A study on Green Infrastructure Gauge and affordance enhancement for sustainable urban areas.

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A study on Green Infrastructure Gauge and affordance enhancement for sustainable urban areas.

持続可能な都市へ向けた グリーンインフラストラクチャーゲージと そのアフォーダンスの向上に関する研究。

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List of abbreviations

ADB	African Development Bank
BMP	Best management practice
BUGS	Benefits of Urban Green Spaces
CBD	Convention on City Biodiversity
CBI	City Biodiversity Index
CH4	Methane
CO	Carbon monoxide
CO2	Carbon dioxide
COP	Conference of Parties
DOC	Document
DU	Diversity of UGS
ETS	Element total score
FRV	Function relative value
FTS	Function total score
GI	Green Infrastructure
GIA	Green Infrastructure Assessment
GIG	Green Infrastructure Gauge
GIS	Geographic Information System
GMP	Green Master Plan
Gov.	Government
ha	Hectares
IBM	International Business Machines Corporation
ICT	Information Communication Technology
JICA	Japan International Cooperation agency
Km^2	Square kilometers
KNBS	Kenya National Bureau of Statistics
KUR	Kenya Uganda Railway
Landsat	Land and satellite
LIVCOM	Livable Communities
LPI	Largest patch index
LSA	Land suitability analysis
LSI	Landscape shape index
LULC	Land use and land cover
M^2	Square meters.
MPS	Mean patch size

MPSI	Mean Patch Shape Index
Ms	Microsoft
N	Number of respondents
NCEO	Nairobi City Environment Outlook
No.	Number
NPO	Nonprofit organization
PA	Perimeter to Area
PDU	Proportional diversity of UGS
Pop.	Population
PSSD	Patch size standard deviation
PUA	Proportional UGS abundance
RandInt	Random Integer
RUAF	Resource centre on Urban Agriculture and Food security
SPSS	Statistical Product and Service Solutions
SW	Special Wards
TA	Total area
UA	UGS abundance
UGN	Urban Grain Network
UGS	Urban Green Spaces
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UPC	UGS per capita
UR	Urban Renaissance
USA	United States of America
WWF	World Wildlife Fund

Abstract

The world population surpassed 7 billion people in late 2011. More than half of this population now lives in urban areas, and virtually all countries of the world are becoming increasingly urbanized. This accelerated trend of human and land urbanization is exacerbating carbon footprints, gobbling up natural and rural areas, degrading the environment, creating food deserts, increasing urban poverty, and establishing unsustainable communities vulnerable to sequels of climate change. Green Infrastructure concept within the urban context focuses to ameliorate negative impacts of these relatively new habitats to man. This study aims to contribute to this evolving concept in both theory and application. It sets out to formulate a framework of gauging Green Infrastructure affordance and explores strategies to enhance its capacity to afford sustainability and livability in urban areas. To achieve the above: (1) Central Nairobi Urban Green Space was analyzed as a representative element of Green Infrastructure. (2) Green Master Plans of selected Japanese municipalities in Tokyo Metropolis were evaluated for their potential as guides for Green Infrastructure implementation. (3) Green Infrastructure Gauge, a tool for evaluating Green Infrastructure affordance in existing and proposed urban areas was formulated. (4) This gauge was consequently applied to evaluate Koshigaya Laketown's Green Infrastructure affordance in both elements and functions. Existing Central Nairobi Urban Green Space was found to lack in size, composition, distribution, and character, while Japanese municipalities' Green Master Plans as currently constituted and implemented cannot be successful guides for optimum Green Infrastructure realization. Koshigaya Laketown includes a wide variety of Green Infrastructure elements and functions, with its Green Infrastructure Gauge established to be '5.75 points' out 10. A proposition for a new urban planning theory of `Urban Grain Network` was put forth; as a strategy to ensure abundance of Green Infrastructure elements and functions in the urban realm. It proposes a symbiotic coexistence of Town and Country in one space and time, which can synergistically enhance sustainability and livability of urban areas.

Keywords: Green Infrastructure, Green Master Plan, Green Infrastructure Gauge, Green Infrastructure affordance, Urban Grain Networks, Sustainability, Urban Livability.

1 CHAPTER 1: Introduction.

1.1 Study background.

1.1.1 World's population, urbanization trends, and their challenges.

According to UN-Pop (2011), the world population was projected to reach 7 billion in late 2011, surpass 9 billion people by 2050, and exceed 10 billion in 2100. More than one half of this world population now lives in urban areas, and virtually all countries of the world are becoming increasingly urbanized (UN-Pop, 2012). At the beginning of the 20th Century, only sixteen cities in the world had a population larger than a million people (Waldheim, 2006). Yet at the close of the century more than five hundred cities had more than a million inhabitants, many boasting more than ten million residents and still expanding (Waldheim, 2006). The urban expansion anticipated in the first quarter of the 21st century is the equivalent of the entire human population attained by the early1930s (Rees, 2003). Some estimates have suggested that; by 2030, 80% of the human population will dwell in urban areas (Ramsar COP11 DOC. 23, 2012). By 2020, the developing countries of Africa, Asia, and Latin America will be home to some 75% of all urban dwellers, and to eight of the anticipated nine mega-cities with populations in excess of 20 million (RUAF, 2012). These trends are changing the landscape of human settlement, with significant implications for living conditions, the environment and development in different parts of the world (UN-Pop, 2012).

An example of such population trends can be seen in the City of Nairobi in Kenya, which UN-Habitat (2006) indicate that has the highest growth rates per annum compared to the other growth rates in Africa. Its population rose from 340,000 people in 1960, to the current residency of more than 4 million people. Of these, 75% of the urban population growth is absorbed by informal settlements which cover only 8.5% of the total residential land area of Nairobi City, but inhabited by at least half of the city's population. Much of Nairobi's urban footprint is unplanned settlement driven by rapid population growth and urban poverty, among other things, including sprawling settlements that handicap the city's delivery of social services and negatively impact the quality of life (Tibaijuka, 2007).

Such changes are begetting challenges especially in cities of developing countries, leaving them bare of essential environmental support systems that lead to low livability index. These challenges include pollution, congestion, crime, lack of recreational and social green spaces, lack of healthy ecosystems and bio diversity, prone to disasters such as flooding, poor residents' health and wellbeing, unreliable sources and use of energy, poor aesthetics, and urban poverty among others. This mass relocation of populations to urban landscapes that are relatively new as human habitats are also disruptive to sense of history, continuity, and stability (Benedict and McMahon, 2006). They also lead to urban sprawl beyond the urban growth boundary where natural areas and farmlands are consumed by the urban fabric of grey infrastructure. Urban development consumes land, fragments the landscape, displaces many native species, and disrupts ecosystem functions (Weber et al., 2006).

It is worthy to note that population growth and urbanization are not necessarily negative aspects. Their management and utilization determine whether they have negative or positive impact to nature, environment, and human society.

1.1.2 Global warming and climate change.

The UN Intergovernmental Panel on Climate Change predicted as far back as 1992 that if emission trends for greenhouse gases continued; the average global temperature would increase by 1.5 - 4.5^{0}C by the middle of the 21st century (UNCED, 1992). Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather (US-EPA, 2013). Greenhouse gases that block the sun's radiant energy from escaping back to space are responsible for the global warming phenomenon, with other related effects including urban heat islands, ozone depletion, and urban dust plumes (Benedict and McMahon, 2006). Climatic and weather changes include extreme changes in precipitation that are bringing about intense and frequent floods, droughts, and heat waves. Others are rising sea levels, warming oceans, as well as melting ice caps and glaciers. As these and other changes become more pronounced in the coming decades, they will likely present challenges to the society and the environment (US-EPA, 2013).

Urban areas are resource poor, and depend on distant resources for their sustenance. This system of energy and material production, transportation, consumption, and waste disposal has brought about most of these emissions that bring about global warming and climate change. Emission of green house gases such as Carbon dioxide (CO_2), Carbon monoxide (CO), Methane (CH_4), and Fluorinated gases are mainly products of this rapid urbanization of man and the urban systems of material supply and use. The problem will increase exponentially, unless the current and future urban areas embrace alternative and sustainable development models that are harmonious with nature and the environment.

1.1.3 Ecological footprint, food deficiencies, and sustainability.

The above outlined urbanization of majority of the world's population and its challenges, as well as global warming and climate change points to an uncertain future of the planet and wellbeing of humanity. In the last few thousand years, the very face of the earth has been modified by man, and although we human animals have modified it to suit ourselves, we have done it so wastefully, thoughtlessly, and, if we do not mend our ways, fatally (Gibson, 1979). There is an Inuit people[1] saying that "we do not inherit the earth from our fathers; we borrow it from our children" (Meakin, 1992). UNCED (1992) or the Rio Summit put forward in Agenda 21, an action plan for developing the planet sustainably through the twenty-first century. Humanity has the ability to make development sustainable and to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs (UN- Bruntland Report, 1987). Contrary to this assertion, urban areas of today are resource deserts. Whilst cities currently only occupy 2% of the Earth's surface, they use 75% of the world's natural resources and generate 70% of all the waste produced globally (Ramsar COP11 DOC. 23, 2012). Early modernist urban sociology unintentionally developed an image of the city as an essentialist reality separate from life supporting ecosystems, which has proved hard to rid and which continues to permeate urban policy and planning (Barthel and Isendahl, 2013). Sustainable development is unthinkable without sustainable urbanization, as urban per capita consumption continues to increase its advance over rural per capita consumption (Smit and Nasr, 1992).

Many factors bear on the ultimate area of a given population's ecological footprint, including the size of the population, the average material standard of living, the productivity of the land/water base, and the (technological) efficiency of resource harvesting, processing, and use (Rees, 2003). Extraction of these resources to feed the cities leaves huge ecological footprints in distant natural rural areas. Activities such as mining, logging, and transport corridors destroy ecosystems, and scar the landscape. The transportation, processing, consumption, and disposal of waste increase not only negative impacts to ecological sensitive areas, but also magnify the problem of global warming and climate change though

[1]Inuit people: aboriginal people that inhabit Arctic regions of Canada, USA, Russia, and Greenland.

emissions and other forms of pollution. The longer these resources are from the urban areas, the larger the carbon foot prints left in transporting them from the extraction point to the consumer and the more expensive they become.

Because urban areas produce minimal natural resources, low income earners are especially vulnerable as their sustenance is dictated by the prevailing market conditions. Low income urban dwellers spend up to 60 - 85% of their income on food every year (Cohen and Garret, 2009). This leaves them with little to meet the other basic needs and wants such as shelter, clothing, and healthcare, as well as decent education for their children, and recreation / leisure. Urban areas that afford alternative sources of food produced within reduce dependency on distant production areas, and lower proportion of income spent on food. Such production, distribution, and consumption of local food within the urban context can boost partial economic and environmental sustainability, and help feed and sustain the growing urban populations. Unfortunately, in the midst of the second wave of space–time compression, with 75% of the global population projected to be urban within a few decades, we are now experiencing a “global generational amnesia” about how to grow food (Colding and Barthel, 2013).

1.1.4 Green Infrastructure (GI) and impetus for its research.

Cities and governments all over the world are continually responding in varying ways, to cope with or remedy the above urban challenges outlined in 1.1.1, 1.1.2, and 1.1.3. However, importance of urban biophysical networks - what would be termed as ‘green assets’ are largely overlooked (Schaffer and Swilling, 2013). Planning tends to focus on the so called ‘grey infrastructure’ networks of energy and material supply system (Weisz and Steinberger, 2010). Constant contact with nature in these relatively new human habitats, which could sustain evolutionary traits, honed over thousands of years in natural settings where mankind developed is lacking.

The population statistics show that the burden of nourishing and sustaining the majority of human population has also been shifted from the ‘Country’ to the ‘Town’. In that sense, human ancient practices that developed in the ‘Country’ such as agriculture, identity, and cultural practices among others are endangered too. Their accommodation plans and concepts ought to be developed, to ensure there is continuity within the changing human settlements, or they shall forever be lost to humanity. New urban strategies are needed to plan for sustainable urban areas that ensure the wellbeing of the existing and future urban communities.

One such strategy is Green Infrastructure (GI), which is being increasingly used to create multidimensional aspects that improve the urban environmental quality, livability, sustainability and quality of life (van Kamp et al., 2003). It involves Eco, Green, or Smart Growth that is shaping future cities, towns, and communities, providing a paradigm shift in urbanization. It provides a framework that can be used to guide future growth and future land development and land conservation decisions to accommodate population growth and protect and preserve community assets and natural resources (Benedict and McMahon, 2006). However, Wright (2011) argue that green infrastructure is ambiguous and essentially “a contested concept”. She points that as an evolving concept; it has been given definitions, but is not yet explicitly “defined” as different interests attach different environmental, social, and economic meanings to it. The term means different things depending on the context in which it is used (Benedict and McMahon, 2006). Wright (2011) asserts that though GI is ambiguous in interpretation and implementation, the ecological, environmental, and societal benefits it affords where practiced cannot be disputed. It can be used as a counter weight to the triple challenges of population explosion, urbanization of most of the world's population, and global warming and climate change, as well as promote sustainability.

The current state of GI in which it has unfrozen meaning and is in an evolution mode (Wright 2011) gives impetus for further research and contribution to its advancement. Most of GI research has been conducted in the US and Europe, with little done in the developing countries where the highest potential for urban growth lies. As pointed out in population trends, the highest urban population growth will be in the developing countries, where by 2050, Africa will have a higher number of people living in cities than Europe, Latin America or North America (WWF and ADB, 2012). It is in these countries that much focus should be directed to in GI research to ensure sustainable development in this expected urban boom. This explosion of urban population is also expected to generate higher populations of urban poor living in informal settlements or slums; groups that are more vulnerable to the impacts of global warming and climate change. Sustainable development in these areas as vested in GI concept can be partially achieved if more researchers from the developing nations take part, and impacts their knowledge and experiences in shaping these future urban frontiers. They cannot, however, research in isolation as they need to build on the foundation already laid by those from the developed nations, and learn from the GI practice already ongoing.

Besides definition and development of GI as a concept, policy formulation and planning strategies, holistic evaluation strategies, and tools of its successful inclusion are particularly scarce. This is true especially at city scale as well as at local or community levels where GI impacts to the benefits of the resident community. There exists such evaluation tools that include but not limited to the following:

Rudolf et al (2002) conceptualized a framework and typology for describing classifying and valuing ecosystem functions, goods and services. Green Infrastructure Assessment (GIA), a tool developed by Maryland Department of Natural Resources focuses on hub and corridor selection at regional level (Weber et al, 2004). Green Factor Score Sheet or Seattle Green Factor (Seattle City, 2012), is a scoring system for landscapes, required in certain parts of Seattle. This is in order to help increase the quantity and improve the quality of urban greenery while allowing flexibility for developers and designers to meet development standards.

City Biodiversity Index (CBI) or (Singapore Index) developed by the Convention on Biological Diversity (CBD, 2010). Though its application is at a city scale, its main stay is in benchmarking biodiversity conservation efforts in the urban context, and self evaluation of progress in reducing the rate of biodiversity loss in urban ecosystems. FRAGSTATS, a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns (McGarigal et al., 2002).

These tools focus on one area of GI to the exclusion of the holistic GI composition. More research is needed on the way GI is being or ought to be valued in cities, and included as an integral part of spatial planning and urban design. This should also include development of evaluation and appraisal tools.

1.2 The study aim and objectives.

Based on the above background, the study aims to contribute to the evolution and development of Green Infrastructure concept, especially at the policy formulation, planning, evaluation, and enhancement at city and community scales. The study aspires to further knowledge on the concept of GI, and further clarify its potential to foster sustainable development. This is within the context of enhancing urban areas capacity to cope with challenges of urban population dynamics, global warming, climate change, ecological footprint, and food deficiencies. The epitome of this envisaged sustainable development is to manifest urban livability especially in the developing nations such as Kenya, my home nation.

It aims to articulate constituents of GI (elements) as well as the benefits it affords (functions) to nature, environment and the residents. Though the GI study is from a general and global perspective mostly focusing on city and community scales, special references are made in regard to the developing nations especially Kenya. These nations have the highest potential for new urban areas and urban population growth. It aims to diversify GI research geographical scope; hence it includes cases from both developing (Kenya) and developed nations (Japan). This is because GI concept ought to have a global outreach to achieve maximum benefits to all of humanity. Special reference is also given to urban agriculture as an element of GI, that can foster sustainability and resource production in resource poor urban areas. The study further aims to evaluate an established urban area (City of Nairobi) for its Urban Green Spaces as a principal representative element of GI. It also aims to answer the following questions: are the various government or municipality policy documents and guidelines already in place adoptable as guidelines for optimum implementation of GI? How can Green Infrastructure be appraised for its inclusion in existing urban areas, or in planning documents for new urban areas? How can we ensure optimum permeation of GI in urban areas, and enhancement of its affordance in life support functions such as population nourishment through locally produced food?

1.2.1 Specific study objectives.

To achieve the above aim, the following six objectives were set:

1) To explore and expound on the GI concept, in both theories and application focusing mainly on its constituent elements and functions at municipal and community scales.

2) To evaluate Urban Green Spaces as a representative element of GI in Central Nairobi using landscape level metrics and GIS spatial analysis.

3) To analyze Green Master Plans (GMPs) by Japanese municipalities as potential agents and catalysts for planning, optimum implementation, and realization of GI in urban areas.

4) To formulate a Green Infrastructure Gauge (GIG), to be used as a tool for evaluation of inclusion of GI in existing urban areas, or in planning documents for proposed new urban areas, or in urban redevelopment projects.

5) To conduct a survey of GI elements and functions affordance in Koshigaya Laketown, and apply the Green Infrastructure Gauge to determine their inclusion levels.

6) To build the case of Urban Grain Networks (UGN) theory, as a new urban spatial planning tool anchored in urban agriculture, that can ensure optimum permeation of GI in urban areas, promote sustainability, and provide abundance in affordance of GI elements and functions.

1.3 Introduction to the study areas.

1.3.1 The City of Nairobi.

Nairobi takes its name from the Maasai language[2] phrase "Enkare Nyorobi", which translates to "the place of cold waters" (Nairobi City Council-NCEO Report, 2007). It owes its birth and growth to the Kenya Uganda Railway (KUR), whose railhead reached Nairobi in May 1899 (Mitullah, 2003). It became the headquarters of Kenya in 1907 after they were moved from the coastal city of Mombasa. The City grew rapidly in the next century to become a major commercial herb in Africa. Much of Nairobi's urban footprint is unplanned settlement driven by rapid population growth and urban poverty among other things. Sprawling informal settlements handicap the city's delivery of social services, and negatively impact the quality of life (Tibaijuka, 2007). In 1927, the boundary of Nairobi was extended to cover 30 square miles (77 km^2). The current boundary was set in 1963 to an area of approximately 266 square miles (686 km^2) (Mitullah, 2003). The city management was under The City Council of Nairobi until March 2013. After which it was taken over by Nairobi County Government under the devolved system of government established under the new constitution of Kenya, promulgated on 27 August 2010.

[2] Maasai language: A Nilotic language spoken by the Maasai People of Southern Kenya and Northern Tanzania.

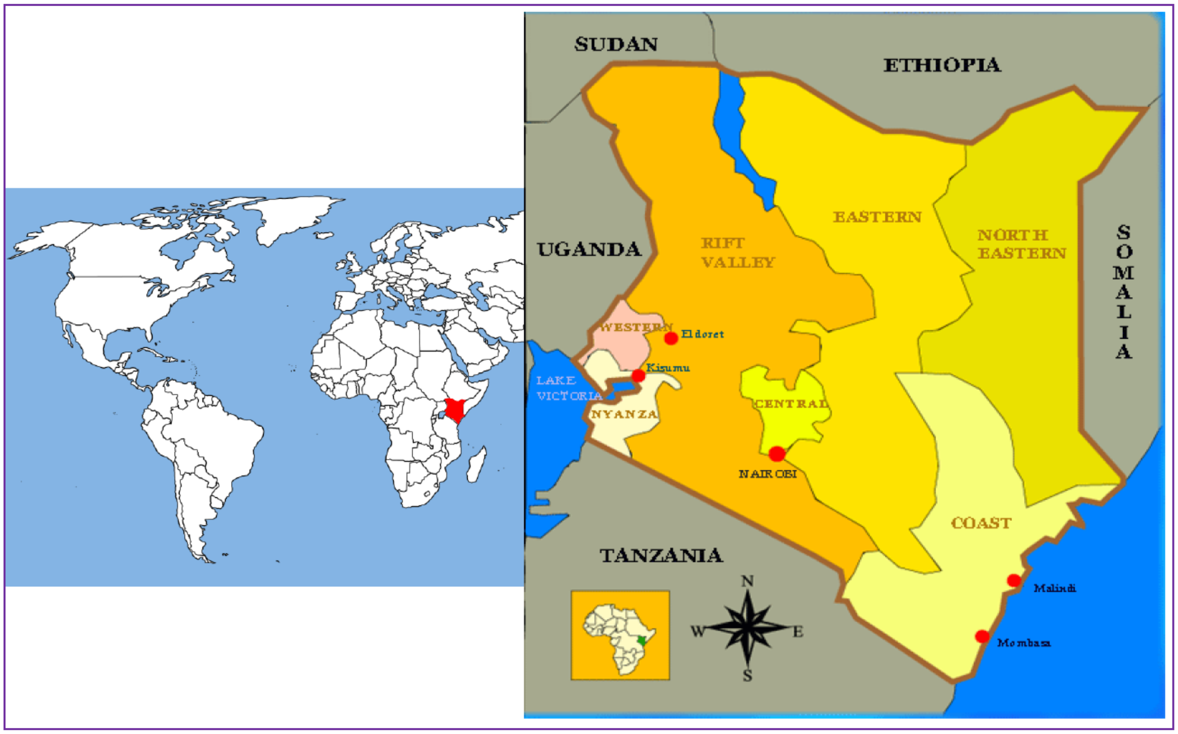

Figure 1: Map showing the location of Nairobi in Kenya.

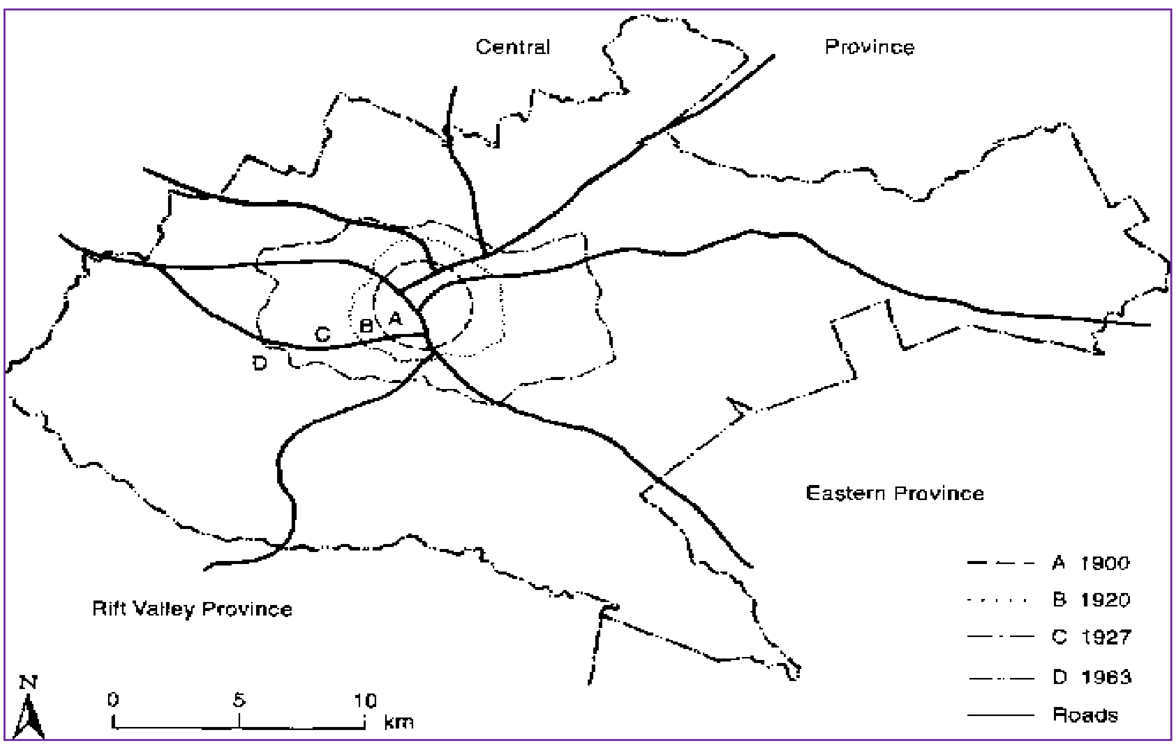

Figure 2: Map of Nairobi showing boundary expansion over time.

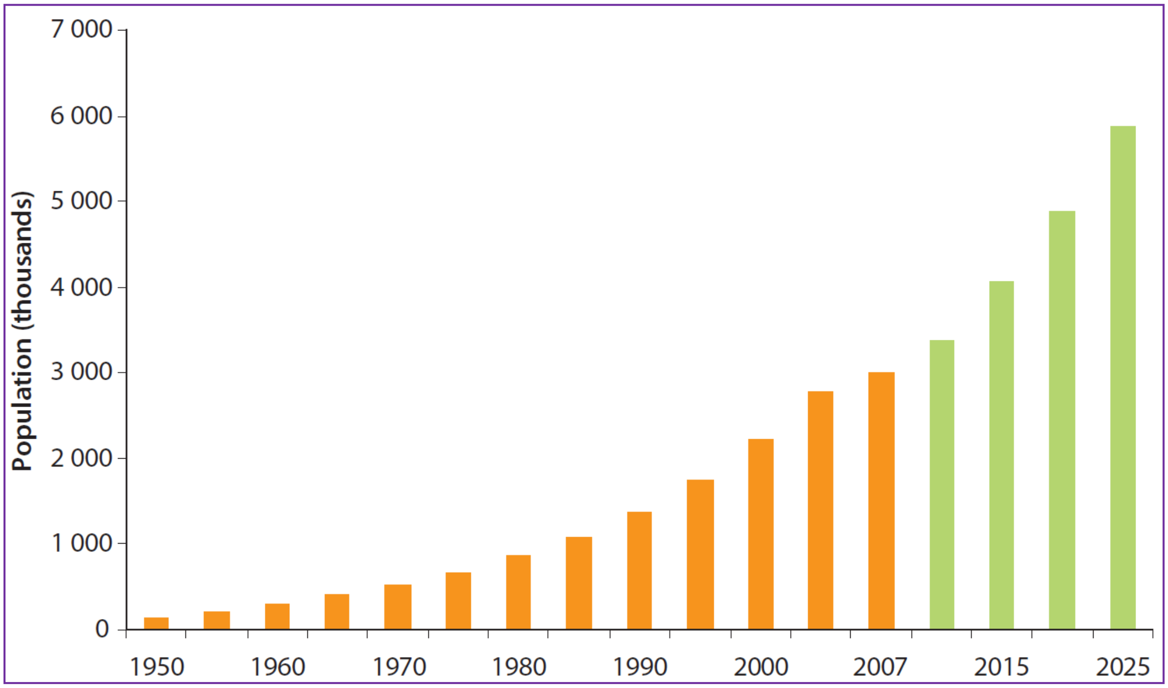

Figure 3: Nairobi's historical and projected population (source; Tibaijuka, 2007).

To deal with the current challenges in the city, the Kenyan Government has established Nairobi Metro 2030 plan, whose mission is "to manage the Nairobi Metropolis by providing sustainable infrastructural services and high quality of life to all its residents, visitors, and investors" (Kenya Gov. 2008). The plan proposes to agglomerate the current Nairobi City with the surrounding municipalities to form Nairobi Metropolitan Region. These municipalities comprise of fifteen independent local authorities namely: Nairobi, Kiambu, Limuru, Machakos, Mavoko, Ruiru, Thika, Kajiado, Karuri, Kikuyu, Tala/Kangundo, Kiambu, Masaku, Olkejuado, and Thika (Kenya Gov. 2008). There are also several ongoing and planned new towns and cities within this metropolis by both the government and private investors. They include Konza ICT City and Tatu City among others; all proposed in open agricultural and pasture land. This renaissance in urban development and its current urban challenges pose Nairobi City as a strong candidate to review in reference to the GI concept.

It was selected for preliminary evaluation of Urban Green Spaces that forms a key component of GI. Its oldest and most urbanized core here in referred to as Central Nairobi was analyzed as a case review. This was to give an insight of an established city, more so in a developing nation for diversity since most of this study has been conducted in Japan which is a developed nation. Highlights of Nairobi City's evaluation as well as the general findings and recommendation of this study can be used to inform sustainable development through the concept of GI. This can be particularly essential in the new cities and towns being establish outside of the current Nairobi City boundaries to avoid repetition of the same spatial and development mistakes existing in Nairobi City today.

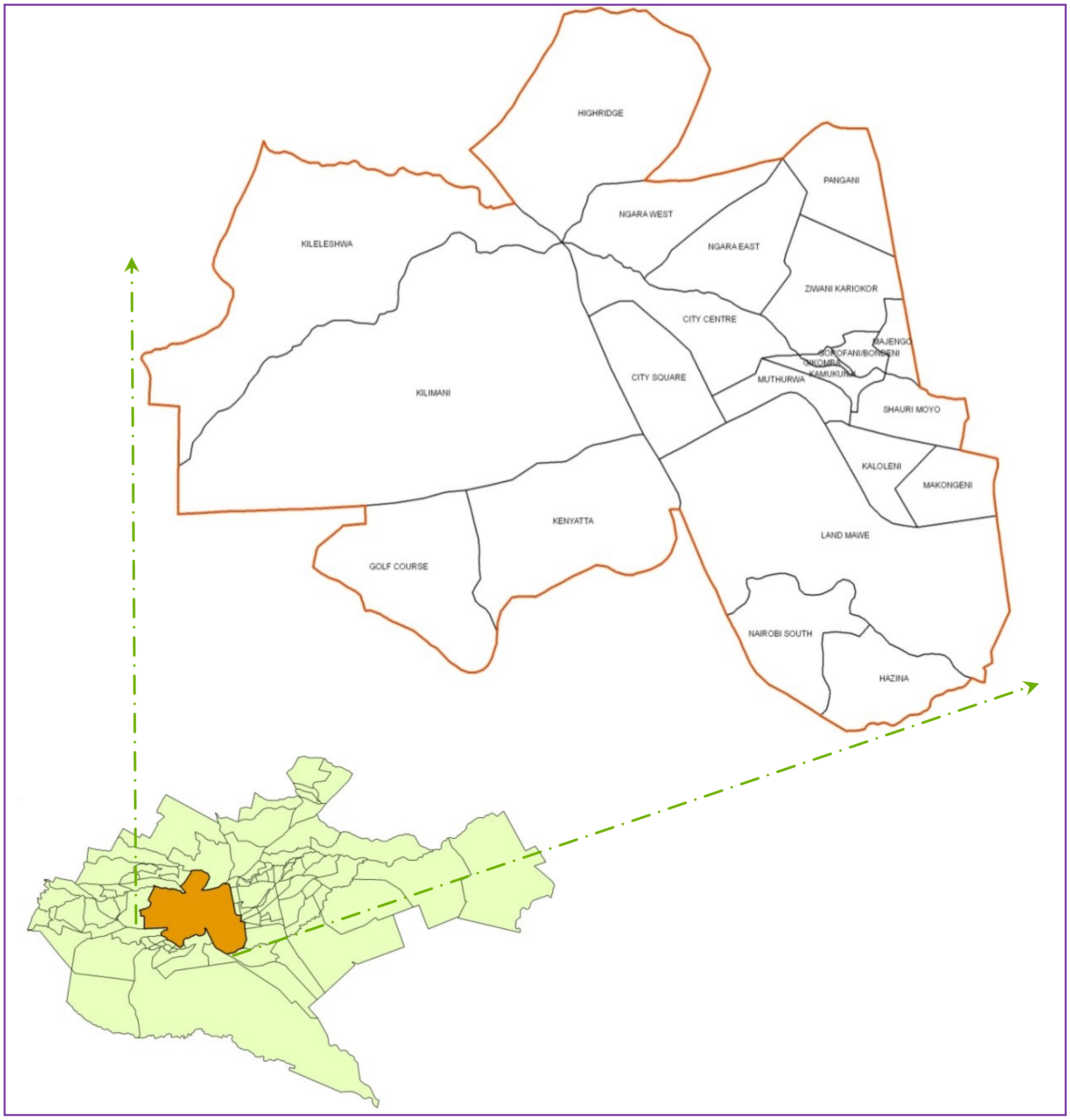

Figure 4: Map showing the location of Central Nairobi.

1.3.2 Tokyo Metropolis area.

Tokyo Metropolis area is one of the most urbanized and densely populated spots on earth. As such, municipalities in its core and suburbia are always grappling with challenges arising from this intense urbanism, and are constantly strategizing for their counter. Its core comprising of the Tokyo 23 Special Wards and their neighboring contiguous suburban cities were selected as part of the study areas for this research. The Tokyo 23 Special Wards are Adachi, Arakawa, Bunkyo, Chiyoda, Chuo, Edogawa, Itabashi, Katsushika, Kita, Koto, Meguro, Minato, Nakano, Nerima, Ota, Setagaya, Shibuya, Shinagawa, Shinjuku, Suginami, Sumida, Toshima and Taito wards. These wards function as independent cities complete with their mayors. The suburban cities include Asaka, Chofu, Higashi Kurume, Ichikawa, Kawaguchi, Kawasaki, Komae, Matsudo, Misato, Mitaka, Musashino, Niiza, Nishi Tokyo, Soka, Toda, Urayasu, Wako, and Yashio cities.

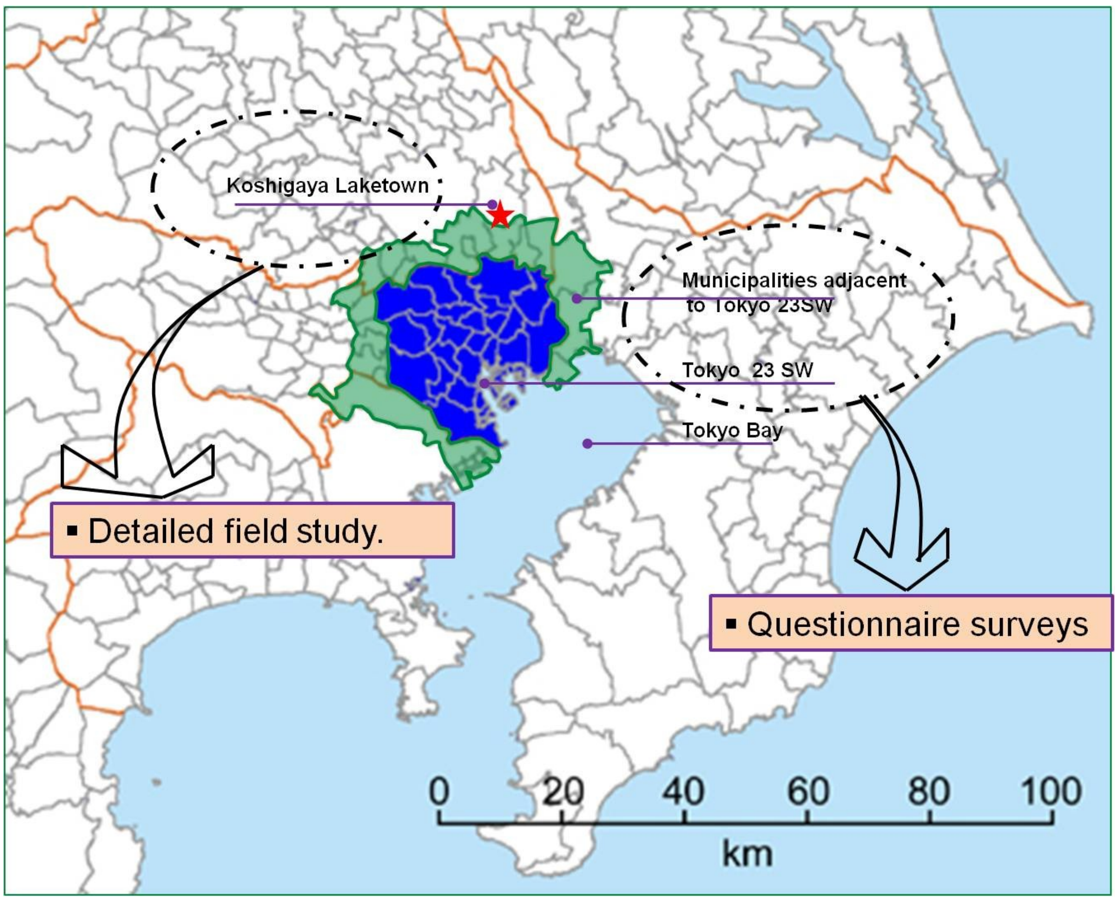

Figure 5: Tokyo 23 special Wards, their contiguous suburban cities, and Koshigaya Laketown.

1.3.3 Koshigaya Laketown.

For detailed case study on GI and application of Green Infrastructure Gauge, Koshigaya Lake was selected. According to UR-Japan (2009) documentation, during the EDO Period Koshigaya area was a post on the Nikko route. It was surrounded by many rivers experiencing a lot flooding in heavy rains. In 1986 the area was examined by Riverine Urban Review Committee, which included experts and government institutions. The area is designated as a case study model. Lake Town Development project began in 1988, and the decision made to initiate City Planning in 1996. The Ministry of Construction approved the project in 1999 and land development began with Urban Renaissance (UR) as executor. In 2008 JR Koshigaya Lake Town train station along Musashino line, and Koshigaya Laketown opened to public.

This is a new and ongoing projected curved out of land formally dominated by rice paddies. It was primarily established with its core as Osagami flood control reservoir. It is located 22km North of Central Tokyo, measuring 225.6 hectares with a projected population of 22,400. Koshigaya Lake Town was considered over other New Towns in Japan because it is a relatively new project that is still ongoing, constructed during the ‘ECO’ era, where many technologies are showcased or being experimented. It was awarded a GOLD AWARD in 2009 by LIVCOM, the World’s only Awards Competition focusing on International Best Practice regarding the management of the local environment, geared towards improving the quality of life of individual citizens through the creation of ‘livable communities’.

Koshigaya Laketown shares some common characteristics with proposed or upcoming Satellite New Towns in Kenya, by the fact that they have, or they are all being carved off agricultural land. UR-Japan (2009) indicates that the project aim is to reduce carbon emissions by 20%, control flooding, utilize cool spot effect, create a water front lifestyle, lead in environmental symbiosis, and create a community under the LIFE-LINK-LAKE concept. It has also played host to training programs by JICA and delegations from overseas local authorities.

1.4 Study framework and methods.

Table 1: Study framework and introduction to study methods.

Chapter		Methods
Chapter 1	Introduction	Study background.
Chapter 2	Literature and case review	▪ Literature review. ▪ Case reviews.
Chapter 3	Evaluation of Central Nairobi UGS	▪ Landscape level metrics and GIS spatial analyst used to analyze UGS characteristics, and identification of its potential expansion areas.
Chapter 4	Green Master Plan (GMP)	▪ Questionnaire survey in 41 municipalities. ▪ Evaluation of Green Master Plans documents from 12 municipalities.
Chapter 5	Green Infrastructure Gauge (GIG) formulation	▪ Questionnaire survey in 41 municipalities. ▪ Green Infrastructure Gauge (GIG) design. ▪ Pilot field survey in Koshigaya Laketown. ▪ Preliminary application of GIG.
Chapter 6	GIG Application	▪Detailed field survey in Koshigaya Laketown. ▪ Documentation of GI elements presence and functions affordance in Koshigaya Laketown. ▪ Application of GIG.
Chapter 7	Conclusion and UGN Proposition	▪ Summary of the main study findings and conclusions. ▪Theoretical proposition for Urban Grain Networks.

To meet the aim and the six objectives set for the study, the research flow is carried out and outlined in chapter by chapter as follows: In **Chapter 1**, the study background is elaborated citing the challenges that exist in urban areas from global literature. These include population and urbanization trends and their challenges, global warming and climate change, as well as ecological footprint, food deficiencies, and sustainability issues. This sets impetus for use of Green

Infrastructure (GI) as a concept that can meet these challenges if applied in planning, development and management of urban areas. The study aim, objectives, framework, methodology and definition of key terms are also introduced. In **Chapter 2**, a detailed literature review pertaining to GI has been carried out. This covers areas such as definitions, background, theory, and a case review.

In **Chapter 3**, Central Nairobi Urban Green Spaces (UGS) have been analyzed as a representative element of GI. Landscape level metrics and GIS spatial analyst have been used to analyze their characteristics, as well as identify areas with potential for expansion of UGS that can enhance GI in the study area. **Chapter 4** examines the Green Master Plans (GMP) of Japanese municipalities as potential guides for GI implementation. A questionnaire survey was conducted among public workers in 41 municipalities, in Tokyo Metropolitan area. Full version Green Master Plan (GMP) documents were obtained, analyzed and data tabulated from sampled municipalities. Data was analyzed in IBM SPSS Statistics 19. In **Chapter 5**, a Green Infrastructure Gauge (GIG) was formulated as a tool for evaluation of GI affordance in existing and proposed urban areas at the planning level. 13 GI elements (hardware) and 21 functions (software) were derived from literature and study of GMP in Chapter 4. A questionnaire survey was carried out to derive relative value for each function. A pilot field survey was carried out in Koshigaya Laketown to test the applicability of GIG. The resultant GIG was applied in **Chapter 6,** to evaluate Koshigaya Laketown GI affordance, in both elements and functions. It was also used to test the hypothesis set from the results of GIG application in Koshigaya Laketown after the pilot study in chapter 5. In view of the findings in the above chapters, **Chapter 7** contains the study conclusion and proposition. Highlights of the areas clarified by the study are made, and in response a new urban planning theory of \`Urban Grain Network\` (UGS) is proposed as a vehicle to promote GI and by extension sustainability of urban areas. Its central thesis is the combination of `urban agricultural network` metaphorically represented by `edible grains`, and `urban planning texture` represented by `wood grains`. This proposes mutual coexistence of Town and Country in one space, which symbiotically enhances GI, for sustainability and livability of the future urban areas.

1.5 Definition of key terms.

The key terms used in this study have been defined as shown in table 1 below.

Table 2: Definition of key terms.

1.	Green Infrastructure (GI)	▪ GI encompass connected networks of multifunctional, predominantly unbuilt, space that supports both ecological and social activities and processes (Kambites and Owen, 2006). ▪ A multifunctional resource, capable of delivering those ecological services and quality of life benefits required by the communities it serves, and needed to underpin sustainability (Natural England, 2009). ▪ A process that promotes a systematic and strategic approach to land conservation of the national, state, regional and local scales encouraging land-use planning and practices that are good for nature and people (Benedict and McMahon, 2006). ▪ It is an adaptable term used to describe an array of products, technologies, and practices that use natural systems, or engineered systems that mimic natural processes (US EPA, 2011). ▪ Natural or built ecosystems, elements, and concepts that encourage land-use planning and practices geared towards interconnectivity; to support sustainability and confer life support benefits to nature and people (by author).
2.	Urban Green Spaces (UGS)	▪ Areas of the landscape that are predominantly composed of vegetated land and water bodies within an urban setup. These include urban parks, greenways, street trees, esplanades and gardens among others, and are seen to provide both salve and respite from the deleterious effects of urbanization (Waldheim 2006).

3.	Green Master Plan (GMP)	▪ Document used by Japanese municipalities; to set out the image, aims and measures for conservation and promotion of green based on Article 4 of the Urban Green Space Conservation Law of 1994 (Japan Gov. 2012).
4.	Green Infrastructure Gauge (GIG)	▪ A method of analyzing and evaluating the level of Green Infrastructure presence in an existing urban area, OR its level of inclusion in a Green / Environmental Master Plan for an existing or a proposed new urban area (by author).
5.	Green Infrastructure Affordance	▪ The possession of GI elements (hardware) by an urban area, which confer functions (software) that benefit the residents, and have a low impact to nature and the environment (by author).
6.	Sustainability	▪ Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (UN- Bruntland Report, 1987).
7.	Green Infrastructure elements	Physical or conceptual tools, systems, products and technologies that contains, promotes and makes available benefits, goods and services of Green Infrastructure (by author).
8.	Green Infrastructure functions	▪ Benefits, goods, and services that Green Infrastructure elements in part or holistically give to nature, environment, and people.
9.	Urban Grain Network (UGN)	▪ An integrated urban system combining urban food production, urban planning, and design concepts that synergize in a network to enhance GI elements and functions (by author).

References.

1. Barthel, S., Isendahl, C. (2013). Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*. Vol. 86, 224 – 234.
2. Benedict, M., A., McMahon, E., T. (2006). *Green infrastructure: Linking landscapes and communities.* Island Press, Washington.
3. City Council of Nairobi (2007) City of Nairobi Environmental Outlook. Retrieved from http://www.unep.org/geo/pdfs/NCEO_Report_FF_New_Text.pdf, accessed on February 10th 2012.
4. Cohen M., J. and Garrett J., L. (2009). The food price crisis and urban food (in)security. IIED and UNFPA: *Urbanization and emerging population issues* - 2.
5. Colding, J., and Barthel, S. (2013). The potential of 'Urban Green Commons' in the resilience building of cities. *Ecological Economics*, Vol. 86, 156-166.
6. Convention on biodiversity (2010). City Biodiversity Index (or Singapore Index) (online). Retrieved from http://www.cbd.int/authorities/doc/User%27s%20Manual-for-the-City-Biodiversity-Index18April2012.pdf, accessed 1st May 2012.
7. Gibson, J., J. (1979, 1986). The theory of affordances. Lawrence Erlbaum Associates, Inc., 1986, New Jersey, USA.
8. Government of the Republic of Kenya (2008). The first edition of Nairobi Metro 2030. Retrieved from http://www.tatucity.com/DynamicData/Downloads/NM_Vision_2030.pdf. (Accessed on 10th June 2013).
9. Japan Government. Urban Green Space Law. http://www.mlit.go.jp/, accessed on August 20th 2012. (In Japanese).
10. Kambites, C. and Owen, S. (2006). Renewed prospects for green infrastructure planning in the UK. *Planning Practice and Research.* Vol. 21 (4), 483-496.
11. McGarigal, K., Cushman, S. A., Neel M. C., Ene, E. (2002). FRAGSTATS: spatial pattern analysis program for categorical maps. University of Massachusets, Amherst.
12. Meakin, S. (1992). The Rio Earth Summit: Summary of the United Nations Conference on Environmental and Development. Retrieved from http://publications.gc.ca/Collection-R/LoPBdP/BP/bp317-e.htm, accessed on March 17th 2013.
13. Mitullah, W. (2003). Understanding Slums: Case Studies for the Global Report on Human Settlements 2003: The Case of Nairobi, Kenya. UNHABITAT, Nairobi.
14. Natural England (2009) Green Infrastructure Guidance (NE176). http://publications.naturalengland.org.uk/publication/35033?category=49002, accessed on November 12th 2011.
15. Ramsar COP11 DOC. 23, 2012.11th Meeting of the Conference of the Parties to the Convention on Wetlands. Retrieved from http://www.ramsar.org/pdf/cop11/doc/cop11-doc23-e-urban.pdf, accessed on March 15th 2013.
16. Rees, W. (2003). Understanding Urban Ecosystems: An Ecological Economics Perspective in Understanding Urban Ecosystems. Springer-Verlag, Newyork.
17. Resource Centre on Urban Agriculture & Food Security (2012). What is urban agriculture? RUAF Foundation. Retrieved from http://www.ruaf.org/node/512, accessed on June 11th 2012.

18. Rudolf, S. de G., Mathew, A. W., Roelof, M. J. B. (2002). A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. *Ecological Economics* Vol. 41, 393-408.

19. Schaffler, A., Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure – The Johannesburg case. *Ecological Economics*, Vol. 86, 246-257.

20. Seattle City, Department of Planning and Development (2012). Seattle Green Factor. Retreived from http://www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/documents/default.htm. (Accessed on May 3 2012).

21. Smit, J., and Nasr, J. (1992). Urban agriculture for sustainable cities: using wastes and idle land and water bodies as resources. *Environment and Urbanization.* Vol. 4, No 2, 141-152.

22. Tibaijuka, A. (2007). Nairobi and its environment. United Nations Environment Programme. Retrieved from http://www.unep.org/dewa/africa/kenyaatlas/PDF/KenyaAtlas_Chapter5.pdf, accessed on May 29th 2013.

23. UN- Bruntland Report, (1987). Report of the World Commission on Environment and Development: Our Common Future. UN Documents. Retrieved from http://www.un-documents.net/our-common-future.pdf, accessed on March 18th 2013.

24. UN-HABITAT (2006). Nairobi Urban Sector Profile. United Nations Human Settlements Programme (UN-HABITAT), Nairobi.

25. United Nations (1992). United Nations Conference on Environment and Development (UNCED). Retrieved from http://www.un.org/geninfo/bp/enviro.html, accessed on March 17th 2013.

26. United Nations Department of Economic and Social Affairs/Population Division (2011). 83 World Population Prospects: The 2010 Revision, Highlights and Advanced Tables. Retreived from http://esa.un.org/unup/, accesed on June 11th 2012.

27. United Nations Population Division (2012). Retrieved from http://www.un.org/en/development/desa/population/theme/urbanization/index.shtml, accessed May 20th 2013.

28. United States Government, Environmental Protection Agency (EPA) (2011). Green infrastructure. http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm, accessed on August 20th 2011.

29. United States Government, Environmental Protection Agency (EPA) (2013). Climate Change: Basic information. http://www.epa.gov/climatechange/basics/, accessed on March 10th 2013.

30. Urban Renaissance Agency-Japan (UR) 2009. Koshigaya Laketown Project. Smart and sustainable urban life with the lake. LivCom Awards 2009. Retrieved from http://www.ur-net.go.jp/urbandesign/awards_pdf/landscape14.pdf, accessed on May 25th 2011.

31. van Kamp, I, Leidelmeijer, K, Marsman, G, and de Hollander, A (2003). Urban environmental quality and human well-being Towards a conceptual framework and demarcation of concepts; a literature study. *Landscape and Urban Planning*, Vol. 65, 5–18.

32. Waldheim C., Ed. (2006). *The Landscape Urbanism* Reader. Princeton Architectural press, New York.

33. Weber, T., Sloan, A., Wolf, J. (2006). Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation. *Landscape and Urban Planning* Vol. 77, 94-110.

34. Weisz, H., Steinberger, J. (2010). Reducing energy and material flow in cities. *Current opinion in material sustainability* Vol. 2, Issue 3, 185–192.

35. World Wildlife Fund (WWF) and Africa Development Bank (ADB), (2012). Africa Ecological Foot Print report: Green Infrastructure for Africa's ecological sustainability. Retrieved from http://www.footprintnetwork.org/images/uploads/africa_ecological_footprint_report.pdf, accessed on June 10th 2013.

36. Wright, H. (2011). Understanding green infrastructure: the development of a contested concept in England. *Local Environment* Vol. 16 (10), 1003–1019.

2 CHAPTER 2: Literature review.

2.1 What is Green Infrastructure?

The term Green Infrastructure (GI) is relatively new, but the concept is not (Benedict and McMahon, 2006).The evolution of GI is far from linear (Wright, 2011), it has its roots in studies of the land and the interrelationship of man and nature that began over 150 years ago (Benedict and McMahon, 2006). These roots form historical lineages that underpin GI concept (Mell, 2008). They include concepts and terms such as parks, park systems, park ways, garden cities, newtowns, national parks, green belts, greenways, ecological city, landscape ecology, landscape urbanism, smart cities, as well as sustainable development.

GI encompass connected networks of multifunctional, predominantly unbuilt, space that supports both ecological and social activities and processes (Kambites and Owen, 2006). It is an adaptable term used to describe an array of products, technologies, and practices that use natural systems, or engineered systems that mimic natural processes (US EPA, 2012). It should be designed and managed as a multifunctional resource, capable of delivering those ecological services and quality of life benefits required by the communities it serves, and needed to underpin sustainability (Natural England, 2009). Benedict and McMahon (2006) define GI as an interconnected green space network that is planned and managed for its natural resource values and for the associated benefits it confers to human populations. It is a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features (Natural England, 2009). Used as a NOUN, Green Infrastructure refers to an interconnected green space network that is planned and managed for its natural resource values and for the associated benefits it confers to human populations (Benedict and McMahon, 2006). While used as an ADJECTIVE, it describes a process that promotes a systematic and strategic approach to land conservation of the national, state, regional and local scales, encouraging land-use planning and practices that are good for nature and people (Benedict and McMahon, 2006).

GI can improve ecological processes, enhance food production, create employment, and promote the use of renewable energy. It entails establishment of green networks and green ways, enhance disaster prevention and mitigation, as well as storm water management. It also promotes green architecture, enhance community, family, and interpersonal bonding, as well as give identity and pride to residents. It includes Low Impact Development (LID), Smart growth and smart conservation strategies, green/ grey interface, conservation developments, and Urban Green Best Management Practices (BMPs). At all its levels, GI can utilize Ian McHarg's (1969) idea of 'physiographic determinism', which claims that natural process should be the basis for determining development (or non development priorities). This idea calls for environmental conscious approach to land use, a concept that resonates well with GI.

However, as an evolving concept, it is thus ambiguous with no single and precise definition (Wright, 2011). Though GI is ambiguous in interpretation and implementation, the ecological, environmental, and societal benefits it affords where practiced cannot be disputed. Wright (2011) expresses this ambiguity and argues that a single and precise meaning of "green infrastructure" is problematic because it is an evolving concept, divided between environmental theory and socio-economic policy. This study aspires to contribute to this evolution of GI, for the betterment of existing and future urban areas. Thus, for the context of this study GI is described as, "natural or built ecosystems, elements, and concepts that encourage land-use planning and practices that focus on interconnectivity; to support sustainability and confer life support benefits to nature and people".

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Green Infrastructure addresses a wide range of urban systems as shown in figures 6 and 7. Balance and vitality in these systems can create sustainable urban environment that is host to thriving nature, as well as environmental, socio-economic, and cultural prosperity.

Figure 6: GI composition (source; US-EPA, 2012).

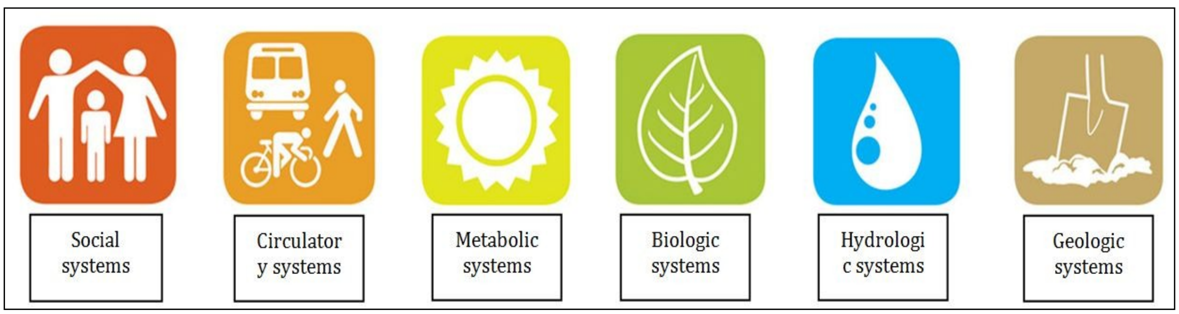

Figure 7: Green Infrastructure systems and function (source; Green Infrastructure WIKI, 2010).

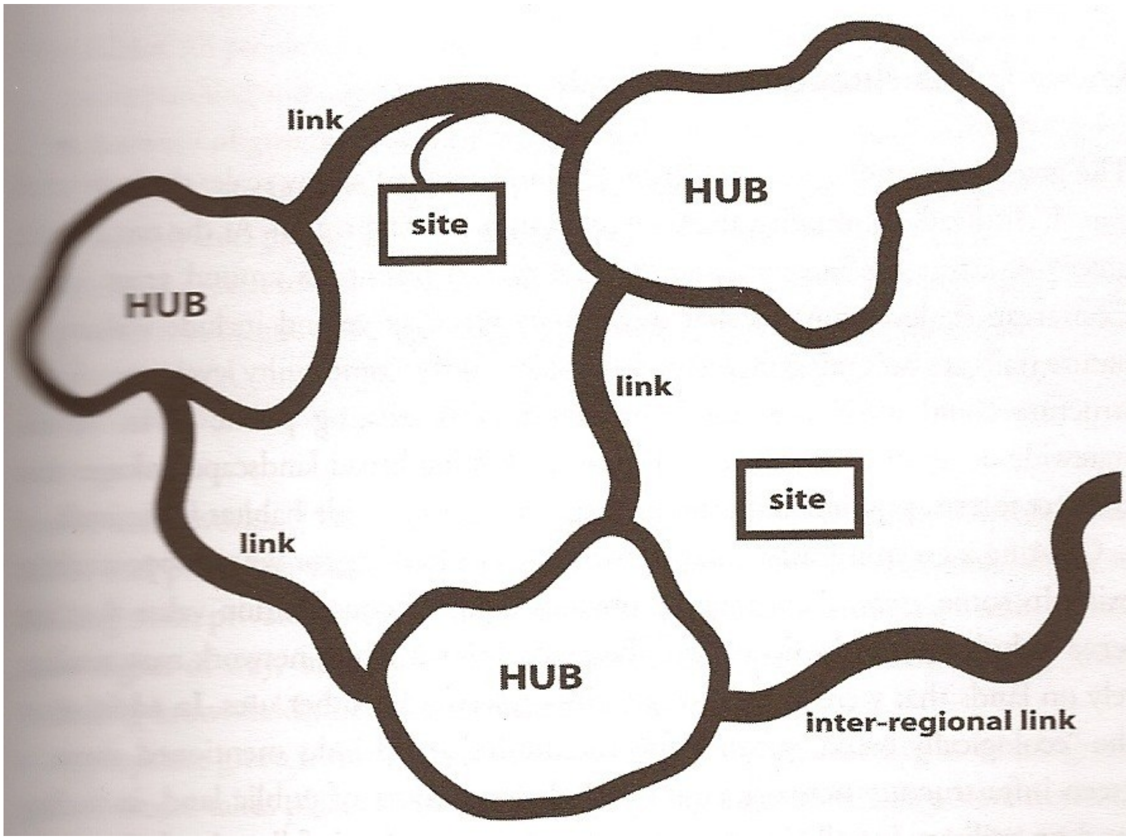

Figure 8: Green Infrastructure composition (source, Benedict and McMahon, 2006).

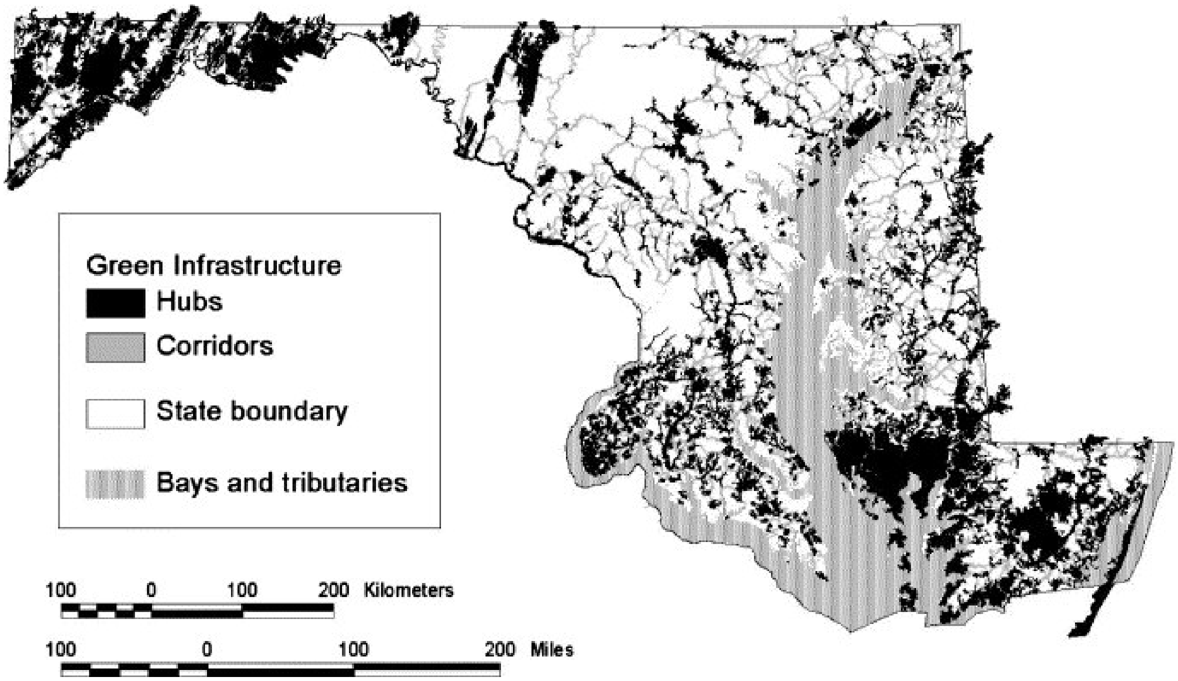

Figure 9: Maryland's Green Infrastructure network (source; Weber et al. 2006).

The Green Infrastructure approach can be implemented at any scale: the individual parcel, the local community, the state (regional) or even multi-state region (Benedict and McMahon, 2006). This study focus is mainly on Green Infrastructure affordances at the local community or city level. The Green infrastructure concept emphasize on connectivity and can exist as a Green Infrastructure network that connects ecosystems, and landscapes. This is a system of hubs, links, and sites that vary in size, function and ownership (Benedict and McMahon, 2006).

2.2 Affordance theory from the Green Infrastructure perspective.

This study has used the term ‘affordance’ in its title, and throughout the document. It can also be found within the document in other variations such as ‘afford’, ‘affords’, ‘afforded’, ‘affordance’ and ‘affordability’. The use of this term has been drawn from ‘The theory of affordances’ by James Jerome Gibson (originally published in 1979). He asserts that the environment affords animals terrain, shelters, water, fire, objects, tools, other animals and human displays. The affordances of the environment is what it offers the animal, what it provides or furnishes, either for good or ill. The environment substances have biochemical offerings and afford manufacture, while surfaces afford posture, locomotion, collision, manipulation and in general behavior. Special forms afford shelter and concealment, while fires afford warming and burning.

Gibson (1979) argued that perhaps the composition and layout of surfaces constitute what they afford. Drawing a similarity to this theory, urban areas affordances are what they are composed off, in terms of elements and surfaces. To that extent, urban areas affordance of GI is those GI elements that they contain. ‘Values’ and ‘meanings’ of things in the environment can be directly perceived, and to perceive them is to perceive what they afford (Gibson, 1979). This perception can be equated to the benefits, functions, or affordances that urban Green Infrastructure elements provide or furnishes the population of the area, and by extension nature and the environment.

2.3 Green Infrastructure elements and functions.

From the affordance theory, the surfaces and other composition of urban areas that form Green Infrastructure elements (hardware) affords benefits or functions (software) that nourish the environment, nature, and human beings. GI is an evolving concept to provide Abiotic, Biotic, and Cultural (ABC) functions in support of sustainability (Ahern, 2007). It establishes ecological capacity and social opportunities of an area, as well as integration of form and function that leads to landscape multifunctionality (Mell, 2008). Green Infrastructure provides a framework that can be used to guide future growth and future land development and land conservation decisions to accommodate population growth and protect and preserve community assets and natural resources (Benedict and McMahon, 2006). There are currently three broad and interrelated core ideas which appear to lead consistently throughout the meaning of GI concept; these are connectivity, multifunctionality, and “green” (Wright, 2011). “Green” is a more implicit idea in definitions and usually represents the elements of Green Infrastructure that act as a basis for environmental improvement (Wright, 2011).

Urban development consumes land, fragments the landscape, displaces many native species, and disrupts ecosystem functions (Weber et al., 2006). GI is viewed as one of the main tools to tackle threats on biodiversity resulting from habitat fragmentation, land use change and loss of habitats (European Commission, 2010 Benedict and McMahon, 2006). It is vital for enhancing ecological areas, corridors, and networks (TEP 2005, Weber et al, 2006, Benedict and McMahon, 2006) that increase ecological connectivity to overcome habitat fragmentation (Natural England, 2009, Weber et al., 2006). It improves overall ecological quality and maintain healthy ecosystems through flood plain areas, wetlands, coastal areas, natural forests and connecting elements such as small water courses, hedgerows, eco-bridges and eco-ducts (European Commission 2010). Such other GI connecting elements include road and rail corridors, cycling routes, pedestrian paths, and right of ways (Natural England, 2009). Linkages also provide space for the protection of historic sites and opportunities for recreational use (Benedict and McMahon, 2006). Links and corridors also include rivers and floodplains, greenways and greenbelts. Healthy ecosystems are part of our life support system and biodiversity is the basis for ecosystems' health and stability (European Commission, 2010). GI enriches habitats and increase biodiversity (Benedict and McMahon, 2002) to restore functioning ecosystems (PGIDP, 2010). Green Infrastructure maintains the integrity of habitat systems and may provide the physical basis for ecological networks (Tzoulas, 2007). In regard to Green Infrastructure Networks, Benedict and McMahon (2006) indicates that: hubs provide space for native plants and animal communities while links tie the system together maintaining vital ecological processes and the health and biodiversity of wildlife populations. GI describes the abundance and distribution of natural features in the landscape like forests, wetlands, and streams (Weber et al., 2006). Such elements of a Green Infrastructure can be seen as preserving and enhancing diversity within ecosystems in terms of habitats, species, and genes (Tzoulas et. al, 2007).

Ecosystem services consist of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare (Costanza et al., 1997). Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997). The elements and components of a complete Green Infrastructure could contribute to ecosystem health, that impacts in many ways to health and quality of life (Weber et al., 2006). A healthy ecosystem will bear ecological functions and ecosystem services that contribute to improved public (individuals and community) health and wellbeing (Tzoulas et al, 2007, Benedict and McMahon, 2001, Natural England, 2009). They provide a sense of solitude, inspiration and tackles ill health (Ahern, 2007, Mell, 2008). GI offers venues for relaxation, and a new way of addressing health issues associated with sedentary lifestyles, obesity, and mental illness (PGIDP, 2010). GI offers increased physical recreation opportunities (Ahern, 2007, Benedict and McMahon, 2002). Natural spaces encourage active lifestyles (PGIDP, 2010), where green spaces offer venues for exercise, play, leisure and practical ‘green gym’ activities (Natural England, 2009). Just as built infrastructure like roads and utilities is necessary for modern societies; green infrastructure provides the ecosystem services that are equally necessary for our well-being (Weber et al., 2006).

Most of GI components act like a native forest by collecting, absorbing, and filtering storm water runoff from roof tops, driveways, patios, and other areas that don’t allow water to soak in (US-EPA, 2012). These GI storm water runoff management components includes but not limited to: rain gardens, green roofs, green walls, infiltration planters/ wells basins, permeable pavements, trees, and tree boxes. Others are vegetated bio-swales, bio-retention systems, constructed wetlands, wet ponds, filter strips, riparian buffers, and natural swimming pools, and created wetlands, reservoirs (Mell, 2008, EPA, 2012, Ahern, 2007). Intact flood plains play an important role in helping alleviate flood by storing water and releasing it back slowly into streams and rivers (European Commission, 2010, Natural England, 2009). Sustainable storm water management also includes retrofitting of Sustainable Urban Drainage (SUDs) solutions and supports efficient management of water resources (Natural England, 2009).

At a local level, GI provides communities with aesthetic and natural resource benefits, manage storm water runoff, mitigate urban heat islands, disaster prevention and mitigation, recreation, food production, ecological wellbeing, and sedimentation among others (US-EPA, 2012). Green Infrastructure (GI) affords Ecosystem Services, that among others include purification of air and water, mitigation of floods and droughts, detoxication and decomposition of wastes, generation and renewal of soil fertility, partial stabilization of climate, moderation of temperature extremes, provision of aesthetic beauty, and intellectual stimulation (Greca et al., 2011, Benedict and McMahon, 2002, 2006, Costanza et al., 1997). Forests, woodland and scrub (TEP, 2005, Benedict and McMahon, 2001, Natural England, 2009) acts as carbon sinks and prevents soil erosion. Wetlands (marshes, floodplains, forest sand bog) absorb pollutants and improve the quality of fresh water supply (European Commission, 2009, Benedict and McMahon, 2002, 2006, Natural England, 2009). GI contributes to Regulation of atmospheric chemical composition such as sequestration of carbon (CO2/O2 balance) and green house gases (O3 for UVB protection, and SOx levels) (Ahern, 2007, Costanza et al., 1997).

It forms the basis for a low carbon economy (PGIDP, 2010) and contributes to a carbon efficient approach to living and low ‘food miles’ (Natural England, 2009). This is mainly in energy production and conservation, especially in providing a setting for renewable energy generation (PGIDP, 2010, Natural England, 2009). GI promotes sustainable transport and reduction of the need to travel by car, as well as making energy efficient and sustainable places to live and work (Natural England, 2009). This is achieved through low carbon transport based on sustainable transport green routes for walking, cycling, water transport, and horse riding that increase access, permeability, and movement (PGIDP, 2010, Natural England, 2009).

GI makes space for nature and natural systems to provide valuable ecosystem services (European Commission, 2010, Benedict and McMahon, 2006), and recognizes, protects and enhances the value of the natural environment (Natural England, 2011). It provides outer classrooms, maintains a vast genetic library (Natural England, 2010, Weber et al., 2006), as well as provides new and inspirational places for education and training (PGIDP, 2010). It promotes environmental education, and acts as a stimulus for artistic and abstract expression (Ahern, 2007). GI forges cultural and historical identity, offering experiences and interpretation of cultural history (European Commission, 2011). It protects and enhances cultural heritage (Natural England). GI is a source of good aesthetics. It surrounds cities with areas of outstanding natural beauty and provides scenery (PGIDP, 2010, Weber et al., 2006). GI is used for visual mitigation, making attractive places for living and working (Natural England, 2009).

GI is at the forefront of disaster prevention and mitigation; it contributes in modification and buffering of climatic extremes (Ahern, 2007). It offers Storm protection, flood control, drought recovery and mitigates other negative effects of changing weather patterns, and makes natural environments resilient in the face of climate change (Costanza et.al, 1997, European Commission, 2010, Natural England, 2009). It also makes direct contribution to improvement of local climate, “proofing” peoples’ homes, as well as communities through cooling effect where it acts as heat sink and in noise reduction, especially in calming of traffic through landscape buffering and attenuation (Natural England, 2009).

An important, but often neglected consideration is how green infrastructure can function as an augmentation, or even an alternative, to existing built infrastructure, dramatically improving cost efficiency and effectiveness in over-stressed systems (Schaffler et al., 2013). The breakdown in ecosystem functions causes damages that are difficult and costly to repair (Weber et al, 2006). Having to find manmade solutions to replace the services that nature offers free is not only technically challenging but also very expensive (European Commission, 2011). The economies of the Earth would grind to a halt without the services of ecological life-support systems, so in one sense their total value to the economy is infinite (Costanza et al., 1997). GI elements decrease cost of public infrastructure and public services (Benedict and McMahon, 2002). Investing in GI makes economic sense; it provides economically important goods and services such as water purification, soil fertilization, and carbon storage among others (European Commission, 2010). It lowers the cost of healthcare (Mell, 2008, PGIDP, 2010) and averts disaster relief and flood damage repair (Benedict and McMahon, 2002). It is a cost effective way of adapting to many of the challenges of the future climate change (PGIDP, 2010). It reduces economic and insurance risk in light of enhanced water resource management (Natural England, 2009). GI can improve economic growth and employment prospects through direct employment in capital projects and future management, as well as increased visitors and visitors spending (European Commission, 2011). These ecologically valuable lands also provide marketable goods and services, like forest products, fish and wildlife, and recreation (Weber et al., 2006)

Working lands form part of GI. These include working farms for agriculture, ranches, forests for lumber (Benedict and McMahon, 2002, 2006) as well as allotment gardens, community gardens and city farms (Natural England, 2009). They form part of primary products such as fish, game, crops, nuts, fruits, extractable through hunting, gathering, subsistence farming or fishing, as well as raw materials such as lumber, fuel, and fodder (Costanza et al., 1997). Urban agriculture is the largest and most efficient tool available to transform urban wastes into food and jobs, with by-products of an improved living environment, better public health, energy savings and management cost reduction (Smit and Nasr, 1992).

Natural systems protected by GI are not all green (Benedict and McMahon, 2006). GI also includes water ways and water features that can be termed as blue infrastructure which is composed of both open and running water (Natural England, 2009). It includes rivers, surface and ground water interactions (Ahern, 2007, TEP, 2005, Benedict and McMahon, 2002), as well as de-canalization of river corridors (Natural England, 2009).

2.4 Urban Green Spaces (UGS); the most common component of Green Infrastructure in cities and towns.

Urban Green space is a key component of GI (Natural England, 2009). It includes parks, street trees, public and private gardens, riparian zones along urban drainage lines, undeveloped ridges, and a variety of urban agricultural spaces such as food- and community based gardens (Schaffler et al., 2013). Others are urban hedgerows, lakes, lawns, green roofs and vacant lots (Larson and Perrings, 2013). Urban Green Spaces are the backbone of Green Infrastructure in cities and towns. Green Spaces have been increasingly designated in cities since the 1880's to counter environmental impacts of urban expansion and intensification (Liu andLiu, 2008). Urban Green Spaces can be defined as outdoor places with significant amounts of vegetation, natural or maintained, public or private as opposed to areas that are paved or have buildings on them (Balram and Dragicevic, 2005). Urban Green Spaces exist as patches (where the landscapes are composed of a mosaic of patches), corridors (linear landscape elements that can be defined on the basis of structure and function, and matrix the most extensive and most connected landscape element that plays a major role in the functioning of a landscape (McGarigal, 2002).

They exist mainly as semi-natural areas, managed parks and gardens, supplemented by scattered vegetated pockets associated with roads and incidental locations (Jim and Chen, 2003), community parks, forested lands and woodlots (Balram and Dragicevic, 2005). They also occur as Non Urbanized Areas (NUAS) that include natural parks, agricultural parks, community supported agriculture, allotment gardens, informal recreational areas, playgrounds, local urban parks and urban gardens (Rosa and Privitera, 2013). UGS provide benefits to the city that helps mitigate the negative effects of urbanization (Ridder, 2004), and are valuable amenity-recreation venues, wildlife refuge and essential livable-city ingredients (Jim, 2004). They provide important cultural ecosystem services to the local communities, and as recreational spaces they attract visitors, provide opportunities for social interactions and, thus, contribute to the development of new social ties and strengthen existing contacts (Kazmierczak, 2013).

Urban green areas have evapotranspiring and permeable features; they are fundamental to increasing urban quality creating more pedestrian friendly and visually pleasant settlements (Greca et al., 2011). They provide reconnections to nature that can provide both recreational and deep psychological benefits to address inter alia, youth violence, disaffected social groups, and psycho-cultural damage. Green spaces can act as effective storm-water attenuation systems, moderating, or even removing, the need to build large new pipe and channel systems that try to transport storm-water out of the city (Schaffler and Swilling, 2013). Trees improve air quality, regulate cities' hydro-climate, promote water and energy conservation, aesthetics, form green belts, provide wildlife sanctuaries, and store carbon (McPherson, 1997). Schaffler et al. (2013) found that in Johannesburg, a 50×50m2 woodland area stores an estimated 32.2 metric tons of carbon per hectare. Urban green commons (UGCs) that include collectively managed parks, community gardens, and allotment areas have potential to manage cultural and biological diversity in cities, diverse learning streams, environmental stewardship, and social–ecological memory (Colding and Barthel, 2013).

The aim of protecting Urban Green Spaces is to meet the recreational and social needs of urban dwellers; to provide facilities for outdoor passive and active recreation; to enhance the aesthetic value of urban areas and improve quality of life, and to enhance the environmental qualities of the urban landscape (NCEO Report, 2007). They often accommodate varied semblances of flora and small animals, providing readily accessible sites with natural ingredients or surrogates of nature for the enjoyment of inhabitants who are otherwise detached from nature (Liu and Liu, 2008). Urban Green spaces generally permit many uses, such as aquatic recreation (swimming, fishing) and other outdoor pursuits, park land, municipal depots, playing fields, golf courses, picnic sites, scout halls, landscape buffers and community paths. (NCEO Report, 2007). Although all UGS can be part of GI not all GI are UGS. UGS fulfills the ecological, environmental, socio-economic functions of GI, but GI is much wider than vegetated areas. It includes elements such as renewable energy installations, low impact mobility systems and other man made fixtures and concepts that are environmental friendly. However, UGS are often the main GI element in urban areas and play anchor to the other elements and systems.

2.5 Urban Agriculture as a component of Green Infrastructure in enhancing urban sustainability.

Urban Agriculture is the practice of growing food and fuels within the daily rhythm of the city or town, produced directly for the market and frequently produced and marketed by the farmers themselves or their associates (Smit and Nasr, 1992). It is embedded into the urban economy and ecology, using urban dwellers as laborers, urban resources like organic waste for compost, and urban waste water for irrigation (RUAF Foundation, 2012). Smit and Nasr (1992) point out that Urban Agriculture includes: (1) aquaculture in tanks, ponds, rivers, and coastal bays. (2) Livestock raised in backyards, along roadsides, and within utilities rights-of-way. (3) Orchards including vineyards, street trees, backyard trees, and (4) vegetables and other crops grown on roof tops, backyards, vacant lots of industrial estates along canals, on the grounds of institutions, on road sides and in many suburban small farms. Cities cover only 2% of earth's surface, but consume 75% of its resources. It is therefore imperative to reduce these food and resource deserts, and make them more livable for the fast increasing global urban population. Urban agriculture is the largest and most efficient tool available to transform urban wastes into food and jobs, with by-products of an improved living environment, better public health, energy savings and management cost reduction (Smit and Nasr, 1992). To achieve future urban resilience, there is need to re-ignite urban minds about the close connection between urban people and their life-support systems. Food security has always been a key resilience facet for people living in cities (Barthel and Isendahl, 2013).

2.5.1 Urban Agriculture from a historical perspective.

Urban farming is mentioned to have been practiced in Ancient Egypt and Machu Pichu among other ancient civilizations. In Utopia, Thomas Moore wrote of the gardens in Amaurot the capital city of Utopia, as having gardens behind their houses full of vines, fruits, herbs and flowers. Dr. Daniel Gottlob Moritz Schreber (1808 – 1861), advocated for development of garden parcels for workers living in cramped city conditions, where the first Schrebergarten or Kleingarten was established in Leipzig in 1864. In 1893 Detroit, due to a financial depression citizens were asked to use any vacant lots to grow vegetables. These were nicknamed Pingree's Potato patches after the mayor who came up with the idea. When the citizenry has low purchasing power, such forms of urban farming can instill food security and sustainability. Barthel and Isendahl (2013) define food security as the situation when people have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs.

In The Garden City concept (1902), Ebenezer Howard envisioned a New Town surrounded by a rural agricultural belt so that the town can feed itself. In the US, during the 1st world war (1914-1918) (Pack, 1919), the great depression (1929-1939) and the 2nd world war (1939-1945), citizens were asked to utilize any available open space to grow food to ensure food security, recreation and to boost morale. This resulted in emergence of War Gardens or Victory Gardens, also to be found in Canada and Europe. Community gardens or allotment gardens emerged in the 1970's as a response to Cities abandonment and rising inflation. They were also aimed at rebuilding social networks and the infrastructure of blighted urban communities.

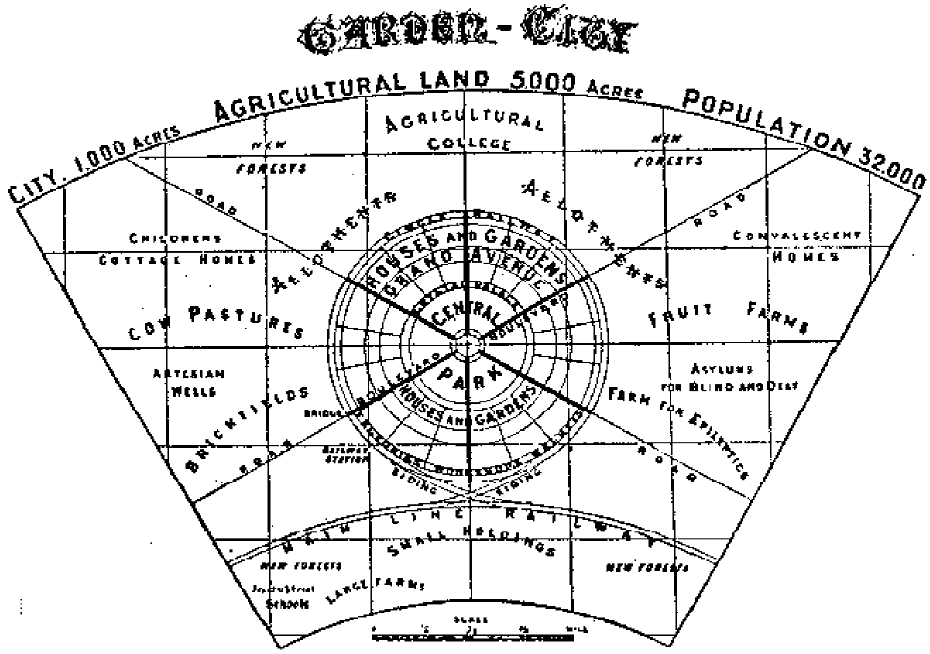

Figure 10: 'The Garden City", a model unit of 32,000 people surrounded by 5000 acres of agricultural land so that the city can feed itself (source; Howard, 1902).

Figure 11: Urban residents buying seeds for planting in War gardens in New Jersey, 1943 (source; Living History Farm's, 2012).

Figure 12: "Every Garden a Munition Plant", a poster advertising War Gardens (source; Pack, 1919).

2.5.2 Urban Agriculture today.

Urban agriculture today can be found in various composition and definition that include the following. Community Garden (a single piece of land gardened collectively by a group of people), and allotment garden/ Kleingarten / Schrebergarten (plots formed by subdividing a piece of land into a few or up to several hundreds of land parcels that are assigned to individuals or families). Other comes in form of urban Farms, roof top gardens, green houses, vertical farms, stacked green houses, and plant factories. These use high density urban farming technologies such as hydroponics, organoponics, rock wool substrate, drip irrigation, and zero tillage among others. Other are experimental underground farming being done by persona o2 in Tokyo, or even the bagriculture (growing crops in bags) practiced by people with limited space. Other features of Urban Farming of today include farmers markets, potlucks, work groups, agricultural tourism, and study tours.

Figure 13: Farming in vacant lot previously used as an informal dumpsite, Kibera Slum in Nairobi, Kenya (source; Annalee Newitz, 2008).

Figure 14: Staff of NTT Facilities, check the roof-top sweet potato farm in Tokyo (source; Toshifumi Kimura).

The challenges of urban agriculture could include soil contamination by heavy metals from the urban areas, which can be ameliorated through testing and decontamination. Economy of scale; can urban farming compete or replace rural large scale industrial farming? Availability of land as urban land is usually expensive. Alternative farming methods and technologies are thus required. Roof top farms, parks, brown fields, vacant lots, or planned urban agriculture belts in new urban areas can provide a solution to this challenge. Legal restrictions and economic impediments to access land and resources. There can also arise conflict with municipal greening policies such as tree crown cover targets, park area per capita targets among others.

Agricultural production is not “the antithesis of the city” – as modernist understandings of urbanity suggests – but is in many cases a fully integrated urban activity (Barthel and Isendahl, 2013). In light of the pressures of urban development and industry on ecosystems, an active civil society and critical scholars are preconditions for mobilizing the ability to protect urban green spaces, to support memory of how to grow food and to re-imagine the city as a place where food can be grown (Barthel and Isendahl, 2013).

2.6 Urban agriculture practice: The case of Havana, Cuba.

Havana is the capital of Cuba, the country's largest city, located on the northern coast of Cuba, and had a population of 2.185 million people in 2001, in an area of 727 km2 consisting of 77% urbanized and 23% non-urbanized land (Colantonio et al. (2007). During the colonial period, the Spaniards constructed defense fortresses that today represent some of the main attractions for heritage tourism. In the mid-1980s, over 50% of the total foodstuffs consumed in Cuba was imported, all made possible by the favorable terms of trade of the socialist bloc (especially for sugarcane), as well as by cheaply provided Russian oil, of which part was re-exported (Novo et. al, 2000). The collapse of the Soviet Union in 1989 caused a shock on the supply lines of food, fertilizers, and oil, which was particularly difficult for the people of Havana (Barthel et al., 2013), which was further compounded by the tightening US embargo. This Economic situation significantly deteriorated, and ushered in the period that was known as the "Periodo Especial" or "Special Period" (Korner et al., 2008). Before 1989, urban agriculture was almost non-existent in Havana. There was no need, not even for the poorest residents, to grow food, as food was distributed by the State, however, because of the food crisis, urban agriculture emerged (Novo et al. 2000). These farms are a unique model for sustainable farming in the world, Cuba's urban agriculture sites are uniformly presented as environmentally sustainable (Korner et al., 2008).

According to Novo et. al., (2000), after the crisis: a start was made to decentralize production and to link production directly to transportation and consumption patterns. The self-supply (*autoconsumo)* plan, initiated in the late 1980s, was expanded. It aimed to increase local food self-sufficiency, reduce the need for transport, refrigeration, storage and other resource-demanding activities. All over Havana, urban gardens were started. For the residents, it was not so much a question of whether, but rather how, they could produce food or raise animals. This was championed as "Production in the community, by the community, for the community", which refers to the cycle of producers, products, marketing and consumers. By 1998, over 8000 officially recognised agricultural production units were operational, in which over 30,000 people were working, putting approximately 30% of Havana's available land under cultivation (Novo et al., 2000). This made Havana unique, because in contemporary cities, spaces and skills related to local food and water management are rapidly vanishing on a grand scale (Barthel et al., 2012).

The following is Premat's (2013) account on Havana's urban agriculture. In 1991 a high-yield organoponic garden was created. It was a large lot of approximately one hectare with rows of raised container beds and drip irrigation used for growing a wide array of vegetables and herbs, including lettuce, spinach, and radishes. It objective was to produce and sell fresh produce to the population directly at source. This site required considerable state investment and was part of an officially-led initiative to link productivity to material incentives in the field of food production, if the government was to retain its long-term commitment to ensuring national food security. Small-scale urban agricultures sites then multiplied in privately-owned courtyards, alleyways, rooftops, previous demolition sites and portions of public parks. Family self-provisioning sites patios and parcelas represent the most popular expression of urban agriculture in Cuba. In Havana alone, there were 104,087 such sites covering an area of approximately 3,595 hectares.

Different expressions of urban agriculture have been shaped by the shifting landscapes of power that have characterized Cuba's move from a position of "communist solidarity" to one of "communist solitary". Novo et al. (2000) notes that: urban agriculture is strongly supported by the government, and governmental institutions play an important role in the organisation of urban farming. The Havana City Government passed a law prohibiting the use of chemical pesticides in agriculture within the citylimits. Thus, the crops are grown almost entirely using active organic methods. The previously banned farmers' markets have been allowed to operate again. In October 1994, 121 farmers' markets opened around the island. In 1993, the Cuban Government issued Law No. 142, breaking up the majority of large state farms into Basic Units of Production (Unidades Básicas de ProducciónCooperativa (UBPCs), small collectives owned and managed by the workers. Law No. 142 aims to connect the workers to the land, encouraging a concrete feeling of responsibility, to make the collective of workers and their families self-sufficient, to connect income directly to the degree of productivity, and to increase autonomy of governance.

Table 3: Characteristics of urban agriculture in Havana (source; Premat, 2013).

Production Sites	Land Tenure	Area Occupied	Main Objective	Land Tenure
Fincas (farms)	private/state	N/A	Commercialization	private/state
Organopónicos Populares (popular organoponic)	state	2000-5000 m^2	Commercialization	state
Huertos intensivos (Intensive gardens)	state	1000-3000 m^2	Commercialization	state
OAR (high yield organoponic)	state	> 1 ha.	Commercialization	state
Autoconsumo estatal (state workplace garden)	state	> 1 ha.	Provisioning of workplace dining rooms	state
Parcela (usufruct plot)	state	<1000 m^2	Household self-provisioning	state
"Productive" Patio	private	<1000 m^2	Household self-provisioning	private

Further, Novo et al., (2000) describe its composition as follows:

- **Popular gardens** (*grupos de parceleros).* The most popular form of urban agriculture in Havana. These gardens more or less spontaneously emerged in yards and on balconies, patios and rooftops in response to the problems of the "special period", food going directly to the family.

- **Basic production co-operative units** (*Unidades Básicas de Producción Cooperativa, UBPCs*). They are the result of the splitting up of state farms. They can be found throughout the country, usually with about 5-10 members.

- **Farms of the State Co-operative Supply Units.** The production of these farms (CSUs) is intended to supply the *cafetarias* of factories2. Most of these farms are on site, as the Worker Centres used to have idle land which, after the crisis, was made productive. Most of the CSUs produce asurplus, which is sold to the workers at the low “State prices”.

- **Individual farms.** Within the city limits of Havana, a number of individual farms (*Campesinos particolares)* typical farm size is about 13 ha. Most of the milk and cut flowers sold in Havana originate from these farms.

- **State farms. T**hree state-run agricultural enterprises (*Empresas Estatales*) in Havana. Their produce is then distributed through the state distribution system.

- ***Organopónicos* and intensive gardens.** A special feature of Havana’s agriculture is the so-called *organopónicos*. These are raised container beds with a high ratio of compost (50%) to hydroponic fibres or soil (50%). The *organopónicos* are used mainly for intensive vegetable production. This system works very well in urban settings; for example, on paved vacant lots or plots with poor soils.

Novo et al. (2000) indicates further advantages of Havana urban agriculture as follows: Urban farmers, on average, sell their produce 20% cheaper than mainstream market traders and effectively counter excessive price increases. Because the produce is bought on the spot and no storage and transport are needed, post-harvest losses are lower as well. Neighbourhood gardens regularly donate food to schools and daycare centers. In an attempt to promote better eating habits and improve nutrition, production units are linked with youth groups and schools. Thus, urban agriculture also improves the quality and variety of food consumed. Havana's residents are now eating more fresh vegetables than before the “special period”. In addition, the popular gardens enhance cohesion and solidarity in the neighborhoods. Development of urban agriculture has created new employment opportunities – an important aspect, since the crisis reduced jobs significantly. Overall, the Government estimates that 117,000 people work in urban agriculture and 26,426 workers are employed in jobs related to urban agriculture. In 1998, urban agriculture accounted for 6-7% of the new jobs. Daily, the city produces 1,400 tons of solid waste from residential areas. Part of the waste is recycled in the newly created centers for producing compost. In total, about 25 units are in place in Havana for the recycling of urban organic waste. An extra contribution to the environment by urban agriculture is the reforestation program (*Mi Programma Verde*). The net environmental impact of urban agriculture thus has been positive, contributing to increasing the greening of urban wasteland, improving water retention, improving the air quality and beautifying the urban landscape.

However, the last point above is in dispute because Colantonio et al. (2007) point out urban agricultural initiatives can be deemed responsible for much of the deforestation that has occurred in Havana in recent years. Urban agriculture has also combined with ill-conceived land use in Havana’s peripheral areas, such as sugar cane plantations and urban agricultural gardens, thereby leading to further deforestation. This in turn, has engendered an alteration of natural drainage and hydrological systems in much of the green belt that was established around Havana in the 1960s.

Korner et al., (2008) notes that in these urban farms, organic methods of food production without any chemical inputs are practiced. At the moment, the small-scale urban farms that need organic fertilizers have their main source as manure - organic fertilizer. In their proposal for the integration of decentralized composting of the organic fraction of municipal solid waste into the waste management system of Cuba, Korner et al., (2008) indicate that the location for such decentralised composting units would optimally be located at urban agricultural farms, which can be found all over Havana. The proposal takes into account the present transport crisis, as well as the limited food supply, partly caused by the lack of fertilizers.

In conclusion; urban agriculture not only transferred food production responsibilities to the city but also turned everyone's attention to smaller spatial scales, such as the neighborhood, in ways that signaled an important reconfiguration of prior government practices (Premat, 2013). Such urban food production strategies have not turned Havana into a wealthy city, but have helped to increase food security resilience in the face of a trade breakdown (Barthel et al., 2012).

Figure 15: Images of urban agriculture plots in Havana, Cuba (source; Noah Friedman-Rudovsky, 2012).

2.7 Green Infrastructure evaluation tools.

Rudolf et al (2002) conceptualized a framework and typology for describing classifying and valuing ecosystem functions, goods and services. The framework however focuses on natural ecosystems and does not cover exhaustively the entire GI constituents as currently formulated. Green Infrastructure Assessment (GIA), a tool developed by Maryland Department of Natural Resources focuses on hub and corridor selection at regional level. It uses ecological importance to guide conservation of natural systems (Weber et al, 2004). It has been applied to come up with Maryland's Green Infrastructure Network. This tool's parameters and focus is of a larger scale and not appropriate for evaluating GI at a local level or community level.

Green Factor Score Sheet or Seattle Green Factor (Seattle City, 2012) is a scoring system for landscapes, required in certain parts of Seattle to help increase the quantity and improve the quality of urban while allowing flexibility for developers and designers to meet development standards. This is applied at a parcel or individual plot level, hence just a part of the whole in addressing GI at a local/ community level. Another evaluation tool is the City Biodiversity Index (CBI) or (Singapore Index) developed by the Convention on Biological Diversity (CBD, 2010). It was developed as a self-assessment tool, to: (i) assist national governments and local authorities in benchmarking biodiversity conservation efforts in the urban context; and (ii) help evaluate progress in reducing the rate of biodiversity loss in urban ecosystems. Though its application is at a city scale, its main stay is in biodiversity conservation efforts and evaluation of progress in reducing the rate of biodiversity loss. This focus excludes other elements of GI composition. They also include FRAGSTATS, a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns (McGarigal et al., 2002).

These tools focus on a particular area of GI to the exclusion of the holistic GI composition. More research is needed on the way GI is being or ought to be valued in cities, with a specific focus on how they might conceivably be incorporated into spatial planning and urban design (Schaffler and Swilling, 2013), as well as development of evaluation and appraisal tools.

2.8 Study's theoretical flow.

This study's flow from Chapter to Chapter is based on the need for further research in Green Infrastructure in order to reduce its ambiguity, and contribute in its evolution (Wright) in reducing the negative impacts urbanism as pointed out pointed out in Chapter 1. In meeting its aims and objectives set in its introduction, the study reviews literature pertaining to the concept of GI, to clarify its definitions, affordances, and composition in terms of elements and functions. Urban Green Spaces have been given special attention as they have been the traditional elements of urban spatial use, and they are still its dominant element especially in provisioning of ecological goods and services, as well as socio-cultural and economic benefits to residents. Urban agriculture is also given prominence as a GI element capable of entrenching urban sustainability and self reliance. This is essential especially in fostering food security and reducing vulnerability of urban residents from global fluctuation in food commodity prices and distribution networks disruptions, especially for the urban poor as exhibited in the case of Havana Cuba.

This affordance of Urban Green Spaces (UGS) as the main element of GI is evaluated in Central Nairobi, to find out its current composition, distribution, size, accessibility. This area was also evaluated to find out whether it contains potential areas for expansion of UGS and entrench GI. Through understanding the 'state' of our green infrastructure, we can begin questioning what type of ecological and technical infrastructure, and planning, is needed to enhance resilience between people and nature in urban environments (Schaffler and Swilling, 2013). But for such expansion or utilization of potential expansion areas to be realized, holistic planning in terms of government or municipalities' intervention through policy formulations, and master planning are necessary (POSA_Japan, 1997). These offers guidance and awareness not only to public policy implementers, but also to private enterprise and the general public in participating to promote GI. To this end, GMPs in Tokyo Metropolis area were evaluated. It is trough such policies, plans and promotion of GI that urban areas that lack in some GI elements can factor their implementation, and enhance those they already poses.

But how can we quantify the success of implementation of such policies, master plans, government, and municipal GI promotion or lack of it, and the final product of GI existent in urban areas or in plans for its implementation? The tools available for this purpose have been shown to focus on specific components of GI and not the holistic gauge of GI existent or proposals. There is need to quantify GI to inform achievements and failures from planning, implementation and management, which can result in its enhancement. Arguing or presenting the case of GI graphically and numerically to governments, municipalities, private enterprise and residents after its gauge, can better its consideration in policy formulation and budgetary allocations, as well as public awareness. Inserting the value of green infrastructure into the matrices of traditional infrastructure choices and budget decision-making criteria is critical if we are to have more sustainable cities (Schaffler et al., 2013). For such reasons, the study formulates a Green Infrastructure Gauge, which is applied in Koshigaya Laketown as a case study.

In conclusion of the above, spatial and conceptual planning strategies ought to be developed in the furthering of GI evolution. Such strategies should focus on enhancing GI elements and functions affordances as outlined in the theory of Urban Grain Networks fronted as a proposition in this study, to foster urban sustainability.

References

1. Ahern, J., (2007). Green infrastructure for cities: the spatial dimension. In: Novotny, V., and Brown, P., (Editors). *Cities of the future: towards integrated sustainable water and landscape management.* IWA Publishing, London. 267–283.
2. Balram, S., Dragicevic, S. (2005). Attitudes towards urban green spaces: integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. *Landscape and Urban Planning*, Vol. 71, 147–162.
3. Barthel, S., Isendahl, C. (2013). Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*. Vol. 86, 224–234.
4. Benedict, M., A., McMahon, E., T. (2006). *Green infrastructure: Linking landscapes and communities.* Island Press, Washington.
5. Benedict, M.A., and McMahon, E.T. (2002). Green infrastructure: smart conservation for the 21st Century. Renewable Resources Journal, Vol. 20 (3), 12–17.
6. City Council of Nairobi (NCEO Report) (2007). City of Nairobi Environmental Outlook. Retrieved from http://www.unep.org/geo/pdfs/NCEO_Report_FF_New_Text.pdf, accessed on February 10th 2012.
7. Colantonio, A., Potter, R., B. (2007). City profile: Havana. Cities, Vol. 23, No. 1, 63–78.
8. Colding, J., and Barthel, S. (2013). The potential of 'Urban Green Commons' in the resilience building of cities. *Ecological Economics*, Vol. 86, 156-166.
9. Convention on biodiversity (2010). City Biodiversity Index (or Singapore Index) (online). Retrieved from; http://www.cbd.int/authorities/doc/User%27s%20Manual-for-the-City-Biodiversity-Index18April2012.pdf, accessed 1st May 2012.
10. Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, Vol. 387, 253–260.
11. De Ridder, K., Adamec V., Bañuelos A., Bruse M., Bürger M., Damsgaard O., Dufek J., Hirsch J., Lefebre F., Pérez-Lacorzana J. M., Thierry A., & Weber C. (2004). An integrated methodology to assess the benefits of urban green space. *Science of the total environment,* Vol. 334–335, 489-497.
12. European Commission. (2010). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: options for an EU vision and target for biodiversity beyond 2010. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0004:FIN:EN:PDF, accessed on May 7th 2013.
13. Gibson, J., J. (1979, 1986). *The theory of affordances.* Lawrence Erlbaum Associates, Inc., 1986, New Jersey, USA.
14. Greca, P., L., Rosa, D., L., Martinico, F., Privitera., R. (2011). The role of non-urbanized areas for eco-sustainable planning in metropolitan region*. Environmental Pollution*, Vol. 159, 2193 – 2202.
15. Green Infrastructure Wiki. (2010). Green Infrastructure systems and function. Retrieved from http://www.greeninfrastructurewiki.com/?t=anon, accessed on November 20th 2010.
16. Howard E. (1902). *Garden Cities of Tomorrow.* Swan Sonnenschein Co., Ltd.

17. Japan Government, Ministry of Land, Infrastructure, and Transport. (2004). Landscape Act (Act No. 110 of June 18, 2004). Retrieved from http://www.mlit.go.jp/crd/townscape/keikan/pdf/landscapeact.pdf, accessed on August 10th 2012.

18. Jim, C. Y. (2004). Green-space preservation and allocation for sustainable greening of compact cities. *Cities,* Vol. 21 No. 4, 311–320.

19. Jim, C. Y., Chen, S. S. (2003). Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing City, China. *Landscape and Urban Planning,* Vol. 65, 95–116.

20. Kambites, C. and Owen, S. (2006). Renewed prospects for green infrastructure planning in the UK. *Planning Practice and Research.* Vol. 21 (4), 483-496.

21. Kazmierczak, A. (2013). The contribution of local parks to neighborhood social ties. *Landscape and Urban Planning,* Vol. 109, 31–44.

22. Korner, I., Saborit-Sanchez, I., Aguilera-Corrales, Y., (2008). Proposal for the integration of decentralized composting of the organic fraction of municipal solid waste into the waste management system of Cuba. *Waste Management,* Vol. 28, 64–72.

23. Larson, E., K., Perrings, C. (2013). The value of water-related amenities in an arid city: The case of Phoenix metropolitan area. *Landscape and Urban Planning,* Vol. 109, 45–55.

24. Liu, S., Liu, B., (2008). Using GIS to assess the ecological-niche for urban green Space planning in Wuxi City, Anhalt University of Applied Science. Bernburg, Germany.

25. Living History Farm. Photo: Buying victory seed in New Jersy, 1943. Retreived from http://www.livinghistoryfarm.org/farminginthe40s/crops_02.html, accessed on June 12th 2012.

26. McGarigal, K., Cushman, S. A., Neel M. C., Ene, E. (2002). FRAGSTATS: spatial pattern analysis program for categorical maps. University of Massachusets, Amherst.

27. McHarg, I. L. (1969). *Design with Nature*. New York: John Wiley & Sons, INC.

28. McPherson, E.G., Nowak, D., Heisler, G., Grimmond, S., Souch, C., Grant, R., Rowntree, D.J. (1997). Quantifying Urban Forest Structure, Function and Value: The Chicago Urban Forest Climate Project. *Urban Ecosystems*, Vol. 1, 49-61.

29. Mell, I. C. (2008). Green Infrastructure: concepts and planning. *FORUM Ejournal*, Vol. 8, 69-80.

30. Natural England (2009). Green Infrastructure Guidance (NE176). http://publications.naturalengland.org.uk/publication/35033?category=49002, accessed on November 12th 2011.

31. Newitz, A. (2008). Kibera's "Instant Farm" System Is the Future of Urban Agriculture. Retreived from http://io9.com/5045470/kiberas-instant-farm-system-is-the-future-of-urban-agriculture, accessed on June 12th 2012.

32. Novo, M., G., Murphy, C. (2000). Urban agriculture in the city of Havana: a popular response to a crisis. *Growing cities, growing food: urban agriculture on the policy agenda*, 329-347.

33. Pack, C., L. (1919).*The War Garden Victorious*. J.B. LIPPINCOTT COMPANY, PHILADELPHIA. An e-book retrieved from; http://www.earthlypursuits.com/WarGarV/WarGardTitle.htm, accessed on June 11th 2012.

34. Parks and Open Space Association (POSA) of Japan. (1997). *Green Master Plan Handbook*. Bunkousha, Tokyo.

35. Plymouth City Council. (2010). Plymouth's green infrastructure delivery plan. http://www.plymouth.gov.uk/green_infrastructure_delivery_plan.pdf, accessed on March 11th 2012.

36. Premat, A. (2013). Havana's Urban Agriculture. Retrieved from http://www.yale.edu/agrarianstudies/colloqpapers/01premat.pdf, accessed March 4th 2013.

37. Resource Centre on Urban Agriculture & Food Security, RUAF Foundation. http://www.ruaf.org/node/512, accessed on November 10th 2012.

38. Rosa, D., L., Martinico, F., Privitera., R. (2013). Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. *Landscape and Urban Planning*, Vol. 109, 94–106.

39. Rudolf, S. de G., Mathew, A. W., Roelof, M. J. B. (2002). A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. *Ecological Economics* Vol. 41, 393-408.

40. Rudovsky, N., F. (2012). Urban Agriculture in Cuba (Photo Essay). North American Congress on Latin America. Retreived from https://nacla.org/news/2012/10/18/urban-agriculture-cuba-photo-essay, accessed on 10th June 2013.

41. Schaffler, A., Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure – The Johannesburg case. *Ecological Economics*, Vol. 86, 246-257.

42. Seattle City, Department of Planning and Development. (2012). Seattle Green Factor. Retreived from http://www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/documents/default.htm, accessed on May 3 2012.

43. Smit, J., and Nasr, J. (1992). Urban agriculture for sustainable cities: using wastes and idle land and water bodies as resources. *Environment and Urbanization.* Vol. 4, No 2, 141-152.

44. TEP. (2005). Advancing the delivery of green infrastructure: targeting issues in England's northwest. http://www.greeninfrastructurenw.co.uk/resources/Advancing_Delivery_of_GI_-_Targeting_Issues.pdf, accessed May 15th 2013.

45. Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, Vol. 81, 167–178.

46. United States Government, Environmental Protection Agency (EPA) (2011). Green infrastructure. http://water.epa.gov/, accessed on August 20th 2011.

47. Weber, T., Sloan, A., Wolf, J. (2006). Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation. *Landscape and Urban Planning*, 77, 94-110.

48. Wright, H (2011). Understanding green infrastructure: the development of a contested concept in England. *Local Environment, Vol.* 16 (10), 1003–1019.

3 CHAPTER 3: Evaluation of Central Nairobi Urban Green Spaces as a component of Green Infrastructure.

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3.1 Introduction.

The quality of a city's environment manifested in its Urban Green Spaces (UGS) reflects in many ways the quality of life and societal behavior found in it. A city devoid of quantity and quality UGS becomes a concrete jungle or a polluted city vulnerable to calamities, behavioral vices, and low livability index. UGS provide benefits to the city that helps mitigate these negative effects (de Ridder et al., 2004). They are valuable amenity-recreation venues, wildlife refuge and essential livable-city ingredients (Jim, 2004). Urban Green Spaces are therefore a primary element of Green Infrastructure, in functions affordance and capacity to host other GI elements. Population explosion in urban areas is continuously threatening the land available for urban green spaces. The increase of urban dwellers is much greater in developing than in developed countries, with high growth rate of urban population easily explained by high birth rates and by large-scale migration from rural to urban areas (Olembo and Rhan, 1987). In the case of Nairobi City, the population increased from 2.14 million in 1999 to about 4.38 million people in 2010 (KNBS ,2010). This has put a lot of pressure on urban public amenities, services and land, where 75% of this population growth is absorbed by informal settlements fueling urban poverty. Land uses that are perceived to make more direct economic returns to public, and private investors constantly consume urban land and by extension urban green spaces.

With accelerated urbanization, the landscape as a whole becomes more fragmented ecologically, more complex compositionally and geometrically (Buyantuyev et al, 2009). In developing countries, municipal intervention where it exists often limits to street planning. It practically never provides for future green space, thus; most new Third World urban areas are commonly treeless (Olembo and Rham, 1987). Urban Green Spaces can be defined as outdoor places with significant amounts of vegetation. They exist in cities mainly as semi-natural areas, managed parks and gardens, supplemented by scattered vegetated pockets associated with roads and incidental locations (Jim and Chen, 2003). A city with high quality and generous green spaces epitomizes proper planning and management, a healthy environment for humans, vegetation, wildlife populations (Godefroid, 2001) and bestows pride on its citizenry. While some cities manage to retain or even extend their green spaces, others experience degradation and destruction (Jim, 2004). We need proper planning control to ensure green spaces for current and future generations (Ahris et al., 2006). Olembo and Rhan (1987) propose extensive urban forestry programs, amenity corridors, wedges in a green-space web (van der Valk, 2002), and linear greenway sites (Flink and Seams, 1993). With lots, green spaces should be allocated in the grounds of residential, office, government, institutional and community land uses (Jim, 2004).

Understanding the structure of urban areas is beneficial to urban management for reasons such as runoff control, urban forest planning, air quality improvement, and mitigation of global climate change (Myeong et al., 2003) that are all vital aspects of GI concept. There are various methodological approaches employed in the field of urban green space analysis, all with diverse aims and results. Nowak et al. (1996) reviews several methods of determining urban green cover from aerial photographs. They include; crown cover scale, transect method, dot method and scanning method, which is more precise, detailed and integrates well with GIS. Buyantuyev (2009) quantifies the land use and land cover change in Phoenix Arizona from 1985 to 2005 using landscape metrics computed from Landsat derived maps that revealed temporal patterns of landscape composition and configuration. Landscape metrics and land uses and land cover areas (LULC) maps, derived from remotely sensed images with various spatial, temporal, and thematic resolutions frequently characterize the patterns of urbanization. Liu and Liu (2008) propose the application of ecological niche modeling techniques that show the necessary distribution estimates of green spaces. They caution that its results should not be used in green space construction, because it does not consider conflicts between spaces and other human barriers.

GIS has proved useful in vegetation distribution, and site selection. This is in relation to ecological and socio-economic variables, assessing impacts on environment for development projects, and in space and resource allocation to conflicting types of use (Liu and Liu, 2008). It is also useful as a tool for GIS documentation and assessment of UGS connectivity in Green Infrastructure networks among others. Suitability analysis is a common and classic GIS application that consist several steps. They include attribute and location-based queries, buffers, spatial-joins and overlays (Gorr and Kurland, 2008). Areas suitable for expansion of UGS can be identified using Land Suitability Analysis (LSA) based on GIS, an effective application within the land-use planning and habitat analysis (Nowak et al., 2003). LSA supported by spatial analysis functions of GIS including data collection, weighting, data integration, analysis and output evaluation (Uy, 2006) can be used to establish various potential values of different areas to receive green spaces. This study employs multiple approaches to analyze the existing conditions of Nairobi Central urban green spaces and identification of the potential areas to expand the same. The above review points out mainly to computer based methods of analyzing and processing data, while this study engages human inputs and judgment that can fill-in gaps in the data. This is vital in adoption and actualization of the results if need be.

3.1.1 The study goals.

1) To analyze the quantitative characteristics of the existing Urban Green Spaces as primary elements of Green Infrastructure (GI), so as to give an insight on its permeation in the study area.
2) Evaluate whether the characteristics of the study area's UGS could afford adequate benefits to influence quality of life, nature, and environmental well being.
3) Find out whether the study area had potential areas that could be utilized for future expansion of UGS to help improve the environment, nature, residents' quality of life, and Green Infrastructure (GI) realization.

3.1.2 The study area.

The study area comprised of the inner wards of the city of Nairobi, composed of the Central Business District and its environs, identified herein as Central Nairobi. It included the areas of Kileleshwa, Kilimani, Golf Course, Kenyatta, Highridge, Ngara East, Ngara West, Ziwani, Pumwani, City Centre, and City Square. Others are Muthurwa, Gikomba, Gorofani/ Bondeni, Kamukunji, Majengo, Shauri Moyo, Kaloleni, Makongeni, Land Mawe, Nairobi South and Hazina. They are the oldest part of the city, most urbanized areas, and exhibits a wide range of land uses. These areas' UGS was analyzed for its size, composition, distribution, and access. This included evaluation of UGS and other land uses and land cover areas (LULC) for their potential in supporting expansion of UGS.

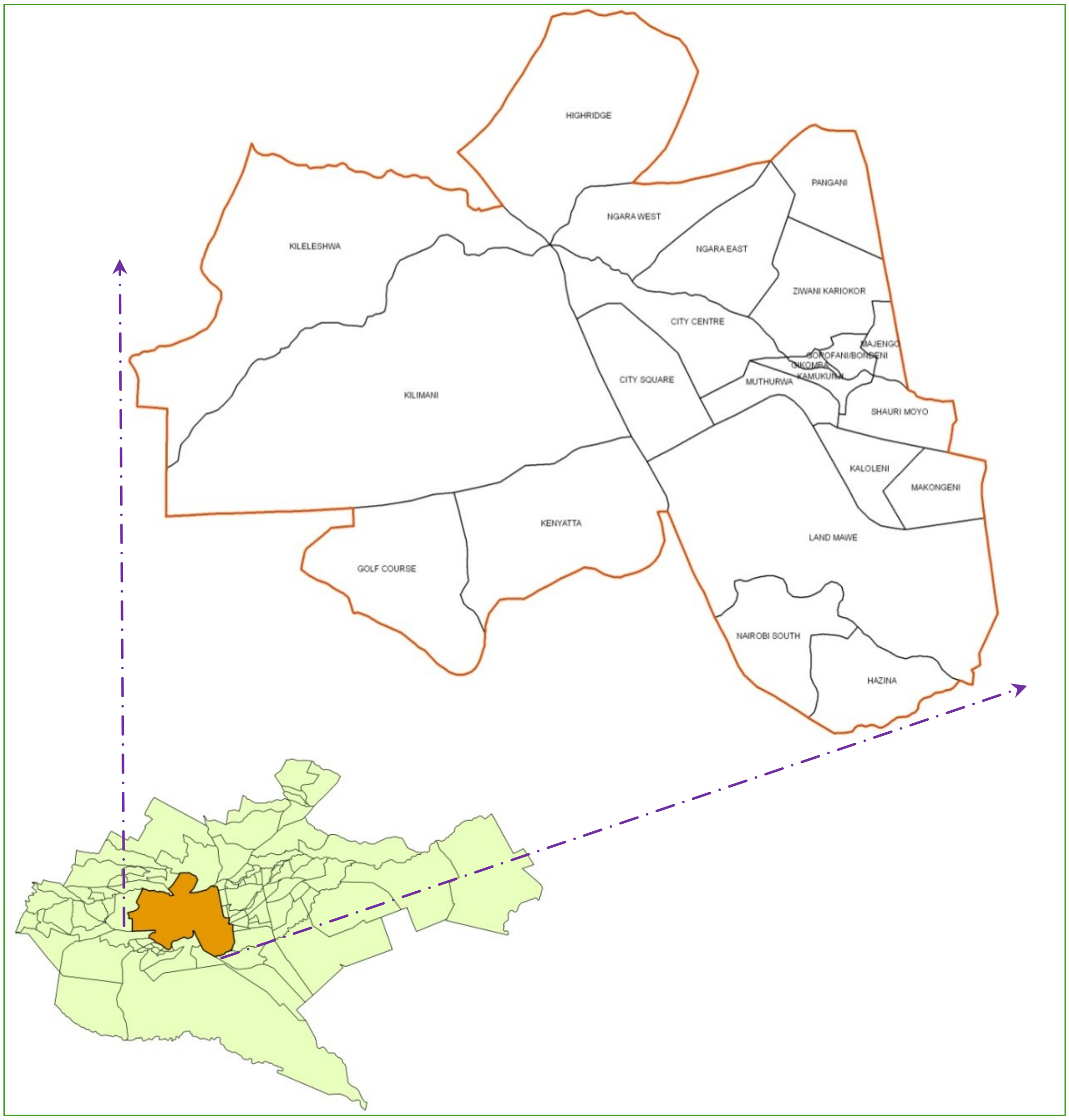

Figure 16: Map of Nairobi City showing the study area (Central Nairobi).

3.2 Methodology

The study used orthographic photographs; GIS vector maps and a UGS suitability checklist as the basic data collection and generation elements. Department of Survey in Kenya provided orthographic photographs and vector maps, and The Nairobi City Council maps containing land use planning and zoning data. Structured interviews were conducted among Nairobi based experts in the fields of urban planning and landscape architecture, including those in the civil service, academic institutions, and private practice. The interviews generated complimentary insight on spatial and other factors influencing UGS in Central Nairobi. They also generated priorities used to calculate the weights of variables used in both suitability checklist and proximity buffering. Orthographic photographs and vector maps were verified and corrected through physical survey of the study area, and data sets prepared and processed in ArcGIS 9.3.1, to create a geodatabase. Similar disjointed layers of both raster and vector data were merged and extracted to the study area. They were subsequently traced, digitized and attributes described for areas forming part of green space. These included areas with: substantive tree canopy, substantive mixture of trees, grass and shrub cover, or substantive wetland vegetation, in both density and extent as seen from the orthographic photographs.

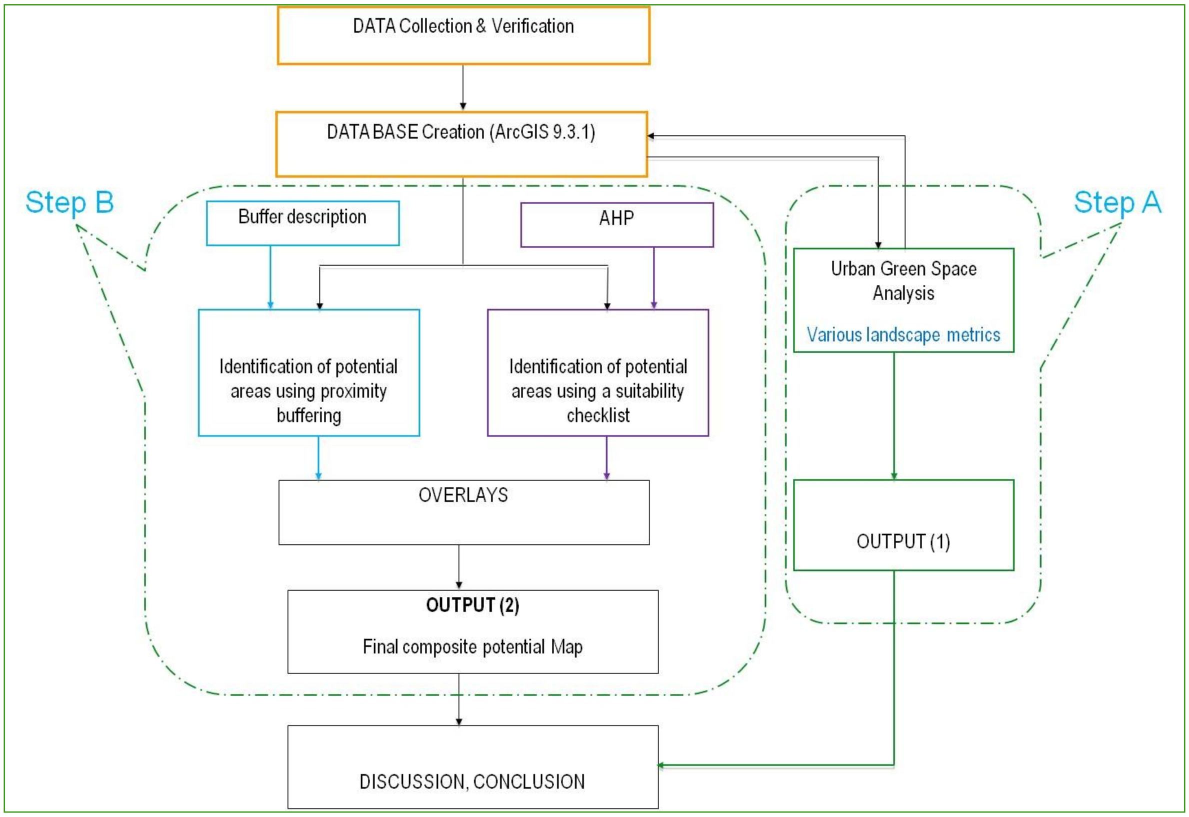

Figure 17: Study methods and framework.

To meet the first objective which was "to analyze the quantitative characteristics of the existing Urban Green Spaces as primary elements of Green Infrastructure (GI)", various landscape metrics were used to analyze the digitized map and its attributes for areas with UGS. The common usage of 'Landscape Metrics' refers exclusively to indices developed for categorical map patterns. They are algorithms that quantify specific spatial characteristics of patches, classes of patches, or entire landscape mosaics (McGarigal 2002). These landscape metrics were adopted to analyze composition and configuration of Central Nairobi UGS as described in Table 1 below. On the second objective which was to "evaluate whether the characteristics of the study area's UGS could afford adequate benefits", UGS per capita (UPC) was calculated and UGS distribution pattern examined. This was done using visual identification of UGS patches, and how they vary across the areas in number, size, shapes, and class.

Table 4: Landscape level metrics and their description (source; McGarigal 2002).

Landscape Metric	Description (unit)
Total area (TA)	The total area of the study area (unit: km^2).
UGS abundance (UA)	Total area occupied by UGS (unit: km^2).
Percentage UGS abundance (%UA)	The percentage of total area (TA) comprised of UGS (unit: %).
Proportional UGS abundance (PUA)	Percentage of total area (TA) comprised of a specific class of UGS (%).
Diversity of UGS (DU)	Number and classes of UGS identified.
Proportional diversity of UGS (PDU)	The percentage area of UGS occupied by a specific class (unit: %).
Landscape shape index (LSI)	Perimeter-to-Area (PA) ratio.
Mean Patch Shape Index (MPSI)	Patch level shape index averaged over all patches of the UGS.
Isolation/ proximity/ nearest-neighbor	Distance to the nearest green space of the same class (unit: km).
Largest patch index (LPI)	Percentage of the landscape occupied by the largest patch (unit: %).
Mean patch size (MPS)	The average area of all patches in the study area (unit: ha).
Patch size standard deviation (PSSD)	The standard deviation of patch size in the entire study area (unit: ha).

The third objective was met through site suitability assessment that involves the creation of suitability maps that identify areas most suitable for a certain activity (Hopkins, 1977). Elements such as rivers, roads, railway lines and utility corridors were traced, verified, classified and digitized. Viable areas to receive UGS were also traced, digitized and their attributes described in a separate layer. An Urban Green Space Suitability Checklist, that entailed variables or parameters used to evaluate the suitability of an area to be converted and developed as UGS was developed. The following variables were evaluated and assigned values based on Analytical Hierarchy Process (AHP) and pair-wise comparison. (i) Areas within 100m proximity of existing UGS (ii) wetlands (iii) riparian areas (iv) bare soil or open grounds (v) demand areas (vi) transportation and or infrastructure corridors (vii) friendly land use planning (viii) those with unfriendly land use planning.

A goal was set ‘to select potential sites for expansion of UGS’, using the variables above as alternatives for reaching that goal, and four factors or criteria to relate the alternatives to the goal. These included; influence on ecological processes, curb pollution or protect resource, extend BUGS, and easy to acquire or convert to UGS. Experts interviewed provided priorities (numerical values representing relative weights for each variable derived from pair-wise comparison in relation to the goal). Consequently, the priorities with resultant weights for each variable were analyzed as follows. Areas within 100m proximity of existing UGS (0.115), wetlands (0.154), riparian areas (0.151, bare soils or open grounds (0.139), demand areas (0.112, transportation and or infrastructure corridors (0.138), friendly land use planning (0.118), and unfriendly land use planning (0.074). The checklist included eight variables, their descriptions and weights. Each space identified as a potential area for expansion of UGS using the checklist was evaluated. If, the space possessed any of the variables, it was accorded full weight or zero weight where it did not. This was done for all the variables against all the identified spaces, and a total score recorded for each. Each space got this score as a new field in its attributes, symbolized into three classes expressed in the resultant map based on their value through a colour gradient as High, Mid and Low Potential. Normalization process was carried out in a separate field, where areas of high potential were assigned a value of 30, mid potential 20, and low potential 10, a step to ensure compatibility during map overlay.

A second process to reduce bias in identification of potential expansion areas of UGS within the study area was employed. Various variables compatible with UGS were identified, digitized and their attributes described. They included existing UGS, rivers and streams, wetlands as well as transportation and infrastructure. Subsequently, relative weight for each variable was derived using Analytical Hierarchy Process (AHP) with the resulting figures as follows. Existing UGS (0.197), rivers and streams (0.274), wetlands (0.281) transportation and infrastructure (0.248). Buffer boundaries were determined as: existing UGS (200m for green space and 100m for sports fields), rivers and streams (60m for rivers and 30m for streams), wetlands (50m), transportation and infrastructure (highway 60m, main road 30m, feeder roads 15m, and railway 50m). Using GIS spatial analyst, a buffer was created for each variable, and each map assigned a colour gradient commensurate with its weight. Eventually, the resulting single variable maps were overlaid to create a single map of 'potential areas through proximity buffering'. They exhibited three varying colour gradients of high, mid and low potential areas. Normalization process for compatibility was done during map overlay. High potential areas were assigned score 15, mid potential 10 and low potential 5, as this process was considered less weighty and accurate than that of checklist application.

Map overlays are a common method for delineating suitable areas (McHarg, 1969). To get a final potential map, the output maps of Suitability Checklist and that of Proximity Buffering processes were overlaid. After overlay, a value for each of the areas was derived, whether existing independently or overlapping with another potential area. The sum of these values was expressed numerically and in colour gradient on the Final Potential Map showing the most to the least potential areas for expansion of UGS.

3.3 Results and Discussion

3.3.1 STEP A: Identification of potential expansion areas through UGS suitability checklist.

The total area (TA) for the study areas is approximately 41.75km2 or 4175 ha. Its Green space abundance total was 4.12km2 or 415.7 ha, with percentage abundance for UGS at 9.86%. This shows Central Nairobi is under endowed since various cities have set much higher thresholds. Hanoi in Vietnam as an example has set its minimum at 18% (Uy, 2006), and of Johannesburg's 164458 ha, a total of 16.1% is covered by trees. Urban parks, mostly utilized and accessed by urban dwellers for their recreational needs cover just 0.78% of the total study area. Urban forests with their bigger role as carbon and dust sinks, as well as biodiversity hosts than any other class occupy only 0.83% of the total study area. Classes occupying the largest portions of UGS includes institutional green space (PUA 2.55% or PDU 25.89%), golf courses (PUA 2.44% or PDU 24.72%), and residential green space (PUA 2.11% or PDU 21.38%). These indicate that most of the UGS is not accessible to the public, but only members of these institutions. They include those that can afford membership fees in the case of golf courses, and homeowners and their families in the case of residential green space. This leaves residents living in apartments, small lot town houses and in the crowded slums of Nairobi having little or no opportunities in accessing green spaces. This is similar to what Kazmierczak (2013) points out that an increasing proportion of urban space is privately developed and managed, thus becoming commodified and exclusionary.

The proportional UGS abundance (PDU) that is the percentage of the total area (TA) composed of each class of UGS is as shown on Table 4. In terms of diversity, nine classes of UGS were identified. Residential green space had the most patches at 34, while urban forest had the least with one patch as also summarized on Table 4. This single patch is the small forest patch of forming part of Nairobi Arboretum. Composition shows low diversity, and lack in essential UGS classes such as neighbourhood parks, children play parks, thematic gardens, and agricultural areas (urban farms) among others. All the above afford GI functions such as provision of avenues for play, recreation, socializing, therapeutic functions, city aesthetics, supplement food supply and expand ecological catchment. The number of patches per class also shows inequalities. Urban parks have just five patches indicating that even if they were evenly spread throughout the study area, they could be far and wide hence inaccessible to most residents. These five patches include Uhuru Park, Central Park, and Jevanjee Gardens which are located close to each other and within the commercial district, negating equitable distribution easy accessibility from the residential areas. According to the now defunct City Council of Nairobi (NCEO-Report, 2007), in the 1990s large areas of public recreational land were indiscriminately grabbed. This led to hitherto elaborately planned open spaces being built up, which has significantly lowered the city's environmental quality and aesthetic value. This explains the low diversity, distribution, and accessibility clarified in this study.

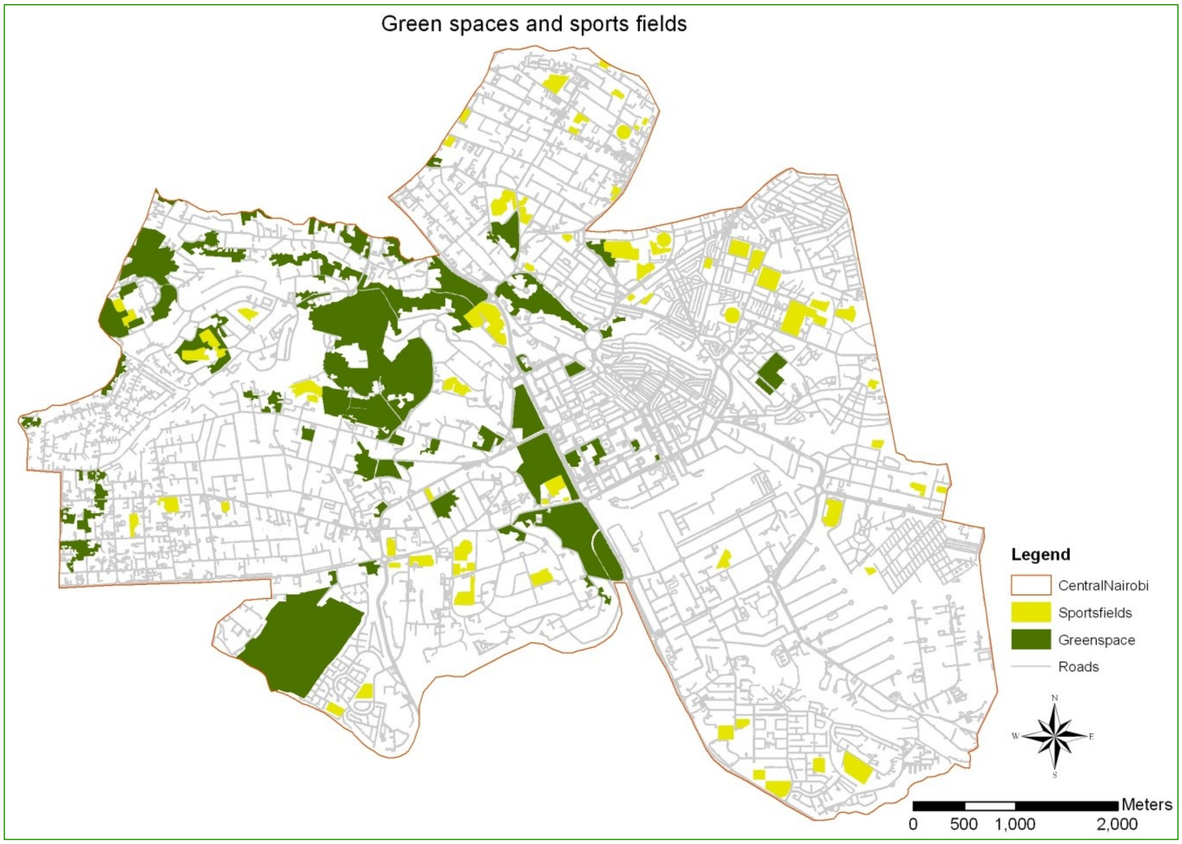

Figure 18: Existing UGS and sports fields' patches after trace over and digitization.

Landscape shape index (LSI) establishes whether a landscape patch shape is compact or not, irregular or convoluted. This was calculated using perimeter-to-area (PA) ratio that established a maximum LSI for green spaces at 0.1035, minimum at 0.0056 and a mean of 0.0471, as well as the standard deviation of 0.0235. It also indicated that the larger patches had a lower PA ratio (more compact) than smaller ones that are more convoluted and irregular. This can be attributed to the fact that larger patches could be products of whole lots or combination of lots with regular geometry predetermined through planning and designated for UGS. Smaller patches could be products of leftover or incidental spaces within lots or across lots. The largest patch measured 0.73km2 or 73.19ha, big enough to form a hub within a Green Infrastructure network. This makes the largest patch index (LPI) to be 1.75%. The mean patch size (MPS) for green spaces was 0.058km2 or 5.80ha, with a patch standard deviation (PSSD) of 0.101km2 or 10.09ha.

Table 5: Landscape metrics attributes.

	Landscape Metric	Attribute
1.	Total area (TA)	41.75km2
2.	UGS abundance (UA)	4.12 km2
3.	Percentage UGS abundance (%UA)	9.86 %
4.	Proportional UGS abundance (PUA)	See table 4
5.	Diversity of UGS (DU)	9
6.	Proportional diversity of UGS (PDU)	See table 4
7.	Landscape shape index (LSI)	0.1035. minimum at 0.0056. mean of 0.0471 standard deviation of 0.0235.
8.	Largest patch index (LPI)	1.75%.
9.	Mean patch size (MPS)	0.058km2
10	Patch size standard deviation (PSSD)	0.101km2

Table 6: UGS diversity, proportional UGS abundance (PUA), and proportional diversity of UGS (PDU).

	Class	Number of patches per class (No.)	Proportional UGS abundance (PUA) (%)	Proportional diversity of UGS (PDU) (%)
1	Urban forest	1	0.83	8.39
2	Urban park	5	0.78	7.89
3	Residential green space	34	2.11	21.38
4	Institutional green space	15	2.55	25.89

5	Commercial area green space	7	0.19	1.97
6	Riparian green space	3	0.80	8.08
7	Golf course	3	2.44	24.72
8	Cemetery green space	3	0.17	1.69

The study area total population in 2010 as per the Kenya National Bureau of Statistics (KNBS, 2010) estimates was 438,376 people. Thus, green space per capita at that time was 9.38m2/person. The western half of the study area contained most of the patches, with the eastern half having just but few patches. This indicates unequal distribution of UGS that affords advantage to the western residents over the eastern counterparts in access, recreation, and contact with nature. The green spaces in the north western part, exhibited a high degree of contagion, with close proximity to neighboring patches. They were also irregular and large, which is conducive for a vibrant ecosystem, and accords residents within their catchment areas a better chance to enjoy recreational and other benefits. The patches found in north eastern and south eastern areas are small, with little or no contagion and have large distances to the nearest neighbor. They also showcase a high level of compactness, which can signal reduced ecological processes and BUGS, and by extension existence of Green Infrastructure (GI). Schaffler and Swilling (2013) report a similar trend in Johannesburg where forest covers approximately 24.2% of the total area of Johannesburg's historically wealthy northern suburbs, while tree coverage in the poorer southern quadrant is approximately 6.7%. They point out that this uneven distribution is almost universally taken as a physical manifestation of unequal access to services across the city. UGS patches in the entire study area do not show any pattern in planning or formation. They appear arbitrary in space and place, indicating piecemeal planning or natural occurrence.

3.3.2 STEP B1: Identification of potential expansion areas through UGS suitability checklist.

A total of 129 patches considered as raw spaces before application of the UGS suitability checklist were identified and digitized. The spaces spread throughout the study area in varying sizes, shapes, and locations. The UGS Suitability checklist was applied and the cumulative weight for each patch computed. The least potential patch scored a total weight of 0.1610; the most potential scoring 0.6680 out of the maximum weight score of 1 and mean potential of 0.4098. Identified potential areas after application of UGS suitability checklist are as shown on Figure 3. Colour gradation symbolizes areas with high potential normalized with score 30, mid potential normalized with score 20 and low potential normalized with score 10 as shown on the map's legend. The high potential patches are large enough and are all over the study area, especially to the eastern half which has few existing UGS.

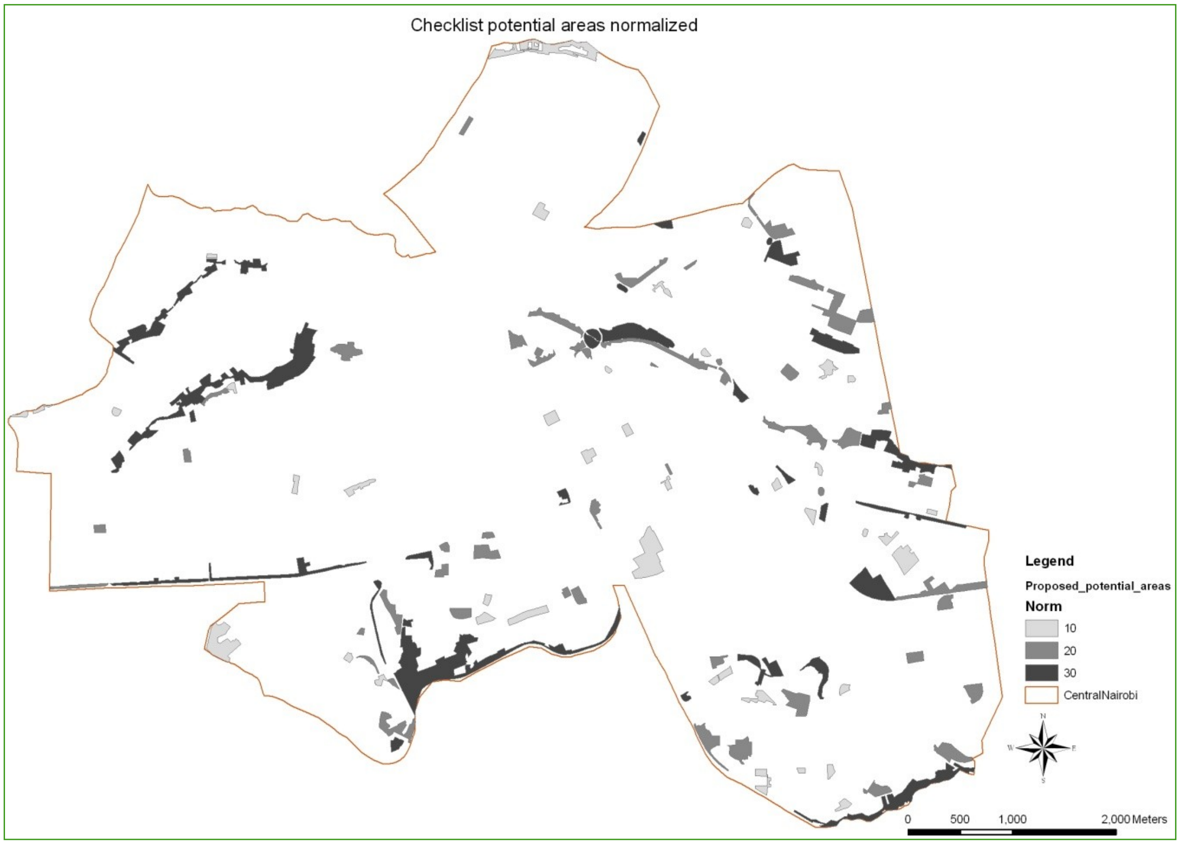

Figure 19: Potential map after UGS checklist application and normalization

3.3.3 STEP B2: Identification of potential expansion areas through proximity buffering.

A potential map was generated for each variable included in proximity buffering based on their derived weights. They included potential areas after transportation and infrastructure buffering, rivers and streams buffering, wetlands buffering as well as existing UGS buffering. They were then overlaid to produce a resultant map containing potential areas after proximity buffer overlays as shown on figure 13. The map indicates colour gradation denoting high potential areas normalized with score 15, mid potential normalized with score 10 and low potential areas with score 5. Proximity buffering resulted in a network of possible linear green spaces that transect through the entire study area. Such buffer zones a long transportation corridor can reduce dust and smoke which are prevalent in Nairobi, screen off eyesores and reduce traffic noise among other benefits. Rivers within the study area are part of Nairobi River Basin, including Nairobi River and Ngong Rivers. Buffering their corridors with UGS as indicated in Figure 4, can enhance their quality, reduce encroachment, and consequently enhance their service to the residents, the environment and restore riparian ecosystems that can be used as a basis for a Green Infrastructure network within Nairobi.

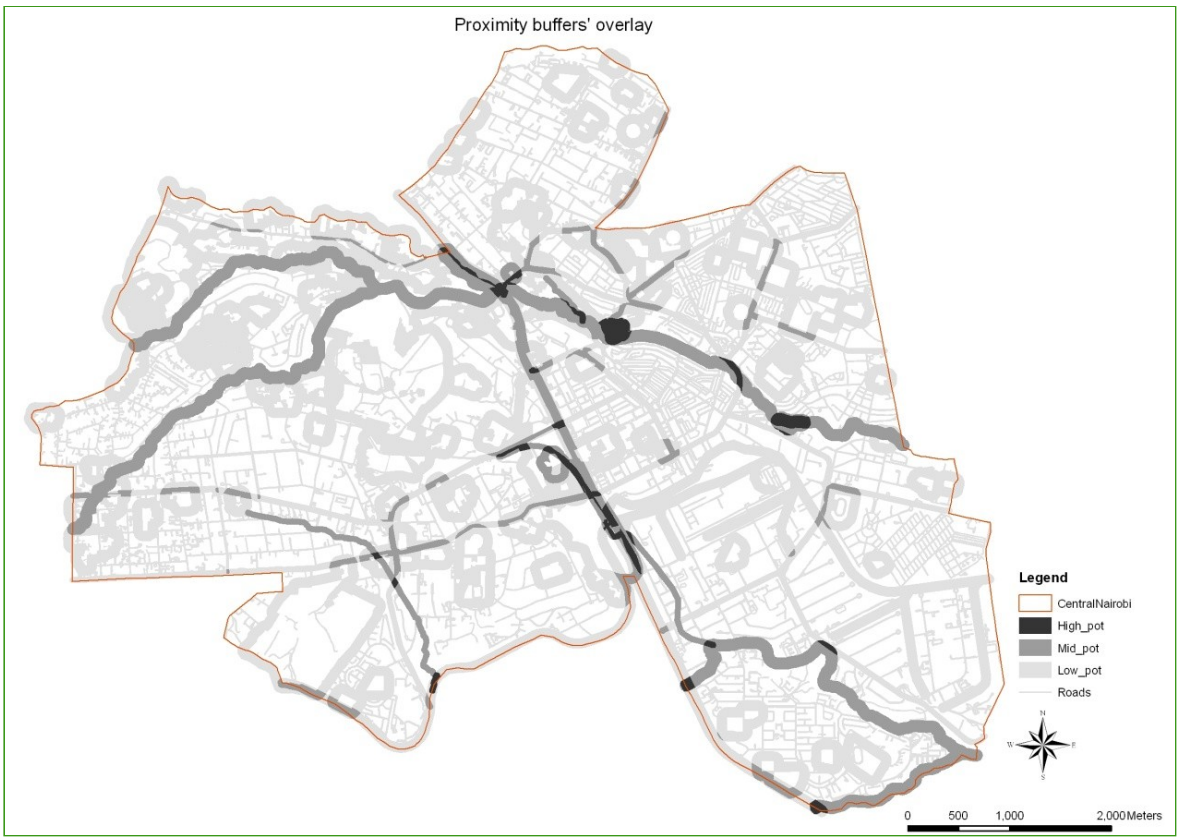

Figure 20:Potential map after proximity buffers overlay and normalization.

3.3.4 Final potential map.

Finally, resultant maps from the two methods ‘UGS suitability checklist application potential areas after classification and normalization’ (Figure 3), and ‘Potential areas after proximity buffers overlay and normalization' (Figure 4) were overlaid. We calculated the sum of normalization score where they overlapped, and where they did not overlap we used the single normalized score. This resulted in the final composite potential map for Central Nairobi (Figure 5). It had three levels of potentiality represented through colour gradation as high potential areas, mid potential areas and low potential areas. This map clearly shows in the study area, where green spaces can be easily expanded. This map was considered realistic in pinpointing where to develop new UGS, because it is a result of two complementing processes. The Final Potential Map shows series of spaces along linear elements such as rivers and roads that have potential for connectivity. Such connectivity of UGS can be adopted to form a Green Infrastructure (GI) system, complete with hubs, corridors, and sites within the study area. This can increase affordance of GI functions that can enhance environmental, natural, and social prosperity within Central Nairobi and beyond.

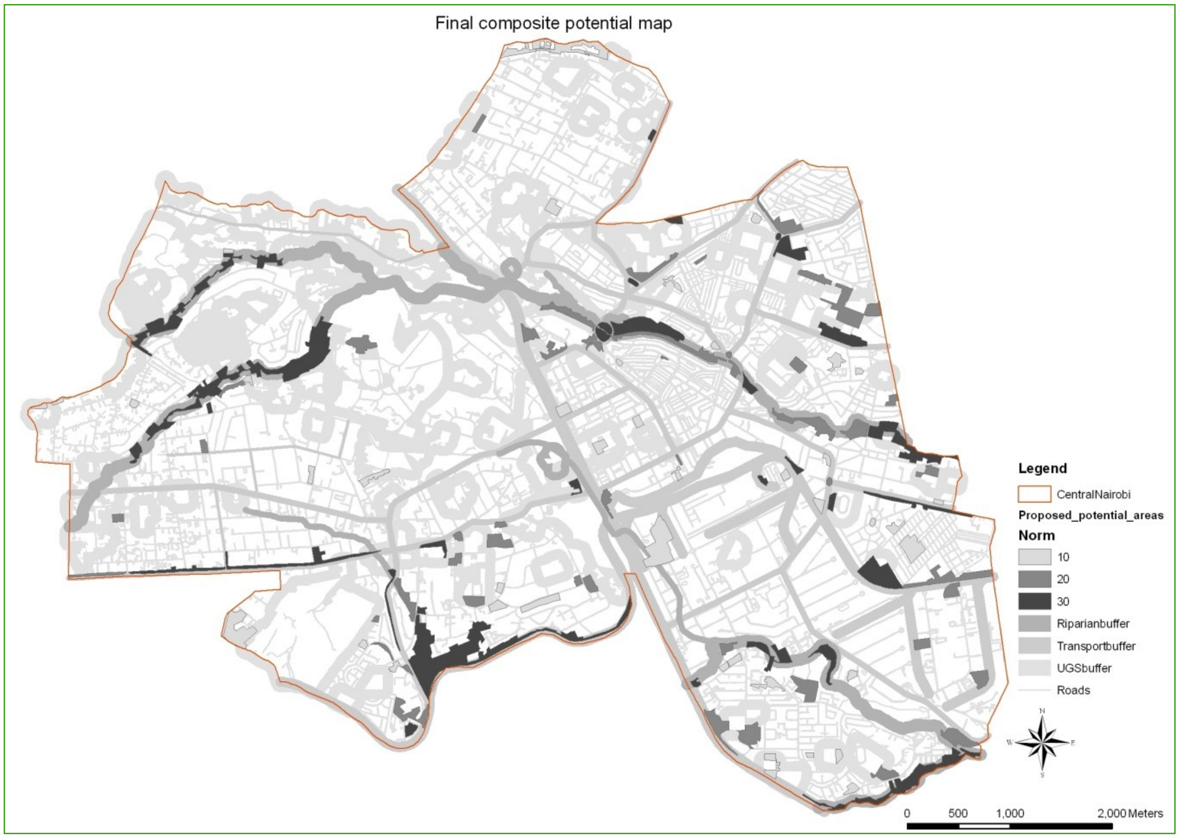

Figure 21: Final composite potential map for UGS expansion in Central Nairobi

3.4 Conclusion

The following conclusions are made based on the study's three objectives:

1) Existing Central Nairobi UGS lacks in size, composition, distribution, and character, that indicates minimal penetration of Green Infrastructure (GI) elements and its functions in the area. The study area has low UGS cover, and the existing UGS lacks diversity in terms of types of green spaces included. It lacks connectivity of UGS, which is a key term in the GI concept. Vital GI elements such as urban agricultural areas, wetlands, and green networks among others are missing, undermining the permeation of GI in Central Nairobi.

2) The characteristics of Central Nairobi's UGS as currently constituted cannot afford adequate benefits to influence quality of life, nature, and environmental well being. Public access spaces such as parks are few, unevenly distributed and lack in variety. Most available spaces are out of public access and utilization due to their ownership or management regimes. The residents have limited access to UGS because of long distances they travel to access them. Lack of diversity in UGS reduces the number of activities residents can engage in. Such UGS types that can be used by the public on daily basis including neighborhood parks and block parks among others are missing. There is bias in access where most UGS patches are located in the Western half, leaving the residents of the Eastern half with minimal, or no access at all to UGS.

3) The study area has a potential areas that could be utilized for future expansion of UGS to help improve the environment, nature, residents' quality of life, and Green Infrastructure (GI) realization. The composite potential map generated can be used as a basis for future selection of areas to develop UGS.

The map can also be used to indicate where not to develop other physical infrastructure, if such areas are found to have high potential for development of UGS. Such developments can be allocated areas found to have low potential for development of UGS.

Authority in charge (Nairobi County Government) should establish UGS targets, and various standards to guide Green Infrastructure space allocations and distribution. These can include; a Green Master Plan (GMP), distance limits for green space catchment areas, green space per capita and UGS classes' composition and distribution. This can improve the city's obligations in providing environmental, socio-cultural, and economic benefits to its citizenry.

If identified potential areas are exploited, they can ensure adequacy, even distribution, and performance to grant residents maximum UGS benefits hence a more livable city. Authority in charge (Nairobi County Government) should establish UGS targets and various standards to guide green space allocations and distribution. These can include; a green master plan, distance limits for green space catchment areas, green space per capita and UGS classes' composition and distribution. This can also include a comprehensive Green Infrastructure (GI) policy and implementation from the small scale of plot level, to a holistic master plan for the entire city and beyond.

The potential map generated shows a series of spaces following particular patterns, especially along linear elements such as rivers, highways, main roads, and railway lines. These spaces and patterns can be adopted to form an interconnected UGS that can be used as a basis for a Green Infrastructure (GI) system within and beyond the study area as shown in figure15.

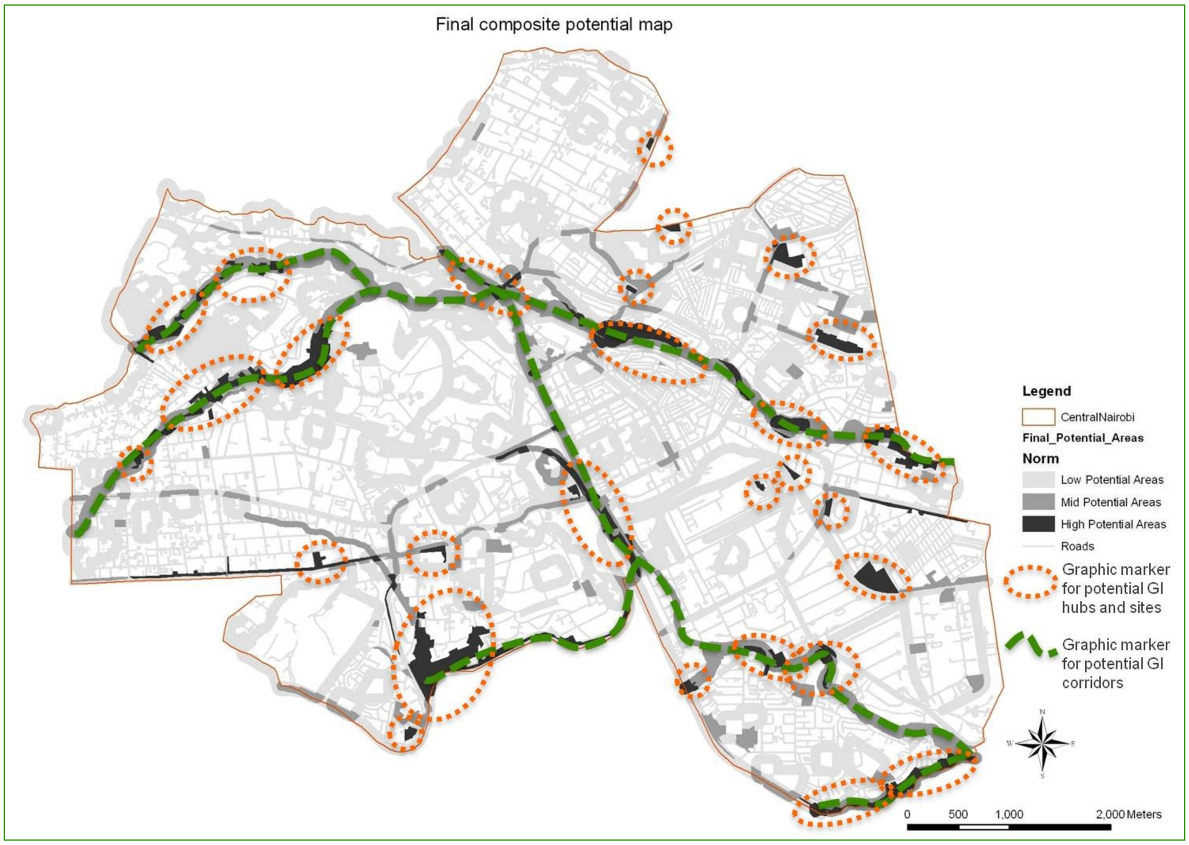

Figure 22: Potential new urban green spaces and green networks locations.

References

1. Ahris, Y., Noordini, C. M., Nafisa, H., Haiza, W. H., Susilawati, S. (2006). A GIS approach in evaluation of metropolitan green area: a case of Sungai Pulai wetland. *Urban Forestry Conference: Managing Urban Green for Sustainable Cities*, 6 - 7 June 2006, Kuala Lumpur.
2. Buyantuyev, A., Wu, J., Gries, C. (2009). Multiple analysis of the urbanization pattern of the Phoenix Metropolitan landscape of USA: time space and thematic resolution. *Landscape and Urban Planning,* Vol. 94, 3 - 4, 206-217.
3. City Council of Nairobi (2007). City of Nairobi Environmental Outlook. Retrieved from http://www.unep.org/geo/pdfs/NCEO_Report_FF_New_Text.pdf, accessed on February 10th 2012.
4. de Ridder, K., Adamec V., Bañuelos A., Bruse M., Bürger M., Damsgaard O., Dufek J., Hirsch J., Lefebre F., Pérez-Lacorzana J. M., Thierry A., & Weber C. (2004). An integrated methodology to assess the benefits of urban green space. *Science of the total environment,* Vol. 334–335, 489-497.
5. Flink, C., Seams, R. (1993). *Greenways: a guide to planning, design, and development*. Washington, D.C., Island Press.
6. Godefroid, S. (2001). Temporal analysis of the Brussels flora as indicator for changing environmental quality. *Landscape and Urban Planning*, Vol. 52, 203-224.
7. Gorr, L. W., Kurland, S.K. (2008). *GIS tutorial; updated for ArcGIS 9.3, Workbook for ArcView 9, Third Edition.* Redlands, California: ESRI Press.
8. Hopkins, L. D. (1977). Methods of Generating Land Suitability Maps: A comparative evaluation. Journal *of the American Planning Association,* Vol. 43: 4, 386–400.
9. Jim, C. Y. (2004). Green-space preservation and allocation for sustainable greening of compact cities. *Cities,* Vol. 21 No. 4, 311–320.
10. Jim, C. Y., Chen, S. S. (2003). Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing City, China. *Landscape and Urban Planning,* Vol. 65, 95–116.
11. Kazmierczak, A. (2013). The contribution of local parks to neighborhood social ties. *Landscape and Urban Planning*, Vol. 109, 31–44.
12. Kenya National Bureau of Statistics (2010). Kenya 1999 population and housing census. *Analytical report on population projections volume VIII*, Nairobi: Republic of Kenya.
13. Liu, S., Liu, B., (2008). Using GIS to assess the ecological-niche for urban green Space planning in Wuxi City, Anhalt University of Applied Science. Bernburg, Germany.
14. McGarigal, K., Cushman, S. A., Neel M. C., Ene, E. (2002). FRAGSTATS: spatial pattern analysis program for categorical maps. University of Massachusets, Amherst.
15. McHarg, I. L. (1969). *Design with Nature.* New York: John Wiley & Sons, INC.
16. Myeong, S., Nowak, D. J., Hopkins, P. F., Brock, R. H. (2003). Urban cover mapping using digital high-spatial resolution aerial imagery. *Urban Ecosystems*, Vol. 5, 243–256.
17. Nowak, D. J., Crane, D. E., Stevens, J. C., Hoehn, R. E. (2003). USDA Forest Service, Northeastern Research Station, Syracuse, New York.
18. Nowak, D. J., Rowntree, R. A., McPherson, E. G., Sisinni, S. M., Kerkmann, E. R., Stevens, J. C. (1996). Measuring and analyzing urban tree cover. *Landscape and Urban Planning*, Vol. 36, 49-57.

19. Olembo, R. J., Rhan, P. (1987). Urban forestry; cities, trees and people. *Unasylva*, 155.

20. Schaffler, A., Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure – The Johannesburg case. *Ecological Economics*, Vol. 86, 246-257.

21. Uy, P.D., Nakagoshi, N. (2008). Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. *Urban Forestry & Urban Greening*, Vol. 7, 25-40.

22. van der Valk, A. (2002). The Dutch planning experience. *Landscape and Urban Planning*, Vol. 58, 201–210.

4 CHAPTER 4: Evaluation of Japanese municipalities' Green Master Plans as a guide for Green Infrastructure planning and realization.

4.1 Introduction

In the face of the fast urbanizing world, many concepts and practices are employed to ameliorate negative impacts and foster livable urban areas. One such tool is Green Infrastructure (GI), which is increasingly used to create multidimensional aspects that improve the urban environmental quality, livability, sustainability and quality of life (van Kamp et al., 2003). Green Infrastructure is an adaptable term used to describe an array of products, technologies, and practices that use natural systems, or engineered systems that mimic natural processes (US EPA, 2011). Benedict and McMahon (2006) define Green Infrastructure as an interconnected green space network that is planned and managed for its natural resource values and for the associated benefits it confers to human populations. It encompasses connected networks of multifunctional, predominantly un-built space that supports both ecological and social activities and processes (Kambites and Owen, 2006). It is a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features (Natural England, 2009). However, as an evolving concept, it is thus ambiguous with no single and precise definition (Wright, 2011). The constituent elements of Green Infrastructure include: waterways and water features (US EPA, 2011), working lands, ecological networks, forests, wetlands, and trails (Benedict and McMahon, 2006). Others are parks and gardens, green roofs and walls, planting plan and management (Natural England, 2009) among others. It is imperative to audit presence of these Green Infrastructure elements that promote ecosystem and human health (Tzoulas et al., 2007) as dealt with in this paper.

Complete or fragments of Green Infrastructure core values can be found in policy papers, legislation, and planning documents across the world. In North Eastern Asia, such policy documents include the Hong Kong Green Master Plan (Hong Kong Gov. 2012), and the 10 year project for Greener Tokyo (Tokyo Metropolitan Gov., 2007). Another document, Natural England's (2009) Green Infrastructure guide clarifies the distinction between planning for open space and Green Infrastructure, identifies its policy support, its functions, and benefits. It also links Green Infrastructure to related concepts such as place-making, explores the role of Green Infrastructure strategies and how to embed it in plan making and in the development management processes.

In Japan, such government policies include the Urban Green Spaces Conservation Law of 1994 that enables Japanese municipalities to draw Green Master Plans (GMP) that set out aims, and measures for conservation and promotion of green within their jurisdictions (Japan Gov., 2012). A Green Master Plan is defined as a comprehensive Green Space Plan by a municipality, that projects the future image, and that is open to public input (POSA-Japan, 1997). There is also indirect contribution of The Landscape Act (Act No. 110 of June 18, 2004) whose article 3 mandates the Japanese national government to formulate and implement comprehensive measures to develop good landscapes, and enlighten people on measures concerning the development of good landscapes (Japan Gov, 2004). Article 4 of the same Act states that: Local governments shall be responsible for formulating and implementing measures to promote the development of good landscapes. With this background, as of March 2011, 648 municipalities had prepared Green Master Plans (GMPs), with 41 more in the development stage (Japan Gov., 2012).

POSA-Japan (1997) includes the following as the compositional elements as the characteristics of GMPs in the Handbook for Green Master Plans. Urban parks, public facility green space, private facility green space, green conservation, natural resource area, agricultural areas, historical and cultural preservation areas, rivers and water ways, forests and woods, environmental conservation, recreational areas, disaster mitigation and landscape formation. Others are; ecological areas, green corridors, green networks, heat island reduction, cycling routes, walking routes, green buffers, green roofs, green walls, and hedges. It also includes biotope, green concepts, residents and community greening, green awareness and events.

However, there is a gap in the formulation process and details level between different cities' Green Master Plans as well as lack of clear implementation strategy (Okuno and Dewancker, 2005). All these documents profess diverse measures to enhance urban ecological, environmental, and social benefits, which are the main functions of Green Infrastructure. It is necessary to audit inclusivity of Green Infrastructure elements, functions, concepts and practices in these Japanese municipalities Green Master Plans, with a view to establish their viability as Green Infrastructure guides. This is timely as some of these Green Master Plans have reached revision stage (Takeuchi, 2012), and can highlight potential improvement areas for comprehensive implementation of Green Infrastructure in the municipalities.

4.1.1 Objectives.

The main aim of this study was to evaluate Japanese municipalities' Green Master Plans as agents of Green Infrastructure (GI) realization. This was achieved through the following objectives: 1) to establish the level of knowledge of Green

Infrastructure concept among the municipal workers. 2) To evaluate awareness of green master plans (GMP) contents by the respondents. Finally, 3) to examine whether there are disparities between theory and practice based on the workers response and contents of the actual Green Master Plans documents. In Japan, Green Master Plans should set out aims, and measures for conservation and promotion of green as mandated in Article 4 of the Green Space Law of 2004 (Japan Gov., 2012). This aspiration resonates well with Green Infrastructure definition as a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features (Natural England, 2009). In that context; are the Green Infrastructure elements adequately included in the Green Master Plans prepared by the municipalities? Are the municipal workers tasked with implementing these Green Master Plans knowledgeable of both Green Infrastructure and the contents of the Green Master Plans in their jurisdiction? If the above questions are not affirmatively answered, then the combined shortfalls of the basic reference document (Green Master Plans) and its implementers (municipal workers) lack of awareness on its contents and Green Infrastructure knowledge, could lead to a weakened realization of Green Infrastructure.

Within Japanese municipalities, there are several other master plans including urban planning master plan, environmental master plan, and water resources master plan among others. All these documents have different specific major aims and subject matter, though traces of Green Infrastructure elements may be found within them. Green Master Plan focus is mainly on setting out aims, and measures for conservation and promotion of green as mandated by Article 4 of the Green Space Law of 2004 (Japan Gov., 2012). As a basic plan, Green Master Plans also include elements of environmental planning, urban planning, and water resources planning found among other related municipal master plans. Its core focus relates to the Green Infrastructure definition, aim, and contents as opposed to the other master plans within the Japanese municipalities. Thus, it was sufficient to limit this study's scope to evaluation of the contents of Green Master Plan documents, Green Infrastructure knowledge, and awareness of Green Master Plan contents by municipal workers.

4.1.2 Study area.

The study was carried out within the Tokyo 23 special wards (denoted as Tokyo 23 SW) that function as independent municipalities, and their neighboring contiguous suburban cities.

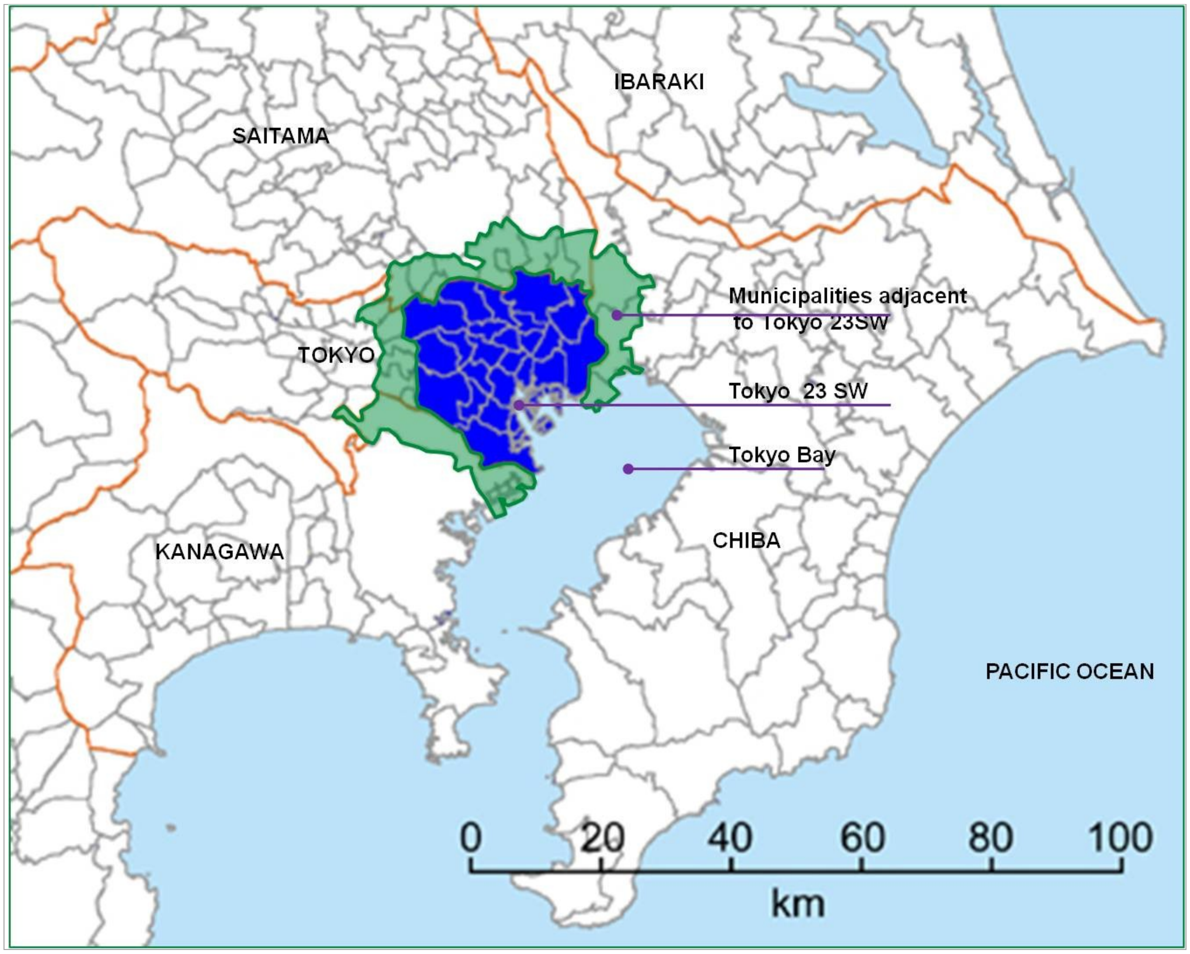

Figure 23: Map showing the study area.

4.2 Research methodology.

4.2.1 Questionnaire survey among municipality`s workers.

The first part of the study employed a questionnaire survey among public workers in 41 municipalities, in Tokyo Metropolitan area. They included workers from the departments of urban planning and development, departments of parks and green space, and the departments of environment. These departments were selected for their involvement in spatial, policy, and management planning in areas touching on Green Infrastructure domain. Their staff members' actions or inactions in implementing these spatial policies and plans have a direct impact on Green Infrastructure realization, hence the need to verify their knowledge of Green Infrastructure, and Green Master Plan contents awareness. This also brings in diversity of respondents potentially with awareness and knowledge on other municipality's basic plans, which include urban planning master plan and environmental master plans from their respective departments.

The questionnaires were distributed in two phases. The first phase was between 1st and 21st December 2011 while the second phase was between 6th and 20th February 2012. They were distributed to 41 municipalities including all the municipalities within the Tokyo 23 special wards, and their neighboring contiguous suburban cities. The Tokyo 23 Special Wards are Adachi, Arakawa, Bunkyo, Chiyoda, Chuo, Edogawa, Itabashi, Katsushika, Kita, Koto, Meguro, Minato, Nakano, Nerima, Ota, Setagaya, Shibuya, Shinagawa, Shinjuku, Suginami, Sumida, Toshima and Taito wards. While the suburban cities included: Asaka, Chofu, Higashi Kurume, Ichikawa, Kawaguchi, Kawasaki, Komae, Matsudo, Misato, Mitaka, Musashino, Niiza, Nishi Tokyo, Soka, Toda, Urayasu, Wako, and Yashio cities. All the responses had been received by 14th March 2012; their validity determined and data coded. They were subsequently analyzed in IBM SPSS Statistics 19.

To ensure high response, questionnaires were hand delivered to the target departments in all the 41 municipalities. A brief explanation about Green Infrastructure, the study objectives, and the questionnaire contents was done to the receiving worker in all departments. This was to ensure uniform basic understanding of the study aim and questionnaire contents, hence improve the validity of responses and subsequent results after analysis. The questionnaire contents were in four parts: (1) introduction about the general study, its objectives, and definition of key terms including Green Infrastructure, and its elements. (2) Questions on the respondents awareness of their municipality having developed a Green Master Plan, and multivariable questions to check their awareness, and level of knowledge about Green Infrastructure. (3) Simple bi-variable questions for respondents to select Green Infrastructure elements they were aware of having been included in their municipality's Green Master Plan from the listed 14 Green Infrastructure elements. (4) Respondents listing of any other(s) Green Infrastructure elements not included in the questionnaire list, but they were aware of presence in their municipality's Green Master Plan. The 14 Green Infrastructure elements listed in the questionnaire were adopted from past research on Green Infrastructure. They include: waterways, water features, and wetlands (US EPA, 2012), nature and natural resources plan, natural protected lands, working lands, ecological networks, forests, wetlands, and cycling and walking routes / trails (Benedict and McMahon, 2006). Others are parks and gardens, green roofs and walls, planting plan, green buffers, green networks, green space management plan (Natural England, 2009) and sustainable energy plan.

4.2.2 Comparison between municipal workers` response and Green Master Plans contents.

The second part of the research was used to meet the third objective. This was to examine whether there are disparities between theory and practice based on the workers response and contents of the actual Green Master Plans documents. Green Master Plan is conceived to be the backbone upon which municipalities should set their goals and operations to realize conservation and promotion of green. Absence of major Green Infrastructure elements from Green Master Plan as a basic reference document may lead to lack of Green Infrastructure awareness among the workers. It can also lead to Green Infrastructure being overlooked in municipal practice and implementation. Also in case of retirement and transfers, institutional memory can be lost upon the new replacement staff. A Green Master Plan is a product of teamwork that sometimes includes external experts. Thus, constant awareness by all concerned municipal workers is essential for its optimum implementation. Extra 10 elements were derived from the other Green Infrastructure elements elicited by the respondents. The respondents from the 40 municipalities that responded listed these in part four of the questionnaire. They were the Green Infrastructure elements that respondents were aware of their existence in their municipalities Green Master Plans, although they were not included in the 14 elements listed in the questionnaire. They include residents or community greening and collaboration, biotope, hedges, green education and awareness, rainwater management and use, ecological areas, corridors and networks, and green research and technology. Others are disaster prevention and mitigation facilities, heat island reduction green facilities and concepts, historical, cultural and identity preservation green facilities, as well as green events and festivals.

Full version Green Master Plan (GMP) documents were obtained directly from sampled municipal offices or downloaded from their websites. They were reviewed, and included Green Infrastructure elements tabulated. These were analyzed and compared to those indicated by the respondents through the questionnaire survey in the sample municipalities. A sample size determination formula adopted from Nassiuma (2000) was used, and an appropriate sample size of 12 municipalities determined. The 12 municipalities sample was selected using stratified random sampling, out of the 40 municipalities where the questionnaires were distributed and valid responses received. Two strata were determined before sampling based on municipality geographical location to ensure inclusivity. The first stratum included 23 municipalities within the Tokyo 23 special wards, and the second stratum 17 municipalities among the suburban cities contiguous to Tokyo 23 special wards. All the municipalities were arranged in alphabetical order and number coded in both strata. Simple random sampling was then carried out from each stratum using the RandInt (Random Integer) function of Ms Excel 2007 to generate random numbers. Municipalities associated with the random numbers generated formed the sample municipalities. A sample of six Green Master Plans was obtained from the municipalities in the first stratum. They included those of Adachi (2007), Chuo (2009), Nerima (2009), Ota (2011), Shinjuku (2009), and Taito (2012). From the second Stratum, six Green Master Plans sampled were those of Chofu (2011), Ichikawa (2004), Kawaguchi (2008), Kawasaki (2008), Misato (2011), and Musashino (2008).

4.3 Results.

4.3.1 Green Infrastructure knowledge and awareness of GMP documents contents.

91 (73.98%) completed, and valid questionnaires were received from 40 municipalities as shown on table 1. In the first categorization, according to municipalities' departments; urban planning development N=31, green space N=35, and environment N=25. In the second categorization, per area; Tokyo 23 SW N=54 and their neighboring contiguous suburban cities N=37. 95.6% of the respondents indicated that their municipalities had prepared Green Master Plans. However, on Green Infrastructure (GI) knowledge, 48.35% indicated they 'do not know' about it, 47.25% 'know a little', 4.4% 'know well' and nobody (0%) indicated to 'know very well'. This trend of limited Green Infrastructure knowledge cut across all the categories which had a strong Bivariate Correlation of more than +0.95 amongst themselves.

Table 7: List of responding municipalities and departments.

No.	Tokyo 23 Special wards	Urban Planning Department	Parks and Greenspace Department	Environment Department	No.	Suburban cities	Urban Planning Department	Parks and Greenspace Department	Environment Department
1.	Adachi	o	o	x	24.	Asaka	o	o	o
2.	Arakawa	o	o	o	25.	Chofu	x	o	o
3.	Bunkyo	x	o	o	26.	Higashi Kurume	o	x	o
4.	Chiyoda	o	x	o	27.	Ichikawa	o	o	o
5.	Chuo	o	o	x	28.	Kawaguchi	o	o	x
6.	Edogawa	o	o	o	29.	Kawasaki	o	o	o
7.	Itabashi	o	o	o	30.	Komae	x	o	x
8.	Katsushika	o	o	o	31.	Matsudo	o	o	x
9.	Kita	x	o	o	32.	Misato	o	o	x
10.	Koto	o	o	x	33.	Mitaka	x	o	o
11.	Meguro	o	o	x	34.	Musashino	o	o	x
12.	Minato	o	o	o	35.	Niiza	o	o	o
13.	Nakano	o	o	x	36.	Nishi Tokyo	o	x	o
14.	Nerima	x	o	o	37.	Soka	x	o	o
15.	Ota	o	o	o	38.	Toda	x	o	x
16.	Setagaya	o	o	x	39.	Urayasu	x	o	o
17.	Shibuya	o	o	x	40.	Wako	x	x	x
18.	Shinagawa	o	o	o	41.	Yashio	o	o	o
19.	Shinjuku	o	x	o					
20.	Suginami	o	o	x					
21.	Sumida	o	x	o					
22.	Toshima	o	o	o					
23.	Taito	x	o	o					

o = Departments whose workers responded. x = Departments whose workers did not respond.

Figure 2 shows that cycling and walking routes presence awareness in Green Master Plans was confirmed by 27.5% of the respondents. Suburban cities had the highest level at 35.1% while Tokyo 23 SW had the lowest at 22.2%. Green buffers awareness levels were similarly low at an average of 34.1% with the highest among green space departments workers (37.1%). Green network had a high presence awareness of 78%, topping 91.4% for respondents from green space departments. Green roofs and walls also had shown a high level of presence awareness at 82.4%, with municipal workers in the Tokyo 23 SW showing a strong awareness of 90.7%. Planting plan had an average awareness level of 57.1% and 68.6% among the green space departments' workers as shown in figure 3. Natural protected areas seem to lag behind with low presence awareness (39.6%) that is even lower at 26.9% among the respondents from the environment departments.

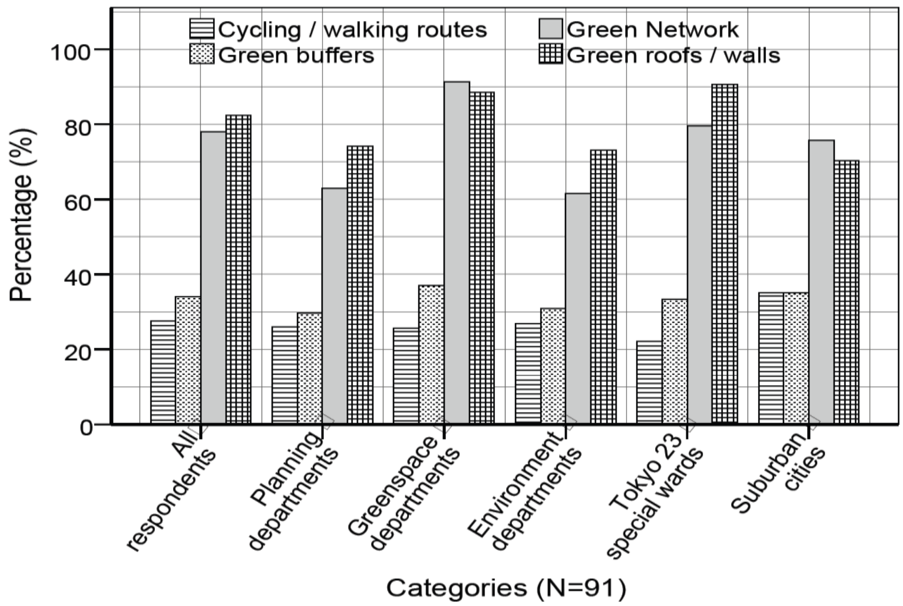

Figure 24: Municipal workers GMP elements awareness by categories I.

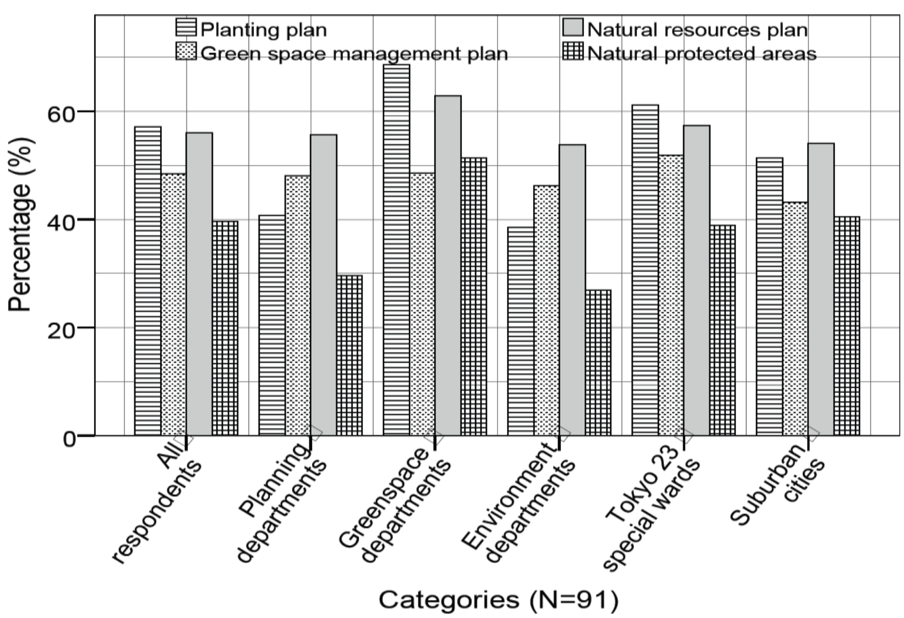

Figure 25: Municipal workers GMP elements awareness by categories II.

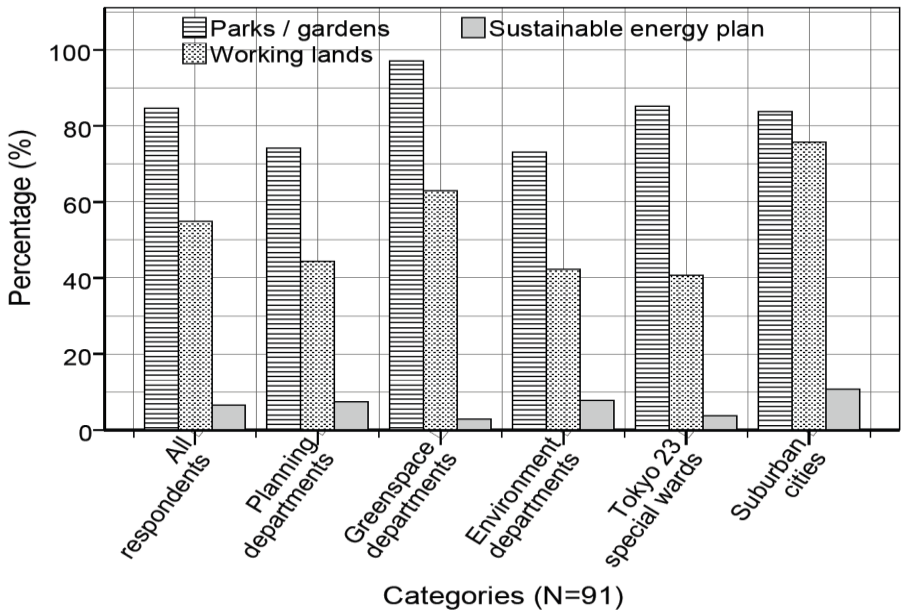

Figure 26: Municipal workers GMP elements awareness by categories III.

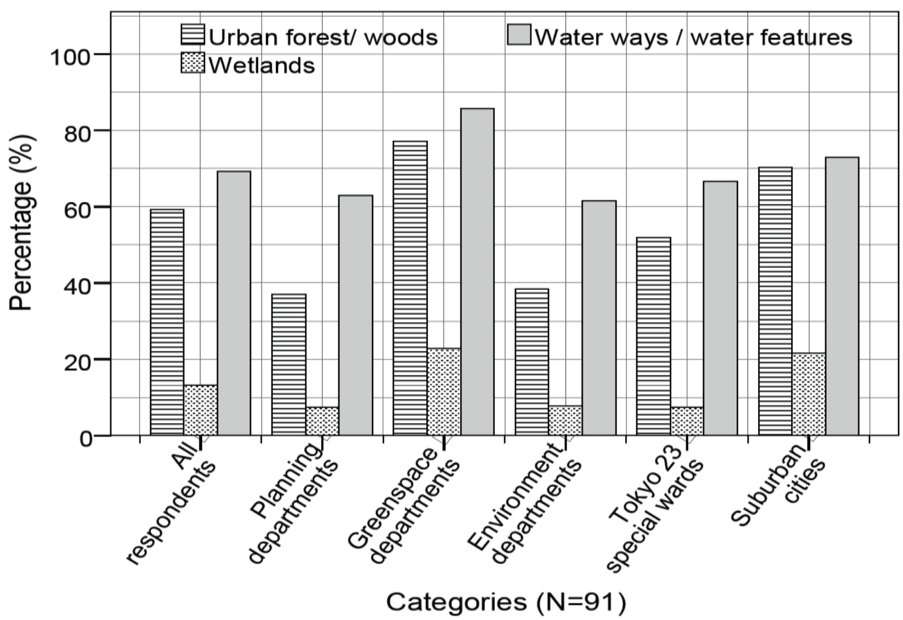

Figure 27: Municipal workers GMP elements awareness by categories IV.

In figure 2, parks and gardens are particularly prominent (84.6%), with the highest presence awareness of 97.1% among the green space departments' workers. The inclusion of working lands (agriculture and natural resource production among others) in Green Master Plans was confirmed by 54.9% of all respondents. Tokyo 23 SW had the lowest presence awareness (40.7%), whereas its neighboring suburban cities had the highest (75.7%). There is an absence in most Green Master Plans or lack of awareness on sustainable energy plans (6.6%) among all the respondents. As shown in figure 5, urban forests and woods awareness stood at an average of 59.3%. Green space departments' workers had the highest level at 77.1% and planning departments having the lowest (37.0%) among all the categories. Awareness of wetlands inclusion in the Green Master Plans was low at 13.2% while that of water ways and water features was strong at 69.2%.

4.3.2 Municipals` workers awareness and GMP contents comparison.

Table 8: Respondents awareness and GMP documents contents.

GI elements.		Sample municipalities.											
	GI elements present in GMPs.	Adachi	Chofu	Chuo	Ichikawa	Kawaguchi	Kawasaki	Misato	Musashino	Nerima	Ota	Shinjuku	Taito
1.	Biotope.	Δ	Δ	Δ	•	Δ	x	Δ	•	x	x	Δ	Δ
2.	Cycling and walking routes.	x	•	Δ	•	•	•	•	•	x	•	Δ	•
3.	Disaster prevention and mitigation facilities.	Δ	Δ	Δ	•	•	x	Δ	Δ	Δ	Δ	Δ	Δ
4.	Ecological areas, corridors, and network.	x	•	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
5.	Green buffers.	O	O	x	•	O	x	Δ	O	O	O	x	O
6.	Green education and awareness.	Δ	Δ	Δ	•	Δ	Δ	Δ	•	Δ	•	Δ	Δ
7.	Green events and festivals.	x	Δ	Δ	Δ	Δ	•	Δ	Δ	Δ	Δ	Δ	Δ
8.	Green network.	x	Δ	•	•	•	•	•	O	•	•	•	•
9.	Green research and technology.	Δ	x	x	x	Δ	x	x	O	x	x	x	x
10.	Green roofs and walls.	•	•	•	•	•	•	•	•	•	O	•	•
11.	Green space management plan.	•	Δ	•	O	x	•	•	•	•	•	O	O
12.	Heat Island reduction green facilities and concepts.	x	Δ	Δ	Δ	•	Δ	Δ	Δ	x	Δ	Δ	Δ
13.	Hedges.	Δ	x	x	Δ	Δ	x	Δ	Δ	Δ	O	Δ	x
14.	Historical, cultural and identity preservation green facilities.	Δ	Δ	Δ	•	•	x	x	Δ	Δ	•	Δ	Δ
15.	Natural protected areas.	•	Δ	O	•	•	•	x	Δ	•	•	•	•
16.	Nature, natural resources plan.	•	•	x	•	•	O	Δ	O	O	•	O	O
17.	Parks and gardens.	•	•	•	•	•	•	•	•	•	•	•	•
18.	Planting plan.	•	x	O	O	x	O	Δ	O	O	O	O	O
19.	Rain water management and use.	x	Δ	x	x	x	x	x	x	Δ	x	x	x
20.	Residents / community greening and collaboration.	Δ	•	Δ	•	•	Δ	Δ	•	Δ	Δ	Δ	•
21.	Sustainable energy plan.	x	x	x	x	x	x	x	x	x	x	x	x
22.	Urban forests and woods.	•	•	Δ	•	•	•	•	•	•	•	•	•
23.	Water ways and water features.	•	•	•	•	•	•	•	•	•	•	•	Δ
24.	Wetlands.	x	x	x	x	O	O	x	x	x	x	x	x
25.	Working lands (agricultural, lumber etc).	•	•	x	•	•	•	•	•	•	•	x	•

O Respondents only. • Respondents and GMP documents.
Δ GMP documents only. x Absent from respondents and GMP documents.

From table 4, sustainable energy plan was not found in any sample municipality Green Master Plans or any awareness among the respondents. Only two respondents from Kawaguchi and Kawasaki Cities mentioned wetlands presence while green research and technology was found in Adachi's and Kawaguchi's Green Master Plans, and mentioned by only one respondent from Musashino City. Rain water management was found only in Green Master Plans of Chofu and Nerima cities, with no awareness recorded amongst all the respondents in the sample municipalities. Elements of green space that include green network, planting plan, park and gardens, as well as water ways and water features seem to have prominence in both Green Master Plans and among the municipal workers. However, there is a solid inclusion in the sample Green Master Plans of residents or community greening and collaboration, green education and awareness as well as historical, cultural and identity preservation through green facilities. There are significant elements indicated by the respondents that cannot be found in the Green Master Plan documents of their municipalities. In table 2, there are 300 cumulative possibilities realized through multiplication of the 25 Green Infrastructure elements and the 12 municipalities sampled. Out of these, 68 (22.67%) are absent, 30 (10%) by respondents only, 90 (30%) in Green Master Plans only, and combined respondents and Green Master Plans 112 (37.33%).

Respondents' awareness and sample Green Master Plans contents comparison reveal that Ichikawa city workers had the highest awareness of the Green Infrastructure elements included in the Green Master Plans. This as shown in figure 6 stood at 60%, followed by both Kawaguchi (52%) and Ota at 44%. Chuo municipality had the least combined presence and awareness level (20%), followed by Shinjuku (24%). On the Green Master Plans contents that workers were not aware of, Misato had the highest number of elements (44%) while Ichikawa and Kawasaki had the least at 16% each. Respondents also claimed presence of some elements that were not found in their municipalities Green Master Plan documents after evaluation. Musashino had the highest such claim at 20% while Misato had the least at 0%. Among the 25 Green Infrastructure elements used for this analysis, figure 6 reveals a high level of absent elements both in the Green Master Plan documents and respondents awareness. Adachi, Chuo, and Kawasaki had the highest number at 32% while Musashino had the least at 12%.

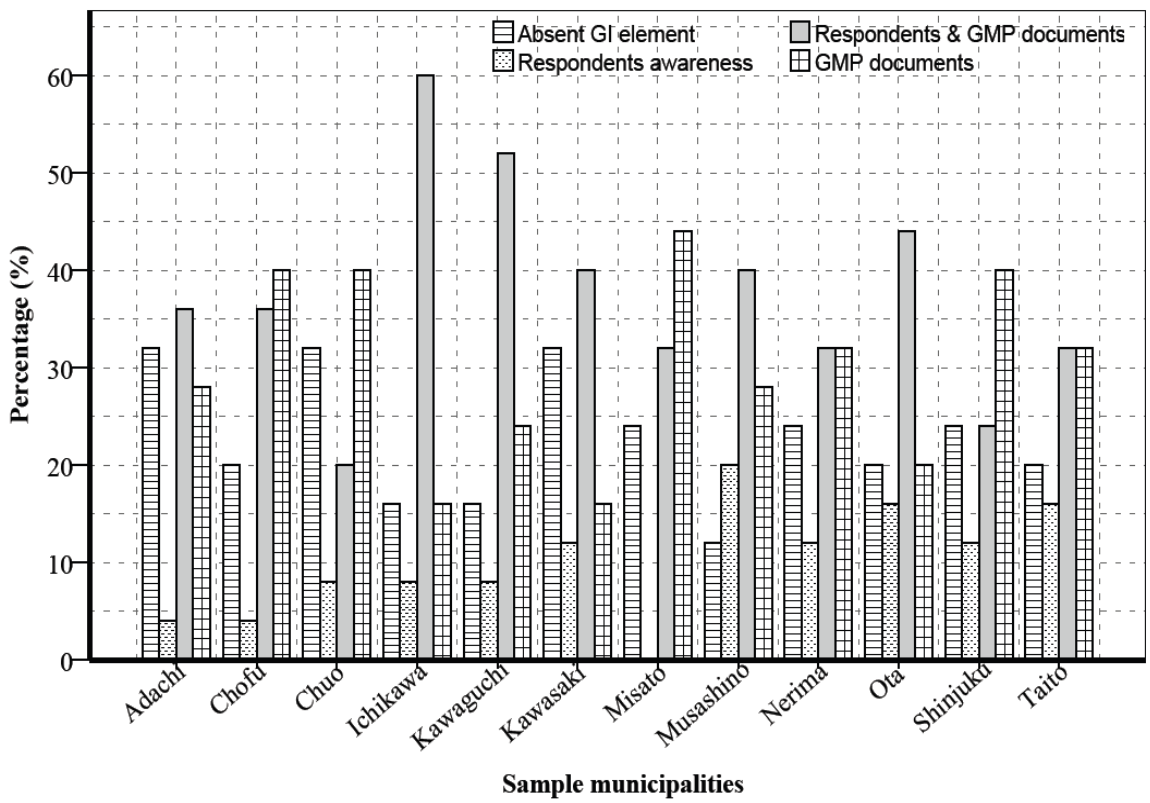

Figure 28: Respondents awareness and sample GMP contents comparison.

4.4 Discussion.

The revelation that only 4.4% responding municipal workers were well informed about Green Infrastructure is the first indicator that Green Master Plans, may not perform well as models for its realization. 48.35% indicated that they had no knowledge of Green Infrastructure, which may be a hindrance to their capacity to implement Green Infrastructure concept in full within their jurisdictions. This is despite the workers confirmation of high presence of Green Master Plans (95.6%), and as indicated that as of March 2011, more than 648 municipalities had Green Master Plans in Japan (Japan Gov., 2012). Walking and cycling routes are essential Green Infrastructure elements that provide a venue for exercise, sport, recreation, and sustainable travel essential for improved health and mental well-being (Kambites and Owen, 2006) of the population. Its presence in the Green Master Plans awareness by the respondents was low at 27.5%. In contrast, elements of urban greening such as green networks (78%), green roofs and walls (82.4%), planting plans (68.6%), parks, and gardens (84.6%) are prominent. They have high levels of awareness across all the respondents and in the sampled Green Master Plan documents. This indicates a bias towards ‘greening of the city’, that is further supported by the Green Master Plan contents where there is a strong presence of these elements in all the 12 sampled cities. It is a positive finding that green roofs and walls are well included (82.4%), especially in Tokyo 23 SW where it is highest (90.7%).

Natural protected areas’ awareness and presence in Green Master Plans stands at a low level (39.6%) in the study area. In the definition of Green Infrastructure, keywords such as natural systems (US EPA, 2012), natural resource values (Benedict and McMahon, 2006), and natural unbuilt space (Kambites and Owen, 2006) are used. These are pointers to the importance of natural protected areas as components of Green Infrastructure, despite their minimal inclusion in the Green Master Plans. They offer biological control services, regulate essential ecological processes and life support systems, and provide indirect benefits to humans such as clean air, water and soil (de Groot et al., 2002). There is a high level of awareness from all the respondents concerning waterways and water features (69.2%), including in the sampled Green Master Plans. This is a positive environmental aspect because waterways and water features provide drainage and natural irrigation, flood prevention, medium for transport, consumptive use (de Groot et al, 2002) and aesthetics purposes among others.

Working lands have an inclusion awareness of 54.9%, but much lower in Tokyo 23 SW that has 40.47%. Green Infrastructure concept advocates for reduction of food deserts and food miles, as well as [3]'*Chisan-chisho'* or localization of food production and consumption (Kimura and Nishiyama, 2008). As such, all Green Master Plans should include this key element to ensure food security and sustainability. In farmland scarce areas like Central Tokyo, alternative farming methods and areas such as roof top gardens, vertical farms, or plant factories can be practiced. Only 6.6% of the respondents indicated awareness of existence of sustainable (renewable) energy plan in their municipalities' Green Master Plan. This was not found in any of the sampled Green Master Plan documents. Sustainable (renewable) energy is a core element of Green Infrastructure. It entails planning for, development and use of alternative energy sources such as solar, wind, hydro, geothermal, and biomass among others. This should be introduced in all the Green Master Plans as a fundamental element of Green Infrastructure, to nurture local energy reliance. Urban forests and woods (56%) also form vital biodiversity pools and carbon sequestration centers. They form stepping stones in

[3] *'Chisan chisho'*, Japanese language for "produce local, consume local".

ecological networks, or hubs in a Green Infrastructure network (Benedict and McMahon, 2006). Only two respondents from among the 12 sampled municipalities mentioned wetlands that had a low awareness level of 13.2%. They perform similar roles to forests, and act as natural sponges that absorb storm water and release it slowly averting floods, trapping sediments, filtering toxins and excess nutrients (Benedict and McMahon, 2006). These two elements should be enhanced to strengthen Green Infrastructure values in Green Master Plans. Among the sampled eight municipalities, rain water management and use was found only in Green Master Plans of Chofu and Nerima cities, and there was no respondents' awareness noted. US EPA (2012) indicates that one of their main Green Infrastructure programs focus is to improve water quality and storm runoff management. Its absence indicates a gap in Green Master Plan capability to ensure Green Infrastructure realization in the study area.

Dominance by urban greening elements and absence of other vital environmental elements makes incomplete the definition that 'Green Infrastructure is a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features (Natural England, 2009)'. This study shows that the 'green spaces' part of the above definition is strong, and the 'other environmental features' part is weak among the Green Master Plan contents. There was widespread presence of citizens' greening and collaboration, green education, as well as historical, cultural, and local identity preservation in the sampled Green Master Plans. This indicates partial Green Infrastructure elements inclusion among the municipalities Green Master Plans, considering the absence of other elements such as sustainable/ renewable energy, wetlands, and rain water management and use.

Elements indicated by the respondents only (10%) but not found in their municipality Green Master Plan can point to no strict adherence to the implementation of the Green Master Plans as laid down in the documents. On this note, successful implementation of the Green Master Plans and the partial Green Infrastructure ideals they contain will be compromised. In comparison of respondents' awareness to Green Master Plan contents, respondents from all the municipalities had below average (cumulatively 35.64%) level. Since Green Master Plans are long term documents, often their developers are not the implementers. This can arise from routine workers transfer to new work stations, retirement, or even Green Master Plans as products of external experts rather than municipal workers themselves. It is crucial to have constant review of the Green Master Plan documents by workers in the concerned departments to keep its contents fresh in their minds.

4.5 Conclusion.

From this study, the following points have been clarified, satisfying its objectives: 1). There is limited Green Infrastructure knowledge among the responding municipal workers. 2). Respondents' awareness of Green Master Plans' contents and Green Master Plan documents themselves are biased towards elements for physical urban greening, which forms just a portion of Green Infrastructure concept. There is a low level of inclusion of vital Green Infrastructure elements such as sustainable energy plans, wetlands, natural protected areas, and rain water management and use. 3). There is a disparity between municipal workers awareness, and contents of Green Master Plan documents by their municipalities.

As set out in the study's main aim, it can thus be concluded that Japanese municipalities' Green Master Plans (GMPs) as currently constituted and implemented cannot be successful guides for optimum Green Infrastructure realization. This lack of vital Green Infrastructure elements renders Green Master Plans incapable of holistic affordance of Green Infrastructure ideals. The disparity between municipal workers awareness and contents of Green Master Plan documents may lead to disconnect between theories and practice. Theories being Green Master Plans documents and contents that form the basis of practice by municipal workers, and practice being workers awareness and actions that can lead to the realization of Green Infrastructure based on Green Master Plans. This makes ineffective implementation of Green Master Plans, and by extension, the partial Green Infrastructure values found in them.

Therefore, Green Master Plans should be constantly monitored and evaluated as pointed out by Takeuchi (2012), in areas such as application and characteristics. They should also be revised accordingly to include new trends in the Green

Infrastructure concept. The partial Green Infrastructure elements found in the Green Master Plans should be enhanced, and those missing introduced in the revision phase of the existing documents, or in the formulation process of new ones. Such revisions should consider inclusivity, in ecological focus (main Green Infrastructure trend in the United States) and social considerations (main Green Infrastructure trend in the United Kingdom), as pointed out by Kambites and Owen (2006). Intra and inter departmental and municipalities' workers sensitization, collaboration and sharing of ideas are necessary, to increase awareness of Green Master Plan contents and Green Infrastructure knowledge. This will help bridge the gap between workers awareness and Green Master Plan documents contents, and reduce disparity between theory and practice.

References

1. Adachi City Government (2007). Green Master Plan. http://www.city.adachi.tokyo.jp/midori/machi/midori/kihonkekaku.html, accessed on May 14th 2012. (In Japanese).
2. Benedict, M. A., and McMahon, E. T. (2006). *Green infrastructure: Linking landscapes and communities*, Island Press, Washington.
3. Chofu City Government (2011). Green Master Plan. http://www.city.chofu.tokyo.jp/, accessed on May 5th 2012. (In Japanese).
4. Chuo City Government (2009). Green Master Plan. https://www.city.chuo.lg.jp/kurasi/kentiku/midorinokihonkeikaku/index.html, accessed on May 9th 2012. (In Japanese).
5. de Groot, R. S., Wilson, M. A., and Boumans R. M .J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics,* Vol. 41, 393-408.
6. United States Government, Environmental Protection Agency (EPA) (2011). Green infrastructure. http://water.epa.gov/, accessed on August 20th 2011.
7. Hong Kong Government (2004) Greening Master Plan. CEDD, 3rd edition. http://www.cedd.gov.hk/eng/greening/doc/CEDD_GMP_Booklet.pdf, accessed on September 23rd 2012.
8. Ichikawa City Government (2004). Green Master Plan http://www.city.ichikawa.lg.jp/gre01/1111000015.html, accessed on June 15th 2012. (In Japanese).
9. Japan Government (2012). Green Master Plan. http://www.mlit.go.jp/, accessed on September 5th 2012. (In Japanese).
10. Japan Government. Urban Green Space Law of 1994. http://www.mlit.go.jp/, accessed on August 20th 2012. (In Japanese).
11. Japan Government. The Landscape Act of 2004. http://www.mlit.go.jp/, accessed on August 24th 2012. (In Japanese).
12. Kambites, C. and Owen, S. (2006). Renewed prospects for green infrastructure planning in the UK. *Planning Practice and Research.* Vol. 21 (4), 483-496.
13. Kawaguchi City Government (2008). Green Master Plan. http://www.city.kawaguchi.lg.jp/kbn/40250020/40250020.html, accessed on May 12th 2012. (In Japanese).
14. Kawasaki City Government (2008). Green Master Plan. http://www.city.kawasaki.jp/530/page/0000023138.html, accessed on May 10th 2012. (In Japanese).
15. Kimura, A. and Nishiyama, M. (2008). The chisan-chisho movement: Japanese local food movement and its challenges. *Agriculture and Human Values. Vol.* 25, 49-64.
16. Misato City Government (2011). Green Master Plan. http://www.city.misato.lg.jp/dd.aspx?menuid=4373, accessed on May 25th 2012. (In Japanese).
17. Musashino City Government (2008). Green Master Plan. http://www.city.musashino.lg.jp/sesaku_keikaku/kankyoubu/midori_kihonkeikaku/004748.html, accessed on May 24th 2012. (In Japanese).
18. Nassiuma, D. K. (2000). *Survey and sampling methods,* University of Nairobi press, Nairobi.

19. Natural England (2009). Green Infrastructure Guidance (NE176). http://publications.naturalengland.org.uk/publication/35033?category=49002, accessed on November 12th 2011.
20. Nerima City Government (2009). Green Master Plan. http://www.city.nerima.tokyo.jp/, accessed on May 14th 2012. (In Japanese).
21. Okuno, S., and Dewancker, B. (2005). Research on master plan for parks and open spaces in designated cities. *Architectural Institute of Japan*, Vol. 44, 613-616.
22. Ota City Government (2011). Green Master Plan. http://www.city.ota.tokyo.jp/kuseijoho/ota_plan/kobetsu_plan/sumai_machinami/midori/sakutei/greenplan oota.html, accessed on May 14th 2012. (In Japanese).
23. Shinjuku City Government (2009). Green Master Plan. http://www.city.shinjuku.lg.jp/seikatsu/file14_04_00001.html, accessed on May 10th 2012. (In Japanese).
24. Taito City Government (2012). Green Master Plan. http://www.city.taito.lg.jp/index/kurashi/kankyo/kankyojyoho/kihonkeikaku/genkyo/kihonkeikaku.html, accessed on May 15th 2012. (In Japanese).
25. Takeuchi, T (2012). A study on the potential of Green Structure Plan as comprehensive spatial control plan. *Landscape Research*. Vol. 75 (5), 601-604.
26. Parks and Open Space Association (POSA) of Japan. (1997). *Green Master Plan Handbook.* Bunkousha, Tokyo.
27. Tokyo Metropolitan Government (2007). Basic Policies for the 10-Year project for Green Tokyo; Regenerating Tokyo's Abundant Greenery. https://www.kankyo.metro.tokyo.jp/nature/attachement/Project_for_Green_Tokyo.pdf, accessed on August 20th 2011.
28. Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Ka´zmierczak, A., Niemela, J., and James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*. Vol. 81, 167–178.
29. van Kamp, I, Leidelmeijer, K, Marsman, G, and de Hollander, A. (2003). Urban environmental quality and human well-being towards a conceptual framework and demarcation of concepts; a literature study. *Landscape and Urban Planning*, Vol. 65, 5–18.
30. Wright, H. (2011). Understanding green infrastructure: the development of a contested concept in England. *Local Environment*, Vol. 16 (10), 1003–1019.

5 CHAPTER 5: Green Infrastructure Gauge: A tool for evaluating Green Infrastructure affordance in existing and future urban areas.

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5.1 Introduction

In the current global momentum of Eco and Smart Growth, Green Infrastructure (GI) concept is proving a popular means to accomplish sustainable development. GI can be implemented at any scale; individual plot, local community, regional, national, or even multinational levels (Benedict and McMahon, 2006). As an evolving concept (Wright, 2011), new tools for planning, developing, managing and evaluating GI in future towns and cities are thus necessary. This is to ensure its optimum inclusion for the benefits of host communities. Rudolf et al. (2002) conceptualized a framework and typology, but this only focuses on natural ecosystems, which are only, one of the components of GI. Green Infrastructure Assessment (GIA) focuses on hub and corridor selection at regional level (Weber et.al, 2006). Green Factor Score Sheet or Seattle Green Factor aims to increase the quantity and quality of planted areas (Seattle City, 2010). This applies to an individual plot hence unsuitable in addressing GI holistically and at a larger scale. City Biodiversity Index (CBI) or Singapore Index (CBD, 2010) also tackles urban biodiversity conservation, planning, and evaluation, and is not inclusive of GI elements. More research is needed on the way in which ecosystem services are being, or ought to be valued in cities, with a focus on how they might conceivably be incorporated into spatial planning and urban design (Schaffler and Swilling, 2013).

To seal the above gaps, the study focuses to develop a Green Infrastructure Gauge (GIG). GIG is defined in this study as “a method of analyzing and evaluating the level of Green Infrastructure presence in an existing urban area, or its level of inclusion in a Green / Environmental Master Plan for an existing or a proposed new urban area”. The aims of this GIG are to maximize presence of GI elements in the future urban master plans and gauge GI status in existing urban areas. Such a gauge can be useful in assessing existing GI or guide future land use planning and developments. This would ensure sufficient inclusion of GI elements, and their multi-functions, essential in conferring ecological wellbeing and quality of life to the population. It can be applied in the case of development of satellite new towns, development of new neighborhoods within boundaries of existing urban areas, rejuvenation projects of old towns, and even during city compaction in case of depopulation.

GI elements are Physical or conceptual tools, systems, products and technologies that contains, promotes and makes available benefits, goods and services of Green Infrastructure. These include but not limited to; nature reserves and ecological networks, working lands, facilities and plans for renewable energy generation and use, greenways and green networks, facilities for rain water harvesting, storage and use. Others are facilities and plans for disaster prevention and mitigation, waterways and water features, green architecture, cycling, walking, and hiking trails, among others. These GI elements afford GI functions, which are benefits, goods and services that Green Infrastructure elements in part or holistically give to nature, environment, and people. These functions are classified as ecological functions (ensures continued ecosystem functions, goods and services provisioning) (Rudolf et.al, 2002), physical and natural environmental functions, and socio-economic functions.

5.1.1 Objectives

The main objectives of this study were: (1) to identify various GI elements and functions they can afford. (2) To formulate a Green Infrastructure Gauge (GIG). (3) To generate GI functions relative values through a questionnaire survey and (4) to test the completed GIG practicability through application in Koshigaya Lake Town.

5.1.2 Study area

The study area comprised of two levels: (1) Tokyo 23 Special Wards (independent functioning municipalities) abbreviated as 'Tokyo 23 SW', and their neighboring contiguous suburban cities. (2) In Koshigaya Lake Town, a new town located within Koshigaya City in Saitama Prefecture, Japan. Tokyo area is one of the most urbanized and densely populated spots on earth. As such, municipalities in its core and suburbia are always grappling with challenges arising from this intense urbanism, and are constantly strategizing for their counter. Municipal workers spearhead these efforts hence suitable as respondents to the survey. On the other hand, Koshigaya Lake Town is a new projected curved out of land formally dominated by rice paddies. It has been constructed in the 'ECO era' and primarily established with its core as Osagami flood control reservoir. There are many GI elements, technologies, and concepts showcased, making it a suitable subject to test GIG after completion.

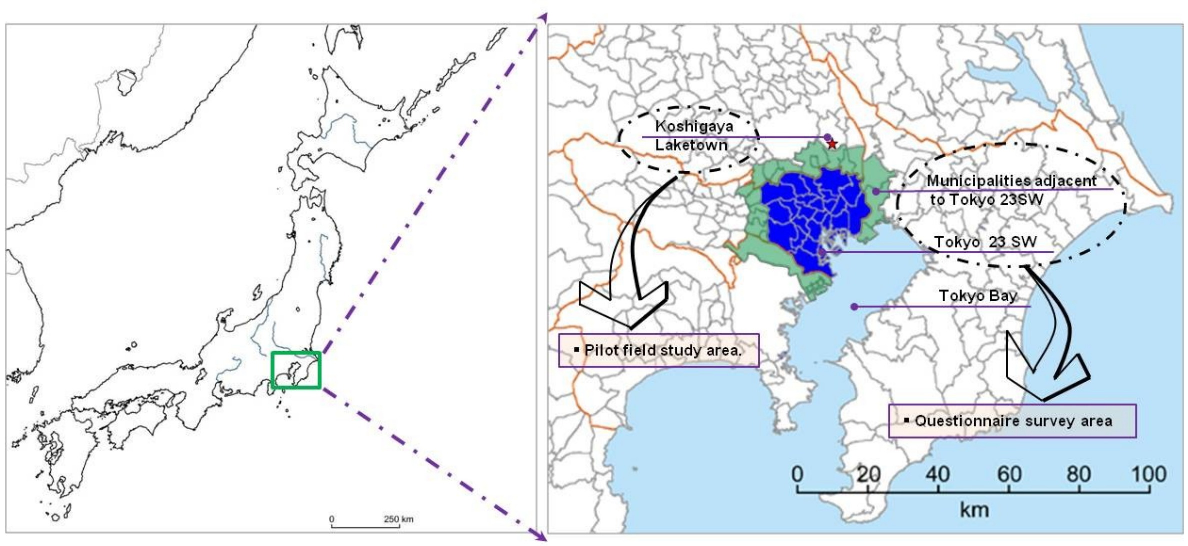


Figure 29: Map showing the study areas and their location.

5.2 Methodology

Through literature review, and review of Green Master Plans (GMP) by Japanese municipalities in the Tokyo region, 13 GI elements and 21 GI functions were identified and described. They are broad and inclusive in their definitions and scope, to cover as many GI aspects as possible, and have universality in application. A matrix with the 13 GI elements on the left end column and the 21 GI functions on the top row was designed. Each GI element was examined for any of the GI functions it afforded, and accorded the value of that or those functions it dispensed. This was repeated for all the GI elements, with a view to establish cumulative level of GI at the planning stage, or as existing in the subject area. Relative value for each of the 21 GI functions was derived through a questionnaire survey to public workers in 41 municipalities within and around Tokyo. Three departments that deal with spatial, environmental and land use planning and management within these municipalities were targeted. These included the department of urban planning and development, department of parks and green Space, and the department of environment. Individual workers provided the GI functions relative value based on their training, experience and personal opinion rather than their departments or municipality policy.

The questionnaire included definition of Keywords such as Green Infrastructure (GI), Green Infrastructure Gauge (GIG), GI elements and GI functions. A reference was also made to the Green Master Plan (GMP) already prepared by many Japanese municipalities, to elicit familiarity by the municipal workers. This was done to prepare the respondents psychologically, create personal awareness, as well as have background knowledge on Green Infrastructure. The GI functions were listed in alphabetical order, to avoid any assumption of author’s preference by the respondents. Descriptions to ensure all the respondents had a common understanding of each GI function were given. Each respondent was to award a score or weight to each function as follows; 5 = very strong, 4 = strong, 3 = Fair, 2 = weak and 1 = very weak. Average relative value for each of the GI functions was calculated based on the scores or weights awarded by all the respondents. Relative value for each GI function was weighted as follows; '0' for absence of the function, '0.4' of the relative value where the elements and their functions are included in planning documents pending implementation. '1' (full relative value) where the elements have been physically implemented, and their function(s) confirmed through field survey.

The final GIG with the inclusion of GI functions relative values (FRV) and provision for cumulative GIG, scores and a legend was completed. The scoring for subject urban area is 'Points' and 'Class' based (SCORING AND CLASS: (0 ~ 1.99 Points = Poor, 2 ~ 3.99 Points = Fair, 4 ~ 5.99 Points = Good, 6 ~ 10 Points = Excellent). GIG applicability was tested in Koshigaya Lake Town, where a pilot field survey to record GI elements and their functions had been carried out.

5.3 Results

The 23 GI functions identified are as shown and described in table 1. They are within three broad classifications of ecological functions, physical and natural environmental functions, and socio-economic functions.

Table 9: 21 GI functions and their descriptions.

	GI function	Description
1.	*Biodiversity promotion*	Vital habitat for wild species, vast genetic bank, harbour plants pollination and dispersal, and migration of wildlife among others.
2.	*Cultural and historical identity*	Has the following value: heritage, worship, fashion, folklore, music, dance, language, film, landmarks, architecture, historical, and traditional practices among others.
3.	*Disaster prevention and mitigation*	Protecting an area against floods, storm damage, landslides, earthquakes, fires, droughts, and mitigation of disaster impact, among others.
4.	*Energy saving*	Reduces energy use, demand, and cost.
5.	*Economic activities support*	Provide marketable goods (such as fish, raw materials, recreation and services), avoided cost, willingness to pay, and hedonic pricing among others.
6.	*Environmental education*	Providing opportunities for cognitive development, awareness, school excursions, and scientific research among others.
7.	*Food / resource production*	Source of food, natural raw materials, biomass, fodder, fish, game, and minerals among others.
8.	*Good aesthetics*	Provide attractive sceneries, decorations, and views among others.
9.	*Improvement of local climate*	Cooling effects to buildings and spaces, mitigation of urban heat island, air circulation, humidity regulation, and wind effect among others.
10.	*Nature conservation*	Maintenance of flora and fauna (such as native species in natural land), and promote natural systems (such as hydrological and nutrients cycles among others).
11.	*Noise reduction*	Buffers and attenuates noise from static or mobile sources before reaching possible disturbance areas.
12.	*Part of larger green network*	A hub, a link, or a site (Benedict and McMahon, 2006) in larger interconnected green spaces and elements.
13.	*Planning structure*	Part of the planning components used in the area overall master plan, either as a physical or philosophical element.

14.	*Pollutants filtration*	Water filtration, air cleaning, trapping of dust, breakdown and removal of toxic nutrients and compounds among others.
15.	*Promotes communal activities*	Provides venues and avenues for community activities and participation, such as festivals and social events among others.
16.	*Public health promotion*	Encourage physical exercises, jogging, walking cycling, therapy, clean environment, elimination of vermin and parasites among others.
17.	*Rain water harvesting*	Capacity to trap, store and use rain water especially for irrigation, and cleaning.
18.	*Recreation opportunity*	Provides a chance for travel to natural ecosystems, ecotourism, outdoor sports, play and relaxation.
19.	*Reduction of green house gases*	Sequestering carbon, reduction in or alternatives to green house gases emitters.
20.	*Reduce public infrastructure cost*	Replaces or reduces public works, alternative transport, and communication means among others.
21.	*Storm water management*	Reduction of runoff via increased infiltration, temporary holding before release, evapotranspiration and or re-use among others.

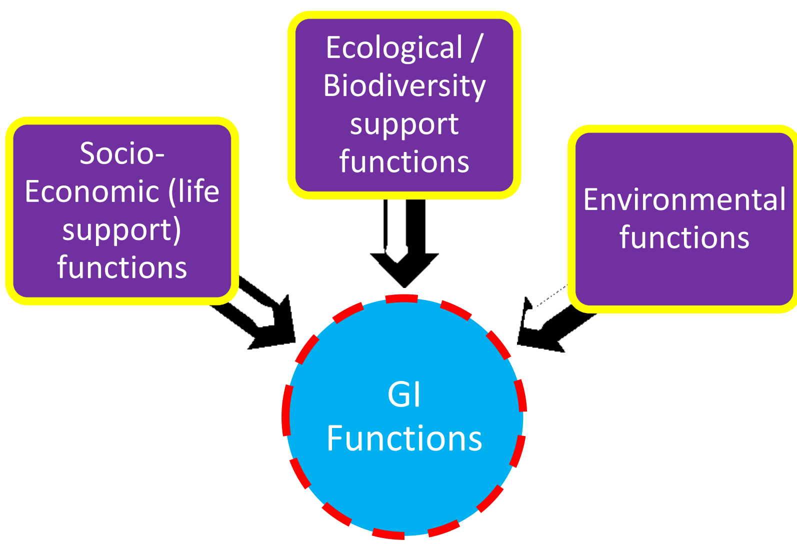


Figure 30: GI functions classification.

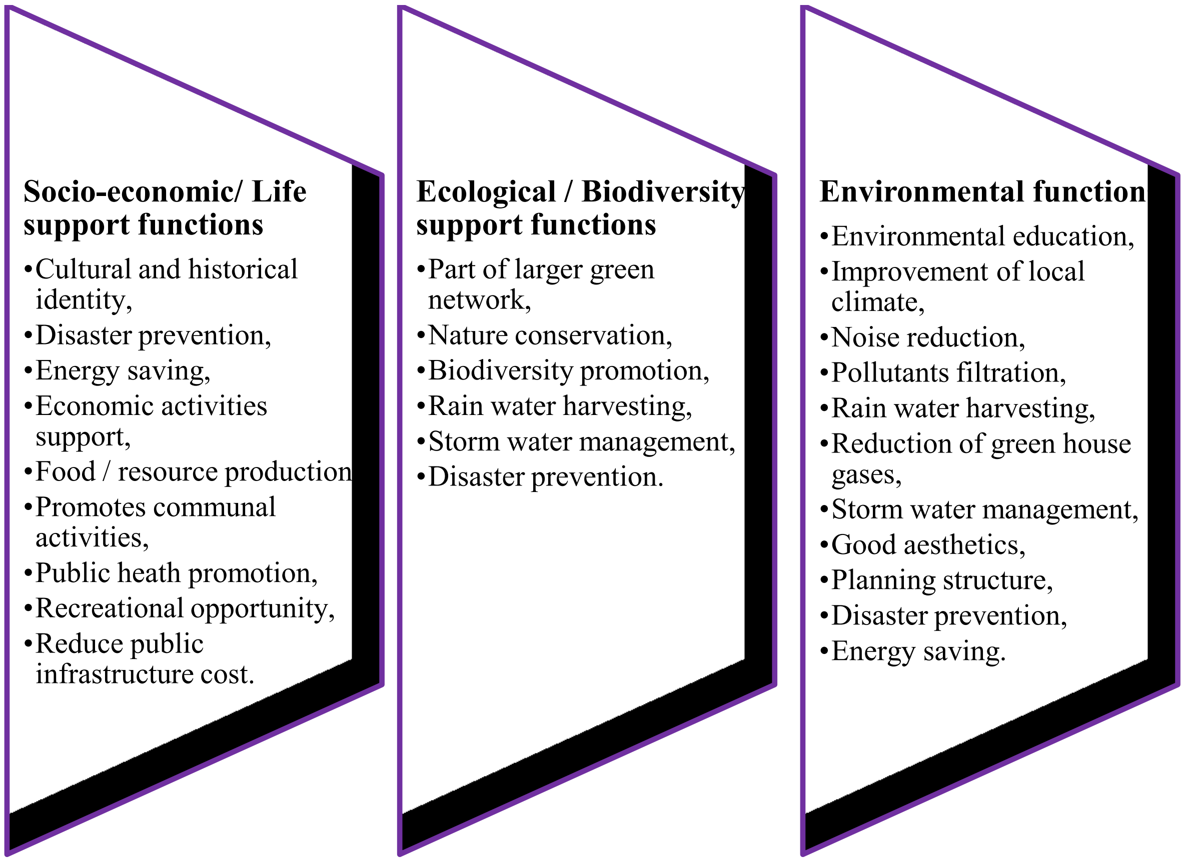


Figure 31: GI functions classification and their distribution.

Out of the 123 questionnaires distributed in 41 municipalities, 91 (73.98%) were filled up and mailed back from 40 municipalities. In the first categorization by area, 54 were from Tokyo 23 SW and 37 from the suburban Cities neighbouring Tokyo 23 SW. In the second categorization, by municipality departments, the valid responses were as follows; Urban Planning Departments (N = 31), Parks and Green Space Departments (N = 35), and Environments Departments (N = 25). The mean relative values for the GI functions were as shown in figure 2.

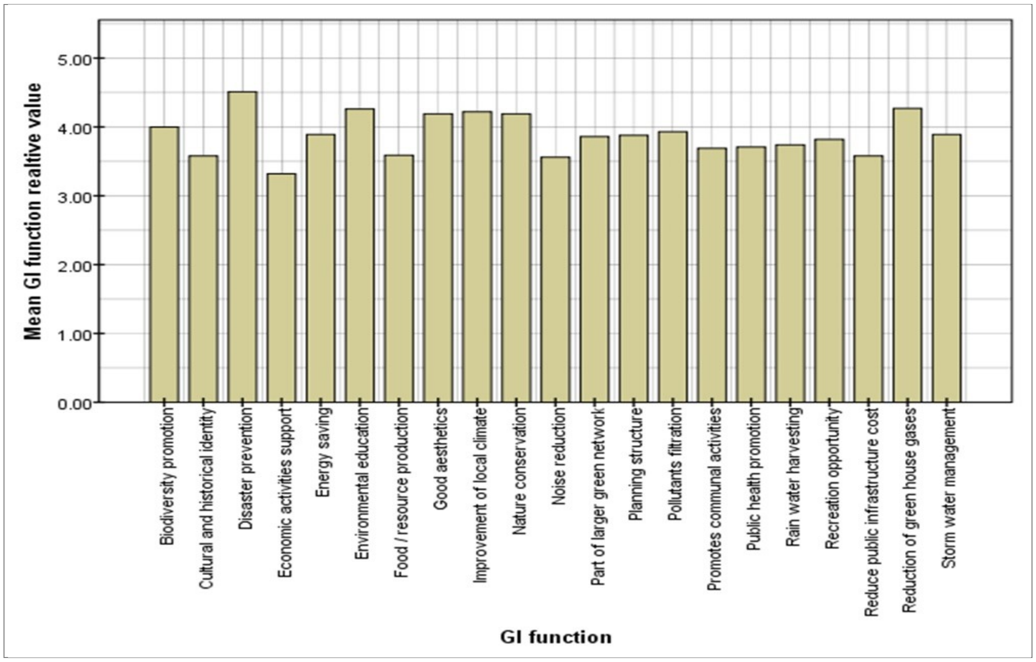


Figure 32: Mean relative values for GI functions from all the respondents.

Respondents identified disaster prevention and mitigation as the most valuable function of GI with a relative value of 4.51 out of 5. Economic activities generation emerged with the least value among the 21 GI functions with 3.32 out of 5. Other GI functions with relative high values include reduction of green house gases (4.27), environmental education (4.26), and improvement of local climate (4.22). Those others with relative lower values were noise reduction (3.56), reduction of public infrastructure cost (3.58), and cultural and historical identity (3.58). The mean cumulative value for all the GI functions from all respondents was 3.89. The results based on the two categories were as shown on figures 3 and 4.

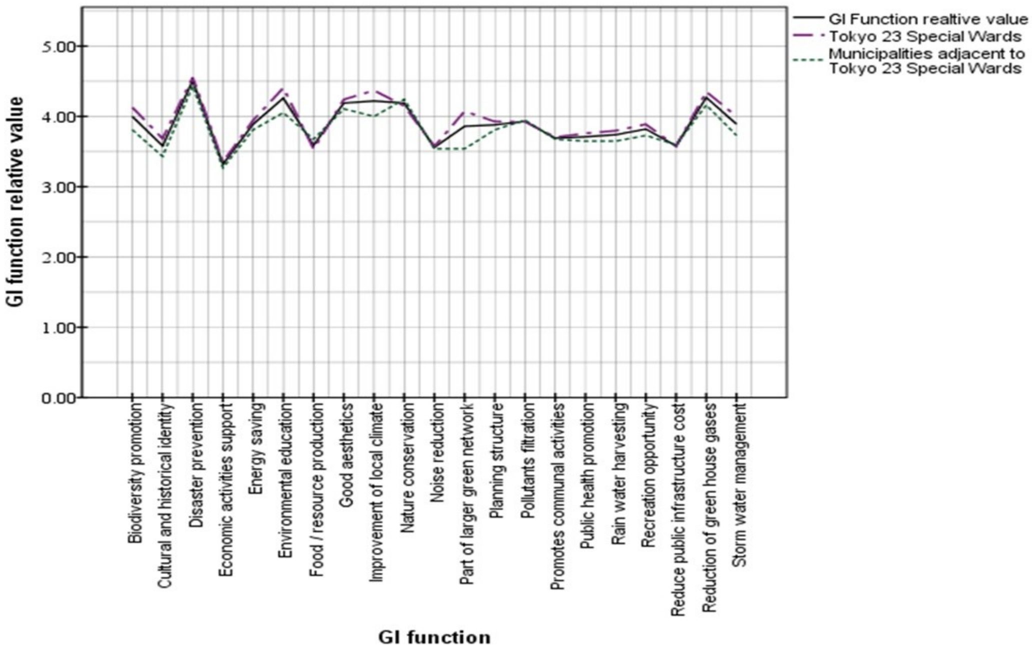


Figure 33: Mean relative values for GI functions based on area categorization.

Public municipal workers in the Tokyo 23 SW also indicated disaster prevention and mitigation function to have the highest value (4.50). Economic support services too came last with 3.35. However, they indicated food and resource production to have the second least value at 3.54. The mean cumulative value for all the GI functions from all the respondents in this category was 3.95 out of 5. From the suburban cities neighbouring Tokyo 23 SW, nature conservation was the second highest valued GI function after disaster prevention and mitigation. Unlike in the Tokyo 23 SW, workers in this category valued food and resource production much higher as the eight least valuable at 3.68. The mean cumulative value for this category was 3.80 out of 5.

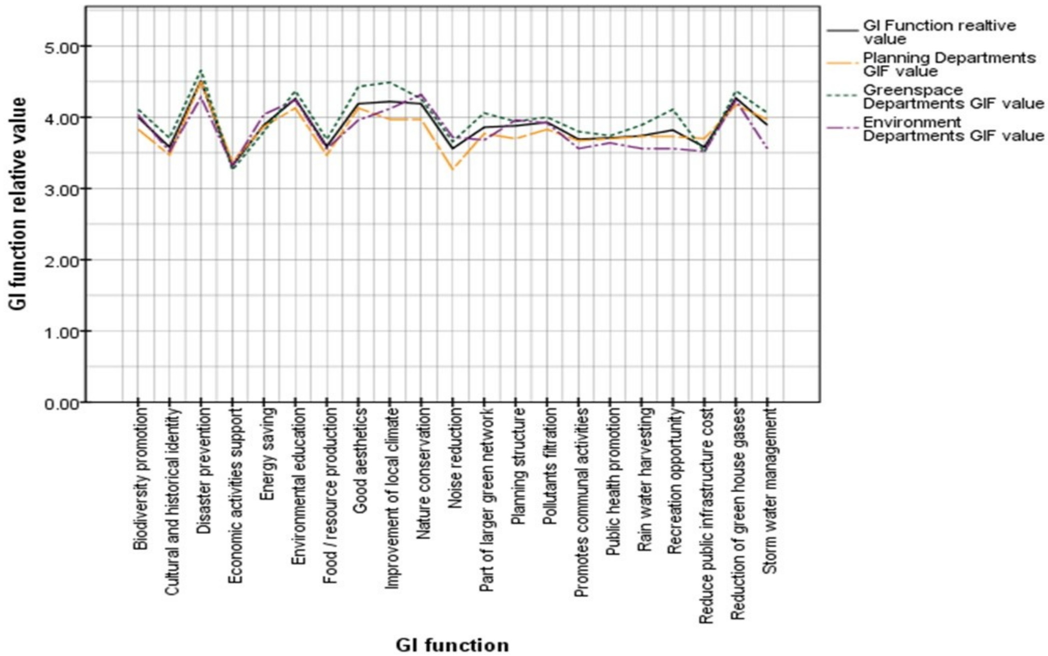


Figure 34: Mean relative values for GI functions based on departments' categorization.

In the second categorization by municipalities' departments (Fig. 4), disaster prevention and mitigation function was the highest valued. It had 4.50, 4.66, and 4.28 in the departments of planning, parks and green space, and environment respectively. Economic support function scored the least in the departments of parks and green space (3.26) and environment (3.32), whereas noise reduction (3.27) was the least valued by workers in the departments of planning. Parks and green space departments' workers rated good aesthetics (4.43), improvement of local climate (4.49), part of larger green network (4.06) and recreation opportunity (4.11) much higher than the average mean. The mean cumulative values for all the GI functions per category were; 3.81 for planning departments, 4.00 for parks and green space departments, and 3.83 for environment departments.

After GIG design completion and inclusion of GI functions' relative values, results from evaluation of Koshigaya Lake Town were as shown on table 2. The gauge (GIG) revealed that reduction of green house gases was the most prevalent and valuable function with a function total score (FTS) of 38.43. Environmental education was second with 38.34 FTS, followed by improvement of local climate with 33.76. Those with the least FTS were food / resource production (2.88), cultural and historical identity (3.58), and economic activities support (3.99). On the other hand, GI elements assessment for their element total score (ETS) was done. Both disaster prevention and mitigation elements and water ways and water features had an (ETS) of 70.40. Rain water harvesting, storage, use, and infiltration elements followed with an ETS of 63.77.

Table 10: Complete Green Infrastructure Gauge (GIG) with results from application in Koshigaya Lake Town.

GREEN INFRASTRUCTURE GAUGE (GIG).

GI ELEMENTS \ GI FUNCTIONS	1. Biodiversity promotion.	2. Cultural and historical identity.	3. Disaster prevention.	4. Energy saving.	5. Economic activities support.	6. Environmental education.	7. Food / resource production.	8. Good aesthetics.	9. Improvement of local climate.	10. Nature conservation.	11. Noise reduction.	12. Part of larger green network.	13. Planning structure.	14. Pollutants filtration.	15. Promotes communal activities.	16. Public health promotion.	17. Rain water harvesting.	18. Recreation opportunity.	19. Reduction of green house gases.	20. Reduce public infrastructure cost.	21. Storm water management.	E.T.S
F.R.V	4.00	3.58	4.51	3.89	3.32	4.26	3.59	4.19	4.22	4.19	3.56	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	
1. Cycling route/ Walking route/ Trail/ Promenade.	0.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	0.00	0.00	3.88	0.00	3.69	3.71	0.00	3.82	4.27	3.58	0.00	39.51
2. Green buffer/ Green belt.	4.00	0.00	0.00	0.00	0.00	4.26	0.00	4.19	4.22	4.19	3.56	0.00	0.00	3.93	3.69	3.71	0.00	0.00	4.27	0.00	3.89	43.91
3. Green network/ Greenway.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Green roofs/ Green walls/ Green curtains.	4.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.27	0.00	0.00	24.83
5. Landscaping plants (trees, shrubs, groundcovers, lawn).	4.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	3.56	0.00	0.00	3.93	3.69	3.71	0.00	3.82	4.27	3.58	3.89	51.01
6. Renewable energy harvesting and use/ Energy saving facilities.	0.00	0.00	0.00	3.89	1.33	4.26	0.00	0.00	0.00	0.00	0.00	0.00	3.88	0.00	0.00	3.71	0.00	0.00	4.27	3.58	0.00	24.92
7. Nature reserve/ Woods/ Forest/ Grasslands.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8. Parks/ Gardens/ Squares/ Beach/ River front	4.00	3.58	0.00	0.00	0.00	4.26	0.00	4.19	4.22	4.19	0.00	0.00	3.88	3.93	3.69	3.71	0.00	3.82	4.27	0.00	3.89	51.63
9. Rain water harvesting, storage, use, and infiltration facilities.	4.00	0.00	4.51	3.89	0.00	4.26	0.00	4.19	4.22	4.19	0.00	0.00	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	63.77
10. Disaster prevention/ mitigation elements	4.00	0.00	4.51	3.89	1.33	4.26	1.44	4.19	4.22	4.19	0.00	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	70.40
11. Water ways/ Water features	4.00	0.00	4.51	3.89	1.33	4.26	1.44	4.19	4.22	4.19	0.00	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	70.40
12. Wetlands/ Bogs/ Peat land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13. Working lands (Farming, natural resource extraction, etc).	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F.T.S	28.00	3.58	13.53	27.23	3.99	38.34	2.88	33.52	33.76	20.95	7.12	7.72	23.28	23.58	25.83	29.68	11.22	22.92	38.43	21.48	23.34	440.38

SCORE: 440.38/1061.84 41.47 % **4.15** Points CLASS: **Good**

LEGEND:

- WEIGHTED VALUES: (**0** = Not present, **0.4** = Planned for, **1** = Present).
- SCORING AND CLASS: (0 ~ 1.99 Points = **Poor**, 2 ~ 3.99 Points = **Fair**, 4 ~ 5.99 Points = **Good**, 6 ~ 10 Points = **Excellent**).
- F.R.V = Function Relative Value from **0** to **5**.
- E.T.S = Element Total Score.
- F.T.S = Function Total Score.

The GIG revealed that there were no elements for green network/ greenway (0.00), wetlands/ bogs/ peat land (0.00), and working lands (farming or natural resource extraction) (0.00). Overall, Koshigaya Lake Town gauge was a score of 4.15 points out of maximum 10 and classified as ‘Good’ in a scale of ‘Poor’ to ‘Excellent’.

5.4 Discussion

Trough this study, it has been established that disaster prevention and mitigation is the most valuable GI function by the Japanese municipalities' workers. This can be attributed to the fact that Japan Archipelago is always experiencing many natural disasters such as the recent March 11 2011 earthquake and Tsunami. Volcanic eruptions and strong typhoons that trigger flooding and landslides are frequent, hence the high awareness and valuation of this GI function. Japan, having one of the lowest unemployment rates and diverse work opportunities may have led municipal workers to attach less value to economic activities support GI function. This could be a different case in countries where unemployment levels are high and opportunities low. It should still be strongly considered for inclusion in future GI planning to lessen the burden of unemployment, and promote economic health and sustainable communities.

The ongoing global debate on climate change seems to work in sensitizing public workers on environmental matters. This might have increased their cognitive consciousness hence the high valuation of reduction of green house gases, environmental education, and improvement of local climate GI functions. The high values attached to these functions give them impetus for inclusion in planning and management of current and future urban areas. This can necessitate avoidance of future consequences of climate and environmental change that could plague future communities.

After categorization of the respondents based on areas and departments, there was no significant deviation from the mean. This shows that the values attached to the GI functions have universality among all the respondents. There were only minor variations across the categories. In Tokyo 23 SW, food and resource production had a much lower value, as opposed to the neighbouring suburban cities that accorded it higher value. Tokyo 23 SW forms the core of the City, with very high population density, and very expensive and scarce land. This reduces the amount of land available for farming and resource production; hence workers in these municipalities may have fewer opportunities to engage in planning and management of such functions. This is in contrast with those in the suburban municipalities with lower population densities, much open and cheaper land that includes urban farms. Another variation was in the suburban cities where natural conservation was second highest valued GI function. These areas could be having more natural environments with GI elements like forests, woods, riparian ecosystems, and Satoyama (Japanese rural landscape) than in central Tokyo.

In case of categorization by municipalities departments, workers in the department of planning valued noise reduction as having the least value. This could be due to their perceived competition from artificial noise reduction elements. Noise shields such as those installed in major highways around Tokyo could have perceived or real effectiveness, over GI elements like earth mounds and green buffers that require time and space to install. Workers in the parks and green space departments emphasized good aesthetics, improvement of local climate, part of a larger green network, and recreation opportunities GI functions. Their importance in improving urban environments and communities' wellbeing saw those awarded higher values than the mean. Such functions must be amplified when planning for the future communities, in order to make them liveable and healthy.

Cumulative value of all the GI functions shows that parks and green space departments' workers attach the greatest value (4.00) to GI. This could be due to their daily engagement in planning and management of vital GI elements such as parks and green networks among others. Those in urban planning departments across the study area attach the least value (3.81) to GI. Being the main contributors to technical aspects relating to land use planning and management, they ought to be more sensitized on the value of GI so as not to overlook it in their daily work engagements. Workers in Tokyo 23 SW also seem to have a higher appreciation of the value of GI than those from the suburb cities. They work in municipalities with land constraints and high population densities hence higher value attachment for the limited GI elements and functions within their jurisdiction.

Koshigaya Lake Town having been built around a flood control reservoir, had its best performing GI elements and highest function total score (FTS) based on this central main feature. Despite the fact that it was curved from rice farming land, it was found to lack working lands (farming and resource extraction) among other essential GI elements. Such a paradox should be resolved through planning and application of reference tools such as GIG, to ensure optimum inclusivity and sustainability. The New Town as existing scored 4.15 points out of 10, and classified as 'Good' since it has many GI elements dispensing numerous GI functions. With complete obliteration of the hitherto existing farmland and farming culture, the project lost essential points based on GIG. It mirrors the architectural phenomenon of scrap and build common in Japan, leading to loss of local identity (Kinoshita et. al, 2012) and heritage. However, if the missing GI elements were to be included, the project could achieve 'Excellent' status, and become a perfect case for sustainable future communities.

5.5 Conclusion

Green Infrastructure functions do not poses uniform or equal values. They afford varying levels of ecological, environmental and socio-economic goods and services. Some GI functions have relatively high values and others relatively lower value attachments. Local conditions in different municipalities influence the workers value attachment to GI functions. As such, it is necessary that a future study should test the GI functions relative values in different parts of the world. This is in order to find out if there are any variations in their values across environmental, cultural, social, and economic backgrounds to enhance GIG universality. As for the response of the municipalities' workers within the study area, it is concluded that their understanding of the GI functions is relatively high and universal. Their response pattern had minimal variation across the categories hence reliability of the results. However, more training and sensitization is needed for public municipal workers on GI especially in the departments of planning and environment. This is to ensure all the workers contributing in land use, spatial planning, policy formulation, management, and enforcement of aspects touching on GI understand its concept and value. Their lower valuation of GI functions can lead to the exclusion of GI in future urban development or redevelopment. This absence of its benefits could expose future communities to ecological, environmental, and socio-economic challenges.

Disaster prevention and mitigation may have a higher value attachment than other functions in the context of workers from disaster prone Japanese municipalities. This does not negate its value in countries less prone to disasters. Disasters either manmade or natural are never anticipated and occur without warning and in unpredictable randomness across the world. Their probability of occurrence can be reduced, and their impact mitigated if they do occur. Thus, this

GI function should be embraced globally to avoid loss of lives, environmental degradation and ecological disturbances all of which are detrimental to the future communities well being. It can be confirmed that the Green Infrastructure Gauge (GIG) formulated is practical as a Green Infrastructure (GI) evaluation tool after application in Koshigaya Lake Town. Its application in such existing urban or planned areas can highlight their GI strengths and weaknesses, and point out possible improvement areas. Finally, as part of possible weakness, this tool (GIG) cannot claim to include all the elements and functions of the ambiguous and fast evolving Green Infrastructure (Wright, 2011). It highlights valuable GI elements and functions future towns and cities can incorporate, to realize ecosystems and environment wellbeing, and herald sustainable future communities.

References

1. Benedict, M., A., and McMahon, E., T. (2006). *Green infrastructure: Linking landscapes and communities*. Island Press, Washington.
2. Convention on biodiversity (2010). City Biodiversity Index (or Singapore Index). Available from: http://www.cbd.int/authorities/gettinginvolved/cbi.shtml, accessed on May 1st 2012.
3. Kinoshita, I., Binder, H., Okabe, A. (2012). *Identity and Sustainability.* Hobunsya Publisher Inc. Tokyo.
4. Rudolf, S. de G., Mathew, A. W., Roelof, M. J. B. (2002). A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. *Ecological Economics,* Vol. 41, 393-408.
5. Schaffler, A., and Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure – The Johannesburg case. *Ecological Economics*, Vol. 86, 246-257.
6. Seattle City. Seattle Green Factor. Department of Planning and Development. Available from: http://www.seattle.gov/dpd/Permits/GreenFactor/Overview/, accessed on May 3rd 2012.
7. Weber, T., Sloan, A., Wolf, J. (2006). Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation. *Landscape and Urban Planning,* Vol. 77, 94-110.
8. Wright, H. (2011). Understanding green infrastructure: the development of a contested concept in England. *Local Environment,* Vol. 16 (10), 1003–1019.

6 CHAPTER 6: Evaluation of Koshigaya Laketown for its Green Infrastructure affordance.

6.1 Introduction

Koshigaya Laketown was considered as a case study to apply Green Infrastrucutre Gauge (GIG) because it is a relatively new project constructed during the 'ECO' era. It is fronted as an experimental project especially in flood control, and has many environmental friendly components included in its planning. It was awarded a GOLD AWARD in 2009 by LIVCOM (Livable Communities). LIVCOM is the World's only awards competition focusing on International Best Practice regarding the management of the local environment, geared towards improving the quality of life of individual citizens through the creation of 'livable communities'.

Having been curved out of agricultural land, it also resonates with Ebenezer Howard's concept of Newtown creation from cheaper open land, as an answer to urban sprawl and challenges of established cities. Such land is more flexible to accommodate elements of GI, hence affordance of life support functions that enhances the wellbeing of the residents. Koshigaya Laketown has also been used by JICA as a training model for foreign urban planners and designers. It is thus important to use it as a case study, to highlight its successes and or pinpoint its failures to the world and for future reference.

6.1.1 Objectives

1) Documentation of existing and planned GI elements in Koshigaya Laketown.
2) To collect empirical data and other evidence of Koshigaya Laketown affordance of life support functions and other GI functions.
3) Estimation of GI level in Koshigaya Laketown using Green Infrastrucutre Gauge (GIG).

6.1.2 Hypothesis

Koshigaya Lake Town scores 4.15 points (out of maximum 10), and can be classified as ‘Good’ (in a scale of ‘Poor’ to ‘Excellent’) after evaluation through Green Infrastructure Gauge (GIG).

6.1.3 Study area

During the EDO Period, Koshigaya area was a post on the Nikko route. It is surrounded by many rivers experiencing a lot flooding in heavy rains. In 1986, examination by Riverine Urban Review Committee (which included experts and government institutions) began, and in 1988 the Lake Town Development project was conceptualized. In 1996 a decision was made to initiate City Planning, and in 1999 the project approval by Ministry of construction, land development began with UR as executor. The area is designated as a case study model. In 2008 JR Koshigaya Lake Town station and town opened to public.

It is located 22km North of Central Tokyo, measuring 225.6 hectares with a projected population of 22,400. Most of the land is controlled by UR, but also the original land owners own some land. Most housing is done by DAIWA Corporation, malls by Aeon Retail (Aeon Mori and Lake Town Outlet) and Aeon Mall (Aeon Kaze). The project is aimed to reduce carbon emissions by 20%, control flooding, utilize cool spot effect, create a water front lifestyle, lead in environmental symbiosis, and create a community under the LIFE-LINK-LAKE concept. It is also used for training programs by JICA and delegations from overseas local authorities (over 420 participants from over 15 countries from 2008 – 2010).

Figure 35: Koshigaya Laketown area before construction began (source; UR-Japan).

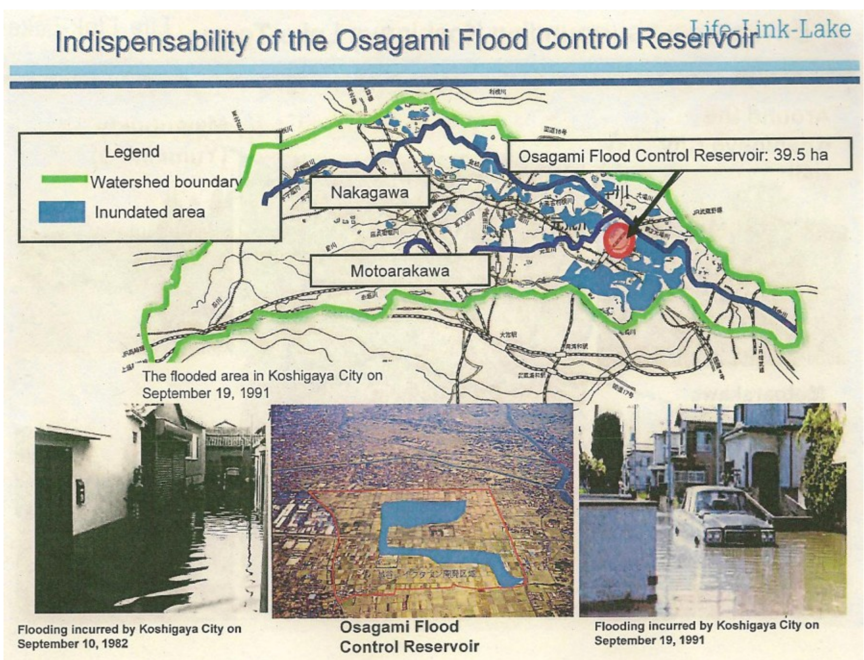


Figure 36: Flooding in Koshigaya Laketown area, a key consideration hence construction of Osagami Flood Control Reservoir (source; UR-Japan).

Figure 37: Koshigaya Laketown master plan aerial perspective impression (source; UR-Japan).

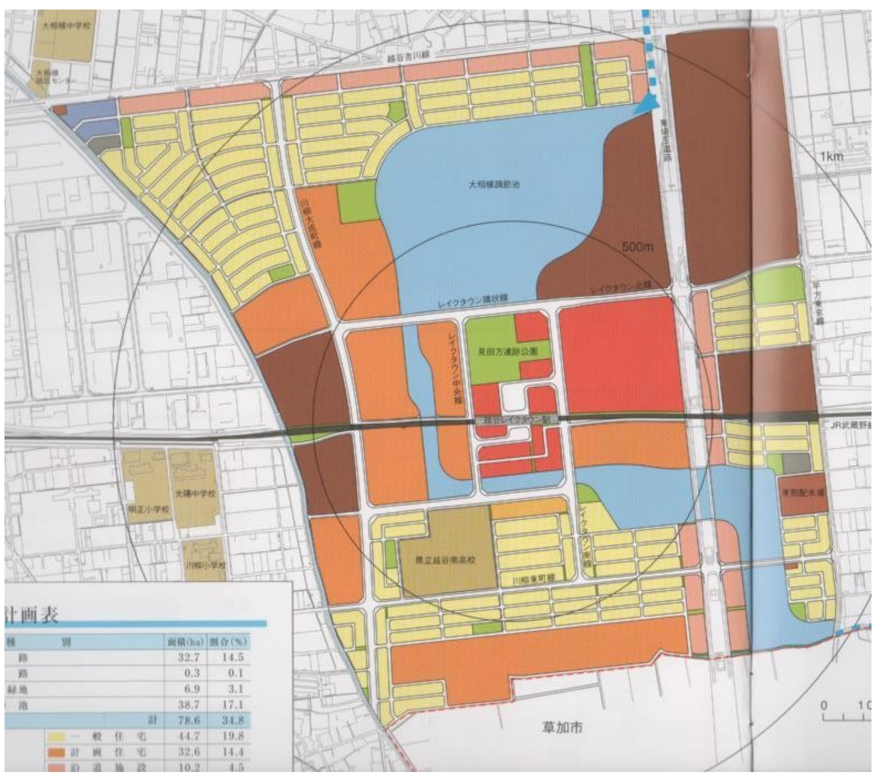


Figure 38: Koshigaya Laketown master plan (source; UR-Japan).

6.2 Methodology.

Secondary data was collected in terms of project documentation from UR (Urban Renaissance) and Mizube no Machizukuri Centre located in Koshigaya Laketown. This includes master plans, concept documents and various past events as well as green technologies demonstrations. Informal interviews with users and management staff were conducted, to verify various observations and documents. Field measurements, counts, trace mapping, events participation, as well as observations were carried out. Demonstration lectures such as those conducted by GEO POWER Company were attended. All this was done to record the various GI elements (hardware) present in Koshigaya Laketown, as well as identification of GI functions (software) they afford.

Figure 39: GI elements (hardware) and the GI function (software) relationship.

Finally, Green Infrastructure Gauge (GIG) developed in chapter 4 was applied, to determine the GI level in Koshigaya Laketown, as well as highlight its strengths and weaknesses.

6.3 Results and discussion.

Table below shows a summary of various GI functions, the elements that afford them, as well as the description of the function.

Table 11:Koshigaya Laketown GI elements, functions and their descriptions.

	GI function	GI Element(s)	Description
1.	Biodiversity promotion	Biotope area	• Various flora and fauna habitat.
2.	Cultural, historical and local identity.	Mitakata Park, Water front area, Osagami reservoir, walking and cycling network.	• Historical artifacts excavation site. • Area landmark. • Unique area events.
3.	Disaster prevention.	Osagami reservoir	• Flood control.
4.	Economic activities support.	Osagami reservoir, park and green system.	• Flea market, advertisements, merchandizing, demonstrations, various fees etc.
5.	Energy saving.	Renewable energy installations, wall plants, reservoir, eco-point system.	• Solar power, geo-power, area cool effect planning, reward for energy saving etc.
6.	Environmental education/ awareness.	Mizube no machizukuri, Mitakata park, water front area.	• Awareness campaigns, events, research results display, new eco friendly designs demo etc.
7.	Food / resource production.	x	• No food or resource production found.
8.	Good aesthetics.	Parks and green system, Osagami reservoir.	• Beautification through landscaping, views, vistas, etc.
9.	Improvement of local climate.	Osagami reservoir, Park and green system, Wall plants, Green curtains.	• Cool effect reducing the local summer temperature and relative humidity conditions in winter.
10.	Nature conservation.	Biotope area.	• Natural area with woody layers, wetland condition and wildlife.
11.	Noise reduction.	x	• No noise reduction elements found.
12.	Part of larger green network.	Reservoir, walking and cycling system, park and green system.	• Reservoir linked to Naka river system. Circulation and green network linked to the larger circulation and green system.
13.	Planning structure.	Walking and cycling network, park and green system, Osagami reservoir.	• Entire town planned around Osagami reservoir. • All walking and cycling routes form the backbone of blocks and urban structure.
14.	Pollutants filtration.	x	• No evidence found of this function.
15.	Promotes communal activities.	Parks and green system, Osagami reservoir, Mizube no machizukuri, walking and cycling network.	• Various community and regional events, as well festivals hosted by the GI elements. • Flea market, running, concerts, etc.
16.	Public health promotion.	Walking and cycling network.	• Exercises, relaxation, social bonding etc.
17.	Rain water harvesting.	x	• No deliberate rain water harvesting for utilization purpose found.
18.	Recreation opportunity.	Osagami reservoir, Park and green system, walking and cycling network.	• Running, jogging, cycling, dancing, sailing, canoeing, picnicking among other forms of recreation found.

19.	**Reduce public infrastructure cost.**	**Osagami reservoir, Park and green system, walking and cycling network.**	• **Flood control, rain water infiltration walking, cycling, eco-points for using public transport etc reduce public infrastructure cost.**
20.	**Reduction of green house gases.**	**Renewable energy facilities, Osagami reservoir, park and green system.**	• **Reduction of CO_2 and other emissions, cool effect planning reduces electricity use in summer.**
21.	**Storm water management.**	**Osagami reservoir, lawn and hollow block surfaced parking lots, infiltration areas.**	• **Retention of storm water for slow release after the storm, infiltration to reduce flow to rivers.**

The figures below show some examples of the various GI elements found in Koshigaya Laketown.

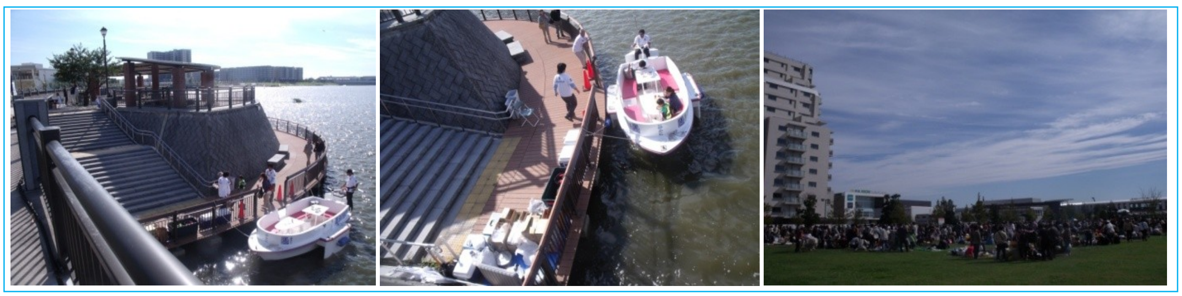


Figure 40: Floating café on lake cruise boat and flea market in Mitakata park as part of GI economic activities support (source; by author, field survey Koshigaya Laketown).

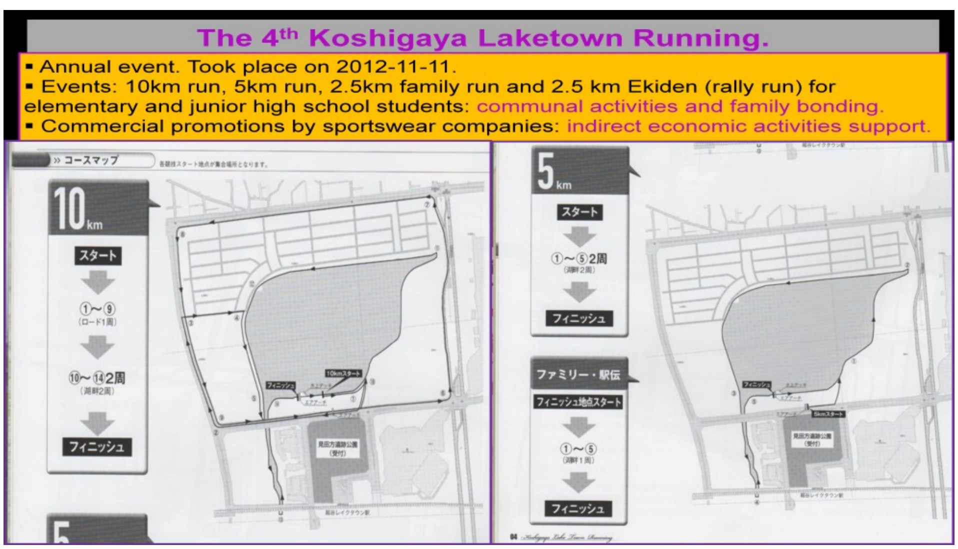


Figure 41: The 4th annual Koshigaya running routes, along the low impact mobility system (source; The 4th Koshigaya Laketown Running).

Figure 42: Parks provisioning in Koshigaya Laketown (source; UR-Japan).

Activities observed in parks and along low impact mobility system (paths and trails) includes: cycling, walking, dog walking, strolling with babies, jogging, photography, motorized children train rides, and roller skating.

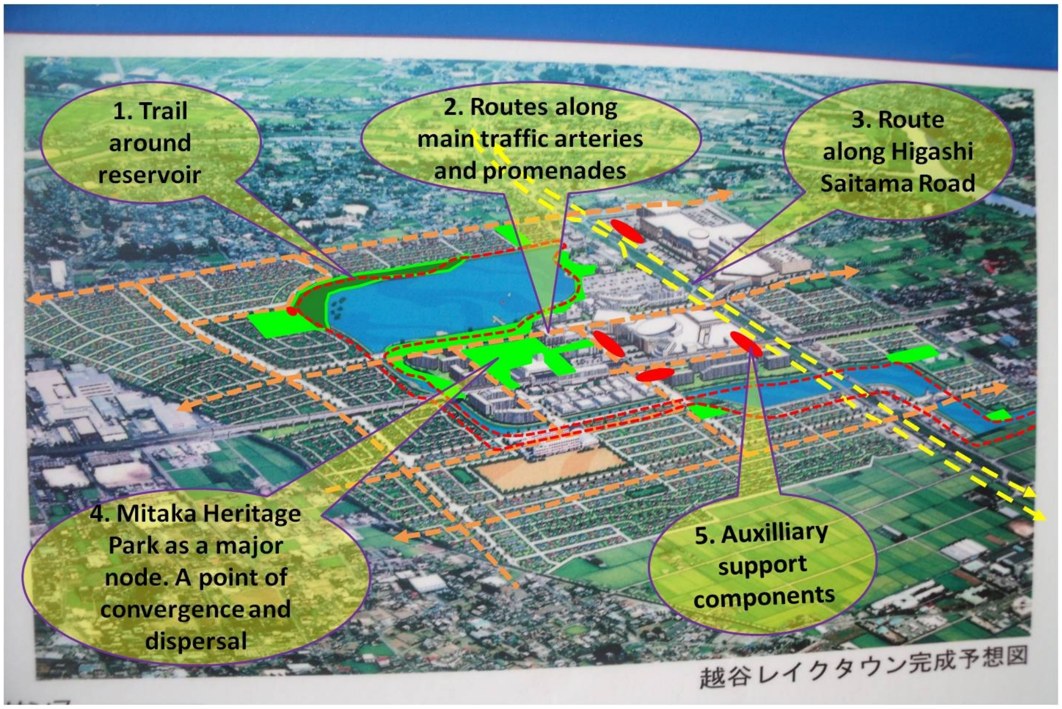


Figure 43: Cycling route, walking route/ trail, premonades and low impact mobility auxiliary facilities(source; author, field survey Koshigaya Laketown).

Figure 44: Low impact mobility trail around Osagami reservoir (source; author, field survey Koshigaya Laketown).

To find out the local environment influence by the various landscapes elements including Osagami Reservoir cool effect concept highlighted by UR, a surface thermo conditions study was carried out on 26th August 2012. This was also to indicate different heat absorption, retention or reflection by various landscape elements present in Koshigaya Laketown. NEC TH – 703 Thermography Camera was used. Six views were photographed from 6 points, with photography spanning between 9 am and 6 pm. Each view photographed in every hour for the 9 hours duration. Surface temperatures analyzed for various landscape elements present in the 6 selected views. Effects on summertime air temperature were recorded. These could influence the thermal comfort of the residents, and reduction of Urban Heat Island. Similar studies indicated this evidence including those done by Yanai and Ohmae (2005) on cooling effect of urban river and open space, and Yokohari et.al. (2001) on cooling effect of paddy fields in residential Tokyo.

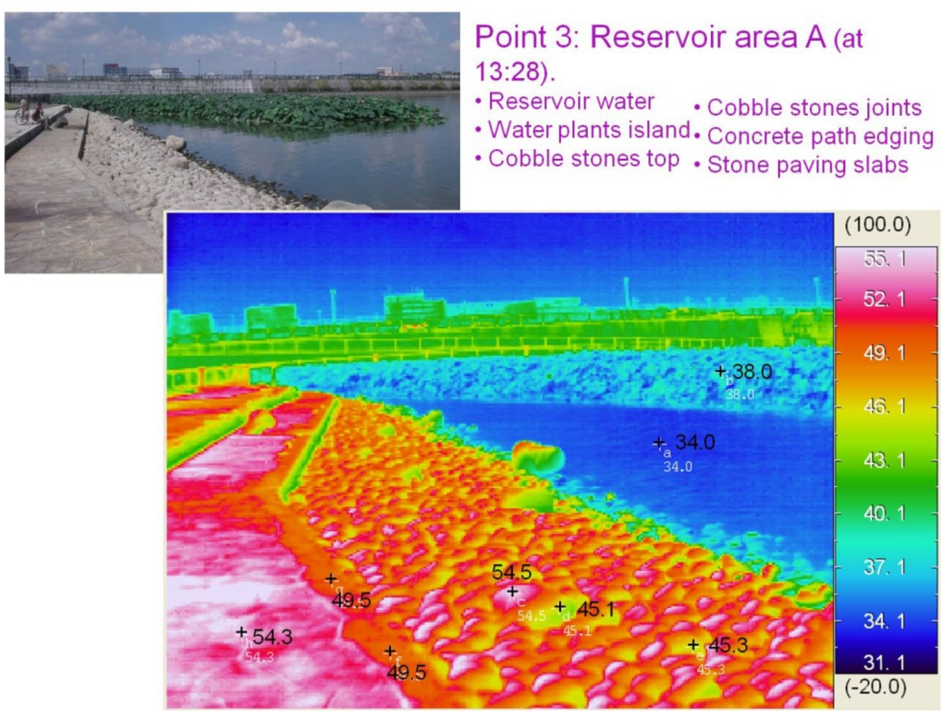


Figure 45: Thermograph towards water Plants Island (source; author, field survey Koshigaya Laketown).

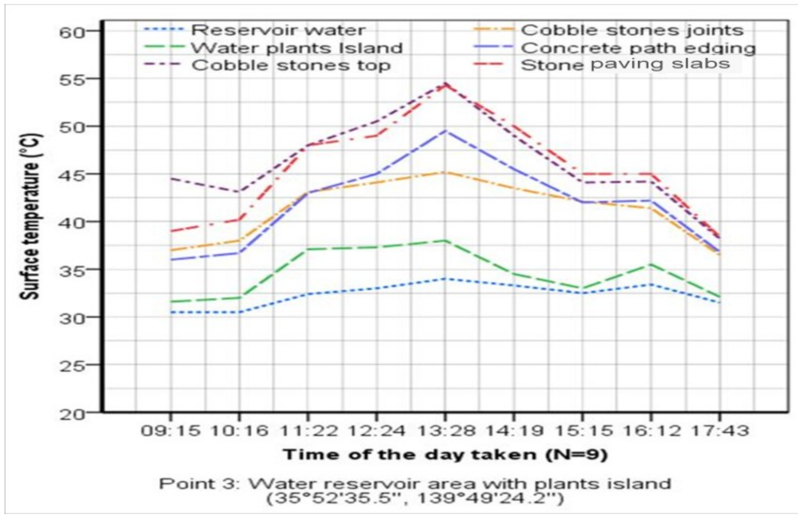


Figure 46: Surface temperatures for various elements and demonstration of cool effect by Osagami reservoir 1.

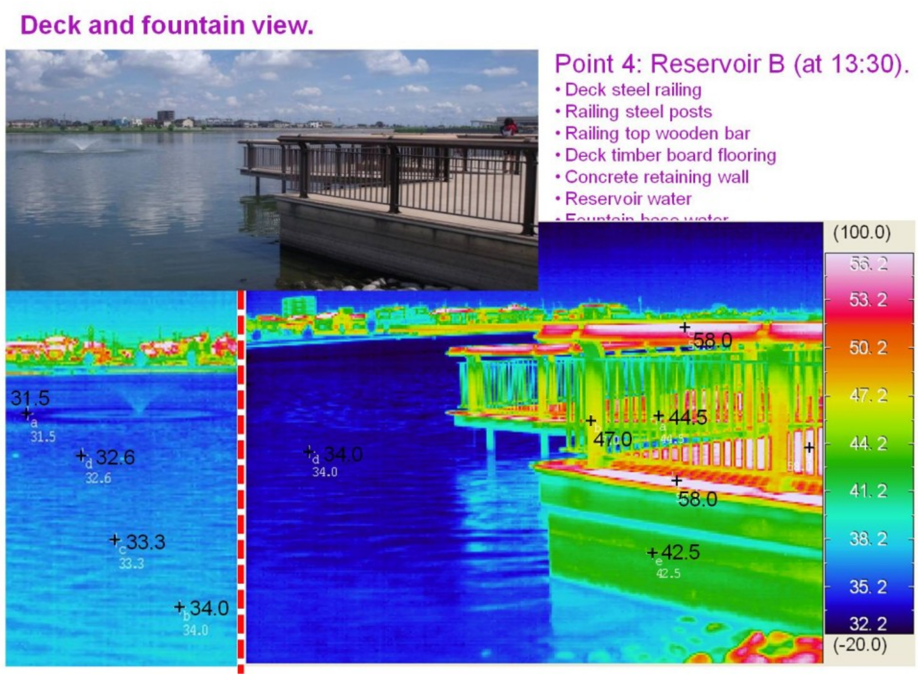


Figure 47: Thermograph towards the fountain and deck (source; author, field survey Koshigaya Laketown).

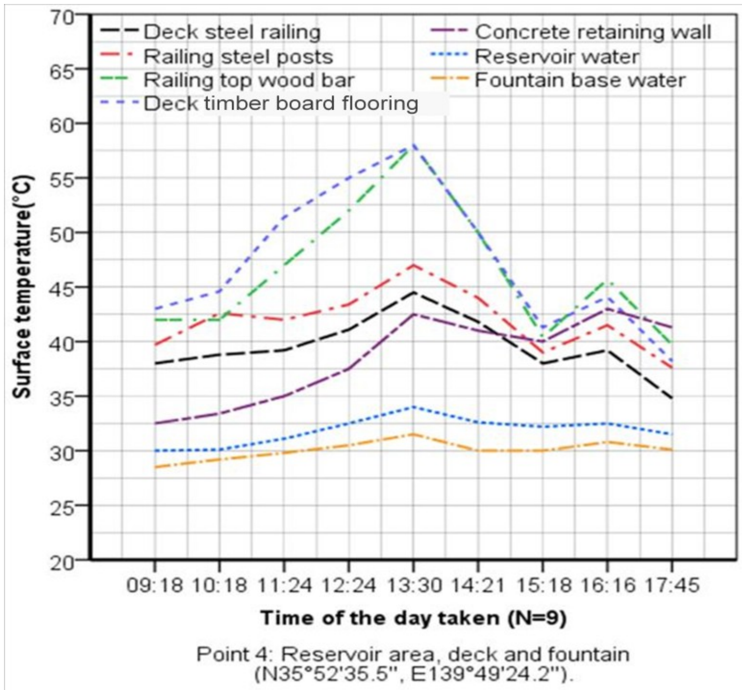


Figure 48: Surface temperatures for various elements and demonstration of cool effect by Osagami reservoir 2.

Figure 49: Dance festival during ECO WEEK in Koshigaya Laketown (source; author, field survey Koshigaya Laketown).

Figure 50: Unique recreation opportunities and group events in Koshigaya Laketown (source; author, field survey Koshigaya Laketown).

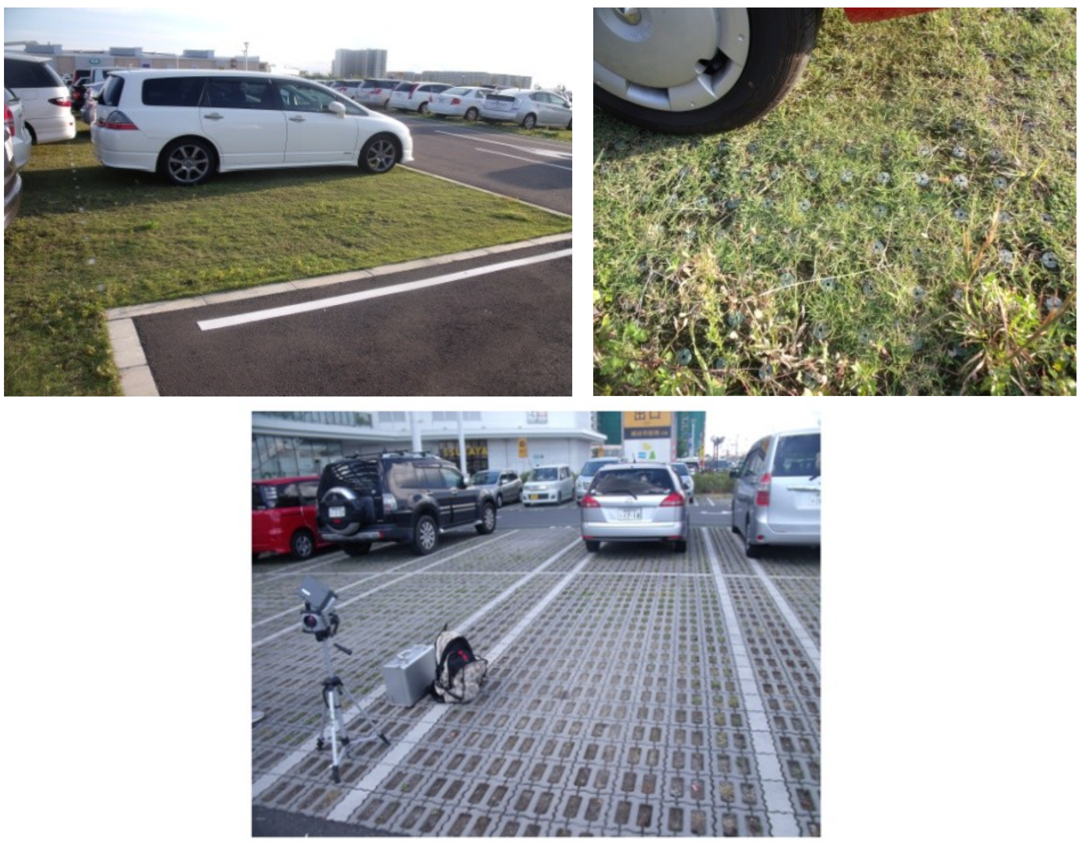


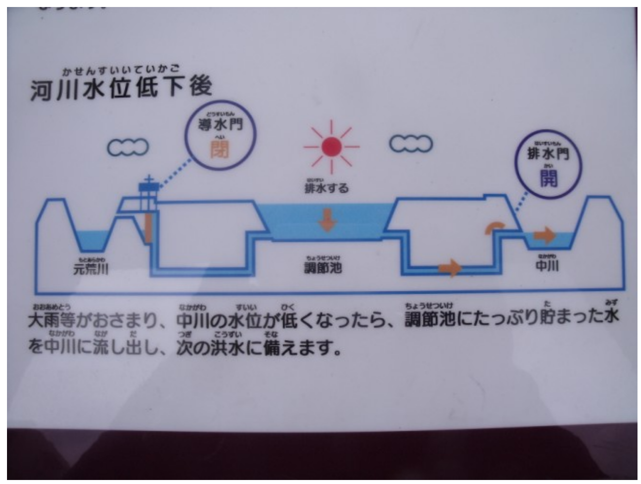
Figure 51: Storm water management; hollow paving blocks and reinforced lawn car parks (source; author, field survey Koshigaya Laketown).

Figure 52: Biotope area, a niche for biodiversity promotion (source; author, field survey Koshigaya Laketown).

1. Renewable energy installations.

2. Pillar greening.

3. Wall greening and green curtains.



4. Flood control and disaster mitigation.

Figure 53: Some of the other forms of GI elements found in Koshigaya Lake town (source; author, field survey Koshigaya Laketown).

Mitakata Heritage Park was found to be the major node in the walking and cycling routes. It is the central point of convergence and dispersal, linking the train station, residential areas, shopping malls, kindergarten, and waterfront areas. It is a multifunctional space that not only hosts residents' daily outdoor activities, but also special events such as flea markets, merchandizing during regional events among others. The water front area can be considered as an area of 'slow life', where users mostly sit on landscape elements including lawns and low walls, and watch unfolding events or sceneries.

Higashi Saitama Road on the other hand forms a major thoroughfare through Koshigaya Laketown, linking it to the regional transportation network. It is a wide promenade with a broad median, forming a major green axis through Laketown. Most of the roads in the project can be described as promenades, with separated vehicular, bicycle and pedestrian traffic that is clearly marked by signage and color coded. These levels of traffic are also separated using vegetation medians and other landscape elements.

Other forms of GI elements found in Koshigaya Laketown include renewable energy installations and demonstrations such as GEO-POWER system for cooling in summer and warming in winter, solar power systems, eco-point system within the shopping malls, environmental awareness programs. There is a key soft role played by Mizube no Machi Zukuri Center in coordinating management and use of the GI infrastructure and systems, together with NPO’s and the enterprise in Koshigaya Laketown.

6.3.1 Green Infrastructure gauge for Koshigaya Laketown.

Table 12: GREEN INFRASTRUCTURE GAUGE (GIG) for Koshigaya Laketown.

GI ELEMENTS \ GI FUNCTIONS	1. Biodiversity promotion.	2. Cultural and historical identity.	3. Disaster prevention.	4. Energy saving.	5. Economic activities support.	6. Environmental education.	7. Food / resource production.	8. Good aesthetics.	9. Improvement of local climate.	10. Nature conservation.	11. Noise reduction.	12. Part of larger green network.	13. Planning structure.	14. Pollutants filtration.	15. Promotes communal activities.	16. Public health promotion.	17. Rain water harvesting.	18. Recreation opportunity.	19. Reduction of green house gases.	20. Reduce public infrastructure cost.	21. Storm water management.	E.T.S
F.R.V.	**4.00**	**3.58**	**4.51**	**3.89**	**3.32**	**4.26**	**3.59**	**4.19**	**4.22**	**4.19**	**3.56**	**3.86**	**3.88**	**3.93**	**3.69**	**3.71**	**3.74**	**3.82**	**4.27**	**3.58**	**3.89**	
1. Cycling route/ Walking route/ Trail/ Promenade.	0.00	0.00	0.00	3.89	3.22	4.26	0.00	4.19	4.22	0.00	0.00	3.86	3.88	0.00	3.69	3.71	0.00	3.82	4.27	3.58	0.00	**46.59**
2. Green buffer/ Green belt.	4.00	0.00	0.00	0.00	0.00	4.26	0.00	4.19	0.00	0.00	0.00	3.86	0.00	0.00	3.69	0.00	0.00	0.00	4.27	0.00	3.89	**28.16**
3. Green network/ Greenway.	4.00	3.58	4.51	3.89	0.00	4.26	0.00	4.19	4.22	4.19	0.00	3.86	3.88	3.93	3.69	3.71	0.00	3.82	4.27	3.58	3.89	**67.47**
4. Green roofs/ Green walls/ Green curtains.	4.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.27	0.00	0.00	**24.83**
5. Landscaping plants (trees, shrubs, groundcovers, lawn).	4.00	3.58	0.00	3.89	3.22	4.26	0.00	4.19	4.22	0.00	0.00	3.86	3.88	0.00	3.69	3.71	0.00	3.82	4.27	0.00	3.89	**54.48**
6. Renewable energy harvesting and use/ Energy saving facilities.	0.00	0.00	0.00	3.89	3.22	4.26	0.00	0.00	0.00	0.00	0.00	0.00	3.88	0.00	0.00	0.00	0.00	0.00	4.27	3.58	0.00	**23.10**
7. Nature reserve/ Woods/ Forest/ Grasslands.	4.00	0.00	4.51	0.00	0.00	4.26	0.00	4.19	0.00	4.19	0.00	3.86	0.00	0.00	0.00	0.00	0.00	3.82	4.27	0.00	3.89	**36.99**
8. Parks/ Gardens/ Squares/ Beach/ River front	4.00	3.58	4.51	3.89	3.22	4.26	0.00	4.19	4.22	0.00	0.00	3.86	3.88	0.00	3.69	3.71	0.00	3.82	4.27	3.58	3.89	**62.57**
9. Rain water harvesting, storage, use, and infiltration facilities.	4.00	3.58	4.51	3.89	3.22	4.26	0.00	4.19	4.22	4.19	0.00	3.86	3.88	0.00	3.69	3.71	3.74	3.82	4.27	3.58	3.89	**70.50**
10. Disaster prevention/ mitigation elements	4.00	3.58	4.51	3.89	3.22	4.26	0.00	4.19	4.22	4.19	0.00	3.86	3.88	0.00	3.69	3.71	3.74	3.82	4.27	3.58	3.89	**70.50**
11. Water ways/ Water features	4.00	3.58	4.51	3.89	3.22	4.26	0.00	4.19	4.22	4.19	0.00	3.86	3.88	0.00	3.69	3.71	3.74	3.82	4.27	3.58	3.89	**70.50**
12. Wetlands/ Bogs/ Peat land	4.00	0.00	4.51	0.00	3.22	4.26	0.00	4.19	0.00	4.19	0.00	3.86	3.88	3.93	0.00	3.71	0.00	3.82	4.27	3.58	3.89	**55.31**
13. Working lands (Farming, natural resource extraction).	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
F.T.S	**40.00**	**21.48**	**31.57**	**35.01**	**25.76**	**51.12**	**0.00**	**46.09**	**33.76**	**25.14**	**0.00**	**38.60**	**34.92**	**7.86**	**29.52**	**29.68**	**11.22**	**34.38**	**51.24**	**28.64**	**35.01**	**611.00**

SCORE: 611.00/1061.84 57.54% 5.75 Points CLASS: Good

LEGEND:

- WEIGHTED VALUES: (0 = Not present, 0.4 = Planned for, 1 = Present).
- SCORING AND CLASS: (0 ~ 1.99 Points = **Poor**, 2 ~ 3.99 Points = **Fair**, 4 ~ 5.99 Points = **Good**, 6 ~ 10 Points = **Excellent**).
- F.R.V = Function Relative Value from 0 to 5.
- E.T.S = Element Total Score.
- F.T.S = Function Total Score.

The GI level of Koshigaya Laketown is ‘5.75 points’ out of the maximum 10, and classified as ‘GOOD’ in a classification ranging from poor to excellent. Most affordable functions are: reduction of green house gases (51.25), environmental education and awareness (51.12), good aesthetics (46.09), and biodiversity promotion (40.0). The least affordable functions include food/ resource production (0.0), noise reduction (0.0), pollution filtration (7.86), rain water harvesting (11.22), and cultural and historical identity (21.48). On the other hand, the most valuable GI elements that afford the most functions are water ways and water features (70.50), disaster prevention and mitigation elements (70.50), as well as rainwater harvesting, storage, use, and infiltration facilities (70.50). These functions are dominated by Osagami reservoir, the central feature in Koshigaya Laketown. The element that affords the least functions is working lands (farming, natural resource extraction) which is nonexistent.

6.4 Conclusion

Koshigaya Laketown includes a wide variety of GI elements and functions, but it could have scored more points and ranked higher on the GIG if the missing elements and their functions were factored in during the planning stage. Having been an agricultural area before development, it lost all agricultural values in crop production, cultural and technical practices that accompany agriculture, water network that was used for irrigation and other farmland biodiversity. With GI planning before hand, elements that have not naturally occurred, or constructed there before can be realized. The project has achieved new GI elements that never existed before such as the biotope area, which has a semblance of a wetland and ecological niche, as well as Osagami reservoir itself.

The study hypothesis that Koshigaya Lake Town scores 4.15 points (out of maximum 10), and can be classified as 'Good' (in a scale of 'Poor' to 'Excellent') after evaluation through Green Infrastructure Gauge (GIG) is proved wrong. After detailed study, the GIG score is 5.75 points as opposed to 4.15 points arrived at after reconnaissance studies during the formulation of GIG.

Referrences

1. Ohmae, M., and Yanai, S. (2005). The cooling effect of urban river and open space on summertime air temperature in coastal city. *Journal of Environmental Information Science,* Vol. 33, No 5, 13 – 20.
2. Yokohari, M., Brown, R., D., Kato, Y., Yamamoto, S. (2001). The cooling effect of paddy fields on summertime air temperature in residential Tokyo, Japan. *Landscape and Urban Planning*. Vol. 53, Issues 1–4, 17–27.
3. Urban Renaissance Agency-Japan (UR). (2009). Koshigaya Laketown Project. Smart and sustainable urban life with the lake. *LivCom Awards 2009*. Retrieved from http://www.ur-net.go.jp/urbandesign/awards_pdf/landscape14.pdf. (Accessed on May 25 2011).

7 CHAPTER 7: CHAPTER VII: Conclusion and proposition.

7.1 General conclusion

The overall conclusions for this study were as follows:

Existing Central Nairobi UGS lacks in size, composition, distribution, and character, that indicates minimal penetration of Green Infrastructure (GI) elements and its functions in the area. The characteristics of existent Central Nairobi's UGS cannot afford adequate benefits to influence quality of life, nature, and environmental well being. However, the study area has potential areas that could be utilized for future expansion of UGS to help improve the environment, nature, residents' quality of life, and Green Infrastructure (GI) realization, as shown by the potential map generated. The composite potential map generated can be used as a basis for future selection of areas and spaces to develop UGS. The potential areas and spaces can be adopted to form an interconnected UGS that can be used as a basis for a Green Infrastructure (GI) system within and beyond Central Nairobi.

There is limited GI knowledge among the responding municipal workers in the municipalities within the Tokyo 23 special wards and neighboring contiguous suburban cities. There is also low level of inclusion of vital GI elements such as sustainable energy plans, wetlands, natural protected areas, and rain water management and use in the GMPs of the above areas, with a bias towards elements for physical urban greening, which forms just a portion of GI concept. Disparity between municipal workers awareness and contents of GMP documents by their municipalities exist. Therefore, Japanese municipalities' Green Master Plans (GMPs) as currently constituted and implemented cannot be successful guides for optimum Green Infrastructure realization.

Green Infrastructure functions do not poses uniform or equal values. Disaster prevention and mitigation has the highest value attachment than other functions among the workers of Japanese municipalities. Green Infrastructure Gauge (GIG) as formulated is confirmed to be practical as a Green Infrastructure (GI) evaluation tool after application in Koshigaya Lake Town. Koshigaya Laketown includes a wide variety of GI elements and functions, but it could have scored more points and ranked higher on the GIG if the missing elements and their functions were factored in during the planning stage. Having been an agricultural area before development, it lost all agricultural values in crop production, cultural and technical practices that accompany agriculture, water network that was used for irrigation and other farmland biodiversity. It literary became a food desert. With GI planning before hand, elements that have not naturally occurred, or constructed there before can be realized. Koshigaya Laketown project has achieved new GI elements that never existed before such as the biotope area, which has a semblance of a wetland and ecological niche, as well as Osagami reservoir itself that has attracted a wide range of flora and fauna.

The research has come up with two new proposed evaluation and planning elements that it gifts to academic research and practice in the areas of urban planning, town and country planning and landscape architecture among other related disciplines. These are:

1) Green Infrastructure Gauge (GIG); a tool for evaluation of Green Infrastructure elements and functions in existing urban areas, or future urban areas at planning stage. It can also be used by planners to guide them in inclusion of GI in urban regeneration or in creation of new neighborhoods and communities.
2) Urban Grain Networks (UGN); an integrated urban system combining urban food production (edible grain), urban planning and design concepts

(wood grain) that synergize in a network to enhance GI elements and functions, as outlined in section 7.2 below.

7.2 Proposition of Uban Grain Network, as a means to enhancing Green Infrastructure in urban areas.

7.2.1 Introduction.

Shortcomings in Green Infrastructure (GI) situation have been pointed out in the evaluation of UGS as part of GI in Central Nairobi, Tokyo 23 Special Wards and their neighboring contiguous suburban cities, as well as in Koshigaya Lake town. These can be addressed through a paradigm shift in planning with GI as the basic concept and tool for defining the character and philosophy of urban areas. Deliberate strategies in policy formulation, conceptual and spatial planning, as well as specific implementation and management goals in attaining GI in urban areas ought to be implemented. Their aim should be to enhance sustainability in the spheres of environment, nature, and social economic welfare of the residents.

One such basic sustenance element is nourishment of the populace. As noted in Koshigaya laketown, urban areas convert hitherto productive land into food and natural resource desserts. They destroy agrarian, natural, and human systems and processes and cover them with immovable urbanscape elements such as roads and buildings that only consume resources but bear none. The study proposes a new planning theory of “Urban Grain Networks” (UGN). This can be used as one of the strategies to create food and resource productivity within the urban areas. It can also give the foundation for incorporation of other GI elements and functions that can enhance sustainability of urban areas. UGN as a new planning theory if applied, can foster a mutual coexistence of Town and Country in one space, which symbiotically enhances GI, for sustainability and livability of the future urban areas.

Early modernist urban sociology unintentionally developed an image of the city as an essentialist reality separate from life supporting ecosystems, which has proved hard to rid and which continues to permeate urban policy and planning (Berthel and Isendahl, 2013). In the midst of the second wave of space–time compression, with 75% of the global population projected to be urban within a few decades, we are now experiencing a “global generational amnesia” about how to grow food (Colding and Barthel, 2013). Because most New towns are carved from agricultural land, there is a need to develop a system that continues the original use in food production, maintain local heritage, culture, identity, lifestyles and agricultural knowledge and technology. Ebenezer Howard’s Garden Cities of Tomorrow (1902), proposed Newtowns surrounded by agricultural land, forming ‘Town and Country’ existing side by side. But Urban Grain Network is hypothesized to integrate these two aspects, and bring this ruralism in the urban realm.

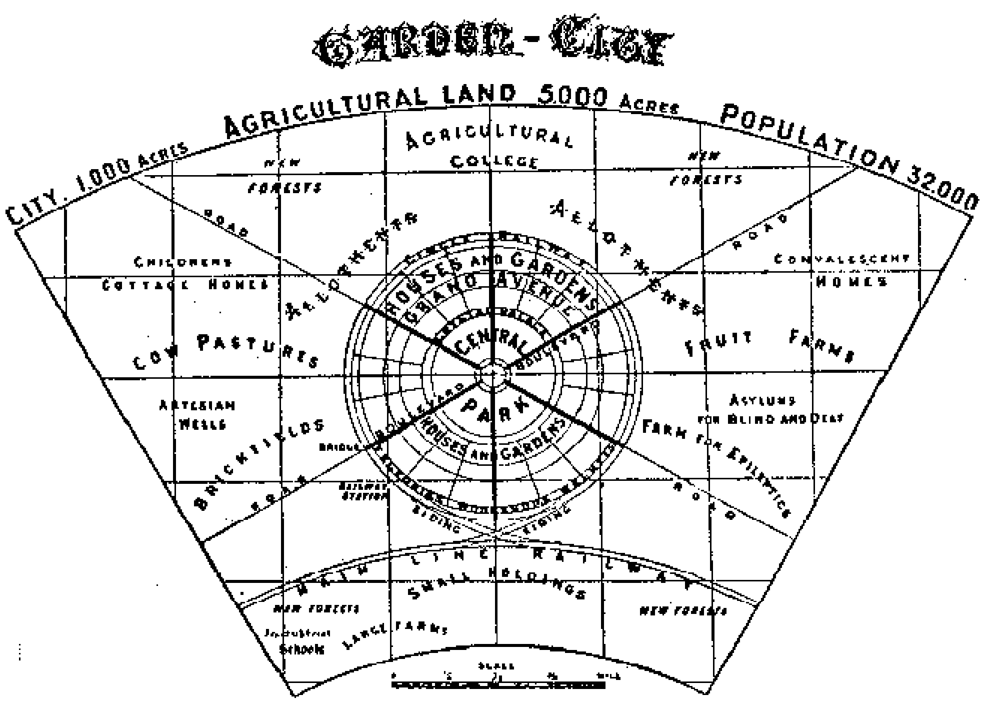


Figure 54: Ebenezer Howard’s concept of ‘The Garden City”, where agricultural land surrounds the town core (source; Howard, 1902).

7.2.2 The grain.

For this proposal, “grain” is used as an abstract (metaphorical) from two perspectives: the “edible grain” that metaphorically represents agriculture, and “wood grains” that represents urban planning system or urban texture.

Figure 55: Edible grains representing agriculture.

Figure 56: Wood grains representing urban planning system or urban texture.

7.2.3 Wood grain and urban planning texture.

Various edible grains, a produce of agriculture, are the main source of calories all over the world. They sustain the world population. If there were no grains and grains domestication, production and consumption, there would be no agrarian revolution that led to civilizations, population explosion, and technological advancement. The grain today is the main ingredient for producing meat, milk, eggs (from animal feeds), beer, bio fuel, and starch, among others. The ‘grain’ is a perfect tool to include rural urbanism, that ensure that; even as human beings become more urban they can still maintain their thousands of years as rural dwellers, where they evolved sustaining themselves from nature and later from agriculture. It is the ultimate symbol for agriculture. Thus, Urban Grain Networks are agricultural systems that are integrated in the urban structure. This network can afford among others GI elements and functions as shown in figure 50.

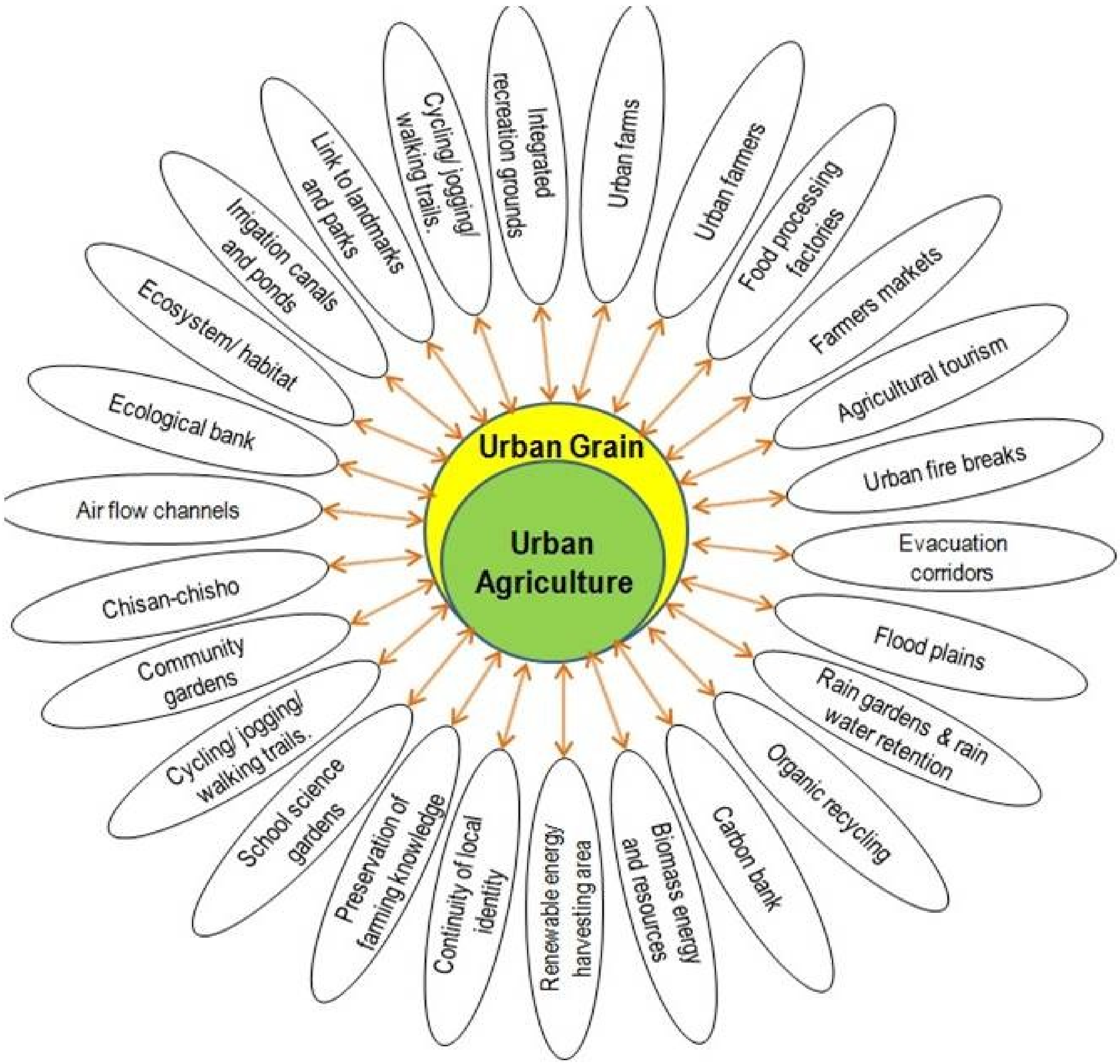


Figure 57: Urban Grain (Urban Agriculture elements and functions) (source; author).

7.2.4 Wood grain and urban planning texture.

Ian MacHarg in his book Design with Nature (1969), champions the use of nature as an inspiration to planning and design. Wood grains are metaphorically used to symbolise morphology (patterns) of districts, blocks, plots, buildings, streets, opens spaces and other features within an urban area (Urban Dictionary, 2012).

Figure 58: The conventional urban grain (source; Warwick Bar).

It represents the scale, height, combination and massing that brings about the urban texture. Incorporation of concepts such as Landscape Urbanism (Waldeheim, 2006), where landscape rather than Architecture is used in organizing urban areas can necessitate inclusion of GI, and a better urban grain and texture. In their book Identity and Sustainability, Kinoshita et.al. (2012), point out that in Japan urban redevelopment work takes the concept of scrap and build as its basic preconception. This practice also takes place in new urban development's taking place in agricultural land and communities. Where local identity, culture, heritage, shrines, totems, landmarks, architecture and communities are 'scrapped' when developing Newtowns, or new neighborhoods. UGN can also include place making that can foster inspiration, people's happiness, and well being. Therefore, Urban grain networks represents nature, ecological and human friendly urban planning and design concepts that improve the texture of the city.

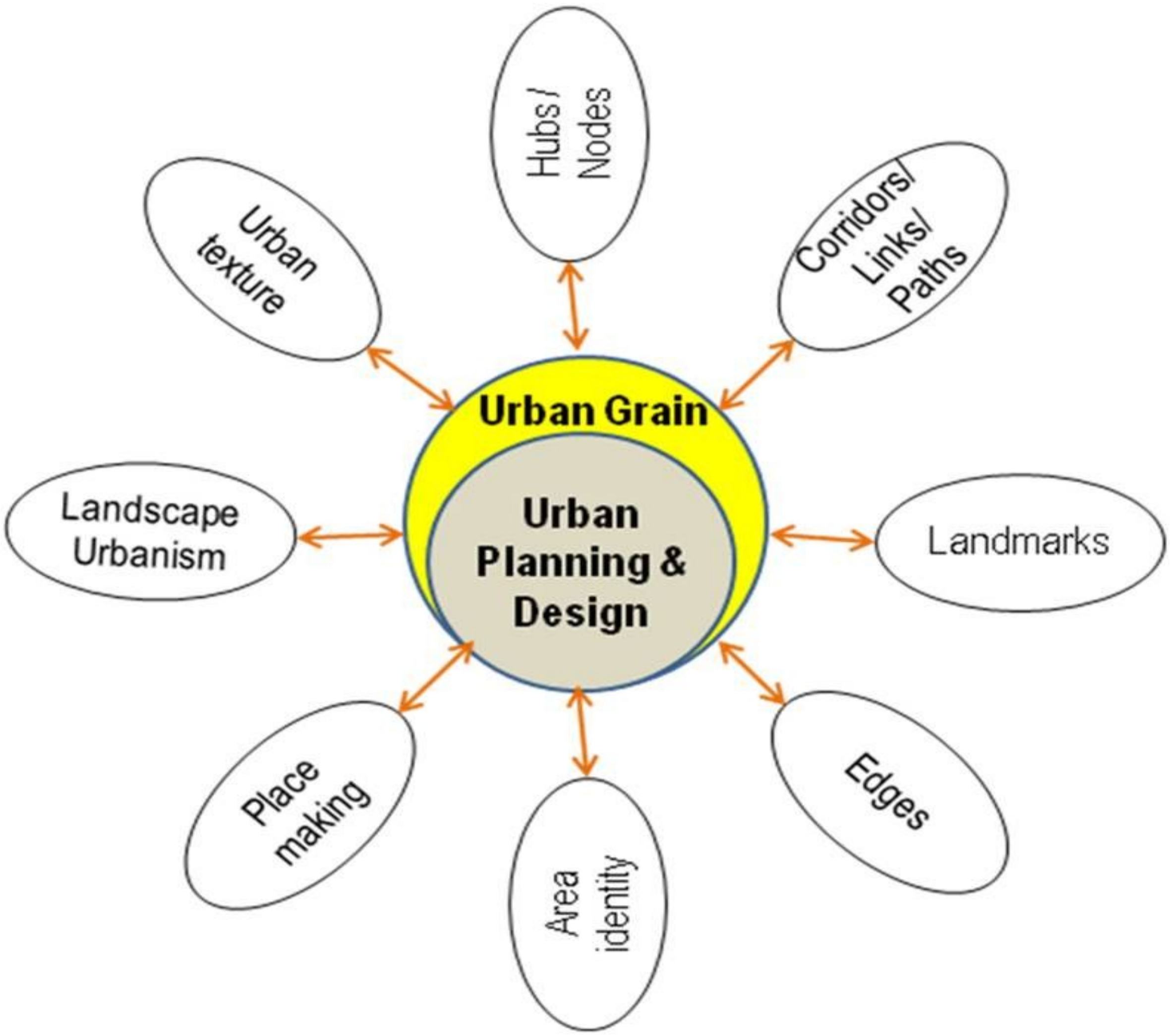


Figure 59: Urban Grain (urban planning elements and functions.

7.2.5 UGN as a multifunctional and hybrid network.

In this sense, Urban Grain Networks are a combination of both the urban agricultural elements and urban planning and design concepts that improve the texture of the city.

Figure 60: The conventional city grain and texture, Shinjuku area, Tokyo, Japan (source, fotozup.com).

Green Infrastructure exists in hubs, corridors, and sites (Benedict and McMahon, 2006). In establishing UGN, these can be mirrored and integrated using urban agricultural network, and concepts like Kevin Lynch's Image of the city (1960) which is represented in Paths, Edges, Nodes, Districts, and Landmarks. Thus Urban Grain Network (UGN) can be defined as: an integrated urban system combining urban food production, urban planning, and design concepts that synergize in a network to enhance GI elements and functions.

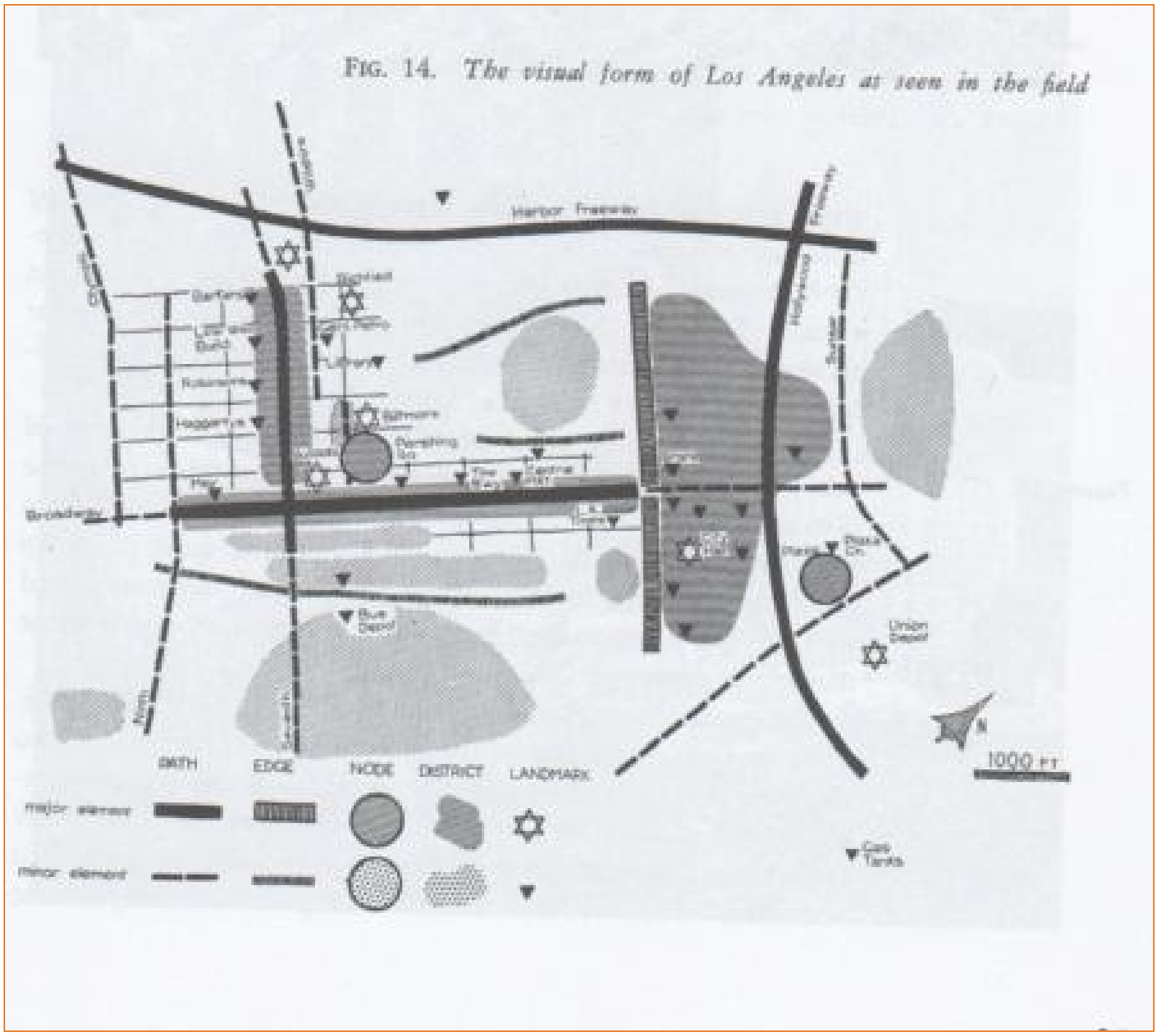


Figure 61: Elements of city imageability and formation of mental maps (source; Lynch, 1960)

Table 13: Composition of the new UGN system.

	Elements	Representatives
1.	▪ Paths (Lynch, 1960) ▪ Corridors (Benedict and McMahon, 2006)	▪ Agricultural corridors, integrated walking, jogging, cycling routes, irrigation canals, tourism circuits. ▪ Integrated ecological areas and networks, etc.
2.	▪ Edge (Lynch, 1960)	▪ River ecosystems, flood plain agriculture, urban fire breaks lee ways. ▪ Transportation corridors, boundaries, etc.
3.	▪ Nodes (Lynch, 1960) ▪ Hubs (Benedict and McMahon, 2006)	▪ Large farms, urban parks, urban forests and wetlands. ▪ Shopping districts, institutions, cultural facilities, etc.
4.	▪ Districts (Lynch, 1960)	▪ Large sections of the city identifiable by their unique characteristics such as types of specialized crops. ▪ One neighbourhood one product. ▪ Areas with a sense of identity and community.
	▪ Landmarks (Lynch, 1960) ▪ Sites (Benedict and McMahon, 2006)	▪ Shopping malls, farmers markets/ stalls, train stations, monuments, etc.

7.2.6 The new symbiotic `Town and Country` and its affordances.

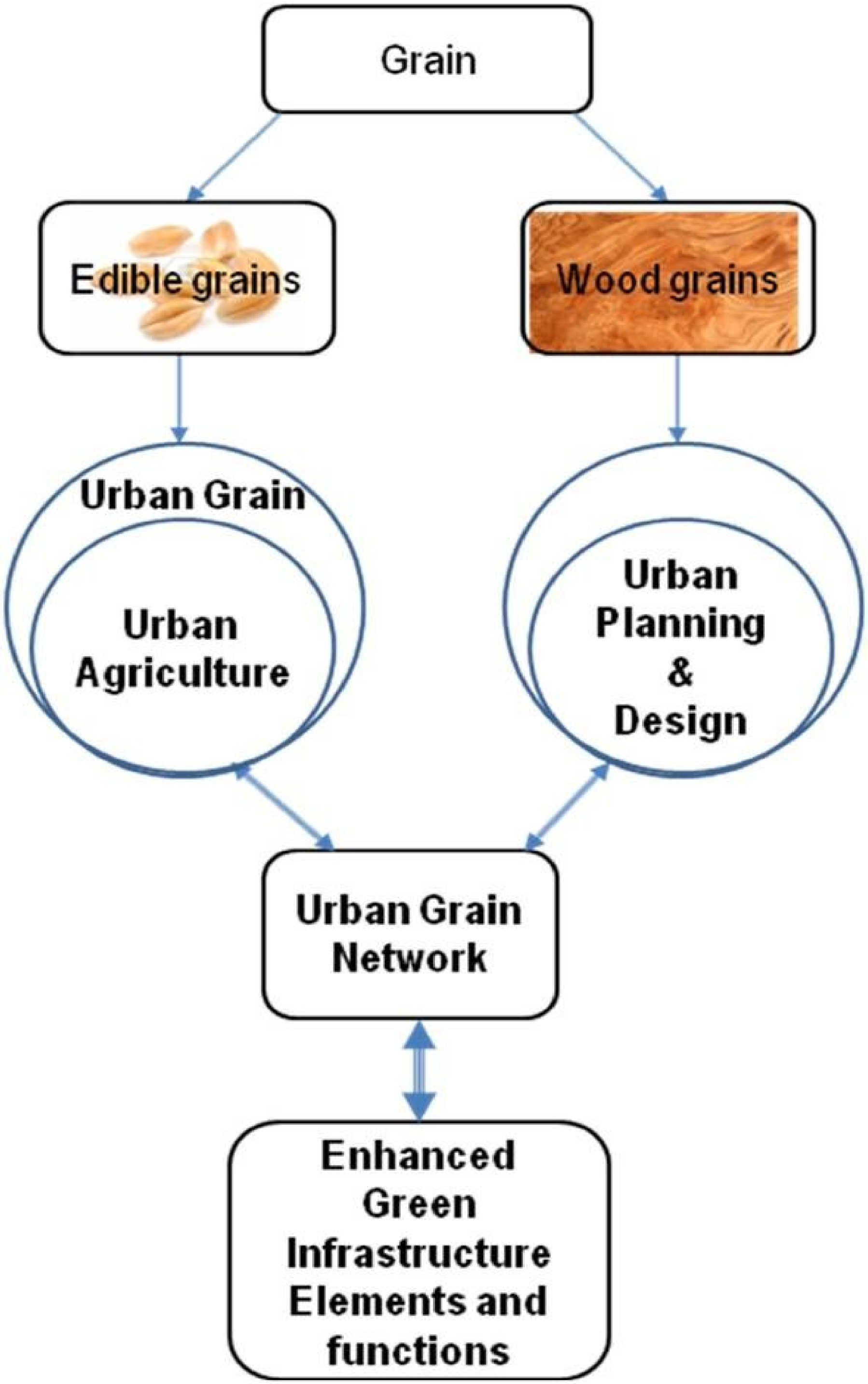


Figure 62: The UGN framework.

Integration of urban agriculture in GI can form the first step in provisioning of both human nourishment and other environmental agenda needed for sustainable urban areas. Green Infrastructure functions afforded by Urban Agriculture include: Food production, economic activities / Employment opportunities. Modification of local climate; heat Island amelioration/ heat sink, wind flow. Aesthetics improvement, carbon sequestration, recreation and public health (relaxation and therapy), and storm water infiltration, management and use. It can also foster local identity and cultural preservation, ecological/ biodiversity promotion, pollutants filtration, environmental education, energy source (biomass, biogas). It can also save energy (locally produced and locally consumed food, no need for transportation and preservation), as well as promote communal activities. It permeates lower-level social forms of water and food management and locally situated social–ecological memories for transmitting practical knowledge between people and across generations, complementing centralized governance of long distance food trade, distribution, and storage (Barthel and Isendahl, 2013).

Other benefits of Urban Agriculture could include increase in entrepreneurial activities (production, packaging and marketing), food cost reduction, and better quality products . Promote Japanese concept of Chisan-chisho 地産地消 – Localization of food production and consumption, (eat local food), elimination of food miles, reduce carbon foot print, recycle organic waste back to energy and nutrients, increase Urban Ecological Foot Print, reduce chronic and emergency food insecurity (in case of breakdown in the chain of food distribution), reduce urban poverty (availability of affordable food). Reduce food deserts, inspire young farmers, and provide continuity of accumulated agrarian knowledge and culture. UGN can be used for storm water infiltration, retention, evapotranspiration, and use in irrigation of edible grains (urban agriculture). It can also be used as the physical urban grain where such storm water management elements become part of the urban planning and texture.

The new urban system can be layered together with the conventional urbanscape of roads, civil works, among others, and interlinked to provide not only sources of food, but also alternative low impact mobility system and slow pace of life in the otherwise fast paced urban life.

Figure 63: The happy urban future with Urban Grain Network (UGN); Japanese University students' mud volleyball tournament held in a rice paddy before planting in a rural setup. Such opportunities and experiences can be created within the urban realm through UGN. (Source; Yaguchi Sumire).

References

1. Adachi City Government (2007). Green Master Plan. http://www.city.adachi.tokyo.jp/midori/machi/midori/kihonkekaku.html, accessed on May 14th 2012. (In Japanese).
2. Ahern, J., (2007). Green infrastructure for cities: the spatial dimension. In: Novotny, V., and Brown, P., (Editors). *Cities of the future: towards integrated sustainable water and landscape management.* IWA Publishing, London. 267–283.
3. Ahris, Y., Noordini, C. M., Nafisa, H., Haiza, W. H., Susilawati, S. (2006). A GIS approach in evaluation of metropolitan green area: a case of Sungai Pulai wetland. Urban Forestry Conference: Managing Urban Green for Sustainable Cities, 6 - 7 June 2006, Kuala Lumpur.
4. Balram, S., Dragicevic, S. (2005). Attitudes towards urban green spaces: integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. *Landscape and Urban Planning*, Vol. 71, 147–162.
5. Barthel, S., Isendahl, C. (2013). Urban gardens, agriculture, and water management: Sources of resilience for long-term food security in cities. *Ecological Economics*, Vol. 86, 224–234.
6. Benedict, M. A., and McMahon, E. T. (2006). *Green infrastructure: Linking landscapes and communities*, Island Press, Washington.
7. Benedict, M.A., and McMahon, E.T. (2002). Green infrastructure: smart conservation for the 21st Century. Renewable Resources Journal, Vol. 20 (3), 12–17.
8. Buyantuyev, A., Wu, J., Gries, C. (2009). Multiple analysis of the urbanization pattern of the Phoenix Metropolitan landscape of USA: time space and thematic resolution. *Landscape and Urban Planning*, Vol. 94 (3 – 4), 206-217.
9. Chofu City Government (2011). Green Master Plan. http://www.city.chofu.tokyo.jp/, accessed on May 5th 2012. (In Japanese).
10. Chuo City Government (2009). Green Master Plan. https://www.city.chuo.lg.jp/kurasi/kentiku/midorinokihonkeikaku/index.html, accessed on May 9th 2012. (In Japanese).
11. City Council of Nairobi (NCEO Report) (2007). City of Nairobi Environmental Outlook. Retrieved from http://www.unep.org/geo/pdfs/NCEO_Report_FF_New_Text.pdf, accessed on February 10th 2012.
12. Cohen M., J. and Garrett J., L. (2009). The food price crisis and urban food (in) security. *IIED and UNFPA: Urbanization and emerging population issues* - 2.
13. Colantonio, A., Potter, R., B. (2007). City profile: Havana. Cities, Vol. 23, No. 1, 63–78.
14. Colding, J., and Barthel, S. (2013). The potential of 'Urban Green Commons' in the resilience building of cities. *Ecological Economics*, Vol. 86, 156-166.
15. Convention on biodiversity (2010). City Biodiversity Index (or Singapore Index) (online). Retrieved from http://www.cbd.int/authorities/doc/User%27s%20Manual-for-the-City-Biodiversity-Index18April2012.pdf, accessed 1st May 2012.
16. Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, Vol. 387, 253–260.

17. de Groot, R. S., Wilson, M. A., and Boumans, R. M. J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics,* Vol. 41, 393-408.

18. de Ridder, K., Adamec V., Bañuelos A., Bruse M., Bürger M., Damsgaard O., Dufek J., Hirsch J., Lefebre F., Pérez-Lacorzana J. M., Thierry A., & Weber C. (2004). An integrated methodology to assess the benefits of urban green space. *Science of the total environment,* Vol. (334–335), 489-497.

19. European Commission. (2010). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: options for an EU vision and target for biodiversity beyond 2010. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0004:FIN:EN:PDF, accessed on May 7th 2013.

20. Flink, C., Seams, R. (1993). *Greenways: a guide to planning, design, and development*. Washington, D.C., Island Press.

21. Gibson, J., J. (1979, 1986). *The theory of affordances*. Lawrence Erlbaum Associates, Inc., 1986, New Jersey, USA.

22. Godefroid, S. (2001). Temporal analysis of the Brussels flora as indicator for changing environmental quality. *Landscape and Urban Planning*, Vol. 52, 203-224.

23. Gorr, L. W., Kurland, S.K. (2008). *GIS tutorial; updated for ArcGIS 9.3, Workbook for ArcView 9, Third Edition.* Redlands, California: ESRI Press.

24. Government of the Republic of Kenya (2008). *The first edition of Nairobi Metro 2030*. Retrieved from http://www.tatucity.com/DynamicData/Downloads/NM_Vision_2030.pdf, accessed on 10th June 2013.

25. Greca, P., L., Rosa, D., L., Martinico, F., Privitera., R. (2011). The role of non-urbanized areas for eco-sustainable planning in metropolitan region. *Environmental Pollution*, Vol. 159, 2193–2202.

26. Green Infrastructure Wiki. (2010). Green Infrastructure systems and function. Retrieved from http://www.greeninfrastructurewiki.com/?t=anon, accessed on November 20th 2010.

27. Hong Kong Government (2004). *Greening Master Plan. CEDD, 3rd edition*. http://www.cedd.gov.hk/eng/greening/doc/CEDD_GMP_Booklet.pdf, accessed on September 23rd 2012.

28. Hopkins, L. D. (1977). Methods of Generating Land Suitability Maps: A comparative evaluation. *Journal of the American Planning Association*, Vol. 43: 4, 386–400.

29. Howard E. (1902). *Garden Cities of Tomorrow.* Swan Sonnenschein Co., Ltd.

30. Ichikawa City Governemnt (2004). Green Master Plan http://www.city.ichikawa.lg.jp/gre01/1111000015.html, accessed on June 15th 2012. (In Japanese).

31. Japan Government (2004). *Green Master Plan*. http://www.mlit.go.jp/common/000996961.pdf. Accessed on September 5th 2011.

32. Japan Government, (1994). Urban Green Space Conservation Act. http://www.japaneselawtranslation.go.jp/law/detail_list/?vm=&re=02&id=1006. Accessed on August 20th 2012.

33. Japan Government, Ministry of Land, Infrastructure, and Transport. (2004). Landscape Act (Act No. 110 of June 18, 2004). Retrieved from http://www.mlit.go.jp/crd/townscape/keikan/pdf/landscapeact.pdf, accessed on August 10th 2012.

34. Jim, C. Y. (2004). Green-space preservation and allocation for sustainable greening of compact cities. *Cities*, Vol. 21 (4), 311–320.

35. Jim, C. Y., Chen, S. S. (2003). Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing City, China. *Landscape and Urban Planning,* Vol. 65, 95–116.

36. Kambites, C. and Owen, S. (2006). Renewed prospects for green infrastructure planning in the UK. *Planning Practice and Research.* Vol. 21 (4), 483-496.

37. Kawaguchi City Government (2008). Green Master Plan. http://www.city.kawaguchi.lg.jp/kbn/40250020/40250020.html, accessed on May 12th 2012. (In Japanese).

38. Kawasaki City Government (2008). Green Master Plan. http://www.city.kawasaki.jp/530/page/0000023138.html, accessed on May 10th 2012. (In Japanese).

39. Kazmierczak, A. (2013). The contribution of local parks to neighborhood social ties. *Landscape and Urban Planning,* Vol. 109, 31–44.

40. Kenya National Bureau of Statistics (2010). Kenya 1999 population and housing census. *Analytical report on population projections volume VIII*, Nairobi: Republic of Kenya.

41. Kimura, A and Nishiyama, M (2008). The chisan-chisho movement: Japanese local food movement and its challenges. *Agriculture and Human Values*, Vol. 25, 49-64.

42. Kinoshita I., Binder H., Okabe A. (2012). *Identity and Sustainability*. Hobunsya Publisher Inc. Tokyo.

43. Korner, I., Saborit-Sanchez, I., Aguilera-Corrales, Y., (2008). Proposal for the integration of decentralized composting of the organic fraction of municipal solid waste into the waste management system of Cuba. *Waste Management* , Vol. 28, 64–72.

44. Larson, E., K., Perrings, C. (2013). The value of water-related amenities in an arid city: The case of Phoenix metropolitan area. *Landscape and Urban Planning*, Vol. 109, 45–55.

45. Liu, S., Liu, B., (2008). Using GIS to assess the ecological-niche for urban green Space planning in Wuxi City, Anhalt University of Applied Science. Bernburg, Germany.

46. Living History Farm. Photo: Buying victory seed in New Jersy, 1943. Retreived from http://www.livinghistoryfarm.org/farminginthe40s/crops_02.html. (Accessed on June 12th 2012).

47. Lynch, K., (1960). *The Image of the City.* MIT Press,Cambridge MA.

48. McGarigal, K., Cushman, S. A., Neel M. C., Ene, E. (2002). FRAGSTATS: spatial pattern analysis program for categorical maps. University of Massachusets, Amherst.

49. McHarg, I. L. (1969). *Design with Nature.* New York: John Wiley & Sons, INC.

50. McPherson, E.G., Nowak, D., Heisler, G., Grimmond, S., Souch, C., Grant, R., Rowntree, D.J. (1997). Quantifying Urban Forest Structure, Function and Value: The Chicago Urban Forest Climate Project. *Urban Ecosystems*, Vol. 1, 49-61.

51. Meakin, S. (1992). The Rio Earth Summit: Summary of the United Nations Conference on Environmental and Development. Retrieved from http://publications.gc.ca/Collection-R/LoPBdP/BP/bp317-e.htm, accessed on March 17th 2013.

52. Mell, I. C. (2008). Green Infrastructure: concepts and planning. *FORUM Ejournal*, Vol. 8, 69-80.

53. Misato City Government (2011). Green Master Plan. http://www.city.misato.lg.jp/dd.aspx?menuid=4373, accessed on May 25th 2012. (In Japanese).

54. Mitullah, W. (2003). Understanding Slums: Case Studies for the Global Report on Human Settlements 2003: The Case of Nairobi, Kenya. UNHABITAT, Nairobi.

55. Musashino City Government (2008). Green Master Plan. http://www.city.musashino.lg.jp/sesaku_keikaku/kankyoubu/midori_kihonkeikaku/004748.html, accessed on May 24th 2012. (In Japanese).

56. Myeong, S., Nowak, D. J., Hopkins, P. F., Brock, R. H. (2003). Urban cover mapping using digital high-spatial resolution aerial imagery. *Urban Ecosystems*, Vol. 5, 243–256.

57. Nassiuma, D K (2000). *Survey and sampling methods,* University of Nairobi press, Nairobi.

58. Natural England (2009). *Green Infrastructure Guidance (NE176).* http://publications.naturalengland.org.uk/publication/35033?category=49002, accessed on November 12th 2011.

59. Nerima City Government (2009). Green Master Plan. http://www.city.nerima.tokyo.jp/, accessed on May 14th 2012. (In Japanese).

60. Newitz, A. (2008). Kibera's "Instant Farm" System Is the Future of Urban Agriculture. Retreived from http://io9.com/5045470/kiberas-instant-farm-system-is-the-future-of-urban-agriculture. Accessed on June 12th 2012.

61. Novo, M., G., Murphy, C. (2000). Urban agriculture in the city of Havana: a popular response to a crisis. *Growing cities, growing food: urban agriculture on the policy agenda*, 329-347.

62. Nowak, D. J., Crane, D. E., Stevens, J. C., Hoehn, R. E. (2003). USDA Forest Service, Northeastern Research Station, Syracuse, New York.

63. Nowak, D. J., Rowntree, R. A., McPherson, E. G., Sisinni, S. M., Kerkmann, E. R., Stevens, J. C. (1996). Measuring and analyzing urban tree cover. *Landscape and Urban Planning*, Vol. 36, 49-57.

64. Ohmae, M., Yanai, S. (2005). The cooling effect of urban river and open space on summertime air temperature in coastal city. *Journal of Environmental Information Science*, Vol. 33, No 5, 13–20.

65. Okuno, S., and Dewancker, B. (2005). Research on master plan for parks and open spaces in designated cities. Architectural Institute of Japan, Vol. 44, 613-616.

66. Olembo, R. J., Rhan, P. (1987). Urban forestry; cities, trees and people. *Unasylva,* 155.

67. Ota City Government (2011). Green Master Plan. http://www.city.ota.tokyo.jp/kuseijoho/ota_plan/kobetsu_plan/sumai_machinami/midori/sakutei/greenplanoota.html, accessed on May 14th 2012. (In Japanese).

68. Pack, C., L. (1919).*The War Garden Victorious*. J.B. LIPPINCOTT COMPANY, PHILADELPHIA. An e-book retrieved from; http://www.earthlypursuits.com/WarGarV/WarGardTitle.htm, accessed on June 11th 2012.

69. Parks and Open Space Association (POSA) of Japan. (1997). *Green Master Plan Handbook.* Bunkousha, Tokyo.

70. Plymouth City Council. (2010). Plymouth's green infrastructure delivery plan. http://www.plymouth.gov.uk/green_infrastructure_delivery_plan.pdf, accessed on March 11th 2012.

71. Premat, A. (2013). Havana's Urban Agriculture. Retrieved from http://www.yale.edu/agrarianstudies/colloqpapers/01premat.pdf, accessed March 4th 2013.

72. Ramsar COP11 DOC. 23 (2012).11th Meeting of the Conference of the Parties to the Convention on Wetlands. Retrieved from http://www.ramsar.org/pdf/cop11/doc/cop11-doc23-e-urban.pdf, accessed on March 15 2013.

73. Rees, W. (2003). *Understanding Urban Ecosystems: An Ecological Economics Perspective in Understanding Urban Ecosystems.* Springer-Verlag, Newyork.

74. Resource Centre on Urban Agriculture & Food Security (2012). What is urban agriculture? RUAF Foundation. Retrieved from http://www.ruaf.org/node/512, accessed on June 11th 2012.

75. Rosa, D., L., Martinico, F., Privitera, R. (2013). Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. *Landscape and Urban Planning*, Vol. 109, 94–106.

76. Rudolf, S. de G., Mathew, A. W., Roelof, M. J. B. (2002). A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. *Ecological Economics,* Vol. 41, 393-408.

77. Rudovsky, N., F. (2012). Urban Agriculture in Cuba (Photo Essay). North American Congress on Latin America. Retreived from https://nacla.org/news/2012/10/18/urban-agriculture-cuba-photo-essay, accessed on 10th June 2013.

78. Schaffler, A., and Swilling, M. (2013). Valuing green infrastructure in an urban environment under pressure – The Johannesburg case. *Ecological Economics*, Vol. 86, 246-257.

79. Seattle City. Seattle Green Factor. Department of Planning and Development. Available from: http://www.seattle.gov/dpd/Permits/GreenFactor/Overview/, accessed on May 3rd 2012.

80. Shinjuku City Government (2009). Green Master Plan. http://www.city.shinjuku.lg.jp/seikatsu/file14_04_00001.html, accessed on May 10th 2012. (In Japanese).

81. Smit, J., and Nasr, J. (1992). Urban agriculture for sustainable cities: using wastes and idle land and water bodies as resources. *Environment and Urbanization.* Vol. 4 (2), 141-152.

82. Taito City Government (2012). Green Master Plan. http://www.city.taito.lg.jp/index/kurashi/kankyo/kankyojyoho/kihonkeikaku/genkyo/kihonkeikaku.html, accessed on May 15th 2012. (In Japanese).

83. Takeuchi, T (2012). A study on the potential of Green Structure Plan as comprehensive spatial control plan. *Landscape Research,* Vol.75 (5), 601-604.

84. TEP. (2005). Advancing the delivery of green infrastructure: targeting issues in England's northwest. http://www.greeninfrastructurenw.co.uk/resources/Advancing_Delivery_of_GI_-_Targeting_Issues.pdf, accessed May 15th 2013.

85. Tibaijuka, A. (2007). Nairobi and its environment. United Nations Environment Programme. Retrieved from http://www.unep.org/dewa/africa/kenyaatlas/PDF/KenyaAtlas_Chapter5.pdf, accessed on May 29th 2013.

86. Tokyo Metropolitan Government (2007). Basic Policies for the 10-Year project for Green Tokyo; Regenerating Tokyo's Abundant Greenery. https://www.kankyo.metro.tokyo.jp/nature/attachement/Project_for_Green_Tokyo.pdf, accessed on August 20th 2011.

87. Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Ka´zmierczak, A., Niemela, J., and James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*. Vol. 81, 167–178.

88. UN- Bruntland Report, (1987). Report of the World Commission on Environment and Development: Our Common Future. UN Documents. Retrieved from http://www.un-documents.net/our-common-future.pdf, accessed on March 18th 2013.

89. UN-HABITAT (2006). Nairobi Urban Sector Profile. United Nations Human Settlements Programme (UN-HABITAT), Nairobi.

90. United Nations (1992). United Nations Conference on Environment and Development (UNCED). Retrieved from http://www.un.org/geninfo/bp/enviro.html, accessed on March 17th 2013.

91. United Nations Department of Economic and Social Affairs/Population Division (2011). 83 World Population Prospects: The 2010 Revision, Highlights, and Advanced Tables. Retreived from http://esa.un.org/unup/, accessed on June 11th 2012.

92. United Nations Population Division (2012). Retrieved from http://www.un.org/en/development/desa/population/theme/urbanization/index.shtml, accessed May 20th 2013.

93. United States Government, Environmental Protection Agency (EPA) (2011) Green infrastructure. http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm, accessed on August 20th 2011.

94. United States Government, Environmental Protection Agency (EPA) (2013). Climate Change: Basic information. http://www.epa.gov/climatechange/basics/, accessed on March 10th 2013.

95. Urban Farm Factory. Retreived from http://urbanfarm.co.jp/urbanfarm, accessed on November 10th 2012.

96. Urban Renaissance Agency-Japan (UR). (2009). Koshigaya Laketown Project. Smart and sustainable urban life with the lake. *LivCom Awards 2009*. Retrieved from http://www.ur-net.go.jp/urbandesign/awards_pdf/landscape14.pdf, accessed on May 25th 2011.

97. Uy, P.D., Nakagoshi, N. (2008). Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. *Urban Forestry & Urban Greening*, Vol. 7, 25-40.

98. van der Valk, A. (2002). The Dutch planning experience. *Landscape and Urban Planning*, Vol. 58, 201–210.

99. van Kamp, I, Leidelmeijer, K, Marsman, G, and de Hollander, A (2003) Urban environmental quality and human well-being Towards a conceptual framework and demarcation of concepts; a literature study. *Landscape and Urban Planning*, Vol. 65, 5–18.

100. Waldheim C., Ed. (2006). *The Landscape Urbanism* Reader. Princeton Architectural press, New York.

101. Weber, T., Sloan, A., Wolf, J. (2006). Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation. *Landscape and Urban Planning* Vol. 77, 94-110.

102. Weisz, H., Steinberger, J. (2010). Reducing energy and material flow in cities. *Current opinion in material sustainability* Vol. 2 (3), 185–192.

103. World Wildlife Fund (WWF) and Africa Development Bank (ADB), (2012). Africa Ecological Foot Print report: Green Infrastructure for Africa's ecological sustainability. Retrieved from http://www.footprintnetwork.org/images/uploads/africa_ecological_footprint_report.pdf, accessed on June 10th 2013.

104. Wright, H (2011). Understanding green infrastructure: the development of a contested concept in England. *Local Environment, Vol.* 16 (10), 1003–1019.

105. Yokohari, M., Brown, R., D., Kato, Y., Yamamoto, S. (2001). The cooling effect of paddy fields on summertime air temperature in residential Tokyo, Japan*. Landscape and Urban Planning*. Vol. 53 (1–4), 17–27.

Appendices

	GI FUNCTIONS	1. Biodiversity promotion.	2. Cultural and historical identity.	3. Disaster prevention.	4. Energy saving.	5. Economic activities support.	6. Environmental education.	7. Food / resource production.	8. Good aesthetics.	9. Improvement of local climate.	10. Nature conservation.	11. Noise reduction.	12. Part of larger green network.	13. Planning structure.	14. Pollutants filtration.	15. Promotes communal activities.	16. Public health promotion.	17. Rain water harvesting.	18. Recreation opportunity.	19. Reduction of green house gases.	20. Reduce public infrastructure cost.	21. Storm water management.	E.T.S
	F.R.V.	4.00	3.58	4.51	3.89	3.32	4.26	3.59	4.19	4.22	4.19	3.56	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	
	GI ELEMENTS																						
1.	Cycling route/ Walking route/ Trail/ Promenade.																						
2.	Green buffer/ Green belt.																						
3.	Green network/ Greenway.																						
4.	Green roofs/ Green walls/ Green curtains.																						
5.	Landscaping plants (trees, shrubs, groundcovers, lawn).																						
6.	Renewable energy harvesting and use/ Energy saving facilities.																						
7.	Nature reserve/ Woods/ Forest/ Grasslands.																						
8.	Parks/ Gardens/ Squares/ Beach/ River front																						
9.	Rain water harvesting, storage, use, and infiltration facilities.																						
10.	Disaster prevention/ mitigation elements																						
11.	Water ways/ Water features																						
12.	Wetlands/ Bogs/ Peat land																						
13.	Working lands (Farming, natural resource extraction).																						
	F.T.S																						

SCORE: 0.00/1061.84 0.00 % 0.00 Points CLASS: XXXX

LEGEND:

- WEIGHTED VALUES: (0 = Not present, 0.4 = Planned for, 1 = Present).
- SCORING AND CLASS: (0 ~ 1.99 Points = **Poor**, 2 ~ 3.99 Points = **Fair**, 4 ~ 5.99 Points = **Good**, 6 ~ 10 Points = **Excellent**).
- F.R.V = Function Relative Value from 0 to 5.
- E.T.S = Element Total Score.
- F.T.S = Function Total Score.

Appendix 1: GIG Template (source; author).

Appendix 2: Gold Award Certificate, awarded to Koshigaya Laketown as a Liveable Community and Environmentally Sustainable Project by LIVCOM in 2009 (source, UR-Japan).

Appendix 3: Biodiversity stamp rally in Koshigaya Laketown during Act Green ECOWEEK 2012. (Participation by author)

Appendix 4: Events map in Koshigaya Laketown during Act Green ECOWEEK 2012, showing various activities taking place within the GI elements.

Appendix 5: Green Events schedule1 in Koshigaya Laketown during Act Green ECOWEEK 2012, showing various activities taking place within the GI elements.

Appendix 6: Green Events schedule 2 within the shopping malls in Koshigaya Laketown during Act Green ECOWEEK 2012.

Appendix 7: Green Events schedule 3 within Koshigaya Laketown during Act Green ECOWEEK 2012.

Appendix 8: Green Events schedule 4 within Koshigaya Laketown during Act Green ECOWEEK 2012.

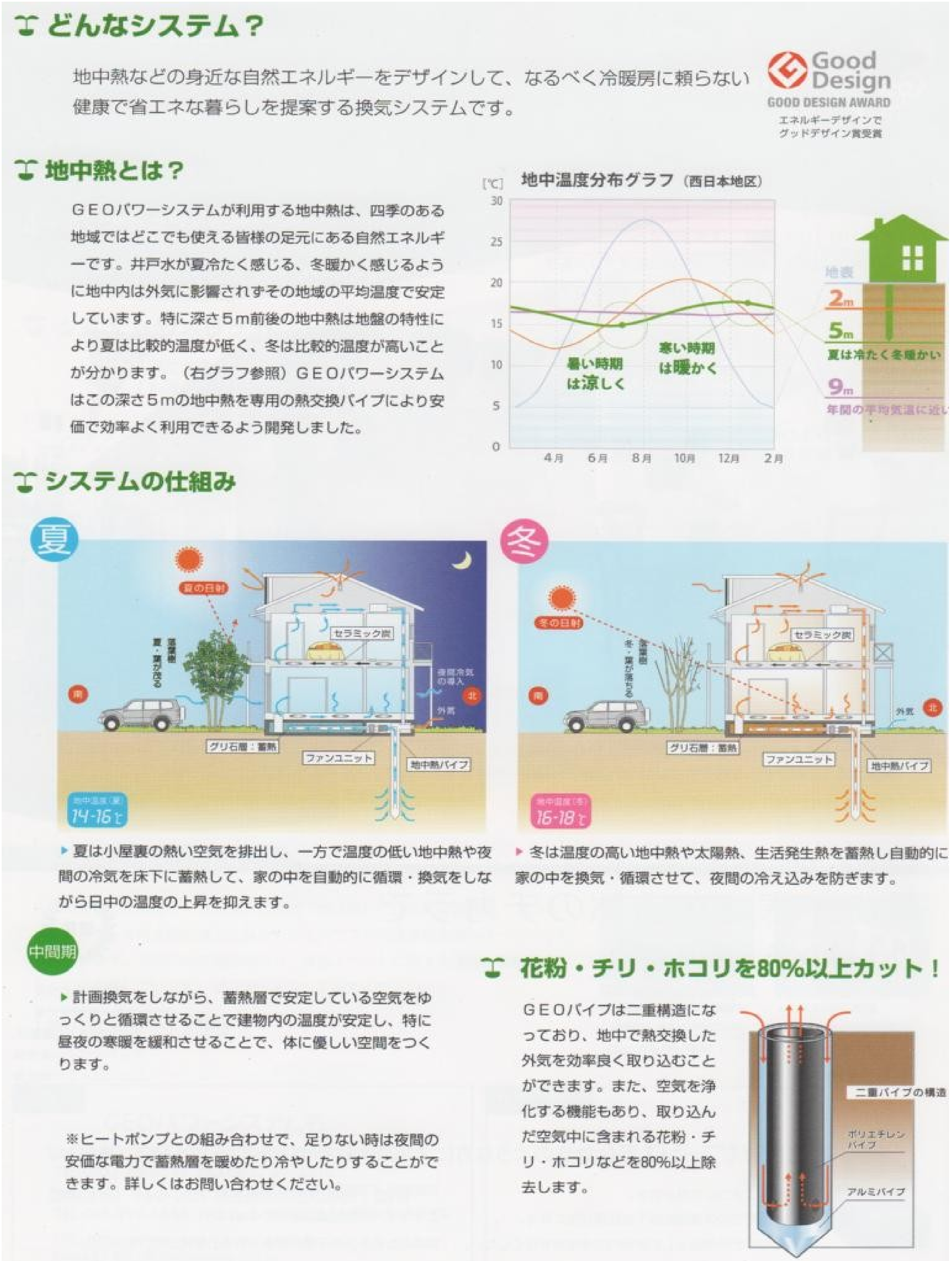
Appendix 9: Green Events schedule 5 within Koshigaya Laketown during Act Green ECOWEEK 2012.

Appendix 10: Lake Cruise and floating café poster in Osagami reservoir (Koshigaya Laketown) during Act Green ECOWEEK 2012.

Appendix 11: Cycling route poster in Koshigaya Laketown during Act Green ECOWEEK 2012. Promoting Low Impact Mobility.

Appendix 12: Storm water management: reinforced lawn parking to allow rain water to infiltrate where it falls in Koshigaya Laketown (source; author, field survey Koshigaya Laketown).

Appendix 13: Storm water management: hollow concrete block parking to allow rain water to infiltrate where it falls in Koshigaya Laketown (source; author, field survey Koshigaya Laketown).



どんなシステム？

地中熱などの身近な自然エネルギーをデザインして、なるべく冷暖房に頼らない健康で省エネな暮らしを提案する換気システムです。

Good Design
GOOD DESIGN AWARD
エネルギーデザインでグッドデザイン賞受賞

地中熱とは？

ＧＥＯパワーシステムが利用する地中熱は、四季のある地域ではどこでも使える皆様の足元にある自然エネルギーです。井戸水が夏冷たく感じる、冬暖かく感じるように地中内は外気に影響されずその地域の平均温度で安定しています。特に深さ５ｍ前後の地中熱は地盤の特性により夏は比較的温度が低く、冬は比較的温度が高いことが分かります。（右グラフ参照）ＧＥＯパワーシステムはこの深さ５ｍの地中熱を専用の熱交換パイプにより安価で効率よく利用できるよう開発しました。

システムの仕組み

夏

▶夏は小屋裏の熱い空気を排出し、一方で温度の低い地中熱や夜間の冷気を床下に蓄熱して、家の中を自動的に循環・換気をしながら日中の温度の上昇を抑えます。

冬

▶冬は温度の高い地中熱や太陽熱、生活発生熱を蓄熱し自動的に家の中を換気・循環させて、夜間の冷え込みを防ぎます。

中間期

▶計画換気をしながら、蓄熱層で安定している空気をゆっくりと循環させることで建物内の温度が安定し、特に昼夜の寒暖を緩和させることで、体に優しい空間をつくります。

※ヒートポンプとの組み合わせで、足りない時は夜間の安価な電力で蓄熱層を暖めたり冷やしたりすることができます。詳しくはお問い合わせください。

花粉・チリ・ホコリを80%以上カット！

ＧＥＯパイプは二重構造になっており、地中で熱交換した外気を効率良く取り込むことができます。また、空気を浄化する機能もあり、取り込んだ空気中に含まれる花粉・チリ・ホコリなどを80%以上除去します。

Appendix 14: GEO Power demonstration, lectures, and use in Koshigaya Laketown (source; Geo Power Systems-Japan). It regulates winter and summer temperatures through use of underground temperatures that remain constant throughout the year.

Appendix 15: Map showing circulation system users and user types observation points A to F (source; author, field survey Koshigaya Laketown).

Point ~A~ observation on 2012-10-8 from 1:30~2:00pm.

	Circulation activity	Gender	Number	Total Number
1.	Cycling	Male	14	33
		Female	19	
2.	Walking	Male	21	39
		Female	18	
3.	Baby on stroller			3
4.	Jogging			0
5.	Roller skating			3
6.	Dog walking			2

Point ~B~ observation on 2012-10-8 from 1:30~2:00pm.

	Circulation activity	Gender	Number	Total Number
1.	Cycling	Male	18	42
		Female	24	
2.	Walking	Male	45	151
		Female	106	
3.	Baby on stroller			5
4.	Jogging			0
5.	Roller skating			0
6.	Dog walking			3

Appendix 16: Circulation system users and user types I (source; author, field survey Koshigaya Laketown).

Point ~C~ observation on 2012-10-8 from 1:30~2:00pm.

	Circulation activity	Gender	Number	Total Number
1.	Cycling	Male	5	8
		Female	3	
2.	Walking	Male	15	29
		Female	14	
3.	Baby on stroller			1
4.	Jogging			0
5.	Roller skating			0
6.	Dog walking			1

Point ~D~ observation on 2012-10-8 from 2:00~2:30pm.

	Circulation activity	Gender	Number	Total Number
1.	Cycling	Male	8	21
		Female	13	
2.	Walking	Male	17	49
		Female	32	
3.	Baby on stroller			2
4.	Jogging			2
5.	Roller skating			0
6.	Dog walking			0

Appendix 17: Circulation system users and user types II (source; author, field survey Koshigaya Laketown).

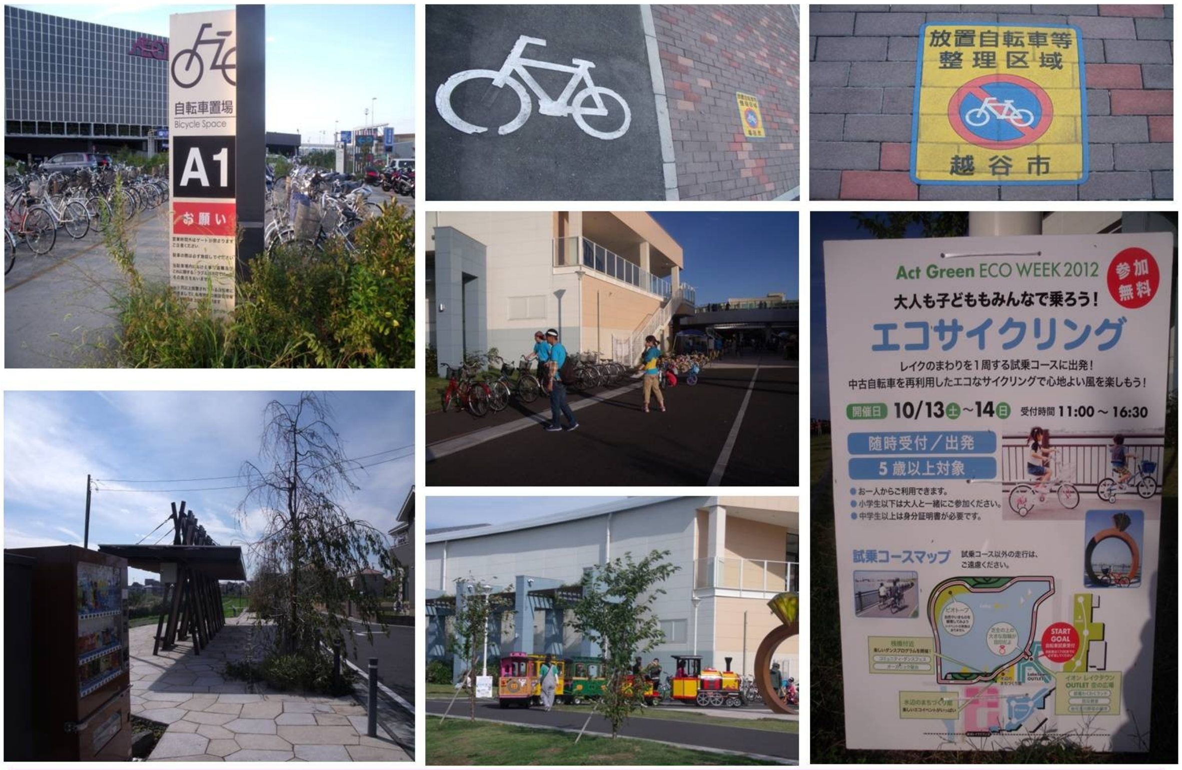
Point ~E~ observation on 2012-10-8 from 2:00~2:30pm.

	Circulation activity	Gender	Number	Total Number
1.	Cycling	Male	1	1
		Female	0	
2.	Walking	Male	7	16
		Female	9	
3.	Baby on stroller			0
4.	Jogging			0
5.	Roller skating			1
6.	Dog walking			0

Point ~F~ observation on 2012-10-8 from 2:00~2:30pm.

	Circulation activity	Gender	Number	Total Number
1.	Cycling	Male	3	8
		Female	5	
2.	Walking	Male	6	10
		Female	4	
3.	Baby on stroller			1
4.	Jogging			0
5.	Roller skating			0
6.	Dog walking			0

Appendix 18: Circulation system users and user types III (source; author, field survey Koshigaya Laketown).



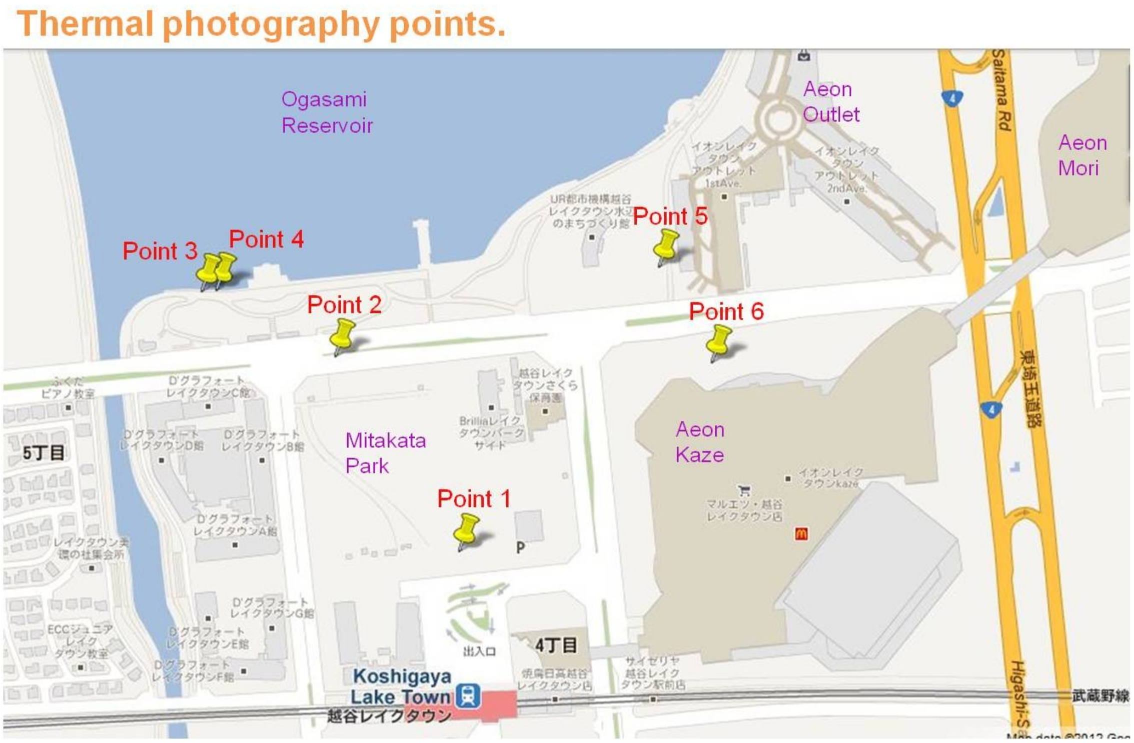
▪ Supports and enhances use, convenience, awareness and safety along the routes.

Appendix 19: Auxiliary support facilities in the circulation system; promoting low impact mobility (source; author, field survey Koshigaya Laketown).

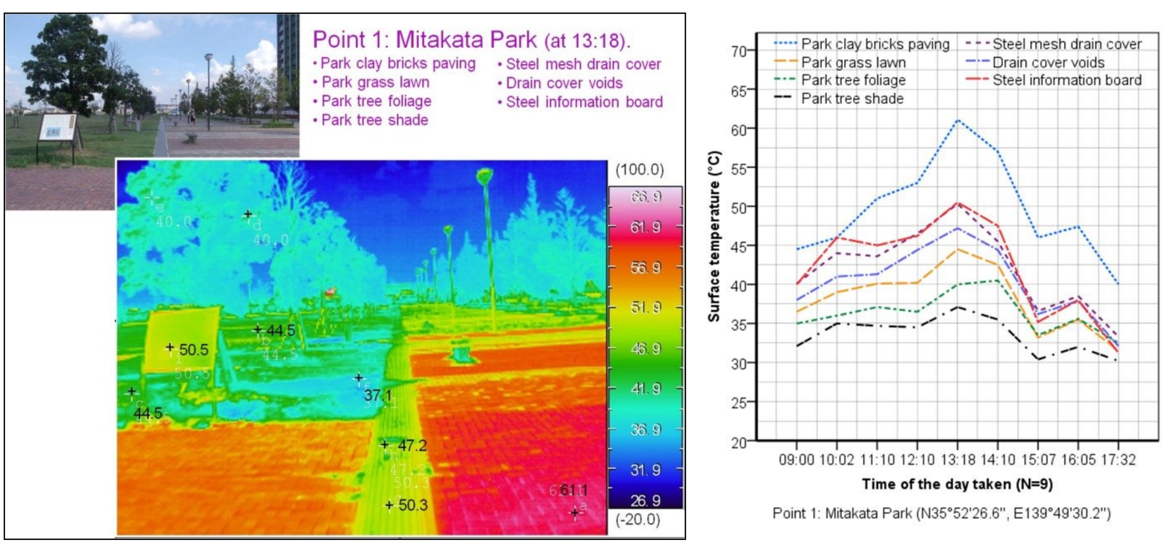
	Event	Date	Store type	Stores occupied	Cost (JPY)	Size	Capacity
1.	3rd	2010-10-16	Pro	27	3000	2.5x2m	300
			Handmade	103	2000		
2.	4th	2010-10-17	Pro	20	3000	2.5x2m	300
			Handmade	130	2000		
3.	5th	2011-10-1	Pro	30	3000	2.5x2m	300
			Handmade	90	2000		
4.	6th	2011-10-2	Pro	25	3000	2.5x2m	300
			Handmade	100	2000		
5.	7th	2012-10-13	Pro	50	3000	2.5x2m	300
			Handmade	250	2000		

Appendix 20: Koshigaya Laketown Mitakata Park Flea Market statistics on store type, size, cost, capacity, and occupation (data source; Rakuichi-Rakuza, Japan).

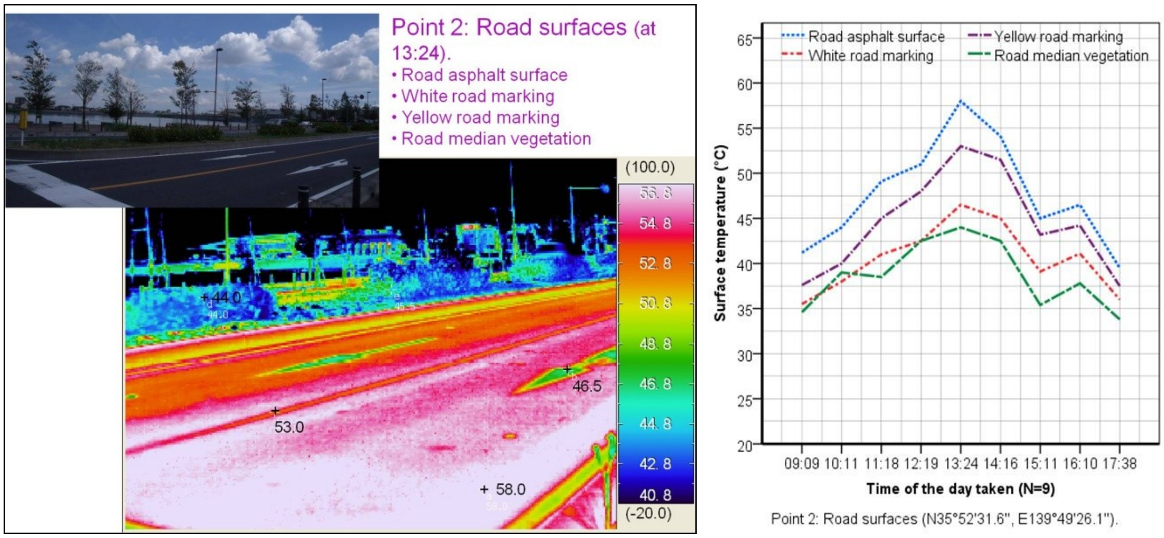
Micro climate modification evaluation: Thermographs. Surface temperatures analyzed for various landscape elements present in the 6 selected views. NEC TH – 703 Thermography Camera was used.



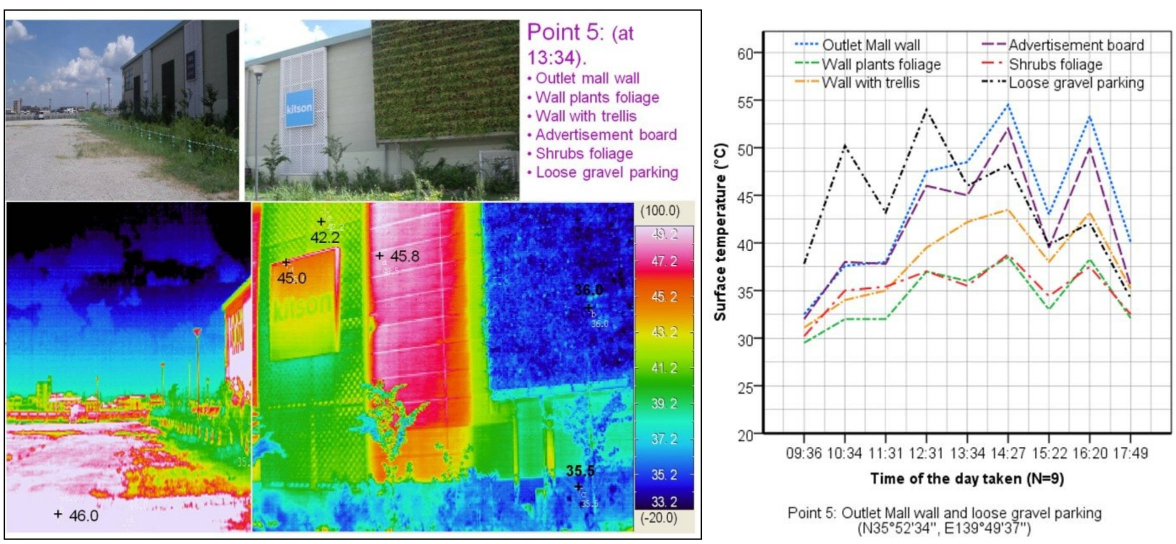
Appendix 21: Map showing points where thermographs were taken.



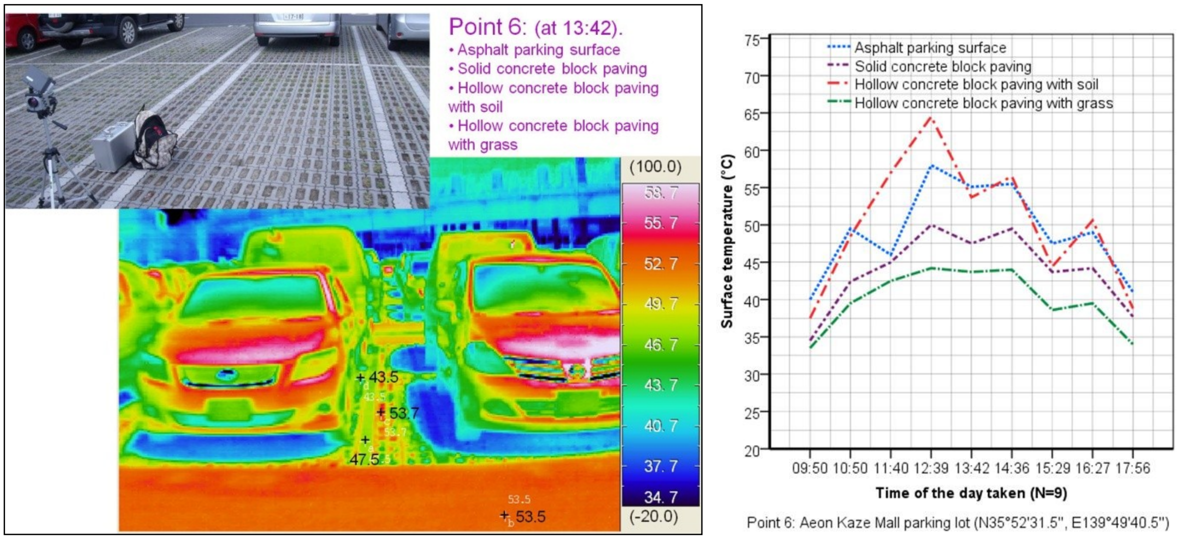
Appendix 22: Point 1: Mitakata Park (source; author, field survey Koshigaya Laketown).



Appendix 23: Point 2: Road crossing (source; author, field survey Koshigaya Laketown).



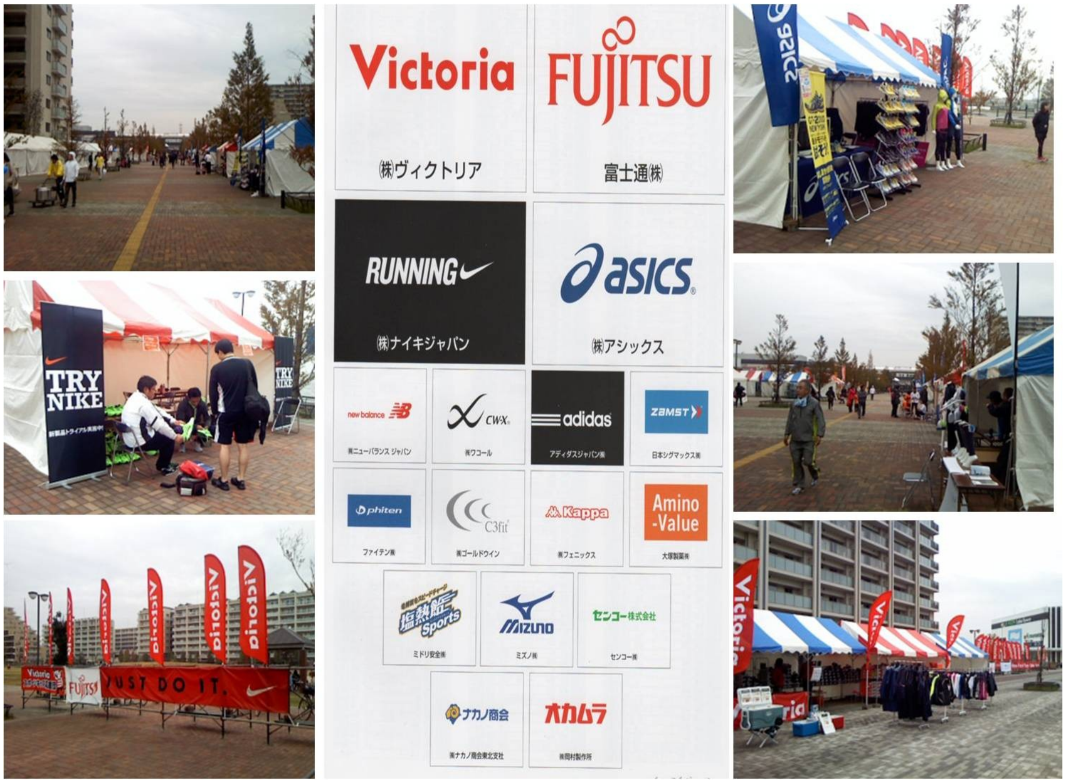
Appendix 24: Point 5: Outlet Mall area and loose gravel parking (source; author, field survey Koshigaya Laketown).



Appendix 25: Point 6: Aeon Mall area and hollow concrete block parking paving (source; author, field survey Koshigaya Laketown).

Koshigaya Laketown Running:

Appendix 26: Some of the participants of The 4th Koshigaya Laketown Running; an annual regional communal event taking place in the circulation system and green spaces of Koshigaya Laketown.



Appendix 27: Sportswear and sports nutrition merchandizing as part of economic function of GI, during 4th Koshigaya Laketown Running; an annual regional communal event taking place in the circulation system and green spaces of Koshigaya Laketown (source; author, field survey Koshigaya Laketown).

Sample questionnaire:

29C

Questionnaire about Green Infrastructure (GI)

グリーンインフラストラクチャーに関するアンケート

研究テーマ: グリーンインフラストラクチャーゲージ(評価)式.

所属:千葉大学　大学院園芸学研究科

目的: 地域/共同体単位での既存、新規の都市エリアを評価するグリーンインフラストラクチャーゲージ(評価)式を創りだす。

キーワード: グリーンインフラストラクチャー (Green Infrastructure)、グリーンインフラストラクチャーエレメンツ (Green Infrastructure elements), グリーンインフラストラクチャーファンクションズ(Green Infrastructure functions), グリーンインフラストラクチャーゲージ(評価)式(Green Infrastructure gauge), 緑の基本計画(Green Master Plan).

定義

a. グリーンインフラストラクチャー (Green Infrastructure):効率的なコスト、持続可能性、生態系などを促進する土地利用計画、コンセプト、実施と物理要素であり、豊かな生態系、環境、人々(生活の質の拡張)に良いもの

b. グリーンインフラストラクチャーエレメンツ (Green Infrastructure elements):グリーンインフラストラクチャーの利益、商品やサービス商品を推進したり、可能にしたりする、物理的でコンセプトとなる、ツール、システム、製品そして技術が含まれる

c. グリーンインフラストラクチャーファンクションズ(Green Infrastructure functions):グリーンインフラストラクチャーエレメンツが自然、環境、人々に部分的もしくは総合的に与える利益、商品、サービス

d. グリーンインフラストラクチャーゲージ(評価)式(Green Infrastructure gauge):存在する都市地域におけるグリーンインフラストラクチャーの存在のレベルを分析、評価する方法。または、存在するまたは提案される計画段階の新しい都市地域のための環境基本計画/緑の基本計画を含む。

下記の質問事項をよく読んで答えてください。

1. あなたの自治体には緑の基本計画はありますか？

☑ はい　□ いいえ

2. あなたはグリーンインフラという概念をご存知ですか。

□ とてもよく知っている　□ よく知っている　□ 少しだけ知っている　☑ 知らない

3. あなたの自治体での緑の基本計画の要素を選んでください。

□ サイクリング・ウォーキングルート

☑ 緑地緩衝帯

☑ グリーンネットワーク

Appendix 28: Sample questionnaire I.

- [x] 屋上緑化、壁面緑化
- [x] 植栽計画(樹木、灌木、地被植物)
- [ ] 緑地管理計画
- [ ] 自然、自然資源
- [ ] 自然保護地
- [x] 公園、庭
- [x] 農地、生産緑地
- [ ] 持続可能な(更新できる)エネルギー計画
- [x] 樹林地、森林
- [ ] 湿地
- [ ] 水路/水系
- [ ] 他にもありましたら書いてください

◆	◆	◆
◆	◆	◆
◆	◆	◆
◆	◆	◆
◆	◆	◆
◆	◆	◆

Green Infrastructure functions evaluation checklist.

グリーンインフラストラクチャーファンクション評価チェックリスト

- 下記のリストは環境面での緑／グリーンインフラストラクチャーの機能の項目です。
- あなた自身はそれぞれどの程度重要と思いますか。
- 生態的、環境的、社会的、観点から次の評点を用いて評価して下さい

5＝ 非常に重要, 4＝ 重要, 3＝ 普通, 2＝ あまり重要でない, 1＝ 重要でない.

Appendix 29: Sample questionnaire II.

29C

	パラメーター (機能)	説明	相対評価
1.	生物多様性の促進	特に(野生)動植物の生息域，広大なジェネティックバンク，植物の成育域(受粉、分散)、野生動物の移動	2
2.	文化、歴史的アイデンティティー(独自性)	次のような価値を持つ; ヘリテージ(習慣・遺産)，礼拝，衣服，民間伝承(フォークロア)，音楽，ダンス，言語，映画，ランドマーク，建築、歴史的・伝統的慣習(習俗)等	4
3.	防災	特に洪水や嵐、台風、地滑り、地震、火事、日照り等から地域を守る。	4
4.	エネルギーセービング(節約) or 省エネルギー	エネルギー使用、需要、コストの削減	4
5.	経済的(付加)価値	市場性のある商品の提供 (例えば海産物、原料、レクレーション等のサービス),アボイデッドコスト (開発や管理等のコストの減額)，購買意欲向上，付加価値上昇等	4
6.	環境教育	環境への意識や知識等を高める教育機会の提供，校外学習，科学研究等	5
7.	食料/資源の生産	食料源，自然原材料，バイオマス，飼料，海産物，猟鳥獣,鉱物等	3
8.	景観	魅力的な景観等.	5
9.	マイクロクライメイト(地域気象)の向上	建物や空間の冷却効果，ヒートアイランドの緩和，空調，湿度抑制，風の効果等.	4
10.	自然保護	植物・動物相の維持(例: 在来種)，自然システムの促進 (例:食物連鎖(水中も含む)等)	4
11.	騒音低減(防音)	住宅地等の騒音対策(静止物、可動物からの騒音の緩和)	3
12.	大きなグリーンネットワークとの関連性	(ハブ，通路、サイトとして)より大きなグリーンネットワークとの関連性	4
13.	全体計画との関連性	物理的に、または概念上全体計画の一部分として組み込まれているかどうか	4
14.	公害汚染対策	浄水，大気汚染防止(換気)，防塵対策，有害物の分解等	4
15.	地域活性化	祭りや社会的イベント等地域を活性化する大通り等の場所の提供等	4

Appendix 30: Sample questionnaire III.

16.	公衆衛生の促進	ジョギング・ウォーキング・サイクリングといった地域住民の健康の保持・向上、セラピー、クリーンエンバイロメント、害虫(獣)や寄生虫の駆除等	4
17.	雨水採取(貯留)	特に灌漑や清浄等に利用する雨水の採取(貯留)能力	2
18.	レクレーションの提供	自然に接する環境の提供, エコツーリズム、アウトドアスポーツ, 遊びやリラクゼーション.	4
19.	温室効果ガスの削減	炭素隔離, 温室効果ガス排出量の抑制や代替エネルギーの利用	2
20.	公共投資(社会資本整備)の削減	公共事業の削減や民間への転換, 代替交通手段の推進等(例:自転車の利用の促進等)	2
21.	雨水管理	浸水(増水)等による排水(流出)の削減, 排水前の一時的貯水, 蒸発散や再利用.	2

5＝ 非常に重要, 4＝ 重要, 3＝ どちらでもない, 2＝ あまり重要ではない, 1＝ 重要ではない.

名前の記入は不要です。全ての個人情報は機密情報として扱い、どんな組織にも公開いたしません。

部局等組織を代表する立場としてではなく、職員個人として記入いただくようお願いいたします。

この結果は統計的に処理され、個人情報及び調査結果を公開、流出することは一切ございません。

ご協力ありがとうございました。

4

Appendix 31: Sample questionnaire IV.

[illegible]

Green Factor Score Sheet

SEATTLE × green factor

Project title:

enter sq ft of parcel

Parcel size *(enter this value first)* * 5,000 SCORE -

	Landscape Elements**	Totals from GF worksheet		Factor	Total
A	**Landscaped areas (select one of the following for each area)**				
1	Landscaped areas with a soil depth of less than 24"		*enter sq ft* 0	0.1	-
2	Landscaped areas with a soil depth of 24" or greater		*enter sq ft* 0	0.6	-
3	Bioretention facilities		*enter sq ft* 0	1.0	-
B	**Plantings (credit for plants in landscaped areas from Section A)**				
1	Mulch, ground covers, or other plants less than 2' tall at maturity		*enter sq ft* 0	0.1	-
2	Shrubs or perennials 2'+ at maturity - calculated at 12 sq ft per plant (typically planted no closer than 18" on center)	*enter number of plants* 0	0	0.3	-
3	Tree canopy for "small trees" or equivalent (canopy spread 8' to 15') - calculated at 75 sq ft per tree	*enter number of plants* 0	0	0.3	-
4	Tree canopy for "small/medium trees" or equivalent (canopy spread 16' to 20') - calculated at 150 sq ft per tree	*enter number of plants* 0	0	0.3	-
5	Tree canopy for "medium/large trees" or equivalent (canopy spread of 21' to 25') - calculated at 250 sq ft per tree	*enter number of plants* 0	0	0.4	-
6	Tree canopy for "large trees" or equivalent (canopy spread of 26' to 30') - calculated at 350 sq ft per tree	*enter number of plants* 0	0	0.4	-
7	Tree canopy for preservation of large existing trees with trunks 6"+ in diameter - calculated at 20 sq ft per inch diameter	*enter inches DBH* 0	0	0.8	-
C	**Green roofs**				
1	Over at least 2" and less than 4" of growth medium		*enter sq ft* 0	0.4	-
2	Over at least 4" of growth medium		*enter sq ft* 0	0.7	-
D	**Vegetated walls**		*enter sq ft* 0	0.7	-
E	**Approved water features**		*enter sq ft* 0	0.7	-
F	**Permeable paving**				
1	Permeable paving over at least 6" and less than 24" of soil or gravel		*enter sq ft* 0	0.2	-
2	Permeable paving over at least 24" of soil or gravel		*enter sq ft* 0	0.5	-
G	**Structural soil systems**		*enter sq ft* 0	0.2	-
		sub-total of sq ft =	*0*		
H	**Bonuses**				
1	Drought-tolerant or native plant species		*enter sq ft* 0	0.1	-
2	Landscaped areas where at least 50% of annual irrigation needs are met through the use of harvested rainwater		*enter sq ft* 0	0.2	-
3	Landscaping visible to passersby from adjacent public right of way or public open spaces		*enter sq ft* 0	0.1	-
4	Landscaping in food cultivation		*enter sq ft* 0	0.1	-
			Green Factor numerator =		-

**** Do not count public rights-of-way in parcel size calculation.***

***** You may count landscape improvements in rights-of-way contiguous with the parcel. All landscaping on private and public property must comply with the Landscape Standards Director's Rule (DR 6-2009)***

Appendix 32: Seattle Green Factor Score Sheet (source; Seattle Gov.).

Urban agriculture:

Appendix 33: Typical urban farm, Nijuseikigaoka, Matsudo Japan (source; author).

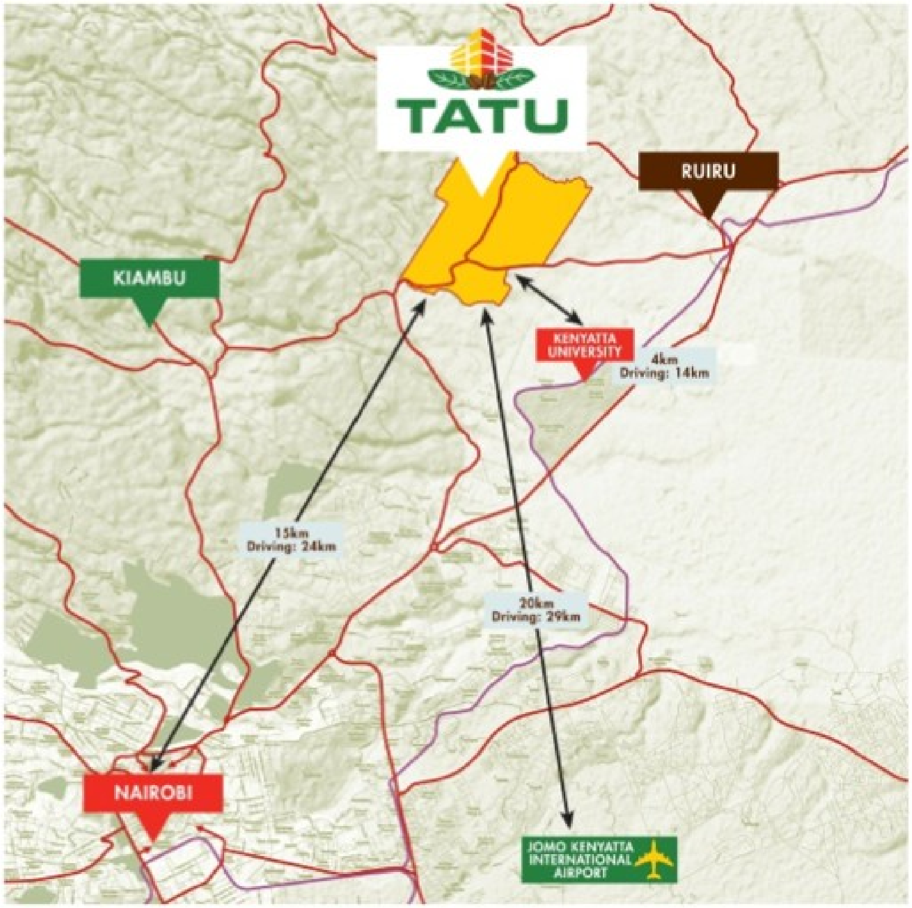
Appendix 34: Rock wool and hydrophonics application in greenhouse tomato cultivation, Tanaka Farm. Sodegaura City, Chiba Prefecture Japan. 2012-2-28 (source; author).

Appendix 35: Pasona O2: Urban Underground Experimental Farming, Tokyo, Japan.

Appendix 36: Ruralism at Shenyang Architectural University Campus, China. Integrated urban agriculture and campus facilities.

Appendix 39: Bird's eye view; plant factories at Kashiwanoha field centre, Chiba University, Japan.

Appendix 37: Interior of plant factories at Kashiwanoha field centre, Chiba University, Japan.



Appendix 38: A poster indicating the location of TATU City, one of the Newtowns under planning or development within the greater Nairobi Metropolitan area. They present new opportunities to implement GI and UGN (source, TATU City).

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