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Analysis of Socio-Ecohydrological Factors Affecting Water Security, Liveability and Sustainability: A Case Study of the Cirebon Metropolitan Region, West Java, Indonesia

Titih Titisari Danielaini

MSc in Water Science and Engineering and in Environmental Management with Specialisation in Integrated Lowland Development and Management Planning; BE in Environmental Engineering

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This thesis is dedicated to the people of West Java

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DECLARATION

Author : TITIH TITISARI DANIELAINI

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I certify that the work presented in this thesis is, to the best of my knowledge and belief, original, except as acknowledge in the text, and that the material has not been submitted, either in full or in part, for a degree at this or any other institution. I certify that I have complied with the rules, requirements, procedures, and policy relating to my higher degree research award of the Western Sydney University.

[redacted]

Author's Signature

TABLE OF CONTENTS

LIST OF PUBLICATIONS

Published Journal Articles:

1. DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2017. *Defining rural–urban interfaces for understanding ecohydrological processes in West Java, Indonesia: Part I. Development of methodology to delineate peri-urban areas*. Ecohydrology & Hydrobiology 18 (1):22-36. doi: 10.1016/j.ecohyd.2017.11.006.

2. DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2017. *Defining rural–urban interfaces for understanding ecohydrological processes in West Java, Indonesia: Part II. Its application to quantify rural–urban interface ecohydrology*. Ecohydrology & Hydrobiology 18 (1):37-51. doi: 10.1016/j.ecohyd.2017.11.007.

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4. DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2019. *Qualitative and quantitative analysis of perceived liveability in the context of socio-ecohydrology: evidence from the urban and peri-urban Cirebon-Indonesia*. Journal of Environmental Planning and Management, 1-29. doi:10.1080/09640568.2018.1524576.

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Presentations

1. DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D 2015. *Urbanisation and climate change: challenges for water future and eco-hydrology of Indonesia*. Presented in the form of a poster at the Symposium of Sustainable Development Goals focusing in the coastal areas, December 8-9, 2015, Hannover, Germany.

2. DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2017. *Understanding urbanisation impacts on ecohydrological satisfaction-based liveability in the Cirebon Metropolitan Region*. Participated in GRS research week-poster presentation, October 2017, Parramatta Campus, Western Sydney University.

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LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
ANOVA	Analysis of Variance
BAPPEDA	*Badan Perencanaan Pembangunan Daerah*/ Local Development Planning Agency
BAPPEDA JABAR	*Badan Perencanaan Pembangunan Daerah Jawa Barat*/ West Java Regional Development Planning Agency
BAPPEKO	*Badan Perencanaan Pembangunan Kota*/ City Development Planning Agency
BBWS	*Balai Besar Wilayah Sungai*/ National River Basin Management Organisation
BLHD	*Badan Lingkungan Hidup Daerah*/ Regional Environment Agency
BMKG	*Badan Meteorologi, Klimatologi, dan Geofisika*/ *T*he Indonesian Agency for Meteorology, Climatology and Geophysics
BPSDA WS	*Balai Pengelolaan Sumber Daya Air Wilayah Sungai*/ Provincial River Basin Management Organisation
BUD	Balanced Urban Development
CCRB	Cimanuk-Cisanggarung River Basin
CF	Coastal Farmer
CM	Cirebon Municipality
CMR	Cirebon Metropolitan Region
CNF	Coastal Non-Farmer
CR	Cirebon Regency
DBMCK	*Dinas Bina Marga dan Cipta Karya*/ Road Development and Human Settlement Agency
DCK	*Dinas Cipta Karya*/ Human Settlement Agency
DCKTR/DTRCK	*Dinas Cipta Karya dan Tata Ruang/Dinas Tata Ruang dan Cipta Karya*/ Human Settlement and Spatial Planning Agency
DISKIMRUM JABAR	*Dinas Permukiman dan Perumahan Jawa Barat*/ West Java Human Settlement and Housing Agency
DISTANBUNAKHUT	*Dinas Pertanian, Perkebunan, Peternakan, dan kehutanan*/ Agriculture, Plantation, Livestock, and Forestry Agency
DISTANNAK	*Dinas Pertanian dan Peternakan*/ Agriculture and Livestock Agency
DPSDA JABAR	*Dinas Pengelolaan Sumber Daya Air Jawa Barat/ West Java Water Resources Management Agency*
DPSDAP	*Dinas Pengelolaan Sumber Daya Air dan Pertambangan*/ Water Resources Management and Mining Agency
DPSDAPE/ DPSDA TAMBEN	*Dinas Pengelolaan Sumber Daya Air, Pertambangan, dan Energi*/ Water Resource Management, Mining, and Energy Agency
DPUPESDM	*Pekerjaan Umum, Perumahan, Penataan Ruang dan Energi Sumber Daya Mineral*/ Public Works, Housing, Spatial Planning, Energy and Mineral Resources Agency
EH	Ecohydrology
EPM	Environmental Planning and Management
ES	Ecosystem Services
ESRI	Environmental Systems Research Institute
FC	Financing
GIS	Geographic Information System
HAC	Household Adaptive Capacity
HS	Human Services
I	Infrastructure
IA	Interdisciplinary Approach
ICC	Information, Communication, and Collaboration
IF	Inland Farmer
INF	Inland Non-Farmer
IPCC	Intergovernmental Panel on Climate Change
IR	Indramayu Regency
IS	Innovation and Services
K/D/BLH	*Kantor/Dinas/Badan Lingkungan Hidup*/ Environment Agency

KESBANGPOL	*Badan Kesatuan Bangsa dan Politik*/ National and Political Unity Office
KR	Kuningan Regency
LULC	Land Use and Land Cover
MMR	Mixed Methods Research
MR	Majalengka Regency
PDAM	*Perusahaan Daerah Air Minum*/ Regional Drinking Water Company
PF	Peri-urban Farmer
PG	Policies and Governance
PNF	Peri-urban Non-Farmer
PS	Peri-urban Services
RF	Rural Farmer
RNF	Rural Non-Farmer
SDGs	Sustainable Development Goals
SE	Sociocultural Environment
SEHS	Socio-Ecohydrological System
SES	Socio-Ecological System
SPSS	Statistical Package for the Social Science
TA	Transdisciplinary Approach
UF	Urban Farmer
UNF	Urban Non-Farmer
UPT	Urban-Peri-urban Transition
UPTF	Urban-Peri-urban Farmer
UPTNF	Urban-Peri-urban Non-Farmer
US	Urban Services
WEAP	Water Evaluation and Planning System
WJP	West Java Province
WSU	Western Sydney University

LIST OF TERMINOLOGIES

Adaptive capacity	*The capacity of actors in a system to influence resilience (Folke et al., 2010)*
Balanced urban development	*A concept of sustainable development that is linked to the liveability of urban areas along with water, food, and energy security concerning place, people and planning through the development of the various planning tools and models that help to analyse and visualise different options and scenarios (Maheshwari et al., 2016).*
Ecohydrology/ hydroecology	*Both imply research at the interface between the hydrological and biological or ecological sciences (Hannah et al., 2004). In practice, many ecologists refer to ecohydrology (Zalewski, 2000) while hydrologists refer to hydroecology (Dunbar and Acreman, 2001). In particular, ecohydrology studies the interplay between water, ecosystem, and society as the basis of integrated knowledge for environmental management (Zalewski et al., 2016a). The evolving paradigm has been changed from interdisciplinarity to transdisciplinarity (Zalewski, 2010)*
Ecosystem services	*The benefits people obtain from ecosystems (Millennium Ecosystem Assessment, 2005). It specifically refers to the benefits human population derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997).*
Governance	*The process of resolving trade-offs and charting a course for sustainability (Boyle et al., 2001).*
Hydrosocial	*The science of people and water as the field of hydrosociology using a new term developed by social scientists, geographers, for describing socioecological nature of water to capture a longer tradition within human geography of understanding natural systems in relation to the social world (Linton, 2008, Wesselink et al., 2017, Linton and Budds, 2014).*
Hydrosociology	*The science of people and water that was initially pointed out by Falkenmark (1979) and also suggested in (Falkenmark, 1977) about the need to gather more knowledge concerning water and its interaction with ecosystems and with society.*
Liveability	*There is no consensus on how to define liveability, but it refers to a relationship between human and environmental system that ensures meeting the human requirements for social amenity, health, and wellbeing. It is about the person-environment fit on the 'here and now' (Newman, 1999, Van Kamp et al., 2003).*
Resilience	*The capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is the capacity to change in order to maintain the same identity (Folke et al., 2010)*
Socio-Ecohydrology	*The term of study to describe interacting components of the current water use landscapes of cities including biophysical factors such as climate, geography, and ecology, and social factors such as administrative structure of water distribution and treatment agencies, water prices and technologies, landscape design and management practices, and the demographics of urban population (Pataki et al., 2011).*
Socio-Ecological System	*Integrated system of ecosystem and human society with reciprocal feedback and interdependence. The concept emphasises the human-in-nature perspective (Folke et al., 2010)*
Socio-Hydrology	*The science of people and water as the field of hydrosociology using a new term developed by hydrological scientists for describing socioecological nature of water to capture new direction in hydrological science for the benefit of society. It aims to understand the dynamics and co-evolution of coupled human-water systems (Sivapalan et al., 2012, Wesselink et al., 2017).*
Sustainability	*There is no consensus on how to define sustainability, but it refers to a relationship between human and environmental systems that ensures meeting human needs in the long term. It is about the person-environment fit in the future or long-term liveability (Alberti, 1996, Van Kamp et al., 2003).*
Urban systems	*They are centred in urban areas showing complex, adaptive, socioecological systems, in which delivery of ecosystem services links society and ecosystems at multiple scales including the connection with their surrounding areas (McGranahan et al., 2005, Grimm et al., 2000).*
Urbanisation	*A multidimensional process that manifest itself through rapidly changing human population and changing land cover (Elmqvist et al., 2013).*
Water Security	*There is no consensus on how to define water security but it refers to the need to balance human and environmental water needs (Srinivasan et al., 2017). Water security represents the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments and economies (Grey and Sadoff, 2007).*

ABSTRACT

Water security, liveability, and sustainability are important concepts in development. These concepts can help planners and managers to construct and achieve an equilibrium of socio-ecohydrological systems over a long period. This study, in the context of balanced urban development, seeks to better understand socio-ecohydrological issues, challenges, options, and strategies for achieving water security, liveability, and sustainability concerning urbanisation and climate change. This includes assessments of the urban and peri-urban environment and communities, and multi-level government institutions.

Water security in this study is defined in the context of a water insecure region as "insufficient accessibility and capability of water sources and services to satisfy the household needs for health, livelihood, ecosystem, and production, coupled with inadequate acceptability and adaptive capacity of households to deal with the ecohydrological changes that impact liveability and sustainability". Liveability is defined in this study as "dynamic interactions between water, people, and the environment as a function of biophysical and socio-economic subsystems in one urban system", while sustainability is defined as "long-term liveability that is ensured via planning approaches and environmental management interventions".

Water security was assessed in the context of socio-ecohydrological change based on (i) the experiences of communities in the access to water and sanitation infrastructures; (ii) the acceptability of water risks from ecohydrological change; (iii) the capability of ecosystem and institutional services to satisfy the needs for health, livelihood, ecosystem, and production; and (iv) adaptive capacity in dealing with the impacts resulting from socio- ecohydrological change. Liveability was assessed based on the communities' perceptions of the most important aspects for liveability, liveability aspects that they are most satisfied with, and liveability aspects that they are least satisfied with, in the urban and peri-urban areas. The results were categorised within four themes: ecosystem, urban, peri-urban, and human services. Sustainability was assessed by combining observed land-use/ hydrological/ climate data and the perceptions of climate change vis-à-vis ecohydrological changes and coping strategies. The study combined place and human-based approaches to assess these three thematic areas combining qualitative and quantitative data for finding interconnection and trade-off for achieving balanced urban development (BUD).

Based on the in-depth case study of Cirebon Metropolitan Region (CMR) in Indonesia, this study explored (i) socio-economic and physical environments of the region including watersheds within the Cimanuk-Cisanggarung River Basin; (ii) community perspectives at different urbanisation levels; and (iii) multi-level government perspectives. This study presents seven analytical frameworks related to different aspects of work reported in this thesis: (i) delineate peri-urban areas; (ii) quantify rural-urban interface ecohydrology; (iii) understand urbanisation impacts on urban and peri-urban ecohydrological based liveability; (iv) identify perceived liveability of urban and peri-urban communities in the context of socio-ecohydrology; (v) classify issues and factors impacting household water insecurity in the context of socio-ecohydrological change; (vi) understand sustainability challenges concerning climate change and urbanisation in the urban system, and identify appropriate adaptation supports for sustaining water security and liveability; (vii) identify the complexity and uncertainty involved in assessing water security, liveability, and sustainability, and to find the linkages between urban and peri-

urban communities, urban and peri-urban ecosystems, and cross-scale institutions for achieving BUD.

The results of this study suggests that issues and challenges of BUD in relation to water security, liveability, and sustainability concerning urbanisation and climate change in the metropolitan region are multiple and complex in nature. This can be better understood using interdisciplinary methods/concepts/theories for identifying the interconnections between water, people, and the environments within a socio-ecohydrological systems thinking framework. As shown in this study, systems thinking approaches provided rigour in data analyses for finding multi-dimensional aspects of water security, liveability, and sustainability.

While the metropolitan region can provide a good laboratory for understanding the urban system, the process of data collections and analyses was quite challenging, particularly in finding the suitable frameworks/methods. Moreover, the existing concepts/labels that were used to categorise and understand urban phenomena were found to be inadequate and unhelpful for describing water security and liveability in the selected case study area and needed new nexus concepts and models. For sustainability objectives, the conceptual boundaries of nexus need to be reframed considering the fit between natural systems and socially constructed institutions with the responsibility to manage them for sustaining water security and liveability. For BUD objectives, a systems approach needs to be conceptualised for gaining better understanding of the complex social and environmental issues; for identifying options and strategies that are robust for a wide range of possible scenarios; and for understanding inter-dependence and inter-connectedness of urban and peri-urban communities and ecosystems, and cross-scale institutions.

The CMR provided evidence that water security, liveability, and sustainability varied across their spatial, institutional, and infrastructure settings as well as communities' socio-economic characteristics. There were six reliable factors affecting water insecurity in the region, namely drought, unhealthy housing and environment, unregulated water use, flood, poor affordability, and poor sanitation. These factors differently affected household water insecurity depending on urbanisation levels and farm/non-farm households. Four urbanisation levels were identified to show significant different ecohydrological processes, namely urban, urban/peri-urban transition (UPT), peri-urban, and rural. Water security was found as the most important aspect for liveability in the region, particularly for the households in the UPT and peri-urban areas, where the changes in land use, water cycle, and climate were highest in observed and perceived data. Urbanisation significantly affected UPT liveability in terms of neighbourhood, watershed, and personal satisfactions. Combined with climate change, it also significantly affected farm and non-farm UPT household water security due to increasing flood events. This study found that the root causes of socio-ecohydrological issues are institutional, biophysical, socio-cultural, and technical constraints.

In this study, water source availability was found as the core of the people-water-food-environment-climate nexus that was dynamically affecting water security, liveability, and sustainability. Enhancing the adaptive capacity of peri-urban communities, together with supporting institutions that facilitate cross-level/sector planning and management is the key for enhancing the resilience of socio-ecohydrological systems for sustainability objectives. This study proposes socio-ecohydrological and infrastructural systems for achieving BUD which include interconnections between people, water, land, and the eight key aspects of BUD: i) environmental planning and management; (ii) infrastructure; (iii)

policies and governance; (iv) innovation and services; (v) information, communication, and collaboration; (vi) sociocultural environment; (vii) household adaptive capacity; and (viii) financing. These research findings suggest the need to implement transboundary, multi-sectoral, multi-scalar, socio-ecological-hydrological and infrastructural systems with diverse actors, priorities, and solutions in urban systems to promote BUD in the coastal urban region.

Keywords: Balanced urban development; Water security; Liveability; Sustainability; Socio-ecohydrology, nexus thinking, systems approach.

There are 10 chapters in the thesis that are presented across four parts:

Part I: Overview

There is one chapter in this part, Chapter 1, which provides the groundwork for this thesis. This includes the rationale of the thesis, key concepts adopted, research framework and thesis structure. Section 1.1 presents the thesis aim, objectives, and research questions. Section 1.2 outlines the rationale for conducting the study and for choosing the CMR for providing evidence. Section 1.3 outlines the positioning of this research within the discipline of environmental studies and sustainability science and contribution to the existing knowledge. Section 1.4 reviews the four concepts adopted, water security, liveability, sustainability, and balanced urban development. This leads to the discussion of developing a research framework, methods, and design for understanding socio-ecohydrological systems using mixed-methods in Section 1.5. Finally, Section 1.6 presents thesis structure.

Part II: Study Area, fieldworks, and ethics

This part has one chapter, Chapter 2, which presents the overview of the study area, fieldwork and human ethics. Section 2.1 describes the focus area of the study, Section 2.2 outlines detailed fieldworks, and Section 2.3 outlines the ethics and reflection in conducting research.

Part III: Literature reviews, knowledge gaps, and evidence

This part presents the literature review on key concepts/theories adopted in this study (water security, liveability, and sustainability) in the context of significant changes in land use, water cycle, and climate for balanced urban development. This includes finding the gap of knowledge to be filled in this Ph.D. study. Also, this part provides empirical evidence in (i) defining peri-urban or rural-urban interfaces for understanding ecohydrological processes; (ii) quantifying rural-urban interface ecohydrology; (iii) the assessment of liveability and water security in the context of socio-ecohydrological change based on survey and the interview to urban/peri-urban householders; (iv) the assessment of sustainability using nexus and socio-ecohydrological systems thinking based on land use/hydrological/climate data, survey and the interviews of both urban/peri-urban communities and multi-level governments. This part has seven chapters. Chapters 3-8 explain the research findings related to water security, liveability, sustainability. Chapter 9 is a synthesis to combine different ideas about water security, liveability, and sustainability in the context of balanced urban development.

Part IV: Conclusions and recommendations

This part is the final part of the thesis. This part has one chapter, Chapter 10 which describes conclusions, implications, limitations and recommendations. Sections 10.1-10.3 provide some overall conclusions, summarises all the research findings under key themes of this study, namely urban and peri-urban ecohydrology, ecohydrological change and impacts, balanced urban development for water security, liveability, and sustainability in the context of socio-ecohydrological systems change. Section 10.4 outlines practical implications and transfer of knowledge, and Section 10.5 indicates limitation of current work and recommendation for future practice and research.

PART I
OVERVIEW

CHAPTER I

LAYING THE FOUNDATION FOR THESIS

1.1 THESIS AIM, OBJECTIVES, AND RESEARCH QUESTIONS

This study addresses the need to improve environmental planning and management in the light of increasing urbanisation and climate change pressures by proposing new ways for understanding an urban system, addressing inequality traps in the rural-urban interfaces, assisting in balancing urban development and sustainability of urban centres, integrating holistic options for resource governance, and recognising sustainability challenges and appropriate adaptation supports for sustaining water security and liveability. Despite increased awareness for developing sustainable and resilient urban systems in the face of unprecedented urbanisation and climate changes (Elmqvist et al., 2013, Meerow et al., 2016, Bai et al., 2016), there is a complex web of issues, challenges, and options in the ways of understanding peri-urban dynamics in the context of changes in land use, water cycle, and climate. This includes resolving the issues of sustainability related to socio-ecohydrological systems that are dealing with the complexity of dynamic interactions between people, water, and the environment.

This study has sought to provide evidence about the need for enhancing peri-urban adaptation strategies for sustaining water security and liveability that is currently overlooked in planning and management. The implications of urbanisation and climate change on the hydrological variability and processes and the need to develop possible adaptations and responses have been increasingly recognised by local sectors and services (IPCC, 2014a). This includes the need for understanding these conditions in the peri-urban areas (Morton, 2014). In particular, the growing interests are to move beyond focusing on disaster resilience to instead concentrate on adaptive management and planning that can connect long-term sustainability visions to short and medium-term resource governance practices within urban systems (Carter et al., 2015, McPhearson et al., 2015, Romero-Lankao et al., 2017). This is particularly relevant when addressing complex social and biophysical interdependency and interconnectedness on the common resources in terms of water security (Allan et al., 2013), liveability (Ruth and Franklin, 2014), and sustainability related to resource governance (Scott et al., 2015, Bhaduri et al., 2015).

Further, this study seeks to better understand balanced urban development (BUD) in the context of changes in land use, water cycle, and climate within a coastal urban region. Coastal areas are likely to experience the most intense changes resulting from urbanisation (Post and Lundin, 1996). Most major cities all over the world are located in coastal areas and are prone to the land and water use conflicts between cities and their hinterlands and to water-related risks such as floods, water pollution and seawater intrusion (Timmerman and White, 1997). The increasing urbanisation, population growth, and climate change will present more challenges to the coastal regions which will be critical to water security. However, these low lying cities have not been the focus of studies in urban development planning (Timmerman and White, 1997) and call attention to managing the sustainability of the cities and their hinterlands (Yeung, 2001). Urbanisation and sustainability in the context of the region also call attention to manage urban and peri-urban liveability (Iimi, 2005, Singh et al., 2016, Maheshwari et al., 2016).

This study aims to better understand the socio-ecohydrological factors underpinning liveability, water security, and sustainability towards BUD in the context of significant changes in land use, water cycle and climate of the coastal urban region. The guiding research question for this study is: ***What strategic options do we have to solve socio-ecohydrological issues underpinning liveability, water security, and sustainability towards BUD****?* This overall research question is divided into four specific research questions that address related specific objectives (Table 1).

Table 1. The research objectives and questions in this study

No	Research objectives	Research questions
1.	To assess the impact of ecohydrological changes resulting from urbanisation on liveability and to identify socio-ecohydrological factors underpinning urban and peri-urban liveability	What are the impacts of ecohydrological changes resulting from urbanisation on liveability? What are the socio-ecohydrological factors underpinning urban and peri-urban liveability?
2.	To identify and evaluate socio-ecohydrological issues and factors affecting water security concerning urbanisation and farm/non-farm households	What are the socio-ecohydrological issues and factors affecting urban and peri-urban water security concerning urbanisation and farm/non-farm households?
3.	To examine sustainability challenges for enhancing urban and peri-urban water security and liveability concerning urbanisation and climate change	What can we learn from questions 1 and 2 combined with the climate change perception and risks to enhance adaptation supports for sustaining water security and liveability?
4.	To develop suitable frameworks and assessment tools to assist in balancing urban development and sustainability of urban centres, concerning the changes in land use, water cycle, and climate	How to develop suitable frameworks and assessment tools for the questions 1, 2, and 3 to assist in balancing urban development concerning the changes in land use, water cycle, and climate?

1.2 RATIONALE AND SIGNIFICANCE

1.2.1 PERI-URBAN AREAS IN THE URBAN SYSTEM

Almost two-thirds of the world's population is projected to be living in urban settings by 2050 (United Nations, 2014). As the world continues to urbanise, sustainable development of cities is increasingly recognised as critical to meet balanced economic, social, and environmental goals (UN-Habitat, 2016). This includes meeting the demands of a growing urban population, to manage urban sprawl and its impacts on spatial inequality, to deal with resource use conflicts, and to adapt with climate change and its impacts on water availability (McGranahan et al., 2005, McDonald et al., 2011, Malano et al., 2014, Singh and Maheshwari, 2014a, Wei and Ewing, 2018). Concerning these challenges, peri-urban areas have an important role in enhancing urban sustainability at the global level (Wandl and Magoni, 2017).

Peri-urban areas are those areas into which cities expand or influence suggesting the importance of peri-urban resources for maintaining urban resilience (Buxton, 2014). Still, peri-urban areas are under unprecedented threat by urban and rural development including increased pressures on water and land resources (Arha et al., 2014). Despite offering immense opportunities for enhancing rural-urban synergies and sustainable cities, peri-urban areas are often overlooked, characterised by increasing marginalisation and environmental degradation due to insufficient environmental planning and management (Allen, 2003, Simon, 2008, Marshall et al., 2009). This implies the need for understanding peri-urban dynamics for supporting balanced urban development. Moreover, in the context of Asia, peri-urban areas are argued by Mc Gee (2010) as critical zones for achieving sustainable development due to their resource base and key areas for achieving food security.

The need for understanding peri-urban areas is particularly relevant for restructuring and rebalancing the way land use planning addresses the concerns of water security, food security, liveability, and sustainability (Malano et al., 2014, Singh and Maheshwari, 2014a). This includes the need to rethink the approaches on adaptive governance for common resource security and on adaptive responses to the changes in land use, water cycle, and climate or in the context of ecohydrology. While existing methodologies for defining rural-urban interfaces are mostly in the context of urban or rural planning including demographic analysis for human settlements (Hugo et al., 2001, Öğdül, 2010, Camaioni et al., 2013, Wandl et al., 2014), this study proposes methodologies to define rural-urban interface ecohydrology for understanding ecohydrological processes in the urban and peri-urban areas.

1.2.2 RETHINKING LIVEABILITY IN THE URBAN SYSTEM

The main challenge in managing urban development is that cities are growing rapidly and expanding to peri-urban landscapes bringing social, economic, and environmental consequences (Redman and Jones, 2005, Angel et al., 2011). Urbanisation provides opportunities for socio-economic growth but a rapid expansion of urban areas also provides more challenges on water and environmental security (Lundqvist et al., 2003). Urban expansion has increased the exposure of urban regions to floods and droughts (Guneralp et al., 2015). Climate change is predicted to exacerbate these existing risks (Dasgupta et al., 2009, Hunt and Watkiss, 2011, Horne et al., 2018). In many places around the world this has drastically increased tension between available water resources and societal demands. This is due to constantly changing dynamics of water which is related to climatic condition, ecosystem status, technology, demography, and consumption patterns (Zalewski et al., 2016a). This suggests that the interaction between water, people, and the environment becomes increasingly complex.

The complexity is considerably high in coastal cities that are exposed not only to urban expansion but also to climate change (Grimm et al., 2008). These dynamic constraints shape the proficiencies of cities for maintaining their infrastructures, delivering reliable supply and services, supporting the lives and livelihood of people and affect the capacity of their natural resources particularly water for sustaining human wellbeing and providing basic ecosystem services such as food production (Ruth and Franklin, 2014, Zalewski et al., 2016a). The efforts for enhancing sustainability thus need liveability to overcome these challenges and to ensure that equity, economics, and environment embrace local preferences (Gough, 2015). This can be done by considering local concerns and values in the urban systems. This includes the peri-urban area because the more urban population and economic growth are placed in this desakota zone, the higher the importance of peri-urban liveability and sustainability (Mc Gee, 2010). This implies the need to achieve balanced urban and peri-urban liveability for sustainable urban development.

Despite the importance of water for enhancing liveability, water is barely considered in the focus of liveability studies, many of which only consider the urban area and neglect peri-urban area (Balsas, 2004, Giap et al., 2014, Tournois, 2018, Zhan et al., 2018). The need for understanding dynamic interactions between water, people, and the environment in the urban system as proposed in this study is particularly relevant for understanding liveability in the context of socio-ecohydrology, identifying the impacts of ecohydrological change resulting from the changes in land use, water cycle, and climate on liveability in the urban and peri-urban areas, and providing methods for balanced urban and peri-urban liveability. This includes understanding the trade-off between the preference of liveability services and performance of liveability services incorporating ecosystem, urban, peri-urban, and human services.

1.2.3 RETHINKING WATER SECURITY IN THE URBAN SYSTEM

Cities are at risk of water insecurity from rapid urbanisation and climatic change which cause a risk of shortage, inadequate quality, excess, and undermining the resilience of natural water systems (Brears, 2017). Water security may be seen as a tolerable water-related risk to society (Grey et al., 2013). However, water-related risks can be viewed differently by individuals, communities, and societies depending on the formal water infrastructures, urbanisation level, and spatial pattern, household adaptation capacity, and the local geology concerning groundwater availability (UNESCO, 2012, Srinivasan et al., 2013). Thus, obtaining the full conceptual, analytical and policy benefits of water security depends primarily on how complex challenges at the interface of water, society, and climate are considered and approached (Zeitoun et al., 2016).

The concept of water security appears due to the evidence of scarcity in the amount of water required to meet human needs (Beck and Walker, 2013). This concern is particularly high in cities as they are significant consumers of ground and surface water located within its boundary and its surrounding areas (Brears, 2017). Increasing urban growth, however, leads to the increase of water transfer from peri-urban areas to cities which conflicts with agricultural water demands (Allen et al., 1999, Lundqvist et al., 2003). This affects water and food security in the urban system because water has functions for economic livelihood in the peri-urban area and for food production to feed the population in cities (Díaz-Caravantes, 2012). Attention to water security, thus, should be paid not only to increased water scarcity but also to the fundamental role of water in both biophysical environment and socio-economic activities (Falkenmark, 2013). This implies the link between water security and liveability.

Urbanisation changes land use from agricultural lands to urban lands as of the most important impacts of urban expansion showing urban and peri-urban land nexus (Tacoli, 1998). However, the implication of growing urban demands on peri-urban water is also critical as many peri-urban activities are highly dependent on water availability (Díaz-Caravantes and Wilder, 2014). It is evident that urban and peri-urban areas experience water scarcity resulting from short supply and increasing demands by different users (Allen et al., 1999). Climate change also exacerbates existing water scarcity affecting food production since water security is highly interlinked with food security (Nguyen, 2002, Naylor et al., 2007, WEF, 2011). This implies the need to achieve balanced urban and peri-urban water security for sustainable urban development.

The future challenge concerning water security is how to balance the rising demand for water with limited supplies (Brears, 2017). A new approach that functions across sectoral and institutional boundaries to create new partnerships among water users and providers is also required including demand-based strategies (UNESCO, 2012). This is critical because the management of water security involves complex decisions concerning multiple dimensions of environmental stressors and multiple human dimensions, including human values and perceptions, problem framing, and the challenges of governance and policy in dealing with the uncertainty (Wheater and Gober, 2015). Thus, it is important to understand water security issues and challenges including vulnerable groups by considering urbanisation and climate change pressures and impacts on biophysical environment and households/communities, the scale of adaptation actions, and the role of institutions in resolving the issues (Srinivasan et al., 2013).

There are two approaches for seeking water security, through certainty and through pluralism (Zeitoun et al., 2016). First, seeking water security through certainty relies on reductionism approaches which focus on simplification and generalisation (Liu et al., 2012, Dongguo et al., 2012, Fengshun et al., 2012, Jaramillo and Nazemi, 2017, Asian Development Bank, 2013a). This approach is useful to simplify complex realities for prioritising, facilitating assessment, tracking progress, and informing decisions across places (Dickson et al., 2016), but it overlooks diversity in society and the complexity of water security issues for informing various effective interventions within places. Second, seeking water security through pluralism relies on complexity approaches that are adapted to particular challenges or communities, and does not necessarily seek to generalise (Jepson, 2014, Kujinga et al., 2014, Aihara et al., 2016, Hadley and Wutich, 2009, Wutich and Ragsdale, 2008). The latter is useful to introduce novel policy options, take benefits of context-specific techniques, and offer more solutions for the most vulnerable communities (Zeitoun et al., 2016), and that suits the research objective of this study.

Despite the progress of seeking water security through complexities, urban and peri-urban areas within a metropolitan region are barely considered in the existing studies. To date, empirical studies for understanding household water security under rapid urbanisation and climate change are not available. This study developed socio-ecohydrological system analytical framework for understanding the complexity of water security issues and challenges in the context of changes in land use, water cycle, and climate. This is applied for assessing household water insecurity at regional and community levels and for providing methods that enable identifying multi-dimensional aspects of water insecurity in the urban systems. This includes assessing the trade-off between community demands and government services in the accessibility to water sources and services, acceptable levels to water risks resulting from ecohydrological change, the existing capability of the ecosystem and government services, and household adaptive capacity to cope with the ecohydrological change.

1.2.4 RETHINKING SUSTAINABILITY FOR ENHANCING WATER SECURITY AND LIVEABILITY

There is a new direction in development worldwide, namely 'the new development agenda 2030 for the world' including 17 sustainable development goals (SDGs) as advocated by the United Nation (UN) during the UN Sustainable Development Summit in New York in September 2015 (UNDP, 2016b). This sustainability agenda shows an emerging need for a paradigm shift in the concept of development to a more humanistic and ecological approach (Hosagrahar et al., 2016). The thought of sustainable development itself was widely acknowledged three decades ago in the Brundtland Report released by the World Commission on Environment and Development (WCED) that suggested a definition of sustainable development as a development that fulfils people's needs for living in the current and future period (WCED, 1987). The concept of sustainability has become more apparent in cities where they have become the main consumers of the earth's ecosystem goods and services, producers and exporters of wastes, and importers of natural resources from other ecosystems (Camagni et al., 1998, McGranahan et al., 2005, Brears, 2017, Hosagrahar et al., 2016).

Cities are important drivers of development and poverty reduction. The unplanned growth of cities, however, threatens sustainable development concerning urban sprawl, high resource depletion, environmental degradation, and increasing socio-economic disparities (Zhang, 2016). Rapid expansion of cities brings new challenges and opportunities including implications for various governance levels for securing urban resource demands. For instance, additional water supplies must be arranged from sources located outside the boundaries of cities which can lead to a conflict with peri-urban water demand for food production (Díaz-Caravantes, 2012, Allen et al., 1999). This water can be conveyed from peri-urban areas located in the upstream of river basins, rivers passing the cities but originating from other areas far away, or rivers from other basins (Lundqvist et al., 2003). For sustaining water supply in terms of quantity and quality, such arrangements need both agreements among multi-level and multi-sector government institutions and socially acceptable agendas for peri-urban communities and interests.

Rapid urban expansion, thus, brings challenges for achieving SDGs 6 and 11. SDG 6 seeks to 'ensure availability and sustainable management of water and sanitation for all' while SDG 11 seeks to 'make cities and human settlements inclusive, safe, resilient and sustainable' (United Nations, 2018). The SDG 6 is closely related to water security while the SDG 11 to liveability. Extreme events associated with climate change will also be a part of the challenge of meeting water security and liveability for cities in developing countries (Horne et al., 2018). The success on achieving water security and liveability and dealing with climate change will depend on aligning with other SDGs, such as SDG 2 to achieve food security and sustainable agriculture and SDG 13 to combat climate change and its impacts (Smith et al., 2018). This is challenging as each goal incorporates social, economic, and environmental aspects and interlinks with other sectoral goals highlighting trade-offs and synergies that will need context-specific actions and adaptive governance process to deal with the uncertainty of complex multi-scale human-environment systems (Griggs et al., 2014).

Water security is interlinked to energy and food security which are also linked to management and policy in a broader political process (Beck and Walker, 2013). Complex interactions between human and environmental systems are also evident at different levels (Scott et al., 2015). A nexus thinking approach that is rooted in holistic systems thinking has been promoted through international meetings (Hoff, 2011) and suggested by international organisations (WEF, 2011) as a useful tool for understanding these interactions and as a guide for enhancing the sustainability of human-environment systems and for managing the complexity and multi-scalar issues. However, the nexus frameworks that places water in the core of the water-energy-food security nexus (Hoff, 2011) and water security as the central of water-energy-food-climate nexus (WEF, 2011) have been assessed by Beck and Walker (2013) as being water-centric and therefore supply-side oriented. Following the definitions of water security (Grey and Sadoff, 2007) and sustainability (WCED, 1987), nexus security needs to be more citizen-centric or person-centric within the urban system, and therefore demand-side oriented focusing on the need of urban and peri-urban residents (Beck and Walker, 2013).

Other nexus frameworks, beyond water-centric, are available which place food as the core of the water, energy, land, and food nexus (Ringler et al., 2013) and place livelihood as the core of water, energy, food, and livelihood nexus (Biggs et al., 2015). This shows that the complexity of nexus concepts is currently defined differently across disciplines. There is no clear definition of the term 'nexus' but it is generally interpreted as a process to link ideas and actions of different actors under different sectors and levels for achieving sustainable development (Endo et al., 2017). Many studies have applied nexus thinking to sustainable development with various research objectives such as the understanding of interdependencies between ecosystem services, policy sectors, spatial planning, and land use (Fürst et al., 2017), for understanding implications of the food-energy-water nexus for nexus governance (White et al., 2017), and for identifying the interconnections between small-scale energy projects in developing countries and the food and water aspects of developments (Terrapon-Pfaff et al., 2018).

Despite this progress, the nexus thinking approach has not been applied to understanding the connections between water security, liveability, and sustainability. In the urban system context, sustainability is about creating a balanced relationship between urban and rural areas, addressing issues related to the land use change required for poverty eradication and increased wellbeing, and improving environmental management for supporting socio-economic activities (Lieberherr-Gardiol, 2008, Camagni et al., 1998, Satterthwaite, 1997, Falkenmark and Folke, 2002). This falls within the scope of governance involving all members of society, from decision makers to the general population. Climate change and urbanisation, however, bring significant impacts on the urban governance for enhancing sustainability, due to increasing water security issues affecting social and economic aspects (Satterthwaite, 2008). This includes how to meet the needs of the present and the future considering peri-urban communities and environment (Satterthwaite, 1997), which are defined as liveability and sustainability (de Haan et al., 2014). Identifying the connections between water security, liveability, and sustainability, thus, will need a nexus thinking approach for understanding the biophysical-socio-institutional opportunities and constraints in dealing with the rapid urbanisation and climate change.

The nexus thinking approach in this study is particularly relevant for understanding the relationship between water, people, environment and climate in the context of water security, liveability, and sustainability, observed environmental change, perceptions about the change and risks, concerns on accessing ecosystem services, and the interests and practices of both communities and governments. This includes identifying adaptation supports required for the most vulnerable group concerning rapid urbanisation and climate change. For achieving sustainability, this works across urban and peri-urban communities and various governance levels, scales, and sectors within a specific geographic, social, and political context (White et al., 2017). Such an approach is required as sustainability is a systems problem requiring collaborative solutions (Fiksel, 2006).

1.2.5 Future urbanisation and climate change and impacts

The highest complexity of dealing with urban expansion will be experienced by developing countries where the greatest growth of the urban population is expected to occur (Redman and Jones, 2005). The fastest rate of urban growth will be in the medium-sized cities with a population of 1-5 million and most people will reside in smaller cities of less than 1 million (Cohen, 2006). In this study, the Cirebon Metropolitan Region (CMR) in Indonesia was selected for providing evidence. Its urban centre, Cirebon City, has a population of less than 1 million and with its surrounding areas, four districts, the population is still less than 5 million. This urban region has experienced rapid urbanisation in the past two decades showing early metropolitan development characteristics (Fahmi et al., 2014). Also, it is a developing coastal metropolitan region that has been identified as vulnerable to climate change concerning floods, droughts, and future sea level rises (Pratiwi et al., 2017, Rositasari et al., 2011).

Therefore, it is worthwhile to use the CMR as a laboratory to understand the impact of future urbanisation and climate change on the urban and peri-urban water security, liveability, and sustainability. As suggested by Redman and Jones (2005), it is crucial to not restrict our studies to the largest and most often studied megacities. Medium-sized and small urban centres should be paid more attention on the development agenda (Lundqvist et al., 2003). When compared to large cities, they make up a significantly higher portion of the overall urban population, have a faster growth rate but considerably underserved basic services, higher poverty, and weaker local government capacity (Cohen, 2006). In terms of planning, medium-sized and small cities have time to address the needs of urban residents for basic infrastructures and ecosystem services and shaping a healthy and friendly city and outskirts before the service gap and environmental degradation level become too overwhelming.

1.3 THE POSITIONING AND CONTRIBUTION OF THIS RESEARCH

This study is developed based on environmental studies and sustainability science which were found as a useful way to provide the science-based human-environment interactions using various interdisciplinary and transdisciplinary methodological approaches, that are prerequisites for understanding the underlying and emerging complexities with the interest of solving multifaceted problems (Ruth, 2015, Brandt et al., 2013, Lang et al., 2012). Water security, liveability, and sustainability are multifaceted in nature and represent dynamic interaction between humans and the environment (de Chazal, 2010, Srinivasan et al., 2017). Concerning urbanisation and climate change, the need to use a systems approach has been suggested to address the complex social and environmental issues in the emergence of sustainable development in the urban systems (Bai et al., 2016). Systems theory highlights the need for understanding inter-dependence and inter-connectedness of social and biophysical systems (Scott et al., 2015).

Massive works have been previously performed in understanding cities from a systems perspective on gaining better understanding of: the interactions between humans and the natural system (Grove and Burch, 1997, Pickett et al., 1997); resource efficiency in relationship to liveability to demonstrate the practical meaning of sustainability (Newman, 1999); the relationships between sustainability and liveability concerning ecological opportunities and constraints (de Chazal, 2010); the interconnections among urbanisation, land and water use restrictions and urban water resources (Giacomoni et al., 2013); the relationship between urbanisation and water vulnerability (Srinivasan et al., 2013); and the likely scenarios resulting from climate change impacts (Ruth and Coelho, 2007, da Silva et al., 2012). Despite this progress, the challenge is how to conceptualise a system approach in the urban system for gaining better understanding of the complex social and environmental issues in simple ways that can be easily understood by urban planners and key decision makers (da Silva et al., 2012, Ruth and Coelho, 2007), and to operationalise it in the context of water security, liveability, and sustainability.

This study explores the boundary of a metropolitan region that can be divided into city and hinterland. Further, city can be compared to its hinterland, based on the urbanisation level, to provide the background for human-environment questions (Pickett et al., 1997). The background can be called the urban-rural gradient (McDonnell et al., 1997, McDonnell and Pickett, 1990). In this study, it is called the rural-urban interfaces. A systems perspective considers cities, their rural hinterlands, and global networks of people, goods and services as inseparable and spatially linked, including the international implications of climate change on local sectors and services (Carter et al., 2015). A systems approach focuses on the linkages, interconnections, and interrelationships between different parts of a system (Campbell, 2016). For understanding urban systems, various stakeholders including their functions and responsibilities, capacity and vulnerability, power and influence, access, interests and perceptions, and the relationships between different actors need to be investigated (Campbell, 2016).

In this study, a systems approach is used to identify the linkages between urban and peri-urban areas specifically: (i) among water, people, and the environment and the trade-off between the preference and performance of ecosystem, urban, peri-urban, and human services in the context of liveability; (ii) trade-off between community demands and government services in the accessibility to water sources and services, acceptable level of water risks resulting from ecohydrological change, existing capability of ecosystem and government services, and household adaptive capacity to cope with the ecohydrological change in the context of water security; and (iii) connection between biophysical, social, and institutional opportunities and constraints and climate vis-à-vis perceptions, interests, and practices of both urban and peri-urban communities and multi-level governments in the context of sustainability.

This includes studying the interactions of many interdependent variables and exploring the underlying principles, structures, and dynamics of change as well as interdisciplinary or transdisciplinary perspectives (Ruth and Coelho, 2007, Sanders, 2008). This study is applied in complex people, water, and environmental systems in different scales that is called socio-ecohydrological systems. Focusing on systems, this study explores new ways of thinking (Sanders, 2008) as well as new ways of responding to urban issues (Campbell, 2016) concerning urbanisation and climate change, by acknowledging a city and its hinterlands within a metropolitan region as one urban system, uncertainty and complexity by using a variety of approaches, recognising change and ability to adapt with the change, and looking across responses from individual, household, local district, regional, and river basin scales.

Thus, this study contributes to the understanding of the nature-science-people relationships in the urban system and how to use such relationships and understanding for the development of urban regions that will be subjected to significant urbanisation and climate change. In particular, this study provides empirical evidence and contributes to enhancing existing tools and methodologies for understanding the complexity of socio-ecohydrological issues underpinning water security, liveability, and sustainability in the context of balanced urban development. This includes providing new definitions of i) liveability in the context of socio-ecohydrology, ii), water security in the context of water insecure regions due to socio-ecohydrological change, iii) nexus thinking in the context of changes in land use, water cycle, and climate, and iv) socio-ecohydrological systems thinking for balanced urban development.

1.4 REVIEWS OF THE CONCEPTS ADOPTED

1.4.1 WATER SECURITY

Water security has different definitions. However, the core idea underpinning water security is the need to balance human and environmental water needs (Srinivasan et al., 2017). For example, GWP (2000) defines water security as a goal where enough safe water can be accessed by any individual at a reasonable price without destroying the environment while Grey and Sadoff (2007) describe water security as available adequate water in a quantity and quality that can be accessed safely for society, the economy, and the environment including a tolerable level of water-related risk. A recent definition suggested by Scott et al. (2013b), is that water security represents sustainable available water in a quantity and quality for society and ecosystem resilience regarding the uncertainty of global changes. Along with these definitions, Spring (2011) notes that improved water security can protect populations from floods, drought and unsafe water that might affect the health of humans and ecosystems.

Water security also refers to a deepened and widened understanding of security that focuses on human beings, nature and societal processes that underlines the double characteristic of the productive and destructive potential of water (Allan et al., 2013). Supporting human life and socio-economic activities in urban regions require continuous water supply as well as high resilience against adverse impacts of floods and droughts resulting from urbanisation and climate change (Srinivasan et al., 2013, Miller et al., 2014, Jaramillo and Nazemi, 2017). The standard of water security is subject to change and varies from one place to another since trade-offs between human and environmental needs depend on societal values (Wheater and Gober, 2015). In this study, water security is defined in the context of changes in land use, water cycle, and climate that is described in more details in the research finding chapter focusing on the links between people, water, environment, and climate.

1.4.2 LIVEABILITY AND SUSTAINABILITY

While liveability and sustainability can be differentiated based on the scale, context, and potential (Gough, 2015), they are related to each other as both concepts come from the same basis of the relationships between people and the environment (de Chazal, 2010). Liveability and sustainability have risen as guiding principles for planning and policy (Ruth and Franklin, 2014). However, the standard of liveability can be different from one place to another and depends on the needs and aspiration of people in the 'here and now' while sustainability includes future needs and aspiration for a longer term of liveability (Van Kamp et al., 2003). Further, liveability is dynamic and unplanned while sustainability is about rate-independent planning (Allen, 2010). Liveability, thus, can be seen as a pure expression of values or desires while sustainability involves not only values but also the capacity to deliver those desires (de Chazal, 2010).

Further, the terms of sustainability and sustainable can be differentiated in that sustainability refers to the desired state of condition that exists over a prolonged time while sustainable suggests a process of achieving sustainability. The term "sustainable" describing the required state of a world system to satisfy basic needs for people was used for the first time by Donella H. Meadows et al. (1972) in the book of *The Limits to Growth*. Many discussions and debates have taken place to define liveability and sustainability but the two concepts are undefinable in one single definition as they are always adapting and changing (de Chazal, 2010). Specific definitions of liveability and sustainability used in this study are described in more detail in the research finding chapters per the study objectives.

1.4.3 BALANCED URBAN DEVELOPMENT

Globally, national and local governments are implementing policies to make cities more sustainable. This needs a dynamic, balanced, and adaptive evolutionary process of the interaction between the physical environmental, social, and economic aspects (Camagni et al., 1998). Ensuring balanced economic, social, and environmental sustainability now and in the medium to long-term future is still the major challenge of urban sustainability (Finco and Nijkamp, 2001). Further, ensuring a balanced rising demand for water with limited supplies is also challenging since this needs demand management strategies through a combination of behavioural, cultural, ecological, economic, institutional, and technological development (Brears, 2017). In the context of balanced urban development (BUD), more innovative research is required for formulating peri-urban policies that will make cities liveable and sustainable and are secure in terms of resources (Maheshwari et al., 2016). For understanding BUD, it needs an interdisciplinary approach (IA) for understanding interconnection between water and land, people, and the environment.

Further, BUD comprises three key themes of concerns, namely place, people and planning. The process of achieving BUD needs a transdisciplinary approach (TA) and engagement of a range of stakeholders for addressing human-environmental issues concerning the changes in land use, water cycle and climate (Maheshwari et al., 2016, Singh et al., 2016). TA refers to integration of two pathways to address "real world problems"; firstly, through the exploration of new options for solving societal problems; and secondly, through the development of interdisciplinary approaches, methods, and general insights related to the problem field (Lang et al., 2012). In this study, BUD is conceptualised by considering urban and peri-urban environments and communities and multi-level government institutions concerning planning and management for liveability, sustainability, and water security that relates to food and energy security.

1.5 RESEARCH FRAMEWORKS, METHODS, AND DESIGN

This study involves problem-solving focused on addressing dynamic interactions between people, water, and the environment in the context of changes in land use, water cycle, and climate. This is applied at different scales considering human-based and place-based approaches for understanding the complexity of impacts and responses. Different fields explaining relationships between people, water, and the environment are available in the existing literatures including ecohydrology (Falkenmark and Rockström, 2004, Zalewski et al., 2016a), hydroecology (Dunbar and Acreman, 2001), socio-hydrology (Sivapalan et al., 2012), hydro-sociology (Falkenmark, 1979), and hydro-social (Linton and Budds, 2014). In general, there are two different paradigms and epistemology differentiated between ecohydrology/ hydroecology/ socio-hydrology and hydro-sociology/ hydro-social, namely positivist/ post-positivist and constructivist and objective and subjective (Wesselink et al., 2017). This study combined those paradigms and epistemologies focusing on addressing the complex issues of people, water, and the environmental interactions for obtaining societal goals in liveability, water security, and sustainability.

This study links theory and practice that can be obtained through various methods focusing on the 'what' and 'how' of the research problems as shown in Table 1. Hence, this study puts research problems and questions as central, and emphasises the importance of trying different methods and then evaluating them based on their effectiveness, through several trial-and-error processes. Such an approach is often labeled by social scholars as a mixed-methods research (MMR) with philosophical paradigm "pragmatism" (Howe, 1988, Savin-baden and Major, 2013, Bryman, 2006, Creswell and Clark, 2011, Teddlie and Tashakkori, 2009). However, Biesta (2010) determines that pragmatism is unable to provide the philosophical foundation for MMR. Most MMR scholars would agree with paradigm "pluralism" as a starting point (Tashakkori and Teddlie, 2010, Teddlie and Tashakkori, 2012) or "integration" e.g interdisciplinary positions, diverse sources of evidence, multiple epistemologies standpoints, facts and values, quantitative and qualitative data, objective and subjective, and constructivism and postpositivism (Johnson and Gray, 2010). Pragmatism, thus, should not be understood as one philosophy among others, but rather a set of philosophical tools that can be used to address problems by integrating all the available methodological tools (Biesta, 2010, Tashakkori and Teddlie, 2010).

There are many definitions of MMR but in general, it is defined as the type of research that combines elements of qualitative and quantitative research approaches for the broad purposes of breadth and depth of understanding and corroboration (Johnson et al., 2007). MMR was applied in this study because neither a qualitative nor quantitative approach can provide a full understanding in environmental studies and sustainability science that are positioned across the natural sciences, social sciences, and humanities (Connolly et al., 2015, Folke et al., 2016, Jerneck et al., 2011). Another reason is this study needs to understand a research objective through multiple research stages (Creswell and Clark, 2011). MMR has immense potential for addressing environmental management and sustainable development issues (Molina-Azorín and López-Gamero, 2014). In this study, MMR was applied through collecting, analysing, and interpreting quantitative and qualitative social and environmental data for understanding human interactions with ecohydrological processes. This study used concurrent strategy for the triangulation of research findings across data sources, household surveys, observed environmental change data, and interviews to both urban and peri-urban communities and key informants from local/regional/river basin government institutions. These were used to validate findings, to find complementarities, and to find overlapping issues that may emerge.

Paradigms or philosophies that guide quantitative data analysis from observed historical data of land use and land cover, water availability and climate are positivism while the household survey, is post-positivism. Positivism holds positive knowledge that is based on natural phenomena and knowledge is discovered by identifying facts rather than something that is produced by humans, while post-positivism challenges the very structures of positivism, also believes in objectivity but sees the findings as probably or most likely true (Savin-baden and Major, 2013). Paradigms or philosophies that guide qualitative data analysis from the household survey, interviews to urban and peri-urban householders, and key informants from the government institutions are social constructionism. Social constructionism suggests that individuals/community construct reality with each other and knowledge may be uncovered by examining interactions and meaning-making between and among individuals/community (Savin-baden and Major, 2013).

Research framework and design of this study are shown in Figure 1.

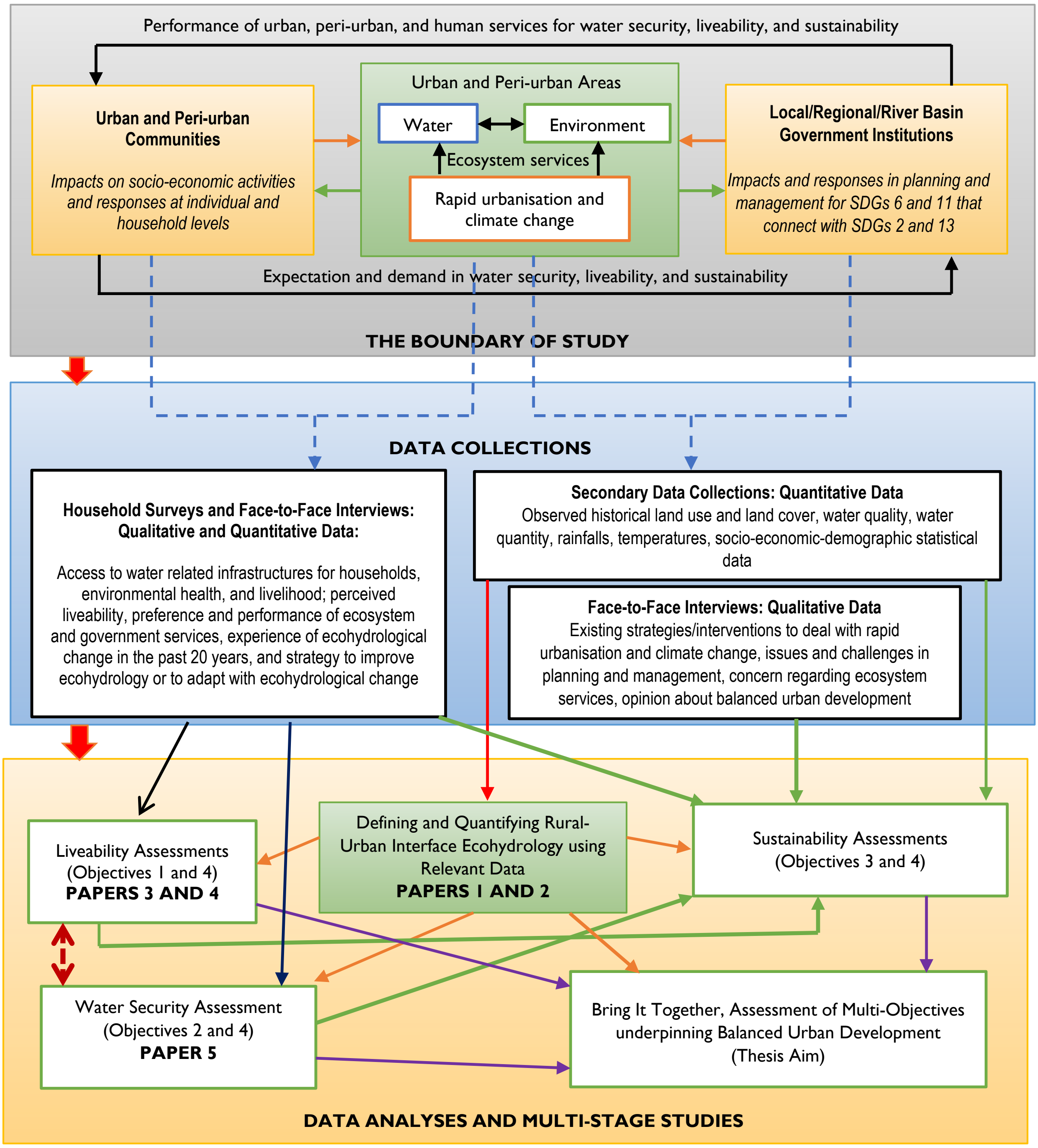

Figure 1. Research framework and design

The highlights of the framework:

This study applied MMR to provide a better understanding of research problems that involves collecting, analysing, and interpreting quantitative and qualitative data (Teddlie and Tashakkori, 2009, Creswell and Clark, 2011). This includes defining and quantifying rural-urban interface ecohydrology as the background of human-environment research questions, relating to water security, liveability, and sustainability towards balanced urban development. This study uses a systems perspective that assumes city as an ecosystem that interlinks with surrounding areas, human as an integral component, interactions between biophysical and socio-economic processes, interdisciplinary or transdisciplinary across humanities, natural and social sciences (Wu, 2008, Bai et al., 2016, Campbell, 2016). This study particularly integrates concepts and methodologies from the social sciences into ecohydrology (EH) as an integrative systemic approach to address issues surrounding water, environment, and people for sustainability objectives (Zalewski, 2004, Hiwasaki and Arico, 2007, Zalewski, 2011).

1.6 THESIS STRUCTURE

This Ph.D. thesis reports multi-stage research in the study of water security, liveability, and sustainability related to the changes in land use, water cycle and climate with evidence from the CMR. There are 10 chapters in this thesis (Table 2). Most chapters include summary, methods, results, and discussions, and concluding remarks. The materials in Chapters 3, 4, 5, 6 and 7 have been respectively published in various peer-reviewed journals: *Ecohydrology and Hydrobiology*; *International Journal of Urban Sustainable Development*; *Journal of Environmental Planning and Management, and Sustainable Cities and Society* (see list of publications and Appendix A-E). Some contents of Chapters 2, 5 and 7 have been presented in the form of posters (see list of publications). Table 2 shows the outline of the thesis.

TABLE 2. OUTLINE OF THE THESIS

Chapter	Title	Content
Chapter 1	Laying the foundation for thesis	Presents the foundation of the thesis, including research objectives and questions, rationale and significance, contribution to knowledge, key concepts adopted, and research framework, method and design
Chapter 2	Study Area, fieldwork, and ethics	Provides information of the selected area, detailed rationales behind choosing the selected area, including data collections, and research ethics
Chapter 3	Defining rural-urban interface ecohydrology	Develops a suitable methodology for defining rural-urban interface ecohydrology based on the socio, economic, and spatial data
Chapter 4	Quantifying rural-urban interface ecohydrology	Validates rural-urban interface definitions and utilises the best delineation for quantifying rural-urban interface ecohydrological state using six proxy indicators
Chapter 5	A framework for evaluating ecohydrological-based liveability	Develops a framework that can identify the interactions of many interdependent variables and explores the underlying principles, structures, and dynamics of change for evaluating ecohydrological-based liveability
Chapter 6	Assessing liveability in the context of socio-ecohydrology	Develops novel methods for assessing qualitative and quantitative perceived liveability in the context of socio-ecohydrology
Chapter 7	Evaluating the complexity of household water security issues	Develops an analytical framework to better understand socio-ecohydrological issues underpinning farm and non-farm household water insecurity
Chapter 8	The nexus of water security, liveability, and sustainability	Investigates interconnections between perceptions, interests, and practices of both urban/peri-urban communities and multi-level governments concerning climate change vis-à-vis ecohydrological changes for sustainability objectives
Chapter 9	Bring it together – Systems thinking for balanced urban development	Develops a synthesis of combining water security, liveability and sustainability for achieving balanced urban development using a socio-ecohydrological systems thinking approach
Chapter 10	Conclusions and recommendations	Describes some overall conclusions of the study and suggestions for future research

PART II
STUDY AREA, FIELDWORK, AND ETHICS

CHAPTER 2
STUDY AREA, FIELDWORK, AND ETHICS

Summary
Data for this research project, as shown in Figure 1, have been collected in the five districts within Cirebon Metropolitan Region (CMR), the West Java Province (WJP), and the Cimanuk-Cisanggarung River Basin (CCRB). This chapter provides further explanations of Section 1.2.5 about why the CMR is selected for this study. This includes the explanation of fieldworks and human ethics.

2.1 INTRODUCTION

2.1.1 WHY INDONESIA AND WHY STUDY A SMALL COASTAL METROPOLIS?

According to the World Bank (2016), Indonesia, among East Asia countries, has the third highest increase in urban areas between 2000 and 2010, after China and Japan. The estimated urban population of the country will continue to grow and by 2035 two out three Indonesians will live in urban areas (Statistics Indonesia, 2013). The number of cities in Indonesia has increased from 45 in 1970 to 98 with an average population of over 550 thousand inhabitants per municipality (Kirmanto et al., 2012). In 1971, there were only three metropolitan cities in Indonesia, namely Jakarta, Surabaya, and Bandung (Setyoko, 2011), while in 2010, total metropolitan cities have increased almost four times. In addition, Indonesia has become the third largest greenhouse gases (GHG) emitter in the world, after the United States and China, due to land use change and deforestation affecting climate change (PEACE, 2007, Jupesta, 2012). Some evidence of climate change in Indonesia: the increasing of annual mean temperatures by 0.3^{0}C, more intense rainfall in 2% to 3% with a shorter rainy season, mean sea levels increased annually from 7 mm to 11 mm (Measey, 2010, Suroso and Firman, 2018).

Many empirical studies have been carried out to study urban growth in the largest metropolitan cities in Indonesia such as Jakarta, Surabaya, Bandung, and Semarang (Firman, 2004, Firman, 2009, Firman, 2003, Firman, 1996, Handayani and Rudiarto, 2014, Setyoko, 2011). These studies suggest that population growth in the fringe cities of the metropolitan region is much higher than in their core city (Gany, 2003, Firman, 2004). Furthermore, the proportion of population in the core city to the total metropolitan population declined due to rapid population growth in the border cities. A smaller city, Cirebon Municipality (CM) shows a similar trend to those larger cities. Urban development patterns of CM and its peripheral area, Cirebon Regency (CR), have shown demographic changes in the past two decades, suggesting CR as the main area of urbanisation in the region (Fahmi et al., 2014). Urban development and agglomeration in the fringe areas of CM have played an extensive role in the Cirebon economy leading to Cirebon being recognised as a new metropolitan region. It has been regulated in the West Java Provincial Regulation No 12/2014 that CM and its fringe areas CR, Kuningan Regency (KR), Majalengka Regency (MR) and Indramayu Regency (IR) are within the boundary of the Cirebon Metropolitan Region (CMR).

Megacities will no longer be acceptable for future urban living and people are more likely to live in medium and smaller cities (Fahmi et al., 2014, the World Bank, 2011). As highlighted by Cohen (2006), the majority of urban dwellers will live in towns and cities with fewer than 500,000 inhabitants. Peripheral cities are expected to urbanise further and experience a more rapid population growth compared to the core cities (Firman, 2004, Asian Development Bank, 2006). In Indonesia, this can be seen in the fringe cities of Jakarta such as Bogor, Tangerang, and Bekasi (Firman, 2004, Goldblum and Wong, 2000, World Bank, 2015). However, economic development in Jakarta has brought some adverse impacts to the environment which diminishes the city's liveability and sustainability (Steinberg, 2007). More people prefer to stay living in the peripheral cities of Jakarta. In addition, climate variability has made the City of Jakarta more vulnerable to flooding and sea level rise disasters (Firman et al., 2011). All these studies have noticed the expansion of urban areas and various environmental problems associated with cities. However, assessments in water security, liveability, and sustainability concerning urbanisation and climate change in the urban and peri-urban areas have yet to be researched. Concerning these facts, the urgency of doing research in planning to minimise the adverse impact of urbanisation and climate change in a smaller city and peri-urban areas will be significantly important to achieve future balanced urban development.

2.1.2 Why study the Cirebon Metropolitan Region?

Urbanisation is a global demographic transition that has massive consequences on the economy, society, and the environment. However, these are yet to be fully understood and need more scrutiny with detailed data at local and regional scales (Wu, 2014). The metropolitan region provides a basis for facilitating interactions and integration among biophysical, socioeconomic, planning, and management towards urban sustainability (Wu, 2008). Dealing with the problem of urban sustainability cannot be done by focusing on individual cities due to the important interactions and constraints of the cities with their surrounding areas; while focusing on the global urban system to study the sustainability of a particular city will also generate impractical outcomes due to a lack of details (Wu, 2008). Thus, for this study, the Cirebon Metropolitan Region (CMR) was selected for understanding urban sustainability concerning SDGs 6 and 11.

Below are several reasons for selection of this study area:

First, the CMR is a metropolitan region in a developing country with a population of the core city, CM, at approximately 300,000 residents (BPS-Statistics Jawa Barat, 2014). CM, together with the CR, KR, MR, and IR will play an important role in the future urban development of the CMR (WJP-MDM, 2013a).

Second, the CMR is a new metropolitan region that is currently receiving more attention from the local, regional, and river basin development planning authorities. There is the potential to get comprehensive views from different level authorities regarding balanced urban development. The river basins where the CMR is located have been identified as being vulnerable to water security issues (Deltares et al., 2012). Rapid urbanisation and climate change are expected to place more pressure on the liveability of such environments which could hamper longer-term objectives to ensure sustainable urban development.

Third, the CMR experienced a rapid change in land use in the past two decades which has the potential for more understanding about its impacts on the liveability of people in the urban and peri-urban areas. Rapid population growth, urbanisation, and climate change have affected urban and peri-urban residents in the CMR through various demographic, ecological, and hydrological changes (Fahmi et al., 2014, Pratiwi et al., 2016, Nitivattananon et al., 2013, Rositasari et al., 2011, Oktriani et al., 2017).

Four, the CMR is located in the north-eastern coast of West Java which is remarkably prone to flooding during the rainy season and drought in the dry season (Directorate General of Water Resources Development, 2010). Currently, flooding and drought disasters are still the major challenges of water management in the CMR which provide an opportunity to understand more about the concerns of water security, liveability, and sustainability.

Last, regarding the future metropolitan development of Cirebon, this coastal region might face more critical situations related to water security, liveability, and sustainability.

2.2 THE FOCUS AREA OF THE STUDY

2.2.1 THE CIREBON METROPOLITAN REGION

This study area is located in the north-eastern part of West Java. Specifically, it is situated between latitude 6^0 30' and 7^0 44' S and longitude 108^0 03' and 108^0 48' E. Five local governments at the district level are involved in the CMR - CM, CR, KR, MR and IR as shown in Figure 2. The total area of the five districts is approximately 3,426 km^2. The CMR covers 32% of this area and is situated between 0 and 857 metres above sea level (Regional Development Planning Board of West Java Province, 2015). The centre of the CMR is CM, a medium size city with a total population of around 300 thousand people. The boundary area of the study covers 45 sub-districts and 483 villages with a population of around 1.6 million people. More than 50% of the population of CMR live in the lowland areas, concentrated in the CM and CR. Five sub-districts are in the CM, 31 sub-districts in the CR, five sub-districts in the KR, three sub-districts in the MR, and one sub-district located in IR. Three out of five political boundaries (CM, CR and IR) are situated in the coastal area, while the rest (KR and MR) are situated in the inland area.

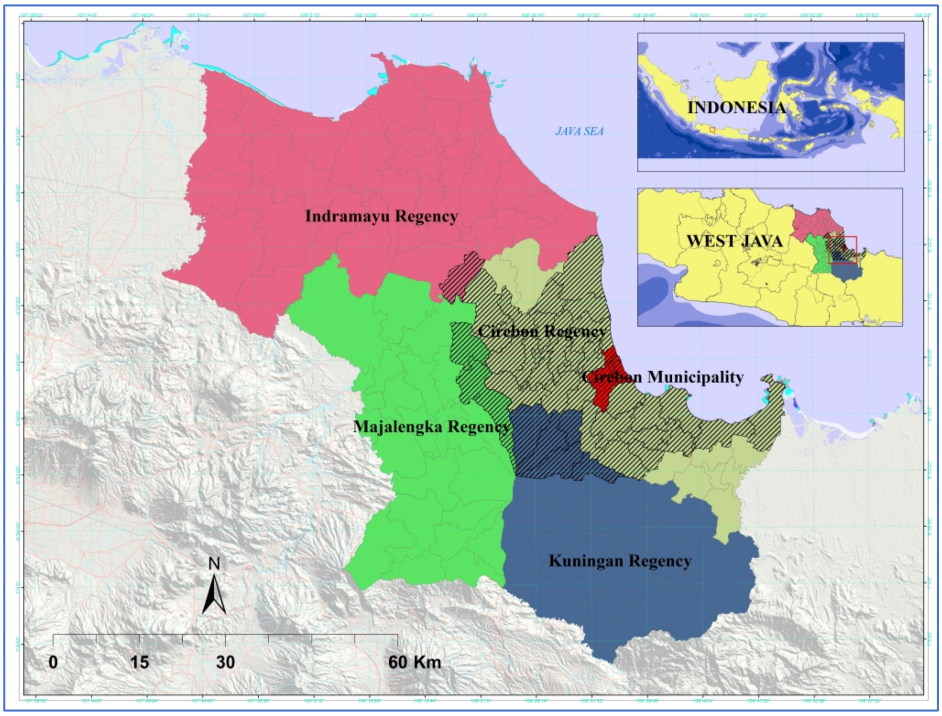

FIGURE 2. MAP OF THE STUDY AREA

Note: the hatched area on the map shows the development areas of CMR

2.2.2 THE CIMANUK CISANGGARUNG RIVER BASIN

The Cimanuk Cisanggarung River Basin (CCRB) is located at 107° 42' 51.02" - 108° 54' 31.38" East Longitude and 6° 14' 43.96" - 7° 23' 56.03" South Latitude, crossing boundary of two provinces, West Java and Central Java, and crossing boundary of eight districts, Garut Regency, Sumedang Regency, CM, CR, MR, KR, IR, and Brebes Regency. The CCRB is under the management authority of national-level government. The CCRB consists of 25 watersheds with total area 7,727.09 km^2. The main watersheds are Cimanuk and Cisanggarung that respectively cover 48.52% and 12.94% from the total area of CCRB.

The CMR is situated in the downstream areas of the CCRB (Figure 3). Cimanuk River is the main source of irrigation water in the CR, IR, and MR while Cisanggarung River is the main source of irrigation water in the CR and KR. A relatively good recording of historical data in meteorology with long-term observation periods are available so it was selected as a focused-study to assess such historical data of water availability and climate. Cimanuk River which covers 3,749.25 square kilometres forms the second largest river in West Java Province (WJP) after Citarum River. According to Resosudarmo (1977), due to the long dry season typical of the Cirebon area, the east monsoon discharges of the Cimanuk River are very low while the west monsoon discharges frequently arrive very late.

CR and IR, as a part of the CMR, are recognised as having major agricultural areas. Together with other districts in the northern plains of West Java such as Karawang and Subang, CR and IR have a function as the rice bowl for WJP and Indonesia. There is Rentang Irrigation System in the lowland of the Cimanuk River covering agricultural areas of about 91,000 hectares. However, farmers in the MR, CR, and IR frequently experience drought issues. The effort to solve this issue has taken place by constructing the Jatigede reservoir to secure water, food, and energy, but until 2019 it has not been fully operationalised. On the other hand, Cisanggarung River which covers 1,000.24 square kilometres has had the Darma reservoir since 1962 to secure an irrigation supply in the dry season (Plate 1).

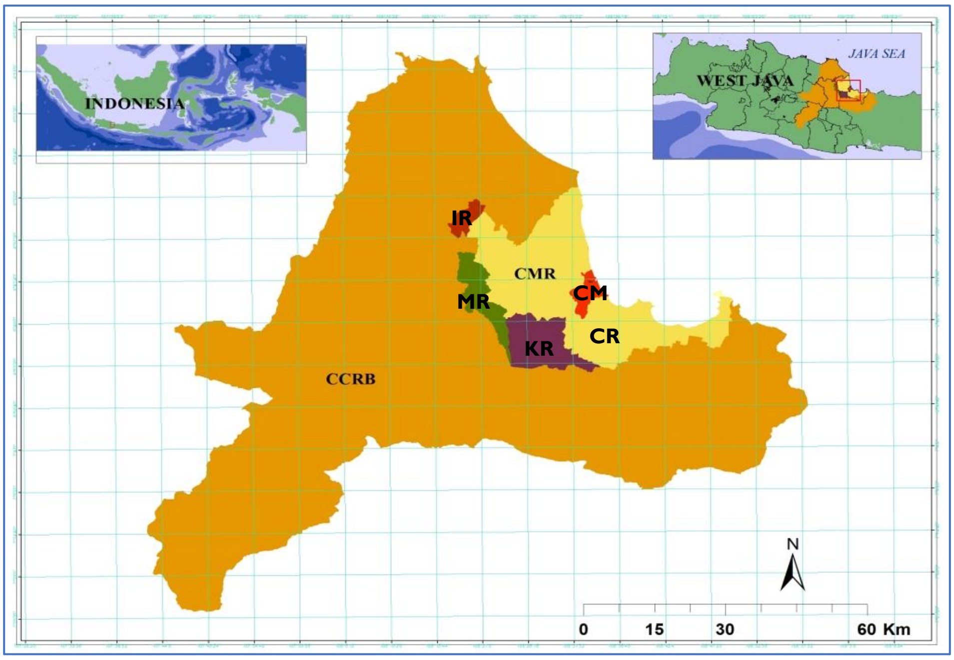

FIGURE 3. LOCATION OF THE CMR WITHIN THE CCRB

PLATE 1. DARMA RESERVOIR

2.3 DETAILED FIELDWORKS

I conducted the fieldworks in three stages. First stage was preliminary fieldwork in December 2015 for informal meetings with key contacts contacted via email or Skype during research proposal preparations. This initial fieldwork was useful to identify the key organisations for study and key persons who could assist with the household surveys, from local NGO and university. Second stage was main fieldwork for primary and secondary data collections in February-July 2016. Last stage was additional fieldwork to update secondary data in January-February 2018.

2.3.1 PRIMARY DATA COLLECTION

Primary data collections included household surveys and face-to-face interviews with 430 householders in the CMR and 43 key informants from 32 government agencies under different sectors and levels (Tables 3 and 4).

TABLE 3. SOCIO-DEMOGRAPHIC FEATURES OF RESPONDENTS

Attributes	Parameter	Percentage from total 430 householders (%)
Place in five districts within CMR *(political boundaries)*	CM	22.6
	CR	49.5
	IR	7.0
	KR	14.0
	MR	7.0
Gender	Male	60.7
	Female	39.3
Occupation	Farmer	52.3
	Non-Farmer	47.7
Length Stay	≤ 30 years	36.7
	More than 30 years	63.3
Distance from the coast	≤ 10 km	48.4
	More than 10 km	51.6
Household size	≤ 3 persons	25.9
	4-6 persons	61.7
	More than 6 persons	12.4
Total participants in each type of occupation		**100**

TABLE 4. KEY INFORMANTS AND THEIR ROLES IN PLANNING AND MANAGEMENT

Government level/ The scale of P&M	Total Institution	Total participants	Role (total participants)	Location (the number of research participants)
National/ River basin	1	2	Programme planning and evaluation of river basin management (1) Operation and Maintenance (1)	Cirebon, CCRB under the Ministry of Public Works (2)
Provincial/ Regional	3	3	Land use policy and spatial planning (1) Human settlement infrastructures (1) Programme planning and evaluation of water resource management (1)	Bandung, WJP (3)
District/ Local	28	38	Land use policy and spatial planning (10) Urban drinking water services (5) Environmental protection, non-physical (5) Food production/Agriculture (4) Water resource management/irrigation (6) Environmental protection-physical, human settlement infrastructures (7) Programme planning and evaluation of human settlement infrastructures (1)	District governments: CM (7) CR (6) KR (7) MR (7) IR (11)
Total	**32**	**43**		

Note: P & M is Planning and Management

2.3.1.1 HOUSEHOLD SURVEYS AND FACE-TO-FACE INTERVIEWS WITH URBAN AND PERI-URBAN COMMUNITIES

For sampling purposes in the CMR, the surveys were organised for 65 villages within 25 sub-districts that were chosen after consultation with the Local Development Planning Authorities (BAPPEDA). Sampling location for household surveys and face-to-face interviews is shown in Figure 4.

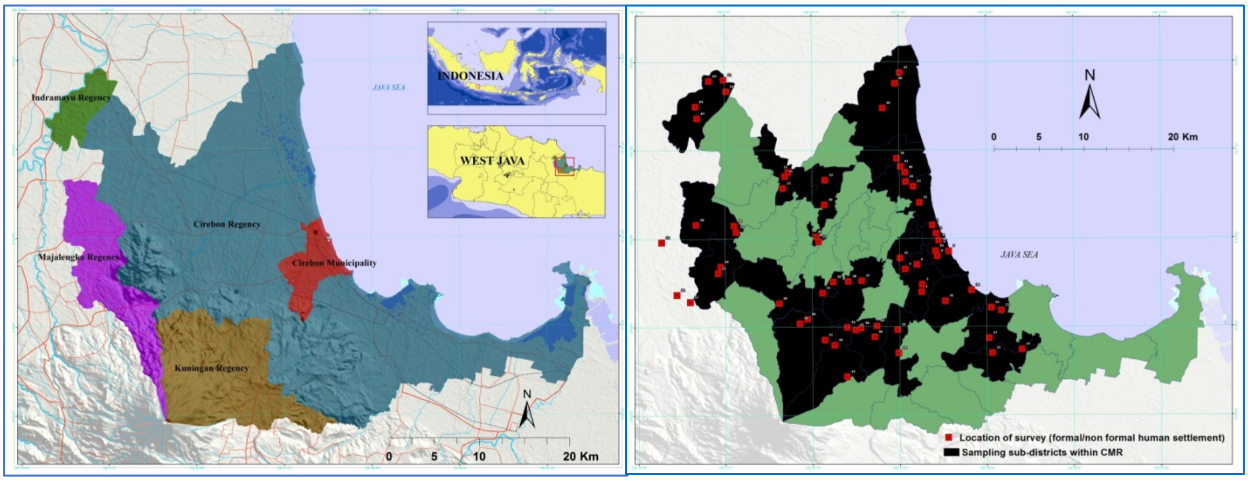

FIGURE 4. MAP OF CMR AND RURAL-URBAN HOUSEHOLD SURVEY IN THE CMR

The 430 respondents were selected through three stages: First, consultation at the district level to identify the sub-districts experiencing the impacts of ecohydrological change; Second, consultation at the selected sub-districts, representing various distances from the coast, to identify villages experiencing water issues and potential sampling areas; Third, a field trip at the village level to apply a random walk method in different directions from the village head office, as a starting point. I was helped by three-trained enumerators for the household surveys.

Interviews were conducted at the same village at any given time, with the enumerators approaching different homes at different directions from the starting point. The survey aimed to grasp the diverse experiences of communities regarding the change of socio-ecohydrological aspects (Figure 1). The fieldwork sites in the CMR range from coastal areas to mountainous areas (Plate 2).

PLATE 2. SURVEYED URBAN AND PERI-URBAN SOCIO-ECOHYDROLOGY

Note: a, b coastal areas in CR; c, d coastal areas in CM; e, f mountainous areas in KR

Only one household was selected randomly at one point. The second household was selected randomly at a further distance from the starting household. If the second householder provided relatively similar responses as the first householder, the survey moved to another village. In the case of scattered areas, we were assisted by a local guide to be shown the paths leading to households.

Example household surveys and face-to-face interviews are shown in Plate 3. In general, the surveys and interviews with the rural householders were relatively easier to conduct than those with the urban householders in terms of the availability of people and their time.

PLATE 3. FACE-TO-FACE INTERVIEWS WITH THE HOUSEHOLDERS

Women respondents in several surveyed households were not confident to conduct the interview alone and they called their neighbours in. While the information of household access to water and sanitation infrastructures concerning their homes was obtained from them, the information of changes in land use, water cycle, and climate surrounding their homes, was obtained based on their agreements with neighbours. In the several surveyed rural areas, women respondents also responded to the interviews while they were washing clothes and washing raw fish on the rivers in front of their homes (Plate 4).

PLATE 4. WOMEN RESPONDENTS DURING THE INTERVIEWS

In addition, we did some interviews outside homes. Most paddy farmers were not at home in the morning while most fishermen were not at home in the evening. Hence, some interviews of the farmers were conducted at the rice fields while interviews of the fishermen were conducted on boats when they took a break from work (Plate 5).

PLATE 5. FACE-TO-FACE INTERVIEWS WITH FARMERS AND FISHERMEN

2.3.1.2 FACE-TO-FACE INTERVIEWS WITH KEY INFORMANTS IN PLANNING AND MANAGEMENT

I interviewed key informants from different level government institutions face-to-face. These interviews took three steps to arrange. First step, I submitted all necessary research documents including cover letters requesting an interview, the list of questions, recommendation letters from the WSU and the Indonesian Ministry of Home Affairs, permission letters to conduct the interviews from the Office of Political and National Unity of WJP and respective district governments, CM, CR, KR, MR, and IR, and participant consent forms. Second step, I arranged the schedules with the key informants endorsed by the selected government institutions. Third step, I conducted an in-depth semi-structured interview with the representatives of 32 government institutions. The government institutions included in the interviews are listed in Table 5.

TABLE 5. LIST OF GOVERNMENT INSTITUTIONS INCLUDED IN THE INTERVIEWS

No	Code	Name	Level/scale In P & M	Total	Position	Role	Location
1	K01	BBWS Cimanuk-Cisanggarung	National/ River Basin	2	DHs	Programme and Planning for River Basin Management; Operation and Maintenance	Cirebon
2	K02	BAPPEDA JABAR	Province/ Regional	1	PL	Regional Planning	Bandung
3	K03	DISKIMRUM JABAR	Province/ Regional	1	PL	Drinking Water and Sanitation Planning	Bandung
4	K04	DPSDA JABAR	Province/ Regional	1	SDH	Programme Planning of Water Resource Management	Bandung
5	K05	DPUPESDM Kota Cirebon	District/ CM	3	SDHs	Water Resource Management; Spatial Planning; Environmental Governance	Cirebon
6	K06	PDAM Kota Cirebon	District / CM	1	DH	Research and Development of Urban Drinking Water Supply and Sanitation	Cirebon

7	K07	BAPPEKO Cirebon	District/ CM	2	SDH; DH	Development of Urban Area and Living Environment; Physical Infrastructures and Environment	Cirebon
8	K08	KLH Kota Cirebon	District/ CM	1	SDH	Conservation and Rehabilitation (Environmental Protection)	Cirebon
9	K09	DPSDAP Kabupaten Cirebon	District/ CR	1	DH	Irrigation	Cirebon
10	K10	BAPPEDA Kabupaten Cirebon	District/ CR	1	SDH	Spatial planning and Environmental Protection	Cirebon
11	K11	DISTANBUNAKHUT Kabupaten Cirebon	District/ CR	1	SDH	Agricultural Production Infrastructures	Cirebon
12	K12	BLHD Kabupaten Cirebon	District/CR	1	SDH	Controlling and Rehabilitation of Environmental degradation	Cirebon
13	K13	PDAM Kabupaten Cirebon	District/CR	1	DE	Urban Drinking Water Supply	Cirebon
14	K14	DCKTR Kabupaten Cirebon	District/CR	1	DH	Land Use and Spatial Planning	Cirebon
15	K15	DSDAP Kabupaten Kuningan	District/KR	2	DH; SDH	Irrigation; Water Resources Conservation	Kuningan
16	K16	DLH Kabupaten Kuningan	District/KR	1	DH	Environmental Conservation	Kuningan
17	K17	BAPPEDA Kabupaten Kuningan	District/KR	1	SDH	Living Environment	Kuningan
18	K18	Dinas Pertanian Kabupaten Kuningan	District/KR	1	SDH	Programme Planning and Evaluation	Kuningan
19	K19	DTRCK Kabupaten Kuningan	District/KR	1	SDH	Clean Water Supply	Kuningan
20	K20	PDAM Kabupaten Kuningan	District/KR	1	Secretary; SO	Urban Drinking Water Production and Quality	Kuningan
21	K21	DBMCK Kabupaten Majalengka	District/MR	2	SDHs	Housing and Spatial Planning	Majalengka
22	K22	DISTANNAK Kabupaten Majalengka	District/MR	1	DH	Food Crops	
23	K23	BAPPEDA Kabupaten Majalengka	District/MR	1	PL	Physical Infrastructure Planning	Majalengka
24	K24	BPLH Kabupaten Majalengka	District/MR	1	DH	Conservation of Living Environment	Majalengka
25	K25	DPSDAPE Kabupaten Majalengka	District/MR	1	SDH	Water Resource Management	Majalengka
26	K26	PDAM Kabupaten Majalengka	District/MR	1	D/HO	Urban Drinking Water Supply	Majalengka
27	K27	BAPPEDA Kabupaten Indramayu	District/IR	2	DH, SDH	Physical Infrastructures; Spatial and Environmental Planning	Indramayu
28	K28	DPSDA TAMBEN Kabupaten Indramayu	District/IR	1	SDH	Improvement and Rehabilitation of Irrigation Schemes	Indramayu
29	K29	BLH Kabupaten Indramayu	District/IR	1	DH	Environmental Governance	Indramayu
30	K30	PDAM Kabupaten Indramayu	District/IR	1	DH	Research and Development in Urban Drinking Water Supply	Indramayu

31	K31	DCK Kabupaten Indramayu	District/IR	5	SDHs	Housing; Spatial Planning; Rural Drinking Water Supply; Programme Planning and Evaluation; Environmental Health	Indramayu
32	K32	DISTANNAK Kabupaten Indramayu	District/IR	1	SO	Food Crops	Indramayu
				43			

Note: K=Key informants, P & M= Planning and Management, D/HO=Director/Head Office; DE=Director of Engineering; DH=Division Head, SDH=Sub-Division Head, PL=Planner, SO=Senior Officer, the abbreviation of the name of institutions can be seen the List of Abbreviations.

Interview data was collected from selected government organisations because of their specialised roles in planning and managing human settlement infrastructures, water, food, and the environment, and their noticeable role in the CMR for sustaining water security and liveability. The interviews with different level government institutions allows me to gain better perspectives on how they perceived each other in terms of responsibility and capacity in planning and management for sustaining water security and liveability. The questions in the interview questionnaires were aimed to provide general guidance for collecting data as shown in Figure 1.

2.3.2 SECONDARY DATA COLLECTION

In addition to the primary data, secondary data of socio-demographic statistical data, historical changes in land use, water availability, and climate were collected from government institutions. Statistical data were obtained from the local statistic agencies. Land use and land cover maps for 2005 and 2014 were obtained digitally from the WJP Development Planning Boards to see the changes in built-up, forest and semi-natural areas. Evaluation of a historical number of farm households and size of farmlands was made based on the available agricultural census in 2013. Historical data of monthly rainfalls, river discharges and river water quality were collected from the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) and the River Basin Organisation (RBO), namely Balai Besar Wilayah Sungai (BBWS) and Balai Pengelolaan Sumber Daya Air (BPSDA)-Wilayah Sungai (WS) Cimanuk-Cisanggarung.

2.4 RESEARCH ETHICS AND REFLECTIONS

Ethics approval for the interviews with both community and government representatives was granted on 18th January 2016 by the Western Sydney University (WSU) Human Research Ethics Committee with the approval number [**H11417**]. The survey was also conducted after obtaining research recommendation letters from the WSU and the Indonesian Ministry of Home Affairs. Further, permission letters from the WJP and the District Governments of CM, CR, KR, MR and IR were granted by the Political and National Unity Offices, known as KESBANGPOL.

The key issues that I had to verify in my research ethic include more information on the context of the research project such as why Indonesia and the CMR, what specific problems or otherwise it encounters regarding sustainability, water security, and liveability, the relationship between the datasets/questions and the research outcomes, and how the different components relate to the research questions. Despite the ethics approval, the WSU Human Research Ethics Committee suggested that more thought on how the different components of information might link up would help focus the research with a more theoretical framework.

I understand that these questions were asked by the WSU Human Research Ethics Committee due to the complexity of the research problems that seemed to be studying three wicked problems. At that time, they did not find well-defined theoretical frameworks to link the questions and the expected research outcomes to understand water security, liveability, and sustainability issues and challenges in the context of changes in land use, water cycle, and climate, and how to use such information for achieving balanced urban development.

I started this research project with the interest in planning for sustainable water use in the context of urbanisation and climate change. This is not only because my professional background is a development planner relating to the water sector, but also because my educational background is in water science and engineering, environmental management in the lowland areas, and environmental engineering all of which closely related to the water sector and to the environment of human settlements.

At that time, my understanding of the research issues was still fragmented to the water sector, positivist/post-positivist approach, engineering solutions, and limited experiences in assessing qualitative data. I initially focused on analysing data through the Water Evaluation and Planning System (WEAP) (Stockholm Environment Institute, 2015). WEAP is a window-based decision support system for assessing integrated water resources management and policy analysis to create a simulation of water demand, water supply, climate data, land use, technology, and socio-economic factors.

However, the household surveys and face-to-face interviews, with both urban and peri-urban communities and key informants from the multi-level government institutions, opened my eyes in that I have to find effective approaches for assessing the collected data to enable me to understand the complexity of water security issues and impacts on liveability in the urban and peri-urban areas. Modelling approaches such as WEAP will not provide a holistic understanding of the subjective concepts such as liveability and water security that should encompass human values.

This study follows the concept of balanced urban development which is defined by Maheshwari et al. (2016) as a concept of sustainable development that is linked to the liveability of urban areas, along with water, food, and energy security. This concept needs an interdisciplinary approach for understanding interconnection between water that connects with food and energy, people, and the environment. This concept also needs the understanding of place, people and planning through the development of the various planning tools and models that help the analysis and visualisation of different options and scenarios that needs a transdisciplinary approach. However, it is not clear in the methodology required for assessing those links. For a novice researcher like me, the way for understanding this concept in practice is quite challenging and needs high resilience in finding a stronger analytic and scientific underpinning of the concept to bring together scholarship and practices.

In the process of analysis for assessing liveability, water security, and sustainability, I faced several difficulties in using the existing concepts and approaches which do not really fit with the context of the study. These include (i) defining peri-urban, (ii) finding strong theoretical background for understanding dynamic interactions between water, people, and the environment concerning urbanisation and climate change, and (iii) finding suitable frameworks for combining quantitative and qualitative data analyses, and apply them for assessing water security, liveability, and sustainability. So, I had numerous trials and errors in the process of finding the best analytical frameworks to assess water security, liveability, and sustainability with respect to balanced urban development.

At the beginning of this study, I considered an interdisciplinary approach with ecohydrology as the framework. Ecohydrology is useful to define the peri-urban area concerning the interplay between water, people, and the environment and for understanding ecohydrological processes by using proxy indicators deriving from available socioeconomic and spatial data. However, the approach focusing on the objective data is not fit for assessing liveability, water security, and sustainability. These three concepts need more understanding of subjective data for understanding dynamic interactions between people and the environment. Then, I considered other interdisciplinary approaches, hydrosocial and socio-hydrology. I combined these two approaches. They are useful for obtaining a holistic understanding of regional water security issues. However, they are too complicated in practice for understanding the variability of household water security issues.

For assessing household water security, I developed a socio-ecohydrological systems thinking and comparing unidimensional and multi-dimensional scale analyses for understanding the complexity of household water security issues in the context of changes in land use, water cycle, and climate. For assessing liveability in the context of socio-ecohydrology, I developed analytical frameworks for understanding the trade-off between the preference of liveability services and performance of liveability services incorporating ecosystem, urban, peri-urban, and human services and for evaluating ecohydrological-based liveability in different urbanisation levels. For assessing sustainability, I explored the people-water-land-environment-climate nexus. This includes finding interconnections between the perceptions, interests, and practices concerning observed ecohydrological change data, urban/peri-urban communities, and multi-level governments towards sustaining water security and liveability.

I learned about the need for finding a strong theoretical background for each stage of analyses based on the responses of journal editors/reviewers. While papers 1-5 have been accepted after having major revisions, I experienced several rejections for papers 6 and 7 after spending almost two and a half years researching, continuously adding more data and analyses, and trying several frameworks to understand the complexity. It took time for me to present the key messages concerning climate change adaptation and sustainable developments goals (SDGs) 6 and 11, how they are related and whether combining them will provide opportunities for finding suitable adaptation supports for enhancing sustainability. Also, it took time for me to find suitable framework and methods for assessing balanced urban development for water security, liveability, and sustainability that involve SDGs 6 and 11 and their links to SDGs 2 and 13.

Despite this issue, the whole PhD journey and research experiences in this study have been immensely rewarding. Chapter 1, Laying the Foundation for Thesis, is my current understanding of the research issues based on the experiences in finding suitable frameworks for assessing water security, liveability, and sustainability in the context of changes in land use, water cycle, and climate. Research objectives and questions that were highly specific focused on the study area were reorganised (Table 6). Specific focused data related to CMR were useful during data collection. However, during data analysis, I considered the suggestions from the WSU Human Research Ethics Committee to make links between different information on datasets for helping the focus of the research with a more theoretical framework. This includes thinking for possible replicability of the assessment methods for other urbanising coastal regions with similar situations.

TABLE 6. LEARNING PROCESS PRE-FIELDWORK VS POST-FIELDWORK

Research Aspect	Pre-Fieldwork and Data Collection	Post-Fieldwork and Data Analysis
Aim	To understand future water security, sustainability and liveability issues and challenges of urban and peri-urban areas of the Cirebon region in Indonesia and develop decision support tools that will assist in planning sustainable water use under significant urbanisation and climate change	To better understand socio-ecohydrological factors underpinning liveability, water security, and sustainability towards balanced urban development (BUD) in the context of significant changes in land use, water cycle and climate of the coastal urban region
Objectives	1. To assess the impact of urbanisation and climate change in the Cirebon region on land use, water availability and water demands; 2. To understand the views and needs of local communities, local and central government agencies and other stakeholders in achieving sustainable water futures while improving liveability and eco-hydrological function of the region; 3. To develop tools and methodologies to assist in strategic planning that integrates physical, social, economic and environmental factors in urban development and planning vis-à-vis water security in the Cirebon region.	1. To assess the impact of ecohydrological changes resulting from urbanisation on liveability and to identify socio-ecohydrological factors underpinning urban and peri-urban liveability; 2. To identify and evaluate socio-ecohydrological issues and factors affecting water security concerning urbanisation and farm/non-farm households; 3. To examine sustainability challenges for enhancing urban and peri-urban water security and liveability concerning urbanisation and climate change; 4. To develop suitable frameworks and assessment tools to assist in balancing urban development and sustainability of urban centres, concerning the changes in land use, water cycle, and climate.
Guiding Research Questions For a PhD thesis	What strategic planning options do we have to achieve balanced urban development in the context of significant changes in land use, water cycle and climate of the region?	What strategic options do we have to solve socio-ecohydrological issues underpinning liveability, water security, and sustainability towards BUD concerning the changes in land use, water cycle and climate?
Specific Research Questions	1. How are rapid urbanisation and climate change scenarios going to impact on the ecohydrology of the Cirebon region? 2. What factors will determine future sustainability and liveability of the Cirebon region? 3. How is the quality and quantity of water in the Cirebon municipality impacting sustainability and liveability of the region and what can be learnt from it for future planning and urban development of the region? 4. What are the perspectives of local stakeholders on water, food production and related ecosystem services of the region? 5. What is the relationship between the ecohydrological functions of the urban and peri-urban areas of Cirebon region and the urbanisation, sustainability and liveability of the region? 6. How do we integrate ecohydrology, liveability and sustainability approaches in the strategic planning of the Cirebon region so that it will achieve water security?	1. What are the impacts of ecohydrological changes resulting from urbanisation on liveability? What are the socio-ecohydrological factors underpinning urban and peri-urban liveability? 2. What are the socio-ecohydrological issues and factors affecting urban and peri-urban water security concerning urbanisation and farm/non-farm households? 3. What can we learn from questions 1 and 2 combined with the climate change perception and risks to enhance adaptation supports for sustaining water security and liveability? 4. How to develop suitable frameworks and assessment tools for the questions 1, 2, and 3 to assist in balancing urban development concerning the changes in land use, water cycle, and climate?

PART III
LITERATURE REVIEWS, KNOWLEDGE GAPS AND EVIDENCE

CHAPTER 3

DEFINING RURAL-URBAN INTERFACE ECOHYDROLOGY

Danielaini, T. T., Maheshwari, B., & Hagare, D. 2017. Defining rural–urban interfaces for understanding ecohydrological processes in West Java, Indonesia: Part I. Development of methodology to delineate peri-urban areas. Ecohydrology & Hydrobiology, 18(1), 22-36. doi: 10.1016/j.ecohyd.2017.11.006

Summary

This chapter provides a methodology for defining rural-urban interface ecohydrology using 11 socio, economic, and spatial variables directly or indirectly related to ecohydrology. Several data analysis techniques were used including multivariate, univariate, and multiple univariate. Based on different classification methods and clustering techniques, eight regional classifications of rural-urban interfaces were proposed and evaluated. The results were mapped by combining Geographic Information System and statistical methods. The results indicate that with the variable included, the multiple univariate clusters using Jenks natural breaks and scoring provides more accurate rural-urban definitions for delineating the peri-urban area. The result of this chapter is required for the background of the following chapter analyses.

3.1 INTRODUCTION

The clear separation between urban and rural has become an essential feature of census systems all over the world and it is used for planning and management approaches. Some Asian countries, such as Thailand, Malaysia, Nepal and Cambodia use an administrative approach to designate places as urban areas, while the Philippines and India adopt mixed administrative and functional criteria (Jones, 2004). Further, there is no global standard or thresholds to classify rural-urban interface environments and even in one single country, urban has been defined in various ways over time. In Ethiopia, Liberia, Spain and Bolivia, for instance, all localities with 2,000 inhabitants or more are defined as urban, while in Sudan, India, and Austria only localities of 5,000 or more are classified as urban (United Nations, 2005). However, the distinct rural-urban interface approach on the census could not sufficiently classify the new settlements in the rural hinterlands resulting from peri-urbanisation. The fact that the difference between urban and rural areas is increasingly blurred is a testament to the confusion associated with the concept of the urban and rural dichotomy (Champion and Hugo, 2004, Tacoli, 1998). The forms of settlement from the extended metropolitan regions include specific features which are not effectively captured in the established dualistic approach of urban and rural (Jones, 2004). This indicates the need to develop new settlement classifications.

Several new classification systems have been proposed in the global context to describe human settlement structures beyond the rural-urban interface dichotomy (Coombes and Raybould, 2001, Dünckmann, 2009, Hugo et al., 2001, Öğdül, 2010, Camaioni et al., 2013, Wandl et al., 2014) but the definitions are diverse. It is impractical to propose a universal standard as different processes of peri-urban development. For instance, peri-urbanisation in developing countries is linked with rural urbanisation, rural-urban migration, and a mixture of agricultural and non-agricultural activities while peri-urbanisation in developed countries is related to urban wellbeing and welfare (Woltjer, 2014). The increasing movement of population to urban centres brings a number of critical challenges affecting peri-urban areas from urban expansions, such as poor sanitation facilities and public health (Singh and Maheshwari, 2014b). Further, in developing countries, population increase is taking place in the growing urban and peri-urban areas that has resulted in serious water pressures, poor water management and severe non-point source pollution (Akissa, 2001). However, current rural-urban interface classifications still focus on spatial planning purposes with little recognition of ecohydrological aspects.

Ecohydrological consideration in planning and management provides an opportunity to cope with the changes in land use, water cycle, and climate, and to create systemic solutions of problems that are integrative and interdisciplinary in nature for understanding the interactions between water, people, and the environment (Wagner and Zalewski, 2009, Zalewski and Wagner, 2008, Zalewski et al., 2008, Sohel, 2015). In particular, Ecohydrological considerations can allow transdisciplinary framework for understanding the problem and implementing the solutions that will enhance environmental sustainability (Zalewski, 2011), including near and within urban areas (Janauer, 2005). In the perspective of ecohydrology, there are three methodological principles for sustainable water ecosystem and societies covering information for understanding structure, states and relationship; knowledge for understanding pattern and processes; and wisdom for using information and knowledge for problem solving (Zalewski et al., 2010, Wagner and Zalewski, 2012, Zalewski, 2011, Zalewski, 2002b, Zalewski et al., 2009):

1. Hydrology - quantification of hydrological cycle analysis from the perspective of socio-economic, spatial, and temporal dynamics with respect to the various forms of human impact;
2. Ecology - analysis of the distribution of various types of interacting organisms living together in a habitat and their potential to enhance the resilience and carrying capacity of ecosystem services for society;
3. Ecotechnology - using dual regulation, biota to control hydrological processes and vice versa, integration of various types of biological and hydrological regulations to improve water quality, biodiversity and freshwater resources, and harmonisation of ecohydrological measures with necessary hydrotechnical solutions such as irrigation systems, reservoir/dam, and sewage treatment plant.

The approach for defining rural-urban interface in this chapter is related to the first principle.

3.2. DEVELOPMENT OF CRITERIA AND ANALYSIS

3.2.1 CRITERIA FOR PERI-URBAN DELINEATION

Eleven variables reflecting rural-urban characteristics were used in this study to define a regional rural-urban interface classification in the CMR. These variables were selected as also providing directly and indirectly some indications of ecohydrology. Five variables, viz., population size (PS), population density (PD), the percentage of the population working in agriculture (PA), literacy rate (LR), and poverty level (PL), were readily available census data in the government statistical reports of the five districts. The other two variables, distance (D) and travel time (T) to the city centre, were derived from Google™ maps. The percentage of built-up area (BA); forest, water bodies, and semi-natural (FWS); and agricultural areas (AA) in the 45 sub-districts was calculated from the available maps of land use and land cover (LULC) using GIS software. The spatial and statistical data were obtained from the West Java Province and associated local government agencies in the five close districts representing rural-urban environment of the census data.

The last variable, total villages defined as urban within sub-districts and counted as the percentage of urban villages in the respective sub-district (UV) was obtained from the census data (Badan Pusat Statistik, 2010). The census results were considered as one of the variables in this study because they provide additional characteristics of smaller human settlement/village scale at a particular sub-district. During the census, one human settlement at the village scale was defined as being in a category of urban or rural village based on the population density, the percentage of the population engaged in agriculture, and the availability and accessibility to the urban facilities. The 2010 Indonesian Census determined a rural-urban interface dichotomy classification for all villages across Indonesia. From 483 villages within CMR, 325 villages (67%) were defined as urban and the rest, 158 villages (33%), were defined as rural.

3.2.2 CLASSIFICATION METHOD FOR PERI-URBAN DELINEATION

Initially, all eleven variables within the datasets for the 45 sub-districts were assessed in terms of variability and inter-correlation among variables. The hierarchical cluster analysis was used to determine the optimal number of clusters for the classification using the elbow method and dendrogram. The elbow criterion is a common rule of thumb to determine what number of clusters should be chosen, for example the k-mean clustering (Madhulatha, 2012) or Jenks natural breaks in GIS (Cromley, 1995). All observed variables were assessed through a hierarchical cluster analysis using Ward's method and squared Euclidean distance to see the natural clusters of the data. Factor analysis was used to discover the simplest method of interpreting the variables datasets and to identify spatial distribution patterns of sub-districts with distinctive urban, distinctive rural and intermediate characteristics based on shared variances. In this study, the principal component was used as an extraction factor to extract maximum variance from the datasets within each component. Eigenvalues >1 was used as the extraction method. Factor loading for each component was obtained by performing a rotation method using a common orthogonal technique, Varimax rotation with Kaiser Normalization, to minimise the number of variables that had high loadings on each factor. The cut-off for a statistically meaningful or significant rotated factor loading in this study was applied at 0.59.

Quick cluster or k-means cluster (multivariate clustering), was applied for the regional rural-urban interface classification based on the factor values. K-means clustering was chosen for this study because it is one of the most popular and simple clustering algorithms to explore structure in the variable datasets (Jain, 2010). For further analysis in the discussion section, k-means clustering from the original datasets and hierarchical clustering from the original datasets were applied to see the effectiveness of factor analysis with principal components in capturing cluster structures. As a comparison, another regional rural-urban interface classification was formulated based on land use and land cover data in the 45 sub-districts using Jenks natural breaks (univariate clustering). This method is one of the most highly regarded approaches in GIS to explore the spatial distribution patterns of attributes across a region based on statistically optimal classification, Jenk's optimisation, that was adapted from Fisher's method (Wei et al., 2016, Cromley, 1995). Further comparison was applied using a combination of scores, based on the threshold cut-off values identified from the natural breaks (Jenks). The new regional classifications were determined through multivariate (M), univariate (U), and multiple univariate (MU) analysis approaches using IBM Statistical Package for the Social Science (SPSS)™ version 24 and GIS version 10.3 developed by the Environmental Systems Research Institute (ESRI). The results were mapped by integrating both GIS and statistical methods.

A framework method to delineate peri-urban area is shown in Figure 5.

3.3 RESULTS

3.3.1 VARIABILITY AND CORRELATION OF RURAL-URBAN VARIABLES

The coefficient of variation was used to find the best variables for defining rural-urban interface classifications in the context of CMR (Table 7). The results show five variables with the coefficient of variation more than 0.5: PD; BA; FWS; PA; and D. Population density per km^2 had the highest variability across CMR sub-districts, presenting this as a very good indicator for classifying rural-urban interface typology.

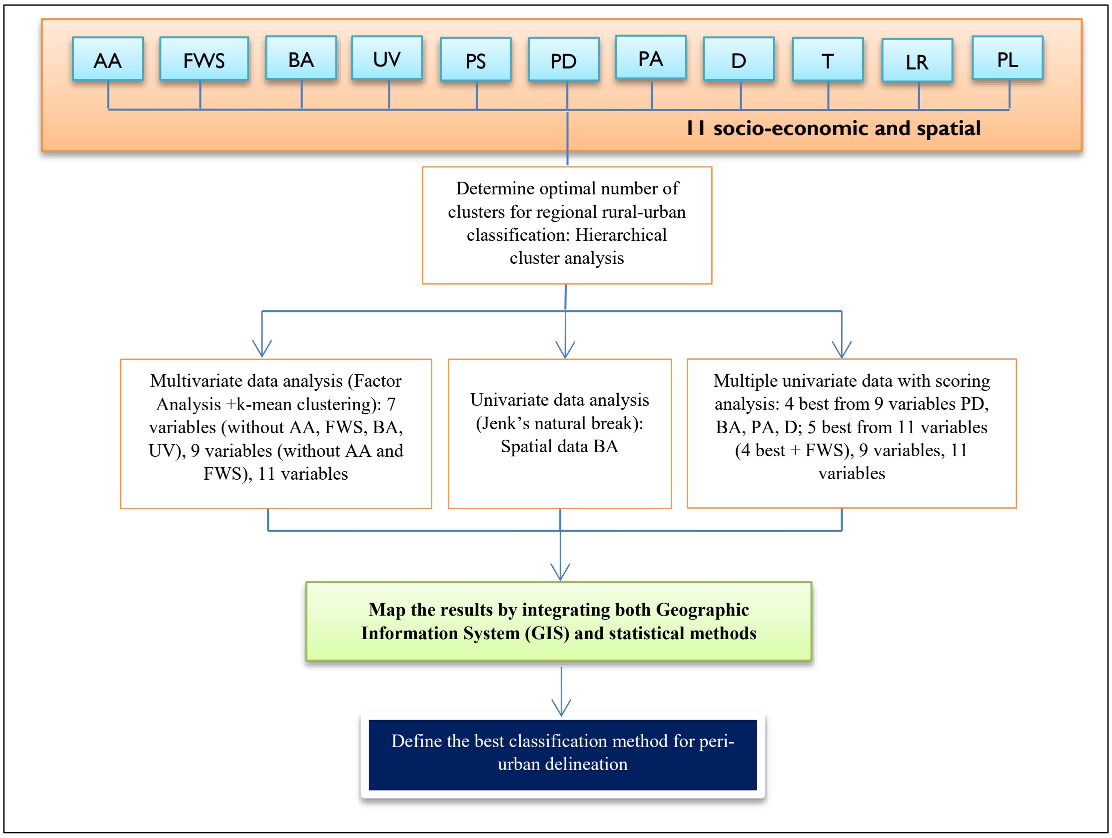

FIGURE 5. FRAMEWORK METHOD FOR DEFINING PERI-URBAN AREAS

Variable names are: agricultural areas (AA), forest, water bodies, and semi-natural (FWS), percentage of built-up area (BA), urban villages (UV), population size (PS), population density (PD), percentage of the population working in agriculture (PA), distance to the city centre (D), travel time to the city centre (T), literacy rate (LR), and poverty level (PL).

TABLE 7. DESCRIPTION OF 11 VARIABLE DATA IN THE 45 SUB-DISTRICTS

Variables for Rural-urban Interface Classification	Code	Minimum Data	Maximum Data	Mean	SD*	Coefficient of variation (SD/Mean)
Agricultural area (%)	AA	0.00	86.88	47.75	21.72	0.45
Forest, water bodies, and semi-natural area (%)	FWS	1.49	74.4	26.84	20.21	**0.75**
Built-up area (%)	BA	5.23	93.73	25.4	19.98	**0.79**
Urban villages within sub-district (%)	UV	0	100	68.53	30.82	0.45
Population size (inhabitants)	PS	22,964	104,001	54,750	18,060	0.33
Population density per km^2	PD	467	18,864	3,453	3,349	**0.97**
Population working in Agriculture (%)	PA	0.46	62.74	22.55	16.24	**0.72**
Distance to city centre (km)	D	0.23	38	17.53	8.98	**0.51**
Travel time to city centre (minutes)	T	1	57	29.76	13.39	0.45
Literacy rate (%)	LR	81.17	96.57	90.74	3.68	0.04
Poverty level (%)	PL	7.14	50.11	24.46	10.8	0.44

*Note: *SD=Standard Deviation. Bold values show variables with the coefficient of variation more than 0.5*

Correlation among the selected variables within CMR is shown in Table 8. BA had a very strong positive correlation with PD but a strong negative correlation with PA, D and T. PA had a very strong negative correlation with UV, and a strong negative correlation with PD, BA and LR, but a strong positive correlation with D and T. In addition, a strong negative correlation was shown between LR and PL.

TABLE 8. CORRELATION COEFFICIENT (R) BETWEEN TWO VARIABLES

	AA	FWS	BA	UV	PS	PD	PA	D	T	LR	PL
AA	1	-0.55**	-0.53**	-0.25	0.09	-0.47**	0.35*	0.22	0.18	-0.54**	0.34*
FWS		1	-0.42**	-0.23	-0.23	-0.42**	0.28	0.45**	0.47**	0.02	0.06
BA			1	0.50**	0.14	**0.94****	**-0.67****	**-0.70****	**-0.67****	0.57**	-0.43**
UV				1	0.46**	0.55**	**-0.80****	-0.53**	-0.56**	0.45**	-0.12
PS					1	0.10	-0.37*	-0.30*	-0.40**	-0.12	0.14
PD						1	**-0.64****	**-0.71****	**-0.70****	0.51**	-0.33*
PA							1	**0.70****	**0.61****	**-0.66****	0.34*
D								1	**0.94****	-0.35*	0.27
T									1	-0.20	0.10
LR										1	**-0.74****
PL											1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

The agglomeration coefficient shows a numerical value at which various cases merge to form a cluster. The agglomeration schedule coefficient was plotted into the line graph showing the coefficient on a y-axis and the number of clusters on the x-axis. The Elbow method helped to plot the number of clusters against the average variance. In this study, the stage where distance coefficient made the biggest jump (step of the elbow) was at 41; this verified the ideal number of the clusters of 45-41=4 clusters which was consistent with the interpretation of the dendrogram (Figure 6).

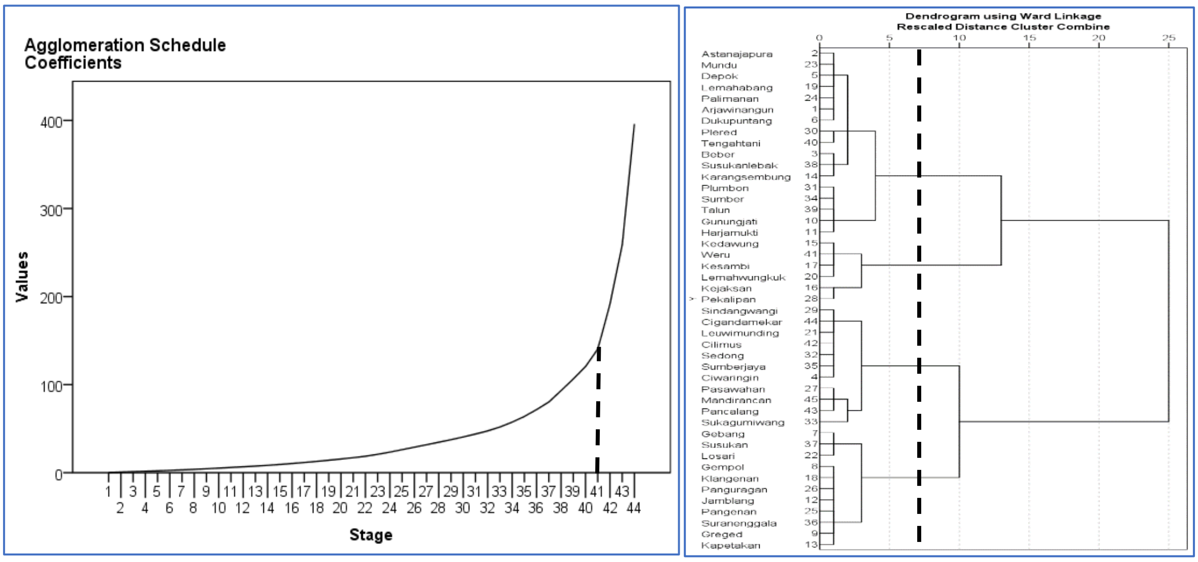

FIGURE 6. ELBOW METHOD AND DENDROGRAM TO DETERMINE THE NUMBER OF CLUSTERS

3.3.2 MULTIVARIATE DATA ANALYSIS

Comparison was applied to the original datasets through the k-means clustering and hierarchical clustering (Figure 7) and synthetic datasets through the k-means clustering (Figure 8). This study found that the classification based on the factor values (synthetic data) in the k-means clustering instead of the original nine datasets through the hierarchical clustering did not necessarily improve the cluster quality or structures of the rural-urban interface classifications. In this study, the regional rural-urban interface classification's results based on factor values of the principal component and hierarchical clustering support similar interpretation. This finding supports the conclusion of the previous study regarding the effectiveness of PCs in capturing the cluster structure investigated by Yeung and Ruzzo (2000). However, the classification based on the k-means clustering using factor values from the principal component analysis instead of the original datasets gave much improvement in the cluster structures. This finding is comparable with the experimental results studied by Venkatesan and Parthiban (2011) that the combination of k-means with PCA improves the performance of basic k-means in terms of accuracy.

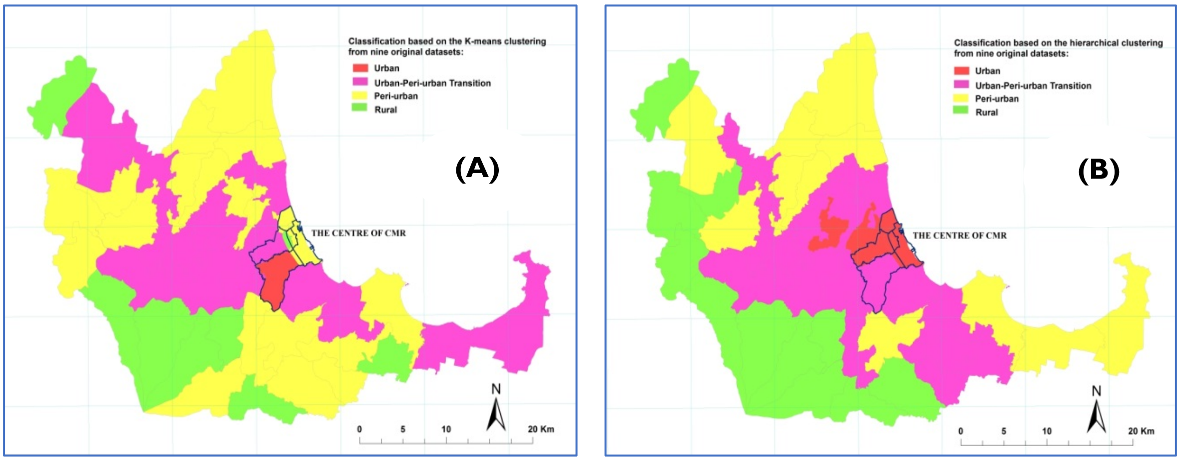

FIGURE 7. REGIONAL RURAL-URBAN CLASSIFICATIONS BASED ON THE ORIGINAL DATASETS (9 VARIABLES): (A) K-MEANS CLUSTERING (B) HIERARCHICAL CLUSTERING

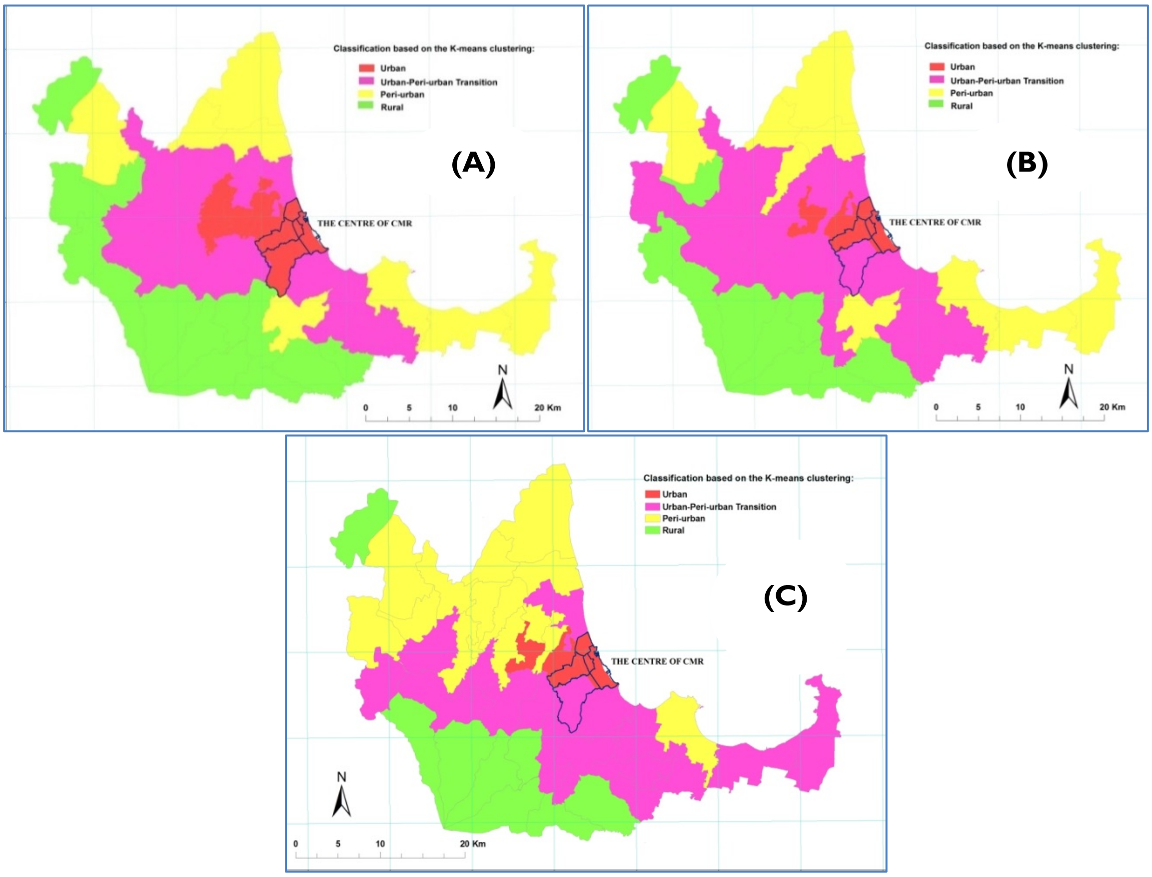

FIGURE 8. REGIONAL RURAL-URBAN CLASSIFICATIONS BASED ON THE SYNTHETIC DATASETS USING K-MEANS CLUSTER ANALYSIS: (A) 7 VARIABLES; (B) 9 VARIABLES; AND (C) 11 VARIABLES

Regional rural-urban classifications in Figures 9 were developed based on the factor values. Factor analysis with a principal component was applied to the seven (without spatial data AA, FWS, BA and census data UV), nine (without spatial data AA and FWS) and 11 variables. The Kaiser-Meyer-Olkin model that measures sampling adequacy was found to be greater than 0.5 (0.61 for seven variables, 0.70 for nine variables, and 0.65 for 11 variables) verifying that the datasets were appropriate for the factor analysis. The Bartlett's test was also found to be significant ($p<0.05$). Two principal components using seven and nine variables and three principal components using 11 variables provided the total variance explained of 77%, 75%, and 79% respectively with alpha values >0.65. The results of factor analysis from the seven and nine variables are shown in Tables 9 and 10. The results from the 11 variables can be seen in the Chapter 4.

TABLE 9. FACTOR LOADING OF 7 VARIABLES

Var	Factor Loading		% Variance Explained		% Variance Explained after Rotation			KMO	Bartlett's Test		
	PC I	PC II	PC I	PC II	PC I	PC II	Total		Approx. χ^2	d.f.	Sig
PS	**-0.59**	0.42	53	24	48	29	77	0.61	256.06	21	<0.001
PD	**-0.72**	-0.43									
PA	**0.76**	0.43									
D	**0.91**	0.21									
T	**0.94**	0.02									
LR	-0.25	**-0.90**									
PL	0.07	**0.87**									
Cronbach's Alpha (α) based on the total eigenvalue					0.83	0.67	0.95				

Note: Var=Variables; PC = Principal Component

TABLE 10. FACTOR LOADING OF 9 VARIABLES

Var	Factor Loading		% Variance Explained		% Variance Explained after Rotation			KMO	Bartlett's Test		
	PC I	PC II	PC I	PC II	PC I	PC II	Total		Approx. χ^2	d.f.	Sig
BA	**0.73**	0.51	56	19%	51	24	75	0.70	405.89	36	<0.001
UV	**0.79**	0.10									
PS	**0.59**	-0.48									
PD	**0.75**	0.44									
PA	**-0.81**	-0.35									
D	**-0.87**	-0.18									
T	**-0.90**	0.00									
LR	0.31	**0.86**									
PL	-0.09	**-0.85**									
Cronbach's Alpha (α) based on the total eigenvalue					0.89	0.70	0.96				

Note: Var=Variables; PC = Principal Component

Factor loading of seven and nine variables shows that Factor I is a principle component with high-correlated factors to the human activities in social and economy implying the need for water supply, water quality risks, open space distribution and climate change pressures. Factor II is a principle component with high-correlated factors to the water management capacity or social dimension implying vulnerable groups regarding water-related problems and resilience that were also related to open space distribution. Adding two spatial variables, AA and FWS, to the nine variables provided one more factor, Factor III (Chapter 4). Factor III is a principal component with a high-correlated factor to the available natural resources, biodiversity, water, and food production. Adding BA to the seven variables increased the explained variance of the Factor I. However, adding AA and FWS to the nine variables decreased the explained variance of the Factor I.

Spatial distributions of factor values based on the 7 and 9 variables at 45 sub-districts are shown on the map in Figures 9 and 10 respectively.

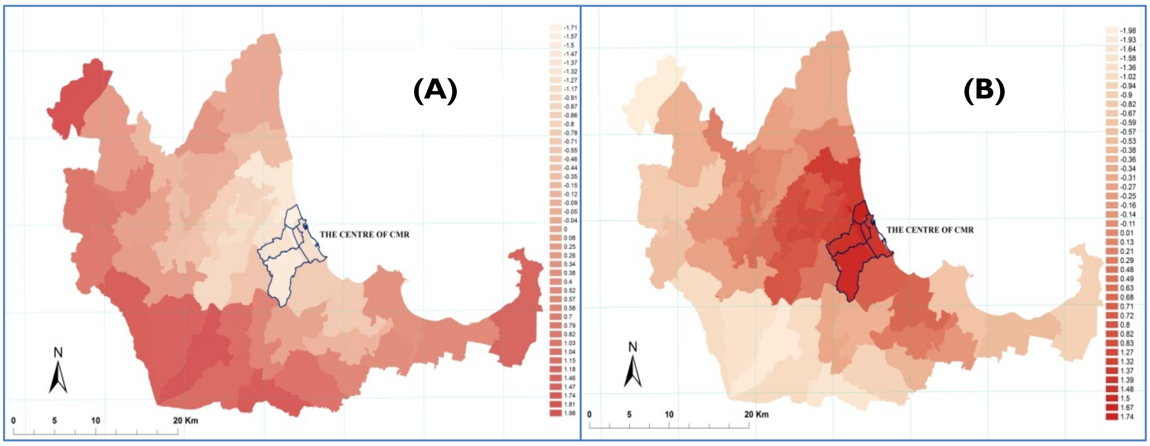

FIGURE 9. SPATIAL DISTRIBUTIONS OF FACTOR VALUES BY SUB-DISTRICTS WITHIN CMR (FACTOR I): (A) 7 VARIABLES; (B) 9 VARIABLES

The darkest colour on the maps indicates the highest factor values of the areas. Factor I from the seven variables loaded strongly on the increase of travel time, distance to the city centre and population working in agriculture and on the decrease of population density and size. Hence, the darkest colour in Figure 9 (A) shows the sub-districts with more rural characteristics. On the other hand, Factor I from the nine variables loaded strongly on the increase of highest percentage of urban villages within sub-district, population density and built-up areas, and on the decrease of travel time and distance to the city centre and population working in agriculture. Hence, the darkest colour in Figure 9 (B) shows the sub-districts with more urban characteristics. From the map in Figure 6, five sub-districts in CM (Kejaksan, Pekalipan, Kesambi, Lemahwungkuk and Harjamukti) and three sub-districts in the CR (Wire, Kedawung, and Gunungjati) have dominantly urban characteristics. On the other hand, Sukagumiwang and Mandirancang were among the sub-districts with distinctive rural characteristics.

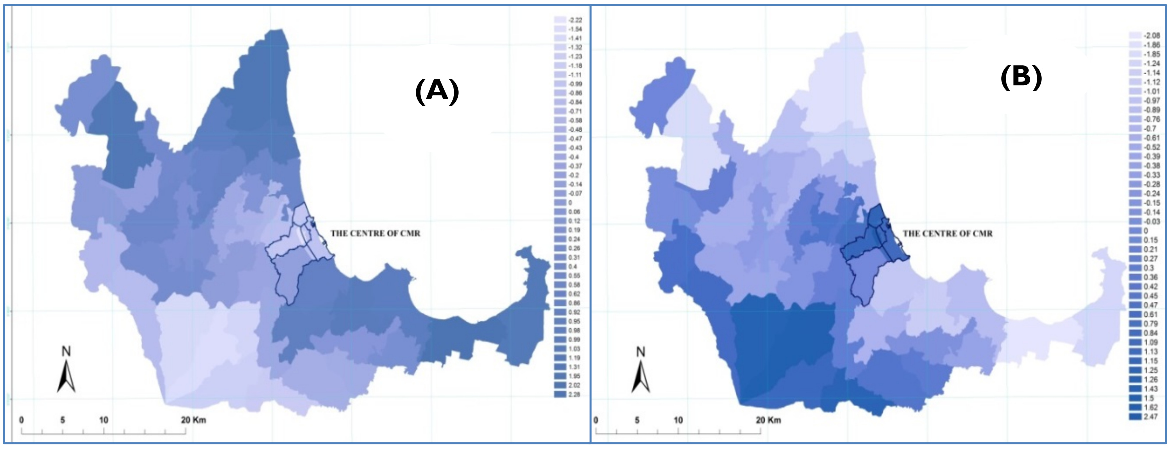

FIGURE 10. SPATIAL DISTRIBUTIONS OF FACTOR VALUES BY SUB-DISTRICTS WITHIN CMR (FACTOR II): (A) 7 VARIABLES; (B) 9 VARIABLES

A different pattern of rural-urban interface characteristics was obtained by applying factor values in the 45 sub-districts based on the Factor II analysis. Factor II from the seven variables loaded strongly on the increase of poverty level and the decrease of literacy rate. Hence, the darkest colour in Figure 10 (a) shows sub-districts with more rural characteristics. On the other hand, Factor II from the nine variables loaded strongly on the increase of literacy rate and the decrease of poverty level. Hence, the darkest colour in Figure 10 (b) shows the areas with more urban characteristics. The classification made by the Factor II analysis shows that five sub-districts in KR (Mandirancang, Pasawahan, Pancalang, Cilimus and Cigandamekar) and sub-districts in CM have distinctive urban characteristics while Kapetakan and Gebang sub-districts were among sub-districts with distinctive rural characteristics.

ANOVA test and post-hoc analysis was applied to assess significant mean difference among four rural-urban clusters from the k-mean clustering from the synthetic values (Table 11).

TABLE 11. SUMMARY OF REGIONAL CLASSIFICATIONS USING FACTOR ANALYSIS COMBINED WITH K-MEANS CLUSTERING

Rural-urban Categories within CMR Total sub-districts=45	Classification method with K-means clustering, ANOVA and post-hoc test									
	7 variables			9 variables (7 variables +UV+BA)			11 variables (9 variables +AA+AFS)			
	Cluster Centres		Number of sub-districts	Cluster Centres		Number of sub-districts	Cluster Centres			Number of sub-districts
	Factor I	Factor II		Factor I	Factor II		Factor I	Factor II	Factor III	
Urban	-1.29*	-0.88	9	1.48*	1.21	6	1.27*	-1.50	-0.39	6
UPT	-0.39*	0.38*	15	0.38*	-0.25*	20	0.35	0.49	0.75	17
Peri-urban	0.29*	1.46*	8	-0.37*	-1.28*	9	-0.10	0.55	-1.01*	14
Rural	1.17*	-0.73	13	-1.32*	0.93	10	-1.51*	-0.89	0.47	8
F statistics	56.9	40.7		51.0	42.1		29.8	24.5	20.9	
P-value	p<0.001	p<0.001		p<0.001	p<0.001		p<0.001	p<0.001	p<0.001	

*. The mean difference is significant compared to other three rural-urban categories at the 0.05 level.
UPT=Urban-Peri-urban Transition
Factor I = Principal component with high correlated factors to human activities in social and economy implying the need for water supply, water quality risks, open space distribution, and climate change pressures
Factor II = Principal component with high-correlated factors to the water management capacity implying vulnerable groups regarding water-related problems and resilience that were also related to open space distribution
Factor III = Principal component with high-correlated factors to the available natural resources, biodiversity, water, and food production

Table 11 shows that additional two variables AA and FWS increase the similarity of intermediate clusters or reduced significant differences between peri-urban and urban-peri-urban transition characteristics. Higher values of Factor I in the classification of seven variables show sub-districts with more rural characteristics while higher values of Factor I in the classification of nine and 11 variables show sub-districts with more urban characteristics. Factor I shows a systematically urbanisation level that is mainly characterised by social and economic activities and is significantly higher in urban, followed by urban-peri-urban transition, peri-urban and rural areas. Factor II shows water management capacity in the CMR is higher in urban, followed by rural, Urban-Peri-urban Transition, and peri-urban areas. Factor III shows food production activities in the peri-urban are significantly higher than other rural-urban categories. However, the highest shared variances of the first factor provided the regional classification through the k-means clustering that emphasised the human activities in social and economic aspects.

3.3.3 UNIVARIATE DATA ANALYSIS

The land use map in Figure 11 shows that human settlement areas are concentrated in the centre of CMR or CM. The pattern of the impermeable area extended along the road, directly to the north-west part of CMR that is currently farmland. This farmland is situated largely in the administrative area of Cirebon Regency. Scattered human settlements can be seen in the south-east of CMR. These settlements form a mixed area of orchards, farmland, and built-up environments. In the south and west part of CMR, forest areas still dominate land use, particularly in the KR and in MR. The map shows that the south part of CM (Harjamukti sub-district) is not fully urbanised as there are some spaces with orchards and farmlands. Urbanisation seems to extend outside the boundary of the city, crossing over into traditionally rural areas and creating a rural-urban environment or peri-urban area.

The changes of built-up areas within the CMR boundary can be further seen from the land cover map between 2005 and 2014. The land cover map in Figure 12 shows the built-up areas in 2014 are comparatively similar to those in 2011. However, compared to the land cover in 2005, it is obvious that land use has changed from once arable land to built-up land in the CMR and that urbanisation has occurred mainly in the CM and CR along the arterial-collector road direct to MR, KR and IR. The open space in the CM has decreased markedly in the 10-year period between 2005 and 2014, indicating the expectation and risk of the city further expanding to its peripheral areas.

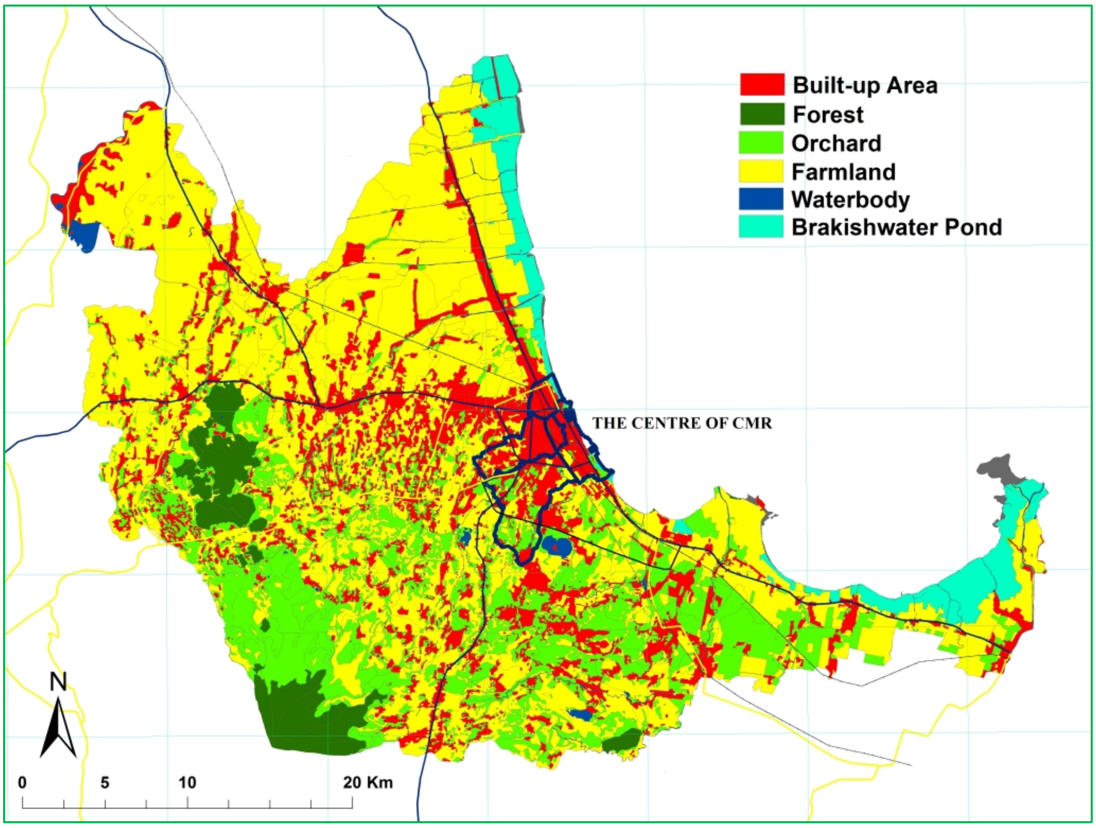

FIGURE 11. LAND USE MAP OF CMR IN 2011

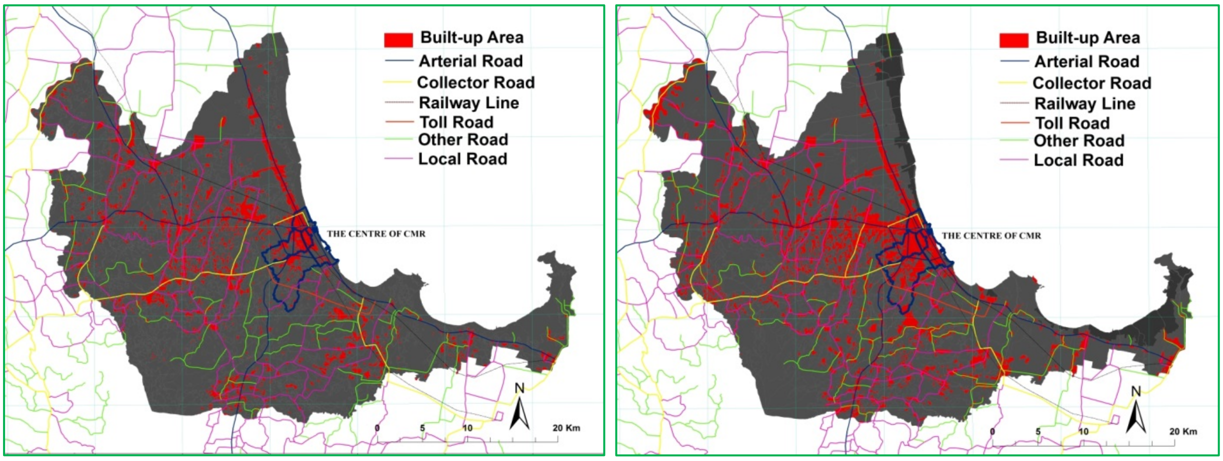

FIGURE 12. COMPARISON OF BUILT-UP AREAS BETWEEN 2005 (LEFT) AND 2014 (RIGHT)

To identify the level of urbanisation of 45 sub-districts within CMR, this study overlaid the land use maps in 2011 with the sub-district administrative boundary. The land use map in 2011 was used for the analysis because that data was considered to most closely reflect the 2010 Indonesian population census data. This study defined rural-urban interface thresholds based on the Jenks natural breaks, with the number of classes being determined from a hierarchical cluster analysis. The regional rural-urban interface classification within CMR was re-identified into the following categories:

(i). Urban (55.8-93.7% built-up area): most areas consist of residential, commercial/ industrial landscapes implying few or no open space distribution.

(ii). Urban-Peri-urban Transition (34.7-55.7% built-up area): greater areas of residential, commercial/ industrial landscape implying fewer open space distributions.

(iii). Peri-urban (15.9-34.7% built-up area): few residential, commercial/industrial landscapes implying larger open space distribution.

(iv). Rural (5.2-15.8% built-up area): scarcely or no residential, commercial/industrial landscapes implying largest area of open space distribution.

Figure 13 depicts these results with four sub-districts defined as "urban", four as "urban-peri-urban transition", 19 as "peri-urban" and 18 as "rural".

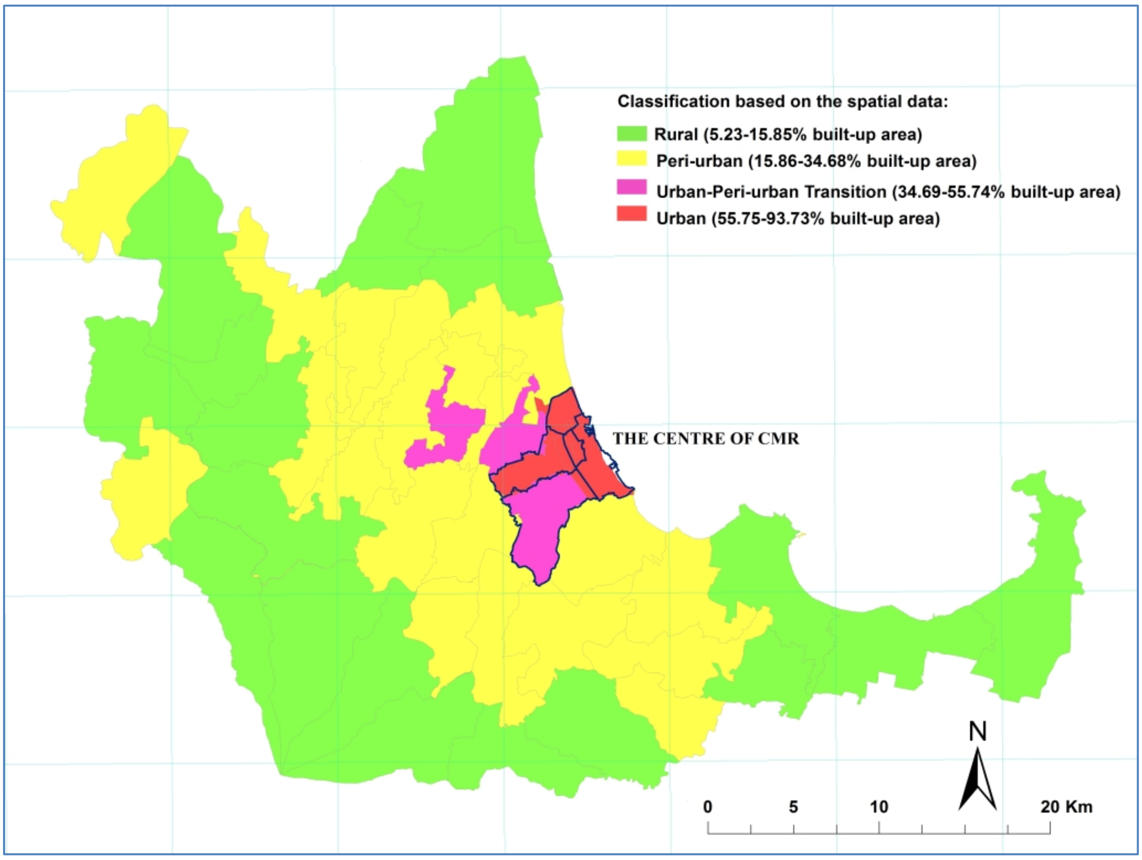

FIGURE 13. A REGIONAL CLASSIFICATION BASED ON THE SPATIAL DATA (BUILT-UP AREA) USING JENKS NATURAL BREAKS

Land use and land cover (LULC) can be used to delineate the rural-urban interface as demonstrated by Huang et al. (2016). This study shows that recognised built-up areas from the LULC analysis can distinguish rural-urban interface gradients from the unsettled land at one end to the compact urban core at the other end (Benza et al., 2016). In the context of ecohydrology, the proportion of built-up area can be used as a proxy to open space distribution. Sub-districts with more urban characteristics have lower open space distribution implying higher risks in the impact of human activities on natural processes, water cycle and local climate. However, relying on regional rural-urban classifications based on the built-up area does not sufficiently describe the complexity of relationship between people, water, and environment, particularly in the socio-economic dimension. As also argued by Zhu (2004), a more refined classification of settlement areas beyond built-up area based dichotomy is required as suggested by Pizzoli and Gong (2007) and (Camaioni et al., 2013), the multidimensional approach in classifying the rural-urban interface should be considered.

3.3.4 MULTIPLE UNIVARIATE DATA WITH SCORING ANALYSIS

This classification was applied to the 11 variables, nine variables, five best variables from the 11 variables, and four best variables from the nine variables. The rural-urban interface variable's thresholds were identified from the datasets considering the results from factor analysis in identifying sub-districts with distinctive urban, rural and intermediate characteristics. Scoring was applied by giving a score of 1 to the rural variable's thresholds, a score of 2 to the variable's threshold closed to rural, a score of 3 to the variable's threshold closed to urban, and a score of 4 to the urban's variable threshold. The regional rural-urban interface classification was then mapped at the metropolitan scale. Table 12 shows rural-urban interface threshold values defined by Jenks natural breaks and scoring given to the 11 variable datasets.

TABLE 12. RURAL-URBAN INTERFACE THRESHOLDS AND SCORING WITHIN 11 VARIABLE DATASETS

No	Criteria	Urban	Score	UPT	Score	Peri-urban	Score	Rural	Score
1	AA (%)	0.0 – 27.5	4	27.6 – 47.0	3	47.1 – 65.5	2	65.6 – 86.9	1
2	FWS (%)	1.4 – 6.2	4	6.3 – 21.0	3	21.1 – 41.7	2	41.8 – 74.4	1
3	BA (%)	55.8 – 93.7	4	34.8 – 55.7	3	16.0 – 34.7	2	5.2 – 15.9	1
4	UV (%)	85.8 – 100	4	55.7 – 85.7	3	22.3 – 55.6	2	0.0 – 22.2	1
5	PS (persons)	71,454 – 104,001	4	52,320 – 71,453	3	35,257 – 52,319	2	22,964 – 35,256	1
6	PD (PS/km^2)	11,901 – 18,864	4	5,905 – 11,900	3	2,559 – 5,904	2	467 – 2,558	1
7	PA (%)	0.5 – 10.0	4	10.1 – 21.6	3	21.7 – 34.3	2	34.4 – 62.7	1
8	D (km)	0.2 – 5.7	4	5.8 – 15.0	3	15.1 – 23.0	2	23.1 – 38.0	1
9	T (minutes)	1.0 – 16.0	4	16.1 – 28.0	3	28.1 – 40.0	2	40.1 – 57.0	1
10	LR (%)	93.6 – 96.6	4	90.9 – 93.5	3	87.2 – 90.8	2	81.2 – 87.1	1
11	PL (%)	7.1 – 16.7	4	16.8 – 25.4	3	25.5 – 34.7	2	34.8 – 50.1	1

Scoring given to the multiple rural-urban interface thresholds in the respective sub-districts is considerably important in this study for comparison of the regional classifications between multivariate and multiple univariate clustering methods. Jenks natural breaks method was useful in determining rural-urban interface thresholds of each variable in the total 11 variable datasets. Different sub-districts had different values in the rural-urban interface variables showing different rural-urban interface characteristics. Overlapping classes in the rural-urban interface category was evident in the sub-districts between the centre of the metropolitan and outer boundary of the metropolitan region. Total scoring was calculated to recapitulate the variation of the rural-urban interface indicator's values in the respective sub-districts for the better classifications and displays in the choropleth maps. The regional rural-urban classification with this method is shown in Figure 14.

3.4 DISCUSSIONS

3.4.1 COMPARING METHODOLOGY FOR PERI-URBAN DELINEATION

Comparative analyses to define pattern and peri-urban delineation using multivariate, univariate and multiple univariate clusters have been considered in this study by integrating statistical attributes and space characteristics in choropleth maps. Univariate analysis was commonly used in the past as general absence of large-scale spatial datasets. Multivariate analysis was commonly applied for spatial typology considering social, economic and geographic aspects (Bogdanov et al., 2008, Alasia, 2004, Öğdül, 2010). The choice of classification method or clustering technique as applied in this study influences the visual interpretation of the underlying pattern of the spatial distribution as remarked by Cromley (1996) and Murray and Shyy (2000). The results in this study also supported previous findings that choropleth maps using the Jenks natural breaks approach are more clearly understood and concluded than either unclassed maps or a more traditional clustering approach (Cromley, 1996). The example of unclassed maps in this study is shown in Figures 9, 10, 11 and 12 while the example of more traditional clustering is shown in Figures 7 and 8. The use of univariate cluster with one variable dataset and multiple univariate clusters with four, five, nine, and 11 variable datasets shows clear patterns in the impacts of giving more variables into the cluster structures of the rural-urban interfaces.

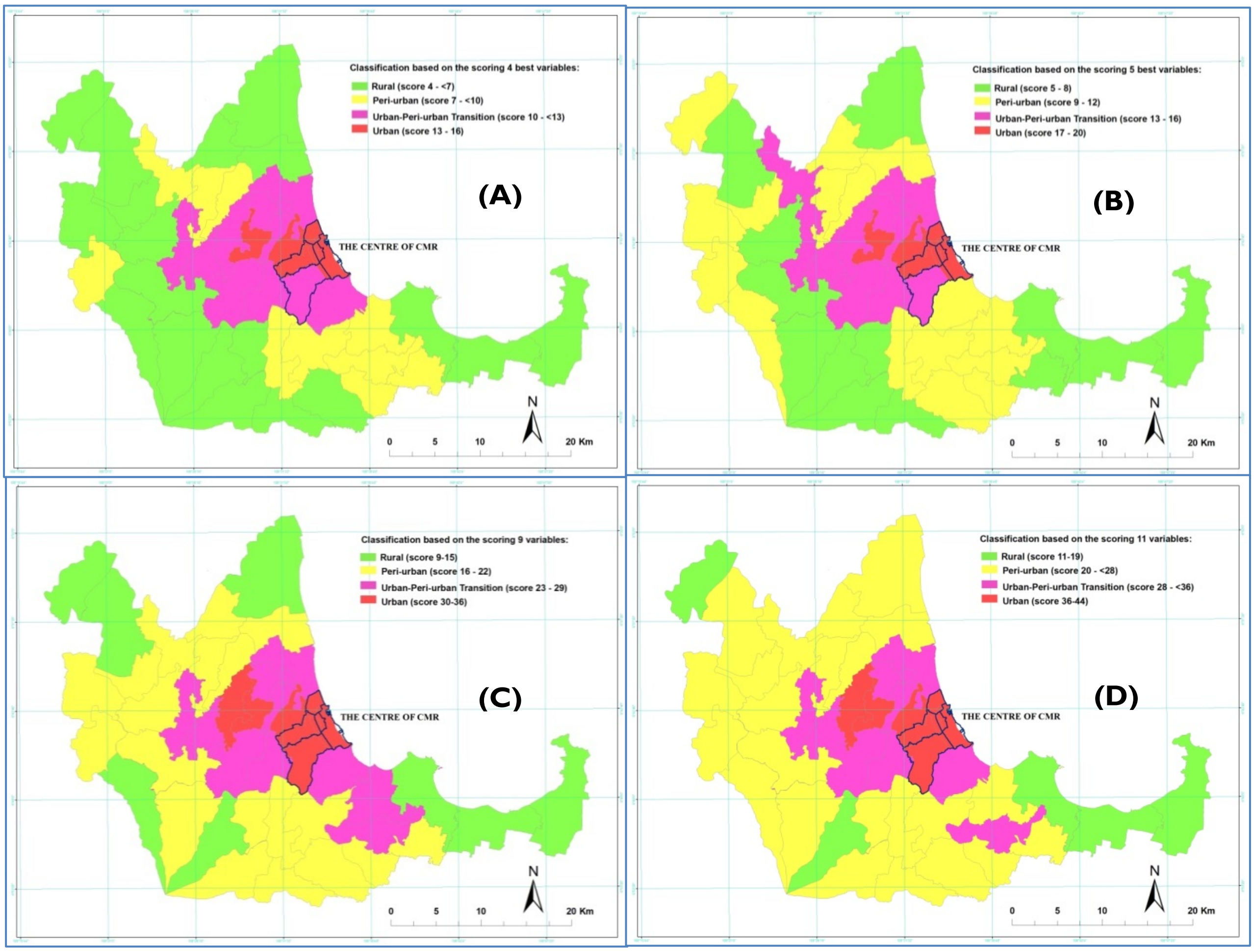

FIGURE 14. REGIONAL CLASSIFICATIONS BASED ON THE MULTIPLE UNIVARIATE CLUSTERS WITH SCORING: (A) 4 BEST FROM 9 VARIABLES; (B) 5 BEST FROM 11 VARIABLES; (C) 9 VARIABLES; (D) 11 VARIABLES

This study has shown the usefulness of combining statistical methods and GIS for clustering method and displaying the pattern and rural-urban interface classifications in the choropleth maps. GIS provides facilities for exploratory analysis through the visual delineation of attribute variation across a region as already reviewed by Murray and Shyy (2000). Both k-means clustering and Jenks natural breaks are non-hierarchical clusters. However, Jenks natural breaks method takes advantage of the univariate data sets while k-means clustering method takes advantage of the multivariate datasets. A drawback of both approaches is that the number of clusters desired in the result must be provided to the given dataset (North, 2009, Jain, 2010). As shown in this study, the comparison of the regional rural-urban interface maps was set in the same number of classes that were identified before determining regional rural-urban interface classification through the k-means multivariate clustering and univariate clustering (Jenks natural breaks method). Basically, both k-mean clustering and Jenks natural breaks clustering methods aim to minimise the sum of the variance within each of the clusters (Cromley, 1996).

The original variable datasets have some outliers. There were several sub-districts within CMR having distinctive values in the rural-urban interface variables. Using the k-means clustering from the original datasets provided the unequal shape of clusters showing obvious outliers in the variable datasets of the rural-urban interface variables. K-means clustering is more sensitive to outliers and does not work well with high dimensional data (Venkatesan and Parthiban, 2011). Moreover, some variables showed strong inter-correlations with other variables. This finding supports the previous reviews that the application of the clustering method directly from the original datasets (continuous variable) does not give efficient cluster structures in cases where the data are vectors of correlated measurements (James and McCulloch, 1990). The k-means clustering is more suitable for ordinal or categorical datasets such as synthetic values from the factor analysis using the principal components which are reflecting meaning categories from the measured variables (Yong and Pearce, 2013, James and McCulloch, 1990). Further, the use of factor analysis with principal components provides easier interpretation of the 11 social, economy and spatial data in the context of ecohydrology. However, the regional classification datasets using multivariate cluster analysis (factor analysis and k-means clustering) as applied in this study, showed less accurate and meaningful results in capturing the variation of the rural-urban interface characteristics compared to the classification from the multiple univariate cluster analysis (Jenks natural breaks) with scoring.

3.4.2 Delineation of peri-urban areas and ecohydrology

Factor analysis in this study shows that human activities in social and economic aspects primarily influenced the characteristics of rural-urban environments. As highlighted by Zalewski and Wagner (2008), the urban environment is characterised by highly condensed anthropogenic systems that should be managed for the efficient flow of water, matter, energy, and information. Urban area (Plate 6) is characterised with significant higher population density, fewer open space distribution and lower agricultural activities compared to peripheral areas (Plate 7).

Plate 6. Human settlement areas in the CM

Plate 7. Human settlement areas in the peripheral CM

Urban area has a function as the centre of social and economic activities in the metropolitan region implying interaction and mobility of people from rural to urban areas for accessing urban services. The high concentration of people and activities in the urban areas implies a high demand of ecosystem services that could not be sufficient if only relying on the urban ecosystem and needed the peri-urban ecosystem. Urban expansion into peri-urban areas challenges sustainable water resources and environment in the region affecting urban and peri-urban liveability, particularly health (Akissa, 2001).

This interrelated and interdependent part between cities and rural hinterlands need to be considered as a system in the environmental management and planning for longer-term liveability or sustainability. As shown in this study, the peri-urban area is one of the spatial categories in the metropolitan development. This area has particular characteristics that need particular attention in planning and management.

Well-defined peri-urban zones will be useful in the quantification of socio-economic and spatial features for managing and developing peri-urban strategies for sustainable regional development. Human activities in social and economic aspects bring impacts to the changes in land uses, water cycles and climate that need transdisciplinary science for solutions of sustainability problems related to people, water and the environment. The knowledge of ecohydrological principles provides the scientific background for regulating the processes and interactions for enhancing water resources, maintaining and restoring biodiversity, providing ecosystem services for societies, building resilience to climatic and anthropogenic impacts, and incorporating cultural heritage perspectives (WBSRC) toward sustainable river basins (Zalewski et al., 2016b, Zalewski, 2013). In particular, the first principle of ecohydrology provides a framework for quantification of hydrological cycle analysis from the perspective of socio-economic and spatial-temporal dynamic with respect to various forms of human impact (Zalewski, 2013). This principle can be used as a starting point for the formulation of a systemic approach (Zalewski and Wagner, 2008). Human activities in the urban and peri-urban that are inseparably and spatially linked should be translated into problem solving approaches. Shaping a healthy and friendly city with outskirts would need an understanding of peri-urban ecosystem for integrated planning and management in the metropolitan region.

Further, the implementation of the ecohydrological approach has to consider the context of generally accepted goals such as sustainable development (Zalewski and Wagner, 2008). The sustainable development goals (SDGs), as advocated by the United Nations in 2015, come into effect in a world that is increasingly urbanising. The urban population is projected to grow to two-thirds of the global population by 2050 (United Nations, 2014). Goal 11 of the SDGs aims to ensure cities and human settlements are inclusive, safe, resilient, and sustainable. Cities, towns, and villages or human settlements in the rural-urban categories need to be planned and managed to fulfil their role as drivers of sustainable development and liveable environments that contribute to quality of life and enhance wellbeing. According to Zalewski and Wagner (2008), urban technical infrastructures has to be complemented with constructed or managed ecological systems with a high potential for pollutant and water retention. As a city need surrounding areas for enhancing sustainability, an ecological system in the metropolitan region could not be effectively managed by only considering urban ecosystems and needs to consider peri-urban ecosystems. Quantification of ecohydrological processes and potential in the rural-urban interfaces including peri-urban zones would be required as a starting point based on the first ecohydrological principle. As shown in this study, socio-economic and spatial data implying some indications of ecohydrology can be used not only for defining rural-urban interface classifications including peri-urban zones but also for better understanding of the rural-urban interface ecohydrology.

3.5 CONCLUDING REMARKS

The methodology proposed for delineation of peri-urban areas in this study provides a suitable framework for quantification of the ecohydrological state of an urbanising area. The study demonstrated that socio-economic and spatial data can be used to define rural-urban interface characteristics that also indirectly relate to ecohydrological aspects of the area. The results show that the application of multivariate and univariate clusters analysis has been valuable in producing the regional rural-urban interface classifications for peri-urban delineation.

By including more variables in the analysis, we were able to capture more meaningful cluster structures for defining rural-urban interfaces. The use of univariate cluster and multiple univariate clusters with scoring shows clear patterns in the impacts of having more variables into the cluster structures for rural-urban interfaces. The results of regional rural-urban interface classification based on factor values of the principal components through the k-means clustering and based on original datasets through the hierarchical clustering support a similar interpretation. Furthermore, the classification based on the k-means clustering using factor values from the principal components instead of the original datasets resulted in improved cluster structures.

In general, the study indicates that the multiple univariate clusters using Jenks natural breaks and scoring provide more accurate rural-urban definitions for peri-urban delineation. Further, a well-defined peri-urban zone as shown by the methodology proposed in this study will assist in the quantification of socio-economic and spatial features in the rural-urban interface including peri-urban area and thus managing regional environment related to water and people more effectively.

CHAPTER 4
QUANTIFYING RURAL-URBAN INTERFACE ECOHYDROLOGY

Danielaini, T. T., Maheshwari, B., & Hagare, D. (2018). Defining rural–urban interfaces for understanding ecohydrological processes in West Java, Indonesia: Part II. Its application to quantify rural–urban interface ecohydrology. Ecohydrology & Hydrobiology, 18(1), 37-51. doi:10.1016/j.ecohyd.2017.11.007

Summary
This chapter validates rural-urban interface definitions proposed in the previous chapter and utilises the best delineation for quantifying rural-urban interface ecohydrological situations. Regional rural-urban classifications from the eight spatial classification methods and the 2010 national census were validated using three rural-urban water indicators from a random sampling of the rural-urban household survey in the CMR. The methodology proposed in this study used 11 socio-economic and spatial variables related to open spaces distribution, biodiversity and ecosystem services, water supply requirement, water quality risks, water management capacity, and climate change pressures. Six proxy ecohydrological indicators were identified, and a composite index using these indicators to quantify the state of ecohydrology at the rural-urban interface was developed and applied to 45 sub-districts of CMR. The findings suggest that urban sub-districts generally have very low capacity in providing ecosystem services and need peri-urban ecosystem services for enhancing urban sustainability and liveability. This approach is potentially useful for objective assessment of the state of ecohydrology and thus for effective urban planning and shaping healthy and friendly cities and their outskirts.

4.1 INTRODUCTION

Population and urbanisation processes will continue to grow in the coming decades. They are predicted to add 2.5 billion people to the world's urban population by 2050 with nearly 90% of the increase concentrated in Asia and Africa (United Nations, 2014). Increasing urbanisation of rural areas surrounding cities is an inevitable part in the urbanisation process. Cities all over the world will face the challenges caused by urban sprawl. At the global level, peri-urban areas will play an important role in enhancing urban sustainability. However, without holistic planning, peri-urban areas could experience significant losses of productive agricultural land, increased runoff and water quality degradation (O'Neill and James, 2014). Further, the increasing population living in urban areas suggests regional sustainability issues will surface because in the extensive urban development, cities are no longer independent and depending on the peri-urban ecosystem services for sustaining human well-being and quality of life (Grimm et al., 2008).

Cities are considered as ecological systems where water cycles, material and energy flow are extremely intense. The quality of life and health in cities becomes more critical as increasing urban population and natural resources degradation. Urbanisation can bring positive impacts to the socio-economic, but it can also bring environmental challenges and social conflicts that are mostly related to sustainable water uses. In particular, increasing water demand for urbanisation and agriculture, combined with pollution, eutrophication, and climate variability raises water restrictions for ecosystems and societies (Zalewski, 2010). Furthermore, urbanisation brings an obvious impact on land use change with higher levels of impervious surfaces that increases flood risk, reduces water infiltration into soils, diminishes base flow and groundwater recharge, and increases storm runoff if there are no mitigation measures in place (Miller et al., 2014, Pataki et al., 2011, Wheater and Evans, 2009). Eliminating water related risks through traditional engineering approaches is no longer sufficient to resolve water issues (Zalewski and Wagner, 2008, Zalewski, 2002b). Ecohydrological approaches along with the needs and priorities of people or societal expectations are required to promote a more sustainable future and to achieve an ultimate goal for the sustainable management of river basins (Zalewski, 2013, Zalewski et al., 2008).

The term of ecohydrology has been used since the 1990s to describe a new scientific way of managing the water cycle for sustainable water use by societies (Zalewski et al., 2008). Yet, the clear separation between urban and rural environment that has become an essential feature of census systems, planning and management approaches has failed to quantify and qualify the impacts of urbanisation on natural processes and wellbeing of people or liveability in the peri-urban areas. Peri-urban areas are characterised by rapid transitional change and sprawling urbanisation that have resulted in considerable loss of biodiversity and natural resources that have important ecohydrological function and protection (Simon and Adam-Bradford, 2016, Elmqvist et al., 2013). It is therefore not surprising that managing natural resource management is more challenging where agricultural and urban areas are highly modified (Zalewski, 2014). Moreover, attention to the peri-urban strategy for sustainable regional/metropolitan development is currently lacking.

This study proposed new proxy indicators and a composite index of the ecohydrological state at the rural-urban interface. The novel element of this study is to develop a new approach for the quantification of the ecohydrological state of the area based on some basic socio-economic and spatial variables differentiating rural-urban interfaces within metropolitan regions. Methodology for peri-urban delineation in the context of ecohydrology was described in the previous chapter, while quantifying the ecohydrological state of the rural-urban interface is the focus of this chapter. Therefore, the main aim of this article is to develop methodology to quantify the ecohydrological state of the rural-urban interface using a number of proxy ecohydrological indicators, rural-urban classification, and composite index related to the state of ecohydrology of the area.

4.2 DEVELOPMENT OF CRITERIA AND ANALYSIS

To understand rural-urban interface ecohydrology in CMR, a survey was conducted across five districts. A total of 430 farmers and non-farmers were randomly drawn from the rural-urban interface households as described in Chapter 2. After a questionnaire pre-test, participants were individually interviewed. The questionnaire consisted of open and close ended questions in the Indonesian language that covered a large range of topics (Appendix 5). These included household characteristics, water sources for basic household requirements and food production, access to water-related services, experiences of water problems, assessment of water quality, importance and performance of water related services for liveability, experiences in the ecohydrological changes in the past 20 years and impacts on liveability, their concerns about future urbanisation, and any strategies to improve sustainable water use. This paper used three rural-urban interface indicators from the random rural-urban household survey: the number of households with access to drinking water services, access to wastewater treatment services, and the number of farmers in the surveyed location to validate the classification' results that best captured the true variations of the rural-urban interface ecohydrology.

4.2.1 PROPOSED INDICATORS AND INDEX FOR RURAL-URBAN INTERFACE ECOHYDROLOGY

Managing sustainable water resources is affected by complex interconnections between socio-cultural and biophysical aspects (Hiwasaki and Arico, 2007). Further, to reach sustainability in water use and rural-urban development, there is a need to consider multifaceted goals involving water resources, biodiversity, ecosystem services, resilience and cultural heritage (WBSRC) aspects (Zalewski et al., 2016b). Considering the WBSRC aspects, six proxy indicators are proposed for evaluating the ecohydrological condition of a given rural-urban interface. These six indicators are then used to develop a composite index, called Ecohydrological State Index for Rural-Urban Interface (ESI_{ru}) at sub-district level. Six proxy indicators of ecohydrological condition of rural urban interface are defined as follows:

(i). Proxy Indicator of Open Space Distribution (PI_{os}): This indicator is estimated as the percentage of built-up area (X_{BA}), a proxy to open space distribution in urbanising area, indicates the impact of human activities on natural processes, water cycle and local climate (Singh, 1998, Pamukcu et al., 2016, Jenerette et al., 2011).

(ii). Proxy Indicator of Biodiversity and Ecosystem Services (PI_{be}): This indicator is taken as the percentage area of forests, water bodies and semi natural area (X_{FWS}) and proportion of agricultural lands (X_{AA}), determines available natural resources implying rural-urban biodiversity, water resources, ecosystem services including cultural heritage and food production (Elmqvist et al., 2013, Janauer, 2016, Millennium Ecosystem Assessment, 2005). It is called in this study.

(iii). Proxy Indicator of Water Supply Requirement (PI_{ws}): This indicator is related to population size (X_{PS}), percentage of population working in agriculture (X_{PA}), and proportion of villages defined as urban in the 2010 national census within sub-district (X_{UV}), indicates the need for rural-urban water supply (Moss, 2014, Simonovic, 2009).

(iv). Proxy Indicator of Water Quality Risk (PI_{wq}): This indicator is related to population density (X_{PD}) and proportion of villages defined as urban in the 2010 national census within sub-district (X_{UV}) that can impact water quality and thus impacts on liveability, including health of human and settlement at rural-urban interface (Howard et al., 2003, Vlahov et al., 2007).

(v). Proxy Indicator of Water Management Capacity (PI_{wm}): This indicator is related to literacy rate (X_{LR}) and poverty level (X_{PL}), influences the capacity of residents for water management, vulnerability in dealing with water-related extreme events and their resilience (Janauer, 2016, Pataki et al., 2011).

(vi). Proxy Indicator of Climate Change Pressure (PI_{cc}): This indicator is related to the distance (X_D) and travel time (X_T) to city centre, determines the commuting needs and accessibility to basic services and indirectly influences climate change and eventually the ecosystem of the area (Grimm et al., 2008, Dawson et al., 2009).

The functional relationship between ESI_{ru} and proxy ecohydrological indicators can be expressed by the following equation:

$$ESI_{ru} = f(PI_{os}, PI_{be}, PI_{ws}, PI_{wq}, PI_{wm}, PI_{cc}) \quad (1)$$

A framework for the development of ESI_{ru} is shown in Figure 15.

4.2.2 Methodology for calculating ESI_{RU}

The new regional classifications methodology developed in the previous chapter was employed here in the process for calculating ESI_{ru}. To determine optimal classification strategy for rural-urban interface ecohydrology, a function of the data distribution was assessed using chi-square analysis to reveal the underlying characteristics of the statistical distribution from the surveyed rural-urban households. Factor analysis was used to discover the simplest method of interpreting the 11 socio-economic and spatial variables related to the six proxy indicators of ecohydrological conditions. In this study, the principal component analysis was used as an extraction factor to extract maximum variance from the datasets within each component. Eigenvalues >1 and fixed number of one factor was used as the extraction method. Factor loading for each component was obtained by performing a rotation method using a common orthogonal technique, Varimax rotation with Kaiser Normalization, to minimise the number of variables that had high loadings on each factor. The cut-off for a statistically meaningful or significant rotated factor loading in this study was applied at 0.60.

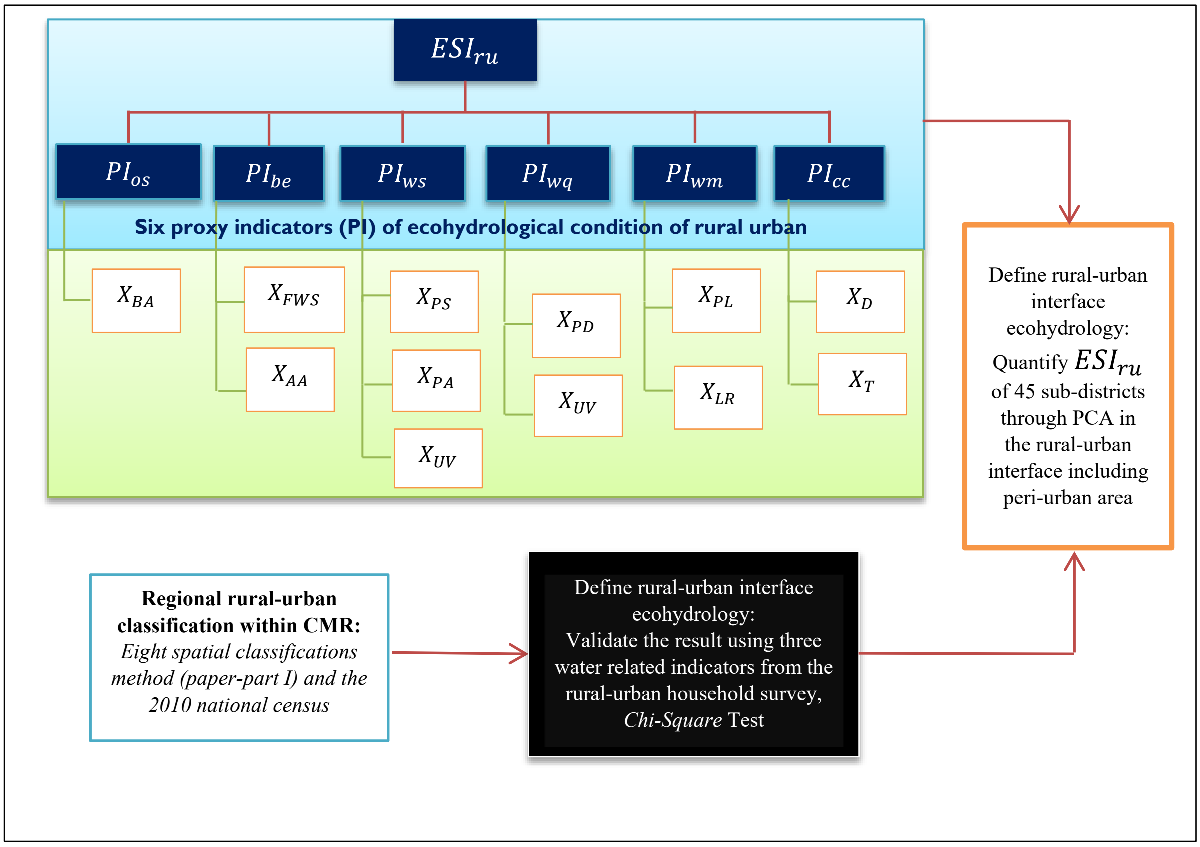

FIGURE 15. FRAMEWORK METHOD FOR QUANTIFYING ESI_{ru} IN THE CMR

Rural-urban ecohydrological conditions in the 45 sub-districts within rural-urban CMR were analysed using Principal Component Analysis (PCA). Given k variables $X_i, X_2, \dots, X_k$, each Principal Component (PC) is a linear combination of original variables measured (X's) obtained as:

$$PC_j = \sum_{i=1}^{k} a_{ij} X_i \quad , \quad j = 1,2,3, \dots . k \qquad (2)$$

PC_j is principal component j; a_{ij} represent the weights for the ith variable for the jth principal component.

Based on the eigenvalues>1, the 11 variables provided three principal components. In this study, analysis of 11 socio-economic and spatial variables with three and one principal components provided high Cronbach's Alpha (≥0.80). Hence, composite index scores in 45 sub-districts were calculated from the PCA with three- and one-dimension solutions.

PCA with three-dimension solutions (eigenvalues>1) provided three Ecohydrological State Indexes for Rural-Urban Interface:

$$ESI_{ru1} = f\left(PI_{os}, PI_{ws}, PI_{wq}, PI_{cc}\right)$$

$$= a_{1ru1}X_{BA} + a_{2ru1}X_{PS} + a_{3ru1}X_{PA} + a_{4ru1}X_{UV} + a_{5ru1}X_{PD} + a_{6ru1}X_{D} + a_{7ru1}X_{T} \qquad (3)$$

$$ESI_{ru2} = f(PI_{wm}) = a_{1ru2}X_{PL} + a_{2ru2}X_{LR} \qquad (4)$$

$$ESI_{ru3} = f(PI_{be}) = a_{1ru3}X_{FWS} + a_{2ru3}X_{AA} \qquad (5)$$

PCA with one-dimension solutions provided one Ecohydrological State Index for Rural-Urban Interface:

$$ESI_{ru} = f\left(PI_{os}, PI_{be}, PI_{ws}, PI_{wq}, PI_{wm}, PI_{cc}\right)$$

$$= a_{1ru}X_{BA} + a_{2ru}X_{FWS} + a_{3ru}X_{AA} + a_{4ru}X_{PS} + a_{5ru}X_{PA} + a_{6ru}X_{UV} + a_{7ru}X_{PD}$$

$$+a_{8ru}X_{PL} + a_{9ru}X_{LR} + a_{10ru}X_{D} + a_{11ru}X_{T} \quad (6)$$

The Y_i composite indices scores from PCA were normalised (N_i) using re-scaling method with the following equation:

$$N_i = \frac{Y_i - minY_i}{maxY_i - \min Y_i} \quad (7)$$

4.3 RESULTS

4.3.1 EVALUATION OF RURAL-URBAN CLASSIFICATION IN THE CONTEXT OF ECOHYDROLOGY

Three indicators from random rural-urban household surveys in the CMR were used for validation of the regional classification results. The first indicator used for this study was the percentage of farmer participants in the surveyed urban-rural areas (F); this was expected to be highest in the rural areas. The second indicator was the percentage of households with access to public drinking water services (D) and the third indicator was the percentage of households with access to public wastewater treatment services (W); these were expected to be highest in the urban areas. The assessments considered the distribution of rural-urban households in the rural-urban categories (H). This test was applied to find whether the indicators of rural-urban interface ecohydrology were consistent with the surveyed household distributions in the rural-urban interface category. The result shows that all the P-values were found to be less than the significance level (0.05); hence the null hypothesis cannot be accepted (Table 13).

TABLE 13. VALIDATION OF THE CLASSIFICATION RESULTS INCLUDING CLASSIFICATION FROM THE 2010 NATIONAL CENSUS

Code	Category from multivariate cluster with 7 variables						Category from multivariate cluster with 9 variables						Category from multivariate cluster with 11 variables					
	U	UPT	P	R	χ^2	P	U	UPT	P	R	χ^2	P	U	UPT	P	R	χ^2	P
F	7.4	20.2	4.7	20.0	27.2	<0.01	3.5	28.6	4.7	15.6	35.3	<0.01	3.5	18.6	15.6	14.7	36.3	<0.01
D	14.7	7.0	5.1	5.1	76.7	<0.01	14.2	10.5	5.1	2.1	144.4	<0.01	14.2	6.3	9.3	2.1	132.9	<0.01
W	12.1	10.9	2.1	3.0	50.4	<0.01	10.7	13.0	2.1	2.3	66.1	<0.01	10.7	8.4	6.7	2.3	64.2	<0.01
H	23.5	36.0	9.8	30.7			16.5	50.0	9.1	24.4			16.5	34.9	22.8	25.8		

Code	Category from univariate cluster with spatial data-built-up variable						Category from the 2010 Indonesian National Census				Category from multiple univariate clusters with scoring to 9 variables					
	U	UPT	P	R	χ^2	P	U	R	χ^2	P	U	UPT	P	R	χ^2	P
F	3.5	4.0	28.6	16.3	30.2	<0.01	31.4	20.9	24.8	<0.01	7.4	7.4	27.0	10.5	31.7	<0.01
D	13.5	1.2	10.7	6.5	110.7	<0.01	25.6	6.3	9.3	<0.01	14.7	2.3	9.5	5.3	62.1	<0.01
W	10.0	2.1	11.4	4.7	52.4	<0.01	24.9	3.3	26.1	<0.01	12.1	5.3	8.6	2.1	42.1	<0.01
H	15.6	7.9	50.2	26.3			70.5	29.5			23.5	17.2	42.3	17.0		

Code	Category from multiple univariate clusters with scoring to 4 best variables						Category from multiple univariate clusters with scoring to 11 variables						Category from multiple univariate clusters with scoring to 5 best variables					
	U	UPT	P	R	χ^2	P	U	UPT	P	R	χ^2	P	U	UPT	P	R	χ^2	P
F	3.5	7.0	16.0	25.8	39.9	<0.01	7.4	4.0	34.4	6.5	42.4	<0.01	3.5	10.2	15.8	22.8	39.9	<0.01
D	14.2	2.3	7.2	8.1	116.8	<0.01	14.7	2.3	13.5	1.4	60.2	<0.01	14.2	4.4	6.5	6.7	114.7	<0.01
W	10.7	5.1	6.5	5.8	65.4	<0.01	12.1	4.9	9.3	1.9	45.9	<0.01	10.7	6.3	3.7		75.6	<0.01
H	16.5	15.3	27.9	40.2			23.5	12.6	52.8	11.2			16.5	19.8	29.5	34.2		

The classification produced by multivariate analysis incorporated a greater proportion of the surveyed households in the urban-peri-urban transition (>34%) than other methods. However, the multivariate analyses did not provide meaningful results as the regional classification through the k-means clustering failed to capture the distinctive urban and rural sub-districts from the all factors. The highest shared variances of the first factor provided the regional classification through the k-means clustering that emphasised to the human activities in social and economy. Hence, formulating a regional rural-urban interface classification by segmenting variables measured into two or three principal components did not provide an accurate definition of the urban and rural sub-districts. As a consequence, the classification also could not provide accurately the sub-districts with intermediate category, urban-peri-urban transition (UPT) and peri-urban.

The 2010 national census identified the greatest proportion (70%) of surveyed households being in urban areas while the rest (30%) were in rural areas. Based on the census classification, three indicators of urban and rural ecohydrology were found to be highest in the urban areas: these being the proportion of farmers and households with access to public drinking water and wastewater treatment services. These results show that the classification of rural-urban interface used in the census failed to identify not only peri-urban characteristics but also rural characteristics. Critically, this demonstrates that the scoring system applied on the 2010 Census did not provide methods to define peri-urban areas.

Compared to the multivariate analysis, the formulation of regional rural-urban interface classifications using univariate cluster and multiple univariate cluster analysis with scoring provided more meaningful results. The classification of the rural-urban interface ecohydrology through Jenks' natural breaks from spatial built-up data and multiple univariate analysis with scoring from 11 variables provided a greater proportion of the surveyed households in the peri-urban (>50%) than other methods. The classification of the rural-urban interface ecohydrology, based on the four best and five best variables, provided for a greater proportion of the surveyed households in rural areas than other methods (>34%). However, using the four and five best criteria did not consider the other important factors of distinctive urban and rural sub-districts.

The regional rural-urban interface classification based on multiple univariate clusters and scoring to the four best, five best and 11 variables yielded higher chi-squared values compared to the classifications based on the spatial data and scoring to the nine rural-urban interface thresholds. Higher chi-squared values mean higher inconsistency between rural-urban interface ecohydrology and distribution of the rural-urban interface households. Based on these results, the multiple univariate clusters with scoring to the nine rural-urban interface thresholds was proven giving more representative of the distribution of the rural-urban interface ecohydrology. This classification method provided the best understanding of the evolution of urbanisation and rural-urban water related characteristics at the metropolitan level. In addition, more accurate definitions of urban, urban-peri-urban transition, peri-urban and rural were obtained through this category. Hence, rural-urban classification from the multiple univariate with scoring analysis to nine variables was used in the further analysis to define rural-urban interface ecohydrology within CMR.

4.3.2 QUANTIFYING THE STATE OF RURAL-URBAN INTERFACE ECOHYDROLOGY

A total of 11 socio-economic and spatial variables were used in the analysis for quantifying rural-urban interface ecohydrology in the urban, UPT, peri-urban, and rural sub-districts within CMR. The Kaiser-Meyer-Olkin model that measures sampling adequacy was found to be greater than 0.5 (0.65 for 11 variables) verifying that the datasets were appropriate for the factor analysis with principal components. The Bartlett's test was also found to be significant ($p<0.05$). Three principal components using 11 indicators provided high alpha values ≥0.80 with a total variance explained of 79% (Table 14).

4.3.2.1 PRINCIPAL COMPONENT ANALYSIS

PC I loaded strongly on the increase of proportion of urban villages within a sub-district, population density, built-up area, and on the decrease of travel time, distance to the city centre and population working in agriculture. PC II loaded strongly on the increased poverty level and the decreased literacy rate and built-up area. PC III loaded strongly on the increase of forests, water bodies, and semi-natural areas and the decrease of agricultural areas. Spatial distribution of factor values based on the 11 indicators at 45 sub-districts is shown in the map in Figure 16. PC I was defined as a principle component with high-correlated factors with socio-economic aspects related to water supply requirement (PI_{ws}), water quality risks (PI_{wq}), open space distribution (PI_{os}), and climate change pressures (PI_{cc}). PC II was defined as a principle component with high-correlated factors to the water management capacity or social dimension (PI_{wm}) implying vulnerable groups regarding water-related problems and resilience that were also related to open space distribution. PC III was defined as a principal component with high-correlated factor to the available natural resources, biodiversity, water, and food production (PI_{be}).

TABLE 14. PRINCIPAL COMPONENT LOADING OF 11 VARIABLES

Var	Principal Component Loading			Proxy Indicators of Ecohydrology	% of Variance Explained (Rotation)				KMO	Bartlett's Test		
	PC I	PC II	PC III		PC I	PC II	PC III	Total		Approx. χ^2	d.f.	Sig
X_{AA}	-0.29	0.53	**-0.70**	$\boldsymbol{PI_{be}}$	30	28	21	79	0.65	1070.58	55	<0.001
X_{FWS}	-0.33	0.05	**0.91**	$\boldsymbol{PI_{be}}$								
X_{BA}	**0.65**	**-0.63**	-0.16	$\boldsymbol{PI_{os}}$								
X_{UV}	**0.84**	-0.09	0.14	$\boldsymbol{PI_{ws}}$, $\boldsymbol{PI_{wq}}$								
X_{PS}	**0.68**	0.48	0.02	$\boldsymbol{PI_{ws}}$								
X_{PD}	**0.67**	-0.57	-0.19	$\boldsymbol{PI_{wq}}$								
X_{PA}	**-0.82**	0.36	-0.06	$\boldsymbol{PI_{ws}}$								
X_{D}	**-0.78**	0.31	0.31	$\boldsymbol{PI_{cc}}$								
X_{T}	**-0.83**	0.15	0.32	$\boldsymbol{PI_{cc}}$								
X_{LR}	0.30	**-0.81**	0.24	$\boldsymbol{PI_{wm}}$								
X_{PL}	-0.02	**0.82**	-0.01	$\boldsymbol{PI_{wm}}$								
Cronbach's Alpha (α) based on the total eigenvalue					0.85	0.80	0.81	0.97				

Note: Var=Variables; PC = Principal Component

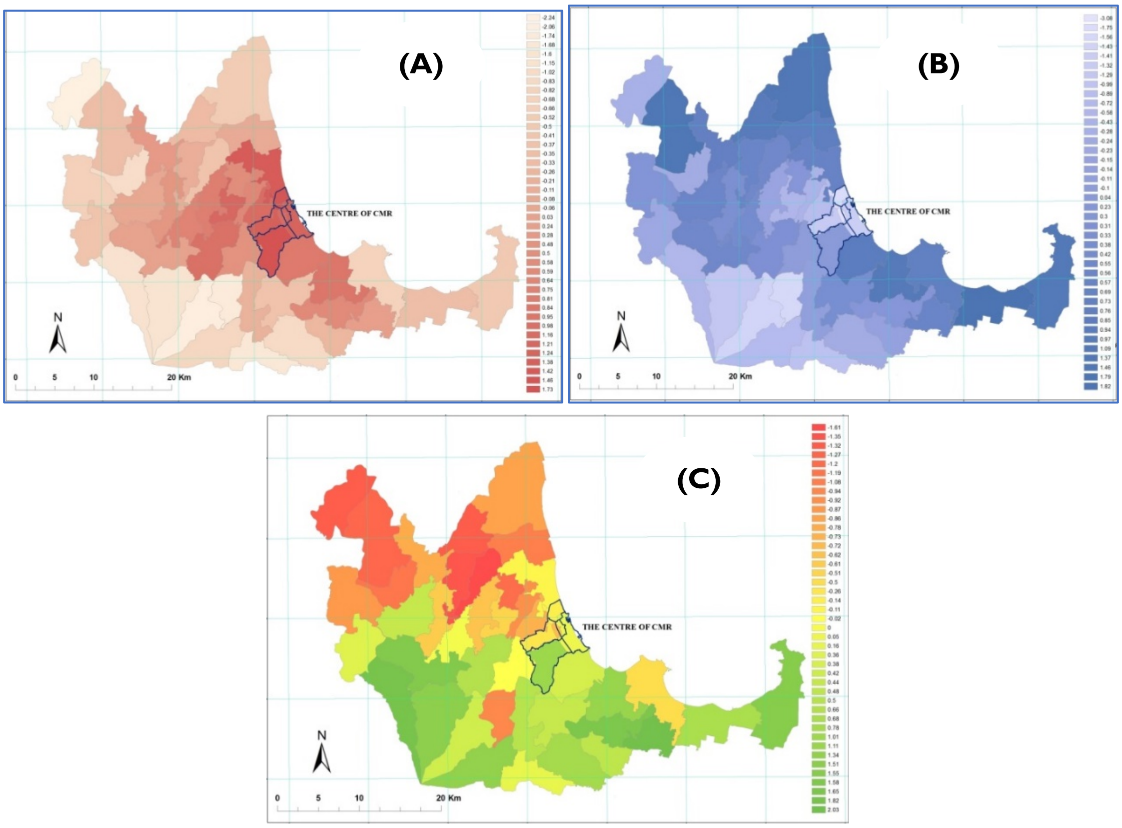

FIGURE 16. SPATIAL DISTRIBUTION OF FACTOR VALUES BY SUB-DISTRICTS FROM ELEVEN VARIABLES: (A) PC I; (B) PC II; AND (C) PC III

Spatial distribution pattern of PC I shows that the darkest colour on the maps indicates the highest factor values of the areas. The darkest colour as shown in Figure 16(a) shows the sub-districts with the lowest distance, travel time and population engaged in agriculture, highest percentage of urban villages within sub-district, population density and built-up areas can be defined as more urban. In the context of ecohydrology, those sub-districts with more urban characteristics have higher built-up areas implying lower PI_{os}; higher population density implying higher PI_{wq}; higher urban villages implying higher level of human activities in social economy in the village settlements within a sub-district and implying higher PI_{ws} and PI_{wq} from urban activities; lower travel time and distance to the city centre implying the areas as the centre of social-economic activities implying higher PI_{cc}; and lower population engage in agriculture implying higher urban activities in non-agriculture or higher PI_{ws} for non-agricultural activities. According to PC I, five sub-districts in CM (Kejaksan, Pekalipan, Kesambi, Lemahwungkuk and Harjamukti) and three sub-districts in the CR (Weru, Kedawung, and Gunungjati) have dominantly human activities in socio-economic aspects, implying lower PI_{os} and higherPI_{ws}, PI_{wq}, and PI_{cc}. On the other hand, Sindangwangi and Mandirancang were among the sub-districts with distinctive minor human activities in socio-economic aspects, implying higher PI_{os} and lowerPI_{ws}, PI_{wq}, and PI_{cc}.

Spatial distribution pattern of PC II shows that the darkest colour on the maps indicates the sub-districts with the highest poverty level and the lowest literacy rate. Hence, the sub-districts with the darker colour as shown in Figure 16 (b) can be defined as more rural. Thus PC II has lower variance in explaining rural-urban characteristics in the CMR compared to the PC I. However, it can explain more in the context of ecohydrology. Those sub-districts with more urban characteristics have lower poverty level and higher literacy rate implying higher PI_{wm} or lower vulnerability and higher resilience regarding water-related problems. According to PC II, five sub-districts in KR (Mandirancang, Pasawahan, Pancalang, Cilimus and Cigandamekar) and four sub-districts in CM (Kejaksan, Pekalipan, Kesambi, and Lemahwungkuk) have more urban characteristics while Kapetakan and Gebang were among sub-districts with more rural characteristics. Critical area with lower PI_{wm}implying higher vulnerability or lower resilience regarding water-related problems within CMR was found in the CR, particularly in the coastal sub-districts (Plate 8).

PLATE 8. HUMAN SETTLEMENT AREAS IN THE COASTAL SUB-DISTRICTS OF CR

Rural-urban pattern from PC III are considerably different than PCs I and II. The green colour indicates the highest factor value while the red colour indicates the lowest factor value. The green colour shows the highest proportion of forests, water bodies, and semi-natural areas and the lowest proportion of agricultural areas. This PC III has the lowest variance in explaining rural-urban characteristic in the CMR, but it can explain more in the context of ecohydrology. Those sub-districts with a higher level of green colour show higher availability of natural resources, biodiversity, and water but lower food production's activities while those sub-districts with a higher level of red colour show lower availability of natural resources, biodiversity, and water but higher food production's activities. According to PC III, Sukagumiwang (IR) and most sub-districts in the north part of the CMR such as Klangenan, Susukan, Plered, Suranenggala, and Kapetakan were among sub-districts with lower natural resources and water availability but higher food production's activities. On the other hand, those in the south part of the CMR such as Harjamukti (CM), Cilimus and Pasawahan (KR), Karangsembung and Dukupuntang (CR), and Sindangwangi (MR) were among sub-districts with higher PI_{be} (Plate 9).

PLATE 9. HIGHER FOOD PRODUCTION ACTIVITIES IN A: KLANGENAN AND B: KAPETAKAN AND HIGHER NATURAL RESOURCES IN C: HARJAMUKTI AND D: PASAWAHAN

4.3.2.2 THE STATE OF ECOHYDROLOGY BASED ON ESI_{ru}

The results of quantifying the state of rural-urban interface ecohydrology using the three principal components are shown in Table 15. Three of the eight urban sub-districts have very high value of ESI_{ru1} in socio-economic aspects (≥ 0.91), namely Harjamukti, Kejaksan and Kesambi while the rest urban sub-districts have high ESI_{ru1} (0.76-0.90).

TABLE 15. ECOHYDROLOGICAL STATE INDEX FOR RURAL-URBAN INTERFACE (ESI_{ru}) IN THE RURAL-URBAN SUB-DISTRICTS WITHIN CMR

Rural-urban sub-districts from the best classification method for defining rural-urban interface ecohydrology in the CMR	ESI_{ru1} *represents* PI_{os}, PI_{ws}, PI_{wq}, PI_{cc}	ESI_{ru2} *represents* PI_{wm}	ESI_{ru3} *represents* PI_{be}
	1	*2*	*3*
Urban			
Harjamukti (Cirebon City)	**1.00**	0.64	0.72
Kedawung (Cirebon District)	**0.86**	**0.45**	0.24
Kejaksan (Cirebon City)	**0.93**	**0.27**	0.40
Kesambi (Cirebon City)	**0.91**	**0.36**	0.37
Lemahwungkuk (Cirebon City)	**0.88**	**0.34**	0.46
Pekalipan (Cirebon City)	**0.86**	**0.00**	0.25
Plumbon (Cirebon District)	**0.77**	**0.60**	0.27
Weru (Cirebon District)	**0.87**	**0.51**	0.30
Peri-urban			
Arjawinangun (Cirebon District)	0.63	0.78	0.23
Beber (Cirebon District)	0.51	0.61	0.58
Cigandamekar (Kuningan District)	0.14	**0.43**	0.49
Cilimus (Kuningan District)	0.36	**0.48**	**0.81**
Ciwaringin (Kuningan District)	0.31	**0.58**	0.12
Dukupuntang (Cirebon District)	0.57	0.74	**0.88**
Gempol (Cirebon District)	0.55	0.74	0.56
Greged (Cirebon District)	0.47	0.71	0.56
Jamblang (Cirebon District)	0.46	0.74	0.00
Karangsembung (Cirebon District)	0.62	0.74	**1.00**
Klangenan (Cirebon District)	0.54	0.75	0.07
Leuwimunding (Majalengka District)	0.46	**0.58**	0.54
Pancalang (Kuningan District)	0.13	**0.31**	0.18
Panguragan (Cirebon District)	0.48	0.83	0.08
Pasawahan (Kuningan District)	0.16	**0.36**	**0.86**
Sedong (Cirebon District)	0.36	**0.58**	0.66
Sumberjaya (Majalengka District)	0.40	0.69	0.20
Suranenggala (Cirebon District)	0.55	0.80	0.15
Susukanlebak (Cirebon District)	0.50	**0.60**	0.57

Rural-urban sub-districts from the best classification method for defining rural-urban interface ecohydrology in the CMR	ESI_{ru1} *represents* PI_{os}, PI_{ws}, PI_{wq}, PI_{cc}	ESI_{ru2} *represents* PI_{wm}	ESI_{ru3} *represents* PI_{be}
	1	*2*	*3*
Urban-Peri-urban Transition (UPT)			
Astanajapura (Cirebon District)	**0.80**	0.85	0.75
Depok (Cirebon District)	0.75	0.71	0.44
Gunungjati (Cirebon District)	**0.92**	0.77	0.41
Lemahabang (Cirebon District)	0.71	0.68	**0.90**
Mundu (Cirebon District)	**0.78**	0.82	0.55
Palimanan (Cirebon District)	0.69	0.70	0.28
Plered (Cirebon District)	0.71	0.67	0.11
Sumber (Cirebon District)	**0.81**	0.69	0.62
Talun (Cirebon District)	0.69	0.61	0.44
Tengahtani (Cirebon District)	0.73	**0.54**	0.19
Rural			
Gebang (Cirebon District)	0.48	1.00	0.63
Kapetakan (Cirebon District)	0.43	0.93	0.21
Losari (Cirebon District)	0.44	0.91	**0.87**
Mandirancan (Kuningan District)	0.04	**0.34**	0.56
Pangenan (Cirebon District)	0.39	0.78	0.30
Sindangwangi (Majalengka District)	0.28	**0.51**	**0.94**
Sukagumiwang (Indramayu District)	0.00	**0.57**	0.08
Susukan (Cirebon District)	0.48	0.99	0.09

Interpretation	*1*	*2*	*3*
0.91-1.00	*Very High*	*Very Low*	*Very High*
0.76-0.90	*High*	*Low*	*High*
0.61-0.75	*Moderate*	*Moderate*	*Moderate*
0.51-0.60	*Low*	*High*	*Low*
<0.50	*Very Low*	*Very High*	*Very Low*

Note:Bold values show a category of "high" or" very high". The scores were obtained from PCA with 3 principal component solutions (eigenvalues greater than 1)

Harjamukti is the only urban sub-district within CMR that still has a moderate availability of natural resources and food production (PI_{be}) with a ESI_{ru3} value of 0.72 while the rest of the urban-sub-districts have very low PI_{be} with ESI_{ru3} values <0.50. In fact, Harjamukti is the place for urban newcomers to find residential areas close to the city centre. A high dynamic change in land use from farmlands to housing/settlement areas in the past decade can be seen in Harjamukti (Plate 10). Among the sub-districts in the city, Harjamukti has the largest size in population and total area, furthest distance from the city centre, but lowest size in density and built-up areas implying highest PI_{ws}, highest PI_{cc}, lowest PI_{wq}, and highest PI_{os}.

PLATE 10. LAND USE FOR FOOD PRODUCTION AND NEW HOUSING AREAS IN HARJAMUKTI

However, among urban-sub-districts, Harjamukti also has the lowest capacity in water management (PI_{wm}) with a ESI_{ru2} value 0.64 while other urban sub-districts in the CM have higher PI_{wm} with ESI_{ru2} values <0.5. Currently, most urban dwellers in the CM (>80%) have access to the gravity flow water systems of PDAM (a formal local drinking water company at the district level) that was transmitted from KR (Pasawahan Sub-District, peri-urban category within CMR). However, Harjamukti's residents have problems in accessing the public water system services because the topography of Harjamukti is comparably higher than other sub-districts in the CM. The higher topography has made the PDAM face problems in the distribution of water supply using gravity system in that area. Further, higher potential decreases of open space distribution in the Harjamukti and the higher potential increase of housing and human settlement will provide more challenges to the future fulfilment of water supply requirements.

Sub-districts that are located in the CR adjacent to the city and linked with the arterial roads or toll-roads such as Kedawung, Weru and Plumbon have shown similar characteristics as urban sub-districts in the city. Sub-districts in the peripheral city in the category of UPT areas also have a high value of ESI_{ru1} in socio-economic aspects, such as Gunungjati (0.92), Sumber (0.81), Astanajapura (0.80), and Mundu (0.78), but lower capacity in water management ESI_{ru2} than those in the urban category (>0.64). Sub-districts located further from the city showed different characteristics. Arjawinangun is the only sub-districts in the peri-urban category with a moderate value of ESI_{ru1}in socio-economic aspects, while the rest, peri-urban districts and all rural districts have low values of ESI_{ru1} (≤0.6). Further, sub-districts located in the foothills of Mount Ciremai such as Sindangwangi (rural sub-district, MR), Pasawahan and Cilimus (peri-urban sub-districts, KR) have high values of ESI_{ru2} in water management capacity and ESI_{ru3} in natural resource availability.

Mean values of ESI_{ru} in the rural-urban categories within CMR are shown in Table 16.

TABLE 16. RELATIONSHIP BETWEEN FOUR RURAL-URBAN CATEGORIES AND MEAN COMPOSITE INDICES

Rural-urban sub-districts within CMR	Mean composite indices scores		
	ESI_{ru1} *represents* $PI_{os}, PI_{ws}, PI_{wq}, PI_{cc}$	ESI_{ru2} *represents* PI_{wm}	ESI_{ru3} *represents* PI_{be}
Urban	0.89 (0.07)*	0.40 (0.21)*	0.38 (0.16)
Urban-Peri-urban Transition (UPT)	0.76 (0.07)*	0.70 (0.09)	0.47 (0.25)
Peri-urban	0.43 (0.15)	0.63 (0.15)	0.45 (0.31)
Rural	0.32 (0.19)	0.75 (0.25)	0.46 (0.34)
F statistics	36.05	6.89	0.19
P-value	<0.001	<0.001	>0.05

** the mean difference is significant at the 0.05 level*

In general, urban and UPT sub-districts in the CMR have significant higher values of ESI_{ru1} in socio-economic aspects compared to the peri-urban and rural sub-districts implying significant higher non-open space areas or lower PI_{os}, higher PI_{ws}, higher PI_{wq}, and higher PI_{cc}. Urban dwellers in the CMR also had significant lower values of ESI_{ru2} related to water management capacity compared to the dwellers that lived in the non-urban sub-districts implying higher PI_{wm} or significant lower vulnerable groups regarding water-related problems and resilience. However, rural-urban sub-districts in the CMR commonly have very low values of ESI_{ru3} for natural resources availability, except sub-districts in Kuningan. In particular, urban sub-districts mostly have insignificant lower PI_{be} compared to the UPT, peri-urban, and rural sub-districts. Spatial distributions of the three Ecohydrological State Indexes for Rural-Urban Interface (ESI_{ru1}, ESI_{ru2}, and ESI_{ru3}) in the rural-urban interface sub-districts within CMR are presented in Figures 17, 18 and 19.

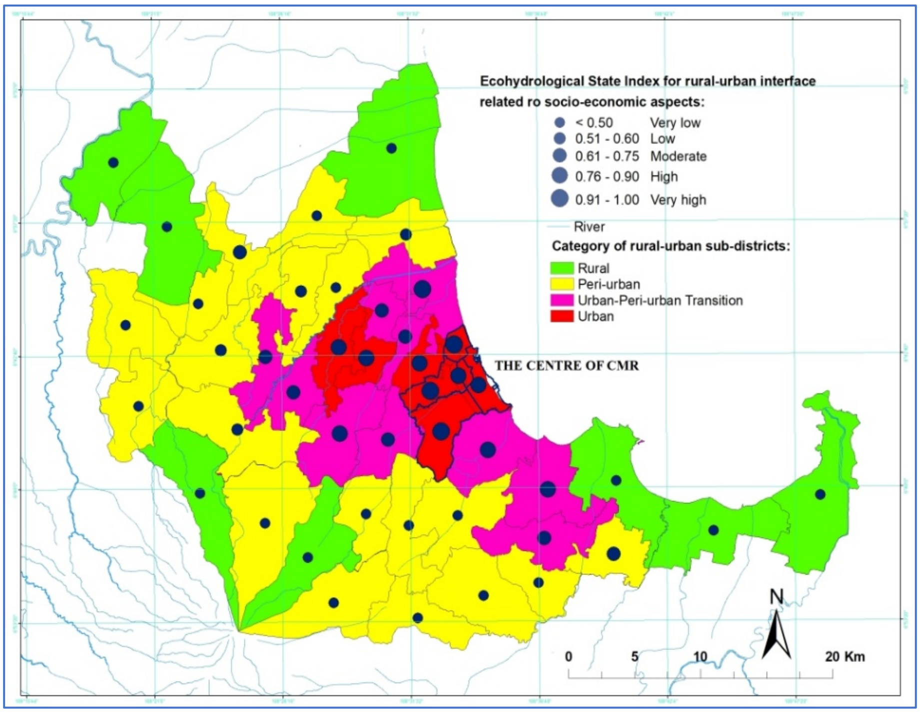

FIGURE 17. SPATIAL DISTRIBUTION OF ESI_{ru1} RELATED TO SOCIO-ECONOMIC ASPECTS

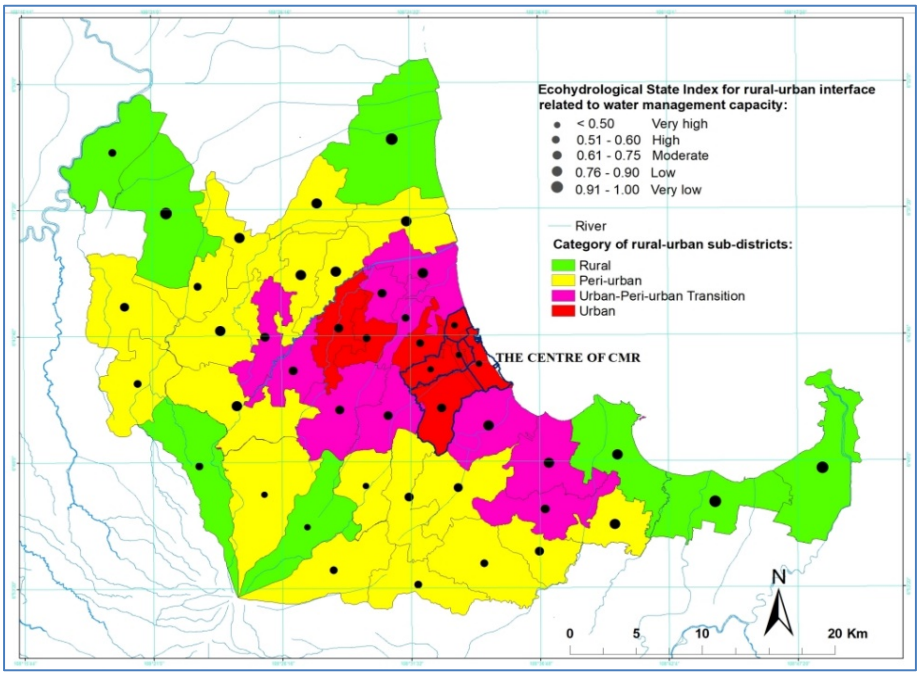

FIGURE 18. SPATIAL DISTRIBUTION OF ESI_{ru2} RELATED TO WATER MANAGEMENT CAPACITY

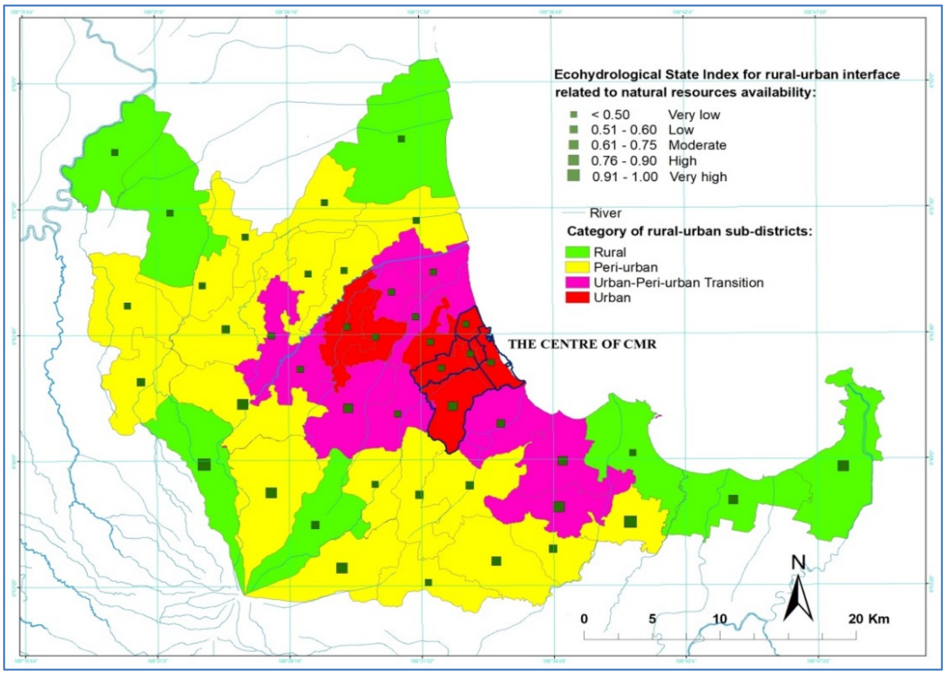

FIGURE 19. SPATIAL DISTRIBUTION OF ESI_{RU3} RELATED TO NATURAL RESOURCES AVAILABILITY

Table 17 shows the ranks of ESI_{ru} values for ecohydrological state in the CMR. The rank of ESI_{ru} depicts rural-urban interface ecohydrology and provides a systematic pattern of ecohydrological changes that fit with the rural-urban interface classification based on nine variables. Additional two variables, availability of agricultural areas and natural resources provided higher scores of ESI_{ru} in Plumbon and Cigandamekar that were respectively positioned in the rank of scores for urban-peri-urban transition and rural sub-districts. The construction of ESI_{ru} weighed highly on the proportion of built-up areas, population density, proportion of population working in agriculture, and distance to city centre. Higher scores of ESI_{ru} represent higher open space distribution (PI_{os}) or smaller extent of impervious areas, lower water quality risks (PI_{wq}), higher water supply requirements (PI_{ws}) for agricultural activities, and lower climate change pressures (PI_{cc}) as situated further from city while lower scores of ESI_{ru}represent the opposite. Based on the values of ESI_{ru}, all urban sub-districts have very low values showing low capacity in providing ecosystem services for urban liveability and regional sustainability as population density in those sub-districts is high.

The lowest ESI_{ru} (<0.25) were obtained for Pekalipan (0.00), Kejaksan (0.12), Kesambi (0.19), and Lemahwungkuk (0.21) implying lowest PI_{os}, highest PI_{wq}, lowest PI_{ws} for agricultural activities, and highest PI_{cc}. The scores that were weighted highly on built-up areas or PI_{os} also show that those urban sub-districts have lowest capacity in providing protection of ecohydrological processes and potential, conservation of biodiversity, maintaining air and water quality or improving the local microclimate. In fact, the city is currently dependent on the peri-urban ecosystem to provide natural resources including water and food. The highest value of ESI_{ru} (>0.91) were obtained from Losari (0.93), Gebang (0.94), and Sukagumiwang (1.00) implying highest PI_{os}, lowest PI_{wq}, highest $PI_{ws}$for agricultural activities, and lowest PI_{cc}. The development of ESI_{ru} from PCA with one-dimension solution however provided low weight from indicators implying water management capacity and ecosystem services in natural resource availability and food production activities. Hence, more accurate ecohydrological state at the rural-urban interface within CMR can be obtained from the PCA with three-dimension solutions.

Table 17. Ranks of Ecohydrological State Index for Rural-Urban Interface ESI_{ru} of 45 sub-districts in the CMR

No	Sub-districts	Level of urbanisation from 9 variables	ESI_{ru}
1	Pekalipan (Cirebon City)	Urban	0.00
2	Kejaksan (Cirebon City)	Urban	0.12
3	Kesambi (Cirebon City)	Urban	0.19
4	Lemahwungkuk (Cirebon City)	Urban	0.21
5	Kedawung (Cirebon District)	Urban	0.27
6	Weru (Cirebon District)	Urban	0.31
7	Harjamukti (Cirebon City)	Urban	0.32
8	Tengahtani (Cirebon District)	Urban-Peri-urban Transition	0.42
9	Gunungjati (Cirebon District)	Urban-Peri-urban Transition	0.43
10	Plumbon (Cirebon District)	Urban	0.43
11	Sumber (Cirebon District)	Urban-Peri-urban Transition	0.49
12	Plered (Cirebon District)	Urban-Peri-urban Transition	0.51
13	Talun (Cirebon District)	Urban-Peri-urban Transition	0.52
14	Depok (Cirebon District)	Urban-Peri-urban Transition	0.53
15	Palimanan (Cirebon District)	Urban-Peri-urban Transition	0.56
16	Lemahabang (Cirebon District)	Urban-Peri-urban Transition	0.58
17	Mundu (Cirebon District)	Urban-Peri-urban Transition	0.59
18	Astanajapura (Cirebon District)	Urban-Peri-urban Transition	0.60
19	Arjawinangun (Cirebon District)	Peri-urban	0.64
20	Beber (Cirebon District)	Peri-urban	0.67
21	Susukanlebak (Cirebon District)	Peri-urban	0.67
22	Leuwimunding (Majalengka District)	Peri-urban	0.69
23	Klangenan (Cirebon District)	Peri-urban	0.69
24	Karangsembung (Cirebon District)	Peri-urban	0.70
25	Gempol (Cirebon District)	Peri-urban	0.72
26	Suranenggala (Cirebon District)	Peri-urban	0.72
27	Dukupuntang (Cirebon District)	Peri-urban	0.73
28	Cilimus (Kuningan District)	Peri-urban	0.73
29	Jamblang (Cirebon District)	Peri-urban	0.74
30	Pancalang (Kuningan District)	Peri-urban	0.75
31	Greged (Cirebon District)	Peri-urban	0.76
32	Ciwaringin (Kuningan District)	Peri-urban	0.77
33	Sumberjaya (Majalengka District)	Peri-urban	0.77
34	Sedong (Cirebon District)	Peri-urban	0.78
35	Panguragan (Cirebon District)	Peri-urban	0.78
36	Pasawahan (Kuningan District)	Peri-urban	0.82
37	Sindangwangi (Majalengka District)	Rural	0.82
38	Cigandamekar (Kuningan District)	Peri-urban	0.84
39	Pangenan (Cirebon District)	Rural	0.84
40	Mandirancan (Kuningan District)	Rural	0.86
41	Susukan (Cirebon District)	Rural	0.89
42	Kapetakan (Cirebon District)	Rural	0.89
43	Losari (Cirebon District)	Rural	0.93
44	Gebang (Cirebon District)	Rural	0.94
45	Sukagumiwang (Indramayu District)	Rural	1.00

Social-economy and spatial data	*Weight*	*Component Loading*	*Ecohydrological Proxy Indicators*
Rank of weight from 11 variables in the 45 (rural-urban interfaces) sub-districts:			
%Built-up area	0.15	-0.90	PI_{os}
Population density	0.15	-0.88	PI_{wq}
%Population working in agriculture	0.14	0.87	PI_{ws}
Distance to city centre	0.14	0.85	PI_{cc}
Travel time to city centre	0.12	0.81	PI_{cc}
%Urban villages in a sub-district	0.10	-0.74	PI_{ws}, PI_{wq}
Literacy rate	0.08	-0.65	PI_{wm}
%Agricultural area	0.04	0.45	PI_{be}
Poverty level	0.04	0.45	PI_{wm}
%forests, water bodies, semi natural area	0.03	0.40	PI_{be}
Population size	0.02	-0.31	PI_{ws}
PCA with 1 principal component solution:			
Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO)		0.61	
% of variance		49	
Bartlett's Test:			
Approx. χ^2		256.06	
d.f		21	
Sig		<0.001	
Cronbach's Alpha (α) based on the total eigenvalue		0.90	
Interpretation:			
0.91-1.00		*Very High*	
0.76-0.90		*High*	
0.61-0.75		*Moderate*	
0.51-0.60		*Low*	
<0.50		*Very Low*	

4.4 DISCUSSIONS

4.4.1 QUANTIFYING RURAL-URBAN INTERFACE ECOHYDROLOGY FOR PLANNING

This study was conducted at a metropolitan region in a developing country on a core city with a population of less than 500,000 residents. According to Cohen (2006), smaller cities and towns under half a million should be paid more attention in the development agenda of urban future because compared to large cities, they have very significant total population, faster growth, considerably underserved basic services, higher poverty, and weaker local government capacity. Moreover, in developing countries, water distribution systems and public sanitation services in cities are typically inadequate. For instance, in the CMR as a focus area of this study, the coverage of sewerage system services is still less than 5% while the service coverage of public water services in the districts surrounding city is still less than 25% of the political boundary (WJP-MDM, 2013a). This will lead to more challenges to improve basic services in the areas that are directly affected by urban expansion. Also, without sufficient wastewater treatment facilities, urban residents will face severe environmental health problems as cities will discharge increasing amounts of waste into freshwater bodies, threatening water quality and aquatic ecosystems. Before the service gap and environmental degradation levels become too overwhelming from evolving into larger cities, the small cities have time to address the needs of urban residents for basic infrastructures and ecosystem services for shaping healthy and friendly city and its outskirts.

In this study, social, economy, and spatial data were used as new indices for assessing ecohydrological potential or defining rural-urban interfaces ecohydrology. A systematic pattern can be found from ESI_{ru} values implying ecohydrological processes and potential in the rural-urban interfaces including the peri-urban zones. Urbanisation transforms rural land uses for agriculture or forestry to urban land uses that is characterised by a large extent of built-up area, high population density, and a lesser proportion of residents engaging in agriculture. Land use practices in the urban zones showed that sub-districts in the city boundary such as Pekalipan, Kejaksan and Kesambi have limited open space distributions or a large expanse of impervious areas, very high population density implying high water quality risks, high water supply requirement for non-agricultural activities, and high climate change pressures. In addition, this study showed that peri-urban sub-districts closed to the city have been directly affected by the urban expansion. More human activities in socio-economic aspects in the UPT zone indicate more basic services for healthy housing and human settlement will be required as well as more efforts for maintaining peri-urban ecosystem services.

Water demands related to land use practices and urbanisation alters rural-urban landscape structures causing stresses to ecosystems and impacts on water quantity and quality (Foley et al., 2005, Sun and Lockaby, 2012). Currently, peri-urban areas are not recognised as an integral part of the functional activities of urban growth. In the context of urban water management, peri-urbanisation brings particular challenges in quantifying and qualifying the impacts of urban spaces on natural processes for managing water quality dynamics (McGrane, 2016). This issue is closely related to the boundary crossing of urban areas into rural areas which is increasing as the population grows. In an urban and regional planning context, a peri-urban zone is a part of spatial categories in the metropolitan development. This area deserved specific planning and management. As highlighted also by Wandl and Magoni (2017), peri-urban areas ask for particular attention and distinctive policy approaches as they are not simply the extension of the urban in the rural areas. Defining rural-urban interface ecohydrology including peri-urban zones would be beneficial in planning for developing rural-urban strategy related to water, people and environment for better liveability and sustainability.

4.4.2 INTEGRATING ECOHYDROLOGY IN URBAN PLANNING

Urbanisation drives environmental changes at multiple scales, from local land use and cover, regional hydrosystems, to the global biogeochemical cycles and climate (Grimm et al., 2008, Sun and Lockaby, 2012, Foley et al., 2005). Converting rural lands to urban uses will bring impacts on watershed ecosystem health and sustainability issues (Sun and Lockaby, 2012). Cities and surrounding areas are catchments of rivers or urban-rural watersheds within river basins. Landscape processes in the rural-urban catchment changed in different ways by human activities in social and economic aspects. High built-up environment in the cities represents less open spaces in those urban environments such as parks and gardens, farmlands, forest and nature reserves. Open spaces are dominated by a natural environment. Less open spaces in the city represent limited continuous function of the ecosystems and survival of nature and landscape values (Maruani and Amit-Cohen, 2007). In particular, the development of peri-urban areas that involves the conversion of rural areas to a changing mix of urban and rural activities and functions can affect ecohydrological function influencing water and land management and food production in the peri-urban areas (Maheshwari et al., 2016). Thus, planning for balanced urban development and an integrated approach that can address the provision of ecosystem services and the maintenance of quality of life within a river basin are required.

In the context of balanced urban development, place, people and planning need to be considered including those in the peri-urban areas (Maheshwari et al., 2016). In the context of ecohydrology, sustainable water management improves a future city's health and functional integration of peri-urban ecosystems into urban development enhances absorbing capacities of urban ecosystems (Zalewski and Wagner, 2008). In this case, regional planning will provide a comprehensive visualisation of the possible flow of waters, services, and population within a defined rural-urban area for optimum liveability-sustainability. As concluded by MacKaye (1940), regional planning is applied human ecology. Hence, the scale of planning activities is a region that commonly contains one major city and has a single macroclimate providing a region-wide control over the soils, ecosystems, and natural processes (Forman, 2014). In the context of regional planning, designing a land that effectively complements ecological reliability with basic human needs will only be accomplished with a healthy landscape and regional ecosystem (Forman, 2014). The harmony between environment and society in the rural-urban interfaces can be supported by applying an ecohydrological system approach to the regulation of the interplay between water and ecosystem (Zalewski and Wagner, 2008).

A systematic method for identifying and evaluation of land most suitable for open space distributions is required for combining metropolitan growth with a network of open spaces that not only protect natural processes but also for amenity and recreation (McHarg, 2014, Maruani and Amit-Cohen, 2007). Ecohydrology (EH) provides a transdisciplinary approach and systemic framework to regulate hydrology, ecosystem, and society interplay to reduce the impacts of floods and droughts, improve human wellbeing, and harmonise ecosystem potential with societal needs (Zalewski, 2010). EH is a problem solving science that emphasises a regulation of processes through effective management of the water and nutrient dynamics from the landscape to aquatic ecosystems (Zalewski, 2007). EH seeks to promote integration of ecology with hydrology to solve issues surrounding water, environment and people to achieve its ultimate goal for the sustainable management of river basins (Zalewski et al., 2008). The three principles of EH not only provide a framework for its implementation but also for harmonisation of EH measures with hydro-technical infrastructures (Zalewski, 2000).

EH principles can be implemented at various scales through the development of integrative scientific methods. First principle of EH was applied in this study for quantifying ecohydrological processes and potential using 11 social, economy and spatial data as ecohydrological proxy indicators at a landscape scale to obtain information and knowledge about rural-urban interface structures, relationships, and patterns in a developing coastal metropolitan region in Indonesia. Yet, to achieve more knowledge about ecohydrological processes, further study regarding quantification of the rural-urban interface water quality and water quantity in the river basin is required. Moreover, to obtain wisdom, the use of information and knowledge for problem solving-formulation in the planning and environmental management for sustainable water uses in the rural-urban interfaces, liveability and sustainability, assessment incorporating rural-urban residents and policy makers are also needed. In particular, there is a need of more studies for understanding the impacts of urban sprawl to the wellbeing of people in the peri-urban areas or liveability for developing more balanced urban development.

The question still remains about how to overcome the separation of urban and rural functions in the current development approach and to combine planning approaches in five districts within CMR in the context of metropolitan region. Strong efforts in bridging separate policies and institutions for integration of basin and spatial planning is also considerably important. In Indonesia, Spatial Planning Law 26/2007 explains how spatial planning can support the water sector. Further, national and provincial plans provide directions for planning at the district level such as 30% space requirement for forest in districts and 30% open space requirement in cities. However, currently long and short-term plans at the national and regional levels do not recognise water resource management as a focus point (Asian Development Bank, 2016c). Therefore, lack of support from non-water sectors and also lack of support in the allocation of budget hampers the application for realising effective integrated water resource management.

4.5 CONCLUDING REMARKS

This study demonstrated that a total of 11 socio-economic and spatial variables can be used for quantifying ecohydrological state of the urban, urban-peri-urban transition (UPT), peri-urban, and rural sub-districts within CMR. Out of these variables, six proxy ecohydrological indicators, viz., PI_{os} , PI_{be} , PI_{ws} , PI_{wq} , PI_{wm} , PI_{cc} were identified and a composite index, called Ecohydrological State Index for Rural-Urban Interface (ESI_{ru}), based on these indicators was developed. Based on these indicators and ESI_{ru}, the first pattern emerged showed the distinctive rural-urban interface ecohydrology related to open spaces distribution, biodiversity and ecosystem services, water supply requirement, water quality risks, water management capacity, and climate change pressures. The second pattern emerged related to the distinctive rural-urban interface ecohydrology in water management capacity. The third pattern was about the distinctive rural-urban interface ecohydrology in the availability of natural resources and food production activities reflecting biodiversity and ecosystem services. The results of quantifying the ecohydrological state in the CMR show that the ESI_{ru} values from PCA with three-dimension solution provide more accurate results than a one-dimension solution. While the typology classifications in this study are unique to the CMR, the methodology relies on publicly available data from the government and Google™ maps thus it could be replicated in other metropolitan areas in Indonesia and elsewhere. The index ESI_{ru} developed in this study can assist in the planning for balanced urban development at a regional scale with an integrated approach that can include the provision of ecosystem services and the maintenance of quality of life within river basins.

CHAPTER 5

A FRAMEWORK FOR EVALUATING ECOHYDROLOGICAL-BASED LIVEABILITY

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Summary

This chapter develops a framework that can identify the interactions of many interdependent variables and explore the underlying principles, structures, and dynamics of change. This aims for evaluating ecohydrological-based liveability, particularly to assess ecohydrological changes and their impacts on urban and peri-urban liveability. Composite indices were developed based on the subjective assessment of selected liveability indicators representing socio-ecohydrological functions of the region. This study identified five underlying structures of satisfaction factors, viz., personal, residential, neighbourhood, regional, and watershed. The study shows that liveability satisfaction varied depending upon the level of urbanisation. The study also indicates that the challenge to improve regional sustainability is significant in the UPT zone where the poor are more likely to live and are more directly affected by urban expansion and degradation of the local ecosystem.

5.1 INTRODUCTION

5.1.1 URBAN ISSUES AND CHALLENGES

The UN-Sustainable Development Goals (SDGs) offer a holistic agenda to pursue integrated economic, social and environmental objectives for human wellbeing. In particular, Goal 11 aims to promote sustainable cities and societies by creating a liveable environment that contributes to enhancing quality of life. Still, there are some persistent and emerging urban issues that need to be addressed to achieve liveability such as unsustainable forms of urban expansion, inequality, and climate change (UN-Habitat, 2016).

In a world that is increasingly urban, SDGs are increasingly relevant (Horne et al., 2018, Parnell, 2016). The urban population is projected to grow to two-thirds of the global population by 2050 (United Nations, 2014). This will inevitably lead to urban expansion. Angel et al. (2011) found that between 1800 and 2000, 90% of cities expanded their areas more than 16-fold; generally two-fold their population growth. The concerns of this are particularly related to an increasing unwieldy urban expansion to peri-urban areas, typically described as "sprawl" (Camagni et al., 2002, Angel et al., 2005). Concerns include several negative impacts on the environment, society, and the economy such as larger loss of arable land, greater competition for resources, growing disparities in household wealth and health, and increasing hazards from climate change (Redman and Jones, 2005, Angel et al., 2011, Bren d'Amour et al., 2017, Keivani, 2010).

Peri-urban areas have enormous potential to play a positive role in accommodating population and urban growths. However, this leads to more challenges in improving basic services in those areas as they are usually situated beyond the coverage of formal networked water and sanitation systems (Allen et al., 2006). Without holistic planning and management, peri-urban areas could experience significant losses of productive agricultural land, increased runoff and water quality degradation affecting liveability (Malano et al., 2014).

5.1.2 LIVEABILITY CONCEPT AND ASSESSMENT

Liveability relates to social, economic and physical aspects of the environment and provides the practical meaning of sustainability in urban development (Newman, 1999). As well as being related to sustainability, liveability relates to the concept of quality of life (Shafer et al., 2000) and is generally understood to describe relationships between people and the environment (de Chazal, 2010, Pacione, 1990). Liveability is thus recognised as being difficult to measure and define (Van Kamp et al., 2003). Newman (1999) highlights that although liveability can never be separated from the natural environment, it is about human environments. Therefore It inherently focuses on human and is a reflection of quality of life, well-being, and satisfaction of the needs of residents, now and in the future (Johnstone et al., 2013, de Haan et al., 2014) and in the nation (Veenhoven, 1996b).

Factors that have substantial impacts on liveability include quality of the environment including locally generated ecosystem services such as water and green open spaces, accessibility to public services and urban amenities, and affordability (Bolund and Hunhammar, 1999, Badland et al., 2014, Kennedy and Buys, 2010, Namazi-Rad et al., 2016, Furlong et al., 2018). However, unwieldy urban expansion contests the quality of life of residents as issues in environmental, social, and economic inequalities emerge (Ewing et al., 2002, Wei and Ewing, 2018, Wang et al., 2018, Ewing, 2017). To deal with these issues, and to achieve sustainable urban development, there is a need to understand how urbanisation impacts liveability.

Many studies confirm that urbanisation has massive impacts on the hydrologic water cycle with the impacts worsening due to climate change (Grimm et al., 2008, Miller and Hutchins, 2017, McGrane, 2016, Astaraie-Imani et al., 2012, Guneralp et al., 2015, Du et al., 2015). The impacts range from increased runoff resulting from the increase of impervious areas causing the degradation of waterways to increased demand for water to satisfy the needs of a growing population. These issues manifest more dramatically in the peri-urban areas of developing countries as they experience faster land use changes and generally lack urban infrastructures (Singh and Maheshwari, 2014a).

It is also widely recognised that the measurement of quality of life or liveability is not adequate to solely consider objective social indicators and needs subjective measures of community satisfaction to gain a clearer picture (Vreugdenhil and Rigby, 1987). Although subjective measurements have some limitations as they tend to be unstable, incomparable and unintelligible, they are crucial to inform public preferences (Veenhoven, 2002). Subjective measurement is useful to complement other indicators already used to inform policy makers on designing and delivering policies (OECD, 2013). Local governments thus have an important function in shaping the local environments as they are directly responsible for planning, providing services and infrastructures to create a liveable place. Further, understanding community experiences and satisfaction with government services helps to inform strategic planning for urban development policy and guide resourcing for urban needs that impact an individual's overall wellbeing and quality of life (Sirgy et al., 2000).

As urban areas continue to grow all over the world, it is thus likely that the liveability of urban and peri-urban dwellers will become more important in defining quality of life. The future success of urban development thereby depends on the capacity of local governments to face a number of critical challenges resulting from the changes in land use, water cycle, and climate. Liveability is usually used to refer to urban spaces (Ruth and Franklin, 2014, Pacione, 2003) but it can be used as a key approach to analysing and planning inhabited landscapes along the rural-urban gradient (Antognelli and Vizzari, 2017). Building on the notion of liveability as a place and human based conception, this study defines liveability as the dynamic interactions between people, the environment and water that show socio-ecological and socio-hydrological systems; in this study, this is called a socio-ecohydrological system. Through this concept, urban and peri-urban areas are considered as one urban system that impacts the perceived quality of life in urban and peri-urban communities.

5.1.3 THE KNOWLEDGE GAP AND AIMS OF THE STUDY

Water is a key input for many activities within the economic, social, and environmental aspects. Several studies have shown that water affects urban liveability in many ways by supporting: (i) economic productivity in agriculture, industry, and households; (ii) public health as water is a basic need for people to live healthy lives; and (iii) environmental protection and amenity by helping to reduce urban heat island, sustain playing fields and parks, create green and blue spaces (Johnstone et al., 2013, de Haan et al., 2014, Hodge et al., 2014). The subjective measurement of liveability for strategic planning, creating healthy environments and sustainability often concentrate on a city context. Little attention is paid to ecohydrology and factors supporting liveability in the peripheral city, especially in the context of developing countries (Tournois, 2018). More attention should be paid to these as water related issues resulting from urbanisation and climate change primarily depend on how water and land are managed and used for the benefits of people.

Further, while many satisfaction assessment studies have focused on housing/ residential, neighbourhood and the local community (Sirgy et al., 2000, Sirgy and Cornwell, 2002, Amérigo and Aragonés, 1997, Jean Vrbka and Raedene Combs, 1993), only a few studies have focused on regional settings in a metropolitan region (Turksever and Atalik, 2001, Mccrea et al., 2005). In a coastal metropolitan region, particularly in a developing country, such as Indonesia, the rapid urban expansion could bring significant environmental challenges and social conflicts due to changes in land use, water cycle and the local climate (Hidajat et al., 2013, Sagala et al., 2013, Pribadi and Pauleit, 2015). We argue that understanding the relationship between ecohydrological changes and liveability at a regional scale is a basis for dealing with sustainability challenges arising from rapid urban expansion. Hence, two specific objectives of this article are: (i) to understand the impacts of ecohydrological changes on liveability of the urban and peri-urban communities due to rapid urbanisation and climate change in the selected metropolitan region in Indonesia; and (ii) to develop a framework for evaluating ecohydrological based liveability to guide balanced urban development.

5.2 METHODOLOGY

This study applied qualitative and quantitative data analysis approaches. We assessed all the qualitative data analysis using NVivo Pro (QSR)™ 11.0 and the quantitative data analysis using SPSS (IBM)™ version 24.

5.2.1. QUALITATIVE DATA ANALYSIS

Thematic analysis was applied to first, assess the communities' experiences in ecohydrological changes and impacts on liveability; second, opinions on the most important strategy to improve environmental quality and water status. All responses from the communities were reviewed individually and were grouped into key words, categories, and/or themes.

5.2.2 QUANTITATIVE DATA ANALYSIS

Categorical correspondence analysis (distance measure: Chi-square, normalisation method: symmetrical) was conducted to represent unordered categories of people's opinion about who has responsibility to improve ecohydrological functions within administrative political boundaries and the rural-urban category. This analysis was used to depict a more global representation of the relationships among unordered categorical variable responses in a low-dimensional space that might not be detected through a pairwise analysis (Sourial et al., 2010). In addition, 15 indicators were selected and assessed in constructing an ecohydrological satisfaction-based liveability index for understanding urbanisation impacts on liveability (Table 18).

The index was developed using each composite satisfaction value weighted by the eigenvalue from the principal component analysis (OECD and JRC European Commission, 2008). The underlying structure of satisfaction factors in the CMR was determined using categorical principal component analysis (CATPCA), combined with factor analysis (FA) and using a varimax rotation method and variable principal normalisation. CATPCA transforms an original set of Likert scale variables into numeric values with optimal scaling (Linting et al., 2007). These transformed variables were used as input data for FA to find the underlying factors of the model. FA (extraction method: principal components, rotation method: Varimax with Kaiser normalisation) transforms variable datasets into fewer new sets of orthogonal variables called Principal Components (PC). The component structures from FA, with the principal components using transformed variable/quantification of Likert scale data are similar to the analysis using CATPCA from the raw variables of the Likert scale data.

TABLE 18. SUMMARY OF LIVEABILITY INDICATORS USED IN THE ANALYSIS

Sustainability Factors	Code	Subjective assessment (perception importance and satisfaction)
Eco-Hydrology	A.1	Sufficient water availability
(Environmental protection)	A.2	Well maintained river
	A.3	Green open spaces in the public area
	A.4	Housing with garden spaces
Society	B.1	Healthy housing
(Social Prosperity)	B.2	Healthy human settlement
	B.3	Healthy waterways
	B.4	Facilities and services for education, public health, amenities
	B.5	Flood protection
	B.6	Drought prevention
Economy	C.1	Housing affordability
(Economic development)	C.2	Employment
	C.3	Mobility
	C.4	Income
	C.5	Water and sanitation infrastructure/ waste water treatment

Given k liveability indicators $X_1, X_2, \dots, X_k$, each PC is a linear combination of original indicators measured (X's) obtained as:

$$PC_j = \sum_{i=1}^{k} a_{ij} X_i \quad , \quad j = 1,2,3, \dots . k$$

PC_j is principal component j; a_{ij} represent the weights for the ith indicator for the jth principal component.

The S_i satisfaction scores or values-raw data (transformed variables/quantification of Likert data) for each individual/household were normalised (N_i) using a re-scaling method with the following formula:

$$N_i = \frac{S_i - minS_i}{maxS_i - \min S_i}$$

Liveability-sustainability index was determined using the following equation, re-scaling to 100:

$$I = \left(\frac{\sum_{i=1}^{Y} w_j N_i}{Y} \right) x\ 100$$

N_i is normalised satisfaction value for individual i; Y represent total households measured, w_j is the weight given to each indicator.

Weight from CATPCA/FA for each indicator w_j was determined using the following equation (OECD and JRC European Commission, 2008):

$$w_j = \frac{\sum_{i=1}^{j} |L_{ij}| E_j}{\sum(\sum_{i=1}^{j} |L_{ij}| E_j)}$$

L_{ij} is the factor loading of the ith indicator on the jth satisfaction factor, E_j is the eigenvalue of the jth satisfaction factor.

$$\sum w_j = 1$$

Sum of weight is equal to 1.

5.3 CONCEPTUAL AND ANALYTICAL FRAMEWORKS

5.3.1 Conceptual framework

Liveability and sustainability influence each-other for sustainable development. As detailed in section 5.1.2, liveability refers to dynamic interactions between people and the environment that focuses on immediate interventions for improving the quality of life (Pacione, 2003, Ruth and Franklin, 2014). Sustainability refers to long-term liveability that can be achieved through a planning approach and management interventions (Flores et al., 1998, Van Kamp et al., 2003, Allen, 2010). Liveability decreases as the resources that can constrain sustainability become scarce but it does not determine sustainability (Allen, 2010). Rather, liveability needs sustainability to consider larger scale and longer-term problems and solutions while sustainability needs liveability to influence locally relevant conditions (Gough, 2015). Since water sustains all life, a holistic approach of liveability will need more attention on the protection of eco-hydrology for sustaining socio-economic development. Peter et al. (1998) describe this as a sustainability framework with a strong paradigm in environmental protection, resource management, and eco-development.

In this study, the linkage between social-economic development and the protection of eco-hydrology is considered as a socio-ecohydrological system. Theoretically, ecohydrology refers to an interdisciplinary science studying dynamic interactions between water, people, and ecosystems for a better environmental management (Zalewski, 2002a, Zalewski, 2010, Jørgensen, 2016). In practice, it refers to an approach for achieving sustainable management of water with the goal to fulfil human needs. This includes multifaceted goals in water resources, biodiversity, ecosystem services, resilience, and cultural heritage (Zalewski, 2000, Zalewski et al., 2016b). Based on the liveability theory, the perceived satisfaction in the services to meet basic human needs affects subjective quality of life that largely depend on the quality of the living environment and capabilities for sustaining the liveability services (Cummins and Nistico, 2002, Veenhoven, 1996a, Veenhoven and Ouweneel, 1995, Veenhoven, 1996b, de Haan et al., 2014, de Chazal, 2010). Hence, liveability stems from the dynamics of socio-ecohydrological systems while sustainability is ensured via planning approaches and environmental management interventions.

Several studies for assessing liveability at a global scale are available in the literature such as the Mercer Quality of Living Survey, Yale & Columbia University's 2005 Environmental Sustainability Index, Economist Intelligence Unit (EIU) Quality of Life Index and Global Liveable Cities Index that mostly focus on comparing and categorising the liveability of major cities in the world (Giap et al., 2014, Woolcock, 2009). However, benchmarks for cities generally have a limitation in informing urban policy as their purpose is not specifically to design for public policy or to link with sustainable development. In practice, and historically, Gross Domestic Product (GDP) and the Human Development Index (HDI) are widely used to measure development progress yet these measures have been evaluated as insufficient for developing strategic urban planning to improve quality of life (Khalil, 2012). These indexes are particularly lacking the preference of the community.

Currently, increasing attention is being given to using community indicators for assessing the outcomes of liveability aspects that go beyond the use of indicators focused more narrowly on economic growth (Olesson, 2012, Wiseman and Brasher, 2008). In the community indicators framework, liveability indicators are selected based on the common topics within environmental, social, and economic themes that are reported by the local community (Olesson, 2012). These include water and public space; health and accessibility; employment; housing affordability; income, mobility; and infrastructures. These topics are also identified by Badland et al. (2014) as being likely to contribute to health and wellbeing. The 15 indicators used in this study were selected from those common topics based on their relevance to the wellbeing of the community in the selected metropolitan region. We included flood protection, drought prevention, water and sanitation infrastructures as the selected region frequently experiences flood and drought events and a significant gap exists in water infrastructures between CM and other four districts within CMR (Directorate General of Water Resources Development, 2010, WJP-MDM, 2013a).

5.3.2 Analytical framework

The liveability analyses were applied to four urbanisation levels to understand how urbanisation impacts communities differently. There were four distinctive characteristics in ecohydrological processes in the selected region; most notably, significant differences in socio-economic activities (Danielaini et al., 2018b).

In the first stage of this study, we assessed information on the experience of the urban and peri-urban communities about ecohydrological changes and impacts. The result provided a model of sustainable development that fit the selected region; describing interconnected environmental protection, social prosperity, and economic development.

In the second stage of this study, we developed an ecohydrological-satisfaction liveability index. First, factor analysis with principal components was applied to identify underlying structures of satisfaction from the 15 selected subjective indicators. Second, different principal components and indexes of five satisfaction structures across the four urbanisation levels within the metropolitan region were examined. Third, ecohydrological satisfaction-based liveability indexes were calculated and weighted by statistical analysis through principal components and by public opinion. The indexes measured and identified liveability aspects which can evaluate impacts of urbanisation and can assess inequality in the environment, socially, and the economy within a metropolitan region.

In the last stage of this study, community opinions on improving socio-ecohydrological systems for sustainability were identified. These include (i) people's opinions on the most important strategy to improve environmental quality and water status; and (ii) people's opinions about who has responsibility to improve ecohydrological functions in their area.

The analytical framework used to evaluate ecohydrological based liveability in the CMR is shown in Figure 20.

5.4 RESULTS AND DISCUSSIONS

5.4.1 Ecohydrological change and impacts

Thematic analysis of the data on ecohydrological change and impacts in the selected study area indicate that urbanisation and deforestation in the past two decades have changed ecohydrological functions and shaped urban and peri-urban water and environments, socio-culture, and the economic aspects (Figure 21). Urbanisation significantly affected the liveability of farmers and fishermen in the urban and UPT areas as it significantly increased built-up areas for non-agricultural activities, decreased surface water quality and affected their livelihood. Deforestation significantly affected liveability of farmers in the rural area as it increased agricultural areas but decreased water availability. In addition, urbanisation and deforestation affected liveability of farmers in the peri-urban area as they increased the competition for water supply for urban and peri-urban activities. Urban and UPT residents experienced higher flood events, while rural and peri-urban residents experienced higher drought events.

The available land cover data from the WJP confirms ecohydrological change in the CMR. From 2005 to 2014, the proportion of built-up areas in the CM increased from 59% in 2005 to 72% in 2014, while in the outskirts, it increased from an average of 9% in 2005 to 18% in 2014. During the same period, the forests, water bodies, and semi-natural areas decreased by 36% in the city and 53% in the outskirts (Danielaini et al., 2018a). According to Fahmi et al. (2014), the growing pattern of urban development in this selected region is generally more extensive with the main urbanising occurring in the CR. This includes significant changes in demography, economic structures, and settlement development. However, this development has not been supported by sufficient ecohydrological protections, as indicated by the survey responses/data in this study.

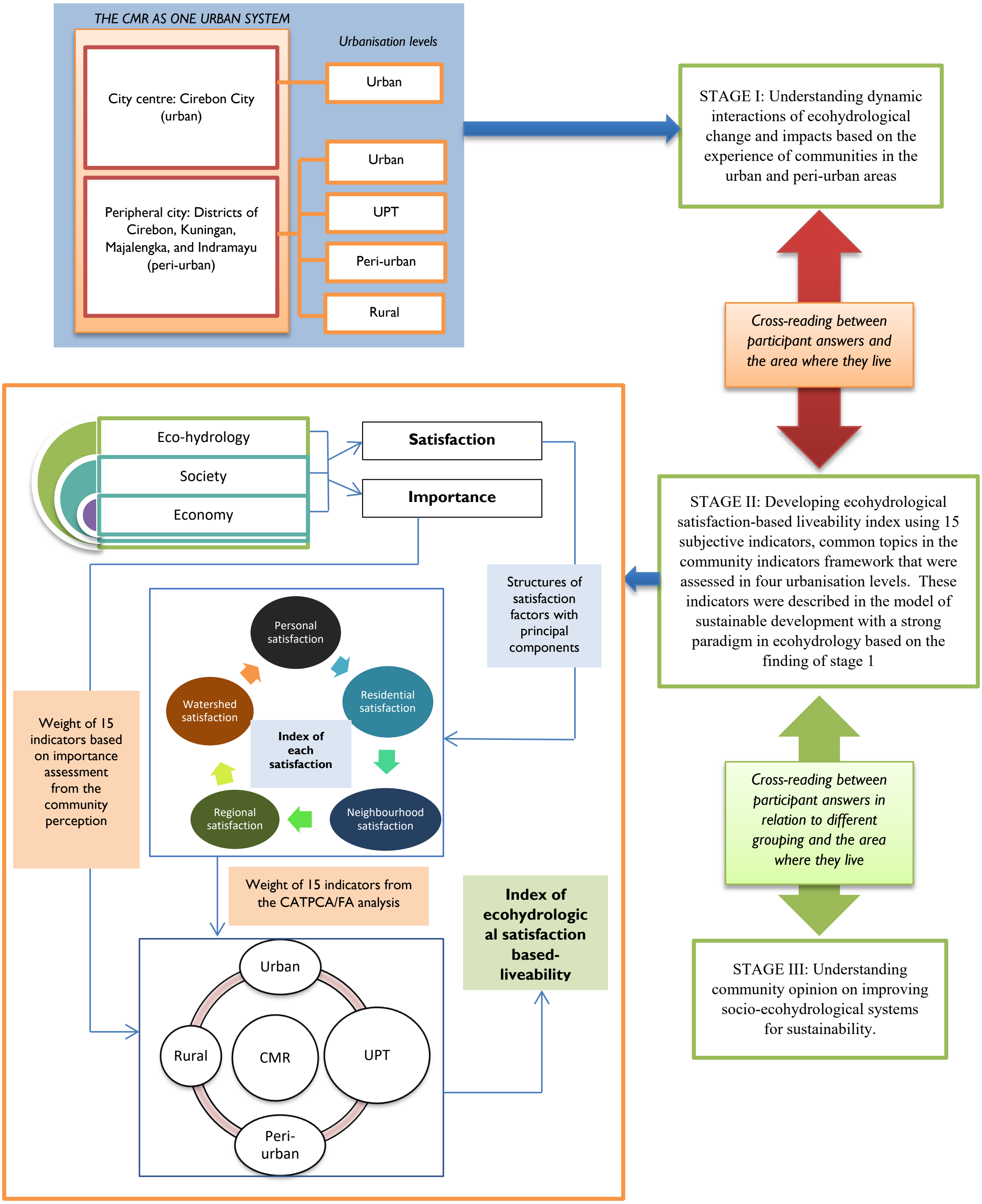


FIGURE 20. ANALYTICAL FRAMEWORK USED IN THE STUDY

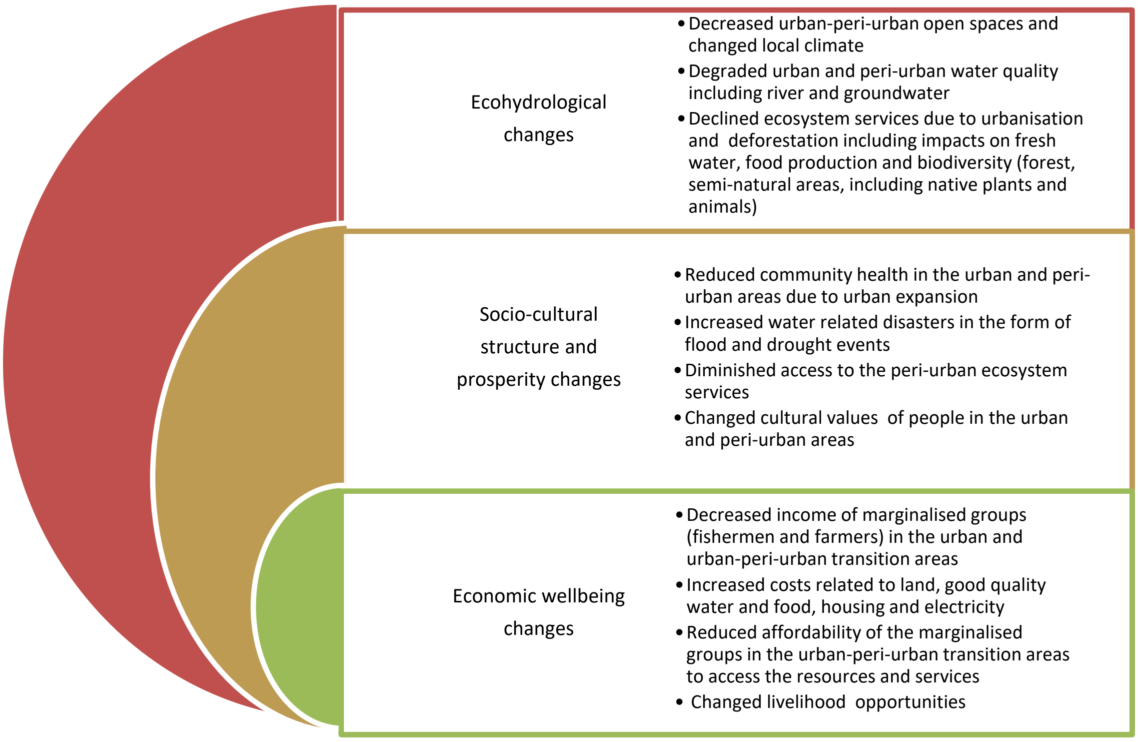


FIGURE 21. ECOHYDROLOGICAL CHANGES AND IMPACTS IN THE URBAN AND PERI-URBAN CMR

A liveable place should have attractive built and natural environments and be socially inclusive, affordable, accessible, healthy, safe and resilient to the impacts of changes in land use, water cycle and climate. This implies local authorities need to identify typical liveability characteristics that respond to communities preference (Tournois, 2018). This study suggests that a sustainable development model with a strong paradigm in ecohydrological protection will help in sustaining liveability and be appropriate for this region. The model includes interactive biophysical, social and economic aspects that recognise the need to concentrate on maintaining ecological and hydrological processes for sustainability. This is particularly true in water insecure regions such as CMR.

5.4.2 EVALUATION OF ECOHYDROLOGICAL BASED LIVEABILITY

5.4.2.1 FACTORS AND PREFERENCE FOR URBAN AND PERI-URBAN LIVEABILITY

Determining the factors with principal components in this study followed standard practice, as suggested by the OECD and JRC European Commission (2008); these include associated eigenvalues larger than one; contribute individually to the explanation of overall variance by more than 10%, and contribute cumulatively to the explanation of the overall variance by more than 60%. The results are included in the *Appendix 1.3 Tables A.1.3.3 - A.1.3.7*. The overall Cronbach's alpha ranged between 0.96 and 0.98, indicating a very high level of reliability (Ahmad and Ahlan, 2015). The Kaiser-Meyer-Olkin (KMO) were more than the minimum acceptable score of 0.5 and Bartlett's value was significant ($p<0.05$) and verified the sampling adequacy for the factor analysis (Kaiser, 1974, Ahmad and Ahlan, 2015).

This study captured several satisfaction dimensions at the community levels, allowing for a better understanding in the variation of community residents' satisfaction (Fitz et al., 2016). Factor analysis with principal components revealed five underlying structures of satisfaction. These were defined as personal satisfaction, residential satisfaction, neighbourhood satisfaction, regional satisfaction, and watershed satisfaction. Recapitulation of liveability aspects contributed to each satisfaction factor in the CMR and four urbanisation levels, as shown in Table 19.

TABLE 19. SUMMARY OF UNDERLYING SATISFACTION FACTORS FOR LIVEABILITY WITHIN METROPOLITAN REGION AND FOUR URBANISATION CATEGORIES

Assessment level	Principal components with factor loadings from highest to lowest within five satisfaction factors (cut-off ≥0.47)									
	Liveability aspects correlated to the personal satisfaction	Rank of importance	Liveability aspects correlated to the residential satisfaction	Rank of importance	Liveability aspects correlated to the neighbourhood satisfaction	Rank of importance	Liveability aspects correlated to the regional satisfaction	Rank of importance	Liveability aspects correlated to the watershed satisfaction	Rank of importance
Metropolitan region	Income; employment; housing affordability	3	Healthy human settlement; healthy housing; housing with garden spaces; green open spaces in the public area; well-maintained river	1	Flood protection; healthy waterways	5	Facilities and services for education, public health and amenities; mobility	4	Sufficient water availability; drought prevention; water and sanitation infrastructure	2
Urban	Income; water and sanitation infrastructure	3	Housing with garden spaces; housing affordability; employment	1	Flood protection; green open spaces in the public area; healthy housing; healthy waterways; healthy human settlement	2	Mobility; facilities and services for education, public health and amenities; well-maintained river	4	Sufficient water availability; drought prevention	5
UPT	Income; employment; housing with garden spaces	4	Healthy human settlement; healthy housing; green open spaces in the public area; healthy waterways; housing with garden spaces	1	Water and sanitation infrastructure; facilities and services for education, public health and amenities; flood protection	2	Mobility; housing affordability; sufficient water availability	5	Drought prevention; sufficient water availability; well-maintained river	3
Peri-urban	Employment; income; mobility; flood protection	3	Healthy human settlement; healthy housing; housing with garden spaces	2	Green open spaces in the public area; housing affordability; housing with garden spaces	4	Healthy waterways; well-maintained river; facilities and services for education, public health and amenities;	5	Drought prevention; sufficient water availability; water and sanitation infrastructure; income	1
Rural	Income, flood protection	3	Healthy housing; healthy human settlement; green open spaces in the public area; housing with garden spaces; employment; healthy waterways	1	Facilities and services for education, public health and amenities; housing affordability; well-maintained river	5	Mobility; flood protection	4	Drought prevention; sufficient water availability; water and sanitation infrastructure	2

Income was found to be a key liveability aspect that contributed to personal satisfaction in the urban, UPT, and rural areas. This included employment in the peri-urban area. This finding confirms the dominance of job and salary as priorities in personal quality of life (Myers, 1988). This is in contrast to Campbell et al. (1976), who pioneered research into quality of life using an American case study, and asserted income has little relevance to satisfaction or subjective wellbeing. However, Cummins (2000), using the homeostatic theory and empirical data, concluded the opposite; that income has a significant influence on the subjective wellbeing of people living in poverty. The level of income can enhance or diminish an individual's resources to meet basic human needs and thereby inform a sense of subjective wellbeing. In this study, economic factors for poor rural/urban dwellers suggested a limited capacity to fulfil their needs related to their physical environment, water and shelter.

In the urban, UPT, and rural areas, residential satisfaction was ranked highest of the most important factors contributing to liveability while in the peri-urban area, it was the second highest after watershed satisfaction. This is because watershed quality in the peri-urban area affects water availability for both households and the economy. This study found that the watershed and house/dwelling characteristics contributed to residential satisfaction as did the surrounding area or neighbourhood and characteristics of the metropolitan region. This study also found that several residential aspects contributed to the satisfaction levels of neighbourhood in the urban areas, namely green open spaces in the public areas; healthy housing; and healthy human settlement. This study thus confirms that residential satisfaction is a complex concept affected by a variety of environmental and socio-demographic characteristics (Lu, 1999). This confirms previous research that, theoretically, residential satisfaction is about the level of the community residents' satisfaction with their house and/or neighbourhood (Amérigo and Aragonés, 1997, Dekker et al., 2011, Lu, 1999). It also confirms studies that have suggested neighbourhood characteristics are important correlations and significant determinants of residential satisfaction (Lu, 1999, Buys and Miller, 2012, Cao and Wang, 2016).

Neighbourhood, as it is used in this study, refers to residents' perceptions and sense of belonging in the particular residential environment rather than a fixed boundary or geographical area (Amérigo and Aragonés, 1997). In this study, the definition of neighbourhood also included the structure of principal components related to ecohydrology and their impacts or solutions, as these factors are closely related to the environment surrounding the house or human settlement in the urban and peri-urban areas. Flood protection was found to be a key liveability aspect contributing to neighbourhood satisfaction of CMR and urban residents (Plate 11). In the UPT area, flood protection also contributed to neighbourhood satisfaction although this was primarily due to the lack of water and sanitation infrastructures, particularly in low income settlement areas such as in Mundu and Astanajapura-CR.

PLATE 11. FLOODING IN THE URBAN CMR

Liveability aspects contributing to regional satisfaction were facilities and services for education, public health and amenities. Traveling to work and access to education and health services are important predictors of regional satisfaction (Turksever and Atalik, 2001, Mccrea et al., 2005). Thus, regional satisfaction in this study refers to the satisfaction of people in the wider area beyond the immediate neighbourhood. Mobility generally contributed to regional satisfaction in the urban, UPT, and rural areas. However, this was not the case for peri-urban residents as it contributed to personal satisfaction. This is arguably because most surveyed residents in the urban and UPT areas used public transport for traveling to work while in the rural area, people walked while in the peri-urban area, residents used private transport. In term of accessibility and affordability, residents in the UPT had the highest satisfaction in their mobility. They benefitted from being relatively close to the urban centre and could purchase more affordable houses than urban residents. Also, the UPT area had the highest average score in the regional satisfaction while the rural and urban areas had the lowest scores. This arguably indicates that residents in both urban and rural areas had low satisfaction with their mobility. While the issue impacting mobility in the urban areas was traffic congestion, in the rural areas it was lack of access to public transport.

In the peri-urban CMR, watershed satisfaction was ranked highest of the important factors contributing to liveability. Sufficient water availability was a key liveability aspect for watershed satisfaction in the urban area while drought prevention was a key liveability aspect for watershed satisfaction in the UPT, peri-urban, and rural areas. CR and IR were reported to be most prone to paddy drought in West Java Province (Surmaini et al., 2015). This study found that watershed satisfaction also has impacts at the household level in UPT, peri-urban, and rural areas. Comparing the service coverage in drinking water systems to each political boundary of the five districts, only CM had service coverage of more than 85% while the other four districts had less than 25% (WJP-MDM, 2013a). This is a significant finding as watershed satisfaction is barely considered in previous satisfaction studies within metropolitan regions (Mccrea et al., 2005). This may be because drought prevention is not an issue for urban residents as they have better technological interventions and the majority of previous studies have considered urban areas.

Water-sanitation infrastructures contributed to personal satisfaction in the urban area. In contrast, water-sanitation infrastructures contributed to neighbourhood satisfaction in the UPT area and to watershed satisfaction in the rural and peri-urban areas. This is arguably because water-sanitation infrastructures are not the concern of most urban residents as approximately 90% of urban residents have access to formal networked drinking water and sanitation systems (WJP-MDM, 2013a). On the other hand, water-sanitation infrastructures in the UPT area rely on location and accessibility to urban infrastructures. For example, the UPT residents who lived in Sumber mostly have access to better infrastructure quality while those living in Mundu and Astanajapura generally cannot access urban infrastructures. According to Fahmi et al. (2014), most residents in CM have a higher-income; Sumber in the CR generally has middle and lower income people; Mundu and Astanajapura in the CR generally have low-income residents. Residents in the peri-urban area had a mix of incomes. Formal networked water systems were available in several surveyed peri-urban sub-districts such as in Arjawinangun, Dukupuntang, and Beber. However, not many peri-urban households could afford this service and most rely on groundwater or spring water, the quantity of which decreases during the dry season (Plate 12).

PLATE 12. TYPICAL GROUNDWATER WELLS USED BY COMMUNITIES IN THE CMR

Further, we found that rural residents in Kapetakan experienced water quantity and quality issues. While Kapetakan is one of the service areas with a formal networked water system in the CR, most rural residents in the area complained as the water system sources water from the river which is generally polluted and low during the dry season. In summary, accessibility to water-sanitation infrastructure was influenced by (i) income levels in the urban area; (ii) the service coverage of urban infrastructure in the UPT area; (iii) income and water availability in the peri-urban area, and (iv) water availability in the rural area.

The importance of ecohydrological protection for liveability was only evident in the data from UPT residents. Urban residents reported economic aspects as the most important while peri-urban and rural residents identified social prosperity as a priority to deal with drought and flood events. The perceived importance of the 15 liveability indicators in the four urbanisation levels can be seen in the *Appendix 1.3 Tables A.1.3.8 – A.1.3.12*.

5.4.2.2 LIVEABILITY IN THE RURAL-URBAN INTERFACES

In developed countries, Kirby and Glavac (2012) point out that high personal satisfaction was found in low density neighbourhoods where the most residential growth occurred. However, developing coastal metropolitan regions in Indonesia showed different results. High personal satisfaction indexes were found in the urban (80.7) and rural (84.1) areas while lower personal satisfaction indexes were found in the rural-urban interfaces, particularly in the UPT area (35.6). Similarly, the highest index of residential satisfaction was found in the urban areas (94.6) while the lowest average scores were obtained in the UPT areas (56.3). Further, the UPT area had the lowest index of neighbourhood and watershed satisfactions. The results show that the challenge to increase liveability within the CMR is located in the UPT area. This peri-urban area of CMR has been directly affected by urban expansion and is where residents have experienced the most ecohydrological changes. All the indexed satisfaction scores within rural-urban categories are shown in Figures 22 and 23. Distribution scores within rural-urban categories in the CMR can be seen in the Appendix *1.3 Figures A.1.3.1 – A.1.3.5*.

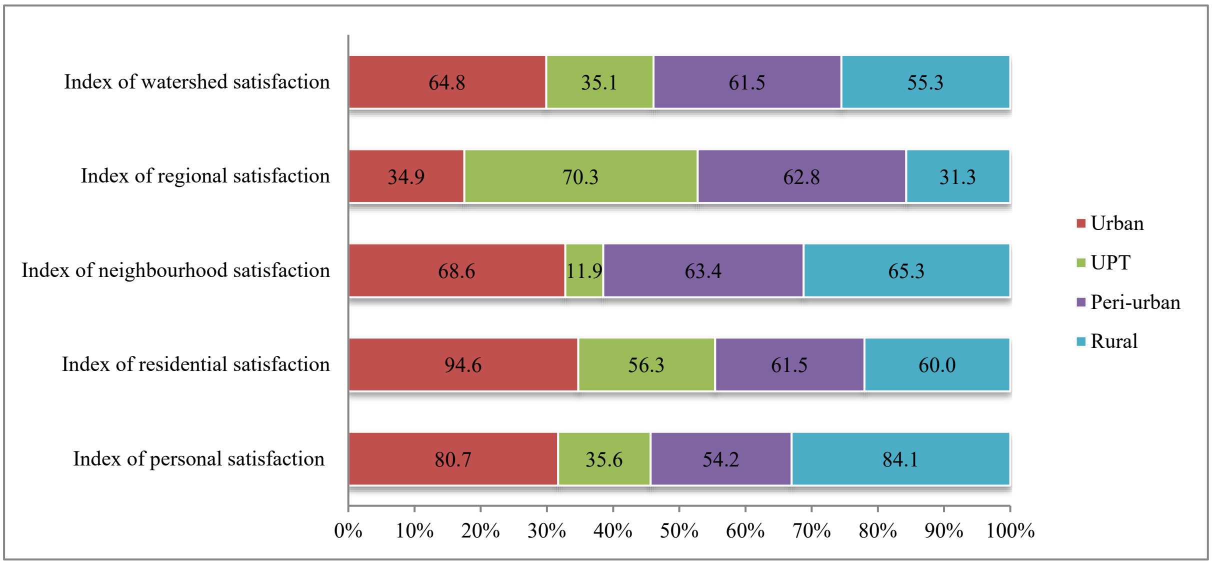


FIGURE 22. SUMMARY OF COMMUNITY SATISFACTION INDEX WITHIN CMR

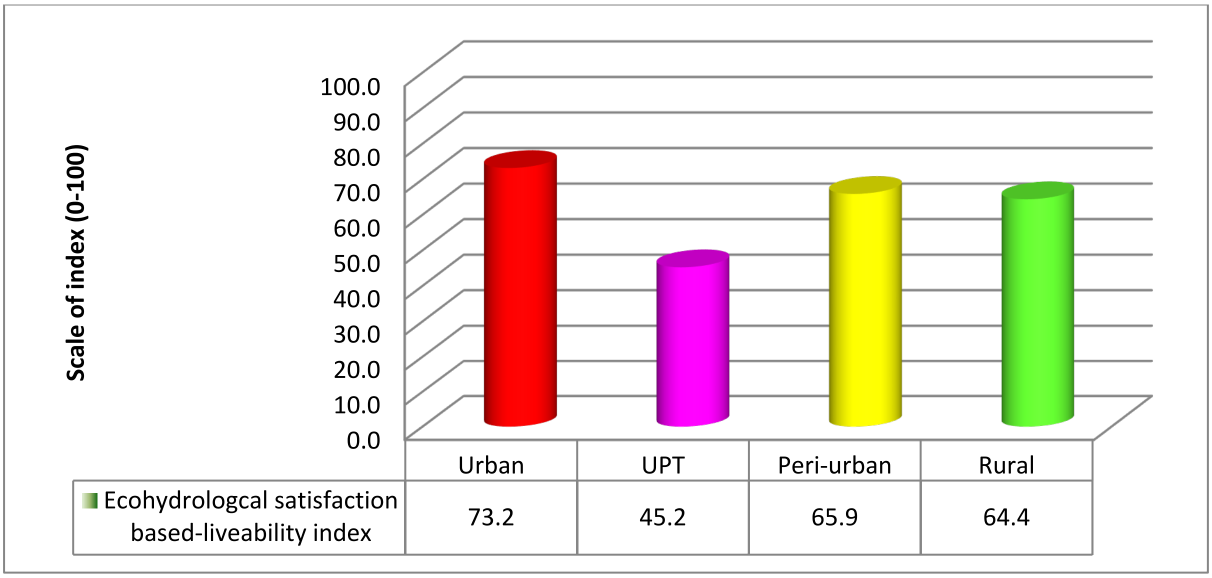


FIGURE 23. SUMMARY OF ECOHYDROLOGICAL SATISFACTION BASED-LIVEABILITY INDEX WITHIN CMR

This study therefore indicates that the urban area is the most liveable place in the CMR as it provides better social capital and economic opportunities, while the UPT area is the least liveable place. These findings imply that if liveability in the UPT, peri-urban and rural areas is not improved, more and more people will be drawn to live in urban area in the CMR. This will lead to higher inequality in accessing liveability aspects for personal, residential, neighbourhood, regional, and watershed satisfactions. This situation may present a barrier to effective economic growth and its role in reducing poverty. We found that although most urban residents were satisfied with better technological interventions to overcome limited resources for socio-economic activities, this was not the case for people with low incomes. This study found: a low income in the urban CMR restricted householders' capacity to access water and sanitation infrastructures; low income in the UPT area restricted householders' capacity to access housing with garden spaces and obtain formal employment in the UPT area; low income in the peri-urban area restricted householders' capacity in mobility and flood protection and to obtain formal employment in the peri-urban area; and low income in the rural area restricted householders' capacity in flood protection.

Compared to mean satisfaction within CMR, urban residents were more dissatisfied with the five indicators related to ecohydrological protection and social prosperity (Figure 24). In particular, urban residents reported the lowest satisfaction levels with green open spaces in public areas and housing with garden spaces. In contrast, urban residents reported highest satisfaction levels with drought prevention, water sanitation infrastructures, income, and flood protection. UPT residents had lower satisfaction levels with 11 liveability indicators particularly income, water sanitation infrastructures, flood protection, and healthy waterways. Similarly, rural residents had lower satisfaction levels in 11 liveability indicators particularly in water sanitation infrastructures, drought prevention, and sufficient water availability. Peri-urban residents had higher satisfaction levels in 13 liveability indicators, excluding sufficient water availability and employment. Urbanisation that should bring better economy and social prosperity was not the case in the UPT area. These results validate the premise that the challenge to obtain sustainable urbanisation and to improve regional liveability in the CMR is primarily located in the UPT zone or the area that was directly affected by urban expansion.

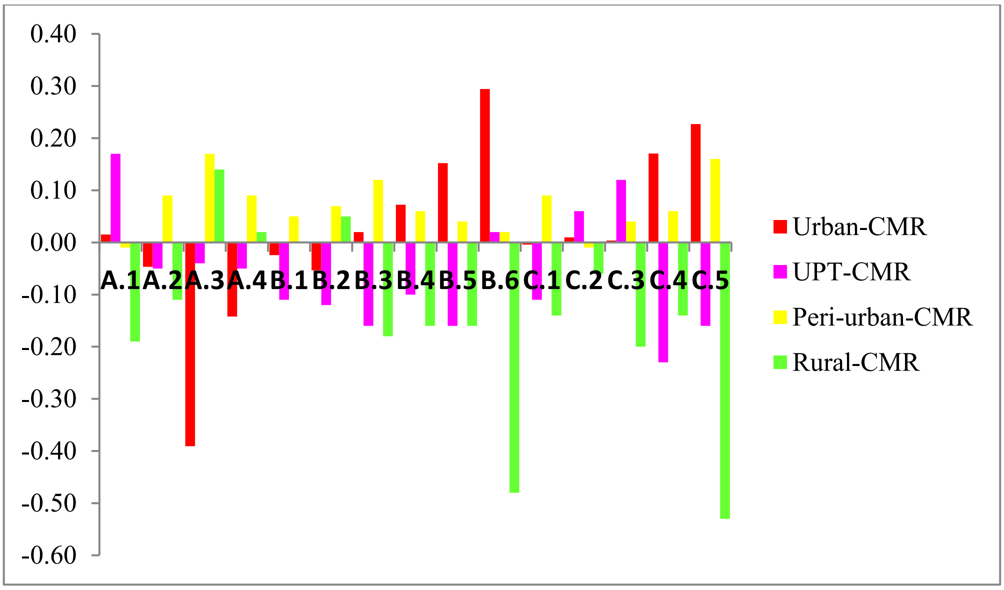


FIGURE 24. DISPARITY OF MEAN SATISFACTION: RURAL-URBAN CATEGORIES AND CMR

5.4.2.3 EFFECTS OF SOCIO-DEMOGRAPHIC ATTRIBUTES ON LIVEABILITY

In this study, the urbanisation level significantly affected personal satisfaction within the CMR ($\beta=0.31$, $p<0.001$). The lower the zoning changes in food production that relied on agricultural land and water, the higher the level of individuals' personal satisfaction within the CMR. Rural-urban residents with a lower number of people in the household were more likely to have higher personal satisfaction levels. On the other hand, residential satisfaction within the CMR was not significantly affected by the level of urbanisation with the residential satisfaction indexes being not much different among rural/urban groups. In this study, the assessment of neighbourhood satisfaction within CMR was significantly affected by the political boundary at the district level ($\beta=0.35$, $p<0.001$) and distance from the coast ($\beta=0.24$, $p<0.01$). Socio-demographic attributes such as gender did not significantly affect neighbourhood satisfaction, confirming previous studies (Oktay and Marans, 2009, Lu, 1999, Buys and Miller, 2012). This study also revealed that regional satisfaction within the CMR was significantly affected by the type of settlement ($\beta=0.17$, $p<0.05$), length of stay ($\beta=0.19$, $p<0.001$), current water problems in flood or drought ($\beta=0.14$, $p<0.001$), and perception of current groundwater quality ($\beta=-0.14$, $p<0.001$). This study confirms that the different physical environment or places affect residential experience and communities' satisfaction (Fried, 1982). Detailed results can be seen in the *Appendix 1.3 Tables A.1.3.13 – A.1.3.17.*

5.4.3 PREFERRED RESPONSIBLE PARTIES AND STRATEGY TO IMPROVE LIVEABILITY

Assessments in the participants' perceptions within rural-urban categories about who needs to take responsibility to improve rural-urban ecohydrological liveability in the CMR revealed that most people in the urban area (CM) said both government and community have the same level of responsibility to contribute to improving urban liveability (Figure 25). UPT dwellers highlighted the importance of the community contributing to the improvement of UPT liveability while peri-urban and rural dwellers underlined the importance of the government in contributing to the improvement of peri-urban and rural liveability. Further, for the majority of participants, protecting waterways and improving the environment of human settlements were the most important strategies to improve liveability (Figure 26). This result aligns with general insights on ecohydrological protection and impacts in the CMR that mostly contributed to residential and watershed satisfactions, as discussed earlier in section 5.4.2.1 and also presented in Table 19.

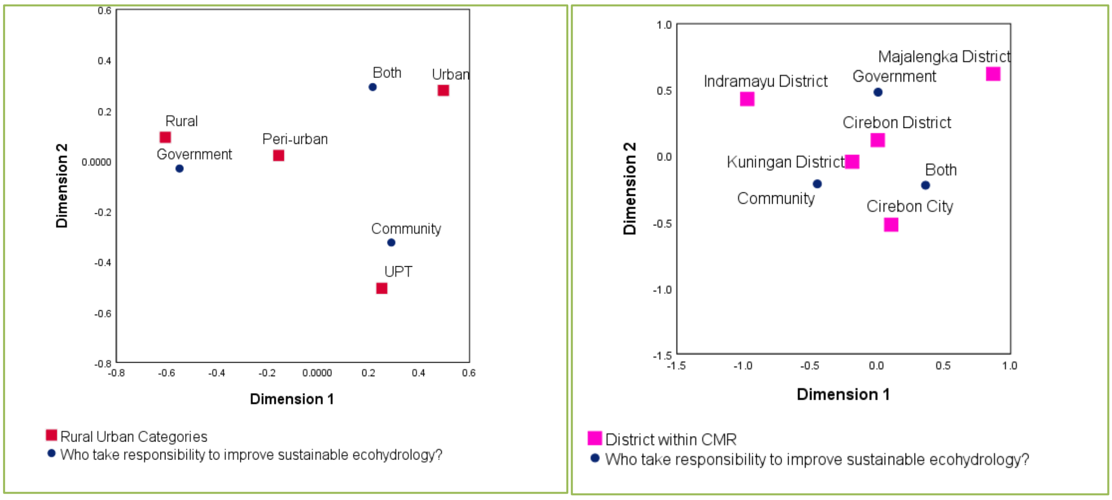


FIGURE 25. SYMMETRIC PLOT OF THE CORRESPONDENCE ANALYSIS REPRESENTING PARTICIPANTS' OPINION ABOUT WHO NEEDS TO TAKE THE RESPONSIBILITY TO IMPROVE RURAL-URBAN ECOHYDROLOGICAL LIVEABILITY

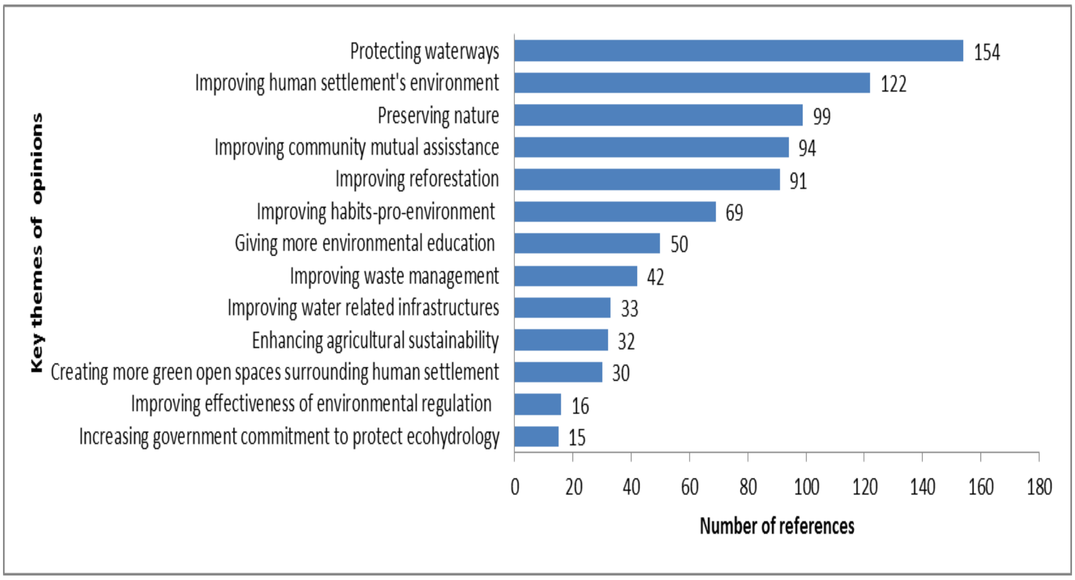


FIGURE 26. PARTICIPANTS' OPINIONS ABOUT THE MOST IMPORTANT STRATEGY DEALING WITH THE CHANGE IN LAND USE, WATER CYCLE AND CLIMATE FOR LIVEABILITY AND SUSTAINABILITY

We assess these responses as a reflection of the cumulative experiences of communities in relation to ecohydrological aspects in the CMR. This region is located in the lower part of CCRB. There are some burning issues in the CCRB that might affect the CMR such as (i) environmental degradation due to increased rate of erosion and sedimentation threatening the sustainability of lakes, reservoirs and irrigation schemes in the downstream; (ii) flood and drought events that frequently occur in the northern coastal areas of IR and CR; (iii) poor water quality; (iv) river based degradation due to river sand mining activities; and (v) sea water intrusion along the north coast of IR, CR, CM (Directorate General of Water Resources Development, 2010). These affected not only farm households who mostly lived in rural and peri-urban areas but also non-farm households who mostly lived in the UPT and urban areas. It is not surprising that watershed protection is the concern of residents in the CMR. Moreover, in this region, urban expansion to meet population growth has encroached on agricultural lands. In addition, most residents in the CMR do not have access to formal networked drinking water supplies and sanitation systems; this includes insufficient drainage systems, sewerage systems, and solid waste handling facilities (Plate 13) that impact the environment quality of human settlement (Regional Development Planning Board of West Java Province, 2015).

PLATE 13. WASTE DISPOSAL PRACTICES IN THE URBAN AND PERI-URBAN COMMUNITIES

This study suggests that considering beneficiary perspectives would be helpful for developing more effective strategies to accommodate inequality traps in the rural-urban interface and enhancing communities' awareness on their environment. People's participation in managing resources sustainably at the local level is important for reaching the global goal of sustainable development. The challenge is to empower communities in the peri-urban and rural areas who have the highest dependency on the government. As highlighted by Keivani (2010), finding the appropriate institutional framework and governance mechanism for policy making and implementation, including empowered communities are among efforts required to face the challenges to urban sustainability.

5.5 CONCLUDING REMARKS

In a water insecure region such as CMR, a sustainable development model with a strong paradigm in ecohydrological protection is appropriate for promoting and maintaining ecological and hydrological processes for sustainability. The study indicates that ecohydrological protection in the CMR contributed to residential and watershed satisfactions. This study also suggests that income and employment generally contribute to personal satisfaction; healthy housing and human settlement contribute to residential satisfaction; flood protection and healthy waterways contribute to neighbourhood satisfaction; urban facilities and mobility contribute to regional satisfaction; and sufficient water availability and drought prevention contribute to watershed satisfaction. This study enhances existing satisfaction studies as watershed satisfaction is barely considered in the previous satisfaction studies within metropolitan regions.

The study provides important insights into factors within metropolitan and rural-urban areas for more effective ecohydrological planning and thereby promotes liveability and a better quality of life in developing metropolitan areas. In particular, the variables related to liveability were found to be different between rural and urban populations showing an inequality of satisfaction to sustainability within the metropolitan region studied. This evaluation of the physical environment and services in the liveability-sustainability framework shows inequality across the CMR was multidimensional. The framework developed in this study for evaluating liveability identifies community factors within metropolitan and rural-urban areas related to place-based attributes and can provide useful information to more effective planning and improvements to promote ecohydrological sustainability and thereby promote liveability and a better quality of life.

This study found that low income in the urban CMR restricted householders' capacity to access water and sanitation infrastructures; low income in the UPT area restricted householders' capacity to access housing with garden spaces and obtain formal employment in the UPT area; low income in the peri-urban area restricted householders' capacity in mobility and flood protection, and to obtain formal employment; and low income in the rural area restricted householders' capacity in flood protection. The study indicates the importance of pro-poor regional policy-based solutions. This is because the poor are more likely to live in peri-urban areas and be more directly affected by urban expansion and the degradation of local ecosystems. Furthermore, it will be crucial for city planners to develop strategies for peri-urban communities that can adapt to future changes in land use, water cycle and climate to promote their liveability and sustainability. Special attention in development planning and management should thus be given to the transitional zones between rural and urban administrations.

Finally, to address inequality traps in the rural-urban interface, the study indicates the need to (i) understand the relationship between community and physical rural-urban environment and services in developing rural/urban strategies for future liveability, sustainability and balanced urban development; (ii) strengthen the capacities of local government to cope with peri-urban development; (iii) preserve agricultural land as an integrated part of economic policy development; (iv) recognise that a clear separation between rural and urban planning is not sufficient to account for peri-urban environmental challenges and social conflicts related to water security; (v) develop suitable policy instruments targeting local governments for protection of peri-urban ecosystems; (vi) develop financing mechanisms targeting individual households or community groups in the rural-urban interface to help access peri-urban ecosystem services; and (vii) empower vulnerable peri-urban communities to manage their own water and sanitation system for liveability and sustainability.

CHAPTER 6

ASSESSING LIVEABILITY IN THE CONTEXT OF SOCIO-ECOHYDROLOGY

Danielaini, T. T., Maheshwari, B., & Hagare, D. 2019. Qualitative and quantitative analysis of perceived liveability in the context of socio-ecohydrology: evidence from the urban and peri-urban Cirebon-Indonesia. Journal of Environmental Planning and Management, 1-29. doi:10.1080/09640568.2018.1524576.

Summary

This chapter develops novel methods for assessing qualitative and quantitative perceived liveability in the context of socio-ecohydrology. Key liveability aspects, viz., ecosystem services (ES), urban services (US), peri-urban services (PS) and human services (HS) were examined. Further, the disparity in the liveability of urban and peri-urban areas that could hamper sustainability was investigated. The study demonstrates that ES, US, PS, and HS in the analytical framework of importance-performance analysis (IPA) can identify the main areas needing intervention to improve urban and peri-urban socio-ecohydrological systems and liveability. This study found that water security is the most important factor for creating liveability in the CMR. Nonphysical environment relating to social relationships with family/neighbours, place attachment related to birth-place and community identity - all of which were categorised as cultural services under HS, is the most satisfied liveability aspect in the CMR. In contrast, water availability, categorised as provisioning services under ES, is the least satisfied liveability aspect in the CMR. The priority to improve liveability should include improving healthy waterways in the UPT area and providing sufficient water availability in the peri-urban and rural areas.

6.1 INTRODUCTION

The concept of liveability has been scrutinised in many parts of the world to better understand how people perceive the quality of the local environment, particularly in relation to urban planning. Various empirical studies of liveability have been undertaken in developed countries such as Australia (McCrea and Walters, 2012), Italy (Antognelli and Vizzari, 2017), and Ireland (Howley et al., 2009), and in developing countries such as Malaysia (Leby and Hashim, 2010), India (Pandey et al., 2014), and Nigeria (Mohit and Iyanda, 2016). These studies confirm the liveability theory that perceived quality of life is not only determined by the physical environment but also by subjective characteristics of local communities (Costanza et al., 2007, Van Kamp et al., 2003, Pacione, 2003). In the context of Indonesia, the Indonesian Association of Planners (IAP) has revealed a Most Liveable City Index (MLCI) 2014; this index has become a benchmark for quality of life in cities based on the perception survey of 1700 respondents in different cities and across different ages (Hardiansah, 2014). The MLCI provides a snapshot analysis showing that the most important factors for creating urban liveability in Indonesia are economy and health facilities while the least important factors are infrastructures and socio-cultures. However, previous studies show that liveability is defined differently across people and places (Ruth and Franklin, 2014). A more rigorous analysis of liveability studies with implementation options for sustainable urban development at a metropolitan scale is still required to promote deeper understanding of what makes a place liveable for urban and peri-urban individuals and households.

The development of urban areas for sustainability and liveability will need more attention as more people will live in urban settings in the future. However, the sustainability of urban development is increasingly challenged by adverse impacts of urbanisation and climate change. These include worsening river water quality; decreasing green open spaces; increasing flood and drought events, increasing local and regional temperatures, changing livelihoods, and health problems (Astaraie-Imani et al., 2012, Gadgil and Dhorde, 2005, Guneralp et al., 2015, Miller and Hutchins, 2017, McMichael et al., 2006). The changes in biophysics and socio-economic subsystems can have direct and indirect impacts on liveability as many aspects of a liveable city or region are related to available water and how water is used and managed (de Haan et al., 2014). In fact, growing populations have caused many cities in the world to suffer from water shortages and experience difficulties in meeting the increased water demand (Zeman, 2012). Climate factors have also exposed urban areas worldwide to an increased risk of flood and drought (Guneralp et al., 2015). In Indonesia, many large cities have experienced alarming decreases in green open spaces (GOS), thereby increasing flood events, river water pollution, and sea water intrusion (Delinom et al., 2009, Fulazzaky, 2014, Firman, 2009, Firman et al., 2011, Gany, 2003, Kirmanto et al., 2012, Marfai and King, 2008, Steinberg, 2007, Ward et al., 2013, Werner, 2014).

Water related problems are not only an issue for large coastal cities in Indonesia but also for smaller coastal cities such as CM where sea water intrusion has occurred in its coastal areas (Rositasari et al., 2011). According to Nitivattananon et al. (2013) CM, as the centre of the CMR, may be impacted by climate change. Water supply is limited because of the short rainy season while increasing rainfall in this rainy season also causes flooding. To meet its existing urban water needs, CM largely depends on water supplied from a spring in KR. Furthermore, Pratiwi et al. (2016) suggest that people who live in the coastal villages of the CR and CM have experienced hardship due to the impacts of climate change. Drought has caused crop failure and disrupted the cycles of rice cultivation while flooding during the rainy season has affected settlement areas. According to Cohen (2006), smaller cities and towns with a population under half a million should pay more attention to the development agenda of urban futures as they have a more significant total population and faster growth compared to large cities. Furthermore, they have a relatively low level of basic services, higher poverty, and weaker local government capacity.

From a planning perspective, it is crucial that the liveability of urban environments be maintained and improved in the light of increasing urbanisation and climate change pressures. However, little is known about rapidly developing areas in Indonesia, such as the CMR, regarding urban and peri-urban perceived liveability factors such as ecosystem services (ES), urban services (US), peri-urban services (PS), and human services (HS). Understanding the perceived importance-performance of liveability services can address subjective features of liveability, complement current objective measures in development such as human development index (HDI), and identify liveability issues and place-based needs for sustainability in this water insecure region. Hence, the objectives of this study were to: (i) identify the most important liveability factors in the CMR compared to the national liveability survey; (ii) examine the most important and the most and least satisfied liveability services in the CMR related to ES, US, PS, and HS; and (iii) compare the gap between importance and performance of the selected 15 liveability services integrating ES, US, PS, and HS aspects which represent the socio-ecohydrological systems in the urban and peri-urban CMR.

The main aim of this study is to use qualitative and quantitative approaches in importance-performance analysis (IPA) as well as use IPA for performance gap analysis of liveability services in urban and peri-urban areas. Also, the methodology developed is expected to assist in balancing urban development and sustainability of urban centres.

6.2 SCIENTIFIC BACKGROUND AND FRAMEWORKS

6.2.1 LIVEABILITY AND THE URBAN DEVELOPMENT

There is a growing interest in understanding the overall environmental quality to assess liveability and sustainability concepts in urban development projects. While some factors affecting the dimension and meaning of liveability are recognised, for example: the needs of community, characteristics of local environment, place-related factors, culture, value, perspective of community, and the researchers' fields and purposes (Hodge et al., 2014, Ruth and Franklin, 2014, Leby and Hashim, 2010, Maheshwari et al., 2016), liveability has multiple meanings across disciplines (Van Kamp et al., 2003, Newton, 2012, de Chazal, 2010, Badland et al., 2014). For instance, Pacione (2003) describes liveability as a function of interactions and behaviours between the attributes of the environment and people. Newman (1999) explains liveability as the private and public requirements for social amenity, health and wellbeing. Veenhoven and Ouweneel (1995) describe liveability as the level of provisions and requirements matching with the needs and capacities of societies. Maheshwari et al. (2016) define liveability as the sense of place or belonging, local community's values and preferences for amenity at certain places, and wellbeing aspects. Longer term liveability can be called sustainability (Flores et al., 1998, Van Kamp et al., 2003).

The terms of liveability and sustainability provide an attractive vision for guiding planning and policy to satisfy the needs of current and future residents. Liveability brings a pragmatic approach to sustainability. Liveability is considered more achievable compared to sustainability as it is focused on immediate interventions for improving a community's quality of life, through combining characteristics of physical and social experiences in a locality (Gough, 2015, Ruth and Franklin, 2014). In practice, there is a need to recognise the possible conflicts in prioritising liveability and sustainability (Godschalk, 2004). While urban system dynamics frequently expand into the peri-urban areas for enhancing urban sustainability, urban encroachment on a peri-urban ecosystem will affect liveability of the peri-urban dwellers and bring more challenges to water management (Singh and Maheshwari, 2014a, Akissa, 2001, Allen, 2003, Maheshwari et al., 2012). In this case, liveability can hamper sustainability (Allen, 2010).

As more people tend to live in urban settings, the development of urban areas for liveability will need more attention in the future. Water will become the focus for future cities to obtain urban liveability, improve health care, and create water sensitive cities (Smith et al., 2014, Howe and Mitchell, 2012). Hence, the operating definition of liveability in the context of socio-ecohydrology, as proposed in this study, refers to dynamic interactions between water, people, and the environment as a function of biophysical and socio-economic subsystems in one urban system.

6.2.2 LIVEABILITY ASSESSMENTS

Increasing attention in the examination of liveability and sustainability was found across multiple disciplines for promoting better urban environments and societies, primarily in the context of resource management, landscape planning and development, health, and environmental quality and policy (Gough, 2015, Newton, 2012, de Chazal, 2010, Godschalk, 2004, Van Kamp et al., 2003, Badland et al., 2014, Matsuoka and Kaplan, 2008, Antognelli and Vizzari, 2016, Howley et al., 2009). However, this has not been the case in the disciplines assessing relationships between humans, water, and the environment such as ecohydrology, socio-ecology, socio-hydrology or socio-ecohydrology (Pataki et al., 2011, Falkenmark, 1977, Falkenmark and Folke, 2002, Wagner and Zalewski, 2009, Zalewski, 2002a, Zalewski et al., 2016b, Zalewski and Wagner, 2008, Sivapalan et al., 2014, Holling, 2001, Alberti, 2008). Several studies have shown that water affects urban liveability in many ways as ecohydrological processes affect humans' wellbeing directly or indirectly (Johnstone et al., 2013, de Haan et al., 2014, Brauman, 2015, Srinivasan et al., 2012, Howe and Mitchell, 2012). Nevertheless, limited attention was found in the assessment of qualitative and quantitative perceived dynamic interactions between water, people, and the environment to deal with sustainability challenges from rapid urbanisation and climate change.

The changes in land use, water cycles, and climate within urban systems and their impacts on liveability need to be identified for integrated planning and management of the environment. Urban and peri-urban landscapes form a linked system representing ecosystem services dynamics that need a particular assessment from the residents, involving perceived liveability, on ES and US (Antognelli and Vizzari, 2016, Antognelli and Vizzari, 2017). However, focusing on US and neglecting PS will lead to insufficient strategic approaches in the peri-urban areas for enhancing environmental benefits and protecting designated areas (Scott et al., 2013a). Changes in the availability of those services will significantly affect all aspects of human wellbeing (Tiberius, 2014, Millennium Ecosystem Assessment, 2003). In this study, any services focusing more on people are defined as HS while ES, US, and PS are the services focusing more on place; specifically, on urban and peri-urban environments and their facilities. Combining the four services aims to illuminate and better understand the dynamic interactions between environmental and individual characteristics that influence liveability, as suggested by previous studies (Pacione, 1990, Van Kamp et al., 2003).

Understanding perceived importance and performance liveability aspects of the urban and peri-urban communities would be considerably beneficial for formulating regional strategies and for enhancing sustainability. To date, identification of liveability indicators within a regional scale and sustainability framework has barely been investigated for assessing patterns and possible conflicts in dealing with inequality of accessing ES, US, PS, and HS in the urban and peri-urban landscapes. In particular, liveability measurements and analyses mostly focus on the urban planning context (Lowe et al., 2013, Howley et al., 2009, Pandey et al., 2014), with limited assessment on understanding the socio-ecohydrological system that shapes urban and peri-urban household water security in the coastal metropolitan regions.

6.2.3 Analytical framework

This empirical study develops an in-depth understanding of the urban and peri-urban community's perceived liveability services through a mixed-method data analysis. It considers qualitative conceptions of the most important, most satisfied, and least satisfied liveability aspects in a developing coastal metropolitan region. Further, 15 selected liveability services that relate to urban and peri-urban ecohydrology are assessed through quantitative importance performance analysis based on the four urbanisation categories namely urban, urban/peri-urban transition, peri-urban, and rural (Danielaini et al., 2018b). Public opinion of the most important liveability aspects in the CMR are categorised into 11 themes, nine themes from the Indonesian Association of Planners (IAP) and another two themes, food and water securities, were added to cover the socio-ecohydrological context. Further, public opinion of the most important, most satisfied, and least satisfied liveability aspects are categorised into a common international classification of ecosystem services (ES) and combined with urban services (US) (Millennium Ecosystem Assessment, 2005, Antognelli and Vizzari, 2016, Antognelli and Vizzari, 2017). This study advances the liveability assessment with an additional theme in economic services and additional categories in peri-urban services (PS) and human services (HS). The analytical framework developed in this study is shown in Figure 27.

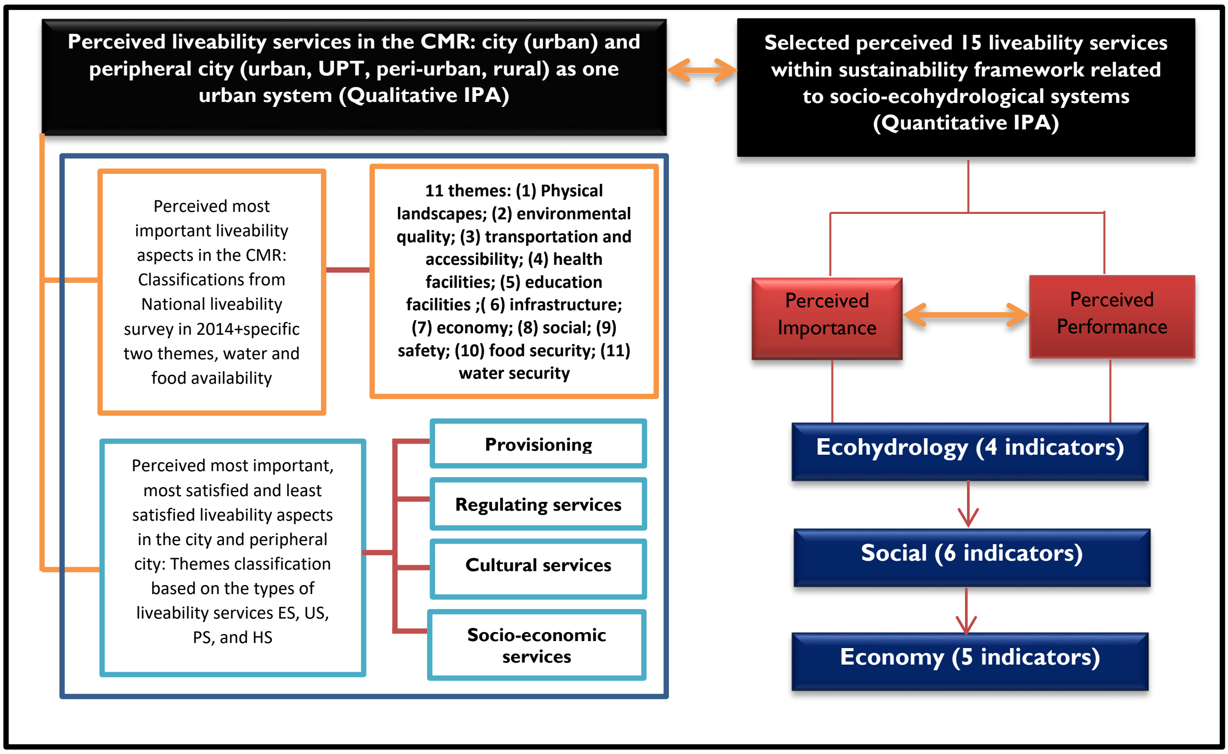


Figure 27. Analytical framework for qualitative and quantitative importance-performance analysis

The definition of ES in this study partly follows the Millennium Ecosystem Assessment (2003) as the benefits people obtain from ecosystems include provisioning, regulating, and cultural services. Supporting services, such as soil formation and photosynthesis, are not included in the ES as they are intermediate services, not directly enjoyed, consumed, or used for human wellbeing (Boyd and Banzhaf, 2007). In addition, US is defined as typical public services and facilities in cities or urban amenities (Tallon and Bromley, 2004, Antognelli et al., 2018). Further, PS is defined as public services and facilities that are usually available in urban and rural areas showing mixed rural and urban characteristics (Tacoli, 1998, Errington, 1994). In this case, US/PS can be differentiated from ES as the former services can be provided independently from ecosystem functions or are completely produced by the socio-economic subsystems (Antognelli and Vizzari, 2016). ES have been considered as related to US/PS within the concept of place liveability with mostly objective features (Antognelli et al., 2018). However, this assessment is lacking a focus on human values or subjective features for understanding liveability which include wellbeing aspects such as sense of place/place attachment, good social relationships, accessibility, affordability, political circumstances, and perceived government support and services. For our purpose, HS was included in the assessment of liveability. HS is defined as wellbeing aspects related to perceived socio-economic and cultural services that are good for human life and relate to personal values (Tiberius, 2014).

Hierarchical classification of liveability services is developed for thematic analysis of perceived qualitative liveability in the context of CMR (Table 20). Type of demands relate to all goods and services that are consumed, directly used, preferred, and available to reduce risks based on the experiences of local communities in the selected region. According to Antognelli and Vizzari (2017), services can be desired or used. If they are desired, they are usually used indirectly, often without real awareness, but needed for risk reduction or simply preferred. Regulating services such as flood protection and drought prevention are typically desired for risk reduction. Preference for services refers some cultural services and socio-economic services that are difficult to define and are related to personal perceptions rather than to a real use. In addition, if the services are used, they can be consumed or used directly.

6.3 METHODOLOGY

6.3.1 DATA COLLECTION

The following open-ended questions were included in the study:

1. What are one or two important aspects for liveability in your region?
2. What are one or two aspects of liveability in your region that you are most satisfied with?
3. What are one or two aspects of liveability in your region that you are least satisfied with?

The three questions were answered by participants based on their experiences of living in that place. We did not ask the aspects to be ranked in those open questions. Their responses were assessed for the most frequent aspects reported by farm and non-farm households in four urbanisation levels.

Closed-ended questions had a 5-point Likert scale (1 = not at all important/very unsatisfied; 2 = slightly important/not satisfied; 3 = moderately important/unsure between satisfied and not satisfied; 4 = important/satisfied; 5 = very important/very satisfied). The participant's preference was requested regarding the importance and satisfaction of 15 liveability services representing socio-ecohydrological systems in the CMR that were grouped into three factors of sustainability (Table 21).

TABLE 20. HIERARCHICAL CLASSIFICATION OF LIVEABILITY SERVICES USED FOR THE THEMATIC ANALYSIS

Theme	Category	Code	Type	Demand type
1. Provisioning services	Provisioning of land, water, and climate for human activities in social and economy (food and non-food production): 1.1 Land 1.2 Water 1.3 Climate	1.1.1 Land availability for farming/housing	ES	D
		1.1.2 Soil fertility (crop productivity)	ES	D
		1.1.3 Food availability	ES	C
		1.2.1 Sufficient water availability	ES	C
		1.2.2 Groundwater and surface-water sources	ES	C
		1.2.3 Drinking water from distribution network	US/PS	C
		1.2.4 Irrigation water from distribution network	PS	C
		1.2.5 Local presence of rivers and seas for transport of people and things	ES	D
		1.3.1 Weather/temperature	ES	D
		1.3.2 Air quality	ES	D
2. Regulating services	2.1 Regulation of natural-physical phenomena 2.2 Mitigation of human impacts-reduction of environmental pollution 2.3 Regulation of natural-biological phenomena	2.1.1 Well-maintained river	ES	R
		2.1.2 Flood protection	ES	R
		2.1.3 Drought prevention	ES	R
		2.2.1 Healthy waterways	ES	R
		2.2.2 Sanitation facilities and waste water treatment	US/PS	R
		2.2.3 Solid waste management	US/PS	R
		2.2.4 Healthy house and human settlement	US/PS	R
		2.3.1 Green open spaces in public area	ES	R
		2.3.2 Housing with green open spaces	ES	R
3. Cultural services	3.1 Aesthetic-local presence of agro-natural elements (land-or sea scapes) 3.2 Natural educational services to enhance awareness to environment and to promote pro-environment behaviours 3.3 Services for physical, spiritual, symbolic, interaction with nature and agro-natural elements	3.1.1 Beautiful landscapes/pleasant environment	ES	D
		3.1.2 Local presence of agro-natural elements	ES	D
		3.2.1 Environmental and cultural educations	US/PS	D
		3.3.1 Cultural heritage and entertainment	US/PS	D
		3.3.2 Spiritual services	US/PS	D
		3.3.3 Societal connectedness to do mutual aids in the communities (*gotong royong**) to maintain the human settlement environment	HS	P
		3.3.4 Place attachment to nature, built-structure, and people as related to birthplace and community identity	HS	P
		3.3.5		
4 Socio-economic services	4.1 Networks for mobility of people, information, and things 4.2 Education services 4.3 Health services 4.4 Safety 4.5 Employment and livelihood 4.6 Societal interaction and family relationship 4.7 Accessibility 4.8 Farmland and housing affordability 4.9 Government services	4.1.1 Local presence of roads	US/PS	D
		4.1.2 Local transport availability (public/private)	US/PS	D
		4.1.3 Local presence of internet, telephone networks, electricity	US/PS	D
		4.2.1 Local presence of school and accessibility	US/PS	D
		4.3.1 Local presence of health facilities	US/PS	D
		4.4.1 Safety	HS	P
		4.4.2 Political circumstance	HS	P
		4.5.1 Job availability	US/PS	P
		4.5.2 Income	HS	P
		4.5.3 Access to capital	HS	P
		4.5.4 Living cost	HS	P
		4.6.1 Relationships with family, neighbours, communities, and authorities	HS	P
		4.7.1 Accessibility to public services, city centre, market, workplace	HS	P
		4.8.1 Farmland affordability	HS	P
		4.8.2 Housing affordability	HS	P
		4.9.1 Government supports and services	HS	P

Source: Adapted from Antognelli and Vizzari (2017) and Millennium Ecosystem Assessment (2005) .
Note: *ES=Ecosystem Services; US=Urban Services; PS=Peri-urban Services; HS=Human Services; C=Consumption; D=Direct Use; P=Preference; R=Risk Reduction. *Gotong royong* is a socio-cultural ethic of generalised social capital in Indonesia that is believed to have originated from the shared collaboration required for producing wet rice in Java (Beard, 2005).

TABLE 21. SELECTED LIVEABILITY SERVICES FOR QUANTITATIVE IMPORTANCE-PERFORMANCE ANALYSIS

No	Sustainability Factors	No	Liveability Services	Code	Type	Demand type
A.	Ecohydrology	1	Sufficient water availability	A.1	ES	C
		2	Well maintained river	A.2	ES	R
		3	Green open spaces in the public areas	A.3	ES	R
		4	Housing with garden spaces	A.4	ES	R
B.	Social	1	Health-house	B.1	US/PS	R
		2	Health-human settlement	B.2	US/PS	R
		3	Health-waterways	B.3	ES	R
		4	Facilities and services for education, public health and amenities	B.4	US/PS	D
		5	Flood protection	B.5	ES	R
		6	Drought prevention	B.6	ES	R
C.	Economy	1	Housing affordability	C.1	HS	P
		2	Employment	C.2	US/PS	P
		3	Mobility	C.3	US/PS	D
		4	Income	C.4	HS	P
		5	Water services infrastructures and affordability	C.5	US/PS	P

Note: *ES=Ecosystem Services; US=Urban Services; PS=Peri-urban Services; HS=Human Services; C=Consumption; D=Direct Use; P=Preference; R=Risk Reduction*

6.3.2 DATA ANALYSIS

This study included both qualitative and quantitative research methods. NVivo Pro (QSR)™ 11.0 software was used for managing the qualitative or text data and obtaining the key themes and visualisation of the participant responses. SPSS (IBM)™ version 24 was used for managing the quantitative or numerical/categorical data and producing descriptive analysis. Analysis was applied based on the total samples in the CMR, 430 households, 23% in city and the rest (77%) in the city surrounds. Those households were defined as urban households (N=101), urban/peri-urban transition (UPT) households (N=74), peri-urban households (N=182), and rural households (N=73) based on the rural-urban interfaces delineation (Danielaini et al., 2018a). Perceived qualitative liveability was analysed following the hierarchical classification of liveability services as already described in the section 6.2.3 while perceived quantitative liveability was analysed using Importance-Performance Analysis (IPA).

The qualitative data analysis searched for themes and patterns in the text data. For our purpose, we combined thematic and content text analyses. The texts were assessed and classified into themes after coding and categorising processes. Thematic analysis provides purely qualitative data while content analysis provides both qualitative and quantitative data such as patterns and frequency of words (Vaismoradi et al., 2013). Themes in this study were socially produced and reproduced within constructionist frameworks to seek structural conditions/socio-cultural contexts; the analysis did not focus on individual psychologies (Braun and Clarke, 2006). To make sense of realities, the texts were analysed, synthesised and interpreted to construct a higher order interpretation (Major and Savin-Baden, 2011).

The quantitative data analysis was conducted using IPA as it is a valuable tool for assessing a multi-perspective evaluation. IPA provides a simple, low-cost, easily understood and useful technique for decision makers. It provides significant support for policy makers and is valuable for evaluating the impact of the implemented program (Riviezzo et al., 2009). The concept of IPA was proposed by Martilla and James (1977) and is well documented in marketing literature (Riviezzo et al., 2009). IPA has attracted various scholars and practitioners from different fields (Feng et al., 2014): for instance in a tourism and hospitality study related to protected area management (Tonge and Moore, 2007); in an urban study related to vitality and viability of town/city (Riviezzo et al., 2009); leisure and recreation (Oh, 2001), water conservation (Warner et al., 2016) and government services (Seng Wong et al., 2011).

This study applied traditional IPA and IPA with gap analysis. Traditional IPA employs importance/ expectation and performance/satisfaction as two independent variables without considering the gap between the two. The means of importance and satisfaction of each liveability service were then plotted in a two-dimensional matrix as shown in Figure 28(a). As a comparison, IPA with gap analyses was applied by considering: (i) the difference between explicit importance and explicit performance of liveability services in four urbanisation categories; and (ii) the gap performance of liveability services between urban/city (focal performance) and peri-urban/peripheral city (competitors' performance). The results of IPA with gap performance were also plotted in a two-dimensional matrix, as presented in Figure 28 (b). The IPA with gap between importance and performance and IPA with performance gap analysis between focal and competitors has been proven by Lin et al. (2009) and Feng et al. (2014) as a more useful and meaningful technique to improve the resource allocation strategy and to identify competitive attributes "salient factors" that need to be maintained or seriously promoted. In this study, regarding the peri-urbanisation process, the competitiveness of liveability services between urban and peri-urban areas for balanced urban development was assessed.

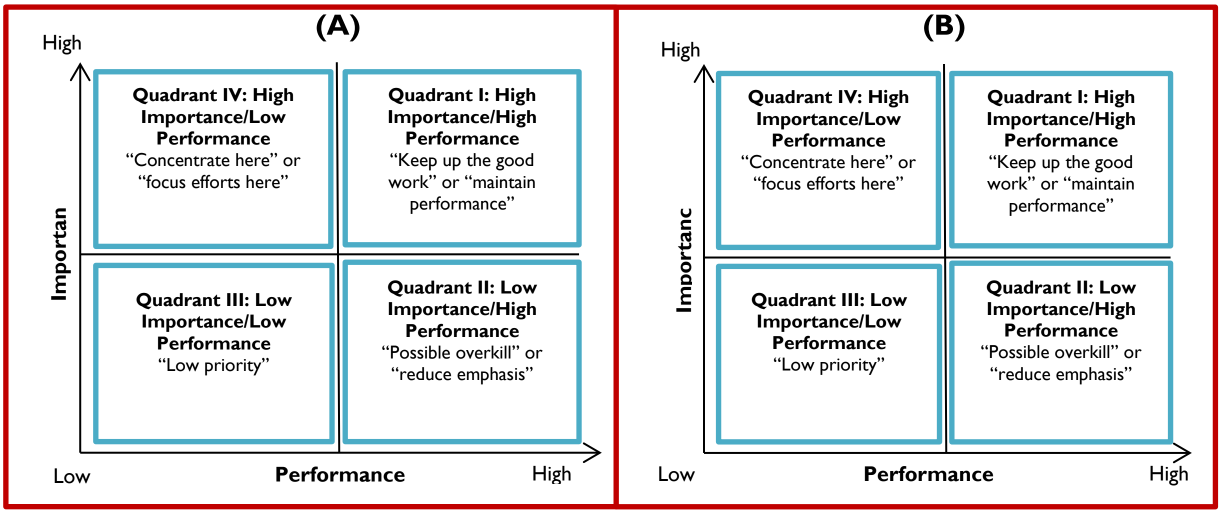


FIGURE 28. IPA: (A) TRADITIONAL IPA; (B) IPA WITH GAP PERFORMANCE BETWEEN URBAN AND PERI-URBAN

Source: adapted from Martilla and James (1977), (Absher et al., 2003), and Feng et al. (2014).

There are two primary methods to control biases, through the design of the research procedure and through statistical solutions (Podsakoff et al., 2003, Podsakoff et al., 2012). Controlling bias in this study was achieved by applying a random selection of respondents, obtaining measured parameters from different sources (objective indicator) to support subjective indicators from the survey; using different response format (Likert scale and open-ended questions), allowing the respondents' answers to be anonymous, using familiar terms and asking simple and focused questions in the questionnaire. To eliminate item ambiguity, demand characteristic, and social desirability related to the questionnaire, a pre-test of the questionnaire was conducted to assess any difficulty in obtaining information during the survey and to make improvements.

6.4 RESULTS

6.4.1 FACTORS FOR CREATING LIVEABLE PLACES

Water is the most frequent word displayed in the responses to the most important factors for creating liveability in the CMR, followed by the words environment, road, accessibility, transport, electricity, and livelihood/economy (Figure 29). Based on the coding references as shown in the hierarchy chart in Figure 29, there are seven significant factors from the 11 themes considered in this study, (reported by >15% of the surveyed households) for creating liveability in the CMR. Ranking from the most important to the least important factors is water security (number of coding references/N=308), economic condition (N=153), environmental quality (N=140), infrastructure (N=123), social (N=114), physical landscapes (N=79), and transportation and accessibility (N=77).

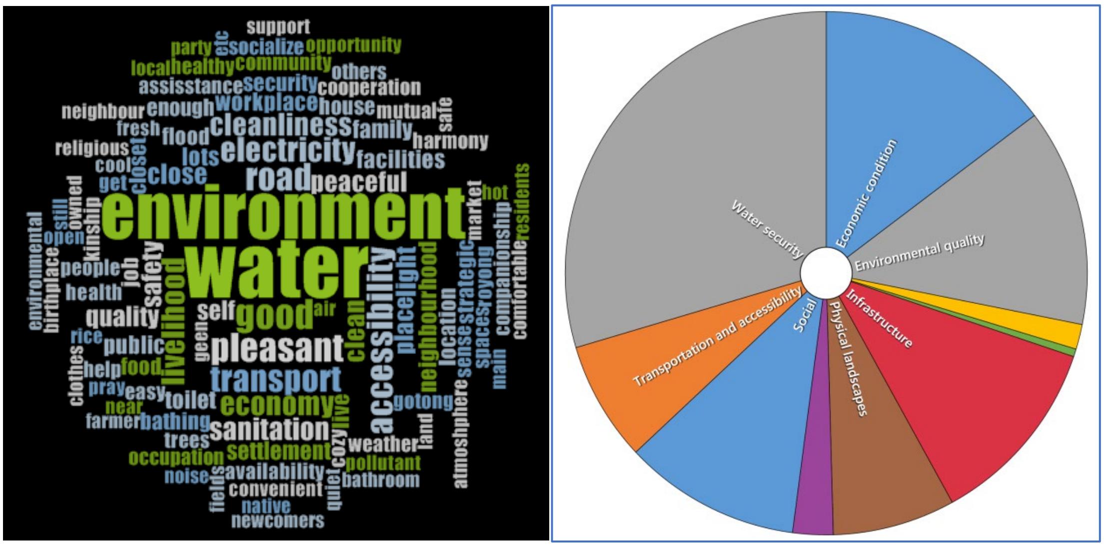


FIGURE 29. THE MOST IMPORTANT FACTORS FOR CREATING LIVEABILITY IN THE CMR

In particular, urban residents in the CMR, including those who lived in CM, considered water security, environmental quality and infrastructure as the most important factors (Figure 30). Based on the coding references, water security is the most important factor for creating liveability in four urbanisation categories in the CMR. The highest coding references for water security were obtained from the UPT and peri-urban households including those who lived in the CR and KR.

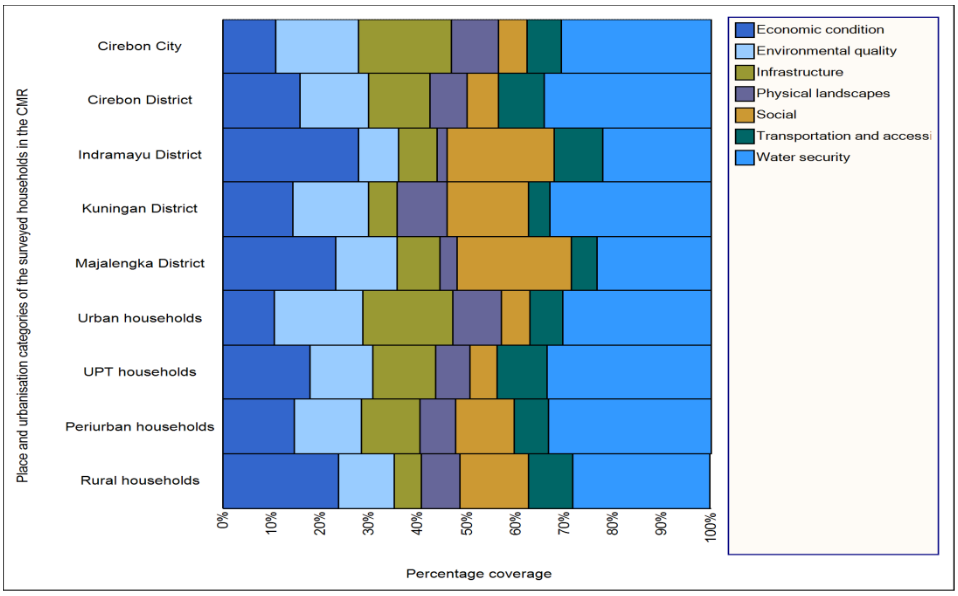


FIGURE 30. THE MOST IMPORTANT LIVEABILITY FACTORS BASED ON THE CODING REFERENCES

Based on the percentage of words coded (Table 22), water was found to be significantly highest in the UPT area (25.5%) followed by the peri-urban area (21.6%) and urban area (18.0%). Specifically, the proportion was found highest in the CR, followed by the proportions in the CM and KR. Economic condition was reported as the most important of liveability factors by the rural residents including those who lived in the IR. On the other hand, environmental quality, infrastructure, and physical landscapes were the most important preferences for making places liveable in the urban areas, particularly in the CM. Similarly, Kuningan residents also reported the highest preference for environmental quality and physical landscapes. Further, social aspects such as relationships with family and neighbours, were reported as the most important preference of peri-urban and rural residents including those who lived in IR, MR, and KR. Transportation and accessibility were reported as the most important liveability factors in UPT and rural areas, particularly in the CR.

TABLE 22. MATRIX OF THE MOST IMPORTANT LIVEABILITY FACTORS BASED ON THE ROW PERCENTAGE

Group of the surveyed households in the CMR	Significant factors for creating liveable places reported by the CMR residents (% words coded per group/ row percentage)						
	Economic condition	Environmental quality	Infrastructure	Physical landscapes	Social	Transportation and accessibility	Water security
1 : Cirebon City	11.7%	20.0%	19.0%	13.4%	5.2%	10.7%	20.0%
2 : Cirebon District	14.0%	16.0%	15.0%	11.4%	8.9%	11.6%	23.2%
3 : Indramayu District	34.1%	5.9%	3.7%	4.1%	38.2%	8.9%	5.2%
4 : Kuningan District	13.2%	20.0%	6.0%	13.0%	21.1%	9.2%	17.6%
5 : Majalengka District	19.4%	13.7%	8.6%	4.6%	34.3%	6.9%	12.6%
6 : Urban households	10.4%	23.2%	16.8%	15.9%	6.2%	9.5%	18.0%
7 : UPT households	17.3%	11.8%	15.0%	10.3%	7.5%	12.8%	25.5%
8 : Peri-urban households	12.9%	15.5%	14.2%	9.3%	17.5%	9.1%	21.6%
9 : Rural households	28.3%	12.0%	3.5%	7.6%	26.2%	12.6%	9.7%

All these results indicate that water is a major concern for the majority of CMR residents as it significantly affects socio-economic activities. This finding is considerably different with the general findings of the national liveability survey in Indonesia which reported that urban residents generally considered economy as the most important factor for creating urban liveability (Hardiansah, 2014).

6.4.2 QUALITATIVE IPA OF LIVEABILITY SERVICES

Environment was the word most frequently displayed in the responses of the most satisfied liveability aspect in the CMR that related to the non-physical environment such as social relationships with family/neighbours and place attachment related to birthplace and community identity (Figure 31). On the other hand, water, which is scarce in the dry season and affects socio-economic activities, was the word most frequently displayed in the responses of the least satisfied liveability aspects in the CMR.

FIGURE 31. WORD CLOUD OF THE MOST SATISFIED (LEFT) AND LEAST SATISFIED (RIGHT) LIVEABILITY ASPECTS IN THE CMR

Based on the beneficiaries' perspectives, urban and peri-urban communities in the CMR considered provisioning services (sufficient water availability) and socio-economic services (job availability and networks for mobility of people, information, and things) as the most important services for creating liveability in the CMR. Societal interactions, family relationships and accessibility to public services were among socio-economic services that surveyed residents in the CMR were most satisfied with, followed by cultural services related to birthplace and community identity. On the other hand, income among socio-economic services was the aspect least satisfied among most surveyed participants as it relates to water availability. This is followed by regulating services that improve health, housing and human settlements and reduce the risk of droughts. Detailed comparisons of the perceived most important, most satisfied, and least satisfied liveability services in the four urbanisation categories in the CMR based on the raw percentage of words coded and based on the coding references per each urbanisation category, are shown in the supplemental data (*Appendix 1.4 Tables A.1.4.1 - A.1.4.3 and Figures A.1.4.1 – A.1.4.3*).

Four major themes of liveability services were considered as the least satisfying liveability services in the urban and peri-urban CMR. These themes include (i) employment and livelihood including income and job availability, particularly in the rural area; (ii) water, including sufficient water availability; (iii) mitigation of human impacts on environmental pollution, including health of house, human settlement, and waterways, particularly in the urban and UPT areas; and (iv) regulation of natural/physical phenomena, including flood protection and drought prevention. Together with networks for the mobility of people, information and objects, all four themes were considered as the most important liveability services in the CMR. Additionally, urban residents also highlighted their least satisfaction with the regulation of natural and biological phenomena such as green open spaces availability which has functions of regulating local climate and enabling social activities. Hence, the selected 15 liveability services (Table 21) collected for the quantitative importance-performance analysis can represent the qualitative responses to evaluate urban management effectiveness and to improve strategic planning for long-term liveability or sustainability.

6.4.3 Quantitative IPA of liveability services

The interview and household survey, ecohydrological changes in the CMR have reportedly affected urban and peri-urban socio-economic activities. Interconnection between ecohydrology and social-economy was indicated to have created a liveable and sustainable urban system in the CMR. A traditional IPA was carried out to obtain an initial strategic analysis, particularly to understand urban and peri-urban communities' perceptions of the liveability services and sustainability factors. IPA with gap analyses was carried out to further propose the resources distribution strategy of improving overall urban and peri-urban liveability and regional sustainability. For traditional IPA, the self-stated importance and performance means were used for plotting the IPA matrix. Median of average of the 15 attributes of importance and performance was used as the coordinate crossing point. The results of traditional IPA in the urban and peri-urban CMR are shown in Figure 32. The computed questionnaire results on means of attribute importance, performance, urban performance, peri-urban performance, gaps between importance and performance, and gaps between urban and peri-urban performance can be seen in the supplemental data (*Appendix 1.4 Tables A.1.4.4 - A.1.4.8*.)

The results identify that the sustainability factor with the highest importance-performance gaps for improving liveability in the urban area is ecohydrology while in the UPT, peri-urban, and rural areas, it is economy. The gap between importance and performance of the selected 15 liveability services is also evident. The scores for performance of liveability services in the four urbanisation categories were generally found to be lower than their importance scores, particularly for healthy waterways in the urban area, income in the UPT and peri-urban areas, and drought prevention in the rural area. Besides those priorities, traditional IPA indicates liveability services that need urgent action to enhance liveability. Income and job availability are among liveability services with high importance but low performance in the four urbanisation categories. This suggests they should be top priorities and targeted for urgent improvement efforts in the CMR. However, the results of the gap analysis provide references to improve the overall quality of services by reducing all liveability service gaps. Further, the assessment of gap performance among the four urbanisation categories informs better liveability definitions for the impact of urbanisation to urban and peri-urban ecohydrology compared to the assessment between city and peripheral city areas.

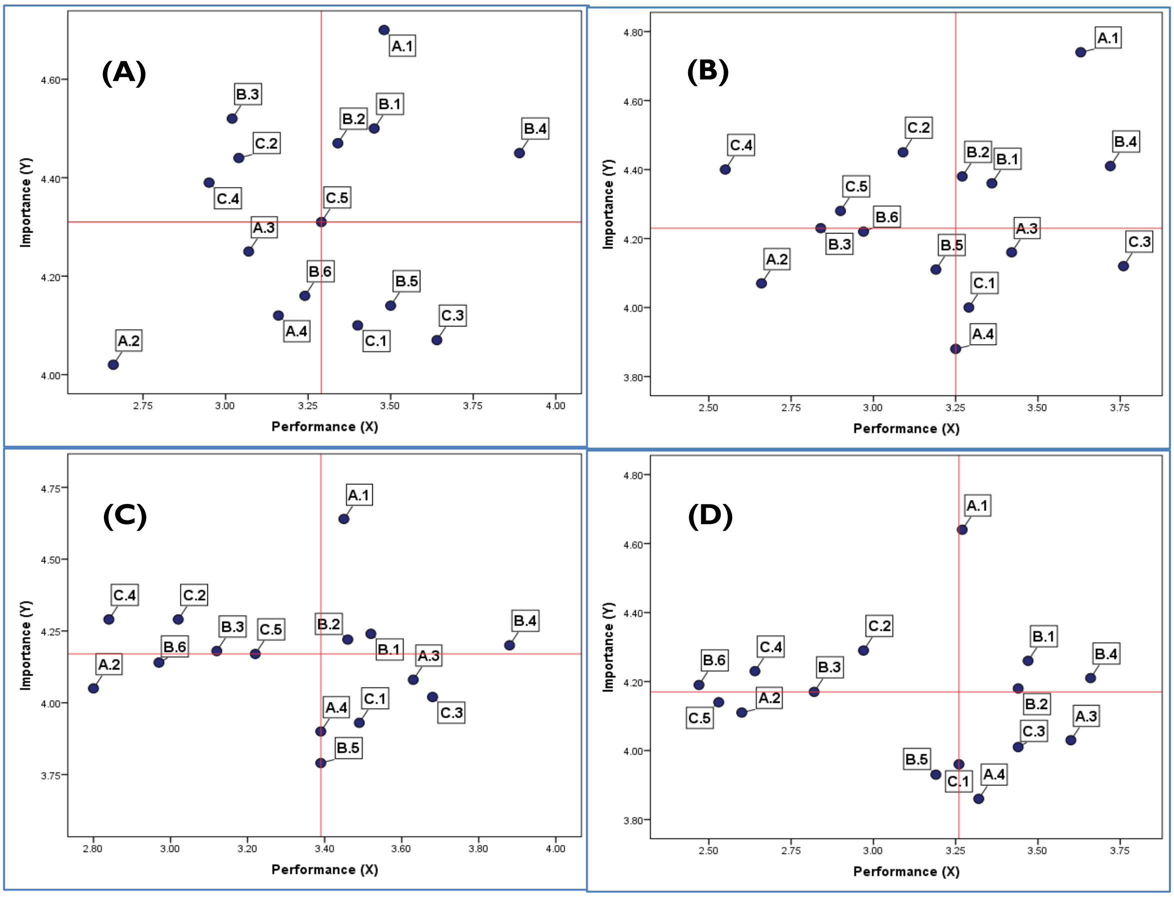


FIGURE 32. TRADITIONAL IPA: (A) URBAN; (B) UPT; (C) PERI-URBAN; (D) RURAL

Note: *A.1-Sufficient water availability; A.2-Well maintained river; A.3-Green open spaces in the public areas; A.4-Housing with garden spaces; B.1-Health-house; B.2- Health-human settlement; B.3-Health-waterways; B.4-Facilities and services for education, public health and amenities; B.5-Flood protection; B.6-Drought prevention; C.1-Housing affordability; C.2-Employment; C.3-Mobility; C.4-Income; C.5-Water services infrastructures and affordability*

The four urbanisation levels in the CMR have characteristics of different ecohydrological processes, technological interventions, and socio-demographic attributes. Figure 33 shows the IPA matrix with the performance differences. City/urban areas performed relatively less well than their outskirts in ecohydrological attributes (green open spaces availability) but performed better in socio-economic attributes. On the other hand, flood protection and drought prevention in the city outskirts had a lower performance compared to the urban centre of the CMR, CM. However, the importance of those services in the peripheral city areas, including UPT, peri-urban, and rural categories, is relatively lower than their importance in the city/urban centre. Further, water infrastructures in the peripheral city performed lower with the same level of importance as in the urban centre that needed improvement, particularly in the rural category.

Some liveability services showed lower performance and higher importance (Quadrant IV) and need urgent action to achieve balanced urban development. These were namely income, facilities and services for education, public health, and amenities. In addition, priority should be given to healthy waterways in the UPT area and to sufficient water availability in the peri-urban and rural areas. Also, suitable interventions are needed to improve job availability in the peri-urban area category. It is noted that available jobs for working in the agricultural sector in the peri-urban area were affected by ecohydrological changes. Conversely, housing with garden spaces, green open spaces in the public areas, housing affordability, and well-maintained rivers (Quadrant II) in the peri-urban and rural areas and mobility/accessibility in the UPT area, are likely to be over-allocated and could be diverted to Quadrant IV.

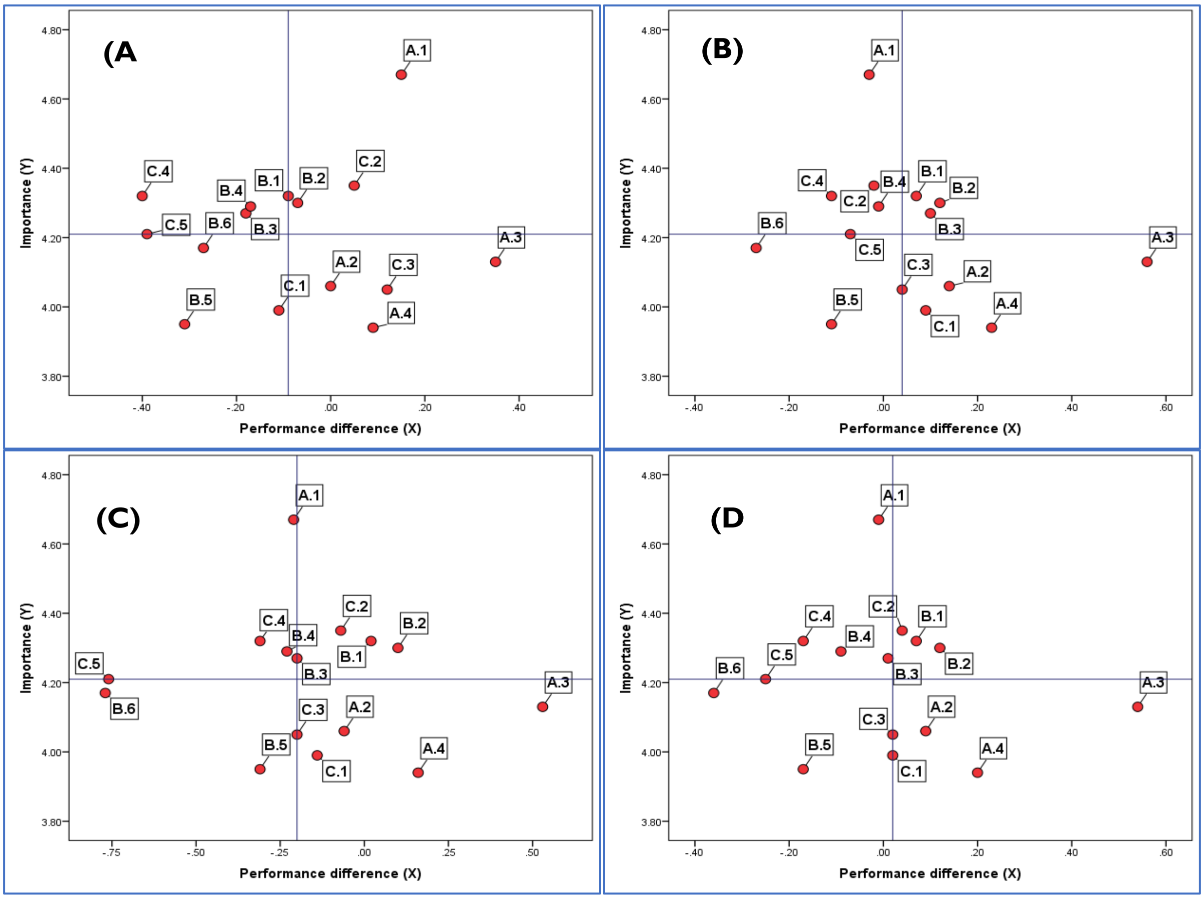


FIGURE 33. IPA WITH PERFORMANCE GAP: (A) BETWEEN UPT AND URBAN; (B) PERI-URBAN AND URBAN; (C) RURAL AND URBAN; (D) CITY AND PERIPHERAL CITY

Note: *A.1-Sufficient water availability; A.2-Well maintained river; A.3-Green open spaces in the public areas; A.4-Housing with garden spaces; B.1-Health-house; B.2- Health-human settlement; B.3-Health-waterways; B.4-Facilities and services for education, public health and amenities; B.5-Flood protection; B.6-Drought prevention; C.1-Housing affordability; C.2-Employment; C.3-Mobility; C.4-Income; C.5-Water services infrastructures and affordability*

6.5 DISCUSSIONS

6.5.1 THE ROLE OF COMMUNITIES VALUES WITH REGARD TO LIVEABILITY

The above results suggest that the working definition of liveability, in the context of socio-ecohydrology, requires a systems thinking approach that considers not only urban communities' but also peri-urban communities' perspectives for representing the urban system (Campbell, 2016). A system approach is particularly important to underlying ecological and hydrological attributes that deliver or constrain system change for sustaining liveability services, especially where urban and peri-urban communities may characterise the system differently (de Chazal, 2010). The change of values and ecohydrology can be found based on the assessments in four urbanisation categories. As shown in Figure 5, the more rural areas were surveyed, the more responses of important liveability factors related to social and economy were obtained. Despite flood and drought events frequently occurring in IR (Daruati et al., 2013, Surmaini et al., 2015, Sagala et al., 2014, Kuswanto et al., 2014), rural residents in the Sukagumiwang-IR did not report water security as the most important aspect for liveability. This is arguably because among 45 sub-districts within CMR, Sukagumiwang is a rural sub-district with the lowest Ecohydrological State Index (ESI) related to socio-economic activities but is higher ESI related to capacity in water management (Danielaini et al., 2018b).

On the other hand, the more urban areas were surveyed, the more responses of important liveability factors in environmental quality, infrastructures, and physical landscapes were obtained. Social and economic factors were not high concerns for the majority of urban residents. All urban sub-districts within CMR have the highest scores of ESI in socio-economic activities but the lowest scores in natural resource availability (Danielaini et al., 2018b). Further, among the five districts in the CMR, only CM has a HDI higher than the average HDI in West Java Province (WJP-MDM, 2013a). In 2017, the HDI, as an aggregate index of health, education, and economy, was ranked from highest to lowest as follows: CM (74.0), KR (67.8), CR (67.4), MR (65.9), and IR (65.6) with the average in West Java Province being 70.7 (http://ipm.bps.go.id/data/provinsi/metode/baru/3200). In the peri-urban and UPT areas, where ecosystem change occurs resulted from urbanisation, deforestation, and agricultural development, more responses of important liveability factors in water security were obtained. Even communities living in KR, where abundant water sources are available, reported a high concern for water security due to the increase in water supplied from their place to CM. The debit flow of water to CM has increased from around 120 cubic meters per hour in 1930 to currently more than 3600 cubic meters per hour (Rahayu, 2016).

Research on perceived liveability in other water-scarce areas such as Bhopal in India (Dehalwar and Singh, 2015) shows that safety, infrastructure and public services, including water supply and drainage, are the most important factors for liveability (Pandey et al., 2014). In this case, the provision of utility services and public amenities has an impact on the perception of the safety and security of residents (Pandey et al., 2013). The role of water on urban liveability is identified in cities in developing countries which generally face a deficit in urban infrastructures and also in developed countries such as Barcelona, Rotterdam, Amsterdam, Copenhagen, and Melbourne that have flood and drought concerns. The water sector in these cities has been proven to affect urban liveability and greening outcomes depending on governance, climate, infrastructure and physical contexts (Furlong et al., 2018). While the available liveability studies focus on a city, this study considered a city and its surrounding areas at different urbanisation levels. The findings show how values can play an important role in assessing ecosystem changes that are affecting liveability in the urban system, defining relationships between people and environment including water, and identifying changing values with regard to liveability (de Chazal, 2010, de Chazal et al., 2008, Allen, 2010).

6.5.2 Qualitative vs. quantitative IPA

The qualitative IPA of perceived liveability developed in this study is useful for obtaining holistic and contextual understandings of people's perceptions and experiences with regard to the 'liveability' of the environment; this includes wellbeing aspects or the 'life ability' of the collective individuals in the urban and peri-urban areas (Camfield et al., 2009). Liveable and sustainable urban systems belong to different qualitative types (Allen, 2010). As shown in this study, values of expectation and perception of satisfaction in the liveability services that include the ecosystem, urban, peri-urban, and human services show a dynamic and unplanned situation. In the CMR, ecosystem services are scarce in urban areas (Danielaini et al., 2018b), but most urban residents are satisfied with the provision of services related to sustainable water uses and resources accessibility through technological intervention. In contrast, most peri-urban residents are least satisfied with the decreasing land availability for farming and food production as affected by ecohydrological changes and insufficient water availability and technological interventions. Liveability thus changes as resources become scarce, and liveability can constrain sustainability but not determine it (Allen, 2010).

The quantitative IPA was found to be a valuable method for effectively identifying critical liveability services to improve the overall quality of life. Traditional IPA, as applied in this study failed to take into account the gap analysis to improve the quality of services which is related to the degree of discrepancy between expectations and perceptions (Lin et al., 2009). Further analysis using IPA with the performance gap between city/urban and peripheral city (urban, UPT, peri-urban, and rural) provides a more complete understanding of the disparities in the liveability services that need to be identified to minimise conflicts that can hamper sustainability for balanced urban development. Through quantitative IPA, ecohydrology was found to play a critical role in urban liveability in the urban CMR while socio-economy plays a significant function for peri-urban liveability. This finding is consistent with the results from qualitative IPA.

Using a mixed method approach, as shown in this study, allows multiple methods to be used to address complex research problems (Creswell, 2003, Creswell and Tashakkori, 2007). Although qualitative data in IPA analysis can maximise the opportunity to obtain high quality and detailed datasets for understanding liveability within a socio-ecohydrological context, it is very costly and time consuming. In contrast, a quantitative data analysis is relatively easier, lower in cost, and faster in terms of data collection and analysis. However, the indicators representing dynamic interactions between biophysical and socio-economic sub-systems should be carefully selected to minimise over generalisation or simplification in the results and analysis. While the results can be complementary, a different IPA approach may identify different managerial and theoretical implications (Feng et al., 2014). Hence, a more integrative study combining qualitative and quantitative IPA and applying the same code, category, and theme for data collection and analysis may improve this study.

6.5.3 Implications of IPA

IPA has underpinned the service theories and has largely focused on methods for measuring expectations and interpreting service quality/performance and gaps within them. Riviezzo et al. (2009) have suggested IPA as an alternative evaluating paradigm for town centre management as it can illuminate significant implications, for both practitioners and academics. However, this method has not previously been used in the context of improving liveability services in the urban system involving ecosystem, urban, peri-urban, and human services in the context of socio-ecohydrology. Qualitative and quantitative IPA in the context of socio-ecohydrology and sustainability frameworks were applied in this study to inform the dynamics of liveability and help identify liveability services that need urgent improvement or are over allocated in CMR. Specifically, this study applied comparative IPA using traditional IPA, IPA with gap importance-performance, and IPA with gap performance between focal performance (city/urban) and competitors (peripheral city/urban, UPT, peri-urban, and rural) that advanced an empirical IPA study and validated previous IPA works (Lin et al., 2009, Feng et al., 2014).

Based on the liveability theory, performance or perceived satisfaction in services to meet basic human needs affects subjective quality of life as this largely depends on the quality of the living environment and its capabilities for sustaining liveability services (Cummins and Nistico, 2002, Veenhoven, 1996a, Veenhoven and Ouweneel, 1995, Veenhoven, 1996b, de Haan et al., 2014, de Chazal, 2010). Hence, liveability comes from the dynamics of socio-ecohydrological systems while sustainability is attached to the planning approach and environmental management interventions (Allen, 2010). IPA with a gap analysis approach can bridge liveability and sustainability concepts for pragmatic purposes to balance supply and demand of liveability services and to develop strategic planning to promote a balanced urban development. As identified from the qualitative IPA in this study, expressions of liveability in water insecure regions, such as CMR, are mostly related to ecohydrology and its role in socio-economic activities. Moreover, with the greater pressures coming from increased urbanisation and climate change in such environments, ecology and hydrology are closely linked and related to biophysical, institutional and cultural barriers that need a socio-ecohydrological approach to effectively address future water challenges (Pataki et al., 2011).

Creating policies that are both place and people based will thus be critical for regional development intervention to improve liveability in the context of socio-ecohydrology. A place based approach is designed in particular to identify and build on embedded local knowledge and values including; sense of community; capacity to mobilise resources and resolve conflicts; and the level of provision of public goods and services (Barca et al., 2012). As a goal of regional planning, liveability also needs a people based approach (Hägerstraand, 2005). Identifying wellbeing aspects and liveability services from the perspective of community is important in approaching demand-based development. Demand refers to the actual use of services consumed by local communities that might be higher or lower than the capacity of ecosystems and institutions to deliver potential services for liveability (Schröter et al., 2012). In this study, a place-based approach was used to better understand the value of natural capital, including water, while a people-based specifically demand-based approach was used to better understand the capacity of institutions to satisfy local communities, regarding their existing environment and socio-economic activities.

6.6 CONCLUDING REMARKS

Based on empirical evidence from the urban and peri-urban areas of Cirebon, the study indicates that IPA can firstly, support a demand-based approach in urban development and secondly, identify place-based needs for environmental planning and management to improve socio-ecohydrological systems for long-term liveability and sustainability. The variations in perceived liveability responses in this study reflect the sense of place, experiences, and perceptual measures of the risks associated with urbanisation, particularly those due to the change of land use, water cycle, and climate to fulfil societal needs in the urban and peri-urban areas.

The study demonstrates that, through qualitative IPA, it is possible to examine holistic concepts and experiences of ecosystem, urban, peri-urban, and human services among the different surveyed groups. Further, the IPA can assist in identifying the liveability services that people are most commonly least satisfied with and which are considerably important for creating a liveable place based on strategic analysis in planning and management for balanced urban development. As such, the IPA matrix provides a basis for developing strategic environmental planning and management.

This study advanced empirical comparative IPA using traditional IPA, IPA with gap importance-performance, and IPA with gap performance in the context of socio-ecohydrology. This approach was found particularly useful in the water insecure region of CMR with its limited resources and existing ecohydrological connections between the city and peripheral city. The findings from the qualitative and quantitative IPA developed in this study can be used for identifying practices and strategies to improve water management, urban vegetation, landscape water use, and cultural services for supporting regional socio-economic development.

An important finding of this study is that although economy and health are the two liveability aspects that the communities in the CMR were least satisfied with, those aspects were not the most important for creating a liveable place in the urban and peri-urban areas. Water security issues are the primary concern of urban and peri-urban communities in the CMR for supporting socio-economic activities in the region. Hence, the approach in environmental planning and management for improving liveability in the CMR should focus on how to secure water for households, urban development and a healthy environment and on enhancing resilience to water related disasters and the economy.

CHAPTER 7
EVALUATING THE COMPLEXITY OF HOUSEHOLD WATER SECURITY ISSUES

Danielaini, T. T., Maheshwari, B., & Hagare, D. 2019. An assessment of household water insecurity in a rapidly developing coastal metropolitan region of Indonesia. Sustainable Cities and Society, 46. doi: 10.1016/j.scs.2018.12.010.

Summary

This chapter develops an analytical framework to better understand socio-ecohydrological issues underpinning farm and non-farm household's water insecurity. Guttman's scale approach was used to assess household water insecurity. Factor and cluster analyses were then applied to confirm the results and identify issues that shaped household water insecurity. The study shows spatial variations of water insecurity concerning urbanisation and farm and non-farm households. The study indicates that dominant factors shaping household water insecurity in the CMR are (i) unacceptable levels in water risks and (ii) inadequate water sources and services to satisfy the population's needs in relation to health, livelihood, ecosystems, and production. In this study, the most water insecure households were found largely in the UPT zone due to limited access to water and sanitation infrastructures, flood events, climate change, and concern of future risks.

7.1 INTRODUCTION

Water security in coastal metropolitan regions in developing Asian countries is under threat from many sources; these include rapid population growth and urbanisation, the increasing rate of groundwater extraction and land subsidence, declining water quality, water-related disasters and climate change. There is evidence that these factors have compromised household water security in rapidly urbanising regions in Asia (Asian Development Bank, 2013a). Indonesia is not a water-scarce country; however, infrastructures, environmental management, and land use planning are not keeping pace with the rapid growth of urban development which leads to increasingly water insecure households (Asian Development Bank, 2013b, Asian Development Bank, 2016b, Asian Development Bank, 2016c, Asian Development Bank, 2016a, Deltares et al., 2012).

These issues are well documented in case studies done on large coastal cities such as Jakarta. Household water security in this metropolis has been threatened by the low coverage of piped water and sanitation services; excessive groundwater pumping; alarming land subsidence; decreasing water quality; and increasing climate-related disasters (Abidin et al., 2011, Delinom et al., 2009, Palupi et al., 1995, Steinberg, 2007, Firman et al., 2011). Increasingly, attention has turned to studying smaller coastal cities such as Cirebon and Makassar, with findings indicating similar issues and higher concerns about the capacity of institutions to effectively manage rapid urbanisation and climate change pressures (Rositasari et al., 2011, Fahmi et al., 2014, Tjandraatmadja, 2013, Tjandraatmadja, 2012).

Water is a critical element in achieving the Sustainable Development Goals (SDGs), particularly Goal 6, to ensure availability and sustainable management of water and sanitation for all (United Nations, 2018). The Asian Development Bank (2016b) reports that the proportion of Indonesian households with access to improved water supply is 67%, mostly being obtained from protected dug wells (29.2%), bore wells (24.1%) and piped water (19.7%). Centralised sewerage systems are limited to a few cities and less than 5% of sewage is properly treated resulting in massive pollution of surface and groundwater sources. While the need to make water security more risk and opportunity oriented has been defined (Grey and Sadoff, 2007), the current thinking in water security is still largely focused on infrastructure.

Recently, the Government of Indonesia prioritised providing access to piped water supply services and to communal and central sanitation facilities as critical measures for obtaining household water security. However, it is not clear whether this strategy will be effective in Java where approximately 60% of residents live in water insecure regions with frequent floods and droughts (Deltares et al., 2012, Yusuf and Francisco, 2009, Asian Development Bank, 2016b). This study aims to better understand household water insecurity in the frame of the dynamic nature of socio-ecological-hydrological interactions that characterise the insecurity of an urbanising region.

Specifically, it: (i) identifies the major concerns of residents regarding water insecurity resulting from urbanisation that shapes ecohydrological change; (ii) investigates whether limited access to water and sanitation infrastructures significantly shapes farm and non-farm household water insecurity in a rapidly developing coastal metropolitan region in Java; (iii) identifies dominant factors and issues that shape household water insecurity in this region at different urbanisation levels; and (iv) develops an analytical framework for assessing farm and non-farm household water insecurity to identify diverse situations in urban and peri-urban areas. Additional comparisons are made in the discussion section to similar cases in other cities/countries.

7.2 THEORETICAL AND CONCEPTUAL FRAMEWORKS

7.2.1 WATER SECURITY DEFINITION

Water security is termed in various perspectives. These include sustainability (GWP, 2000), development and risk (Garrick and Hall, 2014, Grey et al., 2013, Grey and Sadoff, 2007), equity of access related to human rights (Bradley and Bartram, 2013), biodiversity (Vorosmarty et al., 2010), anthropocentric orientation (Stevenson et al., 2012), gender disparity (Wutich, 2009), vulnerability and adaptation (Scott et al., 2012), and the complexity of water-society challenges (Zeitoun et al., 2016). This water security study was applied in the context of sustainability, development and risk.

In the frame of sustainability, water security, at any level from the household to the global, is defined broadly as "*Access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced*" (GWP, 2000). Further, in the frame of development and risk, water security is defined broadly as "*The availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production, coupled with an acceptable level of water-related risks to people, environments, and economies*" (Grey and Sadoff, 2007).

The two definitions were deemed the most appropriate for the study as they address human and ecosystem needs, accessibility, continuity, and affordability as well as provision and risk perspectives. These provide the framework for actions to ensure human and ecosystem health, to provide improved domestic water and sanitation, to decrease the proportion of people who are water-insecure, and to achieve better management (Asian Development Bank, 2016a, GWP, 2000, Bradley and Bartram, 2013, Cook and Bakker, 2012). Section 7.2.3 explains how the definitions are conceptualised in this study.

For our purpose, these two definitions were conceptualised in the context of a water insecure region. We define household water insecurity as "*Insufficient accessibility and capability of water sources and services to satisfy the household needs for health, livelihood, ecosystem, and production, coupled with inadequate acceptability and adaptive capacity of households to deal with the ecohydrological changes, that impact liveability and sustainability*". Liveability in this study is understood in the context of socio-ecohydrology that refers to dynamic interactions between people, water, and the environment; sustainability refers to long-term liveability that is ensured via planning and management interventions (Danielaini et al., 2018c).

7.2.2 WATER SECURITY ASSESSMENTS

7.2.2.1 ASSESSMENT OF WATER SECURITY IN THE CONTEXT OF URBANISATION AND CLIMATE CHANGE

There are an increasing number of studies on urbanisation and climate change and their impacts on water systems, management, and security (Jaramillo and Nazemi, 2017, Astaraie-Imani et al., 2012, Gebremeskel et al., 2004, Meenu et al., 2013, Islam and Gan, 2014, Neumann et al., 2013). However, relying on reductionist or simplified approaches such as modelling are not sufficient to address the complex socio-ecological and socio-hydrological challenges related to the interactions between people, water, and the environmental (Byg and Salick, 2009, Wesselink et al., 2017). A complex or integrative approach that does not seek to generalise the complexity of human-water-ecological challenges is required. In this study, this is achieved by combining comparative research with deeper contextualising work on how local variations occur considering existing knowledge (Zeitoun et al., 2016). In this case, understanding historical experiences helps to test theories of human-environment interactions and can be used for guiding future actions in promoting water security to support sustainable urban development.

7.2.2.2 ASSESSMENT OF WATER SECURITY THROUGH INDICES VERSUS EXPERIENCE-BASED SCALE

Several studies to assess water security have been conducted from using one-variable measures to using several variable measures as a composite index (Gleick, 1996, Sullivan, 2002, Sullivan et al., 2003, Norman et al., 2013, Chaves and Alipaz, 2007, Asian Development Bank, 2013a). Single variable measures, such as water access or water quality or water infrastructures, have been assessed as being inadequate to capture the multifaceted nature of water security (Wheater and Gober, 2013). Composite indexes that incorporate several interdependent dimensions of water security into one are also not sufficient to understand diverse and complex water security issues (Lautze and Manthrithilake, 2012).

Another approach that incorporates several variables to assess water security is experience-based scales or scalograms or Guttman scaling. Guttman scalograms record frequently positive responses, from higher to lower, as well as rank individuals in relation to those responses (Guttman, 1944). This scaling method can be used for widespread applications to quantify qualitative data from attitude and opinion surveys (Clark and Kriedt, 1948), for example, to rank household wealth (Guest, 2000), measure consumer behaviour (Ekinci and Riley, 2000), and assess patients with health issues in mobility disability (Souza, 1999). Recently, Guttman scaling has been used to address household water insecurity (Wutich and Ragsdale, 2008, Hadley and Wutich, 2009, Jepson, 2014). Guttman scaling procedures assess the cumulative or progressive experiences and do not seek to generalise patterns across different socio-economic groups (Wutich and Ragsdale, 2008).

7.2.3 ASSESSMENT OF HOUSEHOLD WATER INSECURITY

Water insecurity at a household level falls within the domain of human development (Jepson, 2014). It can be associated with difficulty in accessing water or issues with the affordability, adequacy, and quality of water for social productivity and a healthy life which is contrary to human rights (UNESCO, 2006, GWP, 2000, Gleick, 1998). Further, water insecurity assessment at a regional level is within the vulnerability and risk domain and can be associated with climate and hydrological changes (Scott et al., 2013b). The assessment of household water insecurity in this study combined those related indicators and used community perspectives/experiences in the urban and peri-urban areas to examine socio-ecohydrological changes resulting from rapid urbanisation.

A recent measurement of household water insecurity using the Guttman's scale as developed by Jepson (2014) identifies issues of household water access, acceptability and its effect on the urban fringe. However, the indicators that focus on domestic water provision are not sufficient to describe household water (in)security as they should include access to piped water systems, improved sanitation and hygiene (Asian Development Bank, 2013a). Water also has a critical function in the economic productivity of farm households. Further, any assessment of household water security in the urban system at the regional scale will need to consider the changes in land use, water cycle, and climate; all of which relate to livelihood, environmental protection, community resilience and urban liveability (Danielaini et al., 2019c).

This study advances previous work on experience-based scaling of household water security. We used an analytical framework at different urbanisation levels in a coastal region, which included accessibility to water and sanitation infrastructures; acceptability of water risks from ecohydrological change; capability of socio-ecohydrological systems to satisfy the needs for health, livelihood, ecosystem, and production; and household adaptive capacity in dealing with the impacts resulting from socio-ecohydrological change (Figure 34).

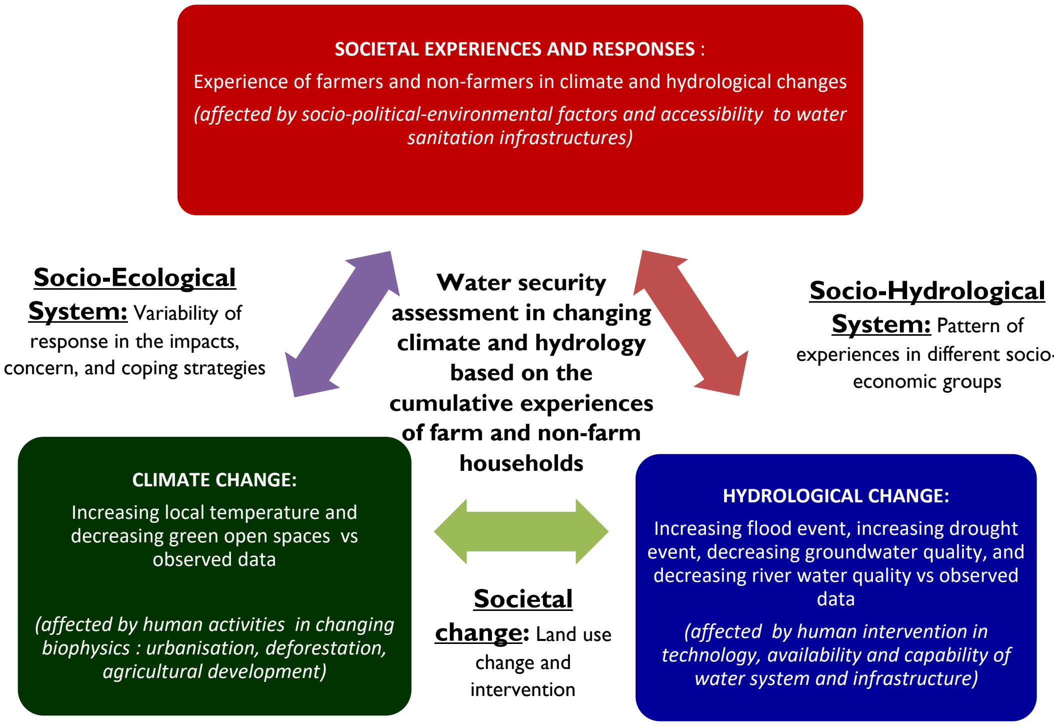


FIGURE 34. ANALYTICAL FRAMEWORK FOR WATER SECURITY STUDY IN THE CMR

7.3 METHODOLOGY

7.3.1 DATA COLLECTION

In the northern coastal region of West Java, economic stress in rural agricultural areas, rather than increased economic opportunities in the urban areas, has exacerbated urbanisation (Winoto and Schultink, 1996). However, the region has not been provided with sufficient ecohydrological protection, including adequate water and sanitation infrastructures, and this significantly decreases the ecohydrological based liveability of residents (Danielaini et al., 2018c). Climate change has also affected the urban and rural areas and residents within CMR (Pratiwi et al., 2017, Rositasari et al., 2011), with several studies reporting frequent floods and droughts in this region (Sagala et al., 2014, Daruati et al., 2013, Pratiwi et al., 2017). While quantitative data about infrastructure at a regional scale are available, little is known at the local level about the complex experience of water insecurity concerning urbanisation and farm/non-farm households.

This study incorporates perspectives from city and peripheral city dwellers in the CMR to examine water security issues. The total area of the CMR is 1,080 km^2 with 73% of it being located in the

Cirebon City and Cirebon District (Regional Development Planning Board of West Java Province, 2015). Hence, the survey was concentrated in these areas; around 70% of the total surveyed households (N=430). The proportion of surveyed households in the city was 23%, while in the peripheral city it was 77%. This percentage represents the proportion of population living in the urban sub-districts which is approximately 21% of the total population in the CMR (Regional Development Planning Board of West Java Province, 2015, Danielaini et al., 2018b). This includes 225 farm householders and 205 non-farm householders across five districts and 25 sub-districts.

In a narrow definition, farm households can be defined as households that were mainly dependent on farming for their livelihoods. Farming plants or animals, either on land (agriculture) or in water (aquaculture), involve interventions to enhance production such as regular stocking, feeding and protection from predators and also implies ownership of the stock being cultivated (FAO, 1997, FAO, 2018). Fishermen capture fish and the activities of hunting fish/ fishing are part of the fisheries sector. In this study, all surveyed households that actively engaged in agricultural activities such as farm cultivation, husbandry and poultry, aquaculture, and fish capture were categorised as farm-households. This study followed a broad definition of farm households as all households with main income sources from agricultural sub-sectors including food crops, horticulture, estate crops, livestock, fishery and forestry (Garner and Campos, 2014, FAO, 2013, Achmad, 2010).

The questions were delivered in different formats to obtain detailed information on the socio-ecohydrological aspects in the region. For example, open-ended questions included "To what extent have ecohydrological functions changed in the past 10 to 20 years?" and "Are there any concerns regarding the change in land use, water cycle and climate? Please specify…." This information was used to assess how householders' positive or negative experiences would inform their responses to the statements of household water insecurity, such as "I have concerns regarding the change in land use, water cycle, and climate from future urbanisation", and "Climate and hydrological changes adversely affect household social and economy".

Closed-ended questions about water sources for drinking listed various possible responses, including bottled water, piped water into dwellings, piped water into yards, public taps, tube well/boreholes, protected dug wells, unprotected dug wells, protected springs, unprotected springs, rainwater and other (surface water, small carts, tanker trucks). The information given by the participant was assessed in the format of positive/negative responses to the statement for assessing household water insecurity, such as "Household members do not have access to improved drinking water sources". If the farmer/non-farmer, as a representative of the household, reported that drinking water was sourced from bottled water/unprotected dug well/unprotected spring/surface water/other, we assessed that response as a positive response to the statement, while if they reported from a piped water/ public tap/ tube well/ borehole/ protected dug well/ protected spring, we assessed that response as a negative response to the statement.

JMP (2017a) has recognised that packaged water and delivered water can potentially deliver safe water, and can be classified as limited, basic or safely managed. However, in this study, we categorised bottled water and delivered water as unimproved facilities due to (i) limitations in the potential quantity, not quality, of the water and (ii) the lack of data on accessibility, availability, and quality, following the JMP criteria (JMP, 2017a, JMP, 2017b, Yu et al., 2016). In addition, according to Ferrier (2001), bottled water should not be considered as a sustainable alternative to tap water. Another example; the close-ended question about the capability of water related services for satisfying the needs for health, livelihood, ecosystem and production used a 5-point Likert scale (1=very unsatisfied; 2=not satisfied; 3=unsure; 4=satisfied; 5=very satisfied). The responses from the participants were also assessed in the format of positive/negative responses to the statement for assessing household water insecurity. For instance," Currently not satisfied with healthy waterways" or" Currently not satisfied with drought prevention" or" Currently not satisfied with income". If the participants selected 1 or 2, that response was assessed as a positive response to the statement, while if they selected 3 or 4 or 5, that response was assessed as a negative response to the statement.

7.3.2 DATA ANALYSIS

Open-ended questions were coded and categorised using NVivo Pro (QSR)™ 11.0 as it is useful for analysing texts from semi-structured interviews and is suitable for organising and interpreting qualitative data (Sotiriadou et al., 2014). Quantitative data analysis from questionnaires, namely (i) factor and cluster analyses of household water insecurity were conducted using SPSS (IBM)™ version 25 and (ii) Guttman scale analysis was conducted using Anthropac 4 (Borgatti, 1996). Different typology groups were developed based on the level of urbanisation namely urban, urban/peri-urban transition (UPT), peri-urban, and rural (Danielaini et al., 2018a). The selected indicators follow Chaves (2012) recommendation that meaningful water security indicators should include cause and effect relationships that cover the pressure-state-response approach such as climate and human pressures, water quantity and quality, state and societal responses.

The survey questions addressed 33 indicators within four dimensions of water security namely access, acceptability, capability and adaptive capacity from the urban and peri-urban communities or beneficiary's perspectives in the regional development areas. Responses were assessed in dichotomous scale, zero for negative responses and one for positive responses. Responses and individual households were then re-arranged in the data matrix. The experience-based indicators used in the scale development are shown in the idealised Guttman scales (Table 23).

Reliability tests for each scale were calculated using three conventional measures namely minimal marginal reproducibility (MMR) that should be less than 0.90, coefficient of reproducibility (CR) more than 0.85, and coefficient of scalability (CS) greater than 0.60 (Guest, 2000, Wutich and Ragsdale, 2008, Hadley and Wutich, 2009). The responses and internal consistency and reliability of the water security assessment using the cumulative experiences of four Guttman scales and 33 indicators were moderately acceptable (0.68-0.71). However, the reliability tests for each scale of water security dimension with CR and CS values were less than acceptable, indicating that the selected statements did not follow the scale procedures to rank questions based on difficulty or cumulative progressive experiences. This indicated the need to focus on capturing diverse related experiences and existing situations within one dimension of water security (Table 24).

As a comparison, the 33 indicators were also assessed using factor analysis with principal components for unidimensional tests (Table 25). Factor analysis was applied as the alternative analysis of the multi-dimensional scale analysis. Household water (in)security classification was determined using cluster analysis from both approaches on different socio-economic groups, based on four urbanisation levels, and farm and non-farm households. Hierarchical cluster analysis was used to define the number of clusters through a dendrogram and the K-mean cluster analysis was used to define water (in)security classification.

7.4 RESULTS

7.4.1 RESIDENTS EXPERIENCES IN ECOHYDROLOGICAL CHANGE CONCERNING URBANISATION

The 225 farm and 205 non-farm householders represented a diversity of demographic characteristics in the study area (Table 26). Their experiences regarding socio-ecohydrological change and impacts in their areas revealed different concerns of water insecurity in the urban, UPT, peri-urban, and rural areas (*Appendix Data Figure A.1.5.1*). The figure depicts word clouds of the100 most frequent display words that people said regarding rural-urban interfaces which indicate that urban residents were most likely to talk about insufficient capability of public drinking water services to satisfy their needs, UPT residents were most likely to talk about floods, and peri-urban and rural residents were more likely to talk about the dry season and droughts.

TABLE 23. IDEALISED GUTTMAN SCALES FOR ASSESSING HOUSEHOLD WATER INSECURITY

No	Selected Indicators for data analysis	Responses									
1a	**Idealised Guttman Scale for insufficient accessibility to water sources and related services**										
1	Household does not have private sanitation facilities	No	No	No	No	No	No	No	No	yes	
2	Household does not have private water facilities	No	No	No	No	No	No	No	yes	yes	
3	Household members do not have access to improved non-drinking water sources	No	No	No	No	No	No	yes	yes	yes	
4	Drainage system is not available surrounding household	No	No	No	No	No	yes	yes	yes	yes	
5	Household members do not have access to improved drinking water sources	No	No	No	No	yes	yes	yes	yes	yes	
6	Household members do not have access to improved sanitation facilities	No	No	No	yes	yes	yes	yes	yes	yes	
7	Household does not have access to public drinking water system	No	No	yes	yes	yes	yes	yes	yes	yes	
8	Household does not have access to public waste water treatment system	No	Yes	yes	yes	yes	yes	yes	yes	yes	
	Score	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
	Definition	Score									
	Adequate water-sanitation access – A1	0-1									
	Marginal water-sanitation access – A2	2									
	Low water-sanitation access – A3	3-4									
	Very low water-sanitation access – A4	5-8									
1b	**Idealised Guttman Scale for inadequate acceptable level to water risks resulting from ecohydrological change**										
9	Having experienced an increase in flood events	No	No	No	No	No	No	No	No	No	yes
10	Currently a having problem in flood/flooding	No	No	No	No	No	No	No	No	yes	yes
11	Having experienced a decrease in groundwater quality	No	No	No	No	No	No	No	yes	yes	yes
12	Currently having a problem in groundwater quality	No	No	No	No	No	No	yes	yes	yes	yes
13	Currently having a problem in water scarcity/drought	No	No	No	No	No	yes	yes	yes	yes	yes
14	Having experienced an increase in drought event	No	No	No	No	yes	yes	yes	yes	yes	yes
15	Having experienced an increase in temperature	No	No	No	yes	yes	yes	yes	yes	yes	yes
16	Having experienced a decrease in river water quality	No	No	yes	yes	yes	yes	yes	yes	yes	yes
17	Having experienced a decrease in green open spaces	No	yes	yes	yes	yes	yes	yes	yes	yes	yes
	Score	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Definition	**Score**									
	Highly likely water risks acceptability – B1	0-1									
	Marginal water risks acceptability – B2	2-3									
	Low water risks acceptability – B3	4-6									
	Very low water risks acceptability – B4	7-9									
1c	**Idealised Guttman Scale for insufficient capability of water sources and services to satisfy the needs for health, livelihood, ecosystem, and production**										
18	Currently not satisfied with flood protection	No	No	No	No	No	No	No	No	No	yes
19	Currently not satisfied with healthy housing	No	No	No	No	No	No	No	No	yes	yes
20	Currently not satisfied with housing with garden spaces	No	No	No	No	No	No	No	yes	yes	yes
21	Currently not satisfied with healthy human settlement	No	No	No	No	No	No	Yes	yes	yes	yes
22	Currently not satisfied with sufficient water availability	No	No	No	No	No	yes	Yes	yes	yes	yes
23	Currently not satisfied with water and sanitation infrastructures	No	No	No	No	yes	yes	Yes	yes	yes	yes
24	Currently not satisfied with drought prevention	No	No	No	yes	yes	yes	Yes	yes	yes	yes
25	Currently not satisfied with healthy waterways	No	No	yes	yes	yes	yes	Yes	yes	yes	yes
26	Currently not satisfied with income	No	yes	yes	yes	yes	yes	Yes	yes	yes	yes
	Score	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Definition	**Score**									
	High intervention capability for satisfying socio-economic activities – C1	0									
	Marginal intervention capability for satisfying socio-economic activities – C2	1-3									
	Low intervention capability for satisfying socio-economic activities – C3	4-6									
	Very low intervention capability for satisfying socio-economic activities – C4	7-9									
1d	**Idealised Guttman Scale for inadequate household adaptive capacity to cope with the ecohydrological change**										
27	Disagree that it is important to use water much more efficiently			No	No	No	No	No	No	No	yes
28	Disagree that it is important to minimise water use consumption			No	No	No	No	No	No	yes	yes
29	Having an opinion that only government has responsibility for improving ecohydrological status*			No	No	No	No	No	yes	yes	yes
30	Water sources and related services are liveability aspects that household members are least satisfied*			No	No	No	No	yes	yes	yes	yes
31	Having no solution to minimise the impacts of climate and hydrological changes*			No	No	No	yes	yes	yes	yes	yes
32	Climate and hydrological changes adversely affect household social and economy*			No	No	yes	yes	yes	yes	yes	yes
33	Having concerns regarding the change in land use, water cycle, and climate from future urbanisation*			No	yes	yes	yes	yes	yes	yes	yes
	Score			**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Definition	**Score**									
	High household adaptive capacity to deal with ecohydrological changes – D1	0-1									
	Marginal household adaptive capacity to deal with ecohydrological changes – D2	2-3									
	Low household adaptive capacity to deal with ecohydrological changes – D3	4-5									
	Very low household adaptive capacity to deal with ecohydrological changes – D4	6-7									

*Adapted from Jepson (2014) and Hadley and Wutich (2009). Most data of statements were obtained from closed-ended questions except *, coding from open-ended questions.*

TABLE 24. VALIDITY AND RELIABILITY TESTS

Validity and Reliability Tests	Water security dimensions			
	Access	Acceptability	Capability	Adaptive Capacity
Construct Validity (Spearman Correlation)	All statements are significantly correlated at 0.01 level (2-tailed) to total cumulative experiences at each dimension of water security			
MMR	0.74	0.72	0.68	0.73
CR	0.84	0.80	0.77	0.79
CS	0.36	0.27	0.30	0.25
Cronbach's Alpha for each scale	0.54	0.47	0.74	0.22
Lambda 2 (Guttman) for four scales	0.71			
Lambda 3 (Guttman) for four scales	0.68			
Cronbach's Alpha for four scales	0.68			

TABLE 25. FACTOR ANALYSIS OF SELECTED WATER SECURITY INDICATORS

	Selected indicators for assessing water (in)security in changing climate and hydrology	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12
		Drought event	**Unhealthy housing & environment**	**Unregulated Water use**	**Limited access**	**Flood event**	**Poor affordability**	**Poor sanitation**	**Water resources issue**	**Water affect issue**	**Climate change**	**Concern of future risks**	**Poverty/ vulnerability**
1	Household members do not have access to improved drinking water sources			0.3			0.3		-0.4				
2	Household members do not have access to improved non-drinking water sources						0.8						
3	Household does not have private water facilities						0.8						
4	Household members do not have access to improved sanitation facilities							0.8					
5	Household does not have private sanitation facilities							0.4					0.5
6	Household does not have access to public drinking water system				0.6								
7	Household does not have access to public waste water treatment system				0.5			0.5					
8	Drainage system is not available surrounding household				0.6								
9	Currently having a problem in water scarcity or drought	0.8											
10	Currently having a problem in flood/flooding					0.8							
11	Currently having a problem in groundwater quality				-0.5								
12	Having experienced a decrease in green open spaces								0.6				
13	Having experienced an increase in temperature										0.6		
14	Having experienced a decrease in groundwater quality							0.3	0.3			0.4	
15	Having experienced a decrease in river water quality								0.7				
16	Having experienced an increase in flood event					0.8							
17	Having experienced an increase in drought event	0.7											
18	Currently not satisfied with sufficient water availability	0.7											
19	Currently not satisfied with housing with garden spaces		0.5										
20	Currently not satisfied with healthy housing		0.9										
21	Currently not satisfied with healthy human settlement		0.9										
22	Currently not satisfied with healthy waterways		0.5									0.4	
23	Currently not satisfied with flood protection					0.4							
24	Currently not satisfied with drought prevention	0.8											
25	Currently not satisfied with income	0.3	0.3										
26	Currently not satisfied with water and sanitation infrastructure	0.5						0.3					
27	Having an opinion that only government has responsibility for improving ecohydrological status												0.7
28	Disagree that it is important to minimise water use consumption			0.9									
29	Disagree that it is important to use water much more efficiently			0.9									
30	Water sources and services are liveability aspects that household members are least satisfied									0.8			
31	Climate and hydrological changes adversely affect household social and economy									0.7	0.3		
32	Having no solution to minimise the impacts of climate and hydrological changes									0.3		0.4	
33	Having concerns of the change in land use, water cycle, and climate from future urbanisation											0.7	
	Lambda 2 (Guttman)	0.76	0.73	0.79	0.49	0.62	0.59	0.54	0.36	0.43	0.29	0.27	0.13
	Eigenvalues	3.77	2.64	1.98	1.93	1.52	1.46.	1.36	1.33	1.24	1.15	1.11	1.01
	Percentage of explained variance	11.4	8.0	6.0	5.8	4.6	4.4	4.1	4.0	3.8	3.5	3.4	3.1

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

TABLE 26. SOCIO-DEMOGRAPHIC FEATURES OF FARM AND NON-FARM HOUSEHOLDS

Attributes	Parameter	Percentage from total 430 households		
		Farm-household (%)	Non-Farm household (%)	Total (%)
Place in five districts within CMR *(political boundaries)*	Cirebon Municipality	7.5	15.1	22.6
	Cirebon Regency	27.0	22.5	49.5
	Indramayu Regency	4.4	2.6	7.0
	Kuningan Regency	8.6	5.4	14.0
	Majalengka Regency	4.9	2.1	7.0
Level of urbanisation	Rural	10.5	6.5	17.0
	Peri-urban	27.0	15.3	42.3
	Urban-Peri-urban Transition (UPT)	7.4	9.8	17.2
	Urban	7.4	16.1	23.5
Gender	Male	35.8	24.9	60.7
	Female	16.5	22.8	39.3
Length Stay	≤ 30 years	15.3	21.4	36.7
	More than 30 years	37.0	26.3	63.3
Distance from the coast	≤ 10 km	20.2	28.2	48.4
	More than 10 km	32.1	19.5	51.6
Household size	≤ 3 persons	14.0	11.9	25.9
	4-6 persons	32.9	28.8	61.7
	More than 6 persons	5.4	7.0	12.4
Total participants in each group		**52.3**	**47.7**	**100**

7.4.2 TYPOLOGY OF WATER SECURITY ISSUES BASED ON THE GUTTMAN SCALE AND CLUSTER ANALYSES

Idealised Guttman scale revealed that householders without private sanitation facilities are likely to have limited access to other water related infrastructures. Householders who experienced increasing flooding events are likely to have experiences in decreasing water quality and open spaces. Householders who were unsatisfied with flood protection are likely to be not satisfied with unhealthy environments. Householders who do not use water efficiently are likely to disagree with minimising water consumption. From the Guttman scale analysis (Table 27), water security was classified into four clusters, namely Water Secure (S1), Marginally Water Secure (S2), Marginally Water Insecure (S3), and Water Insecure (S4).

TABLE 27. MEAN VALUES FOR GUTTMAN SCALE SCORES AND DIFFERENCES AMONG WATER SECURITY CLUSTERS FROM FOUR SCALOGRAMS

Water security classification	Code	Water-sanitation access		Water risks acceptability		Water system capability		Household adaptive capacity		Households (HH)	% total surveyed HH
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Water secure	S1	1.4	1.0	3.7	1.4	1.3	1.2	2.8	1.3	119	27.7%
Marginally water secure	S2	**3.8**	1.0	2.9	1.3	1.5	1.1	2.7	1.2	147	34.2%
Marginally water insecure	S3	2.4	1.3	5.9	1.0	5.3	1.6	2.9	1.2	88	20.5%
Water insecure	S4	**3.9**	1.5	3.7	1.4	5.5	1.3	3.3	1.4	76	17.7%
F		119.9		105.7		332.5		3.7			
Sig		<0.001		<0.001		<0.001		<0.05			

SD=Standard Deviation. Highlighted highest scores indicate water security issues.

The largest percentages of urban households (44.6%) and non-farm households (40.0%) are water secure (Figure 35). Among the four clusters, those households have the best access to water sources and services, but they may have problems in water risk acceptability. Additionally, the highest proportion of UPT, peri-urban, and rural households (>33%) and farm households (39.6%) are marginally water secure. Households in this cluster may have problems in access to water sources and services. On the other hand, more than 25% of UPT and rural households and 22.7% of farm households are marginally water insecure. Households in this cluster have the poorest water risks acceptability. Further, 24.7% of rural households and 21.3% of farm households are water insecure. Households in this cluster have the poorest water and sanitation access, water system capability and household adaptive capacity.

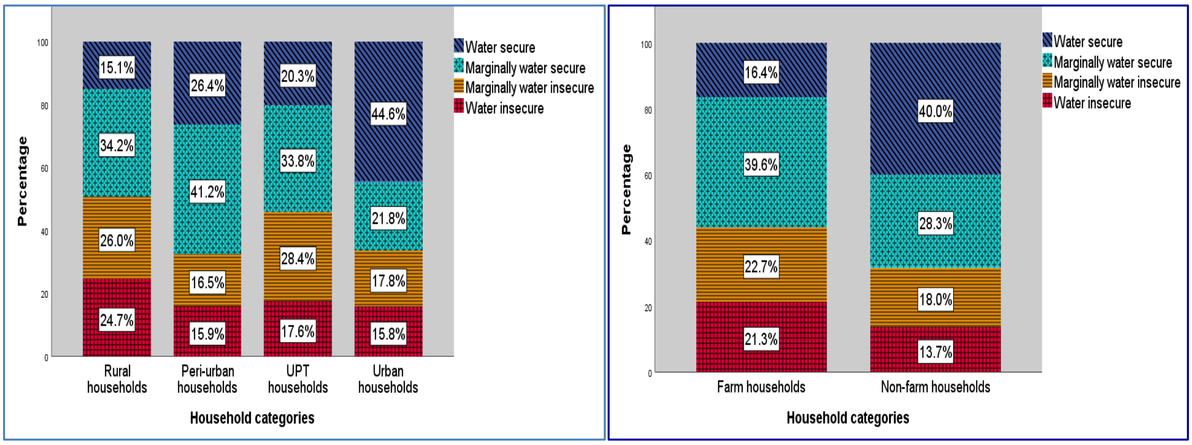


FIGURE 35. WATER SECURITY STATUS OF RURAL/URBAN AND FARM/NON-FARM HOUSEHOLDS IN THE CMR FROM CLUSTERING FOUR SCALOGRAMS

Further analyses see *Appendix Data Tables A.1.5.1- A.1.5.3*, indicate that households in the rural, peri-urban, and UPT areas have significantly higher insufficient access to water sanitation infrastructures than those in the urban area ($p<0.001$). This is particularly true for farm households. UPT households have the highest unacceptable water related risks. However, there are no statistically significant differences in water risk acceptability between UPT households and rural, peri-urban and urban households ($p>0.05$). This is particularly true for both farm and non-farm households in the UPT area. In water system capability, rural households have the lowest water system capability compared to the other three urbanisation level categories. This is particularly true for farm households in the rural area. Urban households have the highest level of inadequate adaptive capacity to ecohydrological change but it is not statistically significantly different than that in the other three categories ($p>0.05$). This is particularly true for farm households in the urban area. In general, farm households have significantly higher water insecurity situations than non-farm households.

7.4.3 TYPOLOGY OF WATER SECURITY ISSUES BASED ON THE FACTOR AND CLUSTER ANALYSES

From the factor analysis with a principle component approach (Table 28), water security was classified into eight clusters, namely Very Highly Water Secure (F1), Highly Water Secure (F2), Water Secure (F3), Marginally Water Secure (F4), Marginally Water Insecure (F5), Water Insecure (F6), Highly Water Insecure (F7), and Very Highly Water Insecure (F8). Figure 36 shows that the proportion of very highly water insecure households is highest in the areas affected by urbanisation, namely UPT (41.9%), urban (34.7%), and peri-urban (27.5%). Flood events combined with climate change may have significantly affected this group (see Table 28). On the other hand, in the areas not affected by the urbanisation process, a larger percentage of households are highly water insecure (49.3%). Drought events, combined with climate change, may have significantly affected this group. Farm households have the highest proportion of the highly water insecure category (30.7%) while non-farm households are in the very highly water insecure category (37.6%).

Further analyses see Tables A.1.5.4 – A.1.5.6, indicate that households in the rural area experience significant higher drought events than those in the peri-urban, UPT, and urban areas ($p<0.001$). They also have significantly lower water access ($p<0.001$) and poorer sanitation facilities ($p<0.01$) than urban households. Similarly, peri-urban and UPT households have significantly lower water access ($p<0.001$) than urban households. This is particularly true for farm households. Compared to the households in the other three categories, peri-urban households have a significant issue with decreasing water resource availability ($p<0.001$) while UPT households have a significant issue with flood events ($p<0.001$). This is particularly true for farm and non-farm households in both areas. Urban households have a significant higher affordability to access improved water sources and services ($p<0.05$) but have unhealthier housing and environments ($p<0.05$) than peri-urban households. This is particularly true for non-farm households.

TABLE 28. MEAN VALUES FOR FACTOR SCORES AND DIFFERENCES AMONG WATER SECURITY CLUSTERS FROM FACTOR ANALYSIS

Water security classification		Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6		Factor 7		Factor 8		Factor 9		Factor 10		Factor 11		Factor 12		HH	%HH
		Drought event		Unhealthy housing & environment		Unregulated Water use		Limited access		Flood event		Poor affordability		Poor sanitation		Water resources issue		Water affect issue		Climate change		Concern of future risks		Poverty/ vulnerability			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Very highly water secure	F1	-1.6	0.7	0.1	1.4	2.3	0.6	-0.7	0.2	-0.7	0.3	2.0	1.7	2.4	0.6	1.4	0.4	1.4	0.6	0.1	0.9	-1.5	1.2	3.2	0.5	3	0.7%
Highly water secure	F2	-0.4	1.4	0.1	1.3	1.2	1.2	-1.1	1.0	0.2	0.7	-0.2	0.4	2.9	0.4	-0.1	1.4	0.7	1.0	-0.6	1.0	-0.7	0.8	3.2	0.7	6	1.4%
Water secure	F3	0.3	1.0	-0.5	0.6	-0.6	0.6	0.4	0.8	0.0	1.0	3.0	0.8	-0.1	0.8	-0.7	0.9	0.2	1.0	-0.1	0.9	0.6	0.6	0.5	0.9	18	4.2%
Marginally water secure	F4	0.1	1.0	0.0	0.9	1.4	1.2	0.7	1.0	-0.1	0.7	-0.1	0.8	-0.3	0.8	0.0	1.0	0.2	1.1	-0.1	1.0	0.0	0.9	-0.3	0.8	78	18.1%
Marginally water insecure	F5	0.1	0.9	0.5	1.3	-0.2	0.9	-0.1	0.9	-0.1	0.9	2.3	1.0	-0.1	0.9	0.6	0.8	-0.8	0.8	0.0	1.0	-0.5	1.0	-0.1	0.8	15	3.5%
Water insecure	F6	0.0	1.0	0.3	1.1	-0.1	0.8	-0.9	0.9	-0.3	0.8	-0.1	0.5	0.8	0.9	0.6	0.8	0.0	1.1	-0.5	1.1	1.1	0.8	-0.7	0.9	60	14.0%
Highly water insecure	F7	0.5	1.0	0.2	1.1	-0.5	0.3	0.1	0.9	-0.2	0.7	-0.4	0.5	0.0	0.9	-0.7	0.9	0.1	1.0	0.2	1.0	-0.2	0.9	0.2	0.8	122	28.4%
Very highly water insecure	F8	-0.5	0.7	-0.3	0.8	-0.4	0.3	-0.1	0.9	0.4	1.3	-0.2	0.4	-0.4	0.8	0.4	0.8	-0.2	0.9	0.2	0.9	-0.3	0.9	0.1	0.8	128	29.8%
F		12.9		4.9		74.9		17.2		5.3		119.9		26.1		21.9		4.5		4.0		19.9		28.8			
Sig		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001			

Note: Highlighted highest scores indicate underlying factors causing water insecurity.

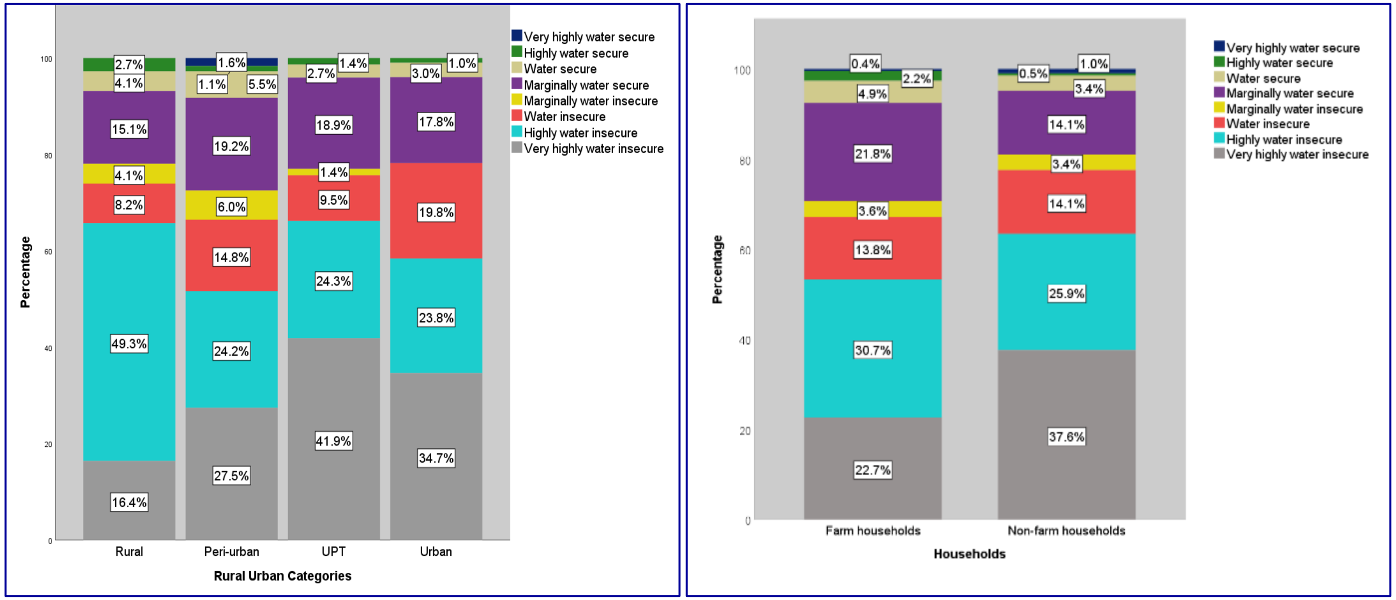


FIGURE 36. WATER SECURITY STATUS OF RURAL-URBAN AND FARM-NON-FARM HOUSEHOLDS IN THE CMR FROM CLUSTERING FACTOR SCORES

7.5 DISCUSSIONS

7.5.1 SOCIO-ECOHYDROLOGICAL ISSUES AFFECTING WATER INSECURITY

It is evident that flood and drought events frequently occurred in the CMR affecting liveability, and that water security is being reported as the most important aspect for liveability in the CMR (Danielaini et al., 2018c, Danielaini et al., 2019c). The findings of this study indicate that household water insecurity is a critical challenge in this coastal metropolitan region. Limited access to water and sanitation infrastructure is a pressing problem of water insecurity in the rural, peri-urban and UPT areas, particularly for farm households. However, compared to the issues of water risks acceptability and water system capability, the issue of water and sanitation access has a less significant impact on shaping water insecurity in the CMR. This study found that floods, droughts, climate change, concern of water risks resulting from urbanisation and climate change, and unhealthy housing and environment significantly influenced water insecurity. Flood events significantly affected water insecurity of farm and non-farm households in the urban expansion area of the CMR while drought events significantly affected that of farm households in the peripheral city particularly within rural area.

This finding aligns with a global assessment that floods and drought remain the two biggest threats to water security worldwide particularly in Indonesia, Guyana, and Brazil (Webb and Iskandarani, 1998). In Indonesia, floods have become a major problem in large metropolitan regions, particularly in areas of Java such as Jakarta, Bandung, and Semarang; floods and drought combined affected 32% of the total cultivated areas; Java was the most affected island (Asian Development Bank, 2016b). In many places around the world, urbanisation is the main driver behind increasing exposure of urban areas to floods and droughts which is further amplified by climate change (Guneralp et al., 2015, De Sherbinin et al., 2016). The cause of flooding in the CMR is relatively similar to larger coastal metropolitan regions in Indonesia, such as Jakarta, namely inadequate public services for flood protection, drainage systems, poor waste management practices that have not kept pace with population and urban growth (Akmalah and Grigg, 2011, Steinberg, 2007). Although the urban centre of CMR has agricultural areas of less than 15% of the city land, the peripheral city is still dominated by agricultural land (56%), making this metropolitan region sensitive to drought (Danielaini et al., 2018a).

7.5.2 HOUSEHOLD WATER INSECURITY IN THE RURAL-URBAN INTERFACES

This study identifies spatial variations of household water insecurity concerning urbanisation level and type of household, farm and non-farm categories that may not appear in the assessment at a national level (Table 29). Farm households are the most water insecure due to drought (*in the rural area*), unregulated water use (*in rural and urban areas*), limited access to water infrastructure (*in the rural, peri-urban, UPT areas*), poor sanitation (*in the rural area*), water resources issues (*in the peri-urban area*), and poverty/vulnerability (*in the peri-urban area*), while non-farm households are the most water insecure due to unhealthy housing and environment (*in the urban area*), flood events (*in the UPT area*), poor affordability to access available water related services (*in the peri-urban area*), unsatisfied with the intervention capability to provide access to water sources and services (*in the urban area*), climate change (*in the UPT area*), and concern of future risks (*in the UPT area*).

This study identified an interesting finding that even in the peri-urban CMR, where water and natural resources are relatively abundant (Danielaini et al., 2018b), water security could not be obtained on its own. Most householders in the peri-urban area who are marginally water secure (41.2%), may have problems with water access. According to Danielaini et al. (2018c), formal networked water systems are available in the several surveyed peri-urban sub-districts, but the majority of its residents could not afford these services, and mostly rely on groundwater or surface water which decreases in quantity during the dry season. Factor analysis confirms this finding; limited access, poor affordability, and water resource issues are the problems of water insecurity for the peri-urban households in the CMR.

TABLE 29. TYPOLOGY RURAL-URBAN OF FARM AND NON-FARM HOUSEHOLDS IN RELATIONSHIP WITH WATER SECURITY STATUS IN THE CMR

Experiences and classification of water security from the surveyed households		Typology farm and non-farm households (HH) in the rural-urban CMR (N=430) and water security status (%)							
		Rural farm HH	Peri-urban farm HH	UPT farm HH	Urban Farm HH	Rural non-farm HH	Peri-urban non-farm HH	UPT non-farm HH	Urban non-Farm HH
Water security classification from the cumulative scores of four scalograms or Guttman scales	S1	17.8	18.1	12.5	12.5	10.7	40.9	26.2	59.4
	S2	28.9	44.8	34.4	40.6	42.9	34.8	33.3	13.0
	S3	24.4	19.8	34.4	18.8	28.6	10.6	23.8	17.4
	S4	28.9	17.2	18.8	28.1	17.9	13.6	16.7	10.1
Water security classification from factor scores or factor analysis of 33 selected indicators	F1	-	0.9	-	-	-	3.0	-	-
	F2	4.4	1.7	3.1	-	-	-	-	1.4
	F3	4.4	6.9	3.1	-	3.6	3.0	2.4	4.3
	F4	17.8	20.7	21.9	31.3	10.7	16.7	16.7	11.6
	F5	2.2	5.2	3.1	-	7.1	7.6	-	-
	F6	8.9	14.7	9.4	21.9	7.1	15.2	9.5	18.8
	F7	46.7	25.9	21.9	34.4	53.6	21.2	26.2	18.8
	F8	15.6	24.1	37.5	12.5	17.9	33.3	45.2	44.9
Total		**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Similarly, although formal networked water systems are available in the surveyed rural area; most householders in Kapetakan have issues with access and water system capability in providing acceptable water quality and quantity. The piped water supply flowing to Kapetakan had issues associated with tap water taste, odour, physical characteristics and not running during the dry season (Danielaini et al., 2018c). Not surprisingly, bottled water use for drinking was found highest in the surveyed rural area (53%), where most residents experienced water scarcity and droughts (56%) and were unsatisfied with water and sanitation facilities (60%). On the other hand, access to formal networked water services is not the issue of urban householders but they are still having issues with acceptable water quantity. The piped water flowing to CM is sourced from a spring in the peri-urban area (Danielaini et al., 2019c). The survey found that tap water in certain areas of CM, such as in Kejaksan and Harjamukti, often flowed intermittently and was inextricably linked to low pressure and insufficient water source availability during the dry season. This issue commonly occurs in many urban regions in developing countries (Lee and Schwab, 2005, Allen et al., 2006, Khatri et al., 2008). The finding is similar with the case study on low-income communities along the United States of America(USA)-Mexico border, South Texas (Jepson, 2014). Water connections there are available if residents can afford them but connections do not guarantee adequate water availability in quality and quantity.

7.5.3 WHY DO THE WATER INSECURITY CLASSIFICATION RESULTS DIFFER?

The reason for different classification results might be due to different aspects of multi-dimensional water security that contributes to the household water security classification. Guttman scales require unidimensionality but water security is a multi-dimensional and complex problem (Jepson, 2014, Hadley and Wutich, 2009). Although the scalograms have been widely used for assessing attitudes and opinion surveys including objective and subjective water security perspectives, the selected four scales in this study obtained poor internal reliability scores for water access, acceptability and adaptive capacity; except for capability of water related services for satisfying socio-economic activities. This test shows that the selected 33 indicators do not adequately fit within the four unidimensional scales, rather within the 12 unidimensional scales as obtained from the factor analysis with principal components. Underlying structures of the selected indicators show the variability of socio-ecological-hydrological systems in the CMR which shape household water insecurity. The underlying factors, with highest to lowest variance explained, were defined as drought, unhealthy housing and environment, unregulated water use, limited water access, flood, poor affordability, poor sanitation, water resources issues, water affect issues, climate change, concern of future risks and poverty/vulnerability. However, the classification of water security from clustering four and 12 scales are able to explain the existing situation of farm and non-farm household water insecurity in the rural-urban interfaces of the CMR.

7.5.4 Implication of this study to water security policy in the water insecure region

The results revealed water security variability among farm and non-farm households at four urbanisation levels in the CMR. These findings present the need for local government to assess the entire range of government interventions in dealing with household water insecurity resulting from urbanisation, and to understand the impacts on farm and non-farm households in the rural-urban interfaces. This includes the need to reframe the government's approach to water supply and monitoring at a household scale. This information is particularly important for developing policies and strategies to enhance regional water security and resilient urban systems for sustainability, particularly for strategic planning in the rural-urban interface areas. Beneficiary perspectives as shown in this study can provide a pathway for the government to obtain a situation whereby a management program can be accepted, satisfying community water needs and achieving a positive evaluation in all relevant water security aspects.

This typical water insecure region, like parts of Southern China, sub-Saharan Africa, South and Southeast Asia, has considerable complex interactions with biophysical, social, economic and political aspects, including risks and uncertainties that need more investment in information, infrastructures and capacity of institutions to deal with the relatively high costs of infrastructure and innovation (Grey et al., 2013). In addition, local perceptions and participation need to be taken into account when introducing new technologies in water infrastructures and management as shown in White Mountain and Shishmaref, Alaska (Marino et al., 2009), Nunavik, Canada (Martin et al., 2007), Paluma's and Ojinaga, along the USA-Mexico Border (Pena and Cordova, 2001), and Central Java, Indonesia (Roma and Jeffrey, 2010).

The findings of this study suggest that providing access to water and sanitation infrastructures will not be sufficient to obtain household water security in this region. The measures should include provision of a tolerable level of water-related risk to mitigate floods and droughts, coupled with providing an acceptable level of water sources and services to the communities. This includes regulating water usage, eradicating poverty to increase affordability, improving socio-ecohydrological systems, and reducing inequality between urban and peri-urban services. Currently, there is a big gap in the availability of water services. CM has service coverage of more than 85% while the other four districts have less than 25% (WJP-MDM, 2013). This study confirms disparities in water insecurity between urban and peri-urban households; not only in access to water infrastructures but also in drought events, affordability, flood events, sanitation infrastructure, and water resource availability. Disparities in water insecurity also exist between farm and non-farm households. This study, therefore, confirms that water insecurity is not uniform across localities nor across population groups (Webb and Iskandarani, 1998, Jepson, 2014).

The present study advances previous work based on scaling of household water security at a regional scale. In particular, this study advances a water security study in the context of planning for balanced urban development to achieve longer term liveability or sustainability (Maheshwari et al., 2016). Nevertheless, more efforts for a better understanding of the dynamics of the inter-relationship between humans and water in terms of water security are still required to solve issues related to drought, floods, institution policy and management, public health and sanitation (Lall et al., 2017). Further, more case studies and interdisciplinary understanding will be important to provide quantification of socio-political parameters and to understand diverse water security issues (James and Shafiee-Jood, 2017). It is important to note that combining qualitative and quantitative methods needs to be considered for advancing household water security assessment and measurement methods as well as for obtaining a more holistic water security concept (Wutich et al., 2017).

7.6 CONCLUDING REMARKS

This study shows spatial variations of water insecurity in the CMR, a water insecure region, concerning urbanisation and farm and non-farm households. This study identified that the major concerns of residents in water insecurity are the capability of water services in urban area, flooding in the UPT area, water resources issues in the peri-urban area and drought in the rural area. Farm households are relatively the most water insecure compared to non-farm households. Providing access to water and sanitation infrastructures will not be sufficient to obtain household water security in this region. Measures to secure this access should include providing a tolerable level of water-related risk, to mitigate floods and droughts, coupled with providing an acceptable level of water sources and services to the communities. This study also identifies the need to include regulating water usage, eradicating poverty to increase affordability, improving socio-ecohydrological systems and reducing inequality between urban and peri-urban services and between farm and non-farm households.

This study has demonstrated how Guttman scaling and factor analysis, combined with clustering methods, can be used to evaluate the water security issues of farm and non-farm households in the urban and peri-urban areas. The first approach of this study considered four water security dimensions, namely access, acceptability, capability, and adaptive capacity. With this approach, 38.2% of the surveyed households are water insecure as they have an inadequate acceptable level to water risks and insufficient capability of water sources and services for health and livelihood. The largest percentage of water insecure households due to acceptability and capability issues were found in the typology of UPT households (46%), while the largest percentage of water insecure households due to access, acceptability, capability, and adaptive capacity issues were found in the typology of rural households (50.7%). There are limitations found in the coefficients of reproducibility and scalability that were below the acceptable range as there is a compromise to be made by researchers between lower validity of measurement and important indicators' exclusion. Application of scalograms under different socio-cultures within diverse complex rural/urban communities might be the cause of this limitation.

The second approach of this study was conducted through a factor analysis which revealed 12 underlying socio-ecohydrological aspects contributing to household water insecurity in the selected region. Six factors were found to be contributing to water insecurity in the rural-urban environment of the region, namely drought, unhealthy housing and environment, unregulated water use, flood, poor affordability, and poor sanitation. Diverse complex socio-ecohydrological systems in the metropolitan region might be the cause of low lambda 2 scores for the other six factors. With this approach, the majority of the surveyed households (75.6%) are water insecure as they have problems related to floods, droughts, climate change, concern of water risks resulting from urbanisation and climate change, and unhealthy housing and environment. The largest percentages of water insecure households due to flood and climate change were found in the typology of UPT households (>37%) while the largest percentages of water insecure households due to drought and climate change were found in the typology of rural farm and non-farm households (>46%). The study shows that household water security classifications from the factor analysis can be used to validate the classification results from the Guttman scaling.

CHAPTER 8

THE NEXUS OF WATER SECURITY, LIVEABILITY, AND SUSTAINABILITY

Summary

This chapter investigates interconnections between water security, liveability, and sustainability using a nexus thinking approach. The approach is applied through understanding local perceptions of climate change in relation to ecohydrological changes that shape urban and peri-urban household water security and therefore liveability. This includes concerns about future risks and coping strategies from both community and government perspectives. The nexus thinking framework applied in this study is useful for understanding people-water-food-environment-climate nexus issues concerning rapid urbanisation. This includes nexus governance at the river basin, regional, and local scales, and recognition of challenges and appropriate adaptation strategies for sustaining water security and liveability. This study found that climate change perception in the CMR was significantly affected by urbanisation levels, occupations, topography, and infrastructures, but it was not significantly affected by the type of settlement, gender, length of stay, age, and household size. This study provides empirical evidence of the need to focus on adaptation strategies concerning climate change and urbanisation to the coastal peri-urban areas, where future urban expansion, land use change and coastal development are expected to increase the exposure to flooding.

8.1 INTRODUCTION

Human activities, through land use change, and natural variability are identified as a major cause of climate change (IPCC, 2013, IPCC, 2014a). Urbanisation, for example, alters rural land use from agricultural to urban with larger amounts of impervious areas, increased urban activities and higher emissions and concentrations of greenhouse gases, air pollution, and aerosols (Sun and Lockaby, 2012, Bazrkar et al., 2015). Urbanisation also influences local and regional climate, particularly minimum temperatures (Gadgil and Dhorde, 2005). Climate change from natural variability can further affect the risks to urban and peri-urban water supplies thereby threatening liveability (Singh and Maheshwari, 2014a). As a consequence of land use and climate change interactions, there is increasing pressures on water supplies and concerns about water security and liveability in the urban and peri-urban areas (Bogardi et al., 2012, Lankao, 2008, Jaramillo and Nazemi, 2017, Singh and Maheshwari, 2014a).

Early impact studies of climate change in an urban context were initially ignored and more focus was placed on ecosystems in relation to agriculture (Rosenzweig et al. (2010)). In Indonesia, for example, studies of climate change were initially focused on rice production, drought and food security (Naylor et al., 2007, Naylor et al., 2001, Falcon et al., 2004). However, rapid population growth and urbanisation processes, have identified urban areas as potential sites of climate vulnerability (Bulkeley and Betsill, 2005). In the Indonesian context, climate change has the potential to affect the water security for many metropolitan regions due to their coastal locations where higher sea levels and temperatures and tidal inundation will affect the fresh water availability. Several studies on climate change are available at the national level (PEACE, 2007, Bappenas, 2010, Measey, 2010, Yusuf, 2010, Bohensky et al., 2013) and at the local level, focusing on large coastal cities such as Jakarta (Firman et al., 2011) and Semarang (Harwitasari and Van Ast, 2011).

A recent study of climate change compared an urban coastal village in the CM to a rural coastal village in the CR (Pratiwi et al., 2016), and indicated that the people living in these two coastal villages have experienced increased flooding and droughts due to climate change. CM has various urban settlements in flood prone areas while its surrounding agricultural lands and farms are prone to drought (Daruati et al., 2013, Sagala et al., 2014, Pratiwi et al., 2016, Danielaini et al., 2018a, Danielaini et al., 2018b). This region is vulnerable to the risks of climate change and rapid urbanisation concerning future sea level rises and seawater intrusion onto inland areas (Rositasari et al., 2011); water scarcity and flooding (Nitivattananon et al., 2013); and socio-economic-demographic changes (Fahmi et al., 2014). Recent studies suggest that flood and drought events have significantly affected rural-urban interface water security and therefore the rural-urban interface liveability of the CMR (Danielaini et al., 2018c, Danielaini et al., 2019a, Danielaini et al., 2019c).

Despite this knowledge, little is known about (i) how the CMR's residents perceive climate change vis-à-vis ecohydrological changes, compared to observed data; (ii) how complex experiences of climate change as a socio-ecological system and hydrological change as a socio-hydrological system shape water security and liveability; (iii) the concerns and perceptions of communities in coping strategies for water security and liveability concerning climate change and urbanisation; and (iv) how the government agencies, at national/provincial/district levels, plan and manage at river basin, regional and local scales for the sustainability objectives concerning climate change and urbanisation. This study aims to advance previous studies about water security related to farm/non-farm households, urbanisation, and liveability in the rural-urban interfaces (Danielaini et al., 2018c, Danielaini et al., 2019a, Danielaini et al., 2019c). Using a nexus approach, it explores perceptions, interests, and practices concerning climate change and urbanisation for understanding appropriate adaptation supports for sustaining water security and liveability in the CMR.

8.2 METHODOLOGY

8.2.1 DATA COLLECTION

Data of perceptions, were collected via surveys and face-to-face interviews of 225 farm householders and 205 non-farm householders from urban and peri-urban communities in CMR (Danielaini et al., 2018c, Danielaini et al., 2019a) and the perspective of 43 key informants from 32 government agencies under different sectors and levels as described in the Chapter 2, Section 2.3. The interview protocols given to the communities in the selected case study area can be found in the previous studies (Danielaini et al., 2019a, Danielaini et al., 2019c). Interview data was collected from selected government organisations because of their specialised roles in planning and managing human settlement infrastructures, water, food, and the environment, and their noticeable role in the CMR for sustaining water security and liveability.

Perception of a change in temperature is the strongest predictor of climate change risks and was assessed in this study as according to Lee et al. (2015). As climate change and urbanisation are related to the changes in land use and the water cycle, this study used primary data from the household surveys and the secondary data of historical changes in land use, water availability, and climate were collected from the government institutions. Land use and land cover maps from 2005 and 2014 were obtained digitally from the WJP Development Planning Boards for estimating the change in built-up, forest and semi-natural areas. Historical data of monthly rainfall and temperatures were collected from the Indonesian Agency for Meteorology, Climatology and Geophysics and CCRB Institution. Historical data of monthly river discharges for irrigation were obtained from the RBO Institution (BBWS) for the 1970 - 2015 periods at the Rentang Barrage which is located on the Cimanuk River. Historical water quality data in the Cimanuk-Cisanggarung watersheds for the 2001 – 2017 periods were obtained from another RBO institution (BPSDA WS) Cimanuk-Cisanggarung, WJP.

The survey area within CMR varies from the coast to the foothills of mountainous areas. Data of rainfall and temperatures were collected from the available meteorological stations within CCRB: (i) Jatiwangi at elevation 42.35 m to represent non-coastal areas; and (ii) Sukapura and Cirebon/BBWS at elevation <10 m to represent coastal areas. In relation to sea level rise, IPCC (2014a) refers to the coastal area as a specific area and population up to 10 m elevations. Rainfall data was collected for Jatiwangi and Sukapura stations during the time periods 1978-2015 and 1981-2015, respectively. While the temperature data collected was for the periods 1978-2015 and 1985-2015 for the respective stations. Any incomplete data were not considered in the analysis.

8.2.2 DATA ANALYSIS

The open-ended interview data were coded and categorised using NVivo Pro (QSR)™ 11.0 for analysing texts from semi-structured interviews and this software is suitable for qualitative data interpretation (Sotiriadou et al., 2014). The climate data and closed-ended questionnaire data were assessed using SPSS (IBM)™. Simple linear regression and bootstrap resampling were carried out to analyse the trends of temperatures, rainfall, and river water discharges and their significance for different assessments within CMR. Trends of total annual rainfall, annual average temperatures, annual seasonal average temperatures and river discharges were calculated and bootstrap resampling 1000x was applied to assess confidence intervals and two-sided p-value (Niles and Mueller, 2016).

To validate the responses of farmers and non-farmers related to the climate risk changes due to drought and flood events, seasonal assessment during the rainy season was focused on average temperatures and river discharges in December, January and February (DJF) for Jatiwangi (non-coastal CMR) and January, February and March (JFM) for Sukapura and Cirebon/BBWS (coastal CMR). Assessment of the dry season was carried out for June, July, and August (JJA) months for non-coastal CMR and July, August and September (JAS) for coastal CMR. The rainy season in Majalengka, where Jatiwangi is located, starts in November while in Cirebon, where Sukapura and Cirebon/BBWS are located, it starts in December (Perdinan et al., 2017). Because of this, temperatures and rainfall on the coastal area were assessed and applied one month later than that on the non-coastal area.

Additionally, a percentage of built-up, forest and semi-natural areas within 45 sub-districts in the CMR were assessed through GIS version 10.3; this was developed by the Environmental Systems Research Institute (ESRI), to evaluate changes in land use and the water cycle. Separate ANOVA with a Tukey's post hoc multiple comparisons test was applied to examine the difference in mean values on the expected significant level between typology groups of farmers and non-farmers. Although Scheffe's test is considered a conservative test to reduce the likelihood of a Type 1 error (Niles and Mueller, 2016, Ho, 2013), when making a large number of comparisons or pairwise comparisons, the Tukey HSD test is more sensitive than Scheffe's test (Brown, 2005). Different typology groups were developed based on: (i) the level of urbanisation: urban, UPT, peri-urban, and rural (Danielaini et al., 2018a, Danielaini et al., 2018b); (ii) the distance from the coast (classified under 0-10 km from the coast and more than 10 km from the coast); and (iii) assessments of perceived temperatures whether they had decreased, stayed the same or increased.

8.3 THEORETICAL AND CONCEPTUAL FRAMEWORKS

8.3.1 CLIMATE CHANGE, WATER SECURITY, AND LIVEABILITY

Global averaged land and ocean surface temperature increased by 0.85°C between 1880 and 2012 (IPCC, 2014b). Global warming is expected to increase extreme weather events of floods and droughts (Schiermeier, 2011, Dai, 2013). IPCC (2014a) highlighted with a very high level of confidence that coastal systems and low-lying areas will increasingly experience submergence, coastal flooding, and erosion as sea levels rise. Risks will vary across regions and affect people depending on the level of adaptation and mitigation (Harwitasari and Van Ast, 2011, Hunt and Watkiss, 2011, McDonald et al., 2011, Adger et al., 2016). Climate change is expected to affect biophysical and socio-economic features that are in many ways affecting water security and liveability (Allan et al., 2013, Addison, 2013). While the link between climate change and water security is evident, suggesting the need for adaptive governance (Honkonen, 2017), a new way of thinking is needed to capture and consider the complex relationships between people, water, and the environment vis-à-vis perceptions/concerns, interests, and practices to promote long term water security and liveability.

8.3.2 NEXUS AND SUSTAINABILITY

Nexus terminology has appeared for nine decades in various disciplines to understand the connection, relationship and interlinkage between different ideas or parameters (Scott et al., 2015). For example, in philosophy, it refers to overlapping experiences and physical objects (Whitehead, 1929); in political science, it refers to the reality of interconnectedness, the fear of breakdown, and the promise of better management (Matthew, 2018); and in ecosystem service science, it refers to interconnectedness between human actions and nature's reactions on different spatial scales and different levels in environmental decision making including policies, spatial planning, land use, and management (Fürst et al., 2017).

Globally, nexus is understood as a process to find an association between ideas and actions of different actors, sectors, and levels for achieving sustainable development (Endo et al., 2017). In the last four decades, the term of nexus emerged in various conferences, research initiatives, and projects using different concepts to show interlinked natural resource use practices in development, e.g., food-energy nexus (Sachs and Silk, 1990), energy-water nexus (Hussey and Pittock, 2012), water-energy-climate nexus (Scott, 2011), water-energy-food nexus (Hoff, 2011), and water, energy, land and food nexus (Ringler et al., 2013). Nexus is seen as a promising approach to describe and address the complex and interrelated nature of resource systems to achieve social, economic, and environmental goals (Hoff, 2011). For these sustainability objectives, the concept of nexus around the world is likely to be varied, depending on the short, medium, and long term goals of the region and sector (Ringler et al., 2013).

8.3.3 NEXUS THINKING FRAMEWORK IN THIS STUDY

Climate change and urbanisation can bring a difficult challenge in balancing competing demands on water, energy, and food resources for sustainability objectives (Hoff, 2011). These global issues are well documented as the cause of: (i) increasing pressures on water source availability in the urban area (Astaraie-Imani et al., 2012, Miller and Hutchins, 2017); (ii) rising urban exposure to water related disasters (Guneralp et al., 2015); (iii) decreasing croplands in the peri-urban area (Bren d'Amour et al., 2017); and (iv) growing competition for resources and emerging disparities in household wealth and health (Redman and Jones, 2005, Keivani, 2010). In this study, we use the nexus framework which shows (i) how perceptions, interests and practices of people and government agencies are shaped by climate change and urbanisation and (ii) how they influence local water security, liveability, and sustainability. The conceptual framework used is shown in Figure 37.

This framework followed the propositions from Stein et al. (2014) that nexus challenges cannot be separated from the perceptions, interests, and practices of actors associated with a nexus. We define operating definition of nexus thinking applied in this study as *a process to find relationships between the perceptions, interests, and practices of urban/peri-urban communities and multi-level governments concerning climate change and urbanisation towards obtaining water security, liveability and sustainability in the urban system*. The perception of people for climate and ecohydrological changes and impacts are closely linked to water security and liveability (Danielaini et al., 2018c, Danielaini et al., 2019a) while the interests and practices of people in managing the impacts are closely linked to adaptation strategies for sustainability (Danielaini et al., 2018c, Danielaini et al., 2019b).

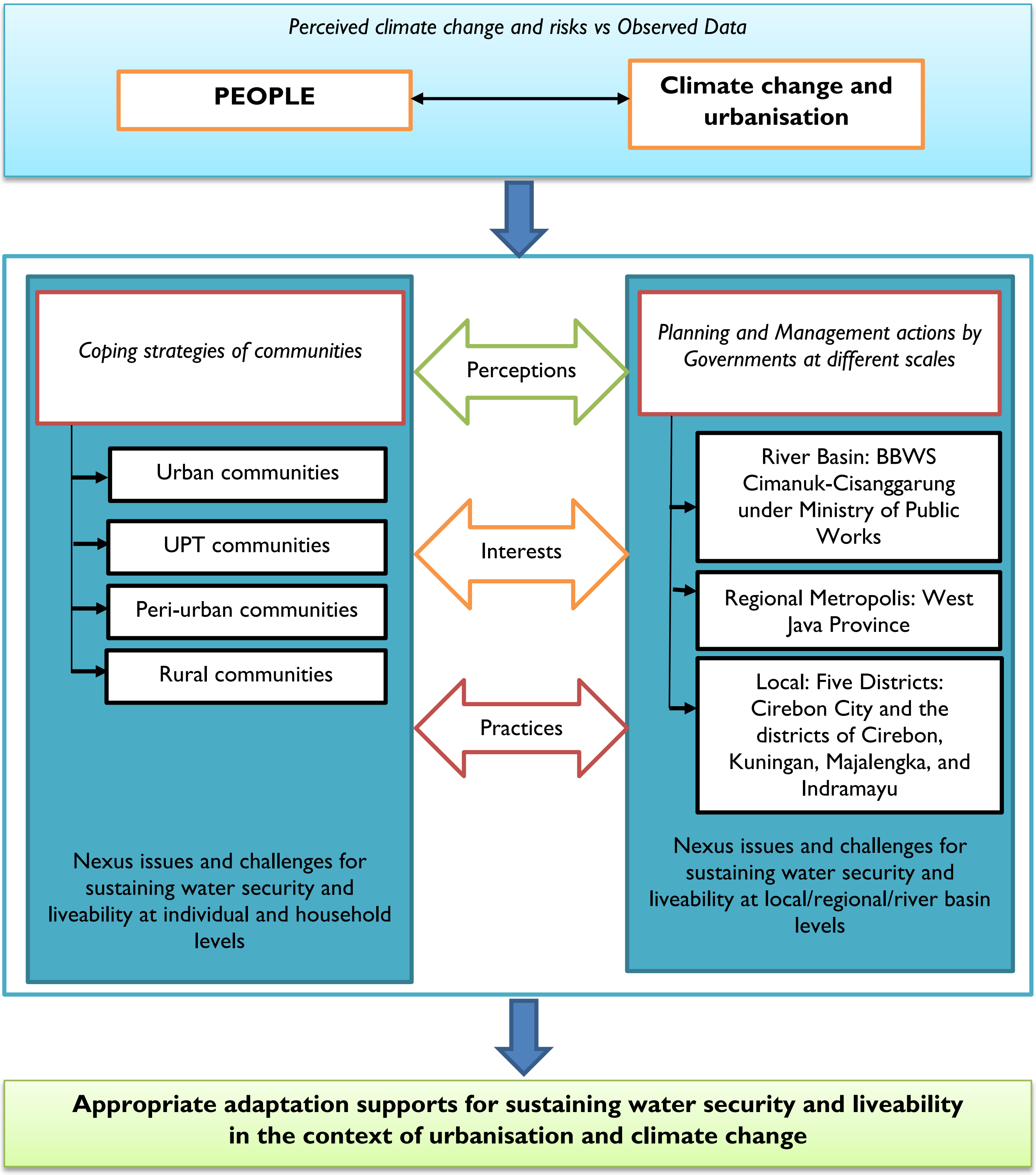


FIGURE 37. THE CONCEPTUAL FRAMEWORK FOR UNDERSTANDING APPROPRIATE ADAPTATION SUPPORTS FOR SUSTAINING WATER SECURITY AND LIVEABILITY

8.4 RESULTS AND DISCUSSIONS

8.4.1 CLIMATE CHARACTERISTICS

Characteristics of temperatures and rainfall from the selected meteorological stations show variations of climate represented by coastal and hilly areas in the study area (Table 30).

TABLE 30. CHARACTERISTICS OF CLIMATE AT NON-COASTAL PERI-URBAN AND COASTAL URBAN METEOROLOGICAL STATIONS

Characteristic of climate	Elevation	Time Series	Max	Min	Mean
Characteristics of average annual rainfalls-Jatiwangi (situated at non-coastal and peripheral city area)	42.35 m	1978-2015	3700 mm	1780 mm	2660 mm
Characteristics of average annual rainfalls-Sukapura and Cirebon/BBWS (situated at coastal and city area)	Sukapura 7 m, Cirebon/ BBWS 9 m	1981-2015	2600 mm	1200 mm	1900 mm
Characteristics of average monthly temperatures-Jatiwangi (situated at non-coastal and peripheral city area)	42.35 m	1978-2015	33^0C	23^0C	26^0C
Characteristics of average monthly temperatures-Sukapura and Cirebon/BBWS (situated at coastal and city area)	Sukapura 7 m, Cirebon/ BBWS 9 m	1. 1985-2015 for mean calculation* 2. 2005-2015 for max-min calculations*	32^0C	25^0C	28^0C

*Note: *Calculation based on the availability of completed data*

Mean temperatures in the coastal area (28^0C) were 2^0C higher than in the hilly area (26^0C). The temperature in the inland areas was generally hotter during the dry season and colder during the rainy season when compared to coastal areas. In addition, the hilly areas generally had a higher rainfall compared to the lowland areas. The average annual rainfall in the hilly area (2660 mm) was 760 mm higher than in the coastal area (1900mm). Variability of rainfall in the hilly area shows a lower monthly and annual coefficient of variation (CV) compared to that in the coastal area (Table 31).

TABLE 31. STATISTICAL DATA OF ANNUAL AND MONTHLY RAINFALL

Month	Descriptive statistics of Jatiwangi rainfall 1978-2015					Descriptive statistics of Sukapura rainfall 1981-2015				
	Min (mm)	Max (mm)	Mean (mm)	SD (mm)	CV	Min (mm)	Max (mm)	Mean (mm)	SD (mm)	CV
January	77	713	433	133	0.31	102	702	343	158	0.46
February	109	736	415	149	0.36	112	748	323	149	0.46
March	162	742	384	131	0.34	109	524	283	112	0.4
April	38	612	282	131	0.46	49	353	197	84	0.43
May	13	416	131	80	0.61	26	215	111	58	0.53
June	0	335	82	80	0.97	4	236	81	68	0.84
July	0	205	38	51	1.35	0	190	50	52	1.04
August	0	191	29	50	1.69	0	138	21	33	1.61
September	0	217	34	49	1.44	0	144	19	33	1.77
October	0	311	118	95	0.81	0	139	43	44	1.03
November	40	757	321	184	0.57	0	872	171	189	1.11
December	198	695	401	141	0.35	40	486	274	122	0.44
Annual rainfalls	**1,785**	**3,735**	**2,667**	**470**	**0.18**	**1,203**	**2,620**	**1913**	**412**	**0.22**

The CV in the hilly area is highest during August (1.69) and lowest during January (0.31) while in the coastal area it is highest during September (1.77) and lowest during March (0.40). Climate variability, including variance in the precipitation, extreme drought as well as severe flood events in Indonesia are associated with El Nino/Southern Oscillation (ENSO) which is characterised by anomalies in both sea surface temperature, El Nino for warming period and La Nina for cooling period, and sea-level pressure, Southern Oscillation (Naylor et al., 2001, Naylor et al., 2007, D'Arrigo et al., 2011). In Java, rainfall variability is affected by complex topography. Rainfall is produced more in the higher topography or over the mountains which are located closer to the southern coast than to the northern coast (Qian, 2008, Qian et al., 2010). Average monthly temperatures from January to December within different periods, 1978-2015, show a remarkable increase while monthly rainfalls show a decrease (Figure 38).

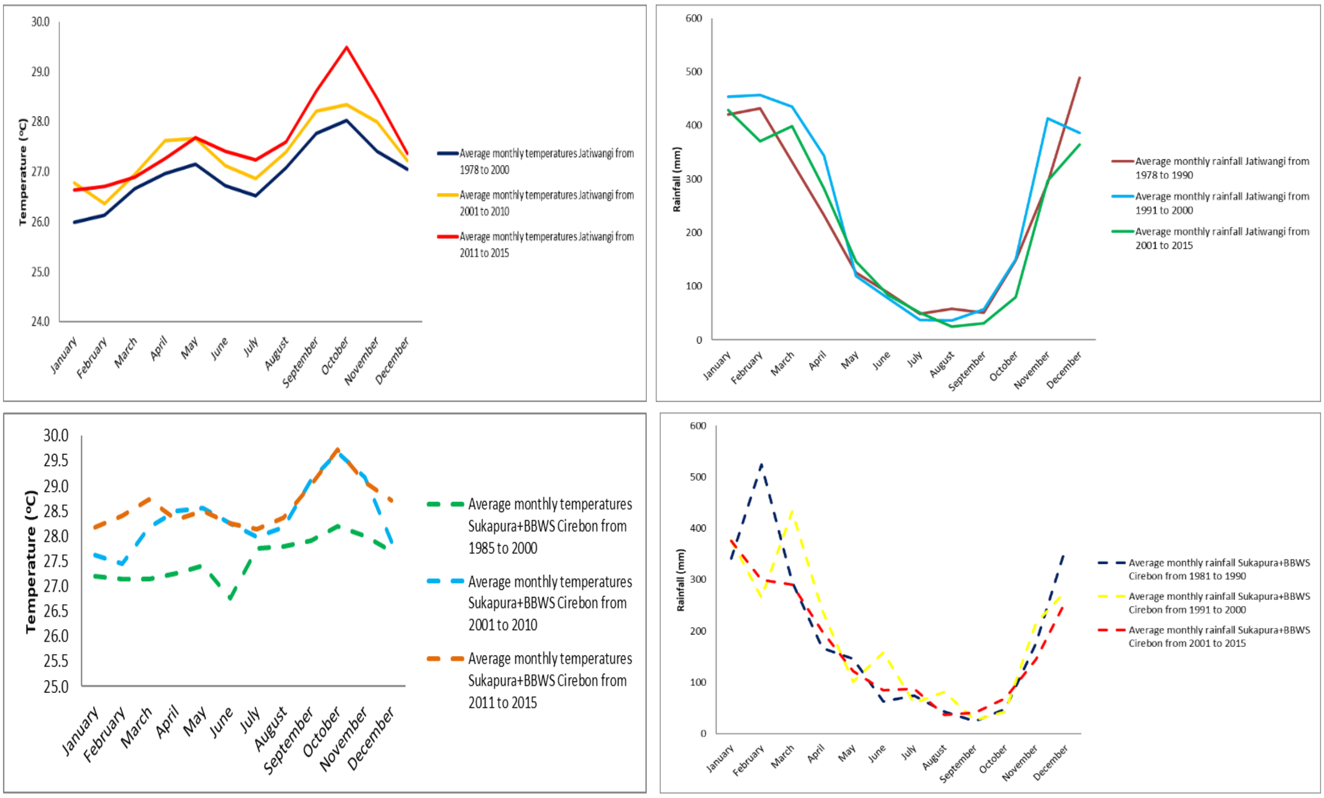


FIGURE 38. HISTORICAL CHANGES IN AVERAGE MONTHLY TEMPERATURES AND MONTHLY RAINFALL

8.4.2 PERCEPTIONS VS OBSERVED DATA

This research aligns with earlier research which asserts that urbanisation has increased warming in urban areas compared to non-urban areas; even in the smaller cities (Ajaaj et al., 2017). Human activities in CM have led to a distinct climate change or urban heat island in comparison to the less built-up areas in the peripheral city of Cirebon. Increasing temperature has been experienced by the majority of CMR residents (64.7%). Figure 39 shows that compared to the peripheral city, areas surrounding CM, the proportion of residents who perceived that temperatures have increased is higher in the city (68.0 %).

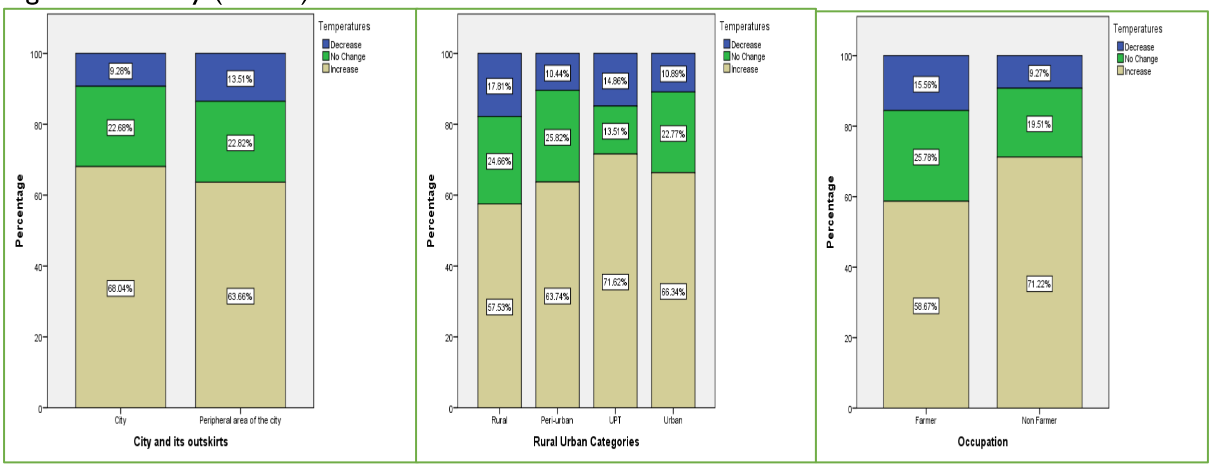


FIGURE 39. PERCEPTIONS OF HISTORICAL CLIMATE CHANGE FOR TEMPERATURES

This is supported with observed data (Table 32). The trend of annual mean temperatures per decade in the city is almost double (0.96^{0}C, $p<0.05$) compared to that in the peripheral city (0.5^{0}C, $p<0.001$).

TABLE 32. OBSERVED CLIMATE CHANGE IN JATIWANGI AND SUKAPURA/BBWS CIREBON

Assessment of climate change (y) per year (x)	Regression Equation with bootstrap resampling 1000x	R-square	Trend	p-value (2-tailed)	Statistically significant
Trend of rainy season rainfalls (DJF)-Jatiwangi	y = -5.82 x + 1366.95	0.29	*decrease 58 mm/decade*	p>0.05	No
Trend of dry season rainfalls (JJA)- Jatiwangi	y = -1.68 x + 182.76	0.02	*decrease 17 mm/ decade*	p>0.05	No
Trend of annual rainfalls- Jatiwangi	y = -6.46 x + 2797.76	0.02	*decrease 65 mm/ decade*	p>0.05	No
Trend of rainy season rainfalls (JFM)-Cirebon	y = -2.95 x + 994.26	0.02	*decrease 30 mm/ decade*	p>0.05	No
Trend of dry season rainfalls (JAS)-Cirebon	y = -0.33 x + 94.46	0.001	*decrease 3.3 mm/ decade*	p>0.05	No
Trend of annual rainfalls-Cirebon	y = -2.42 x + 1950.26	0.003	*decrease 24 mm/ decade*	p>0.05	No
Trend of average maximum temperatures-Jatiwangi	y = 0.034 x + 32.79	0.09	*increase 0.34^{0}C/ decade*	p>0.05	No
Trend of average minimum temperatures- Jatiwangi	y = 0.039 x + 22.74	0.09	*increase 0.39^{0}C/ decade*	p<0.05	Yes
Trend of rainy season temperatures (DJF)- Jatiwangi	y = 0.046 x + 26.07	0.48	*increase 0.46^{0}C/ decade*	p<0.001	Yes
Trend of dry season temperatures (JJA)- Jatiwangi	y = 0.053 x + 26.39	0.68	*increase 0.53^{0}C/ decade*	p<0.001	Yes
Trend of annual mean temperatures- Jatiwangi	y = 0.050 x + 26.62	0.78	*increase 0.50^{0}C/ decade*	p<0.001	Yes
Trend of average maximum temperatures- Cirebon	y = -0.351 x + 33.95	0.63	*decrease 3.51^{0}C/ decade*	p<0.05	Yes
Trend of average minimum temperatures- Cirebon	y = 0.491 x + 22.40	0.71	*increase 4.91^{0}C / decade*	p<0.05	Yes
Trend of rainy season temperatures (JFM)- Cirebon	y = 0.124 x + 26.92	0.61	*increase 1.24^{0}C/ decade*	p<0.001	Yes
Trend of dry season temperatures (JAS)- Cirebon	y = 0.065 x + 27.85	0.35	*increase 0.65^{0}C/ decade*	p>0.05	No
Trend of annual mean temperatures- Cirebon	y = 0.096 x + 27.59	0.58	*increase 0.96^{0}C/ decade*	p<0.05	Yes

On the other hand, the water availability trend shows insignificant decreasing rainfall and river water discharge on the measured condition (Table 32 and Figure 40). However, the majority of householders (>50%) perceived increasing drought events particularly in the peri-urban CMR (61.5%), and the highest proportion of the surveyed householders in the UPT CMR (28.4%) noticed increasing flood events. Peri-urban CMR is the area directly affected by ecohydrological changes resulting from deforestation and agricultural development, while UPT CMR is the area directly affected by ecohydrological changes resulting from urbanisation (Danielaini et al., 2018a). The ecohydrological changes can be seen in the observed selected rural-urban interface watersheds in the CMR (*see Appendix 1.6 Tables A.1.6.1-A.1.6.12*). The results show that most quality parameters were beyond the acceptable threshold limit values with significant trends occurring in the peri-urban and UPT watersheds.

The Cimanuk River has the highest water resources available within the CCRB (Sukardi et al., 2013). Like the seasonal and annual rainfall records, there have been no significant historical trends in the river's discharge since 1970 but an insignificant decrease is evident (Figure 40 and *Appendix 1.6 Table A.1.6.13*). For instance, monthly records of river discharges during the rainy season for ten-year periods reveal a decreased trend of 8.8 m^3 per decade while during the dry season the trend was 2.6 m^3 per decade. The gap between maximum and minimum levels is significant suggesting that farmers in the peri-urban CMR, particularly in the CR, MR and IR, faced water security issues related to drought during the dry season. Moreover, in the past two decades, the decrease of forest areas in the CMR is consistent with the increase of agricultural areas in the peri-urban CMR (Danielaini et al., 2018c). An effort to solve the issue was the construction of the Jatigede Reservoir but until 2019, it has not been fully operationalised (Plate 14).

PLATE 14. JATIGEDE RESERVOIR

This study found that perceptions of climate change in relation to ecohydrological change are not always systematically consistent with observed records. Personal and environmental variability or place-based factors in the CMR affected climate change perception. These include urbanisation level, occupation (farmers or non-farmers), coastal-inland environment or topography, accessibility and performance of water related infrastructures for the household, environment, and livelihood (*see Appendix Tables A.1.6.14-A.1.6.17*). Figure 39 shows that the proportion of residents who perceived that temperatures had increased are located in the peripheral city that had the highest rate of urban expansion or UPT area (71.7%). Amongst the farmers, those who live in the peri-urban area reported the highest overall average perception of temperature change while amongst the non-farmers those who live in the UPT area reported the highest overall average perception (Table 33). The mean perceptions of coastal non-farmers were significantly higher than coastal farmers while in the inland areas, the difference did not meet a significant threshold of $p<0.05$.

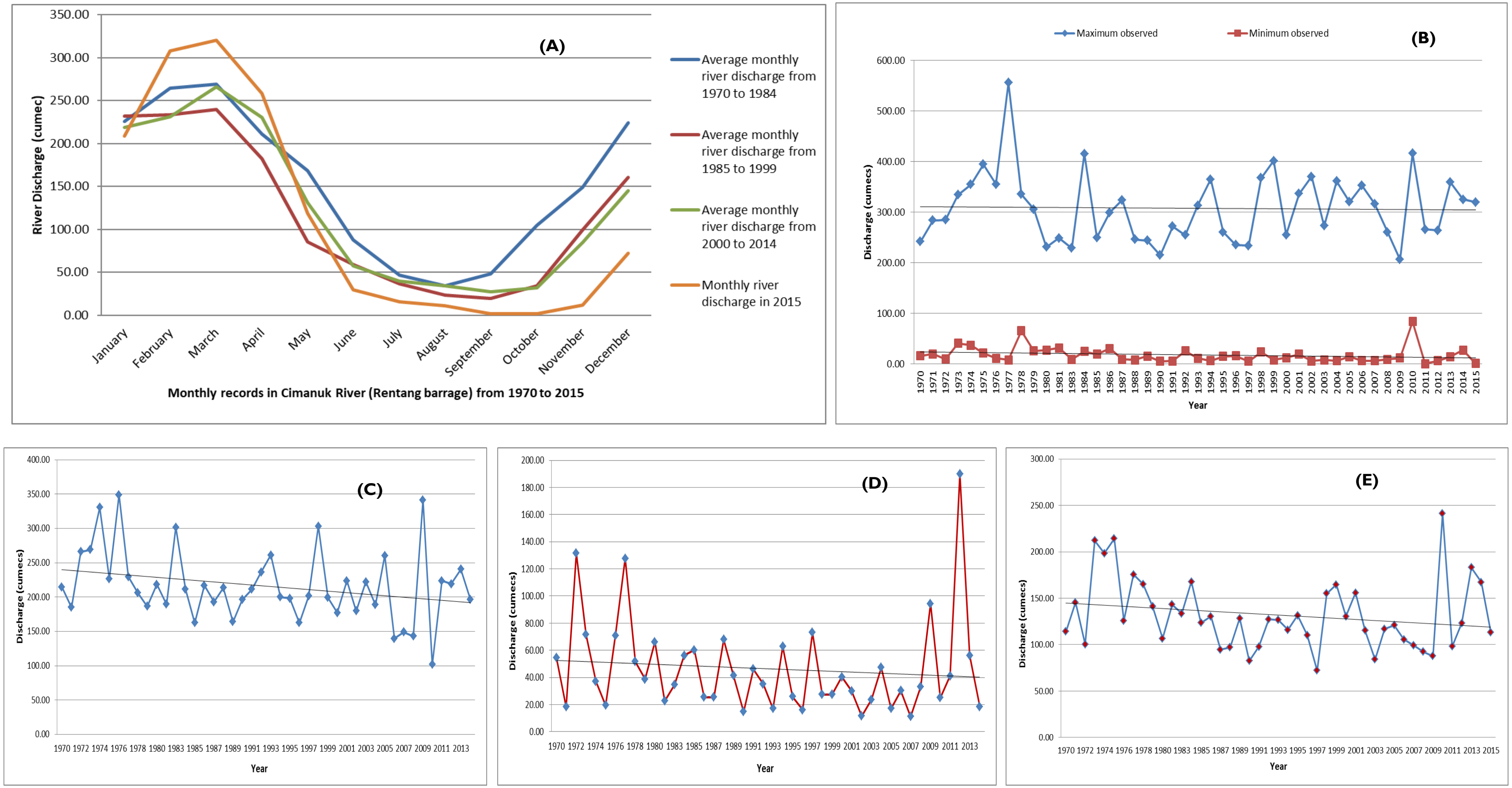


Figure 40. Trends of river water discharge at Rentang Barrage for irrigation on the Cimanuk River: (A) monthly records; (B) maximum-minimum records; (C) average of rainy season records in December-January-February (DJF); (D) average of dry season records in June- July-August (JJA); (E) annual mean records

TABLE 33. RELATIONSHIP BETWEEN FARMER AND NON-FARMER TYPOLOGIES AND PERCEPTION IN CLIMATE CHANGE

Rural-urban farmer and non-Farmer typology	Mean Perceptions of Temperatures	Coastal-inland farmer and non-farmer typology	Mean Perceptions of Temperatures	Coastal Area	Mean Perceptions of Temperatures	Inland Area	Mean Perceptions of Temperatures
RF	3.80 (1.20)	CF	3.80[b] (1.25)	RF	4.35[c] (0.79)	RF	3.46 (1.29)
PF	3.85 (1.11)	IF	3.71[b] (1.17)	PF	4.42[c] (0.90)	PF	3.79 (1.11)
UPTF	3.72 (1.20)	CNF	4.27* (0.94)	UPTF	3.77 (1.14)	UPTF	3.50 (1.52)
UF	3.31* (1.45)	INF	3.82[b] (1.19)	UF	3.31* (1.45)	UF	3.40 (1.27)
RNF	3.71 (1.24)			RNF	4.50 (0.76)	RNF	3.96 (1.05)
PNF	4.05 (1.03)			PNF	4.36[c] (0.93)	PNF	3.92 (1.56)
UPTNF	4.24[a] (1.16)			UPTNF	4.37[c] (0.96)		
UNF	4.19[a] (0.96)			UNF	4.19[c] (0.96)		
F statistic	2.86	F statistic	6.01	F statistic	3.85	F statistic	1.15
p-value	< 0.01	p-value	<0.01	p-value	<0.01	p-value	>0.01

Scale for perceptions in temperature change is 1=rapid decrease, 2=slight decrease, 3=no change, 4=slight increase, 5=rapid increase

RF=rural farmer; PF=peri-urban farmer; UPTF=urban-peri-urban transition farmer, UF=urban farmer; RNF=rural non-farmer; PNF=peri-urban non-farmer; UPTNF=urban-peri-urban transition non-farmer; UNF=urban non-farmer; CF=coastal farmer; IF=inland farmer; CNF=coastal non-farmer; INF=inland non-farmer.

Mean difference is significant at the 0.05 level:

[a] Mean perception of UPTNF and UNF are significantly higher than mean perceptions of UF

[b] Mean perceptions of CF, IF, and INF are significantly lower than mean perceptions of CNF

[c] In the coastal area, mean perceptions of RF, PF, PNF, UPTNF, and UNF are significantly higher than mean perceptions of UF

Accessibility to water related services generally affected participants' perceptions on climate and water risks. In the coastal areas, farmers and non-farmers perceived an increase in temperatures and drought and flood events with a large percentage of coastal rural farmers (76%) and non-farmers (88%) experiencing a rapid increase in drought events and expressing significant concerns about diminishing water and the poor level of public water services. With or without access to public water services, coastal farmers and non-farmers in the rural, peri-urban and UPT areas perceived significantly higher drought events than those in the urban area. Coastal non-farmers with access to the drainage system in the UPT area perceived significantly higher flood events than those in the urban area while coastal farmers without access to the drainage system in the UPT area perceived significantly higher flood events than those in the rural area. Coastal non-farmers had better accessibility to water sanitation infrastructures compared to coastal farmers. However, the difference was not significant in the level of satisfaction to sufficient water availability. Similarly, the satisfaction of the inland farmers and non-farmers on sufficient water availability was affected by the availability and accessibility of water and natural resources. In the inland area, the majority of peri-urban and UPT farmers experienced an increase in drought events that were related to the poor performance of irrigation schemes.

This study provides empirical evidence of the need to focus on adaptation strategies concerning climate change in this coastal metropolitan region to the peripheral city areas, where future urban expansion, land use change and coastal development are expected to increase the exposure to flooding (Neumann et al., 2015). The findings add information to the existing studies that climate change perception is not only affected by local temperatures (Lee et al., 2015), personal experience and knowledge (Lorenzoni and Pidgeon, 2006, Akerlof et al., 2013), topography (Byg and Salick, 2009), available and accessible irrigation infrastructure (Niles and Mueller, 2016) but also urbanisation level, farm/non-farm households, and accessibility and performance of water infrastructures for the household, environment, and livelihood. In this study, the perception is not dependent on the type of settlement, gender, length of stay, age or household size. This reflects the results of a similar study of Tibetan villages where gender and age did not affect climate change perception (Byg and Salick, 2009). However, this result contrasts with a study from the Arctic communities where older generations perceived more change than younger generations (Alessa et al., 2008).

8.4.3 NEXUS OF PERCEPTIONS-INTERESTS-PRACTICES

8.4.3.1 PERSPECTIVES OF URBAN AND PERI-URBAN COMMUNITIES

Future urban development in the urban and peri-urban CMR is expected to exacerbate existing environmental challenges in achieving sustainable water security and liveability. Non-farm householders affected by urbanisation and largely resident in the urban and UPT areas were most concerned about future risks related to water security, environmental security and climate change (Figure 41). This confirms that urban residents are more concerned with the environment than rural residents (Yu, 2014), particularly when it comes to the issues of poor environmental quality, less green open spaces, and climate change.

More than 90% of urban and UPT householders noticed a decrease in river water quality, groundwater quality, and green open spaces. On the other hand, farm householders largely resident in the peri-urban and rural areas have more concerns regarding food production related to their livelihood including the loss of agricultural lands and food availability. However, farm householders in the rural and peri-urban areas were most water insecure due to drought events (Danielaini et al., 2019a).

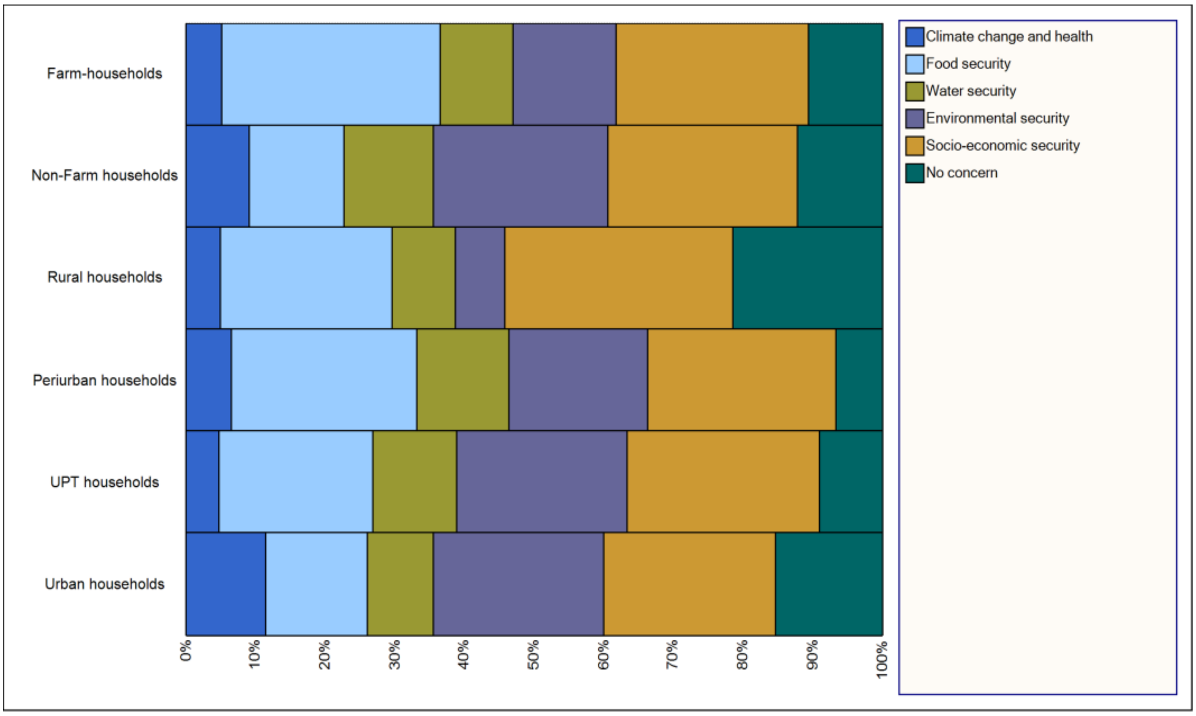


FIGURE 41. RESPONSES OF CONCERNS IN THE CHANGES IN LAND USE, WATER CYCLE, AND CLIMATE

In the CMR, water is perceived as the most important factor for creating liveability as it significantly affects socio-economic activities particularly in the rural-urban interface areas (Danielaini et al., 2019c). In this water insecure region, the concerns of communities in dealing with the pressures on the water-energy nexus or food-energy nexus were found to be less important when compared with water-food nexus. Concerns of coal contamination in water from the Cirebon coal power plant were mostly indicated by fishermen in the coastal Cirebon who need assistance and coping strategies from the government; saving water was considered useful by communities, just in terms of minimising electricity bills (Table 34). This implies that urban and peri-urban competition in water and land uses were dominant concerns of communities in the CMR.

TABLE 34. INTERESTS AND PRACTICES ON COPING STRATEGIES IN RESPONSES TO THE CHANGES IN LAND USE, WATER CYCLE, AND CLIMATE FOR SUSTAINING WATER SECURITY AND LIVEABILITY

	The opinion of coping mechanisms	Distribution of coping strategies based on socio-economic groups (%)						Type of adaptation responses
		Type of households						
		Farm	Non-farm	Urban	UPT	Peri-urban	Rural	
1	**Behaviour-based coping strategies (Total responses=N=323)**							
a.	Protect, preserve, improve natural resources through planting trees, potting plants, not cutting down the trees around water sources, protecting spring water, make room for water, keep green open spaces, protect the available water sources, every house plant trees	32	33	28	33	33	37	PA/ILA/NFA
b.	Nothing to do: PDAM use river water as water source that is poor in quality, river water is polluted by stone wastes, there is no bore water, water is salty, Bengkok land for farming is rented annually from the village government, water is turbid in rainy season, asking neighbours for water, no effort to find solution as water dependency is still high, lack water in dry season	4	2	3	4	2	4	-
c.	Applied situated knowledge on weather, plants depend on the weather	1	1	0	2	0	2	ILA
d.	Applied crop diversification: planting paddy-paddy-palawija (non-paddy crops), planting cassava and trees that less vulnerable to drought	2	1	4	0	0	4	ILA/PA
e.	Adaptation in farming practices: change the crops from paddy into green beans, choose the right cropping patterns, implement crop substitution from paddy to palawija, grow organic paddy to minimise water use, keep planting paddy only in the rainy season	5	0	1	4	1	8	ILA/PA
f.	Apply resource demand strategies: optimise land use, control water use using water metre, save water, use water more efficient, save water and electricity use, save energy consumption, recycle water	3	4	4	5	3	4	NFA
g.	Gotong royong (communal works) to maintain waterways	7	3	4	4	6	6	PA
h.	Farmers discuss, cooperate, and join together	2	0	0	0	1	2	PA
i.	Use river water for bathing and washing to minimise electricity bill	0	1	0	0	0	2	ILA
j.	The mental revolution of young people to be more productive and creative for regeneration in the agricultural sector	1	0	0	4	0	0	NFA
k.	Improving habits pro-environment: put wastes on its place, stop littering on the river, use renewable energy	18	23	17	21	25	12	ILA/NFA
l	Improving communal works (*gotong royong*)	24	32	39	25	26	20	PA/NFA
m.	Not burning rubbish at farm	1	0	0	0	1	0	ILA
n.	Keep working as farmers	1	0	0	0	1	0	ILA
o.	Do not cover the yard full of concrete	0	1	0	2	0	0	ILA
2	**Asset-based coping strategies (N=356)**							
a.	Combining surface and ground-water for water supply through spring, river, groundwater using boreholes and pump machines	11	2	5	0	9	11	PA/ILA
b.	Build public toilets and maximise public sanitation programme to provide toilet access for every house particularly in the coastal area	2	3	2	0	2	6	PA/NFA
c.	Water supply strategies: Build water reservoirs for spring water/rainfall, build dam/levee on the river	7	4	2	5	8	6	PA/NFA

d.	Build and improve drainage system	7	11	12	14	7	2	PA/NFA
e.	Build and improve waterways include irrigation scheme capacity, river channel and human-made canals	12	3	3	7	12	6	PA/NFA
f.	Lots of pump machine and also boreholes but there is no water	1	0	0	0	1	0	NFA
g.	Regulate water distribution network, control water volume	2	2	2	0	3	2	PA
h.	Technical measures to protect waterways include dredging/normalisation of the rivers, keep waterways healthy and not clogging by garbage	8	10	9	5	5	21	PA/NFA
i.	Access to the piped-water system, infiltration wells or bio pores, drill more boreholes, distribute better water quality services	4	4	5	7	2	4	PA/NFA
j.	Improve waste management such as providing rubbish bins at every settlement, build a trash shelter or waste banks every block of settlement, manage garbage at waste banks, build a wastewater treatment plant for natural stone industries to prevent pollution to water bodies and agricultural fields, recycle the garbage	14	10	7	11	14	19	PA/NFA/ILA
k.	Improve human settlement/housing quality through infrastructures for creating a favourable place for living including public facilities for praying, street lights, pathway/road for mobility, safety, environmental cleanliness	27	39	32	46	33	17	PA/NFA
l.	Developing water terracing systems to support growing crops that need irrigation	1	1	1	0	1	2	PA/NFA
m.	Creating more open spaces surrounding human settlement including building city park/more local parks	6	11	19	4	3	6	PA/NFA
3	**Assistance-based coping strategies (N=205)**							
a.	Good collaboration between community and government	1	1	0	0	2	0	PA/NFA
b.	Local government support for farmers: planting diversity programme/crop diversification using drought-tolerant crops, productive plant seeds supports, increase agricultural production, prioritise farmers' welfare, livelihood diversity for farmer that change job during dry season, need government support in dry season as there is no benefit even using water pump as seed price in unstable in dry season	8	1	0	9	7	0	PA/NFA
c.	Apply shift systems and add night patrol shifting in water distribution	2	0	0	0	1	4	PA
d.	Ask help to provincial government to dredge the river	1	0	2	0	0	0	PA
e.	More education on environment, agricultural knowledge, counselling's services, information on better farming to minimise the effect of flood and drought	23	27	29	19	21	30	NFA
f.	Local government commitments for ecohydrological protection: implement zoning regulation, stop coal-loading operation in the harbour, minimise coal wastes pollution (from the Cirebon coal fired plant), relocate industries, reforestation, collaboration, controlling land use through building permit, effectiveness of environmental regulation, regulate septic tank practices and waste handling practices, water distribution from Kuningan to Cirebon, good land use planning and practices, fine for people who do littering in public spaces	61	65	61	66	67	67	PA/NFA
g.	Use open spaces for agriculture	2	5	9	6	0	0	NFA
h.	Paddy fields should be kept for food security	2	0	0	0	2	0	NFA

Note: Individual level adaptive responses based on experiences and knowledge (ILA); planned adaptation responses that are supported by relevant government institutions and communities (PA), and responses needed for adaptation strategies (NFA)

Different coping strategies employed by farm and non-farm households in the urban and peri-urban areas are shown in Table 34. Coping strategies are widely understood to be the way people commit actions within limited resources and various expectations including defence mechanisms, active methods in problem solving and handling pressure (Blaikie et al., 2014). Coping represents short-term responses while adaptation represents long term responses (Susanna, 1993). Adaptation involves various efforts to reduce vulnerability or improve resilience (Adger et al., 2016, Adger and O'Riordan, 2000). The individuals and/or householders in this study coped with various ecohydrological changes and challenges using one of three coping strategies: behaviour-based, asset-based, and assistance-based (Heltberg et al., 2012).

A "nothing to do" response was not considered as an adaptive capacity because adaptation responses include the ability to cope with the external stress (Smit and Wandel, 2006). The results of this study show that asset and behaviour-based strategies were most often recognised as the most important strategies to deal with the ecohydrological changes based on the experience of urban and peri-urban communities in the CMR. Existing coping responses identified as ecohydrological change impacts, included buying expensive bottled water for drinking water, buying water in jerry cans for non-drinking water; farmers/fishermen changing their jobs in the dry season, migration to other cities/countries for work, and mobile tank water for supplying water during drought; these public responses did not increase to cope with the pressures from ecohydrological changes. These results suggest that CMR communities considered their existing coping responses as unsustainable adaptation strategy at the individual or household level. The results also confirm the critical role of risk perceptions in adaptation attitudes (Mase et al., 2017), not only among farmers and non-farmers but also among urban-rural communities.

Collecting data on public opinion of coping strategies was selected to assess the short and medium-term strategies applied and proposed by the community and government. These include identifying local experiences in using available resources and community adaptations to ecohydrological changes. The results show differences in community awareness to the risks of climate and hydrological changes. There were also differences among communities in the preferences for enacting coping strategies that related to benefits and costs, attachment to places, and concerns of future risks. These factors, together with personal experiences, expectations of authorities, and household variability can affect household adaptive capacity and adaptation outcomes (Mortreux and Barnett, 2017). This aligns with other studies that suggest the impacts of climate change on people at the local level are influenced by climate variability, biophysics, social and economic factors (Adger et al., 2016, Adger, 1999, Mendelsohn et al., 2006). More explicitly, it shows how the impacts of climate change, local trends in socio-economic, technological interventions, and extreme weather events such as flood and drought, together with people's values and experiences, inform nexus issues and challenges on the water security and liveability of farmer and non-farm householders in the urban and peri-urban CMR.

This study supports Bohensky et al. (2013) providing counter-evidence to earlier research suggesting that awareness of climate change in Indonesia is low (Leiserowitz, 2007). Environmental change related to climate, landscapes, and water resources exists as both a perceived and measured condition in the urban and peri-urban CMR suggesting the need for adaptation strategies that must move beyond raising awareness to developing dialogue with multiple levels of decision makers for identifying appropriate adaptation supports (Smajgl, 2010). Different types of supports were required for adaptation to the changes in land use, water cycle, and climate. For instance, opinions on creating open and green spaces were highest in the urban area; in the UPT area, improving human settlement infrastructures was the main interest; in the peri-urban area, improving irrigation schemes was the highest demand; and in the rural area, protecting resources and environmental education were the priorities (Table 34).

Limited access to basic infrastructures and services, poor education, and limited employment opportunities are reducing the ability of peri-urban communities to cope with or adapt to the changes in land use, water cycle, and climate (da Silva et al., 2012). Peri-urban areas in this study particularly faced wider issues of poverty, inequality in accessing resources, services, and infrastructures, and policy choices such as dichotomous nature of urban and rural governance, planning, and development (Danielaini et al., 2018c). This suggests the need for multi-level governance with adequate cross-sectoral and cross-scale coordination for sustaining water security and liveability in the metropolitan region.

8.4.3.2 PERSPECTIVES OF MULTI-LEVEL GOVERNMENTS

All the government agencies involved at the national, provincial, and district levels representing river basin, regional and local scales in the CMR were concerned about the nexus of issues. This study found that the government agency with the main role in the planning and management at the river basin scale had the highest concern about the water and food nexus. The number of coding references of this nexus concern was decreasing from the river basin to local scales, similarly with the concern of people, planning, and environment nexus. However, it was different with the concern for the people, water, food, environment, and climate nexus. The district government agencies responsible for local planning and management had the highest concern about this nexus. The concerns, interests, and practices of participants from the government agencies to deal with urbanisation and climate change are detailed in *Appendix Tables A.1.6. 18-19 and Figures A.1.6. 1-3* and are summarised in Table 35. This study found that the water-energy nexus or food-energy nexus was not the main concern of the river basin agency although this agency has built Jatigede Reservoir, which is the second largest reservoir in Indonesia, to provide irrigation water for 90,000 ha of rice fields, control floods, generate 110 MW hydropower plant, and supply 3,500 l/s of raw water for drinking water.

The data indicate that current planning, and management strategies at all levels of government still focus on economic objectives. The data also indicate that although several strategies could enhance current regulation and policy and institutional and governance capacity, the three levels of government had difficulty in implementing the strategies. This included difficulties to (i) implement regulation and policy vis-à-vis integrating land use and water resource planning, adaptation and participation to establish reliable legal frameworks at more local levels, and (ii) change the mindset, culture and behaviour of communities; this failure hindered the effectiveness and efficiency of water-food-people-environment-climate nexus governance. For instance, farmers were usually reluctant to follow the government's instruction about planting and cropping times, and the type of crops to plant causing frequent water-food nexus issues such as crop failures. Local cultures such as "*Sedekah Bumi*" feeling gratitude for God for his blessing in the fertility of farming lands were entrenched in communities with farmers believing God would answer their prayers for better harvests, no disasters.

The government institutions at river basin and regional levels particularly struggled to maintain governance operational efficiency and to create synergy, while the government institutions at the local level struggled with a lack of financial capacity. The nexus challenges were mainly in integrating and combining options for a holistic solution such as integrating various policies across levels and sectors. The problems of governance efficiency were mainly due to (i) unclear roles and overlapping authorities, (ii) insufficient non-structural and cultural measures, and (iii) inconsistencies in programming and budgeting. The problems in building synergy mainly related to (i) conflicts of interest and (ii) unsynchronised action plans. The financial challenges experienced by local government were budget and capacity constraints that made the local agencies highly dependent on those higher in government, for example the ministry and province levels.

TABLE 35. GOVERNMENT CONCERNS, PRACTICES, AND PROBLEMS ON COPING WITH THE CHANGES IN LAND USE, WATER CYCLE, AND CLIMATE FOR SUSTAINING WATER SECURITY & LIVEABILITY

Research participants information concerning strategy to deal with urbanisation and climate change	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level
a. The concerns in planning and management (from highest to lowest responses/number of coding references)	(1) Water-food nexus (50%); (2) People-water-food-environment-climate nexus (25%); People-planning-environment nexus (25%).	(1) People-water-food-environment-climate nexus (60%); (2) People-planning-environment nexus (20%); Water-food nexus (20%)	(1) People-Water-food-environment-climate nexus (70.4%); (2) Water-food nexus (10.2%); (3) People-planning-environment nexus (9.2%); (4) Environment-people nexus (7.1%); (5) Water-environment nexus (3.1%).
b. The strategic focus on planning and management (Responses of ≥67% participants)	(1) Strategy to support economic development; (2) Regulation and policy;	(1) Strategy to support economic development; (2) Institutional and governance capacity; (3) Research, data, and development planning; (4) Regulation and policy.	(1) Strategy to support economic development (2) Regulation and policy; (3) Institutional and governance capacity
b.1 Detailed strategies for economic development	Maximising water facilities and services (physical infrastructures)	Maximising water facilities and services (physical infrastructures)	Maximising water facilities and services (physical infrastructures)
b.2 Detailed strategies in regulation and policy	Regulation to increase water sources; monitoring and evaluation	Land use planning and zoning regulation	Land use planning and zoning regulation
b.3 Detailed strategies in institutional and governance capacity	Multi-level cooperation and collaboration in water sector within river basin (IWRM) and education, training, and dissemination	Multi-level and multi-sector cooperation and collaboration to build synergy within metropolitan region	Multi-sectoral collaboration within the district boundary
c. The problem to implement a strategy (Responses of ≥ 50% participants, from highest to lowest responses)	(1) Institutional and governance capacity; (2) Regulation and policy.	(1) Institutional and governance capacity; (2) Regulation and policy; (3) Implementing strategies for environmental protection.	(1) Institutional and governance capacity (2) Regulation and policy (3) Implementing strategies for economic development
c.1 Detailed problems of institutional and governance capacity	Collaboration; governance operational efficiency; mindset, cultural, and behaviour of communities *(same response level)*	(1) Mindset, cultural, and behaviour of communities; (2) Governance operational efficiency.	(1) Financial capacity (2) Limitation of the institution in management (3) Mindset, cultural, behaviour of communities
c.2 Detailed problems of regulation and policy	Implementation and dealing with nexus challenges such as difficulty in integrating and combining options for a holistic solution	Implementation; land use planning and zoning regulation; and dealing with nexus challenges	Implementation such as integration of land use and water resource planning; adaptation and reliable legal frameworks

The findings show that although planning and management at the local district level faced the highest complexity of nexus issues to implement development objectives concerning the changes in land use, water cycle, and climate, actively dealing with nexus challenges has not been a concern for most local government institutions in the CMR. This suggests that nexus thinking in planning and management has not reached the local level but may be being considered at ministry and province levels. For instance, in river basin planning and management, the government agency under ministry level has adopted the principle of "one basin, one plan, and one management" using the IWRM framework that involves multi-level water related stakeholders including actors in the food sector (Asian Development Bank, 2016c). In regional planning and management, the government agency at the province level has prepared a legal and institutional framework for the development of metropolitan regions that involves different sectors and government agencies at the district level (Regional Development Planning Board of West Java Province, 2015).

Despite this progress, river basin planning and management in the selected region still faces issues in collaboration hindering nexus action. This is due to fragmented mindsets, existing sector-driven management paradigms and the lack of effective communication among related sectors. The finding aligns with the report of the Asian Development Bank (2016c) that stated water resource management (WRM) plans in Indonesia have failed to obtain a synchronised broad application in all sectors involved. Moreover, the WRM plans have not been sufficiently embedded in the national and regional development plans, suggesting inadequate institutional and financial support from non-water sectors. Whilst spatial planning has advanced tools for the integration of plans between different government levels (vertically) and between different sectors (horizontally), regional planning and management still face problems in effectively implementing land use planning and zoning regulations. This is due to the long process in the revision of district and city spatial plans and the requirement to incorporate environmental consideration into policies, plans and programmes in strategic environmental assessments (SEA). Not surprisingly, SEA is perceived as a burden by planning agencies in Indonesia (Victor and Agamuthu, 2014).

Spatial planning and infrastructures were the most common strategies recognised by provincial and local governments to cope with the changes in land use, water cycle, and climate. However, these climate concerns have not been developed into a strategic understanding of the interaction between development and adaptation priorities across different sectoral policy and governance levels. Despite the current understanding in literature that spatial planning plays an important role in climate change adaptation (Wilson, 2006, Hurlimann and March, 2012), a recent study in the northern coast of Java shows that the national, provincial, and local spatial plans could exacerbate exposure to the impacts of climate change (Suroso and Firman, 2018). Prioritising economic growth in development, neglecting ecological protection, together with the lack of risk awareness of planners, and insufficient land use planning are among the possible causes. Incorporating SEA into spatial plans may handle these issues but data availability in terms of accuracy and reliability were reported to be very limited for development planning, environmental studies, and monitoring and evaluation.

Since the Bali 13th United Nations Climate Change Conference (UNFCCC) meeting in 2007, climate change mitigation and adaptation have become an important agenda in Indonesia. Law 17/2007 on Long-Term National Development Plan of 2005-2025, clearly states that long term sustainable development in Indonesia will face threats from climate change. In the context of mitigation, the Government of Indonesia (GoI) issued Presidential Regulation 61/2011 on a National Action Plan for Reducing Greenhouse Gases (GHGs) emission. In the context of adaptation, the GoI has published the National Action Plan on Climate Change Adaptation or RAN-API (Bappenas, 2014). Recently, the GoI published Law 16/2016 to ratify the 2015 Paris Agreement. In addition, in the context of integrating climate change mitigation and adaptation into planning in Indonesia, the GoI has published the "Indonesia Climate Change Sectoral Roadmaps or ICCSR" (Bappenas, 2009, Bappenas, 2010). However, this has not been sufficiently entrenched in planning at lower levels. While the national level governments are more engaged in climate change mitigation, the local level governments are interested in climate change adaptation (Di Gregorio et al., 2019).

Mainstreaming climate change adaptation into the local agenda faced various challenges relating to the capacity of local governments such as a lack of understanding about climate change adaptation and limitations in data availability and financial capacity (Rahman, 2017, Setiadi, 2015, Tjandraatmadja, 2013). This includes the dependency of local governments on national and international initiatives. For example, the five districts within CMR have participated in the P*rogram Kampung Iklim*/Climate Village Programme (Proklim) issued by the Ministry of Environment and Forestry. At the city level, Cirebon city has a multi-stakeholder working group on climate change to assist the community in vulnerable areas initiated by the Mercy Corps and Rockefeller Foundation through the Asian Cities Climate Change Resilience Network (ACCCRN) Program (Pratiwi et al., 2017).

The facts that increasing floods and droughts occurred in the rural-urban interface areas and their impacts on water security and liveability were multidimensional was identified in section 8.4.2 and described in the section 8.4.3.1. This study suggests the need for mainstreaming climate change adaptation at regional and river basin scales. Despite several studies suggest the need for more local responses to climate change adaptation (Adger, 1999, Pratiwi et al., 2017, Byg and Salick, 2009), such approaches do not sufficiently consider the socio-economic-ecological-technological connection of cities to their hinterland areas (Bai et al., 2016, Brenner and Schmid, 2015, da Silva et al., 2012). In this case, the WJP can initiate cross-border district adaptation strategies within the CMR. The RBOs (BBWS and BPSDA WS) can initiate transboundary watersheds adaptation strategies within the CCRB.

It is impossible for the city of Cirebon to undertake climate change adaptation and efforts for sustaining water security and liveability without the involvement of other authorities in surrounding areas and support from higher level governments. For instance, in the drinking water sector, this city is currently dependent on water supplied from Kuningan. To cope with the increasing urban water demands, this city is likely to be dependent on water supplied from the Jatigede Reservoir. This was also the case for the peripheral city areas with high amounts of paddy fields. For irrigation, they are dependent on water supplied from upstream through the Jatigede Reservoir which is seen as water security for the peri-urban economy. This needs multi-scale governance with adequate cross-sectoral and cross-level coordination.

8.4.4 NEXUS OF WATER SECURITY, LIVEABILITY, AND SUSTAINABILITY

The urban area in the CMR has expanded to outer Cirebon City, including Weru and Kedawung (Danielaini et al., 2018b). Compared to other areas in the Cirebon District, these sub-districts have more urban characteristics (Figure 42). Urbanisation and deforestation in the past two decades have changed ecohydrological functions and shaped urban and peri-urban water and environments, socio-culture, and the economic aspects (Danielaini et al., 2018c). Ecohydrological changes resulting from urbanisation in the CMR have significantly affected liveability in the UPT area, particularly in terms of neighbourhood, personal, and watershed satisfactions (Danielaini et al., 2018c). The urbanisation that should bring a better economy and social prosperity was not the case in the UPT area (Danielaini et al., 2018c). When compared to urban and peri-urban residents, UPT residents have lower satisfaction levels in income, water and sanitation infrastructures, flood protection, and healthy waterways. Among four urbanisation levels, the proportions of residents who perceived that temperatures and flood events have increased are highest in the UPT area as described in section 8.4.2. The combination of climate change and floods significantly shaped water insecurity of UPT farm and non-farm households (Danielaini et al., 2019a). In the CMR, householders who were unsatisfied with flood protection are likely to be not satisfied with unhealthy environments (Danielaini et al., 2019a). This is supported by the observed data; which indicate the highest increase of faecal pollution occurred in the UPT watersheds (*see Appendix 1.6 Table A.1.6.15*). Not surprisingly, interests and practices of coping strategies for improving human settlement and housing quality, including improving drainage systems and access to water infrastructures were highest in the UPT area (Table 35).

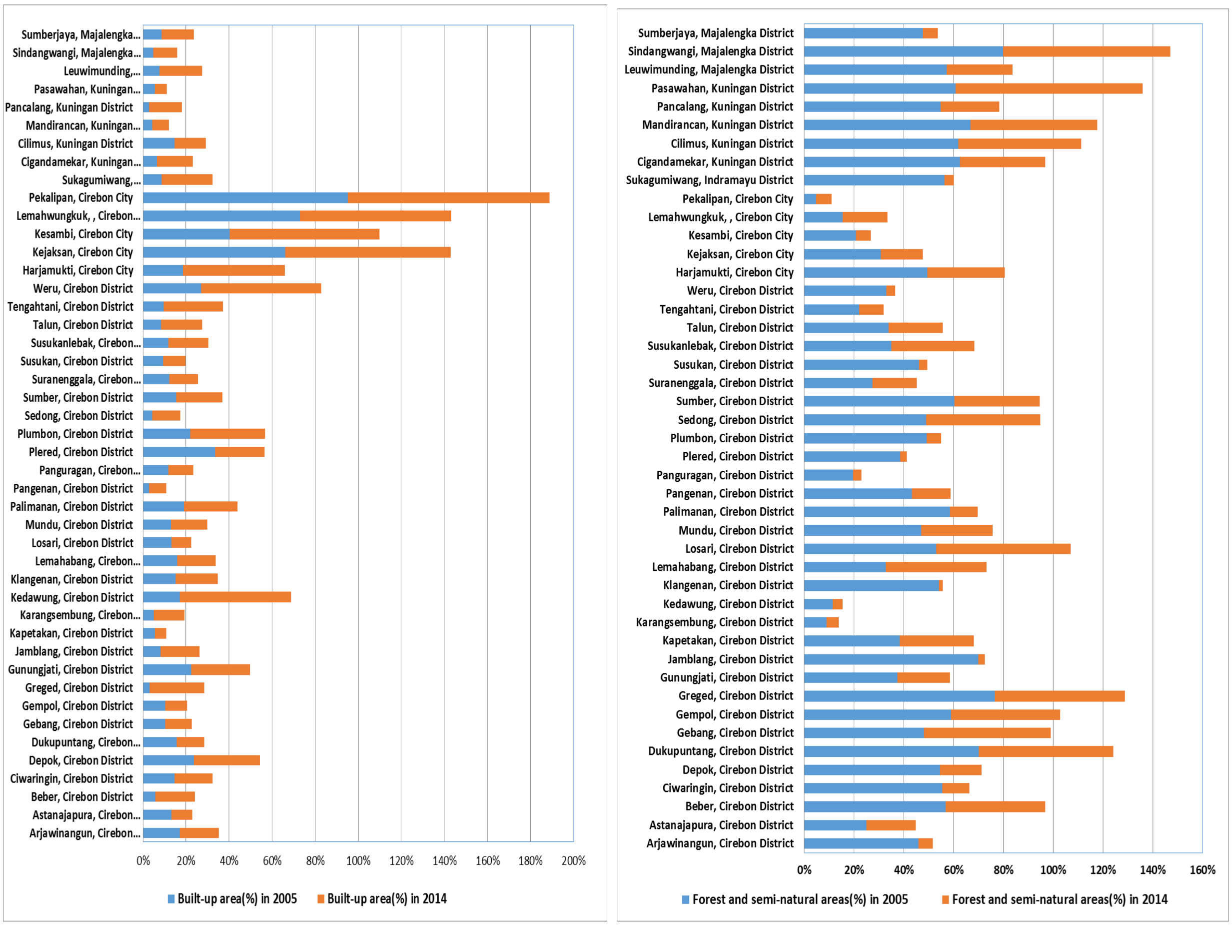


FIGURE 42. COMPARISON OF BUILT-UP AND FOREST, WATER BODIES, AND SEMI-NATURAL AREAS IN 45 SUB-DISTRICTS WITHIN CMR BETWEEN 2005 AND 2014

In the CMR, different types of support were required for sustaining water security and liveability depending on the farm or non-farm households and urbanisation levels. For instance, in the context of water security, farm householders were the most water insecure due to drought and poor sanitation (in the rural area); water resource issue and poverty (in the peri-urban area). On the other hand, non-farm householders were the most water insecure due to unhealthy housing and environment and the issue of acceptable water quantity from the formal network water services (in the urban area); flood events, climate change, and the concern of future risks (in the UPT area), and poor affordability to access water services (in the peri-urban area) as identified by Danielaini et al. (2019a). Further, in the context of liveability, urban areas performed relatively less well than the outskirts in ecohydrological attributes (green open spaces) but performed better in socio-economy; priority should be given to healthy waterways in the UPT area; and to sufficient water availability in the peri-urban and rural areas (Danielaini et al., 2019c). This study, thus, confirms that Sustainable Development Goals (SDGs) such as Goals 6 and 11 for achieving water security and liveability, respectively, provide a window of opportunity for creating multidimensional operational approaches for climate change adaptation (Rodriguez et al., 2018). By understanding peri-urban dynamics, the wider issues of poverty and inequality in accessing resources and services, and insufficient environmental planning and management to cope with the changes in land use, water cycle, and climate can be identified (Danielaini et al., 2018c).

Using nexus thinking framework (Figure 37), this study identifies that regional water security, liveability and sustainability significantly reflects dynamic relationships between people, water, food, environment and climate, particularly where water plays a significant role in activities of urban and peri-urban households, food production and community health. Under climate change and urbanisation pressures, this nexus dynamically affects the liveability of urban and peri-urban communities and the capacity of nexus governance at different levels including individuals, farm and non-farm householders and local, regional and river basin governments (Figure 43). Most communities undertake short-term planning and management for dealing with water insecurity situations and for improving their liveability, but for long-term water security and liveability, the government's role is very crucial. This includes (i) integrated planning and management across nexus, including minimising the gap between nexus thinking and nexus doing; (ii) combining physical and non-physical approaches in development that cares for the interests of communities in dealing with socio-ecohydrological changes. This study suggests that in water insecure regions, such as CMR, it is important for governments to effectively plan water security to support urban and peri-urban households, activities, and environment, for maintaining and sustaining liveability.

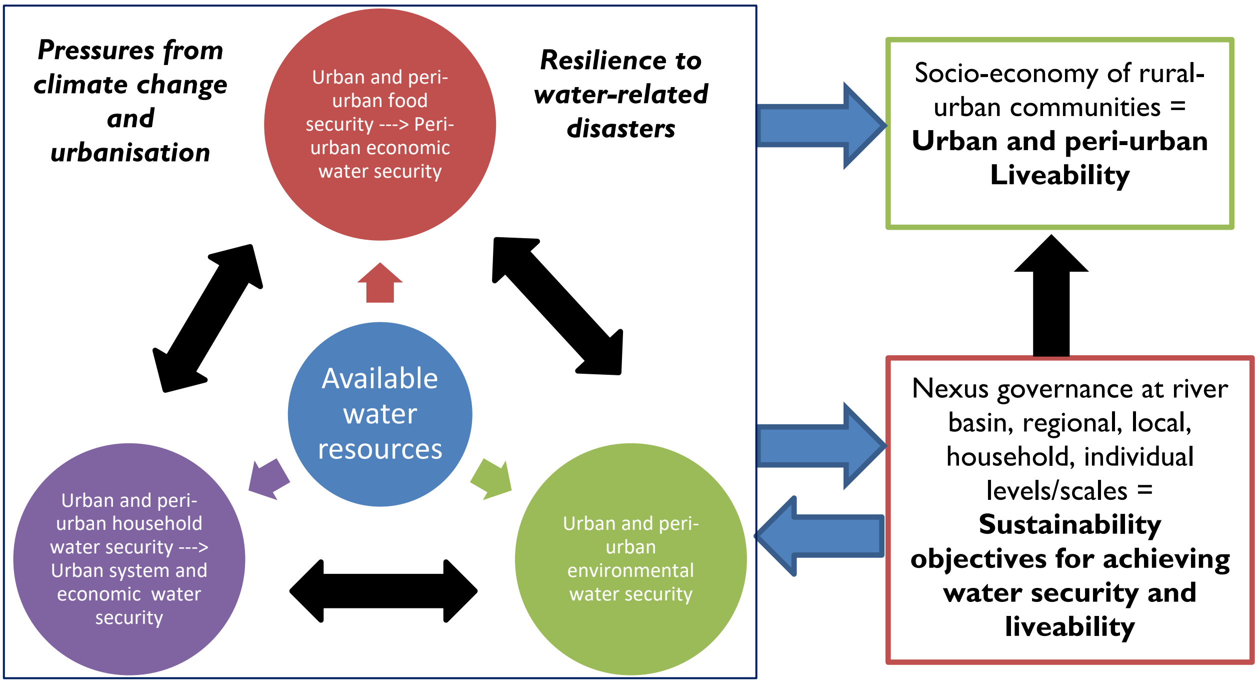


FIGURE 43. THE NEXUS OF WATER SECURITY, LIVEABILITY, SUSTAINABILITY IN THE URBAN SYSTEM USING A CASE STUDY OF WATER INSECURE METROPOLITAN REGION

8.5 CONCLUDING REMARKS

This study shows that the nexus thinking approach provides a framework to appropriately examine the people-water-food-environment-climate nexus issues of farm and non-farm households concerning rapid urbanisation vis-à-vis nexus governance at river basin, regional, and local levels, and to recognise challenges and appropriate adaptation strategies for sustaining water security and liveability. The approach helps to rethink sustainability as a complex adaptive system in the urban development. To address challenges for sustaining water security in the light of increasing urbanisation and climate change pressures, an understanding of biophysical-socio-institutional opportunities and constraints is needed. To address challenges for sustaining liveability in the light of increasing urbanisation and climate change pressures that can be different across people and places, an understanding of dynamic interactions between water, people, and the environment as a function of biophysical and socio-economic sub-systems in one urban system is required. Hence, the conceptual boundaries of the nexus governance for sustainability need to be reframed so as to fit between natural systems and socially constructed institutions with the responsibility to manage them for the benefit of people.

This provides empirical evidence of the need to focus on adaptation strategies concerning climate change and urbanisation to the coastal peri-urban areas, where future urban expansion, land use change and coastal development are expected to increase the exposure to flooding. This study found that the perception of climate change in the CMR was not always consistent with the observed records since it was significantly affected by urbanisation level, occupation, topography, accessibility and performance of water related infrastructures for the household, environment, and livelihood. However, it was not affected by the type of settlement, gender, length of stay, age or household size. Urbanisation and climate change significantly affected UPT communities due to increasing floods and their multi-dimensional impacts to household water security and liveability. The urbanisation that should bring a better economy and social prosperity was not the case in the UPT area. Limited access to basic infrastructures and services, poverty, and unhealthy housing and environment worsened the ability of UPT communities to adapt to the changes in land use, water cycle, and climate.

Since environmental change related to climate, landscapes, and water resources exists as both a perceived and measured condition in the urban and peri-urban CMR, this study suggests the need for adaptation strategies that must move beyond raising awareness to developing dialogue with multiple levels of decision makers for identifying appropriate adaptation supports. Peri-urban areas in this study particularly faced wider issues of poverty, inequality in accessing resources, services, and infrastructures, and policy choices such as the dichotomous nature of urban and rural governance, planning, and development. This study found that the district government agencies responsible for local planning and management had the highest concern about the people-water-food-environment-climate nexus issues. The five district governments within CMR are at the forefront of dealing with climate change impacts that are local and are responsible for incorporating existing individual and household adaptation strategies into local development planning priorities. However, the fact that increasing floods and droughts occurred in the rural/urban interface areas and that district governments had limited capacity to cope with the rapid urbanisation and climate change suggests the need for implementing multi-level governance with adequate cross-sectoral and cross-level coordination. This includes mainstreaming climate change adaptation at the regional and river basin scales to assist cross-border district and transboundary watersheds adaptation strategies.

Mainstreaming multi-level nexus governance in the metropolitan regional development would be the key for managing the risk of resource use trade-offs among water and food sectors that could undermine water security targets for households and economy and therefore affect urban and peri-urban liveability. This includes strengthening the capacity of urban and peri-urban communities and local government institutions to cope with and recover from the impacts of increasing flood and drought events and also to increase collaboration and co-management among five districts in the CMR. Following the need for using SEA within spatial plans, more reliable data, information, and communication among institutions is required including a stronger evidence-base and in-depth analysis of likely resource demands across sectors and resource capacity in the urban and peri-urban areas. Finally, a strategic mainstreaming climate change adaptation into sustainable development goals such as water security and liveability would ideally incorporate an understanding of peri-urban dynamics, since the area between rural areas and urban areas is where the changes in land use, water cycle and climate resulting from urbanisation are highest, notably in the Cirebon District.

CHAPTER 9
BRING IT TOGETHER – SYSTEMS THINKING FOR BALANCED URBAN DEVELOPMENT

Summary

This chapter describes the synthesis of the ideas of water security, liveability and sustainability in the context of balanced urban development (BUD) and describes issues, challenges, options and strategies for achieving BUD using a socio-ecohydrological systems (SEHS) thinking approach. The SEHS analytical framework applied in this study is useful for understanding the complexity and uncertainty involved in achieving BUD and for finding the linkages between social systems, urban and peri-urban communities and cross-scale institutions and biophysical systems. These linkages were assessed through exploring SEHS interconnections, understanding perceptions of SEHS structure at different scales, identifying the non-linear relationships and dependencies of SEHS and differentiating SEHS perspectives. This study proposes socio-ecohydrological and infrastructural considerations for achieving BUD which include interconnections between people, water and land and the eight key aspects of BUD: i) environmental planning and management; (ii) infrastructure; (iii) policies and governance; (iv) innovation and services; (v) information, communication and collaboration; (vi) sociocultural environment; (vii) household adaptive capacity; and (viii) financing. These research findings suggest the need to implement transboundary, multi-sectoral, multi-scalar, socio-ecological-hydrological-infrastructural systems with diverse actors, priorities and solutions in urban systems. To achieve BUD, the complexity and diversity of human values and perceptions need to be considered in the rural-urban development planning and management. These include peri-urban watersheds that were significantly affected by rapid urban expansion and were found as critical zones to promote water security, liveability and sustainability towards BUD.

9.1 INTRODUCTION

The 2030 Agenda for Sustainable Development, declared by the September 2015 General Assembly of the United Nations (UN) in New York, acknowledges cities as key pathways to achieve global Sustainable Development Goals (Parnell, 2016). The United Nations Development Programme (UNDP) states that by 2030, 60% of the global population will live in cities and over 90% of that urban growth will occur in developing countries (UNDP, 2016a). Asia has the highest number of people living in urban areas with the fastest growing urban centres being the small and medium cities with less than one million people (UN-Habitat, 2016). Despite the potential role of such cities in informing urban planning efforts with the emergence of rapid urbanisation, research on urban growth and the subsequent impacts in Asian countries have excessively focused on the problems of large metropolitan areas such as Jakarta (Firman, 2003, Steinberg, 2007, Mc Gee, 2008, Delinom et al., 2009, Firman et al., 2011, Hidajat et al., 2013, Pravitasari et al., 2015). These studies provide empirical evidence that while urbanisation promotes significant socio-economic growth, it also poses considerable environmental challenges related to changes in land use, water cycle and climate. Given these challenges, it is critical to investigate the processes and impacts of rapid urban development on people and the environment in medium and small cities (Redman and Jones, 2005), through extending our understandings of water security, liveability and sustainability (Lundqvist et al., 2003, Danielaini et al., 2018c).

The challenges for cities in the Asia-Pacific Region include coping with the rapid growth of medium and small urban centres, managing the demographic pressures on environment, addressing extreme poverty and inequality and effectively planning to overcome frequent climate change impacts and disasters (UNDP, 2016a). Particular concerns in this region are the impacts of rapid urbanisation and climate change and the manner of handling the multidimensional challenges associated with future water security, liveability and sustainability (Asian Development Bank, 2016a, Mc Gee, 2010). These problems are likely to be significantly more difficult to resolve in small urban centres than large urban centres due to a lack of financial, political, technical and management capacities to cope with a higher level of urbanisation (Cohen, 2006, Biswas and Seetharam, 2008). The direction of urban development should seek to implement sustainable development goal (SDG) 11 to make cities and human settlements inclusive, safe, resilient and sustainable (UN-Habitat, 2016). While it is clear that most actions to achieve sustainable development have to be formulated and implemented locally (Satterthwaite, 1997), all cities face growing difficulties in (i) handling connected and multifaceted issues, (ii) producing sufficient planning systems to respond to rapid urban expansion and (iii) managing the growing interconnection between urban and rural areas effectively (UNDP, 2016a). This implies the need for cities in this region to improve planning and management approaches to urban systems to balance city expansion and achieve water security, liveability and sustainability (Danielaini et al., 2018c, Danielaini et al., 2019c).

In the Indonesian context, the failure to effectively plan and manage land and water resources in line with urban development has led to declining water quality, increased flood risks, degraded water catchments and significant land subsidence in several large coastal cities such as Jakarta and Semarang (Abidin et al., 2011, Delinom et al., 2009, Steinberg, 2007, Marfai and King, 2007). Java in particular is experiencing two conflicting trends; (i) urban expansion to meet population growth encroaching on agricultural lands while (ii) an increasing population demands more food security (Deltares et al., 2012). The peri-urban ecosystem, as an important urban feature for enhancing liveability and sustainability, is thereby under strong pressure from rapid urban expansion (Mc Gee, 2010). The complex issues, challenges, options and strategies to achieve balanced urban development, however, have not been adequately researched, particularly in expanding smaller coastal cities that will continue to expand in the urban future. This chapter identifies and explores these gaps of knowledge. It proposes a socio-ecohydrological systems thinking approach, focusing on a small coastal city and its outskirts within the Cirebon Metropolitan Region (CMR), which is under pressure from rapid urbanisation and climate change and experiences frequent floods and droughts. This study particularly investigates the socio-ecohydrological processes and impacts on people and the environment in the context of changes in land use, water cycle and climate.

9.2 THEORETICAL AND CONCEPTUAL FRAMEWORKS

9.2.1 WATER SECURITY, LIVEABILITY AND SUSTAINABILITY

There is no consensus on how to define water security but the need to balance human and environmental water needs is widely agreed (Srinivasan et al., 2017). The standard of water security is also subject to change and varies from one place to another as trade-offs between human and environmental needs depend on societal values (Wheater and Gober, 2015). A clear understanding of water security issues and challenges needs to include vulnerable groups by considering urbanisation and climate change pressures and impacts on the biophysical environment and households/ communities, the scale of adaptation actions and the role of institutions in resolving the issues (Srinivasan et al., 2013). Similar to water security, there is also no consensus on how to define liveability, due to this being about the person-environment fit on the ‘here and now’ (Van Kamp et al., 2003). There is also no consensus on how to define sustainability, but it is recognised as being about the person-environment fit in the future or long-term liveability (Alberti, 1996, Van Kamp et al., 2003). While liveability and sustainability can be differentiated based on the scale, context and potential (Gough, 2015), they are related as both concepts are based on the relationships between people and the environment (de Chazal, 2010). Like standards for water security, standards for liveability are diverse across different places as both social and environmental aspects that define liveability also vary widely across spaces and through time; thus, any endeavours to develop a sustainability objective to enhance liveability must be based on the understanding of underlying geographic and dynamic behaviours of society and its biophysical environment (Ruth and Franklin, 2014).

9.2.2 BALANCED URBAN DEVELOPMENT AND SYSTEMS THINKING

Balanced urban development (BUD) is a concept of sustainable development that is linked to the liveability of urban areas; this includes water, food and energy security through developing various planning tools and models that help to analyse and visualise different options and scenarios (Maheshwari et al., 2016). BUD incorporates the interdependencies including synergies and trade-offs among various SDGs, such as SDG 2 to achieve food security, SDG 6 to ensure water security, SDG 11 to achieve liveable and sustainable urban systems and SDG 13 to combat climate change and impacts (United Nations, 2018). BUD also recognises peri-urban areas surrounding cities as highly dynamic areas that are characterised by unique social, environmental and economic changes (Singh et al., 2016). In BUD, peri-urban areas are regarded as an integral part of the functional activities which drive growth in urban areas and should be prioritised in policies at both national and global levels (Maheshwari et al., 2016). This is critical because the growth of urban areas is now dominated by vertical and horizontal expansions around city centres and in surrounding areas, mainly into peri-urban zones (Mc Gee and Shaharudin, 2016).

The process of BUD requires an interdisciplinary approach to understand the interconnections between water, people and the environment. Interdisciplinary research integrates ideas and/or tools typically used by two or more traditional research programmes to develop a shared methodological approach across disciplinary frameworks (Khagram et al., 2010, Wickson et al., 2006). The process of BUD also requires a transdisciplinary approach and the engagement of a range of stakeholders concerning place, people and planning to address human-environmental issues regarding changes in land use, water cycle and climate as challenges to achieving sustainability (Maheshwari et al., 2016, Singh et al., 2016). Transdisciplinary research integrates two or more pathways to address "real world problems"; first, through the exploration of new options for solving societal problems; and second, through the development of interdisciplinary approaches, methods, and general insights related to the problem field, which are crucial for the practical path (Lang et al., 2012). This can include the integration of different disciplinary methods and the development of novel research methods to enable efficient and effective learning processes at the science-society interface (Brandt et al., 2013).

Many researchers across numerous disciplines are increasingly adopting or developing an interdisciplinary or transdisciplinary approach in response to sustainability challenges that address human-environmental issues. These include ecohydrology (Zalewski, 2010, Zalewski, 2013) and its synonym hydro-ecology (Hannah et al., 2004), hydrosociology (Falkenmark, 1979), hydrosocial (Linton and Budds, 2014, Budds, 2008), socio-hydrology (Sivapalan et al., 2012), political-ecology (Swyngedouw et al., 2002), and integrated water resources management (Medema et al., 2008). In the context of cities, new ways of thinking (Sanders, 2008) as well as new ways of responding to the complexity of urban issues (Campbell, 2016) are required. This is because to be sustainable, cities need to recognise connected issues as complex systems with many stakeholders who can contribute varying interests and understandings of the dynamism and scale of urbanisation (UNDP, 2016a). One way to enhance the scale and depth of understanding the complexity of urban contexts and therefore the impacts on city boundaries, both within and outside, is by using a systems approach or systems thinking (Campbell, 2016, Bai et al., 2010).

The challenges this research explores are conceptualising a systems approach to urban systems to gain better understandings of the complex social and environmental issues, identifying options and strategies that are useful for the wide range of possible scenarios. Other challenges are related to understanding the complex relationship among infrastructures, ecosystem services, population, and institutions (da Silva et al., 2012, Ruth and Coelho, 2007, McGranahan et al., 2005) and to operationalise it in the context of BUD.

9.2.3 A SOCIO-ECOHYDROLOGICAL SYSTEMS THINKING APPROACH

A systems approach is urgently needed for urban policy making, analysis, and research due to the range and complexity of interdependencies between various SDGs. This challenge is greatest, and most pressing in cities, yet cities cannot act alone to achieve sustainability and need actors and institutions outside the city to work together (Bai et al., 2016, McGranahan and Satterthwaite, 2003). A systems approach may address the complex social and environmental issues cities are increasing facing and may identify gaps and areas of synergy across the goals and targets of the SDGs (Bai et al., 2016, Lim et al., 2018). Previous research into using systems perspectives to understand urban challenges on sustainability, liveability, and water security have used various models such as Human Ecosystem Model (Pickett et al., 1997), Extended Metabolism Model of the City (Newman, 1999), Simplified Conceptual Model and Resilience Characteristics (da Silva et al., 2012), VISTA framework (de Chazal, 2010), and Coupled Human-Environment System (CHES) approach (Srinivasan et al., 2013). No research has yet explored an integrated systems-oriented approach to identify the gaps and connections across the goals and targets of the SDGs in the context of BUD. This study proposes a Socio-Ecohydrological Systems thinking approach for understanding the complexity of socio-ecohydrological issues and challenges underpinning water security, liveability, and sustainability and identifies options and strategies towards balanced urban development in the coastal urban systems including those in the rural-urban interfaces.

This study used the term of ecohydrology (EH) that is defined by Zalewski (2004) as an integrative systemic approach for reversing the degradation of river basin services by regulating hydrological and ecological processes. Hiwasaki and Arico (2007) highlight the need for EH to understand the specific social and cultural dimensions of a given environment in order to define the various and multifaceted relationships people have with the environment; this includes people actions, as well as institutions and governance structures that shape people's actions. Hiwasaki and Arico (2007) further describe two important characteristics of EH: i) an interdisciplinary, integrated, and holistic approach to sustainable management of water resources, targeting a wide range of ecosystems; and (ii) a concept and an approach that link ecology with hydrology in order to consider interactions between water resources and ecosystems and thereby provide solutions to issues surrounding water, environment, and people. EH is acknowledged as the background for the integrative sustainability science (Zalewski et al., 2016a). This study integrated concepts and methodologies from the social sciences into EH to facilitate an interdisciplinary approach and to move EH forwards as a transdisciplinary approach to address human-environmental issues as suggested by Hiwasaki and Arico (2007). This approach is termed as a SEHS thinking approach that has been applied to analyse socio-ecohydrological issues underpinning liveability, sustainability, and water security (Danielaini et al., 2018c, Danielaini et al., 2019a, Danielaini et al., 2019c). In this study, this approach is applied to synthesise BUD.

A socio-ecohydrological systems (SEHS), as used in this study, is defined as an integrated system of human society, water, and the environment with reciprocal feedback and interdependence. The concept, like socio-ecological systems (SES) emphasises the perspective of human-in-nature. While SES is deeply entrenched in resilience studies (Folke, 2006), SEHS aims to understand complex adaptive systems in the context of sustainability. Here, two paradigms shifts are taking place; firstly within ecology a focus on accepting change, and secondly within hydrology a focus on green-water flow related to food production, deforestation, and managing ecosystem services and blue-water flow related to water infrastructures, upstream/downstream balancing of interests, and water pollution (Falkenmark and Folke, 2002). While the sustainability facet focuses on practicing effective management, achieving resource security, and controlling change and growth to enhance resilient and adaptive human-nature systems, the resilience facet focuses on the capacity of human-nature systems to reorganise and recover from change and disturbance (Fiksel, 2006, Ahern, 2011). This implies that the human-nature systems that are resilient to environmental change would be sustainable. SEHS thinking is thus relevant for understanding human-environment concepts including water security, liveability, and sustainability in the context of changes in water cycle, land use and climate.

9.3 METHODOLOGY

9.3.1 DATA COLLECTION

The study was conducted across five districts in the CMR from February to July 2016 and included 25 sub-districts and 65 villages at different elevations between 0 and 500 m above mean sea level as shown in Figure 4, Chapter 2. The average annual temperature and rainfall in the areas range from 23⁰C to 33⁰C and from 1200 to 3700 millimetres (mm) respectively. This study recruited households in rural-urban environments using a random sampling technique. A total of 430 urban and peri-urban dwellers and households were individually interviewed and surveyed at a distance from the coast ranging from 0.3 to 31.6 kilometres (M=10.80; SD=8.15); 97 participants (22.6%) lived in the Cirebon Municipality (CM) while 333 participants (77.4%) lived in the peri-urban area, mostly in the Cirebon Regency (CR). The length of residency of participants ranged from 2 to 90 years (M=37.74; SD=18.51), with 52.3% of the participants being farmers and 60.7% being male. Data was collected using an interview questionnaire that consisted of open and closed-ended questions that covered socio-environmental attributes of the participants (Table 36), closed and open-ended questions for assessing water security (Danielaini et al., 2019a), and liveability and sustainability (Danielaini et al., 2018c, Danielaini et al., 2019c) in the context of socio-ecohydrological change.

TABLE 36. SOCIO-ENVIRONMENTAL ATTRIBUTES OF SURVEYED COMMUNITIES

Attributes	Parameter	Percentage from total 430 participants (%)				
		Rural	Peri-urban	UPT	Urban	Total
Place in five districts within CMR	CM	-	-	-	22.6	22.6
(political boundaries)	CR	5.8	25.6	17.2	0.9	49.5
	IR	7	-	-	-	7
	KR	4.2	9.7	-	-	14
	MR	-	6.3	0.7	-	7
Gender	Male	12.1	24.6	8.6	15.4	60.7
	Female	4.9	17.7	8.6	8.1	39.3
Type of household	Farm household	10.5	27	7.4	7.4	52.3
	Non-Farm household	6.5	15.3	9.8	16.1	47.7
Length of Stay	Less than 10 years	0.9	4	3	4	11.9
	10 – less than 20 years	1.4	2.1	1.4	3	7.9
	20 – 30 years	3	4.2	3.3	3.5	14
	More than 30 years	11.5	31.8	9.6	13.1	66
Distance from the coast	Less than 5 km	5.8	3.2	10.5	17.7	37.2
	5 – less than 10 km	-	2.8	2.5	5.8	11.2
	10 – less than 15 km	2.1	20.2	3.5	-	25.8
	15 – less than 20 km	2.1	9.8	-	-	11.9
	More than 20 km	7	6.3	0.7	-	13.9
Total participants in each urbanisation level		**17**	**42.3**	**17.2**	**23.5**	

In-depth semi-structured interviews were also conducted with the representatives of 32 government institutions to provide data beyond city-level including river basin, and regional level data. This was to better understand diverse sectors, scales in the role of planning and management, actors, priorities, and solutions. Socio-environmental attributes of key informants in planning and management are shown in Table 5, Chapter 2. The interview questionnaire consisted of open-ended questions for understanding decision- makers' perspectives regarding future change of land use, water cycle and climate; strategies for enhancing water security, liveability, and sustainability; and issues, challenges, options, and future strategies for BUD.

In addition to the primary data from the household survey, secondary data on historical ecohydrological changes were collected from government institutions. Land use and land cover maps in 2005 and 2014 were obtained digitally from the West Java Province (WJP) Development Planning Boards to see the change in built-up, forest and semi-natural areas. Evaluation of a historical number of farm households and the size of farmlands was taken based on the available agricultural census in 2013. Historical data of monthly rainfalls, river discharges and river water quality were collected from the Indonesian Agency for Meteorology, Climatology and Geophysics and the River Basin Organisation (RBO), namely *Balai Besai Wilayah Sungai* (BBWS) and *Balai Pengelolaan Sumber Daya Air Wilayah Sungai* (BPSDA-WS) Cimanuk-Cisanggarung. As observed climate data including temperatures and rainfall data analysis, is detailed in Chapter 8, the focus of this chapter is on observed water and land-use data analyses.

9.3.2 Data analysis

A mixed method research approach was used in this study because of its capacity to address important environmental management and sustainability issues (Molina-Azorín and López-Gamero, 2014). A mixed method approach employs both qualitative and quantitative methods to explore and inform complex research problems (Creswell, 2003, Creswell and Tashakkori, 2007). Although this approach is frequently costlier and more time consuming, it provides high quality and detailed data sets (Beal et al., 2013). The qualitative data analysis was conducted using NVivo Pro (QSR)™ 11.0 to search for patterns and themes in the text data. To make sense of realities, the texts were analysed, synthesised and interpreted to construct a higher order interpretation (Major and Savin-Baden, 2011). The quantitative data analysis was conducted using SPSS (IBM)™ version 25 to identify perception patterns, non-linear relationships, differences in ordinal and nominal data and for identifying trends in historically observed numerical data.

9.3.3 Analytical frameworks

Issues and challenges related to water security, liveability, and sustainability are multiple and complex in nature. A systems thinking approach provides an opportunity to examine and understand the complexity of the linkages, interconnections and interrelationships between different parts of a system (Campbell, 2016). In urban systems, a systems thinking approach considers cities, their rural hinterlands, and global networks of people, goods and services as inseparable and spatially linked (Carter et al., 2015). A systems thinking approach also looks at the various stakeholders, their interests and perceptions and the relationships between different actors to consider the urban spaces and wider context (Campbell, 2016). This study applied a socio-ecohydrological systems (SEHS) approach to explore complex people, water, and environmental systems in different scales. The study considered the perspectives of urban and peri-urban community dwellers directly impacted by local-regional socio-ecohydrological change in terms of their resource's security and liveability, and the perspectives of planners and decision makers of multi-level governments with responsibility for planning and management of sustaining liveability of urban and peri-urban communities and of water security for producing food and energy. This includes farm and non-farm householders and multi-sectoral and multi-scalar governments as they have a critical role in identifying and implementing sustainability priorities including options and strategies towards ensuring BUD. The analytical framework for this study is shown in Figure 44.

Ecosystem Services (ES) in this study refers to any ecohydrological processes that have value for urban and peri-urban communities. Urban Services (US) refers to typical public services and facilities in cities. Peri-urban Services (PS) refers to public services and facilities usually available in urban and rural areas that have mixed rural-urban characteristics. Human Services (HS) refers to wellbeing aspects in terms of personal values related to useful socio-economic and cultural services for urban and peri-urban communities (Danielaini et al., 2019c). This study explored the boundary of a metropolitan region that was divided into city and hinterlands and compared based on the urbanisation levels to provide the background for human-environment questions (Pickett et al., 1997). This background, called the rural-urban interface ecohydrology (Danielaini et al., 2018a) has four characteristics of ecohydrological processes that were identified in the CMR as urban, urban/peri-urban transition (UPT), peri-urban, and rural ecohydrology (Danielaini et al., 2018b).

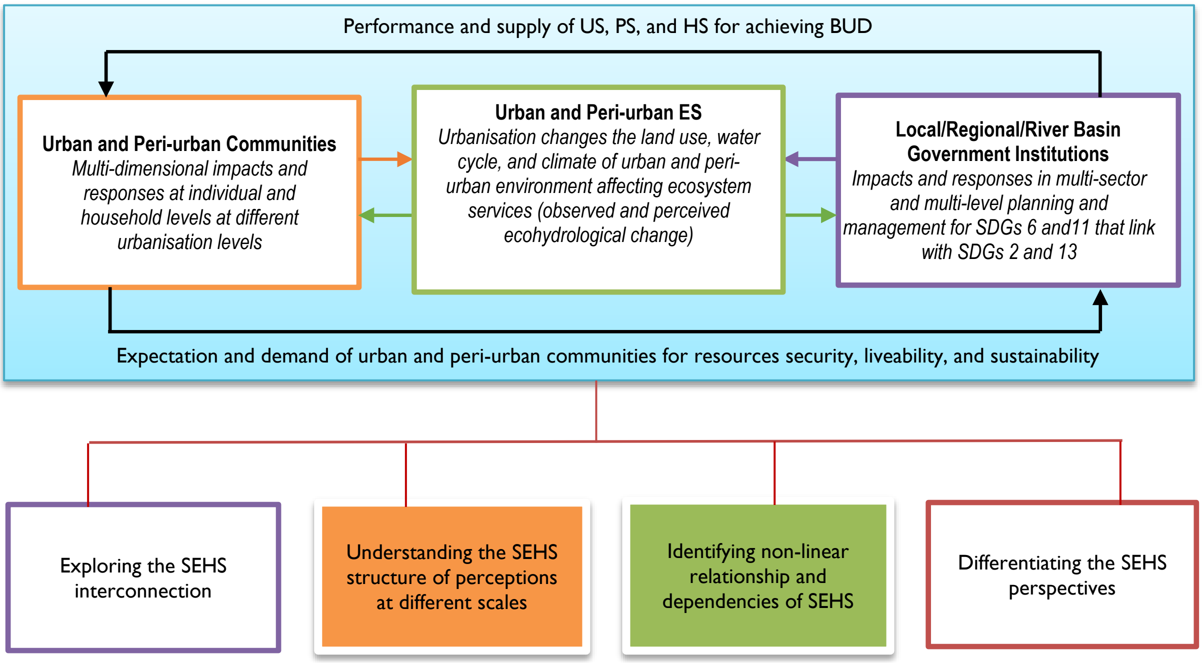


FIGURE 44. SOCIO-ECOHYDROLOGICAL SYSTEMS THINKING ANALYTICAL FRAMEWORK FOR UNDERSTANDING ISSUES, CHALLENGES, OPTIONS, AND STRATEGIES TOWARDS BUD

9.4 RESULTS AND DISCUSSIONS

9.4.1 EXPLORING THE SEHS INTERCONNECTION

The CMR is an area where rural-urban lands interface and floods and droughts occur (Danielaini et al., 2019a, Danielaini et al., 2019c). CMR is located in the north-eastern corner of the WJP in Indonesia and is a new developing coastal metropolitan region. It encompasses Cirebon Municipality (CM), an expanding coastal city with a population of 0.3 million, and its surrounding, two coastal districts of Cirebon (CR) and Indramayu (IR), and two inland districts of Kuningan (KR) and Majalengka (MR) (Danielaini et al., 2018a). It covers a total area of 570-600 km^2 and has a population of 1.6 to 2.4 million distributed over 29-30 sub-districts. By 2030, it is expected to cover a total area of 1080 km^2 with a population of more than 6.5 million distributed over 45 sub-districts and 483 villages (Regional Development Planning Board of West Java Province, 2015). The urban area is continuing to expand covering sub-districts in the CM and fringe sub-districts in the CR (Danielaini et al., 2018a).

In the past two decades, rapid urbanisation in the CMR has changed the rural-urban interface ecohydrology, especially land resources for food production and water resources for securing urban and peri-urban water demands (Danielaini et al., 2018b, Danielaini et al., 2018c). Six reliable factors of socio-ecohydrological issues shape water insecurity in the rural-urban environment of the CMR, namely droughts, floods, poor affordability, unregulated water use, and poor sanitation leading to unhealthy housing and environment (Danielaini et al., 2019a). Further, floods combined with climate change are socio-ecohydrological issues affecting the most water insecure households in the CMR which are mostly located in the UPT area. UPT area has been directly affected by urban expansion and is the least liveable place in the CMR in terms of neighbourhood, watershed, and personal satisfaction (Danielaini et al., 2018c). In the context of socio-ecohydrology, liveability refers to dynamic interactions between water, people and the environment as a function of biophysical and socio-economic subsystems in one urban system (Danielaini et al., 2019c). In this area, and in the wider CMR, non-physical environment relating to social relationships with family/neighbours, place attachment related to birth-place and community identity - all of which can be categorised as cultural services under a type of HS, is the most satisfied liveability aspect. In contrast, water availability, that can be categorised as provisioning services under a type of ES, is the least satisfied liveability aspects in the CMR (Danielaini et al., 2019c). Other least satisfying liveability services in the CMR includes regulating services under a type of US and PS for mitigating the human impacts on the environment including health, flood protection and drought prevention (Danielaini et al., 2019c).

Sufficient water availability (ES) and socio-economic services (HS) are perceived as the most important services for creating liveability in the CMR (Danielaini et al., 2019c). In the CMR, ES is rare in urban areas (Danielaini et al., 2018b), although most urban residents are satisfied with the provision of sustainable water use related services and resources accessibility made possible through technological interventions. On the other hand, the majority of peri-urban residents are least satisfied with the decreasing availability of land for farming and producing food that are affected by ecohydrological changes and insufficient technological interventions (Danielaini et al., 2019c). While the current strategy of government institutions is mainly focused on enhancing infrastructures for supporting socio-economic activities in the CMR (Danielaini et al., 2019b), this study shows that the interface between people, water, and land in the urban system needs to be considered to achieve BUD. Further, this study identifies eight key aspects for enhancing the sustainability of water resources and for achieving BUD in the CMR; these eight aspects represent the concerns of key informants of national, provincial, and district level government institutions (Table 37) and include i) environmental planning and management; (ii) infrastructure; (iii) policies and governance; (iv) innovation and services; (v) information, communication, and collaboration; (vi) sociocultural environment; (vii) household adaptive capacity; and (viii) financing. *Detailed responses can be seen in Appendix 1.7 Tables A.1.7.1-A.1.7.19.*

TABLE 37. THE CONCERN OF KEY INFORMANTS IN PLANNING AND MANAGEMENT BASED ON THE LEVEL OF GOVERNMENT INSTITUTIONS

Key aspects of BUD	Problems in enhancing sustainability of water resources and uses *(The representatives' concern at different level of government institutions)*	Issues and Challenges for achieving BUD *(The representatives' concern at different level of government institutions)*	Options and strategies for achieving BUD *(The representatives' concern at different level of government institutions)*
Environmental planning and management	This is a major concern (100% responses) of representatives of government institutions at the provincial level (WJP) and district level (C/CM), related to land resources	This is a major concern (100% responses) of representatives of government institutions at the national level managing the river basin (RBO-CCRB) related to water resource planning and management and implementation; at the regional level (WJP) related to environmental issues and challenges; at the district level (C/CM) related to environmental issues and challenge and implementation, and (PC/CR) to environmental issues and challenges and water security issues	This is the highest response (100% responses) from representatives of government institutions at the national level managing the river basin (RBO-CCRB) related to transboundary, multi-sector, and multi-scalar approaches; at the regional level (WJP) to integrated, transboundary, multi-sector, and multi-scalar approaches; at the district level (C/CM, PC/CR and KR) to transboundary approach, (PC/MR) to multi-sector and multi-scalar approach, (PC/IR) to transboundary, multi-sector and multi-scalar approach
Infrastructure	This is a major concern (100% responses) of representatives of government institutions at the district level (PC/CR) related to intervention capability of water and sanitation infrastructures	This is a major concern (100% responses) of representatives of government institutions at the national level managing the river basin (RBO-CCRB), related to development issues; and at the district level (C/CM and PC/CR) related to infrastructure for drinking water and sanitation	This is a major response (≥50% responses) from the representatives of government institutions at the district level (city/CM and peripheral city/IR and CR)
Policies and governance	This is a major concern (100% responses) of representatives of government institutions at the provincial level (WJP) related to adaptation and reliable legal frameworks for implementation, and at the district level (C/CM and PC/CR) to manage trade-off or nexus challenges	This is a major concern (100% responses) of representatives of government institutions at the national level managing the river basin (RBO-CCRB) related to water use and social conflicts; at the regional level (WJP) related to water use and social conflicts; and at the district level (C/CM and PC/CR and MR) related to limited institutional capacity	This is the highest response (100% responses) from representatives of government institutions at the national level managing the river basin (RBO-CCRB) related to adaptive and reliable legal frameworks; at the regional level (WJP) to incentive-disincentive; at the district level (peripheral city/KR, MR, CR) related to adaptive and reliable legal frameworks
Innovation and services	This is a minor concern (<50% responses) of representatives of government institutions at the district level (PC/IR)	This is the major concern (≥50% responses) of representatives of government institutions at the national level that manage the river basin (RBO-CCRB) and at the district level (PC/MR) related to planning and management approaches	This is a major response (≥50% responses) from the representatives of government institutions at the district level (peripheral city/IR) and a minor response(<50% responses) from the representative of government institutions at the district level (city/CM, and peripheral city/CR, MR, CR, KR)
Information, communication, and collaboration	This is a major concern (100% responses) of representatives of government institutions at the district level (PC/MR) related to collaboration	This is a major concern (100% responses) of representatives of government institutions at the national level managing the river basin (RBO-CCRB) related to synergy, collaboration, and education, training, and dissemination; and at the district level (PC/CR) related to collaboration; and a major concern (≥50% responses) of the representatives of other district government institutions (C/CM) related to collaboration, synergy, and data availability in terms of accuracy and reliability (PC/IR, KR, MR)	This is the highest responses (100% responses) from representatives of government institutions at the national level managing the river basin (RBO-CCRB) related to collaboration and synergy and a major response (≥50% responses) from representatives of government institutions at the district level (peripheral city/MR, CR, IR, KR) related to collaboration and synergy (city/CM) to learning capacity

Sociocultural environment	This is a major concern (100% responses) of representatives of government institutions at the provincial level (WJP) related to mindset, culture, and behaviour of communities	This is a major concern (100% responses) of representatives of government institutions at the national level managing the river basin (RBO-CCRB), at the provincial level (WJP), and district level (C/CM); and a major concern (≥50% responses) of the representatives of government institutions at the district level (PC/CR, KR, IR) related to mindset, cultural considerations, the behaviour of communities and (PC/MR) cultural preservation.	This is a minor response (<50% responses) from representatives of government institutions at all levels
Household adaptive capacity	This is a minor concern (<50% responses) of representatives of government institutions at the provincial level (WJP) and the district level (PC/CR, MR, and IR)	This is a major concern (≥50% responses) of representatives of government institutions at the district level (C/CM) and a minor concern (<50% responses) of other representatives of government institutions	This is a minor response (<50% responses) from representatives of government institutions at all levels
Financing	This is a major concern (≥50% responses) of all representatives of government institutions at the district level (PC/MR, CR, KR, and IR and C/CM) related to budget and financial capacity	This is a major concern (≥50% responses) of representatives of government institutions at the district level (C/CM) and a minor concern (<50% responses) of the other representatives of government institutions at the district level (PC/MR, IR, CR, KR)	This is a minor response (<50% responses) from representatives of government institutions at all levels

Note: RBO-CCRB=River Basin Organisation - Cimanuk-Cisanggarung River Basin, WJP= West Java Province, C=City, PC=Peripheral City, CM=Cirebon Municipality, CR=Cirebon Regency, KR=Kuningan Regency, MR=Majalengka Regency, IR=Indramayu Regency

9.4.2 Understanding the SEHS structure of perceptions at different scales

CATPCA analysis with varimax rotation was applied to determine the underlying structure of SEHS perception, awareness, and relationship that would best represent the categorical data responses of communities about the changing landscapes with ecohydrological functions due to urbanisation (green open spaces (GOS), food production related to agricultural area (F), and forest availability (FO)), the impact on the water cycle (groundwater quality (GW), river water quality (RQ), flood event (FE) and drought event (DE)) and the local climate/temperature (CL) within CMR based on four urbanisation levels (Table 38). There were significant differences in the perceptions of residents in the CMR about the change of green open spaces ($F(3,426) = 3.28$, $p<0.05$), forest ($F(3,426) = 3.03$, $p<0.05$), flood events ($F(3,426) = 9.61$, $p<0.001$), and drought events ($F(3,426) = 8.22$, $p<0.001$).

A variable principal was chosen as a normalisation method to optimise the association between variables. The solution, with three optimal dimensions, was determined using elbow method applied to the scree plot between the eigenvalue and dimension. A three-component structure with a component loading greater than 0.40 was found in urban, urban/peri-urban transition (UPT), peri-urban, and rural areas of the CMR with total reliabilities of 0.88, 0.89, 0.93, 0.88, and 0.91 respectively. The overall Cronbach's alpha indicated a very high level of reliability (Ahmad and Ahlan, 2015). The Kaiser-Meyer-Olkin (KMO) obtained scores of 0.70, 0.59, 0.54, 0.65, and 0.68, more than the minimum acceptable score of 0.5, and Bartlett's value was significant ($p<0.05$) and verified the sampling adequacy for factor analysis with principal components (Kaiser, 1974, Ahmad and Ahlan, 2015).

Table 38 provides a comparative analysis in the SEHS structures, the patterns of SEHS aspects grouped together, their rank, and how much variation is attributed to each principal SEHS component at different land-use transitions. Within the metropolitan scale in the CMR, the changes of GOS and FO were correlated to the change of CL. The change of DE was correlated with the change of water use in the households and agricultural paddy fields (GW and F), while the change of FE was correlated with the change in RQ. These ecohydrological changes have decreased urban and peri-urban open spaces; they have also increased local temperatures, degraded urban and peri-urban water quality including river and groundwater, declined ES, and increased flood and drought events (Danielaini et al., 2018c). These events affect individual farmers/non-farmers and households in terms of water security (Danielaini et al., 2019a) and liveability (Danielaini et al., 2018c, Danielaini et al., 2019c), and in terms of planning and management responses at local, regional, and river basin scales (Danielaini et al., 2019b).

In particular, according to the assessment of communities in the urban and rural areas, the change of FE was not associated with other measured variables that might be related to the availability and capability of infrastructures/drainage systems. However, in the UPT areas, the change of FE was correlated with the change of GOS and FO. This shows that urban expansion has increased FE that in turn, significantly decreased liveability and household water security in the UPT area (Danielaini et al., 2018c, Danielaini et al., 2019a). Coastal non-farm householders with access to drainage systems in the UPT area experienced higher FE than those in the urban area, while coastal farm householders without access to the drainage systems in the UPT area experienced higher FE than those in the rural area (Danielaini et al., 2019b). In the peri-urban areas, the change of FE was associated with the change of DE that might be linked to unpredictable weather and rainfall intensity. Farm householders in the peri-urban area were the most insecure due to increasing DE affecting F (Danielaini et al., 2019b), while those in the rural areas were the most insecure as DE was connected to GW and FO with limited access to water infrastructures (Danielaini et al., 2019a).

These factors indicate that to achieve BUD for water security, liveability, and sustainability in the CMR, it is very important to understand the interconnections between the city and its surrounding areas. This is because cities are transboundary, multi-scalar, multi-sectoral, socio-ecological-infrastructural systems with diverse actors, priorities, and solutions (Ramaswami et al., 2016).

TABLE 38. MODEL SUMMARY CATPCA: CMR, URBAN, UPT, PERI-URBAN AND RURAL

Principal Components	Variance Accounted For (VAF)		Ecohydrological Changes	Principal Components (PC)		
	Total Eigenvalue	% of variance		1	2	3
Overall participants (n=430, valid 395, mode imputation)						
1	1.70	21.30%	Green Open Spaces (GOS)	**0.71**		
2	1.48	18.44%	Local climate (CL)	0.66		
3	1.15	14.39%	Forest availability (FO)	**0.61**		
Total	**4.33**	**54.11%**	Groundwater Quality (GW)		0.71	
			Drought Events (DE)		**0.69**	
*KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within CMR= 0.70; Bartlett's Test of Sphericity: Approx. Chi-square = 282.16; df = 28; Sig. 0.000; Total Cronbach's Alpha 0.88**			Food production (F)		0.54	
			Flood Events (FE)			**0.90**
			River Quality (RQ)			0.43
Urban participants (n=101, valid 92, mode imputation)						
1	2.02	25.29%	Local climate (CL)	0.73		
2	1.36	17.01%	River Quality (RQ)	0.64		
3	1.11	13.90%	Food production (F)	0.62		
Total	**4.50**	**56.21%**	Green Open Spaces (GOS)	**0.59**		
			Groundwater Quality (GW)		-0.71	
*KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within CMR= 0.59; Bartlett's Test of Sphericity: Approx. Chi-square = 69.44; df = 28; Sig. 0.000; Total Cronbach's Alpha 0.89**			Drought Events (DE)		**0.66**	
			Forest availability (FO)		**0.56**	
			Flood Events (FE)			**0.90**
Urban/peri-urban transition participants (n=74, valid 70, mode imputation)						
1	2.14	26.78%	River Quality (RQ)	0.79		
2	1.61	20.11%	Local climate (CL)	0.78		
3	1.54	19.28%	Food production (F)	0.68		
Total	**5.29**	**66.16%**	Green Open Spaces (GOS)		**0.75**	
			Flood Events (FE)		**-0.63**	
*KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within CMR= 0.54; Bartlett's Test of Sphericity: Approx. Chi-square = 115.43; df = 28; Sig. 0.000; Total Cronbach's Alpha 0.93**			Forest availability (FO)		**0.63**	
			Drought Events (DE)			**0.84**
			Groundwater Quality (GW)			0.81
Peri-urban participants (n=182, valid 163, mode imputation)						
1	1.66	20.80%	Food production (F)	0.75		
2	1.45	18.18%	Groundwater Quality (GW)	0.75		
3	1.19	14.90%	River Quality (RQ)	0.44		
Total	**4.31**	**53.88%**	Green Open Spaces (GOS)		**0.74**	
			Local climate (CL)		0.62	
*KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within CMR= 0.65; Bartlett's Test of Sphericity: Approx. Chi-square = 119.80; df = 28; Sig. 0.000; Total Cronbach's Alpha 0.88**			Forest availability (FO)		**-0.57**	
			Flood Events (FE)			**0.83**
			Drought Events (DE)			**0.56**
Rural participants (n=73, valid 70, mode imputation)						
1	2.31	28.85%	Green Open Spaces (GOS)	**0.75**		
2	1.46	18.26%	Local climate (CL)	0.74		
3	1.10	13.69%	Food production (F)	0.69		
Total	**4.86**	**60.80%**	River Quality (RQ)	0.66		
			Drought Events (DE)		**0.74**	
*KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within CMR= 0.68; Bartlett's Test of Sphericity: Approx. Chi-square = 85.28; df = 28; Sig. 0.000; Total Cronbach's Alpha 0.91**			Groundwater Quality (GW)		0.65	
			Forest availability (FO)		**0.55**	
			Flood Events (FE)			**0.92**

**Total Cronbach's Alpha is based on the total Eigenvalue*

These findings show that to work towards BUD and to enhance rural-urban water security which links with food security and environmental security (Danielaini et al., 2019a), liveability (Danielaini et al., 2019c), and sustainability (Danielaini et al., 2019b) the important interconnections between terrestrial and aquatic ecosystem services and impacts need to be identified to provide effective ecosystem governance solutions (Falkenmark, 2007). In this study, FO, GOS, and F belong to terrestrial ecosystems; GW and RQ belong to aquatic ecosystems; while FE, DE, and CL represent the socio-ecohydrological issues in the selected region. The solutions can be very different as each depends on the scale of the ecosystem; which can vary from local-scale ecosystem protection through to landscape components such as a local forest with high biodiversity, to meso-scale conglomerates of local ecosystems (GWP, 2000). The various solutions also include controlling the side-effects of biophysical change of landscape components in response to societal needs such as pollution affecting environmental security (Falkenmark, 2007). A sustainable future thus depends fundamentally on the capability to manage the trade-offs between water, people, and the environment as argued by Falkenmark and Rockström (2004). This is particularly critical in cities that are complex ecological systems dominated by humans yet intricately connected with their surrounding ecological and hydrological systems (Lundqvist et al., 2003, Alberti, 2008, Bai et al., 2016).

9.4.3 IDENTIFYING NON-LINEAR RELATIONSHIP AND DEPENDENCIES OF SEHS

This study used CATREG to identify the most significant factors affecting SEHS changes within metropolitan areas and at different urbanisation levels (*Appendix 1.7 Tables A.1.7.20-A.1.7.21*). This analysis was useful for multiple regressions of categorical data or a combination of numerical and categorical data and functions for the non-linear transformation of the variables including response variability (Van der Kooij et al., 2006). Factors influencing SEHS within the CMR were most often the city location and its surrounding districts, the political boundaries at the district level connected to the local government role in managing the water-environment ($\beta=0.49$, $p<0.001$) or the distance from the coast ($\beta=0.43$, $p<0.001$). In the urban, UPT, peri-urban, and rural areas, the most influential and significant factors affecting SEHS were the source of drinking water ($\beta=0.45$, $p<0.001$), distance from the coast ($\beta=0.76$, $p<0.001$), political boundaries at district level ($\beta=0.42$, $p<0.001$), and current water problems ($\beta=0.59$, $p<0.01$).

These results imply that a good understanding in the governance system, natural biophysical system, and social system is required to enhance water security, liveability and sustainability towards BUD in the CMR (Falkenmark, 2007). This includes clarifying the water-related determinants which indicate how ecosystems may be disturbed by water management or mismanagement (Falkenmark and Folke, 2002). For instance, the source of drinking water in the urban area is mostly from piped networks which source water from peri-urban spring water in KR. However, this piped water often flowed intermittently and that was inextricably linked to low pressure and insufficient water source availability during the dry season (Danielaini et al., 2019a). On the other hand, water problems in the rural area included droughts and issues with access to and the capability of water systems in providing acceptable water quantity and quality. For example, the piped water supply flowing to Kapetakan, a rural sub-district in the CR, is sourced from the polluted river but was treated inadequately thereby delivering water of unacceptable quality in taste, odour, and physical characteristics. It also did not run at all during the dry season. (Danielaini et al., 2018c).

Figure 45 indicates how each parameter of the independent variables representing socio-environmental attributes links with the data sets of ecohydrological changes representing SEHS. People who lived in the urban and UPT areas reported higher changes in GOS and lower changes in DE compared to people who lived in the rural and peri-urban areas. People who had lived at their current residence for more than 30 years reported a higher change in F and lower changes in FE than those who had lived in the area for less than 30 years. People who worked as farmers assessed there were lower changes in CL, higher changes in F and DE, and a lower change in RQ compared to non-farmers. People who lived in KR, MR, and IR were more likely to indicate lower changes in almost all ecohydrological aspects than those who lived in the CR and CM. Compared to those who lived more than 10 kilometres from the coast, people who lived less than 10 kilometres from the coast were more likely to indicate higher changes in FE and groundwater quality (GW) and also lower changes in RQ, F, and FO. Furthermore, female respondents were more likely to indicate a higher change in FE than male respondents.

These findings reflects the complex coupled human-natural systems in the urban systems, showing the dynamic of land development and resource uses, and their ecological and hydrological impacts as influenced by the spatial patterns of human activities and their interaction with biophysical processes at various scales (Alberti, 2008, Falkenmark, 1977). To achieve BUD, therefore, these complex and diverse human values and perceptions need to be considered in the rural-urban development planning and management.

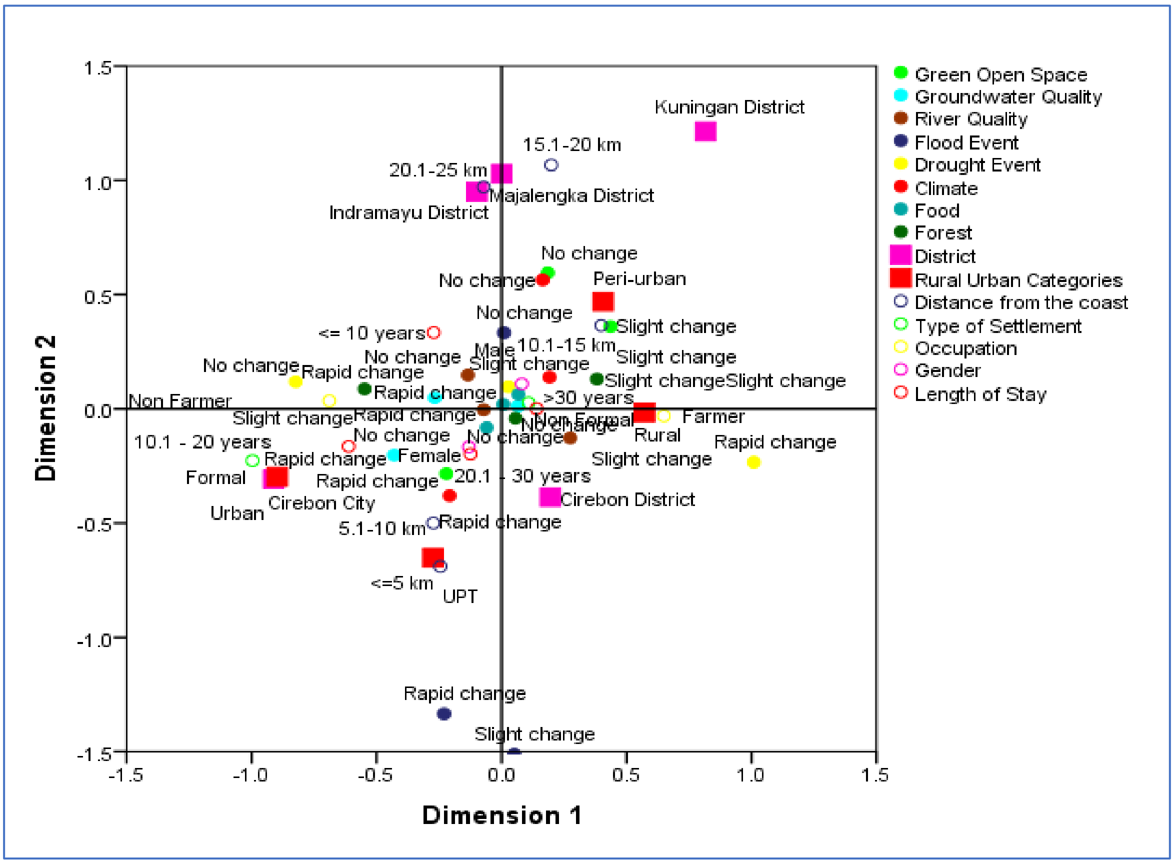


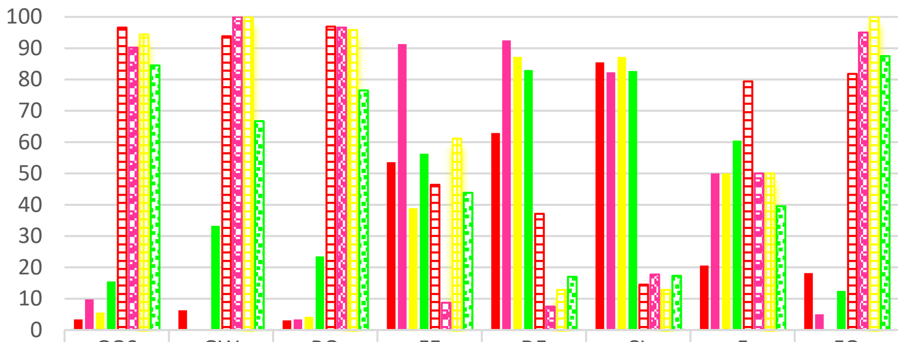
FIGURE 45. NONLINEAR CANONICAL CORRELATION OF PERCEIVED SEHS CHANGES

9.4.4 DIFFERENTIATING THE SEHS PERSPECTIVES

9.4.4.1 PERCEIVED VS OBSERVED ECOHYDROLOGICAL CHANGE

Results of the random household survey indicate that households in the city (40%) and its outskirts (60%) experienced water problems related to flood or flooding and/or drought. More than 75% of the city and peri-urban dwellers also reported degraded river water quality surrounding their place of residence. Further, 44% of the city households and 27% of households in the peripheral city experienced groundwater quality problems in terms of taste (salty), physical appearance (turbid), and odour (bad smell). A majority of residents in the CMR evaluated that GOS, GW, RQ, and FO had decreased while FE, DE, and temperature (CL) had increased in the past two decades (Figure 46). In addition, most urban residents evaluated that F had decreased while the number of rural residents had increased. Residents in the UPT and peri-urban areas reported mixed reviews on F.

These findings indicate that the CMR faces several challenges related to the change of biophysical systems to provide freshwater for human development to enhance rural-urban water security, liveability, and sustainability towards BUD. This requires a strong focus on ensuring water resilience against increasing pressures from rapid urbanisation and climate change, and on securing the role of water in the functioning and stability of biophysical, social, and economic systems (Rockström et al., 2014) that shape liveability and sustainability (Danielaini et al., 2018c, Danielaini et al., 2019c). Resilience as it is used here refers to the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables (Holling, 1973).



	GOS	GW	RQ	FE	DE	CL	F	FO
Increasing- Urban (%)	3.4	6.3	3.1	53.6	62.9	85.5	20.6	18.2
Increasing- UPT (%)	9.8	0.0	3.4	91.3	92.5	82.3	50.0	5.0
Increasing- Peri-urban (%)	5.6	0.0	4.2	38.9	87.2	87.2	50.0	0.0
Increasing- Rural (%)	15.5	33.3	23.5	56.3	83.0	82.7	60.5	12.5
Decreasing- Urban (%)	96.6	93.8	96.9	46.4	37.1	14.5	79.4	81.8
Decreasing- UPT (%)	90.2	100.0	96.6	8.7	7.5	17.7	50.0	95.0
Decreasing- Peri-urban (%)	94.4	100.0	95.8	61.1	12.8	12.8	50.0	100.0
Decreasing- Rural (%)	84.5	66.7	76.5	43.8	17.0	17.3	39.5	87.5

FIGURE 46. TREND OF ECOHYDROLOGICAL CHANGES IN THE RURAL-URBAN INTERFACES

The perception of terrestrial ecosystem services represents the change of ecohydrological landscapes in the CMR, as assessed using the available land cover maps in 2005 and 2014 from the WJP. Each map was categorised into three ecohydrological landscapes, i) built-up area; (ii) agricultural area; and (iii) forest, water bodies, and semi-natural areas (Figure 47).

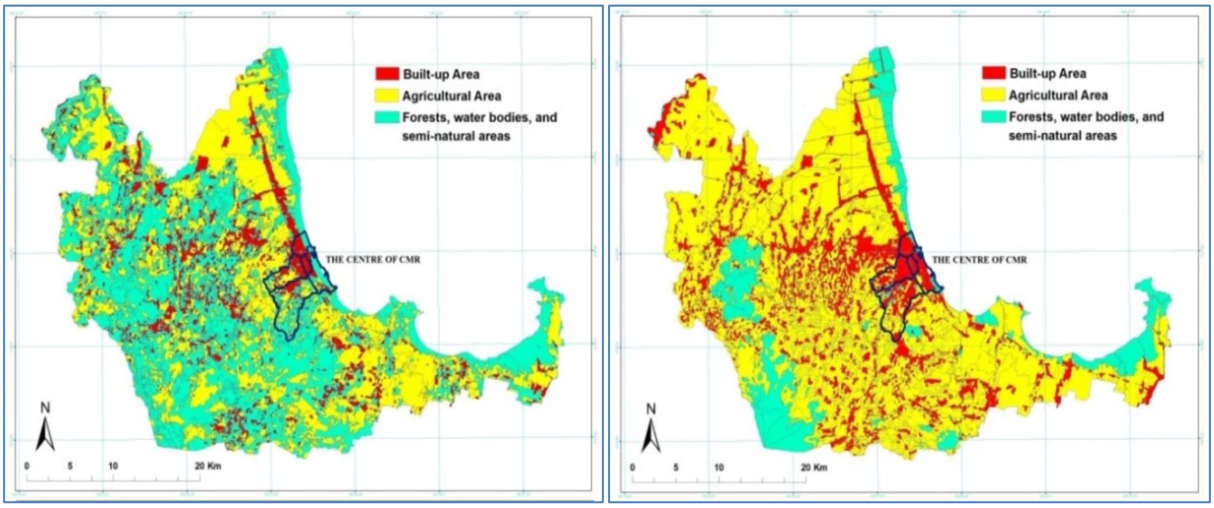


FIGURE 47. THE CHANGE OF ECOHYDROLOGICAL LANDSCAPES IN THE CMR: 2005 (LEFT), 2014 (RIGHT)

From 2005 to 2014, the proportion of built-up areas in CM increased from 59% in 2005 to 72% in 2014. In the city outskirts it increased from an average of 9% in 2005 to 18% in 2014. Peri-urban sub-districts in CR, such as Kedawung and Weru, which are located adjacent to the city, show more urban characteristics (Danielaini et al., 2018a, Danielaini et al., 2018b). From 2005 to 2014, agricultural area in the city decreased by 25%, while in the city outskirts it increased by 59%. During the same period, the forests, water bodies, and semi-natural areas decreased by 36% in the city and 53% in the city outskirts. Overall, there was a considerable change land use during this period in the CMR. In particular, land under agricultural use increased from 35% to 56%, while land under forests, water bodies, and semi-natural uses decreased from 56% to 26%. A comparison between farm households and the average size of farmland per farmer household, between 2003 and 2013 is shown in Table 39.

TABLE 39. FARM HOUSEHOLDS IN THE URBAN AND PERI-URBAN OF CIREBON

City/District	Farmer households		Growth (%)	Percentage of farm households in 2013 in each city/district	Average size of farmland per farmer household	
	2003 (thousand)	2013 (thousand)			2003 (ha)	2013 (ha)
CM	7.5	2.4	-68.0	3%	0.01	0.16
CR	192.8	89	-53.8	17%	0.09	0.55
KR	165.3	113.3	-31.5	45%	0.15	0.30
MR	204.9	156.6	-23.6	52%	0.16	0.35
IR	270.7	166.3	-38.6	39%	0.22	0.72
Total	**841.2**	**527.6**	**-37.3**		**0.62**	**2.07**

Source: Farm's households data is taken from BPS (2013)

The perception of aquatic ecosystem services represents the changes in river water quality in the rural-urban interface watersheds in the CMR (Figure 48).

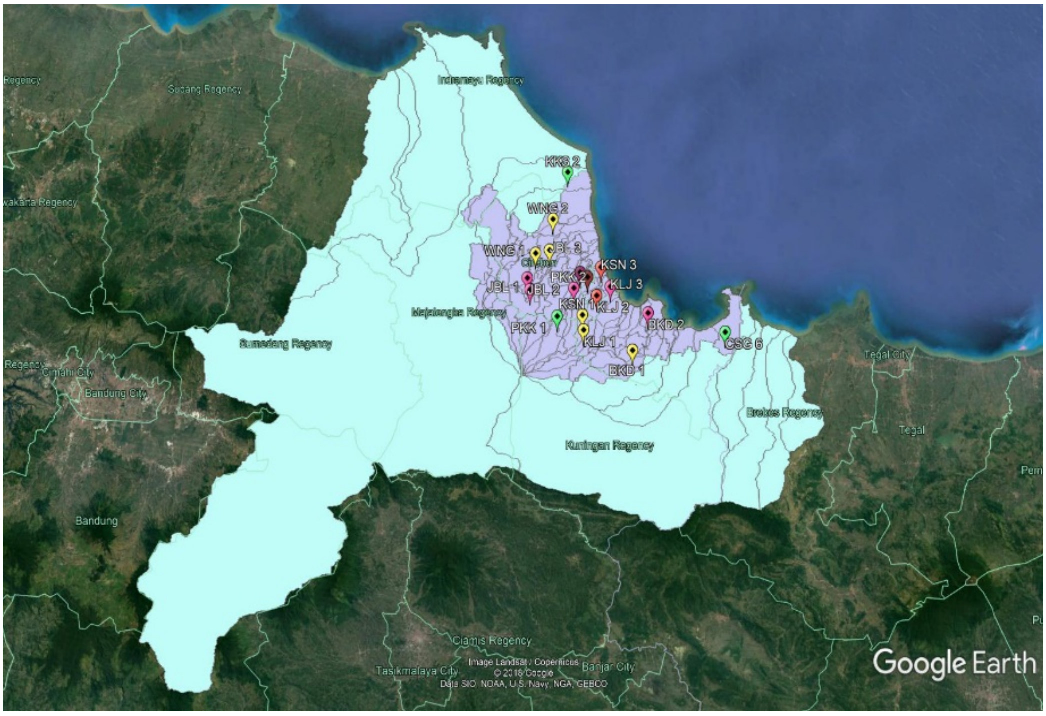


FIGURE 48. SELECTED RURAL-URBAN WATERSHEDS FOR STUDY

Note: green-mark (rural), yellow-mark (peri-urban), pink-mark (UPT), and red-mark (urban)

Observed historical data of river water quality from 2001 to 2017 (Figure 49) show that pollution in rural-urban rivers in the CMR has increased and generally exceed the maximum threshold limit values for Classes I, A, and B (raw water for drinking water supply) of the Indonesian Government Regulation 82/2001, Indonesian Government Regulation 20/1990, West Java Province Governor Decree 58/1998. While the parameters of chemical oxygen demand (COD), biochemical oxygen demand (BOD), dissolved oxygen (DO), NH4, PO4, turbidity, suspended solid (SS), colour, and pH are still suitable for agriculture and hydropower, the parameter of E. Coli exceeded the maximum threshold limit values for all classes of water uses. The urban watershed had the highest average of E. Coli (1.1×10^6 MPN/100 ml), followed by UPT and peri-urban areas (6.7×10^5 MPN/100 ml).

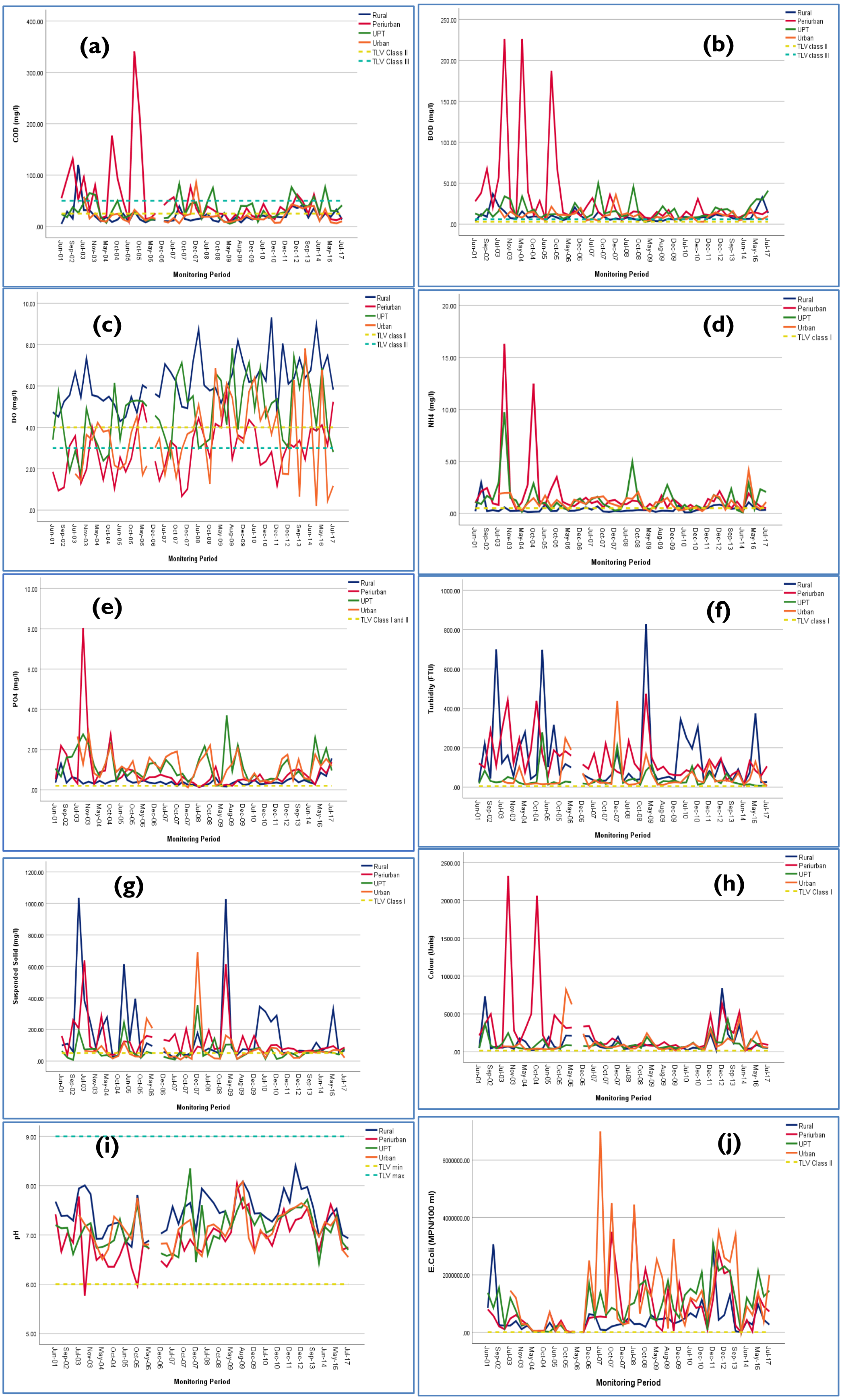


Figure 49. Trend of water quality of rural-urban watersheds: (a) COD; (b) BOD; (c) DO; (d) NH4; (e) PO4; (f) Turbidity; (g) SS; (h) Colour; (i) pH; and (j) E. Coli

The urban watersheds measured in the Kesunean River, for example, had the highest E. Coli reaching up to $1.5x10^6$ MPN/100 ml, compared to the rural, peri-urban, and UPT watersheds. However, a significant annual increase was found in the UPT watersheds at $2.4x10^5$ MPN/100 ml. In addition, peri-urban watersheds commonly had the highest concentration in the parameters COD, BOD, NH4, and colour with an average of 31.2 mg/l, 16.3 mg/l, 0.8 mg/l, and 156.1 units respectively. However, the trend of those parameters in the peri-urban areas showed a significant decrease ($p<0.05$). On the other hand, in the UPT area, parameters COD, BOD, and NO^3 showed an increasing trend. Only rural watersheds reached allowable limit values for DO ≥6 mg/l. Winong River, Pekik River, and Kesunean River at the peri-urban, UPT, and urban areas had DO<4 mg/l. Despite rural watersheds having the highest DO, they had the lowest performance in turbidity and SS likely due to the erosion of exposed soil from crop harvesting in the agriculture-dominated watersheds located upstream. In contrast, urban watersheds had the lowest DO but the highest performance in turbidity and SS likely due to the high sedimentation in the non-agriculture-dominated watersheds located downstream (Plate 15).

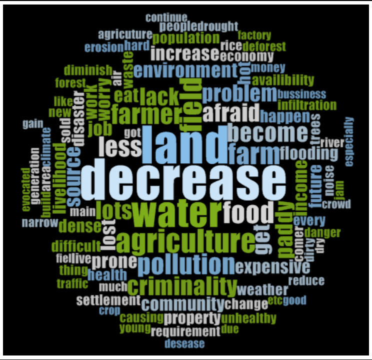
PLATE 15. HIGH SEDIMENTATION ON THE RIVER, KASEPUHAN AREA IN THE CM

Regarding future urbanisation in the CMR, an increase of pollution was a concern of communities in the urban, UPT, and peri-urban areas. Significantly, the highest responses to the risk of pollution were obtained from the urban residents due to their high concern about environmental security for liveability (Danielaini et al., 2019b). UPT residents were mostly concerned about the changes in land use and water cycle largely due to increasing floods or decreasing water security (Danielaini et al., 2019a). Peri-urban residents were mostly concerned about the decrease of agricultural land and water resources for livelihood due to decreasing food security and water security (Danielaini et al., 2019a, Danielaini et al., 2019b), and rural residents were mostly concerned about the decrease of agricultural land or decreasing food security (Figure 50).

Concerns of Urban Dwellers

Concerns of Urban/Peri-urban Transition Dwellers

Concerns of Periurban Dwellers



Concerns of Rural Dwellers

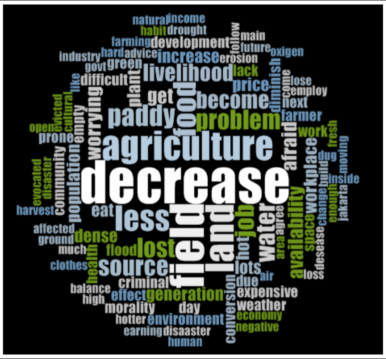


FIGURE 50. WORD CLOUDS OF MOST FREQUENT WORDS DISPLAY IN THE CONCERNS OF URBAN-RURAL DWELLERS REGARDING FUTURE URBANISATION

These findings show that ecohydrological change in the CMR is evident in both perceived and observed data. Different quality terrestrial and aquatic ecosystem services in the rural-urban interface socio-ecohydrology in the CMR, and the factors and impacts discussed above, highlight the complex functions of multi-scale ecological, hydrological, meteorological, oceanographic, and human drivers. Further, this study shows that environmental degradation has affected communities in the areas impacted by urbanisation in the CMR, particularly in the UPT watersheds. This suggests that peri-urban watersheds need more attention in efforts towards achieving BUD, as they are the main source of ES for urban populations (Bolund and Hunhammar, 1999). In summary, ES, combined US, PS, and HS are liveability services critical for achieving water security, liveability, and sustainability towards BUD (Danielaini et al., 2019c).

9.4.4.2 COMMUNITIES VS GOVERNMENTS' PERSPECTIVES

Local communities in the CMR are challenged by water shortages and changing hydrological cycles similar to many areas of the world (Wheater and Gober, 2015, Salinas et al., 2016, Dongguo et al., 2012, Xiao-jun et al., 2012). The experiences of communities in the CMR regarding socio-ecohydrological change and impacts reveal different primary concerns on water insecurity (Table 40). Urban communities were most likely to talk about the insufficient capability of public drinking water services to satisfy their needs, UPT communities were most likely to talk about floods, and peri-urban and rural communities were most likely to talk about the dry season and droughts.

TABLE 40. TWENTY-FIVE MOST FREQUENT KEYWORDS OF SOCIO-ECOHYDROLOGICAL CHANGE AND IMPACTS

NO	Urban			UPT			Peri-urban			Rural		
	Word	Count	(%)	Word	Count	(%)	Word	Count	(%)	Word	Count	(%)
1	*water*	140	5.88	*water*	122	6.50	*water*	330	6.94	*water*	119	6.54
2	*community*	39	1.64	*community*	36	1.92	*river*	103	2.17	*river*	38	2.09
3	*pdam*	38	1.60	*river*	28	1.49	*season*	85	1.79	*season*	38	2.09
4	*lands*	37	1.56	*season*	28	1.49	*community*	74	1.56	*dry*	36	1.98
5	*river*	34	1.43	*flooding*	25	1.33	*dry*	69	1.45	*drought*	29	1.59
6	*season*	30	1.26	*paddy*	22	1.17	*paddy*	56	1.18	*lands*	26	1.43
7	*settlement*	23	0.97	*dry*	21	1.12	*plant*	46	0.97	*community*	24	1.32
8	*farming*	22	0.92	*settlement*	18	0.96	*drought*	41	0.86	*pdam*	22	1.21
9	*plant*	21	0.88	*environment*	17	0.91	*crop*	40	0.84	*paddy*	16	0.88
10	*dry*	21	0.88	*housing*	17	0.91	*lands*	40	0.84	*harvest*	13	0.71
11	*housing*	20	0.84	*groundwater*	16	0.85	*housing*	39	0.82	*village*	13	0.71
12	*groundwater*	19	0.80	*pdam*	16	0.85	*village*	38	0.80	*flood*	12	0.66
13	*waste*	19	0.80	*plants*	16	0.85	*waste*	36	0.76	*groundwater*	12	0.66
14	*development*	18	0.76	*village*	15	0.80	*government*	33	0.69	*rubbish*	11	0.60
15	*flooding*	17	0.71	*factory*	14	0.75	*groundwater*	33	0.69	*trees*	11	0.60
16	*crop*	16	0.67	*services*	14	0.75	*farmer*	32	0.67	*agriculture*	10	0.55
17	*people*	15	0.63	*people*	13	0.69	*pdam*	31	0.65	*government*	10	0.55
18	*government*	14	0.59	*garbage*	12	0.64	*pump*	30	0.63	*farmer*	9	0.49
19	*city*	12	0.50	*polluted*	11	0.59	*people*	28	0.59	*plant*	9	0.49
20	*drainage*	12	0.50	*wastes*	11	0.59	*farm*	26	0.55	*settlement*	9	0.49
21	*environment*	11	0.46	*land*	9	0.48	*irrigation*	26	0.55	*crop*	8	0.44
22	*metropolitan*	11	0.46	*rainfall*	9	0.48	*job*	24	0.50	*salty*	8	0.44
23	*services*	11	0.46	*smell*	9	0.48	*stone*	24	0.50	*wastes*	7	0.38
24	*Cirebon*	10	0.42	*drainage*	8	0.43	*harvest*	22	0.46	*drinking*	7	0.38
25	*green*	10	0.42	*government*	8	0.43	*polluted*	20	0.42	*job*	7	0.38

Note: pdam refers to the public drinking water services owned by the local governments; stone refers to the activities of natural stone industries in the Bobos

Water insecurity is increasing in the CMR with an increasing gap between water supply and demand, particularly in the UPT and peri-urban areas. This is due to insufficient urban planning and adaptation efforts to manage the ecohydrological changes (Danielaini et al., 2019a, Danielaini et al., 2019b). The results verify that changes in ecohydrological landscapes from urbanisation and deforestation exacerbate concerns about water security issues in the peri-urban communities more than in urban communities (Danielaini et al., 2019c). The most vulnerable area for water security and liveability issues in the CMR is located in the Cirebon District (CR). One of the main concerns of peri-urban communities is river water pollution due to the activities of natural stone industries in Bobos, CR affecting their health and rice production (Plate 16).

PLATE 16. RIVER WATER POLLUTION DUE TO THE NATURAL STONE INDUSTRIES IN BOBOS

Water security risks in the CMR, as identified in this study, are framed by water supply and demand imbalances in quantity and quality, water pollution, climate variability, flood and drought events, and reliability of water supply and sanitation services. The survey and interview results from urban and peri-urban communities in this study found that the root causes of socio-ecohydrological issues which shape water security and therefore liveability in the CMR include institutional, biophysical, socio-cultural, and technical constraints (Figure 51).

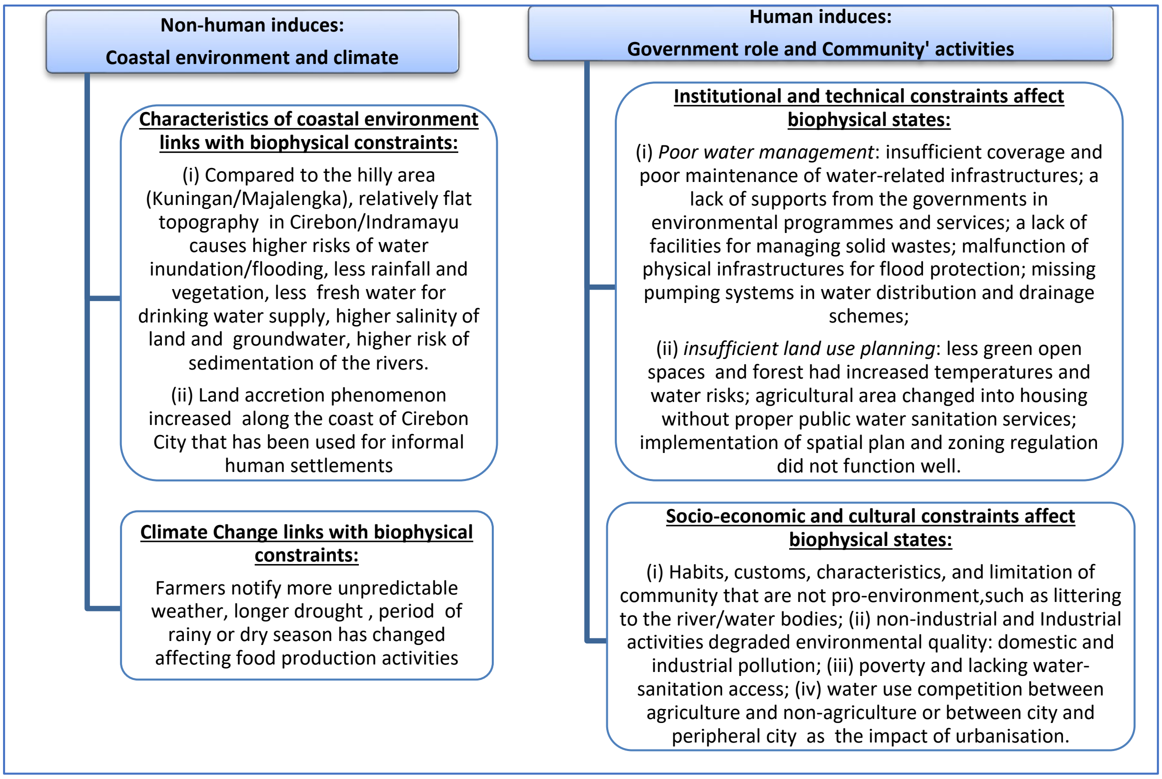


FIGURE 51. THE ROOT CAUSES OF SOCIO-ECOHYDROLOGICAL ISSUES IN THE CMR

Socio-ecohydrological issues in the CMR encompass broader socio-political dimensions as water systems in the region are managed by multi-level government institutions. These socio-ecohydrological issues also have multi-level and dimensional effects on individuals, households, communities, and systems. For instance, flood and drought issues in the region have caused frequent crop failure thereby decreasing the income of peri-urban farmers in the CMR. This can then cause mobility/migration to other regions and even other countries to find a better livelihood (Danielaini et al., 2018c, Danielaini et al., 2019b). Migration to other places to find a better livelihood is traditionally considered a coping strategy in the face of unexpected crises (Basu et al., 2015). It also shows individuals' resilience via their ability to build and increase their own capacity for learning and adaptation to environmental change (Wardekker et al., 2010).

This study found water use conflicts between urban and peri-urban communities. To meet existing urban water needs, urban CMR largely depended on water resources supplied from Kuningan. The Local Governments of CM and KR signed a Memorandum of Understanding in 2004 that the City/CM, would allocate a budget to compensate KR for maintaining spring water quantity and quality (Hendrayanto and Soedomo, 2013). It is not surprising that the communities surrounding the source of the spring water transmitted and distributed to the city perceived an increase in green open spaces/forest availability. However, they were concerned that the transmission pipes for distributing the spring water to the city had been replaced by bigger pipes. The debit flow of water to the city thus increased from around 33 Litres per second (L/s) in 1930 to currently more than 1000 L/s (Danielaini et al., 2019c).

Different water requirements and local conditions in the CMR encompass the availability and accessibility to available water resources or infrastructures; capability of drinking, irrigation, drainage water systems to provide reliable water and sufficient environmental protection and resilience within the community to deal with water and environmental changes (Figure 52).

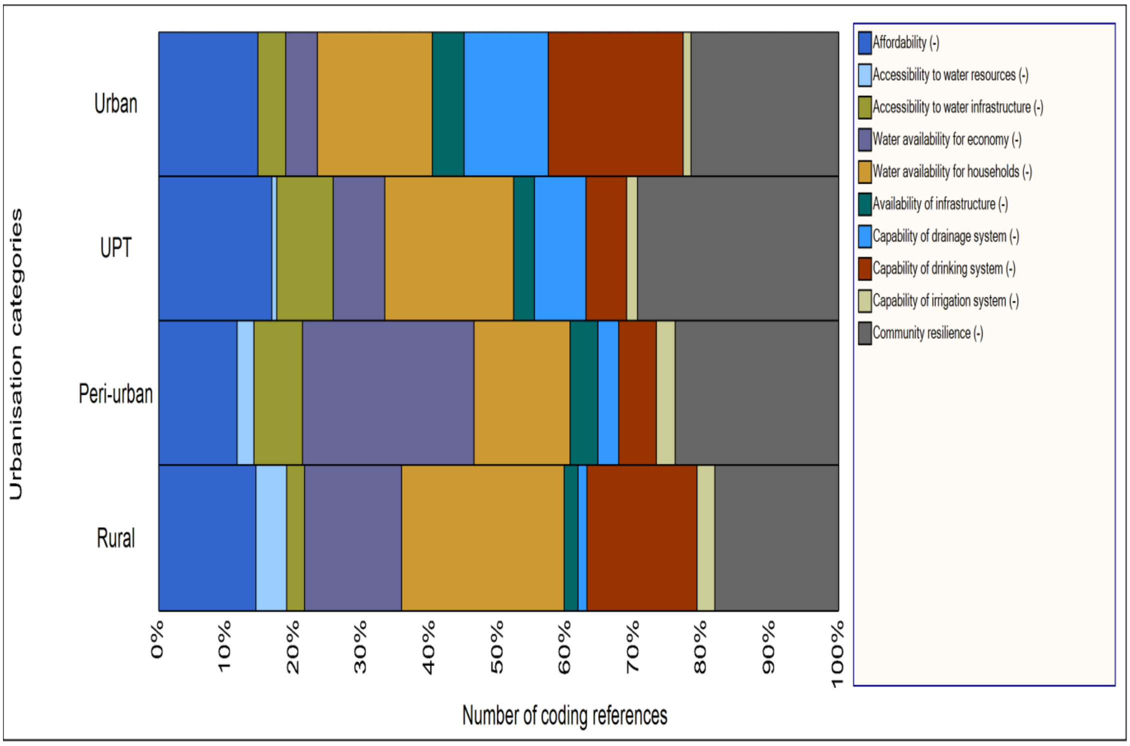


FIGURE 52. WATER (IN) SECURITY NATURE IN THE CMR

Water service coverage varies across the CMR. Comparing the coverage of the drinking water system to each political boundary of the five districts, only CM has service coverage of more than 80% while the other four districts have less than 25% (WJP-MDM, 2013b). CM is one of the smallest cities in Indonesia with a total area only 3,736 ha. It is also one of twelve cities in Indonesia with a form sewerage system (Prihandrijanti and Firdayati, 2011), with four waste water treatment plant (WWTP) facilities or piped sewerage systems, namely Kesenden, Ade Irma, Perumnas Utara, and Perumnas Selatan. However, the sewerage system services only cover approximately 15% of CM (Hendrawan et al., 2013). Within the CMR, the service coverage is less than 5% while on-site systems using septic tanks are less than 50%. The limited coverage of domestic wastewater treatment system services in the CMR, thus, does not prevent the discharge of domestic wastewater into the river and water bodies.

The existing urban water system in the CM to satisfy household water demand is under increased pressure from urbanisation and population growth and more reliable water resources are needed. Reliability refers to how water systems can minimise operation failure and work within acceptable levels to deliver satisfactory services in quantity and quality (Butler et al., 2017, Loucks, 1997). While the majority of urban communities do not have concerns with water accessibility, they are concerned about the increasing occurrences of the water supply not servicing their households (Danielaini et al., 2019a). In contrast, the existing water systems in communities in the coastal peri-urban CMR that source polluted river water face issues around water capability and reliability to satisfy household water demand as the water supply is decreasing in quality (Danielaini et al., 2018c). This situation was found in the Kapetakan Sub-District, CR. Water security issues are even worse in the peri-urban CMR which is lacking water resources availability and missing technological interventions. This situation was found in the Slangit-Klangenan Sub-District, CR.

To help address water security issues and manage supply in the CMR, the Indonesian government has constructed the Jatigede Dam and Reservoir on the Cimanuk River, which outside the boundary of CMR. Within the Cimanuk-Cisanggarung River Basin (CCRB), the Cimanuk watershed has the highest amount of water resource availability, with 7.43 billion m^3/year of surface water and 0.47 billion m^3/year of groundwater (Sukardi et al., 2013). Constructing dams and reservoirs is one water supply management strategy at basin level that aims to maintain sustainable water use and improve water availability in the dry season, reduce the effect of drought events in the lower parts of the river, and solve water security issues in the CMR (Deltares et al., 2012). However, some social resistance to the dam arose from communities in Sumedang. These communities are outside the boundary of CMR but were directly impacted by the reservoir construction through resettlements, displacement, insufficient compensation, and adverse environmental impacts. While constructing more dams and water reservoirs can overcome drought and water scarcity in a dry season, specific measures need to be taken in other areas to overcome multi-dimensional water security issues.

Based on the interviews with key informants of local, regional, and river basin planning and management, this study identified environmental planning and management (EPM), policies and governance (PG), and financing (FC) as dominant socio-ecohydrological issues and challenges to achieving sustainability objectives towards BUD. Environmental issues and challenges, water security issues, water use and social conflicts, land use planning and management, dealing with the trade-off or nexus issues and challenges, and budget and financial capacity fall under these three areas (Table 41). The challenge of working across these areas remains a key challenge in achieving BUD. Ecosystem services and environmental problems thus tend to be neglected in urban systems and elsewhere: while ES are taking place beyond the urban boundary, the benefits of ES typically cross administrative and sectoral boundaries, making ES even more challenging to be regulated and managed by public agencies (McGranahan et al., 2005).

Fragmented approaches to planning and policy implementation further compound the emergence of effective environmental governance and is a common issue in developing and emerging countries (Kurian and Ardakanian, 2015). Although the multi-level governments in this study had invested heavily in the construction of infrastructures including dams, reservoirs, drinking water and sanitation infrastructures, and irrigation schemes, the service delivery parameters such as quality, reliability, and affordability had until recently, been overlooked by existing planning processes and structures. This included little discussion of operational and maintenance costs, spatial and temporal variations in biophysical environments and socio-economic changes within communities as resource users. This lack of information meant decision makers were incapable of responding effectively to the effects of the increasing variability in floods and droughts in the CMR. These are also governance challenges for the water-energy-food nexus (Scott et al., 2015).

Most of the key informants reported the need for transboundary (across districts/watersheds), multi-sector, and multi-level or scalar approaches for enhancing environmental planning and management and for enhancing collaboration and synergy to achieve BUD. However, integrated governance as a basis for implementing and managing water security, liveability concerning health, and socio-ecohydrological systems as strategies towards BUD has, until recently, been missing. For successful planning and management, flexible institutions and organisations that monitor, interpret, and shape ecohydrological change are required. This includes developing a proper coping capability to secure wider social acceptance of the measures, arrangements for resolution of disputes, and attention to existing nestedness in catchments and ecosystems (Falkenmark and Folke, 2002). It is also critical to explore a range of governance considerations concerning different levels of authority, multiple actors, and different sectors within watersheds and socio-ecohydrological systems (Parkes et al., 2010).

TABLE 41. SUMMARY OF SOCIO-ECOHYDROLOGICAL GOVERNANCE ISSUES, CHALLENGES, OPTIONS AND STRATEGIES FOR SUSTAINABILITY OBJECTIVES CONCERNING BUD

Planning and Management for SDGs	**Problems in enhancing sustainability of water resources and uses** *(Responses of ≥ 50% participants, ranked from highest to lowest responses)*	**Issues and Challenges for achieving BUD** *(Responses of ≥ 50% participants, ranked from highest to lowest responses)*	**Options and strategies for achieving BUD** *(Responses of ≥ 50% participants, ranked from highest to lowest responses)*
River Basin Scale	PG (governance operational efficiency), EPM (approach in planning and management), ICC (synergy and collaboration), SE (mindset, cultural, behaviour of communities)	EPM (water resources planning and management, implementation, environmental issues and challenges, water security issues, land resource planning and management, issues and challenges in the approach in planning and management, monitoring and evaluation), PG (water use and social conflicts, local and regional economic development, regulation concerning water sources in terms of quantity, quality, and continuity, regulation concerning land uses), ICC (collaboration; synergy; education, training, and dissemination), SE (mindset, cultural, behaviour of communities; cultural preservation), I (infrastructure development issues), IS (approach in planning and management)	EPM (Transboundary approach; multi-sector and multi-level or scalar approach), ICC (collaboration and synergy; increase learning capacity), PG (adaptive and reliable legal framework for regulation, incentive-disincentive, political will and leadership)
Regional Scale	1. PG (adaptation and reliable legal frameworks for implementation; governance operational efficiency), EPM (land, water, approach in planning and management), SE (mindset, cultural, behaviour of communities) 2. I (social resistance), ICC (synergy)	EPM (environmental issues and challenges), PG (water use and social conflicts), SE (mindset, cultural, behaviour of communities)	EPM (Integrated approach; transboundary approach; multi-sector and multi-level or scalar approach), PG (incentive-disincentive, adaptive and reliable legal frameworks for regulation)
Local Scale	1. PG (dealing with trade-off/nexus challenges) 2. FC (budget and financial capacity) 3. EPM (land), I (intervention capability of water and sanitation infrastructures) 4. SE (mindset, cultural, behaviour of communities)	EPM (environmental issues and challenges, water security issues, implementation, land resource planning and management, issues and challenges in the approach in planning and management), ICC (collaboration and synergy), I (infrastructure for drinking water and sanitation), SE (mindset, cultural, behaviour of communities)	EPM (Transboundary approach), ICC (collaboration and synergy)
SDG 11	1. PG (adaptation and reliable legal frameworks for implementation), EPM (land) 2. I (intervention capability of water and sanitation infrastructures) 3. FC (budget and financial capacity)	EPM (environmental issues and challenges, water security issues, implementation, land resource planning and management, issues and challenges in the approach in planning and management), PG (local and regional economic development, water use and social conflicts), SE (mindset, cultural, behaviour of communities)	EPM (Transboundary approach), ICC (collaboration and synergy
SDG 6	1. PG (dealing with trade-off/nexus challenges) 2. EPM (approach in planning and management), FC (budget and financial capacity)	EPM (environmental issues and challenges, water security issues, implementation), PG (water use and social conflicts, governance operational efficiency), ICC (collaboration), SE (mindset, cultural, behaviour of communities), I (infrastructure for drinking water and sanitation)	EPM (Transboundary approach)
SDG 2	1. EPM (land), ICC (*synergy*) 2. PG (dealing with trade-off/nexus challenges, local economic development), SE (mindset, cultural, behaviour of communities) 3. I (intervention capability of water and sanitation infrastructures), FC (budget and financial capacity)	EPM (environmental issues and challenges, water security, land resource planning and management, issues and challenges in the approach in planning and management), PG (water use and social conflicts, regulation concerning land uses, local and regional economic development, limited institutional capacity in management), SE (mindset, cultural, behaviour of communities; cultural preservation), ICC (collaboration and synergy), IS (cluster-based economy for food production, industry, and water conservation vs sporadic economy that is vulnerable to change, innovation in food production, and approach in planning and management) , I (infrastructure for livelihood)	ICC (collaboration and synergy; regular reliable data and information resources), EPM (Transboundary approach; multi-sector and multi-level or scalar approach), PG (adaptive and reliable legal frameworks for regulation)
SDG 13	1. FC (budget and financial capacity) 2. PG (dealing with trade-off/nexus challenges), EPM (land), I (intervention capability of water and sanitation infrastructures), SE (mindset, cultural, behaviour of communities)	EPM (environmental issues and challenges, water security issues, implementation, issues and challenges in the approach in planning and management), ICC (collaboration and synergy), SE (mindset, cultural, behaviour of communities), I (infrastructure for drinking water and sanitation, infrastructure for the environment), PG (limited institutional capacity in management), FC (budget or financial capacity in Cirebon Municipality)	EPM (Transboundary approach; integrated approach; multi-sector and multi-level or scalar approach), ICC (collaboration and synergy; increase learning capacity)

Note: EPM=Environmental Planning and Management; PG=Policies and Governance; ICC=Information, Communication, and Collaboration; SE=Sociocultural Environment; I=Infrastructure, FC=Financing; IS=Innovation and Services, HAC=Household Adaptive Capacity

Financing is a major consideration in promoting BUD, with finance being one of the main problems in enhancing socio-ecohydrology to achieve SDGs 2, 6, 11, and 13. This highlights that socio-ecohydrological systems thinking (SEHS) needs to be more than including the impact of people and biophysics on water budgets (Pataki et al., 2011). Rather, SEHS should be considered as a method of designing desirable social and ecohydrological outcomes in water security, food security, liveability, and sustainability towards BUD. This includes finding a compromise, where necessary, among SDGs by minimising the gaps between the expectations and demands of urban and peri-urban communities for resources security, liveability, sustainability, and the performance and supply of ES, US, PS, and HS for BUD.

9.4.5 Systems thinking for BUD

This study proposes that sustainable future for urban development depends fundamentally on the capability to minimise avoidable problems such as incautious land use, changes, pollution, and erosion and to manage the trade-offs between different interests and stakeholders, especially in the case of unavoidable problems such as consumptive water use. Falkenmark (2007) also highlights these areas as critical challenges of ecosystem governance. In the urban systems, complex socio-ecohydrological systems are evident at different levels. Based on research findings in the previous four sections, the interconnection between people, water, and land and the eight key aspects of BUD, can be depicted as a social-ecological-hydrological-infrastructural system (Figure 53). These research findings thus assert the need for implementing transboundary, multi-sectoral, multi-scalar, socio-ecological-hydrological and infrastructural systems with diverse actors, priorities, and solutions in the urban systems to advance BUD.

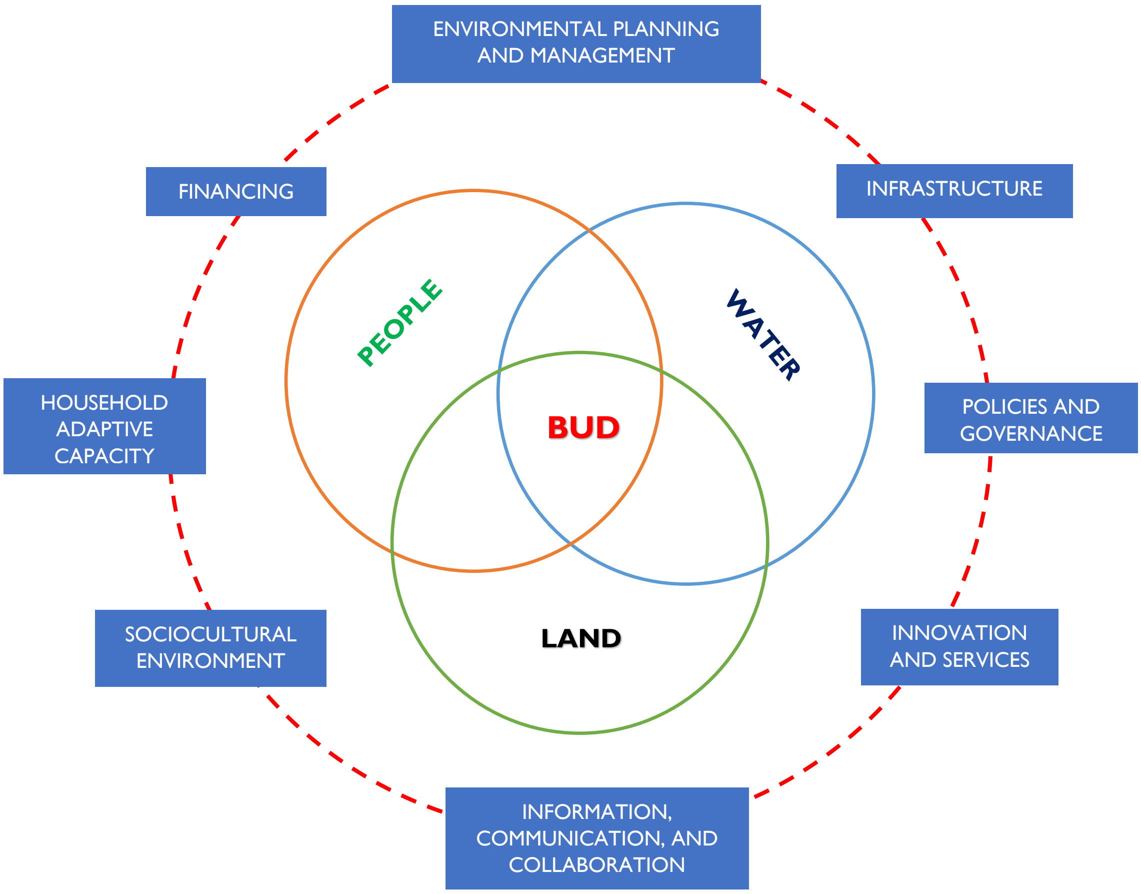


Figure 53. Social- ecological-hydrological-infrastructural systems for achieving BUD

Systems theory highlights the need for understanding inter-dependence and inter-connectedness of social and biophysical systems (Scott et al., 2015). In developing socio-ecohydrological systems (SEHS) thinking as an analytical framework to explore water security, liveability, and sustainability in the CMR, this study has identified the complexity and uncertainty involved in achieving BUD. It has also identified linkages between urban and peri-urban communities, urban and peri-urban ecosystems, and cross-scale institutions. In this case, SEHS thinking can be used for the analysis of water security (Danielaini et al., 2019a), liveability (Danielaini et al., 2018c, Danielaini et al., 2019c), and their nexus with food security and sustainability (Danielaini et al., 2019b), and also for the synthesis of BUD. As argued by Barton and Haslett (2007), systems thinking involves both analysis and synthesis; while analysis provides explanations of how things work, synthesis provides understanding of purpose by putting things into context.

Developing a clear understanding of the complexity of socio-ecohydrological systems may enhance information, communication, and collaboration between multi-level government institutions and universities. This, in turn, may help to develop more interdisciplinary and transdisciplinary research programmes for place-based, comparative, long-term research, to learn from existing management programs, upgrade and maintain monitoring systems, and support evidence-based policies and practices (Carpenter et al., 2009). Further, the difficulties in regulating the effects of uncertainty of socio-ecohydrological systems may be solved by establishing robust feedback circles between structural changes within communities of resource users, biophysical processes, and policy/ programme interventions (Berkes, 2002). It is, thus, necessary for policy and science communities to create and implement socio-ecohydrological systems thinking, policies to guide them, assessments to predict the consequences, and to then evaluate the outcomes of these steps to promote water security that links with food security and energy security, liveability and sustainability towards BUD.

9.5 CONCLUDING REMARKS

The analytical framework of socio-ecohydrological systems (SEHS) thinking has the potential to comprehensively examine balanced urban development (BUD) in the urban system. It may achieve this by exploring the SEHS interconnection, understanding the SEHS structure of perceptions at different scales, identifying non-linear relationship and dependencies of SEHS, and differentiating the SEHS perspectives. Local knowledge, experiences, and responses of urban/peri-urban communities and multi-level governments in the trend of ecohydrological change and impacts play a significant role in characterising multi-dimensional aspects of water security, liveability, and sustainability in the urban system. To better understand issues, challenges, options and strategies towards achieving BUD, the complexity and diversity of human values and perceptions need to be considered in developing, planning and managing SEHS. This includes the interface between people, water, land, and the infrastructures concerning ecosystem, urban, peri-urban, and human services; the interconnections between terrestrial and aquatic ecosystem services and impacts concerning effective ecosystem governance solutions; and the most influential and significant factors affecting SEHS in the rural-urban interface areas. In this study, the perception of terrestrial ecosystem services represents the changes in the ecohydrological landscapes, while the perception of aquatic ecosystem services represents the changes in river water quality in the rural-urban interface watersheds. This suggests the peri-urban watershed is a critical zone for achieving BUD, since it is the main source of ecosystem services for urban populations.

The expanding urban areas are the vulnerable areas in the CMR with water security and liveability issues. This study identified institutional, biophysical, socio-cultural, and technical constraints as the root causes of SEHS issues that shape water security and therefore liveability in the CMR. Despite the multi-level government agencies investing heavily in the construction of infrastructures in the CMR, including dams and reservoirs, drinking water and sanitation infrastructures, and irrigation schemes, the service delivery parameters such as quality, reliability, and affordability have, until recently been overlooked by existing planning processes and structures. This includes little discussion of costs related to operation and maintenance, spatial and temporal variations in biophysical environment and socio-economic change within communities as resource users, causing decision makers to be incapable of responding effectively to the effects of increased variability of SEHS issues. This study thus advocates SEHS be considered as a method of designing desirable social and ecohydrological outcomes in water security that links with food security and energy security, liveability, and sustainability towards BUD. This includes finding compromise among these SDGs by minimising the gaps between expectation and demand of urban and peri-urban communities for resources security, liveability, and sustainability, and performance and supply of ES, US, PS, and HS for BUD. For achieving BUD, this study also advocates the need for implementing transboundary, multi-sectoral, multi-scalar, socio-ecohydrological and infrastructural systems with diverse actors, priorities, and solutions in the urban systems.

PART IV
CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 10
CONCLUSIONS AND RECOMMENDATIONS

Summary

Specific conclusions of this thesis have been described at the end of chapters 3-9. This chapter describes the overall conclusions of the study summarised under key themes of urban and peri-urban ecohydrology, impacts of ecohydrological change, and balanced urban development. A number of practical implications, transfer of knowledge, limitations and recommendations for future practice and research are also provided based on this study.

10.1 URBAN AND PERI-URBAN ECOHYDROLOGY

It is evident from this study that even in a small urban region, a city has a relatively low capacity for providing ecosystem services and need peri-urban ecosystem services for enhancing urban sustainability and liveability. This study shows that the urban area has expanded bringing more human activities into the peri-urban area. This indicates more basic services for healthy housing and human settlements are required as well as more efforts for maintaining peri-urban ecosystem services. Peri-urbanisation has brought challenges for managing the water quality dynamic, particularly in the rural-urban interface watersheds. Ecohydrological consideration allows integrative and transdisciplinary frameworks for understanding the problems related to the interactions between water, people, and the environment. Socio-economic and spatial data, implying some indications of ecohydrology, can be used for defining rural-urban interface classifications including peri-urban zones that would be beneficial in the planning for developing a rural-urban strategy related to water, people, and the environment. Also, these data can be used for a better understanding of the rural-urban interface ecohydrology, including open spaces distribution, biodiversity and ecosystem services, water supply requirement, water quality risks, water management capacity, and climate change pressures. This objective was obtained through developing new indices for assessing ecohydrological potential and identifying the level of priority for management interventions for enhancing liveability and sustainability.

It is also evident from this study that ecohydrological changes resulting from urbanisation and deforestation have shaped urban and peri-urban liveability negatively due to increasing water insecurity in the region. Urbanisation has significantly affected the liveability of farmers and fishermen in the urban and UPT area as it significantly increased built-up areas, which are used for non-agricultural activities and decreased surface water quality. Deforestation significantly affected the liveability of farmers in the rural-area as it increased agricultural areas and decreased water availability. In addition, urbanisation and deforestation affected the liveability of farmers in the peri-urban area as it increased competition for water supply for urban and peri-urban activities while also decreasing water availability in terms of quality and quantity. The framework developed for assessing ecohydrological-based liveability in this study is useful for identifying the interactions of many interdependent variables and exploring the underlying principles, structures, and dynamics of ecohydrological change and impacts on liveability. This includes personal, residential, neighbourhood, regional, and watershed satisfaction factors for achieving liveability. The framework is also useful to identify inequality traps in the rural-urban interface concerning liveability. The challenge to increase the liveability of urban regions is in the UPT area. This area has been directly affected by urban expansion and is where residents have experienced the most ecohydrological changes resulting from urbanisation.

10.2 SOCIO-ECOHYDROLOGICAL FACTORS SHAPING WATER SECURITY, LIVEABILITY, AND SUSTAINABILITY

It is evident from this study that by developing socio-ecohydrological systems thinking for understanding inter-dependence and inter-connectedness of social and biophysical systems, the complexity of multidimensional socio-ecohydrological aspects underpinning water security, liveability, and sustainability can be identified. It is also evident that combining ecosystem, urban, peri-urban, and human services can illuminate, and lead to better understanding of, the dynamic interactions between environmental and individual characteristics including the trade-off among those services that influence liveability in the rural-urban interfaces. Further, it is evident that the nexus thinking approach which is rooted in holistic systems thinking provides a framework to appropriately examine the people-water-food-environment-climate nexus issues of farm and non-farm households concerning rapid urbanisation vis-à-vis nexus governance at river basin, regional, and local levels, and to recognise challenges and appropriate adaptation strategies for sustaining water security and liveability.

This study identifies the role of water security on liveability in developing countries that generally face a deficit in urban infrastructures and also in developed countries that have flood and drought concerns. The CMR faces a lack of urban infrastructures and experiences flood and drought events; water security is the most important factor for creating liveability in this developing coastal urban region. Non-physical environment relating to social relationships with family/neighbours, place attachment related to birthplace and community identity - all of which are categorised as cultural services under HS, is the most satisfied liveability aspect in the CMR. In contrast, water availability, which is categorised as provisioning services under ES, is the least satisfied liveability aspect in the CMR. Further, income and facilities and services for education, public health, and amenities in the peri-urban CMR showed lower performance and higher importance when compared to urban CMR, all of which need urgent action to achieve BUD.

This study suggests that providing access to water and sanitation infrastructures will not be sufficient to obtain household water security in the CMR. The measures should include provision of a tolerable level of water-related risk to mitigate floods and droughts, coupled with providing an acceptable level of water sources and services to the communities. This study indicates six reliable factors of socio-ecohydrological issues that shape water insecurity in the rural-urban environment of the CMR, namely droughts, flood, poor affordability, unregulated water use, and poor sanitation leading to unhealthy housing and environment. Droughts significantly affect water insecurity of rural farm and non-farm households, while flooding affects UPT farm and non-farm households. The most water insecure households were found largely in the UPT zone due to insufficient water and sanitation infrastructures to keep pace with the increase of urban population, flood events, climate change, and concern of future risks.

Furthermore, this study found that environmental planning and management; policies and governance; and financing are dominant socio-ecohydrological issues and challenges for achieving sustainability objectives towards balanced urban development in the CMR. This study also found little discussion of operational and maintenance costs, spatial and temporal variations in biophysical environments and socio-economic changes within communities as resource users. This lack of information meant decision makers were incapable of responding effectively to the effects of the increasing variability in floods and droughts in the CMR. This study indicates that although several strategies were available to enhance current regulation and policy and institutional and governance capacity, the three levels of government had difficulty in implementing the existing strategies. This included difficulties to (i) implement regulation and policy vis-à-vis integrating land use and water resource planning, adaptation and participation to establish reliable legal frameworks at more local levels, and (ii) change the mindset, culture and behaviour of communities. This failure hindered the effectiveness of water-food-people-environment-climate nexus governance.

10.3 BALANCED URBAN DEVELOPMENT

10.3.1 ISSUES AND CHALLENGES

It is evident from this study that the district government agencies responsible for local planning and management had the highest concern regarding the people-water-food-environment-climate nexus issues when compared to provincial and national government agencies responsible for regional and river basin planning and management. The highest changes in land use, water cycle and climate including increasing floods and droughts and decreasing water quality occurred in the rural-urban interface areas where local governments had limited capacity to cope with the rapid urbanisation and climate change. While the current strategy of government institutions mainly focused on enhancing infrastructures for supporting socio-economic activities in the CMR, this study found that the interface between people, water, and land in the urban system needs to be considered for achieving balanced urban development. Although the multi-level governments in this study had invested heavily in the construction of infrastructures, the service delivery parameters such as quality, reliability, and affordability had until recently, been overlooked by existing planning processes and structures. The challenge for achieving BUD is to empower communities in the peri-urban and rural areas who have the highest dependency on the government. Additionally, empower local government planners and decision makers with knowledge for applying a systems thinking approach in planning and management so that they are able to handle connected issues, understand complex systems with many stakeholders and their varying interests and understand the dynamism and scale of urbanisation.

10.3.2 OPTIONS AND STRATEGIES

While this research focuses specifically on CMR, the findings are relevant to other urbanising coastal regions with similar socio-economic conditions, as they are likely to face similar challenges. This study indicates that considering beneficiary perspectives would be helpful for developing more effective strategies to accommodate inequality traps in the rural-urban interface and to enhance communities' awareness of their environment. People's participation in managing resource sustainably at the local level is important for reaching the global goal of sustainable development. This study also indicates that considering multi-level government perspectives concerning balanced urban development would be helpful for developing options and strategies of cross-scale institutional planning and management in dealing with the changes in land use, water cycle, and climate for achieving water security, liveability, and sustainability. For successful planning and management, flexible institutions and organisations that monitor, interpret, and shape ecohydrological change are required including the development of a proper coping capability in securing social acceptance of measures, arrangements for resolution of disputes, and attention to existing nestedness in catchments and ecosystems. It is also critical to explore a range of governance consideration, concerning different levels of authority, multiple actors, and different sectors within watersheds and socio-ecohydrological systems. For achieving BUD, research findings in this study suggest the need for implementing transboundary, multi-sectoral, multi-scalar, socio-ecological-hydrological and infrastructural systems with diverse actors, priorities, and solutions in urban systems to promote resource security, liveability, and sustainability.

10.4 PRACTICAL APPLICATIONS AND TRANSFER OF KNOWLEDGE

10.4.1 KEY LESSONS FOR URBAN PLANNERS AND WATER MANAGERS

There are two key findings for urban planners or water managers who may be interested in practical application of this research in the study area:

Stakeholder Engagement

This study indicates that solving water and land resources conflicts by understanding land suitability and land uses, strengthening community participation in management of natural resources, and enhancing the collaboration of government institutions in planning and management of water and land resources would address problems concerning water security. The development of the community of interests and institutions in which authority being shared by external and internal actors is further required due to two facts: (i) water in the study area, CCRB, is a transboundary natural resource in its reach, uses, and implications across eight districts and two provinces and (ii) land in the study area, CMR, is a political boundary natural resource within five districts and one province. These approaches can be promoted by customary law for shared natural resources, facilitated by provincial and central government agencies, implemented by local government agencies, and supported by local communities in the whole basin.

As identified in this study, the water future of the CMR depends on both external drivers and internal changes in the demographic and socio-economic setting of the CCRB. This puts pressure on the key actors, the CM Government that should take simultaneous actions by engaging into active dialogue with its district neighbours and its upstream neighbours to support urban development and the regional processes of Cirebon Metropolis. At a national level, the BBWS that manages the CCRB already incorporates the interests of the Central and Provincial Governments in the CCRB development for constructing Jatigede Dam and Reservoir that will directly impact districts in the CCRB including five districts within CMR. The benefits of Jatigede Reservoir cover water security, food security, and energy security. Regardless of this progress, urban planners and water managers should prepare further measures to reduce water and land use conflicts among stakeholders in the affected districts that need more cooperation and negotiations.

Currently, several negotiations exist in the CMR concerning local, regional, and inter-regional developments. This includes a cooperation agreement between CM and KR concerning water security, a cooperation agreement between CR, MR, and IR concerning water and food security, and KUNCI BERSAMA, inter-regional cooperation agreement involving nine districts in the Province of West Java and Central Java, namely CM, CR, KR, MR, Brebes, Banjar, Ciamis, Cilacap, and Pangandaran concerning border area development focusing on infrastructure. Despite these policy commitments, as identified in this study, inequality persists and large disparities remain regarding access to natural resources, employment, health, and education within five districts in the CMR affecting liveability, and regarding the capacity of local government to deliver liveability services for obtaining sustainability. This suggests the need of government policy makers, supported by urban planners and water managers at local-regional-river basin levels, to align its policies with its people, to ensure these policies meet the expectations of local communities, and to enhance collaboration in planning and management of water and land resources.

In summary, two important actions that can be implemented for stakeholder engagement are: (i) strengthening cooperation and negotiations among stakeholders to minimise water and land use conflicts and (ii) enhancing collaboration in planning and management of water and land resources to achieve water security, liveability, and sustainability.

Urban and Peri-urban Environmental Planning and Management for Obtaining BUD

This study finds that water is a key aspect for obtaining a liveable place in the urban and peri-urban CMR because of three reasons: (i) water is a key input for economic productivity in agriculture, industry, and households; (ii) water is a basic need for living healthy; (iii) water helps to reduce urban heat island, sustain playing fields and parks, create green and blue spaces. Concerns in less water affecting economic productivity and health were obtained mostly from peri-urban residents while concerns in less green open spaces affecting air temperature were obtained mostly from urban residents. While urban residents were mostly satisfied with drought prevention, water sanitation infrastructures, income, and flood protection, peri-urban residents were mostly dissatisfied with those aspects. In general, this study finds that rising urban population in the peri-urban area pressures on basic services, infrastructure, land, and the environment which undermine the liveability of peri-urban area. This suggests the need to improve peri-urban planning and management concerning urbanisation.

For improving the liveability of urban and peri-urban CMR, the results of this study suggest that the urban planners of CM Government and the water managers of CR Government should incorporate the expectation of urban and peri-urban residents in planning and management to increase the proportion of green open spaces and to improve the accessibility of water infrastructures. The urban planners and water managers of CM and CR Governments need to be concerned about the impacts of urban expansion surrounding the border area between CM and CR. To cope with the increase of urban population in the peri-urban area, the CM and CR governments should improve access of peri-urban communities to basic services, new livelihood, health and education. As identified in this study, these liveability services showed lower performance and higher importance in the peri-urban CMR that need urgent action to achieve BUD. In terms of livelihood, suitable interventions are needed to improve job availability in the peri-urban area because available jobs for working in the agricultural sector in the peri-urban area were affected by urbanisation and climate change.

This study indicates the importance of defining peri-urban ecohydrology in environmental planning and management for understanding the interface between water, land and people in the selected metropolitan region and for developing a rural-urban strategy related to water, land, and people for achieving BUD. This study recognises that the existing rural-urban dichotomy that is deeply rooted in planning systems is insufficient for dealing with the changes in land use and water cycle resulting from urbanisation and climate change in the peri-urban context. This study identifies that managing the peri-urban environment has significant impacts for obtaining water security, liveability and sustainability of urban and rural development. Hence, for sustaining water security and liveability in the study area, urban planners at district and provincial levels should make sure to incorporate wider social and environmental objectives in district and metropolitan spatial plans.

Water managers at regional and river basin levels should make sure that basin plans are based on existing regional strategic plans (provincial and district development plans, spatial plans), catchment conservation plans, and many sectoral plans such as agriculture and energy. Water managers at a river basin level should make sure that the implementation of basin plans should support (i) the expectation of local communities regarding water security and liveability and (ii) the expectation of district and provincial governments regarding sustainability.

10.4.2 Transferable knowledge to another city in another country

Peri-urban areas in this study particularly faced wider issues of poverty, inequality in accessing resources, services, and infrastructures, and policy choices such as the dichotomous nature of urban and rural governance, planning, and development. This study found that the district government agencies responsible for local planning and management had the highest concern about the people-water-food-environment-climate nexus issues. The five district governments within CMR are at the forefront of dealing with climate change impacts that are local and are responsible for incorporating existing individual and household adaptation strategies into local development planning priorities. However, the fact that increasing floods and droughts occurred in the rural/urban interface areas and that district governments had limited capacity to cope with the rapid urbanisation and climate change suggests the need for implementing multi-level governance with adequate cross-sectoral and cross-level coordination. This includes mainstreaming climate change adaptation at the regional and river basin levels to assist cross-border district and transboundary watersheds adaptation strategies.

This study indicates that water and land resources are politically sensitive in the study area as in many areas worldwide. This calls innovative strategies from governments in approaching environmental planning and management (i) to improve sustainable use of natural resources, (ii) to enhance multi-stakeholder participation, (iii) to address the root cause in power, poverty and inequality and (iv) to deal with the uncertainty and direct/indirect impacts of climate variability and change. This study finds that local governments need to develop innovation ways to strengthen the financing capacity and to improve district land water management. This includes to increase their revenue base and to promote public investments in basic infrastructures. Functional cooperation agreements on the use of transboundary water were also found being critical to the sustainable socio-economic development of the city and its neighbours. Such collaboration can take place around financing, implementation, monitoring and evaluation, and knowledge generation that can help to realise any opportunities arising from urbanisation and climate change as well as to address the risks.

This study identifies that the issues in water security, liveability, and sustainability in the CMR are basically related to the overarching issues of rapidly growing cities in developing countries. These include the lack of response in planning and management to overcome the challenges of rapid population growth, urbanisation, transboundary resource management, socio-economic disparity across rural-urban communities, power inequality across local districts, and the influence of climate variability and change. Moreover, cities in low-income and lower middle-income economies in Asia and Africa face specific problems such as a lack of access to quality water, sanitation and electricity; a lack of systematic urban planning; a lack of institutional capacities, and poor governance. To overcome these problems, multi-stakeholder processes are required from initially focusing on immediate issues of concern, short-term action associated with the provision of basic infrastructures, to long-term vision focusing on promoting sustainable linkages between rural and urban areas.

This study identifies the interconnections between people, water, land, and the key aspects of balanced urban development (BUD), namely i) environmental planning and management; (ii) infrastructure; (iii) policies and governance; (iv) innovation and services; (v) information, communication, and collaboration; (vi) sociocultural environment; (vii) household adaptive capacity; and (viii) financing. This study finds that environmental planning and management, policies and governance, and financing are dominant socio-ecohydrological issues and challenges to achieving sustainability objectives towards BUD in the CMR. These findings may represent socio-ecohydrological issues of many rapidly developing coastal metropolitan regions which the characteristics are similar to the study area. This study also provides a new approach in the analysis of peri-urban interface focusing on the improvement of regional environment to achieve BUD which is transferable to another metropolitan region in another country with the characteristic of social, economy, and the environmental are similar to the CMR in Indonesia. The analysis includes rural and urban environments to address a broader process of socio-ecohydrological change affecting the peri-urban water security and liveability and their nexus in the context of regional sustainability.

In summary, three aspects of transferable knowledge from this study to another city in another country are: (i) content knowledge in the overarching issues of a rapidly growing city in a developing country concerning water security, liveability, and sustainability; (ii) procedural knowledge of how to answer questions and solve problems concerning water security, liveability, and sustainability; and (iii)evidence-based knowledge in understanding the nexus of people, water, land and the key aspects required to promote balanced urban development.

10.5 LIMITATIONS OF CURRENT WORK AND RECOMMENDATIONS FOR FUTURE PRACTICE AND RESEARCH

10.5.1 LIMITATIONS OF THE RESEARCH

There are four key limitations of the research reported in this thesis that need to be considered for further research:

First, This study integrates insights about the complex behaviour of socio-ecohydrological systems within one urban system and uses several frameworks for analysis. However, the problems of a mismatched world view may arise and different characteristics of socio-ecohydrological systems would be varied among different urban regions. These may bring difficulties for the novice researchers in (i) integrating different philosophical perspectives; (ii) integrating findings from different disciplines; and (iii) integrating the case-specific knowledge in theory and practice that may help urban planners and water managers for solving problems related to water security, liveability, and sustainability beyond municipal boundaries. This limitation is particularly true when the researchers have to conduct research alone; they have to work with people from government institutions or communities in finding the connection between people, water and land; and they have to work outside of their typical methods and use multiple methods in addressing complex and multi-faceted issues.

Second, the investigation of urban and peri-urban liveability used a mixed method approach that allows multiple methods to address complex research problems. Qualitative data analysis is able to maximise the opportunity to obtain high quality and detailed datasets for understanding liveability within a socio-ecohydrological context. However, it is very costly and time consuming. In contrast, quantitative data analysis is relatively easier, lower in cost, and faster in terms of data collection and analysis and being able to obtain generalised datasets. However, the indicators representing dynamic interactions between biophysical and socio-economic sub-systems should be carefully selected to minimise over generalisation or simplification in the results and analysis.

Third, the investigation of factors affecting urban and peri-urban household water insecurity used two approaches, a Guttman scaling model and factor analysis. The first approach is applied using four assumption group factors, namely access, acceptability, capability and adaptive capacity. The result shows the limitation in the coefficients of reproducibility and scalability of factors, acceptability and adaptive capacity, that were below the acceptable range. Application of this scalograms analysis under different socio-cultures within diverse complex rural/urban communities might be the cause of this limitation. The second approach is applied without assumption group of factors. This exploratory factor analysis is useful to find the numbers of common factors from the survey data. The result shows that there were 12 underlying socio-ecohydrological aspects contributing to household water insecurity in the selected region. However, only six factors were reliable contributing to water insecurity in the metropolitan region, namely drought, unhealthy housing and environment, unregulated water use, flood, poor affordability, and poor sanitation. This result shows the limitation in the scale of reliability of the other six factors, namely limited access, water affect issue, water resources issue, climate change, concern of future risks and poverty. Diverse complex socio-ecohydrological systems in one metropolitan region might be the cause of low lambda 2 scores for these factors.

Four, this study used nexus thinking approach for understanding the interconnections between people, water, food, the environment and climate including nexus governance at the river basin, regional, and local scales concerning sustainability and used socio-ecohydrological systems thinking approach for synthesising the ideas of water security, liveability and sustainability in the context of balanced urban development. These approaches are useful to recognise challenges and appropriate adaptation strategies and to understand the complexity and uncertainty involved for achieving sustainability objectives. However, this study may suffer from the impact of a strong regional focus that the results cannot be generalised to other regions. Combining qualitative and quantitative data collection and analysis in this study is also a time-consuming process. Besides, it takes time for the novice researchers to be familiar with the concepts and tools of nexus/systems thinking approaches.

10.5.2 RECOMMENDATIONS FOR FUTURE PRACTICE AND RESEARCH

It is evident from this study that it is impossible for the city to undertake climate change adaptation and efforts in sustaining water security and liveability without the involvement of other authorities in surrounding areas and support from higher level governments. Continued changes in land use, water cycle and climate resulting from urbanisation and climate change are likely to pose complex challenges to local government in achieving sustainable urban development objectives, particularly to city and peripheral city planners and water managers in developing countries. For future practice, this study suggests the need for city planners to develop strategies whereby peri-urban communities can adapt to future changes in land use, water cycle and climate to promote their liveability and sustainability. Special attention in development planning and management should thus be given to the transitional zones between rural and urban administrations. This includes the need for water managers to implement multi-level governance with adequate cross-sectoral and cross-scale coordination including to mainstream climate change adaptation at regional and river basin scales to assist cross-border district and transboundary watersheds adaptation strategies. Mainstreaming multi-level nexus governance in the metropolitan regional development would be the key for managing the risk of resource use trade-offs among water and food sectors that could undermine water security targets for households and economy and therefore affecting urban and peri-urban liveability. This includes strengthening the capacity of urban and peri-urban communities and local government institutions to cope with and recover from the impacts of increasing flood and drought events, and for increasing collaboration and co-management among stakeholders.

For future research, this study suggests four significant recommendations:

First, the need for developing a clear understanding of the complexity of socio-ecohydrological systems that may enhance information, communication, and collaboration between multi-level government institutions and universities. This, in turn, may help to develop more interdisciplinary and transdisciplinary research programmes for place-based, comparative, long-term research, to learn from existing management programs, to upgrade and maintain monitoring systems, and support evidence-based policies and practices. These include integrating knowledge from scientific and non-scientific communities to deal with location-specific issues and challenges and generating new ways of thinking and new ways of responding to complex socio-ecohydrological changes in the urban systems.

Second, while the results of qualitative and quantitative data analyses in the investigation of urban and peri-urban liveability can be complementary, a more integrative study combining qualitative and quantitative data analysis and applying the same code, category, and theme for data collection and analysis may improve this mixed-method liveability study. Quantitative data analysis using Importance Performance Analysis is recommended to follow the result of qualitative data analysis using the codes and categories in four themes, namely Provisioning Services, Regulating Services, Cultural Services, and Socio-Economic Services. This may help to enrich contextual understandings of people's perceptions and experiences with regard to the 'liveability' of the urban and peri-urban environment.

Third, in situation of relatively little theoretical or empirical basis to make strong assumptions about how many common factors exist or what specific measured variables these common factors are likely to influence urban and peri-urban household water insecurity, factor analysis in this study is probably a more sensible approach than Gutmann-scaling model. However, it is essential to carefully consider sensible decisions in selecting measured variables and samples for identifying diverse factors affecting household water insecurity in one metropolitan region due to complex human-environment systems. These include (i) different experiences of householders in the access to water and sanitation infrastructures; (ii) different acceptability of householders in water risks from ecohydrological change; (iii) different capability of ecosystem and institutional services to satisfy the needs of householders for health, livelihood, ecosystem, and production; and (iv) different adaptive capacity of householders in dealing with the impacts resulting from socio- ecohydrological change. It is recommended to include at least four measured variables for each common factor that is expected to emerge because there is considerable uncertainty about the nature of the common factors and their relations to the measured variables.

Four, Concerning the application of systems thinking to practical policy issues, training in systems thinking for practitioners (e.g., urban planners, water managers, policy makers) and researchers is recommended to develop (i) more coherent strategies for achieving BUD, (ii) more effective interventions to cope with household water insecurity that affect liveability in the urban and peri-urban areas, and (iii) better analysis of systemic risk, complexity, and uncertainty regarding the impacts of urbanisation and climate change on water security, liveability, and sustainability. The training may include qualitative principles, quantitative methods, simple models, complex models and examples depending on the intended target audience. Research and collaboration between government institutions and universities on specific priority issues for obtaining BUD are required (i) to improve methodology and tools for systems analysis/modelling, (ii) to adapt the local, regional, and river basin institutions to systems thinking to meet new challenges, (iii) to apply systems-based approaches for development co-operation to meet diverse needs and aspirations; and (iv) to guide multi-stakeholder processes towards sustainable linkages between rural and urban areas.

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APPENDICES

APPENDIX 1: SUPPLEMENTAL DATA

APPENDIX 1. 1 DEFINING RURAL-URBAN INTERFACE ECOHYDROLOGY

DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2017. Defining rural–urban interfaces for understanding ecohydrological processes in West Java, Indonesia: Part I. Development of methodology to delineate peri-urban areas. Ecohydrology & Hydrobiology 18 (1):22-36. doi: 10.1016/j.ecohyd.2017.11.006.

APPENDIX 1. 2 QUANTIFYING RURAL-URBAN INTERFACE ECOHYDROLOGY

DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2017. Defining rural–urban interfaces for understanding ecohydrological processes in West Java, Indonesia: Part II. Its application to quantify rural–urban interface ecohydrology. Ecohydrology & Hydrobiology 18 (1):37-51. doi: 10.1016/j.ecohyd.2017.11.007.

Appendix 1. 3 A framework for evaluating ecohydrological-based liveability

DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2018. A framework for evaluating ecohydrological-based liveability in a rapidly urbanising region of Indonesia. International Journal of Urban Sustainable Development:1-19. doi: 10.1080/19463138.2018.1531874.

Table A.1.3.1 Summary of the sociodemographic attributes in the household survey

Attributes	Parameter	Percentage from total 430 households (%)		
		Farm (%)	Non-Farm (%)	Total (%)
Place in five districts within CMR *(political boundaries)*	CM	7.5	15.1	22.6
	CR	27.0	22.5	49.5
	IR	4.4	2.6	7.0
	KR	8.6	5.4	14.0
	MR	4.9	2.1	7.0
Level of urbanisation	Rural	10.5	6.5	17.0
	Peri-urban	27.0	15.3	42.3
	UPT	7.4	9.8	17.2
	Urban	7.4	16.1	23.5
Gender	Male	35.8	24.9	60.7
	Female	16.5	22.8	39.3
Type of settlement	Formal	0.7	8.8	9.5
	Non-Formal	51.6	38.9	90.5
Length Stay	Less than 10 years	3.0	8.9	11.9
	10 – less than 20 years	2.3	5.6	7.9
	20 – 30 years	6.5	7.5	14.0
	More than 30 years	40.5	25.5	66.0
Distance from the coast	Less than 5 km	15.8	21.4	37.2
	5 – less than 10 km	4.4	6.8	11.2
	10 – less than 15 km	16.0	9.8	25.8
	15 – less than 20 km	6.8	5.1	11.9
	More than 20 km	9.3	4.6	13.9
Household size	Less than and/or equal 3 persons	14.0	11.9	25.9
	4 – 6 persons	32.9	28.8	61.7
	More than 6 persons	5.4	7.0	12.4
Total		**52.3**	**47.7**	

Table A.1.3.2 Reliability coefficient of the questionnaire in the urban-rural continuum of CMR

Group to Measure	Attributes of Importance			**Attributes of Satisfaction**		
	Cronbach's Alpha	Highest Cronbach's Alpha if one Item Deleted	One Item deleted	Cronbach's Alpha	Highest Cronbach's Alpha if one Item Deleted	One Item deleted
Urban (N=101)	0.72	0.73	Drought prevention	0.81	0.82	Mobility
UPT (N=74)	0.68	0.70	Well-maintained river	0.75	0.75	Mobility
Peri-urban (N=182)	0.71	0.72	Flood protection	0.79	0.79	Mobility
Rural (N=73)	0.76	0.76	Employment	0.83	0.84	Mobility
CMR (N=430)	0.74	0.74	Mobility	0.80	0.81	Mobility

Table A.1.3.3 Satisfaction structure and composite index of ecohydrological satisfaction-based liveability within CMR

Principal Components	Cronbach's Alpha	Variance Accounted For (VAF) Total Eigenvalue	% of variance	Satisfaction to ecohydrology related services	Satisfaction Factors (Principal Components) 1	2	3	4	5
Overall participants (n=430, valid cases 392, Expectation maximization imputation)					*Residential*	*Watershed*	*Personal*	*Regional*	*Neighbourhood*
1	0.75	2.77	18.45%	Sufficient water availability	0.18	**0.83**	0.06	0.01	-0.22
2	0.66	1.99	13.25%	Well-maintained river	**0.47**	0.22	-0.07	-0.07	0.37
3	0.64	1.81	12.07%	Green open spaces in the public area	**0.66**	-0.06	0.18	-0.26	0.10
4	0.42	1.54	10.24%	Housing with garden spaces	**0.69**	0.07	0.32	-0.22	-0.04
5	0.52	1.38	9.17%	Healthy housing	**0.80**	0.16	0.16	0.16	0.10
Total	**0.96***	**9.48**	**63.19%**	Healthy human settlement	**0.81**	0.11	0.08	0.17	0.09
				Healthy waterways	0.44	0.16	-0.02	0.36	**0.50**
				Facilities and services for education, public health, amenities	0.09	0.07	0.05	**0.77**	-0.14
				Flood protection	0.11	0.08	0.17	-0.07	**0.85**
KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within CMR= 0.75; Bartlett's Test of Sphericity: Approx. Chi-square = 1826.21; df = 105; Sig. 0.000 (p<0.001)				Drought prevention	0.04	**0.75**	0.19	-0.04	0.29
				Housing affordability	0.20	0.11	**0.63**	-0.07	0.01
				Employment	0.16	0.01	**0.71**	0.19	0.15
				Mobility	-0.15	0.01	0.12	**0.74**	0.12
				Income	0.05	0.24	**0.79**	0.09	0.01
				water and sanitation infrastructure/ waste water treatment	0.09	**0.73**	0.18	0.19	0.22
Index of each satisfaction factor (scale 0-100)					**63.1**	**59.9**	**49.2**	**28.6**	**56.2**
Index of ecohydrological satisfaction based-liveability using weighted method CATPCA/FA and public opinion (scale 0-100)							**59.7 and 56.6**		

**Total Cronbach's Alpha is based on the total Eigenvalue; Model summary of satisfaction factors using CATPCA/FA with rotation method: Varimax; normalization method: Variable Principal*

Table A.1.3.4 Satisfaction structure and composite index of ecohydrological satisfaction-based liveability at urban CMR

Principal Components	Cronbach's Alpha	Variance Accounted For (VAF) Total Eigenvalue	% of variance	Satisfaction to ecohydrology related services	Satisfaction Factors (Principal Components) 1	2	3	4	5
Urban participants (n=101, valid cases 99, Expectation-maximization imputation)					*Residential*	*Neighbourhood*	*Personal*	*Regional*	*Watershed*
1	0.69	2.69	17.94	Sufficient water availability	0.03	-0.05	0.17	0.03	**0.83**
2	0.72	2.64	17.59	Well-maintained river	0.12	0.31	-0.10	**-0.51**	0.39
3	0.61	2.00	13.34	Green open spaces in the public area	0.01	**0.72**	-0.14	-0.33	0.04
4	0.55	1.95	12.99	Housing with garden spaces	**0.97**	0.05	0.05	-0.01	-0.07
5	0.63	1.78	11.85	Healthy housing	0.18	**0.62**	0.45	-0.17	0.34
Total	**0.98***	**11.06**	**73.71**	Healthy human settlement	0.15	**0.56**	0.40	-0.28	0.32
				Healthy waterways	0.10	**0.62**	0.31	0.09	0.14
				Facilities and services for education, public health, amenities	0.06	-0.19	0.07	**0.80**	0.07
				Flood protection	-0.08	**0.84**	-0.14	0.15	-0.02
KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within Urban CMR= 0.63; Bartlett's Test of Sphericity: Approx. Chi-square = 1095.26; df = 105; Sig.<0.001				Drought prevention	-0.02	0.39	-0.01	0.07	**0.72**
				Housing affordability	**0.97**	0.03	0.04	0.00	-0.06
				Employment	**0.84**	0.03	0.04	0.01	0.21
				Mobility	0.00	0.22	0.01	**0.88**	0.09
				Income	0.02	0.04	**0.88**	0.05	-0.12
				water and sanitation infrastructure/ waste water treatment	0.06	-0.02	**0.82**	0.14	0.31
Index of each satisfaction factor (scale 0-100)					**94.6**	**68.6**	**80.7**	**34.9**	**64.8**
Index of ecohydrological satisfaction based-liveability using weighted method CATPCA/FA and public opinion (scale 0-100)							**73.2 and 73.1**		

**Total Cronbach's Alpha is based on the total Eigenvalue; Model summary of satisfaction factors using CATPCA/FA with rotation method: Varimax; normalization method: Variable Principal*

Table A.1.3.5 Satisfaction structure and composite index of ecohydrological satisfaction-based liveability at UPT CMR

Principal Components	Cronbach's Alpha	Variance Accounted For (VAF) Total Eigenvalue	% of variance	Satisfaction to ecohydrology related services	Satisfaction Factors (Principal Components) 1	2	3	4	5
Urban-peri-urban transition participants (n=74, valid cases 67, Expectation-maximization imputation)					*Residential*	*Neighbourhood*	*Watershed*	*Personal*	*Regional*
1	0.73	2.92	19.47	Sufficient water availability	-0.02	-0.04	**0.63**	0.16	**-0.55**
2	0.61	2.21	14.70	Well-maintained river	0.32	0.29	**0.55**	0.09	0.18
3	0.57	1.81	12.05	Green open spaces in the public area	**0.69**	-0.15	0.05	0.32	-0.22
4	0.54	1.77	11.77	Housing with garden spaces	**0.48**	-0.32	0.06	**0.57**	-0.18
5	0.43	1.63	10.89	Healthy housing	**0.86**	0.11	0.03	0.05	0.06
Total	**0.97***	**10.33**	**68.89**	Healthy human settlement	**0.91**	0.12	0.01	-0.09	0.03
				Healthy waterways	**0.65**	0.28	0.26	-0.15	0.18
				Facilities and services for education, public health, amenities	0.13	**0.76**	-0.15	0.13	0.16
				Flood protection	0.19	**0.65**	0.45	-0.14	-0.12
				Drought prevention	0.04	-0.10	**0.81**	0.10	0.13
KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within UPT CMR= 0.63; Bartlett's Test of Sphericity: Approx. Chi-square = 362.09; df = 105; Sig. < 0.001				Housing affordability	0.26	-0.21	0.19	0.30	**0.57**
				Employment	-0.07	0.22	0.34	**0.65**	0.01
				Mobility	-0.10	0.09	0.06	0.07	**0.85**
				Income	0.00	-0.01	-0.04	**0.84**	0.25
				water and sanitation infrastructure/ waste water treatment	0.00	**0.88**	0.04	-0.01	-0.09
Index of each satisfaction factor (scale 0-100)					**56.3**	**12.0**	**35.1**	**35.6**	**70.3**
Index of ecohydrological satisfaction based-liveability using weighted method CATPCA/FA and public opinion (scale 0-100)						**44.7 and 45.8**			

**Total Cronbach's Alpha is based on the total Eigenvalue; Model summary of satisfaction factors using CATPCA/FA with rotation method: Varimax; normalization method: Variable Principal*

Table A.1.3.6 Satisfaction structure and composite index of ecohydrological satisfaction-based liveability at peri-urban CMR

Principal Components	Cronbach's Alpha	Variance Accounted For (VAF) Total Eigenvalue	% of variance	Satisfaction to ecohydrology related services	Satisfaction Factors (Principal Components) 1	2	3	4	5
Peri-urban participants (n=182, valid cases 164, Expectation-maximization imputation)					*Watershed*	*Residential*	*Personal*	*Neighbourhood*	*Regional*
1	0.65	2.17	14.44	Sufficient water availability	**0.83**	0.13	0.00	0.06	0.12
2	0.68	2.11	14.07	Well-maintained river	0.05	0.14	-0.05	0.28	**0.72**
3	0.62	1.89	12.61	Green open spaces in the public area	0.03	-0.02	-0.02	**0.77**	0.17
4	0.58	1.78	11.84	Housing with garden spaces	0.19	**0.48**	0.07	**0.62**	-0.03
5	0.57	1.71	11.43	Healthy housing	0.10	**0.91**	0.14	0.15	0.13
Total	**0.96***	**9.66**	**64.38**	Healthy human settlement	0.05	**0.92**	0.06	0.04	0.19
				Healthy waterways	0.01	0.21	0.22	-0.01	**0.78**
				Facilities and services for education, public health, amenities	0.22	-0.01	-0.02	-0.13	**0.55**
				Flood protection	-0.16	0.18	**0.57**	0.18	0.29
				Drought prevention	**0.84**	-0.08	0.07	0.12	0.00
KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within peri-urban CMR= 0.72; Bartlett's Test of Sphericity: Approx. Chi-square = 813.18; df = 105; Sig.< 0.001				Housing affordability	0.06	0.13	0.33	**0.64**	-0.12
				Employment	0.14	0.07	**0.77**	0.21	0.01
				Mobility	0.11	-0.04	**0.60**	-0.39	0.00
				Income	**0.49**	0.12	**0.61**	0.17	-0.03
				water and sanitation infrastructure/ waste water treatment	**0.61**	0.22	0.23	-0.08	0.28
Index of each satisfaction factor (scale 0-100)					**61.6**	**61.5**	**54.2**	**63.4**	**62.8**
Index of ecohydrological satisfaction based-liveability using weighted method CATPCA/FA and public opinion (scale 0-100)						**67.1 and 64.6**			

**Total Cronbach's Alpha is based on the total Eigenvalue; Model summary of satisfaction factors using CATPCA/FA with rotation method: Varimax; normalization method: Variable Principal*

Table A.1.3.7 Satisfaction structure and composite index of ecohydrological satisfaction-based liveability at rural CMR

Principal Components	Cronbach's Alpha	Variance Accounted For (VAF) Total Eigenvalue	% of variance	Satisfaction to ecohydrology related services	Satisfaction Factors (Principal Components) 1	2	3	4	5
Rural participants (n=73, valid cases 62, Expectation-Maximization imputation)					*Residential*	*Watershed*	*Personal*	*Regional*	*Neighbourhood*
1	0.81	3.40	22.69	Sufficient water availability	0.08	**0.80**	0.03	-0.04	-0.08
2	0.75	2.50	16.67	Well-maintained river	0.40	0.32	0.07	0.20	**-0.60**
3	0.50	1.72	11.44	Green open spaces in the public area	**0.76**	0.20	-0.07	-0.10	-0.09
4	0.52	1.58	10.51	Housing with garden spaces	**0.75**	0.22	-0.11	-0.34	0.11
5	0.46	1.51	10.07	Healthy housing	**0.82**	0.13	0.17	0.22	0.21
Total	**0.97***	**10.71**	**71.38**	Healthy human settlement	**0.80**	0.16	0.06	0.30	0.15
				Healthy waterways	**0.47**	0.36	-0.29	**0.49**	-0.17
				Facilities and services for education, public health, amenities	0.18	0.16	-0.10	0.36	**0.72**
				Flood protection	-0.16	0.27	**0.79**	-0.02	-0.03
KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) within rural CMR= 0.76; Bartlett's Test of Sphericity: Approx. Chi-square = 419.51; df = 105; Sig. <0.001				Drought prevention	0.20	**0.81**	0.18	0.02	0.13
				Housing affordability	0.37	0.36	-0.08	0.04	**0.63**
				Employment	**0.51**	-0.11	0.41	0.40	-0.01
				Mobility	-0.02	-0.05	-0.04	**0.85**	0.16
				Income	0.15	0.09	**0.83**	-0.07	-0.12
				water and sanitation infrastructure/ waste water treatment	0.24	**0.77**	0.21	0.04	0.22
Index of each satisfaction factor (scale 0-100)					**60.0**	**55.3**	**84.1**	**31.3**	**65.3**
Index of ecohydrological satisfaction based-liveability using weighted method CATPCA/FA and public opinion (scale 0-100)					**67.1 and 61.7**				

**Total Cronbach's Alpha is based on the total Eigenvalue; Model summary of satisfaction factors using CATPCA/FA with rotation method: Varimax; normalization method: Variable Principal*

Table A.1.3.8 Weights for the liveability indicators within CMR

Liveability Aspects (Satisfaction Assessment)	Weight CATPCA/FA	Ranks	Liveability Aspects (Importance Assessment)	Weight Public Opinion	Ranks
Healthy human settlement	0.11	1	Employment	0.13	1
Healthy housing	0.11	1	Income	0.11	2
Sufficient water availability	0.09	2	Sufficient water availability	0.11	2
Housing with garden spaces	0.08	3	Drought prevention	0.08	3
Green open spaces in the public area	0.07	4	Healthy housing	0.07	4
Income	0.07	4	Mobility	0.07	4
Drought prevention	0.07	4	Green open spaces in the public area	0.07	4
Water and sanitation infrastructure/ waste water treatment	0.07	4	Housing affordability	0.06	5
Flood protection	0.06	5	Healthy waterways	0.05	6
Employment	0.06	5	Healthy human settlement	0.05	6
Facilities and services for education, public health, amenities	0.06	5	Facilities and services for education, public health, amenities	0.05	6
Mobility	0.05	6	Flood protection	0.04	7
Housing affordability	0.04	7	Water and sanitation infrastructure/ waste water treatment	0.04	7
Well-maintained river	0.04	7	Housing with garden spaces	0.03	8
Healthy waterways	0.02	8	Well-maintained river	0.03	8

Table A.1.3.9 Weights for the liveability indicators within urban area

Liveability Aspects (Satisfaction Assessment)	Weight CATPCA/FA	Ranks	Liveability Aspects (Importance Assessment)	Weight Public Opinion	Ranks
Housing affordability	0.12	1	Housing affordability	0.12	1
Housing with garden spaces	0.12	1	Employment	0.12	1
Employment	0.09	2	Income	0.12	1
Flood protection	0.09	2	Drought prevention	0.11	2
Income	0.07	3	Sufficient water availability	0.08	3
Mobility	0.07	3	Healthy housing	0.08	3
Green open spaces in the public area	0.06	4	Healthy waterways	0.06	4
Water and sanitation infrastructure/ waste water treatment	0.06	4	Healthy human settlement	0.06	4
Facilities and services for education, public health, amenities	0.06	4	Facilities and services for education, public health, amenities	0.05	5
Sufficient water availability	0.06	4	Well maintained river	0.05	5
Healthy housing	0.05	5	Water and sanitation infrastructure/ waste water treatment	0.04	6
Healthy waterways	0.05	5	Mobility	0.04	6
Drought prevention	0.04	6	Green open spaces in the public area	0.03	7
Healthy human settlement	0.04	6	Flood protection	0.02	8
Well-maintained river	0.02	7	Housing with garden spaces	0.02	8

Table A.1.3.10 Weights for the liveability indicators within urban-peri-urban transition area

Liveability Aspects (Satisfaction Assessment)	Weight CATPCA/FA	Ranks	Liveability Aspects (Importance Assessment)	Weight Public Opinion	Ranks
Healthy human settlement	0.13	1	Green open spaces in the public area	0.11	1
Healthy housing	0.12	2	Employment	0.11	1
Water and sanitation infrastructure/ waste water treatment	0.10	3	Housing affordability	0.11	1
Green open spaces in the public area	0.08	4	Income	0.11	1
Facilities and services for education, public health, amenities	0.07	5	Well-maintained river	0.11	1
Income	0.07	5	Housing with garden spaces	0.10	2
Healthy waterways	0.06	6	Sufficient water availability	0.08	3
Mobility	0.06	6	Facilities and services for education, public health, amenities	0.05	4
Drought prevention	0.06	6	Healthy human settlement	0.04	5
Flood protection	0.06	6	Drought prevention	0.04	5
Employment	0.05	7	Healthy housing	0.04	5
Sufficient water availability	0.04	8	Water and sanitation infrastructure/ waste water treatment	0.03	6
Housing with garden spaces	0.04	8	Healthy waterways	0.03	6
Well-maintained river	0.04	8	Flood protection	0.02	7
Housing affordability	0.02	9	Mobility	0.01	8

Table A.1.3.11 Weights for the liveability indicators within peri-urban area

Liveability Aspects (Satisfaction Assessment)	Weight CATPCA/FA	Rank s	Liveability Aspects (Importance Assessment)	Weight Public Opinion	Rank s
Healthy human settlement	0.12	1	Drought prevention	0.13	1
Healthy housing	0.11	2	Flood protection	0.13	1
Drought prevention	0.10	3	Income	0.10	2
Sufficient water availability	0.10	3	Sufficient water availability	0.09	3
Employment	0.07	4	Mobility	0.08	4
Healthy waterways	0.07	4	Green open spaces in the public area	0.07	5
Green open spaces in the public area	0.07	4	Employment	0.06	6
Well-maintained river	0.06	5	Healthy waterways	0.06	6
Water and sanitation infrastructure/ waste water treatment	0.05	6	Well-maintained river	0.06	6
Housing affordability	0.05	6	Housing affordability	0.05	7
Income	0.05	6	Water and sanitation infrastructure/ waste water treatment	0.04	8
Housing with garden spaces	0.04	7	Healthy human settlement	0.04	8
Mobility	0.04	7	Healthy housing	0.03	9
Flood protection	0.04	7	Facilities and services for education, public health, amenities	0.03	9
Facilities and services for education, public health, amenities	0.03	8	Housing with garden spaces	0.03	9

Table A.1.3.12 Weights for the liveability indicators within rural area

Liveability Aspects (Satisfaction Assessment)	Weight CATPCA/FA	Ranks	Liveability Aspects (Importance Assessment)	Weight Public Opinion	Ranks
Healthy housing	0.12	1	Drought prevention	0.13	1
Healthy human settlement	0.11	2	Flood protection	0.13	1
Green open spaces in the public area	0.10	3	Mobility	0.12	2
Housing with garden spaces	0.10	3	Water and sanitation infrastructure/ waste water treatment	0.11	3
Drought prevention	0.08	4	Employment	0.10	4
Sufficient water availability	0.08	4	Sufficient water availability	0.09	5
Water and sanitation infrastructure/ waste water treatment	0.08	4	Housing affordability	0.07	6
Income	0.06	5	Well-maintained river	0.05	7
Mobility	0.06	5	Housing with garden spaces	0.05	7
Flood protection	0.06	5	Healthy housing	0.04	8
Employment	0.05	6	Income	0.03	9
Facilities and services for education, public health, amenities	0.04	7	Facilities and services for education, public health, amenities	0.03	9
Housing affordability	0.03	8	Healthy waterways	0.03	9
Well-maintained river	0.03	8	Healthy human settlement	0.02	10
Healthy waterways	0.02	9	Green open spaces in the public area	0.01	11

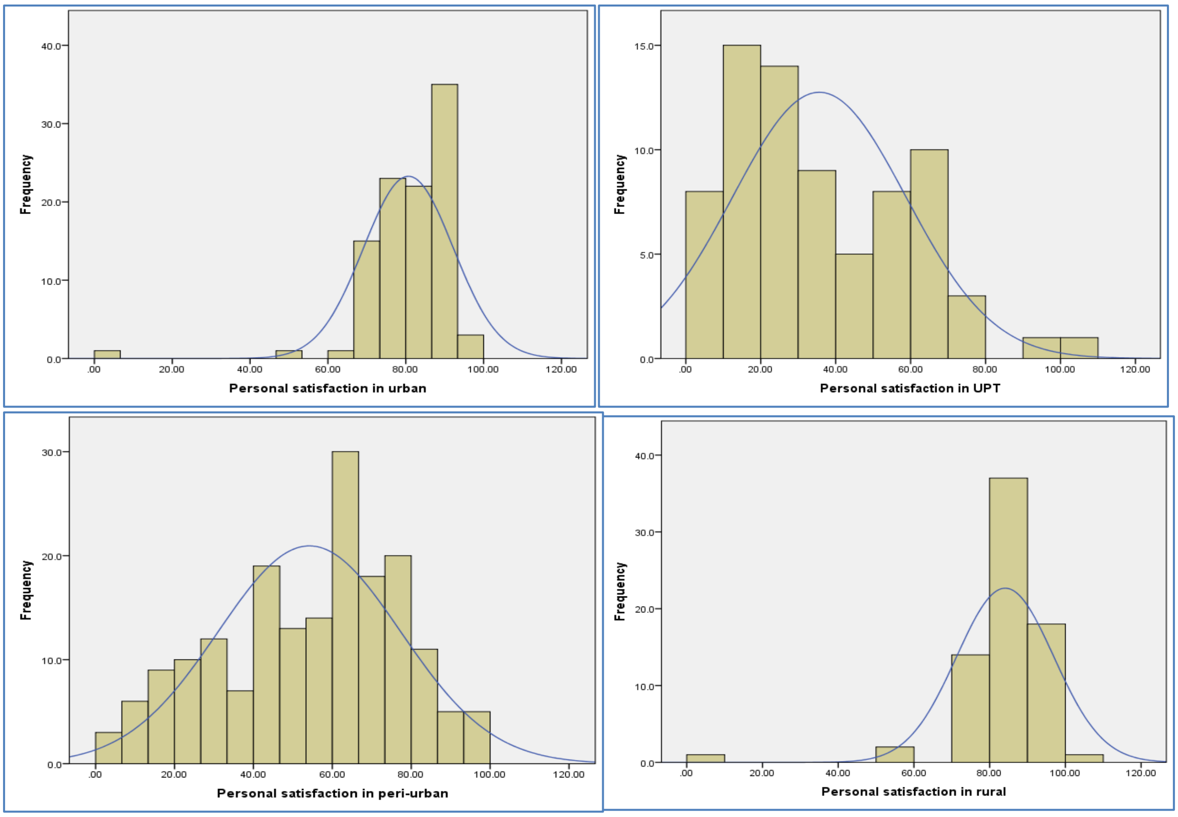

Figure A.1.3.1 Distribution of personal satisfaction scores

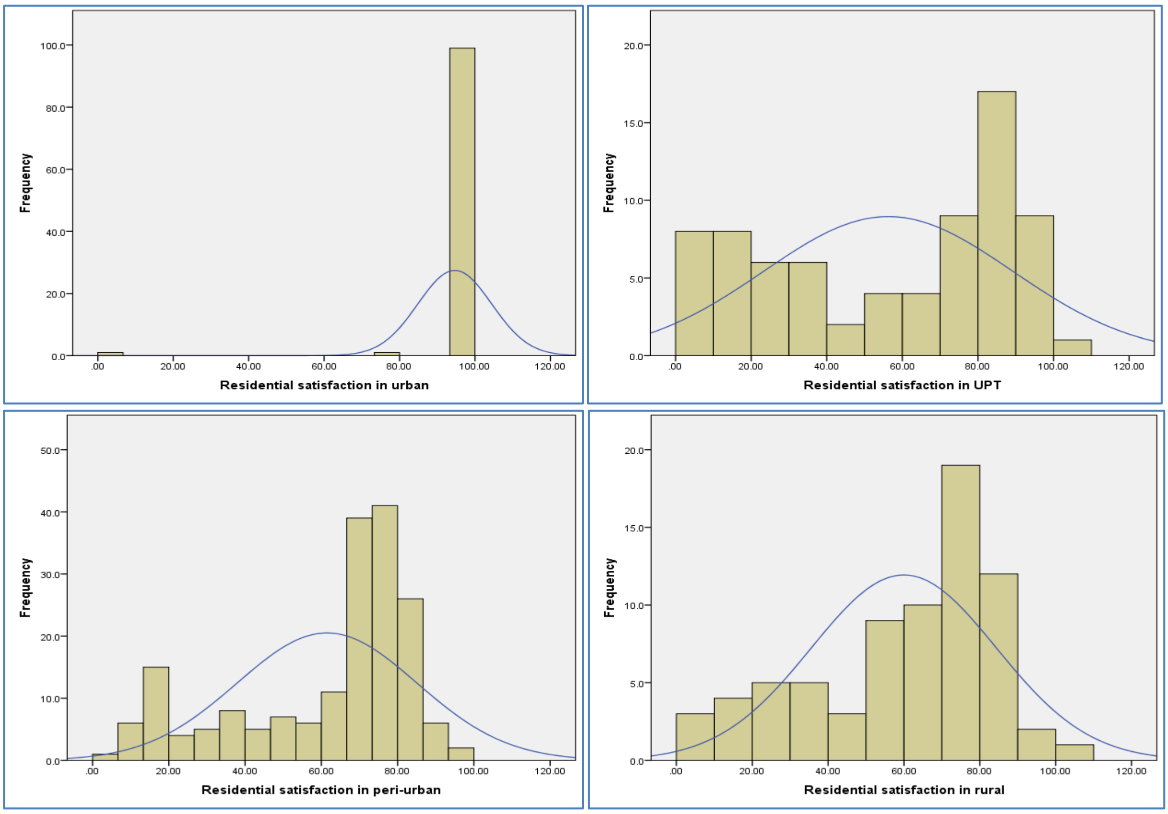

Figure A.1.3.2 Distribution of residential satisfaction scores

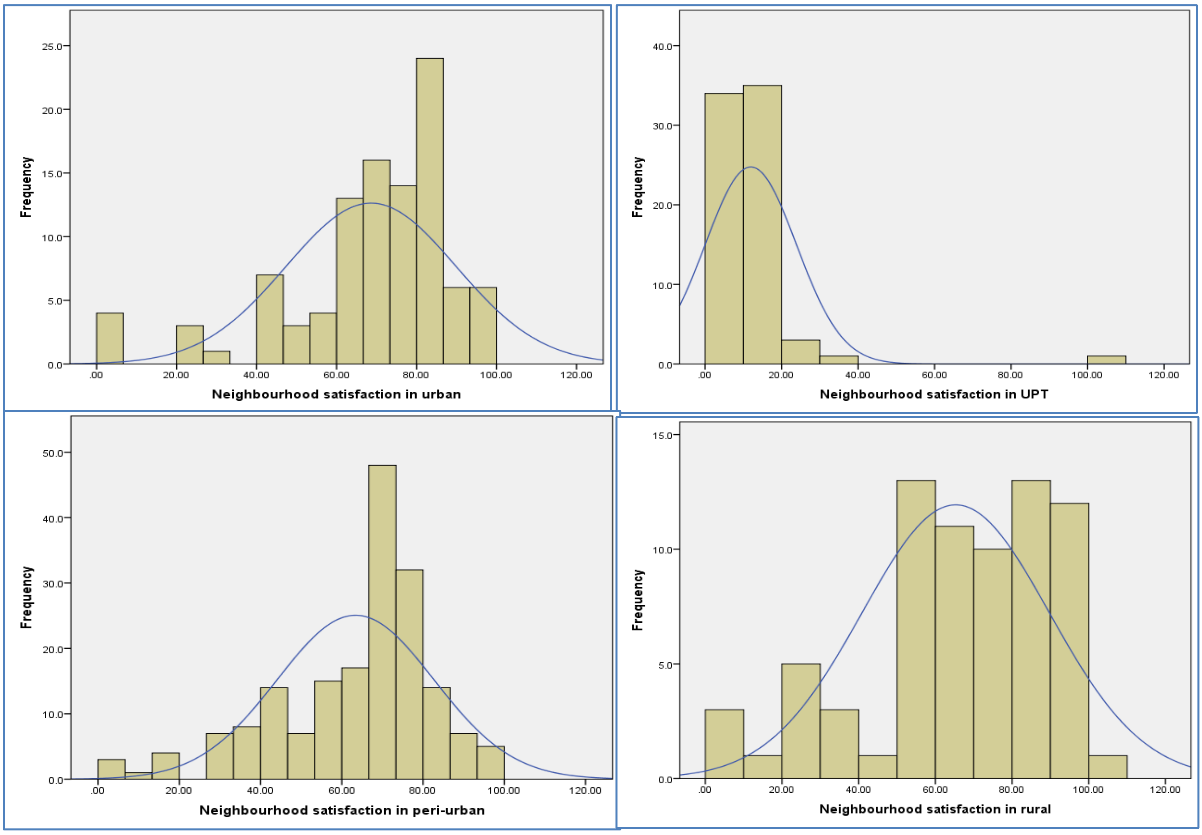

Figure A.1.3.3 Distribution of neighbourhood satisfaction scores

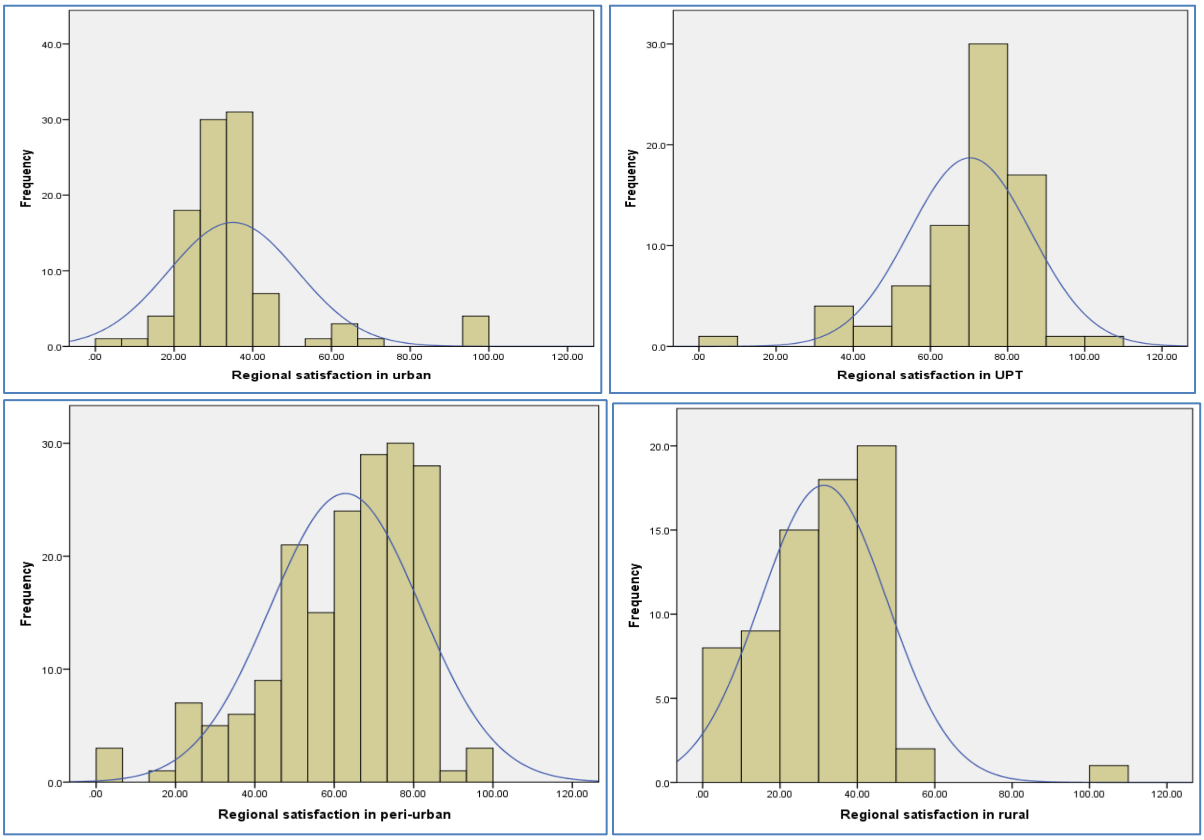

Figure A.1.3.4 Distribution of regional satisfaction scores

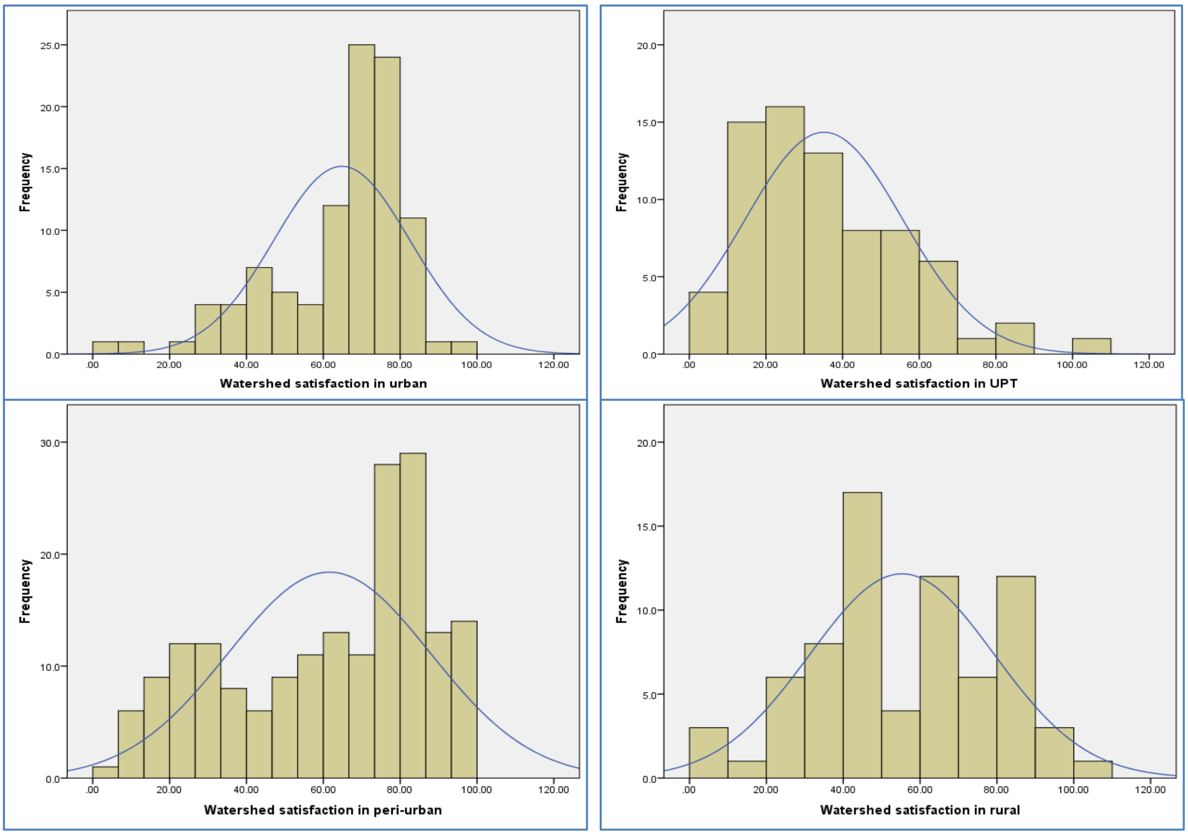

Figure A.1.3.5 Distribution of watershed satisfaction scores

Table A.1.3.13 Effect of socio-demographic attributes and perception of ecohydrological changes on the personal satisfaction

Coefficients (CATREG)					
	Standardized Coefficients				
Independent variables:	Beta	Bootstrap (1000) Estimate of Std. Error	df	F	Sig.
Political boundary at district level	0.29	0.10	4	7.856	0.000
Level of urbanisation	0.31	0.11	3	7.902	0.000
Distance from the coast	0.24	0.16	4	2.424	0.048
Type of settlement	0.04	0.05	1	0.538	0.464
Occupation	0.10	0.05	1	3.581	0.059
Gender	0.02	0.04	1	0.435	0.510
Length of stay	-0.07	0.08	2	0.660	0.517
Household size	-0.10	0.06	2	3.354	0.036
Perception of changes in green open spaces surrounding human settlement	0.13	0.06	2	4.519	0.011
Perception of changes in groundwater quality	0.03	0.09	1	0.121	0.728
Perception of changes in river quality	0.006	0.07	1	0.008	0.930
Perception of changes in flood event	0.07	0.09	1	0.619	0.432
Perception of changes in drought event	-0.12	0.07	2	2.437	0.089
Perception of changes in climate	0.03	0.07	1	0.182	0.670
Perception of changes in food	-0.18	0.07	1	6.301	0.012
Perception of changes in forest	-0.03	0.07	1	0.140	0.708
Current water problems (flood and or drought)	0.09	0.05	5	3.914	0.002
Perception of current river water quality	0.04	0.04	2	0.857	0.425
Perception of current groundwater quality	0.12	0.04	7	8.731	0.000
Dependent variable: Personal satisfaction in the CMR					

Table A.1.3.14 Effect of socio-demographic attributes and perception of ecohydrological changes on the residential satisfaction

Coefficients (CATREG)					
	Standardized Coefficients				
Independent variables:	Beta	Bootstrap (1000) Estimate of Std. Error	df	F	Sig.
Political boundary at district level	0.17	0.07	4	7.115	0.000
Level of urbanisation	0.10	0.06	3	2.332	0.074
Distance from the coast	0.26	0.09	4	8.584	0.000
Type of settlement	0.12	0.06	1	4.600	0.033
Occupation	0.06	0.04	1	2.079	0.150
Gender	0.03	0.04	1	0.520	0.471
Length of stay	0.12	0.06	3	3.401	0.018
Household size	0.06	0.06	2	0.950	0.388
Perception of changes in green open spaces surrounding human settlement	-0.09	0.05	2	2.617	0.074
Perception of changes in groundwater quality	-0.08	0.07	1	1.364	0.244
Perception of changes in river quality	-0.07	0.06	2	1.388	0.251
Perception of changes in flood event	-0.12	0.13	1	0.845	0.358
Perception of changes in drought event	0.02	0.08	2	0.070	0.932
Perception of changes in climate	0.04	0.07	1	0.311	0.577
Perception of changes in food	-0.09	0.12	1	0.611	0.435
Perception of changes in forest	-0.06	0.06	2	1.295	0.275
Current water problems (flood and or drought)	0.06	0.04	5	1.934	0.088
Perception of current river water quality	0.09	0.04	2	4.542	0.011
Perception of current groundwater quality	0.21	0.05	7	20.300	0.000
Dependent variable: Residential satisfaction in the CMR					

Table A.1.3.15 Effect of socio-demographic attributes and perception of ecohydrological changes on the neighbourhood satisfaction

Coefficients (CATREG)					
	Standardized Coefficients				
Independent variables:	Beta	Bootstrap (1000) Estimate of Std. Error	df	F	Sig.
Political boundary at district level	0.35	0.13	4	7.555	0.000
Level of urbanisation	0.24	0.22	3	1.158	0.326
Distance from the coast	0.24	0.11	3	4.713	0.003
Type of settlement	0.04	0.04	1	0.929	0.336
Occupation	0.10	0.05	1	3.574	0.059
Gender	0.08	0.04	1	3.152	0.077
Length of stay	0.04	0.08	1	0.262	0.609
Household size	0.07	0.07	1	0.874	0.351
Perception of changes in green open spaces surrounding human settlement	0.10	0.05	2	3.458	0.032
Perception of changes in groundwater quality	-0.16	0.06	1	3.740	0.054
Perception of changes in river quality	-0.24	0.06	1	19.563	0.000
Perception of changes in flood event	-0.13	0.06	2	4.051	0.018
Perception of changes in drought event	0.04	0.07	1	0.225	0.635
Perception of changes in climate	0.10	0.06	2	2.401	0.092
Perception of changes in food	0.04	0.08	1	0.289	0.591
Perception of changes in forest	-0.14	0.05	2	6.956	0.001
Current water problems (flood and or drought)	0.20	0.06	5	12.095	0.000
Perception of current river water quality	0.11	0.05	2	5.935	0.003
Perception of current groundwater quality	0.08	0.04	7	4.570	0.000
Dependent variable: Neighbourhood satisfaction in the CMR					

Table A.1.3.16 Effect of socio-demographic attributes and perception of ecohydrological changes on the regional satisfaction

Coefficients (CATREG)					
	Standardized Coefficients				
Independent variables:	Beta	Bootstrap (1000) Estimate of Std. Error	df	F	Sig.
Political boundary at district level	0.17	0.13	4	1.649	0.161
Level of urbanisation	0.15	0.15	3	1.015	0.386
Distance from the coast	-0.11	0.20	2	0.323	0.724
Type of settlement	0.17	0.07	1	6.496	0.011
Occupation	0.04	0.04	1	1.092	0.297
Gender	0.003	0.03	1	0.012	0.914
Length of stay	0.19	0.06	2	9.882	0.000
Household size	0.03	0.08	1	0.123	0.726
Perception of changes in green open spaces surrounding human settlement	-0.06	0.07	2	0.675	0.510
Perception of changes in groundwater quality	-0.05	0.07	1	0.612	0.434
Perception of changes in river quality	0.06	0.07	2	0.782	0.458
Perception of changes in flood event	-0.08	0.08	1	0.923	0.337
Perception of changes in drought event	-0.08	0.06	2	1.893	0.152
Perception of changes in climate	-0.08	0.09	1	0.728	0.394
Perception of changes in food	0.06	0.09	1	0.443	0.506
Perception of changes in forest	0.08	0.11	1	0.604	0.437
Current water problems (flood and or drought)	0.14	0.06	5	6.316	0.000
Perception of current river water quality	0.05	0.04	2	1.676	0.188
Perception of current groundwater quality	0.14	0.04	7	9.847	0.000
Dependent variable: Regional satisfaction in the CMR					

Table A.1.3.17 Effect of socio-demographic attributes and perception of ecohydrological changes on the watershed satisfaction

Coefficients (CATREG)					
	Standardized Coefficients				
Independent variables:	Beta	Bootstrap (1000) Estimate of Std. Error	df	F	Sig.
Political boundary at district level	0.13	0.07	4	3.706	0.006
Level of urbanisation	0.18	0.08	3	5.240	0.001
Distance from the coast	0.11	0.10	2	1.153	0.317
Type of settlement	0.03	0.04	1	0.605	0.437
Occupation	0.02	0.03	1	0.493	0.483
Gender	0.03	0.03	1	0.801	0.371
Length of stay	0.07	0.05	2	1.766	0.172
Household size	0.02	0.05	2	0.099	0.906
Perception of changes in green open spaces surrounding human settlement	-0.07	0.05	2	2.616	0.074
Perception of changes in groundwater quality	-0.13	0.05	2	7.483	0.001
Perception of changes in river quality	0.05	0.06	1	0.857	0.355
Perception of changes in flood event	-0.01	0.07	1	0.009	0.923
Perception of changes in drought event	-0.32	0.06	2	31.920	0.000
Perception of changes in climate	-0.03	0.06	1	0.168	0.682
Perception of changes in food	0.10	0.08	2	1.420	0.243
Perception of changes in forest	0.04	0.04	2	0.862	0.423
Current water problems (flood and or drought)	0.31	0.05	5	36.478	0.000
Perception of current river water quality	0.11	0.04	2	8.061	0.000
Perception of current groundwater quality	0.19	0.04	7	21.791	0.000
Dependent variable: Watershed satisfaction in the CMR					

APPENDIX 1. 4 ASSESSING LIVEABILITY IN THE CONTEXT OF SOCIO-ECOHYDROLOGY

DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2019. Qualitative and quantitative analysis of perceived liveability in the context of socio-ecohydrology: evidence from the urban and peri-urban Cirebon-Indonesia. Journal of Environmental Planning and Management, 1-29. doi:10.1080/09640568.2018.1524576.

Table A.1.4. 1 The most important liveability services based on the surveyed urban and peri-urban households in the CMR

Type of liveability services	Group of the surveyed households in the CMR based on the urbanisation levels (% words coded per item of liveability services/ row percentage)			
	A : Urban households	B : UPT households	C : Peri-urban households	D : Rural households
1 : 1. Provisioning services	31.4%	15.0%	42.0%	11.5%
2 : 1.1 Land	23.9%	4.4%	56.5%	15.2%
3 : 1.1.1 Land availability for farming or housing	0.0%	0.0%	0.0%	0.0%
4 : 1.1.2 Soil fertility	0.0%	0.0%	0.0%	0.0%
5 : 1.1.3 Food availability	23.9%	4.4%	56.5%	15.2%
6 : 1.2 Water	31.0%	18.5%	41.9%	8.5%
7 : 1.2.1 Sufficient water availability	29.8%	15.0%	43.9%	11.2%
8 : 1.2.2 Groundwater and surface-water sources	25.6%	36.8%	37.6%	0.0%
9 : 1.2.3 Drinking water from distribution network	94.3%	5.7%	0.0%	0.0%
10 : 1.2.4 Irrigation water from distribution network	0.0%	0.0%	0.0%	0.0%
11 : 1.2.5 Local presence of lakes, rivers, seas for transport of people and things	0.0%	0.0%	0.0%	0.0%
12 : 1.3 Climate	36.3%	3.2%	37.1%	23.4%
13 : 1.3.1 Weather	41.5%	0.0%	31.9%	26.6%
14 : 1.3.2 Air quality	33.7%	4.1%	36.7%	25.5%
15 : 2. Regulating services	33.4%	19.0%	39.4%	8.3%
16 : 2.1 Regulation of natural-physical phenomena	15.8%	21.8%	57.1%	5.3%
17 : 2.1.1 Well-maintained river	100.0%	0.0%	0.0%	0.0%
18 : 2.1.2 Flood protection	13.8%	34.5%	37.9%	13.8%
19 : 2.1.3 Drought prevention	3.3%	21.1%	72.2%	3.3%
20 : 2.2 Mitigation of human impacts-reduction of environmental pollution	40.7%	17.9%	34.8%	6.6%
21 : 2.2.1 Healthy waterways	100.0%	0.0%	0.0%	0.0%
22 : 2.2.2 Sanitation facilities and waste water treatment	45.0%	17.1%	37.2%	0.8%
23 : 2.2.3 Solid waste management	58.2%	17.9%	23.9%	0.0%
24 : 2.2.4 Healthy house and human settlement	37.7%	18.1%	37.2%	7.1%
25 : 2.3 Regulation of natural-biological phenomena	35.7%	30.4%	14.3%	19.6%
26 : 2.3.1 Green open spaces in public area	44.4%	37.8%	17.8%	0.0%
27 : 2.3.2 Housing with green open spaces	33.3%	14.3%	0.0%	52.4%
28 : 3. Cultural services	28.8%	8.7%	39.8%	22.7%
29 : 3.1 Aesthetic-local presence of agro-natural elements (land-or sea scapes)	47.2%	15.1%	31.1%	6.6%
30 : 3.1.1 Beautiful landscapes or pleasant environment	37.0%	19.4%	37.6%	6.1%
31 : 3.1.2 Local presence of agro-natural elements	73.6%	0.0%	18.9%	7.6%

32 : 3.2 Natural educational services to enhance awareness to environment and to promote pro-environment behaviours	100.0%	0.0%	0.0%	0.0%
33 : 3.2.1 Environmental and cultural educations	100.0%	0.0%	0.0%	0.0%
34 : 3.3 Services for physical, spiritual, symbolic, interaction with nature and agro-natural elements	21.7%	5.4%	43.0%	29.9%
35 : 3.3.1 Cultural heritage and entertainment	32.8%	6.0%	50.0%	11.2%
36 : 3.3.2 Spiritual services	11.8%	0.0%	49.0%	39.2%
37 : 3.3.3 Societal connectedness to do mutual aids in the communities (gotong royong) to maintain the human settlement environment	19.8%	13.5%	42.9%	23.8%
38 : 3.3.4 Place attachment to nature, built-structure, and people as related to birthplace and community identity	19.8%	0.0%	36.0%	44.2%
39 : 4. Socio-economic services	24.8%	15.0%	37.3%	22.9%
40 : 4.1 Networks for mobility of people, information, and things	37.5%	16.7%	34.6%	11.3%
41 : 4.1.1 Local presence of roads	53.9%	10.3%	20.5%	15.4%
42 : 4.1.2 Local transport availability	22.4%	20.0%	43.6%	13.9%
43 : 4.1.3 Local presence of internet, telephone networks, electricity	62.8%	11.5%	23.1%	2.6%
44 : 4.2 Education services	0.0%	0.0%	0.0%	0.0%
45 : 4.2.1 Local presence of school and accessibility	0.0%	0.0%	0.0%	0.0%
46 : 4.3 Health services	61.5%	0.0%	28.9%	9.6%
47 : 4.3.1 Local presence of health facilities	61.5%	0.0%	28.9%	9.6%
48 : 4.4 Safety	26.7%	11.1%	46.7%	15.6%
49 : 4.4.1 Safety	33.3%	5.0%	39.7%	22.0%
50 : 4.4.2 Political circumstances	14.3%	23.1%	58.2%	4.4%
51 : 4.5 Employment and livelihood	23.3%	17.4%	34.6%	24.7%
52 : 4.5.1 Job availability	25.2%	12.8%	37.6%	24.3%
53 : 4.5.2 Income	19.4%	23.9%	32.8%	23.9%
54 : 4.5.3 Access to capital	0.0%	100.0%	0.0%	0.0%
55 : 4.5.4 Living cost	0.0%	0.0%	0.0%	100.0%
56 : 4.6 Societal interaction and family relationship	14.4%	3.4%	45.9%	36.3%
57 : 4.6.1 Relationships with family, neighbours, communities, and authorities	14.4%	3.4%	45.9%	36.3%
58 : 4.7 Accessibility	6.2%	24.8%	29.8%	39.1%
59 : 4.7.1 Accessibility to public services, city centre, market, workplace	6.2%	24.8%	29.8%	39.1%
60 : 4.8 Farmland and housing affordability	26.6%	13.8%	38.3%	21.3%
61 : 4.8.1 Farmland affordability	66.7%	0.0%	0.0%	33.3%
62 : 4.8.2 Housing affordability	20.7%	15.9%	43.9%	19.5%
63 : 4.9 Government services	0.0%	100.0%	0.0%	0.0%
64 : 4.9.1 Government supports and services	0.0%	100.0%	0.0%	0.0%

TABLE A.1.4. 2. THE MOST SATISFIED LIVEABILITY SERVICES BASED ON THE SURVEYED URBAN AND PERI-URBAN HOUSEHOLDS IN THE CMR

Type of liveability services	Group of the surveyed households in the CMR based on the urbanisation levels (% words coded per item of liveability services/ row percentage)			
	A : Urban households	B : UPT households	C : Peri-urban households	D : Rural households
1 : 1. Provisioning services	41.6%	15.3%	30.9%	12.2%
2 : 1.1 Land	44.1%	0.0%	27.0%	28.8%
3 : 1.1.1 Land availability for farming or housing	61.9%	0.0%	0.0%	38.1%
4 : 1.1.2 Soil fertility	42.9%	0.0%	21.4%	35.7%
5 : 1.1.3 Food availability	38.1%	0.0%	38.1%	23.8%
6 : 1.2 Water	43.4%	19.5%	26.0%	11.1%
7 : 1.2.1 Sufficient water availability	36.2%	21.9%	24.7%	17.2%
8 : 1.2.2 Groundwater and surface-water sources	41.0%	20.5%	37.7%	0.8%
9 : 1.2.3 Drinking water from distribution network	100.0%	0.0%	0.0%	0.0%
10 : 1.2.4 Irrigation water from distribution network	0.0%	0.0%	0.0%	0.0%
11 : 1.2.5 Local presence of lakes, rivers, seas for transport of people and things	0.0%	0.0%	0.0%	0.0%
12 : 1.3 Climate	57.0%	5.9%	34.1%	3.0%
13 : 1.3.1 Weather	62.1%	0.0%	37.9%	0.0%
14 : 1.3.2 Air quality	40.6%	25.0%	21.9%	12.5%
15 : 2. Regulating services	35.2%	15.5%	42.8%	6.6%
16 : 2.1 Regulation of natural-physical phenomena	34.5%	9.0%	43.5%	13.1%
17 : 2.1.1 Well-maintained river	0.0%	0.0%	0.0%	0.0%
18 : 2.1.2 Flood protection	31.6%	0.0%	63.2%	5.3%
19 : 2.1.3 Drought prevention	39.1%	12.4%	34.3%	14.3%
20 : 2.2 Mitigation of human impacts-reduction of environmental pollution	33.1%	21.0%	41.3%	4.6%
21 : 2.2.1 Healthy waterways	100.0%	0.0%	0.0%	0.0%
22 : 2.2.2 Sanitation facilities and waste water treatment	17.7%	13.7%	65.7%	2.9%
23 : 2.2.3 Solid waste management	17.7%	13.7%	65.7%	2.9%
24 : 2.2.4 Healthy house and human settlement	32.7%	21.5%	41.1%	4.7%
25 : 2.3 Regulation of natural-biological phenomena	24.1%	27.6%	41.4%	6.9%
26 : 2.3.1 Green open spaces in public area	0.0%	40.7%	37.0%	22.2%
27 : 2.3.2 Housing with green open spaces	35.0%	21.7%	43.3%	0.0%
28 : 3. Cultural services	30.0%	18.7%	35.7%	15.6%
29 : 3.1 Aesthetic-local presence of agro-natural elements (land-or sea scapes)	36.8%	22.9%	33.2%	7.1%
30 : 3.1.1 Beautiful landscapes or pleasant environment	36.5%	23.4%	33.5%	6.7%
31 : 3.1.2 Local presence of agro-natural elements	55.4%	15.2%	23.2%	6.3%

32 : 3.2 Natural educational services to enhance awareness to environment and to promote pro-environment behaviours	100.0%	0.0%	0.0%	0.0%
33 : 3.2.1 Environmental and cultural educations	100.0%	0.0%	0.0%	0.0%
34 : 3.3 Services for physical, spiritual, symbolic, interaction with nature and agro-natural elements	20.0%	13.1%	42.5%	24.5%
35 : 3.3.1 Cultural heritage and entertainment	0.0%	0.0%	25.0%	75.0%
36 : 3.3.2 Spiritual services	13.8%	15.2%	48.6%	22.5%
37 : 3.3.3 Societal connectedness to do mutual aids in the communities (gotong royong) to maintain the human settlement environment	24.2%	13.4%	40.8%	21.7%
38 : 3.3.4 Place attachment to nature, built-structure, and people as related to birthplace and community identity	18.5%	10.5%	49.4%	21.6%
39 : 4. Socio-economic services	31.3%	16.2%	40.8%	11.7%
40 : 4.1 Networks for mobility of people, information, and things	62.8%	0.0%	37.2%	0.0%
41 : 4.1.1 Local presence of roads	72.4%	0.0%	27.6%	0.0%
42 : 4.1.2 Local transport availability	42.9%	0.0%	57.1%	0.0%
43 : 4.1.3 Local presence of internet, telephone networks, electricity	0.0%	0.0%	0.0%	0.0%
44 : 4.2 Education services	30.8%	0.0%	69.2%	0.0%
45 : 4.2.1 Local presence of school and accessibility	30.8%	0.0%	69.2%	0.0%
46 : 4.3 Health services	0.0%	0.0%	0.0%	0.0%
47 : 4.3.1 Local presence of health facilities	0.0%	0.0%	0.0%	0.0%
48 : 4.4 Safety	29.6%	20.3%	41.3%	8.8%
49 : 4.4.1 Safety	22.2%	16.9%	50.7%	10.3%
50 : 4.4.2 Political circumstances	39.0%	24.8%	30.1%	6.1%
51 : 4.5 Employment and livelihood	20.7%	10.5%	59.3%	9.6%
52 : 4.5.1 Job availability	18.3%	11.9%	59.3%	10.5%
53 : 4.5.2 Income	31.2%	19.7%	44.3%	4.9%
54 : 4.5.3 Access to capital	0.0%	0.0%	0.0%	0.0%
55 : 4.5.4 Living cost	0.0%	0.0%	100.0%	0.0%
56 : 4.6 Societal interaction and family relationship	28.3%	16.7%	41.3%	13.7%
57 : 4.6.1 Relationships with family, neighbours, communities, and authorities	28.3%	16.7%	41.3%	13.7%
58 : 4.7 Accessibility	35.3%	17.8%	37.8%	9.1%
59 : 4.7.1 Accessibility to public services, city centre, market, workplace	35.3%	17.8%	37.8%	9.1%
60 : 4.8 Farmland and housing affordability	30.0%	7.2%	57.8%	5.0%
61 : 4.8.1 Farmland affordability	0.0%	0.0%	0.0%	0.0%
62 : 4.8.2 Housing affordability	30.0%	7.2%	57.8%	5.0%
63 : 4.9 Government services	66.2%	0.0%	33.8%	0.0%
64 : 4.9.1 Government supports and services	66.2%	0.0%	33.8%	0.0%

TABLE A.1.4. 3. THE LEAST SATISFIED LIVEABILITY SERVICES BASED ON THE SURVEYED URBAN AND PERI-URBAN HOUSEHOLDS IN THE CMR

Type of liveability services	Group of the surveyed households in the CMR based on the urbanisation levels (% words coded per item of liveability services/ row percentage)			
	A : Urban households	B : UPT households	C : Peri-urban households	D : Rural households
1 : 1. Provisioning services	23.5%	15.2%	48.3%	13.0%
2 : 1.1 Land	26.0%	0.6%	73.4%	0.0%
3 : 1.1.1 Land availability for farming or housing	0.0%	0.0%	100.0%	0.0%
4 : 1.1.2 Soil fertility	34.2%	0.8%	65.0%	0.0%
5 : 1.1.3 Food availability	0.0%	0.0%	100.0%	0.0%
6 : 1.2 Water	25.0%	14.1%	45.8%	15.0%
7 : 1.2.1 Sufficient water availability	10.5%	9.6%	62.1%	17.9%
8 : 1.2.2 Groundwater and surface-water sources	34.2%	22.9%	27.4%	15.5%
9 : 1.2.3 Drinking water from distribution network	52.6%	21.6%	20.5%	5.3%
10 : 1.2.4 Irrigation water from distribution network	19.8%	4.7%	60.5%	15.1%
11 : 1.2.5 Local presence of lakes, rivers, seas for transport of people and things	87.5%	12.5%	0.0%	0.0%
12 : 1.3 Climate	37.1%	25.4%	37.6%	0.0%
13 : 1.3.1 Weather	26.7%	17.8%	55.6%	0.0%
14 : 1.3.2 Air quality	35.6%	24.5%	39.9%	0.0%
15 : 2. Regulating services	28.8%	15.2%	46.4%	9.6%
16 : 2.1 Regulation of natural-physical phenomena	22.4%	16.1%	46.9%	14.6%
17 : 2.1.1 Well-maintained river	55.0%	2.4%	42.6%	0.0%
18 : 2.1.2 Flood protection	38.8%	31.4%	29.8%	0.0%
19 : 2.1.3 Drought prevention	11.9%	8.0%	55.8%	24.3%
20 : 2.2 Mitigation of human impacts-reduction of environmental pollution	31.7%	18.8%	45.4%	4.1%
21 : 2.2.1 Healthy waterways	32.0%	25.9%	39.5%	2.6%
22 : 2.2.2 Sanitation facilities and waste water treatment	15.4%	16.9%	62.6%	5.1%
23 : 2.2.3 Solid waste management	16.7%	18.1%	59.4%	5.8%
24 : 2.2.4 Healthy house and human settlement	42.1%	15.0%	36.9%	6.1%
25 : 2.3 Regulation of natural-biological phenomena	78.7%	5.2%	16.1%	0.0%
26 : 2.3.1 Green open spaces in public area	77.5%	5.5%	17.0%	0.0%
27 : 2.3.2 Housing with green open spaces	83.3%	0.0%	16.7%	0.0%
28 : 3. Cultural services	32.0%	14.5%	46.0%	7.6%
29 : 3.1 Aesthetic-local presence of agro-natural elements (land-or sea scapes)	100.0%	0.0%	0.0%	0.0%
30 : 3.1.1 Beautiful landscapes or pleasant environment	100.0%	0.0%	0.0%	0.0%

31 : 3.1.2 Local presence of agro-natural elements	0.0%	0.0%	0.0%	0.0%
32 : 3.2 Natural educational services to enhance awareness to environment and to promote pro-environment behaviours	33.6%	4.3%	52.7%	9.4%
33 : 3.2.1 Environmental and cultural educations	33.6%	4.3%	52.7%	9.4%
34 : 3.3 Services for physical, spiritual, symbolic, interaction with nature and agro-natural elements	21.9%	44.1%	19.1%	14.8%
35 : 3.3.1 Cultural heritage and entertainment	67.7%	0.0%	32.3%	0.0%
36 : 3.3.2 Spiritual services	31.9%	0.0%	68.1%	0.0%
37 : 3.3.3 Societal connectedness to do mutual aids in the communities (gotong royong) to maintain the human settlement environment	0.0%	79.2%	0.0%	20.8%
38 : 3.3.4 Place attachment to nature, built-structure, and people as related to birthplace and community identity	51.7%	17.2%	12.1%	19.0%
39 : 4. Socio-economic services	24.4%	16.7%	43.0%	16.0%
40 : 4.1 Networks for mobility of people, information, and things	21.5%	15.5%	39.7%	23.3%
41 : 4.1.1 Local presence of roads	9.7%	11.7%	41.3%	37.4%
42 : 4.1.2 Local transport availability	44.8%	28.1%	27.1%	0.0%
43 : 4.1.3 Local presence of internet, telephone networks, electricity	14.6%	0.0%	36.4%	49.1%
44 : 4.2 Education services	21.4%	0.0%	78.6%	0.0%
45 : 4.2.1 Local presence of school and accessibility	21.4%	0.0%	78.6%	0.0%
46 : 4.3 Health services	0.0%	100.0%	0.0%	0.0%
47 : 4.3.1 Local presence of health facilities	0.0%	100.0%	0.0%	0.0%
48 : 4.4 Safety	25.5%	11.7%	28.1%	34.7%
49 : 4.4.1 Safety	25.5%	11.7%	28.1%	34.7%
50 : 4.4.2 Political circumstances	0.0%	0.0%	0.0%	100.0%
51 : 4.5 Employment and livelihood	19.4%	16.2%	45.6%	18.8%
52 : 4.5.1 Job availability	11.3%	19.6%	50.4%	18.8%
53 : 4.5.2 Income	25.0%	12.6%	44.1%	18.3%
54 : 4.5.3 Access to capital	17.7%	0.0%	60.4%	21.9%
55 : 4.5.4 Living cost	0.0%	0.0%	100.0%	0.0%
56 : 4.6 Societal interaction and family relationship	15.9%	32.7%	4.4%	46.9%
57 : 4.6.1 Relationships with family, neighbours, communities, and authorities	15.9%	32.7%	4.4%	46.9%
58 : 4.7 Accessibility	38.0%	12.0%	44.7%	5.3%
59 : 4.7.1 Accessibility to public services, city centre, market, workplace	38.0%	12.0%	44.7%	5.3%
60 : 4.8 Farmland and housing affordability	45.1%	6.5%	38.3%	10.1%
61 : 4.8.1 Farmland affordability	0.0%	0.0%	100.0%	0.0%
62 : 4.8.2 Housing affordability	70.6%	10.2%	3.4%	15.8%
63 : 4.9 Government services	20.7%	17.1%	43.2%	19.1%
64 : 4.9.1 Government supports and services	20.7%	17.1%	43.2%	19.1%

Table A.1.4. 4. Means of attribute importance-performance in the urban CMR

No	Sustainability Factors	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	No	Liveability services	Variable Code	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	Sig
A.	Ecohydrology	4.27	3.09	1.18	1	Sufficient water availability	A.1	4.70	3.48	1.22	<0.001
					2	Well maintained river	A.2	4.02	2.66	1.36	<0.001
					3	Green open spaces in the public areas	A.3	4.25	3.07	1.18	<0.001
					4	Housing with garden spaces	A.4	4.12	3.16	0.96	<0.001
B.	Social	4.37	3.41	0.96	1	Health-housing	B.1	4.50	3.45	1.05	<0.001
					2	Health-settlement	B.2	4.47	3.34	1.13	<0.001
					3	Healthy-waterways	B.3	4.52	3.02	1.50	<0.001
					4	Facilities and services for education, public health and amenities	B.4	4.45	3.89	0.56	<0.001
					5	Flood protection	B.5	4.14	3.50	0.64	<0.001
					6	Drought prevention	B.6	4.16	3.24	0.92	<0.001
C.	Economy	4.26	3.26	1.00	1	Housing affordability	C.1	4.10	3.40	0.70	<0.001
					2	Employment/job availability	C.2	4.44	3.04	1.40	<0.001
					3	Mobility/transportation	C.3	4.07	3.64	0.43	<0.001
					4	Income	C.4	4.39	2.95	1.44	<0.001
					5	Water services infrastructures and affordability	C.5	4.31	3.29	1.02	<0.001

Table A.1.4. 5. Means of attribute importance-performance in the UPT CMR

No	Sustainability Factors	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	No	Liveability services	Variable Code	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	Sig
A.	Ecohydrology	4.21	3.24	0.97	1	Sufficient water availability	A.1	4.74	3.63	1.11	<0.001
					2	Well maintained river	A.2	4.07	2.66	1.41	<0.001
					3	Green open spaces in the public areas	A.3	4.16	3.42	0.74	<0.001
					4	Housing with garden spaces	A.4	3.88	3.25	0.63	<0.001
B.	Social	4.28	3.23	1.05	1	Health-housing	B.1	4.36	3.36	1.00	<0.001
					2	Health-settlement	B.2	4.38	3.27	1.11	<0.001
					3	Healthy-waterways	B.3	4.23	2.84	1.39	<0.001
					4	Facilities and services for education, public health and amenities	B.4	4.41	3.72	0.69	<0.001
					5	Flood protection	B.5	4.11	3.19	0.92	<0.001
					6	Drought prevention	B.6	4.22	2.97	1.25	<0.001
C.	Economy	4.25	3.12	1.13	1	Housing affordability	C.1	4.00	3.29	0.71	<0.001
					2	Employment/job availability	C.2	4.45	3.09	1.36	<0.001
					3	Mobility/transportation	C.3	4.12	3.76	0.36	<0.001
					4	Income	C.4	4.40	2.55	1.85	<0.001
					5	Water services infrastructures and affordability	C.5	4.28	2.90	1.38	<0.001

TABLE A.1.4. 6. MEANS OF ATTRIBUTE IMPORTANCE-PERFORMANCE IN THE PERI-URBAN CMR

No	Sustainability Factors	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	No	Liveability services	Variable Code	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	Sig
A.	Ecohydrology	4.17	3.32	0.85	1	Sufficient water availability	A.1	4.64	3.45	1.19	<0.001
					2	Well maintained river	A.2	4.05	2.80	1.25	<0.001
					3	Green open spaces in the public areas	A.3	4.08	3.63	0.45	<0.001
					4	Housing with garden spaces	A.4	3.90	3.39	0.51	<0.001
B.	Social	4.13	3.39	0.74	1	Health-housing	B.1	4.24	3.52	0.72	<0.001
					2	Health-settlement	B.2	4.22	3.46	0.76	<0.001
					3	Healthy-waterways	B.3	4.18	3.12	1.06	<0.001
					4	Facilities and services for education, public health and amenities	B.4	4.20	3.88	0.32	<0.001
					5	Flood protection	B.5	3.79	3.39	0.40	<0.001
					6	Drought prevention	B.6	4.14	2.97	1.17	<0.001
C.	Economy	4.14	3.25	0.89	1	Housing affordability	C.1	3.93	3.49	0.44	<0.001
					2	Employment/job availability	C.2	4.29	3.02	1.27	<0.001
					3	Mobility/transportation	C.3	4.02	3.68	0.34	<0.001
					4	Income	C.4	4.29	2.84	1.45	<0.001
					5	Water services infrastructures and affordability	C.5	4.17	3.22	0.95	<0.001

TABLE A.1.4. 7. MEANS OF ATTRIBUTE IMPORTANCE-PERFORMANCE IN THE RURAL CMR

No	Sustainability Factors	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	No	Liveability services	Variable Code	Mean of Importance (I)	Mean of Performance (P)	Gap I-P	Sig
A.	Ecohydrology	4.16	3.20	0.96	1	Sufficient water availability	A.1	4.64	3.27	1.37	<0.001
					2	Well maintained river	A.2	4.11	2.60	1.51	<0.001
					3	Green open spaces in the public areas	A.3	4.03	3.60	0.43	<0.001
					4	Housing with garden spaces	A.4	3.86	3.32	0.54	<0.001
B.	Social	4.16	3.17	0.99	1	Health-housing	B.1	4.26	3.47	0.79	<0.001
					2	Health-settlement	B.2	4.18	3.44	0.74	<0.001
					3	Healthy-waterways	B.3	4.17	2.82	1.35	<0.001
					4	Facilities and services for education, public health and amenities	B.4	4.21	3.66	0.55	<0.001
					5	Flood protection	B.5	3.93	3.19	0.74	<0.001
					6	Drought prevention	B.6	4.19	2.47	1.72	<0.001
C.	Economy	4.13	2.97	1.16	1	Housing affordability	C.1	3.96	3.26	0.70	<0.001
					2	Employment/job availability	C.2	4.29	2.97	1.32	<0.001
					3	Mobility/transportation	C.3	4.01	3.44	0.57	<0.001
					4	Income	C.4	4.23	2.64	1.59	<0.001
					5	Water services infrastructures and affordability	C.5	4.14	2.53	1.61	<0.001

TABLE A.1.4. 8. MEANS OF ATTRIBUTE IMPORTANT, PERFORMANCE, AND PERFORMANCE DIFFERENCES BETWEEN FOCAL PERFORMANCE OF THE URBAN CENTRE AND ITS OUTSKIRTS OR COMPETITORS

Liveability services	Variable code	Mean importance within CMR	Performance (P)						Performance difference (Gap P)			
			Urban (X1)	UPT (X2)	Peri-urban (X3)	Rural (X4)	City (Z1)	Peripheral city (Z2)	X2-X1	X3-X1	X4-X1	(Z2-Z1)
Sufficient water availability	A.1	4.66	3.48	3.63	3.45	3.27	3.46	3.45	0.15	-0.03	-0.21	-0.01
Well maintained river	A.2	4.03	2.66	2.66	2.80	2.60	2.64	2.73	0.00	0.14	-0.06	0.09
Green open spaces in the public areas	A.3	4.13	3.07	3.42	3.63	3.60	3.04	3.58	0.35	0.56	0.53	0.54
Housing with garden spaces	A.4	3.94	3.16	3.25	3.39	3.32	3.14	3.34	0.09	0.23	0.16	0.20
Health-housing	B.1	4.32	3.45	3.36	3.52	3.47	3.41	3.48	-0.09	0.07	0.02	0.07
Health-settlement	B.2	4.29	3.34	3.27	3.46	3.44	3.30	3.42	-0.07	0.12	0.10	0.12
Healthy-waterways	B.3	4.26	3.02	2.84	3.12	2.82	2.99	3.00	-0.18	0.10	-0.20	0.01
Facilities and services for education, public health and amenities	B.4	4.31	3.89	3.72	3.88	3.66	3.89	3.80	-0.17	-0.01	-0.23	-0.09
Flood protection	B.5	3.95	3.50	3.19	3.39	3.19	3.48	3.31	-0.31	-0.11	-0.31	-0.17
Drought prevention	B.6	4.16	3.24	2.97	2.97	2.47	3.23	2.87	-0.27	-0.27	-0.77	-0.36
Housing affordability	C.1	3.99	3.40	3.29	3.49	3.26	3.38	3.40	-0.11	0.09	-0.14	0.02
Employment/job availability	C.2	4.36	3.04	3.09	3.02	2.97	3.00	3.04	0.05	-0.02	-0.07	0.04
Mobility/transportation	C.3	4.06	3.64	3.76	3.68	3.44	3.63	3.65	0.12	0.04	-0.20	0.02
Income	C.4	4.32	2.95	2.55	2.84	2.64	2.91	2.74	-0.40	-0.11	-0.31	-0.17
Water services infrastructures and affordability	C.5	4.22	3.29	2.90	3.22	2.53	3.26	3.01	-0.39	-0.07	-0.76	-0.25

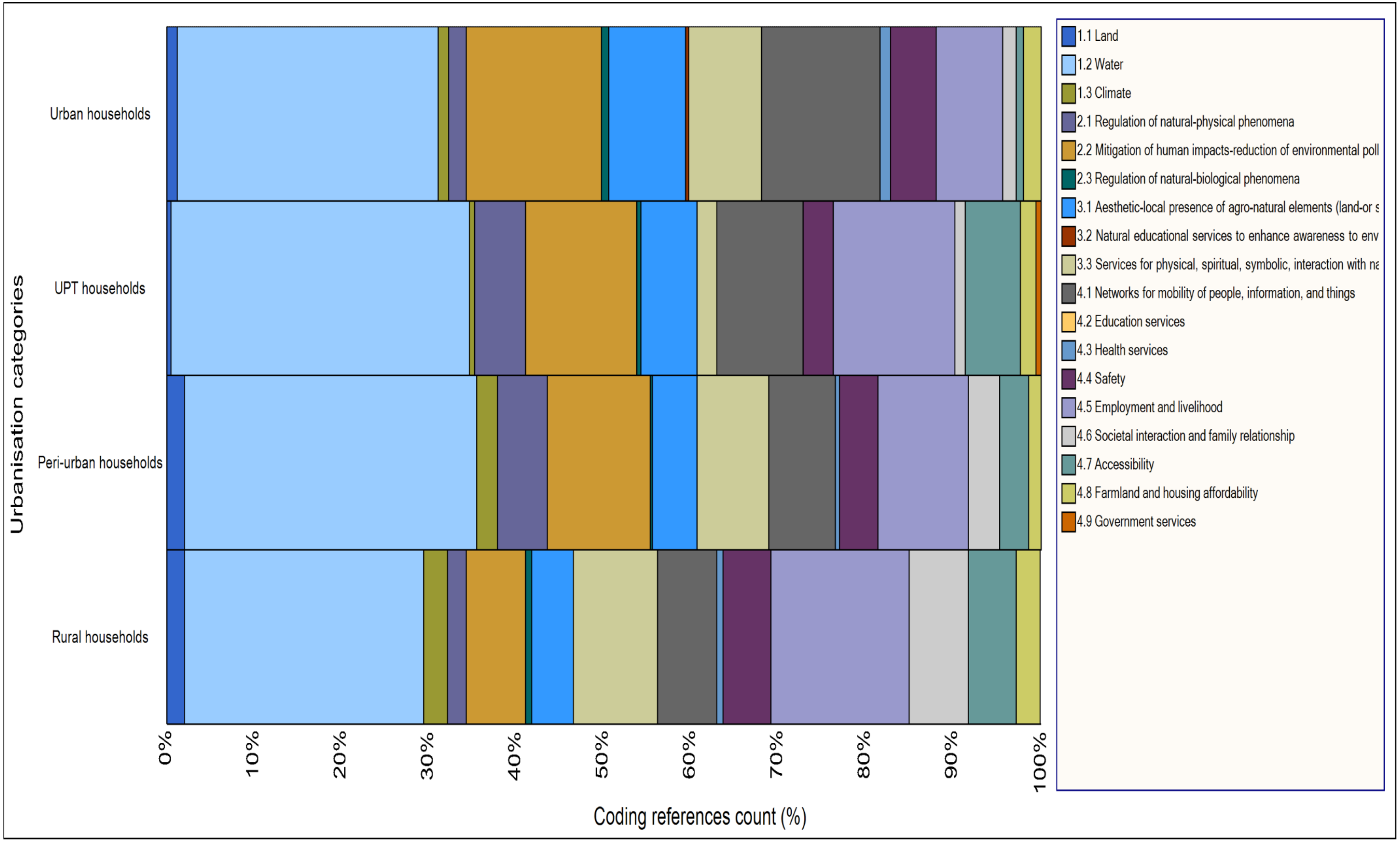

FIGURE A.1.4. 1. VISUALISATION OF MOST IMPORTANT LIVEABILITY SERVICES (SECOND ORDER OF THE HIERARCHICAL THEMES)

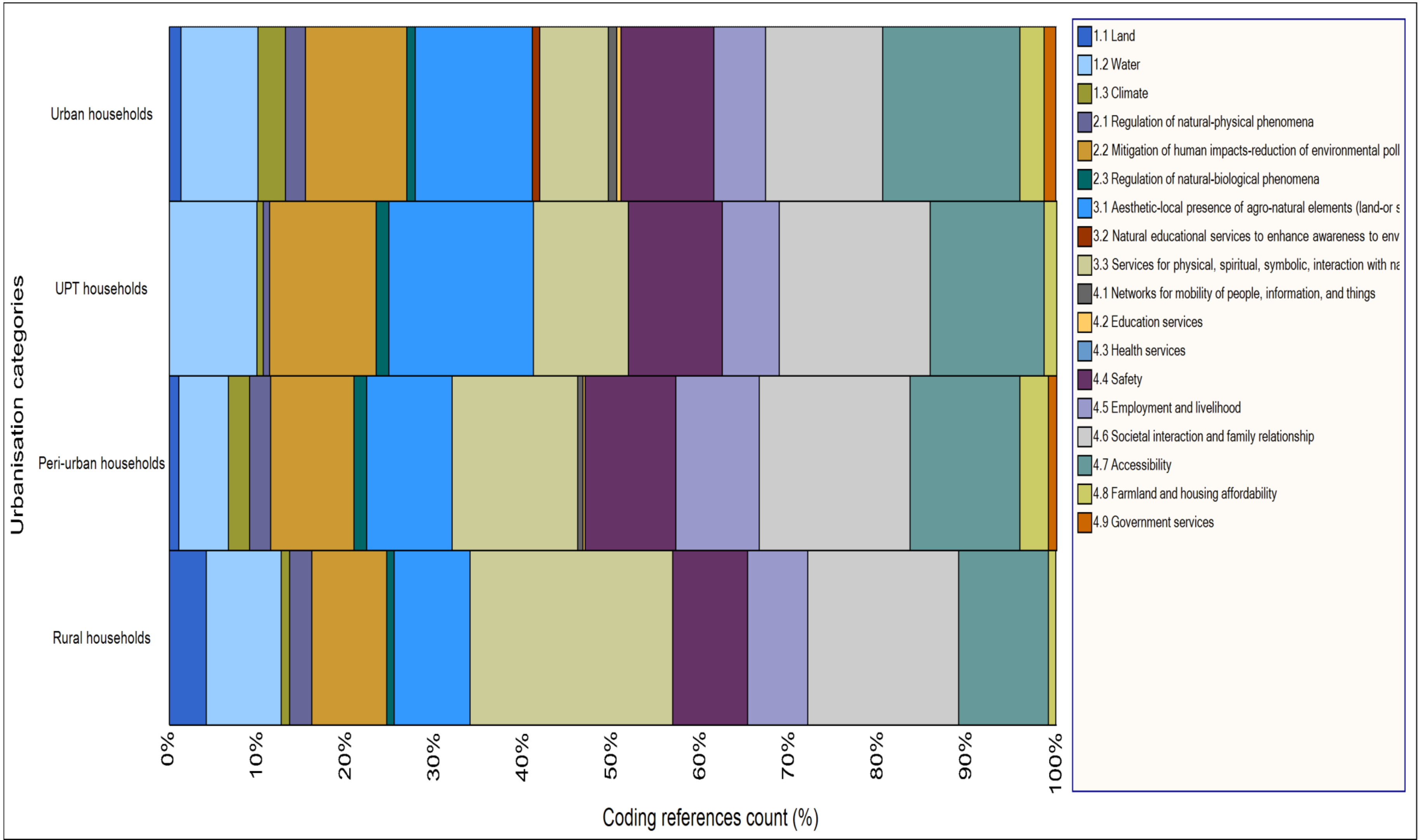

FIGURE A.1.4. 2. VISUALISATION OF MOST SATISFIED LIVEABILITY SERVICES (SECOND ORDER OF THE HIERARCHICAL THEMES)

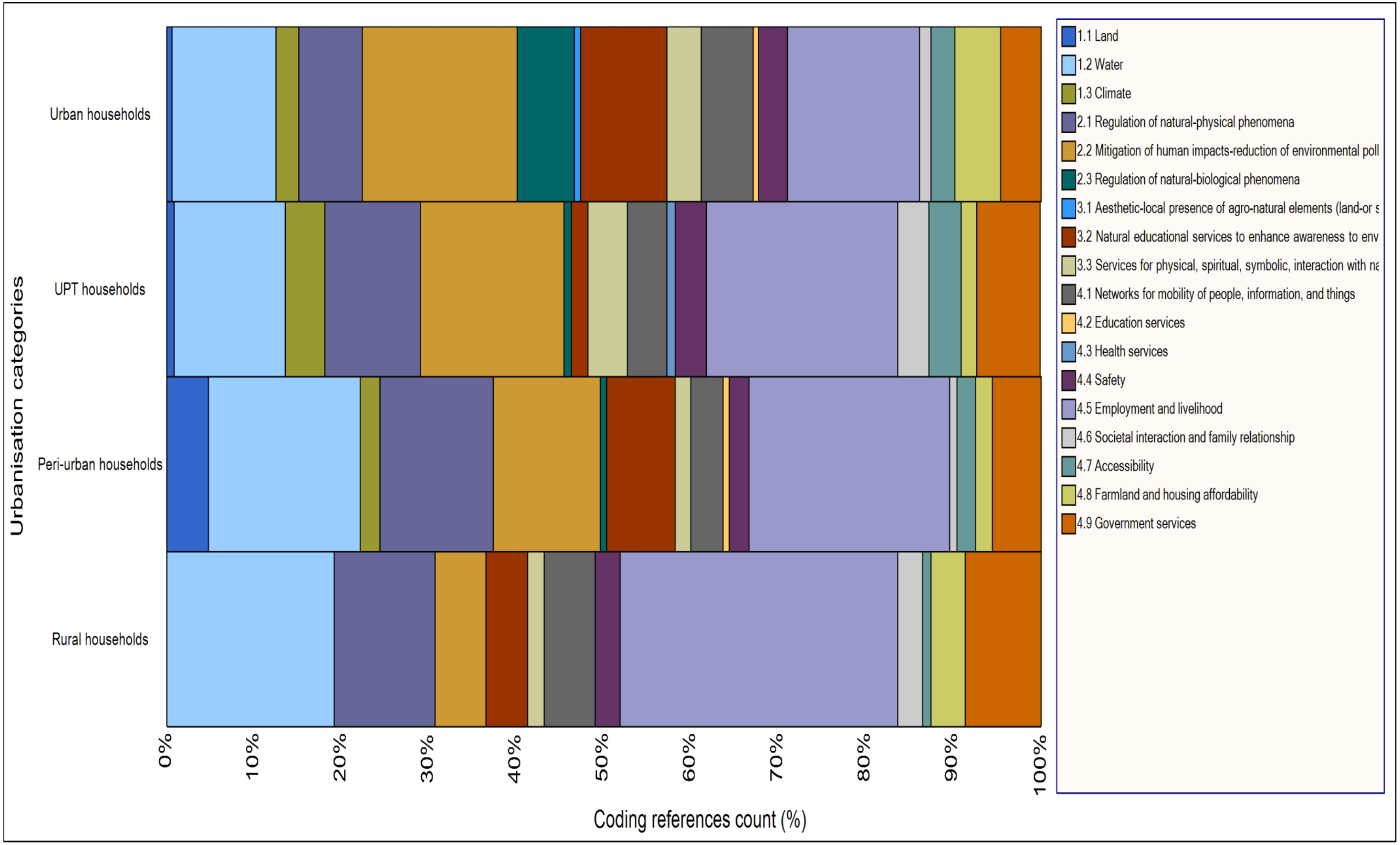

FIGURE A.1.4. 3. VISUALISATION OF LEAST SATISFIED LIVEABILITY SERVICES (SECOND ORDER OF THE HIERARCHICAL THEMES)

Appendix 1. 5 Evaluating the complexity of household water security issues

DANIELAINI, T. T., MAHESHWARI, B., & HAGARE, D. 2019. An assessment of household water insecurity in a rapidly developing coastal metropolitan region of Indonesia. Sustainable Cities and Society, 46. doi: 10.1016/j.scs.2018.12.010

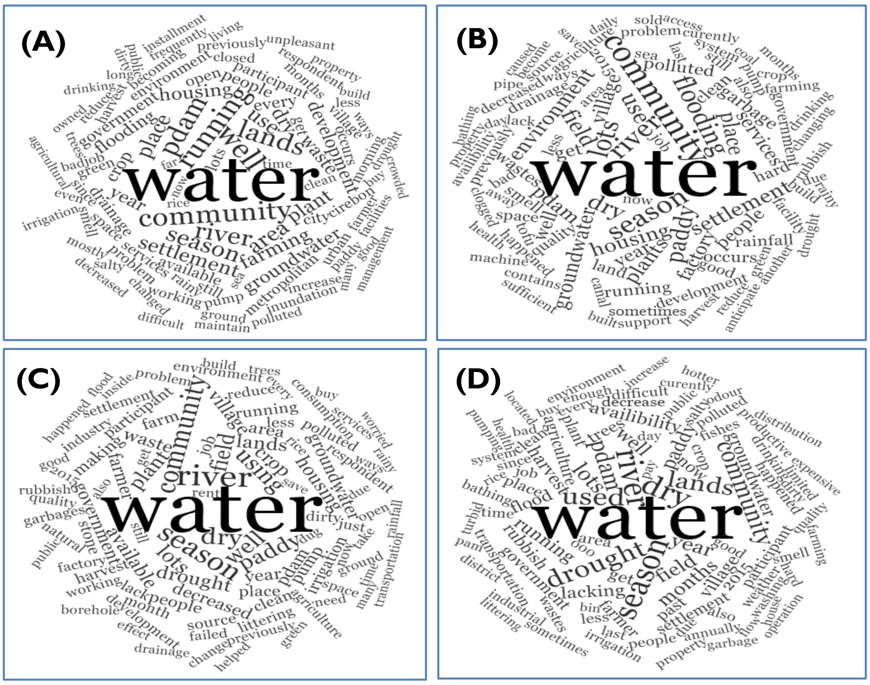

FIGURE A.1.5. 1. WORD CLOUD OF 100 MOST FREQUENT DISPLAY WORDS OF THE INFORMATION ABOUT THE CHANGES IN LAND USE, WATER CYCLE AND CLIMATE AND IMPACTS WITHIN CMR: (A) URBAN; (B) UPT; (C) PERI-URBAN; (D) RURAL

TABLE A.1.5. 1. MEAN VALUES FOR GUTTMAN SCALE SCORES AND DIFFERENCES AMONG FOUR URBANISATION LEVELS

Type of households	Issue in water-sanitation access		Issue in water risks acceptability		Issue in water system capability		Issue in household adaptive capacity		HH	% total surveyed HH
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Rural households	3.3	1.4	3.8	2.2	3.7	2.5	2.8	1.3	73	17.0%
Peri-urban households	3.1	1.5	3.9	1.5	2.5	2.2	2.9	1.3	182	42.3%
UPT households	3.2	1.3	4.3	1.9	3.3	2.2	2.8	1.2	74	17.2%
Urban households	1.9	1.6	3.6	1.4	2.9	2.4	3.0	1.3	101	23.5%
F	17.0		2.3		5.1		0.4			
Sig	<0.001		>0.05		<0.01		>0.05			

SD=Standard Deviation. Highlighted highest scores indicate water security issues

TABLE A.1.5. 2. MEAN VALUES FOR GUTTMAN SCALE SCORES AND DIFFERENCES BETWEEN FARM AND NON-FARM HOUSEHOLDS

Type of households	Issue in water-sanitation access		Issue in water risks acceptability		Issue in water system capability		Issue in household adaptive capacity		HH	% total surveyed HH
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Farm households	3.3	1.5	4.0	1.7	3.3	2.4	2.9	1.3	225	52.3%
Non-Farm households	2.4	1.6	3.7	1.7	2.6	2.2	2.8	1.2	205	47.7%
F	5.9		2.2		3.3		0.8			
Sig	<0.001		<0.05		<0.01		>0.05			

SD=Standard Deviation. Highlighted highest scores indicate water security issues.

TABLE A.1.5. 3. MEAN VALUES FOR GUTTMAN SCALE SCORES AND DIFFERENCES AMONG URBAN/PERI-URBAN FARM AND NON-FARM HOUSEHOLDS

Farm and non-farm HH in four urbanisation levels	Issue in water-sanitation access		Issue in water risks acceptability		Issue in water system capability		Issue in household adaptive capacity		HH	% total surveyed HH
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Rural farm household	3.3	1.4	3.9	2.2	3.8	2.3	3.0	1.3	45	10.5%
Peri-urban farm household	3.3	1.5	4.1	1.4	2.8	2.2	2.8	1.2	116	27.0%
UPT farm household	3.6	1.4	4.6	2.1	3.7	2.2	2.8	1.3	32	7.4%
Urban Farm household	2.6	1.5	3.6	1.3	4.1	2.6	3.3	1.5	32	7.4%
Rural non-farm household	3.2	1.3	3.6	2.2	3.5	3.0	2.4	1.1	28	6.5%
Peri-urban non-farm household	2.6	1.5	3.5	1.6	2.1	2.0	3.1	1.4	66	15.3%
UPT non-farm household	2.9	1.2	4.0	1.7	3.0	2.1	2.8	1.1	42	9.8%
Urban non-Farm household	1.6	1.6	3.6	1.5	2.3	2.1	2.8	1.2	69	16.0%
F	11.4		1.9		5.1		1.6			
Sig	<0.001		>0.05		<0.001		>0.05			

SD=Standard Deviation. Highlighted highest scores indicate water security issues.

TABLE A.1.5. 4 MEAN VALUES FOR FACTOR SCORES AND DIFFERENCES AMONG FOUR URBANISATION LEVELS FROM FACTOR ANALYSIS

Urbanisation levels	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6		Factor 7		Factor 8		Factor 9		Factor 10		Factor 11		Factor 12		HH	%HH
	Drought event		Unhealthy housing & environment		Unregulated Water use		Limited access		Flood event		Poor affordability		Poor sanitation		Water resources issue		Water affect issue		Climate change		Concern of future risks		Poverty/ vulnerability			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Rural	0.47	1.0	0.00	1.0	0.04	1.1	0.01	0.8	0.05	0.9	0.03	1.1	0.20	0.9	-0.54	1.2	0.08	1.0	-0.24	1.1	-0.23	0.9	0.04	1.1	73	17.0%
Peri-urban	0.04	1.0	-0.15	0.9	-0.05	1.0	0.21	0.9	-0.26	0.7	0.13	1.1	0.03	1.0	0.28	0.8	-0.08	1.0	0.03	0.9	0.02	1.0	0.11	1.0	182	42.3%
UPT	-0.06	0.9	0.14	1.0	0.03	0.9	0.22	1.0	0.58	1.5	-0.04	0.8	0.10	1.0	-0.07	0.9	-0.15	1.0	0.14	1.0	0.11	0.9	-0.09	0.9	74	17.2%
Urban	-0.37	0.9	0.17	1.1	0.04	1.0	-0.56	1.1	0.00	1.0	-0.23	0.8	-0.27	0.9	-0.07	1.0	0.20	1.0	0.02	1.1	0.06	1.1	-0.16	0.9	101	23.5%
F	10.8		2.9		0.2		15.9		13.5		2.8		3.8		13.2		2.4		1.9		1.8		1.7			
Sig	<0.001		<0.05		>0.05		<0.001		<0.001		<0.05		<0.01		<0.001		>0.05		>0.05		>0.05		>0.05			

Note: Highlighted highest scores indicate underlying factors causing water insecurity.

TABLE A.1.5. 5. MEAN VALUES FOR FACTOR SCORES AND DIFFERENCES BETWEEN FARM AND NON-FARM HOUSEHOLDS FROM FACTOR ANALYSIS

Type of occupation	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6		Factor 7		Factor 8		Factor 9		Factor 10		Factor 11		Factor 12		HH	%HH
	Drought event		Unhealthy housing & environment		Unregulated Water use		Limited access		Flood event		Poor affordability		Poor sanitation		Water resources issue		Water affect issue		Climate change		Concern of future risks		Poverty/ vulnerability			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Farm households	0.32	0.96	-0.03	0.97	0.06	1.08	0.24	0.97	-0.03	0.98	-0.06	1.05	0.16	0.98	0.03	0.99	-0.07	1.00	-0.13	1.05	-0.01	0.98	0.12	1.02	225	52.3%
Non-Farm households	-0.35	0.92	0.04	1.03	-0.07	0.90	-0.26	0.97	0.04	1.02	0.06	0.95	-0.18	1.00	-0.03	1.02	0.08	1.00	0.14	0.92	0.01	1.02	-0.13	0.96	205	47.7%
F	7.3		-0.7		1.3		5.4		-0.7		-1.2		3.6		0.7		-1.6		-2.8		-0.2		2.7			
Sig	<0.001		>0.05		>0.05		<0.001		>0.05		>0.05		<0.001		>0.05		>0.05		<0.01		>0.05		<0.01			

Note: Highlighted highest scores indicate underlying factors causing water insecurity.

TABLE A.1.5. 6. MEAN VALUES FOR FACTOR SCORES AND DIFFERENCES AMONG FARM AND NON-FARM HOUSEHOLDS IN THE RURAL-URBAN INTERFACES FROM FACTOR ANALYSIS

Farm and non-farm HH in four urbanisation levels	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6		Factor 7		Factor 8		Factor 9		Factor 10		Factor 11		Factor 12		HH	%HH
	Drought event		Unhealthy housing & environment		Unregulated Water use		Limited access		Flood event		Poor affordability		Poor sanitation		Water resources issue		Water affect issue		Climate change		Concern of future risks		Poverty/ vulnerability			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Rural farm household	0.6	1.0	-0.1	0.8	0.2	1.2	0.0	0.8	0.2	1.0	-0.1	0.9	0.3	1.0	-0.5	1.2	0.2	1.0	-0.3	1.2	-0.2	0.9	0.1	1.2	45	10.5%
Peri-urban farm household	0.3	1.0	-0.2	0.9	0.0	1.0	0.3	0.9	-0.3	0.7	0.1	1.2	0.2	1.0	0.3	0.8	-0.2	1.0	0.0	0.9	0.0	1.0	0.1	1.0	116	27.0%
UPT farm household	0.3	0.9	0.1	0.9	0.1	1.0	0.6	1.0	0.7	1.5	-0.2	0.9	0.2	1.0	0.0	1.0	-0.3	1.0	0.0	1.0	0.0	1.0	0.1	1.0	32	7.4%
Urban Farm household	0.1	0.9	0.5	1.2	0.3	1.1	-0.1	1.1	-0.1	1.0	-0.5	0.4	-0.1	0.9	-0.2	1.0	0.0	1.0	-0.3	1.4	0.3	1.0	0.2	0.9	32	7.4%
Rural non-farm household	0.3	1.0	0.2	1.3	-0.2	0.9	0.0	0.7	-0.1	0.7	0.2	1.3	0.1	0.9	-0.6	1.3	-0.2	1.0	-0.1	1.0	-0.3	1.0	-0.1	1.1	28	6.5%
Peri-urban non-farm household	-0.4	0.9	-0.1	1.0	0.0	1.0	0.0	0.9	-0.2	0.7	0.2	0.9	-0.2	1.0	0.2	0.9	0.0	1.0	0.1	0.9	0.1	1.1	0.1	1.0	66	15.3%
UPT non-farm household	-0.4	0.8	0.2	1.0	0.0	0.9	-0.1	0.8	0.5	1.5	0.0	0.6	0.0	1.1	-0.1	0.9	-0.1	1.0	0.3	1.0	0.2	0.8	-0.2	0.8	42	9.8%
Urban non-Farm household	-0.6	0.8	0.0	1.0	-0.1	0.9	-0.8	1.0	0.0	1.0	-0.1	0.9	-0.4	1.0	0.0	1.0	0.3	1.0	0.2	0.9	-0.1	1.1	-0.3	0.9	69	16.0%
F	11.5		2.4		0.8		10.6		6.2		2.2		3.1		6.0		2.1		2.2		1.4		2.0			
Sig	<0.001		<0.05		>0.05		<0.001		<0.001		<0.05		<0.01		<0.001		<0.05		<0.05		>0.05		>0.05			

Note: Highlighted highest scores indicate underlying factors causing water insecurity.

APPENDIX 1. 6 THE NEXUS OF WATER SECURITY, LIVEABILITY, AND SUSTAINABILITY

TABLE A.1.6. 1 TREND OF COD

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of COD	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_COD	2001-2017	R_COD =-0.06t+22.8	*decreases 0.6 mg/l per decade*	>0.1	5.0	119.7	21.1	17.2
Peri-urban	P_COD	2001-2017	P_COD=-1.52t+90.66	*decreases 15 mg/l per decade*	<0.01	10.0	341.0	50.8	58.6
UPT	UP_COD	2001-2017	UP_COD=0.22t+27.89	*increases 2.2 mg/l per decade*	>0.1	5.5	83.0	33.6	20.0
Urban	UR_COD	2001-2017	UR_COD=-0.008t+21.18	*decreases 0.08 mg/l per decade*	>0.1	6.0	85.5	21.0	15.2

TABLE A.1.6. 2 TREND OF DO

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of DO	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_DO	2001-2017	R_DO =0.04t+5.12	*increases 0.4 mg/l per decade*	<0.001	4.3	9.3	6.2	1.2
Peri-urban	P_DO	2001-2017	P_DO=0.03t+2.09	*increases 0.3 mg/l per decade*	<0.01	0.7	5.7	2.9	1.2
UPT	UP_DO	2001-2017	UP_DO=0.04t+3.63	*increases 0.4 mg/l per decade*	<0.01	1.7	7.8	4.7	1.6
Urban	UR_DO	2001-2017	UR_DO=0.02t+2.91	*increases 0.2 mg/l per decade*	>0.1	0.2	7.8	3.6	1.9

TABLE A.1.6. 3 TREND OF BOD

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of BOD	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_BOD	2001-2017	R_BOD =-0.04t+10.76	*decreases 0.4 mg/l per decade*	>0.1	3.7	37.0	9.8	6.6
Peri-urban	P_BOD	2001-2017	P_BOD=-1.33t+64.65	*decreases 13.3 mg/l per decade*	<0.01	5.0	226.0	30.1	48.5
UPT	UP_BOD	2001-2017	UP_BOD=+0.04t+15.29	*increases 0.4 mg/l per decade*	>0.1	2.5	50.0	16.2	10.6
Urban	UR_BOD	2001-2017	UR_BOD=-0.09t+13.24	*decreases 0.9 mg/l per decade*	>0.1	3.0	36.0	10.6	5.9

TABLE A.1.6. 4 TREND OF NH4

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of NH4	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_NH4	2001-2017	R_NH4 =-0.001t+0.45	*decreases 0.01 mg/l per decade*	>0.1	0.1	3.0	0.4	0.4
Peri-urban	P_NH4	2001-2017	P_NH4=-0.06t+3.13	*decreases 0.6 mg/l per decade*	<0.05	0.3	16.3	1.7	2.7
UPT	UP_NH4	2001-2017	UP_NH4=-0.02t+1.76	*decreases 0.2 mg/l per decade*	>0.1	0.1	9.7	1.4	1.5
Urban	UR_NH4	2001-2017	UR_NH4=-0.006t+1.24	*decreases 0.06 mg/l per decade*	>0.1	0.2	4.1	1.1	0.7

TABLE A.1.6. 5 TREND OF PO4

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of PO4	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_PO4	2001-2017	R_PO4 =0.001t+0.42	*increases 0.01 mg/l per decade*	>0.1	0.2	1.6	0.4	0.3
Peri-urban	P_PO4	2001-2017	P_PO4=-0.02t+1.46	*decreases 0.2 mg/l per decade*	<0.05	0.1	8.0	0.9	1.2
UPT	UP_PO4	2001-2017	UP_PO4=-0.007t+1.35	*decreases 0.07 mg/l per decade*	>0.1	0.2	3.7	1.2	0.7
Urban	UR_PO4	2001-2017	UR_PO4=-0.011t+1.46	*decreases 0.11 mg/l per decade*	>0.1	0.1	2.9	1.1	0.7

TABLE A.1.6. 6 TREND OF NO3

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of NO3	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_NO3	2001-2017	R_NO3 =0.05t+1.69	*increases 0.5 mg/l per decade*	<0.05	0.1	13.6	3.0	2.4
Peri-urban	P_NO3	2001-2017	P_NO3=-0.02t+5.32	*decreases 0.2 mg/l per decade*	>0.1	0.1	31.8	4.8	5.0
UPT	UP_NO3	2001-2017	UP_NO3=0.06t+1.70	*increases 0.6 mg/l per decade*	<0.001	0.1	13.7	3.3	2.1
Urban	UR_NO3	2001-2017	UR_NO3=0.05t+2.02	*increases 0.5 mg/l per decade*	<0.1	0.5	15.2	3.5	2.9

TABLE A.1.6. 7 TREND OF TURBIDITY

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of Turbidity	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_Turbidity	2001-2017	R_Turbidity =-2.02t+199.31	*decreases 20.2 FTU per decade*	>0.1	16.3	827.7	145.8	182.3
Peri-urban	P_Turbidity	2001-2017	P_Turbidity=-2.97t+217.85	*decreases 29.7 FTU per decade*	<0.01	11.0	474.0	139.2	102.8
UPT	UP_Turbidity	2001-2017	UP_Turbidity=-0.43t+51.81	*decreases 4.3 FTU per decade*	>0.1	7.0	277.5	40.5	49.7
Urban	UR_Turbidity	2001-2017	UR_Turbidity=0.05t+49.36	*increases 0.5 FTU per decade*	>0.1	5.0	437.5	50.8	76.2

TABLE A.1.6. 8 TREND OF SS

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of Suspended Solid	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_SS	2001-2017	R_SS =-3.01t+248.78	*decreases 30.1 mg/l per decade*	>0.1	19.0	1034.3	168.9	220.6
Peri-urban	P_SS	2001-2017	P_SS=-2.15t+180.32	*decreases 21.5 mg/l per decade*	<0.1	35.5	638.0	123.3	120.6
UPT	UP_SS	2001-2017	UP_SS=-0.38t+72.28	*decreases 3.8 mg/l per decade*	>0.1	7.5	353.5	62.2	61.9
Urban	UR_SS	2001-2017	UR_SS=-0.56t+87.21	*decreases 5.6 mg/l per decade*	>0.1	9.5	690.5	71.3	106.2

Table A.1.6. 9 Trend of Colour

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of Colour	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_Colour	2001-2017	R_Colour =0.024t+115.53	*increases 0.24 units per decade*	>0.1	22.3	839.3	116.2	158.1
Peri-urban	P_Colour	2001-2017	P_Colour=-8.92t+510.16	*decreases 89 units per decade*	<0.05	24.5	2324.5	273.7	435.1
UPT	UP_Colour	2001-2017	UP_Colour=0.31t+92.72	*increases 3.1 units per decade*	>0.1	16.0	431.0	100.9	84.5
Urban	UR_Colour	2001-2017	UR_Colour=1.02t+78.58	*increases 10.2 units per decade*	>0.1	15.0	821.0	107.8	137.4

Table A.1.6. 10 Trend of pH

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of pH	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_pH	2001-2017	R_pH =0.003t+7.38	*increases 0.03 per decade*	>0.1	6.8	8.4	7.5	0.4
Peri-urban	P_pH	2001-2017	P_pH=0.012t+6.63	*increases 0.12 per decade*	<0.01	5.8	8.1	6.9	0.5
UPT	UP_pH	2001-2017	UP_pH=0.006t+6.98	*increases 0.06 per decade*	>0.1	6.4	8.4	7.1	0.4
Urban	UR_pH	2001-2017	UR_pH=0.004t+7.00	*increases 0.04 per decade*	>0.1	6.5	8.1	7.1	0.4

Table A.1.6. 11 Trend of E. Coli

Average of Watersheds quality in the CMR	Code	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend of E. Coli	p-value (2-tailed)	Min	Max	Mean	SD
Rural	R_Coli	2001-2017	R_Coli =4.2x10^3t+3.5x10^5	*increases 4.2x 10^4 MPN/100 ml per decade*	>0.1	1.37E+01	3.07E+06	4.63E+05	5.93E+05
Peri-urban	P_Coli	2001-2017	P_Coli=1.62x10^4t+3.9x10^5	*increases 1.62x 10^5 MPN/100 ml per decade*	<0.05	2.15E+01	4.30E+06	8.19E+05	9.30E+05
UPT	UP_Coli	2001-2017	UP_Coli=2.4x10^4t+3.1x10^5	*increases 2.4 x 10^5 MPN/100 ml per decade*	<0.001	1.05E+01	3.10E+06	9.50E+05	7.60E+05
Urban	UR_Coli	2001-2017	UR_Coli=2.2x10^4t+6.9x10^5	*increases 2.2 x 10^5 MPN/100 ml per decade*	>0.1	1.00E+01	7.00E+06	1.32E+06	1.47E+06

Location of watersheds	Selected Rivers and sampling points
Rural	Cisanggarung River@ Losari-Cirebon; Pekik River @ Mandirancang-Kuningan; Kumpulkuista River@ Kapetakan-Cirebon
Peri-urban	Winong River @ Klangenan and Arjawinangun- Cirebon
UPT	Pekik River @ Kedawung and Tengah Tani-Cirebon
Urban	Kesunean River @ Harjamukti-Cirebon City

TABLE A.1.6. 12 AVERAGE WATER QUALITY PARAMETERS IN THE RURAL-URBAN INTERFACE WATERSHEDS

More selected rivers and sampling points	Code	The source of pollution	COD (mg/l)	BOD (mg/l)	DO (mg/l)	NH4 (mg/l)	PO4 (mg/l)	Turbidity (FTU)	SS (mg/l)	Colour (units)	pH	E. coli (MPN/100 ml)
WATERSHEDS IN RURAL AREA												
Cisanggarung River@ Losari-Cirebon	CSG 6	Agricultural and rural activities	20.8	9.9	5.8	0.4	0.4	238.5	269.8	114.6	7.5	7.8E+05
Pekik River @ Mandirancang-Kuningan	PKK 1	Agricultural and rural activities	15.2	6.0	6.7	0.3	0.6	52.3	93.7	57.5	7.4	2.1E+05
Kumpulkuista River@ Kapetakan-Cirebon	KKS 2	Agricultural and rural activities	27.4	13.6	6.0	0.6	0.3	146.7	143.3	176.4	7.6	4.0E+05
Average water quality parameters in rural area			**21.1**	**9.8**	**6.2**	**0.4**	**0.4**	**145.8**	**168.9**	**116.2**	**7.5**	**4.6E+05**
WATERSHEDS IN PERI-URBAN AREA												
Bangkaderes River @ Karangsembung-Cirebon	BKD 1	Agricultural and peri-urban activities	20.8	9.1	6.9	0.5	0.4	192.1	220.9	107.6	7.9	3.5E+05
Kalijaga River @ Beber-Cirebon	KLJ 1	Agricultural and peri-urban activities	17.1	8.2	5.6	0.2	0.4	19.5	42.9	43.7	6.7	5.6E+05
Kesunean River @ Beber-Cirebon	KSN 1	Agricultural and peri-urban activities	31.9	12.6	6.8	0.5	0.4	70.0	75.4	110.4	7.4	5.3E+05
Winong River @ Klangenan- Cirebon	WNG 1	Peri-urban activities	27.0	13.4	2.1	1.0	0.7	101.2	122.7	122.5	6.7	9.5E+05
Winong River @ Arjawinangun- Cirebon	WNG 2	Industrial activities from PT Rajawali II	74.6	46.8	3.7	2.4	1.1	177.3	123.9	425.0	7.1	6.8E+05
Jamblang River @ Klangenan-Cirebon	JBL 3	Agricultural and peri-urban activities	16.0	7.5	4.5	0.5	0.7	78.4	91.6	127.6	7.0	9.2E+05
Average water quality parameters in peri-urban area			**31.2**	**16.3**	**4.9**	**0.8**	**0.6**	**106.4**	**112.9**	**156.1**	**7.1**	**6.7E+05**
WATERSHEDS IN URBAN-PERI-URBAN TRANSITION (UPT) AREA												
Bangkaderes River @ Astanajapura-Cirebon	BKD 2	Agricultural and UPT activities	33.4	16.3	5.0	0.5	0.7	134.5	176.0	74.5	7.5	6.2E+05
Kalijaga River @ Mundu-Cirebon	KLJ 3	UPT activities	21.6	10.3	6.6	0.3	0.5	67.2	62.3	99.1	7.8	4.9E+05
Jamblang River @ Sumber-Cirebon	JBL 1	Fishery and agricultural activities	8.7	4.7	6.6	0.3	0.7	131.1	186.4	52.0	7.4	3.8E+05
Jamblang River @ Palimanan-Cirebon	JBL 2	Agricultural and UPT activities	13.2	6.6	6.2	0.3	0.6	156.4	205.3	76.8	7.3	6.4E+05
Pekik River @ Kedawung -Cirebon	PKK 2	Agricultural and UPT activities	13.8	7.1	6.0	0.3	0.6	20.8	46.5	49.4	7.1	7.0E+05
Pekik River @ Tengah Tani-Cirebon	PKK 3	UPT, industrial, and market activities	53.5	25.4	3.4	2.5	1.7	60.2	77.9	152.1	7.2	1.2E+06
Average water quality parameters in UPT area			**24.0**	**11.7**	**5.6**	**0.7**	**0.8**	**95.0**	**125.7**	**84.0**	**7.4**	**6.7E+05**
WATERSHEDS IN URBAN AREA												
Kalijaga River @ Harjamukti-Cirebon City	KLJ 2	Agricultural and urban activities	24.2	10.8	6.9	0.3	0.5	77.0	100.1	82.3	7.9	6.7E+05
Kesunean River @ Harjamukti-Cirebon City	KSN 2	Urban and home-industrial activities	21.5	10.5	3.1	0.8	0.9	49.6	67.9	104.4	7.1	1.5E+06
Kesunean River @ Harjamukti-Cirebon City	KSN 3	Urban, hospital, public transport station activities	20.4	10.7	4.0	1.3	1.3	52.0	74.7	111.1	7.2	1.1E+06
Average water quality parameters in urban area			**22.0**	**10.7**	**4.7**	**0.8**	**0.9**	**59.5**	**80.9**	**99.3**	**7.4**	**1.1E+06**
*Threshold Limit Values (TLV) Class I**			***≤10***	***≤2***	***≥6***	***≤0.5***	***≤0.2***		***≤50***		***6-9***	***≤1000***
*TLV Class II**			***≤25***	***≤3***	***≥4***	***-***	***≤0.2***		***≤50***		***6-9***	***≤5000***
*TLV Class III**			***≤50***	***≤6***	***≥3***	***-***	***≤1***		***≤400***		***6-9***	***≤10000***
*TLV Class IV**			***≤100***	***≤12***	***≥0***	***-***	***≤5***		***≤400***		***5-9***	***≤10000***
*TLV Class A***								***≤5***		***≤15***	***6.5-8.5***	***0***
*TLV Class B***					***≥6***	***≤0.5***					***5-9***	***≤2000***
*TLV Class C***					***>3***	***≤0.02***					***6-9***	
*TLV Class D***											***5-9***	
*TLV Class A****			***-***	***-***	***-***	***-***		***≤5***		***-***	***6.5-8.5***	***0***
*TLV Class B****			***≤10***	***≤6***	***≥6***	***≤0.5***		***-***		***-***	***5-9***	***≤2000***
*TLV Class B: C: D****			***≤10***	***≤6***	***>3***	***≤0.02***		***-***		***-***	***6-9***	***≤2000***

**The values of TLV refer to the Indonesian Government Regulation 82/2001: Class I is for drinking water supply; Classes II, III, IV are water quality for recreation, fishery, livestock, irrigation, industry. Class II has highest water quality compared to the classes III and IV.*

***The values of TLV refer to the Indonesian Government Regulation 20/1990: Class A means that water can be used directly for drinking; Class B means that water can used as raw water for drinking water supply; Class C means that water can be used for fishery and livestock; Class D means that water can be used for agriculture, urban activities, industry, and hydropower.*

**** The values of TLV refer to the West Java Province Governor Decree No 58/1998: Class A means that water can be used directly for drinking; Class B means that water can used as raw water for drinking water supply; Class B: C: D mean that water can be used as raw water for drinking water supply; recreation, fishery, livestock, irrigation, industry, urban activities, and hydropower.*

TABLE A.1.6. 13 HISTORICAL CHANGE IN WATER AVAILABILITY FOR IRRIGATION ON THE CIMANUK RIVER (RENTANG BARRAGE)

Assessment of water availability change for irrigation (y) per (x) year	Assessment Period	Regression Equation with bootstrap resampling 1000x	Trend	p-value (2-tailed)	Statistically significant
Trend of average monthly river discharges in rainy season (DJF)-Cimanuk/Rentang	1970-2015	y = -0.88 x + 235.15	*decrease 8.8 cumecs per decade*	p>005	No
Trend of average monthly river discharges in dry season (JJA)-Cimanuk/Rentang	1970-2015	y = -0.26 x + 52.13	*decrease 2.6 cumecs per decade*	p>005	No
Trend of annual mean river discharges-Cimanuk/Rentang irrigation scheme	1970-2015	y = -0.58 x + 145.19	*decrease 5.8 cumecs per decade*	p>005	No

TABLE A.1.6. 14 RELATIONSHIP BETWEEN FARMER AND NON-FARMER PERCEPTION OF CLIMATE AND WATER RISKS/HYDROLOGICAL CHANGES

Group	Current water Problems	Mean Perceptions											
		Coastal Area		Inland Area		Urban Area		UPT area		Peri-urban area		Rural area	
		DE	FE	DE	FE	DE	FE	DE	FE	DE	FE	DE	FE
FT1	NWP 40%, F 11%, D 49%, F+D 0%	3.07[a] (1.49)	3.13 (0.83)	3.85 (1.53)	3.05 (0.39)	2.13 (1.13)	2.88 (0.35)	4.14 (1.07)	3.43 (1.13)	4.07 (1.49)	3.07 (0.47)	3.33 (1.63)	3.00 (0.00)
FT2	NWP 40%, F 5%, D 50%, F+D 5%	4.00 (0.88)	2.86 (0.77)	3.66 (1.01)	3.02 (0.26)	3.67[d] (0.71)	2.56 (0.73)	4.25 (0.96)	3.25 (0.50)	3.91 (0.93)	3.00 (0.25)	3.23 (1.17)	3.15 (0.38)
FT3	NWP 27%, F 5%, D 58%, F+D 10%	4.09 (1.10)	3.21 (0.79)	3.91 (1.14)	2.91 (0.53)	3.33[e] (1.29)	3.20 (0.41)	4.05[g] (1.02)	3.57 (0.81)	4.06 (1.10)	2.89 (0.55)	4.12 (1.07)	2.92 (0.74)
NFT1	NWP 58%, F 13%, D 29%, F+D 0%	3.33 (0.71)	3.22 (0.44)	3.40 (1.12)	3.07 (0.26)	3.40 (0.89)	3.40 (0.55)	2.75 (0.50)	3.00 (0.00)	3.43 (0.98)	3.00 (0.00)	3.63 (1.19)	3.13 (0.35)
NFT2	NWP 71%, F 0%, D 23%, F+D 6%	3.21[b] (0.79)	3.00 (0.67)	3.31 (0.95)	3.00 (0.00)	3.00 (0.74)	3.08 (0.79)	2.83 (0.98)	3.00 (0.00)	3.62 (0.87)	2.92 (0.28)	3.50 (0.58)	3.00 (0.00)
NFT3	NWP 56%, F 16%, D 25%, F+D 3%	3.42[c] (0.80)	3.12 (0.82)	3.60 (1.01)	3.00 (0.20)	3.13[f] (0.66)	2.88 (0.76)	3.59 (0.76)	3.47 (0.84)	3.58 (0.99)	3.02 (0.26)	4.06 (1.00)	3.06 (0.44)
F statistic		5.90	0.58	1.28	1.08	3.34	1.62	3.43	0.76	1.61	0.95	1.56	0.41
p-value		<0.001	> 0.05	>0.05	>0.05	<0.01	>0.05	<0.01	>0.05	>0.05	>0.05	>0.05	>0.05

NWP= no water problem, F= flood problem, D= drought problem, F+D= both flood and drought problems, DE=Drought Event; FE=Flood Event. Scale for perceptions is 1=rapid decrease, 2=slight decrease, 3=no change, 4=slight increase, 5=rapid increase. FT1= Farmer with perception that temperatures had decreased; FT2 = Farmer with perception that temperatures had stayed the same; FT3 = Farmer with perception that temperatures had increased; NFT1= Non-farmer with perception that temperatures had decreased; NFT2 = Non-farmer with perception that temperatures had stayed the same; NFT3 = Non-farmer with perception that temperatures had increased. Mean difference is significant at the 0.05 level:

a Mean perception of coastal farmers with perceptions that temperatures had decreased are significantly lower than mean perceptions of coastal farmers with the perception that temperatures had increased

b Mean perceptions of coastal non-farmers with perceptions that temperatures had stayed the same are significantly lower than mean perceptions of coastal farmers with the perception that temperatures had increased

c Mean perceptions of coastal non-farmers with perceptions that temperatures had increased are significantly lower than mean perceptions of coastal farmers with the perception that temperatures had increased

d Mean perceptions of urban farmers with perceptions that temperatures had stayed the same are significantly higher than mean perceptions of urban farmers with a perception that temperatures had decreased

e Mean perceptions of urban farmers with perceptions that temperatures had increased are significantly higher than mean perceptions of urban farmers with a perception that temperatures had decreased

f Mean perceptions of urban non-farmers with perceptions that temperatures had increased are significantly higher than mean perceptions of urban farmers with a perception that temperatures had decreased

g Mean perceptions of UPT farmers with perceptions that temperatures had increased are significantly higher than mean perceptions of UPT non-farmers with the perception that temperatures had stayed the same

TABLE A.1.6. 15 RELATIONSHIP BETWEEN PERCEPTIONS OF CLIMATE AND WATER RISKS CHANGES AND TYPOLOGY BASED ON THE ACCESSIBILITY TO WATER-RELATED SERVICES IN THE COASTAL AREA

Rural-urban farmer and non-Farmer typology	Mean perceptions in the coastal areas											
	Access to public water supply services		Without access to public services for water supply		The drainage system is available in the human settlement		The drainage system is not available in the human settlement		Access to irrigation system services		Without access to irrigation system services	
	Climate (T)	Drought	Climate (T)	Drought	Climate (T)	Flood	Climate (T)	Flood	Climate (T)	Drought	Climate (T)	Drought
RF	4.50[a] (0.67)	4.58[a] (0.79)	4.00 (1.00)	4.80 (0.45)	4.44[c] (0.73)	3.44 (0.88)	4.25 (0.89)	2.63 (0.52)	4.27 (0.90)	4.45[f] (0.82)	-	-
PF	4.64[a] (0.50)	4.45[a] (0.69)	2.00 (0.00)	5.00 (0.00)	4.83[c] (0.41)	2.50 (0.84)	4.00 (1.10)	3.00 (0.00)	4.29 (1.11)	4.57[f] (0.79)	4.60 (0.55)	4.40 (0.55)
UPTF	4.20[b] (0.45)	4.20[b] (0.84)	3.67 (1.24)	4.05 (1.12)	4.27 (0.79)	3.55 (0.69)	3.40 (1.24)	3.67[e] (1.05)	3.63 (1.26)	4.38[f] (0.89)	3.86 (1.07)	3.43 (1.27)
UF	2.60 (1.40)	2.87 (1.30)	3.94 (1.20)	3.35 (1.17)	3.16 (1.50)	2.95 (0.62)	3.54 (1.39)	2.92 (0.49)	3.83 (1.27)	3.33 (1.07)	4.17 (0.98)	3.33 (1.37)
RNF	4.80[a] (0.45)	5.00[a] (0.00)	4.00 (1.00)	4.67 (0.58)	4.60 (0.89)	3.40 (0.55)	4.33 (0.58)	3.00 (0.00)				
PNF	4.20[b] (1.10)	4.00 (1.00)	4.44 (0.88)	3.67 (0.71)	4.50[c] (0.85)	2.90 (0.57)	4.00 (1.15)	3.00 (0.00)				
UPTNF	3.75 (0.96)	3.50 (0.58)	4.46 (0.95)	3.35 (0.56)	4.44[c] (0.92)	3.56[d] (0.92)	4.00 (1.22)	3.20 (0.45)				
UNF	4.33[b] (0.93)	3.04 (0.68)	3.86 (0.96)	3.33 (0.66)	4.25[c] (1.00)	2.92 (0.79)	3.78 (0.44)	3.22 (0.44)				
F statistic	7.25	11.68	1.78	4.11	3.74	3.33	0.73	2.53	0.93	4.45	0.94	1.39
p-value	<0.001	<0.001	>0.05	<0.001	<0.001	<0.01	>0.05	<0.05	>0.05	<0.01	>0.05	>0.05

Scale for perceptions is 1=rapid decrease, 2=slight decrease, 3=no change, 4=slight increase, 5=rapid increase; T=Temperature
Mean difference is significant at the 0.05 level:
[a] Mean perception of a rural farmer, peri-urban farmer, and rural non-farmer are significantly higher than mean perceptions of the urban farmer and urban non-farmer
[b] Mean perceptions of UPT farmer, peri-urban non-farmer and urban non-farmer are significantly higher than mean perceptions of urban farmer
[c] Mean perceptions of rural farmer, peri-urban farmer, peri-urban non-farmer, UPT non-farmer, and urban non-farmer are significantly higher than mean perceptions of urban farmer
[d] Mean perceptions of UPT non-farmer are significantly higher than mean perceptions of urban non-farmer
[e] Mean perceptions of UPT farmer are significantly higher than mean perceptions of rural farmer
[f] Mean perceptions of rural farmer, peri-urban farmer and UPT farmer are significantly higher than mean perceptions of urban farmer

TABLE A.1.6. 16 RELATIONSHIP BETWEEN PERCEPTIONS OF CLIMATE CHANGE AND WATER RISKS CHANGE AND TYPOLOGY BASED ON THE ACCESSIBILITY TO WATER-RELATED SERVICES IN THE INLAND AREA

Rural-urban farmer and non-Farmer typology	Mean perceptions in the non-coastal areas											
	Access to public water supply services		Without access to public services for water supply		The drainage system is available in the human settlement		The drainage system is not available in the human settlement		Access to irrigation system services		Without access to irrigation system services	
	Climate (T)	Drought	Climate (T)	Drought	Climate (T)	Flood	Climate (T)	Flood	Climate (T)	Drought	Climate (T)	Drought
RF	3.80 (1.30)	4.20 (0.84)	3.39 (1.31)	3.00 (1.13)	3.45 (1.40)	2.95 (0.51)	3.50 (1.07)	3.00 (0.00)	3.52 (1.28)	3.15 (1.13)	2.00 (0.00)	5.00 (0.00)
PF	4.38 (0.87)	4.00 (1.35)	3.70 (1.12)	3.96[a] (1.10)	4.00 (1.04)	2.91 (0.38)	3.42 (1.15)	3.05 (0.57)	3.86 (1.16)	3.73 (1.17)	3.63 (0.99)	4.53 (0.82)
UPTF	-	-	3.50 (1.52)	4.17 (0.74)	3.50 (1.92)	3.00 (0.00)	3.50 (0.71)	3.00 (0.00)	2.67 (1.53)	4.33[b] (0.58)	3.00 (0.00)	5.00 (0.00)
UF	-	-	-	-	-	-	-	-	-	-	-	-
RNF	3.00 (0.00)	4.00 (0.00)	3.42 (1.30)	3.42 (0.90)	3.25 (1.24)	3.00 (0.37)	4.00 (1.41)	3.00 (0.00)				
PNF	4.33 (0.98)	3.83 (0.83)	3.85 (1.05)	3.45 (1.04)	3.93 (1.10)	3.03 (0.16)	4.08 (0.90)	3.00 (0.00)				
UPTNF	3.00 (0.00)	3.00 (0.00)	4.00 (1.61)	3.55 (1.37)	4.10 (1.37)	3.00 (0.00)	3.00 (2.83)	3.00 (0.00)				
UNF	-	-	-	-	-	-	-	-				
F statistic	1.10	0.29	0.80	3.84	1.72	0.67	0.81	0.05	2.04	3.12	1.46	0.30
p-value	>0.05	>0.05	>0.05	<0.01	>0.05	>0.05	>0.05	>0.05	>0.05	<0.05	>0.05	>0.05

Scale for perceptions is 1=rapid decrease, 2=slight decrease, 3=no change, 4=slight increase, 5=rapid increase; T=Temperature
Mean difference is significant at the 0.05 level:
[a] Mean perception of the peri-urban farmer are significantly higher than mean perceptions of rural farmer
[b] Mean perceptions of UPT farmer are not significantly higher than mean perceptions of the rural farmer and peri-urban farmer

TABLE A.1.6. 17 RELATIONSHIP BETWEEN CLIMATE PERCEPTIONS OF THE COASTAL AND INLAND FARMER AND NON-FARMER AND SATISFACTION TO WATER-RELATED SERVICES

Mean satisfaction to the water-related services in coastal and inland areas

Rural-urban farmer and non-Farmer typology	Coastal				Inland			
	Sufficient water availability	Flood protection	Drought Prevention	Water sanitation infrastructures	Sufficient water availability	Flood protection	Drought Prevention	Water sanitation infrastructures
FT1	3.13 (1.19)	2.85 (1.11)	2.67 (0.82)	3.00 (1.00)	4.35 (0.49)	3.90 (0.55)	4.10 (0.31)	4.10 (0.45)
FT2	3.29 (1.20)	3.14[a] (0.95)	2.64 (1.00)	2.93 (1.14)	4.43 (0.50)	3.61 (0.87)	4.05 (0.61)	4.19 (0.39)
FT3	3.14 (1.05)	3.40[a] (0.92)	2.41 (0.82)	2.55 (0.92)	4.72[c] (0.45)	3.81 (0.63)	4.22 (0.45)	4.14 (0.38)
NFT1	3.78 (0.83)	3.00 (1.00)	3.22 (0.83)	3.22 (0.97)	4.47 (0.52)	4.14 (0.35)	4.07 (1.03)	4.20 (0.42)
NFT2	3.53 (0.91)	3.74[b] (0.73)	3.42 (0.96)	3.68 (0.82)	4.88[c] (0.34)	3.67 (0.79)	3.81 (0.83)	4.13 (0.34)
NFT3	3.50 (1.03)	3.36[b] (0.76)	3.22 (0.90)	3.13 (1.05)	4.81[c] (0.40)	3.77 (0.58)	4.04 (0.39)	4.11 (0.37)
F statistic	0.46	7.07	2.89	2.28	6.67	1.65	1.74	0.34
p-value	>0.05	<0.001	<0.05	>0.05	<0.001	>0.05	>0.05	>0.05

Scale for liveability satisfaction is 1=not at all satisfied, 2=unsatisfied, 3=unsure, 4=satisfied, 5=very satisfied
Mean difference is significant at the 0.05 level:
[a] Mean satisfaction of farmer with the perception that temperatures had stayed the same and had increased are significantly higher than mean satisfaction of farmer with the perception that temperatures had decreased
[b] Mean satisfactions of non-farmer with the perception that temperatures had stayed the same and increased are significantly higher than mean satisfaction of farmer with the perception that temperatures had decreased
[c] Mean satisfactions of farmer with the perception that temperatures had increased and non-farmer with perceptions that temperatures had stayed the same and increased are significantly higher than mean satisfaction of farmer with the perception that temperatures had decreased and stayed the same

Table A.1.6. 18 Research participants' information concerning practices to cope with the changes in land use, water cycle, and climate

Research participants information concerning practices to deal with urbanisation and climate change	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	Total (43)
Strategy to support social prosperity	0%	33.33%	28.95%	27.91%
Strategy to support environmental protection	50%	0%	47.37%	44.19%
Research, data, and development planning	0%	100%	55.26%	55.81%
Institutional and governance capacity	50%	100%	73.68%	74.42%
Regulation and policy	100%	66.67%	76.32%	76.74%
Strategy to support economic development	100%	100%	84.21%	86.05%
Total (unique)	100%	100%	100%	100%

Note: the responses from ≥50% participants at three scales/levels of government institutions are detailed further for an in-depth understanding

Table A.1.6.18. 1 Detailed strategies in supporting economic development

Research participants information concerning practices to deal with urbanisation and climate change	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	Total (43)
Local economic development: *Develop new potential rice fields including technical, semi-technical and rainfed irrigated rice fields*	0%	0%	2.63%	2.33%
Maximising water facilities and services: *Dominated by strategies to providing physical infrastructures or technical measures*	100%	100%	84.21%	86.05%
Total (unique)	100%	100%	84.21%	86.05%

Note: the responses from ≥50% participants at two or three scales/levels of government institutions are detailed further for an in-depth understanding

TABLE A.I.6.18. 2 DETAILED STRATEGIES IN REGULATION AND POLICY

Research participants information concerning practices to deal with urbanisation and climate change	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	Total (43)
Incentive-disincentive	0%	33.33%	7.89%	9.3%
Regulation to increase water sources in terms of quantity, quality, and continuity for drinking water and irrigation	100%	33.33%	21.05%	25.58%
Monitoring and evaluation	50%	33.33%	31.58%	32.56%
Land use planning and zoning regulation: *Planning documents such as RTRW and RDTR (spatial planning for obtaining regional and local development priorities), KLHS (protecting environment), PLP2B (protecting productive farming lands)*	0%	66.67%	52.63%	51.16%
Total (unique)	100%	66.67%	76.32%	76.74%

Note: the responses from ≥50% participants at two or three scales/levels of government institutions are detailed further for an in-depth understanding

TABLE A.I.6.18. 3 DETAILED STRATEGIES IN INSTITUTIONAL AND GOVERNANCE CAPACITY

Research participants information concerning practices to deal with urbanisation and climate change	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	Total (43)
Multi-level and/or multi-sector cooperation and collaboration	50%	100%	23.68%	30.23%
Education, training, dissemination	50%	0%	34.21%	32.56%
Governance operational efficiency	0%	33.33%	34.21%	32.56%
Collaboration within districts boundary: multi-sectors	0%	0%	50%	44.19%
Total (unique)	50%	100%	73.68%	74.42%

Note: the responses from ≥50% participants at two or three scales/levels of government institutions are detailed further for an in-depth understanding

TABLE A.I.6.18. 4 DETAILED STRATEGIES IN RESEARCH, DATA, AND DEVELOPMENT PLANNING

Research participants information concerning problems implementing practices to obtain water security, liveability, and sustainability	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	Total (43)
Information	0%	0%	2.63%	2.33%
Masterplan, DED, action plan	0%	66.67%	39.47%	39.53%
Studies related to water, environment, infrastructures, climate change, and regional development planning	0%	66.67%	23.68%	25.58%
Total (unique)	0%	100%	55.26%	55.81%

TABLE A.1.6. 19 RESEARCH PARTICIPANTS' INFORMATION CONCERNING PROBLEMS IMPLEMENTING A STRATEGY FOR SUSTAINING WATER SECURITY AND LIVEABILITY

Research participants information concerning problems implementing strategies to obtain water security, liveability, and sustainability	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	Total (43)
Strategy to support economic development	0%	33.33%	65.79%	60.47%
Strategy to support environmental protection	0%	66.67%	31.58%	32.56%
Institutional and governance capacity	100%	100%	97.37%	97.67%
Regulation and policy	50%	100%	86.84%	86.05%
Research, data, and development planning	0%	0%	5.26%	4.65%
Strategy to support social prosperity	0%	33.33%	26.32%	25.58%
Total (unique)	100%	100%	100%	100%

Note: the responses from ≥50% participants at three scales/levels of government institutions are detailed further for an in-depth understanding

TABLE A.1.6.19. 1 DETAILED PROBLEMS OF INSTITUTIONAL AND GOVERNANCE CAPACITY

Research participants information concerning problems implementing strategies to obtain water security, liveability, and sustainability	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	**Total (43)**
Financial capacity	0%	33.33%	73.68%	67.44%
Collaboration	50%	0%	28.95%	27.91%
Education, training, dissemination	0%	0%	5.26%	4.65%
Governance operational efficiency: *government institution, method, and instrument*	50%	66.67%	28.95%	32.56%
Limitation of institution in management	0%	33.33%	63.16%	58.14%
Mindset, cultural, behaviour of communities: *Difficulty to change the mindset, habit, and culture of communities concerning to water security and liveability issues including the reluctance of farmers to follow government instructions in farming practices such as cropping season; type of crops*	50%	100%	50%	53.49%
Synergy	50%	66.67%	39.47%	41.86%
Total (unique)	100%	100%	97.37%	97.67%

Note: the responses from ≥50% participants at two or three scales/levels of government institutions are detailed further for an in-depth understanding

TABLE A.1.6.19. 2 DETAILED PROBLEMS OF REGULATION AND POLICY

Research participants information concerning problems implementing strategies to obtain water security, liveability, and sustainability	The scale of planning and management= River Basin (2); national government level	The scale of planning and management = Regional (3); provincial government level	The scale of planning and management = Local (38); district government level	**Total (43)**
Implementation: *integration of land use and water resource planning; adaptation and reliable legal frameworks; participatory; conflicting, contradiction and overlapping regulations*	50%	100%	78.95%	79.07%
Dealing with nexus challenges: *Difficulty in integrating and combining options for holistic solutions*	50%	66.67%	36.84%	39.53%
Land use planning and zoning regulation	0%	100%	44.74%	46.51%
Monitoring and evaluation	0%	0%	7.89%	6.98%
Regulation to increase water sources in terms of quantity, quality, and continuity	0%	33.33%	7.89%	9.3%
Total (unique)	50%	100%	86.84%	86.05%

Note: the responses from ≥50% participants at two or three scales/levels of government institutions are detailed further for an in-depth understanding

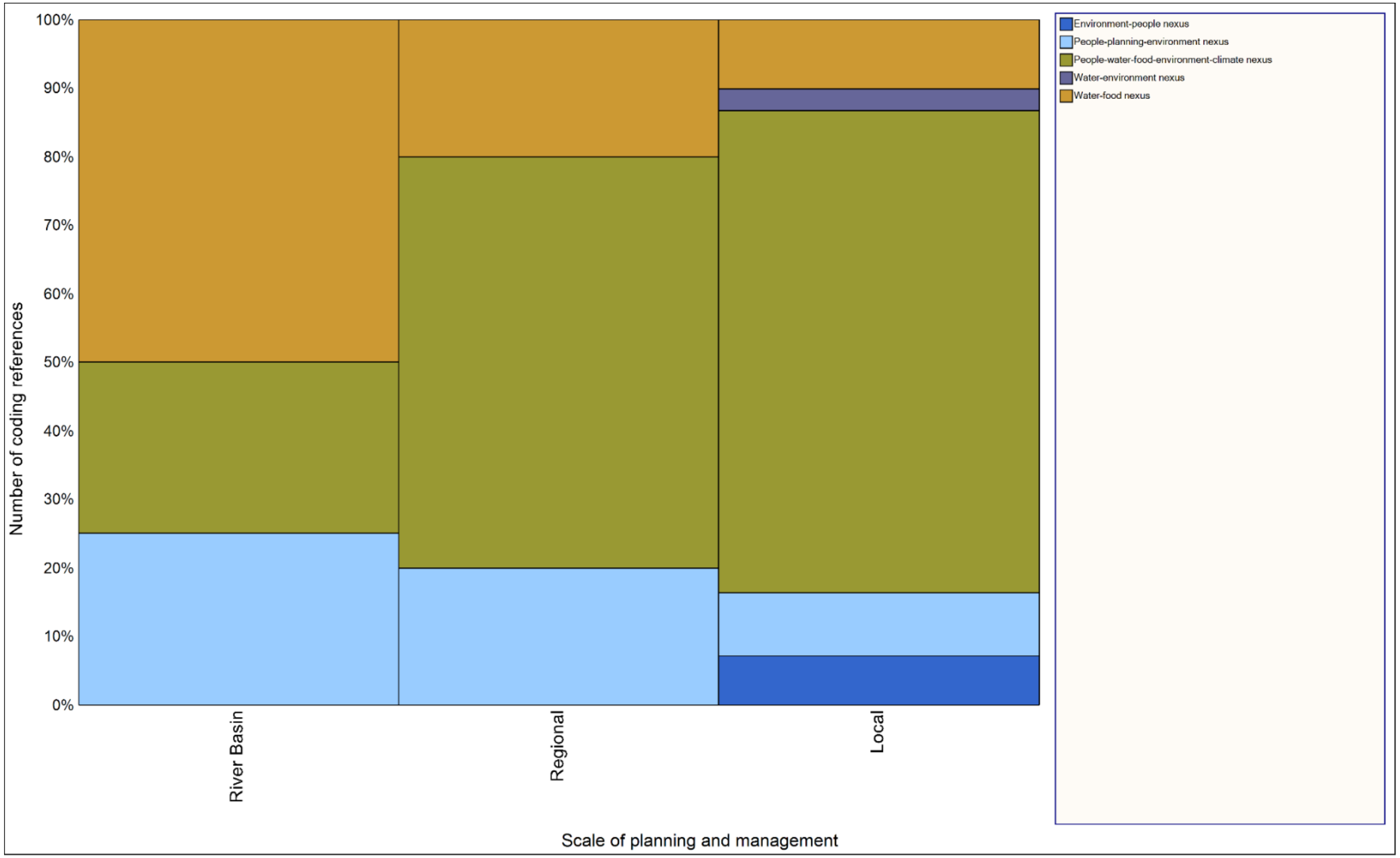

FIGURE A.1.6. 1 NEXUS OF CONCERNS OF ECOSYSTEM SERVICES IN THE CONTEXT OF CHANGES IN LAND USE, WATER CYCLE, AND CLIMATE

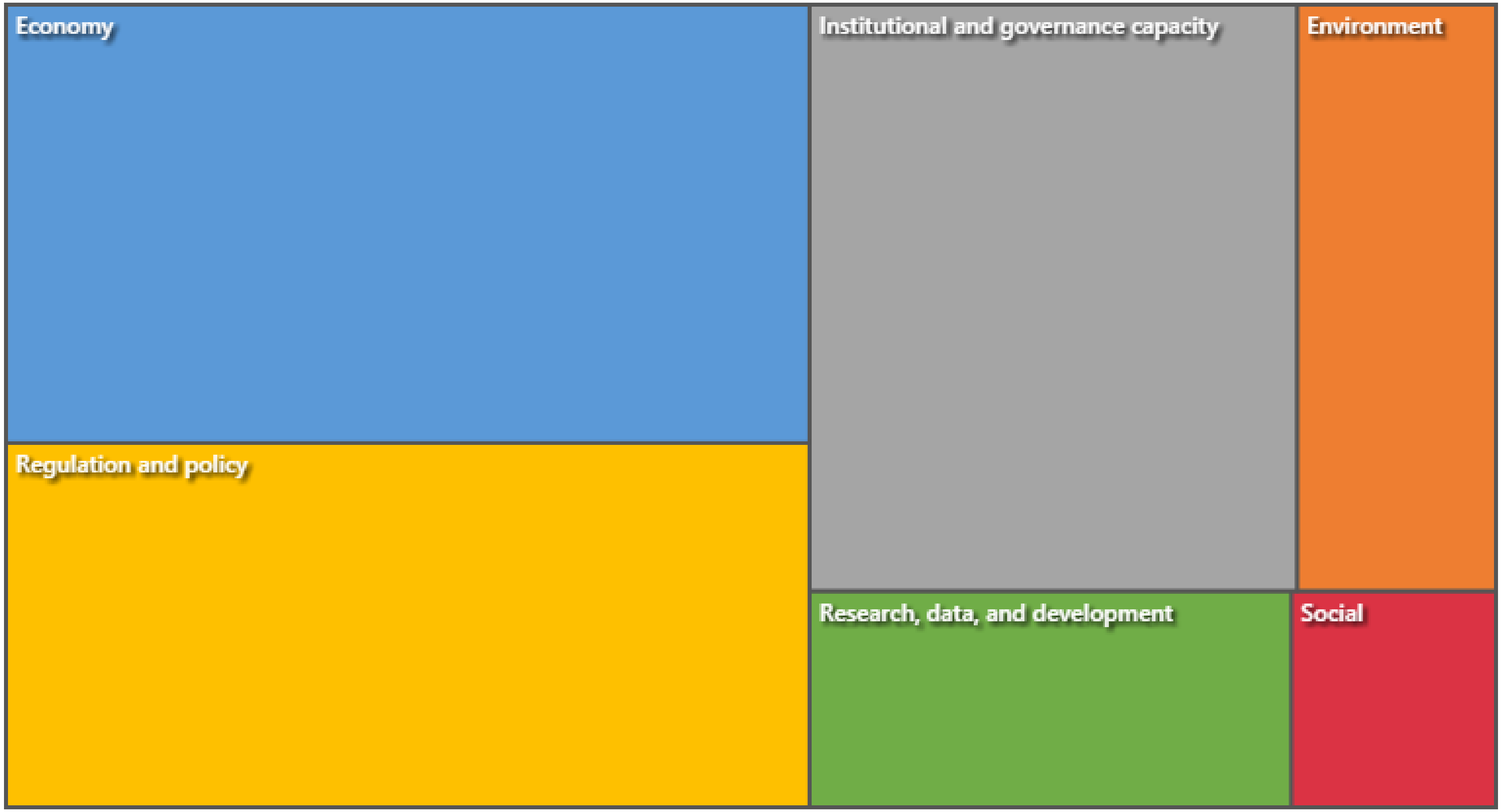

FIGURE A.1.6. 2 NUMBER OF ITEMS CODED RELATED TO THE STRATEGY IMPLEMENTED BY THE SELECTED INSTITUTION TO COPE WITH THE CHANGES IN LAND USE, WATER CYCLE, AND CLIMATE

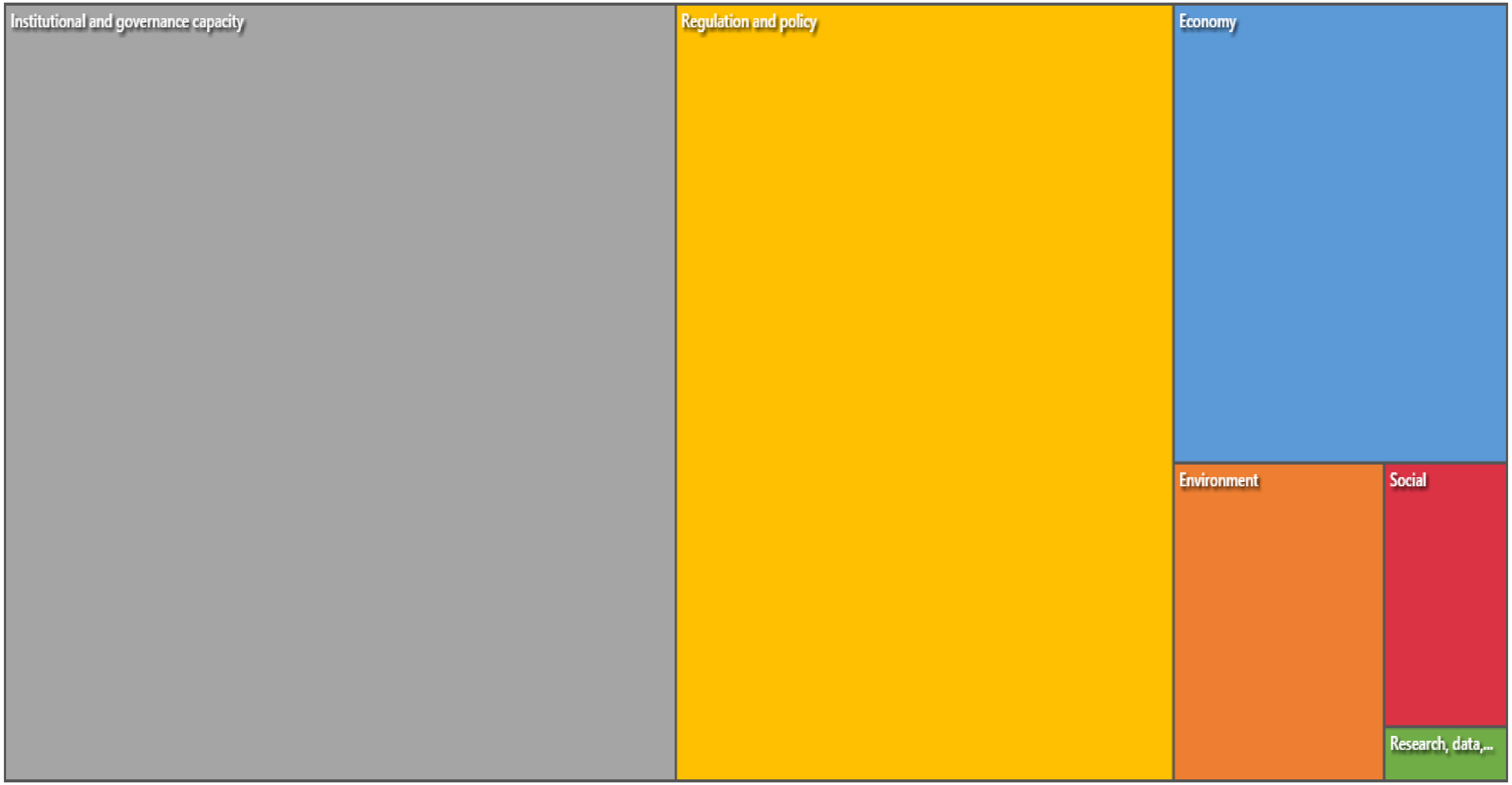

FIGURE A.1.6. 3 NUMBER OF ITEMS CODED RELATED TO THE PROBLEMS OF IMPLEMENTING STRATEGIES BY THE SELECTED INSTITUTION TO COPE WITH THE CHANGES IN LAND USE, WATER CYCLE, AND CLIMATE

APPENDIX I. 7 BRING IT TOGETHER – SYSTEM THINKING FOR BALANCED URBAN DEVELOPMENT

Table A.1.7. 1 Issues and challenges for achieving BUD based on the level of government institution in P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Household Adaptive Capacity	0%	0%	71.43%	0%	0%	0%	18.18%	16.28%
Innovation and Services	50%	0%	0%	16.67%	28.57%	71.43%	45.45%	32.56%
Financing	0%	0%	71.43%	16.67%	14.29%	42.86%	45.45%	34.88%
Infrastructure	100%	33.33%	100%	100%	28.57%	71.43%	81.82%	74.42%
Sociocultural Environment	100%	100%	100%	83.33%	71.43%	57.14%	63.64%	76.74%
Information, Communication, and Collaboration	100%	33.33%	85.71%	100%	71.43%	71.43%	90.91%	81.4%
Policies and Governance	100%	100%	100%	100%	57.14%	100%	72.73%	86.05%
Environmental Planning and Management	100%	100%	100%	100%	100%	100%	100%	100%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table A.1.7. 2 Issues and challenges for achieving BUD in Environmental Planning and Management based on the level of government institution in P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Monitoring and evaluation	50%	33.33%	42.86%	16.67%	0%	28.57%	9.09%	20.93%
Water resource planning and management	100%	33.33%	71.43%	33.33%	14.29%	0%	18.18%	30.23%
Issues and challenges in the approach in planning and management	50%	33.33%	85.71%	66.67%	28.57%	85.71%	9.09%	48.84%
Land resource planning and management	50%	33.33%	71.43%	66.67%	14.29%	85.71%	45.45%	53.49%
Implementation	100%	0%	100%	50%	28.57%	85.71%	54.55%	60.47%
Water security issues	50%	33.33%	85.71%	100%	28.57%	42.86%	72.73%	62.79%
Environmental issues and challenges	50%	100%	100%	100%	71.43%	71.43%	81.82%	83.72%
Total	100%	100%	100%	100%	100%	100%	100%	100%

TABLE A.1.7. 3 ISSUES AND CHALLENGES FOR ACHIEVING BUD IN INFORMATION, COMMUNICATION, AND COLLABORATION BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	Total (43)
Gap of situational knowledge communities-governments	0%	0%	0%	16.67%	0%	0%	0%	2.33%
Need more in-depth environmental analysis	0%	0%	28.57%	0%	0%	0%	0%	4.65%
Education, training, dissemination	50%	0%	14.29%	16.67%	0%	14.29%	9.09%	11.63%
Data availability in terms of accuracy and reliability	0%	0%	57.14%	50%	14.29%	28.57%	18.18%	27.91%
Synergy	50%	33.33%	57.14%	50%	28.57%	57.14%	54.55%	48.84%
Collaboration	50%	33.33%	71.43%	83.33%	28.57%	42.86%	72.73%	58.14%
Total	100%	33.33%	85.71%	100%	71.43%	71.43%	90.91%	81.4%

TABLE A.1.7. 4 ISSUES AND CHALLENGES FOR ACHIEVING BUD IN INFRASTRUCTURE BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Housing	0%	0%	0%	0%	0%	14.29%	0%	2.33%
Infrastructure for water conservation	0%	0%	14.29%	0%	0%	0%	0%	2.33%
Network and human settlement infrastructures	0%	0%	0%	0%	0%	14.29%	9.09%	4.65%
Old infrastructures need to be replaced	0%	0%	28.57%	0%	0%	0%	0%	4.65%
Infrastructure development issues	100%	33.33%	0%	0%	0%	0%	0%	6.98%
How to provide sufficient infrastructures for metropolitan development	0%	0%	0%	33.33%	0%	28.57%	9.09%	11.63%
Infrastructure for livelihood	0%	33.33%	0%	16.67%	0%	0%	54.55%	18.6%
Infrastructure for the environment	0%	0%	71.43%	66.67%	14.29%	42.86%	45.45%	41.86%
Infrastructure for drinking water and sanitation	0%	0%	100%	100%	28.57%	28.57%	45.45%	51.16%
Total	100%	33.33%	100%	100%	28.57%	71.43%	81.82%	74.42%

TABLE A.1.7. 5 ISSUES AND CHALLENGES FOR ACHIEVING BUD IN POLICIES AND GOVERNANCE BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Inequality	0%	0%	28.57%	16.67%	14.29%	0%	9.09%	11.63%
Regulation concerning land uses	50%	33.33%	28.57%	33.33%	14.29%	42.86%	18.18%	27.91%
Regulation concerning water sources in terms of quantity, quality, and continuity	50%	33.33%	14.29%	50%	28.57%	42.86%	9.09%	27.91%
Limited institutional capacity in management	0%	0%	71.43%	83.33%	0%	71.43%	18.18%	39.53%
Local and regional economic development	50%	33.33%	28.57%	33.33%	0%	71.43%	54.55%	39.53%
Governance operational efficiency	0%	33.33%	28.57%	66.67%	42.86%	42.86%	45.45%	41.86%
Water use and social conflicts	100%	66.67%	57.14%	66.67%	0%	71.43%	45.45%	51.16%
Total	100%	100%	100%	100%	57.14%	100%	72.73%	86.05%

TABLE A.1.7. 6 ISSUES AND CHALLENGES FOR ACHIEVING BUD IN SOCIOCULTURAL ENVIRONMENT BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Cultural preservation	50%	0%	28.57%	50%	0%	57.14%	0%	23.26%
Mindset, cultural, behaviour of communities	100%	100%	100%	83.33%	71.43%	28.57%	63.64%	72.09%
Total	100%	100%	100%	83.33%	71.43%	57.14%	63.64%	76.74%

TABLE A.1.7. 7 ISSUES AND CHALLENGES FOR ACHIEVING BUD IN FINANCING BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Anticipation costs in dealing with climate change and social resistance	0%	0%	0%	0%	0%	0%	9.09%	2.33%
Budget or financial capacity	0%	0%	57.14%	16.67%	14.29%	42.86%	36.36%	30.23%
Taking water supplied from Jatigede Reservoir is too expensive	0%	0%	14.29%	0%	0%	0%	0%	2.33%
Total	0%	0%	71.43%	16.67%	14.29%	42.86%	36.36%	32.56%

TABLE A.1.7. 8 ISSUES AND CHALLENGES FOR ACHIEVING BUD IN INNOVATION AND SERVICES BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Cluster-based economy for food production, industry, and water conservation vs sporadic economy that is vulnerable to change	0%	0%	2.63%	2.33%
Innovation in food production	0%	0%	2.63%	2.33%
Online based programmes to make the coordination faster and easier	0%	0%	2.63%	2.33%
Urbanisation is inevitable process, but it can be controlled	0%	0%	2.63%	2.33%
How green infrastructure as a global concept can be implemented to a local concept t	0%	0%	5.26%	4.65%
Approach in planning and management	50%	0%	23.68%	23.26%
Total	50%	0%	34.21%	32.56%

Research participants information	Planning and Management Role in People, Planning, Water, Food, and the Environment Nexus = Planning (13)	Planning and Management Role in People, Planning, Water, Food, and the Environment Nexus = Water (17)	Planning and Management Role in People, Planning, Water, Food, and the Environment Nexus = Food (4)	Planning and Management Role in People, Planning, Water, Food, and the Environment Nexus = Environment (9)	**Total (43)**
Cluster-based economy for food production, industry, and water conservation vs sporadic economy that is vulnerable to change	0%	0%	25%	0%	2.33%
Innovation in food production	0%	0%	25%	0%	2.33%
Online based programmes to make the coordination faster and easier	0%	5.88%	0%	0%	2.33%
Urbanisation is inevitable process, but it can be controlled	7.69%	0%	0%	0%	2.33%
How green infrastructure as a global concept can be implemented to a local concept to control development	0%	5.88%	0%	11.11%	4.65%
Approach in planning and management	23.08%	29.41%	25%	11.11%	23.26%
Total	23.08%	35.29%	75%	22.22%	32.56%

TABLE A.1.7. 9 OPTIONS AND STRATEGIES FOR ACHIEVING BUD BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Sociocultural Environment	0%	0%	0%	33.33%	0%	0%	9.09%	6.98%
Household Adaptive Capacity	0%	0%	14.29%	16.67%	0%	14.29%	27.27%	13.95%
Financing	0%	0%	42.86%	33.33%	0%	14.29%	18.18%	18.6%
Infrastructure	0%	33.33%	57.14%	50%	0%	28.57%	54.55%	37.21%
Innovation and Services	0%	0%	42.86%	33.33%	28.57%	42.86%	54.55%	37.21%
Policies and Governance	100%	100%	28.57%	66.67%	85.71%	85.71%	45.45%	65.12%
Information, Communication, and Collaboration	100%	33.33%	71.43%	83.33%	57.14%	85.71%	63.64%	69.77%
Environmental Planning and Management	100%	100%	100%	100%	71.43%	100%	90.91%	93.02%
Total	100%	100%	100%	100%	100%	100%	100%	100%

TABLE A.1.7. 10 OPTIONS AND STRATEGIES IN INFORMATION, COMMUNICATION, AND COLLABORATION BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Flexible forums for communication	0%	0%	14.29%	0%	0%	0%	0%	2.33%
Regular reliable data and information sources	0%	0%	14.29%	33.33%	0%	14.29%	18.18%	13.95%
Learning capacity	50%	33.33%	57.14%	16.67%	14.29%	28.57%	18.18%	27.91%
Collaboration and synergy	100%	33.33%	28.57%	66.67%	42.86%	85.71%	54.55%	55.81%
Total	100%	33.33%	71.43%	83.33%	57.14%	85.71%	63.64%	69.77%

TABLE A.1.7. 11 OPTIONS AND STRATEGIES IN POLICIES AND GOVERNANCE BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Governance capacity	0%	0%	14.29%	0%	0%	0%	9.09%	4.65%
Political will and leadership	50%	0%	14.29%	16.67%	0%	42.86%	9.09%	16.28%
Institutional capacity	0%	33.33%	0%	33.33%	28.57%	42.86%	0%	18.6%
Incentive-disincentive	50%	100%	0%	16.67%	28.57%	28.57%	9.09%	23.26%
Adaptive and reliable legal frameworks for regulation	100%	66.67%	0%	50%	57.14%	57.14%	27.27%	41.86%
Total	100%	100%	28.57%	66.67%	85.71%	85.71%	45.45%	65.12%

TABLE A.1.7. 12 OPTIONS AND STRATEGIES IN ENVIRONMENTAL PLANNING AND MANAGEMENT BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Central-national	50%	0%	0%	0%	0%	0%	0%	2.33%
Local scale and separate sectoral approach	50%	0%	28.57%	0%	0%	0%	0%	6.98%
Natural-based development	0%	33.33%	28.57%	16.67%	0%	0%	0%	9.3%
Situational and adaptive management approaches	50%	0%	14.29%	50%	0%	0%	9.09%	13.95%
Multi-sector and multi-level or scalar approach	100%	66.67%	14.29%	16.67%	0%	71.43%	54.55%	39.53%
Integrated approaches	50%	100%	14.29%	50%	42.86%	42.86%	45.45%	44.19%
Transboundary approach	100%	66.67%	100%	83.33%	71.43%	42.86%	54.55%	69.77%
Total	100%	100%	100%	100%	71.43%	100%	90.91%	93.02%

TABLE A.1.7. 13 PROBLEMS IN ENHANCING SUSTAINABILITY BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Innovation and Services	0%	0%	0%	0%	0%	0%	9.09%	2.33%
Household Adaptive Capacity	0%	33.33%	0%	33.33%	0%	14.29%	9.09%	11.63%
Sociocultural Environment	50%	100%	71.43%	50%	42.86%	42.86%	45.45%	53.49%
Information, Communication, and Collaboration	50%	66.67%	57.14%	66.67%	57.14%	100%	45.45%	62.79%
Financing	0%	33.33%	57.14%	83.33%	71.43%	85.71%	72.73%	67.44%
Infrastructure	0%	66.67%	71.43%	100%	57.14%	28.57%	90.91%	67.44%
Environmental Planning and Management	50%	100%	100%	50%	71.43%	85.71%	63.64%	74.42%
Policies and Governance	50%	100%	100%	100%	71.43%	85.71%	72.73%	83.72%
Total	100%	100%	100%	100%	100%	100%	100%	100%

TABLE A.1.7. 14 PROBLEMS IN ENVIRONMENTAL PLANNING AND MANAGEMENT BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Safety and health	0%	0%	0%	0%	14.29%	28.57%	0%	6.98%
People	0%	0%	28.57%	33.33%	0%	0%	0%	9.3%
Environmental issues	0%	33.33%	14.29%	0%	0%	42.86%	9.09%	13.95%
Water	0%	66.67%	57.14%	16.67%	14.29%	14.29%	9.09%	23.26%
Approach in planning and management	50%	66.67%	71.43%	16.67%	28.57%	42.86%	36.36%	41.86%
Land	0%	100%	100%	50%	14.29%	71.43%	36.36%	53.49%
Total	50%	100%	100%	50%	71.43%	85.71%	63.64%	74.42%

TABLE A.1.7. 15 PROBLEMS IN FINANCING BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Strict digital budget and accounting rules	0%	33.33%	0%	16.67%	0%	0%	0%	4.65%
Budget or financial capacity	0%	33.33%	57.14%	83.33%	71.43%	85.71%	72.73%	67.44%
Total	0%	33.33%	57.14%	83.33%	71.43%	85.71%	72.73%	67.44%

TABLE A.1.7. 16 PROBLEMS IN INFORMATION, COMMUNICATION, COLLABORATION BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Information	0%	0%	0%	16.67%	0%	0%	0%	2.33%
Public awareness and knowledge of the existence of legal regulations is still low and the integration of policy holder	0%	0%	0%	0%	14.29%	0%	0%	2.33%
Studies	0%	0%	0%	0%	0%	14.29%	0%	2.33%
Education, training, dissemination	0%	0%	0%	16.67%	14.29%	0%	0%	4.65%
Regular reliable data and information	0%	0%	0%	0%	14.29%	14.29%	0%	4.65%
All regulations to control land use will be useless if there is not awareness and participation from the communities an	0%	0%	0%	0%	14.29%	42.86%	0%	9.3%
Collaboration	50%	0%	42.86%	16.67%	0%	71.43%	18.18%	27.91%
Synergy	50%	66.67%	28.57%	33.33%	42.86%	57.14%	36.36%	41.86%
Total	50%	66.67%	57.14%	66.67%	57.14%	100%	45.45%	62.79%

TABLE A.1.7. 17 PROBLEMS IN INFRASTRUCTURE BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Housing backlog	0%	0%	0%	0%	0%	14.29%	0%	2.33%
Too many illegal watchers	0%	33.33%	0%	0%	0%	0%	0%	2.33%
Transportation lines of Pantura or north coast significantly affect the economic level of Indramayu	0%	0%	0%	0%	0%	0%	9.09%	2.33%
Problem to provide infrastructure in the peri-urban areas to control urbanisation	0%	0%	0%	0%	14.29%	14.29%	0%	4.65%
Social resistance concerning water infrastructure construction, use, benefits and demands including in the process of improving slum areas, reservoir	0%	66.67%	42.86%	50%	14.29%	14.29%	27.27%	30.23%
Intervention capability of water and sanitation infrastructures	0%	0%	71.43%	100%	42.86%	14.29%	72.73%	53.49%
Total	0%	66.67%	71.43%	100%	57.14%	28.57%	90.91%	67.44%

TABLE A.1.7. 18 PROBLEMS IN POLICIES AND GOVERNANCE BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Local economic development	0%	0%	0%	16.67%	0%	0%	27.27%	9.3%
Regulation	0%	33.33%	14.29%	16.67%	14.29%	28.57%	18.18%	18.6%
Governance operational efficiency	50%	66.67%	42.86%	50%	14.29%	0%	0%	23.26%
Limitation of institution in management	0%	33.33%	71.43%	66.67%	0%	0%	18.18%	27.91%
Adaptation and reliable legal frameworks for implementation	0%	66.67%	57.14%	33.33%	28.57%	71.43%	18.18%	39.53%
Dealing with trade-off or nexus challenges	0%	33.33%	71.43%	66.67%	42.86%	57.14%	54.55%	53.49%
Total	50%	100%	100%	100%	71.43%	85.71%	72.73%	83.72%

TABLE A.1.7. 19 PROBLEMS IN SOCIOCULTURAL ENVIRONMENT BASED ON THE LEVEL OF GOVERNMENT INSTITUTION IN P & M

Research participants information	Level of government = National Government (2)	Level of government = Provincial Government (3)	Level of government = Local Government at district level: Cirebon Municipality (7)	Level of government = Local Government at district level: Cirebon Regency (6)	Level of government = Local Government at district level: Kuningan Regency (7)	Level of government = Local Government at district level: Majalengka Regency (7)	Level of government = Local Government at district level: Indramayu Regency (11)	**Total (43)**
Mindset, cultural, behaviour of communities	50%	100%	71.43%	50%	42.86%	42.86%	45.45%	53.49%
Total	50%	100%	71.43%	50%	42.86%	42.86%	45.45%	53.49%

TABLE A.1.7. 20. SOCIO-ENVIRONMENTAL ATTRIBUTES INFLUENCING COMMUNITY PERCEPTUAL MEASURES OF RISKS IN THE CHANGES OF ECOHYDROLOGICAL LANDSCAPES, WATER CYCLE, AND CLIMATE

Ecohydological Variable Measured: Dependent Variable	Socio-environmental attributes: Independent Variables	Multivariate				Bivariate
		Beta Coefficients	Degrees of freedom	F-value	CATREG Model summary	r (spearman)
Assessment to the changes of Green Open Space (GOS) in the past two decades	Place-Political Boundary at District Level (D)	0.69	4	11.534***	N=430 F=2.201*** Adjusted R square = 0.154	-0.226**
	Rural-Urban Categories (RUR)	0.35	3	2.664*		0.145**
	Distance from the Coast (DC)	0.32	3	5.538***		-0.139**
	Type of Settlement (TS)	0.05	1	1.479		-0.063
	Occupation (O)	0.08	1	2.140		0.096*
	Gender (G)	0.01	1	0.047		0.037
	Length of Stay (LS)	0.17	2	1.878		-0.021
	Sources for Drinking Water (DW)	0.12	4	6.713***		-0.026
	Sources for Other Water Uses (NDW)	0.15	5	10.393***		-0.060
	Sanitation Facility (SF)	0.17	5	11.732***		-0.156**
	Current Water Problem (CWP)	0.14	5	8.354***		-0.069
	Current River Water Quality Problem (CRP)	0.05	2	1.441		-0.039
	Current Groundwater Quality Problem (CGP)	0.09	5	4.463***		-0.105*
Assessment to the changes of Groundwater Quality (GW) in the past two decades	Place-Political Boundary at District Level (D)	0.13	4	1.477	N=430 F=1.631** Adjusted R square = 0.058	0.021
	Rural-Urban Categories (RUR)	0.13	3	0.879		0.022
	Distance from the Coast (DC)	0.29	4	7.450***		0.078
	Type of Settlement (TS)	0.01	1	0.048		-0.034
	Occupation (O)	0.10	1	3.303		0.037
	Gender (G)	0.02	1	0.422		0.061
	Length of Stay (LS)	-0.05	2	0.302		-0.036
	Sources for Drinking Water (DW)	0.10	4	6.139***		0.005
	Sources for Other Water Uses (NDW)	0.05	5	1.011		-0.043
	Sanitation Facility (SF)	0.14	5	7.012***		0.064
	Current Water Problem (CWP)	0.14	5	7.019***		-0.044
	Current River Water Quality Problem (CRP)	0.07	2	2.555		-0.065
	Current Groundwater Quality Problem (CGP)	0.21	5	9.672***		-0.027
Assessment to the changes of River Quality (RQ) in the past two decades	Place-Political Boundary at District Level (D)	0.30	4	7.654***	N=430 F=3.381*** Adjusted R square = 0.185	-0.051
	Rural-Urban Categories (RUR)	0.17	3	1.803		-0.004
	Distance from the Coast (DC)	0.35	4	13.562***		0.021
	Type of Settlement (TS)	0.04	1	0.900		0.065
	Occupation (O)	0.13	1	4.573*		0.019
	Gender (G)	0.02	1	0.484		0.020
	Length of Stay (LS)	0.05	1	0.361		0.075
	Sources for Drinking Water (DW)	0.12	4	7.102***		0.095*
	Sources for Other Water Uses (NDW)	0.14	5	6.745***		-0.059
	Sanitation Facility (SF)	0.12	5	8.209***		0.131**
	Current Water Problem (CWP)	0.21	5	17.960***		-0.071
	Current River Water Quality Problem (CRP)	0.35	2	41.156***		-0.337**
	Current Groundwater Quality Problem (CGP)	0.12	5	9.538***		-0.031
Assessment to the changes of Flood Event (FE) in the past two decades	Place-Political Boundary at District Level (D)	0.23	4	2.761*	N=430 F=8.887*** Adjusted R square = 0.441	-0.194**
	Rural-Urban Categories (RUR)	0.14	3	0.725		0.133**
	Distance from the Coast (DC)	-0.25	5	10.899***		-0.301**
	Type of Settlement (TS)	0.03	1	0.654		-0.021
	Occupation (O)	0.02	1	0.588		-0.005
	Gender (G)	0.10	1	5.788*		0.126**
	Length of Stay (LS)	0.11	2	5.643**		0.072
	Sources for Drinking Water (DW)	0.10	4	6.739***		-0.016
	Sources for Other Water Uses (NDW)	0.06	5	2.457*		-0.071
	Sanitation Facility (SF)	0.21	5	8.404***		0.113*
	Current Water Problem (CWP)	0.55	5	120.654***		-0.098*
	Current River Water Quality Problem (CRP)	0.05	2	2.936*		-0.101*
	Current Groundwater Quality Problem (CGP)	0.09	5	4.632***		-0.080

*p<0.05, **p<0.01, ***p<0.001

Ecohydological Variable Measured: Dependent Variable	Socio-environmental attributes: Independent Variables	Multivariate				Bivariate
		Beta Coefficients	Degrees of freedom	F-value	CATREG Model summary	r (spearman)
Assessment to the changes of Drought Event (DE) in the past two decades	Place-Political Boundary at District Level (D)	0.24	4	6.728***	N=430	0.151**
	Rural-Urban Categories (RUR)	0.22	3	10.127***	F=7.662***	-0.257**
	Distance from the Coast (DC)	0.16	5	1.446	Adjusted R square = 0.400	0.092
	Type of Settlement (TS)	0.09	1	4.076*		0.197**
	Occupation (O)	0.10	1	4.733*		-0.343**
	Gender (G)	0.04	1	1.949		-0.057
	Length of Stay (LS)	-0.09	2	2.859		0.101*
	Sources for Drinking Water (DW)	0.07	4	3.630**		0.025
	Sources for Other Water Uses (NDW)	0.13	5	11.064***		0.015
	Sanitation Facility (SF)	0.10	5	8.754***		0.058
	Current Water Problem (CWP)	0.50	5	126.400***		-0.266**
	Current River Water Quality Problem (CRP)	0.08	2	5.422**		-0.123*
	Current Groundwater Quality Problem (CGP)	0.15	5	15.655***		0.099*
Assessment to the changes of Climate (CL) in the past two decades	Place-Political Boundary at District Level (D)	0.40	4	7.167***	N=430	-0.132**
	Rural-Urban Categories (RUR)	0.19	3	1.686	F=2.018***	0.068
	Distance from the Coast (DC)	0.30	5	2.44*	Adjusted R square = 0.093	-0.111*
	Type of Settlement (TS)	0.06	1	1.543		-0.034
	Occupation (O)	0.14	1	5.376*		0.101*
	Gender (G)	0.03	1	0.808		-0.021
	Length of Stay (LS)	0.13	2	1.959		-0.010
	Sources for Drinking Water (DW)	0.15	4	10.982***		-0.072
	Sources for Other Water Uses (NDW)	0.18	5	10.285***		-0.191**
	Sanitation Facility (SF)	0.14	5	10.383***		-0.018
	Current Water Problem (CWP)	0.13	5	8.338***		-0.068
	Current River Water Quality Problem (CRP)	0.03	2	0.617		-0.066
	Current Groundwater Quality Problem (CGP)	0.13	5	8.921***		-0.090
Assessment to the changes of Food availability/production (F) in the past two decades	Place-Political Boundary at District Level (D)	0.15	4	2.888*	N=430	0.079
	Rural-Urban Categories (RUR)	0.10	3	1.580	F=2.523***	-0.040
	Distance from the Coast (DC)	0.28	4	7.590***	Adjusted R square = 0.130	0.092
	Type of Settlement (TS)	0.11	1	3.654		0.007
	Occupation (O)	0.13	1	5.584*		-0.029
	Gender (G)	0.02	1	0.183		0.032
	Length of Stay (LS)	0.19	2	11.981***		0.176**
	Sources for Drinking Water (DW)	0.17	4	11.999***		0.110*
	Sources for Other Water Uses (NDW)	0.16	5	9.668***		-0.125**
	Sanitation Facility (SF)	0.24	5	22.101***		0.172**
	Current Water Problem (CWP)	0.20	5	15.053***		-0.129**
	Current River Water Quality Problem (CRP)	0.04	2	0.587		-0.086
	Current Groundwater Quality Problem (CGP)	0.13	5	6.985***		0.033
Assessment to the changes of Forest availability (FO) in the past two decades	Place-Political Boundary at District Level (D)	0.34	4	9.713***	N=430	-0.107*
	Rural-Urban Categories (RUR)	0.23	3	2.506	F=1.740**	0.134**
	Distance from the Coast (DC)	0.46	5	23.906***	Adjusted R square = 0.069	0.042
	Type of Settlement (TS)	0.08	1	1.965		0.069
	Occupation (O)	0.02	1	0.204		-0.006
	Gender (G)	0.05	1	1.682		-0.074
	Length of Stay (LS)	0.05	2	0.282		0.036
	Sources for Drinking Water (DW)	0.11	4	4.453**		0.068
	Sources for Other Water Uses (NDW)	0.13	5	7.022***		0.040
	Sanitation Facility (SF)	0.15	5	10.206***		-0.013
	Current Water Problem (CWP)	0.09	5	3.973**		-0.020
	Current River Water Quality Problem (CRP)	0.05	2	2.029		-0.050
	Current Groundwater Quality Problem (CGP)	0.12	5	6.439***		0.045

*p<0.05, **p<0.01, ***p<0.001

TABLE A.1.7. 21. SOCIO-ENVIRONMENTAL FACTORS INFLUENCING COMMUNITY PERCEPTUAL MEASURES ECOHYDROLOGICAL CHANGES IN THE METROPOLITAN, URBAN, UPT, PERI-URBAN AND RURAL AREAS

Ecohydrological Changes in each measurement level: Dependent Variable	**Socio-environmental attributes: Independent Variables**	Multivariate				
		Beta Coefficients	Degrees of freedom	F-value	CATREG Model summary	
Metropolitan Region	Place-Political Boundary at District Level (D)	0.49	4	12.79***	N=430	0.000
	Rural-Urban Categories (RUR)	0.21	3	2.52	Multiple R=0.59	0.058
	Distance from the Coast (DC)	0.43	5	21.22***	R square=0.35	0.000
	Type of Settlement (TS)	0.02	1	0.19	Adjusted R square = 0.23	0.664
	Occupation (O)	0.17	1	9.89**		0.002
	Gender (G)	0.00	1	0.01	Apparent prediction error=0.65	0.930
	Length of Stay (LS)	0.15	2	7.34***		0.001
	Sources for Drinking Water (DW)	0.30	18	31.06***		0.000
	Sources for Other Water Uses (NDW)	0.27	14	27.88***		0.000
	Sanitation Facility (SF)	0.12	5	6.45***		0.000
	Current Water Problem (CWP)	0.29	5	32.33***		0.000
	Current River Water Quality Problem (CRP)	0.11	2	5.28***		0.006
	Current Groundwater Quality Problem (CGP)	0.16	7	11.58***		0.000
Urban	Place-Political Boundary at District Level (D)	0.25	1	2.41	N=101	0.126
	Distance from the Coast (DC)	0.40	1	4.73*	Multiple R=0.75	0.034
	Type of Settlement (TS)	0.16	1	1.37	R square=0.56	0.247
	Occupation (O)	0.32	1	3.99	Adjusted R square = 0.27	0.050
	Gender (G)	0.14	1	1.85		0.179
	Length of Stay (LS)	0.23	1	0.81	Apparent prediction error=0.44	0.372
	Sources for Drinking Water (DW)	0.45	9	9.00***		0.000
	Sources for Other Water Uses (NDW)	0.39	9	7.90***		0.000
	Sanitation Facility (SF)	0.35	3	7.46***		0.000
	Current Water Problem (CWP)	0.25	5	3.86**		0.004
	Current River Water Quality Problem (CRP)	0.25	2	3.54*		0.035
	Current Groundwater Quality Problem (CGP)	0.37	6	11.97***		0.000
Urban-Peri-urban Transition	Place-Political Boundary at District Level (D)	0.22	1	2.15	N=74	0.151
	Distance from the Coast (DC)	0.76	3	13.42***	Multiple R=0.84	0.000
	Type of Settlement (TS)	0.19	1	1.50	R square=0.70	0.229
	Occupation (O)	0.26	1	4.36*	Adjusted R square = 0.34	0.044
	Gender (G)	0.12	1	1.36		0.252
	Length of Stay (LS)	0.52	3	7.96***	Apparent prediction error=0.30	0.000
	Sources for Drinking Water (DW)	0.60	10	13.5***		0.000
	Sources for Other Water Uses (NDW)	0.29	7	2.46*		0.036
	Sanitation Facility (SF)	0.24	2	3.34*		0.047
	Current Water Problem (CWP)	0.53	3	7.68***		0.000
	Current River Water Quality Problem (CRP)	0.03	2	0.11		0.898
	Current Groundwater Quality Problem (CGP)	0.32	4	6.20***		0.001
Peri-urban	Place-Political Boundary at District Level (D)	0.42	2	17.04***	N=182	0.000
	Distance from the Coast (DC)	0.38	5	10.83***	Multiple R=0.71	0.000
	Type of Settlement (TS)	0.23	1	2.92	R square=0.51	0.090
	Occupation (O)	0.11	1	2.03	Adjusted R square = 0.29	0.157
	Gender (G)	0.02	1	0.08		0.772
	Length of Stay (LS)	-0.14	1	0.83	Apparent prediction error=0.49	0.364
	Sources for Drinking Water (DW)	0.36	17	9.92***		0.000
	Sources for Other Water Uses (NDW)	0.32	11	7.34***		0.000
	Sanitation Facility (SF)	0.14	5	2.9*		0.016
	Current Water Problem (CWP)	0.39	4	26.53***		0.000
	Current River Water Quality Problem (CRP)	0.18	2	4.86**		0.009
	Current Groundwater Quality Problem (CGP)	0.13	5	4.82***		0.000
Rural	Place-Political Boundary at District Level (D)	0.35	2	1.57	N=73	0.226
	Distance from the Coast (DC)	-0.62	3	2.05	Multiple R=0.85	0.129
	Type of Settlement (TS)	0.02	1	0.02	R square=0.72	0.887
	Occupation (O)	0.11	1	0.85	Adjusted R square = 0.30	0.363
	Gender (G)	0.10	1	0.43		0.516
	Length of Stay (LS)	0.20	2	1.74	Apparent prediction error=0.28	0.193
	Sources for Drinking Water (DW)	0.35	9	2.19		0.053
	Sources for Other Water Uses (NDW)	0.40	9	1.41		0.230
	Sanitation Facility (SF)	0.22	3	1.53		0.226
	Current Water Problem (CWP)	0.59	3	4.73**		0.008
	Current River Water Quality Problem (CRP)	0.21	2	2.35		0.114
	Current Groundwater Quality Problem (CGP)	0.41	7	2.99*		0.017

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

TABLE A.I.7. 22 ISSUES AND CHALLENGES FOR ACHIEVING BUD BASED ON SCALE OF P&M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Household Adaptive Capacity	0%	0%	18.42%	16.28%
Innovation and Services	50%	0%	34.21%	32.56%
Financing	0%	0%	39.47%	34.88%
Infrastructure	100%	33.33%	76.32%	74.42%
Sociocultural Environment	100%	100%	73.68%	76.74%
Information, Communication, and Collaboration	100%	33.33%	84.21%	81.4%
Policies and Governance	100%	100%	84.21%	86.05%
Environmental Planning and Management	100%	100%	100%	100%
Total	100%	100%	100%	100%

TABLE A.I.7. 23 ISSUES AND CHALLENGES FOR ACHIEVING BUD BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Household Adaptive Capacity	23.08%	11.76%	25%	11.11%	16.28%
Innovation and Services	23.08%	35.29%	75%	22.22%	32.56%
Financing	38.46%	29.41%	0%	55.56%	34.88%
Infrastructure	76.92%	76.47%	50%	77.78%	74.42%
Sociocultural Environment	61.54%	76.47%	100%	88.89%	76.74%
Information, Communication, and Collaboration	76.92%	82.35%	75%	88.89%	81.4%
Policies and Governance	100%	82.35%	100%	66.67%	86.05%
Environmental Planning and Management	100%	100%	100%	100%	100%
Total	100%	100%	100%	100%	100%

Note: The main role in SDG was identified based on the role in planning-water-food-climate nexus governance.

TABLE A.I.7. 24 ISSUES AND CHALLENGES IN ENVIRONMENTAL PLANNING AND MANAGEMENT BASED ON SCALE OF P&M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Monitoring and evaluation	50%	33.33%	18.42%	20.93%
Water resource planning and management	100%	33.33%	26.32%	30.23%
Issues and challenges in the approach in planning and management	50%	33.33%	50%	48.84%
Land resource planning and management	50%	33.33%	55.26%	53.49%
Implementation	100%	0%	63.16%	60.47%
Water security issues	50%	33.33%	65.79%	62.79%
Environmental issues and challenges	50%	100%	84.21%	83.72%
Total	100%	100%	100%	100%

TABLE A.I.7. 25 ISSUES AND CHALLENGES IN ENVIRONMENTAL PLANNING AND MANAGEMENT BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Monitoring and evaluation	23.08%	29.41%	0%	11.11%	20.93%
Water resource planning and management	15.38%	41.18%	25%	33.33%	30.23%
Issues and challenges in the approach in planning and management	61.54%	35.29%	50%	55.56%	48.84%
Land resource planning and management	100%	29.41%	50%	33.33%	53.49%
Implementation	61.54%	64.71%	0%	77.78%	60.47%
Water security issues	61.54%	58.82%	100%	55.56%	62.79%
Environmental issues and challenges	84.62%	82.35%	100%	77.78%	83.72%
Total	100%	100%	100%	100%	100%

Note: The main role in SDG was identified based on the role in planning-water-food-climate nexus governance.

TABLE A.1.7. 26 ISSUES AND CHALLENGES IN INFORMATION, COMMUNICATION, AND COLLABORATION BASED ON SCALE OF P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Gap of situational knowledge communities-governments	0%	0%	2.63%	2.33%
Need more in-depth environmental analysis	0%	0%	5.26%	4.65%
Education, training, dissemination	50%	0%	10.53%	11.63%
Data availability in terms of accuracy and reliability	0%	0%	31.58%	27.91%
Synergy	50%	33.33%	50%	48.84%
Collaboration	50%	33.33%	60.53%	58.14%
Total	100%	33.33%	84.21%	81.4%

TABLE A.1.7. 27 ISSUES AND CHALLENGES IN INFORMATION, COMMUNICATION, AND COLLABORATION BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Gap of situational knowledge communities-governments	0%	0%	25%	0%	2.33%
Need more in-depth environmental analysis	15.38%	0%	0%	0%	4.65%
Education, training, dissemination	15.38%	17.65%	0%	0%	11.63%
Data availability in terms of accuracy and reliability	38.46%	23.53%	25%	22.22%	27.91%
Synergy	38.46%	47.06%	50%	66.67%	48.84%
Collaboration	46.15%	64.71%	50%	66.67%	58.14%
Total	76.92%	82.35%	75%	88.89%	81.4%

Note: The main role in SDG was identified based on the role in planning-water-food-climate nexus governance.

TABLE A.1.7. 28 ISSUES AND CHALLENGES IN INFRASTRUCTURE BASED ON SCALE OF P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Housing	0%	0%	2.63%	2.33%
Infrastructure for water conservation	0%	0%	2.63%	2.33%
Network and human settlement infrastructures	0%	0%	5.26%	4.65%
Old infrastructures need to be replaced	0%	0%	5.26%	4.65%
Infrastructure development issues	100%	33.33%	0%	6.98%
How to provide sufficient infrastructures for metropolitan development	0%	0%	13.16%	11.63%
Infrastructure for livelihood	0%	33.33%	18.42%	18.6%
Infrastructure for the environment	0%	0%	47.37%	41.86%
Infrastructure for drinking water and sanitation	0%	0%	57.89%	51.16%
Total	100%	33.33%	76.32%	74.42%

Table A.1.7. 29 Issues and challenges in Infrastructure based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Housing	7.69%	0%	0%	0%	2.33%
Infrastructure for water conservation	7.69%	0%	0%	0%	2.33%
Network and human settlement infrastructures	0%	11.76%	0%	0%	4.65%
Old infrastructures need to be replaced	0%	11.76%	0%	0%	4.65%
Infrastructure development issues	7.69%	11.76%	0%	0%	6.98%
How to provide sufficient infrastructures for metropolitan development	7.69%	5.88%	25%	22.22%	11.63%
Infrastructure for livelihood	23.08%	17.65%	50%	0%	18.6%
Infrastructure for the environment	46.15%	35.29%	0%	66.67%	41.86%
Infrastructure for drinking water and sanitation	46.15%	52.94%	25%	66.67%	51.16%
Total	76.92%	76.47%	50%	77.78%	74.42%

Note: The main role in SDG was identified based on the role in planning-water-food-climate nexus governance.

Table A.1.7. 30 Issues and challenges in Policies and Governance based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Inequality	0%	0%	13.16%	11.63%
Regulation concerning land uses	50%	33.33%	26.32%	27.91%
Regulation concerning water sources in terms of quantity, quality, and continuity	50%	33.33%	26.32%	27.91%
Limited institutional capacity in management	0%	0%	44.74%	39.53%
Local and regional economic development	50%	33.33%	39.47%	39.53%
Governance operational efficiency	0%	33.33%	44.74%	41.86%
Water use and social conflicts	100%	66.67%	47.37%	51.16%
Total	100%	100%	84.21%	86.05%

Table A.1.7. 31 Issues and challenges in Policies and Governance based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Inequality	23.08%	11.76%	0%	0%	11.63%
Regulation concerning land uses	38.46%	11.76%	75%	22.22%	27.91%
Regulation concerning water sources in terms of quantity, quality, and continuity	23.08%	35.29%	0%	33.33%	27.91%
Limited institutional capacity in management	30.77%	35.29%	50%	55.56%	39.53%
Local and regional economic development	61.54%	23.53%	50%	33.33%	39.53%
Governance operational efficiency	38.46%	58.82%	0%	33.33%	41.86%
Water use and social conflicts	53.85%	58.82%	75%	22.22%	51.16%
Total	100%	82.35%	100%	66.67%	86.05%

Note: The main role in SDG was identified based on the role in planning-water-food-climate nexus governance.

Table A.1.7. 32 Issues and challenges in Sociocultural Environment based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Cultural preservation	50%	0%	23.68%	23.26%
Mindset, cultural, behaviour of communities	100%	100%	68.42%	72.09%
Total	100%	100%	73.68%	76.74%

TABLE A.I.7. 33 ISSUES AND CHALLENGES IN SOCIOCULTURAL ENVIRONMENT BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Cultural preservation	23.08%	23.53%	50%	11.11%	23.26%
Mindset, cultural, behaviour of communities	53.85%	76.47%	75%	88.89%	72.09%
Total	61.54%	76.47%	100%	88.89%	76.74%

TABLE A.I.7. 34 OPTIONS AND STRATEGIES FOR ACHIEVING BUD BASED ON SCALE OF P&M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Sociocultural Environment	0%	0%	7.89%	6.98%
Household Adaptive Capacity	0%	0%	15.79%	13.95%
Financing	0%	0%	21.05%	18.6%
Infrastructure	0%	33.33%	39.47%	37.21%
Innovation and Services	0%	0%	42.11%	37.21%
Policies and Governance	100%	100%	60.53%	65.12%
Information, Communication, and Collaboration	100%	33.33%	71.05%	69.77%
Environmental Planning and Management	100%	100%	92.11%	93.02%
Total (unique)	100%	100%	100%	100%

TABLE A.I.7. 35 OPTIONS AND STRATEGIES FOR ACHIEVING BUD BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Sociocultural Environment	0%	0%	25%	22.22%	6.98%
Household Adaptive Capacity	38.46%	0%	0%	11.11%	13.95%
Financing	23.08%	23.53%	0%	11.11%	18.6%
Infrastructure	38.46%	29.41%	50%	44.44%	37.21%
Innovation and Services	46.15%	29.41%	50%	33.33%	37.21%
Policies and Governance	53.85%	70.59%	75%	66.67%	65.12%
Information, Communication, and Collaboration	84.62%	41.18%	100%	88.89%	69.77%
Environmental Planning and Management	92.31%	94.12%	75%	100%	93.02%
Total	100%	100%	100%	100%	100%

TABLE A.I.7. 36 OPTIONS AND STRATEGIES IN INFORMATION, COMMUNICATION, AND COLLABORATION BASED ON SCALE OF P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Flexible forums for communication	0%	0%	2.63%	2.33%
Regular reliable data and information sources	0%	0%	15.79%	13.95%
Learning capacity	50%	33.33%	26.32%	27.91%
Collaboration and synergy	100%	33.33%	55.26%	55.81%
Total	100%	33.33%	71.05%	69.77%

Table A.I.7. 37 Options and strategies in Information, Communication, and Collaboration based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Flexible forums for communication	7.69%	0%	0%	0%	2.33%
Regular reliable data and information sources	15.38%	5.88%	50%	11.11%	13.95%
Learning capacity	30.77%	17.65%	0%	55.56%	27.91%
Collaboration and synergy	76.92%	35.29%	50%	66.67%	55.81%
Total	84.62%	41.18%	100%	88.89%	69.77%

Table A.I.7. 38 Options and strategies in Policies and Governance based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Governance capacity	0%	0%	5.26%	4.65%
Political will and leadership	50%	0%	15.79%	16.28%
Institutional capacity	0%	33.33%	18.42%	18.6%
Incentive-disincentive	50%	100%	15.79%	23.26%
Adaptive and reliable legal frameworks for regulation	100%	66.67%	36.84%	41.86%
Total (unique)	100%	100%	60.53%	65.12%

Table A.I.7. 39 Options and strategies in Policies and Governance based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Governance capacity	0%	0%	25%	11.11%	4.65%
Political will and leadership	7.69%	23.53%	0%	22.22%	16.28%
Institutional capacity	23.08%	17.65%	25%	11.11%	18.6%
Incentive-disincentive	30.77%	23.53%	25%	11.11%	23.26%
Adaptive and reliable legal frameworks for regulation	46.15%	35.29%	50%	44.44%	41.86%
Total	53.85%	70.59%	75%	66.67%	65.12%

Table A.I.7. 40 Options and strategies in Environmental Planning and Management based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Central-national	50%	0%	0%	2.33%
Local scale and separate sectoral approach	50%	0%	5.26%	6.98%
Natural-based development	0%	33.33%	7.89%	9.3%
Situational and adaptive management approaches	50%	0%	13.16%	13.95%
Multi-sector and multi-level or scalar approach	100%	66.67%	34.21%	39.53%
Integrated approaches	50%	100%	39.47%	44.19%
Transboundary approach	100%	66.67%	68.42%	69.77%
Total	100%	100%	92.11%	93.02%

Table A.1.7. 41 Options and strategies in Environmental Planning and Management based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Central-national	0%	5.88%	0%	0%	2.33%
Local scale and separate sectoral approach	7.69%	5.88%	0%	11.11%	6.98%
Natural-based development	15.38%	5.88%	0%	11.11%	9.3%
Situational and adaptive management approaches	15.38%	11.76%	25%	11.11%	13.95%
Multi-sector and multi-level or scalar approach	23.08%	41.18%	50%	55.56%	39.53%
Integrated approaches	46.15%	41.18%	25%	55.56%	44.19%
Transboundary approach	69.23%	76.47%	50%	66.67%	69.77%
Total	92.31%	94.12%	75%	100%	93.02%

Table A.1.7. 42 Problems in enhancing sustainability based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Innovation and Services	0%	0%	2.63%	2.33%
Household Adaptive Capacity	0%	33.33%	10.53%	11.63%
Sociocultural Environment	50%	100%	50%	53.49%
Information, Communication, and Collaboration	50%	66.67%	63.16%	62.79%
Financing	0%	33.33%	73.68%	67.44%
Infrastructure	0%	66.67%	71.05%	67.44%
Environmental Planning and Management	50%	100%	71.05%	72.09%
Policies and Governance	50%	100%	84.21%	83.72%
Total	100%	100%	100%	100%

Table A.1.7. 43 Problems in enhancing sustainability based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Innovation and Services	0%	0%	0%	11.11%	2.33%
Household Adaptive Capacity	15.38%	11.76%	0%	11.11%	11.63%
Sociocultural Environment	38.46%	47.06%	75%	77.78%	53.49%
Information, Communication, and Collaboration	61.54%	58.82%	100%	55.56%	62.79%
Financing	61.54%	64.71%	50%	88.89%	67.44%
Infrastructure	69.23%	64.71%	50%	77.78%	67.44%
Environmental Planning and Management	76.92%	64.71%	100%	77.78%	74.42%
Policies and Governance	76.92%	94.12%	75%	77.78%	83.72%
Total	100%	100%	100%	100%	100%

Table A.1.7. 44 Problems in Environmental Planning and Management based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Safety and health	0%	0%	7.89%	6.98%
People	0%	0%	10.53%	9.3%
Environmental issues	0%	33.33%	13.16%	13.95%
Water	0%	66.67%	21.05%	23.26%
Approach in planning and management	50%	66.67%	39.47%	41.86%
Land	0%	100%	52.63%	53.49%
Total	50%	100%	73.68%	74.42%

Table A.I.7. 45 Problems in Environmental Planning and Management based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Safety and health	15.38%	0%	25%	0%	6.98%
People	7.69%	0%	25%	22.22%	9.3%
Environmental issues	0%	17.65%	25%	22.22%	13.95%
Water	23.08%	23.53%	25%	22.22%	23.26%
Approach in planning and management	38.46%	52.94%	25%	33.33%	41.86%
Land	61.54%	35.29%	100%	55.56%	53.49%
Total	76.92%	64.71%	100%	77.78%	74.42%

Table A.I.7. 46 Problems in Financing based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Strict digital budget and accounting rules	0%	33.33%	2.63%	4.65%
Budget or financial capacity	0%	33.33%	73.68%	67.44%
Total	0%	33.33%	73.68%	67.44%

Table A.I.7. 47 Problems in Financing based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Strict digital budget and accounting rules	7.69%	0%	0%	11.11%	4.65%
Budget or financial capacity	61.54%	64.71%	50%	88.89%	67.44%
Total (unique)	61.54%	64.71%	50%	88.89%	67.44%

Table A.I.7. 48 Problems in Information, Communication, and Collaboration based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Information	0%	0%	2.63%	2.33%
Public awareness and knowledge of the existence of legal regulations is still low and the integration of policy holders is not optimal.	0%	0%	2.63%	2.33%
Studies	0%	0%	2.63%	2.33%
Education, training, dissemination	0%	0%	5.26%	4.65%
Regular reliable data and information	0%	0%	5.26%	4.65%
All regulations to control land use will be useless if there is not awareness and participation from the communities and supports from the policy decision makers	0%	0%	10.53%	9.3%
Collaboration	50%	0%	28.95%	27.91%
Synergy	50%	66.67%	39.47%	41.86%
Total	50%	66.67%	63.16%	62.79%

Table A.I.7. 49 Problems in Information, Communication, and Collaboration based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Information	0%	0%	25%	0%	2.33%
Public awareness and knowledge of the existence of legal regulations is still low and the integration of policy holder	0%	5.88%	0%	0%	2.33%
Studies	7.69%	0%	0%	0%	2.33%
Education, training, dissemination	7.69%	5.88%	0%	0%	4.65%
Regular reliable data and information	0%	11.76%	0%	0%	4.65%
All regulations to control land use will be useless if there is not awareness and participation from the communities an	7.69%	11.76%	0%	11.11%	9.3%
Collaboration	30.77%	23.53%	25%	33.33%	27.91%
Synergy	30.77%	47.06%	75%	33.33%	41.86%
Total	61.54%	58.82%	100%	55.56%	62.79%

Table A.I.7. 50 Problems in infrastructure based on scale of P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Housing backlog	0%	0%	2.63%	2.33%
Too many illegal watchers	0%	33.33%	0%	2.33%
Transportation lines of Pantura or north coast significantly affect the economic level of Indramayu	0%	0%	2.63%	2.33%
Problem to provide infrastructure in the peri-urban areas to control urbanisation	0%	0%	5.26%	4.65%
Social resistance concerning water infrastructure construction, use, benefits and demands including in the process of improving slum areas, reservoir	0%	66.67%	28.95%	30.23%
Intervention capability of water and sanitation infrastructures	0%	0%	60.53%	53.49%
Total	0%	66.67%	71.05%	67.44%

Table A.I.7. 51 Problems in infrastructure based on the main role in SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Housing backlog	7.69%	0%	0%	0%	2.33%
Too many illegal watchers	0%	5.88%	0%	0%	2.33%
Transportation lines of Pantura or north coast significantly affect the economic level of Indramayu	0%	0%	25%	0%	2.33%
Problem to provide infrastructure in the peri-urban areas to control urbanisation	7.69%	5.88%	0%	0%	4.65%
Social resistance concerning water infrastructure construction, use, benefits and demands including in the process of improving slum areas, reservoir	30.77%	47.06%	25%	0%	30.23%
Intervention capability of water and sanitation infrastructures	53.85%	41.18%	50%	77.78%	53.49%
Total	69.23%	64.71%	50%	77.78%	67.44%

TABLE A.I.7. 52 PROBLEMS IN POLICIES AND GOVERNANCE BASED ON SCALE OF P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Local economic development	0%	0%	10.53%	9.3%
Regulation	0%	33.33%	18.42%	18.6%
Governance operational efficiency	50%	66.67%	18.42%	23.26%
Limitation of institution in management	0%	33.33%	28.95%	27.91%
Adaptation and reliable legal frameworks for implementation	0%	66.67%	39.47%	39.53%
Dealing with trade-off or nexus challenges	0%	33.33%	57.89%	53.49%
Total	50%	100%	84.21%	83.72%

TABLE A.I.7. 53 PROBLEMS IN POLICIES AND GOVERNANCE BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Local economic development	7.69%	0%	50%	11.11%	9.3%
Regulation	30.77%	11.76%	25%	11.11%	18.6%
Governance operational efficiency	23.08%	29.41%	25%	11.11%	23.26%
Limitation of institution in management	38.46%	23.53%	0%	33.33%	27.91%
Adaptation and reliable legal frameworks for implementation	61.54%	35.29%	25%	22.22%	39.53%
Dealing with trade-off or nexus challenges	46.15%	58.82%	50%	55.56%	53.49%
Total	76.92%	94.12%	75%	77.78%	83.72%

TABLE A.I.7. 54 PROBLEMS IN SOCIOCULTURAL ENVIRONMENT BASED ON SCALE OF P & M

Research participants information	Scale of planning and management = River Basin (2)	Scale of planning and management = Regional (3)	Scale of planning and management = Local (38)	**Total (43)**
Mindset, cultural, behaviour of communities	50%	100%	50%	53.49%
Total	50%	100%	50%	53.49%

TABLE A.I.7. 55 PROBLEMS IN SOCIOCULTURAL ENVIRONMENT BASED ON THE MAIN ROLE IN SDG

Research participants information	Main role in multi-sectoral planning for enhancing liveability-sustainability-SDG 11 (13)	Main role in sectoral planning and management for water security-SDG 6 (16)	Main role in sectoral planning and management for food security-SDG 2 (4)	Main role in non-sectoral planning and management for combating ecohydrological change including climate change-SDG 13 (10)	**Total (43)**
Mindset, cultural, behaviour of communities	38.46%	47.06%	75%	77.78%	53.49%
Total	38.46%	47.06%	75%	77.78%	53.49%

APPENDIX 2: ETHICS APPROVAL FROM THE WESTERN SYDNEY UNIVERSITY

Locked Bag 1797
Penrith NSW 2751 Australia
Office of Research Services

University of Western Sydney

ORS Reference: H11417

HUMAN RESEARCH ETHICS COMMITTEE

18 January 2016

Professor Basant Maheshwari
School of Science and Health

Dear Basant,

I wish to formally advise you that the Human Research Ethics Committee has approved your research proposal H11417 "PLANNING FOR WATER SECURITY, SUSTAINABILITY AND LIVEABILITY IN A GROWING COASTAL URBAN REGION: A CASE STUDY OF CIREBON, INDONESIA", until 30 November 2018 with the provision of a progress report annually if over 12 months and a final report on completion.

Conditions of Approval

1. A progress report will be due annually on the anniversary of the approval date.

2. A final report will be due at the expiration of the approval period.

3. Any amendments to the project must be approved by the Human Research Ethics Committee prior to being implemented. Amendments must be requested using the HREC Amendment Request Form: http://www.uws.edu.au/__data/assets/pdf_file/0018/491130/HREC_Amendment_Request_Form.pdf

4. Any serious or unexpected adverse events on participants must be reported to the Human Ethics Committee via the Human Ethics Officer as a matter of priority.

5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the Committee as a matter of priority

6. Consent forms are to be retained within the archives of the School or Research Institute and made available to the Committee upon request.

Please quote the registration number and title as indicated above in the subject line on all future correspondence related to this project. All correspondence should be sent to the email address humanethics@uws.edu.au.

This protocol covers the following researchers:
Basant Maheshwari, Dharmappa Hagare, Titih Danielaini

Yours sincerely

[redacted]

Professor Elizabeth Deane
Presiding Member,
Human Researcher Ethics Committee

APPENDIX 3: RECOMMENDATION LETTER FROM THE MINISTRY OF HOME AFFAIRS

KEMENTERIAN DALAM NEGERI
REPUBLIK INDONESIA
DIREKTORAT JENDERAL POLITIK DAN PEMERINTAHAN UMUM
Jl. Medan Merdeka Utara No. 7 Tlp. 3450038 Ps. 2285 Jakarta 10110

REKOMENDASI PENELITIAN
NOMOR : 440.02/852/Pol PUM.

a. Dasar : 1. Peraturan Menteri Dalam Negeri Nomor 41 Tahun 2010 tentang Organisasi dan Tata Kerja Kementerian Dalam Negeri (Berita Negara Republik Indonesia Tahun 2010 Nomor 316), sebagaimana telah diubah dengan Peraturan Menteri Dalam Negeri Nomor 14 Tahun 2011 tentang Perubahan Atas Peraturan Menteri Dalam Negeri Nomor 41 Tahun 2010 tentang Organisasi dan Tata Kerja Kementerian Dalam Negeri (Berita Negara Republik Indonesia Tahun 2011 Nomor 168);

2. Peraturan Menteri Dalam Negeri Nomor 7 Tahun 2014 tentang Perubahan Atas Peraturan Menteri Dalam Negeri Nomor 64 Tahun 2011 tentang Pedoman Penerbitan Rekomendasi Penelitian.

b. Menimbang : Surat dari School of Science and Health, Western Sydney University Tanggal 7 Januari 2016 Perihal Rekomendasi untuk Pengumpulan Data dan Riset.

MEMBERITAHUKAN BAHWA :

a. Nama /Obyek : Titih Titisari Danielaini.

b. Jabatan/Alamat Identitas : Peneliti Utama / Jl. Megasari II No.12 Rt/Rw. 001/009 Komplek BTN Joglo Kel. Sawahgede Kec. Cianjur Kab. Cianjur Prov. Jawa Barat/ No.Hp.082217588228/ No.KTP.3203015609790007.

c. Untuk : 1) Survey lapangan dan pengambilan data primer, sekunder (kuesioner, wawancara dll), dengan proposal berjudul ***"Planning For Water Security, Sustainability and Liveability in a Growing Coastal Urban Region: A Case Study of Cirebon, Indonesia";***

2) Lokasi penelitian : Provinsi Jawa Barat;
3) Waktu/lama penelitian : Maret s/d Juli 2016;
4) Anggota tim peneliti : -
5) Bidang penelitian : Kesehatan;
6) Status penelitian : Baru.

d. Melaporkan hasil penelitian kepada Menteri Dalam Negeri c.q. Dirjen Polpum, paling lambat 6 bulan setelah selesai penelitian.

Demikian rekomendasi ini dibuat untuk digunakan seperlunya.

Jakarta, 26 Februari 2016
a.n [redacted]
POLITIK [redacted] UMUM
[redacted]

BUDI PRASETYO, SH, MM
Pembina Utama Madya (IV/d)
NIP. 19570108 198703 1 001

Tembusan:
Yth. Kaban Kesbangpol Provinsi Jawa Barat;

Note: The research involves multi-level/scale government institutions including the Cimanuk-Cisanggarung River Basin that cross-provinces: West Java and Central Java. The recommendation letter was issued by the Ministry of Home Affairs. However, to ensure smooth data collection processes, the researcher also requested the permission letters to conduct the interviews and household surveys, from the Governments in the West Java Province and five districts in the CMR.

APPENDIX 4: INFORMATION AND CONSENT FORMS

1. Household Surveys and Face-to-Face Interviews

School/Institute Name: School of Science and Health
Western Sydney University
Locked Bag 1797
Penrith NSW 2751
Australia
Telephone: +61 2 4570 1691 (Hawkesbury Campus)

Email: ssh@westernsydney.edu.au

Participant Information Sheet (General) - Questionnaire

Project Title: Planning for water security, sustainability, and liveability in a growing coastal urban region: a case study of Cirebon, Indonesia.

Project Summary: The broad aim of the study is to understand future water security, sustainability, and liveability issues and challenges of urban and peri-urban areas of the Cirebon region in Indonesia and develop decision support tools that will assist in planning sustainable water use under significant urbanisation and climate change. The role of community and institutional drivers in relationship with the coastal environment will be assessed to understand the nature-science-people relationships and how to use such relationships and understanding for development regions that will be subjected to significant urbanisation and climate changes.

You are invited to participate in a research study being conducted by Titih Titisari Danielaini, a PhD Student at School of Science and Health - Hawkesbury Campus under the Supervision of Professor Basant Maheshwari (Professor in School of Science and Health) and Doctor Dharma Hagare (Senior Lecturer in Engineering and Construction Management, School of Computing, Engineering and Mathematics).

The study is being sponsored by the School of Science and Health-Western Sydney University and Australia Award Scholarship-Department of Foreign Affairs and Trade-Australian Government.

What will I be asked to do?
You are invited to take part in a research study designed to look at community experience in urban and peri-urban of a growing coastal urban region-Cirebon, West Java, Indonesia in accessing water-related parameters to understand the water role in sustainability and liveability and to know what preference strategy to improve eco-hydrology in their place.

How much of my time will I need to give?
Interview answering the questionnaire should take approximately 30-45 minutes

What specific benefits will I receive for participating?
The compensation will be made for your participation with the payment in the form of a gift worth $2.

Will the study involve any discomfort for me? If so, what will you do to rectify it?
If at any stage you feel uncomfortable about the questions that I ask during the interview then let me know and we can move onto the next question or finish the interview if that is what you wish.

How do you intend to publish the results?
Please be assured that only the researchers will have access to the raw data you provide. All information collected from this interview will remain strictly confidential and will be disclosed only with your permission, the findings will be published but identities of participants and organisations will not be revealed in the publications.

The findings of the research will be published in Ph.D. thesis report and Journal or conferences related to water security, sustainability, and liveability.

*Please note that the minimum retention period for data collection is five years.

Can I withdraw from the study?
Participation is entirely voluntary, and you are not obliged to be involved. If you do participate, you can withdraw at any time without giving a reason.

If you do choose to withdraw, any information that you have supplied may still be used and given to others until the end of the research study, as necessary to insure the integrity of the study and or study oversight.

Can I tell other people about the study?
Yes, you can tell other people about the study by providing them with the chief investigator's contact details. They can contact the chief investigator to discuss their participation in the research project and obtain an information sheet.

Data storage
There are a number of government initiatives in place to centrally store research data and to make it available for further research. For more information, see **http://www.ands.org.au/** and **http://www.rdsi.uq.edu.au/about**. Regardless of whether the information you supply or about you is stored centrally or not, it will be stored securely and it will be de-identified before it is made to available to any other researcher.

What if I require further information?
Please contact - **Titih Titisari Danielaini, PhD student, Hawkesbury Campus, School of Science and Health, Western Sydney University, +61 2 4570 1691**- should you wish to discuss the research further before deciding whether or not to participate.

Ms. Titih Titisari Danielaini
Contact: 0449992158
Email: T.Danielaini@uws.edu.au or T.Danielaini@westernsydney.edu.au

Prof Basant Maheshwari
Contact: (02) 45701235
Email: b.maheshwari@uws.edu.au or b.maheshwari@westernsydney.edu.au

What if I have a complaint?
This study has been approved by the University of Western Sydney Human Research Ethics Committee. The Approval number is **[H11417]**

If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Office of Research Services on Tel +61 2 4736 0229 Fax +61 2 4736 0013 or email humanethics@uws.edu.au.

Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

If you agree to participate in this study, you may be asked to sign the Participant Consent Form.

Human Research Ethics Committee
Office of Research Services

Participant Consent Form

This is a project-specific consent form. It restricts the use of the data (
by the named investigators.

Project Title: Planning for water security, sustainability, and liveability in a growing coastal urban region: a case study of Cirebon

I,____ [name of participant] consent to participate in the research project titled **Planning for water security, sustainability, and liveability in a growing coastal urban region: a case study of Cirebon**.

I acknowledge that:

I have read the participant information sheet or have had read to me and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I consent to the participation in the research project may involve an interview and audio–recording as part of the data collection procedures.

I understand that my involvement is confidential and that the information gained during the study may be published but no information about me will be used in any way that reveals my identity.

I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher/s now or in the future.

Signed:

Name:

Date:

Return Address: **Ms. Titih Titisari Danielaini, School of Science and Health, Building M15, Room M15.G.20, Hawkesbury Campus, Western Sydney University.**

This study has been approved by the University of Western Sydney Human Research Ethics Committee. The Approval number is: **[H11417]**

If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Office of Research Services on Tel +61 2 4736 0229
Fax +61 2 4736 0013 or email humanethics@uws.edu.au. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

2. Face-to-Face Interviews to Multi-level Government Representatives

School/Institute Name: School of Science and Health
Western Sydney University
Locked Bag 1797
Penrith NSW 2751
Australia
Telephone: +61 2 4570 1691 (Hawkesbury Campus)

Email: ssh@westernsydney.edu.au

WESTERN SYDNEY UNIVERSITY

Participant Information Sheet (General) - Interview

Project Title:

Planning for water security, sustainability, and liveability in a growing coastal urban region: a case study of Cirebon, Indonesia.

Project Summary: The broad aim of the study is to understand future water security, sustainability and liveability issues and challenges of urban and peri-urban areas of the Cirebon region in Indonesia and develop decision support tools that will assist in planning sustainable water use under significant urbanisation and climate change. The role of community and institutional drivers in relationship with the coastal environment will be assessed to understand the nature-science-people relationships and how to use such relationships and understanding for development regions that will be subjected to significant urbanisation and climate changes.

You are invited to participate in a research study being conducted by Titih Titisari Danielaini, a PhD Student at School of Science and Health - Hawkesbury Campus under the Supervision of Professor Basant Maheshwari (Professor in School of Science and Health) and Doctor Dharma Hagare (Senior Lecturer in Engineering and Construction Management, School of Computing, Engineering and Mathematics).

The study is being sponsored by School of Science and Health-Western Sydney University and Australia Award Scholarship-Department of Foreign Affairs and Trade-Australian Government.

What will I be asked to do?
You are invited to take part in a research study designed to understand institutional drivers or decision makers perspective regarding future change of land use, water cycle and climate; strategy in water infrastructure development and distribution for sustainability in the Cirebon region; water resources planning objective for water security combined with land use planning objective for sustainability and liveability

How much of my time will I need to give?
The interview should take approximately 30 minutes

What specific benefits will I receive for participating?
The compensation will be made for your participation with the payment in the form of a gift worth $5.

Will the study involve any discomfort for me? If so, what will you do to rectify it?
With your consent the interview will be recorded to ensure accuracy of the interview data. I will inform you when the recorder is being turned on or off. If you wish, I will provide you with a copy of the transcript and you are welcome to edit the transcript if necessary. If at any stage, you feel uncomfortable about the questions that I ask during the interview then let me know and we can move onto the next question or finish the interview if that is what you wish.

How do you intend to publish the results?
Please be assured that only the researchers will have access to the raw data you provide. All information collected from this interview will remain strictly confidential and will be disclosed only with your permission, the findings will be published but identities of participants and organisations will not be revealed in the publications.

The findings of the research will be published in PhD thesis report and Journal or conferences related to water security, sustainability and liveability.

*Please note that the minimum retention period for data collection is five years.

Can I withdraw from the study?
Participation is entirely voluntary and you are not obliged to be involved. If you do participate, you can withdraw at any time without giving a reason.

If you do choose to withdraw, any information that you have supplied may still be used and given to others until the end of the research study, as necessary to insure the integrity of the study and or study oversight.

Can I tell other people about the study?
Yes, you can tell other people about the study by providing them with the chief investigator's contact details. They can contact the chief investigator to discuss their participation in the research project and obtain an information sheet.

Data storage
There are a number of government initiatives in place to centrally store research data and to make it available for further research. For more information, see **http://www.ands.org.au/** and **http://www.rdsi.uq.edu.au/about**. Regardless of whether the information you supply or about you is stored centrally or not, it will be stored securely and it will be de-identified before it is made to available to any other researcher.

What if I require further information?
Please contact - **Titih Titisari Danielaini, PhD student, Hawkesbury Campus, School of Science and Health, Western Sydney University, +61 2 4570 1691**- should you wish to discuss the research further before deciding whether or not to participate.

Ms. Titih Titisari Danielaini
Contact: 0449992158
Email: T.Danielaini@uws.edu.au or T.Danielaini@westernsydney.edu.au

Prof Basant Maheshwari
Contact: (02) 45701235
Email: b.maheshwari@uws.edu.au or b.maheshwari@westernsydney.edu.au

What if I have a complaint?
This study has been approved by the University of Western Sydney Human Research Ethics Committee. The Approval number is [**H11417**]

If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Office of Research Services on Tel +61 2 4736 0229 Fax +61 2 4736 0013 or email humanethics@uws.edu.au.

Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

If you agree to participate in this study, you may be asked to sign the Participant Consent Form.

Human Research Ethics Committee
Office of Research Services

Participant Consent Form

This is a project specific consent form. It restricts the use of the data collected to the named project by the named investigators.

Project Title: Planning for water security, sustainability, and liveability in a growing coastal urban region: a case study of Cirebon

I, ____ [name of participant] consent to participate in the research project titled **Planning for water security, sustainability, and liveability in a growing coastal urban region: a case study of Cirebon**.

I acknowledge that:

I have read the participant information sheet or have had read to me and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I consent to the participation in the research project may involve an interview and audio–recording as part of the data collection procedures.

I understand that my involvement is confidential and that the information gained during the study may be published but no information about me will be used in any way that reveals my identity.

I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher/s now or in the future.

Signed:

Name:

Date:

Return Address: **Ms. Titih Titisari Danielaini, School of Science and Health, Building M15, Room M15.G.20, Hawkesbury Campus, Western Sydney University.**

This study has been approved by the University of Western Sydney Human Research Ethics Committee. The Approval number is: [**H11417**]

If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Office of Research Services on Tel +61 2 4736 0229
Fax +61 2 4736 0013 or email humanethics@uws.edu.au. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

APPENDIX 5: QUESTIONNAIRES

1. Household Surveys and Face-to-Face Interviews

WESTERN SYDNEY UNIVERSITY

Locked Bag 1797
Penrith NSW 2751
Tel: +61 2 9852 5222

No Questionnaire:	Unique ID for data entry:

HOUSEHOLD SURVEY QUESTIONNAIRE (BENEFICIARIES PERSPECTIVE)
English Version

Planning for Water Security, Sustainability and Liveability in the Growing Coastal Urban Region: A Case Study of Cirebon, Indonesia

The objective of the survey

To understand beneficiaries perspective regarding factors and water's role for liveability and sustainability, important factors based on resident preference, resident's experience of satisfaction, understanding of water influence for making liveable place, what preference strategy to improve ecohydrology in their place

Consent (More detailed information and signature in the Participant-Consent- Form)

All information will be kept strictly confidential for data analysis or research purposes only. We will not record the respondent name. Any information given will not be linked directly to the respondent.

Name of the interviewer : ______________________

Interviewer's Code : ______________________

Date of interview : ______________________

Time of interview : Start: __________ Finish: __________

A. PROFILE OF RESPONDENT

A.1 **Location**

Name of the City/District (select one of the options below)

1	**2**	**3**	**4**	**5**
Cirebon City	Cirebon District	Kuningan District	Majalengka District	Indramayu District

Name of sub-district and village: ______________________________

Distance from the coast (km): ______________________ *(filled by the interviewer)*

Type of settlement : **1.** Formal **2.** Non-Formal

Related Job : **1.** Farmer

2. Non-Farmer

A.2 Sex : 1. Male 2. Female

A.3 Questions regarding the household

How long have you been living in this area? ……………………………………………….

How many people live in your household? ….……………………………………………….

B. WATER SECURITY ASPECT IN THE REGION

On this part, you will be asked regarding water sources for basic household needs and food production, water problems to understand water security aspect in the region.

Please select which situation relates to you.

B.1 **Water Sources for drinking and others**

Drinking water	Other water utilisation (such as bathing, washing)	Ownership of the facility	Access to public water services (PDAM/KSM)
1. Bottled water	1. Bottled water	1. Individual	1. Yes
2. Piped water into dwelling	2. Piped water into dwelling	2. Public	2. No
3. Piped water into yard	3. Piped water into yard		
4. Public tap	4. Public tap		
5.Tube well or borehole	5.Tube well or borehole		
6. Protected dug well	6. Protected dug well		
7. Unprotected dug well	7. Unprotected dug well		
8. Protected spring	8. Protected spring		
9. Unprotected spring	9. Unprotected spring		
10. Rainwater	10. Rainwater		
11. Other: ……………..	11. Other: ……………..		

B.2 **Available water for food production** *(For farmer respondents)*

Access to Irrigation Services	**Water Source for watering plant**
1. YES Status of irrigation: 1. Fully irrigated 2. Partially irrigated	1. Groundwater 2. Canal 3. River 4. Other…………
2. No	

B.3 **Access to Wastewater services and type of Sanitation facility**

Sanitation Facility	Access to wastewater treatment services (sewerage system)	Ownership of the facility
1. Piped sewer system	1. Yes 2. No	1. Individual 2. Public
2. Septic tank		
3. Pit Latrine		
4. Composting toilet		
5. Other …………………………..		

B.4 **Availability of drainage system and experience of water problems in the settlement**

Drainage System	**Water problems**
1. Available in the settlement area	1. Flood
2. Not available	2. Drought/water scarcity
	3. No water problems

B.5 **Question regarding water quality**

What is your opinion regarding to river water quality in your region?

a. Dirty
b. Clean
c. Other…………

Do you have any problem regarding to groundwater quality in your region?

a. Yes, specify……………………………..
b. No

C. FACTORS CONTRIBUTING TO LIVEABILITY

On this part, you will be asked about your preference regarding the importance and satisfaction of liveability indicators as well as the influence of water to other aspects of liveability.

What are the one or two most important indicators for the liveability in your region? ....
....
....
....

Select one of the options (1-5) for the following liveability indicators

How much important the liveability indicators below to you?

Liveability Indicators		Not at all important	Slightly important	Moderately important	Important	Very important
Ecohydrology	Sufficient water availability	1	2	3	4	5
	Well maintained river	1	2	3	4	5
	Green open spaces in the public area	1	2	3	4	5
	Housing with garden spaces	1	2	3	4	5
	Agriculture and forest area that closed to the city	1	2	3	4	5
Social	Health-housing	1	2	3	4	5
	Health-settlement	1	2	3	4	5
	Healthy waterways	1	2	3	4	5
	Facilities and services for education, public health, amenities	1	2	3	4	5
	Flood protection	1	2	3	4	5
	Drought prevention	1	2	3	4	5
Economy	Housing affordability	1	2	3	4	5
	Employment	1	2	3	4	5
	Mobility (transportation)	1	2	3	4	5
	Income	1	2	3	4	5
	Infrastructure related to water and sanitation/waste water treatment	1	2	3	4	5

How much water influences liveability in your region?

a. Not at all influential
b. Not influential
c. Somewhat influential
d. Influential
e. Very influential

What are the one or two aspects of liveability in your region that you're most satisfied and least satisfied?
....
....
....

Select one of the options (1-5) for the following liveability indicators

How much are you satisfied with liveability indicators below?

Liveability Indicators		Not at all Satisfied	Unsatisfied	Unsure	Satisfied	Very Satisfied
Ecohydrolog	Sufficient water availability	1	2	3	4	5
	Well maintained river	1	2	3	4	5
	Green open spaces in the public area	1	2	3	4	5
	Housing with garden spaces	1	2	3	4	5
	Agriculture and forest area that closed to the city	1	2	3	4	5
Social	Health-housing	1	2	3	4	5
	Health-settlement	1	2	3	4	5
	Healthy waterways	1	2	3	4	5
	Facilities and services for education, public health, amenities	1	2	3	4	5
	Flood protection	1	2	3	4	5
	Drought prevention	1	2	3	4	5
Economy	Housing affordability	1	2	3	4	5
	Employment	1	2	3	4	5
	Mobility (transportation)	1	2	3	4	5
	Income	1	2	3	4	5
	Infrastructure related to water and sanitation/waste water treatment	1	2	3	4	5

D. EXPERIENCES OF ECOHYDROLOGY CONCERNING URBANISATION IN THE REGION

On this part, you will be asked regarding your experience during your stay in land use change and water problems due to urbanisation. *Select one of the options (1-5) for the following aspects.*

To what extent these aspects have changed in the past 10 to 20 years?

Aspects	Not at all change	Slightly change	Extremely change	Specify: 1. Increase	2. Decrease
Green open space	1	2	3	1	2
Groundwater quality	1	2	3	1	2
River quality	1	2	3		
Flood events	1	2	3	1	2
Drought events	1	2	3	1	2
Climate	1	2	3	1	2
Biodiversity	1	2	3	1	2
(Food/Forest)	1	2	3	1	2

Are there any concerns regarding the change in land use, water cycle and climate to your health?

a. Yes
   Specify…………………………………………………………………………………………
b. No

E. STRATEGY TO IMPROVE ECOHYDROLOGY FOR SUSTAINABILITY

On the last part, you will be asked your opinion to improve ecohydrology in your region.

What is the most important strategy to improve the condition of environment related to water in your region? Who need to take the responsibility to improve water and environmental quality? ……… ………

Select one of the options (1-5) for the following activities
How much do you agree with the activities below that can do by the community?

Activities	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
Minimising water use consumption (e.g. choosing water efficient shower, toilet, tap, and appliances or choosing plants with low water needs)	1	2	3	4	5
Using water much more efficient (e.g. washing vehicle on the lawn to water grass at the same time, installing monitoring device for water use)	1	2	3	4	5
Maximising green open space (e.g. planting vegetation, grass and minimising paving or outdoor area for groundwater recharge, control heat radiation and flood)	1	2	3	4	5
Protecting waterways from pollution (e.g. minimising domestic pollution to the river and drainage system)	1	2	3	4	5

Are there, if any, strategies not mention above that you think very important to do?
(Particularly for farmer respondents, what is your strategy to minimise water consumption for irrigation or strategy to adapt with water situation)

No Kuesioner:	ID khusus untuk memasukkan data:

SURVEI RUMAH TANGGA DENGAN KUESIONER (PERSPEKTIF MASYARAKAT)
Versi Bahasa Indonesia

Planning for Water Security, Sustainability and Liveability in the Growing Coastal Urban Region: A Case Study of Cirebon, Indonesia

Tujuan Survei

Untuk memahami pandangan masyarakat mengenai aspek ketahanan air, faktor dan peranan air dalam mewujudkan wilayah yang layak huni dan berkelanjutan, faktor penting dan kepuasan tinggal di lingkungan berdasarkan preferensi masyarakat, memahami pengaruh perubahan lahan, siklus air dan iklim terhadap kehidupan masyarakat dan strategi dalam meningkatkan kualitas ekohidrologi

Persetujuan (Informasi lebih lengkap dan tanda tangan persetujuan pada "Participant-Consent-Form")

Semua informasi yang didapatkan dari hasil kuesioner akan disimpan secara hati-hati dan rahasia untuk kepentingan analisis data dan hanya tujuan untuk penelitian. Semua informasi yang diberikan akan dianalisis tidak terkait langsung dengan data pribadi dari responden.

Nama Pewawancara : ______________________

Kode Pewawancara : ______________________

Tanggal Wawancara : ______________________

Waktu wawancara : Mulai: __________ Selesai: __________

A. PROFIL RESPONDEN

A.1 **Lokasi**

Nama Kota/Kabupaten (lingkari nomor dari pilihan di bawah ini)

1	2	3	4	5
Kota Cirebon	Kabupaten Cirebon	Kabupaten Kuningan	Kabupaten Majalengka	Kabupaten Indramayu

Nama Kecamatan atau Desa/Kelurahan: ____________________________________

Jarak dari pantai (km) : ________________________ *(Diisi oleh pewawancara)*

Tipe perumahan : **1.** Formal **2.** Non-Formal *(Diisi oleh pewawancara)*

Pekerjaan : **1.** Petani

2. Non-Petani

A.2 **Jenis Kelamin** : **1.** Laki-laki **2.** Perempuan

A.3 **Pertanyaan terkait responden**:

Berapa lama anda tinggal di daerah ini? ………………………………………………………………

Berapa orang yang tinggal di dalam rumah ini? …………………………………………………..

B. MEMAHAMI KETAHANAN AIR DI WILAYAH TEMPAT TINGGAL

Pada bagian ini, anda akan ditanya terkait sumber air untuk keperluan dasar rumah tangga dan atau produksi makanan, serta permasalahan air di lingkungan tempat tinggal.

Lingkari pilihan dari setiap pernyataan di bawah ini yang menggambarkan situasi anda.

B.1 **Sumber air untuk minum dan penggunaan lainnya**

Sumber air untuk Minum	Sumber air untuk mandi, cuci dan lainnya	Kepemilikan fasilitas
1. Air kemasan	1. Air kemasan	1. Pribadi
2. Air ledeng dengan jaringan pipa masuk rumah	2. Air ledeng dengan jaringan pipa masuk rumah	2. Umum
3. Air ledeng dengan jaringan pipa hanya sampai halaman	3. Air ledeng dengan jaringan pipa hanya sampai halaman	
4. Keran/Hidran umum	4. Keran/Hidran umum	
5.Sumur pompa atau sumur bor	5.Sumur pompa atau sumur bor	
6. Sumur gali terlindungi	6. Sumur gali terlindungi	
7. Sumur gali tidak terlindungi	7. Sumur gali tidak terlindungi	
8. Mata air terlindungi	8. Mata air terlindungi	
9. Mata air tidak terlindungi	9. Mata air tidak terlindungi	
10. Air hujan	10. Air hujan	
11. Lainnya: ……………..	11. Lainnya: ……………..	

B.2 **Ketersediaan sistem irigasi dan pengalaman permasalahan mengairi tanaman**

(Pertanyaan khusus untuk responden petani)

Akses terhadap pelayanan sistem irigasi	Sumber Air
1. Ya Status irigasi: 1. Irigasi penuh/panen 3x 2. Irigasi sebagian	1. Air tanah 2. Saluran air 3. Sungai/pompanisasi 4. Lainnya…………
2. Tidak	

B.3 **Akses terhadap pelayanan air limbah dan tipe fasilitas sanitasi**

Fasilitas sanitasi	Akses pelayanan air limbah/sistem pembuangan air limbah permukiman	Kepemilikan sanitasi
1. Sistem pembuangan perpipaan	1. Ya 2. Tidak	1. Pribadi 2. Umum
2. Tangki septik		
3. Cubluk		
4. Jamban pupuk		
5. Lainnya …………………………..		

B.4 **Ketersediaan sistem drainase dan pengalaman masalah terkait di lingkungan permukiman**

Sistem Drainase	Masalah terkait drainase dan air
1. Tersedia di lingkungan permukiman	1. Banjir
2. Tidak tersedia	2. Kekeringan/kesulitan mendapatkan air
	3. Tidak ada masalah

B.5 Pertanyaan mengenai kualitas air

Bagaimana pendapat bapak/ibu dengan kualitas air sungai di sekitar tempat tinggal?

a. Kotor
b. Bersih
c. Lainnya………….

Apakah ada permasalahan dengan kualitas air tanah?

a. Ya, jelaskan……………………………..
b. Tidak

C. FAKTOR YANG MEMPENGARUHI KELAYAKHUNIAN WILAYAH

Pada bagian ini, anda akan ditanya mengenai tingkat kepentingan dan kepuasan pilihan indikator layak huni serta tingkat pengaruh air terhadap aspek layak huni.

Sebutkan satu atau dua indikator yang menurut anda paling penting mempengaruhi kelayakhunian lingkungan tempat tinggal anda?

....

....

....

Lingkari satu dari lima skala pilihan indikator layak huni yang tersedia.

Seberapa penting indikator layak huni di bawah ini bagi anda?

Indikator layak huni		Sangat Tidak Penting	Sedikit Penting	Cukup penting	Penting	Sangat Penting Sekali
Eko-hidrologi	Ketersediaan air yang cukup	1	2	3	4	5
	Sungai yang terawat dengan baik	1	2	3	4	5
	Ketersediaan RTH di arena publik	1	2	3	4	5
	Perumahan dengan taman/kebun	1	2	3	4	5
Sosial	Permukiman yang sehat	1	2	3	4	5
	Lingkungan permukiman yang sehat	1	2	3	4	5
	Saluran air yang sehat dan tidak tercemar	1	2	3	4	5
	Fasilitas dan pelayanan pendidikan, kesehatan masyarakat, kenyamanan/rekreasi	1	2	3	4	5
	Perlindungan banjir	1	2	3	4	5
	Antisipasi kekeringan	1	2	3	4	5
Ekonomi	Keterjangkauan harga rumah	1	2	3	4	5
	Ketersediaan pekerjaan	1	2	3	4	5
	Ketersediaan transportasi umum yang memadai	1	2	3	4	5
	Tingkat pendapatan	1	2	3	4	5
	Ketersediaan sarpras air bersih dan sanitasi	1	2	3	4	5

Sebutkan satu atau dua aspek layak huni yang menurut anda paling memuaskan dan paling tidak memuaskan di wilayah tempat tinggal anda?

....

....

....

Pilih satu dari lima pilihan skala indikator layak huni di bawah ini

Seberapa puaskah anda dengan indikator layak huni di bawah ini?

Indikator layak huni		Sangat Tidak puas	Tidak puas	Antara puas dan tidak puas	Puas	Sangat puas sekali
Eko-hidrologi	Ketersediaan air yang cukup	1	2	3	4	5
	Sungai yang terawat dengan baik	1	2	3	4	5
	Ketersediaan RTH di arena publik	1	2	3	4	5
	Perumahan dengan taman/kebun	1	2	3	4	5
Sosial	Permukiman yang sehat	1	2	3	4	5
	Lingkungan permukiman yang sehat	1	2	3	4	5
	Saluran air yang sehat dan tidak tercemar	1	2	3	4	5
	Fasilitas dan pelayanan pendidikan, kesehatan masyarakat, kenyamanan/rekreasi	1	2	3	4	5
	Perlindungan banjir	1	2	3	4	5
	Antisipasi kekeringan	1	2	3	4	5
Ekonomi	Keterjangkauan harga rumah	1	2	3	4	5
	Ketersediaan pekerjaan	1	2	3	4	5
	Ketersediaan transportasi umum yang memadai	1	2	3	4	5
	Tingkat pendapatan	1	2	3	4	5
	Ketersediaan sarpras air bersih dan sanitasi	1	2	3	4	5

D. PENILAIAN PERUBAHAN EKOHIDROLOGI AKIBAT URBANISASI

Pada bagian ini, anda akan ditanya mengenai pengalaman tinggal terkait aspek perubahan lahan dan masalah air karena laju urbanisasi. Pilih satu nilai dari setiap pilihan indikator di bawah ini.

Seberapa besar tingkat perubahan faktor ini dalam 10-20 tahun terakhir?

Aspek	Tidak berubah	Sedikit berubah	Sangat berubah	Keterangan: 1.Meningkat 2. Menurun
Ruang terbuka hijau	1	2	3	1 2
Kualitas air tanah Kualitas air sungai	1 1	2 2	3 3	1 2 1 2
Kejadian Banjir Kejadian Kekeringan	1 1	2 2	3 3	1 2 1 2
Iklim/cuaca	1	2	3	1 2
Keanekaragaman hayati: Makanan (flora/fauna) Hutan	 1 1	 2 2	 3 3	 1 2 1 2

Apakah ada yang perlu dikhawatirkan dengan perubahan lahan, siklus air dan iklim?

a. Ya
   Jelaskan…………………………………………………………………………………………
b. Tidak

E. STRATEGI MEMPERBAIKI EKOHIDROLOGI UNTUK KEBERLANJUTAN

Pada bagian terakhir kuesioner ini, Bapak/ibu akan diminta pendapatnya mengenai tindakan yang diperlukan untuk memperbaiki ekohidrologi di wilayah tempat tinggal.

Strategi apa yang menurut Bapak/Ibu dinilai paling penting dilakukan untuk meningkatkan kondisi ekohidrologi di wilayah ini? Siapakah yang bertanggungjawab untuk melakukan hal tersebut?
……
……….

Pilih satu skala penilaian dari setiap kegiatan di bawah ini.

Seberapa anda setujukah dengan kegiatan yang bisa dilakukan oleh masyarakat?

Kegiatan	Sangat tidak setuju	Tidak setuju	Netral	Setuju	Sangat Setuju
Mengurangi penggunaan air (seperti memilih fasilitas kamar mandi yang hemat air atau tanaman yang tida memerlukan banyak air)	1	2	3	4	5
Menggunakan air dengan lebih daya guna (seperti mencuci kendaraan di atas rumput atau ruang terbuka agar sekalian menyirami tanaman atau memasang meteran atau alat kendali penggunaan air)	1	2	3	4	5
Memaksimalkan ruang terbuka hijau (seperti menanam tanaman, rumput, meminimalkan penggunaan alas beton di luar bangunan untuk pengisian air tanah, kendali radiasi panas dan banjir)	1	2	3	4	5
Melindungi saluran air dari pencemaran (seperti meminimalkan pencemaran rumah tangga terhadap sungai dan saluran drainase)	1	2	3	4	5

Apakah ada kegiatan yang belum disebutkan dan penting untuk dilakukan oleh masyarakat? Khususnya bagi para petani, kegiatan apakah yang penting untuk dilakukan agar mengurangi kebutuhan air irigasi atau tindakan penyesuaian kalau ada banjir atau kekeringan?)

Catatan khusus Pewawancara terkait Responden/tempat tinggal responden:

2. Face-to-Face Interviews to Multi-Level Government Representatives

WESTERN SYDNEY UNIVERSITY

Locked Bag 1797
Penrith NSW 2751
Tel: +61 2 9852 5222

No Interview:	Unique ID for data entry:

INTERVIEW TO THE GOVERNMENT (LOCAL-PROVINCIAL-NATIONAL)

English Version

Planning for Water Security, Sustainability and Liveability in the Growing Coastal Urban Region: A Case Study of Cirebon, Indonesia

Objective of the Survey To understand decision-makers perspective regarding future change of land use, water cycle and climate; strategy in water infrastructure development and distribution for sustainability in the Cirebon region; water resources planning objective for water security combined with land use planning objective for sustainability and liveability
Consent (More detailed information and signature in the Participant-Consent- Form) All information will be kept strictly confidential for data analysis only. Specific data information related to the respondent will be used limited to correspondence and not to be informed or published.

A. PROFILE OF RESPONDENT

Name of Institution	
Level of Government	**Local Government Authority (LGA)**: 1. Cirebon Municipality 2. Cirebon District 3. Kuningan District 4. Majalengka District 5. Indramayu District **Provincial Government (Regional Development Authority)**: 6. West Java Province **Central Government (River Basin Authority)** : 7. BBWS Cimanuk-Cisanggarung
Name of respondent	
Position in the institution	
Phone	
Email	
Educational background	
Experience in water-related sector (years)	

B. Interview Guides

Please answer based on your experience and knowledge regarding the responsibility of the institution in water related sector.

1. Regarding the burning issue of Greater Cirebon Metropolitan development and “flood and drought” in the region, is there any possibility to develop an appropriate strategy to manage balanced urban development and water problems regarding future urbanisation and climate change? At what scale (district/municipality, metropolitan/regional, watershed)? Why and why not?

2. What kind of strategies are planned to cope with the changes in land use, water cycle, and climate that has been considered to be implemented by your institution?? Do you think that strategy already sufficient to cope with the future urbanisation (metropolitan development) and climate change? Why and why not?

3. What concerns do your institutions have regarding ecosystem services (water/ food/ flood control/ recreational and cultural benefits)? Is there available policy and strategy to increase ecosystem services in your region (institution)? What kind of strategy?

4. What kinds of problems are being faced in implementing policy to enhance sustainable water-related services or water security in your region? (related to green open space policy, water use, water infrastructure development, water distribution)

5. What is your opinion about the issue and challenge in integrating water resource planning into land use planning for water security, sustainability, and liveability in the region regarding metropolitan development? (linked with the future scenario of urbanisation, land use change from agriculture to non-agriculture in Cirebon-Majalengka-Kuningan-Indramayu, controlling runoff for flood protection, climate change impact in the coastal region)

WAWANCARA UNTUK INSTITUSI PEMERINTAH (LOKAL-PROVINSI-NASIONAL)

Versi Bahasa Indonesia

Planning for Water Security, Sustainability and Liveability in the Growing Coastal Urban Region: A Case Study of Cirebon, Indonesia

Tujuan Survei Untuk memahami pandangan para pengambil kebijakan terkait perubahan tata guna lahan, siklus air dan iklim di masa depan, strategi dalam pengembangan infrastruktur dan pendistribusian air untuk pembangunan berkelanjutan di wilayah Cirebon, penggabungan tujuan perencanaan sumber daya air untuk ketahanan air dan perencanaan tata guna lahan untuk mewujudkan wilayah yang berkelanjutan dan layak huni
Persetujuan (Informasi lebih lengkap dan tanda tangan persetujuan pada "Participant-Consent-Form") Semua informasi dari hasil wawancara baik dalam bentuk rekaman maupun tulis akan disimpan secara hati-hati dan rahasia untuk kepentingan analisis data. Informasi khusus terkait responden akan digunakan dalam batas kepentingan korespondensi dan bukan untuk diinformasikan ke publik.

A. PROFIL RESPONDEN

Nama Institusi	
Level pemerintah	**Pemerintah daerah kabupaten/kota**: 1. Kota Cirebon 2. Kabupaten Cirebon 3. Kabupaten Kuningan 4. Kabupaten Majalengka 5. Kabupaten Indramayu **Pemerintah Provinsi**: 6. Provinsi Jawa Barat **Pemerintah Pusat**: 7. BBWS Cimanuk-Cisanggarung
Nama responden	
Posisi atau jabatan di organisasi	
Telepon	
Email	
Latar belakang pendidikan	
Pengalaman kerja di sektor terkait air (tahun)	

B. Pedoman Wawancara

Mohon dijawab berdasarkan pengalaman dan pengetahuan Bapak/Ibu mengenai tanggungjawab institusi terkait sektor air

1. Sehubungan dengan bahasan penting yang sedang hangat didiskusikan yaitu pengembangan Metropolitan Cirebon Raya dan permasalahan banjir dan kekeringan di daerah pantura, apakah memungkinan mengembangkan strategi yang tepat untuk pengembangan kota secara seimbang (desakota atau ekosistem petanian dan perkotaan) dan menangani permasalahan air terkait urbanisasi dan perubahan iklim di masa depan? Pada skala apa (kabupaten/kota, wilayah metropolitan, Daerah Aliran Sungai/DAS)? Mengapa ya atau tidak?

2. Strategi apa yang telah dipertimbangkan institusi Bapak/Ibu untuk mengatasi perubahan tata guna lahan, siklus air, perubahan iklim? Apakah menurut Bapak/Ibu strategi tersebut sudah mencukupi untuk menghadapi tingkat urbanisasi dan perubahan iklim di masa mendatang? Mengapa ya atau tidak?

3. Apa yang menjadi fokus perhatian institusi Bapak/Ibu terkait layanan ekosistem di wilayah ini (air, makanan, pengendalian banjir, pemanfaatan lingkungan/alam untuk rekreasi dan pengembangan budaya)? Apakah tersedia kebijakan dan strategi untuk meningkatkan layanan ekosistem di wilayah Bapak/Ibu? Bisa dijelaskan strateginya seperti apa?

4. Permasalahan apa yang dihadapi dalam mengimplementasikan kebijakan untuk meningkatkan layanan air secara berkelanjutan atau ketahanan air di wilayah Bapak/Ibu? (terkait kebijakan ruang terbuka hijau, pemanfaatan air, pembangunan infrastruktur dan pendistribusian air)

5. Bagaimana pandangan Bapak/Ibu mengenai isu dan tantangan mengintegrasikan perencanaan sumber daya air ke dalam perencanaan tata guna lahan untuk mewujudkan ketahanan air, keberlanjutan, dan kelayakhunian wilayah terkait pengembangan metropolitan Cirebon? (dihubungkan dengan kemungkinan urbanisasi, perubahan lahan pertanian ke non pertanian di daerah Cirebon-Majalengka-Kuningan-Indramayu, pengendalian limpasan air hujan/sungai untuk perlindungan terhadap banjir dan dampak perubahan iklim di daerah pantai)