areas were further subdivided into four categories: the green spaces of schools, parks, and shrines and a further category of other green spaces. Fig. 2 shows the original GIS map in which shaded areas denote green spaces.

Using this map, the sizes of green spaces were calculated in relation to each respondent based on the reported address. Specifically, each respondent's address was plotted on the GIS at the Zip-code level, and circles with a radius of 800 m were drawn that extended from the center point of each Zip-code area. Then, the physical sizes of green spaces within the range of each circle were calculated. These sizes were calculated separately for each type of green space, namely forest, the green spaces of schools, parks, shrines, and other green spaces.

Tsurumi and Managi (2015), who also used the LSA to calculate the physical size of green spaces in Japan, found that green spaces located within a radius of 100 m to 500 m were more influential than those within other radiuses extending from 0 m to 2,000 m. However, applying 1,000 m as the radius, Krekel et al. (2016) found a positive relationship between the green coverage rate and residents' satisfaction. Using the green coverage rate for each administrative district, assumed to take the shape of a circle, and a median radius of approximately 750 m, Ambrey and Fleming (2014a) also found a positive association between green spaces and life satisfaction. The findings of the above studies indicate that no definitive range exists for analyzing the effect of neighborhood green spaces on human well-being. In the present study, 800 m, calculated as the distance that an average person could walk in 10 minutes, was adopted as the circle radius. Thus, this distance is aligned with the survey question in which respondents were asked to self-report the extent of green spaces based on the criterion of a 10-minute walk.

Table 22: Definitions of green spaces in CHAPTER V.

			Definition
Self-reported extent of green spaces			The subjective degree of neighborhood green spaces (1-10 Likert-scale, where 1 = very few, and 10 = many)
Physical size of green spaces (calculated using a circle with an 800 m radius from the centroids of addresses)	Forest		Physical size of peri-urban forests located next to a highly urbanized area (ha)
	Urban green spaces		Physical size of green spaces scattered in an urban area (ha)
		School's green spaces	Physical size of green spaces on the grounds of schools (ha)
		Park's green spaces	Physical size of green spaces on the grounds of maintained parks (ha)
		Shrine's green spaces	Physical size of green spaces on the grounds of shrines or temples (ha)
		Other green spaces	Physical size of green spaces on grounds other than listed above, such as riverside green and derelict green (ha)

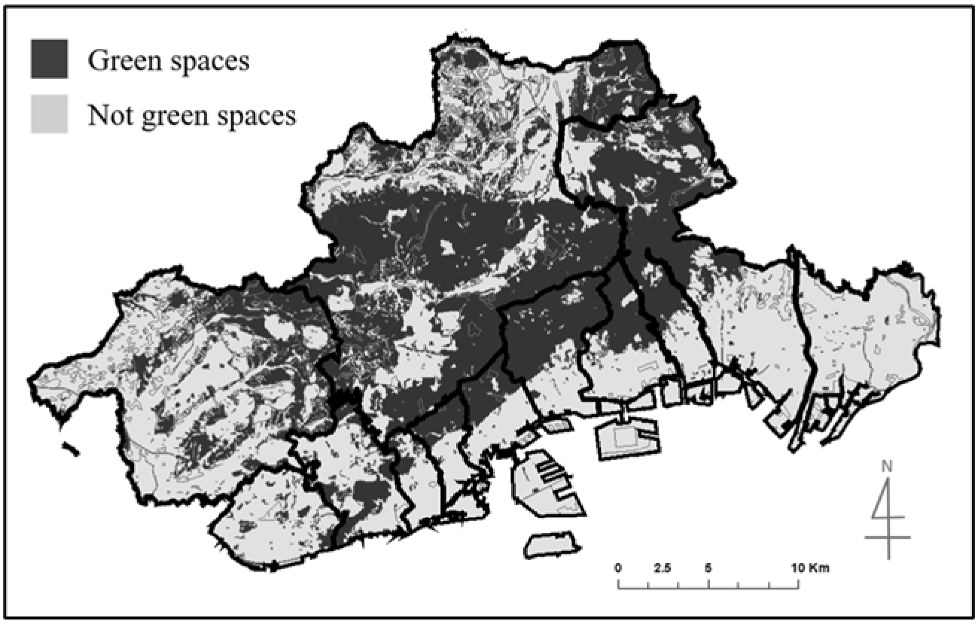

Figure 3 (reprint): Physical data on green spaces obtained using GIS in the study area.

5.3. Study V-1: Determinants of Subjective Perceptions of the Extent of Green Spaces

5.3.1. Method Applied for Study V-1

A multiple regression analysis was performed to calculate the effects of different types of green spaces on their self-reported extent. The self-reported extent of green spaces was used as the dependent variable, and each type of physical green space was used as an independent variable, as shown in Eq. (1).

$$Self\text{-}reported\ extent\ of\ green\ spaces_i = \sum_{k=1}^{n} \gamma_k X_{ki} + \varepsilon_i \qquad (1)$$

where i denotes each respondent, X denotes each type of physical green space, and ε denotes the error term. Because the dependent variable was of an ordinal scale, an ordered logit model was applied. Table 23 presents a summary of the data used in this section.

Table 23: Descriptive statistics for green spaces (n = 1,189).

Variable	Unit	Mean	Std. Dev.	Min.	Max.
Self-reported extent of green spaces	Index	4.95	2.73	1	10
Physical size of “forest”	ha	15.48	29.57	0	189.91
Physical size of “school's green spaces”	ha	0.40	1.66	0	18.86
Physical size of “park's green spaces”	ha	1.61	3.15	0	22.34
Physical size of “shrine's green spaces”	ha	0.34	0.71	0	4.59
Physical size of “other green spaces”	ha	2.32	4.89	0	29.16
Physical size of “aggregated urban green spaces”	ha	4.67	5.90	0	29.84

5.3.2. Study V-1: Results and Discussion

Table 24 shows the estimation results of the regression analysis. All of the estimated variables were positive and statistically significant at the 5% level. This finding indicates that marginal increases in physical green spaces within a radius of 800 m enhanced the extent of green spaces self-reported by residents. Importantly, the coefficients differed substantially, implying that residents’ perceptions of same-sized physical green spaces could differ. The largest coefficient of 0.263 was obtained for the green spaces of shrines, whereas the smallest coefficient, 0.0309, was obtained for forests. Accordingly, the effect of the green spaces of shrines was 8.5 times that of forests, despite both being the same size. This result seems to be plausible because residents living adjacent to a forest are unlikely to notice a marginal increase in forest size. It is noteworthy that there were substantial differences, even among the coefficients of each type of urban green space. Thus, the effects of the green spaces of shrines were approximately 4.1, 7.9, and 3.9 times greater than those of the green spaces of schools, parks, and other green spaces on the self-reported extents of these areas.

Considered as sacred groves, the green spaces of Japanese shrines, in which relatively old-growth forests have been established, are often protected on a religious basis. Generally, increasing tree height corresponds to increasing age, with a tendency for massive trees to be found in the green spaces of shrines. This may be one of the reasons for the comparatively greater effect of the green spaces of shrines on self-reported green spaces. Moreover, according to Ishii et al. (2010), the green spaces of shrines contain many native plant species, including rare species, and have special ecological characteristics compared with other urban green spaces. Given that levels of biodiversity are reported to affect people's perceptions of green spaces (Dallimer et al., 2012; Carrus et al., 2015), this factor too could account for the large coefficient of the green spaces of shrines.

According to Hofmann et al. (2012), who studied the criteria used by residents to distinguish green spaces, the degree of canopy closure is the most important criterion. Considering this finding, the extent of green spaces self-reported by residents seems to have been affected strongly by the degree of canopy closure. It can be inferred that the reason for the small coefficient obtained for parks is that these green spaces are maintained and thinned so that residents can enjoy them safely. In other words, tree density could be a key determinant of the self-reported extent of green spaces.

Table 24: Estimation results for Study V-1.

Variable		Coefficient	t-value
Physical size of forest		0.0309***	14.46
Physical size of urban green spaces	school	0.0639**	2.08
	park	0.0335**	1.97
	shrine	0.2632***	3.57
	other	0.0669***	6.14

Note: The results are for an ordered logit model. The dependent variable is self-reported green spaces. n = 1,189; Pseudo R-square = 0.0569; Log likelihood = -2,511.09

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.4. Study V-2: The Discrepancy in Monetary Valuations

5.4.1. Method, Data and Model applied in Study V-2

Data used in Study V-2

The LSA entails the performance of regression analysis on data relating to the subjective degree of satisfaction, considered as a dependent variable. In this study, the life satisfaction of respondents was measured using methods applied in previous LSA studies (e.g., Tsurumi and Managi, 2015). Respondents were asked, "On the whole, how satisfied do you normally feel?" They responded according to a scale ranging from 1 (extremely unsatisfied) to 10 (extremely satisfied). The marginal value of non-market goods was calculated in monetary terms using the substitution rate between the marginal effects of respondents' incomes and the marginal effects of non-market goods on life satisfaction.

A number of factors affecting life satisfaction should be included as control variables in the LSA to estimate these marginal effects. Control variables used in this study were selected as follows. First, the convenience of respondents' geographical locations was considered an important factor regulating their life satisfaction. Geographical convenience has been assessed conventionally using the geographical characteristics of each address, such as the number of retail stores nearby, distance to the nearest railway station, and distance to the nearest hospital. However, these geographical variables often do not have significant effects on life satisfaction (Tsurumi and Managi, 2015). This may be partly because geographical characteristics are inherently reflected in land or housing prices (Rosen, 1974). If this is the case, satisfaction derived from geographical convenience is balanced out by dissatisfaction relating to high house rents or prices. Accordingly, a subjective degree of convenience was applied to the geographical characteristics of each address. Therefore, residents could evaluate and compare their subjective convenience degree with their considerations relating to their house rents or prices.

Second, the study area comprised four cities with different administrative characteristics. Kobe is the largest of the four cities (55,700 ha), accounting for 75% of the total area. The city is subdivided into nine wards, each with separate administrative features. Therefore, the characteristics of Kobe's nine wards and those of the three other cities were controlled for through the inclusion of regional dummies in the LSA. Taking into account goodness of fit, three dummy variables were used in the models: the "Kita/Nishi ward dummy," the "Higashinada ward dummy," and the "Nishinomiya city dummy." The Kita and Nishi ward dummies were aggregated into the "Kita/Nishi ward dummy" because these wards share the common feature of being located on the north side of Mt. Rokko, whereas the other survey areas are located on the south side. These two sides differ significantly: the north side is still largely rural, whereas the south side has been developed into a highly urbanized and populated region.

Other control variables considered in the model included personality indicators, which were introduced to remove the effect of fluctuating personalities in responses relating to subjective satisfaction. Table 25 shows the questionnaire items and the definitions applied for constructing personality indicators. Table 26 presents a summary of the descriptive statistics for the indicators used in the regression models in Study V-2. Although the original questions were presented in Japanese, they have been translated into English, as shown in Table 25. The number of observations fell from 1,189 in Study V-1 to 1,186 in Study V-2 because of the omission of respondents who did not report their incomes.

Table 25: Questionnaire items.

Variable	Question content	Definition
Life satisfaction	On the whole, how satisfied do you normally feel?	1 (extremely unsatisfied) to 10 (extremely satisfied)
Female dummy	Are you male or female?	female = 1, man = 0
Age	How old are you?	from 25 to 65 years, at 10-year intervals
Income	Please describe the income of your household from the last year.	the closest income among 1,000, 3,000, 5,000, 7,000 9,000, and 11,000 thousand JPY
Marriage dummy	Are you married?	married = 1, other = 0
Unemployment dummy	What is your occupation?	unemployment = 1, otherwise = 0
Subjective degree of convenience	To what extent do you satisfied with geographical convenience of your living place?	1 (extremely unsatisfied) to 10 (extremely satisfied)
Kita/Nishi ward dummy	Please tell us your address.	living in Kita or Nishi wards = 1, other = 0
Higashinada ward dummy	Please tell us your address.	living in Higashinada ward = 1, other = 0
Nishinomiya city dummy	Please tell us your address.	living in Nishinomiya city = 1, other = 0

Table 26: Descriptive statistics for respondents (n = 1,186).

Variable	Unit	Mean	Std. Dev.	Min.	Max.
Life satisfaction	Index	6.81	1.80	1	10
Female dummy	-	0.49	0.50	0	1
Age	Year	46.56	13.70	25	65
Income	10,000-Yen	375.55	305.05	100	1100
Marriage dummy	-	0.61	0.49	0	1
Unemployment dummy	-	0.08	0.27	0	1
Subjective degree of convenience	Index	6.86	1.98	1	10
Kita/Nishi ward dummy	-	0.16	0.37	0	1
Higashinada ward dummy	-	0.11	0.31	0	1
Nishinomiya city dummy	-	0.22	0.41	0	1

Analytical Procedure and the LSA Model

As shown in Fig. 3, Study V-2 entailed two main analyses: LSA estimates with and without the self-reported extent of green spaces. For the analysis in which the self-reported extent was absent, the marginal effects of physical green spaces on life satisfaction were estimated using an ordered logit model.

The self-reported extent of green spaces was used as an intermediate variable in the other analysis in which it was included, and a 2SLS analysis (for more detail of the 2SLS, see Bowden and Turkington, 1990) was performed. Using the physical sizes of green spaces as instrumental variables (IVs) in the first stage of the 2SLS analysis enabled the effects of marginal variations in physical size on the self-reported extent to be estimated. Subsequently, in the second stage of the analysis, the effect of the self-reported extent of green spaces on life satisfaction was calculated. Accordingly, by comparing differences in the estimate values obtained in the analyses conducted with and without the variable of self-reported extent of green spaces, the extent to which self-reported data filters the effect of physical data on life satisfaction was assessed.

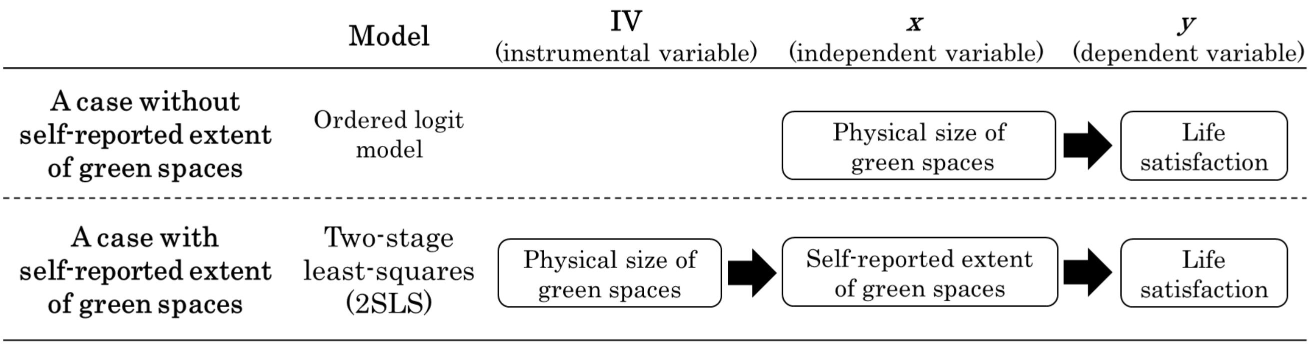

Figure 9: Process of the life satisfaction approach applied with and without the self-reported extent of green spaces.

In the LSA model, the monetary value of non-market goods was calculated by applying Eq. (2) as follows (Frey et al., 2010).

$$LS = f(x,y,z) \tag{2}$$

where LS denotes self-reported life satisfaction derived from the survey questionnaire response, x denotes non-market goods (green spaces in this study) to be assessed, y denotes income, and z denotes other factors that affect respondents' life satisfaction. The marginal willingness to pay (MWTP) value for the marginal variation of x was obtained by differentiating Eq. (2) and defining $dLS = 0$. This process is expressed in Eq. (3) as follows.

$$\mathrm{MWTP} = -\frac{\mathrm{dy}}{\mathrm{dx}} = \frac{\partial \mathrm{f}/\partial \mathrm{x}}{\partial \mathrm{f}/\partial \mathrm{y}} \tag{3}$$

In the analysis in which the self-reported extent of green spaces was not used, the MWTP values of physical green spaces were calculated using Eqs. (2) and (3). However, the calculation process was different for the 2SLS analysis, entailing the use of the self-reported extent of green space. The latter calculations were conducted separately in two stages as shown in Eqs. (4) and (5):

First stage: $$\mathrm{x} = \mathrm{g}(\mathrm{y}, \mathrm{z}, \theta) \tag{4}$$

Second stage: $$LS = \mathrm{f}(\mathrm{x}, \mathrm{y}, \mathrm{z}) \tag{5}$$

where θ denotes IVs. In the second-stage regression, the LSA was applied with x, which was estimated during the first stage. The value obtained by multiplying the coefficient of θ by the coefficient of x coincided with the increment of LS in response to the increment of self-reported green spaces under the condition of an increase in physical green spaces by 1 ha. The monetary value $MWTP_{2SLS}$ was estimated by dividing this value by the estimated coefficient of y, as shown in Eq. (5).

$$\mathrm{MWTP_{2SLS}} = -\frac{\mathrm{dy}}{\mathrm{dx}}\frac{\mathrm{dx}}{\mathrm{d}\theta} = \frac{\partial \mathrm{f}/\partial \mathrm{x}}{\partial \mathrm{f}/\partial \mathrm{y}}\partial \mathrm{g}/\partial \theta \tag{6}$$

5.4.2. Study V-2: Results and Discussion

Monetary Valuation Model without the Self-reported Extent of Green Spaces

Table 27 shows the estimation results of the ordered logit model for the analysis in which the self-reported extent of green spaces was omitted. The “aggregated urban green spaces,” which was the sum of the physical sizes of all urban green spaces, was used as a variable of physically measured data along with “forest.” Aggregated urban green spaces were used because urban green spaces classified in schools, parks, and shrines did not have statistically significant effects on respondents’ life satisfaction. This is partly because classification of each observed type of green space reduced its number. However, the use of aggregated urban green spaces did not preclude the main objective of Study V-2, namely a comparison of the estimated values with and without the self-reported extent of green spaces.

As indicated in Table 27, statistically significant and positive coefficients were obtained for both forest spaces and aggregated urban green spaces. All control variables were statistically significant, and their signs were consistent with those in the literature. An exception was the estimated coefficient of the unemployment dummy, which was insignificant. This exception may be partly attributed to the fact that the questionnaire did not investigate whether unemployed people were seeking jobs. Thus, those who were unwilling to work, and whose unemployment status may not have significantly affected their life satisfaction, were included among the unemployed.

Notably, the coefficients of neighborhood green spaces indicated that their marginal increases within an 800 m radius enhanced respondents' subjective life satisfaction levels. This finding is in agreement with those of Ambrey and Fleming (2014a) and Krekel et al. (2016), who demonstrated that a positive relationship existed between physically measured green spaces within neighborhoods and self-reported life satisfaction. Based on a comparison of the coefficients, the effect of aggregated urban green spaces on life satisfaction was approximately 4.4 times greater than that of forests. This can be attributed to the scarcity value of urban green spaces as opposed to forests, given that urban green spaces within a neighborhood of a radius of 800 m are generally smaller than forests. This result is consistent with the finding of Tsurumi and Managi (2015) that as green spaces in a neighborhood become smaller, the marginal effect on residents' life satisfaction increases. Kopmann and Rehdanz (2013) also found that the value of natural areas tends to increase as their size decreases.

The MWTP for a 1 ha increase in physical green spaces was calculated from the estimation results using Eq. (2). The calculation results indicated that the annual MWTP values per family unit for a 1 ha increase were 216,152 JPY for aggregated urban green spaces, and 48,931 JPY for forests. These results suggest that the average person can pay 216,152 JPY for a 1 ha increase in aggregated urban green spaces. Tsurumi and Managi (2015), who similarly calculated the values of green spaces, showed that the average WTPs for a 1% increase in the green coverage rate within radiuses of 100–300 m and 300–500 m from residential areas were 93,714 JPY and 160,065 JPY, respectively. Converting the WTP value for a 1% increase into WTP value for a 1 ha increase resulted in values of about 373,100 JPY for a 100–300 m radius, and 318,600 JPY for a 300–500 m radius. Thus, the estimated values obtained in this study, namely 216,152 JPY for aggregated urban green spaces and 48,931 JPY for forests, do not differ significantly from those of the previous study, considering that a radius of 800 m from residential areas was used as a criterion in the present study.

Table 27: LSA estimation results for the analysis without self-reported green spaces.

Variable	Coefficient	z-value
Female dummy	0.5281***	4.35
Age	-0.5282**	-1.88
$(Age)^2$	0.00067**	2.05
Income	0.00084***	4.08
Marriage dummy	0.3141**	2.49
Unemployment dummy	-0.1223	-0.59
Subjective degree of convenience	1.2827***	27.54
Kita/Nishi ward dummy	0.4558***	2.76
Higashinada ward dummy	0.6428**	3.49
Nishinomiya city dummy	0.2512**	1.86
Physical size of "forest"	0.0041**	2.17
Physical size of "aggregated urban green spaces"	0.0182*	1.94

Note: The results are for an ordered logistic regression model. The dependent variable is life satisfaction.

n = 1,186; Pseudo R-square = 0.2604; Log likelihood = -1,714.02

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Monetary Valuation Model with Self-reported Green Spaces

Table 28 shows the 2SLS estimation results for the analysis using self-reported green spaces. The results of the first and second stages are shown separately. As expected, the coefficients obtained for both forests and aggregated urban green spaces in the first stage were statistically significant and positive. This result implies that their marginal increases enhanced the extent of green spaces self-reported by respondents. In the second stage, the self-reported extent of green spaces had a significantly positive effect on life satisfaction. The coefficients for most of the control variables were estimated to be the same as those of the estimation results described in before section, although some regional dummies did not have statistically significant effects. In addition, the validity of the IVs was tested using a Sargan test of over-identifying restrictions (Sargan, 1958). A chi-square value of 0.5346 and a p-value of 0.4647 were obtained, indicating that there was no significant correlation between the error term of the original regression model and the IVs; hence, all of the IVs used in this study were valid.

Eq. (5) was performed to calculate MWTPs for the condition of an increase of green spaces by 1 ha using the positive effects of the self-reported extent of green spaces on life satisfaction. The results of the calculation indicated that the annual MWTP per family unit for a 1 ha increase was 104,713 JPY for aggregated urban green spaces. Applying 2SLS analysis, the MWTP for forests was estimated to be 33,845 JPY.

Table 28: LSA estimation results for the analysis with self-reported green spaces.

First-stage

Instrumental variable	Coefficient	t-value
Physical size of "forests"	0.0362***	9.42
Physical size of "aggregated urban green spaces"	0.112***	14.77
Constant	2.6788***	3.15

Note: The results are for the 2SLS model. The instrumental variable is subjectively perceived green area.

n = 1186; Adjusted R-square = 0.2861

Only coefficients of instrumental variables are shown.

Second-stage

Variable	Coefficient	z-value
Self-reported extent of green spaces	0.0565**	2.00
Female dummy	0.3896***	5.06
Age	-0.0495**	-2.53
$(\text{Age})^2$	0.00055***	2.61
Income	0.00060***	4.53
Marriage dummy	0.3100***	3.87
Unemployment dummy	-0.1688	-1.26
Subjective degree of convenience	0.6303***	33.45
Kita/Nishi ward dummy	0.1526	1.35
Higashinada ward dummy	0.1899*	1.65
Nishinomiya city dummy	0.1402	1.62
Constant	2.5522***	5.85

Note: the results are for the 2SLS model. The dependent variable is life satisfaction.

n = 1,186; R-square = 0.5836

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Comparison of the Results of the Two Analyses with and without Self-reported Green Spaces

The aim of Study V-2 was to compare the estimation results of the two analyses. Table 29 presents a summary of annual MWTP estimates per family unit for a 1 ha increase for both analyses. For the analysis in which self-reported green spaces were omitted, the estimated MWTPs were 216,152 JPY for aggregated urban green spaces and 48,931 JPY for forests. These values were 104,713 JPY for aggregated urban green spaces and 33,845 JPY for forests in the analysis that included self-reported green spaces as the intermediate variable.

In sum, the values of green spaces estimated with the LSA differed significantly according to whether the self-reported extent of green spaces was included in the analysis. Thus, including the extent of green spaces self-reported by respondents as an intermediate variable between life satisfaction and green spaces led to a marked depreciation in the marginal values of green spaces. The cause of this depreciation, which was not just the sizes of green spaces, determined the self-reported extent of green spaces. This inference appears plausible, as the results of Study V-1 indicated that the self-reported extent of green spaces could fluctuate depending on their type, even though their physical sizes were the same. Jiang et al. (2017) also confirmed that remotely-sensed sizes of green spaces differed from people's subjective perceptions of them. Apart from physical size, dimensions such as the degree of canopy closure (Hofmann et al., 2012), recreational areas (Riechers et al., 2017), disturbances relating to traffic noise, poor quality pavements, building density and esthetics around green spaces (Kothencz and Blaschke, 2017; Nordh and Østby, 2013; Peschardt et al., 2016), and richness of biodiversity (Dallimer et al., 2012; Carrus et al., 2015) are also presumed to affect residents' perceptions of green spaces.

Finally, the degree of variance of the estimated values of aggregated urban green spaces in the analyses with and without self-reported green spaces was compared with the degree of variance of the estimated value of forest in the analyses with and without self-reported green spaces. Specifically, for both aggregated urban green spaces and forests, the estimated value in the analysis that included self-reported green spaces was divided by the estimated value in the analysis in which they were omitted. The resulting ratios were 0.48 and 0.69 for urban green spaces and forests, respectively. This finding indicates that the estimated values for aggregated urban green spaces demonstrated greater variation than those for forests when self-reported green spaces was used as an intermediate variable. Thus, the values of urban green spaces fluctuated more when people's perceptions were included. This result is attributable to the fact that the self-reported extent of green spaces is affected more by marginal changes in urban green spaces compared with marginal changes of forest, as indicated in Study V-1.

Table 29: Comparison of the estimated MWTPs obtained in the analyses conducted with and without the self-reported extent of green spaces.

	"aggregated urban green spaces"	"forests"
A case without the self-reported extent of green spaces (*A*)	216,152 JPY	48,931 JPY
A case with the self-reported extent of green spaces (*B*)	104,713 JPY	33,845 JPY
The ratio of *B* to *A* (*B*/*A*)	0.48	0.69

Note: Monetary values are annual MWTP values per household for an increase of 1 ha.

5.5. Conclusion

Two studies were conducted using two types of data for green spaces: GIS-based physical data and self-reported data obtained from responses to a questionnaire-based survey. In Study V-1, multiple regression analysis was performed to explore the effects of different types of physical green spaces on the self-reported extent of green spaces. The results indicated that residents' perceptions of same-sized green spaces differed substantially, depending on their type. The impact of a marginal increase in dispersed green spaces in an urban area on the self-reported extent of green spaces was greater than that of a marginal increase in peri-urban forests. Moreover, of these dispersed urban green spaces, those associated with shrines had more impact on people's perceptions than those maintained in parks and schools. This may be partly because green spaces around shrines generally contain large and old trees, which are likely to affect residents' perceptions substantially. CHAPTER II revealed that the influence of shrine's green spaces on well-being is particularly significant, and the results of this study are consistent with this. Other factors, such as the density of trees, recreational areas, and ecological quality are presumed also to impact on residents' perceptions of green spaces. Therefore, further research of the relationship between the features of green spaces and residents' perceptions is recommended.

The above findings contribute to the field of environmental valuation. Generally, the LSA is applied to calculate the economic value of environmental goods based on the influence of the physical attributes of target goods on respondents' self-reported life satisfaction. However, the influence of self-reported attributes of environmental goods on respondents' life satisfaction also warrants attention, because people's subjective perceptions are often a key criterion in political contexts. Thus, in Study V-2, two LSA-based analyses were conducted: one in which the self-reported extent of green spaces was excluded, and one in which the self-reported extent of green spaces was used as an intermediate variable between life satisfaction and green spaces. A comparison of the estimated values from the two analyses revealed that they differed considerably, depending on whether the self-reported green spaces were used as an intermediate variable. It implies that the physical sizes of green spaces are not the only determinant of the self-reported extent of green spaces, which is in line with the finding of Study V-1.

The findings of this study indicate that economic valuations of green spaces, even for same-sized areas, fluctuate according to residents' recognition of the quantity of green spaces. This is a valuable insight that has important implications for urban planning and management. For planning efforts aimed at improving residential environments with limited urban spaces to be effective and efficient, the preferences of the residents should be taken into consideration. A related finding of this study is that people's perceptions play a filtering role. By conducting surveys of residents' preferences regarding urban green spaces, government agencies or urban planners can ascertain the details of these preferences, which will enable them to better understand peoples' valuations of urban green spaces, including the quantity and quality of green spaces. In this respect, this study revealed that areas of green space associated with shrines were generally perceived as being larger than other green spaces. In light of this finding, the provision of green spaces with similar characteristics to those of green spaces associated with shrines, such as those endowed with many native plant species and rich biodiversity, would contribute to increasing the extent of residents' self-reporting of green spaces within their neighborhoods.

However, this study had some limitations. First, it focused on types of green spaces as the quality of green spaces. Other factors, such as levels of biodiversity and vegetation density, should be treated as determinants of the extent of self-reporting of green spaces in evaluations of efficient land use in urban areas. Second, the relationship between the characteristics of residents and the extent of self-reporting of green spaces is salient. For example, those who visit their neighborhood green spaces more frequently may feel that there is a larger amount of green space within their neighborhoods. If this is the case, creating accessible green spaces and promoting residents' visits to them would contribute to increasing the extent of peoples' self-reporting of green spaces. Correctly understanding urban residents' perceptions of ecosystems and designing environmental policies that take these perceptions into account will encourage residents' contact with nature. In order to break the negative feedback loop that leads to a dilution of interactions with nature, it will be necessary to accumulate more research on how the ecosystems is perceived by the population.

CHAPTER VI

General Discussion and Conclusion

General Discussion of Four Case Study

This dissertation examined human-nature interactions through four case studies. First, CHAPTER II analyzed what kind of urban ecosystem services increase life satisfaction. The results showed that an increase in the area of urban green spaces increases life satisfaction, and that even green spaces of the same area have different effects on life satisfaction if they differ in quality. Given that shrine and temple green spaces were estimated to have a particularly large impact on well-being among other green spaces, it can be inferred that old and large trees, as typified by shrine and temple green spaces, are important. This suggests that it is critical to focus not only on the quantity of urban ecosystem services, but also on their quality.

In addition, in CHAPTER II, LSA was used to estimate the monetary value per unit increase in urban green space. While traditional environmental valuation methods are based on utility theory and thus cannot value the benefits that residents unconsciously receive from the environment, LSA can value the benefits that they also receive unconsciously. If the purpose of environmental policy is to improve the well-being of urban residents, it is essential to use life satisfaction as a criterion for environmental valuation. The monetary value per unit increase in urban green space estimated in this chapter tends to be higher than the value estimated by the traditional environmental valuation method based on utility theory. One of the reasons for the difference in value is considered to be that the traditional valuation method can only estimate the value perceived by the residents, while the LSA can also estimate the value received unconsciously. This has implications for environmental policy. If the valuator unconsciously benefits from the environmental goods, traditional valuation methods may underestimate their value. Policy makers are expected to design environmental policies that take this into account.

In order to break the negative feedback loop that leads to the dilution of interactions with nature, it is important to increase opportunities for residents to interact with nature and cultivate their orientation to do so. The orientation toward nature is assumed to manifest itself as a willingness to conserve the natural environment around them. The study in CHAPTER III estimated WTP for conserving neighborhood green spaces and analyzed which people had higher WTP. Two factors in the formation of WTP were given special attention: the frequency of contact with nature in childhood and the sense of connectedness to nature. The results showed that the higher the frequency of contact with nature, the stronger the sense of connectedness to nature, and the stronger the sense of connectedness to nature, the higher the WTP.

The study is significant because it combines environmental economic methods. Investing in environmental policies at a cost that deviates from residents' WTP may lead to a backlash from residents. Therefore, it is useful to measure environmental awareness in monetary terms when considering environmental policies. The results of this study support, from an environmental economics perspective, that fostering residents' sense of connectedness to nature can lead to the creation of better urban ecosystems. It is interesting to observe that those who have a strong sense of connectedness to nature emphasize "the provision of recreational and educational opportunities" among the functions of urban green spaces. This finding suggests that those who had more frequent contact with nature in their childhood would prefer that the next generation also have frequent contact with nature. This study confirms the importance of increasing the frequency of contact with nature in order to properly manage urban ecosystems.

Previous studies have shown that the extinction of experience is ongoing, especially in urban areas (Soga and Gaston, 2016). Reduced frequency of contact with nature can lead to degradation of the natural environment. CHAPTER III suggests that this phenomenon can be passed on from one generation to the next. However, studies on the impact of less frequent contact with nature on urban residents' satisfaction in ecosystems are still lacking. Although previous studies have confirmed that urban residents with less frequent contact with nature have less attachment to the surrounding natural environment (Soga et al., 2016), few studies have investigated this using objective numerical indicators. Therefore, CHAPTER IV focused on the level of biodiversity in urban ecosystems, as approximated by the eDNA method, and analyzed its relationship with urban residents. Specifically, it was analyzed whether the relationship between the level of biodiversity and subjective satisfaction in nearby nature changes depending on the frequency of contact with nature. The results suggest that urban residents who have less frequent contact with nature in their childhood have lower levels of subjective satisfaction with the waterfront area at higher levels of biodiversity. The result of this study implies that urban residents who have less contact with nature do not want to have rich urban ecosystems around them. In other words, a negative feedback loop of reduced interaction with nature is already in progress for some urban residents.

In the urban area discussed in CHAPTER IV, rivers with low biodiversity tended to be paved with concrete. This suggests that some urban residents prefer man-made rivers with better recreational capacity and safety than rivers with high biodiversity. Pitt (2019) found that urban residents' use of blue spaces depends largely on cleanliness, lighting, and surveillance. If rich biodiversity does not improve the satisfaction of urban residents, it will be difficult to implement environmental policies to enrich biodiversity. Policy makers need not only to enrich biodiversity of urban ecosystems, but also to accurately understand what kind of rivers urban residents want, and make efforts to reflect residents' preferences in their policies. It is desirable to form natural environments that urban residents, whose orientation toward nature has already been weakened, will want to visit.

In CHAPTER II, it was noted that the value of urban green spaces estimated by LSA tends to be higher than the value measured by traditional environmental valuation methods. It was pointed out that one of the factors contributing to this difference in value is that urban residents unconsciously benefit from urban ecosystems, and CHAPTER IV is related to this point. Contrary to the findings of CHAPTER IV, many previous studies have confirmed that urban residents benefit greatly from urban areas with rich biodiversity (Díaz et al., 2006; Knight et al., 2022). If urban residents do not want rich biodiversity despite the tremendous benefits they receive from it, one of the reasons could be that they do not properly recognize the benefits they receive. After all, if they properly valued the benefits, they would want rich biodiversity. If environmental policies to enrich biodiversity are promoted without taking into account the intentions of residents, it may lead to a decrease in the subjective well-being of residents. Efforts should be made to design environmental policies that both improve the subjective well-being of residents and enrich biodiversity of urban ecosystems.

In order to pay attention to the intentions of urban residents, it is important to focus not only on objective environmental indicators, but also on the subjective perceptions of residents. The study in CHAPTER V focused on the amount of urban green space as subjectively perceived by residents. The results showed that residents' perceptions of the amount of green space varied depending on the quality of the green space, even for the same area of green space. Among the various urban green spaces, shrine and temple green spaces had a particularly large impact on subjective green spaces. This result is consistent with the results of CHAPTER II, which showed that shrine and temple green spaces have a relatively large impact on life satisfaction.

Furthermore, in CHAPTER V, the LSA used in CHAPTER II was extended to a two-stage least squares based LSA. In the first stage, the impact of physical green spaces on subjective green spaces was estimated, and in the second stage, the impact of subjective green spaces on life satisfaction was estimated. As a result, it was found that the impact of physical green spaces on life satisfaction is estimated to be small when passing through the filter of subjective amount of green spaces. This is consistent with the point made in CHAPTERS II and IV that urban residents unconsciously benefit from urban green spaces. Although CHAPTER V focused only on the size and type (land use) of green spaces, various other factors, such as tree species and density, are considered to affect the subjective amount of green space. In addition, when urban green spaces affect subjective well-being, not only the subjective amount, but also the subjective availability, the subjective distance, and many other factors are considered to be involved. Consideration of these subjective measures is essential for designing environmental policies that improve residents' subjective well-being. A better understanding of residents' perceptions of the environment will lead to more opportunities for residents to interact with nature and foster a nature-loving orientation.

In CHAPTERS II and V, LSA was used to derive suggestions that cannot be derived from traditional utility-based valuation methods. This does not mean, however, that traditional environmental valuation methods are no longer useful. While LSA is adept at estimating values of which the subject of the valuation is unconscious, traditional valuation methods have other advantages. When considering the use of market frameworks for ecosystem conservation, traditional methods that estimate value from market behavior can provide useful information. In other words, it is important to choose which valuation method to use depending on the purpose of the valuation and the type of ecosystem service being valued.

Discussion in the Context of the Study Area: Hanshin Region and Singapore

The Hanshin region, the main study area of this dissertation, is part of the second largest metropolitan area in Japan. CHAPTER III only focused on Singapore, which is an extremely densely populated urban area with a unique characteristic that has experienced a significant increase in green cover over the past few decades. Although this dissertation has discussed the results of the case studies in order to draw general implications, it is also important to consider the characteristics of the study areas. In this section, a contextual discussion of the Hanshin region and Singapore is presented.

The Hanshin region was the study area for the three case studies in this dissertation. The most significant feature of the Hanshin region is that the nature-rich Mt. Rokko rises very close to the urban area. In most places in the Hanshin region, residents can see Mt. Rokko stretching from east to west when they look north. Previous studies have confirmed that the presence of a green window view from home improves life satisfaction and mental health (Soga et al., 2021). Mt. Rokko is believed to improve the well-being of residents in the Hanshin region. In the studies of this dissertation, the effects of having green spaces near one's home on life satisfaction were analyzed, but the results may have been different if Mt. Rokko had not been present. If Mt. Rokko, which is several kilometers away from home, acts as a substitute for green space near home, it is possible that the impact of green space near home on life satisfaction is reduced by the presence of Mt. Rokko. Conversely, if Mt. Rokko did not exist, the estimated value of green spaces around the home might have been even higher. It should be noted that in places such as Tokyo and Osaka, where forests are rarely seen, the value of green spaces scattered around urban areas may be relatively high.

Nevertheless, according to a survey conducted in 2011 by Kobe City, which is located in the Hanshin region, only 21.9% of its residents are satisfied with the amount of greenery around their homes (Kobe City, 2011). Similarly, according to a survey conducted in 2018 by Nishinomiya City, which is also located in the Hanshin region, 39.4% of respondents were satisfied with the amount of green spaces near their homes (Nishinomiya City, 2020). The results of these surveys indicate that the percentage of people who are satisfied with green spaces in the Hanshin region is less than half, suggesting that there is still room for improvement. Despite the fact that the nature-rich mountain forest of Mt. Rokko is very close by, there is a significant number of people who are not satisfied with the amount of green space. In 2016, the Kobe City government significantly updated the " Biodiversity Kobe Plan" (Kobe City, 2016), which seeks to promote the conservation of urban ecosystems under the leadership of the government and with the participation of citizens, civic groups, businesses, and other stakeholders. Like these efforts, the Hanshin region needs to take a proactive approach to creating and conserving urban ecosystems under the leadership of the government.

The urban rivers in the Hanshin region, which are discussed in CHAPTER IV, also have characteristics unique to this region. Due to the steep gradients in the Hanshin region, the rivers have a low volume of water at any given time. When heavy rainfall occurs, the rivers tend to overflow, causing enormous flood damage many times in the past. In addition, the Great Hanshin-Awaji Earthquake of 1995 caused other problems in that many rivers could not carry water for firefighting and could not be used as evacuation sites (Hyogo Prefectural Kobe Civil Engineering Office, 1997). Against this background, the perspective of disaster prevention has been emphasized in the development of rivers. In CHAPTER IV, it was mentioned that even in urban areas, it is desirable to emphasize the importance of river biodiversity and to develop urban rivers as places where urban residents can experience the richness of nature. However, disaster prevention functions should not be neglected, as well as biodiversity and recreational functions. The need for recreational functions is easily recognized by residents, but the need for disaster prevention functions is difficult to recognize in normal times. Policy makers need to keep in mind that overemphasizing residents' preferences in river development may lead to neglecting hard-to-recognize functions such as disaster prevention.

CHAPTER IV also mentioned the possibility that some residents may seek recreational functions from rivers rather than biodiversity. If urban residents do not seek a rich natural environment due to a decline in opportunities for contact with nature, it will be important to encourage their orientation toward contact with nature through environmental education and nature observation events, etc. According to a survey conducted in Kobe City in 2015, 63% of respondents were aware of the term "biodiversity" and 11% were aware of "ecosystem services" (Kobe City, 2016). The lack of interest and knowledge among urban residents regarding ecosystem conservation was also identified as a problem in the "Biodiversity Kobe Plan" (Kobe City, 2016). By changing residents' attitudes through environmental education, it will be easier to create and maintain urban ecosystems that enhance residents' well-being.

The case study in CHAPTER III is the only one in this dissertation that focuses on Singapore. Despite being an extremely densely populated urban area, Singapore is a country that has been active in environmental conservation and greening policies. Between 1986 and 2007, the population increased from 2.7 million to 4.6 million, while the green cover increased from 35.7% to 46.5% (National Parks, 2019). The Singapore Green Plan 2030, formulated in 2021, aims to plant 1 million trees in the country by 2030, increase the area of nature parks by about 200 ha, and have a nature park within a 10-minute walk of every resident (Government of Singapore, 2023). The reason for the country's continuous greening policy can be attributed to the people's high awareness of environmental conservation, in addition to the country's abundant national finances, which ranked fifth in the world in terms of GDP per capita in 2022 (IMF, 2022).

In CHAPTER III, the study focused on the process by which environmental awareness is promoted, but it must be noted that the target area was selected as an exemplary urban area that is also rich in natural environment. CHAPTER III revealed that people who have had more contact with nature in the past have a stronger awareness of environmental conservation. This implies the possibility of a virtuous cycle in which the increase in the number of natural environments that residents can easily come into contact with in the future will further raise people's overall environmental awareness and further enrich the natural environment. However, the results achieved in Singapore are not necessarily applicable to other regions. Singapore is an exemplary region with a moderately successful national greening policy, and different results can be expected in regions where environmental awareness is not as high. CHAPTER III is unique in that it quantifies environmental awareness as WTP. Since it is possible to compare WTP in monetary units, it will be necessary in the future to analyze what factors contribute to increasing WTP in areas where WTP is not so high.

Policy Implications and the Dynamics of Human-nature Interactions

Through the four case studies, two factors have emerged that make urban ecosystem management difficult. The first is that urban residents' desire for rich ecosystems diminishes as their experience of nature diminishes. The second is that urban ecosystems preferred by residents may not maximize their well-being. There are two aspects to the latter problem: the first is that residents themselves fail to make choices that maximize their own well-being. As shown in CHAPTERS II and V, urban residents may unconsciously receive benefits from their neighborhood ecosystems. Since urban residents can only make decisions about policies based on their perceived benefits, they fail to make choices that maximize their own well-being when they unconsciously receive benefits. The second aspect is that when the preferences of residents are diverse, minority preferences are not reflected in conservation policies if the preferences of the majority are given priority. As shown in CHAPTER IV, residents' preferences for urban ecosystems are diverse. Policies that prioritize the preferences of those who tend to favor biodiversity may reduce the well-being of those who tend not to favor biodiversity. This section presents strategies for addressing these difficulties.

First, one response to the diminishing needs of urban residents for rich ecosystems is to increase their experience of nature. To do this, it is important to understand what kind of urban ecosystems residents desire and to design urban ecosystems that they will want to visit. Figure 10 is an extension of Figure 4 presented in CHAPTER III. There are two feedback loops, the below loop is a positive loop that increases residents' well-being, and the above loop is a negative loop that decreases residents' well-being. To provide an explanation based on the positive feedback loop, first, more opportunities to interact with nature increase contact with nature. Opportunities here refer to the presence of places and organisms that are the subject of nature-related activities, such as nearby green spaces and wildlife. As indicated in CHAPTER III, as contact with nature increases, so does the sense of connectedness to nature and the orientation toward nature. Ideally, an increase in WTP would lead to an increase in the budget invested in environmental policies, resulting in the conservation and improvement of the natural environment. In other words, a virtuous cycle is created in which there are even more opportunities. The above loop is where the process turns negative. It is important to note that in the feedback loop, the government can only intervene in the opportunity. In order to realize the positive feedback loop, it will be necessary for the government to create green environments that residents will want to visit.

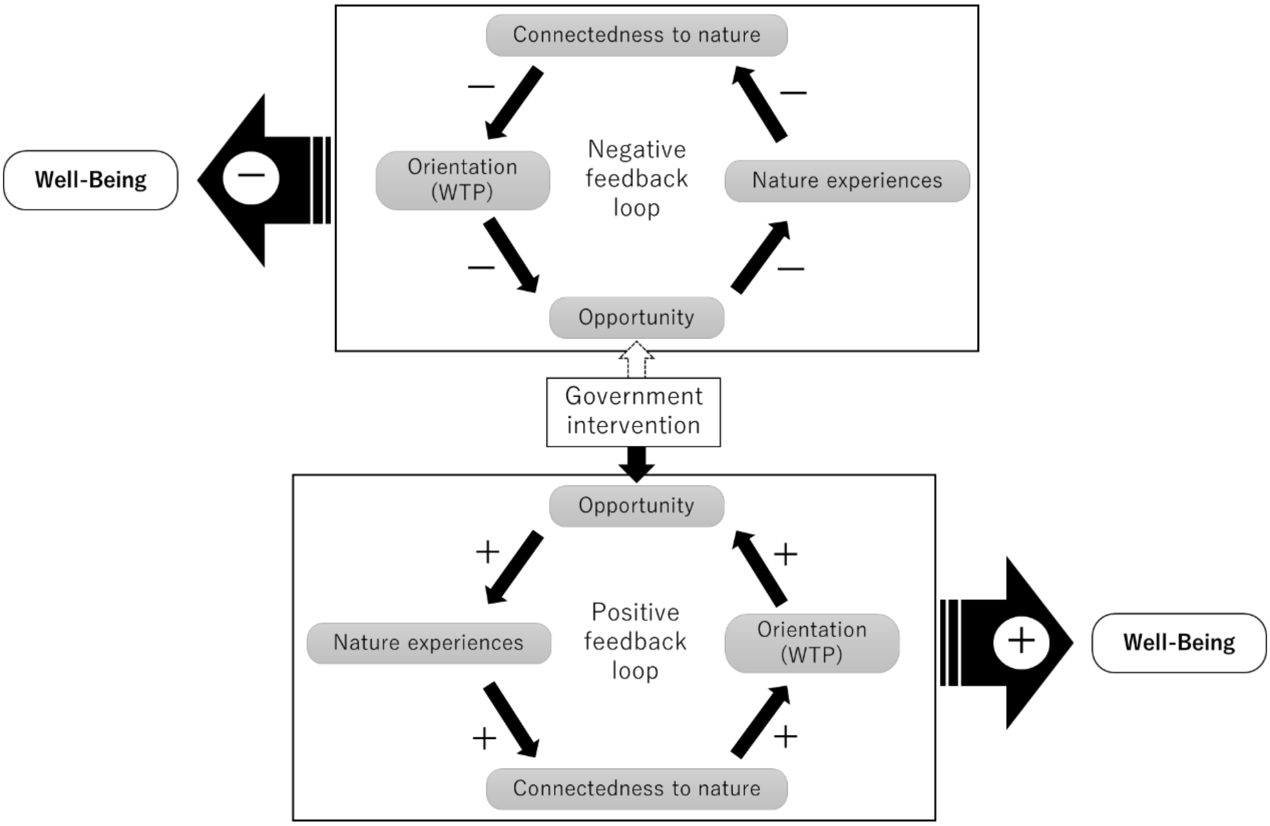

Figure 10: The dynamics of human-nature interactions (authors' formulation).

Next, possible solutions to the problems associated with the fallacy between preferences and well-being are presented. As indicated earlier, there are two aspects to this problem: the failure of residents to make choices that maximize their own well-being, and the neglect of the well-being of a minority group. For the former, one solution is to enhance residents' knowledge of ecosystems. One of the reasons why residents cannot maximize their own well-being is that they do not consciously benefit from ecosystems, so environmental education can enhance their knowledge and make them aware of the fact that they benefit enormously from ecosystems. However, this approach has its limitations because it is sometimes difficult to make people aware of the benefits of ecosystems, such as when ecosystems contribute to mental health. Therefore, policy makers, such as experts and government officials, should not be too constrained by residents' preferences, but sometimes it is necessary to implement paternalistic policies aimed at maximizing residents' well-being. It is also important to consider that residents' preferences may focus too much on short-term pleasure and too little on long-term well-being. Policymakers are expected to both reflect residents' preferences and consider factors that are not reflected in residents' preferences, but that improve residents' long-term well-being.

Paternalistic policies can also be a solution to the problem that the well-being of a minority group is neglected because of the diversity of residents' preferences. It is necessary for policymakers to make adjustments when policies supported by the majority reduce the well-being of the minority. For example, if the majority wants rivers with low biodiversity, it is not enough to simply increase the number of rivers with low biodiversity. If the long-term well-being of residents, which is often overlooked, is taken into account, the creation of high-biodiversity rivers can also improve the lives of those who seek low-biodiversity rivers. When policymakers take paternalistic decisions, surveys of residents, such as the one used in this dissertation's case study, can provide useful information. By understanding, through surveys and analysis, what ecosystems residents consciously and unconsciously benefit from, policymakers can take into account the fallacy between preferences and well-being.

The above ecosystem management difficulties and possible responses were derived by linking the implications of the four case studies. The questions and challenges that emerged from each case study formed the basis for the next case study. All of the studies used social surveys, focused on the preferences and perceptions of residents, and attempted to derive not only theoretical but also practical implications. All of the case studies, each from a different perspective, demonstrated once again how difficult ecosystem management is. Future research is needed on how to guide urban residents to make choices that maximize their own well-being, and how to make reasonably paternalistic policies without being overly constrained by residents' preferences. IPBES (2019) assumes that people's values vary widely from person to person and region to region, and the lack of information on heterogeneity is cited as a problem. Furthermore, the lack of information on the non-material benefits of ecosystems to people compared to material and regulating benefits is also cited as a problem. In this dissertation, more specific problems have been extracted from case studies that address these issues that international organizations are paying attention to. The identification of issues that need to be addressed in the future is an important outcome of this dissertation.

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