

A GIS-Based Analysis Approach for Evaluating Green Infrastructure Plan: A Case Study of Makassar Region

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<https://hdl.handle.net/2324/1959118>

出版情報 : Kyushu University, 2018, 博士 (工学) , 課程博士
バージョン :
権利関係 :



A GIS-Based Analysis Approach for Evaluating Green Infrastructure Plan: A Case Study of Makassar Region

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
KYUSHU UNIVERSITY, JAPAN

IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF ENGINEERING

By
Poppy Indrayani

July 2018

**A GIS-BASED ANALYSIS APPROACH FOR
EVALUATING GREEN INFRASTRUCTURE
PLAN: A CASE STUDY OF MAKASSAR
REGION**

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to the
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Fukuoka, Japan
July, 2018

DEPARTMENT OF CIVIL AND STRUCTURAL ENGINEERING
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CERTIFICATE

The undersigned hereby certify that they have read and recommended to the Graduate School of Engineering for the acceptance of this thesis entitled, “*A GIS-Based Analysis Approach for Evaluating Green Infrastructure Plan: A Case Study of Makassar Region*” by **Poppy Indrayani** in partial fulfillment of the requirements for the degree of **Doctor of Engineering**.

Dated: July, 2018

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Abstract

Indonesia is one of the highest urbanizing countries in Asia and its future will be shaped by its cities. In 2011 the population was 51% at urban area, and the projected to become 85% by 2050. Makassar is the largest city in Eastern Indonesia and part of the Mamminasata Metropolitan Area. Nowadays, over 86% of the Makassar region is occupied for urban uses. The built-up area has expanded far faster than the population, indicating an increasingly lower density of the city. The loss of prime green land has appeared to be a major problem. Moreover, it is located on the coast within an extensive coastal plain which is also subject to flooding every year. Due to the rapid growth of development, Tallo River Area has been becoming inside of urban area. The near future it will be exactly at the middle of the city. The local government proposes to create Tallo River Area where the city can strategically manage urban development in the land that is now undeveloped because it is subject to regular flooding. Nevertheless, it is endorsed in the Mamminasata Spatial Plan (2006) and The Makassar City's Spatial Plan (2012). Therefore, to mitigating flood risks as well as managing the water resources, and increasing nature and green spaces have become more serious concerns. Tallo River Area has a crucial role both in the environmental and development of Makassar City.

Green Infrastructure (GI) is strategically planned and managed networks of natural lands, working landscapes and other open spaces that bring multiple benefits. It is applied to support ecological stability in the landscape by conservation or restoration of ecosystems and their connectivity, and to apply to the management of floods at the local level through the use of natural systems to treat polluted runoff. Geographic Information System (GIS) serves as a good decision support system and tools in environmental issues as well as planning the Green Infrastructure. Thus, the research objectives are divided into two parts: (i) to evaluate prospective Green Infrastructure across Tallo River Area by GIS throughout analyzing the land-use changes, ecological connectivity, and flood disaster risk at the regional scale of Makassar; and (ii) to propose the Green Infrastructure network planning within Tallo River Area at local scale, in accordance with the city's spatial plan where there are gaps or areas of need to put into evaluation network design.

Chapter 1 provides a briefly introduction to the description of the sustainable

urban development involving the sustainable and site design, site data and analysis concepts. By the literature reviews, definitions of Green Infrastructure by the Country regions have been discussed. Connectivity is a key element of Green Infrastructure plans, not only within elements of the Green Infrastructure plan itself, but the plan should also create connections between local institutions and people. The goal of a network design is to delineate an interconnected Green Infrastructure system that incorporates both benefits to nature and to people.

Chapter 2, development of grid-mesh based land-use maps from the available topology features have been performed in GIS. Spatial analyses of land-use changes have been evaluated to investigate pattern of transition in the Makassar region, and the details analysis has been simulated to characterize the land-use values change into urban. It is found that about 32% of agricultural fields and 41% of garden fields of 1997 are converted into urban. The increasing phenomenon of urban area has led to the existence of the fishpond (13.5%) in Makassar region. In Tallo River Area, mangroves, shrubs, and gardens have been identified as degraded areas and mostly converted into fishponds.

Chapter 3, the Ecological Connectivity Index (ECI) in the Makassar region has been evaluated through the spatial identification of ecological functional areas by different patch size spectrum and development of Barrier Effect Index (BEI) model based on Marulli and Mallarach, 2005. The ECI shows a significant decline between 1997 and 2012 due to the loss of agriculture and agroforest mosaics and mangrove forests. Negative changes in connectivity levels have occurred in the former natural-space around the Makassar region, both at West and East part of the city. It is found that the mangrove forest and shrubs field has relatively high impact levels to the ecological connectivity index changes. Furthermore, some areas have been identified in Tallo River Area for the conservation of the potential of ecological connectivity and the restoration of the loss of the vital natural sites.

Chapter 4, a GIS matrix analysis has been conducted to establish spatial vulnerability to flood and risk at local context based on the BNPB (Indonesian National Board for Disaster Management) framework. Based on the available of local statistical data and geospatial information, the Flood Hazard Index (FHI) has been developed. The Flood Vulnerability Index (FVI) is performed in GIS. The FVI study aggregated the local indicators to a single composite index that enable spatial vulnerability representation from various social, physical, economic, and environmental factors. Furthermore, Flood Risk Index (FRI) has been determined to analyze the distribution of risk components at sub-district level. Determination of the FRI level has been calculated by matrix model from the variables of the FHI and FVI. In the vicinity of Tallo River Area, sub-districts of Panaikang,

Tamalanrea Indah, and Pampang have been identified as the areas with high potential impacts from flood risks in term of physical and environmental aspects.

Chapter 5, the goal setting by local government has been studied to identify the main objectives in accordance to the city's spatial plan. Identification of key issues for Green Infrastructure plan has been conducted to indicate the potential Green Infrastructure functions in Tallo River Area. Moreover, three spatial themes have been identified that are landscape and biodiversity, flood risk and climate change adaptation, and community and access to greenspace. Analysis element has been conducted for the Green Infrastructure network design model. In particular, the connected landscape biodiversity network has been simulated in GIS to evaluate a patch dispersal distance between existing and planning. Synthesis plan element has also been performed to assess the Green Infrastructure network design model in terms of flood risk factors and other feasibility factors. This assessment leads to the identification of priorities for implementation zones in Tallo River Area.

Chapter 6, the current study results on the evaluation of Green Infrastructure plan has been concluded and the remained research issues have been discussed for future challenges in GIS analysis approach.

Acknowledgements

I owe an enormous debt of gratitude to my supervisor, Prof. Yasuhiro Mitani, of the Environmental Geotechnology Laboratory for his advice, strictly supervising, forehanded discussion, kindly encouragement and continual support throughout this doctoral research. My deepest thank also goes to Assistant Prof. Hiro Ikemi who has kindly assisted me with his suggestion, constructive comments, and supervision on my research. I greatly thank and appreciate Prof. Yukihiro Shimatani, of the Department of Urban and Environmental Engineering and Associate Prof. Satoko Seino, of the Department of Urban and Environmental Engineering, for their careful examination and valuable comments on my thesis.

I am grateful to Mayor of Makassar City for the generous supports and assistances, which have provided Makassar statistical and spatial data for this research. I wish also to acknowledge the enormous support given by Fajar University, for his assistance with respect to the development of my doctoral research.

I wish to acknowledge the Environmental Geotechnology Laboratory, who had given me opportunity to be in GIS research group, as an International doctoral program. During three years in laboratory, I had learned much about GIS both in science and technology aspects.

I would like to express my thanks to all the staffs and students of Prof. Mitani's Laboratory for their kind helps and supports during the period of study. In addition, my sincerest thank also goes to the Indonesian Dikti Scholarship which has provided me the financial support during the doctoral study.

Finally, I will always be indebted to my family to Nidia, Dyfia, Dzaky, Aya, Abqary, and particularly my husband for his constant support and strictly supervising throughout the period of my candidature, and this thesis would not have been possible but for their contribution. Lastly, I am forever indebted to my Mighty Lord Allah SWT for the strength, nourishment, and opportunities which I have been blessed with all the time in my life.

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Notations

B_1 is the barrier type of urban

B_2 is the barrier type of water

B_3 is the barrier type of fishpond

C_1 is the natural type of forest

C_2 is the natural type of mangrove forest

C_3 is the natural type of swamp field

C_4 is the natural type of paddy field

C_5 is the natural type of garden field

C_6 is the natural type of shrub field

N_1 is the neutral type of crop field

BEI is the relative of barrier effect index

Y is the entire barrier effect in the landscape

Y_i is the value of the barrier effect in a pixel

Y_{max} is the maximum value of the barrier effect calculated on a given area

Y_s is the effect of a single barrier from a given point

b_s is the weight of each barrier type

ln is the natural logarithm

k_{s1} and k_{s2} are constants for logarithmic decreasing function

d'_s is the adapted cost distance per barrier type

α is the alpha

a_n is the affectation coefficient for a number n

A_n is the affectation value for a number n

M_c is the potential affinity matrix

$X_{cr'}$ is the each type of ecological functional area

X_I is the impedance surface

X_C is the effect of the barriers

X_Y is the potential affinity matrix

d'_r is the distance at cost analysis

x is the total adapted cost distance value

x_i is the adapted cost-distance value in a pixel

$x_{\max}$ are the maximum adapted cost-distance values on a given area

$x_{\min}$ are the minimum adapted cost-distance values on a given area

ECI is the relative of ecological connectivity index

C' is the ecological functional areas

ha is the metric system unit of hectare

X_j is the normalized value (ranging from 0 to 1) of the indicator j of a vulnerability component

x_j is the value of the indicator j

W_j is the weight of the indicator j

VI_{social} is the composite indicator for social vulnerability

$VI_{physical}$ is the composite indicator for physical vulnerability

$VI_{economic}$ is the composite indicator for economic vulnerability

$VI_{environmental}$ is the composite indicator for environmental vulnerability

FVI is the flood vulnerability index

FHI is the flood hazard index

FRI is the flood risk index

CHAPTER 1

Introduction

1.1 Sustainable Urban Development

1.1.1 Sustainable and site design

Humans have a significant impact on the world environment (Ehrlich and Holdren, 1971). In 1987 the Brundtland Commission published *Our Common Future*, which recognized that to avoid or at least minimize the environmental impacts of human behavior it is necessary for society to adopt a sustainable approach to development. In February of 1996 the President's Council on Sustainable Development (PCSD) identified 10 goals, but the first 3 really encompass them all: health and the environment, economic prosperity, and equity. Equity refers to social equity (equal opportunity) and intergenerational equity (equity for future generations). *Sustainability* was defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Since World War II the growth of suburban development has been the most important and possibly the most environmentally damaging trend (Irwin and Bockstael, 2007). At the beginning of the twenty first century more people live in the suburbs than in the former urban centers. As sprawl continues, we consume more and more land per person, more infrastructures per person, and have a greater environmental impact as well. The impacts of development and land-use patterns were well documented during the last half of the twentieth century (Goetz et al., 2004). Impacts include a loss of water quality, fragmented and lost wildlife habitat, human health issues, introduction of invasive exotic plants, loss of biodiversity, falling groundwater tables, and more. Fragmentation is known to be closely associated with a loss of biodiversity and resilience in landscapes. As development proceeds, isolated "islands" of green space and narrow visual buffers give some aesthetic appeal to the finished site, but they are commonly without significant ecological value.

The world's oceans are warming as well because of global warming effect

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(Intergovernmental Panel on Climate Change, 2007). The temperature of the sea is expected to rise and influence the weather. Thermal expansion of the ocean and increases in runoff from glaciers and ice fields are expected to continue and result in rising ocean levels. As sea levels continue to raise increases in shore and beach erosion should be anticipated along coastlines. Barrier island communities may experience significant losses. Rising sea levels will also complicate floods on tidal influenced rivers and streams. Increased storm surges may back up streams and change flood plain characteristics. The implications of climate change may be significant. Increased erosion and perhaps slope destabilization in some places can be expected with such an increase. Coastal communities may experience an increase in flooding and beach erosion. Flood prone areas may increase in size as the sea levels rise. Public health officials and communities may become more sensitive to areas of standing water as subtropical and tropical diseases expand their range.

Design strategies in affected coastal communities may provide significant opportunities for innovation and problem solving. Anticipated warming in most places will result in increasing cooling costs for buildings and homeowners. Properly locating a building on the site and planning plantings to lower energy costs will become even more important elements of the site plan. As temperatures increase, plants growing at their southern range may be subject to significant heat and increasing drought-related stresses. Some places may see a shift in native species, particularly those living at the margins of their tolerance. Global climate change models anticipate a broad range of impacts. These impacts are believed to be under way already and will begin to manifest significant changes on the environment within the next 25 years and beyond. Many of these changes and impacts have direct implications for the development of land.

Although water is a renewable resource, supply issues do exist and promise to become more significant as time passes. Annual natural variations in precipitation can result in local and regional water management issues and conflicts. It is unclear to what degree these natural variations will be exacerbated at the local level by climate change, but most climatologists agree that extreme weather events and patterns will become more frequent and more persistent. This suggests that periods of wet or dry weather patterns may last longer and be more intense. Conservation is the most affordable and practical approach to the water issues facing communities. It is recommended that low-impact design be utilized to reduce the water demand of a site and to maximize the amount of runoff retained on the site. Employing vegetated swales, constructing rain gardens, using permeable paving, and reducing lawn areas are important elements of water

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conservation in the site design. The use of gray water and recycled water for landscape purposes, selecting native plants, and collecting and storing runoff on site also contribute to reducing the impact of site development. Working with architects to install green roofs and designing on-site sewage collection systems can also be part of the conservation strategy (Schmidt, 2008).

In most countries, trends in population and demographics have important implications for planners, and the developing countries are projected to increase in future. With the anticipated increase in population, the need for water and energy conservation and planned growth becomes even more important and smart growth becomes critical (Pendall, 2003). For communities in some parts of the country, development pressure will grow, and local government will have the opportunity to deal with growth-related issues including open space and public facilities before the crush. It is widely believed that the world is facing a time of increasing energy supply issues. We have leveraged the tremendous concentration of energy found in these fuels to create ever-more productive processes and systems, which in turn enabled the production of lower cost products, faster, cheaper transportation, and new materials. Ever-growing demand will result in higher energy costs and tighter supply, and energy conservation and efficiency will become more important considerations in development of all forms.

To meet the challenges of sustainability we need to change our behaviors to adapt to a paradigm of economic prosperity, social equity, and environmental sustainability but these goals have traditionally been viewed as antagonistic or mutually exclusive. Site design and planning today have started to move beyond the practices and paradigm of the past. Contemporary site planning and design is changing to adopt into practice much of the knowledge and information gained as our awareness of environmental risks has improved. Sustainability requires a broader and deeper view of site planning.

1.1.2 Sustainability and the green site

The site exists as part of a larger landscape and ecosystem, and sustainable site design must include broad considerations of the environmental role of the site as well as the program or intention of the project. Sustainable design must recognize and retain as many of the functional elements of a site as possible but also consider the relationships between the site under consideration and the community at large. Change tends to come slowly to the land development process, but it does come eventually. Many communities are requiring greener development, better street design, and more sensible use of resources and capital. These development

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trends embrace a sustainable environment and a robust economy, which are not mutually exclusive concepts as they are often portrayed today. Sustainability is not and cannot be anti-development; instead, it is the basis for thoughtful, intelligent, and rational development. Change brings many challenges. As we begin to think about sustainability and land development, it is important to note the contribution land development and construction make to our economic well-being.

Context for sustainability is in its infancy, but the dialogue is well under way. Important voices are encouraging us not to go back but forward, and to solve problems through design. Although no single set of guidelines has emerged, there is a growing recognition of the principles that lead to sustainable design and development. Sustainable site planning must include considerations of the impact of development on the local ecosystem, the global ecosystem, and the future (Woods Hole Research Center, 2007). Sustainability concerns go beyond the selection of materials. The layout of a site, the types and character of groundcover, and the management of the various landscape functions are critical issues. All of these issues have implications. First, what is the role of site development in contributing to these effects, and how might those effects best be mitigated? Second, given that these decisions will influence the use and function of a site, how do we account for these changes in planning and design? Site planning, design, and development professionals are moving toward including sustainability as a matter of practice.

The site planning and design professions are embracing the concerns with sustainability as we grow more aware of issues of climate change, energy, and the anticipated pressures of continued population growth. More to the point, communities and clients are also requiring more sensitive and intelligent design. The opportunities to address these concerns are expected to grow in years to come. Although much has been done to improve our understanding of our relationship with the environment, much more remains to be done; the design paradigms of the future are just now being formed. Begin to consider issues for site and community design that go beyond mitigating the impacts of site disturbance and the disruption of environmental services. As concern with energy conservation and efficiency grow, transit planning and local sources of energy are likely to become important to communities (Battles and Burns, 2000). Likewise, concern over quality of life issues may lead to a greater premium on communities that provide more manageable commutes or to walkable communities. In addition, access to local food and other resources may become important elements in the sustainable community of the near future.

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1.1.3 Site data and spatial analysis

In many respects, site analysis is the most important step in the successful site design process. The purposes of site analysis are to gather spatial data for preliminary planning, evaluate the site for compatibility with the proposed project. The value of the site analysis is in its clear and complete identification of issues and the character of the site as they relate to a proposed use. The site analysis should be as far-reaching and broad in scope as feasible, but it is usually subject to fairly limited resources. The site data includes some important points, as follow.

- (1) *Location.* The first consideration of the site analysis is to locate the site. Site location entails more than simply locating the site on a map. Location, in this sense, refers to the project's relationship to the community.
- (2) *Collecting site information.* Site analysis is an interpretive process. A broad array of information is collected from fairly limited individual sets of information, and these data sets are combined to project a future use of the land. In general, preliminary site assessments are based on precious little new information; that is, much of the analysis is based on existing sources of information or firsthand observation. It is how the site information is understood and used that makes the difference in site analysis.
- (3) *Topography.* The most basic element of site analysis is the lay of the land. The topography of a site may dictate the purposes for which the site may be used and eventually the layout of the proposed project. The location of buildings and roads, pedestrian circulation, and the arrangement of stormwater features are all commonly affected by topography. The analyst must consider how the existing topography affects the proposed use. Other elements of the site analysis include the identification of canyons, wetlands, rock outcroppings, existing structures, unique habitats or natural features, neighboring land-uses, and utility locations. Flat and low areas present their own concerns. Boggy or wet areas may be wetlands and restrict development. Sites that are low or flat may be difficult to drain and present difficult design challenges of their own. The location of rights of way, easements, and other encroachments is also important. Findings of the site analysis may indicate that further research is required to determine the stability of slopes, hydrologic conditions, or the extent of wetlands. The site analysis is the foundation of the plan. It will provide the framework from which the planning and design are developed.
- (4) *Aerial photograph.* An aerial photograph is also helpful in presenting the site analysis data. Example of series of historic aerial photographs show the site conditions at three different times in the past (**Figures 1.1, 1.2, and 1.3**).

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Fig. 1.1 Aerial photograph of same site showing conditions in 2001



Fig. 1.2 Aerial photograph of same site showing conditions in 2010

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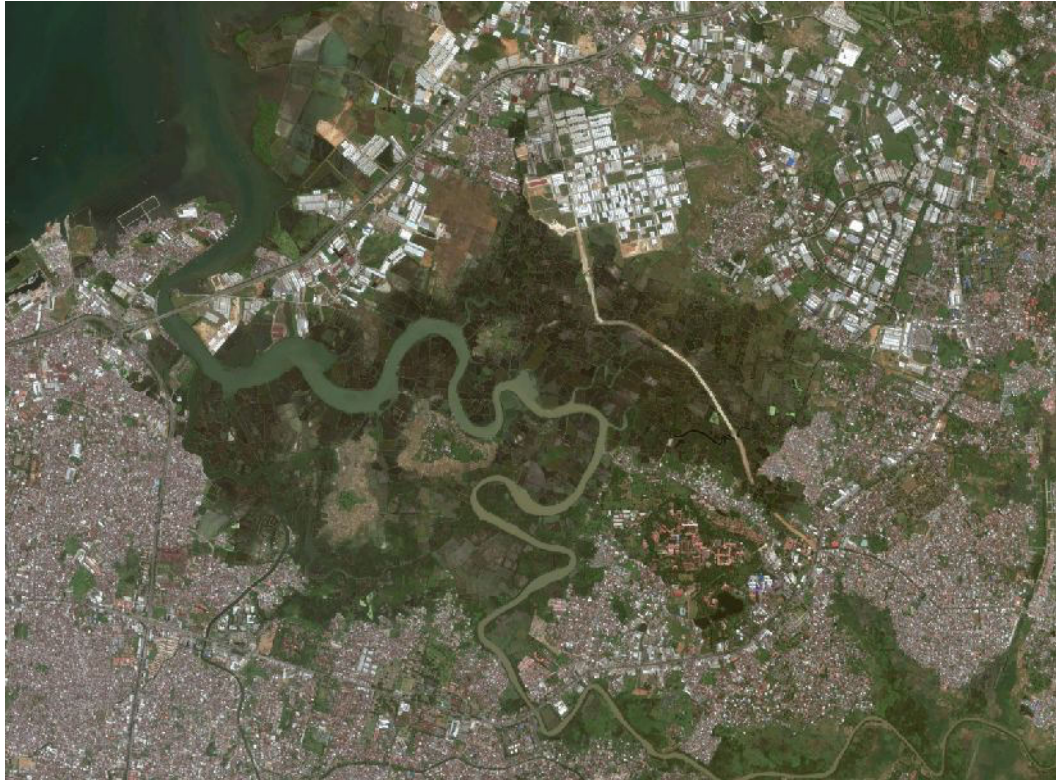


Fig. 1.3 Aerial photograph of same site showing conditions in 2015

- (5) *Hydrology.* The presence of water on the site and the general pattern of drainage are key concerns of the site analysis. Water is often the key feature of a site. Waterfront the presence of a stream or pond brings added value, but it also raises concerns for development. The presence of a surface water feature may be coincidental with a fairly high water table or shallow geological features. Drainage patterns should be carefully observed in the field as well as being examined in published sources of information. The presence of associated wetlands and floodplains must be preliminarily located, and the location and extent of riparian zones should be noted. The location of water features and other hydrologically linked features of the site should be carefully observed and evaluated. Sites located along streams in the lower reaches of a watershed may be affected by conditions higher in the watershed. Begin to identify storm water management strategies in the site analysis. The drainage pattern of the site and the presence of water features will indicate the likely location of storm water collection facilities.
- (6) *Local records and history.* Occasionally zoning may include overlay zones that have important implications for land-use. Overlay zones such as steep slope restrictions, watershed protection, historic preservation, or aquifer protection may severely limit land development activities or require a higher order of

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performance from the design, construction, and operation of a site.

- (7) *Infrastructure*. The location of surface and subsurface utilities is part of the site analysis. The analyst should identify the location, capacity, and access for all necessary utilities, as well as the requirements for connections. Of particular importance might be moratoriums on sanitary sewer or water connections or exorbitant connection fees. Equally important is consideration of the interferences between utilities either on the site or in bringing the utilities to the site. Access to public water and sewer should be evaluated. The capacity of existing water and sewer may be of concern in some communities and should be evaluated at an early stage. The capacity of road networks to accommodate proposed traffic is also a concern.

1.2 Green Infrastructure

1.2.1 Definitions of Green Infrastructure

The concept of Green Infrastructure was developed out of the discipline of ecological planning. Green Infrastructure is seen as an approach to conservation planning that combines the efforts of previous planning methodologies and practices in the United States into a systematic framework that can encompass larger landscapes and broader planning goals. Gray infrastructure describes the functional support system of urbanized areas, Green Infrastructure the noun refers to nature's life support system. Green Infrastructure the adjective refers to an approach to conservation planning that is landscape-scale, driven by a broad-reaching public process, and results in an implementation strategy to protect an ecological network of conservation lands (McDonald et al., 2005). Green Infrastructure is a term that is appearing more and more frequently in land conservation and development discussions across the country and around the world. Green Infrastructure means different things to different people depending on the context in which it is used. For example, some people refer to trees in urban areas as Green Infrastructure because of the "green" benefits they provide, while others use Green Infrastructure to refer to engineered structures (such water treatment facilities) that are designed to be environmentally friendly.

By the literature reviews, we developed the following definitions for Green Infrastructure by the Country areas in the United States, European Countries, and Japan.

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- (1) *In the United States.* Definition of Green Infrastructure is strategically planned and managed networks of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations. It is important to stress that Green Infrastructure is not anti-development but a sustainable approach that brings multiple benefits, including economical benefits, provides ecosystem services, supports tourism and enhances quality of life. The United States Environmental Protection Agency (EPA) has extended the concept of Green Infrastructure to apply to the management of stormwater runoff at the local level through the use of natural systems, or engineered systems that mimic natural systems, to treat polluted runoff. It is important to plan both Green and Gray Infrastructure simultaneously and both should be given equal opportunity in the planning process and planned as complementary systems.
- (2) *In the European Countries.* Definition of Green Infrastructure is an interconnected complex of both natural and semi-natural ecosystems to ensure ecosystem health and the provision of ecosystem services. Main purpose is to support ecological stability in the landscape by conservation or restoration of ecosystems and their connectivity. The European Green Infrastructure is an important part of the new (post-2010) EU strategy for biodiversity and biodiversity policy. It is one of the main tools to tackle threats on biodiversity resulting from habitat fragmentation, land-use change and loss of habitats. Green Infrastructure will play a decisive role in integrating biodiversity into other policies, such as agriculture, forestry, water, marine and fisheries, regional and cohesion policy, climate change mitigation and adaptation, transport, energy and land-use policy.
- (3) *In Japan.* Green Infrastructure is achieved through an integrated approach to land-use management and careful strategic spatial planning on climate change adaptation and disaster prevention strategies to local and regional. Green Infrastructure is effectively utilized as a means of alternative or supplementary artificial infrastructure functions such as disaster prevention and water purification with the natural environment in land-use, promoting the natural environment, the economy, and the beneficial measures for society.

Furthermore, green space is thought of as isolated parks, where Green Infrastructure emphasizes interconnected systems (Benedict et al., 2006). Interconnected open space is important for two reasons, the first is ecological; the second is human (Erickson, 2006). In current efforts to achieve sustainable urban

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development, Green Infrastructure has the same dignity as technological infrastructure has had in traditional urban planning (Sandstrom, 2002). Taking a landscape-scale focus for conservation planning is the foundation for Green Infrastructure planning, a strategic conservation planning approach that builds on conservation planning approaches of recent years. The planning and scientific analysis that has served as a foundation for regional biodiversity networks, often called reserves are the roots of the Green Infrastructure approach (McDonald et al., 2005). McDonald et al. (2005) broadens the definition of Green Infrastructure that Green Infrastructure as the interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to health and quality of life. Therefore, in our view, Green Infrastructure is the ecological framework needed for environmental, social and economic sustainability.

1.2.2 Green Infrastructure planning and examples

Connectivity is a key element of Green Infrastructure plans, not only within elements of the Green Infrastructure plan itself, but the plan should also create connections between local institutions and people (Sandstrom, 2002). A diversity of stakeholders helps give the plan a strong base for developing the goals that will guide future planning efforts. A wide range of stakeholders can also help to generate public support for Green Infrastructure planning. This stage in the planning process is very similar to what is done for other types of environmental plans. Greenways almost always begin with two key elements: an outstanding natural or cultural feature and committed visionary leadership. Setting goals, bringing people together and garnering support for a Green Infrastructure plan is not easy, therefore visionary leadership (Flink et al., 1993). Setting goals, bringing people together and garnering support for a Green Infrastructure plan is not easy, therefore visionary leadership in the form of an advisory committee or a local leader is a critical component in this stage of the planning process.

A wide range of plan goals further distinguishes Green Infrastructure planning from previous strategies. Green Infrastructure plans must include goals for the protection of ecological functions, as well as protection of working lands, and open space for human benefit. These are factors that have been covered in other plan types, but typically not included all within one plan (McDonald et al., 2005). It should be noted that not all areas will include all possible conservation

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objectives, but a plan should still be considered a Green Infrastructure plan if it incorporates and balances all salient conservation goals for the area. Goals for Green Infrastructure plans must be made for the entire landscape within the plan area. It is critical that the plan makers recognize the ecological context of the region they are planning for. Long-term ecological integrity depends upon the integrity of native species, the size and configuration of habitats within the landscape, integrity of the physical environment, and the context of the landscape (Perlman et al., 2005).

Ecosystems are interconnected and dynamic systems. They do not end and begin where the administration lines are drawn on a map. Green Infrastructure planning must take into account that an area's resources are influenced and affected by the resources and population of neighboring regions. Drawing upon landscape ecology and conservation biology theories and practices within an environmental planning framework can ensure that Green Infrastructure plans integrate and account for all of these factors (McDonald et al., 2005).

The goal of a network design is to delineate an interconnected Green Infrastructure system that incorporates both benefits to nature and to people. Similar to the goal setting stage, the analysis of the Green Infrastructure network should be based on current theories from ecology and land-use planning. The Green Infrastructure network should focus on creating meaningful links between habitats and ecosystem functions, understanding biodiversity at the local, landscape, and ecosystem scale, identifying critically valuable habitat areas, and the interaction of all these elements with the features of the built environment (Sandstrom, 2002). The design of the Green Infrastructure network should be based on the results of a thorough analysis of the plan area to determine the type and range of resources within the region.

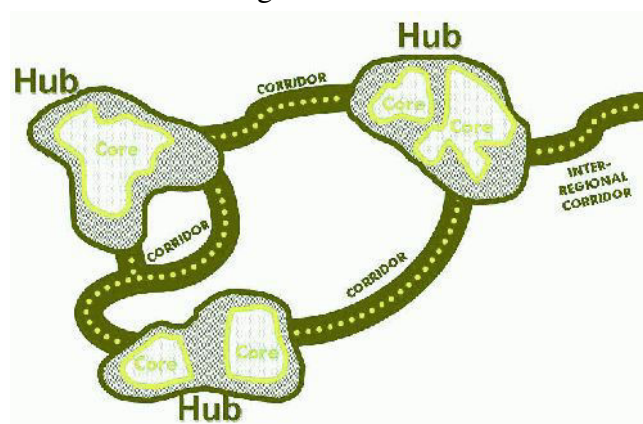


Fig. 1.4 Picture illustrates a hub/corridor framework which is ideal to protect the ecological integrity of an area and is commonly used in Green Infrastructure planning

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McDonald et al. (2005) recommends conducting the analysis around each individual Green Infrastructure goal, and then compiling that information to define the entire network. The design of the network should utilize a hub and corridor framework, with stepping stones to facilitate healthy wildlife habitat. **Figure 1.4** provides an illustrated example of the design that this type of framework should seek to replicate. Hubs are essential features in a Green Infrastructure network. They are defined as large, ecologically significant natural areas which serve two important purposes. The first purpose is to provide habitat for animal and plant species that cannot thrive in small patches of open space that exist in highly fragmented landscapes. Populations that are small, isolated, or subdivided into small groups because of restricted dispersal can be particularly susceptible to inbreeding and extinction (Falk, 2006). Without genetic variation, the population of a species will deteriorate. Natural corridors that link hubs are intended to link the gene pools of two populations. The wide movement of wildlife, even plants, along a natural corridor is essential for the survival of some species, especially those fairly high up on the food chain. If confined to a single nature reserve, even a quite large one, species can become an island population and possibly perish (Little, 1990). The gene pools of many remnant native populations have been seriously eroded, so that what persists today is often a small remnant of the original diversity. Small gene pools are more prone to inbreeding, as well as random genetic change from drift. Populations that formerly exchanged genes regularly may have also become genetically isolated by habitat fragmentation (Schwartz, 1993). The second purpose of a hub is to provide areas for wildlife to forage and breed. Another key component of the network is that it should include a broad diversity of land-uses.

A Green Infrastructure is intended to protect a wide variety of natural areas and ecosystems as well as including provisions for the protection of working lands and cultural heritage sites. This distinguishes Green Infrastructure plans from previous types of environmental planning. The plan should also contain information about the geographical distribution of the Green Infrastructure network. The network should be easily accessible, with equitable distribution of green spaces throughout the planned area because there is a strong need for nature that is easily accessible to residents. Restoring hub and linkage gaps is a crucial component to any Green Infrastructure plan, as most network designs will contain holes in the form of developed or degraded lands (McDonald et al., 2005). Gaps within the network are acceptable, as long as they are identified and the need for detailed analysis is accepted (Randolph, 2004). A geographic representation map of the Green Infrastructure network should be included to aid conservation efforts.

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Fig. 1.5 Picture illustrates building a Green Infrastructure for Europe (Source: European Commission, 2013)

Figure 1.5 shows the illustration of planning a Green Infrastructure for Europe. Green Infrastructure planning should be the first step in the land-use planning and design process. Just like our built infrastructure, our Green Infrastructure should be carefully planned, designed, and invested in far in advance of development. Green Infrastructure planning should also be coordinated with planning for gray infrastructure roads, bike trails, water, electric, telecommunication and other essential community support systems. Integrated planning and design should connect the two in a more effective, economic and sustainable network. Green Infrastructure initiatives should use approaches similar to those used for the planning, design and financing of built infrastructure. Green Infrastructure should be:

- (1) *Designed holistically.* Like our transportation system, Green Infrastructure should be designed to link diverse green space elements into a system that functions as a whole, rather than as separate, unrelated parts.
- (2) *Planned comprehensively.* Like our electric power and telecommunication systems, our green space systems need to be planned comprehensively to provide ecological, social and economic benefits, functions, and values.
- (3) *Laid out strategically.* Like our roads and water systems, our green space systems need to be laid out strategically to cross multiple jurisdictions and incorporate green space elements at each level of government.
- (4) *Planned and implemented publicly.* Like our built infrastructure systems, our Green Infrastructure systems should be planned and implemented with input

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from and involvement of the public, including community organizations and private landowners.

- (5) *Grounded in the principles and practices of diverse professions.* Like the design and planning of our transportation, water, electrical and phone systems, green space systems should be based on sound science and should build on the knowledge of professional disciplines such as landscape ecology, urban and regional planning, and landscape architecture.
- (6) *Funded up-front.* Like other infrastructure systems, our green space systems need to be funded as a primary public investment. In other words, Green Infrastructure should be funded up front with other essential services, rather than with money that is left over after all other services have been provided.

Green Infrastructure planning should take place at all scales from the community parcel, to the local, and regional and statewide scales. At the regional level this could mean protecting the connectivity of broad wildlife movement corridors to connect regional ecology. At the local level this could mean designing zones around green spaces. At the community level this could mean creating greenways to link existing parks. Numerous conservation initiatives are occurring across the United States that embody Green Infrastructure concepts and approaches. These projects encompass a diversity of scales and landscape types. The following are a few examples.

(1) Continental Scale and Multi-State Initiatives

- Sky Islands Network: a continental scale conservation initiative linking wilderness areas, parks and reserves and crossing the U.S. Mexico border (www.skyislandalliance.org/siwn.htm)
- Yellowstone to Yukon: a continental scale conservation initiative linking wilderness areas, parks and reserves and crossing the U.S. Canada border (www.rockies.ca/y2y/).
- Southeastern Ecological Framework: a regional conservation assessment identifying diverse ecological green space elements throughout the Southeast (www.geoplan.ufl.edu/epa/index.html).

(2) Statewide Initiatives

- State of Maryland Green Print Program: a statewide scale conservation initiative protecting forests, wetlands, river corridors and other critical ecological areas as a part of the state's Smart Growth initiative (www.dnr.state.md.us/greenways/greenprint/).
- State of Florida Statewide Greenways System: a state wide scale conservation and recreation system that incorporates a linked ecological

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network designed to benefit Florida's wildlife and people (www.geoplan.ufl.edu/projects/greenways/greenwayindex.html)

(3) Regional Initiatives

- Chicago Wilderness Biodiversity Conservation Plan: a regional biodiversity conservation initiative developed by a public, private and nonprofit alliance and incorporating Green Infrastructure concepts and principles (www.chiwild.org/biodiversity.html).
- Twin Cities Minnesota Metro Greenways: a regional Green Infrastructure network design that identifies, protects and restores important ecological resource features in a multi-county metropolitan area (www.dnr.state.mn.us/greenprint/metro-green.html).
- Portland, Oregon Metro Greenspace Program: a regional conservation initiative that protects and restores natural areas and recreational open spaces through a partnership of state, regional and local government agencies and nongovernmental community organizations (www.metro-region.org/parks/parkfuture.html).

(4) Local and Community Initiatives

- Montgomery County, Maryland, Legacy Open Space: a comprehensive open space initiative that will target and protect exceptional resource lands over a 10 year period (www.mc-mncppc.org/legacy/index.html).
- Palm Beach County, Florida, Linked Open Space Network Conservation Greenways/Wildlife Corridors: a community open space and land conservation effort that incorporates a system of conservation greenways, wildlife corridors, trails and other conservation and recreational spaces that benefit both the environment and the community (www.pbcgov.com/pzb/).
- Kinston/Lenoir County, North Carolina, Green Infrastructure Plan: a community Green Infrastructure plan encompassing conservation and recreation objectives as well as hazard mitigation (<http://www.GreenInfrastructure.net/kinstonlenoir.htm>).

Many people believe that Green Infrastructure represents the next generation of conservation action because it forges an important connection between land conservation and land-use planning. Traditional land conservation and Green Infrastructure planning both focus on environmental restoration and preservation, but Green Infrastructure also concentrates on the place, shape, and location of development and its relationship to important natural resources and amenities. Unlike more conventional conservation approaches, Green Infrastructure

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strategies actively seek to promote more efficient and sustainable land-use and development patterns, as well as protect natural ecosystems. As described in the previous section, Green Infrastructure differs from traditional conservation efforts in the following ways:

- It focuses on the protection of connected natural ecosystems as the framework for both conservation and development.
- It recognizes that physical linkage between green space elements is key to sustaining natural ecosystems and landscape processes.
- It emphasizes the importance of planning and protecting Green Infrastructure before development.
- It recognizes the need to connect green space elements across multiple jurisdictions, scales and landscape types.
- It focuses on the creation of a green space vision that excites and engages people and guides implementation actions.
- It considers the needs of both nature and humans addressing both the environmental effects of proposed development and the economic well-being of a community. In doing these entire things, Green Infrastructure also helps provide a framework for development, ensuring that developers, citizens and communities capture the cost advantages of location and create and protect community amenities.

1.2.3 Adaptation to urban flooding with Green Infrastructure

There are several strategies to create a more natural and sustainable way of flood adaptation and storm water management worldwide (Hoyer et al., 2011). These approaches focus on creating adapted cities able to live with flooding and not on attempts to protect the affected sites from water in the first place. A key element of a sustainable approach is the integration of greenways, wetlands, parks, forest preserves, and native vegetation in urban surroundings in order to naturally manage storm water, decrease the risk of flooding, reduce pollution and improve the overall water quality. The Green Infrastructure has successfully been proven applicable even to urban surroundings.

Since floodplains offer incontestable natural advantages there is a general trend towards densification and urban settlements there which continues rapidly. Due to the fact that a considerable proportion of the human population is affected, an increasing effort of implementing hard structured engineered defense can be observed since the middle of the 20th century. There will always remain a high risk of failure when only adapting with structural, hard-engineering measures.

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Even when trying to identify an urban approach to urban flooding it has to be considered that, in most cases, the densely built up surrounding might not be the origin of a flood. Considering these circumstances, flood adaptation for urban areas should review the whole catchment to determine the most effective solution. Even when adequate measures are taken in the appropriate location, flooding will still occur in urban areas. This is the reason for alternative measures usually being designed to rather minimize the impacts than to try control the risks (Jha et al., 2012). The way land is occupied that is one of the key aspects of flood mitigation and adaptation. One aspect is to provide enough space and green areas in river flood plains to let water flow where it is appropriate (White, 2008).

The avoidance of unnecessary flood defenses and natural processes is elementary when trying to create a more sustainable approach to urban flooding. Structural engineering defenses should particularly be avoided where they would remove areas of fluvial or coastal floodplains (Baca, 2009). Not only the areas next to streams are suitable for urban greening (e.g. wetlands, environmental buffer zones) to contribute to a qualified way to reduce flood impacts. A general reduction of sealed surfaces leads to an increased direct infiltration potential of urban areas. As a result, the quantity of runoff is downsized, relieving conventional sewer systems and at the same time enhancing the quality of subterranean water. Accordingly, the impacts of extreme intensities of rainfall are reduced and the probability of severe urban flooding is lowered. However, since there is a high pressure of development in densely built up areas, there is always a lack of free space. In order to be able to use the available space as efficiently as possible and to achieve justifiable land consumption, those areas have to provide multifunctional use. In the wet period, the main purpose of green spaces is to reduce the impacts of flooding, while at other times they can be used for recreation. Moreover, trying to implement Green Infrastructure has other benefits such as reducing the urban heat island effect and the local level of CO² emissions.

Investing in Green Infrastructure seems to be much more cost effective than using conventional flood defenses. It is now realized that it is far less expensive to buy or protect floodplain areas rather than investing in technical structures (McMahon, 2000). Especially, newly industrialized and developing countries should pay attention to manage the expansion of new urban areas in a way which reduces the future impacts of flooding. Particularly in terms of floods, social or economic interests might appear to be of a bigger importance.

Green Infrastructure is capable of reducing stormwater runoff as well as providing buffer volumes for overflowing rivers and thus reduces the impact of flood events in urban surroundings. Wetlands are temporarily flooded green

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spaces that provide storage volume and ecological functions. If catchments feature such areas, peak flows can be buffered significantly. Wetlands have positive effects on the ground water quality and provide additional benefits, such as potential recreational use (Foster et al., 2011). Those biotopes can either be artificially constructed or be natural. In order to protect the ecological functions, polluted runoff coming from high traffic roads must not be discharged directly in these areas (Hoyer et al., 2011). Since wetlands provide multiple ecological benefits, they are highly sensitive to interferences and need maintenance to avoid succession. This fact should particularly be taken into account since the attempt to artificially establish a new ecologically working wetland is very difficult.

Figure 1.6 shows the picture of a wetland park as Green Infrastructure for mitigating the flood events in urban surroundings. Retention ponds are vegetated landscape depressions featuring soil of high permeability. The most important function is that stormwater is drained and filtered from pollutants, and thus the total runoff volume is reduced. Moreover, these interventions have the capacity to detain large amounts of water and buffer peaks of flooding, which additionally reduces impacts downstream. In order to keep the land consumption as low as possible, retention ponds should be designed to provide multifunctional usage in dry periods. The main difference to wetlands is that retention ponds are usually of slightly smaller dimension and that they are not primarily designed to provide ecological benefits. As a result, they are less sensitive, less expensive and easier to maintain compared to wetlands (Hoyer et al., 2011).



Fig. 1.6 Picture illustrates a wetland park in Hong Kong City as Green Infrastructure for mitigating the impact of flood events in urban surroundings

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Moreover, when going beyond the purpose of implementing Green Infrastructure in order to adapt to urban flooding, there are other elements land-use planning is capable of. Since specific ways of exploitation feature specific vulnerabilities, it is obvious that those more sensitive to flooding should be situated in less affected zones. To give an example, a hospital has a very high vulnerability to urban flooding since this function is indispensable in state of emergency. On the other hand, flooding of marginal regions of residential areas is a considerable catastrophe for individuals, but does not have a significant impact on the entire city; hence those areas are defined as less vulnerable. Land-use plans should ideally consider existing flood management plans in order to be able to assess the appropriate use in the appropriate location. Prohibited and buffer zones are most likely defined when identifying special areas of conservation.

1.3 Land–Use Planning Issues of the Makassar Region

1.3.1 Overview of Makassar City

Makassar is the largest city in Eastern Indonesia and the capital of the province of South Sulawesi. It is located on the south-western coast of the island of Sulawesi, facing Makassar Strait. Makassar is part of the Mamminasata metropolitan area which covering the city of Makassar and the regencies of Gowa, Maros and Takalar, (**Figure 1.7**). Mamminasata metropolitan area has a population of about 2.5 million which is expected to grow to around 2.9 million in 2020 (Parasati, 2013). Based on the statistical demographic data in 2012 provided by the government of Makassar City, the population reached approximately 1.4 Million peoples, while the average population growth rate was about 1.5% during the last ten years. Distribution map of the population density in sub-district scales in the Makassar City in 2012 is presented in **Figure 1.8**.

Over the last two decades, the population of the regencies has exceeded the growth of Makassar, though most of the new employment is within the city boundary. Over 86% of the area of Makassar is covered for urban uses, with an overall density of 77 ppHa. Urbanized areas of surrounding regions of Gowa, Maros and Takalar have an even lower density of less than 20 ppHa, scattered over a wide area. The built-up area has expanded far faster than the population, indicating an increasingly lower density of the city. The loss of prime agricultural land would appear to be a major problem throughout Mamminasata, and the

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sprawl is a major contributor to the lack of increase in the productivity of the Makassar City. Moreover, the city is becoming less serviceable as it sprawls.



Fig. 1.7 Geographic location of the Makassar City, the Tallo River Area, and the Mamminasata region

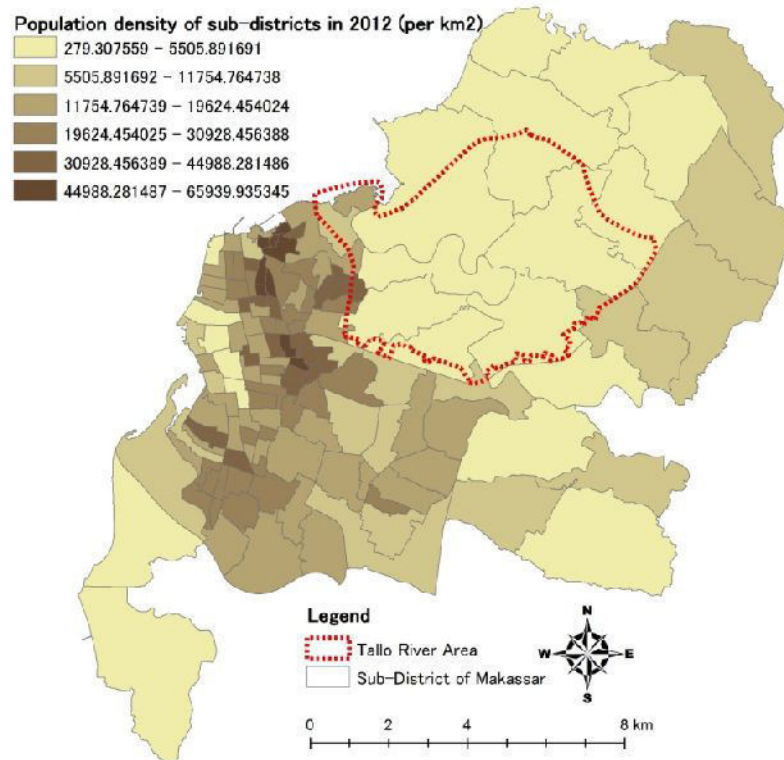


Fig. 1.8 Distribution map of population density at sub-districts based on the demographic statistical data in 2012

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1.3.2 Urban flood disaster management issues

Since 1900 flooding in Indonesia is ranked as the second most frequent and fourth most economically damaging natural disaster after wildfires, earthquakes and volcanic eruptions, causing an estimated 4,493 deaths, affecting 6.2 million people and resulting in US\$ 2.4 billion in damages (Riyanti et al., 2011). Of the 90 flood events recorded since 1900, some 47 have occurred since 1998 resulting in 2,592 deaths, affecting 3 million people and causing financial losses of US\$ 1.6 billion. In the same time period Indonesia recorded more flood disasters than any other South-east Asian country. Flood incidences are perennial occurrences and have been increasing in severity during the past decade, especially in Jakarta where the multiple threats of rapid and poorly controlled urbanization, combined with severe watershed degradation, have increased run-off substantially. A combination of inadequate retention basins, an under-sized drainage network and land subsidence has created the conditions for prolonged and extensive flooding during high rainfall events. The floods of January 1996, February 2002 and February 2007 were especially devastating. The 2007 event inundated 235 km², about 36% of the city by up to several meters in some areas. The 2007 flood affected more than 2.6 million people and forced 340,000 to flee their homes. Over 70 people died and outbreaks of disease caused by the flood waters affected over 200,000 people. The estimated financial and economic losses from the 2007 flood amounted to US\$ 900 million.

Prolonged flooding in urban areas of Indonesia is a regular occurrence and appears to be on the increase due to a combination of reduced water retention capacity, expanding urbanization with the inevitable increase in non-absorptive surfaces, watershed degradation and a reduction in the hydraulic capacity of urban drainage systems caused by a multitude of factors, chief among which are broken and blocked drains and serious under-funding of the sector especially in operation and maintenance. Reliable data on urban drainage at the national level and in particular urban flooding, the most damaging manifestation of a failure by government to cope with heavy rainfall events and consequent high run-off, are difficult to come by. The National Geospatial Agency of Indonesia has produced an Indonesian Flood Hazard Map Based on data provided by the National Action Plan for Disaster Risk Reduction (BNPB) that provides a flood risk level map using three categories of risk from high, medium and to low for each area. The scale is, understandably, very small and areas mapped under each category far too large and generalized to be of value in assessing the flood risk within a particular city or, for that matter, the major cause or causes of the flooding.

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The causes of flooding in cities vary according to geographical location, topography, land-use and watershed condition, and this is reflected in the BNPB's criteria for determining flood risk. Cities located on the coast within an extensive coastal plain such as Makassar which are subject to flooding from inland and from the sea. Those cities in experience the most extensive and damaging flooding because of their low-lying position and the additional flood threat from the sea. Flooding in urban areas of Indonesia is a recurrent event that appears to be on the increase for a variety of reasons, most of which are well known. The floods inflict millions of dollars worth of direct and indirect economic and financial losses to the state and to individuals through damage to property and infrastructure and lost productivity. The causes of flooding are many but the initial trigger for a flood is a high intensity rainfall event either directly over the urban area or in the catchment of the urban area. Whether rainfall intensities have increased in recent years and will continue to do so as a result of changes occurring in the world's climates, or whether intensities have remained the same but runoff increased as a result of urban expansion and land-use changes, the fact remains that river discharge peaks are often more frequent and of greater magnitude than before. Increased urbanization, reduced water retention capacity, out-dated drainage design, blocked drains and land subsidence exacerbate the impact of the increased river discharges and resultant flash flooding. In coastal locations, flooding is often a two-directional event with upstream flooding from river discharge combining with flooding from the sea during high tide events and storm surges. This situation is compounded by the low lying nature of the land and the difficulty of achieving gravitational drainage seawards. Flooding is a serious and regular occurrence in many parts of Makassar, especially during the wet season. The specifics of flooding in Makassar are described as follows.

- a) Overflow of the River Tallo Area creates ponds of water in the housing estates, all of which have a high population density.
- b) The lack of areas with a formal drainage system.
- c) The inability of the water catchment area to absorb the volume of water produced during high rainfall events combined with the inadequacies of the urban drainage network and the exacerbation of the flood problem when high rainfall and high tides coincide.
- d) High sedimentation in tertiary and secondary drains due to blockages by solid waste and sediment.
- e) Many drainage channels have been covered as a result of urban expansion and thus it is difficult to normalize the channel.
- f) Population growth and rapid urban development have caused changes in

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land-use. Areas that used to be agricultural land or forest has been converted into housing estates and industrial areas. This trend has spread out to nature reserves, protected forest and conservation areas that should act as water catchment reserves. The impact of such development is seen in the increasing volume of runoff during the rainy season, frequent drought during dry season and highly variable river base flows throughout the year.

Therefore, the Municipality is taking steps to prevent the flood problems through an integrated approach to urban drainage that takes into account engineering, environmental, social and economic aspects. Hence, adaptation to urban flooding with Green Infrastructure should be taken to promote urban development planning in future.

1.3.3 Tallo River Area development plan

Tallo River has a catchment area of 407 km² starting at Mount Kallapolompo (elevation 725 m), and the main river is 72 km long. The lowland of the river extends from beyond the city limits, with a slope of less than 5%. The riverbank is in its natural state or made of earthen walls to fishponds, without flood-control works. Most of the length of Tallo River in the project area appears in natural condition, with most of the river flanked by mangrove and nipah palm. In fact humans have planted the trees along embankments built for fish and prawn ponds. Most of the river is shallow, and will require dredging to increase its capacity to handle flooding. There has been a significant loss of fish population in recent decades, and most fishing is now in the open sea.

Nevertheless close to the city centre, Tallo is a large area of undeveloped land, the large area of wetland on downstream Tallo River, seen clearly on the accompanying picture (**Figure 1.9**). This hole in the urban area covers much of the original Tallo kingdom, with its centre at the mouth of the river. Therefore, the Downstream Tallo River Area has special significance for two reasons. One is the location of the ancient Tallo kingdom, and second is largely untouched by urban development. Since regional autonomy in 2001, Makassar city has proposed to develop this area as a cultural centre and green centre for the city. This is endorsed in the Mamminasata spatial plan (2006) which identifies the river as a special development area. The city's spatial plan identifies three special development areas: i) The Tallo Heritage City focusing on Tallo District, ii) Tallo River integrated development area, and iii) Lakkang Island protected area.



Fig. 1.9 Bird-eye picture shows the downstream of the Tallo River Area

In Tallo River Area, the peninsula to the south of the river mouth is proposed to be developed as Heritage City, behind which the river is to be retained in a natural state as a city park and green spaces. This park will be surrounded by a levee with a main road thoroughfare with high density mixed-use development along it facing the park. Behind this, a large area will become flood-free for development of industry, warehousing, education and housing. In the middle is Lakkang Island which will be retained as a rural community. Hence, converting the land-use of the Tallo River Area will require data coordination, spatial analysis and integrated planning to ensure that the potential natural, economic, and social development arising from future urbanization are optimized to improve the quality of life, ecological restoration, and mitigate the flood risks.

1.4 GIS for Green Infrastructure Evaluation

1.4.1 GIS and geospatial model

Geographic Information System (GIS) is one of the most evolving aspects of geospatial technology. It evolved from desktop application in the 1980s into enterprise GIS in the 1990s and into distributed GIS. Even the technology of distributed GIS is evolving. It has changed from mobile GIS to web GIS and it is currently developing into cloud GIS (Longley et al., 2001). Many research studies

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on varying spatial issues of global concern such as global warming and sea level rise, urbanization, and environmental management. The world as a whole is becoming highly geospatially-enabled and there is the need to study trends and patterns and also communicate these phenomena with the evolving spatial technologies such that end users would benefit from this advancement in technological development. Since climatic changes and human activities could amount to the degradation of our natural environment, there is the need to acquaint ourselves more and embrace the vast emerging geospatial technologies in solving a number of environmental challenges to humanity today (Goodchild et al., 2011). Geospatial technology is the specialized set of information technologies that include Aerial Photography, Remote Sensing, Surveying, and Global Positioning Systems that support a wide variety of uses. This stretches from data acquisition to data storage, manipulation, image analysis, geo-visualization and display and data output. These disciplines if properly harnessed and globally would play enviable roles in the sustainability of our environment (MacDougall, 2011). Some of the identified GIS applications of geospatial technology globally include the following:

- Flooding, environmental degradation and climate studies,
- Agriculture and Precision Farming,
- In the Health Sector and Paramedics,
- In the Mining and Extractive Industry,
- City planning, Transportation, Communication Network designs and in Aviation Industry,
- Traffic and Accident control and prevention,
- Crime Mapping and hot-spots delineations,
- Land-use and Land cover Studies for sustainability,
- General Developmental control and resource inventory and allocations,
- Emergency planning and alternative route development,
- Development of agronomical data and early warning data for food security issues, and
- Preservation of wild life and biodiversity.

1.4.2 Spatial analysis of Green Infrastructure network

Green Infrastructure is described above as a tool for providing ecological, economic and social benefits through natural solutions, helping us to understand the advantages nature offers human society and to mobilize investments that sustain and enhance these benefits. This explicitly relates to the exclusive use of

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expensive grey infrastructure which typically only fulfils single functions such as drainage or transport, whereas nature often provides multiple solutions that are also cheaper, more robust, let alone more sustainable economically and socially. One of the major attractions of Green Infrastructure is its ability to perform multiple functions on the same piece of land and/or water (**Figure 1.10**). These functions can be environmental (e.g. conserving biodiversity or adapting to climate change), social (e.g. providing water drainage or green space), and economic (e.g. supplying jobs and raising property prices). Such as Green Infrastructure has the potential to offer win-win solutions by tackling several problems and unlocking the greatest number of benefits within a financially viable framework. The benefits are expressed in functions and services provided by ecosystems, which are the basis for Green Infrastructure. They include provisioning services such as fresh water and wood; regulating and maintenance services such as pollination and climate control; and cultural services such as recreation and cultural benefits. The roles of Green Infrastructure elements do not always fall into distinct categories during practical implementation. They are highly interdependent. For example, societal wellbeing in coastal and river areas depends on flood retention by wetlands or natural drainage systems, which in turn depend directly on the provision of ecosystem services, such as soil and water retention. These in turn are highly reliant on biodiversity to uphold the health of the ecosystems to provide ecosystem services. Another example is the case of Natura 2000 sites which are key natural areas but with the increasing emphasis on ecosystem protection, they tend also to include elements of ecological corridors.

GIS and geospatial technology serves as a good decision support system and tools in environmental issues and sustainability as well as Green Infrastructure planning. It has been proved as an appropriate tool for managing decisions relating to environmental concerns and spatial analysis of Green Infrastructure network issues (Goodchild et al., 2011). Land-use changes can be monitored by means of readily available remotely sensed imageries and aerial photographs of different spatio-temporal resolutions which can be analyzed. Furthermore, the use of GIS enhances a better means or techniques of spatial data capture and the distribution analysis. This could be done in real time and thus will reduce the time and energy needed in data acquisition for solving Green Infrastructure network problems. Therefore, GIS spatial analysis has enabled the use of geospatial data and application of satellite/space techniques to solve a number of environmental related problems such as identification of Green Infrastructure elements. Identification of Green Infrastructure elements can thus be approached at different scales, depending on the study's objective:

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- Landscape-level analysis (at a proposed maximum resolution < 1 km) is to identify rural Green Infrastructure elements or ecosystem services and functions (capacity). The connectivity among different Green Infrastructure elements has to be analyzed on a case-per-case basis, since it might be necessary for landscapes planning.
- Local-scale analysis (at a recommended resolution < 100 m) is to identify urban Green Infrastructure such as parks and green patches, among others.

In additional, spatial connectivity analysis can be essential in these Green Infrastructure networks. The development of a conceptual framework for the definition and mapping of Green Infrastructure elements should be considered as a first step to produce a spatial analysis model and methodology that can be used for assessing a number of ecological functional areas and their connectivity.



Fig. 1.10 Key attraction of natural solutions is its multi-functionality, i.e. its ability to provide several functions and benefits on the same spatial area (Source: Ecotec & NENW, 2008)

1.5 Research Design and Stages

1.5.1 Research objectives and methodology

Green Infrastructure refers to a strategically planned and managed network of green spaces and other environmental features vital to the sustainability of any urban area. Besides, Green Infrastructure is also a term used to refer to strategies for handling storm water. With regard to the evaluation form of Green Infrastructure planning in Tallo River Area, Makassar City, Indonesia, it will be necessary to take advantage of the multi-functionality and regional uniqueness of Green Infrastructure such as wetlands, mangroves and other natural features serve to protect coastlines and flooding, which are its most important local characteristics. Hence, Tallo River Area should be designed and managed as multifunctional resource capable of delivering a wide range of environmental and quality of life benefits, including maintaining and improving ecological functions, climate change adaptation, and flood mitigation and management. Therefore, the main objectives of this research are divided into two parts:

- to evaluate prospective Green Infrastructure across Tallo River Area by GIS through analyzing the spatial multiple functionality i.e. ecological connectivity and flood disaster risk of the regional scale of Makassar City; and
- to propose the Green Infrastructure planning within Tallo River Area according to the development plan of local government where there are gaps or areas of need and investigate the issues, opportunities, threats and priorities to put into evaluation design.

The overall methodology concept of Green Infrastructure evaluation is based on the steps summarized in **Figure 1.11**. The study has two entry points that illustrate the multi - functionality of Green Infrastructure: i) ecological connectivity evaluation, and ii) flood disaster risk evaluation through land use development and analysis. The first stream of analysis is the evaluation and mapping of ecological connectivity index at regional scale of Makassar City. The second stream of analysis is the evaluation and mapping of flood disaster risk. Having identified the spatial coverage of the ecological connectivity and flood disaster risk, the next step in the assessment is the spatial analysis of Tallo River Area for Green Infrastructure planning. This involves the identification of detailed development components of Tallo, and the establishment of key issues for Green

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Infrastructure plan, for example ecological connectivity which can includes the potential demand for a given ecological service, the socio-economic factors such as food production and access to green spaces, or consideration for ecological protection of endangered species. The resulting identified elements of Tallo River Area are then aggregated for Green Infrastructure network analysis that identifies multiple functionality areas for conservation and/or restoration based on the delivery of good ecosystem services and flood disaster mitigation. Accordingly, relevant spatial components of Green Infrastructure across the Tallo River Area should further be analyzed and explored to reveal whether the data is appropriated in GIS model that it can be used for mapping Green Infrastructure network.

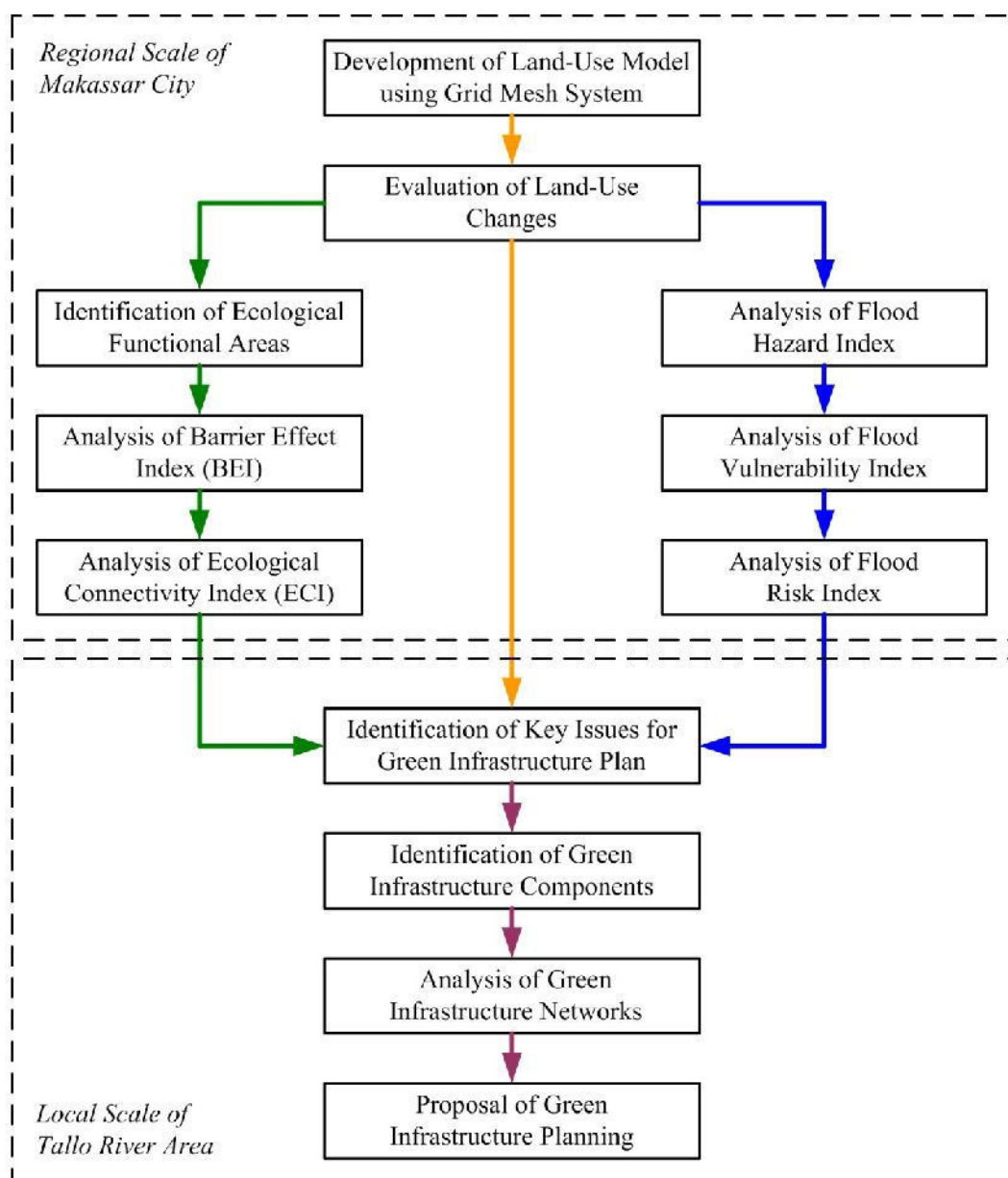


Fig. 1.11 Overall research methodology of Green Infrastructure evaluation

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Thus, evaluation of Green Infrastructure planning across Tallo River Area can be approached at local context and scales. The methodology proposed in this research is enabling to process the analysis of interdependent and connectivity among Green Infrastructure components on case-per-case basis, using a GIS. The identified and mapped Green Infrastructure components could be integrated into several networks, as aggregated in GIS, and aggregated components could then be spatially analyzed based on the theoretical model.

1.5.2 Phases of research and thesis structures

In order to perform an analysis of Green Infrastructure evaluation within GIS, research challenges and stages that need to be tackled are:

- 1) Construction and mapping of land-use series of the Makassar region using geospatial information available at regional scale analysis, and simulation of land-use changes to examine the detail of urban transition phenomena during 15 years;
- 2) Development model of ecological connectivity evaluation by conducting the spatial analysis of ecological functional areas, evaluation of ecological barrier index analysis, and evaluation of ecological connectivity index analysis at Makassar region;
- 3) Development model of flood disaster risk evaluation by performing the spatial analysis of flood hazard index, evaluation of vulnerability to floods, and evaluation of flood risk index analysis at Makassar region; and
- 4) Establishment of a proposal of Green Infrastructure planning of Tallo River Area by considering the spatial multiple functional analysis of the Green Infrastructure components and by taking into consideration their connectivity.

In this research, the thesis consists of six chapters that are briefly described as follows.

Chapter one (1) provides a brief introduction to the description of the sustainable urban development involving the sustainable and site design, site data and analysis concepts. By the literature reviews, definitions of Green Infrastructure by the Country regions such as United States, European Countries and Japan have been described in this chapter. As a research background, development of urbanization and land-use planning issues in the Makassar region have been presented to point out the major issues that need to be studied. An introduction of GIS for the utilizing geospatial information, data analysis and methodology has been given to illustrate the capability of GIS for Green

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Infrastructure evaluation study. The major challenges for spatial analysis of Green Infrastructures are also described. Overall overview of the research design and stages is presented in the end of Chapter 1.

Chapter two (2) describes the development methodology of land-use mapping using GIS and the grid mesh system. The roles of GIS for utilizing available geospatial information at regional scales for constructing the land-use map series are presented. An analysis of the land-use changes during 15 years in the Makassar region has been done. Detail analysis of spatial and temporal urban transition simulation is presented. Furthermore, analyses of the land-use value changes into other values have been discussed in this chapter. By the evaluation study of the land-use changes, degradation of land-use areas have been identified clearly and further research stage of ecological connectivity evaluation can be developed and discussed in next chapter.

Chapter three (3) presents the methodology of the evaluation of ecological connectivity using GIS modeling approach and development of spatial model of ecological connectivity index. Identification of ecological functional areas for different spectrum sizes has been analyzed and the ecological functional areas of Makassar region have been developed. Barrier effect index modeling has been conducted by GIS model. Analyses of barrier effect index changes have been discussed in this chapter. Establishment of resultant maps for ecological connectivity index is performed. Analyses of ecological connectivity index changes during 15 years in Makassar region have been conducted. Furthermore, a differentiation analysis of ecological connectivity index due to urban transition of Makassar City is presented to describe the effect of urban expansion to the negative changes in connectivity.

Chapter four (4) focuses on the evaluation of flood disaster risk of Makassar region. The available statistical data, geospatial information and flood hazard map for evaluation of flood hazard, vulnerability to flood and flood risk is discussed. A flood research scenario by the recent flood hazard information provided by the local government is also discussed. An evaluation of vulnerability to flood at local context involved the indicator composition of the social, economic, physical, and environmental components is performed. Establishment of flood vulnerability component maps has been conducted in this chapter. Flood assessment risk map has been established and analysis of flood risk index at local scale has been discussed to describe the flood risk and potential impact level at sub-districts.

Chapter five (5) deals with the zoning analysis at Tallo River Area for the evaluation of Green Infrastructure planning. The existing situation, detailed development component plan by local government is described in this chapter.

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Identification of key issues for Green Infrastructure plan has been performed to point out the Green Infrastructure opportunities assessment. Development of Green Infrastructure components and network analysis has been conducted in this chapter. The proposal of Green Infrastructure network planning is discussed and the comparative study with the Tallo project planned by the local government is also presented.

Chapter six (6) gives an overall discussion and conclusions of my current study. Furthermore to continue address the remained research issues, a future approach are discussed.

1.6 Summary

By the literature reviews, definitions of Green Infrastructure by the Country regions have been discussed. Connectivity is a key element of Green Infrastructure plans, not only within elements of the Green Infrastructure plan itself, but the plan should also create connections between local institutions and people. The goal of a network design is to delineate an interconnected Green Infrastructure system that incorporates both benefits to nature and to people.

CHAPTER 2

Spatial Analysis of Land-Use Changes Evaluation

2.1 Development of Land-Use Maps

2.1.1 Land-use model by Geoprocessing analysis

Models of land-use change are tools to support the analysis of the causes and consequences of land-use changes in order to better understand the functioning of the land-use system and to support land-use planning and policy. Models are useful for disentangling the complex suite of socio-economic and biophysical forces that influence the rate and spatial pattern of land-use change and for estimating the impacts of changes in land-use. Furthermore, models can support the exploration of future land-use changes under different scenario conditions. Summarizing, land-use models are useful and reproducible tools, supplementing our existing mental capabilities to analyze land-use change and to make more informed decisions (Costanza and Ruth, 1998). The group of descriptive land-use change models represents a wide variety of modeling traditions and theoretical backgrounds. Reviews that characterize and classify land-use models are provided by Lambin (1997) and Kaimowitz and Angelsen (1998) for deforestation, Miller et al. (1999) for integrated urban models, Lambin et al. (2000) for agricultural intensification models, and by Bockstael and Irwin (2000) for land-use models based on economic theory. Agarwal et al. (2001) reviews a selection of 19 models based on their spatial, temporal and human-choice complexity. Briassoulis (2000) gives a more extended review of all types of land-use models. In this current study, we will not conducted such characterization models, but focus on development of grid-mesh based land-use map from a number of topology features of historical land-use systems from hardcopy or digital data that need to be taken into account by historical land-use changes evaluation. Based on the previous of topology features provided by local government, a spatial grid-mesh model of land-use has been conducted, for creating a grid-mesh matrix of land-use values, and these matrix values are used in land-use change simulation models.

In this research, Geoprocessing tool is used that one of the most powerful components of a GIS modeling. Geoprocessing is a framework and set of tools for processing geographic and related topology data. The large suite of geoprocessing tools can be used to perform spatial analysis in an automated way. By the regional scale of boundary analysis of Makassar City, the grid-mesh system with 50 meter size was selected to obtain the aggregated values of land-use. Land-use maps in 1997 and 2012 were developed from the availability of topology features of 1:50.000 scales which data is provided from the local government of Makassar City. **Table 2.1** shows defined categories for land-use values from the topology features in the Makassar region for 1997 and 2012.

For construction of land-use map using a grid-mesh system, a GIS geoprocessing analysis has been performed. **Figure 2.1** shows the flowchart of GIS geoprocessing methodology for creating land-use model with grid-mesh of 50 meter size. In this GIS process, the defined polygons of land-use boundary from the topology features are intersected with polygon of grid-mesh system. The original of grid-mesh system is created by the orientation of the world grid system. The small scale of grid-mesh system is then converted into 50 meter of size to obtain the standard of grid-mesh for land-use model analysis by the automation process in GIS. **Figure 2.2** illustrates the grid-mesh system development from the global grid-mesh system into the regional grid-mesh of 50 m size. The intersected land-use polygon with grid-mesh of 50 meter size is spatially calculated to select the maximum area of land-use value in each of the grid-mesh feature. Maximum area of the land-use value will be then calculated in the grid-mesh polygon and it's converted into point data. The grid-mesh polygon of 50 meter and the converted points are analyzed by spatial joining to define the single of land-use value in each grid-mesh. Accordingly, grid-mesh based land-use can be easily constructed.

Table 2.1 Land cover categories from the topology features of the land-use systems in 1997 and 2012

Land cover	
B ₁	Urban
B ₂	Water
B ₃	Fishpond
C ₁	Forest
C ₂	Mangrove forest
C ₃	Swamp field
C ₄	Paddy field
C ₅	Garden field
C ₆	Shrub field
N ₁	Crop field

SPATIAL ANALYSIS OF LAND-USE CHANGES EVALUATION

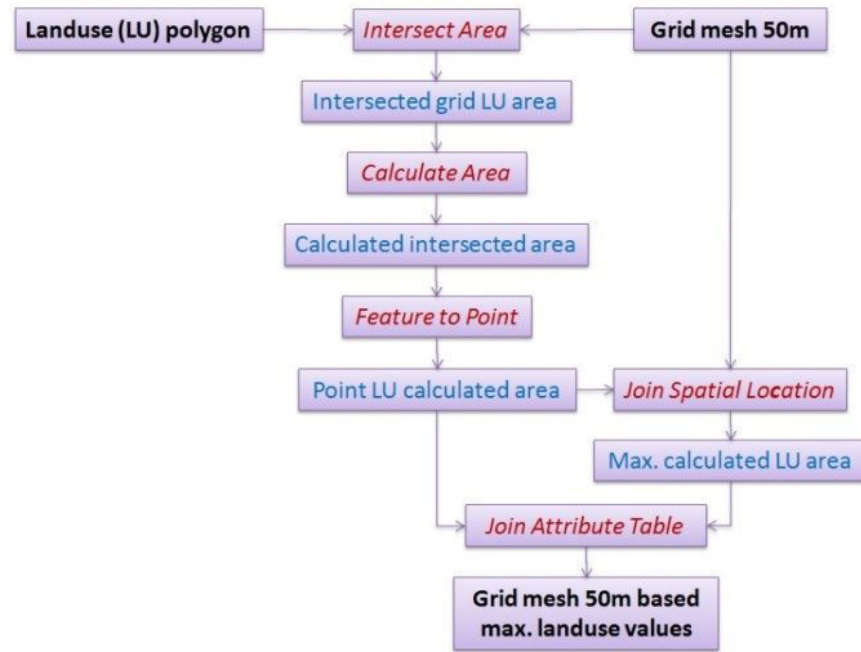


Fig. 2.1 Flow chart of geoprocessing model methodology to create the land-use matrix model with grid-mesh of 50m size

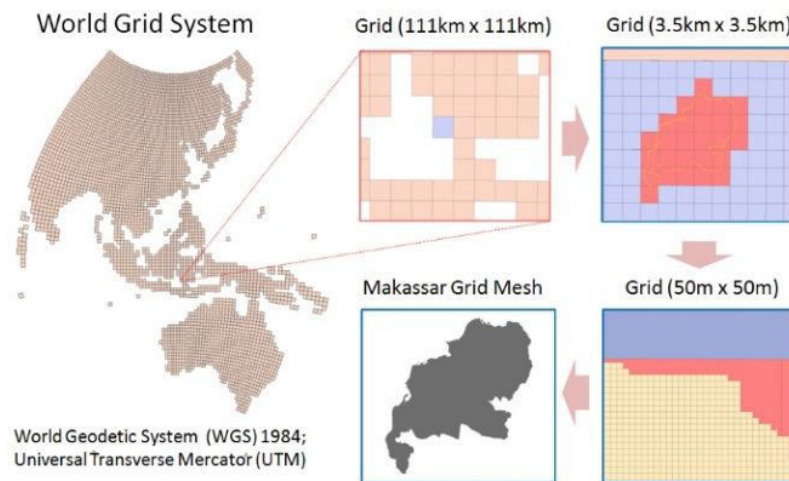


Fig. 2.2 Illustration of the original grid-mesh system to obtain the regional grid-mesh system of 50 m size for land-use map analysis unit

2.1.2 Grid-mesh based land-use map in 1997 and 2012

During 15 years period, the land-use changes are important to simulate for the Makassar region. Availability of topology features of the land-use system both in digital and hardcopy are obtained in the year of 1997 and 2012, by the scale of 1:50,000. **Figure 2.3** and **Figure 2.4** presents the construction of the grid-mesh based land-use maps in 1997 and 2012, respectively.

SPATIAL ANALYSIS OF LAND-USE CHANGES EVALUATION

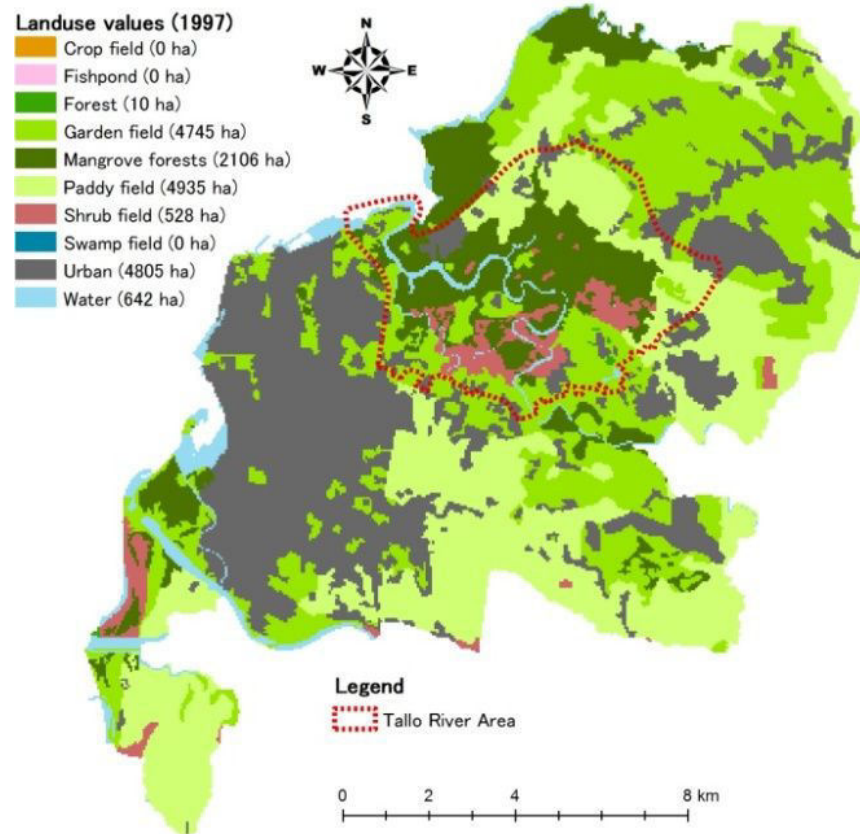


Fig. 2.3 Grid-mesh based land-use map model in Makassar region (1997)

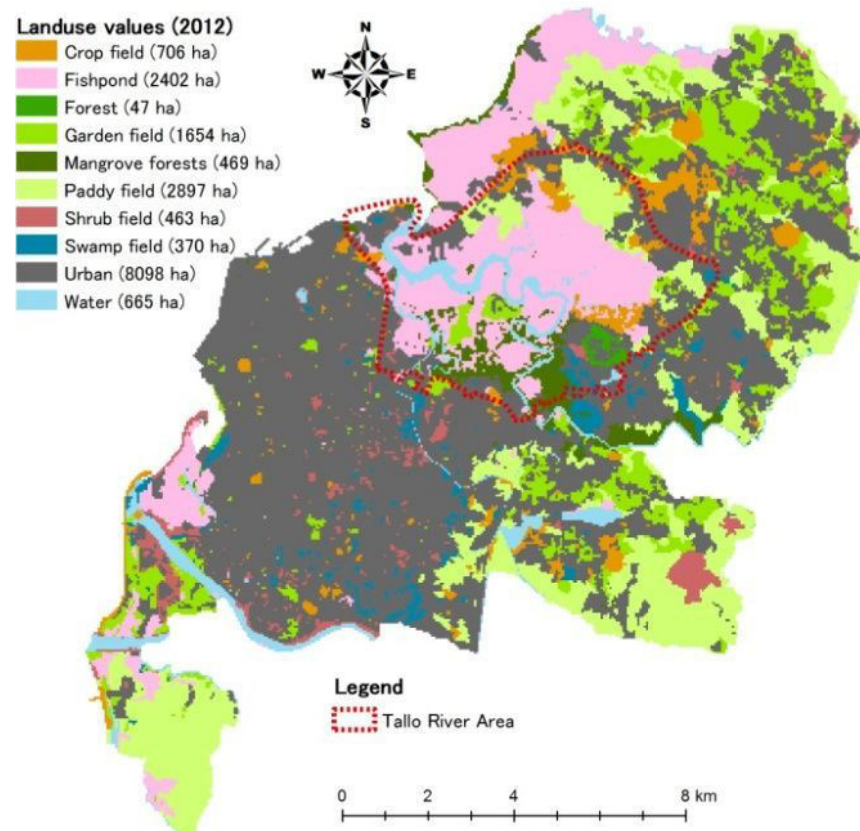


Fig. 2.4 Grid-mesh based land-use map model in Makassar region (2012)

2.2 Spatial Analysis of Land-Use Changes

2.2.1 Evaluation of land-use transition between 1997 and 2012

By utilizing the grid-mesh based land-use maps, a spatio-temporal analysis of land-use transition based on 50 m size (0.25 hectares area size) was performed. **Table 2.2** shows the land-uses for the period of 1997-2012 have shown important changes, which urban surface has grown up from 4,805 to 8,098 hectares which represent almost twice the urban expansion of a 15 years period. In the land-use map of 1997, the existence of crop field, fishpond, swamp field has not been clearly visible. In that year, the population did not extensively affect urban area development. In 1997, Makassar was comprised of 27% urban area, 27.8% paddy fields, 26.7% garden fields, and 11.9% mangrove forests. In 2012, mangrove forest area reduced and the crop land increased the Makassar area. In 2012, urban area has increased to 45.6% of the Makassar area, in contrast to the decrease of paddy fields to 16.3% and garden fields to 9.3%. The increasing phenomena of urban area from 1997 to 2012 have led to the existence of fishpond (13.5%) and swamp field (2.1%) land covers in 2012. In addition, the occurrence of swamp field and fishpond which was counted as 15.6% from the Makassar area, has transformed the pattern of low land mangrove forests and shrubs fields in the vicinity of Tallo River Area. In 2012, mangrove forest area reduced to 2.6% and the crop land increased to 4.0% of the Makassar area. **Figure 2.5** illustrates the land-use compositions of the Makassar region, in 1997 and 2012. Detail land-use transition analysis, for each important of land-use value is described in next section.

Table 2.2 Comparative area of land-use in 1997 and 2012

Land-use values	1997		2012	
	ha	%	ha	%
Crop field	0	0.0	706	4.0
Fishpond	0	0.0	2402	13.5
Forest	10	0.1	47	0.3
Garden field	4744	26.7	1654	9.3
Mangrove forest	2106	11.9	469	2.6
Paddy field	4935	27.8	2897	16.3
Shrub field	528	3.0	463	2.6
Swamp field	0	0.0	370	2.1
Urban	4805	27.0	8098	45.6
Water	643	3.6	665	3.7
Total	17771	100	17771	100

SPATIAL ANALYSIS OF LAND-USE CHANGES EVALUATION

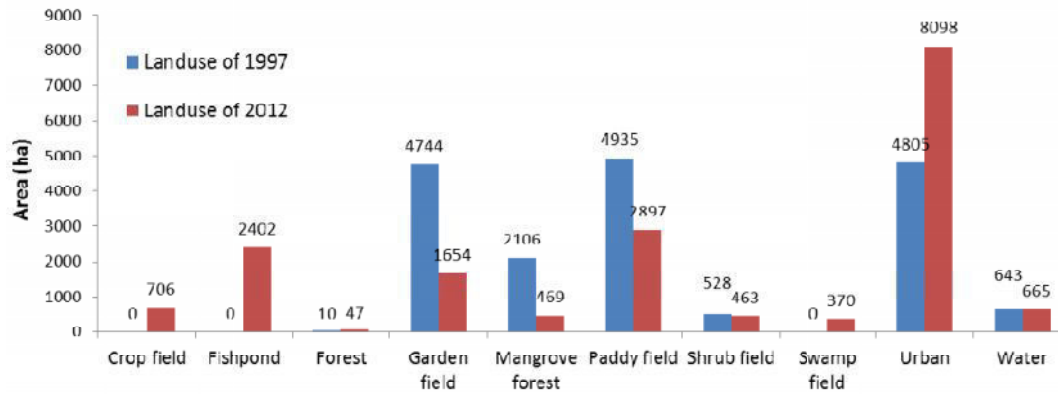


Fig. 2.5 Comparison of land-use values of the Makassar region in 1997 and 2012

2.2.2 Detail analysis of land-use changes

2.2.2.1 Analysis of land-use change of paddy field

Table 2.3 shows the paddy field in 1997 changed to other land-use categories in 2012. **Figure 2.6** shows the comparative the land-use changed in 2012 from paddy field. In 2012, urban area increased to occupy 32.0% of the total area of paddy field. The increasing phenomena of urban area from 1997 to 2012 led to the existence of the crop fields (4.2%), fishponds (4.3%) and swamp fields (3.4%) in 2012. Spatial distribution of paddy fields converted into urban areas is shown in **Figure 2.7**. It is shown in the maps that agricultural fields are mostly occupied by urban area in the South and East part of the Makassar City. This is because during the past one and half decade, Makassar City has experienced rapid urban transformation, represented by significant changes and large-scale expansion of the urban landscape over the agricultural fields. Declines in the intensity of agricultural land-use and farmland abandonment have been discovered in many areas. This has posed additional challenges for the preservation of natural agriculture ecosystems.

Table 2.3 Paddy field converted into other land-use values in 2012

Land-use value		Land-use changed		
Name	Area (ha)	Name	Area (ha)	Area (%)
Paddy field	4935	Crop field	209	4.2
		Fishpond	214	4.3
		Forest	0	0.0
		Garden field	211	4.3
		Mangrove forest	37	0.7
		Shrub field	129	2.6
		Swamp field	170	3.4
		Urban	1581	32.0
		Water	136	2.8
		Total	2687	54.4

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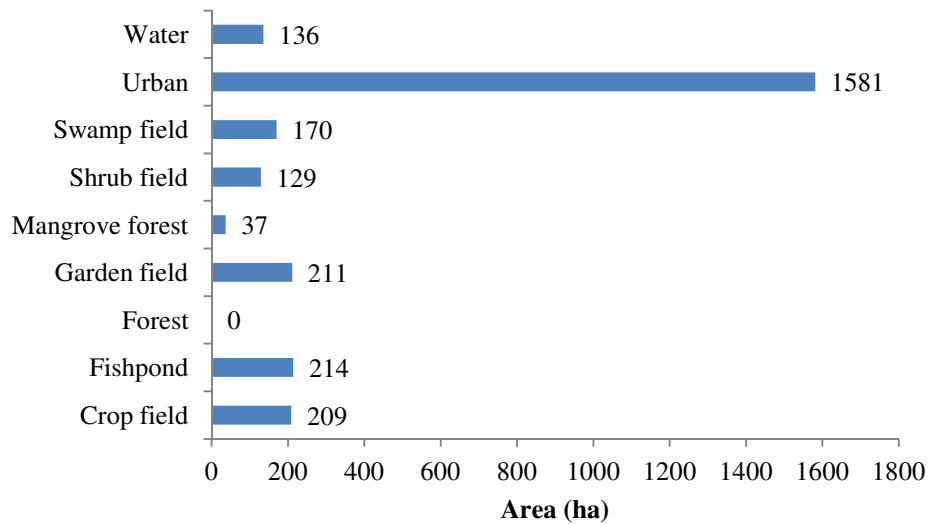


Fig. 2.6 Comparison of the land-use changed in 2012 from paddy field

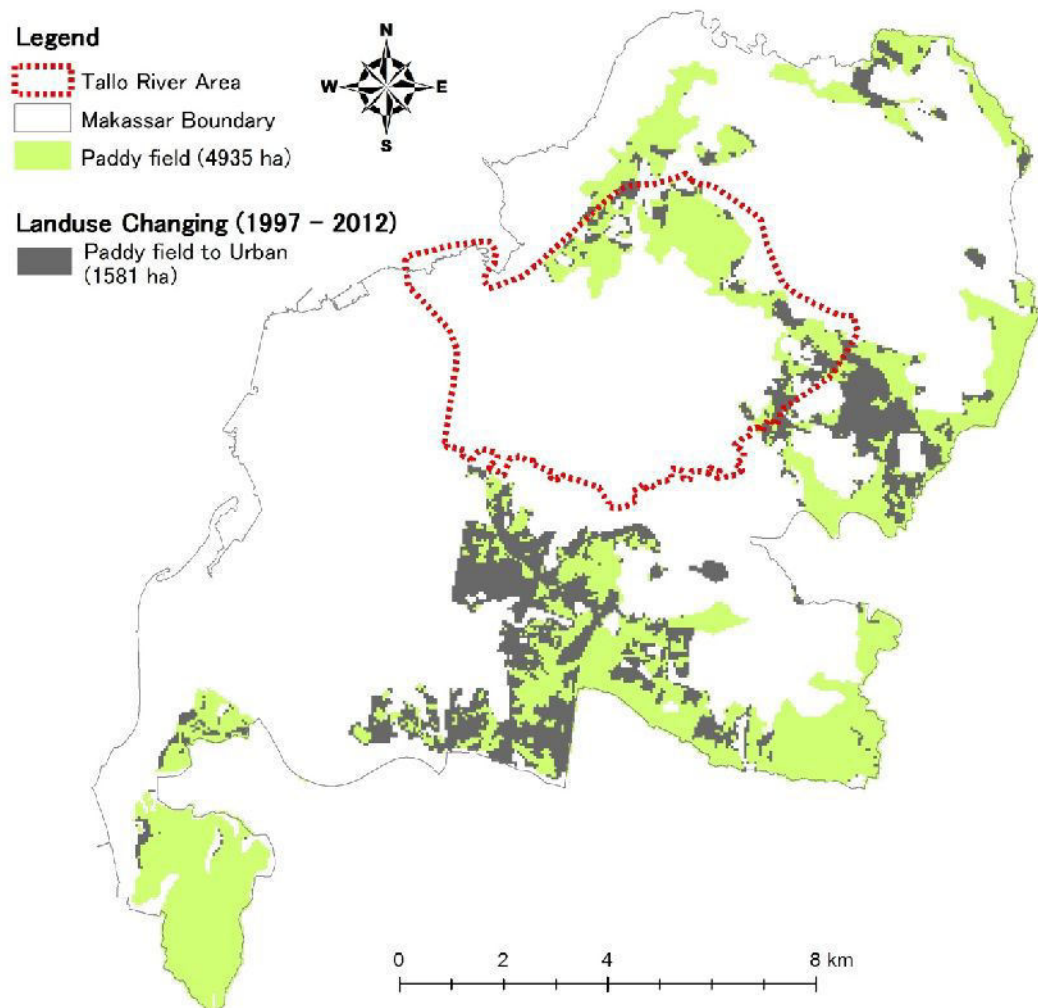


Fig. 2.7 Spatial distribution of paddy field converted into urban area

Moreover, from the land-use transition analysis, it can be noted that in 1997, agriculture played a predominant role, particularly in the plain area in the Makassar region. The availability of water from the river to agriculture irrigation has determined the agriculture development pattern. The population in 1997 was small and distributed in the agricultural villages established to take advantage of the possibilities of irrigation from the Tallo River Area. The population of some sub-districts reflected the urban settlements in the Makassar region. All of the sub-district development was carved out of potentially useful agricultural land and garden land; although the area was very large that has dominated the sub-districts at this time.

2.2.2.2 Analysis of land-use change of garden field

Table 2.4 shows the garden field in 1997 changed to other land-use categories in 2012. **Figure 2.8** shows the comparative the land-use changed in 2012 from garden field. It depicts that the garden fields of 1997 have large changed to other land-use categories in 2012. From the land-use transition analysis, it is found that about 41.3% of garden fields have changed into urban areas. At the same time, some of garden fields converted into paddy fields (10.2%). The increasing phenomena of urban area from 1997 to 2012 have led to the existence of crop field (6.9%), fishpond (6.4%), mangrove forest (2.4%) and swamp field (2.3%) land covers in 2012.

Spatial distribution of garden fields converted into urban areas is shown in **Figure 2.9**. It is shown in the map that urban area spread evenly in the area of garden field in the Makassar region. However, urban expansion can lead to a rise in the off-farm garden opportunities and the resulting food shortage in the garden.

Table 2.4 Garden field converted into other land-use values in 2012

Land-use value		Land-use changed		
Name	Area (ha)	Name	Area (ha)	Area (%)
Garden field	4745	Crop field	327	6.9
		Fishpond	303	6.4
		Forest	38	0.8
		Mangrove forest	483	10.2
		Shrub field	193	4.1
		Swamp field	111	2.3
		Urban	1962	41.3
		Water	65	1.4
		Total	3482	73.4

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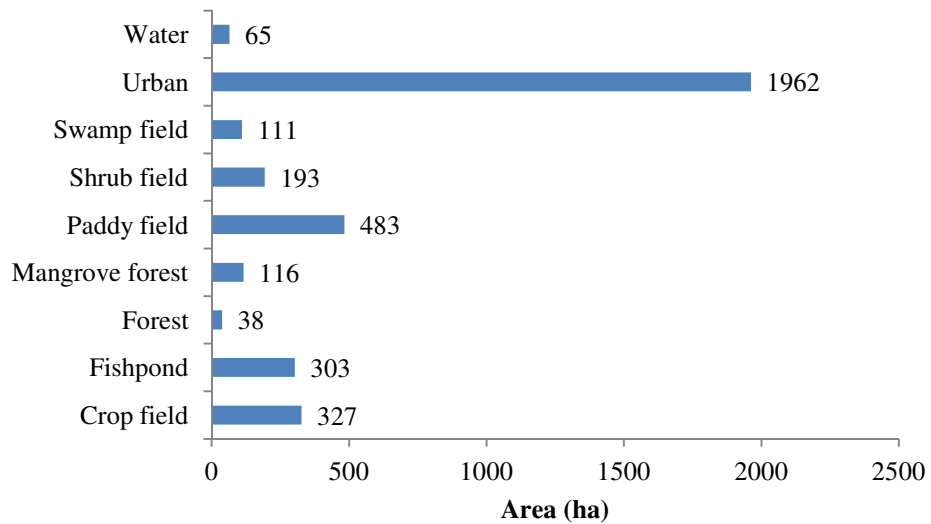


Fig. 2.8 Comparison of the land-use changed in 2012 from garden field

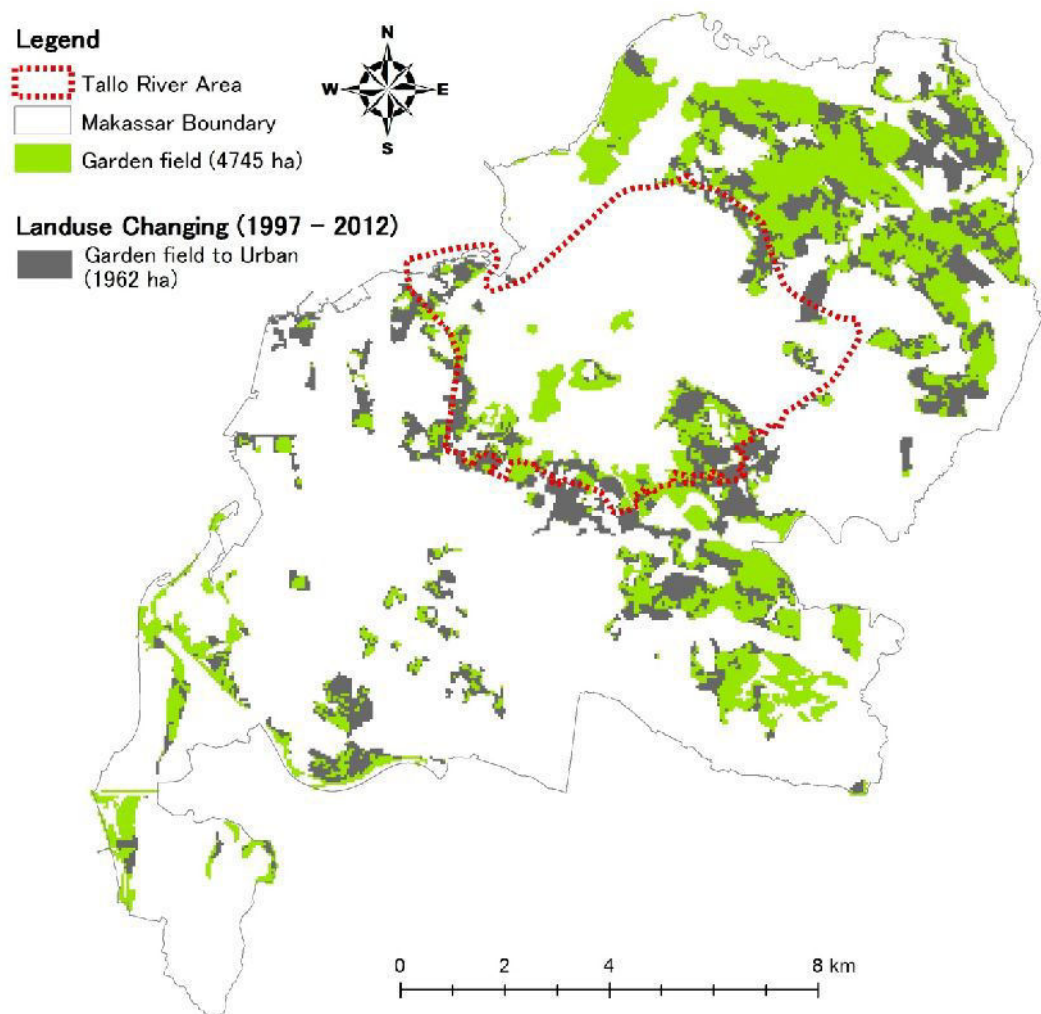


Fig. 2.9 Spatial distribution of garden field converted into urban area

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2.2.2.3 Analysis of land-use change of mangrove forest

Table 2.5 shows the mangrove forest in 1997 changed to other land-use categories in 2012. It is an importance of understanding the dynamic of land-use changes of the Makassar region in a spatial and temporal way to the protection of the degradation of mangrove environment which has been hugely changed into fishpond. **Figure 2.10** shows the comparative the land-use changed in 2012 from mangrove forest. Based on the land-use transition analysis, it is found that about 79.1% mangrove forests have changed into fishpond areas. At the same time, some of mangrove forests have converted into urban areas (4.6%). The Makassar region has lost around 2036 hectares (ha) of mangroves since 2012, equivalent to 96.7% loss of total mangrove areas according to land-use changes assessment study.

Table 2.5 Mangrove forest converted into other land-use values in 2012

Land-use value		Land-use changed		
Name	Area (ha)	Name	Area (ha)	Area (%)
Mangrove forest	2106	Crop field	21	1.0
		Fishpond	1666	79.1
		Forest	0	0.0
		Garden field	32	1.5
		Shrub field	36	1.7
		Swamp field	19	0.9
		Urban	97	4.6
		Water	113	5.4
		Total	1984	94.2

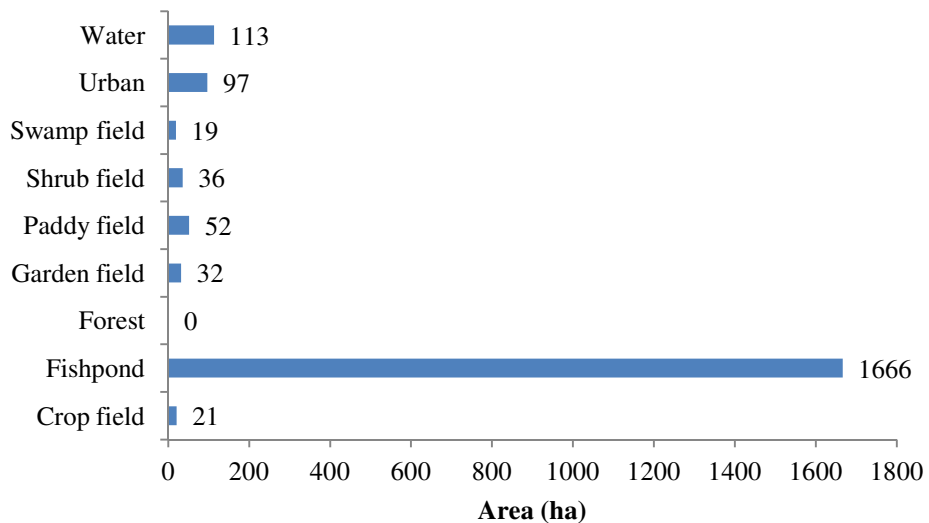


Fig. 2.10 Comparison of the land-use changed in 2012 from mangrove forest

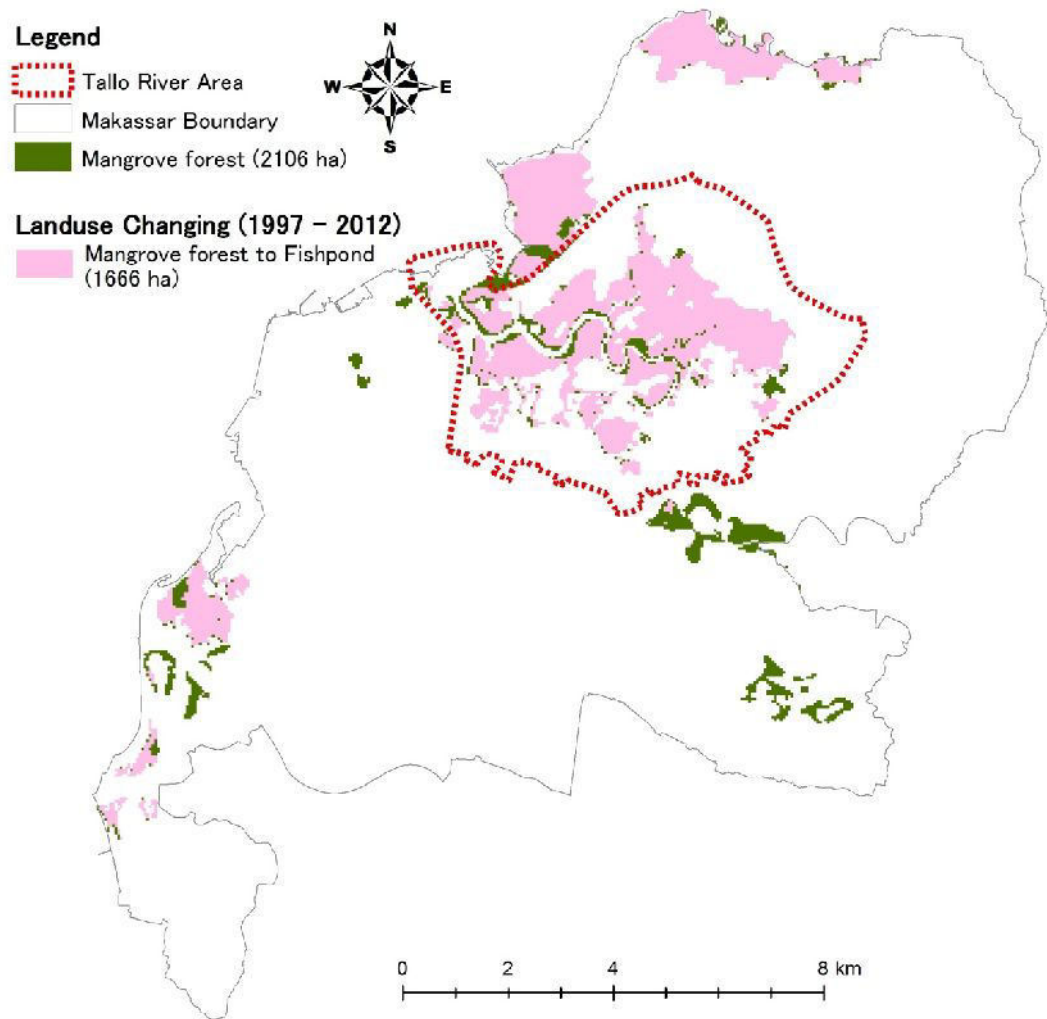


Fig. 2.11 Spatial distribution of mangrove forest converted into fishpond areas

In the land-use map of 2012, large fishpond area is developed due to conversion of mangrove forest for local peoples to do fishery. It is perhaps that in the recent year, the impact of large scale of regular flooding in the vicinity of Tallo river basin as natural drainage area which supported the local peoples to make the fishpond as a livelihood. It is noted that in the Eastern part of Makassar region, the surface land area was bordered by the sea, some of the sea area was assumed as future reclaimed land. Moreover, spatial distribution of mangrove forest converted into fishpond areas is shown in **Figure 2.11**.

2.2.2.4 Analysis of land-use values converted into urban areas

Table 2.6 shows that the land-use values in 1997 converted into urban area in 2012. From the land-use transition analysis, it can be noted that in 2012, garden fields (24.2%) and paddy field (19.5%) are mostly occupied by urban areas of the Makassar City. Comparison of the land-use changed from land-use values to

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urban areas in 2012 can be seen in **Figure 2.12**. Spatial distribution of land-use values in 1997 converted into urban areas in 2012 is shown in **Figure 2.13**.

It is illustrated that most of areas in the Makassar region occupied by urban settlement since 2012. Increased economic development and population pressure on Makassar region are the major drivers for the transformation of land-use values to urban areas. Moreover, the influences of cross-regional migration in the Mamminasata Metropolitan Area are recent issues. The Mamminasata Metropolitan Area is covering the city of Makassar and the regencies of Gowa, Maros, and Takalar with a population of about 2.5 million which expected to grow to around 2.9 million in 2020 (Parasati, 2013).

Table 2.6 Land-use values in 1997 converted into urban area in 2012

Land-use value			Land-use changed	
Name	Area (ha)	Area (%)	Name	Area (ha)
Crop field	0	0.0	Urban	3806
Fishpond	0	0.0		
Forest	1	0.0		
Garden field	1962	24.2		
Mangrove forest	97	1.2		
Paddy field	1581	19.5		
Shrub field	56	0.7		
Swamp field	0	0.0		
Water	109	1.3		
Total	3806	100.0		

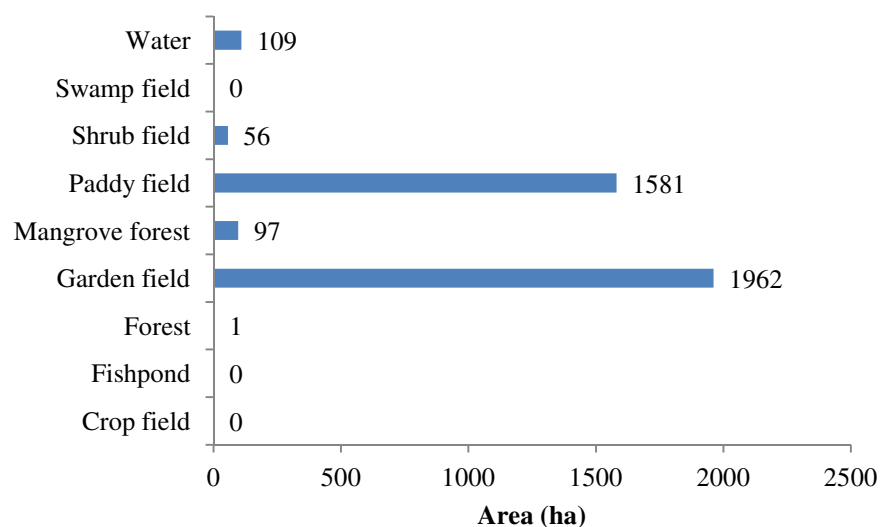


Fig. 2.12 Comparison of the land-uses in 1997 changed into urban in 2012

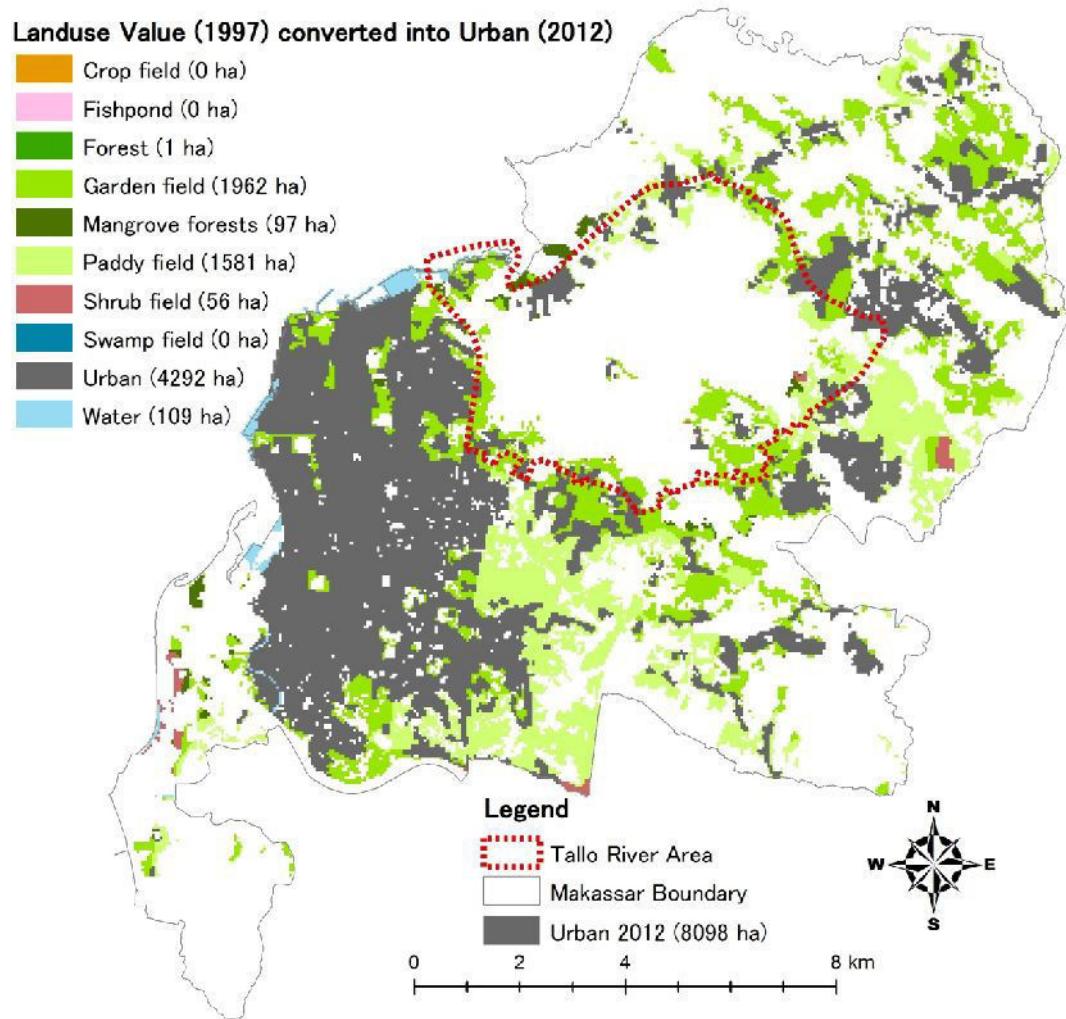


Fig. 2.13 Spatial distribution of other land-use values in 1997 converted into urban area in 2012

2.3 Zone Analysis of Land-Use Changes in Tallo River Area

2.3.1 Land-use planning by local government

Tallo River Area is a large area of undeveloped land and the large area of wetland covered by mangrove forest on downstream Tallo River, and located close to the city centre. This hole in the urban area covers much of the original Tallo kingdom, with its centre at the mouth of the river. Land-use changes in the Tallo River Area are important to study because this is the large open green ecological area remained in the Makassar region. The peninsula to the south of the river mouth is proposed to be developed as Heritage City, behind which the river is to be retained

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in a natural state as a city park and green space. In the middle is Lakkang Island which will be retained as a rural community. This park will be surrounded by a levee with a main road thoroughfare with high density mixed-use development along it facing the park. Behind this, a large area will become flood-free for development of urban in accordance with the city plan.

Therefore, this study evaluates the land-use planning which a proposal by the government of Makassar City to develop the Tallo River Area for new urban development. Prior to the land-use changes in the Tallo River Area, establishment of land-use planning map is necessary to be done. For establishing the land-use planning map, first, a digital data created by the local government was converted into GIS database. Converted data is processed by GIS by data manipulating, editing, updating, and compiling the new spatial data. **Figure 2.14** shows the result of land-use planning of the Tallo River Area which created from the previous data of city plan. Land-use planning categories included 11 land-use values.

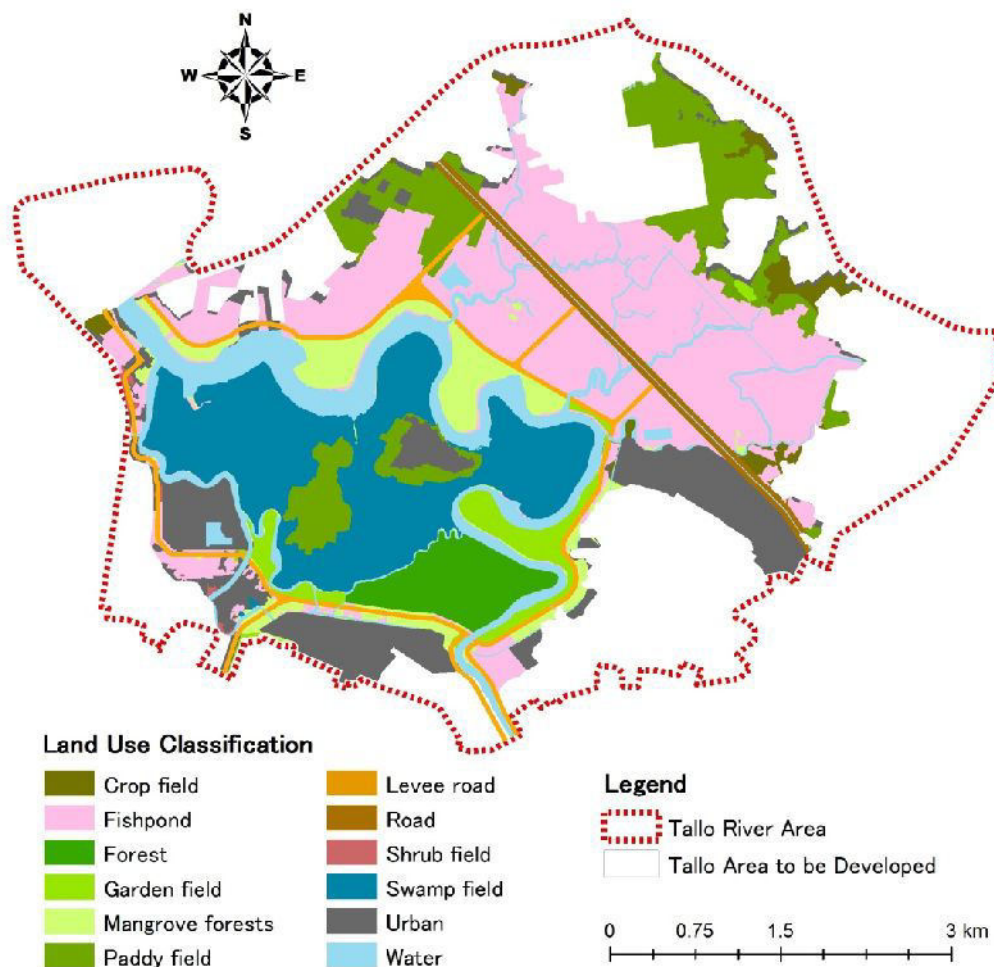


Fig. 2.14 Land-use planning of Tallo River Area by local government

2.3.2 Comparative analysis of land-use values

Figure 2.15 shows the distribution of land-use values in 1997 in the Tallo River Area. In 1997, most of Tallo River Area was occupied by wetland system covered mangrove forest. Shrub field and garden field were also moderately dominant in this area. Distribution of land-use values in 2012 can be seen in **Figure 2.16**. **Table 2.17** shows the comparison of land-use values of Tallo River Area in 1997, and 2012. It depicts that in 1997, mangrove forest, shrub field, paddy field and garden field area has occupied to 50.6%, 16.0%, 12.8% and 12.3% of the Tallo River Area, in contrast to the decrease in 2012 to 10.6%, 0.2%, 9.0% and 3.1%, respectively. Moreover in land-use of 2012, mangrove forest is mostly changed into fishponds. However, remained mangrove forest is still existed sparsely in the West and South part of Tallo River Area. For shrub field, almost all of the area has been disappeared in 2012 due to increased of fishponds. Shrubs and mangroves will be primarily prioritization areas for restoration in Tallo River Area.

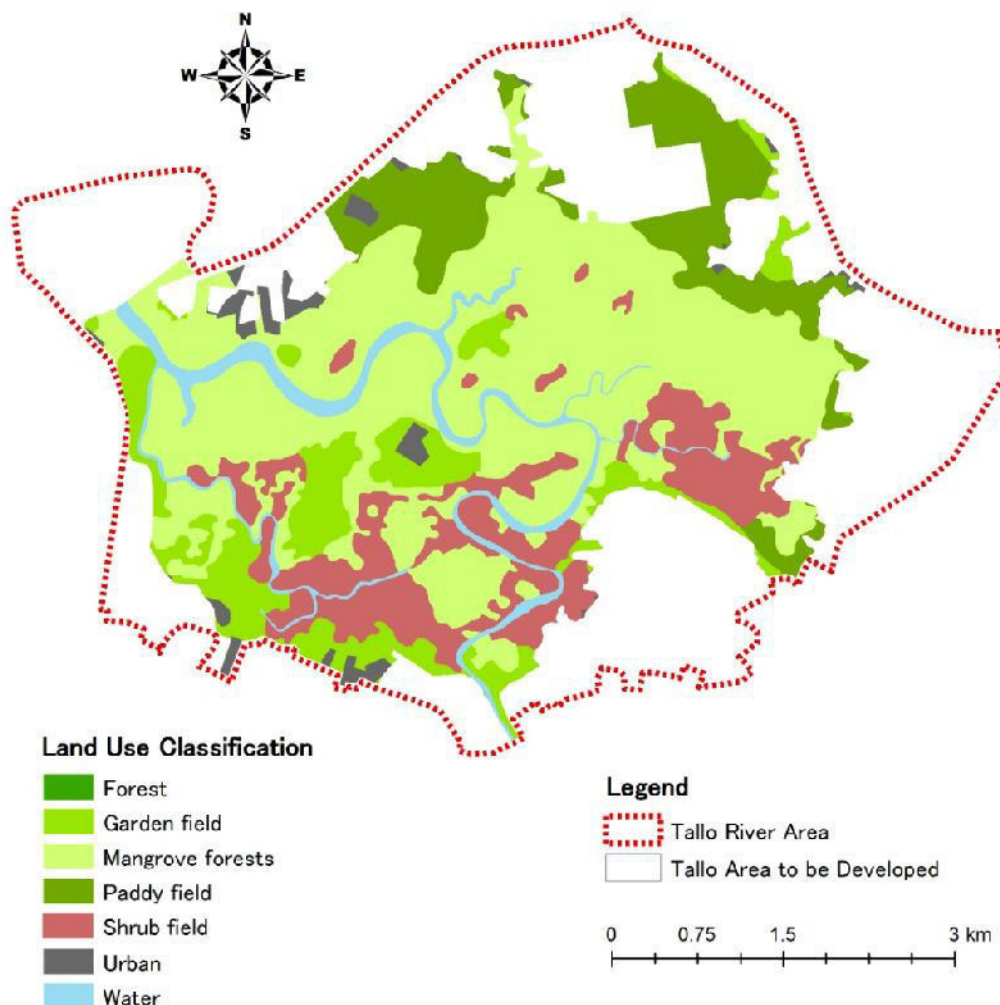


Fig. 2.15 Land-use values of Tallo River Area in 1997

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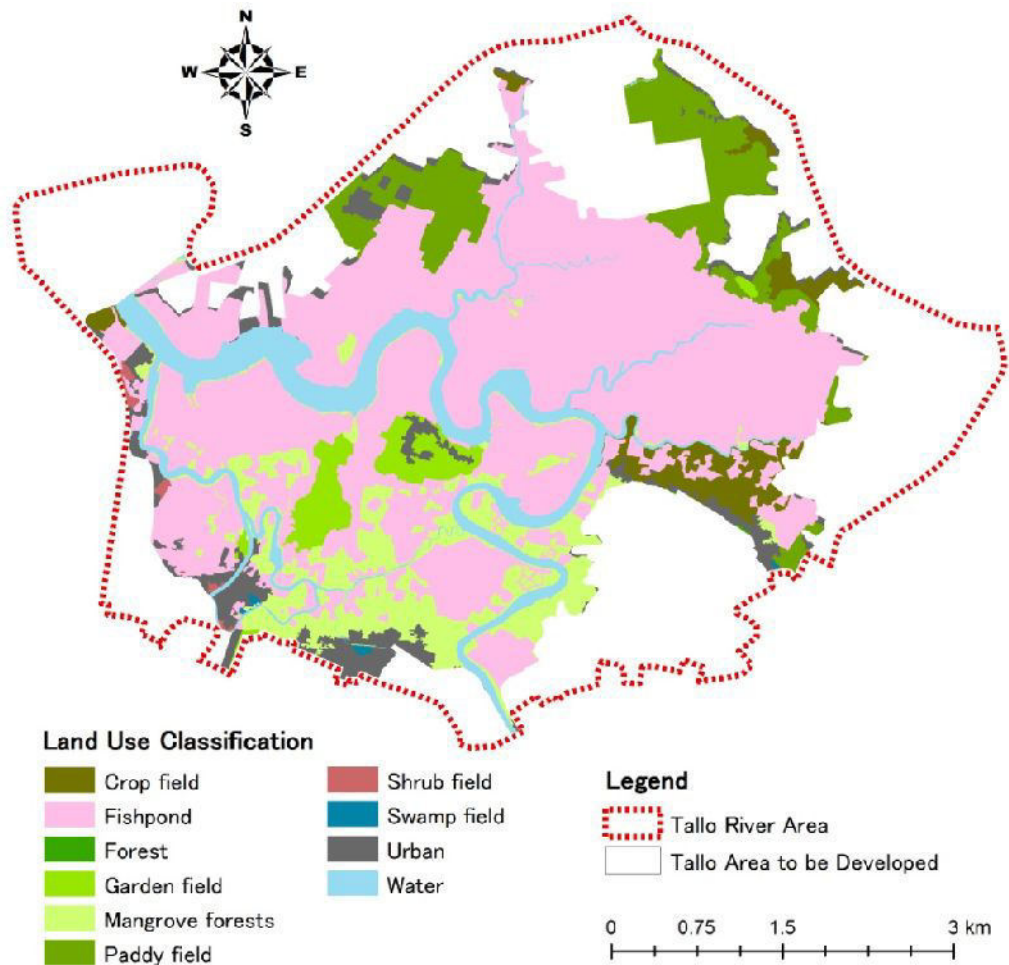


Fig. 2.16 Land-use values of Tallo River Area in 2012

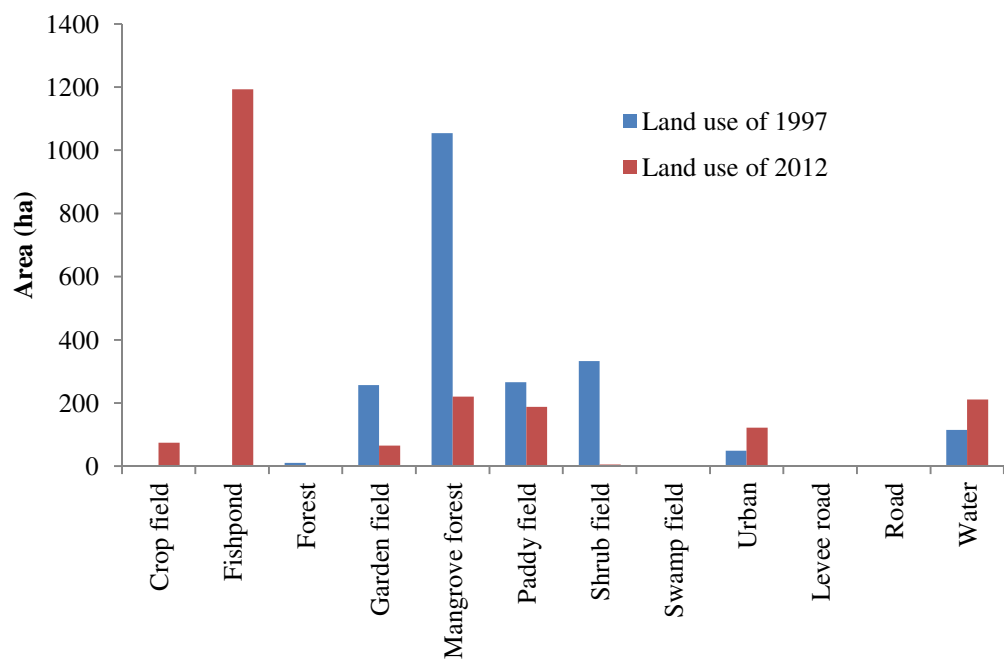


Fig. 2.17 Comparison of land-use values of Tallo River Area in 1997 and 2012

Table 2.7 Comparative percentage of area of land-use in 1997 and 2012

Land-uses	1997		2012	
	ha	%	ha	%
Crop field	0	0.0	74.71	3.6
Fishpond	0	0.0	1193.38	57.3
Forest	10	0.5	0.37	0.0
Garden field	256.75	12.3	65.56	3.1
Mangrove forest	1054.14	50.6	220.61	10.6
Paddy field	266.11	12.8	187.6	9.0
Shrub field	332.22	16.0	5.17	0.2
Swamp field	0	0.0	2.37	0.1
Urban	48.65	2.3	121.6	5.8
Water	114.84	5.5	211.34	10.1
Total	2082.71	100	2082.71	100

2.4 Summary

As the fifth fastest growing city in Indonesia, land-use changes in the Makassar region have shown remarkable changes as the consequences of urban expansion during the last 15 years. Development of land-use maps from the available topographic maps have been performed in this research. Land-use changes analysis has been evaluated to investigate pattern of change in the Makassar City. GIS geoprocessing model has been used to develop the land-use maps from the available topographical data, and matrix analysis has been applied to simulate the spatio-temporal land-use changes from 1997 to 2012. Based on the developed land-use maps, details of land-use changes have been simulated based on grid-mesh of 50 m size to characterize land-use transition in the Makassar region over the last 15 years.

The results of the spatio-temporal analysis showed that there has been an important change in land-use in the 1997-2012 periods. Land-uses for the period of 1997-2012 have shown important changes, urban surface has grown up from 4,805 to 8,098 hectares which represents almost twice the urban expansion of a 15 years period. GIS analysis results showed that urban land expansion is associated with a decline in most of agricultural land and garden field. It is found that about 32% of agricultural fields and 41% of garden fields of 1997 are converted into urban area in 2012. The area of fishponds, a measurement of crops field, is existed with increased urban land-use. The increasing phenomenon of urban area from 1997 to 2012 has led to the existence of the land covers of fishpond (13.5%) and swamp field (2.1%) in 2012. Urban expansion has a large negative impact on

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mangrove forest. About 79% of mangrove forests in Tallo River Area are converted into fishponds. This study has clearly pointed out the importance of understanding the dynamic of land-use changes of the Makassar region in a spatial and temporal way to the protection of the environment.

Spatial Analysis of Ecological Connectivity Evaluation

3.1 Identification of Ecological Functional Areas

3.1.1 Theoretical concepts

Understanding the relationships between spatial pattern and ecological processes across a range of scales is the central part that landscape ecologists have emphasized (Turner et al., 2001). Since Carl Troll, a German biogeographer, coined the term landscape ecology in 1939, many landscape ecologists have developed its definitions to effectively reflect the key issues to be stressed (Risser et al., 1984; Turner, 1989; Forman and Godron, 1986; Pickett and Cadenasso, 1995; Nassauer, 1997; Wiens, 1999; Wu and Hobbs, 2007) and to guide the direction toward which the emerging approach should proceed with a rigorous theoretical baseline. By simply looking at the various definitions made in the evolutionary course of landscape ecology, two characteristics can be commonly found. One is the constant concerns on pattern (structure), process (function), dynamics (change) and scale, which were already conceived in the original definition and epitomized by Turner and her colleagues (Turner et al., 2001). For the general framework, many substantial and procedural theories have been developed and well documented in Ahern's work (2005). He suggests a typology for sustainable landscape planning, including a theoretical orientation; resource or goal orientations; inter-disciplinary versus trans-disciplinary; strategic orientation and spatial concepts. This seems to be adaptable to many derivative planning approaches as well, such as ecological planning (Thompson and Steiner, 1997; Steiner, 2000), and landscape ecological planning (Musacchio, 2008).

The sustainable principles in the city context have been portrayed in publications relating to the ecological city (Platt et al., 1994; Register, 2006), green city and sustainable city (Walter, 1992). In a narrow sense, such endeavors relate to make amenity cities function in balance with nature to the extent of human's pleasures. The concepts of an environment-friendly city and healthy city

are slightly beyond this, and attempt to create far much sound environment. In a broader sense, it views a city as an organic complex where urban activities and spatial structure should achieve the properties of ecosystems such as diversity, self-support, circulation, and stability. The conservation and restoration of urban biodiversity and ecosystems, and material circulation is intensified within an existing urban system. The specific topics related to landscape connectivity in planning literature include the studies on open space networks, greenways, and ecological networks. Some network studies focus only on a single purpose such as quality of life (Shafer et al., 2000), which is often based on the human ecosystem perspective (Bubolz et al., 1980; Force and Machlis, 1997). Others emphasize its multi-functional capacity for nature corridors, cultural and recreational accessibility, alternative transportation route, and useful educational resources (Tan, 2006). But specific literature for passive linear recreational activities is not as common (Cook, 2000). Networking under-utilized lands along linear elements may not be relevant to the study, but considering implications to increasing connectivity through site restoration is possible. Ecological networks emphasize the network coherence that is based on ecological processes (Opdam et al., 2006). While fewest studies use ecological networks for practical reasons such as identifying a linked reserve system or conservation area prioritization (Weber, 2006), the most significant role played in landscape planning has been the use of ecological networks as a spatial concept (Cook and Lier, 1994; Vuilleumier and Prelaz-Droux, 2002).

Evidently, human land use and development are quickly fragmenting and decreasing the amount of available open space suitable for habitat (Ahern, 2006). In many areas with increasing sprawl, fragmentation has turned out to be virtually inevitable. Intensively exploited landscapes often display fragmentation, where patches of semi-natural habitat become progressively diminished and isolated (Selman, 2006). Fragmentation of the landscape affects habitat size and shape, and distance from other areas of suitable habitat. Organisms dependent on a particular habitat size or distance (or both) from the edge of their habitat are pressured by the increase of edge environment that accompanies fragmentation. This, in turn, affects species diversity directly and indirectly, as many biologists argue that habitat fragmentation is the single greatest threat to the biological diversity of native species (Noss, 1991; Mac et al., 1998).

Habitat destruction caused by fragmentation affects not only the quantity of species, but also the quality of those species that survive. Generalists or edge species, which are able to survive in a variety of habitats, are less likely to suffer from habitat loss and fragmentation than specialist species, which require unique

pockets of habitat. Likewise, all species have a minimum area point how large a given habitat area must be for a viable population to survive. Different species groups will have different minimum area requirements and thus will be affected differently by habitat fragmentation and loss (Forman, 1995).

Generally, biodiversity tends to decline with increasing urbanization. The centers of metropolitan cities will have fewer species than less-developed areas on the urban-suburban-rural-natural gradient. Species diversity may actually be greater, however, in highly developed suburban areas than in less-disturbed environments. According to the intermediate disturbance hypothesis (Cook and Lier, 1994), species richness or diversity will be greater in moderately disturbed environments than in either heavily disturbed areas (such as city centers) or lightly disturbed habitats (such as intake forestland outside the city limits). As the significance of regional biodiversity and associated land use is widely perceived, novel efforts for integrating ecological information with planning and design processes began to emerge. A considerable body of literature about planning and applied design research has the same goal of regional biodiversity, but the terminology often varies depending on planning intention.

For example, ecological network focuses on ecological core areas surrounded by buffer areas, and corridors connecting the core areas (Forman, 2008). The generally used definition of landscape connectivity emphasizes not only spatial properties of the landscape (structural connectivity), but also ecological processes and organisms mobility (functional connectivity). While structural connectivity measures how connected or spatially continuous landscape elements are, functional or behavioral connectivity refers to how connected an area is for an ecological process, such as dispersal of plants and animals, and energy and nutrient flows.

For example, ecological network (Cook and Lier, 1994; Cook, 2000; Cook, 2002; Vuilleumier and Prelaz-Droux, 2002; Opdam et. al., 2006) theoretically provides a spatially explicit landscape framework on which ecological function can be well performed. However, it tends to focus more on how landscape structure is spatially organized simply by mapping them out, rather than delving into what is, and would be, going on in the real landscape. A challenge to implementation is an insufficient understanding of ecological knowledge in planning applications: thus, ecological effects of networks are rather implicit. This may be overcome by linking scientific properties of functional connectivity to planning concepts to create sustainable landscapes. In next section, it is described the methodology using GIS to define the spectrum size analysis for ecological functional areas of Makassar region.

3.1.2 Spatial analysis of ecological functional areas

Promoting landscape connectivity, the degree to which a landscape facilitates the movement of individuals has become a global conservation priority to mitigate the widespread anthropogenic landscape modifications and their impacts on biodiversity (Crooks and Sanjayan, 2006). In ecology, connectivity of a landscape is typically described along a spectrum of low to high for either structural or functional connectivity. Structural connectivity is a physical attribute of a landscape (e.g. the configuration of land-cover types or habitats) and is typically measured using landscape metrics such as patch size, isolation or other fragmentation/network measures, or by identifying linear features that are thought to act as conduits (Taylor et al., 1993). This research method begins with the identification of what we define as ecological functional areas. Decision about the ecological functional areas (ecological core areas) that need to be connected is important for assessing the ecological connectivity. Furthermore, it is important to decide what kind of connectivity network would be required to allow the flux of energy, matter, genetic information, and so on, that is necessary to sustain the ecological processes, allowing the long term conservation of biodiversity (Gonzalez et al., 2011). However, in highly populated and fragmented landscapes, ecological functional areas do have an intrinsic value, independently of the level of connectivity that they may have (Girvetz et. al., 2008).

Using 1:50,000 scales of land-use maps in 1997 and 2012, a topological analysis of the land cover categories are performed to identify the ecological functional areas. **Table 3.1** shows the land cover categories resulted from the topological analysis of land-use maps using GIS. In this study, spatial analysis of ecological functional areas in the patch size spectrum in 1997 was conducted to simulate the percentage of area distributions for each land-use value. Six values of land covers in 1997 were analyzed using the perception of patch numbers in the patch size spectrum (**Table 3.2**). Different of spectrum sizes gives different of ecological areas. The comparative distribution of the patch size spectrum is illustrated by **Figure 3.1**. Furthermore, similar GIS process analysis was done for land cover categories in 2012. The perception of patch numbers in the patch size spectrum is shown in **Table 3.3**. The comparative distribution of the patch size spectrum in 2012 is presented by **Figure 3.3**. As a result, optimum quantitative criteria for ecological functional areas in the city scale of the Makassar region can be categorized for the patch size spectrum III in which simple ecological functional areas are defined by applying quantitative criteria for a minimum surface ($S_r = 50\text{ha}$) depending of each land-use cover, based on a review of

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existing literature (Andrén, 1994; Bender et al., 1998; Fahring and Merriam, 1994; Virgós et al. 2002). Although paddy land area itself may have a less important role for biodiversity, when combined with adjacent vegetation patches, it may convey ecological function that it cannot otherwise, and was considered in this study. However, the areas that could not be considered simple ecological functional areas can be grouped into “forest mosaics” or “agricultural mosaics” or “agroforest mosaics”, based on existing literature (Forman, 1990; Virgós et al. 2002). By this approach, spatial analysis allowed obtaining five types of ecological functional areas that are grouped into forest, mangrove forest, swamp field, agriculture mosaic and agroforest mosaic. **Figure 3.2a** and **Figure 3.2b** shows the agriculture mosaic areas and agroforest mosaic areas classification in 1997, respectively. Furthermore, all remaining areas were considered as fragmented areas.

Table 3.1 Land cover categories resulted from topological analysis

Land cover			
B1	Urban	C3	Swamp field
B2	Water	C4	Paddy field
B3	Fishpond	C5	Garden field
C1	Forest	C6	Shrub field
C2	Mangrove forest	N1	Crop field

Table 3.2 Ecological functional areas in the patch size spectrum in 1997

1997		The perception of patch numbers in the patch size spectrum (%)				
Values	Total area (ha)	I (Sr =< 10ha)	II (10ha < Sr =<50ha)	III (50ha < Sr =<100ha)	IV (100ha < Sr =<200ha)	V (Sr >= 200ha)
Forest	8.58	2	0	0	0	0
Mangrove forest	2088.57	26	34	14	13	15
Swamp field	0	0	0	0	0	0
Paddy field	4805.79	4	7	12	34	47
Garden field	4705.47	48	39	48	42	38
Shrub field	520.2	19	19	26	11	0
	12128.61	100	100	100	100	100

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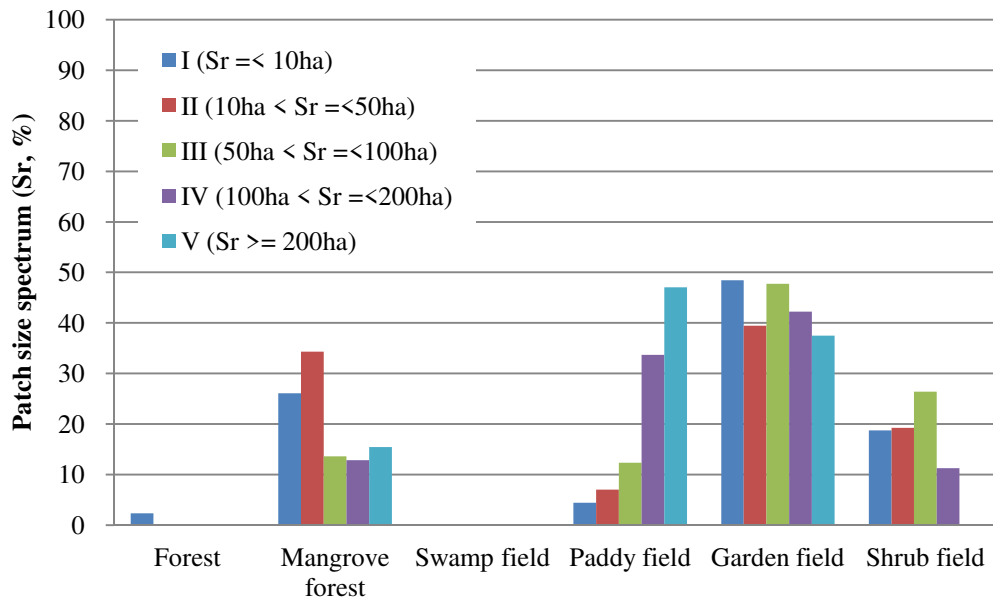


Fig. 3.1 Percentage of patch size spectrum for land cover types in 1997

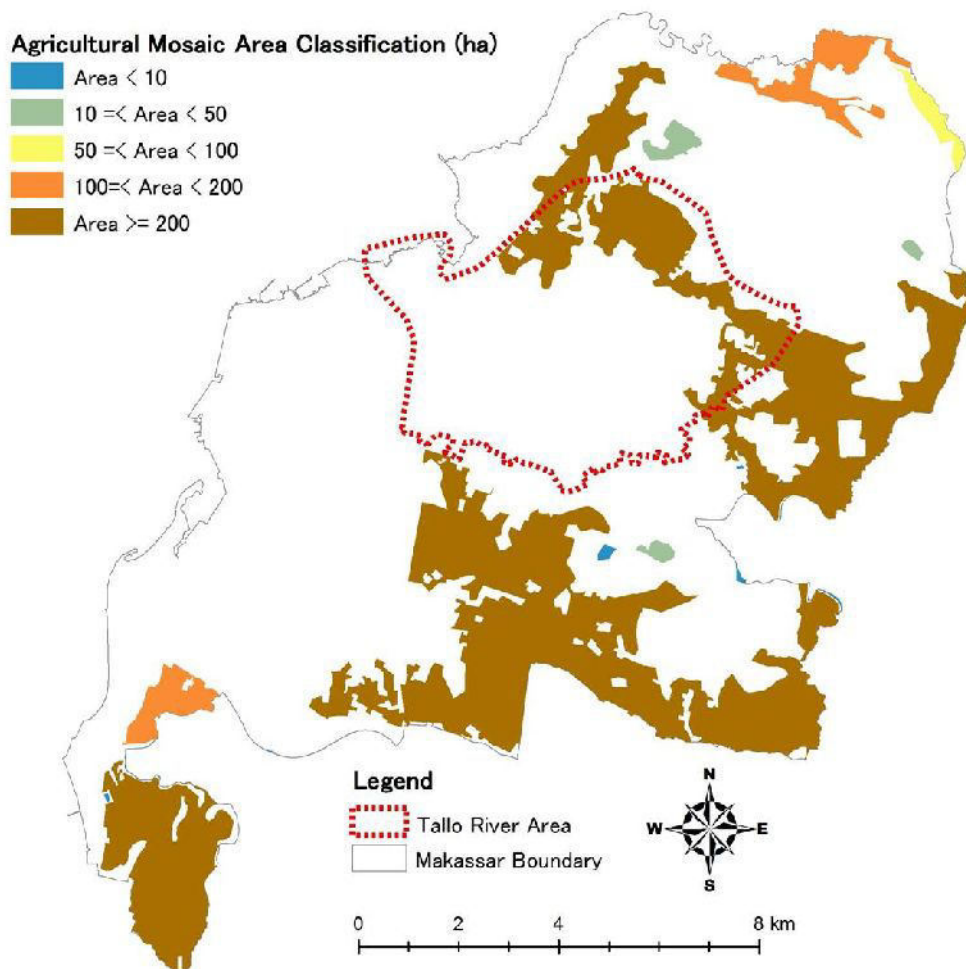


Fig. 3.2a Agricultural mosaic area classification in 1997

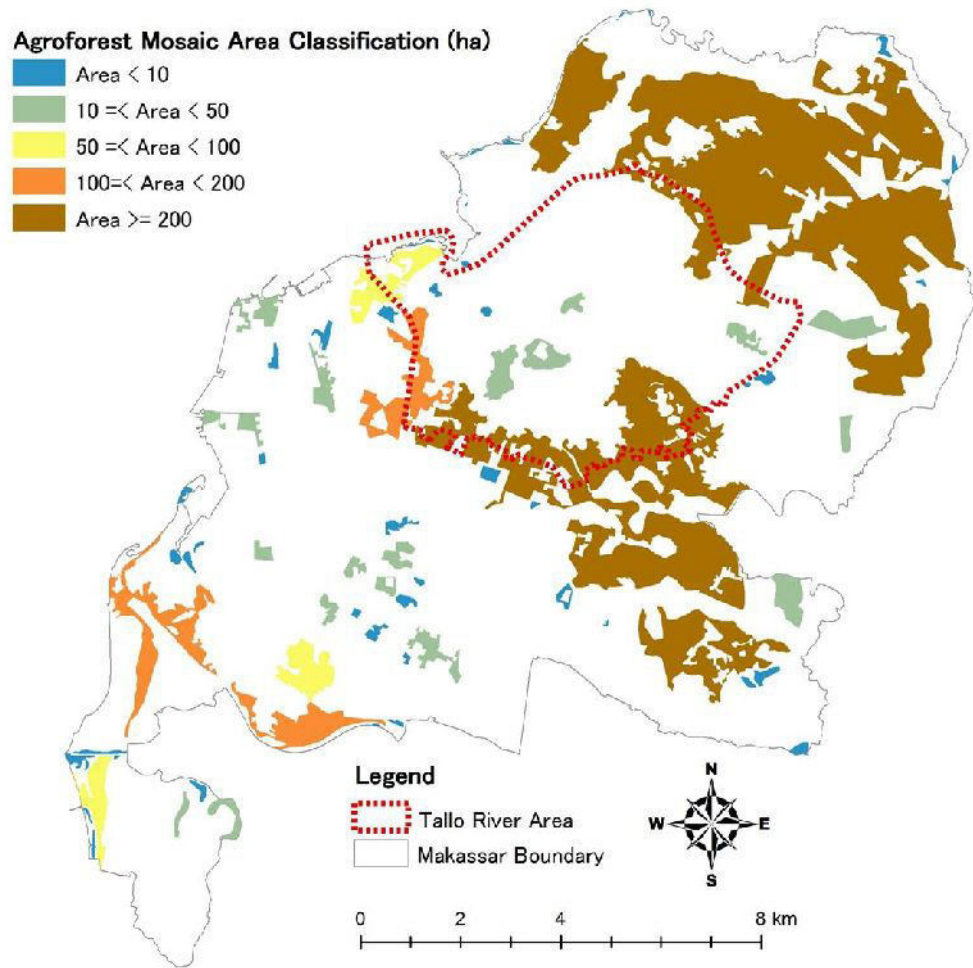


Fig. 3.2b Agroforest mosaic area classification in 1997

Table 3.3 Ecological functional areas in the patch size spectrum in 2012

2012		The perception of patch numbers in the patch size spectrum (%)				
Values	Total area (ha)	I (Sr ≤ 10ha)	II (10ha < Sr ≤ 50ha)	III (50ha < Sr ≤ 100ha)	IV (100ha < Sr ≤ 200ha)	V (Sr ≥ 200ha)
Forest	44.52	3	0	0	0	0
Mangrove forest	471.69	11	7	8	30	0
Swamp field	382.74	18	7	7	0	0
Paddy field	2795.54	15	29	37	45	89
Garden field	1663.63	32	48	37	25	11
Shrub field	476.58	21	9	11	0	0
	5834.7	100	100	100	100	100

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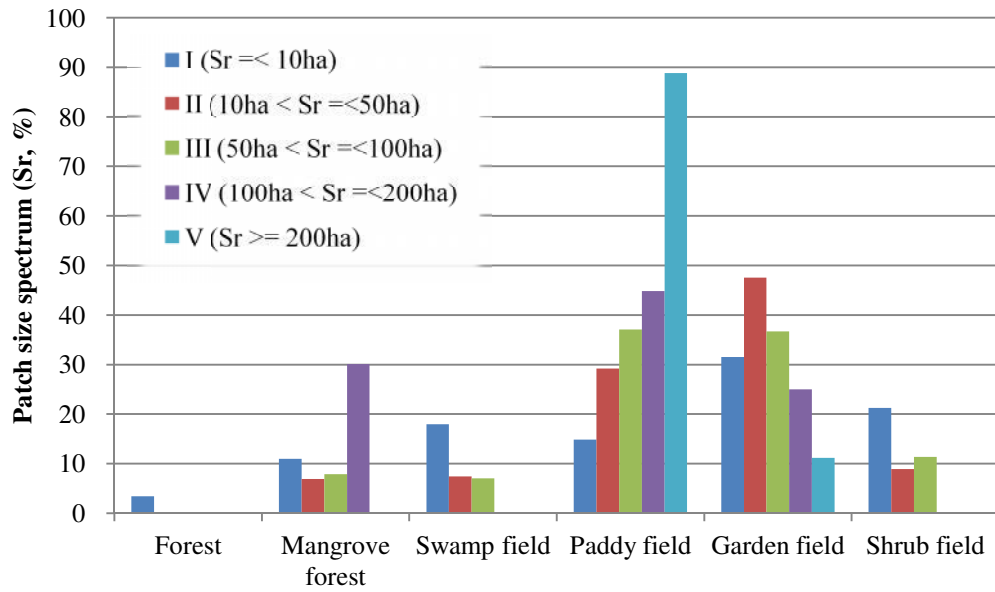


Fig. 3.3 Percentage of patch size spectrum for land cover types in 2012

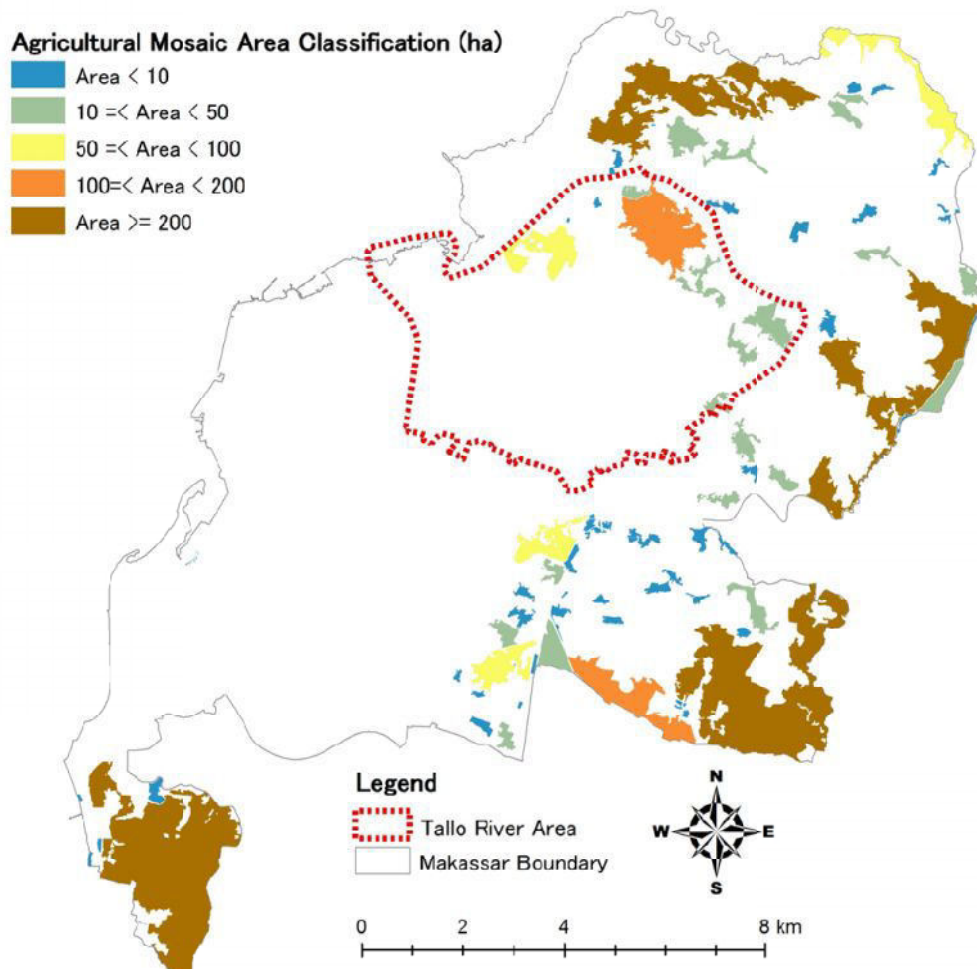


Fig. 3.4a Agricultural mosaic area classification in 2012

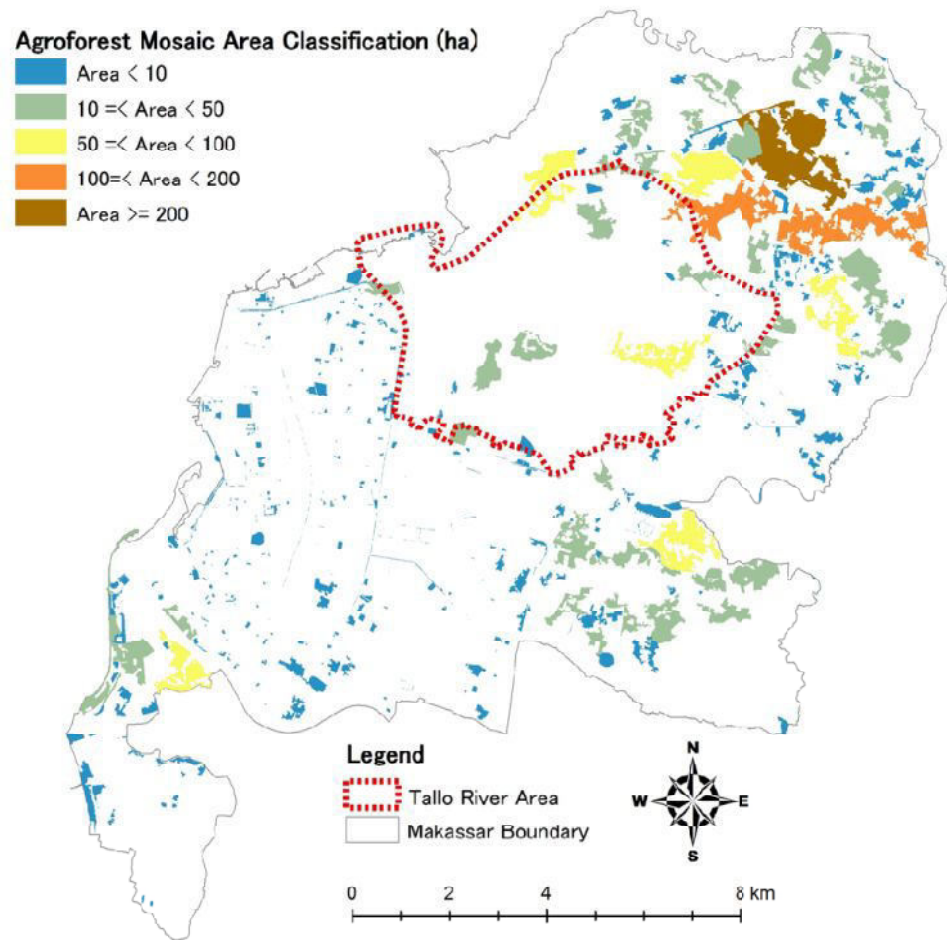


Fig. 3.4b Agroforest mosaic area classification in 2012

Furthermore, **Figure 3.4a** and **Figure 3.4b** shows the agriculture mosaic areas and agroforest mosaic areas classification in 2012, respectively. All remaining areas were considered as fragmented areas. It is decided that ecological functional areas should include mosaics, because it has been proven the existence of a strong correlation between diversity of habitats (i.e. mosaic landscape) and biodiversity. In the study area, extensive agroforest mosaics are the second habitat in terms of vertebrate diversity, after wetlands and many endangered bird species are concentrated on agroforest mosaic landscapes (Pino et. al., 2000).

3.1.3 Establishment of resultant maps for ecological functional area

The spatial analysis of ecological functional areas in the Makassar region has been performed, as shown in **Table 3.4**. Forest is relative small spectrum size (less than 50 hectares), thus it is not included in the ecological functional areas in this study. Distribution of the ecological functional areas in 1997 and 2012 for spectrum III is created by GIS is shown in **Figure 3.5a** and **Figure 3.5b**, respectively. **Figure**

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3.6 shows the comparative of the ecological functional areas for spectrum I and spectrum II both in 1997 and 2012.

Table 3.4 Comparative of the ecological functional areas for spectrum III

Code	Land cover	Class	Total area (ha)		1997		2012	
			1997	2012	ha	%	ha	%
C ₁	Forest	Forest	8.58	44.52	0	0	0	0
C ₂	Mangrove forest	Mangrove forest	2088.57	471.69	1610.2	77.1	239.13	50.7
C ₃	Swamp field	Swamp field	0	382.74	0	0	52.4	13.7
C ₄	Paddy field	Agriculture mosaic	4805.79	2795.54	4711.8	98	2222.43	79.5
C ₅	Garden field	Agroforest mosaic	4705.47	1663.63	4088.34	86.9	634.93	38.2
C ₆	Shrub field		520.2	476.58	237.47	45.6	84.73	17.8
Total			12128.61	5834.7	10647.81		3233.62	

Ecological Functional Areas (10647.81 ha)

- Paddy field (4711.80 ha)
- Garden field (4088.34 ha)
- Mangrove Forest (1610.20 ha)
- Shrubs (237.47 ha)

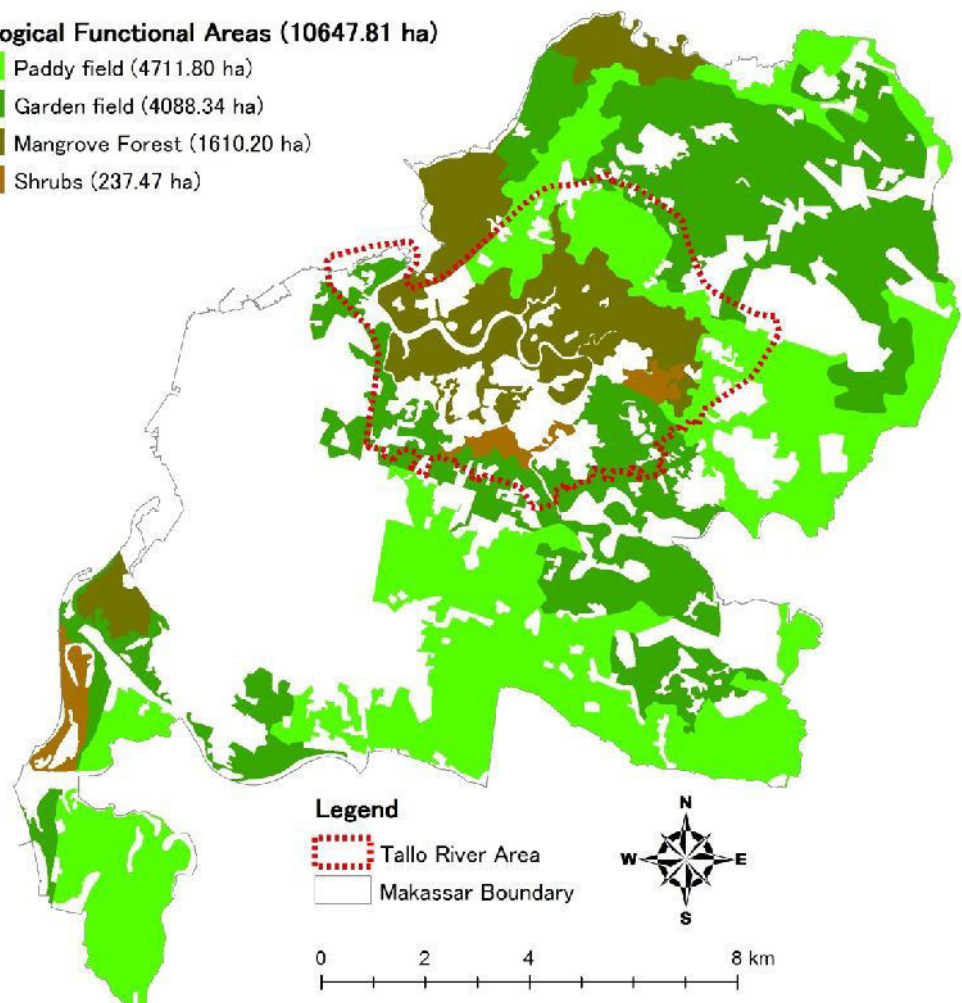


Fig. 3.5a Distribution of the ecological functional areas in 1997 for spectrum III

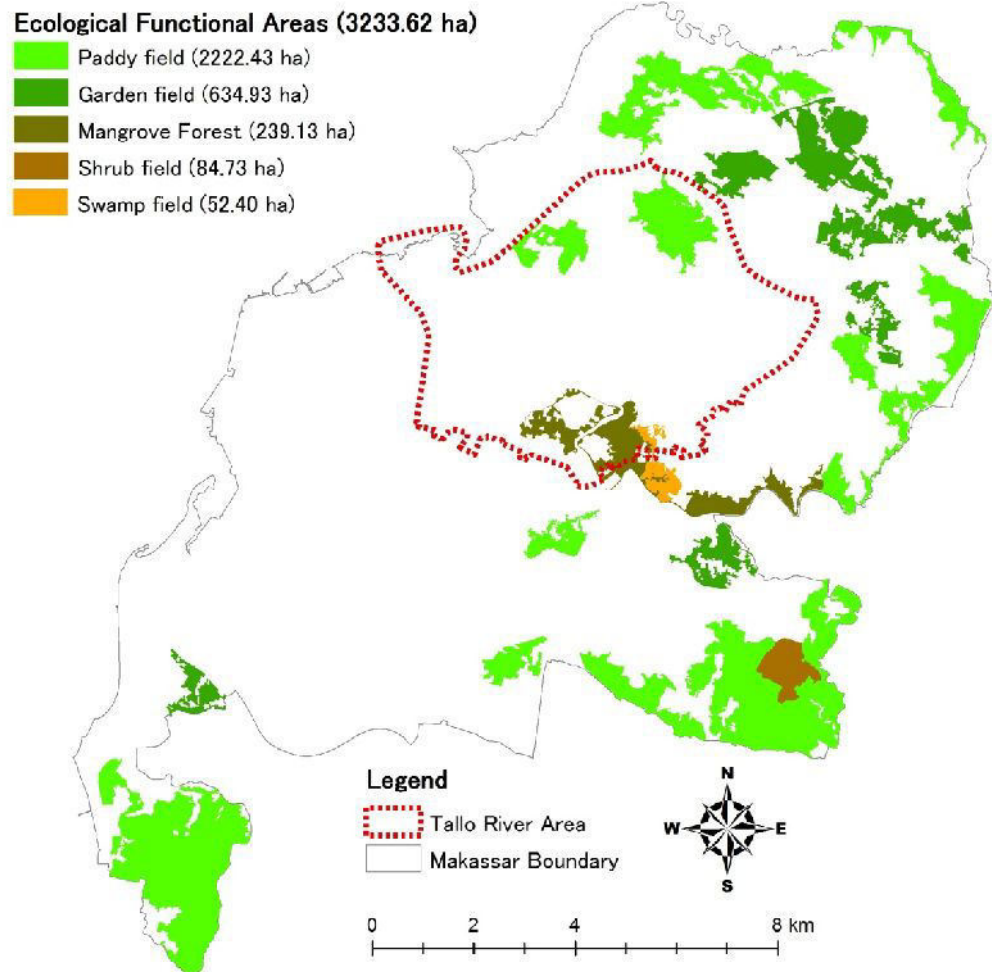


Fig. 3.5b Distribution of the ecological functional areas in 2012 for spectrum III

3.1.4 Analysis of ecological functional area changes

Changing the ecological functional areas (at spectrum III) in the Makassar region is shown in **Figure 3.7**. As expected, the ecologically functional areas C'r (55.42%) of the total area in 2012 is lower than the ecologically functional areas C'r (87.79%) in 1997. The largest ecologically functional areas in 1997 are paddy field covering 98.0% of the total area, followed by garden field and mangrove forest which cover 86.9% and 77.1%, respectively.

In 2012, paddy field, garden field and mangrove forest decreased into 79.5%, 38.2% and 50.7% of the total area, respectively. In particular, small swamp field, which hold the vertebrate biodiversity (13.7% of the total area) are the important habitat type, and therefore the most vulnerable. To deal with the landscape ecological connectivity analysis, the following sections of the Barrier Effect Index (BEI), and the Ecological Connectivity Index (ECI) is described in following section.

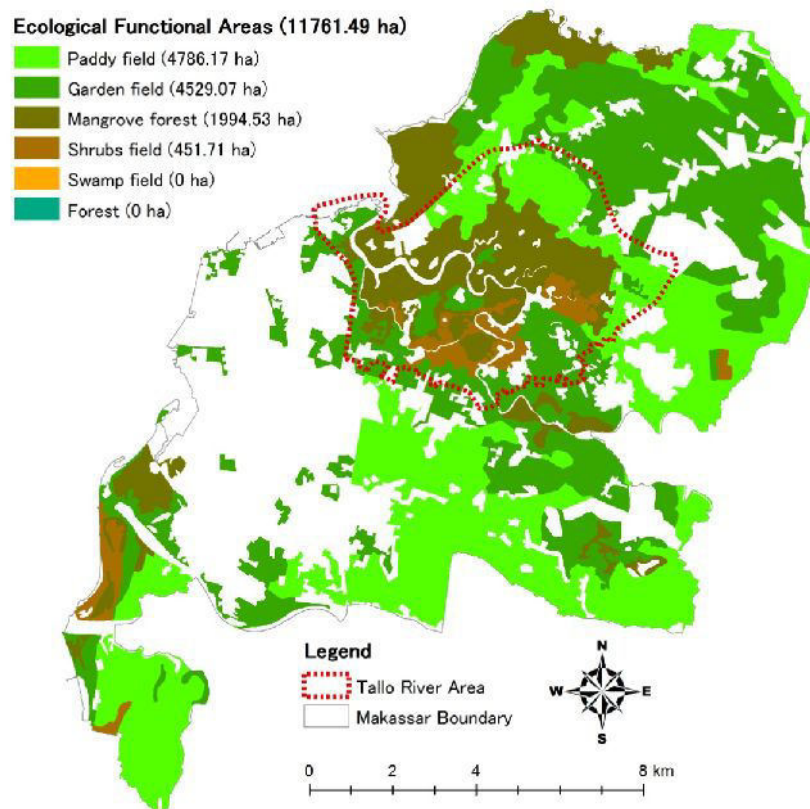


Fig. 3.6a Distribution of the ecological functional areas in 1997 for spectrum II

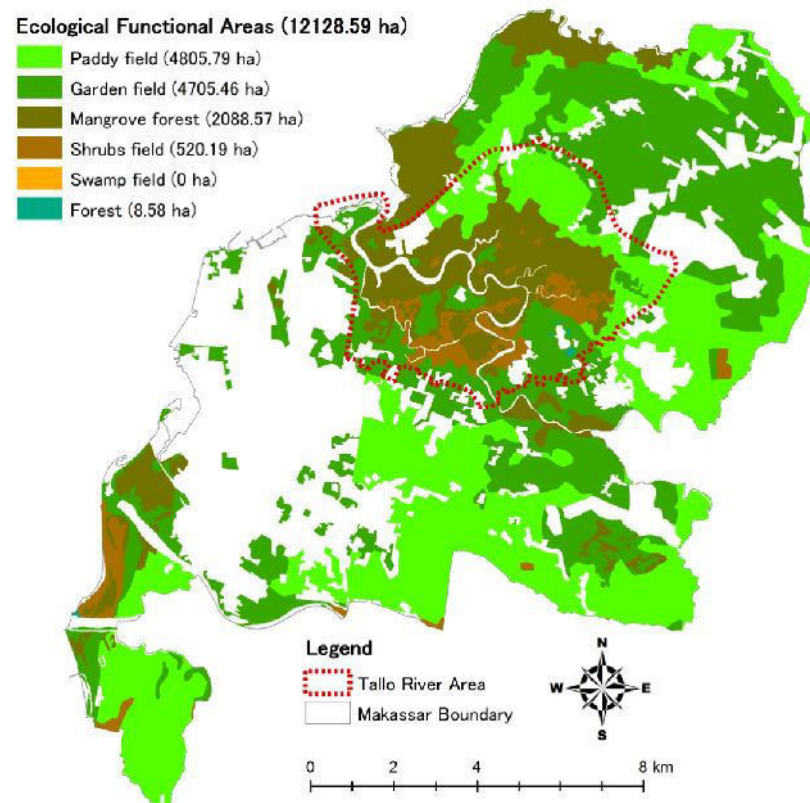


Fig. 3.6b Distribution of the ecological functional areas in 1997 for spectrum I

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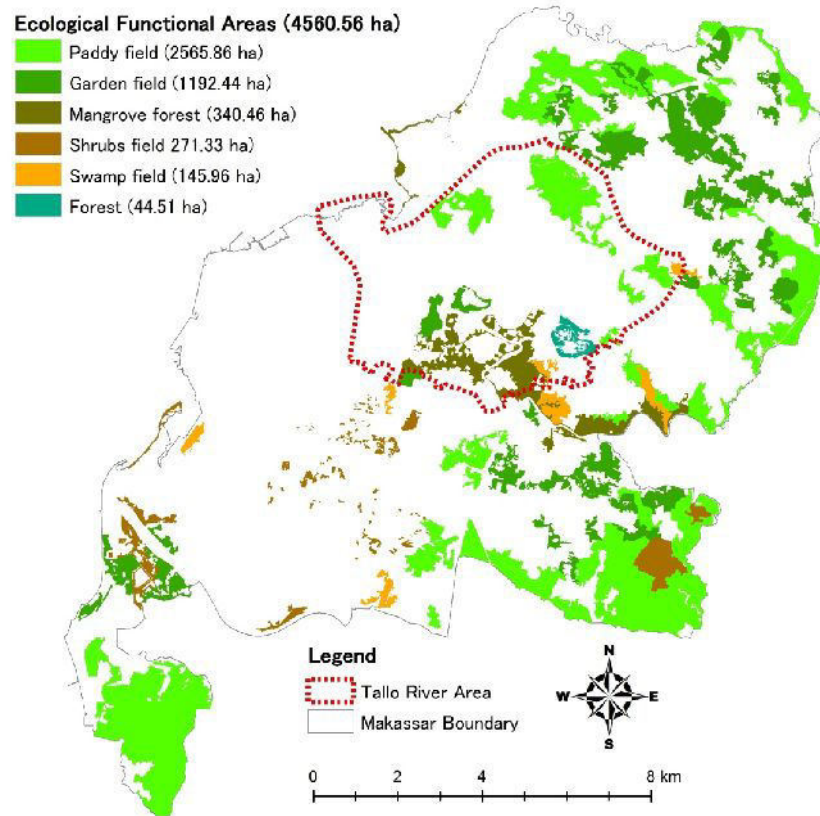


Fig. 3.6c Distribution of the ecological functional areas in 2012 for spectrum II

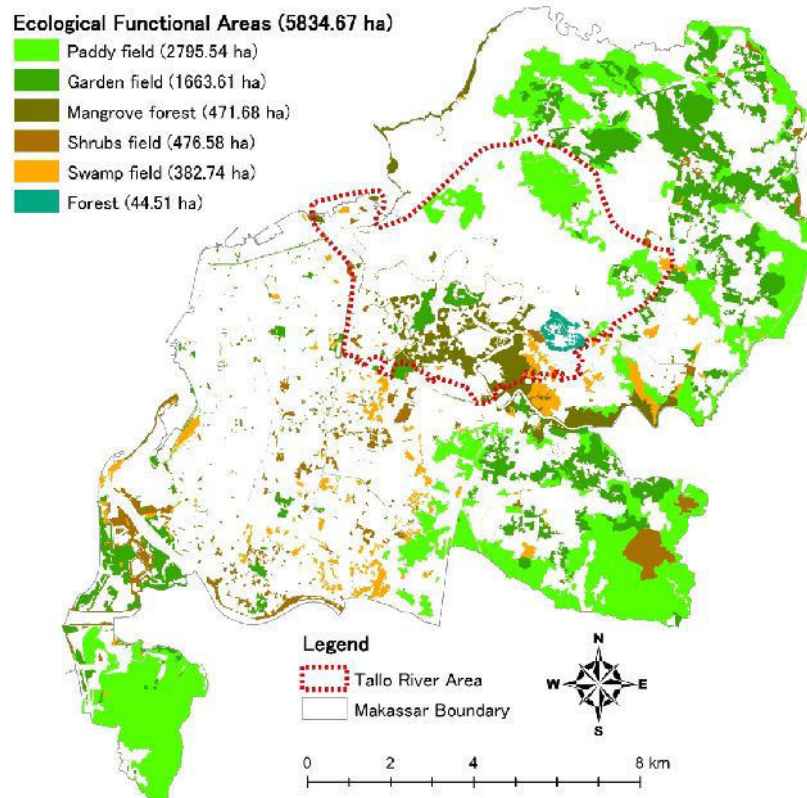


Fig. 3.6d Distribution of the ecological functional areas in 2012 for spectrum I

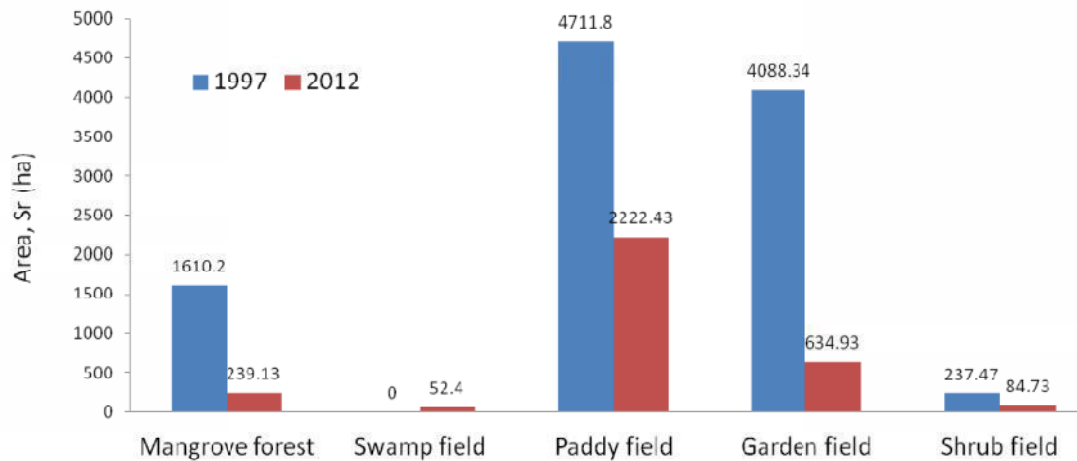


Fig. 3.7 Changing the ecological functional areas for spectrum III (1997 to 2012)

3.2 Analysis of Barrier Effect Index (BEI)

3.2.1 Landscape barrier effect modeling

Urban development and artificial structures often hinder the movement of ecological processes. It is especially true of species that do not disperse easily or widely or that have limited abilities to negotiate obstacles. Barriers include all artificial land uses that create obstacles to the flow of energy, information, or matter across the matrix, in other words, the landscape resistance. Barriers to animal dispersal at the ground level are abundant in urban and suburban systems, including culverts, concrete ditches, asphalt surfaces, fences, walls, railroads, and even swimming pools. Roads are undoubtedly a major obstacle blocking the travel of many species. A considerable body of literatures discloses the evidence of the effects of roadways such as road kills. Unless any green design treatments are made along the road corridors (e.g., greenways), small animals and limited-ranging species cannot cross the roads at all (Eigenbrod et al., 2008). Since the width of roads and traffic volume are important determinants of species distribution and abundance and cause frequent species mortality, the barrier weight on local arteries was doubled for highways and freeways. Water can be used either as a major habitat for such species as waterfowl or at least as resting places for the species passing over the landscape. At the same time, it also can act as a very strong barrier for some species like terrestrial vertebrates. Since this study does not consider water body related species.

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The ecological connectivity model is primarily based on the cost-distance analysis that considers the different urban habitat patches and an impedance surface which incorporates the barrier effect and a potential affinity matrix (Marulli and Mallarach, 2005). To calculate the effects of artificial barriers on ecological and landscape connectivity, a barrier effect index (BEI) is defined as follows:

$$BEI = \frac{Y_i}{Y_{max}} \quad (3.1)$$

where,

Y_i is the value of the barrier effect in a pixel, and

Y_{max} is the maximum value of the barrier effect calculated on a given area.

The BEI is based on the weight that each barrier type (see in **Table 3.6**), the affected land use class, and the distance from the barrier, according to a potential impact matrix and a logarithmic relationship with distance are assigned. Thus, it reflects an impedance surface, where a_i corresponds to the maximum significantly affected distance for each type of barrier, and A_i corresponds to the potential impact value for each type (see in **Table 3.7**).

Based on the literature (Marulli and Mallarach, 2005) it is assumed that the effect of a single barrier from a given point is logarithmic and decreasing as distance increases, according to the following spatial algorithm model expression.

$$Y_s = b_s - k_{s1} \ln (k_{s2}(b_s - d'_s) + 1) \quad (3.2)$$

where,

b_s is the weight of each barrier type,

k_{s1} and k_{s2} are constants for logarithmic decreasing function (**Table 3.5**), and

d'_s is the adapted cost distance per barrier type.

Constants k_{s1} and k_{s2} are needed for adjusting the shape of the function to a specific logarithmic fall (see in **Figure 3.8**).

Table 3.5 Constants value (k_{s1} and k_{s2})

b_s	k_{s1}	k_{s2}	$k_{s1} + k_{s2} \ln (b_s)$
20	11.1	0.253	11.86
40	22.21	0.123	22.66
60	33.32	0.096	33.71
80	44.42	0.063	44.70
100	55.52	0.051	55.75

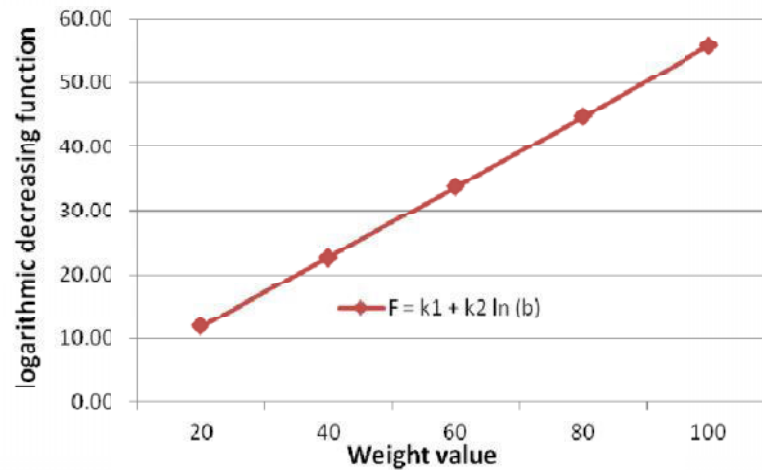


Fig. 3.8 Correlation of constants value (k_{s1} and k_{s2}) and logarithmic decreasing function

3.2.2 Weighted value system for BEI calculation

To reflect the barrier effects in measuring ecological connectivity, a group of artificial attributes were designated with different weights on each attribute depending on the relative influence on the entire landscape (**Table 3.6**). The maximum level of weight was given to the built-up areas comprised of high and medium-density residential development, along with commercial and industrial areas, because the built-up areas are for the most time impermeable to movement of many species. The low-density residential areas do not exist within the site boundary according to the Makassar region land use standard (2012) and thus were not considered for the barrier effect analysis. Instead, the smallest barrier effect weight was given to some public facility building blocks scattered throughout the region because they have a similar influence as a barrier within the low-density residential areas. A potential impact matrix and a logarithmic relationship with distance are assigned, is shown in **Table 3.7**.

Table 3.6 Weighted value system for the calculation of the Barrier Effect Index (Modified from Marulli and Mallarach, (2005))

Code	Type	Weight (b_s)	ks_1^a	ks_2^a
B ₁	Urban	$b_1 = 100$	$k1_1 = 55.52$	$k2_1 = 0.051$
B ₂	Water	$b_2 = 60$	$\frac{b}{b}$	$\frac{b}{b}$
B ₃	Fishpond	$b_3 = 60$	$\frac{b}{b}$	$\frac{b}{b}$

^a Constants for a logarithms decreasing function ($\alpha=0.3$)

^b For $s = 2$ there is not surrounding spatial affectation

Table 3.7 Impact matrix for the calculation of the Barrier Effect Index

Code	Type	Classes included ^a	Affectation coefficient (a_1) ^b	Affectation value (A_1)
V ₁	Neutral	N ₁	$a_1=1000m$	$A_1=0.10$
V ₂	Agriculture	C ₄ , C ₅	$a_2=750m$	$A_2=0.13$
V ₃	"Natural"	C ₁ , C ₂ , C ₃ , C ₆	$a_3=500m$	$A_3=0.20$
V ₄	Barrier	B ₁ , B ₂ , B ₃	$a_4=250m$	$A_4=0.40$

($A_n=b_1/a_n$)

^a class description in previous table

^b a_1 defines the maximum significantly affected distance by each type

3.2.3 Cost distance analysis using GIS grid module

The BEI model applies the cost distance analysis using the grid module of the GIS program and uses requires two GIS layers; a source layer and a friction resistance layer as the input of the model: one origin surface (X_{Bs} ; $s = 1 - n$) for each barrier type (B_s) (**Table 3.6**) and one impedance surface (X_A) from the potential impact matrix (M_A) (**Table 3.7**). The source layer indicates the habitat patches from which the connectivity is calculated. This may be a single patch, or a complex of patches (Adriaensen et al., 2003).

The principal algorithm underlying the cost-distance analysis is the least-cost method. The least-cost algorithm calculates the cumulative costs to move from one cell to another in the entire landscape (Adriaensen et al., 2003). The average cost value to move through the particular cell is given back to the cell with the rules of edge to edge distance and eight neighbor-cell calculations where vertical, horizontal, and diagonal movement is allowed (**Figure 3.9**). In case of diagonal directions, the cost is multiplied by the square root of two to compensate for the longer distance (ESRI, 2010). In this way, the cost value in each cell represents the distance to the source, measured as the least effort (lowest cost) in moving over the resistance layer.

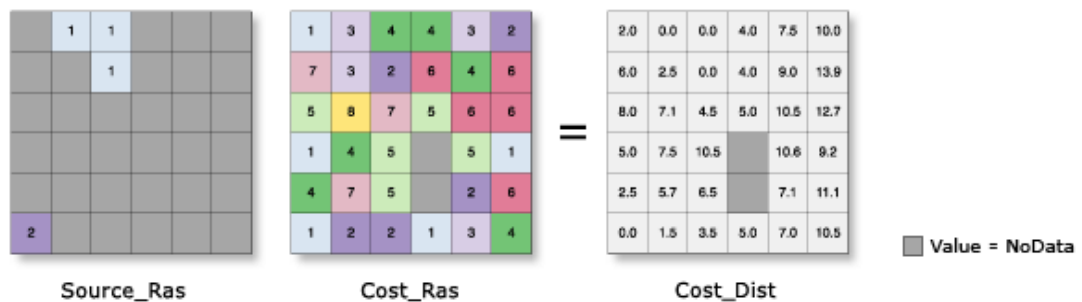
**Fig. 3.9** Cost distance calculation using grid system in GIS (ESRI, 2010)

Table 3.8 Ranking of the barrier effect in the landscape (Modified from Marulli and Mallarach, 2005)

Barrier Effect Index (BEI = $(Y_i/Y_{\max})$)	Effect	Type of barriers
0	Non existent	Lack of anthropogenic barriers. Total permeability of matter, energy and information
1	Low impact	Small and scattered barriers, such as isolated farms
2		High ecological permeability remains
3		Low density residential areas
4	Medium impact	Medium ecological permeability remains
5		Scattered urban, commercial or industrial areas
6		Low ecological permeability
7	Very high	Synergic combination of urban areas
8		Very low ecological permeability
9		Synergic combination of large, high density urban areas
10	Critical impact	Minimum ecological permeability

In this study, the resistance layer uses two surfaces such as barrier surface and impedance surface. While the barrier surface assigns the pre-specified weight values on each raster cell based on the land use class and the barrier weight system, the impedance surface was made by the potential affinity matrix that considers to what extent each cell in the grid is similar to the neighboring cells. From this process, an adapted cost distance was obtained ($d'_s = b_s - d_s$; where, $b_s - d_s > 0$; being d_s =cost distance). In this way, the model individually calculates the barrier effect Y_s for each subclass type.

Thus, the entire barrier effect Y in the landscape is defined as the addition of the effects of all barrier types on a given area. The reason for this is that a combination of different barrier types, such as highways, and urban areas, has a potential effect much greater than the maximum impact of each individual type of barrier. In other words, it is a way of taking into consideration cumulative impacts. From this process, a barrier effect surface is obtained.

$$Y = \sum_{s=1}^{s=n} Y_s \quad (3.3)$$

BEI is a relative index, which means that for each given area where it is applied it has been designed to give values within an ordinal scale from 0 to 10 (see in **Table 3.8**). The reason for this is twofold. First, barrier impact cannot be

easily measured in absolute terms, being always a function of the diverse natural systems or landscapes that are affected and the organisms that move within it. Second, grouping the high variability of continuous BEI potential values using a conventional discrete decimal scale helps in making interpretations and comparisons easier.

3.2.4 Establishment of resultant maps for BEI

Using the GIS spatial analysis, the resultant maps of the barrier effect index have been established to evaluate the area that has a high effect from the barrier. **Figure 3.10a** shows the established map resulting from the application of the Barrier Effect Index (BEI) on the Makassar region in 1997. Furthermore, **Figure 3.10b** shows the established map resulting from the application of the Barrier Effect Index (BEI) on the Makassar region in 2012.

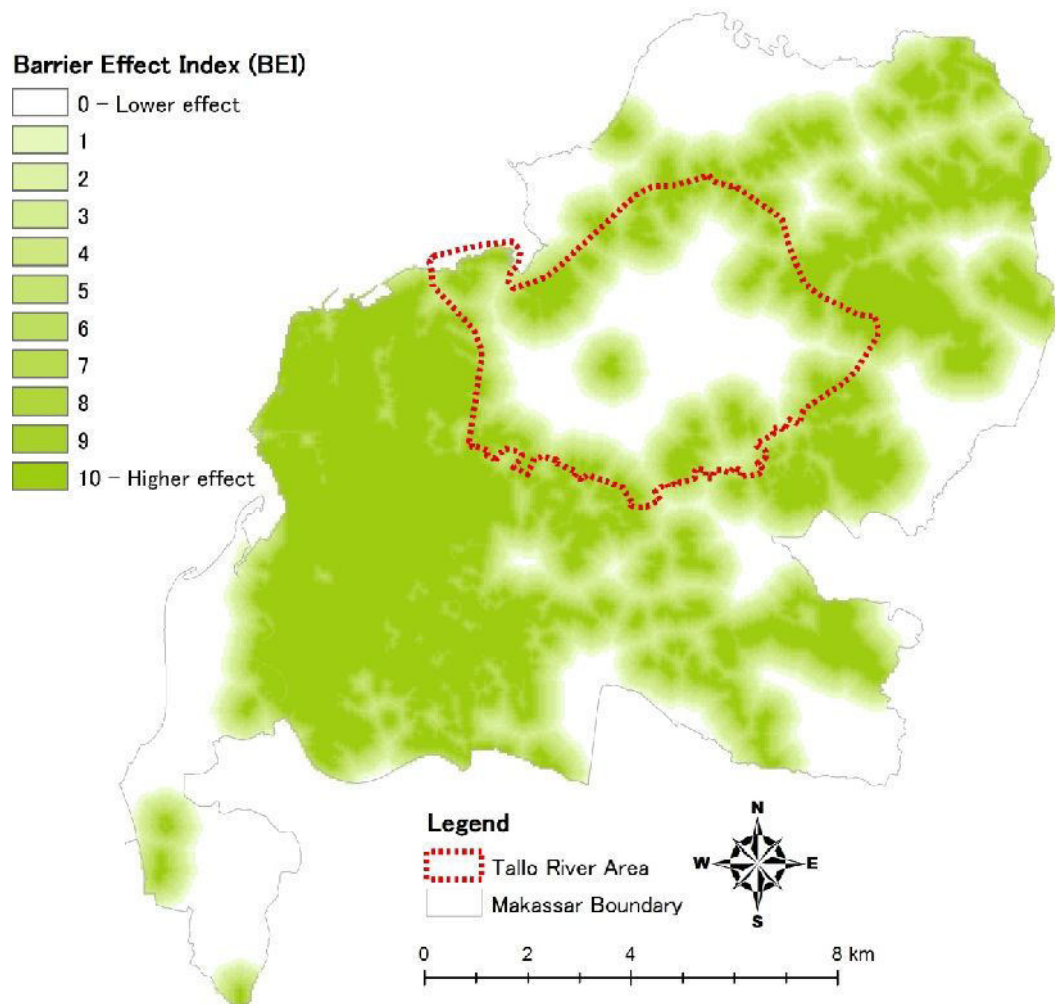


Fig. 3.10a Maps resulting from the application of the Barrier Effect Index (BEI) on the Makassar region in 1997

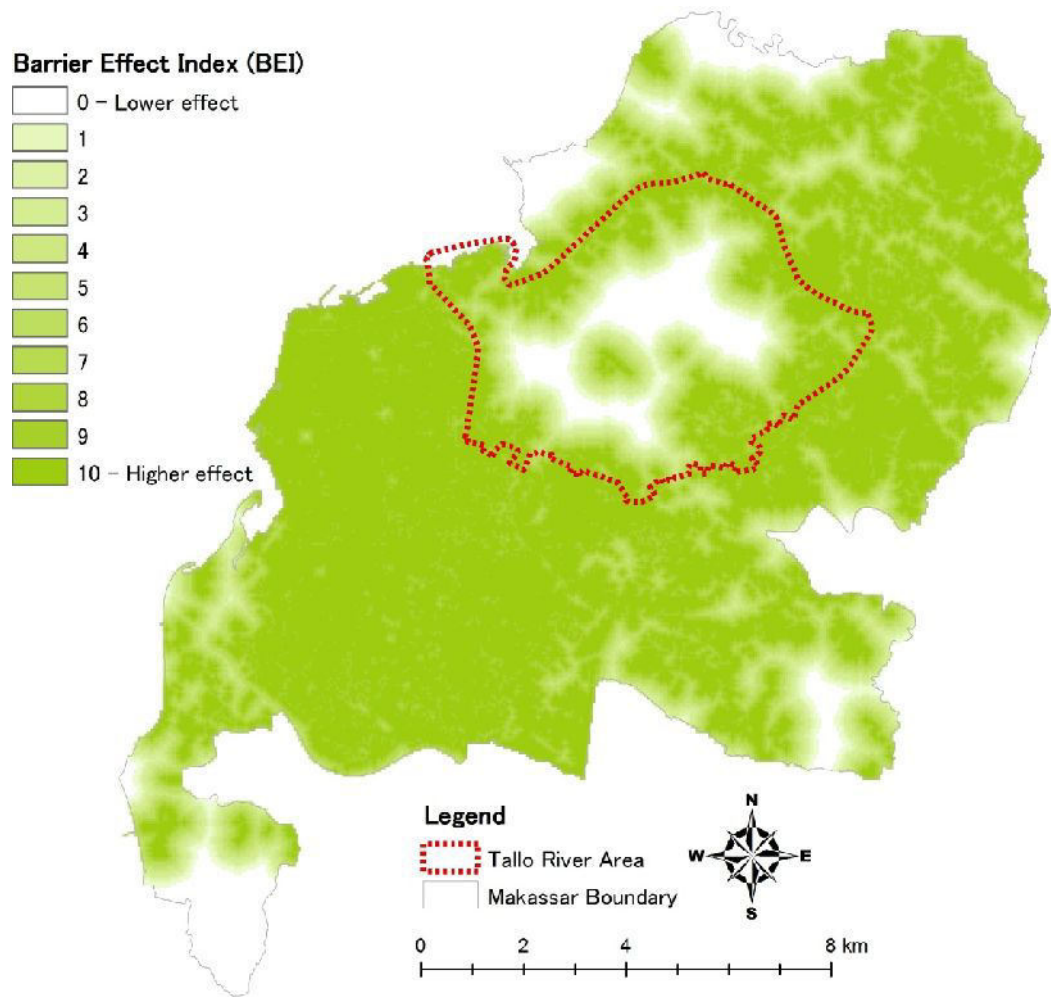


Fig. 3.10b Maps resulting from the application of the Barrier Effect Index (BEI) on the Makassar region in 2012

3.2.5 Analysis of the BEI changes from 1997 to 2012

The application of the barrier effect index to the Makassar region showed that generally in 1997 at least 61.08 % of the Makassar area is under negative impact from artificial barriers, and was increased at least 83.54% in 2012 (**Figure 3.11**). As illustrated by **Figure 3.11**, effect of the barrier index from no existent to medium impacted area in 1997 was decreased in 2012; meanwhile effect of the barrier index from medium to higher impacted area was increased in 2012. It is expected that scattered urban, commercial or industrial areas and high density urban areas have been increased in the Makassar region during 15 years. Moreover, the maps resulting from application of the BEI show the distribution of areas from 1997 to 2012 with little affected by barriers in the Tallo River Area (marked by red-dotted lines), in contrast with the pervasive impacts spreading in the central part of the Makassar region, specially the eastern part of city.

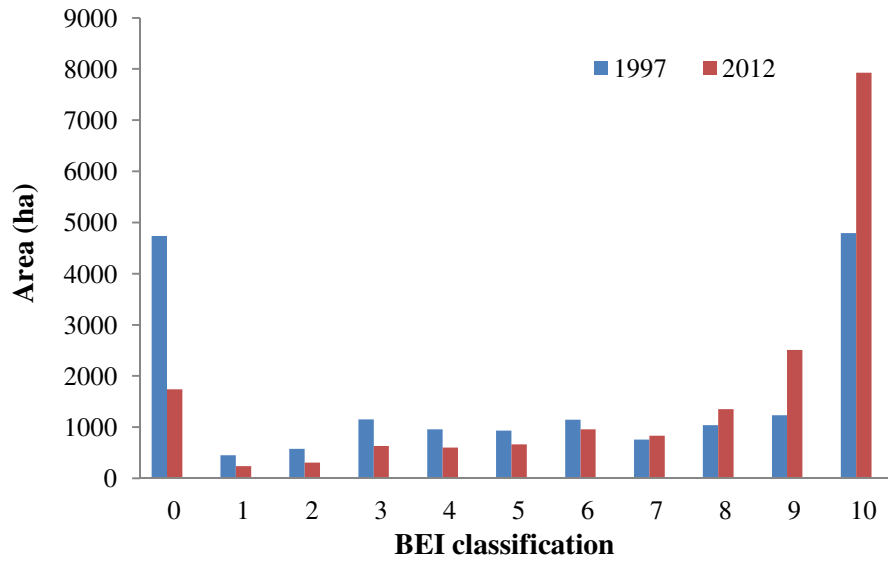


Fig. 3.11 Comparison of the Barrier Effect Index (BEI) at each index level

3.3 Analysis of Ecological Connectivity Index (ECI)

3.3.1 Landscape ecological connectivity modeling

A GIS based spatial analysis was used as a most important method for assessing landscape ecological connectivity. The landscape ecological connectivity modeling largely consists of four parts including: identification of natural land covers, filtering out ecological functions patches, evaluating barrier effects, and generation of landscape ecological connectivity index (ECI) and resultant maps. This whole process was based on a modified version of Marulli and Mallarach (2005)'s approach. The main characteristic of landscape ecological connectivity modeling developed by Marulli and Mallarach (2005) is that the least-cost distance method and map algebra are used as key means in connectivity quantification. The reason why this study moderately employs Marulli and Mallarach 's approach is that, first, the spatial scales of the research settings are the same, both of which deal with the urban region as their study area for landscape connectivity modeling; second, our study case has similar landscape problems is facing including rapid urban sprawl and simultaneous need for natural remnants conservation; third, despite complicated intermediate stages in the computational process, the ultimate products of applying their method appears in the form of a series of maps showing the range of numeric values of ecological connectivity across the region, which is easy to understand compared to other

methods measuring landscape connectivity.

Ecological connectivity refers to the functional aspects of the actual connection between the different elements of the landscape, from energy to information and matter, for instance nutrient cycles, pollen dispersion, and movements of flora or fauna populations. An ecological connectivity index (ECI) is defined based on a cost-distance model that considers the different “functional ecological areas” and an “impedance surface” which incorporates the “barrier effect” Y and a “potential affinity matrix” M_C for all the land use types (**Table 3.9**). This matrix includes the potential affinity range of values that we assumed. It is reasonable to expect among the different types of ecological functional areas. In the calculation of ECI the barriers effect surface X_Y is very significant. However, among the areas where the barrier effect is minor, the surface of the affinity matrix X_C reveals interesting nuances that fully justify their elaboration. The model applies the Cost Distance function of the GIS program (ESRI, 2010), using two databases:

- a) “origin surface” for each type of ecological functional area (X_{C_r} ; $r = 1 - 6$); and
- b) “impedance surface” resulting from the application the effect of the barriers and the potential affinity matrix ($X_I = X_C + X_Y$).

In this way, an adapted cost distance by each type of ecological functional area ($d'_r \leq 20000$ in order to avoid distorted results when several classes get combined) is obtained. Finally, the total adapted cost distance value x for all the ecological functional area types is calculated, according to the following expression:

$$x = \sum_{r=1}^{r=n} d'_r \quad (3.4)$$

To facilitate interpretation and comparisons, to transform the continuous values of the cost distance to discrete values based on a decimal scale is selected. Thus, the ECI is calculated as follows:

$$ECI = 10 - 9 \frac{\ln (1+(x_i-x_{\min}))}{\ln (1+(x_{\max}-x_{\min}))^3} \quad (3.5)$$

where,

x_i is the adapted cost-distance value in a pixel, $x_{\max}$ are the maximum and $x_{\min}$ are the minimum adapted cost-distance values on a given area.

It is considered that this index reflects a kind of “general ecological connectivity”, since its computation includes all the ecological functional

areas (C'). Thus, it is a generic approach which is not tied to specific indicator species. An interesting propriety of the ECI is that it has a relativistic distribution of values, always giving values between 0 and 10. This feature is useful to compare different alternatives. Ranking distribution of ECI overestimates areas with high ecological fragmentation allowing the identification of areas of low absolute value.

3.3.2 Establishment of resultant maps for ECI

Using the GIS spatial analysis, the resultant maps of ecological connectivity index have been established to evaluate the area that has a high ecological connectivity. **Figure 3.12a** and **Figure 3.13a** shows the established map resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 1997 and in 2012 by spectrum III, respectively. Furthermore, **Figure 3.12b-3.12c** and **Figure 3.13b-3.13c** shows the established map resulting from the application of the ECI in 1997 and in 2012 by spectrum II and I, respectively.

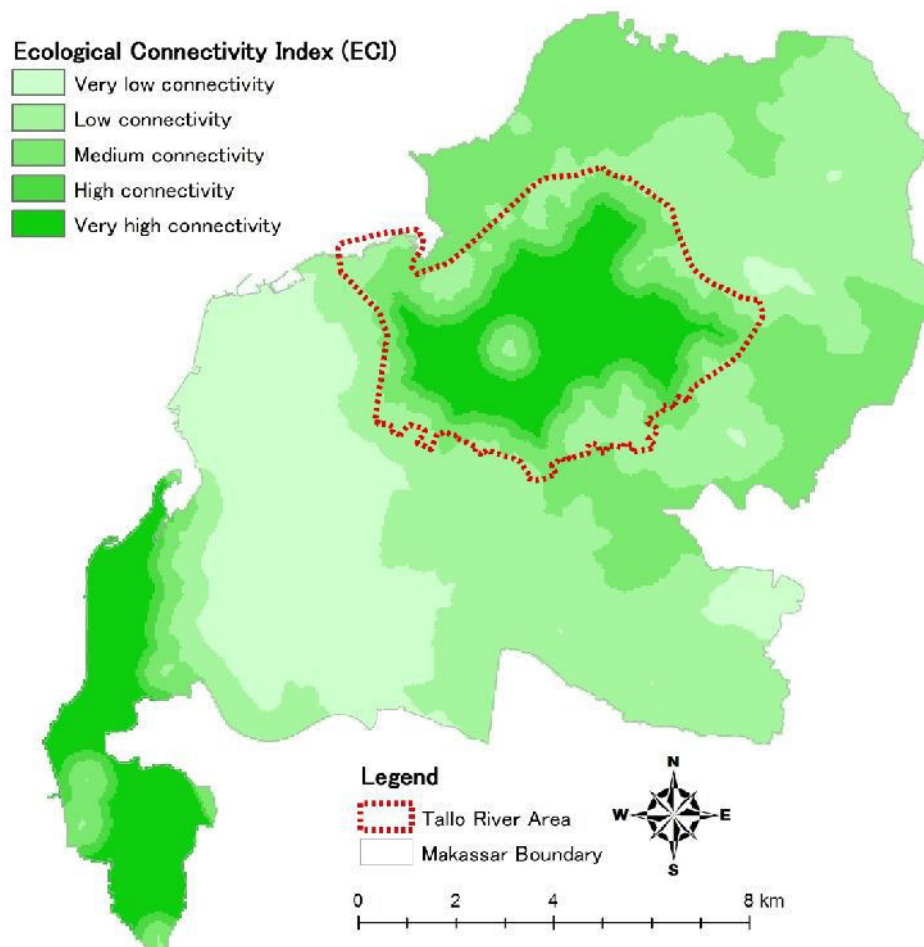


Fig. 3.12a Maps resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 1997 (Spectrum III)

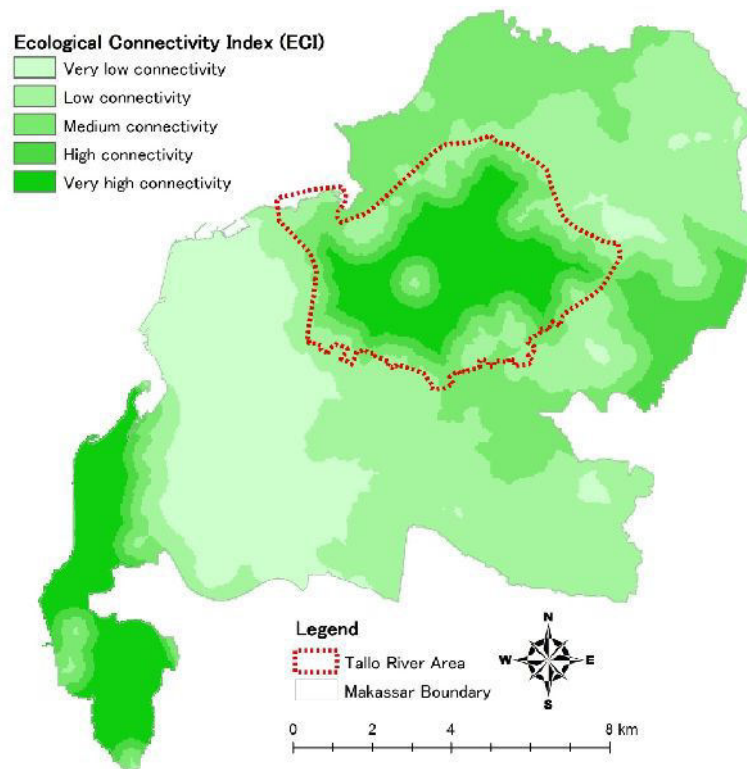


Fig. 3.12b Maps resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 1997 (Spectrum II)

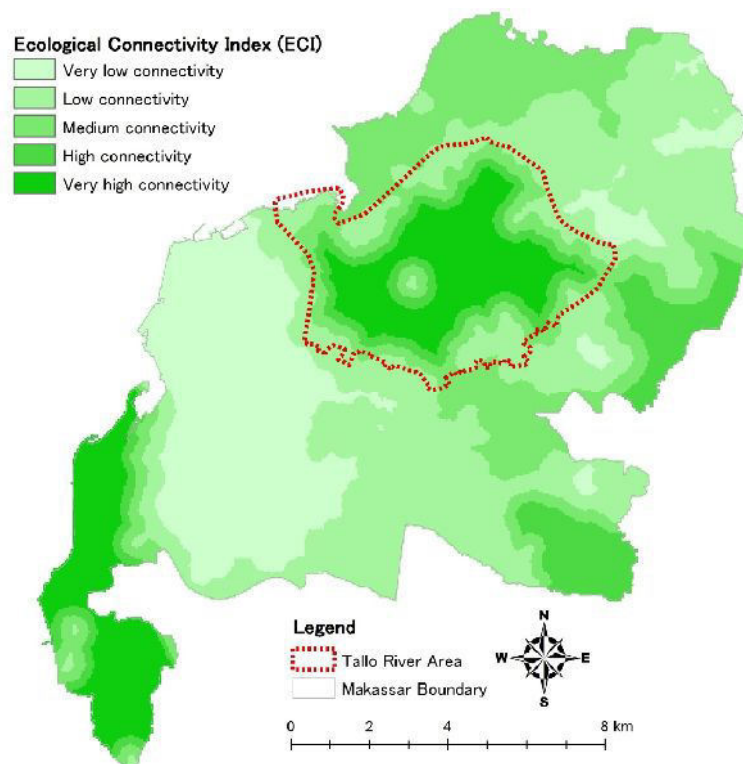


Fig. 3.12c Maps resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 1997 (Spectrum I)

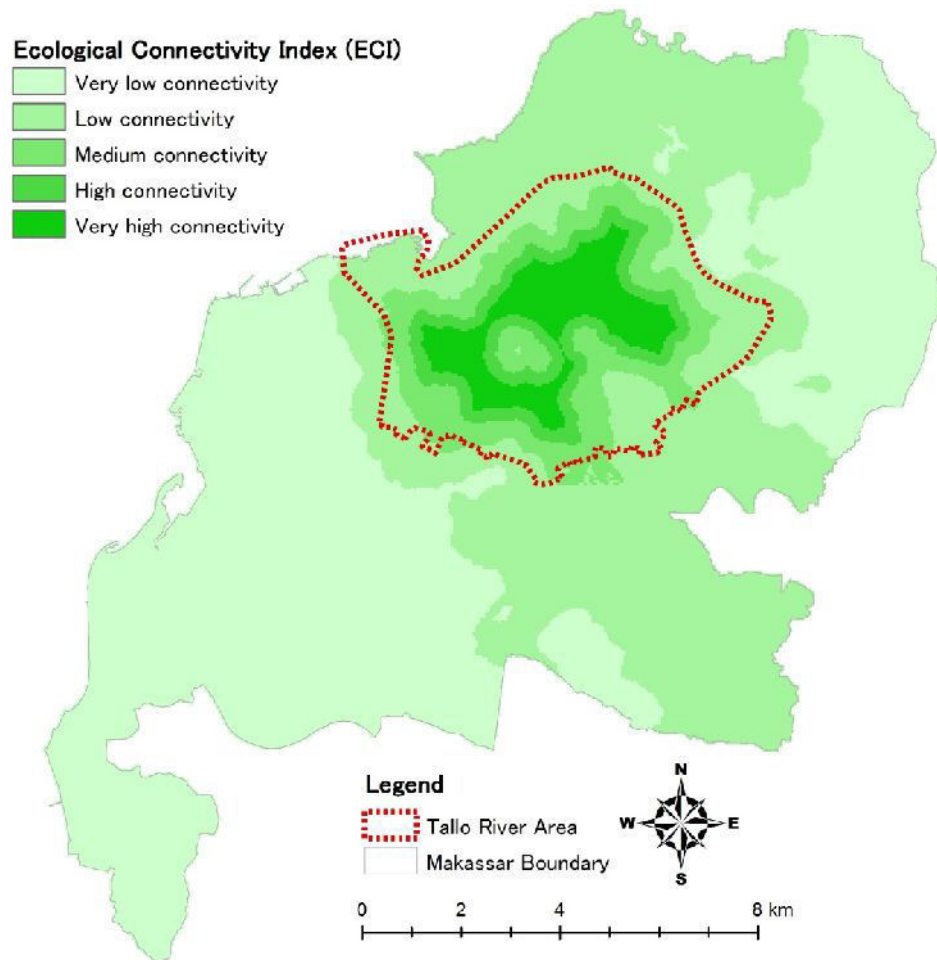


Fig. 3.13a Maps resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 2012 (Spectrum III)

3.3.3 Analysis of the ECI changes from 1997 to 2012

The GIS methodology employed in this study to assess ecological connectivity in the Makassar region can reveal spatial process such as assess spatial differentiation of ecological connectivity index from urban expansion between 1997 and 2012. The analysis result obviously show that land use changes between 1997 and 2012 which occurred in the Makassar region have in turn caused profound changes on landscape pattern. While in 1997, the Makassar region was mainly a paddy field, garden field and mangrove forest, recently it is an urban area where urban spaces occupy most of the area. There has been a large decrease in ecological connectivity in the entire Makassar region due to the high fragmentation produced by urban sprawl (**Figure 3.16**). **Table 3.9** and **3.10** shows the comparative area of ECI in different size spectrum in 1997 and 2012, respectively. Comparative chart is shown in **Figure 3.14** and **3.15**.

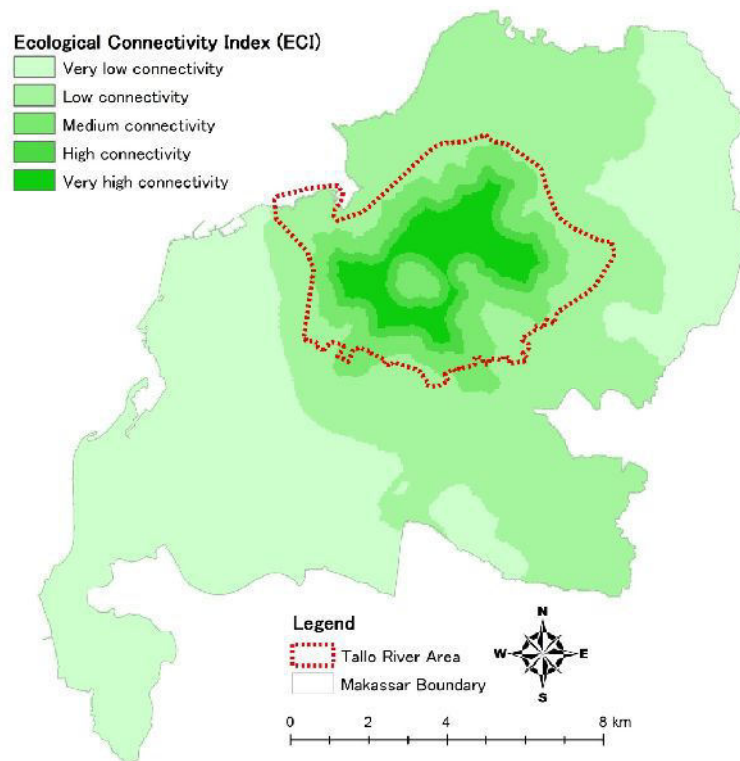


Fig. 3.13b Maps resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 2012 (Spectrum II)

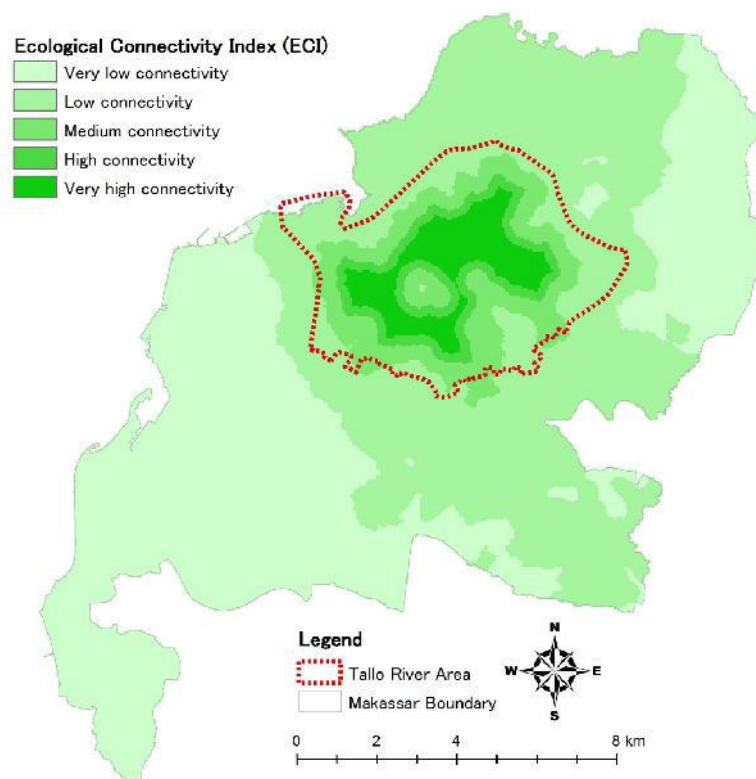


Fig. 3.13c Maps resulting from the application of the Ecological Connectivity Index (ECI) on the Makassar region in 2012 (Spectrum I)

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Table 3.9 ECI in 1997 with different spectrum size

ECI class	Spectrum I		Spectrum II		Spectrum III	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
1	3707.75	20.86	3563.5	20.05	3516.5	19.79
2	6261.25	35.23	6712.75	37.77	6801.5	38.27
3	3676.75	20.69	3750.25	21.10	4393.25	24.72
4	1777.25	10.00	1396.5	7.86	711.75	4.01
5	2347.75	13.21	2347.75	13.21	2347.75	13.21
Total:	17770.75	100.00	17770.75	100.00	17770.75	100.00

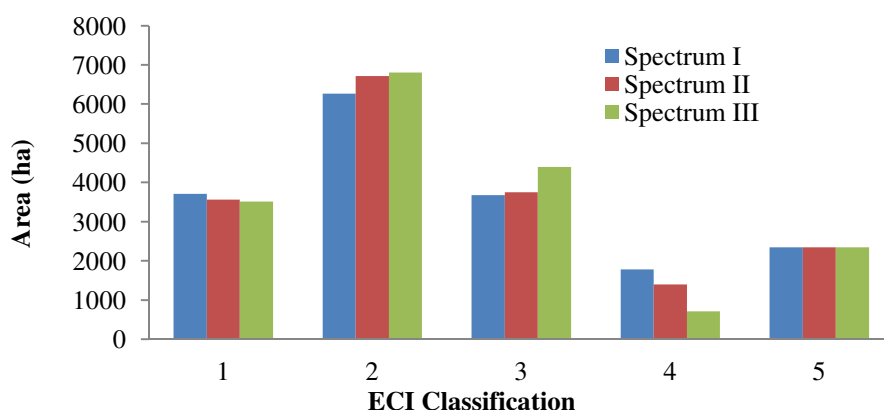


Fig. 3.14 Comparison of the ECI in 1997 for different size spectrum

Table 3.10 ECI in 2012 with different spectrum size

ECI class	Spectrum I		Spectrum II		Spectrum III	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
1	7872.25	44.30	7995	44.99	8659.25	48.73
2	7475.25	42.06	7232.75	40.70	6714.25	37.78
3	1220.5	6.87	1290.75	7.26	1126.25	6.34
4	514	2.89	563.5	3.17	582.25	3.28
5	688.75	3.88	688.75	3.88	688.75	3.88
Total:	17770.75	100.00	17770.75	100.00	17770.75	100.00

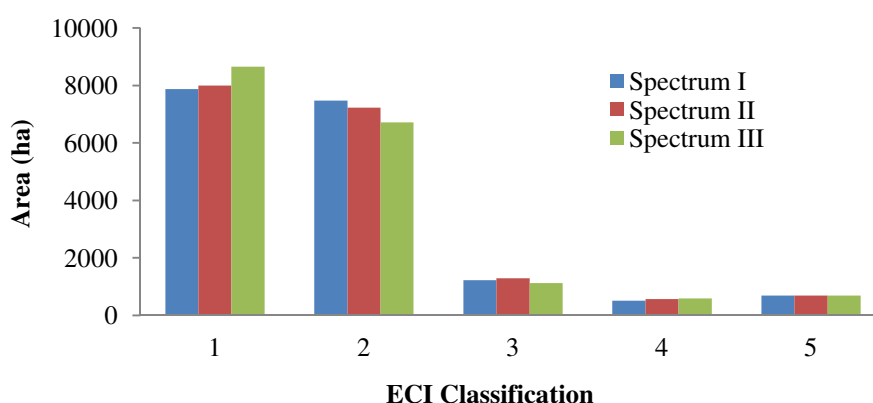


Fig. 3.15 Comparison of the ECI in 2012 for different size spectrum

SPATIAL ANALYSIS OF ECOLOGICAL CONNECTIVITY EVALUATION

From a landscape ecological point of view, one of the main trends in the Makassar area during the last fifteen years has been the rapid fragmentation and transformation of the natural landscape, creating numbers of patches of habitat, increasingly smaller and disconnected. Conversion of land-use values in 1997 into urban area in 2012, such as paddy field to urban, garden field to urban, mangrove forest to urban and shrubs field to urban has resulted different levels of impact on the ECI (**Figure 3.17**). The distribution differentiation of ECI due to conversion of each land use value (1997) changed into urban (2012) using analysis of GIS, that shows the shrub and mangrove forest in the vicinity of Tallo River Area has relatively high impact levels to the ECI (**Figure 3.18**). Therefore, a development plan is currently being considered in the Tallo River Area and if appropriately designed could mitigate the loss of ecological connectivity. Moreover, there is an urgent need for green infrastructure strategies that facilitate the protection and restoration of environment, especially the remaining few mangrove forest, swamp field and agricultural field in the Tallo River area. Study on the GIS based green infrastructure planning coordinated with ecological connectivity analysis is essential.

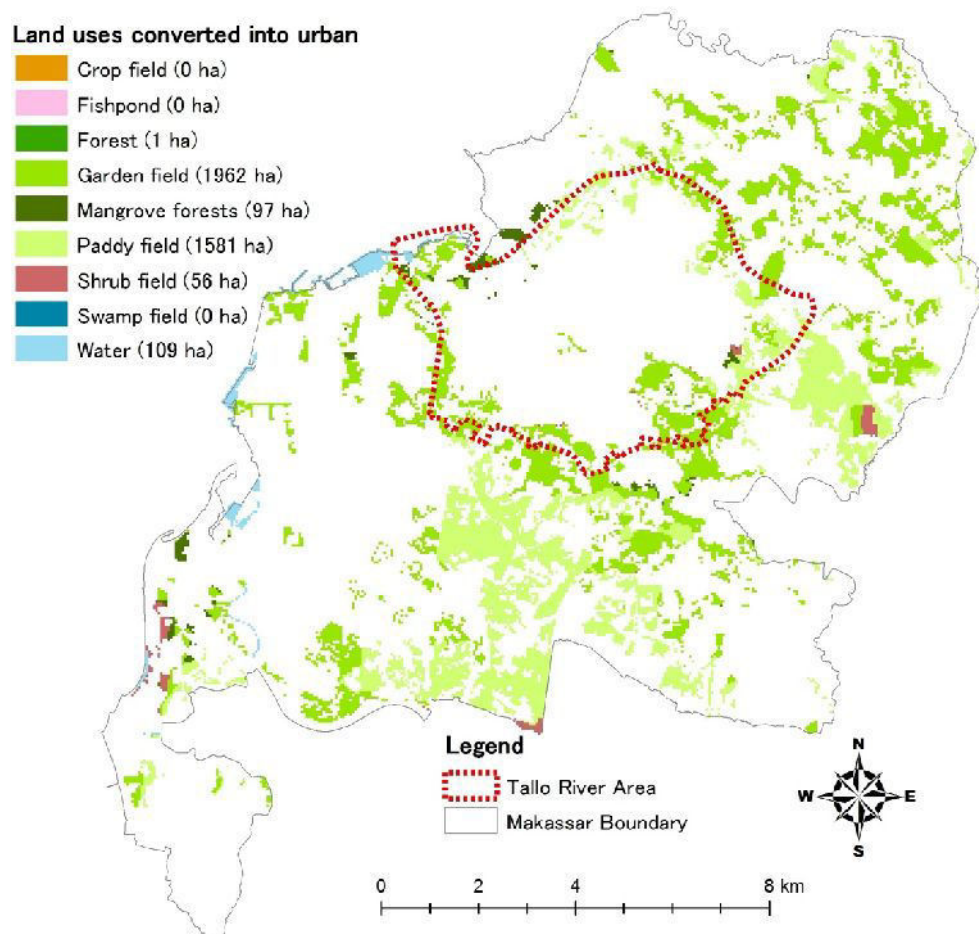


Fig. 3.16 Land use values changed into urban from 1997 to 2012

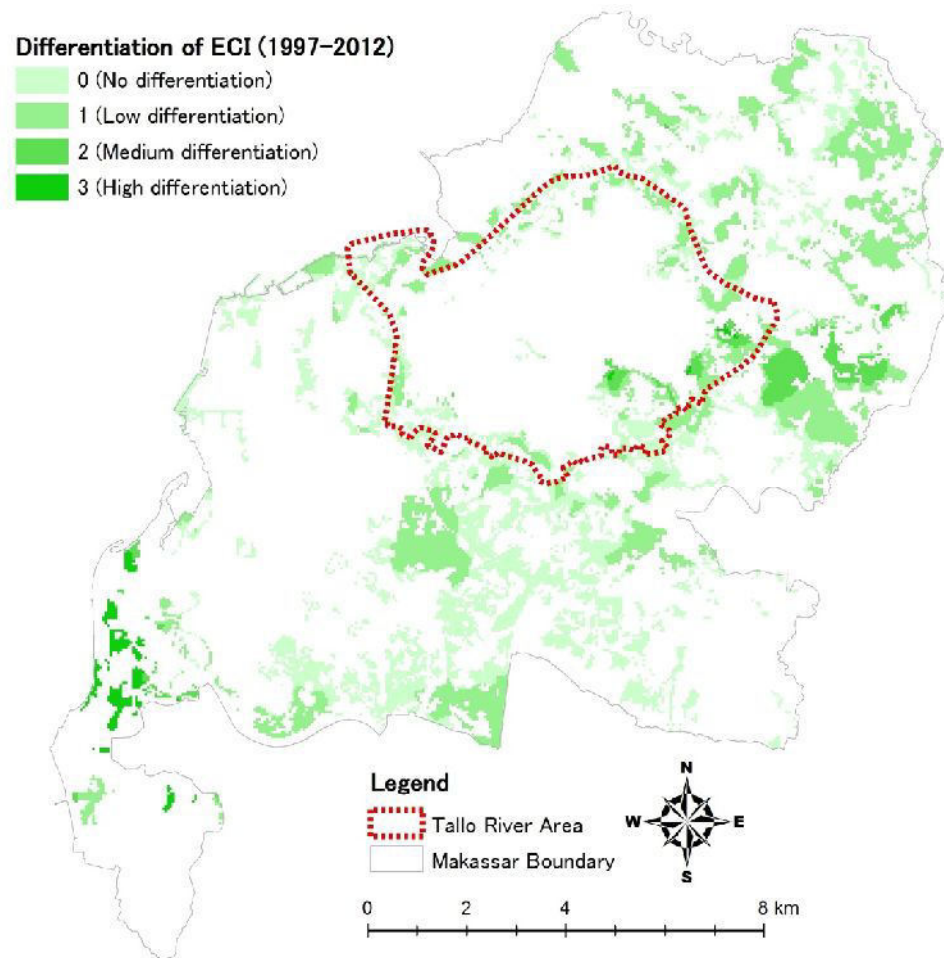


Fig. 3.17 Differentiation of the ECI due to land use values changed into urban from 1997 to 2012

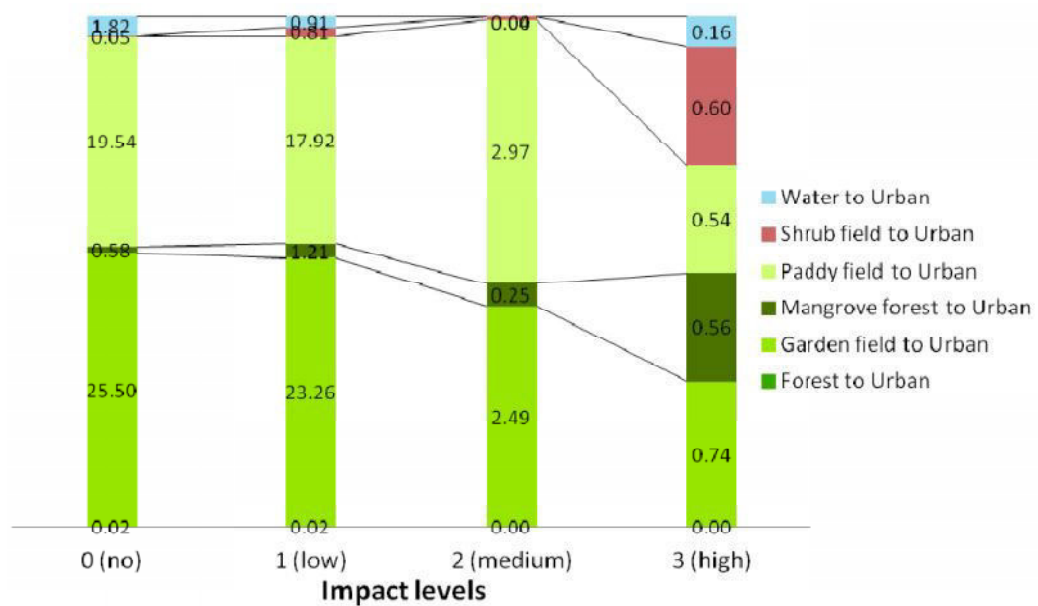


Fig. 3.18 Differentiation of ECI resulting from the conversion of each land use to urban from 1997 to 2012

Table 3.11 Results of the application of the Ecological Connectivity Index (ECI) (1997 and 2012)

ECI	Category	1997		2012	
		ha	%	ha	%
1	Very low connectivity	3517	19.79	5264	29.62
2					
3	Low connectivity	6802	38.27	8624	48.53
4					
5	Medium connectivity	4393	24.72	2612	14.70
6					
7	High connectivity	712	4.01	583	3.28
8					
9	Very high connectivity	2348	13.21	689	3.88
10					
Total		17771	100	17771	100

Furthermore, Ecological Connectivity Indices (ECI) has sharply decreased between 1997 and 2012 due to the impact of the urban development of low-density scattered suburbs. In 1997, around 13% of the land enjoyed a high or very high level of connectivity, and almost 4% in 2012. On the contrary, only 38% held this consideration in 1997 with up to 49% of the region possessing low connectivity (**Table 3.11**).

3.4 Summary

The ecological connectivity index of Makassar region has been evaluated through the spatial identification of ecological functional areas by different patch size spectrum and the barrier effect index evaluation based on Marulli and Mallarach, 2005. The ECI shows a significant decline between 1997 and 2012 due to the loss of mangrove lands, agricultural and agro-forestry mosaics. Urban sprawl of Makassar leading to loss of landscape diversity had very significant environmental impacts by isolating the remaining green lands. Negative changes in connectivity levels have occurred in the former natural-space around the Makassar region, both at West and East part of the city. It is found that the mangrove forest and shrubs field has relatively high impact levels to the ecological connectivity index changes. Furthermore, some areas have been identified in Tallo River Area for the conservation of the potential ecological connectivity between natural areas, and the restoration of the loss of the vital natural sites.

Spatial Analysis of Flood Risk Evaluation

4.1 Analysis of Flood Hazard Index

4.1.1 Characteristics of flood threat in the Makassar region

Since 1900 flooding in Indonesia is ranked as the second most frequent and fourth most economically damaging natural disaster after wildfires, earthquakes and volcanic eruptions, causing an estimated 4,493 deaths, affecting 6.2 million people and resulting in US\$ 2.4 billion in damages (Riyanti et al., 2017). The causes of flooding in cities vary according to geographical location, topography, land-use, and watershed condition. Cities located on the coast within an extensive coastal plain such as the city of Makassar, which are subject to severe flood risks from inland and from the sea.

The Makassar region has topography with a slope of 0-2° (flat) and a slope of 3-15° (undulating) land with lowland stretching at an altitude between 0-40 meters above sea level (**Figure 4.1**). Due to topography condition, many sub-districts of Makassar are regularly flood experiences during rainy season, especially at the time of rain along with rising tide. Generally, the topography is grouped into two parts. First, the west to the north is relatively low close to the coast. Second, Eastern part is area with hilly topography. The urban development of Makassar tends to lead to the Eastern part of the City. This is visible with the vigorous housing development in sub-districts. The Makassar region is covered by three watershed systems that are Tallo watershed, Manyikkoaya watershed, and Jeneberang watershed (**Figure 4.2**). About 81% of watershed area in Makassar is covered by Tallo watershed. About 11% and 8% of watershed areas is covered by Manyikkoaya and Jeneberang watershed. By the GIS hydro tool, watershed analysis has been conducted to identify the sub-catchment, stream network lines, and drainage points of Tallo, especially in Makassar region. **Figure 4.3a, 4.3b and 4.3c** shows the simulation results of hydrological model in GIS using the available of Digital Elevation Model (DEM) data.

SPATIAL ANALYSIS OF FLOOD RISK EVALUATION

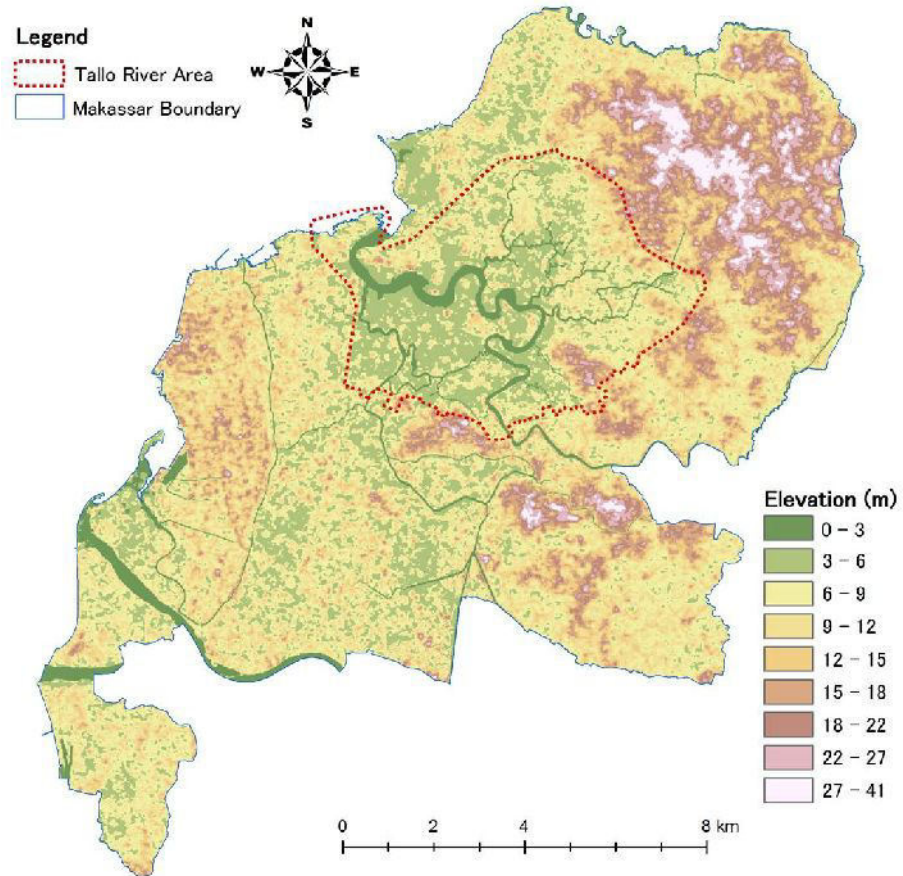


Fig. 4.1 Topographical condition of the Makassar region

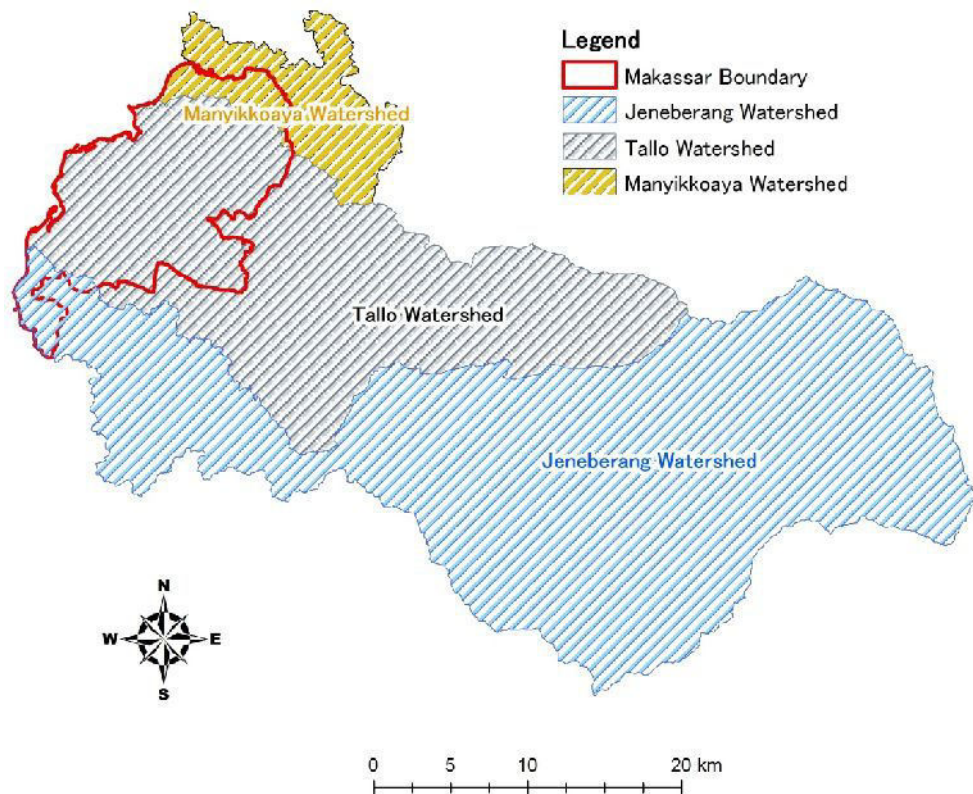


Fig. 4.2 Three watershed systems which covering the Makassar region

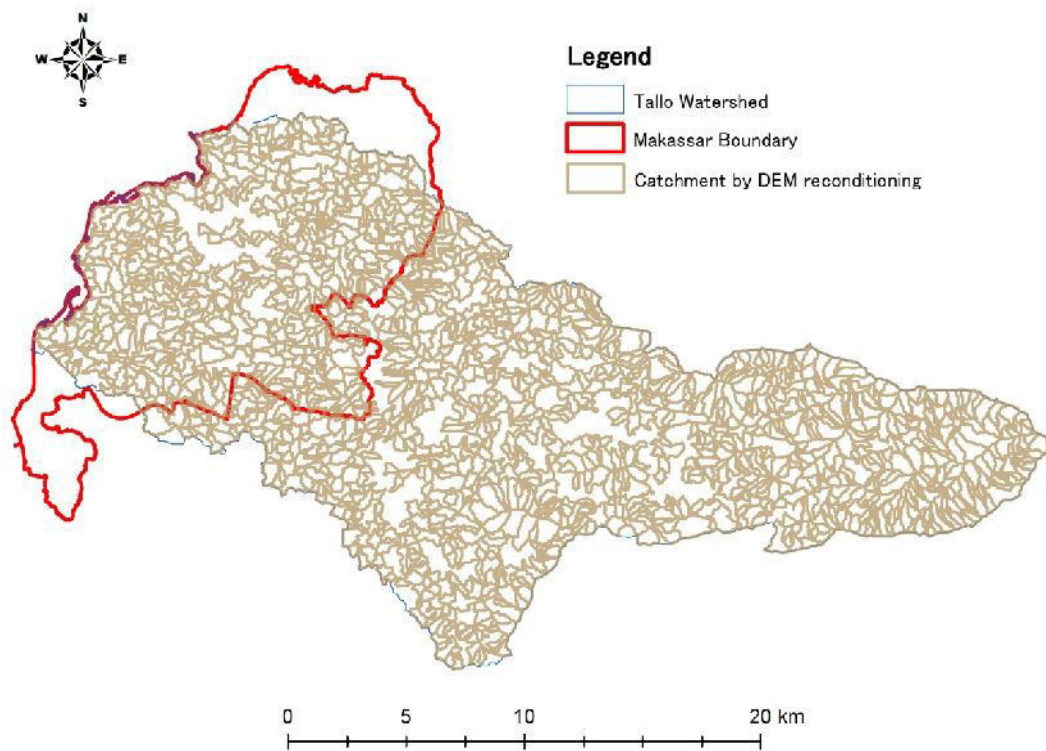


Fig. 4.3a Tallo's catchment system created by DEM with threshold of 0.5km^2

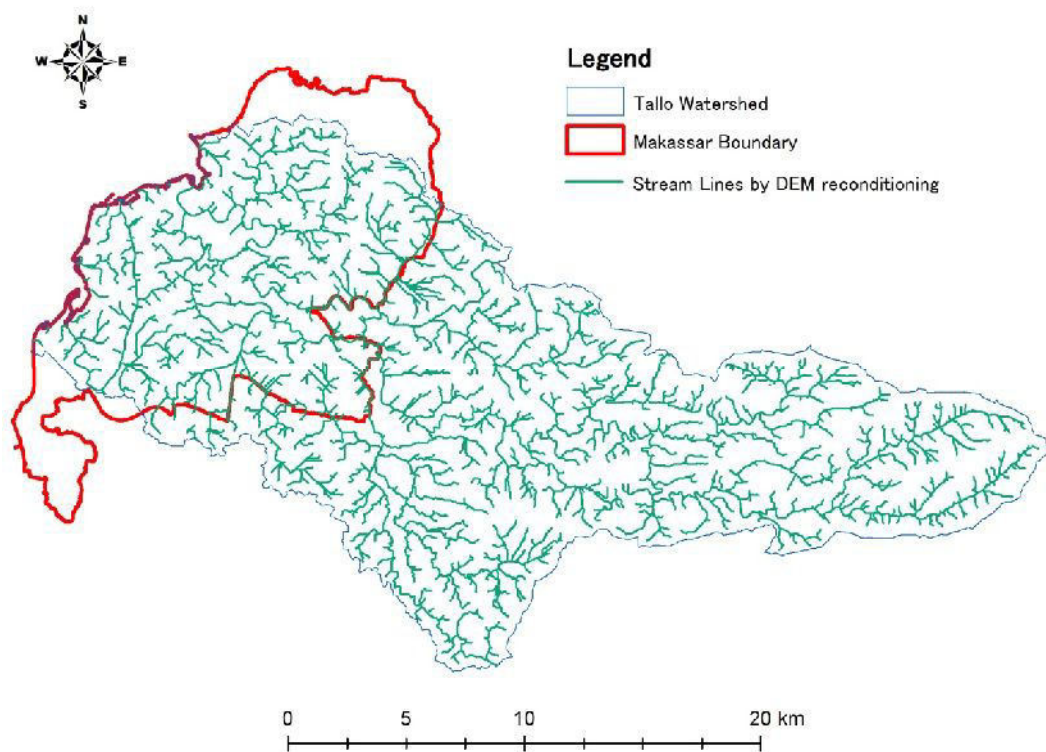


Fig. 4.3b Tallo's stream line networks

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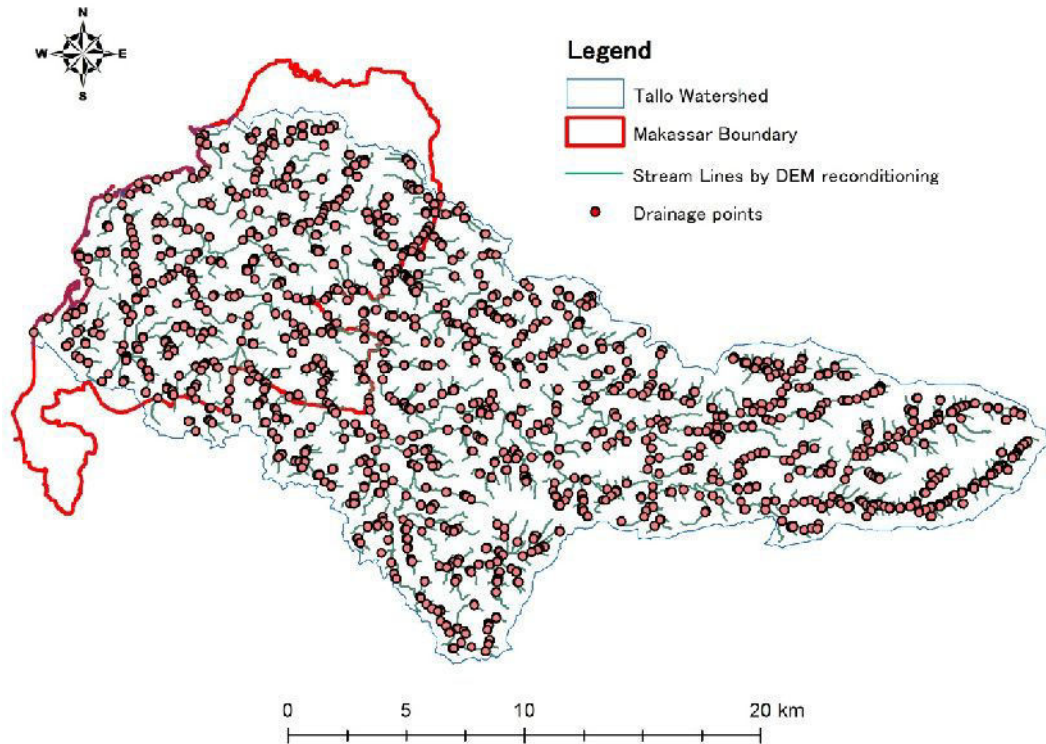


Fig. 4.3c Tallo's drainage points

Climate data is mainly used the measurement from local climatology station obtained from Meteorology and Geophysics Agency Region IV of Makassar. From maximum rainfall per day from the year of 1979 to 2016 shows that the amount of rainfall as average value is 156.4 mm per day. The average maximum rainfall per day in the Makassar region for the last 37 years is shown in **Figure 4.4a**. Furthermore, **Figure 4.4b** shows the average monthly rainfall from January to December which depicts that in January the amount of rainfall is about 700 mm. The lowest amount of rainfall occurs on August about 8 mm.

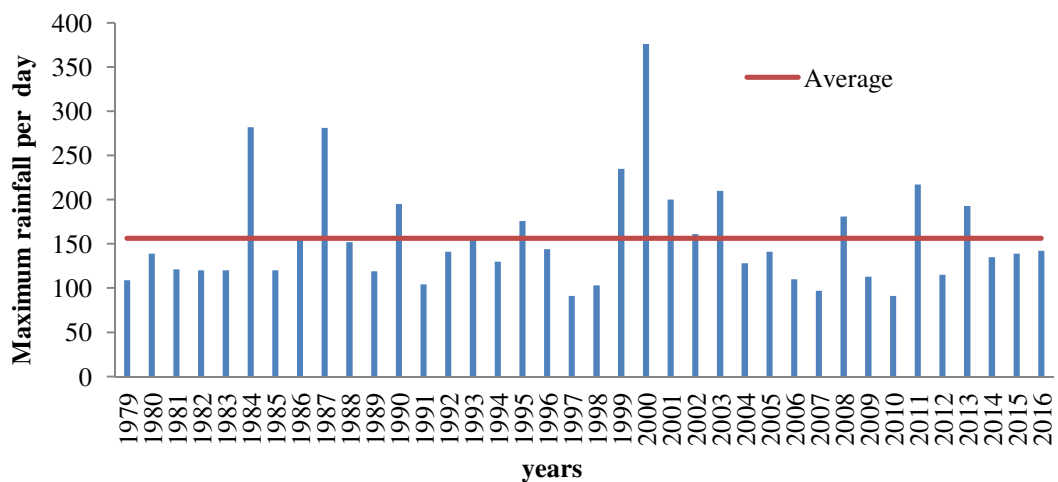


Fig. 4.4a Maximum daily rainfall for the last 37 years for the Makassar region

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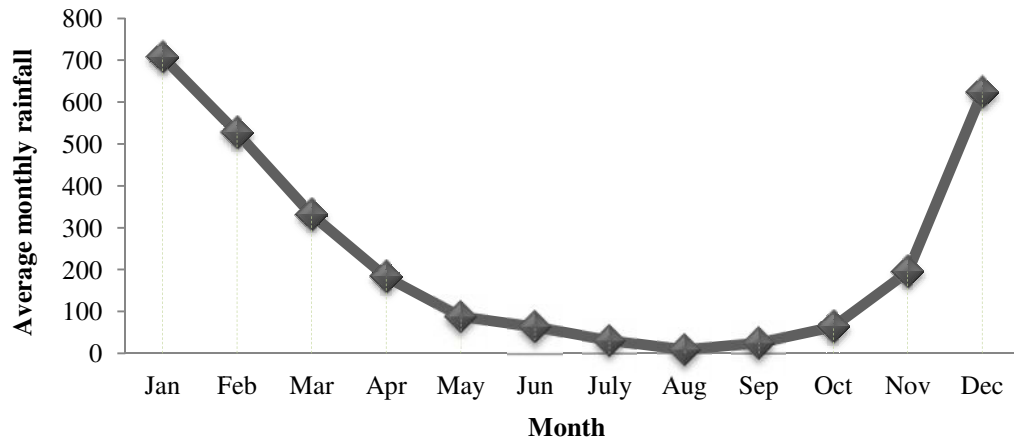


Fig. 4.4b Average monthly rainfall for the last 37 years in the Makassar region

Table 4.1 Detail monthly rainfall from 2007 to 2014

Year	Monthly rainfall (mm)											
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2007	626	379	227	122	36	198	5	3	-	71	217	629
2008	561	927	334	155	8	49	62	4	1	102	229	769
2009	1030	536	104	86	34	34	45	-	-	111	17	523
2010	947	296	342	207	242	102	92	67	290	280	183	668
2011	624	570	612	357	104	6	-	2	1	59	145	987
2012	568	421	493	223	219	61	58	-	-	28	103	417
2013	1168	480	371	281	143	192	112	1	1	61	195	764
2014	888	301	304	223	173	122	39	6	-	-	111	577

Almost every year, some parts of the Makassar region experienced flooding. Generally, floods occur in month of December to February, which is duration time of the highest rainfall every year (see **Figure 4.4b**). Some of the huge floods that ever occurred were in 1984 and 1987. In recent years, major floods occurred in 1999, 2000 and 2013, and most of the city area experiencing flooding. **Table 4.1** shows the monthly rainfall in 2013 was high values compare to other years, recently.

4.1.2 Characteristic impacts of urban flood occurrence in 2013

In January 2013, floods struck the Makassar region which is mainly located in the districts of Biringkanaya, Tamalanrea, Tallo, Manggala, Rappocini, and Panakukkang with a total flooded area of more than 3000ha. **Figure 4.5** shows the boundary of districts, catchments of Tallo, and flooded catchments in Makassar region that affected by the floods in 2013. By the GIS analysis, it is found that the

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flooded areas are mostly located in the catchments with the minimum elevation at 8.5m, maximum elevation at 20m, and average elevation at 10.8m. **Figure 4.6** shows the histogram of calculation elevation at catchments and flooded catchment areas (marked by arrow line). Moreover, the flooded area has minimum slope at 0 degree, maximum slope at 7.3 degree and average slope at 1.8 degree. **Figure 4.7** shows the histogram of calculation slope at catchments and flooded catchment areas (marked by arrow line).

Number of total peoples affected by these floods reaches 101,972 inhabitants, as recorded values by Indonesian Regional Disaster Management Agency (BPBD). Numbers of impacted peoples located in the sub-districts of Kassi-Kassi, Panaikang Karunrung and Tamalanrea Jaya are 10,961, 9,651, 9,532 and 8,735 inhabitants, respectively. Picture of flood impacts in some part of sub-district of Antang is illustrated in **Figure 4.8**. The comparative of land cover area affected by floods in 2013 is shown in **Figure 4.9**. It is shows that the flood impacts are mainly to the agricultural field (about 1200 ha) and the urban settlement areas (about 750 ha).

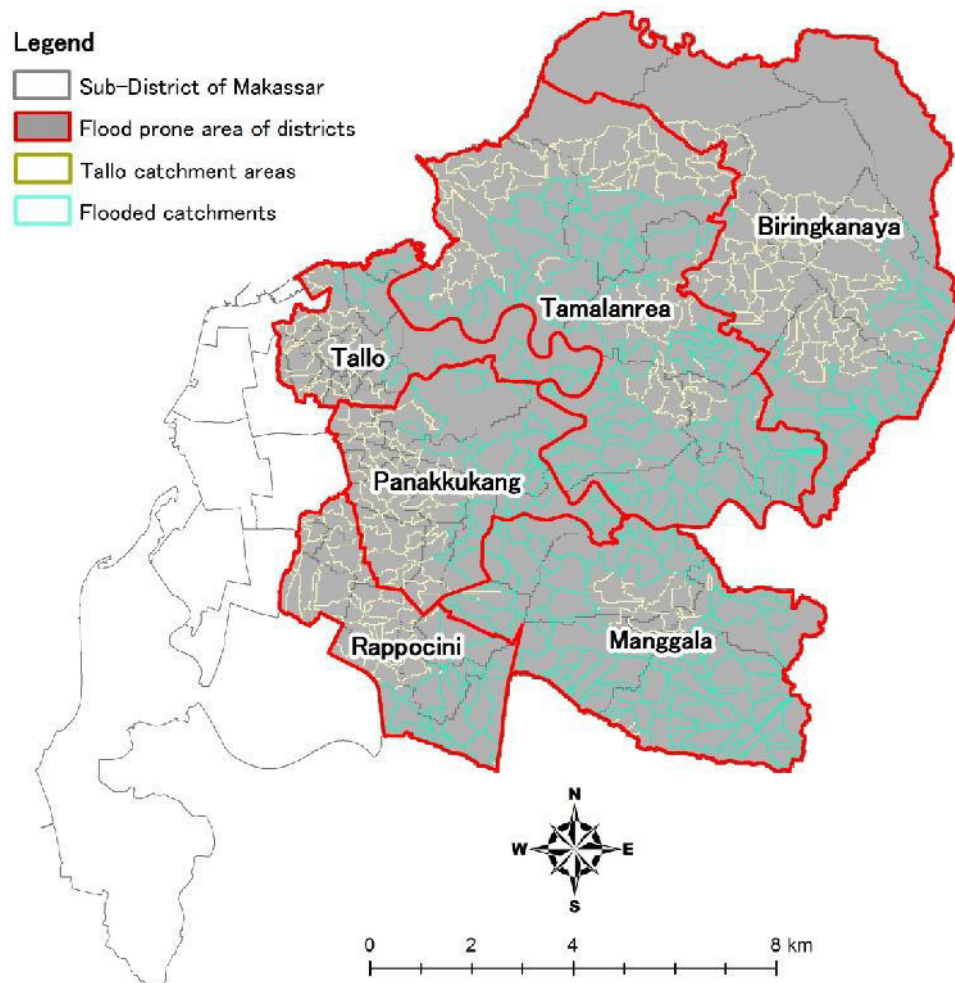


Fig. 4.5 Districts and catchment areas affected by urban flood occurrence in 2013

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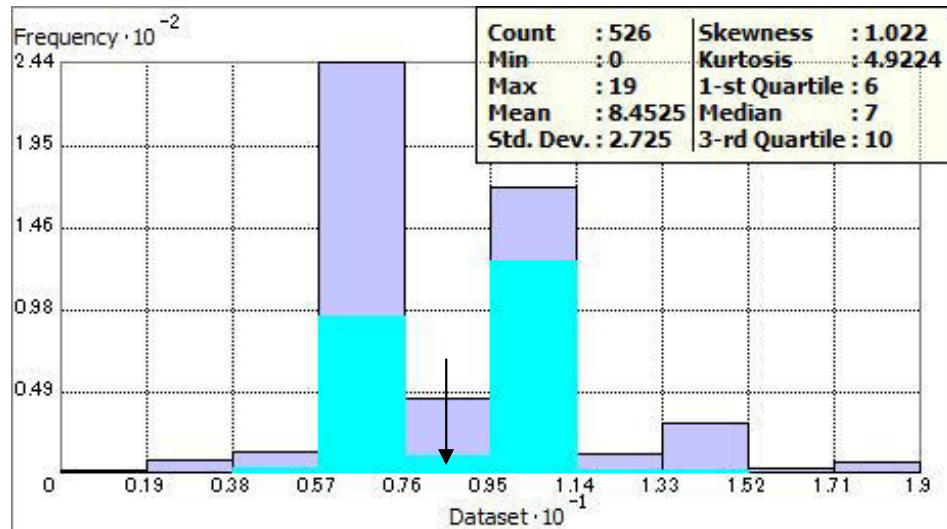


Fig. 4.6a Histogram of the minimum elevation at catchments and flooded areas

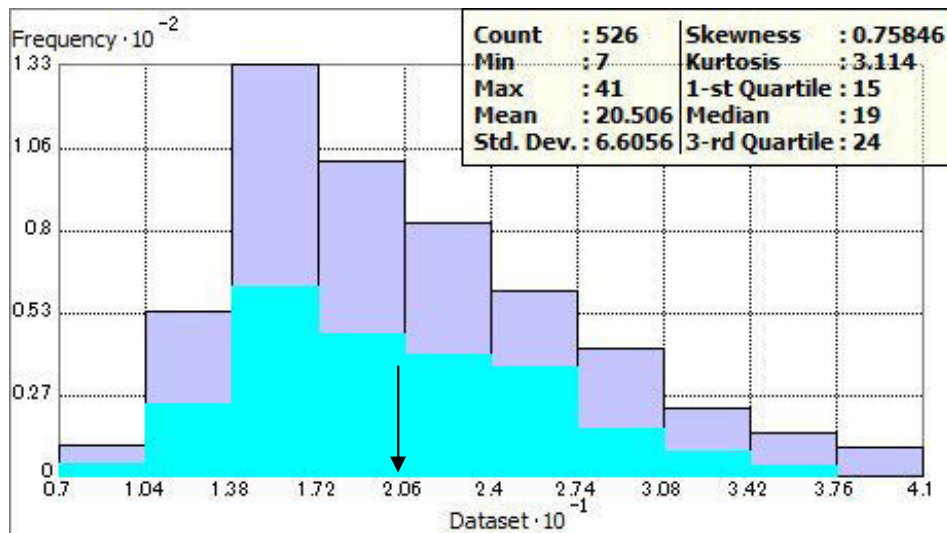


Fig. 4.6b Histogram of the maximum elevation at catchments and flooded areas

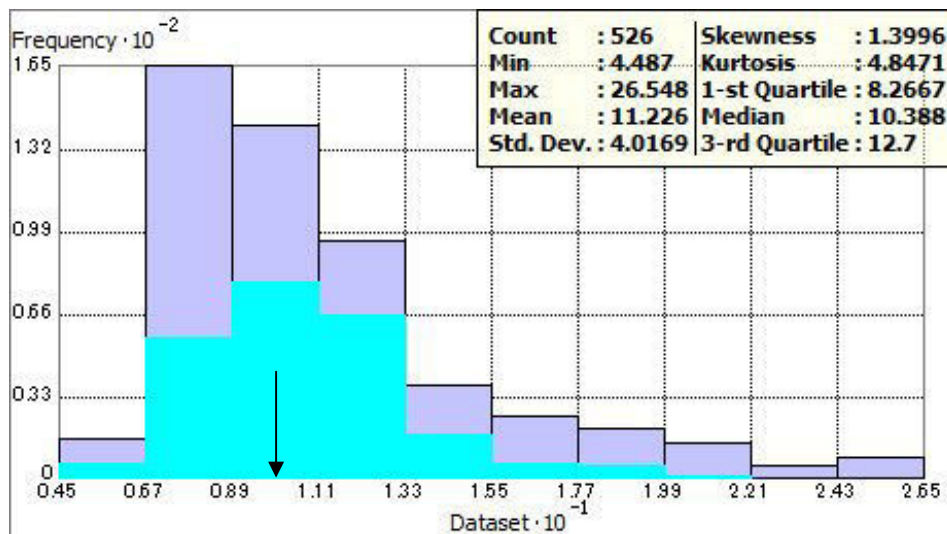


Fig. 4.6c Histogram of the average elevation at catchments and flooded areas

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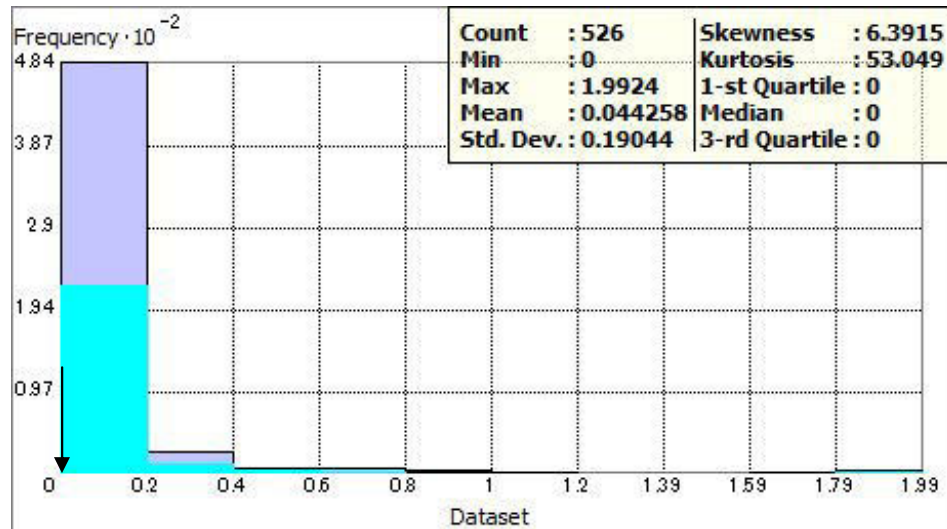


Fig. 4.7a Histogram of the minimum slope (deg.) at catchments and flooded areas

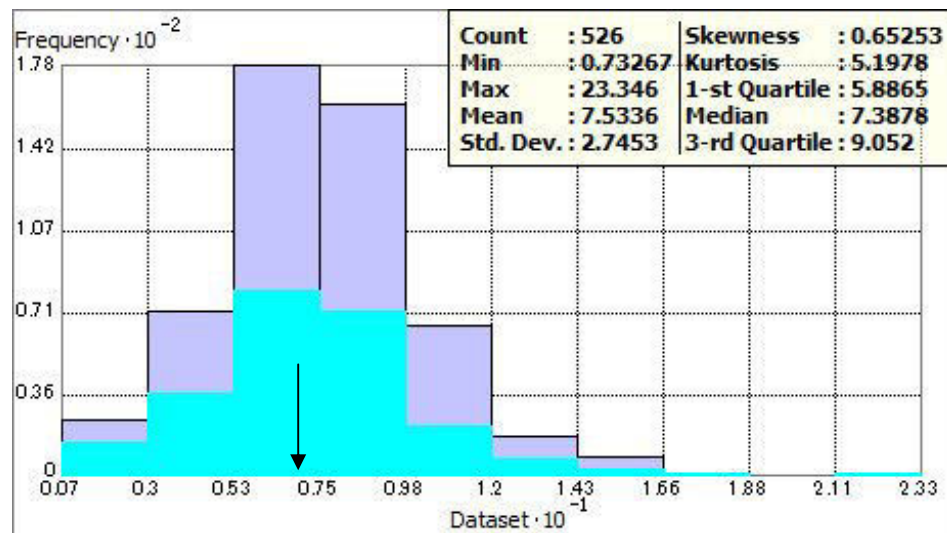


Fig. 4.7b Histogram of the maximum slope (deg.) at catchments and flooded areas

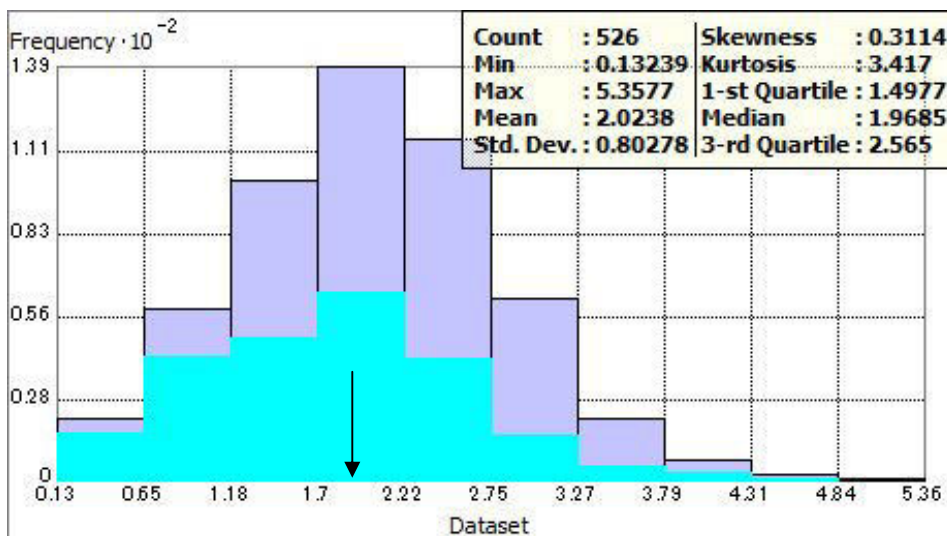


Fig. 4.7c Histogram of the average slope (deg.) at catchments and flooded areas

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Fig. 4.8 Photos of flood impacts at sub-district of Kassi-Kassi

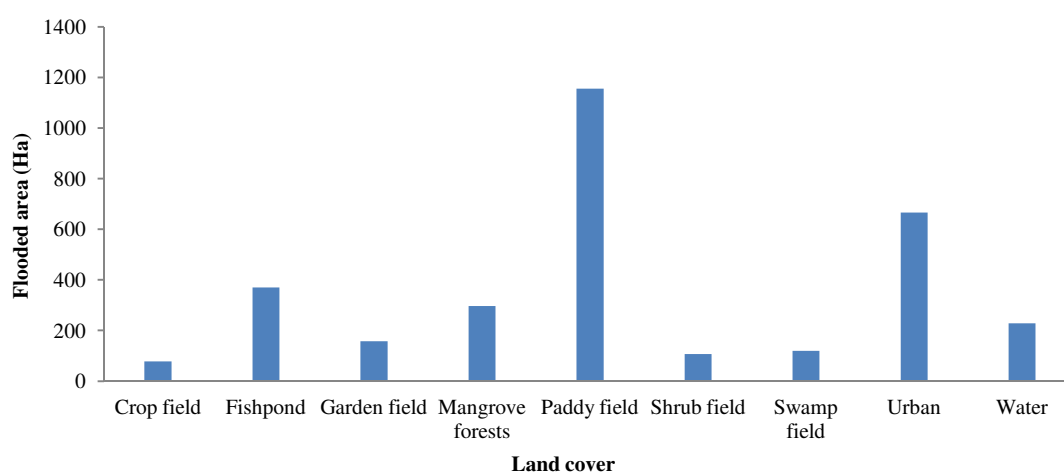


Fig. 4.9 Comparative of land covers area (ha) affected by floods in 2013

Table 4.2 Land cover impacted by flooded area in the Makassar region

Land cover	Flooded area by flood depth in cm (%)							
	0-50		50-100		100-150		150-200	
	Ha	%	Ha	%	Ha	%	Ha	%
Crop field	7	0.87	71.25	6.40	0	0.00	0	0.00
Fishpond	115.25	14.28	112.25	10.09	142.25	11.92	0.25	0.38
Garden field	22.5	2.79	61.5	5.53	56.75	4.75	17	25.76
Mangrove forests	13.25	1.64	97	8.72	171.75	14.39	15	22.73
Paddy field	236.75	29.34	367.75	33.05	533.75	44.72	17	25.76
Shrub field	0.75	0.09	20.75	1.86	86	7.21	0	0.00
Swamp field	21.75	2.70	35	3.15	62.5	5.24	0.25	0.38
Urban	276.25	34.23	285.5	25.66	90.75	7.60	13.75	20.83
Water	113.5	14.06	61.75	5.55	49.75	4.17	2.75	4.17
Total	807	100	1112.75	100	1193.5	100	66	100

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In addition, the land cover areas have affected by floods in 2013 to 17.89 % of the Makassar region. Paddy field and urban has high impacted area to 36.34% and 20.60% of the total flood area, respectively. The increasing phenomenon of urban area from 1997 to 2012 have caused the land cover of fishpond (11.64%) and mangrove field (9.34%) also affected by floods in 2013. **Table 4.2** shows the comparison of the land cover area (hectares) classifying by flooded depth.

4.1.3 Establishment of flood hazard index map in 2013

Flood survey and measurements were conducted by the coordination between the governments of the city of Makassar and the Indonesian Regional Disaster Management Agency (BPBD). Flood hazard map in the Makassar region in 2013 was already published (**Figure 4.10**). In this study, historical records of flood events in 2013 are used as major flood hazard scenario for risk assessment. The flood hazard index will be compiled based on data and historical records of events that have occurred in the Makassar region. The flood hazard index is structured based on two main components, namely the possibility of a threat (boundary flooded areas) and the magnitude of impacts (flood depths) recorded for the flood disaster.

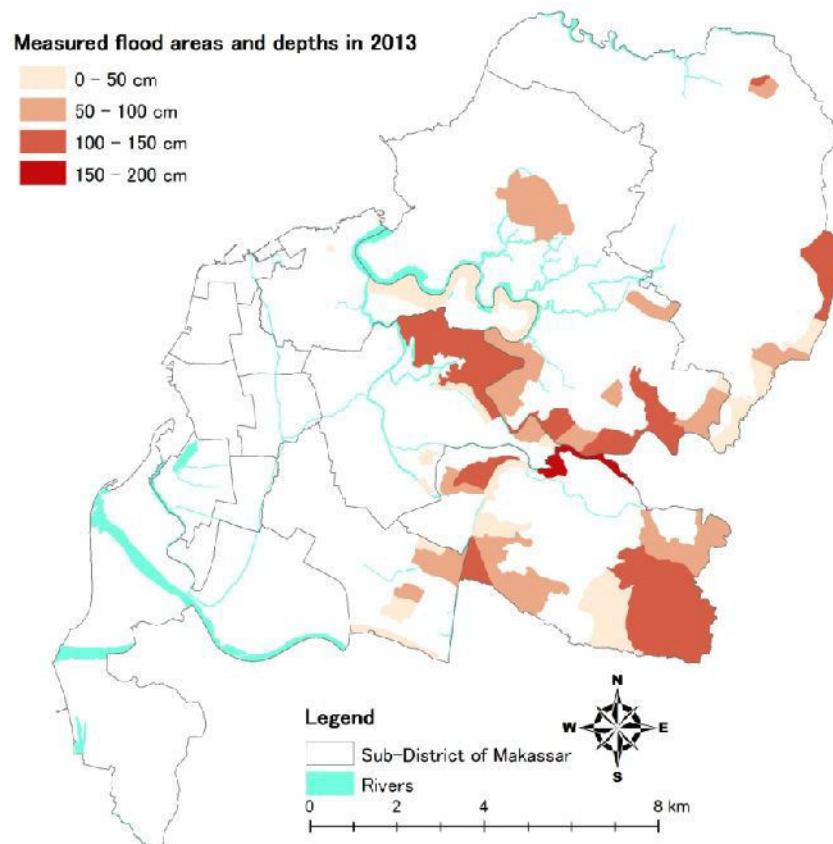


Fig. 4.10 Historical flood hazard maps based on the measurement data in 2013

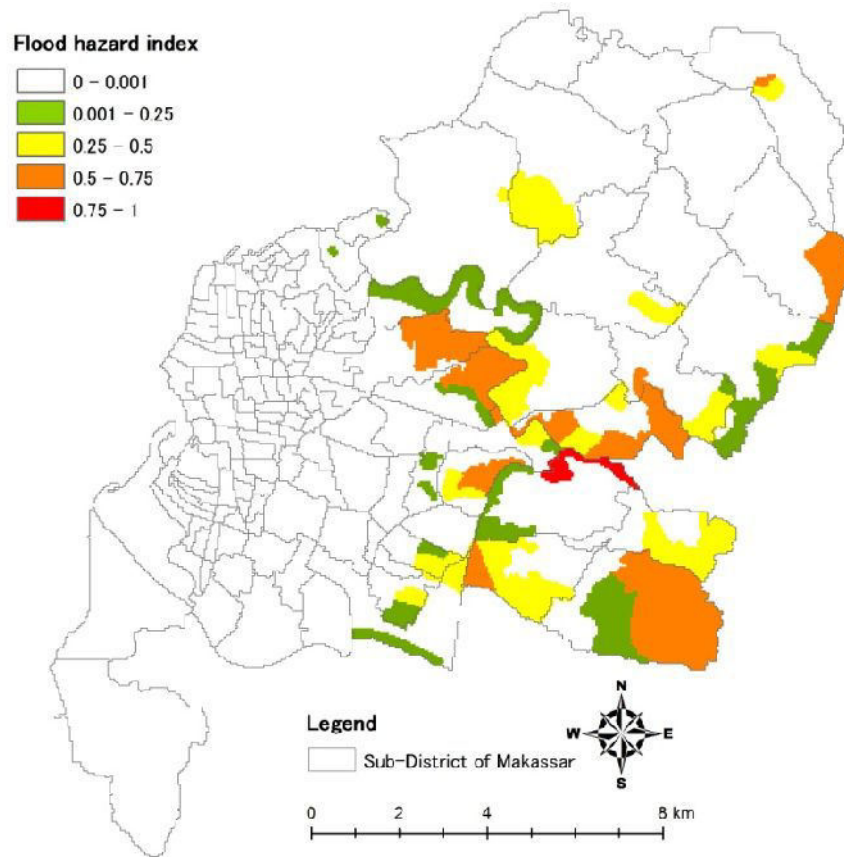


Fig. 4.11 Flood hazard index map generalized from the predefined data by BPBD

As measurement data in 2013 by the local government with BPBD, the established flood hazard map with the spatial information of flood depth and areas is used to construct the flood hazard index by GIS. Prior to the preparation of flood hazard index map, flood areas and depths are analyzed using the GIS matrix tool. The matrix classification of flood index system can be implemented after all spatial data on the study area is obtained from predefined statistical data source.

The flood hazard index of the Makassar region represents a first attempt at providing a consistent, regional-wide spatial index of flood hazard. It was generated using a GIS and empirical approach that can easily be updated data by interpretation of higher resolution DEM and/or additional flood line maps. To make the flood hazard index comparable at least in dimensions, the hazard index used in the analysis is converted to a value between 0 and 1, where 0 is the minimum value of the hazard, and 1 is the maximum value. Furthermore, the data obtained are then divided into 4 threat classes (very low, low, medium, and high) to provide easily calculation for flood risk index analysis. The generated flood hazard index map by GIS is shown in **Figure 4.11**. It is shows that the Southern to East parts of the Makassar region falls into moderate intensity flood zones.

4.2 Analysis of Flood Vulnerability Index

4.2.1 The concept of flood vulnerability

It is expected that, due to climate change, coastal communities around the world will be increasingly affected by floods. In fact, some are already considered vulnerable to ongoing climatic variability (IPCC 2007a, b; Mirza, 2003). Climate change is expected to cause accelerated sea-level rise with elevated tidal inundation, increased flood frequency, accelerated erosion, rising water tables, increased saltwater intrusion, increasing storm surges and increasing frequency of cyclones (Fenster and Dolan, 1996). Vulnerability is considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (Balica et al., 2009; Scheuer et al., 2010; Willroth et al., 2010). More specifically in the case of floods, a system is susceptible to floods due to exposure in conjunction with its capacity or incapacity to be resilient, to cope, recover or adapt to the extent. The concept of vulnerability is approached from different disciplines and professional fields such as academia, disaster management agencies, climate change community and agencies (Fuchs et al., 2011). While there is no universal definition, the definition varies so widely that, in interdisciplinary context, the term becomes almost useless without further specification (Hufschmidt, 2011).

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability is defined as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes”. Concerning climate change vulnerability, it refers to the state of susceptibility to harm from exposure to climate hazards, and the ability of a unit of analysis to cope with, and recover from, such exposure as well as manage incremental and long-term change in climate. Though many definitions exist, the concept of vulnerability in this study considers the local approach provided by BNPB framework. By this approach, vulnerability has specific spatial, socio-economic-demographic, environmental and physical contexts that impose challenges to research on vulnerability to flooding (BNPB, 2012), is shown in **Figure 4.12**. The BNPB framework was developed to improve vulnerability assessment in Indonesia, as part of risk evaluation and risk management in the context of disaster risk management in Indonesia. It fulfills a need for standards and guidance in estimating vulnerability as the critical component of risk at local context (BNPB, 2012).

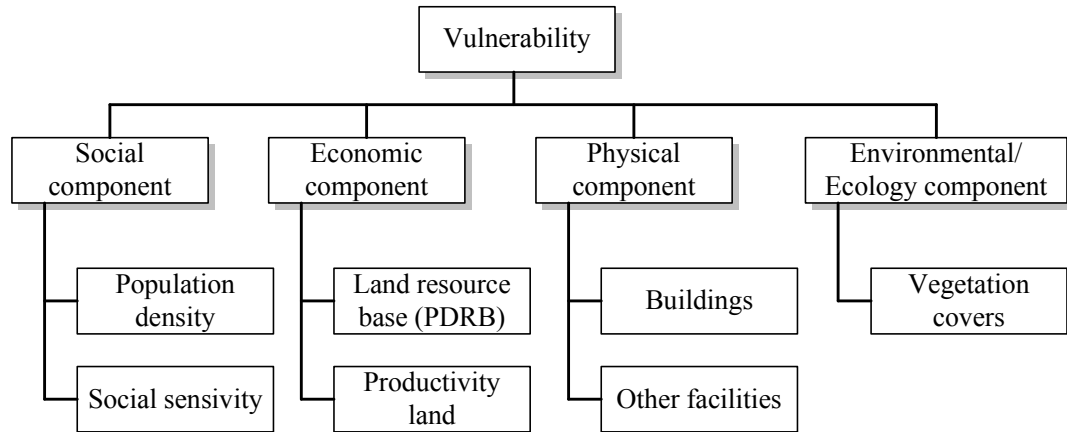


Fig. 4.12 Indicator composition of local context for vulnerability analysis based BNPB framework

It is a framework to guide systematic assessments of vulnerability to assess key factors and various spatial dimensions of vulnerability. The BNPB framework better fits the local context, since the data that are necessary for the framework are available and easily accessible in the study area. Indeed, in this paper, all the indicators considered, related to exposure, susceptibility and resilience, are covered by the BNPB framework. Following this framework, our approach involves statistical spatial analysis, the development of composite indicators and the use of spatial and non-spatial data.

4.2.2 Selection of relevant indicator variables

The first step in vulnerability assessment is to select appropriate indicators. Some of the indicators, in general, belong to two of the factors. Due to the definition in this study, the indicators are considered only for one of the factors. The relationship between urban vulnerability components and indicators by BNPB framework analysis is illustrated in **Table 4.3**. The method presented in this study uses the BNPB framework as a reference analysis to assess vulnerability. In this study, key factors of the BNPB framework analysis are defined as follows.

1) *Exposure (E)*: In this study, it was measured by the number of people per sub-district area, differently exposed to flood due to their location; and as the socio-environmental factors that aggravate the intensity of the hazard. Exposure is calculated by considering the density of the population per sub-district area (E1), percentage of the population under poverty (E2), land resource base (E3), productive land (E4), and percentage of the vegetation cover (e.g. protected forest, natural forest, mangrove, shrubs) (E5).

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Table 4.3 Indicator values for each components of vulnerability according the BNPB framework

Component	Indicators					
	Exposure		Susceptibility		Resilience	
	Local context	Definition	Local context	Definition	Local context	Definition
Social	Population density (inhabits/km ²)	People per km ²	% of age (<5 and >65 years)	Percentage of children under 5 or elderly above 65	% of disable peoples	% of any kind of disabilities
	% of poverty	Percentage of population under poverty	% of gender (women)	Percentage of women		
Physical			Building codes	Building values divided into the houses, public facilities, and critical facilities e.g. water supply		
Economic	Productive land	Income-producing unit e.g. farm				
	Land resource base (PDRB)	Total available local budget				
Environmental	Vegetation covers	Protected forest, natural forest, mangrove, shrubs area (ha) in sub-districts				

2) *Susceptibility (S)*: Children under 5 years and the elderly (above 65 years), and women are considered to be the groups most susceptible to harm in the case of flood events. Based on local context, susceptibility is calculated by considering the percentage of number of children less than 5 years or elderly above 65 years (S1), percentage of women per sub-district area (S2), and the number of building related to the structural value and importance (S3).

3) *Resilience (R)*: Affected communities become more resilient to flood when they

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are able to recover from the hazard. The recovery process presumes the availability of sufficient means and risk transfer tools. It seems, therefore, that the disable peoples e.g. homeless, literacy rate, and handicap for lack of resilience for a given sub-districts (R1).

4.2.2.1 Social vulnerability component

The indicators used for social vulnerability are population density, percentage of poverty, percentage of ages (5< and >65 years), percentage of gender, and percentage of disability (**Figure 4.13**). The index of social vulnerability is derived from the average of weight of population density (60%), and weight of social sensitivity (40%) consisting of percentage of poverty (10%), percentage of ages (10%), percentage of gender (10%), and percentage of disability (10%). Index conversion parameters are described in **Table 4.4**, as follows.

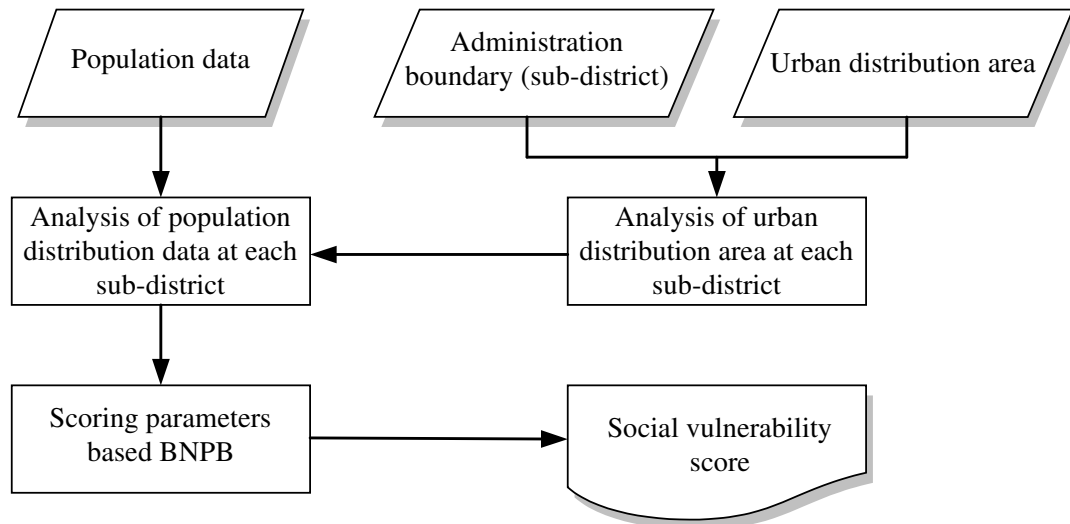


Fig. 4.13 Flowchart of BNPB framework analysis for social vulnerability assessment

Table 4.4 Index conversion parameters for social vulnerability indicator

Parameter	Code	Weight (%)	Value			Score
			Low	Medium	High	
Population density (inhabits/km ²)	E1	60	<500	500-1000	>1000	X_j
Percentage of poverty (%)	E2	10				
Percentage of ages (%)	S1	10	<20	20-40	>40	
Percentage of gender (%)	S2	10				
Percentage of disability (%)	R1	10				

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For the practical implementation, the score was normalized by dividing the vulnerability value x_j by the number of vulnerability items, i.e. the maximum vulnerability value is 1. The normalized composite vulnerability was then calculated based on the equation:

$$X_j = \frac{x_j - \text{Min}(x_j)}{\text{Max}(x_j) - \text{Min}(x_j)} \quad (4.1)$$

where,

X_j is the normalized value (ranging from 0 to 1) of the indicator j of a vulnerability component (E , S , R); x_j is the value of the indicator j ; $\text{Max}(x_j)$ and $\text{Min}(x_j)$ are respectively the maximum and minimum values of the indicators j of the vulnerability component.

Thus, the normalized indicators were aggregated using the following equation, according to their respective components (E ; S ; R):

$$VI_{social} = \sum_{j=1}^k W_j X_j \quad (4.2)$$

where,

VI_{social} is the composite indicator with (E , S , R) referring to the three components of vulnerability; W_j is the weight of the indicator j ; and X_j is the normalized value of the indicator j .

4.2.2.2 Physical vulnerability component

The indicators used for physical vulnerability are building house density, availability of public facilities, and availability of critical facilities (**Figure 4.14**). House density is obtained by dividing built area with the area of sub-district (in hectare), and multiplied it by the unit price of each building code parameters. Index of physical vulnerability is obtained from the average weight of house density (40%), availability of public facilities (30%), and availability of critical facilities (30%). Index conversion parameters are described in **Table 4.5**, as follows. Thus, the normalized indicators were aggregated using the following equation, according to their respective components (E):

$$VI_{physical} = \sum_{j=1}^k W_j X_j \quad (4.3)$$

where,

$VI_{physical}$ is the composite indicator with (E) referring to the three components of vulnerability; W_j is the weight of the indicator j ; and X_j is the normalized value of the indicator j .

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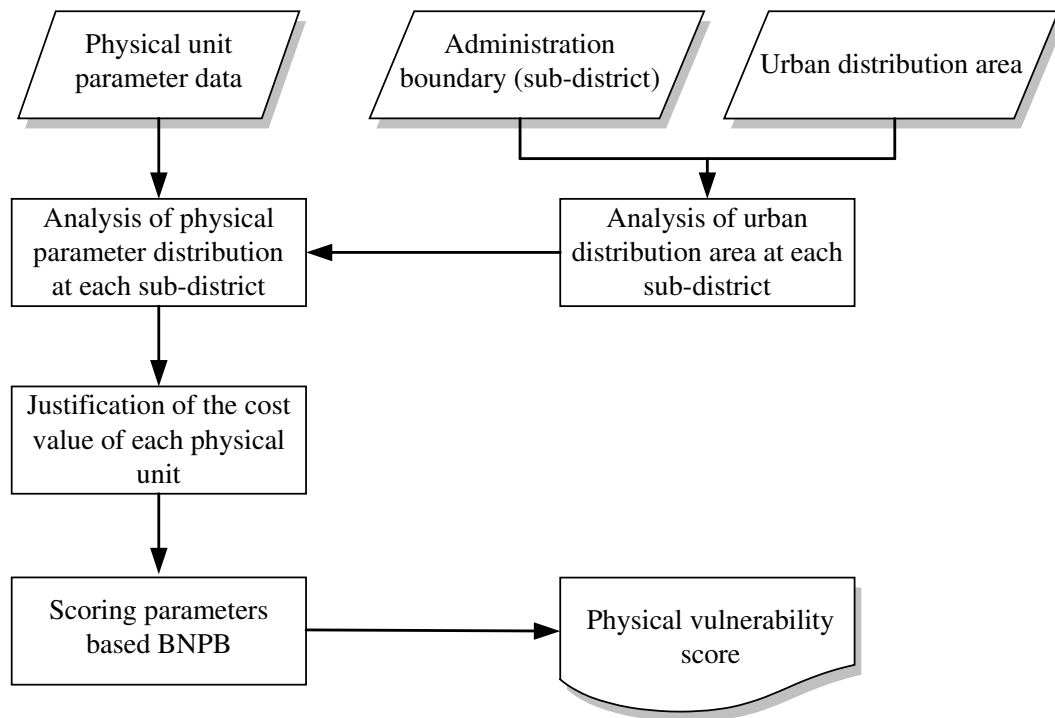


Fig. 4.14 Flowchart of BNPB framework analysis for physical vulnerability assessment

Table 4.5 Index conversion parameters for physical vulnerability indicator

Parameter	Code	Weight (%)	Value			Score
			Low	Medium	High	
Houses (Rp in Millions)	S3a	40	<400	400-800	>800	X_j
Public facilities (Rp in Millions)	S3b	30	<500	500-1000	>1000	
Critical facilities (Rp in Millions)	S3c	30	<500	500-1000	>1000	

4.2.2.3 Economic vulnerability component

The indicators used for economic vulnerability are the area of productive land (e.g. paddy fields, garden field) in the value of rupiah, and the land resource base of PDRB (Gross Regional Domestic Product) for agriculture sector (**Fig. 4.15**). The area of productive land can be obtained from land-use maps and the PDRB of statistical data at district or sub-district can be analyzed. The index of economic vulnerability is derived from the weight of the area of productive land (60%), and weight of the land resource base (40%). Index conversion parameters are also described in **Table 4.6**, as follows.

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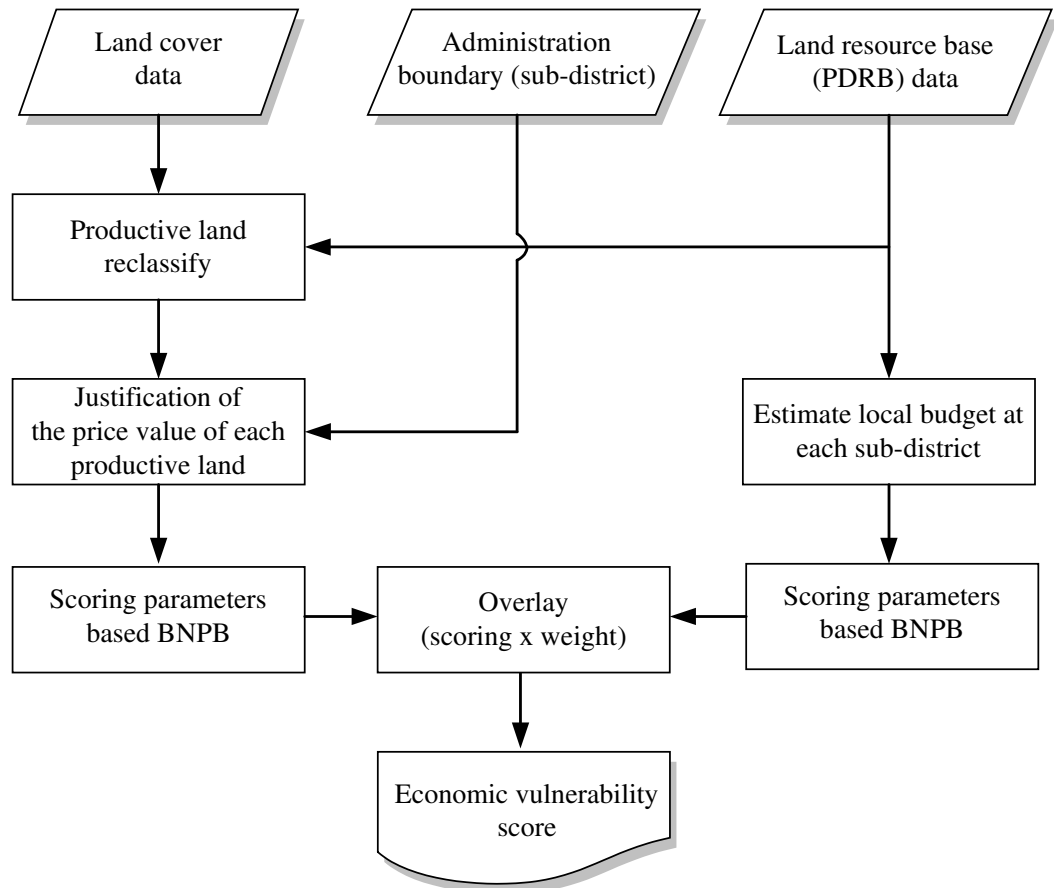


Fig. 4.15 Flowchart of BNPB framework analysis for economic vulnerability assessment

Table 4.6 Index conversion parameters for economic vulnerability indicator

Parameter	Code	Weight (%)	Value			Score
			Low	Medium	High	
Productive land (e.q. paddy field, garden field) (Rp in Millions)	E3	60	<50	50-200	>200	X_j
Land resource base (PDRB) (Rp)	E4	40	<100	100-300	>300	

Thus, the normalized indicators were aggregated using the following equation, according to their respective components (E):

$$VI_{economic} = \sum_{j=1}^k W_j X_j \quad (4.4)$$

where,

$VI_{economic}$ is the composite indicator with (E); W_j is the weight of the indicator j ; and X_j is the normalized value of the indicator j .

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4.2.2.4 Environmental vulnerability component

The indicators used for environmental vulnerability are land cover (protected forests, natural forests, mangroves, and shrubs). Environmental vulnerability index is different for each type of threat, and it is obtained from the average weight of the land cover type (**Figure 4.16**). The index of environmental vulnerability is derived from the weight of the area of protected forest (30%), weight of the natural forest (30%), weight of the mangrove (20%), and the shrubs (10%). Index conversion parameters are also described in **Table 4.7**, as follows.

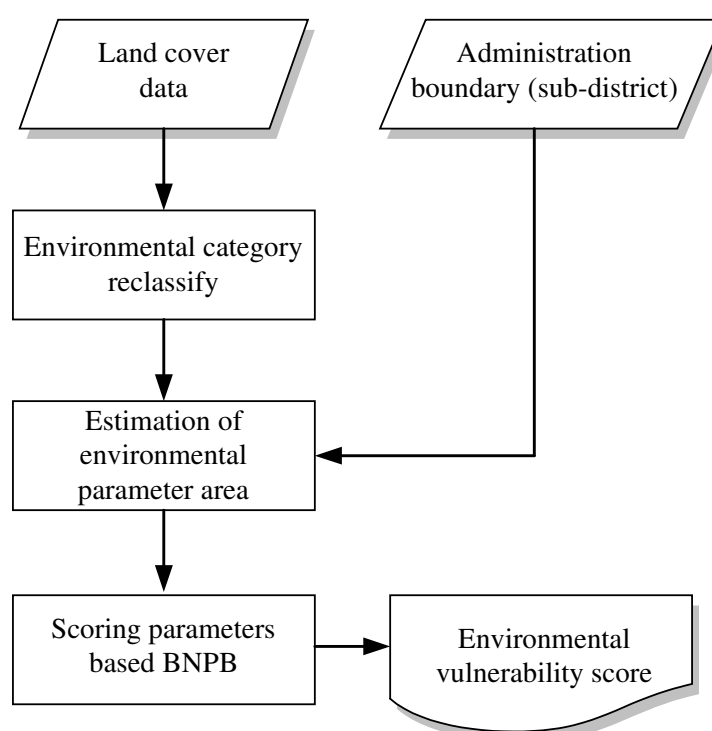


Fig. 4.16 Flowchart of BNPB framework analysis for environmental vulnerability assessment

Table 4.7 Index conversion parameters for environmental vulnerability indicator

Parameter	Code	Weight (%)	Value			Score
			Low	Medium	High	
Protected forest (ha)	E5a	40	<20	20-50	>50	X_j
Natural forest (ha)	E5b	40	<25	25-75	>75	
Mangrove (ha)	E5c	10	<10	10-30	>30	
Shrubs (ha)	E5d	10	<10	10-30	>30	

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Thus, the normalized indicators were aggregated using the following equation, according to their respective components (E):

$$VI_{environmental} = \sum_{j=1}^k W_j X_j \quad (4.5)$$

where,

$VI_{environmental}$ is the composite indicator with (E); W_j is the weight of the indicator j ; and X_j is the normalized value of the indicator j .

4.2.2.5 The overall flood vulnerability index

Finally, flood vulnerability is the result of the product of social, economic, physical and environmental vulnerability component, with different weighting factors. In semi-quantitative analysis, the lack of specific information about the sensitivity factor is compensated by the weight factor. The best weighting factors are obtained through the consensus of expert opinions (BNPB, 2012). A methodology emerged into a consensus is the Analytic Hierarchy Process (AHP). AHP is a measurement methodology by pair-wise comparison and relies on expert judgments to obtain priority scales. This is the scale that measures form relative. Comparisons are made using an absolute scoring scale, which represents how much one indicator dominates the other in relation to a particular flood disaster. Therefore, all the weighting factors used for vulnerability analysis are the result of the AHP process. The flood vulnerability index is shown in the equation, as follow.

$$FVI = (VI_{social} \times 40\%) + (VI_{physical} \times 25\%) + (VI_{economic} \times 25\%) + (VI_{environmental} \times 10\%) \quad (4.10)$$

Total FVI of each sub-district area is calculated by four vulnerability components. This index value is described as follows (**Table 4.8**). The index gives a number from 0 to 1, signifying low to high urban flood vulnerability and shows which sub-district areas need detailed investigation for selecting more effective measures. This methodology shows that FVI provides a reliable source for broad overview of flood vulnerability to take appropriate strategies.

Table 4.8 Flood vulnerability interpretation (Balica, 2012)

Index value	Description
< 0.01	Very small vulnerability to floods
0.01 - 0.25	Small vulnerability to floods
0.25 - 0.50	Vulnerability to floods
0.50 - 0.75	High vulnerability to floods
0.75 - 1	Very high vulnerability to floods

4.2.3 Establishment of flood vulnerability component maps

In the research, all the information on the above mentioned four components of flood vulnerability is effectively presented and processed using GIS tool. As described in the previous section, a total number of nine indicators are used based BNPB framework analysis to quantify the flood vulnerability of the Makassar region. These nine indicators from four vulnerability components were selected from BNPB framework analysis and data set. The layout for collecting and integrating the data, along with the sequential procedural steps for data processing and representation are outlined in **Figure 4.17**. The vulnerability illustrates the concept of layering data using a GIS, as well as combining vulnerability components to assess the overall vulnerability to flood.

Data used in this study obtained from various sources of local government of Makassar City. Information related to socio-environmental problems was collected in all the sub-district areas. The measured parameter for this study was the building cost values and agriculture production values per district area. As for population survey, the data were obtained from the statistical data report of sub-districts. As a variety of social data were involved in the study, the input technique into the GIS was critically important, especially where data showed a level of sub-districts.

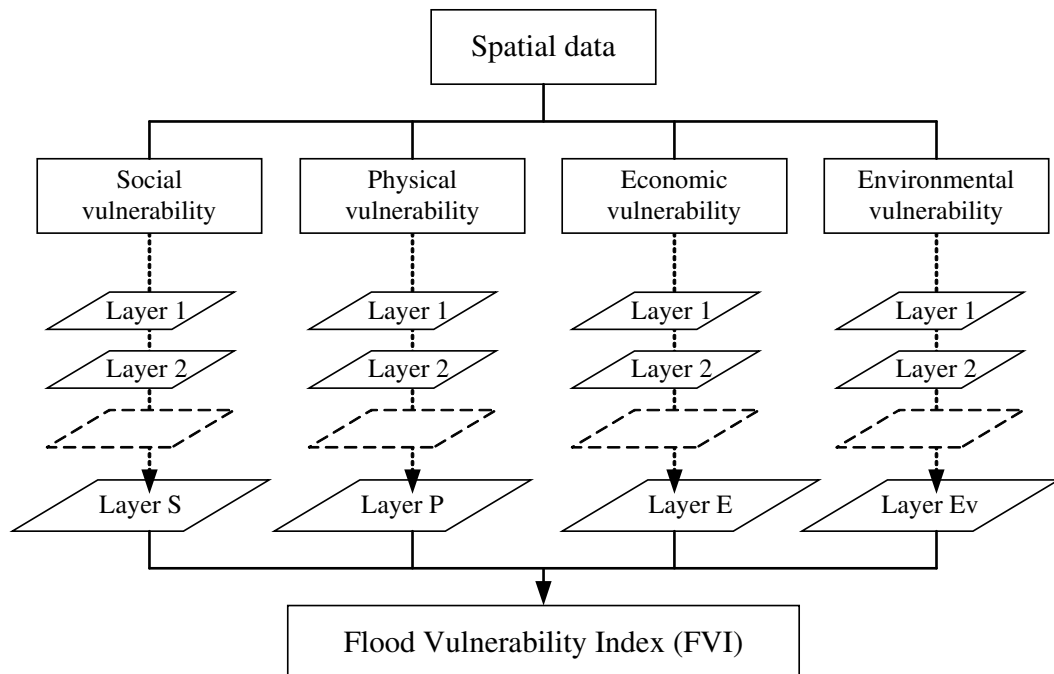


Fig. 4.17 Organization of spatial database layers for flood vulnerability index process

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The parameters for this study included the social component indicators such as population density, and social sensitivity. As building to physical impacts (e.g., houses, public facilities and critical facilities), the term “building construction cost values”, in this study, relates to flood damage, it takes into account both cost damages based the area of building according to the assumed local values.

The secondary data concern the economic and environmental component indicators. The land-use data were extracted from the developed land cover map (with a 50 m resolution) using spatial analysis tools. Vegetation cover was extracted from a land cover data provided by local government.

4.2.3.1 Social vulnerability related database layers

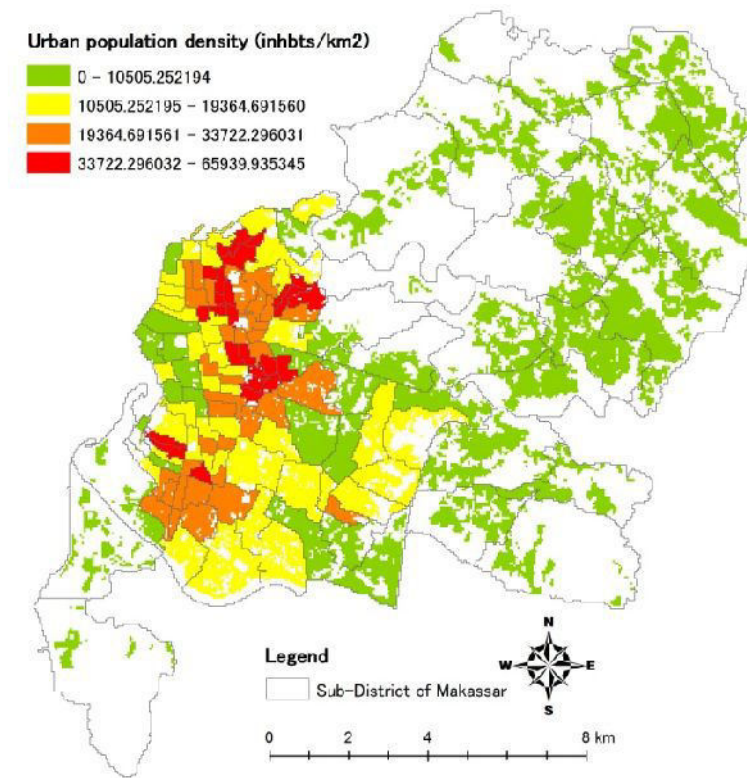
Data is collected from available government, geospatial and satellite data, and observation of statistical databases. In the spatial analysis, research is addressed regarding annual statistical data provided by the government of Makassar City, population information extraction, GIS processing, and vulnerability indicator analysis. It is to deal with population data in 2012 for sub-districts scale for identification and population density, poverty ratio, vulnerable age ratio, gender ratio, and disability ratio. In this study, population data, etc. are created based on the administration boundary of sub-districts, as shown in **Figure 4.18**. The Jenks natural breaks classification method in GIS is applied to estimate the distribution data in maps. The resulting BNPB score classification of spatial analysis identified the sub-districts most vulnerable areas.

It is found that the urban poor living along the coast and along rivers are among the most vulnerable, as the people live in areas most affected by current flood hazards. Flooding threatens their livelihoods and physical safety, and this compounds their existing social vulnerabilities of low income peoples and lack of access to water which influence to the human health. Finally, through observation data, an analysis was carried out represents the gender ratio, poverty ratio, age ratio and disability ratio shows how vulnerability affects some sub-districts in the Makassar region.

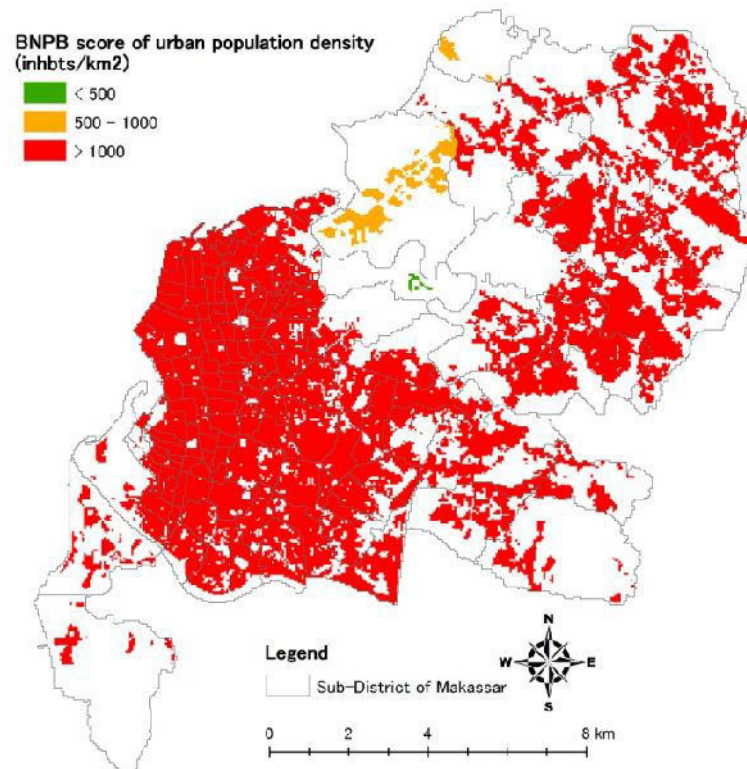
4.2.3.2 Physical vulnerability related database layers

The recent increase in frequency and severity of flooding in the Makassar City has led to a shift in the perception of risk associated with flood hazards. This has extended to the risks posed to importance of buildings that suffer from flooding are particularly concerning for those charged with maintaining such buildings. In this study, building features are created based on the spatial database of the RTRW (Spatial Urban Planning) of the Makassar, as shown in **Figure 4.19**.

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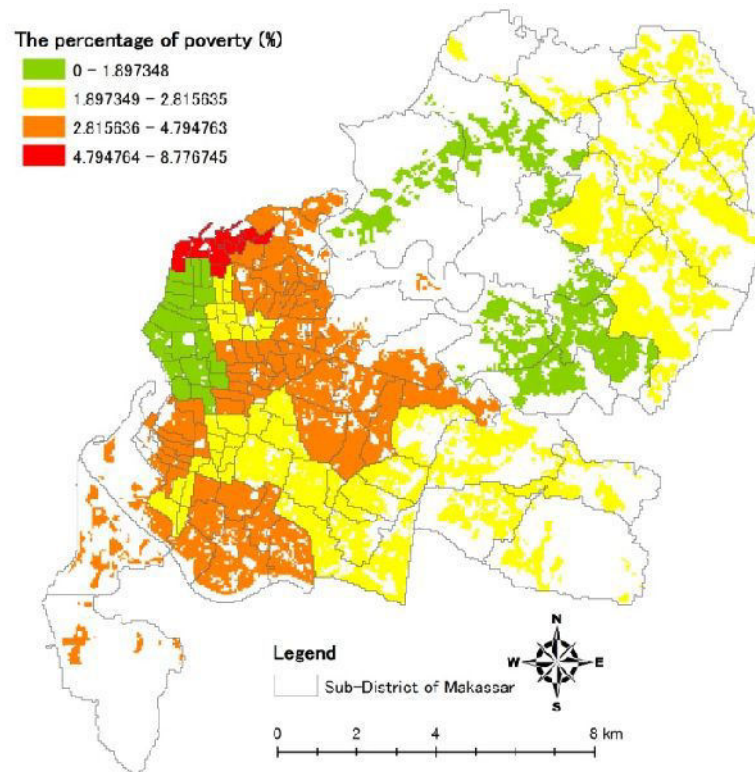
(Urban population density)



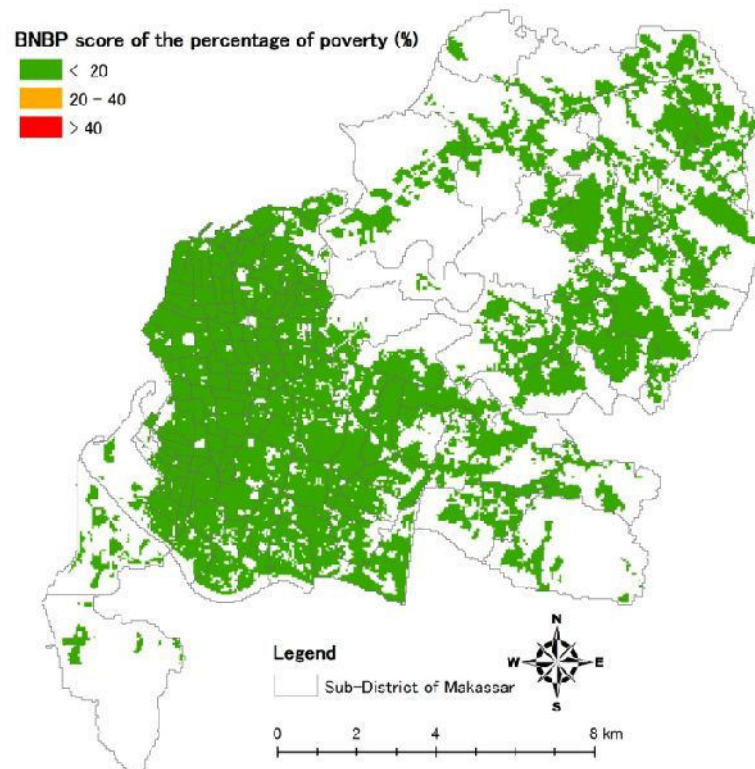
(BNBP scoring of urban population density)

Fig. 4.18a Relevant spatial indicator layers for social vulnerability component

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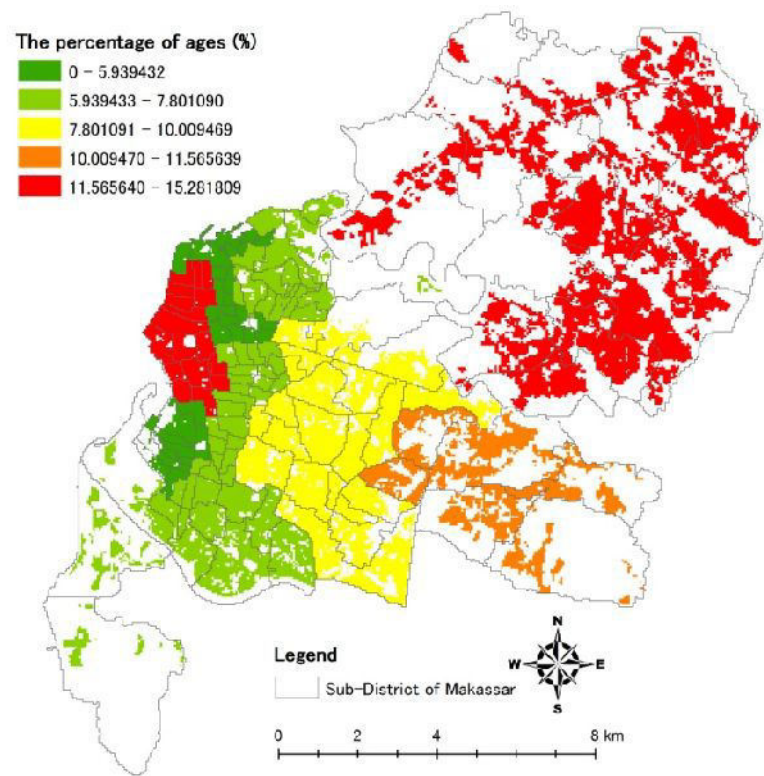
(The percentage of poverty)



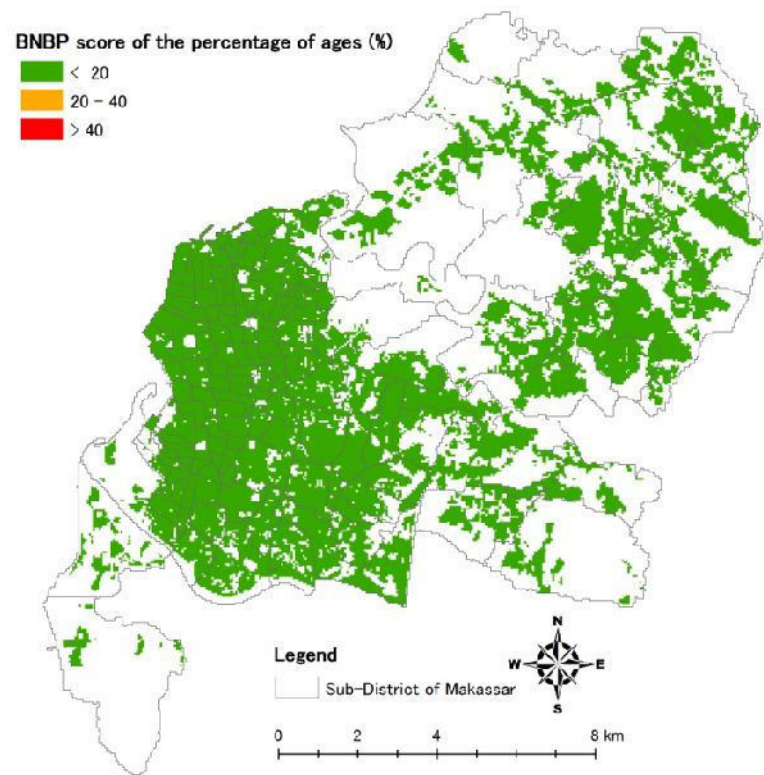
(BNBP scoring of the percentage of poverty)

Fig. 4.18b Relevant spatial indicator layers for social vulnerability component

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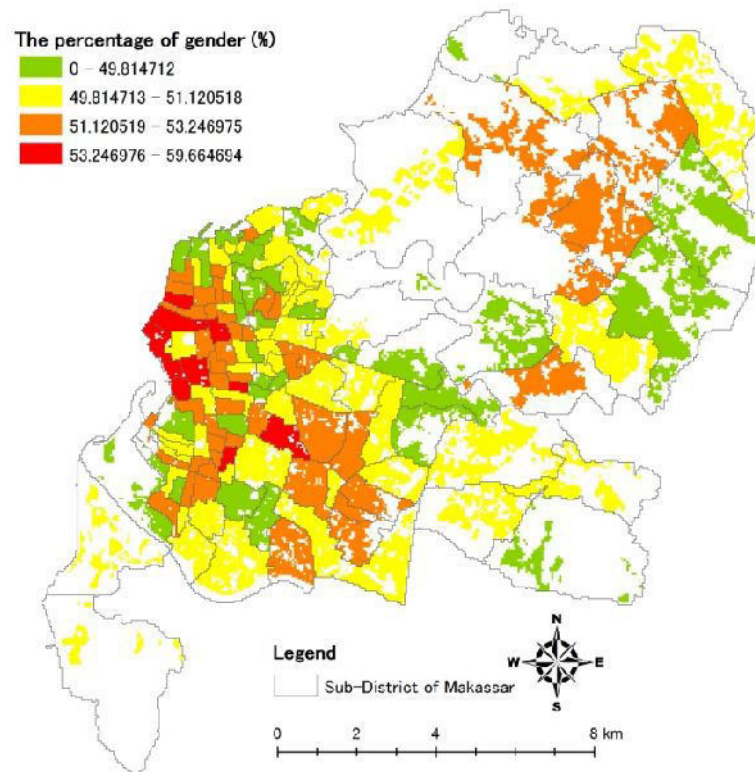
(The percentage of ages)



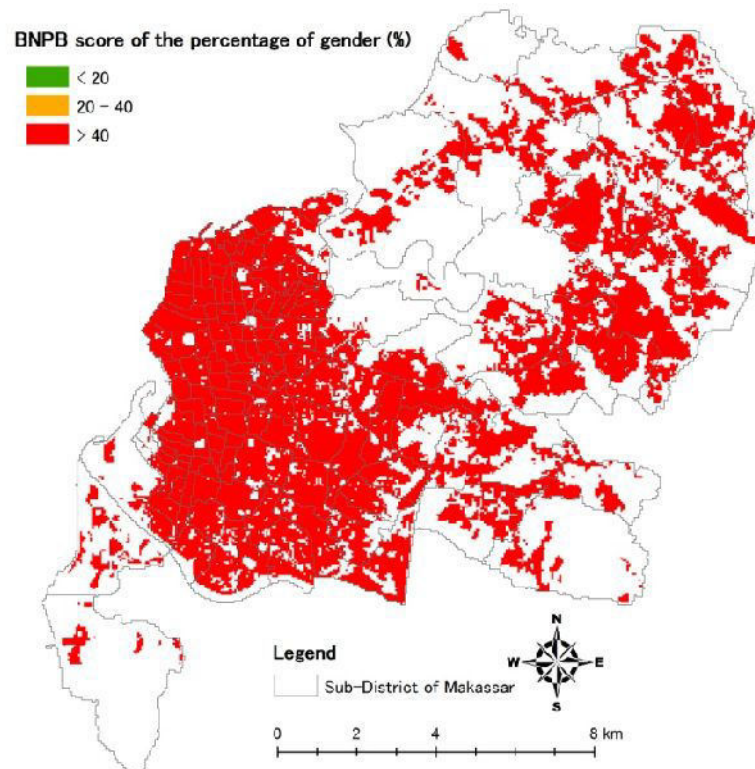
(BNBP scoring of the percentage of ages)

Fig. 4.18c Relevant spatial indicator layers for social vulnerability component

SPATIAL ANALYSIS OF FLOOD RISK EVALUATION



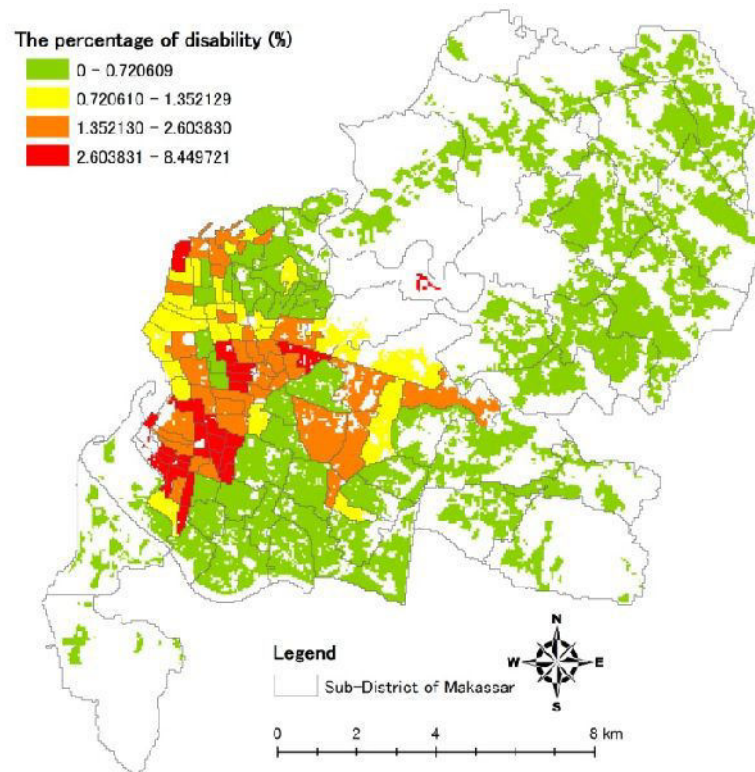
(The percentage of gender)



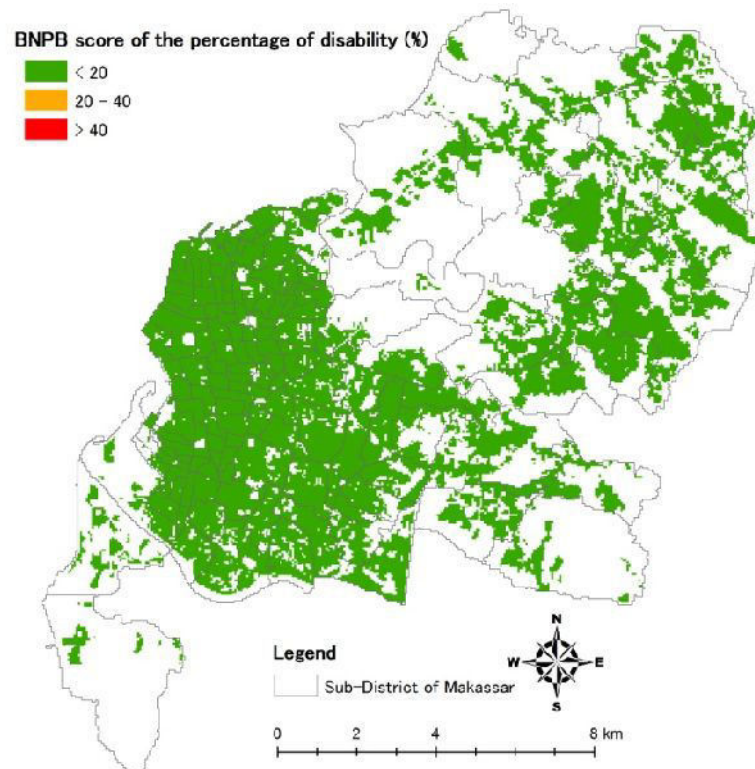
(BNPB scoring of the percentage of gender)

Fig. 4.18d Relevant spatial indicator layers for social vulnerability component

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(The percentage of disability)



(BNPB scoring of the percentage of disability)

Fig. 4.18e Relevant spatial indicator layers for social vulnerability component

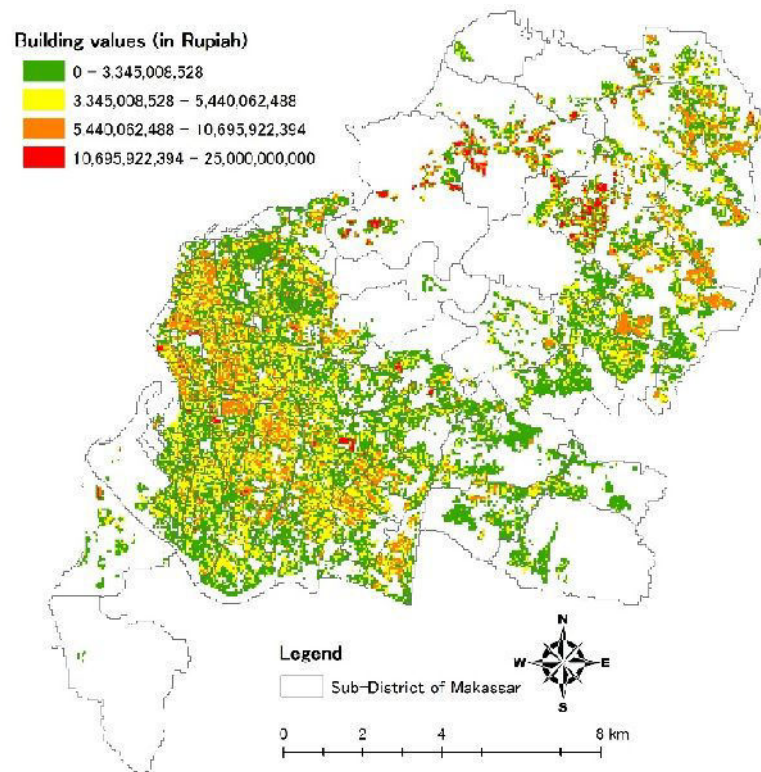
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Methodology is carried out using the results of the building's technical and functional analysis which provides guidance for classification of buildings (PU, 2006), as shown in **Table 4.9**. This occurs through appraisal of vulnerability indicators related to the physical building and their function values.

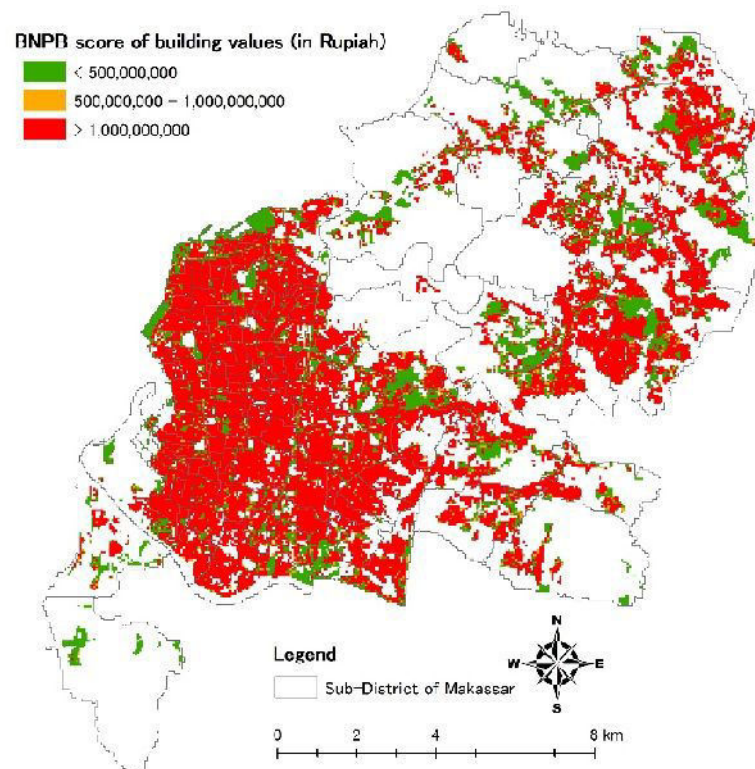
Table 4.9 Building classifications and it estimated local values (PU, 2006)

Building classifications	Weight	Building categories	Explanation	Estimated cost values (Rp) per area (m ²)
Houses	40%	Simple	Building area less than or equal 70 square meter	1,000,000 ~ 2,500,000
		Complex	Building area more than 70 square meter	2,500,000 ~ 5,000,000
Public facilities	30%	Commerce	Building commerce e.q. markets, shopping malls, restaurants	5, 000,000 ~ 10,000,000
		Industry	Building industries e.q. factories	
		Hospitality	Building hospitality e.q. hotels, motels, inns	
		Tourist attraction	Building tourist attraction e.q. cinema, swimming pool	
		Storage	Building storage e.q. warehouse	
		Laboratory	Building for laboratory	
		Worship place	Building for worship places e.q. mosques, churches, temples	
		Offices	Building offices e.q. governmental offices, banks	
		Terminal	Building terminal e.q. station bus, airport, sea port	
		Educational service	Building for educational services e.q. Universities, schools	
		Health service	Building for educational services e.q. hospital, polyclinic, maternity	
		Culture	Culture building e.q. museums, arts	
		Sport service	Building for sport services e.q. stadium	
		Memorial	Building for cemetery e.q. monument	
		Basic public service	Building for basic public services e.q. electricity, water treatment plant, telecommunication, waste management	
Critical facility	30%	Defense	Building for defenses e.q. military, polices	10,000,000 ~ 15,000,000

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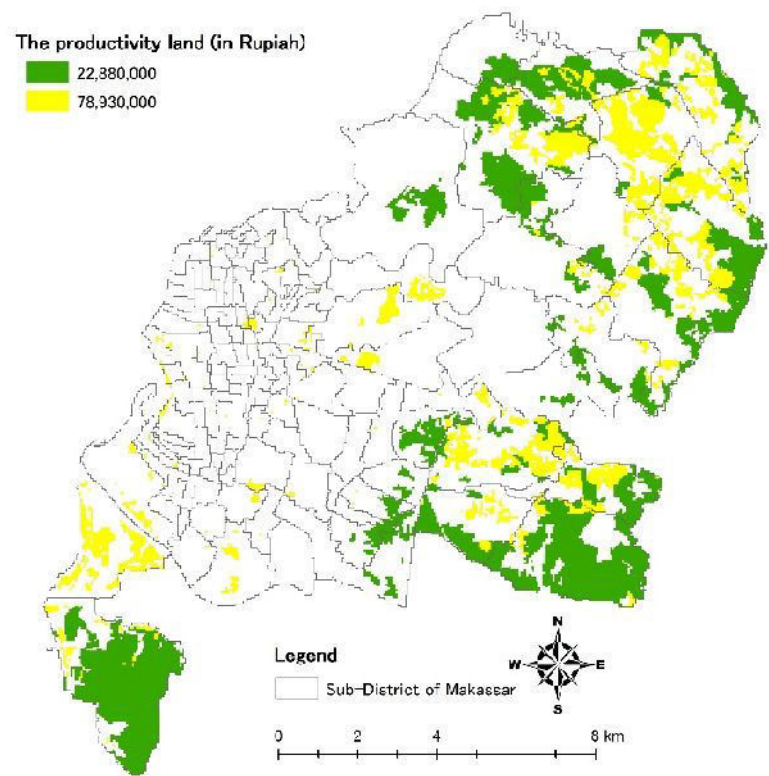
(Building cost values)



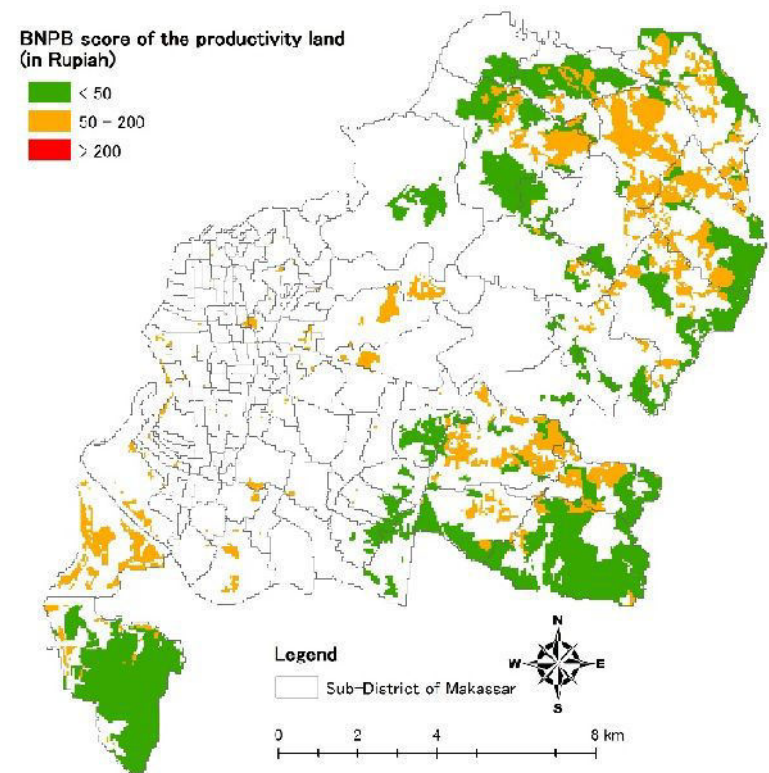
(BNPB scoring of the building cost values)

Fig. 4.19 Relevant spatial indicator layers for physical vulnerability component

SPATIAL ANALYSIS OF FLOOD RISK EVALUATION



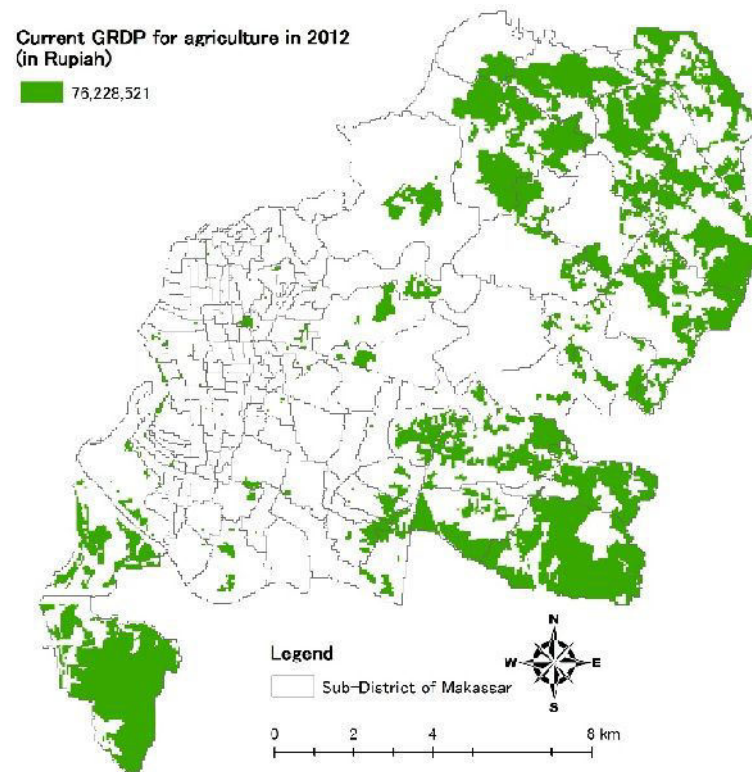
(Productive land)



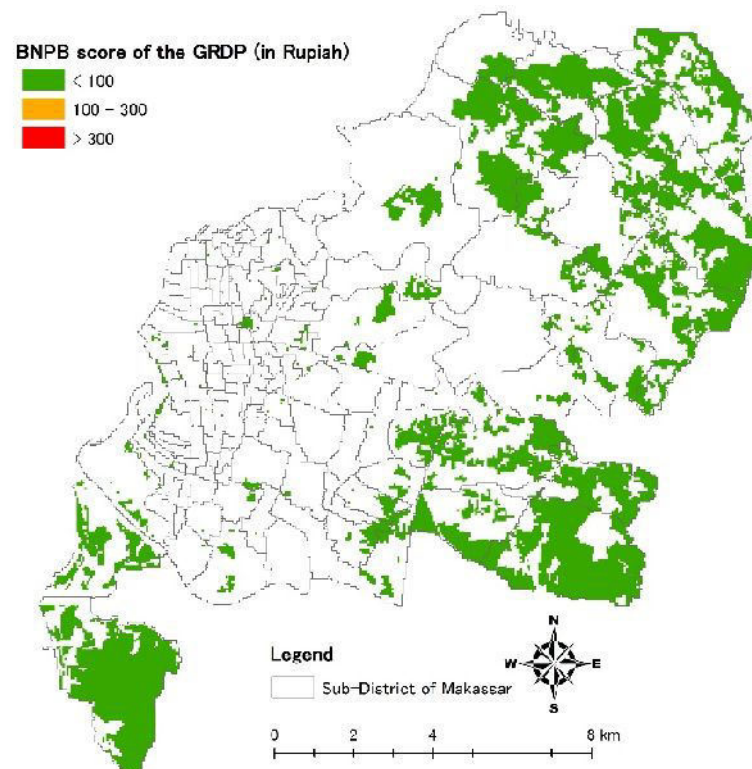
(BNPB scoring of productive land)

Fig. 4.20a Relevant spatial indicator layers for economic vulnerability component

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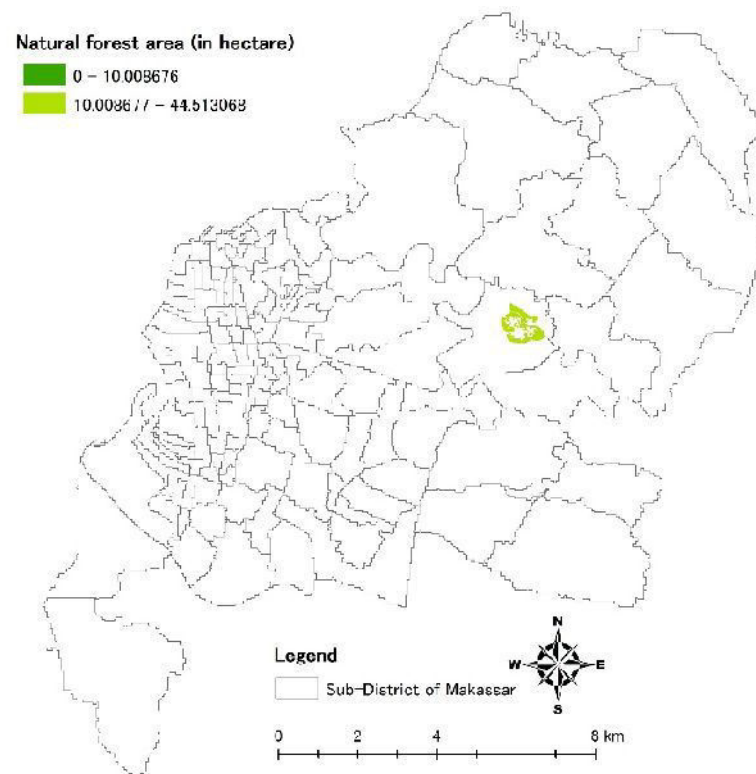
(Land resource base of agriculture (PDRB))



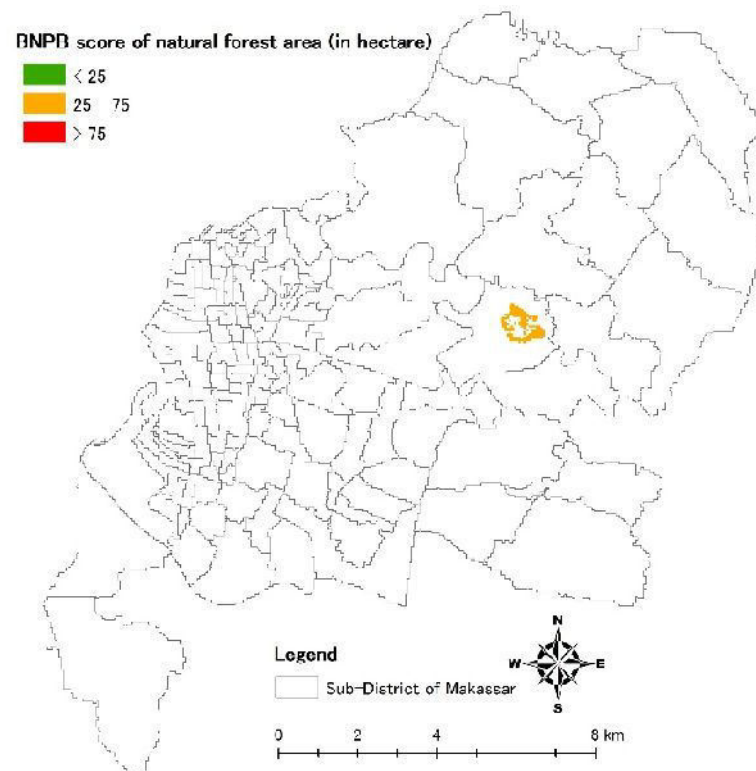
(BNPB scoring of land resource base)

Fig. 4.20b Relevant spatial indicator layers for economic vulnerability component

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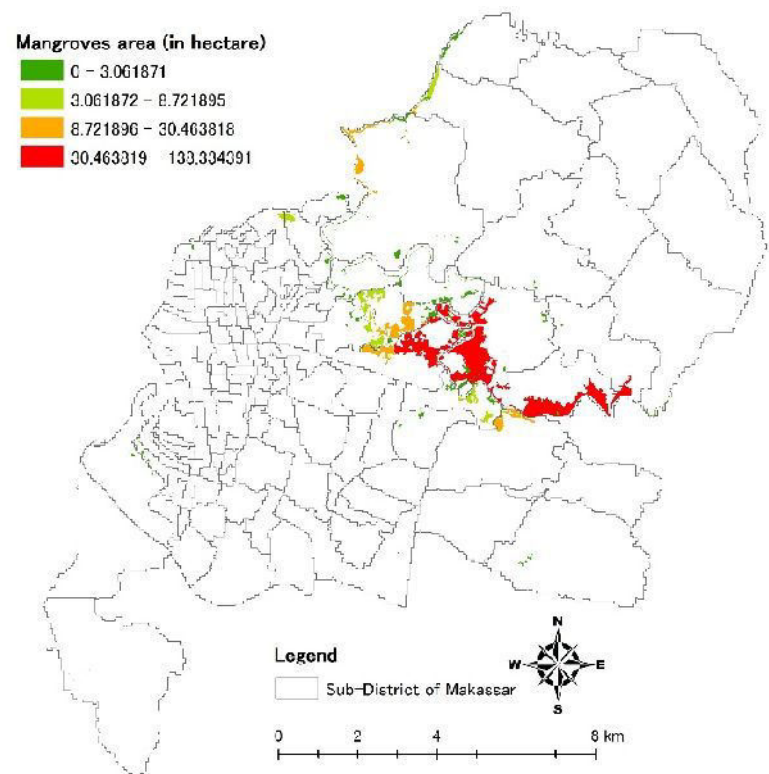
(Natural forest)



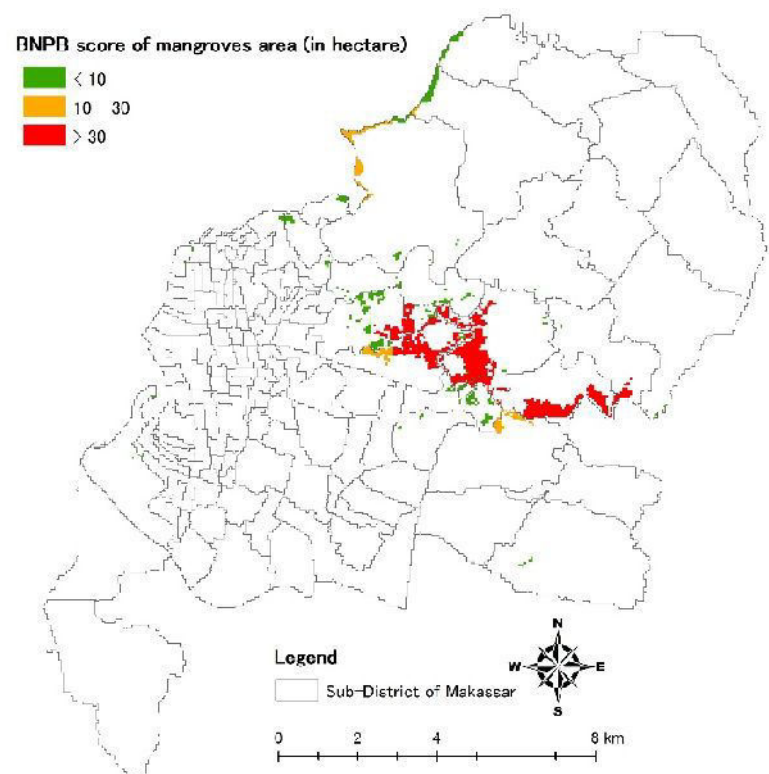
(BNPB scoring of natural forest)

Fig. 4.21a Relevant spatial indicator layers for environmental vulnerability component

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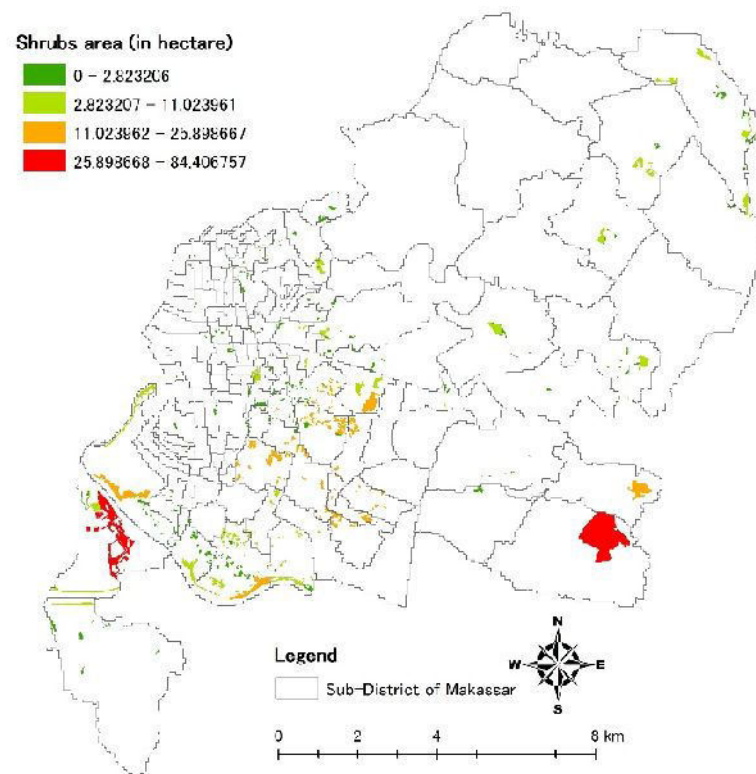
(Mangroves)



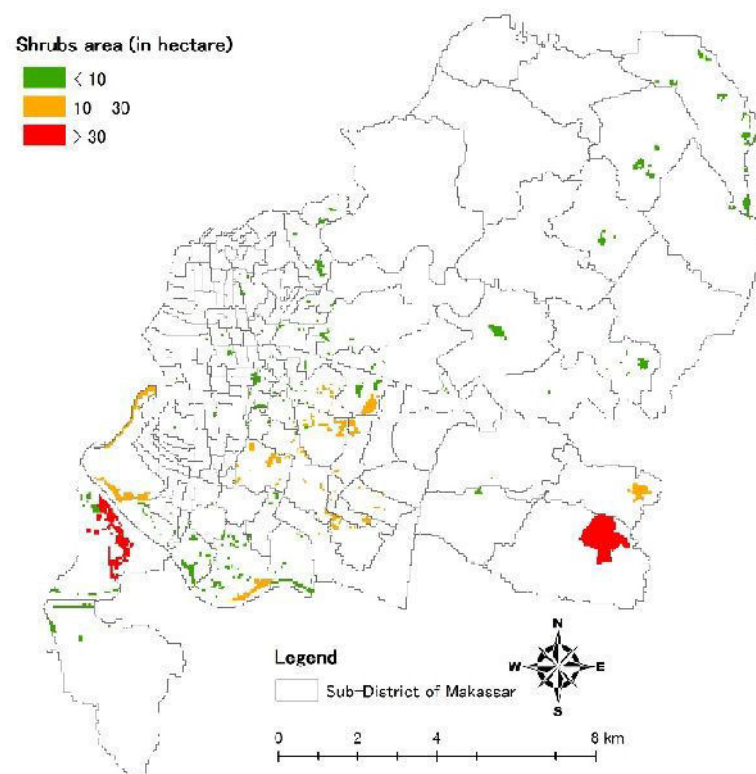
(BNPB scoring of mangroves)

Fig. 4.21b Relevant spatial indicator layers for environmental vulnerability component

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(Shrubs)



(BNPB scoring of shrubs)

Fig. 4.21c Relevant spatial indicator layers for environmental vulnerability component

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4.2.3.3 Economic vulnerability related database layers

In this study, the land-use map in 2012 was developed from the availability of digital topographic maps of 1:50.000 scales provided by the Regional Development Planning Agency of Makassar. Land-use division was determined based on land-use boundary line of the topographic maps. The land-use divisions for 1997 and 2012 were reclassified into 10 categories (Indrayani et al., 2016). By utilizing the developed land-use map, an analysis of land-use values based on 0.25 hectares area size was performed to identify the productive land such as paddy field, garden field, and fishpond. It is also to deal with population data in 2012 for sub-districts scale for identification of land resource base value (PDRB) and agriculture values. The database layers related to the economic vulnerability components are shown in **Fig. 4.20**.

4.2.3.4 Environmental vulnerability related database layers

The vulnerability assessment involved measuring and mapping by neighborhood the susceptibility to floods and an assessment of environmental vulnerability focusing on natural forests, mangroves and shrubs, which play an essential role in minimizing impact to ecology. Relevant spatial indicators were developed using a land cover data, is shown in **Fig. 4.21**.

4.2.4 Evaluation of vulnerability components

In this section, the results obtained through the spatial analysis for all single and composite indicators used for the GIS grid calculation of the final map for vulnerability components. This following section is compartmentalized by evaluation of vulnerability components (social, physical, economic and environment).

4.2.4.1 The social vulnerability component

The values of the social component indicators were used as described above. The results of the social component are shown in **Figure 4.22**. Five indicators, belonging to all factors of vulnerability, were used to determine the social vulnerability values. These were population, percentage of poverty, percentage of gender, percentage of ages and percentage of disabled population. Those indicators were statistically measured and spatially represented. Using these criteria, some of sub-district stands out as the most vulnerable to floods, mainly due to its high number of people living in flood-prone areas.

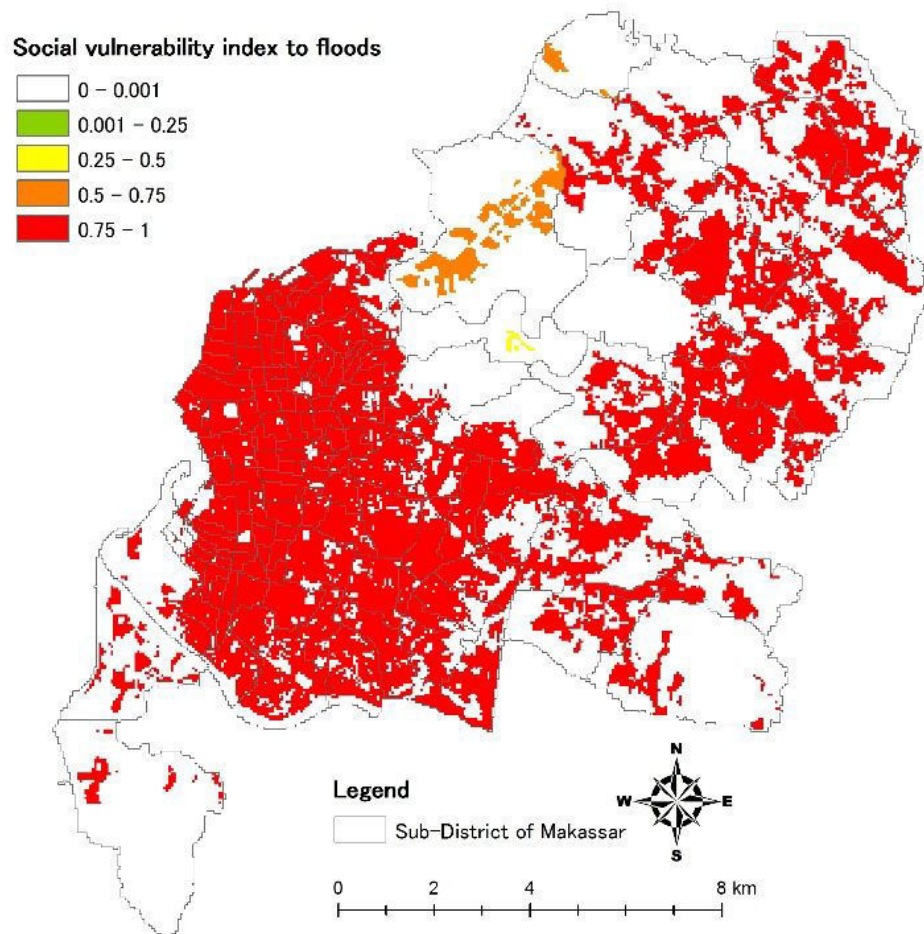


Fig. 4.22 Social vulnerability index to floods

The urban population density map shows a high population density ranging about from 10,505 to 65,939 inhbs/km². The density map shows that the district is compactly populated. The spatial distribution of the population does not show side dependence and also did not depend on how large a sub-district is. The 1,800,000 inhabitants are sparsely distributed in the district. For the calculation of lack of resilience, one local indicator was used. Disable peoples, who represent the group with least capacity to recover from flood damages without external help, are, in general, sparsely distributed across the West part of the Makassar region. The disable people ratio per sub-district appears low as well. All of the sub-districts have a literacy rate less than 10%. The lower disable peoples are mostly located in the north-east and south-east.

Concerning the spatial distribution of the percentage of ages (elderly) throughout the sub-district, it is shows that percentage of ages is very high in the northern east of sub-district and these people are more concentrated in the recent urban development area and particularly in the south-east and in the northern-west of Makassar region. The percentages of gender (women) are less represented in

the South-east part of the sub-district. Only in the Northern west of the sub-districts show a high representation of females, significantly above 50%. Poverty is more concentrated in the Northern west part of the sub-district.

The combination of the five local indicators gives the social vulnerability map of the sub-district. The social vulnerability map highlights five degrees of index which from very small to very high vulnerability to flood. Most of the sub-district has a social vulnerability to flooding that varies from high to very high. Most areas with very high social vulnerability are located in the west part of the Makassar region.

4.2.4.2 The physical vulnerability component

The values of the physical component indicators were used, described in the section above; the results of the physical component are shown in **Figure 4.23**. Three indicators are used to determine the physical vulnerability values. When examining the physical susceptibility, it can be seen that Makassar region is the most exposed to floods. This is mainly due to its high number of building with the high cost values. It is the result of the combination of three local indicators: building houses, building public facilities, and building critical facilities. Concerning the spatial distribution of the buildings throughout the sub-district, **Figure 4.23** shows that physical vulnerability index is very low in the northern-east part of Makassar region and these building are more concentrated along the Tallo river basin area, and particularly in the north-east, in sub-districts such as. Most of the centre part of the Makassar region shows a high representation of physical vulnerability, significantly above more than half area of sub-districts (**Figure 4.23**). Medium to high physical vulnerability are more concentrated in the southeast of the sub-district. As presented in **Figure 4.23**, there is very little small physical vulnerability to floods, particularly in the ones that are located in the north-east of Makassar region. Concerning urban development, most of sub-districts in particular have the high physical vulnerability index to floods. These sub-districts are mostly located in the center and west part of the sub-district. More than half of the sub-districts have susceptibility ranging from high to very high and are sparsely distributed.

4.2.4.3 The economic vulnerability component

Two indicators are used to determine the economic vulnerability values. They are productive land of agriculture and the land resource base (PDRB). The result of the economic component is shown in **Fig. 4.24**. It can be seen using these criteria that Makassar is the fairly vulnerable economically to floods.

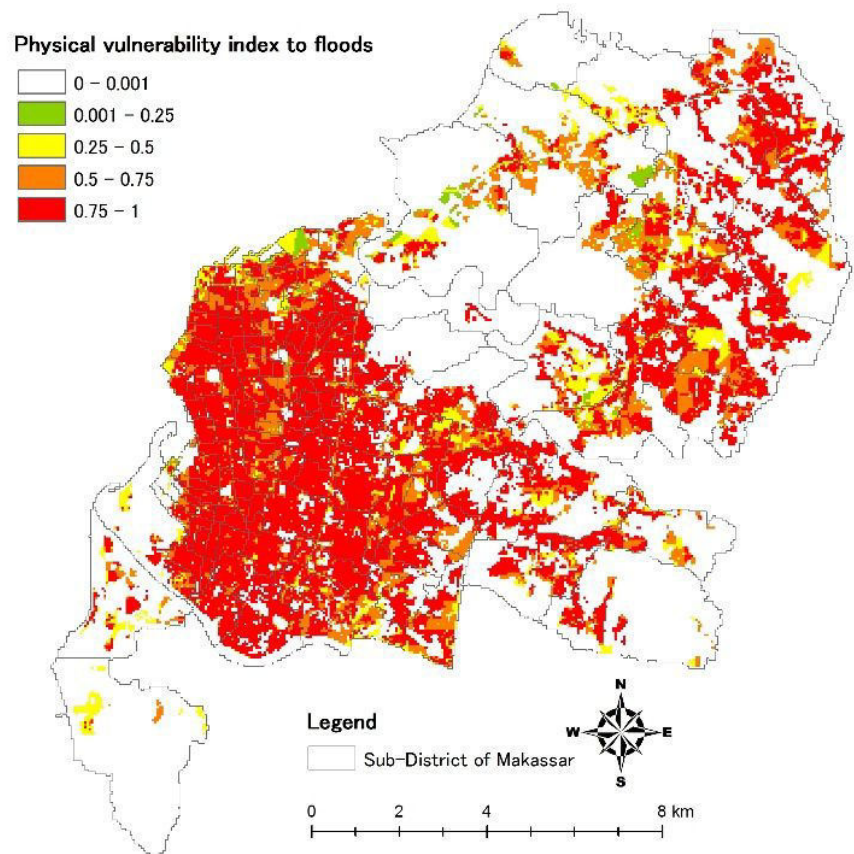


Fig. 4.23 Physical vulnerability index to floods

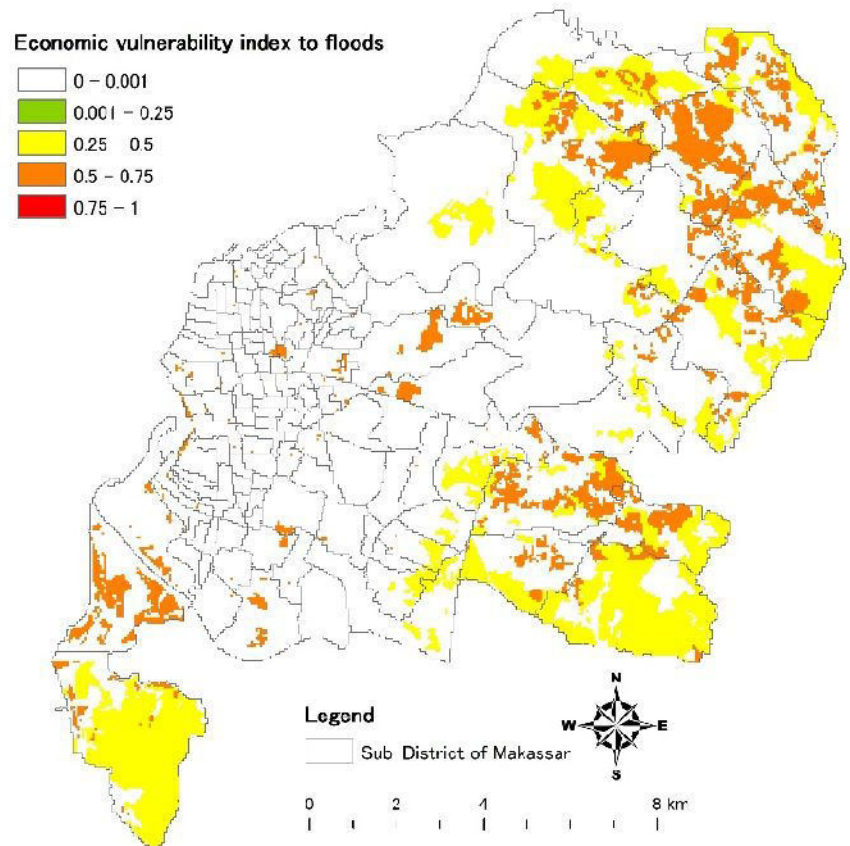


Fig. 4.24 Economic vulnerability index to floods

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4.2.4.4 *The environmental vulnerability component*

The environmental component shows the involvement of ecological systems in the flood management process. As seen in **Figure 4.25**, the most vulnerable environment is mangroves, having high environmental exposure, small storage capacity as well as being highly exposed to flood hazards. Shrubs and Mangroves area as having the higher environmental vulnerability, about 84 and 138 hectares areas, respectively, with smaller number of distribution areas. The forest has the lowest environmental vulnerability to floods; these areas are the least exposed from floods.

The environmental component is the result of the combination of three local indicators: natural forest, mangroves and shrubs. The vegetation cover of the sub-districts that are located in the west of the sub-district appears very low. As a result of the combination of the three local indicators described above, the sub-district presents exposure mostly in six sub-districts. These sub-districts are mostly located in the center and south part of the sub-district and have exposure ranging from high to very high and are sparsely distributed.

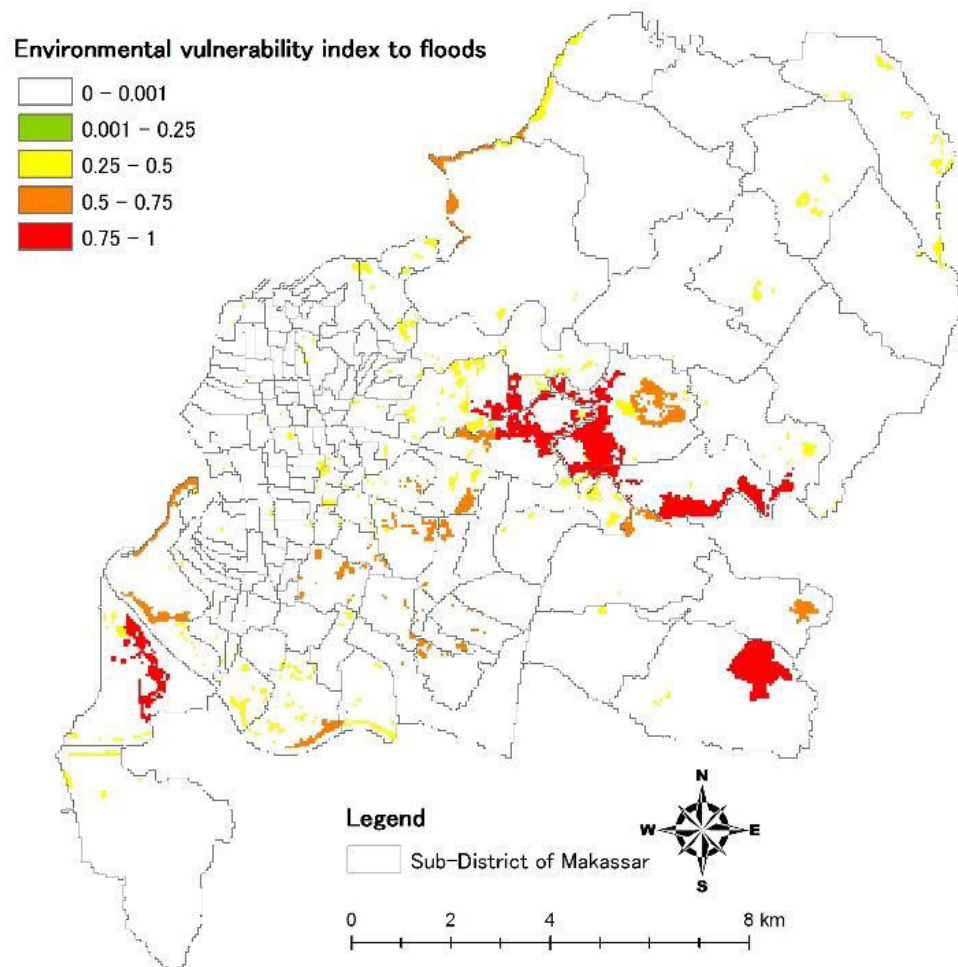


Fig. 4.25 Environmental vulnerability index to floods

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4.2.4.5 The overall vulnerability to flood

Exposed to social, economical and environmental factors such as population density, productive land of agriculture and ecological vegetation covers, the Makassar region faces a moderate vulnerability to floods. The indicator population density and social sensitivity is considered during the whole study as an indicator that belongs to the social component. From the overall results can be seen that social and physical indicator influences among other the ranking. From a social perspective, the population density is high and evenly distributed in sub-districts, generally people experience floods. Makassar, which ground elevation just above current sea levels, is regularly impacted by tropical flooding and has very little resilience.

The spatial distribution of vulnerable areas of the sub-district is presented in **Table 4.10**. Districts of Mamajang, Ujung Pandang and Wajo are also highly vulnerable areas, largely because of the degree of exposure (both population density and environmental aspect). Districts of Bontoala and Makassar are moderately high vulnerable areas, largely because area is physically vulnerable to floods, while Tamalate, Tallo, Manggala and Biringkanaya have equally low vulnerability, mostly because both have slightly less population and building than the other districts, even though the environmental indicators are still significant.

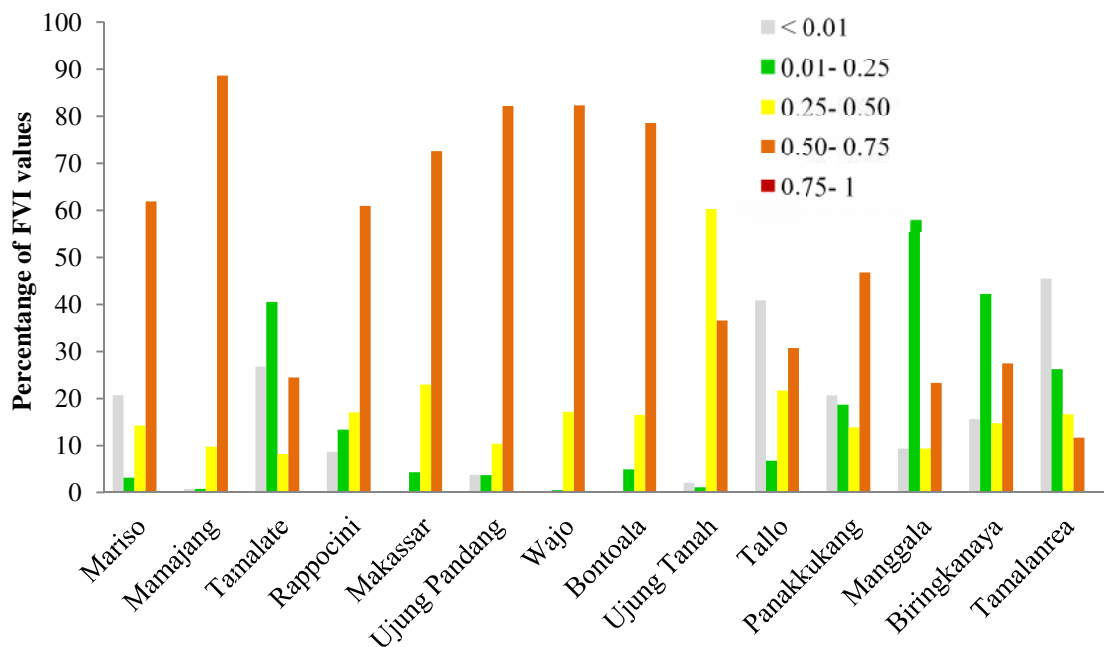


Fig. 4.26 Comparative flood vulnerability index at districts

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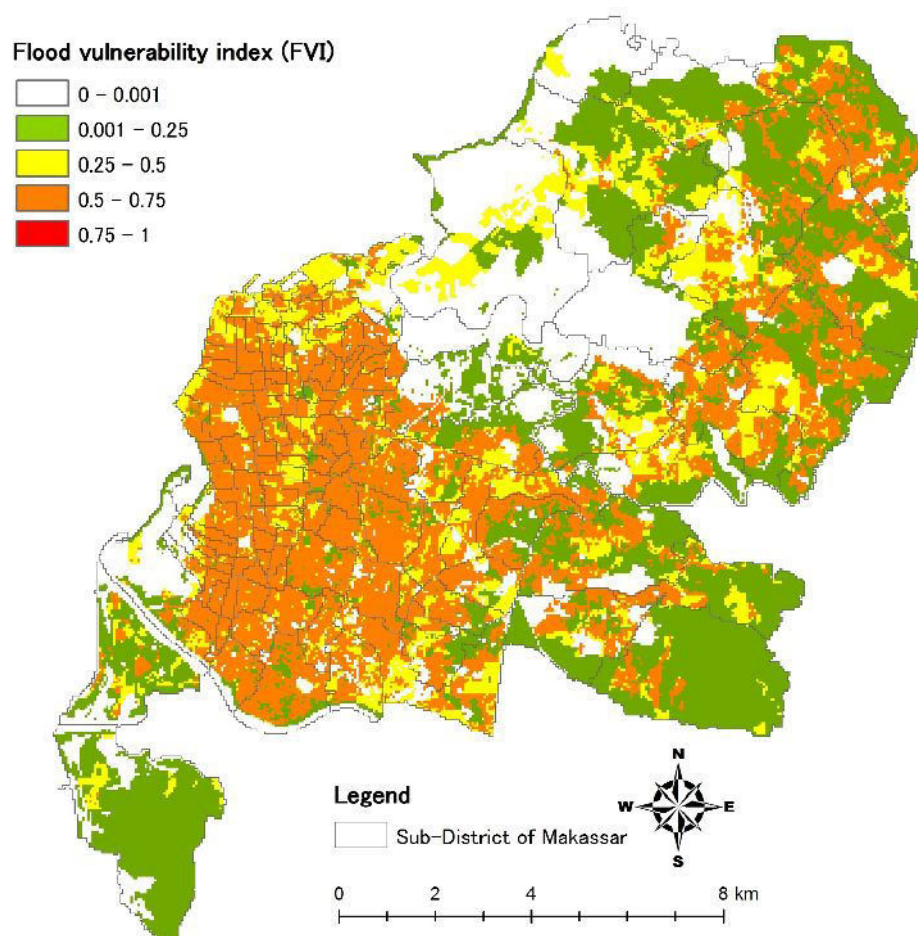


Fig. 4.27 Overall vulnerability index to floods in the Makassar region

Table 4.10 Percentage of flood vulnerability index values according to the districts in 2012

District name	Percentage of index values				
	< 0.01	0.01- 0.25	0.25- 0.50	0.50- 0.75	0.75- 1
Mariso	20.72	3.16	14.22	61.9	
Mamajang	0.79	0.79	9.79	88.63	
Tamalate	26.77	40.53	8.2	24.49	
Rappocini	8.64	13.35	17.05	60.96	
Makassar	0.09	4.35	22.97	72.59	
Ujung Pandang	3.78	3.69	10.36	82.16	
Wajo	0	0.48	17.2	82.32	
Bontoala	0	4.92	16.5	78.58	
Ujung Tanah	2.09	1.13	60.23	36.55	
Tallo	40.88	6.76	21.66	30.7	
Panakkukang	20.66	18.7	13.87	46.77	
Manggala	9.38	57.93	9.37	23.32	
Biringkanaya	15.63	42.19	14.75	27.43	
Tamalanrea	45.45	26.22	16.64	11.69	

As a result of the combination of the four composite indicators of the vulnerability components, the highest vulnerability to flood affects almost at the centre-west and the south-west. More than 50% of the sub-districts have a vulnerability index varying from moderate to high (**Figure 4.26**). The lowest vulnerabilities are sparsely distributed throughout the district at the north-east and south-east. The districts with lowest vulnerability are Ujung Tanah, Tallo, Panakukkang, Manggala, Biringkanaya, and Tamalanrea (**Figure 4.27**).

4.3 Analysis of Flood Risk Index

4.3.1 Spatial risk index model

Risk assessment is a complex spatial process aiming at evaluating the different aspects that can disrupt or destruct a system (UN, 2004). Traditionally, risk assessment relies on mathematical models to establish the likelihood of a given event occurring with a given degree of intensity in a given site. The major limitation of this approach is that risk necessarily entails spatial uncertainty and it is necessary to make realistic hypotheses about possible future scenarios (Ahmad and Simonovic, 2013). For complex systems which comprise many components over significant geographical areas, the understanding of all factors involved in a risk situation is particularly demanding. Therefore, risk assessment approaches require to taking into account all relevant social, physical, economic, and environmental aspects, in order to define the vulnerability to floods (BNPB, 2012). Flood risk assessment has two main components that are hazard and vulnerability. The hazard is a measure of the physical intensity of the threat at a particular location and the associated probabilities of these intensities. Hazard is location dependent. For example, flood hazard at a location near the coast and with a flat land. Vulnerability is a measure of the damage that the danger can cause. The synthesis of data and the essential mapping of the spatial relationships between hazard phenomena and the elements at risk can benefit from the use of GIS tool.

In most cases, risk term has been defined in relation to the purposes of different science in which disaster management methods were required. Despite a lot of definitions in literature, the concept of risk with regard to “hazard” and “vulnerability” seems to be the most accepted in flood risk management so it is significant to know that “risk” is completely a human subject (Briguglio, 2003). Preparation of the flood risk assessment index requires additional spatial analysis

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after obtaining the required indices (vulnerability and hazard). The flood risk assessment index provides an overview of the area related to the risk level of a flood disaster in an area. The analysis process should be implemented for all flood areas that exist in each sub-district. Determination of risk level is calculated by using vulnerability index and flood hazard index (BNPB, 2012). The risk index level determination by the BNPB framework is calculated by using the matrix, as shown in **Table 4.11**. Determination is calculated by linking the two index values in the matrix. The matrix value is defined by the BNPB framework analysis. The color of the grid cell represents the risk level of a flood disaster in that area in which green color is lower risk and red color is higher risk.

Indicators used for risk analysis will be selected based on availability and local context. To make the index comparable at least in dimensions, the risk index used in the analysis is converted to a value between 0 and 1, where 0 is the minimum value of the original indicator, and 1 is the maximum value. In the case of low numbers that are numerous indexes and vary in sometimes high number, therefore the index classification by logarithmic conversions will be performed instead of linear conversions (BNPB, 2012). **Table 4.11** shows the result of index classification model for risk assessment definition of the study area based on BNPB framework. Flood risk indexes are classified by 7 classes from very low, low, low to medium, medium, medium to high, high, and very high. In this case, the risk index is calculated based on the multiple of the indices. For risk index mapping analysis, a combination of vector-based GIS layers and grids is used, where index grid data is mainly stored using a vector, where the risk index can be easily calculated in a grid matrix format.

Table 4.11 Flood risk matrix model by the BNPB framework analysis

		Hazard									
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Vulnerability	0.1	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
	0.2	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
	0.3	0.03	0.06	0.09	0.12	0.15	0.18	0.21	0.24	0.27	0.30
	0.4	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40
	0.5	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
	0.6	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.60
	0.7	0.07	0.14	0.21	0.28	0.35	0.42	0.49	0.56	0.63	0.70
	0.8	0.08	0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80
	0.9	0.09	0.18	0.27	0.36	0.45	0.54	0.63	0.72	0.81	0.90
	1.0	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00

Table 4.12 Specific flood risk classification model by local context (BNPB, 2012)

No		Flood risk levels	Definition of risk
1		Very low [0.01 - 0.05]	Possible minimal disruption
2		Low [0.05 - 0.15]	} Possible minor disruption
3		Medium low [0.15 - 0.25]	
4		Medium [0.25 - 0.40]	} Possible significant disruption
5		Medium high [0.40 - 0.50]	
6		High [0.50 - 0.70]	} Possible severe disruption
7		Very high [0.70 - 1.00]	

4.3.2 Establishment of flood assessment risk index map

Using the local context, the classification definition of potential impacts from the spatial-temporal risk level is presented in **Table 4.13**. Flood risk assessment index map is established from the inputs of hazard index values and vulnerability index values which described in the previous section, is shown in **Figure 4.28**.

Table 4.13 Classification definition of potential impacts according to the BNPB

Potential impacts			
Very low	Low to Medium	Medium to High	Very High
<i>Minimal disruption</i>	<i>Minor disruption</i>	<i>Significant disruption</i>	<i>Severe disruption</i>
Generally no widespread impact, however there may still be; •Isolated and minor flooding of low-lying land and roads •Little or no disruption to travel although wet road surfaces could lead to difficult driving conditions	•Localized flooding of land and roads •Localized flooding could affect individual properties •Localized disruption to key sites identified in flood plans (e.g. public utilities) •Local disruption to travel, longer journey times	•Flooding affecting properties and parts of communities •Damage to buildings is possible •Potential disruption to infrastructure (e.g. utilities) •Disruption to travel network is expected. A number of roads are likely to be closed	•Widespread flooding affecting a significant number of properties and communities •Danger to life from fast flowing and / or deep water. •Widespread disruption or loss of infrastructure (e.g. utilities) •Large scale evacuation may be required •Severe disruption to travel networks.

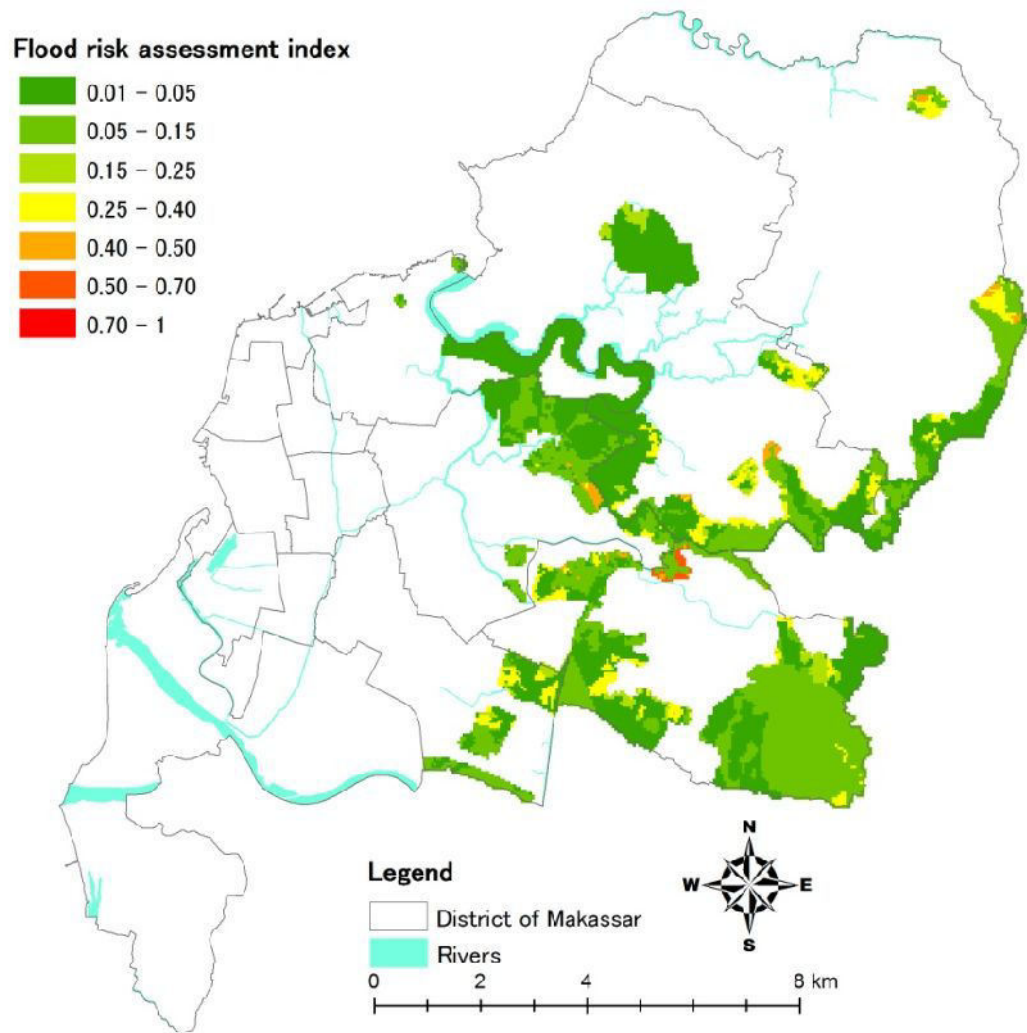


Fig. 4.28 Flood risk assessment index map

4.3.3 Analysis of flood risk index at sub-district level

4.3.3.1 Flood risk to the social component

The results of the risk assessment index in social component are shown in **Table 4.14**. Five indicators, belonging to all factors of vulnerability, were used to determine the risk index levels. These were population, percentage of poverty, percentage of gender, percentage of ages and percentage of disabled peoples. Those indicators were statistically measured and spatially calculated in GIS. Using these spatial criteria, sub-districts of Antang, Tamalanrea, and Sudiang Raya in Manggala District stands out as the most risk in social aspects, mainly due to its high number of people living in flood prone areas. Comparison of impacted area at sub-district scales in social aspect classified by risk index level is shown in **Figure 4.29**.

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Table 4.14 Risk assessment index in social component at sub-district scales

Sub-district	Flooded area	Risk index levels (%)								
		Ha	%	VL	L	ML	M	MH	H	VH
Bangkala	375.75	231	61	79	0	0	0	21	0	0
Tamangapa	763.5	605.75	79	91	0	7	0	0	2	0
Manggala	350.25	169.75	48	79	0	0	0	21	0	0
Antang	531.25	158	30	64	0	27	0	0	0	9
Batua	190	92.5	49	76	0	0	0	16	8	0
Tamalanrea Indah	503.25	142	28	90	0	0	0	10	0	0
Tamalanrea Jaya	375.5	273.25	73	78	0	0	0	14	8	0
Tamalanrea	389.25	100.75	26	62	0	13	0	17	8	0
Kapasa	669.25	51.25	8	46	0	0	0	54	0	0
Parangloe	1080.25	7.5	1	27	0	0	73	0	0	0
Bira	871.5	180	21	92	0	0	0	7	0	0
Gunung Sari	375.25	81.25	22	40	0	47	0	13	0	0
Karunrung	131.5	68	52	42	0	40	18	0	0	0
Kassi-kassi	106.25	56.75	53	51	0	11	0	38	0	0
Pampang	334.25	167	50	100	0	0	0	0	0	0
Panaikang	304.25	160.25	53	79	0	17	0	0	3	0
Paropo	127	27	21	14	0	86	0	0	0	0
Tello baru	162	48.25	30	66	0	15	0	9	10	0
Buloa	95.25	4.5	5	39	0	61	0	0	0	0
Tallo	62.75	6.25	10	32	0	68	0	0	0	0
Lakkang	342.5	200.75	59	100	0	0	0	0	0	0
Paccerakkang	750	196	26	75	0	21	0	4	0	0
Sudiang Raya	647.5	118.25	18	75	0	0	0	0	25	0
Sudiang	623.75	33.25	5	46	0	0	0	42	12	0

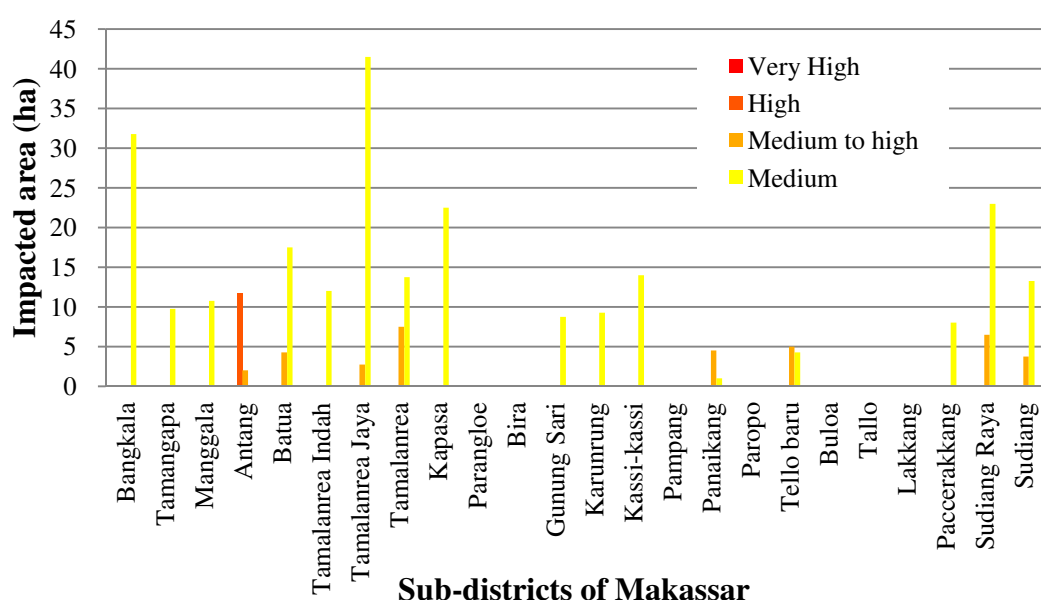


Fig. 4.29 Comparison of impacted area by risk index level at sub-district scales for social component

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Table 4.15 Risk index assessment in physical component at sub-district scales

Sub-district		Flooded area		Risk index levels (%)						
Name	Area (Ha)	Ha	%	VL	L	ML	M	MH	H	VH
Bangkala	375.75	231	61	79	0	2	6	9	4	0
Tamangapa	763.5	605.75	79	91	1	3	3	1	0	0
Manggala	350.25	169.75	48	79	0	5	10	6	0	0
Antang	531.25	158	30	64	1	14	12	0	1	7
Batua	190	92.5	49	76	0	0	2	7	12	3
Tamalanrea Indah	503.25	142	28	90	0	0	1	1	8	0
Tamalanrea Jaya	375.5	273.25	73	78	0	2	4	9	5	1
Tamalanrea	389.25	100.75	26	62	1	10	6	4	17	0
Kapasa	669.25	51.25	8	46	0	0	13	17	23	0
Parangloe	1080.25	7.5	1	27	0	0	40	33	0	0
Bira	871.5	180	21	92	0	1	7	0	0	0
Gunung Sari	375.25	81.25	22	40	20	27	2	11	0	0
Karunrung	131.5	68	52	42	1	39	5	13	0	0
Kassi-kassi	106.25	56.75	53	51	0	13	12	24	0	0
Pampang	334.25	167	50	100	0	0	0	0	0	0
Panaikang	304.25	160.25	53	79	0	11	6	0	1	2
Paropo	127	27	21	14	19	52	15	0	0	0
Tello baru	162	48.25	30	66	1	7	7	5	3	10
Buloa	95.25	4.5	5	39	6	56	0	0	0	0
Tallo	62.75	6.25	10	32	16	52	0	0	0	0
Lakkang	342.5	200.75	59	100	0	0	0	0	0	0
Paccerakkang	750	196	26	75	0	13	8	2	2	0
Sudiang Raya	647.5	118.25	18	75	0	0	8	11	1	5
Sudiang	623.75	33.25	5	46	0	0	4	17	23	11

4.3.3.2 Flood risk to the physical component

The buildings which a high density is mostly located at sub-districts of Tamalanrea and Kapasa in Tamalanrea District, and Antang in Manggala District. The spatial distributions of the building such industrial buildings, educational buildings, hospital buildings are densely distributed in the Tamalanrea district. Therefore, higher risk indexes in physical component are located in the Tamalanrea District. The results of the risk assessment index in physical component are shown in **Table 4.15**. Comparison of impacted area at sub-district scales in physical aspect classified by risk index level is presented in **Figure 4.30**. It is shows that the sub-district of Tamalanrea has the high impacted area for the physical component. Following by the sub-district of Tamalanrea Jaya, Antang, Kapasa and Batua, most of these areas are located in the Northern east part of the Makassar region which moderately high impacted area from the flood risk.

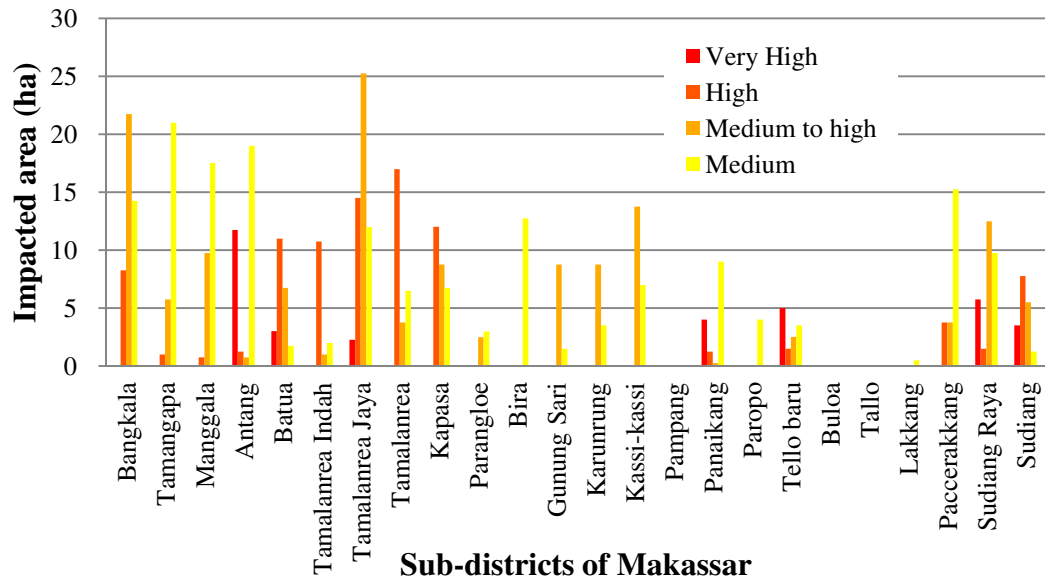


Fig. 4.30 Comparison of impacted area by risk index level at sub-district scales for physical component

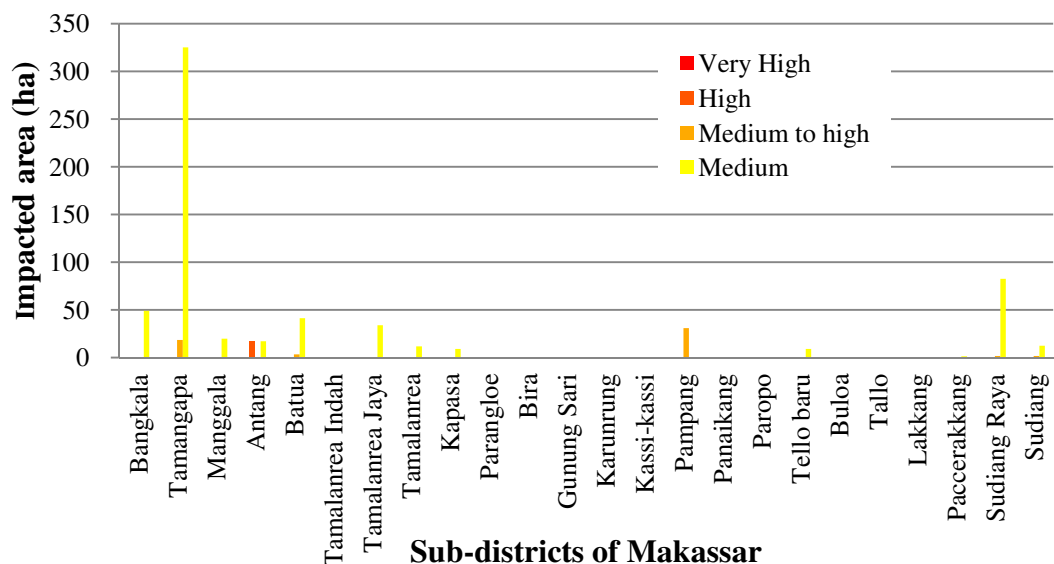


Fig. 4.31 Comparison of impacted area by risk index level at sub-district scales for economic component

4.3.3.3 Flood risk to the economic component

For the calculation of risk index to the economical values, the indicator of agricultural sector was used. Concerning the spatial distribution of the paddy field throughout the Makassar region, **Table 4.16** shows that area percentage of risk index is high in the sub-district of Antang, Pampang, Tamangapa in the Northern east of the Makassar region, and these sub-districts are more concentrated in the production of paddy in the Makassar region in 2012. Comparison of impacted area at sub-district scales in economical aspect is shown in **Figure 4.31**.

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Table 4.16 Risk index assessment in economic component at sub-district scales

Sub-district		Flooded area		Risk index levels (%)						
Name	Area (Ha)	Ha	%	VL	L	ML	M	MH	H	VH
Bangkala	375.75	231	61	49	0	30	21	0	0	0
Tamangapa	763.5	605.75	79	23	20	0	54	3	0	0
Manggala	350.25	169.75	48	30	0	59	12	0	0	0
Antang	531.25	158	30	60	19	0	11	0	11	0
Batua	190	92.5	49	33	0	19	45	4	0	0
Tamalanrea Indah	503.25	142	28	100	0	0	0	0	0	0
Tamalanrea Jaya	375.5	273.25	73	88	0	0	12	0	0	0
Tamalanrea	389.25	100.75	26	59	0	29	12	0	0	0
Kapasa	669.25	51.25	8	54	0	28	18	0	0	0
Parangloe	1080.25	7.5	1	100	0	0	0	0	0	0
Bira	871.5	180	21	69	0	31	0	0	0	0
Gunung Sari	375.25	81.25	22	82	2	17	0	0	0	0
Karunrung	131.5	68	52	72	4	24	0	0	0	0
Kassi-kassi	106.25	56.75	53	60	16	23	0	0	0	0
Pampang	334.25	167	50	81	0	0	0	19	0	0
Panaikang	304.25	160.25	53	100	0	0	0	0	0	0
Paropo	127	27	21	100	0	0	0	0	0	0
Tello baru	162	48.25	30	78	3	0	19	0	0	0
Buloa	95.25	4.5	5	100	0	0	0	0	0	0
Tallo	62.75	6.25	10	100	0	0	0	0	0	0
Lakkang	342.5	200.75	59	100	0	0	0	0	0	0
Paccerakkang	750	196	26	33	46	20	1	0	0	0
Sudiang Raya	647.5	118.25	18	29	0	0	70	1	0	0
Sudiang	623.75	33.25	5	56	0	2	38	5	0	0

4.3.3.4 Flood risk to the environmental component

The environmental component shows the involvement of ecological systems in the flood risk management process. The environmental component is the result of the combination of three local indicators: natural forest, mangroves and shrubs. The vegetation cover at the sub-districts that are located in the west of the Makassar region appears very low. As shown in **Table 4.17**, the most high risk index to the environment component is distributed in the sub-districts of Tamangapa, Tamalanrea Jaya, Panaikang and Pampang. Among these sub-districts, Tamangapa and Tamalanrea Jaya are potentially the higher environmental impacts, about 85 and 71 hectares areas, respectively (**Figure 4.32**).

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Table 4.17 Risk index assessment in environmental component at sub-district scales

Sub-district		Flooded area		Risk index levels (%)						
Name	Area (Ha)	Ha	%	VL	L	ML	M	MH	H	VH
Bangkala	375.75	231	61	100	0	0	0	0	0	0
Tamangapa	763.5	605.75	79	86	0	0	0	0	0	14
Manggala	350.25	169.75	48	92	0	0	8	0	0	0
Antang	531.25	158	30	91	0	0	0	0	9	0
Batua	190	92.5	49	100	0	0	0	0	0	0
Tamalanrea Indah	503.25	142	28	48	0	1	0	0	51	0
Tamalanrea Jaya	375.5	273.25	73	70	0	0	0	0	3	26
Tamalanrea	389.25	100.75	26	86	0	5	0	0	8	0
Kapasa	669.25	51.25	8	100	0	0	0	0	0	0
Parangloe	1080.25	7.5	1	100	0	0	0	0	0	0
Bira	871.5	180	21	100	0	0	0	0	0	0
Gunung Sari	375.25	81.25	22	100	0	0	0	0	0	0
Karunrung	131.5	68	52	100	0	0	0	0	0	0
Kassi-kassi	106.25	56.75	53	97	0	1	2	0	0	0
Pampang	334.25	167	50	74	0	0	12	0	0	15
Panaikang	304.25	160.25	53	62	0	1	4	0	0	34
Paropo	127	27	21	100	0	0	0	0	0	0
Tello baru	162	48.25	30	83	2	15	0	0	0	0
Buloa	95.25	4.5	5	94	6	0	0	0	0	0
Tallo	62.75	6.25	10	92	8	0	0	0	0	0
Lakkang	342.5	200.75	59	99	1	0	0	0	0	0
Pacerakkang	750	196	26	99	1	0	0	0	0	0
Sudiang Raya	647.5	118.25	18	99	0	0	1	0	0	0
Sudiang	623.75	33.25	5	100	0	0	0	0	0	0

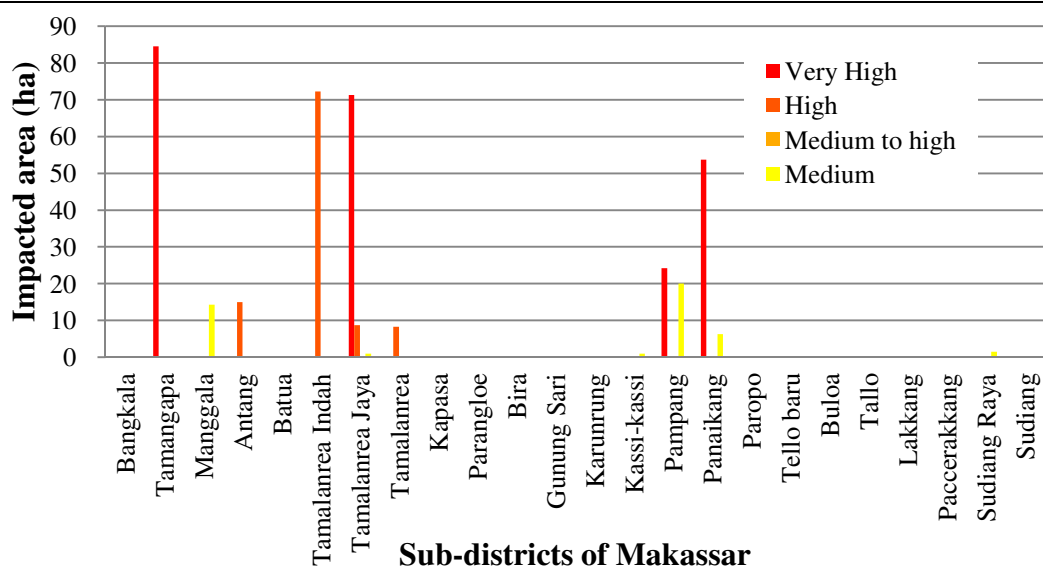


Fig. 4.32 Comparison of impacted area by risk index level at sub-district scales for environmental component

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4.3.3.5 Overall of risk index component

As a result of the composite vulnerability components (social, physical, economic, and environmental) described above in the previous section, the sub-district presents the wide area with high risk index that are mostly located in Antang, and following by Sudiang Raya, Tamalanrea Jaya and Tamangapa (**Figure 4.33**). Sub-districts of Tamalarea, Batua, and Panaikang are moderately high risk areas. **Table 4.18** depicts the overall risk index at sub-district scales.

In addition, the Makassar region including the coastline is vulnerable to flooding and this vulnerability can be exacerbated by changes in both the occurrence of severe rainfall events. Local conditions such as low-lying lands and slow surface water drainage increase the risk of flooding. As for the entire area of the Makassar region, only about 50% of the area of surface water runoff can be controlled by the urban drainage systems.

Table 4.18 Composite risk index assessments at sub-district scales

Sub-district		Flooded area		Risk index levels (%)						
Name	Area (Ha)	Ha	%	VL	L	ML	M	MH	H	VH
Bangkala	375.75	231	61	58	21	7	14	0	0	0
Tamangapa	763.5	605.75	79	21	78	0	2	0	0	0
Manggala	350.25	169.75	48	67	12	15	6	0	0	0
Antang	531.25	158	30	33	58	0	0	1	7	0
Batua	190	92.5	49	28	48	1	19	5	0	0
Tamalanrea Indah	503.25	142	28	39	51	1	8	0	0	0
Tamalanrea Jaya	375.5	273.25	73	37	42	5	15	1	0	0
Tamalanrea	389.25	100.75	26	42	33	4	14	7	0	0
Kapasa	669.25	51.25	8	28	18	10	44	0	0	0
Parangloe	1080.25	7.5	1	27	0	73	0	0	0	0
Bira	871.5	180	21	92	0	8	0	0	0	0
Gunung Sari	375.25	81.25	22	40	47	2	11	0	0	0
Karunrung	131.5	68	52	42	40	5	14	0	0	0
Kassi-kassi	106.25	56.75	53	51	11	13	25	0	0	0
Pampang	334.25	167	50	67	33	0	0	0	0	0
Panaikang	304.25	160.25	53	46	51	0	1	3	0	0
Paropo	127	27	21	14	86	0	0	0	0	0
Tello baru	162	48.25	30	47	34	0	9	10	0	0
Buloa	95.25	4.5	5	39	61	0	0	0	0	0
Tallo	62.75	6.25	10	32	68	0	0	0	0	0
Lakkang	342.5	200.75	59	100	0	0	0	0	0	0
Paccerakkang	750	196	26	74	21	0	4	0	0	0
Sudiang Raya	647.5	118.25	18	4	71	0	19	5	0	0
Sudiang	623.75	33.25	5	3	43	3	40	11	0	0

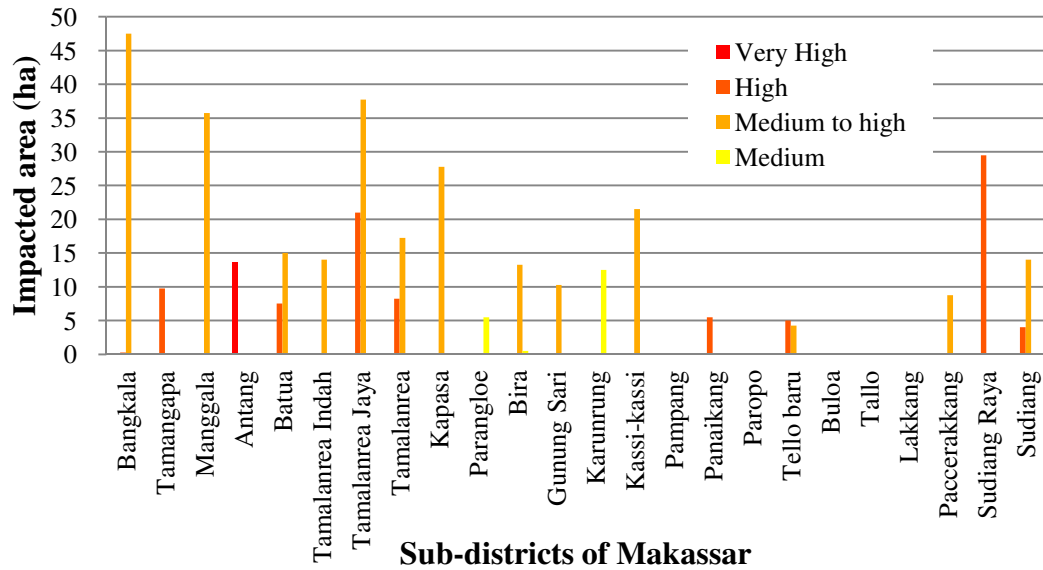


Fig. 4.33 Comparative impacted area by risk index level at sub-district scales for overall components

The urban area mainly located in the Western part of Makassar, while the other Eastern part such as Districts of Biringkanaya, Tamalanrea, Manggala and Panakukkang are still experiencing problems due to the lack of systematic flood control, respectively. As a result, these areas are frequently flood disaster still occurs. In this study, districts which almost experience with flood are analyzed for their flood risk index. **Figure 4.34** shows the result of percentage of risk area for the risk components at each impact level for districts of Biringkanaya, Manggala, Panakkukang, Rappocini, Tallo, Tamalanrea, respectively. Furthermore, **Table 4.19** shows the potential impact levels for those districts.

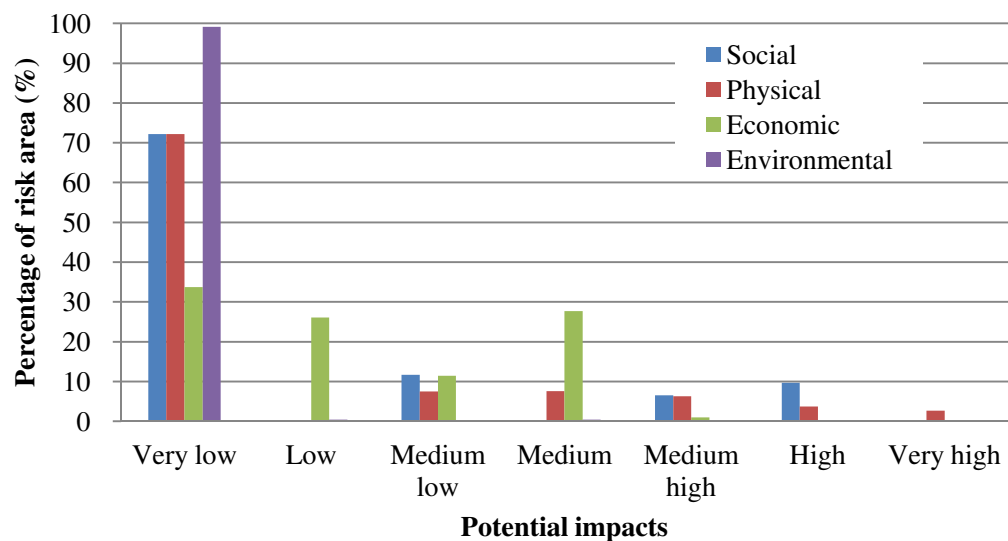


Fig. 4.34a Percentage of risk area at impact levels for Biringkanaya District

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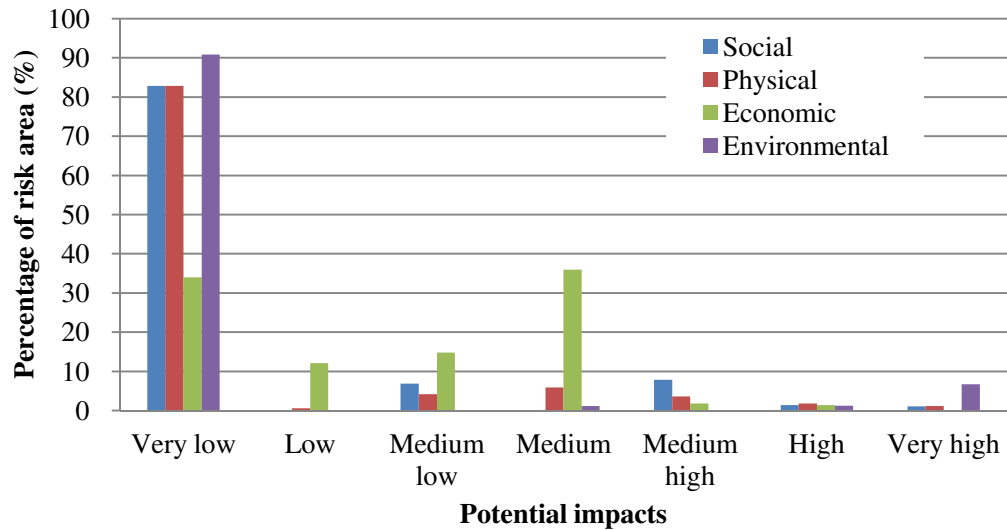


Fig. 4.34b Percentage of risk area at impact levels for Manggala District

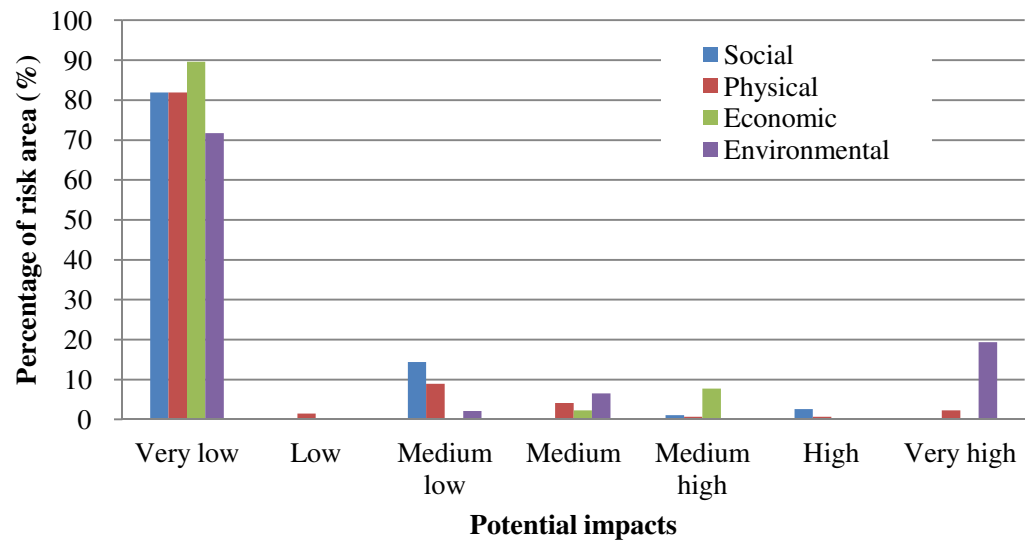


Fig. 4.34c Percentage of risk area at impact levels for Panakkukang District

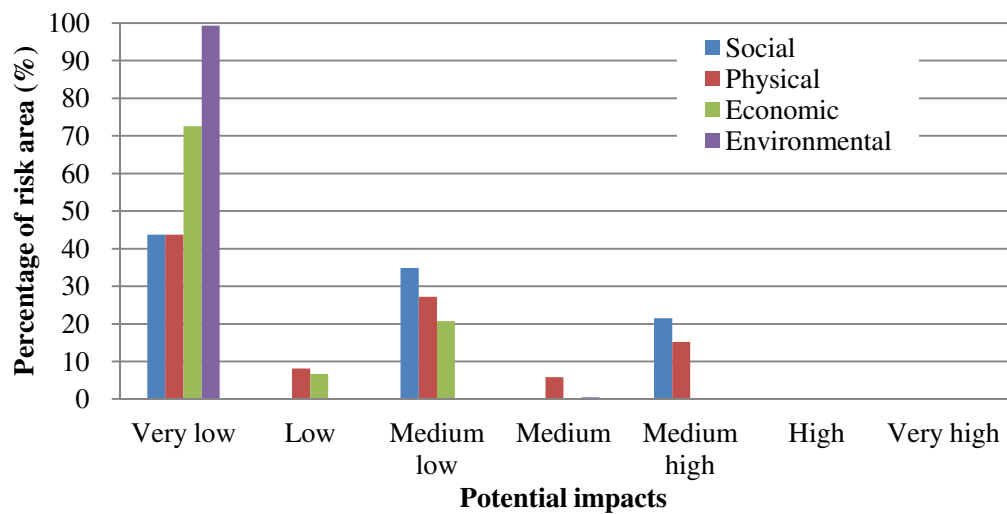


Fig. 4.34d Percentage of risk area at impact levels for Rappocini District

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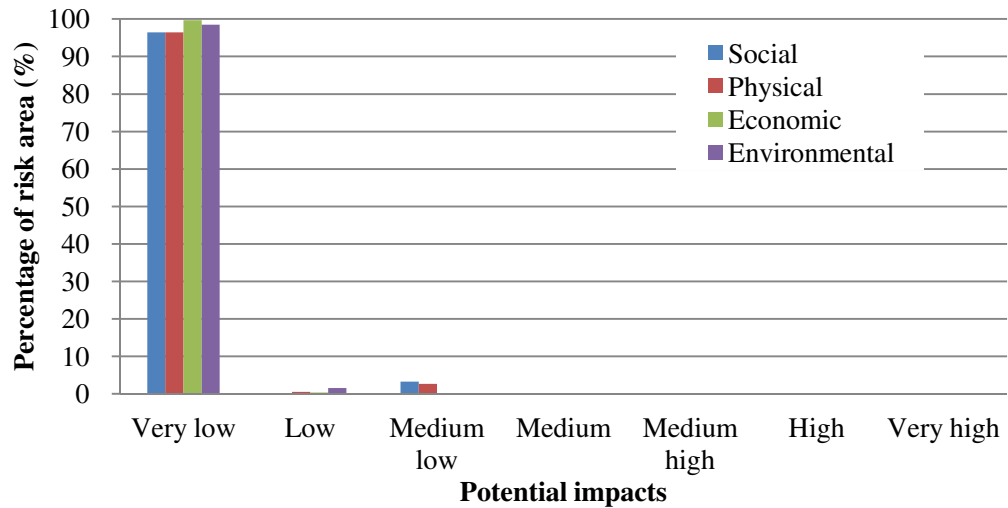


Fig. 4.34e Percentage of risk area at impact levels for Tallo District

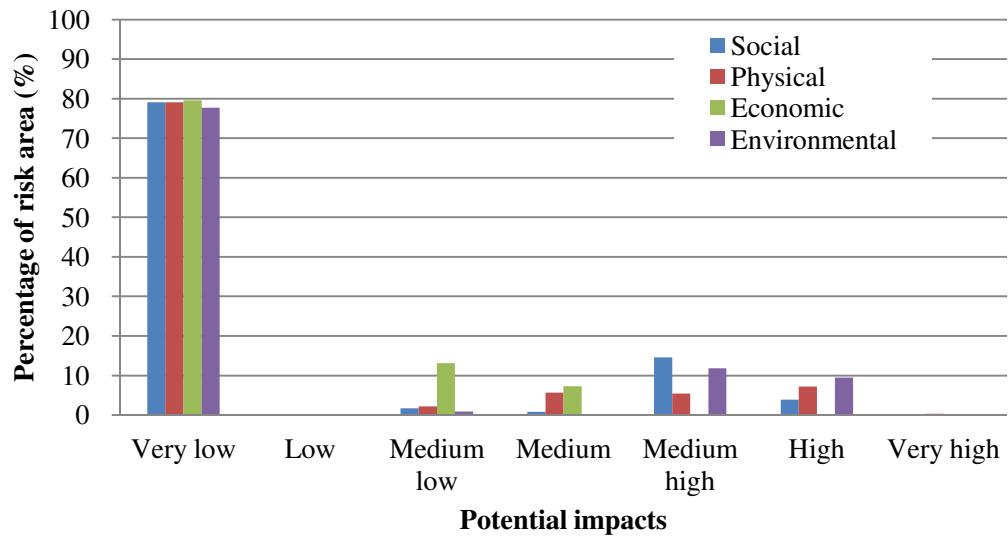


Fig. 4.34f Percentage of risk area at impact levels for Tamalanrea District

Table 4.19a Potential impact levels for Biringkanaya District

No.	Potential impact levels	Components of flood risk area (%)			
		Social	Physical	Economic	Environmental
1	Very low	72	72	34	99
2	Low	0	0	26	0
3	Medium low	12	7	11	0
4	Medium	0	8	28	0
5	Medium high	7	6	1	0
6	High	10	4	0	0
7	Very high	0	3	0	0
Total		100	100	100	100

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Table 4.19b Potential impact levels for Manggala District

No.	Potential impact levels	Components of flood risk area (%)			
		Social	Physical	Economic	Environmental
1	Very low	83	83	34	91
2	Low	0	1	12	0
3	Medium low	7	4	15	0
4	Medium	0	6	36	1
5	Medium high	8	4	2	0
6	High	1	2	1	1
7	Very high	1	1	0	7
Total		100	100	100	100

Table 4.19c Potential impact levels for Panakkukang District

No.	Potential impact levels	Components of flood risk area (%)			
		Social	Physical	Economic	Environmental
1	Very low	82	82	90	72
2	Low	0	1	0	0
3	Medium low	14	9	0	2
4	Medium	0	4	2	7
5	Medium high	1	1	8	0
6	High	3	1	0	0
7	Very high	0	2	0	19
Total		100	100	100	100

Table 4.19d Potential impact levels for Rappocini District

No.	Potential impact levels	Components of flood risk area (%)			
		Social	Physical	Economic	Environmental
1	Very low	44	44	73	99
2	Low	0	8	7	0
3	Medium low	35	27	21	0
4	Medium	0	6	0	0
5	Medium high	21	15	0	0
6	High	0	0	0	0
7	Very high	0	0	0	0
Total		100	100	100	100

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Table 4.19e Potential impact levels for Tallo District

No.	Potential impact levels	Components of flood risk area (%)			
		Social	Physical	Economic	Environmental
1	Very low	96	96	100	98
2	Low	0	1	0	2
3	Medium low	3	3	0	0
4	Medium	0	0	0	0
5	Medium high	0	0	0	0
6	High	0	0	0	0
7	Very high	0	0	0	0
Total		100	100	100	100

Table 4.19f Potential impact levels for Tamalanrea District

No.	Potential impact levels	Components of flood risk area (%)			
		Social	Physical	Economic	Environmental
1	Very low	79	79	80	78
2	Low	0	0	0	0
3	Medium low	2	2	13	1
4	Medium	1	6	7	0
5	Medium high	15	5	0	12
6	High	4	7	0	9
7	Very high	0	0	0	0
Total		100	100	100	100

Furthermore, the Makassar region is crossed by two large river estuaries, thus forming a watershed system such as the Jeneberang and Tallo rivers. Tallo river basin flows coastal area of the city of Makassar through districts of Manggala, Panakukang, Rappocini, Tallo, Tamalanrea, and Biringkanaya. Widespread residential areas in the sub-district's watershed caused high surface water flow from rainfall and problem of infiltration into the soil due to paved roads, buildings, etc. Increased the surface water flow causes more floods and increasingly widespread struck several sub-districts.

Table 4.20 illustrates the percentage area of sub-district in the flood districts. This risk can be increased by human actions including clearing of natural vegetation for urban development areas, the development of settlements in the flood plains of Tallo river flood plain as well as by changing weather patterns.

Table 4.20 Flood districts and their percentage areas of sub-districts

District		Sub-district		
Name	Area (Ha)	Name	Area (Ha)	Area (%)
Manggala	2210.75	Bangkala	375.75	17
		Tamangapa	763.5	35
		Manggala	350.25	16
		Antang	531.25	24
		Batua	190	9
Tamalanrea	3889	Tamalanrea Indah	503.25	13
		Tamalanrea Jaya	375.5	10
		Tamalanrea	389.25	10
		Kapasa	669.25	17
		Parangloe	1080.25	28
		Bira	871.5	22
Rappocini	613	Gunung Sari	375.25	61
		Karunrung	131.5	21
		Kassi-kassi	106.25	17
Panakkukang	927.5	Pampang	334.25	36
		Panaikang	304.25	33
		Paropo	127	14
		Tello baru	162	17
Tallo	500.5	Buloa	95.25	19
		Tallo	62.75	13
		Lakkang	342.5	68
Biringkanaya	2021.25	Paccerakkang	750	37
		Sudiang Raya	647.5	32
		Sudiang	623.75	31

4.4 Summary

Spatial and temporal analysis for flood vulnerability and risk assessment has been simulated in GIS with the aim to establish a flood risk index at sub-district scales for urban flood scenario in the Makassar region. The flood hazard index has been established based on the historical flood hazard maps and measurement of flood occurrence in 2013 provided by the local government of the Makassar. The overall vulnerability assessment to floods has been conducted based on the local framework analysis of the BNPB (Indonesian National Board for Disaster Management) and the use of GIS modeling approach. To establish spatial vulnerability to flood and risk index map, a spatial matrix analysis has been performed. Using a GIS grid-mesh of 50 meter scales as the spatial treatment unit analysis, the study aggregated the local indicators to a single composite index that

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enable spatial vulnerability representation at sub-district levels. These indicators were composed from various social, physical, economic, and environmental factors. Furthermore, Flood risk index has been determined to analyze the distribution of risk components at sub-district level. Determination of the risk level has been calculated by matrix model from the variables of the vulnerability and flood hazard. In the vicinity of Tallo River Area, sub-districts of Panaikang, Tamalanrea Indah, and Pampang have been identified as the areas with high potential impacts from flood risks in term of physical and environmental aspects.

CHAPTER 5

Spatial Analysis of Green Infrastructure Plan Evaluation

5.1 Strategic Context

5.1.1 National and regional context

Indonesia is one of the fastest urbanizing countries in Asia and its future will be shaped by its cities. In 2011 the population was 51% urban and the projected to become 85% by 2050 (Parasati, 2013). Indonesia's "big bang" decentralization of 2001 was a major redesign of the state. After 12 years, the advantages and disadvantages of the new design are becoming clearer. Many large cities are now competently planning their futures and managing their affairs. Three laws, introduced to improve land-management (Law 26/2007 on spatial planning, Law 41/2009 on sustainable protection of farmland, and Law 2/2012 on land acquisition for public use), are not yet having their intended impact (Turner et al., 2003). It is in the light of these concerns that the government is currently preparing a new national urban development policy and program, and planning through innovative development programs in a number of metropolitan areas including Mamminasata Area (covering the city of Makassar, Maros Regency, Gowa Regency and Takalar Regency).

5.1.2 City context

Makassar is the largest city in Eastern Indonesia and the capital of the province of South Sulawesi. It is located on the south-western coast of the island of Sulawesi, facing Makassar Strait. Makassar is part of the Mamminasata metropolitan area, which has a population of about 2.5 million which is expected to grow to around 2.9 million in 2020. Around 1.4 million people live within the City boundary. Over the last two decades, the population of the regencies has exceeded the growth of Makassar, though most of the new employment is within the city boundary. Urbanized areas of surrounding regions of regencies have an even

lower density of less than 20 ppHa, scattered over a wide area. The built-up area has expanded far faster than the population, indicating an increasingly lower density of the city. The loss of prime agricultural land would appear to be a major problem throughout Mamminasata, and the sprawl is a major contributor to the lack of increase in the productivity of the city. The city is becoming less serviceable as it sprawls. Yet close to the Makassar city centre, Tallo is a large area of undeveloped land, the large area of wetland on downstream Tallo River. This hole in the urban area covers much of the original Tallo kingdom with its centre at the mouth of the river. Since regional autonomy in 2001, Makassar has proposed to develop this area as a cultural centre and green centre for the city. This is endorsed in the Mamminasata spatial plan (2006) which identifies the river as a special development area. The city's spatial planning identifies three special development areas: (i) the Tallo Heritage City, (ii) Tallo River integrated development area, and (iii) Lakkang Island protected area. In the ancient Tallo kingdom, the city will built defenses along the coast, to protect against flooding from sea, and a port for free trade on the river. Makassar again recognizes the threat from the sea as one of nature, climate change, storms. The proposed Heritage City will be protected from the sea by a sea port and major residential development. The combination of the reclamation and wetland development adjacent to the proposed green park will have a dramatic impact on the form of Mamminasata.

5.2 Tallo Development Plan

5.2.1 Project plan description

This study identifies the boundaries of the development plan area, as illustrated on the **Figure 5.1**. Tallo Heritage City and Green Park consists of three strategic areas defined in the figure: (i) Tallo Heritage City covering Kelurahan Tallo, (ii) part of the Tallo River Integrated Development Area which covers the river and its immediate embankment, and (iii) Lakkang Island conservation area. The area available for development covering land adjacent to the Tallo Green Park is currently undeveloped or partially developed as the hole in Makassar. Most of this land is currently subject to regular flooding and will be made flood free by the proposed works, thus available for urban development. The following **Table 5.1** indicates objectives and beneficiaries of the whole project, showing benefit

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indicators where appropriate, and indicators used in appraisal over the period of development of the area.

Table 5.1 Objective and beneficiaries of Tallo project plan

Objective	Beneficiaries	Benefit indicators
Riverside Park	All citizens of Makassar and visitors/tourists	Number of visitors to the park Tourist time in South Sulawesi spent at park
Land made free of flooding	Those who will find work and home in a location close to the centre of Makassar	Number of jobs Number of residents
Access and high density development	Those able to locate businesses (industry, warehousing and commerce) in high density development	Number of businesses locating in the area
	Those who will find work, home and business in a location close to the centre of Makassar	Number of jobs Number of residents Number of trips to and from and through the area
	Those able to walk to place of work or place of doing business	Numbers of residents walking to work and place of doing business
Lower income housing support	Lower income families locating in the development area	Number of lower income families finding housing in area
	Fishermen in improved housing and stronger communities	Improved housing and economy of communities living on river bank
Capacity of the community	Lakkang island residents	People of Lakkang Island have formed as strong association to promote cultural heritage Improved economy of the people of Lakkang
	Fishermen families	Fishermen families have formed a strong community association to promote their uniqueness Improved economy of the fishermen families
Capacity of the city government	Poor income people able to have housing close to place of work Public by receiving improved services Local government employees	Urban environment is clean and provided with appropriate levels of services such as schools and community facilities Level of productivity
Minimized relocation of households	Current community living in the area	Number of households displaced by the development.

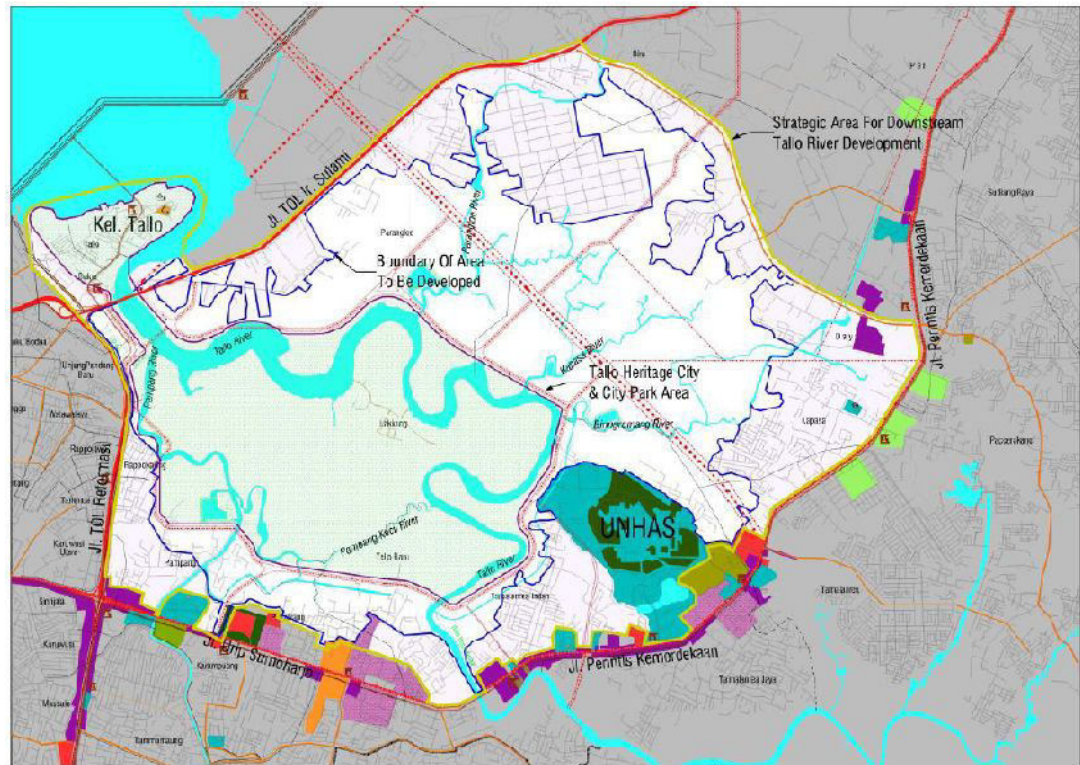


Fig. 5.1 Boundaries of the development plan area

The overall objective in accordance with the spatial plan will lead to:

- A city green park, including Lakkang Island to be retained as a rural area with a traditional village and tourist activity for the population of Makassar and visitors;
- Land made free of flooding that can be used for the development of industry, warehousing, education and housing in accordance with the city plan that can create home; and
- Access to and around this land (by road and river), in such a way that will promote high density of both housing and work-place, and attract a large population that can living and work close to the park, making public transport by both road and river cost effective for both the public and transport companies. This effectively will create a second commercial district for the city facing the park, with the primary non-polluting industrial and warehousing zone for the city.

5.2.2 Existing situation

Land use in the Tallo River area is divided into several zones, namely: (i) Kelurahan Tallo, (ii) south of the river, (iii) north of the river, (iv) Lakkang Island,

(v) the Tallo River, and (vi) the area around the university campus. Kelurahan Tallo is the site of the ancient kingdom of Tallo. The area south of the river is bounded by Jalan Perintis Kemerdekaan and to the north by Pampang River and Lakkang Island. Land uses along Jalan Perintis Kemerdekaan are medium density, behind which are fishponds bounded by cultivated nipah palm. The area to the north is the catchment of a number of small rivers flowing into Tallo River, between the toll road and the university campus. The river bank is planted with nipah palm on the earth walls of fish ponds. Between the fishponds and the urban development are some rice fields. To the west, both sides of the toll road are low density industry and warehousing mixed with residential.

The land on Lakkang Island is mainly fishponds. The river bank is planted with mangrove and nipah palm, with some village housing concentrated between two small piers. Close to the housing are some rice fields and fruit trees. Tallo River is still used for transporting goods (timber) and people, especially those living on Lakkang which does not have a bridge to the city. The river gives the feeling of natural freshness as mangroves and nipah palm grow along its banks, though at some places, especially near the toll road bridge, there is fishermen housing. The river is still used for fishing, using lines, nets and fishing rigs. The photos of existing situation can be seen in the **Figure 5.2**.

There are only two main-road bridges crossing Tallo River, Tello Bridge on Jalan Perintis Kemerdekaan to the east and the toll road bridge to the west, providing little alternative access in cases of emergency. Both bridges have capacity less than the roads that lead to them. The Tallo area has little road access from east or west. The state of the infrastructure is typical of most other cities. There is little consideration for pedestrians. Garbage collection service is inadequate and garbage floats down the river from city drains. Poor drainage and inadequate maintenance programs lead to a high level of damaged roads. Sanitation is inadequate, resulting in putrid water coming from city drains into the river.

Kelurahan Tallo is the location of the centre of the original kingdom of Tallo. Access to Kelurahan Tallo is in a dismal state of disrepair, and the location where there used to be the entrance gate is now a temporary garbage disposal site. The population of Kelurahan Tallo is about 3.5% of the total of the population of Makassar. The population is increasing at 2.08% per year. Kelurahan Tallo is the location of historic sites, including the graveyard of the ancient kings of Tallo and several other archaeological remains. Housing areas within Kelurahan Tallo are relatively dense, mostly single story timber dwellings, close together, many over the water, crossing the river-line.

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River dock



Boat



Transportation



Fisherman village



Fisherman



Lakkang Island



Tallo King's grave yard



Japanese bunker in Lakkang Island

Fig. 5.2 Photos of the existing situation in the Tallo River Area

Tallo River has a catchment area of 407 km² starting at Mount Kallapolompo (elevation 725 m), and the main river is 72 km long. The lowland of the river extends from beyond the city limits, with a slope of less than 5%. The riverbank is in its natural state or made of earthen walls to fishponds, without flood-control works. Because of this condition, the area around the river often floods. Most of the length of Tallo River in the study area appears in natural condition, with most of the river flanked by mangrove and nipah palm. In fact humans have planted the trees along embankments built for fish and prawn ponds. Most of the river is shallow, and will require dredging to increase its capacity to handle flooding. There has been a significant loss of fish population in recent decades, and most fishing is now in the open sea. The vegetation along the river, mainly nipah palm and mangrove, is mostly in healthy condition. This vegetation serves to protect the riverbank so that the meandering of the river does not vary from year to year. It also serves to protect wildlife including the fish population. Upstream of Tallo area are several retention reservoirs. Also in this upstream area is a swamp by nipah palm. These swamps and lakes help retain water at flood time, which mitigates flooding downstream. River Tallo passes Makassar City, and collects waste water from the city, including plastic, paper, domestic sewage and factory waste. As a result the quality of water in the lower area of the river is getting worse.

A narrow bifurcation of the river linking to Pampang River creates Lakkang Island. The plan for retaining Lakkang Island as a conservation area is well-supported by the peoples. Land is used for ponds, rice-fields, and a small amount of plantation. This area is can serve an environmental buffer zone for flooding, and its green area can absorb air pollution. Its natural resources can serve as a tourist attraction, and for nature research. In the city plan, Lakkang Island is a strategic protection area, directed to conservation of water and land and allocated as a zone for environmental benefit, preservation and conservation.

5.2.3 Detailed Development Components

5.2.3.1 Tallo river system flood free

A levee is built along the boundary of the riverside park, on both sides of the river between the toll road bridge and the Jalan Perintis Kemerdekaan Bridge (Tello Bridge). Some parts of this levee will be combined with the other road lines. At west area, the levee will be built at the front of fishermen housing, creating a dock for their boats. The levee is diverted from the riverbank at the location of a proposed sewerage plant. Several flood-gates with pump houses are to be

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constructed on the tributaries and outlet to the river to prevent river flood waters entering the land behind the levee. Sewerage plants, which are combined with stabilization ponds to reduce pollution levels of water flowing into the river, will be provided at the tributaries of the river. The flood gate designs are based on the fifty year return period design discharge. Water quality stabilization ponds reduce the pollution levels (mainly Biological Oxygen Demand (BOD) and sediment concentrations) in the drainage water before entering the river. The three streams to the north of the river will be connected by canals within the road allocation for the city's Outer Ring Road, and along other roads. The following **Table 5.2** shows the detailed components of development plan for Tallo river system flood free.

Table 5.2 Detailed components for river system flood free

Sub-component	Location	Function
Levee	North of Tallo River and to the south of Tallo River, Pampang small river and Pampang River	Prevents flooding of area behind levee
	Tamalanrea Indah (East area)	Prevents flooding of area behind levee
Docks	Rappokalling (West area)	Allows community and business access to river
Flood gates with pump-housing	At tributaries	Disposes water into river at times of flooding, enables river flushing
Water quality stabilization ponds	At larger tributaries	Lower BOD levels before water enters Tallo River
Connecting canals	Linking the three tributaries in area north of the river	Allows flushing of canals and rivers
	Tamalanrea Indah (East area)	Acts as retention pond and link between Tamalanrea and drainage systems in university area
	Tello Baru-Panaikang (South area)	Diverts drainage to Pampang River
Dredging	At river mouth, and potentially along the river	Increases river flow, provides material for reclamation

Table 5.3 Detailed components for access with higher density

Sub-component	Location	Function
Outer Ring Road	Linking to the toll road through the north of the river	Providing access from the south of the city and opening up a vast area of land north of the river
Riverside road	Linking outer ring road to Panakkukang, mostly on the levee	Creating access to west and south of the riverside park and high density
	North side of river	Access to park and high density development, link to toll road
	From Panakkukang to toll road, Tallo Heritage City, and future port	Completion of riverside road, access to Tallo Heritage City
Part, alternative access to city	North of outer ring road	With riverside road creates access into city and to new development area
High density development	Along riverside road	Real estate development for mixed use at density to promote public transport
River transport	Along river with piers at strategic locations	Alternative public transport to city and future reclamation areas
Cycle path	Along levee	Providing access for cycles

5.2.3.2 Access with higher density

Table 5.3 shows the detailed components of development plan for access with higher density. Two main roads are proposed as the mainframe of this component which makes the whole area accessible for development. The first is part of Mamminasata plans, the outer ring road. It cuts across the middle of the large area to the north of Tallo River, from Jalan Perintis Kemerdekaan to the toll road. The function of this road is primarily to serve industrial and warehousing areas. Later it will extend to the east and south, linking to the southern part of Mamminasata, and will extend west into the proposed industrial area west of the toll road and to a proposed large reclamation area. The second main road is the Riverside Road, to be located along the flood control levee. It will link with the industrial zone to the north-west of Tallo River, cross the toll-road close to the toll road bridge, then wrap around the proposed parkland returning to cross the toll road to the south of the bridge, linking to Tallo Heritage City and finally to the new port facility in

reclaimed land to the west of Tallo. A second river crossing will link the two ends of the road upstream from the toll road bridge. This road will serve primarily as access to the green park and to a ribbon of high density mixed use between park and the industrial warehousing areas behind it. It will be provided with four lanes for private vehicles, special bus lanes, wide footpath space and extensive planting of avenue trees. The city will also develop river transport. Three of these piers will be under river bridges, and one at the university campus, at points to maximize demand by linking to other transport modes at nodes planned for high density developments. Two others will be on the island of Lakkang, to help promote tourism in the area.

5.2.3.3 *Heritage city and Green Park*

As few items remain from the original kingdom, the proposed Heritage City will consist of cultural symbols more than restored relics. The main symbols proposed are the use of space, as indicated in the following illustration. The key components of the concept are:

- Demarcation of the line of defense with a roadway and views to the west from each of the fortresses, and rehabilitation of the mangrove forest that hides the view of the port from the sea;
- An avenue along the river front symbolizing the ancient port, with the boat-building facility retained;
- Creating a park area around the inauguration monument, with facilities for all future city inaugurations;
- Creating a park area where it assume the international trade was carried out, and at this point create a new local market place for local cultural products; and
- Creating a park where ceremonies can be held, and a facility for weddings and festivals, with access to the river as many ceremonies have bathing rituals. Also providing a cultural centre and school for traditional dance music and drama, an education facility for children to learn about their cultural roots, and a Tallo Heritage Museum.

Being more symbolic than physical, it is propose that the development of Tallo Heritage City be based on study of the culture and oral history. It is also propose that the community restores and modernizes its traditional local organization known as Gallarang, which would be similar to Banjar in Bali. Furthermore, the city envisions the entire area within the riverside road to be developed as a city park. This area will be comprised of the following parts:

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- The river to be used for recreation and river transport, but also for more intensive fishing. Stabilization ponds mentioned above will be needed to assure water quality to sustain a tourist industry;
- Lakkang Island to be retained as a rural community and a tourist destination to display traditional village life;
- Areas of mangrove forest;
- Retaining nipah-nipah plantations along most of the river bank;
- Traditional stilt housing to be retained and improved on selected parts of the river bank; and
- A large area for university farming, fisheries and forest research to the south of Lakkang Island.

A number of park areas providing a variety of recreation uses. It is designed that a number of these initiatives:

- Mangrove planting at select locations on the north bank of the river and on Lakkang; and
- Pedestrian and cycle tracks along entire riverside road levee, with a line of trees adjacent to the levee.

Table 5.4 Detailed components for create heritage city and city park

Sub-component	Location	Function
Heritage city	Kelurahan Tallo	Preservation of cultural heritage, development of a cultural centre
Riverside parks	Locations along river to be determined	A gathering point for academia with society
		Recreation area
		Worker and family recreation area
Lakkang Island conservation	Lakkang Island	Urban green space and conservation of traditional rural lifestyle
Mangrove planting	Locations along river to be determined	Protection and enhancement of bio-diversity
Cycle paths	Along levee and length of parkland	Recreation, access for park maintenance
Remainder of river park		Recreation uses

5.2.3.4 *Improved housing and community*

It is proposed that improvement of river-bank fishermen housing at Buloa next to the toll road bridge, and potentially in locations along the river in Kelurahan Tallo, as part of the effort to preserve culture and heritage, and make the area more attract for tourism. At present the general quality of this housing is poor to very poor, but in Buloa and many parts of Tallo the main problem is sanitation which is relatively easily addressed.

The opportunity is to enable these communities to improve their welfare by making the housing more attractive and accessible, for fishermen to sell their catch and to provide simple restaurants to tourists on the river. It is proposed that the communities in these areas prepare building and neighborhood plans. It is anticipated that the density of these areas could reach over 1000 ppHa in places. The neighborhood plans process will assure the availability of community space and prevent both slumming and take-over by a richer community.

Sites for primary school and mosque will act as anchors to attract people to join the new communities. It is anticipated that the ministry for housing and the city will provide apartment housing at strategic locations in the area. These should be planned close to transport nodes.

Table 5.5 Detailed components for improved housing and community

Sub-component	Location	Function
Housing in Tallo Heritage City	Kelurahan Tallo	Preservation of cultural heritage, development of a cultural centre
River-bank fishermen housing	Buloa, Tallo	Traditional stilt housing over the water
Guided densification	North of university campus, Tamalanrea Indah, and Panaikang	Higher density development in existing low income areas
Informal housing within block development	Block developments on outer ring road	Higher density development of new low income areas

5.3 Key Issues for Green Infrastructure Plan

This section describes the baseline characteristics and the key Green Infrastructure issues. The following sections have been identified as important in identifying Green Infrastructure potential.

5.3.1 Biodiversity

Key issues are then identified for biodiversity conservation in relation to the planning of Green Infrastructure. Biodiversity issues in north and south area of Tallo occurred due to the Mangrove ecosystem degradation. These environmental degradations is mainly caused by: (i) Human activity that includes land clearing for residential and industrial; ponds and firewood, (ii) The condition and quality of the environment that covers domestic household waste, sedimentation, water quality, and (iii) Pests and diseases. The Local Biodiversity Action Plan for Tallo River Area identifies mangrove species which are of high ecological interest in a local context and lists actions required to conserve and enhance them. There are 4 species which were found based on the results of the mangrove vegetation identification in the Tallo River Area. The species are *Avicenia alba*, *Avicenia marina*, *Rhizophora mucronata* and *Rhizophora apiculata* (Bando et al., 2017). The biodiversity restoration program in the study area of Tallo is shown in **Figure 5.3**. Existing nature conservation sites would form the core areas of a future ecological network. Many such sites require active management to sustain their biodiversity value (for example swamp fields), is shown in **Figure 5.4**.



Fig. 5.3 Photos of the mangrove plantation by the local government and community for restoration program in sub-district of Panaikang

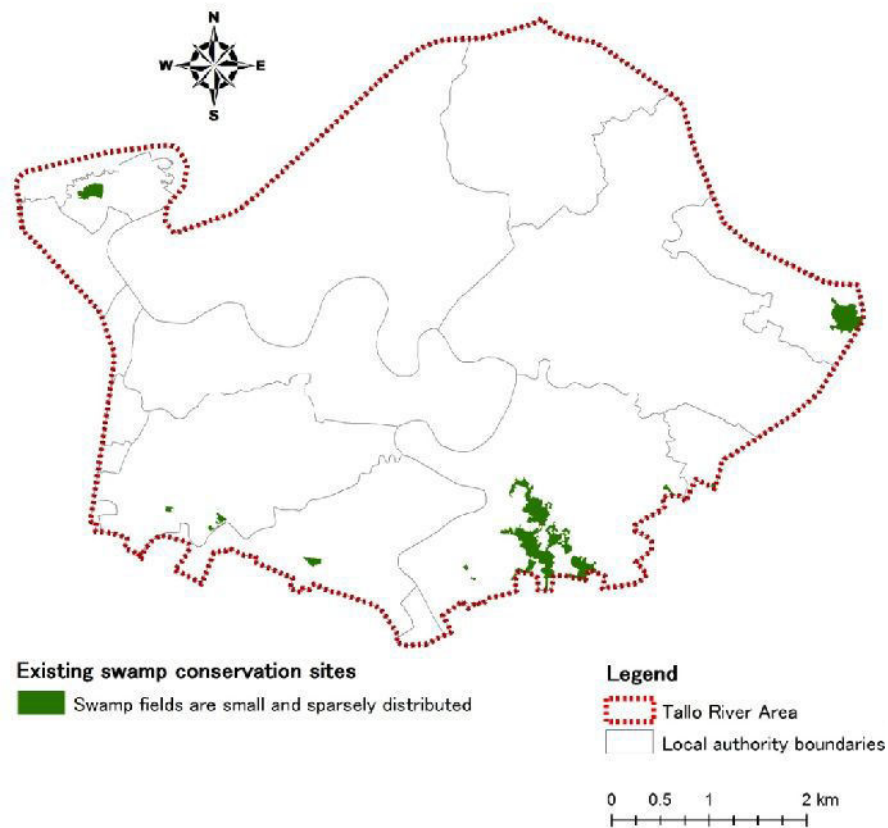


Fig. 5.4 Existing natural conservation sites for swamp fields

Patches of habitats which are fragmented in between areas of development and intensively fishponds may be too distant from one another to permit species to re-colonize formerly occupied sites. This issue may be particularly acute in the following landscape character areas of the Tallo:

- Shrubs - where shrubs are small and sparsely distributed (**Figure 5.5a**);
- Mangroves - where many mangrove trees have been removed limiting connectivity (**Figure 5.5b**);
- Paddy - where shrubs are sparsely distributed (**Figure 5.5c**);
- Garden - where many garden fields have been removed limiting connectivity (**Figure 5.5d**); and
- Forest - where forests are sparsely distributed (**Figure 5.5e**).

One of the goals is to achieve conservation of Lakkang Island and Tallo River as an urban green area for ecotourism. The mangrove planting program along the river, nipah palm trees around stabilization ponds will have an impact on increasing biodiversity which in turn will promote ecotourism. Planting in the riverside parks should be selected to encourage birdlife.

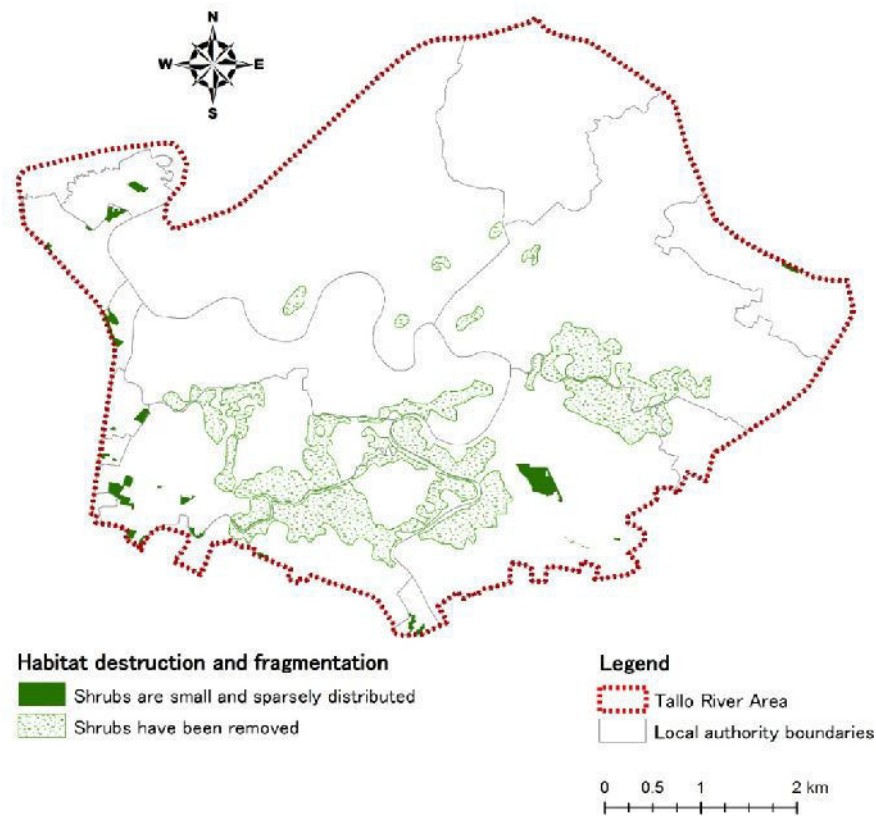


Fig. 5.5a Habitat destruction and fragmentation for shrubs

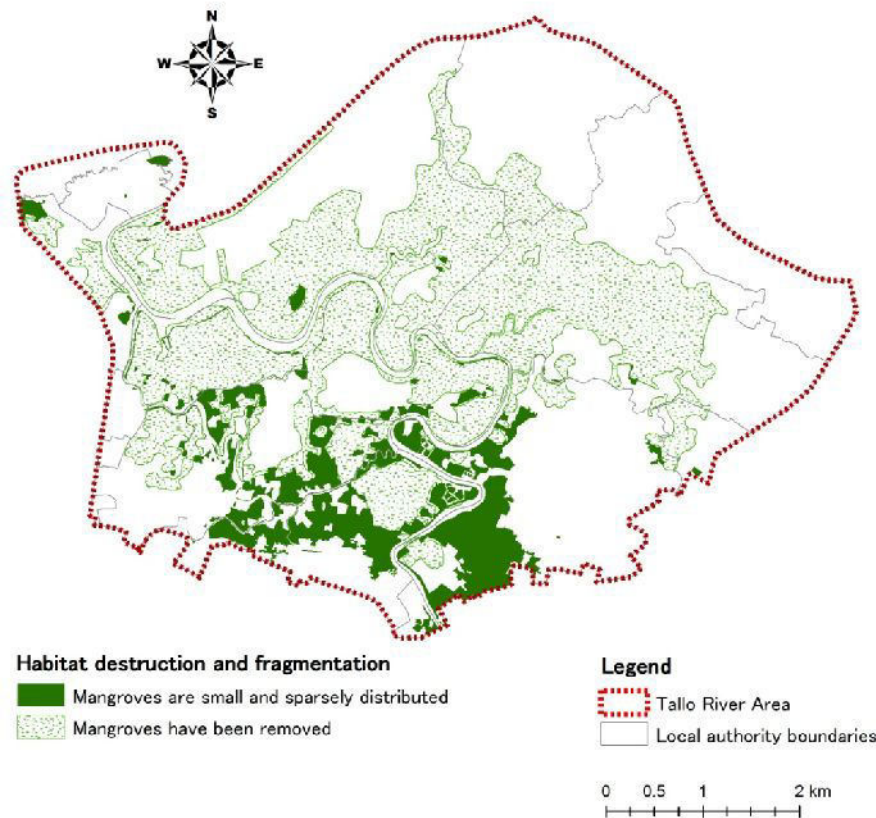


Fig. 5.5b Habitat destruction and fragmentation for mangroves

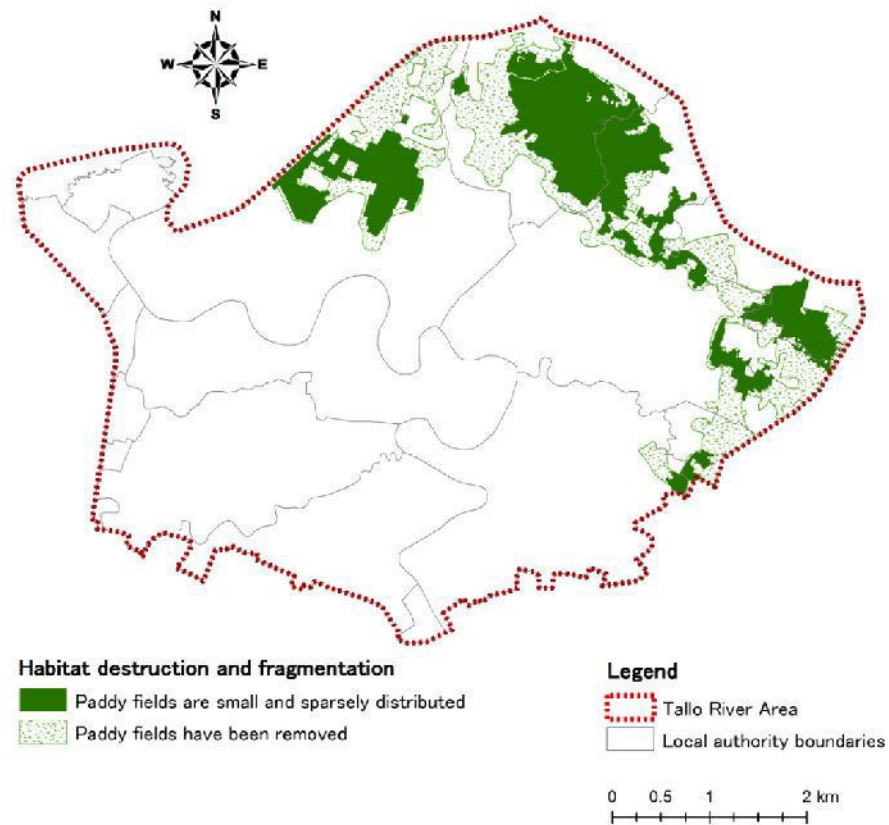


Fig. 5.5c Habitat destruction and fragmentation for paddy fields

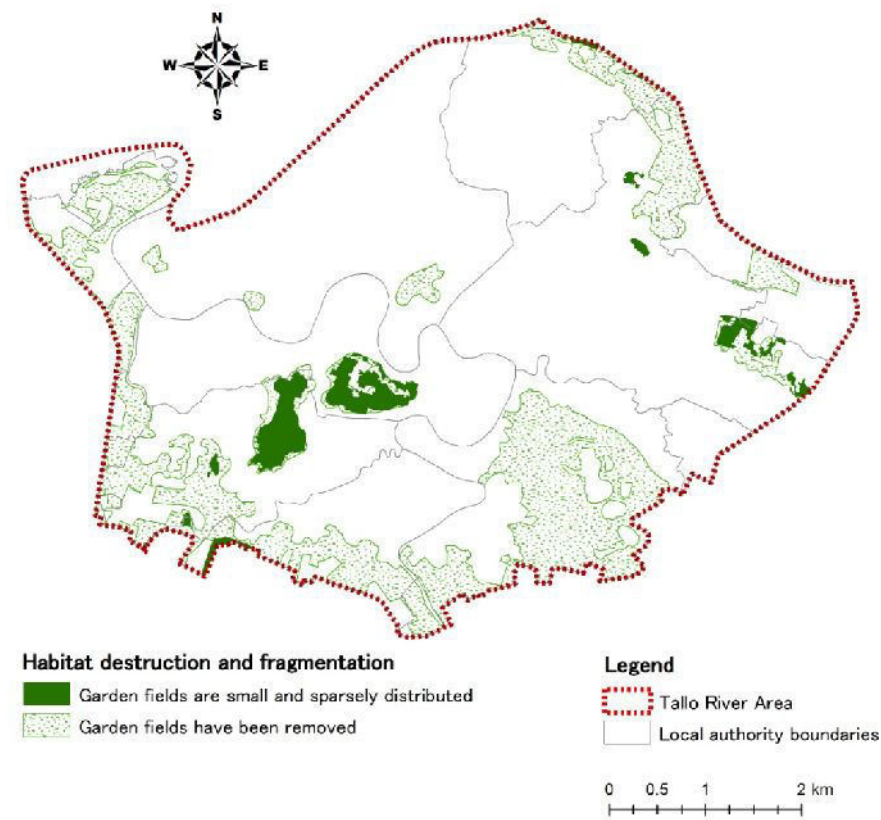


Fig. 5.5d Habitat destruction and fragmentation for garden fields

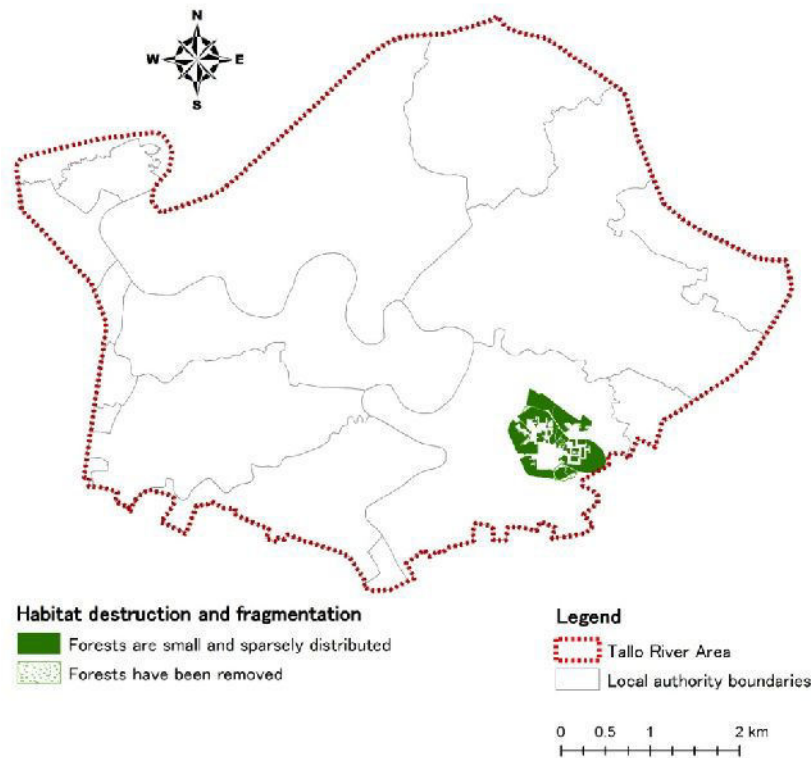


Fig. 5.5e Habitat destruction and fragmentation for forests

River and streams in the Tallo are frequently disconnected from their floodplains and/or canalized severely limiting the natural processes of flooding, erosion and sedimentation and associated wetland habitats. Cultivation frequently occurs up to the edge of many water courses in the Tallo, limiting the development of mangrove vegetation and wetlands. The biodiversity value may be affected in this way. Additionally, high fishing rates on fishpond by fisherman prohibits flowering of many shrubs herbs and prevents gardens from establishing a mature sward which is required by many invertebrates, birds, reptiles and small mammals for feeding, sheltering and nesting.

Therefore, important points to inform the Green Infrastructure plan are:

- Seek to maintain, enhance, restore or add to biodiversity and geological conservation interests;
- Place emphasis on habitats and species not subject to specific legal protection such as landscape features of importance for wildlife corridor or stepping stones for movement and local wildlife sites; and
- Promotes trees as one of the main tools in urban regeneration and greening programmes as well as using trees to provide ecosystem and other social services.

5.3.2 Water resources and flood risk

Tallo River is one of the rivers that flow in the vicinity of Makassar City. Due to the rapid growth of development, this river has been becoming inside of urban area. The near future it will be exactly at the middle of the city. Nowadays the Makassar water demand has been fulfilled by Lekopancing water supply system and Bili-Bili water supply system. However, in the near future the rapid population growth caused the more water supply system. Tallo River may be one of the water resources for developing a new water supply system. But unfortunately, Tallo River basin does not provide much space for reservoir sites, because most of the catchment area is lowland. The construction of dam will not be effective and efficient, both for providing raw water and flood control purpose.

The simulated flood risk zones and the principal water courses within the Tallo are shown in **Figure 5.6**. A flood risk zone denotes a low to high probability of a future flooding risk, whereby all development proposals should be accompanied by a flood risk assessment. Using flood risk modeling, it is identified significant risk area of sub-districts of the Tallo, primarily around South part of Tallo River Area, and associated tributary water courses as being in low to moderate flood risk areas (**Figure 5.7**). The water courses within the Tallo lie mainly on geology of sedimentation of alluvium, clay, mud, gravel, and limestone rock, which is moderate permeable.

Within the Flood Hazard Assessment (FHA) by the local government of Makassar and Regional Disaster Agency (BPBD) in 2013, it is provided flood hazard maps, and one of the recommendations for policy considerations is to enhance and restore the river corridor in Tallo River Area. This would include assessing the condition of existing components. Any restoration and/or renewal of the components should ensure that the design life is commensurate with the design life of the development. The FHA recommends that development contributions should be sought for this flood hazard mitigation. Those proposing development should seek opportunities to undertake river restoration. Another objective in the FHA includes protecting Greenfield functional flood plain from future development and reinstating areas of functional floodplain which have been developed. **Figure 5.8** shows the flood zones divided by the levels of ecological connectivity index which can be used as important zones for analyzing the Greenfield functional flood plain. In addition to the above measures and spatial analysis, consideration should be given to restoration of functional floodplain and creation of flood flow pathways, as well as identifying, allocating and safeguarding appropriate sites for flood storage.

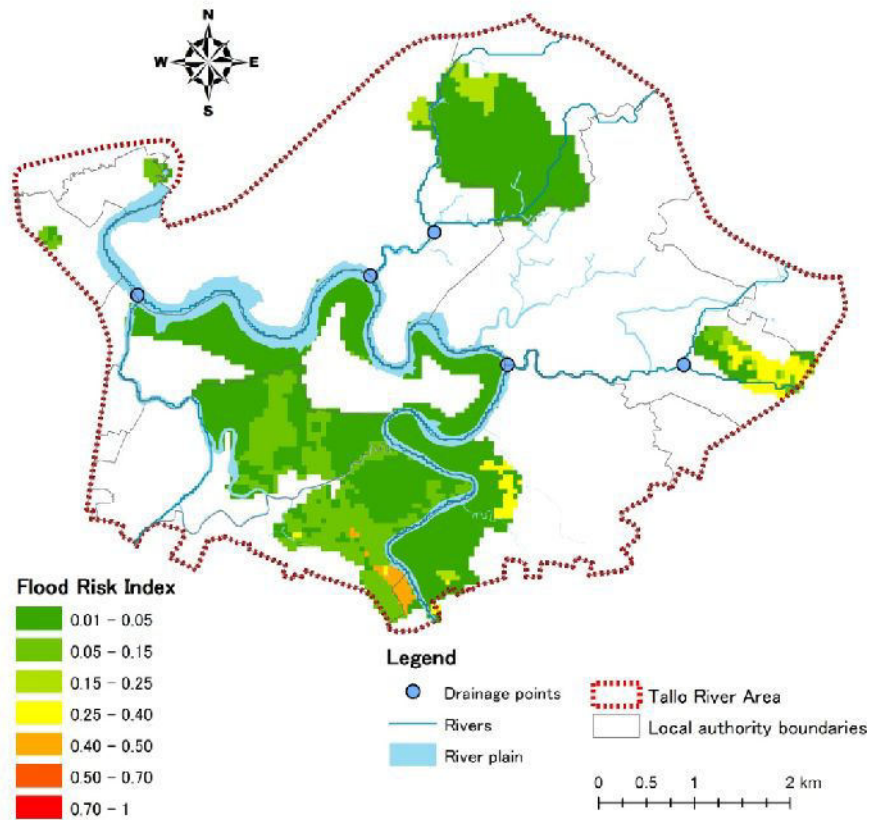


Fig. 5.6 Spatial modeling of flood risk index in Tallo River Area

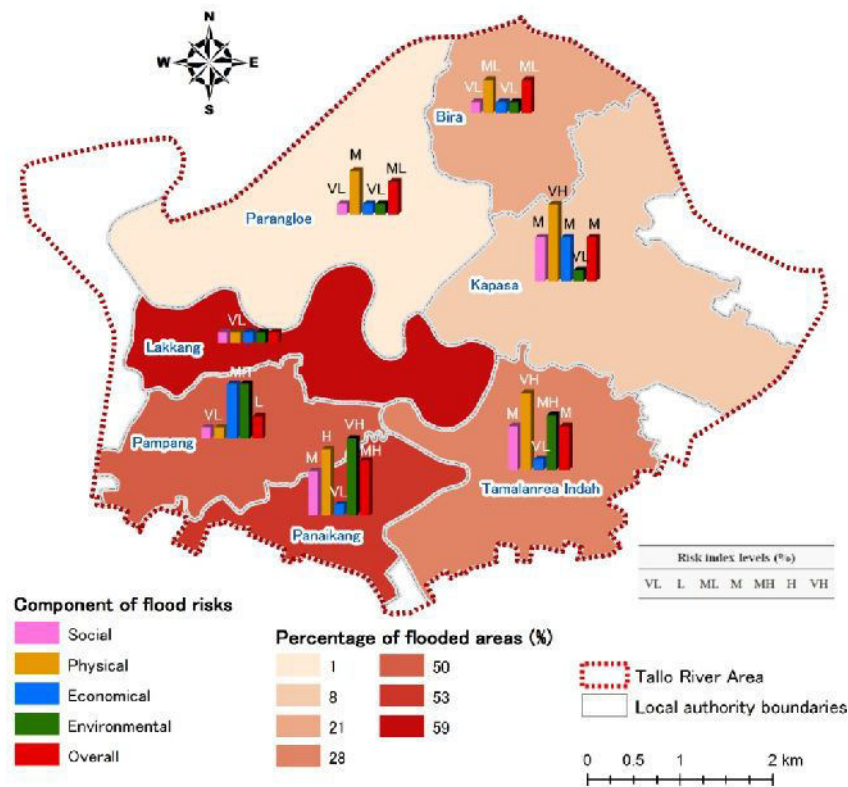


Fig. 5.7 Generalized flood risk levels for each sub-district in Tallo River Area

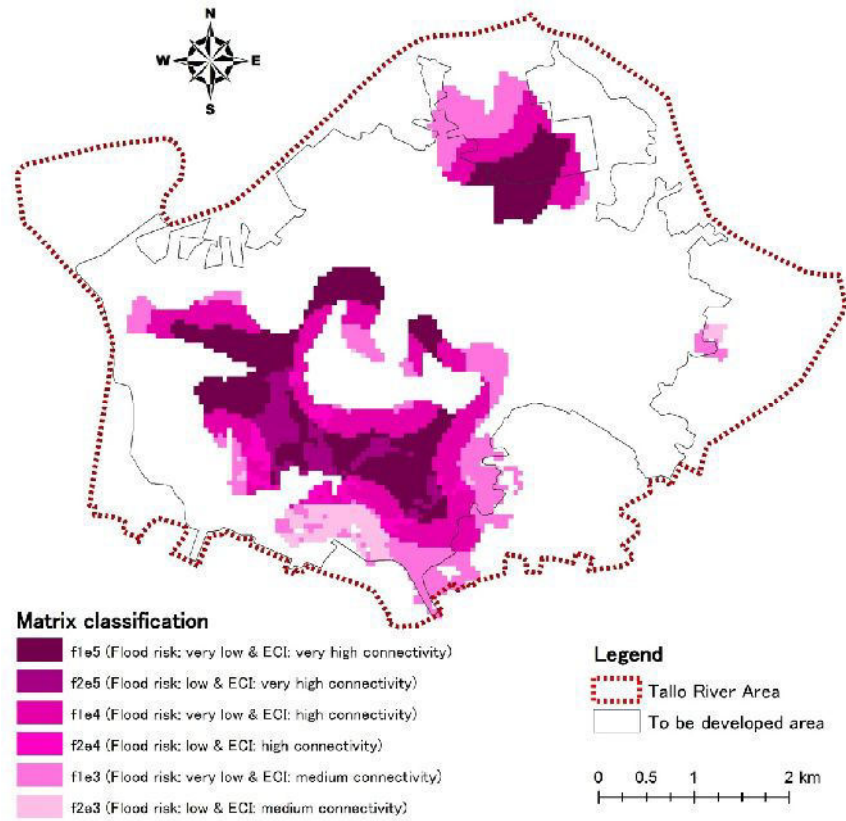


Fig. 5.8a Flood zone I (high ECI in low flood risk)

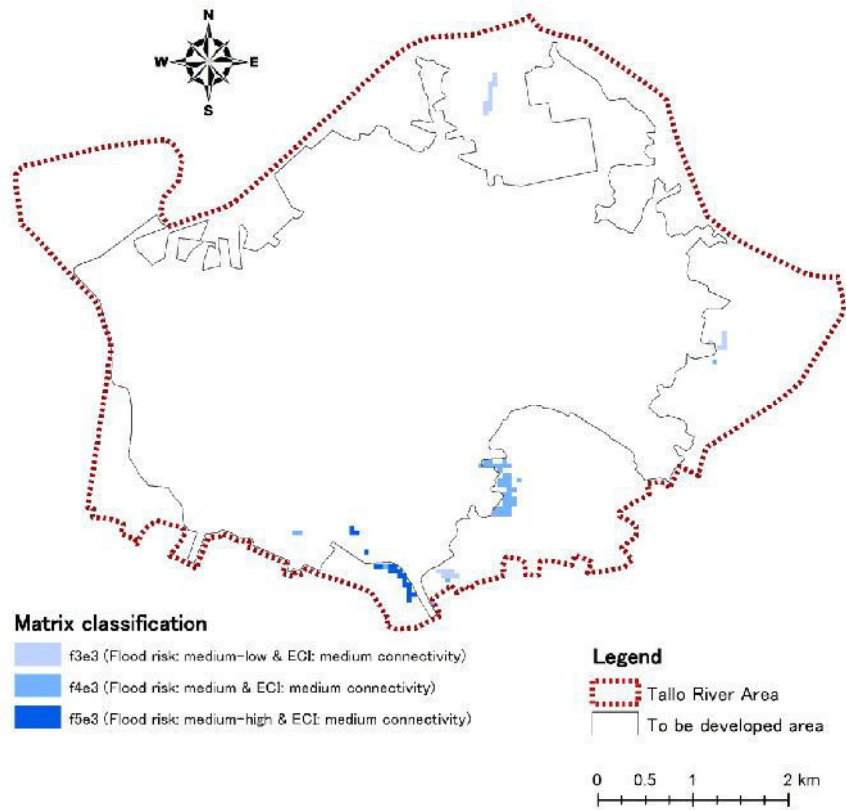


Fig. 5.8b Flood zone II (medium ECI in medium flood risk)

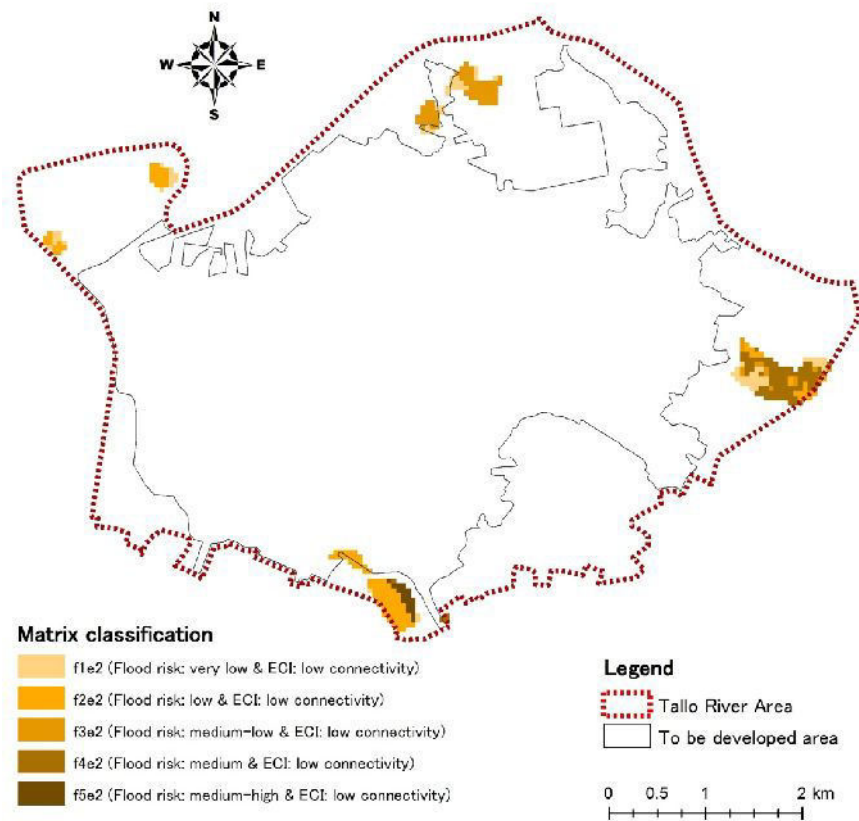


Fig. 5.8c Flood zone III (low ECI in high flood risk)

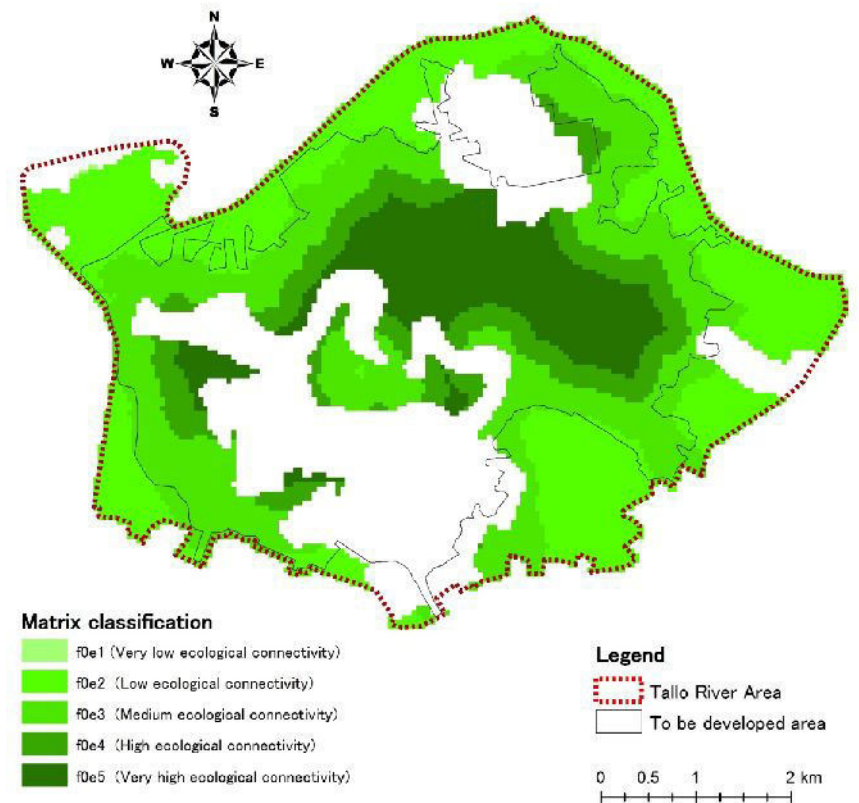


Fig. 5.8d Flood zone IV (ECI in outside flood zones)

Therefore, important points to inform the Green Infrastructure plan are:

- Makassar has history of regular flooding within the Tallo, most significantly in 2013. The FHA identifies several purpose built flood storage facilities within the Tallo. A key issue in relation to such facilities will be ongoing management to ensure efficient operation during a future flood event; and
- It is recommended that river corridors are enhanced and natural reservoir i.e. swamps are restored for flood risk management and ecological conservation benefits as referred to the flood zones analysis, and further culverting avoided.

5.3.3 Food production

The demand for allotments and community garden should be addressed and acted on appropriately, allocating areas for restoring and enhancing existing facilities to encourage food growing and promote related self-sufficiency. **Table 5.6** shows the authority boundaries with their allotments to encourage food growing which some of areas are currently no community gardens, farms or other food growing initiatives within the Tallo. Allotments and community gardens and paddy should also be incorporated as part of new developments of greenspaces such as Sub-district of Lakkang, Pampang, and Panaikang. Community greenspaces such as community farms and allotments act as points of interest along footpaths and cycle routes and can encourage people to engage more with their local environment. There is also the opportunity to form friends groups and volunteer projects for restoration and maintenance at community gardens and greenspaces. **Figure 5.9** shows the loss area of food production in the Tallo from 1997 to 2012. Steep declines in farming incomes and increased financial pressures have led many land owners to seek more profitable land uses. Diversification of sub-districts may provide opportunities for new Green Infrastructure and right of way agreement with land owners.

Table 5.6 Total area of allotments and food production area within Tallo

Authority Area			Paddy (ha)		Garden (ha)	
Name	Area (ha)	Allotments (ha)	1997	2012	1997	2012
Bira	300.01	53.71	196.62	117.44	31.55	1.68
Kapasa	632.21	46.02	169.44	92.17	73.46	17.19
Lakkang	341.92	2.05	0	0	36.14	29.1
Pampang	321.16	20.97	0	0	116.51	33.5
Parangloe	640.53	35.27	153.08	75.59	18.84	0
Tamalanrea Indah	449.57	41.25	10.6	3.53	236.87	0
Panaikang	227.06	16.57	0	0	67.28	5.27

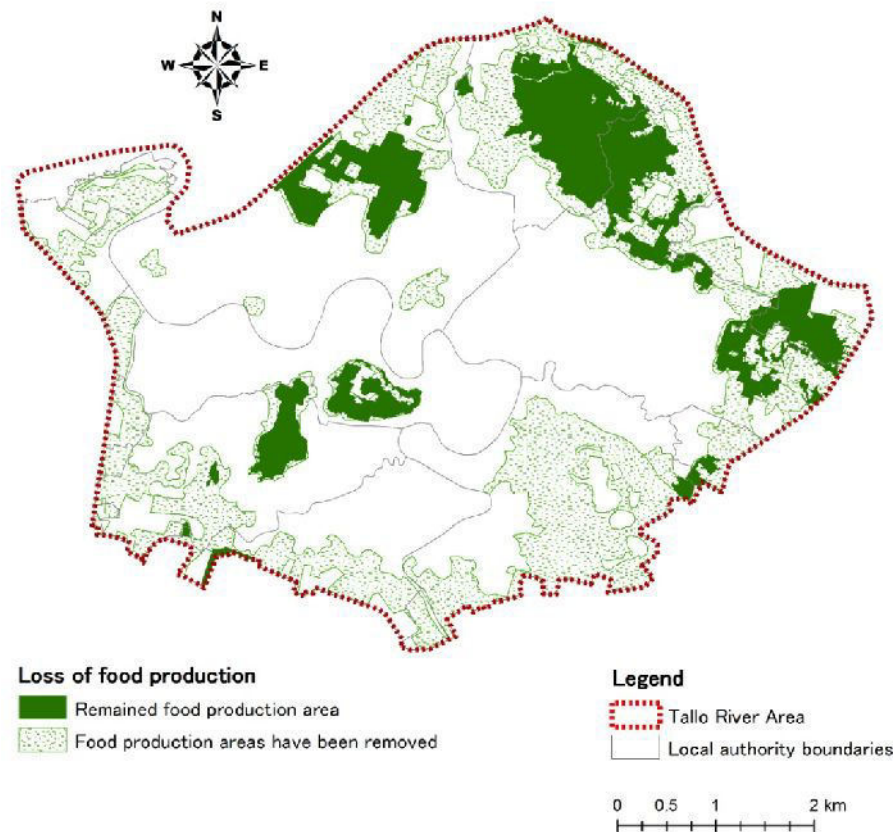


Fig. 5.9 Loss area of food production in Tallo River Area

5.3.4 Place and cultural heritage

This section summarizes the sense of place of the Lakkang Island in Tallo, with reference to landscape character and cultural heritage. Lakkang is a delta or many people call it an island that is located in the middle of Makassar, it is flanked by Tallo and Pampang River. Back in early 1943 when Indonesia was colonized by Japan, the Nippon soldiers were there for about seven months. At that time, Lakkang Island was chosen as a place to hide and keep their self from ground attack by Indonesian soldiers. Nippon built seven bunkers in Lakkang Island to save their logistics and as places to defend from the attack. After Hiroshima bombing, Nippon soldiers eventually left, and leaving that seven bunkers. Today, there are only three bunkers which still exist in Lakkang Island. The small roads, lush bamboo trees around, and ponds can be found in Lakkang Island. In this modern era, Lakkang still exist with their traditional lifestyle. When Makassar grow up day by day to become Metropolitan city as the biggest city in Eastern Indonesia, Lakkang Island stand still as a small island which harmonize the modernization with their traditional. Prohibition to develop a business among

local people is still retained. There's only an elementary school in this island, those kids who wants to continue their education to high school have to study in Makassar which means they have to across the river everyday to go to school. In 2006, Lakkang Island served as center of World Habitat Day with the theme "Cities Magnets of Hope" according to what local people's hope for harmonious life without urbanization and traditional atmosphere which is still defended, in accordance with their desire to live in peace and no longer separated from this lovely place.

Accessibility of the Tallo's landscape is also considered. A number of Green Infrastructure plan issues are also reflected in the local character areas identified within the Tallo, such as:

- Crossed by a network of footpaths and way marked routes within the Tallo;
- Some access to river although this is often intermittent;
- Restoration of mangroves, which does not always reflect underlying landscape character, though such restoration schemes are often of biodiversity and nature conservation interest;
- Little river access to Lakkang Island;
- Landscape quality objectives should be considered in the protection, management and planning of geographical areas; and
- Promote the link between Green Infrastructure and the ability of open greenspaces to protect important remains that occur within development sites.

5.3.5 Transport routes

The Tallo is crossed by a narrow network of paths and rights of way between west and east part (see in **Figure 5.10**), most densely concentrated within the west and east part. Footpaths are most distributed in the Tallo, where a larger scale and less intact landscape and field boundary pattern is evident. In addition to the network of paths and rights of way, there is an extensive river way network within Tallo.

At the local level, a number of shared use boat routes have been identified within Tallo. These include a route within the north part and along the south part. Two long distance walking routes cross the Tallo and link it to the Lakkang Island landscape to the east, and to the south. The local government identifies the following relevant issues:

- Lack of public transport links to the network inside Tallo areas;
- Need for additional safe accessible roads beyond the Lakkang sites; and
- Variable physical accessibility for the mobility impaired.

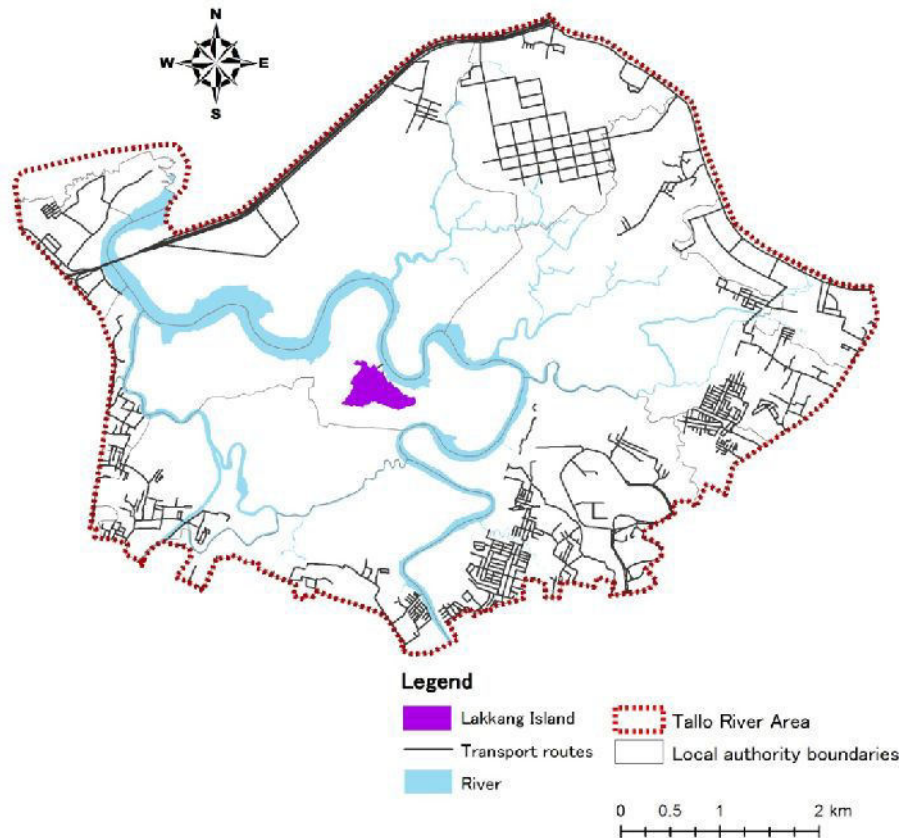


Fig. 5.10 Transport routes within Tallo

Therefore, important points of transport routes to inform the Green Infrastructure plan are:

- Promote walking and cycling by creating networks between amenities, residential and employment areas;
- Providing links between smaller settlements and centre and development of greenways and quiet roads;
- Making the most effective use of river paths; and
- Ensure that new developments and infrastructure proposals improve walking and cycling access.

5.3.6 Accessible greenspace

A number of larger greenspace within the Tallo have been accorded significant local importance. Some of these have notable cultural associations have been gifted to local communities such as Mangrove Park at the south part of Tallo. Accessibility was mapped by overlying the existing roads and greenspace area within the Tallo to the nearest distance travel to the open sites (**Figure 5.11**).

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Accessibility values were defined by the nearest distance from road as following **Table 5.7**. The nearest open space site is simulated, as a greenspace area of 50 to 100ha within 13.83m of the Tallo. This comprises some of 50 to 100 hectare of mangroves with wide views across the south part of the Tallo River.

Table 5.7 Greenspace and accessibility from the road

Greenspace		Accessibility (near distance from road, m)	
Area (ha)	Location	Mean	Max
0.1 to 1	Sparsely distributed in centre part of Tallo	299.46	1045.54
1 to 10	Sparsely distributed in west part of Tallo	189.96	666.14
10 to 50	Moderately distributed in west-south part of Tallo	50.89	130.45
50 to 100	Largely distributed in south-east part of Tallo	6.91	13.83

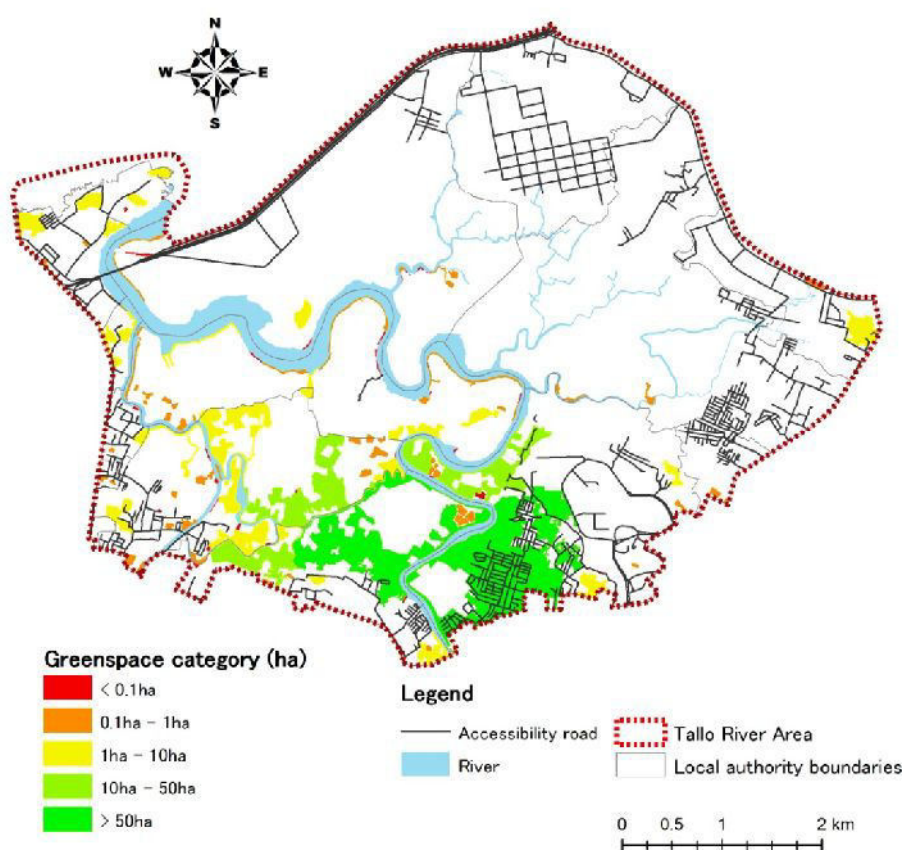


Fig. 5.11 Existing greenspace and accessibility from road lines

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Applying data of land use to the greenspace hierarchy suggest that there is deficiency in this scale of green space provision to the northern and eastern parts of the Tallo. There may be the need to create new strategic greenspace to meet some of the recreational deficiency at northern side of Tallo River or to provide a strategic site which is more accessible. Value of open space was considered separately, based on the following:

- Context - accessibility and proximity to other existing open space provision, as this may affect value;
- Level and type of use; and
- Wider benefits offered e.g. social/community and wider environmental benefit in terms of landscape and biodiversity.

Therefore, important points to inform the Green Infrastructure plan are:

- Promote the multifunctional nature of urban greenspace as an important environmental as well as social resource;
- Recognition of the importance of sport, both in its own right and as a tool to achieve core public goals; and
- Promote active recreation using the natural resource in the Tallo.

5.3.7 Green Infrastructure opportunity assessment

Using the information gathered above currently, capturing the environmental and socioeconomic characteristics of the Tallo, and with reference to Green Infrastructure framework a set of five functions have been identified for Green Infrastructure in the Tallo. These potential functions are set out in **Table 5.8**, which also states their relationship to the environmental and social themes described above. The assessment of opportunities in relation to functions is split into two parts under each function: i) high level opportunities, where relevant, in relation the functions below, supported by ii) more detailed opportunity analysis in relation to specific locality areas. There are no clear standards in terms of provision of Green Infrastructure to perform various functions, such as alleviating flood risk and mitigating climate change. We have therefore undertaken a high level assessment of current functional deficits and potential future functional needs in the Tallo. We have taken into account both accessible and non-accessible land. To enable us to more effectively highlight where potential future functional needs might arise we have looked at the impact on each of the functions if development were to take place defined by the government of Makassar City.

Table 5.8 Potential Green Infrastructure functions in Tallo

	Function	Environmental and Socio-economic themes
Habitat provision and access to nature	to provide wildlife habitats	Biodiversity
	to provide opportunities to access nature	
Resource management and climate change adaptation	to provide sustainable water resource management	Water resources
	to alleviate flood risk	Flooding
	to allow adaptation to climate change	Climate change
Productive landscapes	to provide food	Food
Landscape setting and context	to provide landscape setting and to conserve and enhance landscape and cultural heritage	Landscape
		Cultural Heritage
	to provide a high quality environmental in which live and work	Standard of living
Access, recreation and movement	to provide sustainable transport/access routes	Sustainable transport routes
	to provide recreational opportunities	Accessible greenspace

5.3.7.1 *Habitat provision and access to nature*

High level opportunities for habitat provision and access to nature can be described as follow.

- Large nature conservation sites provide opportunities for recreation and access to nature including natural play. For example, opportunities may exist around the Tallo River corridor which sits at a strategic Mangrove forest between the river and the south part of urban to alleviate flood risk;
- Canal and river corridors provide opportunities for habitat creation/restoration, promote species movement and act as transport and recreation corridors;
- Restoration and regeneration of new mangrove habitat promotes adaptation to climate change;
- Wildlife rich landscapes strengthen sense of place and complement heritage conservation; and

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- An overarching GI opportunity should be to develop an ecological network for northern part and southern part of Tallo. This should identify the following:
 - a) Core areas: the most important habitats containing populations of the rarest or most vulnerable species for example, mangroves, shrubs, and swamps. These areas should be strictly protected by legal and policy mechanisms and surrounded (where possible) by non-damaging land uses (buffering). New large wildlife sites (core areas) could also be created, providing alternative recreational spaces, reducing visitor pressure issues with existing sites.
 - b) Enhancement areas: land which is of moderate or low ecological value but which could benefit from enhancement measures. Examples include restoration of defunct shrubs, reinstatement of pollarding in mangrove of cultivation up to the edges of water courses to allow nipah palm vegetation and wetlands to establish;
 - c) Areas for restoration: areas of land which are of currently low ecological value but hold potential for habitat creation. Examples in the Tallo include former paddy, areas of improved wetland and canalized rivers and streams;
 - d) Wildlife corridors: linear habitats which promote species dispersal. In the Tallo there are numerous streams, road, and river corridors which could be managed as linear woodlands to support species dispersal.

Therefore, opportunities by locality area can be described as follow.

1. Sub-district of Panaikang

Panaikang has a number of Sites of Nature Conservation with large area of mangrove plantation at riverside. If future housing development was located in this area it has the potential to put additional pressure on these conservation areas, and increase fragmentation and reduce connectivity between the mangrove sites. Therefore, any new development in the area should incorporate features such as wildlife corridors between these sites and other measures that actively allow the movement of wildlife and replace lost habitat such as the planting of native mangrove tree species alongside roads and the encouragement of wildlife friendly wetlands. Changes to management of existing sites should be considered to provide an enhanced and extended range of habitats to expand the range of wetland habitats.

2. Sub-district of Tamalanrea Indah

Tamalanrea Indah has some of the best habitat provision in the neighborhood with single sites that cover significant areas such as the substantial cluster of mangroves that provide excellent wildlife corridors and opportunities to

improve linkage of sites. However little of the habitat within this locality area is accessible, and there may be a need for new accessible habitat creation. Any new development in the Tamalanrea Indah could potentially have a significant adverse effect on mangroves in particular but also threaten the other habitat provision in the locality area and increase fragmentation of sites.

3. Sub-district of Parangloe

The northern part of the Tallo, Parangloe locality area is well served by habitat sites, although only a few of mangroves, paddy fields are accessible by the public. The central and southern areas of the locality area have particularly poor habitat provision. There is significant potential for locating new development of industrial in this locality area, so it would need to be accompanied by new sites for habitat provision such green park, and that were accessible to the public in the central and southern part of the locality area, to ensure that this function does not experience an increased deficit. If mangrove restoration along the coastal sea in this locality area, mangrove habitat provision would benefit from the creation of wildlife corridors which would help reduce the isolation of these existing industrial sites and benefit climate change adaptation.

4. Sub-district of Bira

Bira has fairly good coverage of accessible habitat provision, with large paddy field exist. There are some significant sites of industrial to the north and south of the existing development. These sites may well also be put under pressure if any new development is allowed in the locality area. Given the constrained town centre nature of the locality area, efforts should be made to increase habitat provision and access to nature through small scale sites and linear corridors through the centre of Tallo and innovative measures such as ensuring that centre green parks are wildlife friendly. This could be realized through reduced intensity of landscape management regimes and urban greening proposals.

5. Sub-district of Kapasa

The locality area of Kapasa has a couple of small biodiversity sites. However, the River stream provides important wildlife corridors. The locality area has the poorest biodiversity function in terms of Green Infrastructure in the Tallo. Any future development in this locality area should seek to enhance biodiversity and the current wildlife corridors in the locality area improving connectivity to other sites in neighboring areas.

6. Sub-district of Pampang

This locality area on the west side of the Tallo similarly has poor biodiversity functionality. Government would provide a significant area for biodiversity and

drainage water treatment area. The importance of this wildlife corridor may increase in importance if new development is located in the locality area, especially as there is a large amount of drainage wastewater in the locality area. Any new development should seek to create new wildlife habitats such as shrubs and swamps and increase the biodiversity function and water resource management of this locality area.

7. Sub-district of Lakkang

The locality area of Lakkang only has a couple of large biodiversity sites. However, the River lines provide important wildlife corridors. The locality area has the biodiversity and culture heritage function in terms of Green Infrastructure in the Tallo. Any future development in this locality area should seek to enhance biodiversity and the current wildlife corridors in the locality area improving connectivity to other sites in neighboring areas.

Moreover, key Green Infrastructure messages are pointed as follow.

- Effort needs to be made on the west and east part of the Tallo to improve habitat provision and access to it. This will especially be the case if new development is located in these locality areas otherwise significant deficiencies may occur;
- If new development is located in west and east part of the Tallo, significant accessible habitat provision or enhanced links between existing sites will be needed to avoid a deficiency in this function;
- Although Tallo has good provision, little of it is accessible, therefore limiting opportunities to access nature in the Lakkang; and
- The more constrained locality areas like Parangloe and Tamalanrea Indah and Lakkang and Pampang could benefit from increased wildlife corridors and a change in the management of open spaces that currently have degraded biodiversity function in order to increase provision in these locality areas.

5.3.7.2 *Resource management and climate change adaptation*

High level opportunities for water resources management and climate change adaptation can be described as follow.

- Protection of green field functional flood plain (e.g. in the mangroves, and in floodplain areas to the west-south part of Tallo) as part of the semi or natural greenspace network, seeking opportunities for associated wetland biodiversity enhancement;
- This should extend to creating new and expanded areas of linked water/wetlands (permanently and seasonally wet) to provide areas of flood

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storage in light of climate change, supported by appropriate management plans which balance biodiversity and operational objectives;

- Reinstatement of areas of functional floodplain which have been/are being developed. Development proposals through which these are delivered should seek to include breaking out rivers in culverts and restoration of more naturalistic edge profiles;
- Opportunities should also be sought to make space for water and flood storage, and to accommodate climate change adaptation and used to inform the overall site layout, in new developments, or retrofitted as part of watercourse enhancements within the urban area;
- Expansion and upgrading of existing flood storage facilities in light of future growth, with creation of new flood storage facilities in step with phasing of future developments (capacity determined through detailed modeling and site investigation for specific developments);
- Subject to more detailed Flood Risk Assessment, the canal network inside Tallo may provide a valuable temporary flood storage and transfer function; and
- Within the wider landscape, an opportunity may be provided to control surface water runoff e.g. ditched field boundaries, swamps, shrubs and vegetated mangrove margins to field boundaries.

Furthermore, opportunities by locality area can be described as follow.

1. Sub-district of Panaikang

There are significant corridors of land in Panaikang that are classified as being in flood risk zone. Whilst much of the flood zone is over open space, there is a section through Pampang which affects current development. Therefore this deficiency at Panaikang needs to be addressed. Open space which overlaps the flood risk zone needs to be protected from any future development and managed in a way that increases the benefit of its water management function (such as implementation of wetland scrapes and changes of management wetland etc, to allow greater flexibility/adaptability in times of flood). Any new development in this locality area (especially that which is close to the flood risk zones) should seek to not exacerbate the flood risk.

2. Sub-district of Tamalanrea Indah

Tamalanrea Indah currently has little function in terms of flood risk management. This area is largely built up; therefore opportunities to improve the flood storage capacity around this current development should be sought. The biggest opportunity may lie between the units on the mangroves as a large

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area of this is likely to be covered with impermeable surfaces presently.

3. Sub-district of Parangloe

There is a small amount of land in the locality area that counts as flood risk zone, but this does not currently intersect with any other development or greenspace. Any future development would have to ensure that it avoided these areas and provided open space such as Green Park to help provide flood attenuation.

4. Sub-district of Bira

Bira has significant areas that are covered by flood risk zone in the south east of the locality area covering Industrial sites, in the south east of the locality area. These sites should be managed to enhance their water management functions (such as reducing impermeable surfaces) and if new development is located in the locality area new open spaces should be created to protect these flood risk areas and enhance their water management function.

5. Sub-district of Kapasa

Kapasa has the moderately concentration of area that is covered by flood risk zone. Many parts of this flood risk area are covered by existing open space. However there is a need for greater functional flood sites and this need will be increased if development occurs in this locality area. This could be partly realized through more flexible approaches to landscape management to urban stretches of the Tallo River.

6. Sub-district of Pampang

There is a significant amount of the locality area especially in the east which is covered by flood risk zone which cover garden field. These sites need to be protected from any development and more of this functional flood risk land protected to ensure that it can carry out its function to the full (as part of an expanded wetland greenspace network).

7. Sub-district of Lakkang

There are lower areas of flood risk zone around the edges of the locality area including an area to the west and east which partially covers the garden field. There is a deficit of open space that performs this flood risk management function and this should be taken into account when identifying new open spaces especially in light of new development (potential forest, agricultural field, which could also contribute to an enhanced landscape setting).

Moreover, key Green Infrastructure messages are pointed as follow.

- Pampang and Panaikang have significant areas within the flood risk zone and would benefit from open space being designated around these flood risk zones

to help protect and appropriately manage them for this function; and

- Lakkang and Tamalanrea Indah would benefit from the implementation of conservation management techniques and more flexible management in relation to soft landscape i.e. agricultural field, forest, mangrove forest in the linear areas through existing development that are covered by the flood risk zones and also to ensure any future development in these locality areas does not exacerbate any problems.

5.3.7.3 *Landscape setting and context*

High level opportunities for landscape setting and context can be described as follow.

- Bringing mangrove forest, shrubs, and swamps back into management to promote biodiversity and ground flora, and also to sustain nipah palm tree cover the river corridor in the longer term;
- Creation of coastal flood risk reduction based mangrove forests to link and create new habitat corridors, to restore aspects of landscape character and to provide resilience to climate change;
- Restoration of agriculture to field margins and roadsides to link/create corridors and make reference to former landscape character, and also to former agriculture fields to relate greenways/corridors to their wider landscape;
- A key opportunity is to enhance existing river/wetland corridors, through managed realignment and restoration of wetland landscape features/associated habitats, and to provide climate change adapted landscapes;
- Conservation and enhancement of the landscape setting of Lakkang Island such as Heritage place, with use made of associated opportunities of interpretation to make reference to site history and landscape context, and to form destination points;
- Use opportunities to create softer, more transitional settlement edges, with use of native woodland for screening and to integrate settlement edges, as well as to link existing habitats;
- Wetlands and floodplains form a key component of this landscape. There is the opportunity to link and expand this network to deliver a more resilient, climate change adapted landscape (e.g. around the south part of Tallo River Area) and to reflect historic landscape character, as part of new strategic greenspaces, or as the landscape setting for development; and
- River valleys and wetland corridors should also link to the established greenway network and opportunities for enhanced access to these floodplain corridors should be required.

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Furthermore, opportunities by locality area can be described as follow.

1. Sub-district of Panaikang

Panaikang has no designated sites of cultural heritage interest, but has one site of mangrove land. Efforts should be made to protect and enhance the landscape setting in the locality area especially if new development is proposed.

2. Sub-district of Tamalanrea Indah

Tamalanrea Indah locality area has no designated cultural heritage features. Efforts should be made to enhance and restore the landscape and landscape structure and also as a basis for movement and wildlife corridors in the locality area, especially if new development is proposed here, in order to ensure a high quality environment that will attract people to live and work in the locality area.

3. Sub-district of Parangloe

The majority of the locality area like the rest of the north-east part of the Tallo is covered by the agricultural area, which is an attractive and gently rolling, well farmland landscape of historic character. New development in this locality area may threaten this landscape and therefore any new development needs to be sensitive to its landscape in both setting and design.

4. Sub-district of Bira

Bira contains a number of listed Industrial buildings. It is uncertain what impact any future development may have. If infill and development intensification were to occur the settings of these sites should be conserved.

5. Sub-district of Kapasa

Kapasa is largely urban in character. New development is unlikely to have a significant impact on landscape in this locality area.

6. Sub-district of Pampang

Pampang have little cultural heritage and landscape interest. Effort should be made to enhance the landscape in the locality area especially if new development is proposed here in order to ensure a high quality environment that will attract people to live and work in the locality area.

7. Sub-district of Lakkang

Lakkang has the most significant provision of Cultural Heritage and Landscape designations in the Tallo. The most significant site is Lakkang Island and Garden Park. However, the majority of these sites are not accessible to the public. New development in this locality area could have an adverse impact on these sites and the landscape setting of the locality area and any new development should be sensitive in its design to this landscape setting, and where possible seek to increase public access to these sites.

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Moreover, key Green Infrastructure messages are pointed as follow.

- The west side of the Tallo (Parangloe, Pampang and Panaikang) have the least interest in terms of cultural heritage and landscape and therefore efforts need to be made to enhance, restore and manage the landscape in this locality area, as part of the GI proposals; and
- Lakkang has a high quality landscape and cultural interest however much of it is not accessible to the public. A key opportunity may be to enhance access, to bring the landscape in.

5.3.7.4 *Access, recreation and movement*

High level opportunities for access, recreation and movement can be described as follow.

- Enhanced and safe green transport links (for a variety of users - pedestrians, cyclists, and boats) between attractively designed and well managed greenspace sites, to provide an incentive for their use and to assist in easing deprivation;
- Creation of a route hierarchy to link new urban greenways clearly to longer distance routes to facilitate access to the wider landscape (e.g. the north-east landscape and the river valley network) - a potential walk to health initiative;
- Creation of new radial routes from riverside road, to connect to the longer distance network. This could take the form of a new urban, shared use greenway/radial route, linked to Lakkang village centre by the river corridors which converge on the centre; This could link to creation of a hierarchy of variable distance radial health routes, designed with equal access considerations and shared use in mind;
- Ensure that provision is made for the widest possible variety of social and cultural groups and their needs within the Green Infrastructure network - natural play (Green Infrastructure as outdoor classroom, and to facilitate opportunities for healthy living/access to nature), and dedicated recreational facilities;
- Investigate enhancement of links and accessibility/legibility in urban areas where in close proximity to valued open spaces, such as Green Park;
- Consider new allotment and community garden provision as an integral part of new community greenspace associated with future urban extensions; and
- Make greater use of river corridors such as disused road lines, to create additional green corridors/green tracks (shared use) and enhanced network connections;

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Furthermore, opportunities by locality area can be described as follow.

1. Sub-district of Panaikang

Panaikang has good accessibility to open space and a high density of footpaths, cycleways and greenways. Improvements could be made to the accessibility of these routes to Lakkang centre and this should be considered if new development is located in the locality area.

2. Sub-district of Parangloe

Parangloe has some of the best provision of recreational facilities in the Tallo, and facilities are well distributed throughout the locality area. Although the locality area contains long distance footpaths, the provision of footpaths and cycleways is one of the poorest in the Tallo as a whole. Efforts should be made to increase provision especially to south part of Parangloe.

3. Sub-district of Tamalanrea Indah

The urban parts in the north of the locality area have good recreation provision. Although there is some provision of footpaths, cycleways and greenways in places they are disjointed and do not create easy links to the centre of Lakkang and the southern part of the locality area also has poor provision. The locality area (and Tallo) would benefit from improved accessibility and connectivity and any new development that is proposed for the area should try to increase walking and cycling routes that link in to the Lakkang centres and also increase accessible recreational opportunities around new developments.

4. Sub-district of Bira

The northern, more densely populated part of the locality area has good provision of recreation sites and footpaths and cycleways. Any new development in the south of the locality area would need to ensure that it was linked into the centre by a network of walking and cycling routes to ensure a deficiency in provision does not occur.

5. Sub-district of Kapasa

The built up parts of the locality area have good provision of accessible recreational facilities and footpaths. There is a deficiency of cycleways in the locality area. This is something that should be taken in to consideration if new development is located in the locality area. Improved cycleways and footpaths that link into Lakkang centre and other local amenity centre should also be required as part of any new development.

6. Sub-district of Pampang

Pampang provides a significant percentage of the recreational provision in the locality area although it is less accessible to the public. There is good provision of footpaths radiating out from Pampang in the south of the locality area but

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provision is less good around Lakkang and there is a deficiency in cycleways and greenways. There would need to be an increase in accessible recreational space and walking and cycling routes if any new development occurred in this locality area. The creation of new strategic greenspace on environmentally constrained (floodplain) land to the east of Pampang may be able to assist in this respect - a positive gateway to the east of the Pampang, which could also deliver landscape and biodiversity enhancements.

7. Sub-district of Lakkang

Lakkang currently has adequate provision of recreational facilities and has a good coverage of outdoor recreation facilities. There is also good coverage of walking and cycling paths that radiate inwards towards Lakkang centre. If new development was proposed in the locality area access routes would need to be extended to both Pampang and also radiating outwards to nearby urban such as Panaikang and Tamalanrea Indah.

Moreover, key Green Infrastructure messages are pointed as follow.

- Parangloe and Kapasa currently have deficiencies in cycleways and if new development were to occur in these locality areas accessible recreational provision and sustainable travel routes will need to be increased; and
- If new development is proposed in Parangloe and Kapasa and Lakkang significant new recreational provision will be needed along with new walking and cycling routes linking into both west and east part.

5.4 Proposed Green Infrastructure Network

This section sets out the development of the proposed Green Infrastructure network for Tallo River Area, and describes the Green Infrastructure zones and component strategic Green Infrastructure plans or spatial interventions.

5.4.1 Developing the component network

Three spatial themes were explored for planning Green Infrastructure in the Tallo. These focused respectively on i) landscape and biodiversity, ii) flood risk and climate change adaptation, and iii) community and access to greenspace. Below are shown the three spatial themes for Green Infrastructure within the Tallo, which responded to the opportunities identified in previous sections. The three themes were brought together to develop an integrated network to address these

Green Infrastructure themes and functions. The respective components of the proposed Green Infrastructure Network (access links, sites and zones) according the Tallo development plan are described in the following section.

5.4.1.1 Landscape and biodiversity

This was proposed through creation of a series of landscape enhancement, conservation and restoration zones (**Figure 5.12**). These were notably in relation to the Mangrove of Tallo (sustaining and securing the long term future of this diverse landscape), agriculture landscapes (opportunities to interpret, understand and enjoy these safely as part of new accessible natural greenspaces), and the distinctive network of rivers and tributary watercourses which cross landscape and townscape of Lakkang Island (landscape restoration and enhancement, providing for habitats, access to nature and recreation).

5.4.1.2 Flood risk and climate change adaptation

This was proposed through consideration of a wider range of functions that could be offered by land within the Tallo ((**Figure 5.13**)). For example restored wetlands in the flood plain zone, which have the potential to provide new, linked habitats as well as flood storage and water resource management. Moreover, wetlands and forests regulate water availability and serve as natural water purification systems and can be applied across a range of urban settings, helping to reduce urban temperatures and carbon emissions. Within Tallo, woodland restoration (forest, mangrove forest, shrubs) can increase the resilience and climate change adaptation potential of the landscape. Mangroves coastal ecosystems offer significant opportunities for climate change adaptation and mitigation, including livelihood support, food security and storm/flood protection. In addition, Green Park can and will make a valuable contribution to helping both to reduce concentrations of greenhouse gases in the atmosphere (the cause of climate change), and to help adapt effectively to the impacts of change (building resilience to a changing climate).

5.4.1.3 Community and access to greenspace

This was proposed through the potential for a series of different activity zones, community parkland as common ground, to address issues of lack of greenspace, and to increase links/permeability in neighborhoods where this is an issue, also consideration of the common ground in its wider sense, opportunities for local food production ((**Figure 5.14**)). A series of shared use radial and linked routes which link key tourist and recreation, provide opportunities for accessibility.

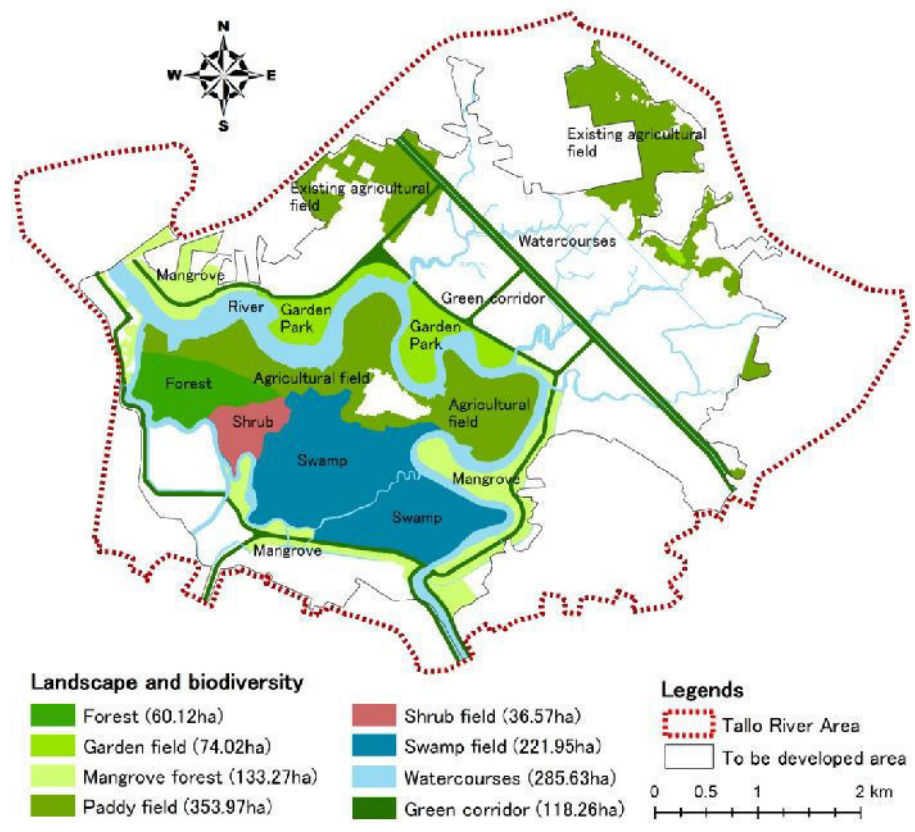


Fig. 5.12 Component of the proposed GI network (landscape and biodiversity)

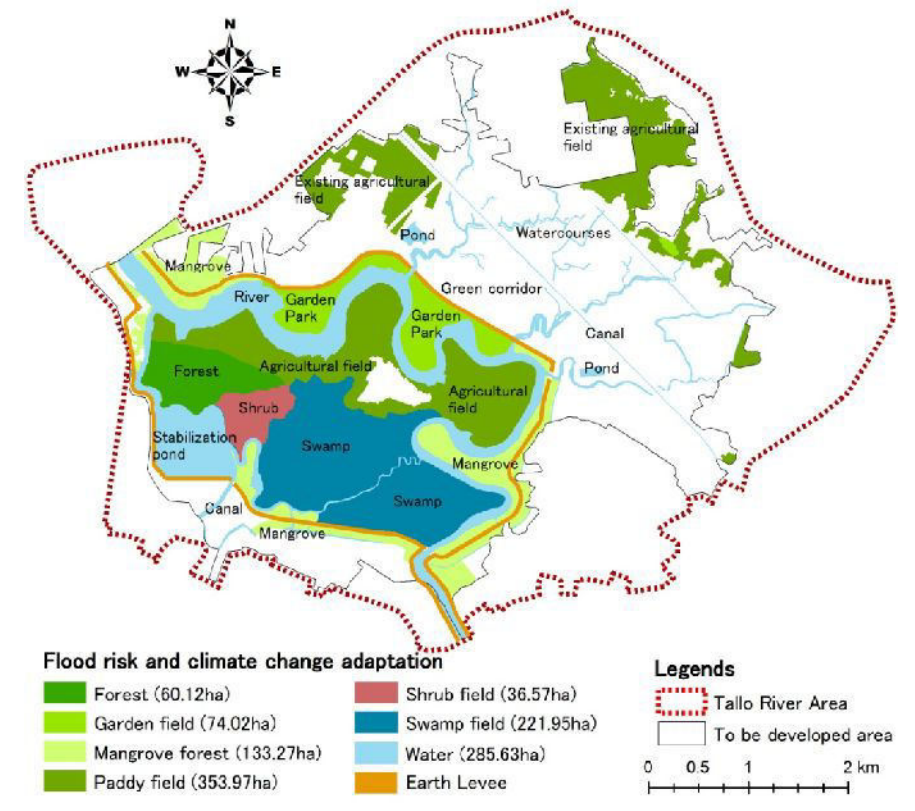


Fig. 5.13 Component of the proposed GI network (flood risk and climate change adaptation)

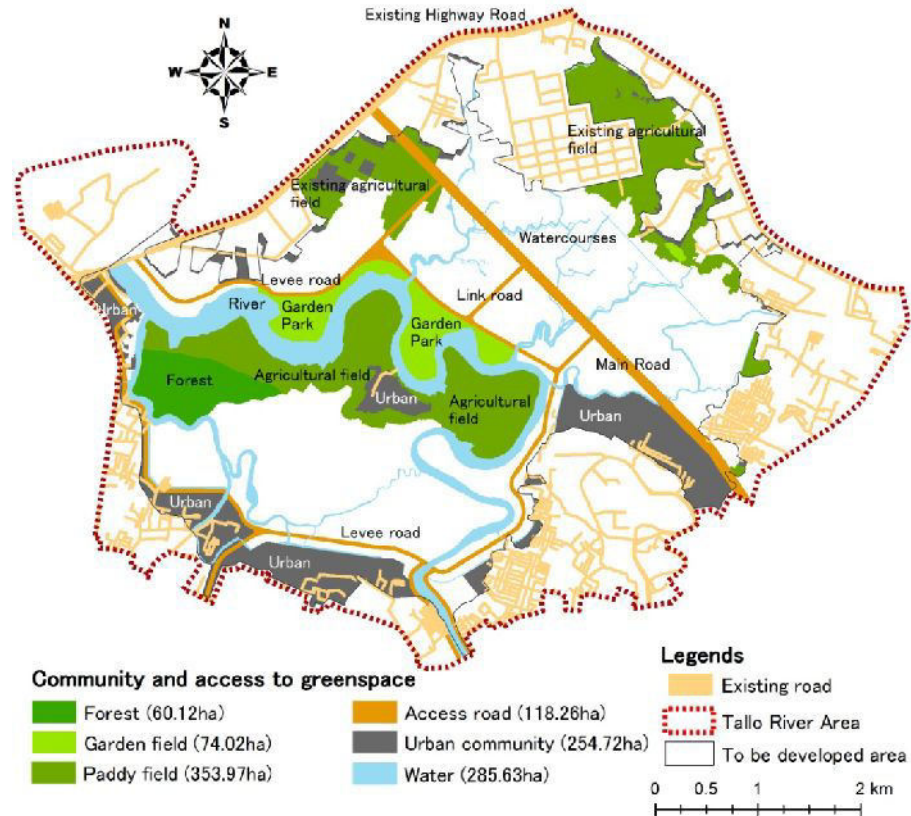


Fig. 5.14 Component of the proposed GI network (community and access to greenspace)

5.4.2 Analyzing of the connected landscape network

There are many network based metrics that can be used to assess both local whole-network characteristics as well as the importance of individual patches. In this study, we used the Matrix Green tool in GIS to compare the connectivity of the landscape network analysis between the land-use existing, proposed plan by government and a proposal of Green Infrastructure network of this study. Matrix Green supports two kinds of analyses. The first is focused on the whole landscape/network level (component based analysis and patch distance analysis), and the second is focused on individual patches contributions to landscape connectivity (betweenness centrality).

A component is a set of patches that are connected for a certain dispersal distance. Any patch within a component can be reached from any other patch within component but not from patches outside the component. Hence, a component can be seen as an isolated segment of the landscape in terms of connectivity. The size of the component is the total size of all the patches that are connected. The smaller the total area of the component, the less likely it will be

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able to support a viable population. Component analysis is therefore particularly useful when assessing the level of large scale connectivity, i.e. the connectivity from a landscape perspective.

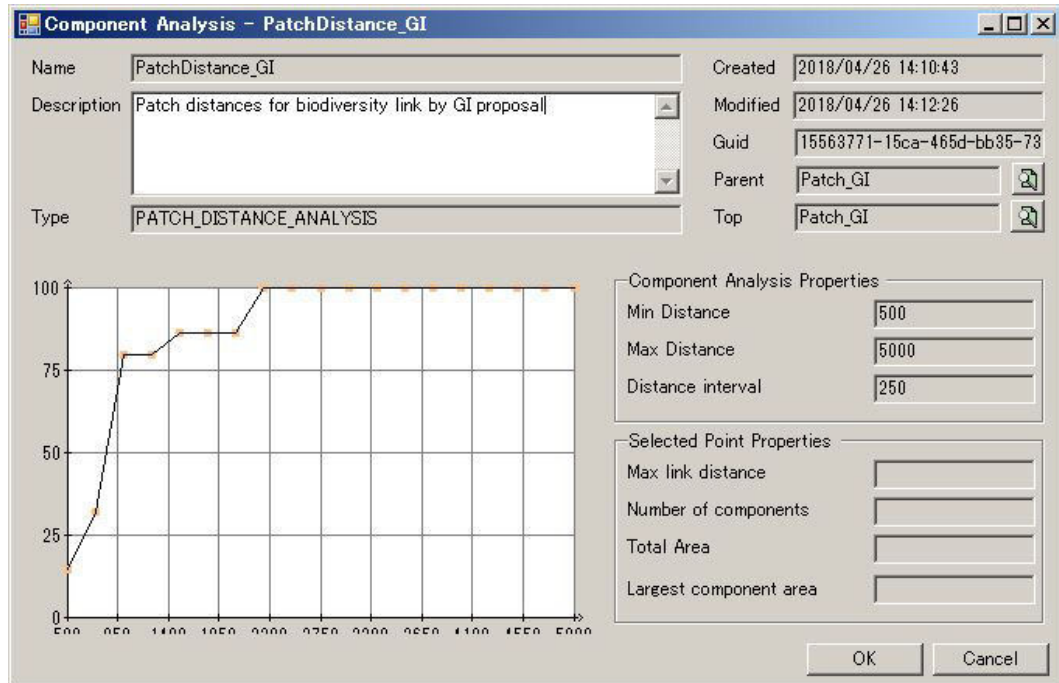


Fig. 5.15 Diagram from a patch range analysis (the GI network proposal)

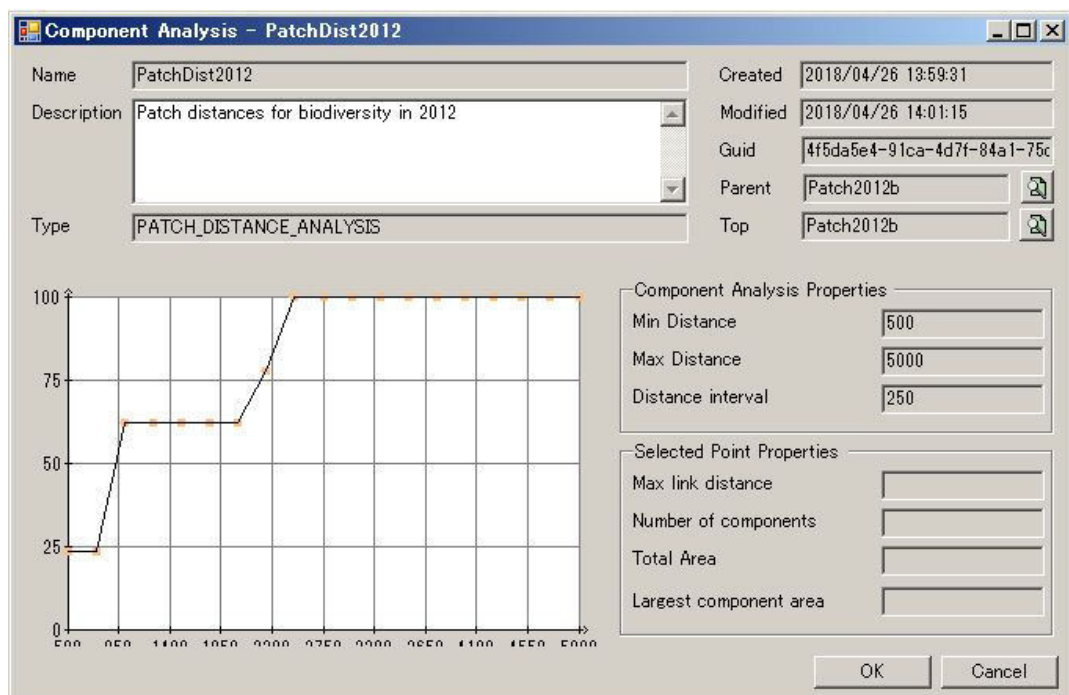


Fig. 5.16 Diagram from a patch range analysis (the existing landscape)

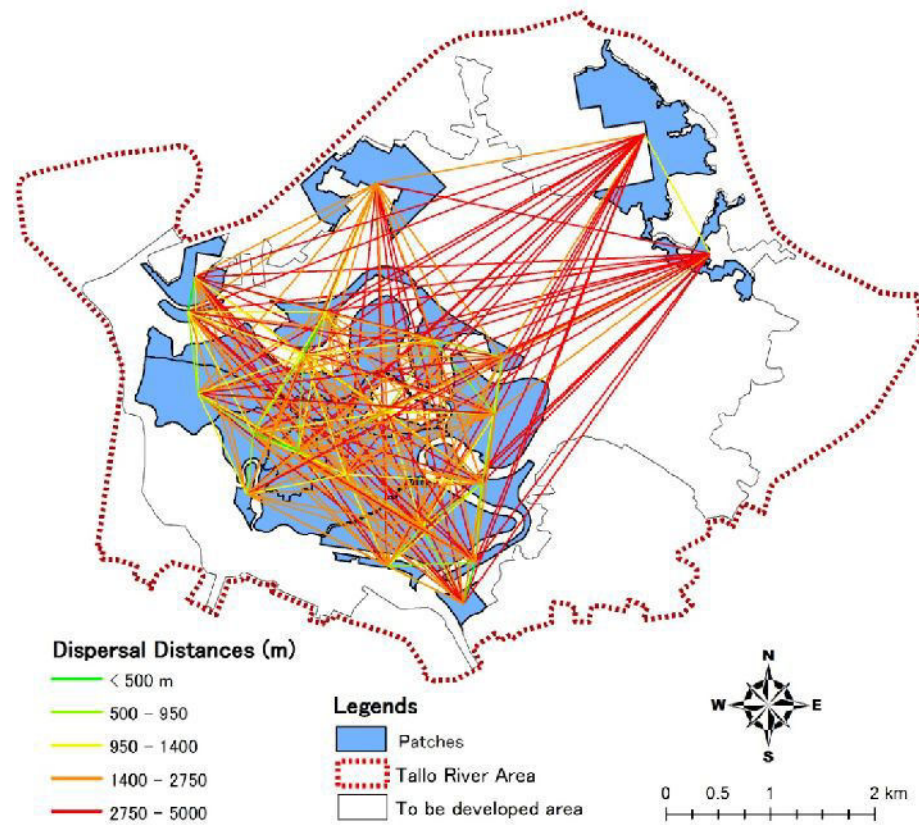


Fig. 5.17 Patch and a link set of dispersal distances (the GI network proposal)

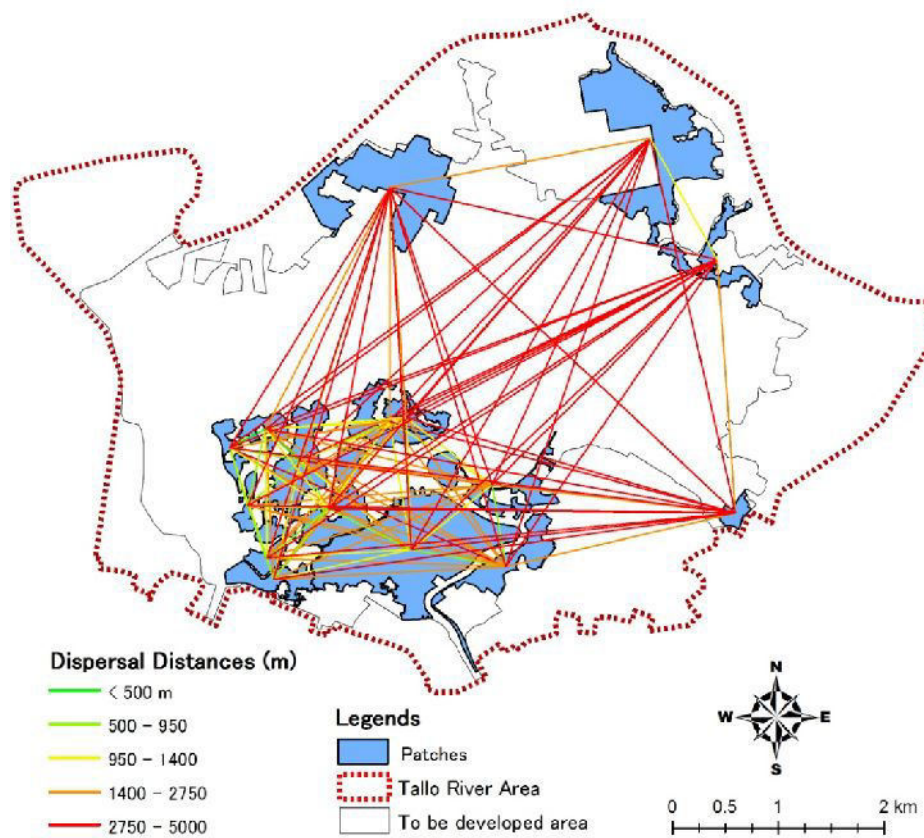


Fig. 5.18 Patch and a link set of dispersal distances (the existing landscape)

5.4.2.1 *Comparative dispersal distance analysis*

Patch distance analysis creates a diagram illustrating the size of the largest component for a range of maximum dispersal distances. Hence, it can be used to study whether there are any critical thresholds in terms of maximum dispersal distances in the landscape. It can also be used to get an overview of how all connected the landscape is for different species with different dispersal distances. Hence, this analysis can be defines as a macro analysis since it will create a range of link set, and then do a component based analysis for each of these link sets.

The results of component based analysis for patch distances of Green Infrastructure proposal and the existing landscape are presented in the **Figure 5.15** and **Figure 5.16**, respectively. The curve in the diagram shows the size (in % area) of the largest component for that specific maximum dispersal distance. It is shows that the existing landscape (**Figure 5.18**) has lower in % area of the largest component and higher maximum dispersal distance where its compared to the landscape proposed by Green Infrastructure network (**Figure 5.17**). It is means that the existing landscape tends to lower of the connectivity from current landscape perspective than the proposal, and the proposed landscape structure by the Green Infrastructure network plan gives improvement for all the connected the landscape.

5.4.3 **Green Infrastructure Network Proposal**

A series of landscape zones have been developed as a framework for Green Infrastructure planning. Zones are analyzed as a landscape perspective within the Tallo. **Figure 5.19** shows the proposal of the Green Infrastructure network coping to the study of the development component plan of Tallo River Area by local government. The proposed zones respond to distinctive aspects of the landscape and environmental character of the Tallo. Distinctive aspects of character include the ancient landscape of Lakkang Island. In defining zones, consideration has also been given to opportunities to enhance existing urban character to deliver a wider range of functions and to increase its flood risk mitigation and climate change adaptation potential through urban greening and improved landscape structure. The final key consideration has been links and connections in terms of access and habitat landscape and in identifying potential for enhancement.

The identified and mapped Green Infrastructure elements are integrated into two Green Infrastructure networks, as ecological connectivity function and flood risk mitigation aggregated. Green Infrastructure conservation network comprises areas providing key ecological functions such as in South part of Tallo.

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Conservation is defined as priority zones in order to maintain essential connectivity of natural habitats such as mangrove forests. One of the major attractions of the proposed Green Infrastructure network is its ability to perform multiple functions on the same piece of land use value for example, mangrove forests and swamps are designed to the habitat landscape enhancement and flood hazard mitigation. This Green Infrastructure network study proposes a preliminary solution that works with recent knowledge and spatial data, but is open for improvement as soon as more and better input data becomes available at local scale. The resulting Green Infrastructure network is based on the best information currently available at Makassar city level; any improvements on the input data side will help refine the resulting network of Green Infrastructure elements. The connectivity analysis is not exclusively related to specific habitats, and much more to the areas that deliver other ecosystem services, since the latter must be analyzed case by case of habitat.

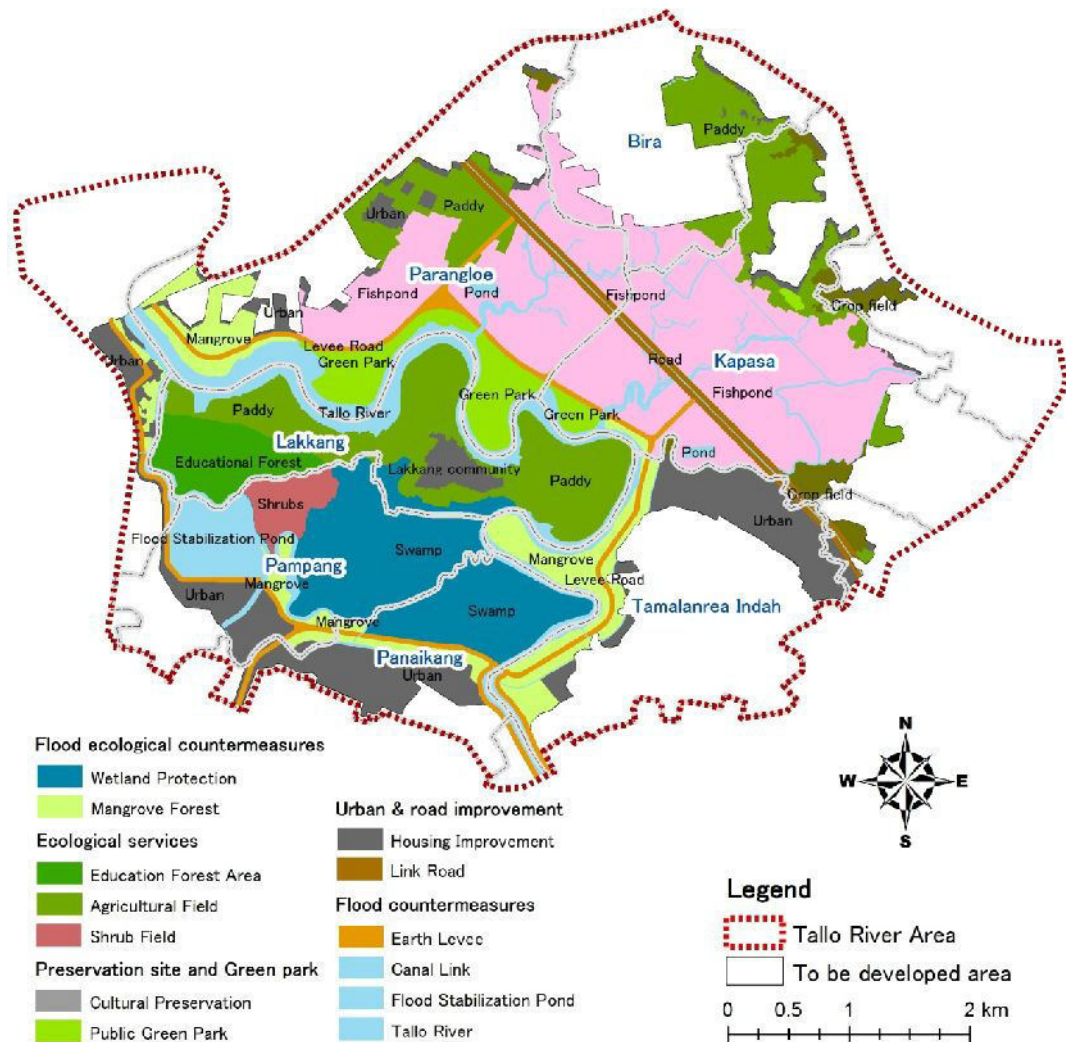


Fig. 5.19 Proposed Green Infrastructure Network of Tallo

5.4.4 Spatial comparative land-use values

Comparative of land-use values between the past, the existing, the planned by local government (see in **Figure 5.21**) and the proposed Green Infrastructure planning in the Tallo River Area are presented in **Table 5.19** and **Figure 5.20**.

Table 5.9 Comparative of land use value within Tallo

LU value	Past (1997)		Existing (2012)		Government Planned		Proposed GI Network	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Crop field	0	0.00	174.74	8.41	38.67	1.86	38.67	1.86
Fishpond	0	0.00	1190.08	57.26	501.17	24.11	507.17	24.40
Forest	0	0.00	0.37	0.02	81.3	3.91	60.12	2.89
Garden field	256.86	12.36	65.56	3.15	69.77	3.36	74.02	3.56
Mangrove	1059.37	50.97	120.52	5.80	117.52	5.65	133.27	6.41
Paddy field	266.11	12.80	186.6	8.98	249.19	11.99	353.97	17.03
Levee road	0	0.00	0	0.00	76.96	3.70	76.99	3.70
Road	0	0.00	0	0.00	41.3	1.99	41.3	1.99
Shrub field	332.52	16.00	5.17	0.25	0	0.00	31.01	1.49
Swamp field	0	0.00	2.37	0.11	362.12	17.42	221.48	10.66
Urban	48.65	2.34	121.6	5.85	254.72	12.26	254.72	12.26
Water	114.84	5.53	211.34	10.17	285.63	13.74	285.63	13.74
Total:	2078.35	100	2078.35	100	2078.35	100	2078.35	100

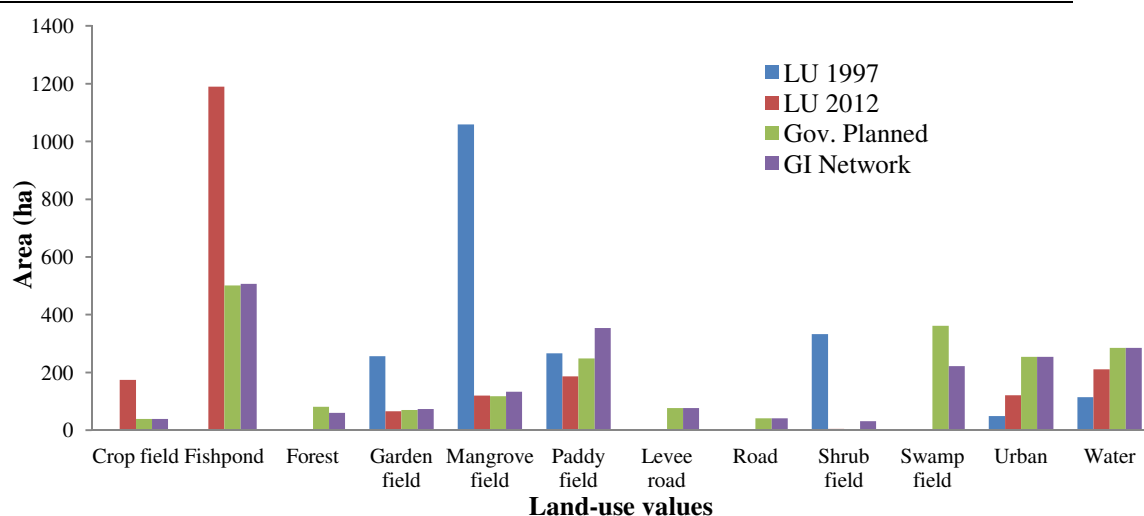


Fig. 5.20 Comparative land use zones within Tallo



Fig. 5.21 Tallo development planned by local government

5.5 Summary

The goal setting by local government has been studied to identify the main objectives in accordance to the city's spatial plan. Identification of key issues for Green Infrastructure plan has been conducted to indicate the potential Green Infrastructure functions in Tallo River Area. Moreover, three spatial themes have been identified that are landscape and biodiversity, flood risk and climate change adaptation, and community and access to greenspace. Analysis element has been conducted for the Green Infrastructure network design model. In particular, the connected landscape biodiversity network has been simulated in GIS to evaluate a patch dispersal distance between existing and planning. Synthesis plan element has also been performed to assess the Green Infrastructure network design model

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in terms of flood risk factors and other feasibility factors. This assessment leads to the identification of priorities for implementation zones in Tallo River Area.

CHAPTER 6

Conclusions and Discussion

6.1 Summary and conclusions

This study has evaluated the prospective of Green Infrastructure planning in Tallo River Area for Makassar region by conducting the spatial analysis and modeling using a GIS approach. The Green Infrastructure network of Tallo River Area has been designed at local scale based on the context of ecological connectivity, flood disaster risk, and the plan's goals of the local government for the protection of ecological functions, as well as protection of working lands, flood hazard mitigation, and open space for local human benefit.

In Chapter 2, it is described that the land-use changes in the Makassar region have shown remarkable changes as the consequences of urban expansion during the last 15 years. Development of land-use maps from the available topographic maps have been performed and details of land-use changes have been simulated based on grid-mesh of 50 m size scale to characterize land-use transition. Urban surface has grown up from 4,805 to 8,098 hectares which represents almost twice the urban expansion of a 15 years period. From the spatial land-use transition analysis, it can be noted that in 1997, agriculture played a predominant role, particularly in the plain area in the Makassar city. The increasing phenomenon of urban area from 1997 to 2012 has led to the existence of fishponds (13.5% of the Makassar area) in 2012. Moreover, a large area of fishpond is developed due to conversion of mangrove forest for local peoples to do fishery. It is perhaps that in the recent years, the impact of regular flooding has turned the Tallo River basin into a natural drainage catchment area, supporting the local peoples to create the fishpond as a livelihood. In addition, the occurrence of swamp fields and fishponds were counted as 15.6% from the Makassar region has transformed the pattern of mangrove forest and shrubs field in the vicinity of Tallo River Area.

Chapter 3 evaluated the ecological connectivity index of the Makassar region for assessment of the impacts of land-use change into the ecological connectivity. Ecological functional areas are simulated by different spectrum models that need

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to be evaluated for assessing the ecological connectivity at regional scale of Makassar. With the landscape ecological connectivity analysis, a calculation model developed by Marulli and Mallarach (2005) is applied because of the spatial scales of the research settings are the similar, both of which deal with the urban region, similar landscape problems is facing including rapid urban sprawl and simultaneous need for natural remnants conservation. This ecological connectivity model is primarily based on the cost-distance analysis that considers the different urban habitat patches and an impedance surface which incorporates the barrier effect. From a landscape ecological point of view, one of the main trends in the Makassar area during the last 15 years has been the rapid fragmentation and transformation of the natural landscape, creating numbers of patches of habitat, increasingly smaller and disconnected. In 1997, around 13% of the land enjoyed a high or very high level of connectivity, and almost 4% in 2012. On the contrary, only 38% held this consideration in 1997 with up to 49% of the region possessing low connectivity. Conversion of land-use values in 1997 into urban area in 2012, such as paddy field to urban, garden field to urban, mangrove forest to urban and shrubs field to urban has resulted different levels of impact on the ECI. It is shows that the shrub and mangrove forest in the vicinity of Tallo River Area has relatively high impact levels to the ECI. Some critical areas have been identified for the preservation of the potential ecological connectivity in the Tallo River Area between natural areas, and the restoration of remaining mangrove forest and agricultural and agro-forestry mosaics.

Chapter 4 developed the spatial and temporal flood risk index assessment of Makassar region. Historical record of flood events in 2013 has been used as flood hazard scenario for evaluation of risk assessment. This basically data for flood hazard maps are provided by the local government. A spatial process and dataset registration at GIS is conducted to create the flood hazard index map. The concept of vulnerability in this study considers the local context. By this approach, vulnerability has specific spatial, socio-economic-demographic, environmental and physical contexts. The spatial analysis process for integrating the registered statistical dataset and linking to the vulnerability indicator model are established. As a result of the combination of the four composite indicators of the vulnerability, the highest vulnerability to flood affects almost at the centre-west and the south-west. More than 50% of the sub-districts have a vulnerability index varying from moderate to high. The lowest vulnerabilities are sparsely distributed throughout the district at the north-east and south-east. Preparation of the flood risk assessment index requires additional spatial analysis after obtaining the required indices (vulnerability and hazard). The flood risk assessment index has

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been evaluated for all flood areas that exist in each sub-district. Determination of risk level is determined based on BNPB framework analysis.

Chapter 5 proposed the Green Infrastructure planning for Tallo River Area. Using the recent information gathered analysis and modeling results from the previous chapters, capturing the environmental and socio-economic characteristics of the Tallo, and with reference to Green Infrastructure framework, a set of five functions have been identified for Green Infrastructure in the Tallo. The assessment of opportunities in relation to functions is split into: analysis of high level opportunities and analysis in relation to specific locality areas (sub-district areas around Tallo). Three spatial themes were explored for planning Green Infrastructure in the Tallo. These focused respectively on i) landscape and biodiversity, ii) flood risk and climate change adaptation, and iii) community and access to greenspace. A series of landscape zones have been developed as a framework for Green Infrastructure planning, and analyzed as a landscape perspective within the Tallo. The proposed zones respond to distinctive aspects of the landscape and environmental character of the Tallo. In defining zones, consideration has also been given to opportunities to enhance existing urban character to deliver a wider range of functions and to increase its flood risk mitigation and climate change adaptation potential through urban greening and improved landscape structure. The final key consideration has been links and connections, in terms of access and habitat landscape, and in identifying potential for enhancement.

6.2 Discussion and future research

Makassar is the largest city in Eastern Indonesia and the capital of the province of South Sulawesi. Due to high urban growth and its sprawl, there is an urgent need for strategies that facilitate the protection and restoration of ecologically connected landscapes for remaining few natural and agricultural spaces of the Makassar region. At the same time, floods are anticipated to happen more strictly in the future because of climate change, unplanned rapid urbanization, change in land-use pattern, and poor watershed management. The Makassar region including the coastline is vulnerable to flooding and this vulnerability can be exacerbated by changes in both the occurrence of severe rainfall events. Local conditions such as low-lying lands and slow surface water drainage increase the risk of flooding. Inadequately planned infrastructural development and urban development of Makassar in the floodplain can also give rise to flood risk.

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The Tallo River is a main river that flow in Makassar vicinity. Yet close to the Makassar City centre, Tallo River Area is a large area of undeveloped land, the large area of wetland on downstream Tallo River. This hole in the urban area covers much of the original Tallo kingdom with its centre at the mouth of the river. In Tallo River Area, mangroves and shrubs are important forested wetlands and now it is banned to conversion mangroves into fishpond. The rate of mangrove and shrub loss is significantly higher than the loss of any other vegetation types. If deforestation continues, it can lead to severe losses of biodiversity and livelihoods, in addition to salt intrusion in coastal areas (Fahrig, 2003). Therefore, the degradation of vital areas should be putted into the first priorities for restoration action.

The goal of a Green Infrastructure network design is to delineate an interconnected element system. Network design criteria should be developed and based on ecological and land-use planning theories and utilize an integrated landscape-scale approach. The network design should be created by conducting a suitability analysis or using a similar method (based on determined network criteria) to calculate a range of resource values for the study area. The network design should utilize a hub/corridor framework and incorporate a diversity of land-uses. These network components ensure that important resource areas are protected and linked to provide the optimal environment for an area's ecological systems. The network analysis should be able to identify gaps in the network, allowing to as certain significant areas that are prime for restoration efforts. Restoring hub and linkage gaps is a crucial component to any Green Infrastructure plan, as most network designs will contain holes in the form of developed or degraded lands.

A Green Infrastructure will help reconnect existing nature areas and improve the overall ecological quality, mitigation against the floods and the negative effects of climate change. However, it is best achieved through strategic level spatial planning which enables spatial interactions between different land-uses to be investigated over a large geographical area. Furthermore, future research should work to establish a comprehensive spatial analysis of synergies and selected ecosystem services, especially when provisioning and cultural services are also considered. This may lead to the development of additional connectivity analyses among key service areas when relevant, both conceptually and spatially.

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