

**Identifying the potential of green infrastructure
planning in rural and peri-urban informal
settlements of South Africa**

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PREFACE

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- Mom and dad may the Lord bless and shine His face upon you both. Your sacrifice of love and devotion to His calling of being parents in giving your best as you gave in His will and not your own, I am truly grateful.

ECCLESIASTES 12:12-14

And further, by these, my son, be admonished:
of making many books there is no end; and
much study is a weariness of the flesh. (13)

Let us hear the conclusion of the whole matter:
Fear God, and keep his commandments: for
this is the whole duty of man. (14) For God
shall bring every work into judgment, with every
secret thing, whether it be good, or whether it
be evil.

KING JAMES VERSION

ABSTRACT

A strong definition to use when thinking of Green Infrastructure (GI) would be the “natural and semi-natural areas, strategically planned with other environmental features, designed and managed so as to provide a wide array of eco-systemic services” (Miccoli et al., 2014:1082). Ahern et al., (2014:256) confirms this definition while adding that GI is the “spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to the public, in support of sustainability”. Natural systems, also known as eco-systems, are identified and planned in such a way as to include anthropogenic dimensions (Ojea, 2015:41; Travers et al., 2013:21). This brings forth an adaptive ecosystem service where the ecosystem serve in the ways that were changed by human-induced alterations of society and natural systems (Beumer & Martens, 2014:99). A diversified concept, such as GI, Roberts et al., (2012:168) argue, integrates with numerous challenges of human and natural interactions, especially from a strategic spatial view. This research, however, applied GI to informal settlements in rural and peri-urban regions.

Rural and peri-urban (RPU) regions raises unique considerations in terms of GI (Green Infrastructure) planning, because such regions are more interconnected with natural surrounding elements (like water, trees, plants, birds, insects, etc.) in comparison to human-built spaces (e.g. tarred streets, concrete foundations, steel structures, etc.). Urban sprawl, affecting RPU areas in man-made and natural landscapes, is argued to represent land levelling and stripping off natural benefits, while decreasing water permeability, towards no specific built growth pattern and discourage ecosystems' eligibility to function. Many poor communities establish informal settlements that create densely built sites in vulnerable natural areas. These sites, such as in riparian corridors, coastal ecosystems, and steep hills, are chosen by informal settlement communities because of the availability to accessible, cheap, and sometimes free, environmental services. Such unplanned development that results from sprawl could potentially impact socio-ecologically valuable and sensitive regions through air pollution, sewage discharge into watercourses, infill of wetlands from urbanization, and deforestation. The potential of GI planning has been identified for rural and peri-urban informal settlements, in order to provide more insight into such natural and man-made spatial planning relations.

Multiple spatial and temporal scales exist within the ecology of the landscape, land-use development, human settlement planning, and infrastructure planning. Regional planning scales, commonly preferred regarding GI planning, crosses various ecosystem service boundaries, administrative and political authority zones to comprehend spatial planning complexities. Urban metabolic systems are directed by regulating land use planning directions, which transforms

regional environments collectively. This research argues that by identifying the potential of GI planning in RPU informal settlement regions, sustainable development approaches and strategic landscape management can be strengthened in order to mutually benefit human livelihoods, as well as the spatial integrity of natural systems. Although GI can be planned and implemented on various spatial planning scales, ranging from global, national, regional, metropolitan, district or house/block areas, this research focuses on the sub-regional district scale. This research applied a sub-regional district scale in order to identify the potential of GI planning in RPU regions through applied GI planning principles.

The GI planning principles used in this research were considered on the sub-regional district scale of the eThekweni Municipality, KwaZulu Natal, South Africa. From here the influence of RPU informal settlements was identified by using established GI, represented as Metropolitan Open Space Systems (MOSS). ArcGIS 10.4.1 was used to project various buffer widths (required to protect and conserve GI) over informal settlement points, as to determine the potential influence informal RPU settlements may have on established GI. GI planning principles were then applied to these buffers which overlapped from informal settlements and established GI, in order to create strategic spatial maps portraying the influence of RPU informal settlements, in regards to GI planning potential.

Lessons learned by identifying the potential of GI planning from the influence of RPU informal settlements illustrate visible and discernible regions for further GI planning while comprehending individual and collective space, for the multi-functionality and spatial connectivity of GI. The potential influence of RPU informal settlements was identified as it was unknown towards spatial planning. Through identifying these influence patterns spatial planning can comprehend natural and strategically built spatial planning scales in order to include the anthropogenic connection with nature. However, this is limited exclusively to RPU informal settlement regions.

Key terms:

Green infrastructure planning

Green infrastructure principles

Rural and peri-urban informal settlements

Spatial integrity

Strategic spatial planning

OPSOMMING

'n Sterk definisie met betrekking tot Groen Infrastruktuur (GI) is die "natuurlike en semi-natuurlike areas, strategies beplan met ander omgewings kenmerke, ontwerp en bestuur ter voorsiening van 'n wye verskeidenheid van ekosistematiese dienste" (Miccoli *et al.*, 2014:1082). Ahern *et al.*, (2014:256) bevestig hierdie definisie met die bygevoeging dat GI is die "ruimtelik en funksioneel geïntegreerde stelsels en netwerke van beskermde landskappe wat geondersteun word met beskermde, kunsmatige en hibriede infrastruktuur van beboude landskappe wat verskeie komplementêre ekosisteem- en landskapfunksies bied aan die publiek, ter ondersteuning van volhoubaarheid ". Natuurlike sisteme, ook bekend as ekostelsels, word geïdentifiseer en beplan om antropogeniese dimensies in te sluit (Ojea, 2015: 41; Travers *et al.*, 2013: 21). Dit bring voort 'n aanpasbare ekosisteemdiens, waar die ekosisteem funksioneer op wyse wat verander is deur mensverwante veranderinge in die samelewing en natuurlike sisteme (Beumer & Martens, 2014:99). 'n Gediversifiseerde konsep, soos GI bespreek Roberts *et al.*, (2012: 168) met betrekking tot integrering is daar talle uitdagings van menslike en natuurlike interaksies, veral vanuit 'n strategiese ruimtelike beskouing. Hierdie navorsing pas GI se strategiese beskouing van uit 'n informele nedersettings perspektief in landelike en peri-stedelike gebiede.

Landelike en interstedelike-streke (LIS) bring unieke oorwegings in terme van GI beplanning, omrede 'n sterker kontinuiteit van natuurlike omliggende elemente (soos water, bome, plante, voëls, insekte, ens.) in vergelyking met menslike geboue (bv. teerstrate, betonfondasies, staalstrukture, ens.). Stedelike verspreiding, wat LIS-gebiede in mensgemaakte en natuurlike landskappe beïnvloed, veroorsaak landelike gelykmaking en vermindering van natuurlike voordele, terwyl waterpermeabiliteit verminder word, met geen spesifieke bou patroon en ontmoedig die funksionering van ekosisteme. Verskeie arm gemeenskappe vestig informele nedersettings met digte geboue behuising in kwesbare natuurgebiede. Hierdie plekke, soos in oewer-korridors, kus-ekostelsels en steil heuwels, word gekies deur informele nedersetting gemeenskappe as gevolg van die beskikbaarheid van toeganklike, goedkoop en soms gratis omgewingsdienste (bv water, hout, gras en klei grond). Sulke onbeplande ontwikkeling wat voortspruit uit stedelike verspreiding kan die sosio-ekologies waardevolle en sensitiewe streke beïnvloed deur lugbesoedeling, rioolafvoer in waterlope, invloed van vleilande uit verstedeliking en ontbossing. Die potensiaal van GI beplanning is geïdentifiseer vir landelike en peri-stedelike informele nedersettings, ten einde meer insig te bied vir sulke natuurlike en mensgemaakte ruimtelike beplanning areas.

Veelvuldige ruimtelike en tydelike skale bestaan binne die ekologie van die landskap, grondgebruikontwikkeling, nedersetting beplanning en infrastruktuurbeplanning. Streeksbeplanningskale, wat algemeen verkies word ten opsigte van GI-beplanning, kruis verskeie ekosisteemdiensgrense, administratiewe en politieke gesagsones om ruimtelike

beplanningskompleksiteit te begryp. Stedelike metaboliese stelsels word georiënteer deur die regulering van grondgebruiksbeplanning aanwysings, wat gesamentlike plaaslike omgewings transformeer. Hierdie navorsing beweer dat deur die potensiaal van GI-beplanning in LIS-informele nedersettingsgebiede te identifiseer, volhoubare ontwikkelingsbenaderings en strategiese landskapsbestuur versterk kan word ten einde tweevoudig menslike lewensbestaan bevoordeel, asook die ruimtelike integriteit van natuurlike stelsels. Alhoewel GI beplan en geïmplementeer kan word op verskillende ruimtelike beplanningsskale, wat wissel van globale, nasionale, streeks-, metropolitaanse, distrik- of huise- / blokareas, fokus hierdie navorsing op die sub-streeks distrikskaal. Hierdie navorsing het 'n sub-streeksdistrikskaal toegepas om die potensiaal van GI-beplanning in LIS-streke deur middel van toegepaste GI-beplanningbeginsels te identifiseer.

Die GI-beplanningbeginsels wat in hierdie navorsing gebruik is, is oorweeg op die sub-streeksdistrikskaal van die eThekweni Munisipaliteit, KwaZulu-Natal, Suid-Afrika. Van hieruit is die invloed van LIS informele nedersettings geïdentifiseer deur gebruik te maak van gevestigde GI, verteenwoordig as Metropolitan Open Space Systems (MOSS). ArcGIS 10.4.1 is gebruik om verskeie bufferwydtes (wat benodig word om GI te beskerm en te beskerm) oor informele nedersettingspunte te projekteer om die potensiële invloed wat informele LIS-nedersettings op gevestigde GI het, te bepaal. GI beplanningbeginsels is toegepas op hierdie buffers wat oorvleuel van informele nedersettings en gevestigde GI om strategiese ruimtelike kaarte te skep wat die invloed van LIS-informele nedersettings uitbeeld, met betrekking tot GI-beplanningspotensiaal.

Lesse wat geleer word deur die potensiaal van GI-beplanning te identifiseer uit die invloed van LIS-informele nedersettings, illustreer sigbare en onderskeibare streke vir verdere GI-beplanning, terwyl individuele en kollektiewe ruimtes vir die multi-funksionaliteit en ruimtelike konektiviteit van GI begryp word. Die potensiële invloed van LIS informele nedersettings is geïdentifiseer omdat dit onbekend was vir ruimtelike beplanning. Deur die identifisering van hierdie invloedpatrone kan ruimtelike beplanning natuurlike en strategiese geboude ruimtelike beplanningsskale beter begrip om die menslike verband met die natuur in te sluit. Dit is egter uitsluitlik beperk tot LIS-informele nedersettingsstreke.

Sleutelsterme

Groen infrastruktuur beplanning

Groen infrastruktuur prinsipe

Streeks en -interstedelike informele nedersettings

Ruimtelike integriteit

Strategiese ruimtelike beplanning

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SECTION A: LITERATURE OVERVIEW

CHAPTER 1: INTRODUCTION AND SUBSTANTIATION

1.1 Introduction

Green infrastructure (GI) has various definitions, mainly acknowledged as “natural and semi-natural areas, strategically planned with other environmental features, designed and managed so as to provide a wide array of eco-systemic services” (Miccoli *et al.*, 2014:1082). Ahern *et al.*, (2014:256) confirms this definition while adding that GI is the “spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to the public, in support of sustainability”. Natural systems, known as ecosystems, are identified and planned in such a way as to include anthropogenic dimensions (Ojea, 2015:41; Travers *et al.*, 2013:21). This brings forth an adaptive ecosystem service where the ecosystem serves in the ways that were changed by human-induced alterations of society and natural systems (Beumer & Martens, 2014:99). A diversified concept, such as GI, influences the numerous challenges of human and natural interactions especially from a spatial view for strategic contextual, natural, and manmade infrastructure development (Roberts *et al.*, 2012:168).

One of the major components of the earth’s life support systems is the biosphere, wherein GI is intrinsically interwoven. Ecosystems function within the biosphere and are defined as “a community of different species interacting with one another and with their non-living environment of matter and energy” (Miller & Spoolman, 2012:57). The UN-Habitat (2015:5) argues that the urban and territorial challenges of “climate change, safety security, disaster resilience, ecosystem connectivity, green infrastructure, food security, health, diet, and nutrition” are linkages towards long-term sustainability through a natural approach such as with GI planning (Bobbins & Culwick, 2015:34; Chelleri *et al.*, 2015:128; EC, 2012:25). There is a high degree of multi-functionality that has to meet the complex socio-ecological system integration between humans and ecological aspects, which exist in the infrastructure of cities and landscapes, if this is to be strategically developed and managed (Carpenter *et al.*, 2012:137; Miller & Spoolman, 2012:8; Pakzad & Osmond, 2016:69). GI planning stems from challenges within the urban regions, and that is overcome by using ecosystem-service based solutions within a modern man-made surrounding (Allen, 2012:17; Mayer *et al.*, 2012:58). In this sense, GI entails a close interrelationship between human-built infrastructure and nature. Whereas this current research specifically limits the study area from identified informal settlement regions.

Rural and peri-urban (RPU) regions raises unique considerations in terms of GI planning, because such regions are more interconnected with the natural surroundings (water, trees, plants, birds, insects, etc.) in comparison to human-built spaces (e.g. tarred streets, concrete foundations, steel structures, etc.) (La Greca *et al.*, 2011:2197; Tzoulas *et al.*, 2007:173). Human activities within RPU landscapes, as is the case in any human-built space, negatively affects the spatial integrity of ecosystem services and habitat functions (Alberti, 2005:181; Dale *et al.*, 2000:644; Frank *et*

al., 2012:31; Miller & Spoolman, 2012:195). The potential of GI planning can strengthen future opportunities for higher spatial sustainability where artificial and natural environments meet, especially within fragmented, dismantled and obstructing landscape units (Cilliers & Cilliers, 2016:7; Young *et al.*, 2014:2572).

This research furthermore considers GI planning on a strategic sub-regional district scale to identify the potential of GI planning that crosses administrative boundaries to reach RPU informal settlements. Urban in rural regional landscapes are highly shaped by the collective infrastructure development through urban metabolic systems. Such metabolic systems are directed by regulating land use planning directions that transform regional environments collectively. This research argues that by determining the potential of GI planning in RPU informal settlement regions, sustainable development approaches and strategic landscape management can be strengthened in order to mutually benefit human livelihoods as well as the spatial integrity of natural systems.

1.2 Problem statement

Rural and peri-urban areas pose unique challenges in terms of urban sprawl, as well as the impact thereof on the spatial integrity of natural landscapes. Urban sprawl results in the depletion of natural resources faster than it can be naturally restored (Colding, 2011:229). Utveckling (2013:1) argues that it is difficult to provide access to basic services for informal settlements, as these dwellers are marginalized in government development plans. A cruel cycle has occurred between under-compensating for slum dwellers' needs and the slum dwellers' capacity to develop the environment in an uncontrolled way.

South-Africa's urban areas are expanding exponentially (Gibbs *et al.*, 2014:1; Schäffler & Swilling, 2013:246). The metropolitan areas of South Africa are especially placing pressure on their natural landscape fragmentation. Ecosystem services of urban areas were already threatened, even before the fragmentation caused by high-density informal and traditional settlements sprawl in rural and peri-urban areas (Bobbins & Culwick, 2015:38; Schäffler *et al.*, 2013:7; UNs-CBD & SRC, 2014:16). This makes the influence of informal settlement distribution a daunting task for spatial, landscape, and environmental management planning and development (Cilliers *et al.*, 2013:688; Ibem & Adeyemi, 2015:118; Utveckling, 2013:1).

Identifying the potential of GI planning from informal settlement development provide more strategic spatial planning perspective on the required space and potential influence on that space from anthropogenic activities. This research addressed the potential problem that urban sprawl through RPU informal settlements could potentially pose to GI development and the need to address such an issue in urban and regional planning directions. South Africa is a rich country in space, habitat, biodiversity and urban sprawling, making the issue of identifying the potential GI planning a problem to be researched.

1.3 Research questions

Main research question:

- a. What is the potential of GI planning in rural and peri-urban informal settlement regions, as perceived from a sub-regional district scale?

Sub-research questions:

- a. How are urban, rural and peri-urban areas defined and related to GI planning?
- b. How was GI planning potential determined as part of the strategic spatial planning from RPU informal settlement regions?
- c. What South African environmental and spatial planning legislation relates to the potential of GI planning and RPU informal settlement areas?
- d. What is the identified potential of GI planning in the metropolitan case study of the eThekweni municipality?

1.4 Aims and objectives of the research

This current research aims to:

- Identify the potential of GI planning related to RPU informal settlement areas, as perceived on a sub-regional district scale.

The objectives of the research include:

- 1) Defining urban, rural and peri-urban areas to compliment GI planning approaches from informal settlements and challenges in rural and peri-urban regions.
- 2) Determining how GI planning's strategic spatial planning should be established and from part of RPU informal settlement region integration.
- 3) Explain contextually GI planning in African and South African RPU regions in view of infrastructure developments, informal settlement challenges and environmental and spatial planning legislation.
- 4) Explain the methodology for identifying the potential of GI planning in RPU informal settlements.
- 5) Describe the identified results from identified GI potential in the eThekweni municipality RPU informal settlements areas

- 6) Determine conclusions and research recommendations based on the theoretical and empirical bases of identified GI planning potential from informal settlements in RPU areas

1.5 Research Methodology

1.5.1 Literature study

The literature study considers the potential of GI planning, focusing specifically on RPU informal settlements. The overview of urban, peri-urban and rural dynamics is contextualised to understand how infrastructure need relates to spatial settlement development, especially within natural and semi-natural environments.

The geographic and legislative context of the South African planning environment in which GI planning is employed, is also described. It informs on the legal sphere that GI planning is subject to, within the South Africa spatial planning context.

A methodology to identify GI potential is explained accordingly. A Geographic Information System (GIS) approach is integrated with GI planning principles, in order to identify the potential of GI. This information is applied in the empirical study within the eThekweni municipality of KwaZulu-Natal.

1.5.2 Empirical study

The land cover of human and natural elements were taken within multiple GIS data layers. National GIS data was provided by the eThekweni municipality and the South African National Biodiversity Institute's (SANBI) GIS data inventories. Buffer standards taken from the diverse scientific literature were applied to the GIS data of identified GI, through metropolitan Open Space System (MOSS) areas, and identified informal settlement households. As the buffers from shacks and the buffers from MOSS overlaps, such areas were demarcated as the potential GI. Taking the various overlapped GIS maps against various GI planning principles, a strategic spatial representation of the identified potential of GI "planning" maps were created in ArcGIS 10.4.1. The following points explain the order of the empirical study

1. Define buffer standards

Different buffer standards is chosen on the diversity of ecological planning elements in the targeted area

2. Determine the units to be buffered and clip the overlapping units

Informal settlements in rural and peri-urban areas represent the influence units. The influence is taken from duplicating the same buffer distance from ecological elements (e.g. rivers, wetlands and grassland) unto RPU informal settlement units to determine the potential intersection of informal settlements inside ecological landscape required function and protection space

3. Apply GI planning principles chronologically from the clipped buffers sections

A progressive influence determination of the GI planning principles in respect to the identified buffer influence from RPU informal settlements is drawn from applying GI planning principles. Chronologically the first principle map development is the "Connectivity principle, then "Multifunctionality principle and lastly a Holistic principle is created on top of each previous principle map development.

4. Results

Is then a three stage map development of scale, function and potential GI planning potential identification from RPU informal settlements?

A set of theoretical derived GI planning principles was used to rationalize the GI planning direction in order to protect and conserve GI corridors from the influence of informal settlement regions in the district municipality of eThekweni. In this manner, the influence that rural and peri-urban informal settlements have on the local ecosystems can potentially be identified. It can also be used to investigate further strategic spatial planning developments in terms of ecological landscaping and informal settlement planning.

1.6 Research hypothesis

GI planning can be applied in rural and peri-urban informal settlement regions following specific GI principles on a sub-regional district scale as can be indicated by the case study of the eThekweni municipality in South Africa.

1.7 Limitation of this research

This research is limited to the following context:

- Literature and empirical contexts are drawn to developing countries' rural and peri-urban regions, especially the influence of informal settlements, and the potential of GI planning related to such areas. Information related to urban areas, developed countries and formal settlements are acknowledged but not considered as the focus of this research.
- This research focuses on the regional planning scale for informal settlements and GI planning. The various dynamics of the green-grey continuum was not included in detail but scoped from a strategic planning perspective. In other words, the land use planning scale for specific engineering applications of combined built infrastructure with natural elements is too small in scale for the strategic spatial planning perspective used in this research.
- GI planning, in the context of this research, did not use a rural-to-urban gradient approach but instead provided strategic principles to enhance the fluidity of spatial knowledge dispersion through the rural-urban context. ArcGIS 10.4.1 best suited as the spatial model

to use in regards to access to data and effectiveness from various possibilities to identify the potential of GI planning's diver's spatial planning elements.

- This research case study taken from the eThekweni municipality's was demarcated specifically to illustrate how the potential of GI planning in RPU informal settlement regions within South Africa, can be identified from a sub-regional district scale. Thus, a full identification of the eThekweni Municipality GI potential was not identified as rural and peri-urban regions provided the limitation of such demarcation.
- GIS data has been buffered from the possible impact of informal settlements on MOSS types. These are by no means accurate on a local level and further analysis would be needed from other influence as of industrial, transport and formal housing can contribute to the influence of ecosystem functioning on a regional perspective. The current study of identifying GI planning potential form RPU informal settlements neglects private or public ownership divisions for land classifications due to insufficient data.

Only an overview of the board planning legislation was given, and there are several programs, initiatives and municipal by-laws that were not taken into consideration within the case study. This is due to the necessity of a regional planning scale perspective for GI planning that differs from the spatial land use planning scale for grey infrastructure which is subject to local municipal planning level.

1.8 Research design

“People-centred” planning, implementing and integrating locals is not optional, but a necessity in research towards sustainable development of human livelihoods (De Jong, 2014:44). In settlement planning there is a definite need for new approaches in conservation and development (Benedict *et al*, 2014:5). The research design proceeded from such a perspective to integrate GI planning to assist in spatial informal settlement planning directives. This research follows De Vos (2002:202) and Kumar (2014:17) reference to mix-methods of including quantitative and qualitative research that should be ideal for GI-related planning approaches. This dissertation aimed to provide a broad view of GI principles to assist in conceptualizing identifying GI planning potential for a regional context. GI principles are taken from Hansen and Pauleit (2014:516) and Roe *et al.*, (2013:653) characterize GI planning for adaptive strategic spatial planning to represent the qualitative aspect of this research.

The relationship of qualitative research to practical implementation are based on critical theoretical literature, going beyond just knowing something, but putting meaningful research in context (Willis, 2007:87). Willis (2007:188) provides the guidelines for qualitative research combined with the mixed methods research (de Vos *et al*, 2011:439) that ensures both quantitative and qualitative research is balanced appropriately within GI and spatial planning context. A mix-method research, has been aligned in a “systematic review” whereas this research used GIS (Geographic Information Systems) data for vegetation types, river networks and other open space features representing a qualitative platform whereupon the integration of informal settlement as points represent the quantitative data for this research. The combination of qualitative and quantitative data, to identify the potential of GI planning in RPU informal settlements, satisfies the GI planning potential identification context.

1.9 Structure of the research

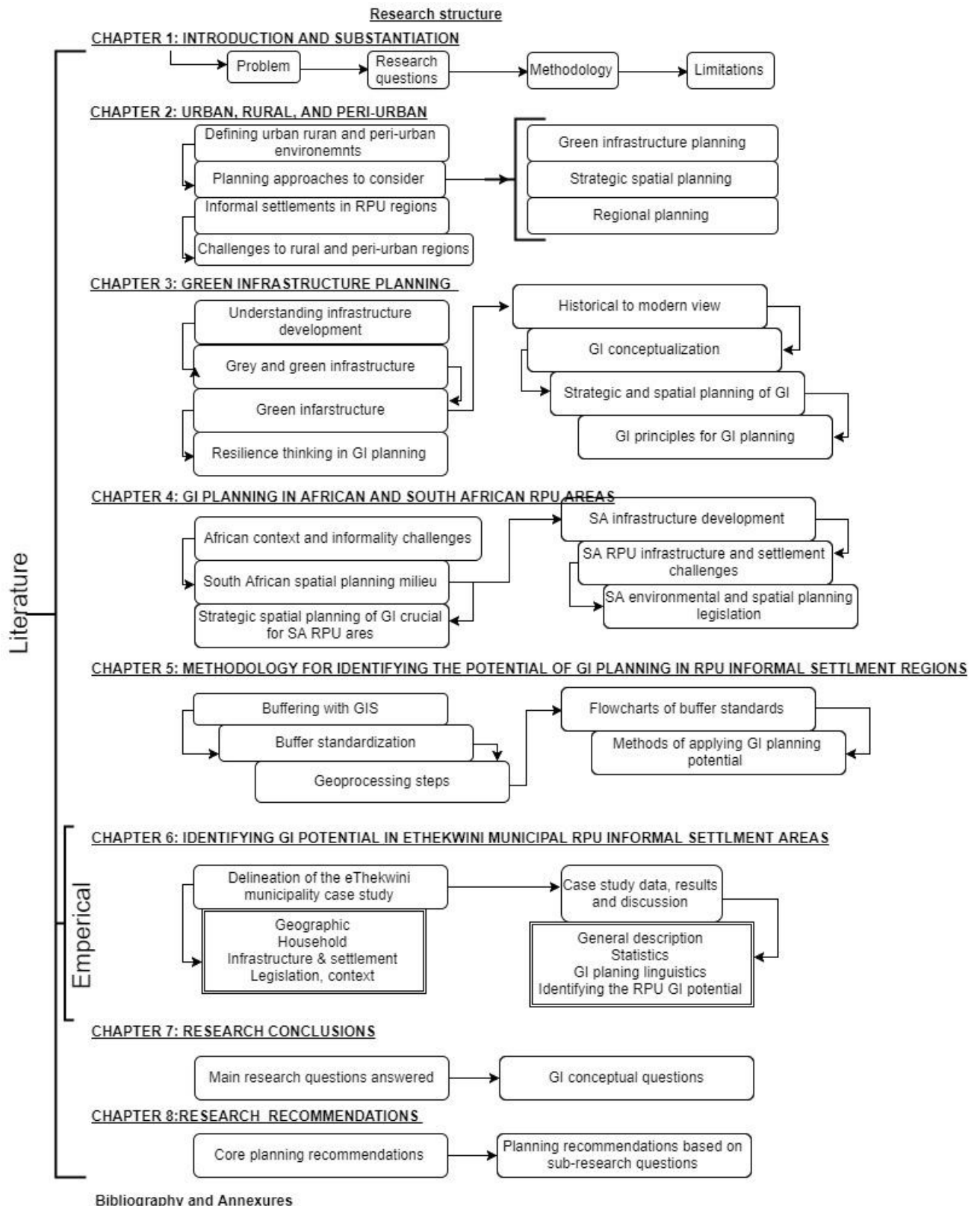


Figure 1-1: Structure of the research

Source: Authors creation (2017)

1.10 List of definitions

The following definitions relate to core concepts used in this research.

Table 1-1: List of definitions

Term	Definition
Adaptive planning	Planning that can be changed according to certain conditions for a more efficient end-result. (Kato & Ahern, 2008:543; Ahern 2007:276)
Built environment	Man-made structures, features, and facilities viewed collectively as an environment in which people live and work. (Oxford University Press, 2017:1)
Carrying capacity	The maximum number of users that can be sustained by a given set of land resources (Pacione, 2009:675).
Ecosystem services	Humans benefit from the provisioning, supporting, regulating and cultural services of ecosystems (Ahern <i>et al.</i> , 2014:256; Andersson <i>et al.</i> , 2014:446; TEEB, 2011:3)
Environment"	"environment" means the surroundings within which humans exist and that are made up of- (i) the land, water and atmosphere of the earth; (ii) micro-organisms, plant and animal life; (iii) any part or combination of (i) and (ii) and the interrelationships among and between them; and (iv) the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being; (NEMA, Act 107 of 1998:9)
Environmental benefits	Benefits people obtain from ecosystems, direct and indirectly as things outside of ecological systems impute cultural meanings, recreation, and spiritual fulfilment (Fisher <i>et al.</i> , 2009; 644).
Green Infrastructure (GI)	Ahern <i>et al.</i> , (2014:256) explains "Spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to the public, in support of sustainability. As well as Benedict and McMahon (2012:3) referring to green infrastructure as the "interconnected green space network (including natural areas and features, public and private conservation land, working lands with conservation values, and other protected open spaces) that is planned and managed for its natural resource values and for the associated benefits to human populations".
Green infrastructure planning	The integration of strategic spatial planning and green infrastructure (Cilliers and Cilliers, 2016:5)
Green perspective	Is from the "concept 'environment' incorporates the biotic and abiotic elements of the earth system, including the interacting ecosystem processes and the services that the environment renders. These services include, amongst others, the recycling of matter by means of biochemical processes within a closed system in line with the law of conservation of matter, as well as the transfer of energy through ecosystems in line with the first and second laws of thermodynamics" (Strydom and King, 2009:3)
Habitat Banking	Defined as "a market where credits from actions with beneficial biodiversity outcomes can be purchased to offset the debt from environmental damage (Naumann <i>et al.</i> , 2011b:24)
Human settlement	An area for a population of people to live together and coexist which comprises of (a) physical components of shelter and infrastructure; and (b) services such as education, culture, health, and welfare to which the physical elements provide support (UN, 1997).
Informal settlement	Settlements that occur on land which has not been surveyed and proclaimed as residential areas which are usually situated on the outskirts of urban areas. The

	structures in these settlements are usually informal and temporary (StatsSA, 2003: 187).
Integration	Combine or be combined to form a whole (South African Concise Oxford dictionary, 2002:599)
Integration	Combining elements to enhance functioning
Livelihood	Is the life-sustaining capitals of individual and communities by human and material resources. These capitals form the driving force behind the structural transformation of society and associated processes. This capital determines the vulnerability that livelihoods have against shocks, trends, and seasonality (Brook & Dávila, 2000:175; Jones <i>et al.</i> , 2016:154; MEA, 2005:33; Prain & Lee-smith, 2010:15; Stokols <i>et al.</i> , 2013:6)
Peri-urban	The geographic area between rural and urban areas, including informal or formal settlements (Marshall <i>et al.</i> , 2009:3)
Resilience	Resilience is the capacity of a system, be it an individual, a forest, a city or an economy, to deal with change and continue to develop. It is about the capacity to use shocks and disturbances like a financial crisis or climate change to spur renewal and innovative thinking (SRC, 2014a:3)
Rural area	The geographic area outside cities or towns that can include formal or informal settlements (Fabricius & Collins, 2007:91; Marshall <i>et al.</i> , 2009:23)
Rural and peri-urban	The geographic area outside cities or towns and between rural to urban areas that can include formal or informal spaces but is dominated by de facto spatial land use activities and development (Fabricius & Collins, 2007:91; Marshall <i>et al.</i> , 2009:23).
Socio-ecological resilience thinking	Embraces learning, diversity and above all the belief that humans and nature are strongly coupled to the point that they should be conceived as one social-ecological system (SRC, 2014a:3)
Transdisciplinary	A horizontal and vertical integration of disciplines in several fields) includes human communities partaking in combined concerns of bio-ecology and economics with those ethics, anthropology, urban planning, psychology, sociology and other fields (Stokols <i>et al.</i> , 2013:4).
Urbanization	Is a multidimensional process that manifests itself through rapidly changing human populations and changing land cover (Elmqvist <i>et al.</i> , 2013:x)

Source: Authors creation (2017)

1.11 List of abbreviation

The following abbreviations used in this research:

Table 1-2: Abbreviations

Acronym	Description
(AVMP)	Animal and Veld Management Programme
ABC-services	Abiotic, Biotic and Cultural services
CAPs	Community-Based Adaptation Plans
CBI	Critical Biodiversity Index
CRDP	Comprehensive Rural Development Strategy
CSO	Combined Sewer Overflow
DAFF's	Department of Agriculture, Forestry, and Fisheries
DCCP	Durban Climate Change Partnership
D-MOSS	Durban Metropolitan Open Space System
DRDLR	Department of Rural Development and Land Reform
EIA	Environmental Impact assessment
EIMP	Environmental Implementation and Management Plan
EIS	Ecological Importance and Sensitivity
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EMS	Environmental Management System
EPCPD	Environmental Planning and Climate Protection Department
GDP	Gross Domestic Product
GEAR	Growth, Employment and Redistribution Strategy
GI	Green Infrastructure
GIS	Geographic Information Systems
HIV	Human Immunodeficiency Virus
I&AP	Interested and Affected Parties
IAIA	International Association for Impact Assessment
ICT	Information and Communication Technology
IDP	Integrated Development Plan
IL	International Law
IPAP2	Industrial Policy Action Plan 2
ISRDS	Integrated and Sustainable Rural Development Strategy
LEED	Leadership in Energy and Environmental Design
LID	Low impact development
LPG	Liquid Petroleum Gas
MCPPP	Municipal Climate Protection Programme
MSDF	Municipal Spatial Development Framework
MTSF	Medium Term Strategic Framework
MUD	Management Up-Down
NARYSEC	National Rural Youth Service Corps
NDP	National Development Plan
NEMA	National Environmental Management Act
NGP	New Growth Path
NL	National Law
NPC	National Planning Commission
NSDF	National Spatial Development Framework
PES	Present Ecological States
PICC	Presidential Infrastructure Coordinating Commission
R	Rand
RDA	Rural Development Agency
RDF	Rural development Framework
RDP	Reconstruction and Development Programme
RIDFF	Rural Investment and Development Financing Facility
RPU	Rural and Peri-Urban
RVCP	River Valley Catalytic Programme
S2E	Services 2 Ecosystems

SA	South Africa
SDF	Spatial Development Framework
SDI's	Slum/Shack Dwellers International
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
SIP	Strategic Infrastructure Projects
SPLUMA	Spatial Land Use Management Act
SUDS	Sustainable Urban Drainage Systems
WC	Water Closets

Source: Authors creation (2017)

CHAPTER 2: URBAN, RURAL, AND PERI-URBAN REGIONS

Figure 2-1 illustrates the structure of Chapter two.

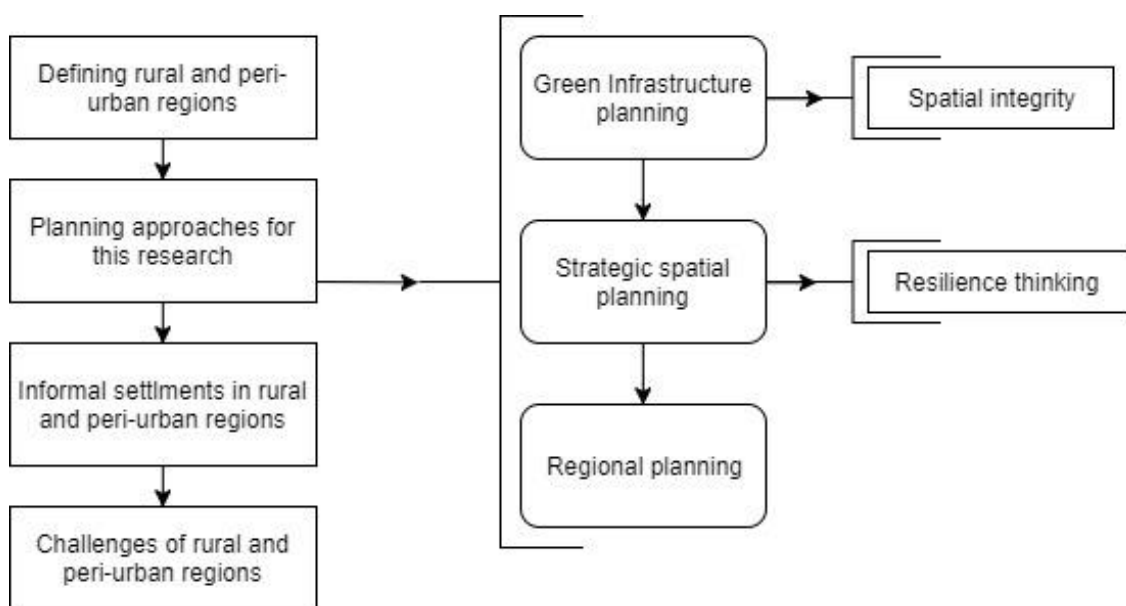


Figure 2-1: Structure of Chapter two

Source: Created from Draw (2017)

2.1 Introduction

The spatial interrelationship between urban, rural and peri-urban (RPU) regions is a complex system that is continually planned and developed as to sustain the complexity of anthropogenic metabolisms (Grimm *et al.*, 2000:574). The conceptual understanding of urban-rural boundaries dictates and prescribes most definitions and planned a set of boundaries and frameworks for spatial land use planning (Gómez-baggethun *et al.*, 2015:177). The context of rural, peri-urban and urban regions should be well understood before considering any spatial planning initiatives that influence the ecosystem, landscape, or any type of socio-ecological system, such as GI planning (Niemelä, 2011:299; Phearson *et al.*, 2016:3).

Spatial planning operates on various scales, ranging from local, regional, national, trans-national and international levels (Corbridge, 1998:45; Laforteza *et al.*, 2013:103). GI planning acknowledges mixed built and natural infrastructure inside an ecological dependent environment that will strategically influence the RPU regions to accommodate decentralisation (Dou *et al.*, 2014:2815; Du Plessis & Landman, 2002:131). This current study does not present strategies for such interventions but rather advocates the approach that, when planned, the potential of GI planning in RPU informal settlement regions should be strategically identified.

Land use planning is aimed at reaching developmental and spatial outcomes inclusive of sustainable goals, available resources, future demands, aesthetics and the like. As this current

research focuses on regional strategic planning, the capacity of strategic spatial planning builds upon the local dispersion of zoning, planning, and land uses in order to identify what is urban, rural and peri-urban areas with its associated activities.

2.2 Defining rural and peri-urban regions

NEMA (Act 107 of 1998:9) defines "Environment" as the "environment" means the surroundings within which humans exist and that are made up of-; the land, water and atmosphere of the earth; micro-organisms, plant and animal life; any part or combination of (i) and (ii) and the interrelationships among and between them; and the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being. Understanding the environment as a complex platform of multi-functional elements is important when dealing with spatial planning and developmental boundaries thereof (Saroop & Allopi, 2015:15; Schäffler & Swilling, 2013:247; Strydom and King, 2009:3; Young & McPherson, 2013:68).

Globally, urban and rural land covers a small percentage of terrestrial surfaces but has a profound impact that reaches beyond land-use boundaries (Goddard *et al.*, 2010:90). Demographia (2015:132) explains that urban areas are a continuous built-up landmass of urban development, which can fit within a metropolitan area's labour market. Urban areas stem from city centres, defined in different ways of administrative, morphological or functional platforms, which differ from socio-political boundaries (EEA, 2015:15). The majority of urban areas have systems of governmental spheres regulating various sizes of society. Douglas *et al.*, (2011:8) illustrate that cross-Atlantic governance systems differ in urban area classification since it spans from 4000 people/km² in Japan to 200 people/km² in Australia. A result of these wide disparities, the following description of rural, peri-urban, and then urban areas, are provided for the purposes of this current research:

Rural or non-urbanized areas are defined as "outdoor" places with a significant abundance of vegetation. In contrast to semi-natural areas which only represent the natural remnants in urban areas (La Greca *et al.*, 2011:2194). Agriculture, wetlands, and forestry are the common associations of land development within rural boundaries (Münch *et al.*, 2016:3; Prain & Leesmith, 2010:18). Douglas *et al.*, (2011:9) stated, that in order to qualify as a rural area for settlement planning, an area needs to provide for at least 1 person/ha. Rural regions have a major ecological dependency compared to urban areas. This is due to agglomerative socio-ecological benefits that the landscape offers society, beyond ownership classification (Jones *et al.*, 2016:154; Niemelä, 2014:300; Young *et al.*, 2014a:2574).

Peri-urban (or suburban expansion) is defined as the area between urban and rural areas, have similar land use development as rural, but more sensitive to change from urban morphology (EEA, 2015:37; Torres, 2008:3). The deciding factor in peri-urban classification is the type, pattern, and

spatial relation of settlements, rather than the socio-economic or environmental elements. Fritsche (2015:52) recognizes such areas as urban sprawls, informal slums, and new urban configurations. Contemporary urban changes, such as the decline of traditional land use in the peri-urban landscape, have changed the way people in cities perceive and interact with the biosphere (Andersson *et al.*, 2014:445). Such peri-urban areas consist of land use transitions that are more subject to the systematic processes of change, with high levels of mobility (Parkinson, 2003:75; Tavares *et al.*, 2012:433). Planners, in general, recognise peri-urban areas as major barriers to the long-term sustainable development of urban to rural regions (Ingram *et al.*, 2012:253; Torres, 2008:6). This research clearly classifies all slum development on urban land-uses as peri-urban, and all such settlements in rural areas as rural in its own right.

Urban areas, on the other hand, are defined as the main territorial planning zone for rural and peri-urban anthropogenic movements (Laforteza *et al.*, 2013:104). Defining urban areas fall into what is viewed as a city and city centres. These regions will propel the growth of the suburb and surrounding rural regions (Miller & Spoolman, 2012:57). Inside city zones and central business districts, peri-urban and rural areas tend to sprawl by way of informal settlement or urban agricultural nodes (Lee *et al.*, 2015:139). Defining urban areas is a complex matter that differs continentally. Africa and Asian countries, for example, intermixes urban, rural and peri-urban areas without clear boundaries of separation (Tacoli, 1998:148). A possible reason for such complexity is urban sprawl (Benedict & McMahon, 2001:9; Colding, 2011:228). Cilliers (2014:41) argues that urban sprawling represents land levelling and stripping off of natural benefits while decreasing water permeability, promoting no specific built growth pattern, and discouraging ecosystems' eligibility to function (Utveckling, 2013:1; Schäffler, 2011:51). Urban sprawl is also an unplanned, incremental urban development that limits terrestrial ecosystems, mainly through soil sealing in the urban fringe (EEA, 2015:37). Urban edges or fringes have mixed land uses that serve as the crossway between rural to urban regions. For the practicality of rural to urban coinciding boundaries, this research considered the activities and land-uses of the urban fringe and edge areas as part of peri-urban areas.

2.2.1. Strategic spatial planning in rural and peri-urban regions

The UN-Habitat (2015:10-3) requests “urban-rural interdependence” that distributes good practices and policies, mutually beneficial, by “strengthening the capacity of rural service centres, and small, intermediate and secondary towns in order to attract populations, increase investments, create jobs, and reduce reliance on primate cities, as a strategy to promote decentralized growth.” McGregor and Simon (2012:41) explain that livelihood strategies reflect urban to rural interdependence, but suggest that research must be done if planned interventions are to benefit the poor. This research deals mainly with informal settlement potential influence on RPU regions GI.

The UN-Habitat (2015:12) mentions that rural and peri-urban areas depend on access to urban area services, employment opportunities, and markets. RPU regions also pertain to large capacities of population diversities. Seto *et al.*, (2012:7689) further explain that the suburbs outside the city “gates” sometimes have more people than the city itself. Thus a research boundary is coupled to developing, rather than developed, countries. Africa’s planning environment relate more to South American and Asian developing countries (Baud *et al.*, 2015:226; De Zeeuw *et al.*, 2011:155; Hoyt, 2003:4;). This research does not generalize RPU regions in developing countries but focuses on the broad similarities and principles of such planning environments.

Rural-urban movement of society’s spatial migration (of people, knowledge or goods) is an acknowledged theme through urban and regional planning studies (Fritsche *et al.*, 2015:52; Nhlozi, 2012:29; Utveckling, 2013:1). The UN-Habitat (2015b:7) urges that the following urban-rural directions should be followed:

- Reducing environmental impacts, including Reducing air and soil pollution; protecting forests, water, and watersheds; avoiding land fragmentation; defending ecosystems and biodiversity.
- Efforts should be made to use planned city extensions and infills, low-carbon and smart cities as well as other strategies that promote density and compact human settlements. Investing in innovative and sustainable rural infrastructure should also be a priority, such as decentralized power networks based on renewable energy, long-lasting roads, and well-organized periodic services, such as markets, health clinics, and long-distance education.

RPU regions are more dependent on natural resources and the services thereof, compared with urban regions'. These landscapes provide various ecosystem services that are used in multiple sectors of industrial, agricultural and tourism, especially within biographical realms (Kremen, 2005:477; MEA, 2005:5; TEEB, 2011a:5-7). Settlement infrastructure development should direct communities to optimally benefit from the surrounding landscape values, without diminishing the future potential thereof. Conducting settlement planning in a way that has adaptive preparedness for the unexpected, all the while being aware of the possible hazards or disasters, are all part of urban resilience development. They also exist within practices such as “soft engineering” (Pickett *et al.*, 2013:180; UNDP, 2014:7). Disasters and poverty are not always fast acting or sudden events (Turok, 2015:4). It can slowly change to allow stress and pressure to accumulate, the result being that the planning teams fail to handle these slow changes. This is either because changes are invisible to them, or because the complexity of capabilities are too resistant and no action can be agreed upon (Harrison *et al.*, 2014:21).

2.3 Planning approaches considered for purpose of this research

RPU regions compass to numerous dimensions of the Anthropocene and natural environments. The three main planning approaches included for the purposes of this research is 1) GI planning, 2) regional planning and, 3) strategic spatial planning. All three of these planning approaches are interlinked. Various interfaces between these three approaches exist in terms of objectives, explained accordingly.

2.3.1. Green infrastructure planning

GI delivers ecosystem services for a concentrated landmass, rather than target a community group since natural services are not limited to human-built boundaries (Dige *et al.*, 2014:45). A clear definition for such GI stems from Ahern *et al.*, (2014:256) as the “spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to the public, in support of sustainability”. Young *et al.*, (2014:2573) explains that the approach of Ahern *et al.*, (2014:256) is good for the overall system elements (scale, goals, landscape context, and strategy) but lacks, an investment policy and planning for advanced community GI complexity or regulatory service delivery. When identifying the potential for GI, this research directs the potential from RPU informal settlements, on a sub-regional district level, in a way that compliments the GI definition of Ahern *et al.*, (2014:256).

Another planning approach that defines GI, used by Benedict and McMahon (2012:3), refers to GI as the “interconnected green-space network (including natural areas and features, public and private conservation land, working lands with conservation values, and other protected open spaces) that is planned and managed for its natural resource values and for the associated benefits to human populations”. A prominent object, presented in Benedict and McMahon (2012:3) and Ahern *et al.*, (2014:256), is the strategic manipulation of landscapes (including areas and regions with associated land uses) to harness ecosystem services from combined man-made planning and management (Miccoli *et al.*, 2014:1082). This research will use the definitions of Ahern *et al.*, (2014:256) and Benedict and McMahon (2012:3) to identify the potential of GI planning from the influence of RPU informal settlement regions.

A GI planning approach is complex in itself but also has to deal with ever-changing city-dynamics. Elmqvist *et al.*, (2013:v) explains how the anthropocentric challenges of contemporary urbanisation are recognized more on the “hardware” of cities (built infrastructure, transportation, housing, sanitation, water work) than on the “software” of cities (gravitating a lifestyle, culture, learning institutions to pool human capital), and even less on nature-based infrastructure of cities (parks, gardens, watersheds, biodiversity and ecosystem). Natural systems known as ecosystems are identified and planned to include anthropogenic dimensions, which bring forth adaptive eco-systemic services where the ecosystem adapt in areas changed by natural systems and human-induced alterations of society (Beumer & Martens, 2014:99). A diversified concept,

such as GI, influences numerous challenges of the city and ecosystem interrelationships, from a spatial view, for strategic contextual natural and human-built infrastructure development. When dealing with before mentioned challenges the following aspects of Bohemen (2002:193) should be striving towards and is followed in this research, in order to identify the potential of GI planning from RPU informal settlements:

- Place land abstractions (thoughts, ideas, and concepts) visible and discernible
- Make complex natural processes visible and comprehensible
- Expose systems and processes that were previously hidden
- Emphasize the anthropogenic connection with nature

GI planning functions within human space, as explained by Gómez-Baggethun and Barton (2013:236). GI links with spatial regions of ecosystem services and habitats “directly managed or affected by energy and material, flows from the urban core and suburban lands, including city catchments, and peri-urban forests and cultivated fields”. GI spaces revolve around various categories of ecosystem services (further description of each service is found in Alberti, (2005:175), Colding *et al.*, (2014:449), European Commission, (2012:19), Daniel *et al.*, (2012:8813), MEA, (2005:40), TEEB, (2010c:18, 2010d: 21) and Turok, (2015:4). Annexure three elaborates on an ecosystem service matrix for deeper insight into the complexity of GI planning elements, whereas Figure 2-2 only provides a short summary of ecosystem services.

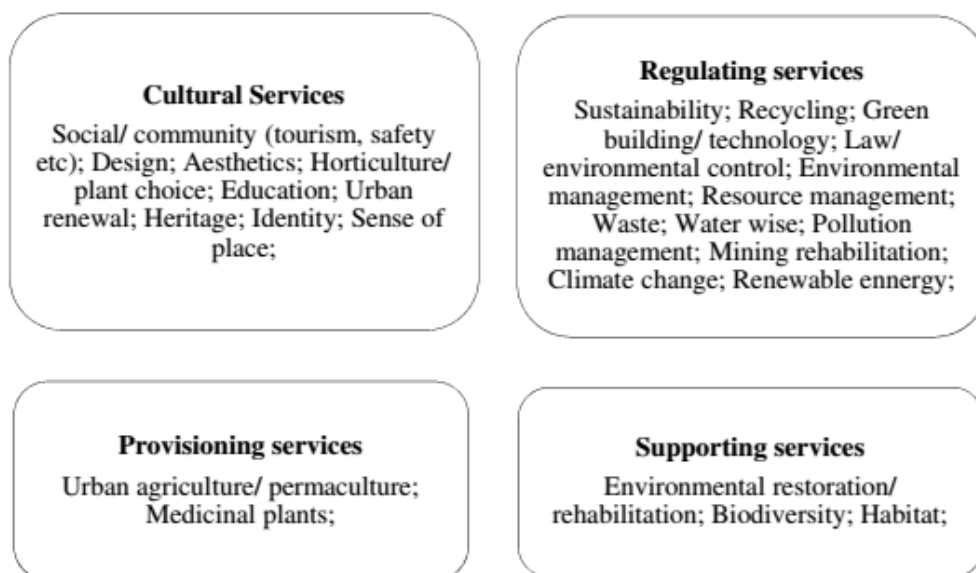


Figure 2-2: Four categories of ecosystem services with sub-divisions

Source: Breed *et al.*, (2014:7)

In comprehending the complex nature of GI which is interwoven with urban metabolism, there is a high degree of misapplication to what constitutes GI and what does not. Spatial planning in GI is the spatial composition and configuration of landscape elements in order to determine the functioning of the landscape and to specify the movement of how nutrients and water flow (Ahern,

2007:270). This research functions within a sub-regional district planning scale to comprehend Figure 2-2 and Annexure three supports the argument to perform a potential identification on a sub-regional district scale in order to understand where further spatial planning for GI should proceed. Complexity and city-dynamics of

RPU informal settlement, that compliments the list of GI misapplication by Benedict *et al.*, (2012:15) are:

- **A program.** It is a philosophy of organized strategy that provides a framework for planning conservation and development.
- **A panacea.** It cannot be everything to everyone. In all planning systems and processes, GI planning is associated with trade-offs to higher efficiency and effectiveness.
- **A short-term solution.** Long-term commitment is non-negotiable, in order to suit ecological systems comprehensively.
- **An isolated effort.** Coordination of many people is needed.
- **A government program.** Although led by the state, regional or local government, it relies on all sectors of the community, both private and public.
- **Smart growth, no growth, or anti-development.** By identifying the key ecological processes and functions in GI planning, the delineation of a sustainable relationship between humans and nature emerges (Ahern, 2007:2).
- **Elitist.** All people within a community of region benefit from GI planning. As well as the implementation thereof, which is an aspect highly valued by RPU informal settlements.
- **A system of greenways.** Greenways are a component/asset of GI, for there are broader ecological sustainability goals
- **Schoolyards, playgrounds, or other parcels of green space.**

This list, presented by Benedict *et al.*, (2012:15), of what GI does not portray, puts GI in an adaptive and integrative class, which underpins a complex conceptual understanding and development. GI is mostly known for multi-functionality, as it moves past human control and the boundaries thereof (Barau, 2015:286; Connop *et al.*, 2016:2; Miccoli *et al.*, 2014:1083). GI finds harmony between socio-ecological systems in a human-dominated environment (Bergsten & Galafassi, 2014:10; Hansen & Pauleit, 2014:522; Tzoulas *et al.*, 2007:170). GI cannot be limited to a single scale dimension (Tzoulas *et al.*, 2007:170). Identifying the potential of GI planning from RPU informal settlements in this research functions on a sub-regional planning scale that

comprehends GI complexity. In other words, it attains the spatial integrity that is required for GI planning.

2.3.1.1. GI's fundamental importance is spatial integrity

Integrity is seen as an indicator of an object's quality, as well as a collective standard for the object. It all depends on the object. For instance, dealing with ecosystems, the ecological integrity can determine the quality of land cover types and its crucial ecosystem functions, e.g. indicators for abiotic heterogeneity, biodiversity or reduction of nutrient loss (Hansen & Pauleit, 2014:522). Approaches taken to enhance ecological integrity in human-dominated landscapes can contribute to human well-being (DeClerk *et al.*, 2006:538; Ingram *et al.*, 2012:4). GI planning is a spatial indicator, which reflects the required spatial integrity in order to conduct strategic spatial planning. Thus, identifying the potential of GI planning includes a broad enough spatial planning region to compensate for the required spatial integrity of GI.

Schäffler *et al.*, (2013:70) explains that spatial integrity coincides with GI planning to promote socio-ecological integrity. Ecology is defined as always being centred on the interactions involving organisms and the structure and processes that these organisms generate or are involved in (Ingram *et al.*, 2012:4; Pickett *et al.*, 2013:2). Ecology in human spheres has four principles of natural capital, namely 1) dependence on solar energy, 2) biodiversity, 3) control of population growth and, 4) cycling of nutrients (Miller & Spoolman, 2009:60). Natural capital has a higher spatial dependency from RPU informal settlements in developing countries than with less developed countries. Specifically in terms of factors influencing land-use decision, such as time, species, place, disturbance, and landscape elements (Dale *et al.*, 2000:648; Grimm *et al.*, 2000:579; Putz *et al.*, 2000:686; Zipperer *et al.*, 686 In ESA, 2000; Schulttz *et al.*, 2015:7374). In this manner, GI planning from ecosystem services can strengthen spatial integrity as "to be protected not only for itself but because it is essential for human life and society" (Scott *et al.*, 2013:563). Thus, before GI planning can occur to develop functional ecosystem services the potential of such a planning approach has to be identified, whereas this research illustrates this approach based on RPU informal settlement influence.

Spatial integrity is mainly the efficiency and effective interrelationships of networks between the abiotic, biotic, and cultural services in different landscape scales (Abunnasr, 2013:13). To harness such spatial integrity in modern urban society, a vital step towards sustainable development should come from profitable and cost-benefit GI planning (Chang *et al.*, 2012:496; Hălbac-Cotoară-Zamfir, 2009:290). Table 2-1 helps in understanding ecosystem services through a categorization of ABC-functions that provides an overview of the type of habitat thresholds that are necessary to equip GI elements into effective and efficient spatial implementation (Ahern, 2007:269; Hansen & Pauleit, 2014:518). GI planning's bio-capacity is influenced through developing infrastructure that complement the ABC-function in different planning scales. Thus, when identifying the potential rather than the capacity of GI planning, the understanding of the

various ABC planning elements will provide more clarity into why this research has chosen a regional scale to conduct GI planning.

Table 2-1: ABC-functions.

Abiotic	Biotic	Cultural
Surface: groundwater interactions	Habitat for generalist species	Direct experience of natural ecosystems
Soil development process	Habitat for specialist species	Physical recreation
Maintenance of hydrological regime (s)	Species movement routes and corridors	Experience and interpretation of cultural history
Accommodation of disturbance regime (s)	Maintenance of disturbances and successional regimes	Provide a sense of solitude and inspiration
Buffering of nutrient cycling	Biomass production	Opportunities for healthy social interactions
Sequestration of carbon and (greenhouse gasses)	Provision of genetic reserves	Stimulus of artistic/abstract expressions (s)
Modification and buffering of climate extremes	Support of flora: fauna interaction	Environmental education.

Source: Adapted from Ahern (2007:269) and Bergsten & Galafassi (2014:10).

2.3.2. Regional planning

Academically regional planning is defined as the “clarification of social objectives in the ordering of activities in supra-urban space” (Friedmann, 1963:168). Glasson and Marshall (2007:4) state that the decision-making power of regional planning acts as the “ground rules” for a dynamic process of balanced socio-economic and environmental development, as with GI planning. Regional planning deals with the complex interrelationships of spatial planning as a whole (Friedmann & Weaver, 1979:34). Any occurrence of infrastructure development falls in the category of regional planning's top-down view for strategic bottom-up planning.

Friedmann and Weaver (1979:33) described regional planning as the conscious direction and collective integration of all the activities which rest collaboratively on the use of the earth as a site, as a resource, as a theatre, and as a structure. The region has to be seen as a “natural” unit, defined unambiguously by its abandoned space (Friedmann, 1963:169). Thus, in *Designing with Nature*, Van der Ryn and Cowan (2009:8) explains that “landscape ecology, landscape architecture, regional planning, and conservation have shown a promising convergence toward a spatial vocabulary—patch, edge, core, buffer, corridor, matrix—and supporting design principles that protect biodiversity at all levels of scale”. Regional planning has theoretical “roots” close in alignment with environmental stewardship, whereby this current research equates such a planning view as vital, in order to conduct harmonized local settlement development; in order to “design with nature” (Department of Transportation, 2006:65; Mell, 2010:202; Putz, 2000:680; Steffen *et al.*, 2011:740; UNECA, 2008:99; Young *et al.*, 2014a:2580)

To capture the art of spatial planning concerned with human settlements, regional planning is of as critical importance to existing as a sub-conscious element in all planners (Dewar & Uytenbogaardt, 1991:13; Schäffler *et al.*, 2013:140). Dewar and Uytenbogaardt (1991:13) argue that “enabling environments and thus enabling plans-encapsulates qualities which are timeless: qualities, frequently captured in very different forms, which reflect the understanding of history and which can be reinterpreted, and re-discovered, over time” (Pérez-campuzano *et al.*, 2016:135). Such timeless qualities that educate society in contextual spatial resilience, come from “discovery” planning: seeking possibilities that genuinely enrich society (Dewar and Uytenbogaardt, 1991:13; Haider *et al.*, 2015:7). Incorporating these timeless qualities as a necessary sub-conscious paradigm shift in strategic spatial planning is much needed for GI planning. Using this to identify the potential of GI planning, the spatial integrity is made visible and the adequate regional planning can be aligned to address GI planning to create timeless quality spaces.

Planning with regional scales should sustain local settlement planning, rather than set fixed development without local contextualization (Frank *et al.*, 2012:31). The CSIR (2000:2-2) suggests certain points when developing a settlement, as to optimally diversify and increase the capacity for pedestrian movement opportunities; quality public-spatial environment. Each aspect of the CSIR’s starting points fully relies on regional planning comprehensiveness. As regional planning is sensitive to the socio-ecological landscape dynamics, the ambiguity in local spatial planning should become more transparent as it reflects regional strategic spatial planning capacity (Van der Ryn & Cowan, 2009:8).

Multiple spatial and temporal scales exist when combining the ecology of a landscape, the land-use, human settlements and infrastructure, into a functioning organism (Brown & Everard, 2015:69; Haider *et al.*, 2015:9; Phearson *et al.*, 2016:6). Table 2-2 illustrates the different spatial and temporal (progressive) scales for spatial planning. The green shaded rows in Table 2-2 illustrate the regional planning scale that GI planning is commonly applied to, comprehending various scale dynamics that exist between ecosystem service boundaries, as well as the administrative and political authority zones between humans and nature (Brown & Everard, 2015:68; Demuzere *et al.*, 2014:111; Dunn, 2010:64; Vandermeulen *et al.*, 2011:199; Weber *et al.*, 2006:96). This research focuses on the sub-regional district scale when considering informal settlements and the potential of GI planning.

Table 2-2: Scales of spatial planning

Scale	Examples of scale types	Time-lapse (interval)
Global	Transnational, international scales e.g. climate change	Very long-term e.g. decades-centuries
National	e.g. economic, transport and housing policies	Long-term e.g. decades
Region	Sectoral, regional and sub-regional scales e.g. employment opportunities, water catchment	Long-term e.g. decades to years
Metropolitan area	City scale and naturalistic corridors e.g. urban services and amenities	Moderate to long-term e.g. decades to years
District	Community and neighbourhood scales e.g. zoning,	Moderate time period e.g. years
House/block	Project and site-specific scale e.g. individual building	Short to moderate time period e.g. years to months

Source: Adapted from (Connop *et al.*, 2015:2; Corbridge, 1998:45; EEA, 2015:49; Mell, 2014:615; Naumann *et al.*, 2011a:17; Young *et al.*, 2014:2573)

Including local contextualization for regional planning, comprehensiveness lies within quality bottom-up planning (Colding *et al.*, 2013:1046; Roy & Ganguly, 2009:1). Jongerden *et al.*, (2014:8) state, that as the “concept of activity space (that) sensitize us to look carefully to the spatial organization of activities, instead of presupposing them by adding adjectives like “rural” and “urban” or “local” and “global. Rather the local is defined not by the state of global but by its connections”. This implies that the relational standing of areas is determined by its surrounding scaled environments. In this dissertation, dealing with the potential of GI planning on a sub-regional district scale, the RPU area relations fall within the demarcated land uses, in order to determine rural, urban and peri-urban areas. Addressing the potential of GI planning from the bottom-up informal settlement types in order to provide an appropriate local contextualization within regional planning directions.

Regional planning involves various physical characteristics of urban areas and urban flows as presented in Figure 2-3. Achieving the flow presented in Figure 2-3 does not mean each step follows one after another. As time flows, the urban morphology continues to build and intertwine into the various scales mentioned in Table 2-2 (Tiwarly & Kumar, 2014:351; Tzoulas *et al.*, 2007:170). Urban to regional morphology occurs in the background of any society, meaning, spatial planning has to be sensitive and take responsibility in managing complex and complicated urban to rural systems (Schoeman, 2010:36). Thus, it is important to identify broad enough areas for GI planning to compensate for the complexity of physical characteristics and flows of urban areas. This research used a regional planning approach to identifying the potential of GI planning in a sub-regional district scales to include the long-term process of GI as presented in Figure 2-3.

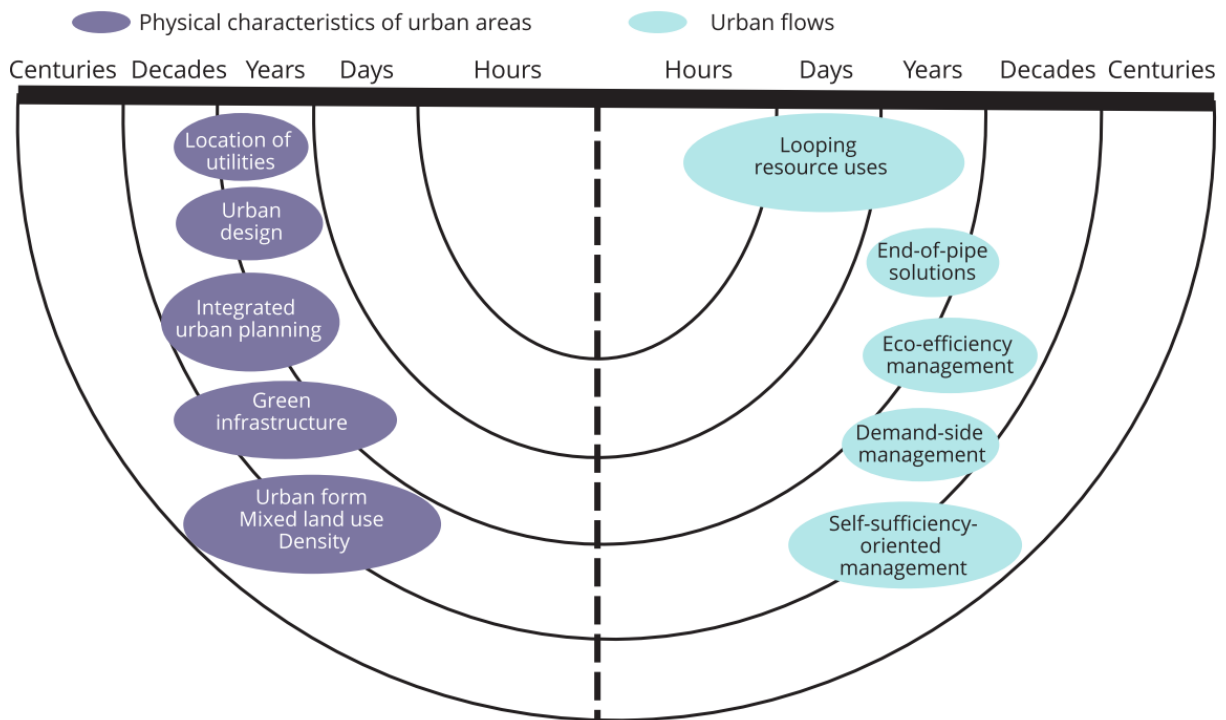


Figure 2-3: Sequential investment for a better return towards resource-efficient cities
 Source: EEA (2015:50)

2.3.3. Strategic spatial planning

Including local contextualization for regional planning, comprehensiveness lies within quality bottom-up planning (Colding *et al.*, 2013:1046; Roy & Ganguly, 2009:1). Jongerden *et al.*, (2014:8) state, that as the “concept of activity space (that) sensitize us to look carefully to the spatial organization of activities, instead of presupposing them by adding adjectives like “rural” and “urban” or “local” and “global. Rather the local is defined not by the state of global but by its connections”. This implies that the relational standing of areas is determined by its surrounding scaled environments. In this dissertation, dealing with the potential of GI planning on a sub-regional district scale, the RPU area relations fall within the demarcated land uses, in order to determine rural, urban and peri-urban areas. Addressing the potential of GI planning from the bottom-up informal settlement types in order to provide an appropriate local contextualization within regional planning directions.

Albrechts (2006:1152) states “strategic spatial planning involves designing plan-making structures and developing content, images, and decision frameworks for influencing and managing spatial change; it is about building new ideas and processes that can carry the ideas forward, thus generating ways of understanding, ways of building agreements, and ways of organizing and mobilizing for the purpose of exerting influence in different areas”. Strategic planning weaves together strategies for building resilience from multi-functionality, (bio)diversity, multi-scale networks, as well as promoting redundancy, modularization, and adaptive capacity that stimulates complimenting clusters of diverse growth areas (Novotny, 2010:145). GI planning

is built on strategic spatial planning theory with resilience as a strong by-product of the planning approach.

The definition of resilience used in this research is taken from a socio-ecological resilience viewpoint, stated as the “(i) Amount of disturbance a system can absorb and remain within a domain of attraction; (ii) capacity for learning and adaptation; (iii) degree to which the system is capable of self-organizing” (Novotny, 2010:145; Quinlan et al., 2015:3). Phearson et al., (2016:5) argue that cities should be seen as social-ecological systems in itself, guiding and monitoring ecosystem services through integrative science. Stockholm Resilience Centre (2014a:3) elaborates by adding that “resilience is the capacity of a system, be it an individual, a forest, a city or an economy, to deal with change and continue to develop. Resilience thinking embraces learning, diversity and above all the belief that humans and nature are strongly coupled, to the point that they should be conceived as one social-ecological system.” This research embraces the concept suggested by Meerow and Newell (2016:3), that resilience is an ecosystem’s ability to maintain basic functional characteristics in the face of disturbance. Identifying the potential of GI planning from RPU informal settlement disturbance provides the first steps to answer the five W’s for urban resilience asked by Meerow and Newell (2016:9): Resilience for Who, What, When, Where, and Why.

Natural based infrastructure partakes in spatial dimensions, as explained by Rockström *et al.*, (2009:472) as the global biogeochemical cycles of major physical circulation systems on the planet, known as planetary boundaries (EPA, 2014:1; Foster *et al.*, 2011:4; Mell, 2013:159). The focus point of planetary boundaries pertains to the degree of risk that the global community is willing to take, with a timeframe that is short enough to influence daily decisions, while influencing decision-making processes, whether or not estimated thresholds are crossed (Rockström *et al.*, 2009:471). Identifying the strategic spatial planning involves ecosystem services that are fundamentally integrated with the state of planetary boundaries. A change in the planetary elements can collectively have a change in the boundaries thereof. Strategic spatial planning provides the overall planning approach for this study, as to identify the potential of GI planning to comprehend the probable impact on ecosystem services that can potentially contribute to change in the planetary elements.

Strategic spatial planning incorporates the vulnerability of past, present, and future problems, as well as the challenges, disasters and opportunities in order to influence human livelihood capitals (Albrechts, 2006:1152). Vulnerability principles can be found in numerous processes and systems involving both humans and nature (UNDP, 2014a:1). Actions leading to insufficient human livelihoods is perceptible to disasters. Disasters can refer to as being hazards that interact with human vulnerability, changing the degree of the vulnerability (an element always present in human livelihoods) (Ackermann, 2013:18). Resilience thinking bulwarks vulnerability by the inclusion of anthropogenic aspects of the urban metabolism. Using the Meerow and Newell

(2016:9) five W's for urban resilience, and this research's theme, the identified GI potential could provide the "what" and "where" needed to apply GI planning from the influence of RPU informal settlements. These determine the "who" and "why" to identify GI potential. When the identified GI planning potential will be developed cannot be determined by only identifying the potential. The identified GI potential is part of but the first steps towards answering Meerow and Newell's five W's for achieving urban resilience development from socio-ecological systems.

2.4 Informal settlements in rural and peri-urban regions

Torres (2008:4) extends the vocabulary used for neighbourhoods that are inhabited by the poor as "slums, shantytowns, illegal settlements, ghettos or segregated areas", but this phenomenon is also labelled as peri-urban, suburban, periphery, exurban and urban fringe boundaries (Smith & Stirling, 2009:3). When identifying the influence of informal settlements the accuracy of location, will then determine the areas of the environment to be strategically planned for, making spatial information of human and nature of critical value. Understanding such information adds to the efficient spatial integration of a more "safe-to-fail" strategy, which contains and mitigates development failure (Ahern, 2011:342; Brook & Dávila, 2000:179; EEA, 2015:37). Households lacking in one or more of the following five amenities are trademarks of informal settlement classification: A household that has (1) durable housing; (2) a sufficient living area; (3) access to improved water; (4) access to improved sanitation facilities; and/or (5) secure tenure" (UN Habitat, 2010:3; Weakly, 2013:59). Such challenges flow into the urban fabric of the Anthropocene, which makes GI planning more complex when dealing with the ecosystems.

Informal settlements' geographic location and population density give way to various challenges for strategic spatial planning. Pauchard and Barbosa (2013:594) explain that many poor communities establish informal settlements that are often densely built in vulnerable areas, such as riparian corridors, coastal ecosystems, and steep hills. These unplanned developments have severe impacts on the ecologically valuable and sensitive regions:

- sewage discharge into watercourses
- infill of wetlands for urbanization
- deforestation (Du Plessis & Landman, 2002:29; Hambati, 2013:935; Schäffler, 2011:47).

For instance, a decrease in ecosystem services could stimulate natural events. A specific example would be when frequent land and mudslides into established settlements (formal or informal) are caused by deforestation (Hambati, 2013:924; Pauchard and Barbosa, 2013:594). The overtone that informal settlements have with ecosystems is generally negative. An example is taken from Gómez-Baggethun *et al.*, (2015:180) that recognizes natural systems as regulators of local temperature and buffers of the effect caused by urban heat islands by serving as a regulating service of ecosystems. The increase of informal settlements not only decrease water

and vegetation cover, which creates a micro-heat islands, but also contributes to the overall stress that urban heat islands place on the environment (Martine & Mcgranahan, 2013:17; Matthews *et al.*, 2015:2; Seto *et al.*, 2014:7688). On a neighbourhood scale, the community most severely affected by human or natural pressures, are the poor communities identified throughout informal settlements. Weakley (2013:32) clarifies that the “right” to control and exploit nature is not in the hands of humans. However, without the support of the local government, acting upon spatial resource development, such as GI planning, the Anthropocene will be stuck with these challenges (Utveckling, 2013:iv).

Property reduction rights are an international subject of protecting and expanding asset bases’ improving land tenure regimes and securing water rights. All the while expanding social protection and community participation, especially by women (Hoyt, 2003:6). Kombe (2005:134) states that due to informal settlement densification, there is a lack of foresighted land use structure, the absence of public surveillance, uneconomical land use distribution, developmental patterns, and the increasing of public threats. Relocating an informal settlement is in many ways non-negotiable. However, continual upgrading of public spatial structure for private and public investment and movement systems is the preferred development direction (CSIR, 2000:3-7). Utveckling (2013:3) warns that relocating the poor away from their current urban accessibilities could turn that community into protest, court cases, and even cultivate hostile neighbourhood interactions. Vollmer and Grêt-Regamey (2013:1553) describes informal settlements’ allocation along waterways distinctly because of the availability of accessible, cheap, and sometimes free, ecosystem services. Spatial land use planning, such as GI planning, could be a vital bridge of persuasion that ensures functional reconciliation of environmental resources, settlement livelihoods, and governmental management.

2.5 Challenges of rural and peri-urban regions

Various government spheres have conducted different ways to evaluate and plan for informal settlements, as well as how to empower these poor communities. The UN-Habitat (2013a:6) uses spatial information of urban slums, adequate housing, land tenure security, access to safe drinking water, and adequate sanitation, to enhance human livelihood strategies. Because of this, informal settlement shaping policies are aimed at directing large demands on infrastructure towards health, safety, transport, and energy (Ibem & Adeyemi, 2015:120; Marais & Ntema, 2013:93). Such policy frameworks are a time-consuming process that needs continual updates that reflect local settlement dynamics (EEA, 2015:50; Saroop & Allopi, 2015:14). Abbott (2002:308) states that community participation has various areas for local authority policy creation that will be needed if the identified potential of GI planning is to be realised.

The UN-Habitat (2013b:11) argues that wasteful city expansion, through the city-regions, drives climate change by increasing the risks of basic services and delivery of public goods (water supply, physical infrastructure energy, transport etc.), as well as affecting industrial production,

local economies, assets and livelihoods (SACN, 2009:24; Vollmer & Grêt-Regamey, 2013:1543). Vast amounts of the land mass are reformed through the housing, transport, and energy infrastructure, but the strategic placing thereof is questionable in all facets pertaining to informal settlement planning and management. A concern addressed by GI planning (Saroop & Allopi, 2013:411). This current research tends to enhance the strategic spatial planning potential of settlement planning, especially in RPU regions which are dominated by slum development.

Another challenge, when considering upgrading informal settlements, is the counterproductive effect through internal separation; changing the ethnic drivers of cultural activities and closing neighbourhood relationships (Massey, 2014:293). Informal settlements have a de facto development direction through placing community spaces above certain levels of basic services and food production networks, due to the mobility and flexibility of such social activities (Massey, 2014:293). Berquist *et al.*, (2015:1722) argue that upgrading projects with local authorities may lead to the required sector integration. This can be done through community networking, managing systems of learning, and the mutual support of the city. Such social-landscape alterations can decrease vulnerability (that is mainly socially constructed) while informality is a case of settlement adaptability in its own right. Hazards and disasters can be decreased by harmonizing settlement dynamics specific to local environments (Weakley, 2013:37). Management of informal settlements' conflicts covers broad categories of land use rights and activity spaces. However, such terrestrial planning boundaries and patterns will assist in achieving development harmony of planning ventures as broad and diverse as GI planning.

Within RPU land uses, zoning and planning, human settlements function in the urban-rural gap that poverty leaves, persisting from generation to generation (UN-Habitat, 2015:10-4). Kombe, (2005:129) claims this is seen in various scales of urban development and that it “puts damaging pressure on environmental resources as (the) city boundaries and population grows rapidly”. Fluctuating levels of poverty exist as the “urban poor experience much higher costs of living, especially for low-income groups living in informal settlements. The opportunities and capabilities available to them are higher than in rural areas” (UN-Habitat, 2015:10-4). The UN-Habitat (2015:10-4) revealed that 1.4 billion poor people live on less than US\$1.25 (R18.20) a day. Of these, 78% lives in rural areas, having almost two-thirds of the extremely poor engaging in agriculture. Investing quality regional planning in RPU regions has a major development implication to better livelihood circumstances for the society and the economy. The following Figure 2-4 illustrates the vicious cycle of the urban-rural poverty gap, and the land formation influences thereof.

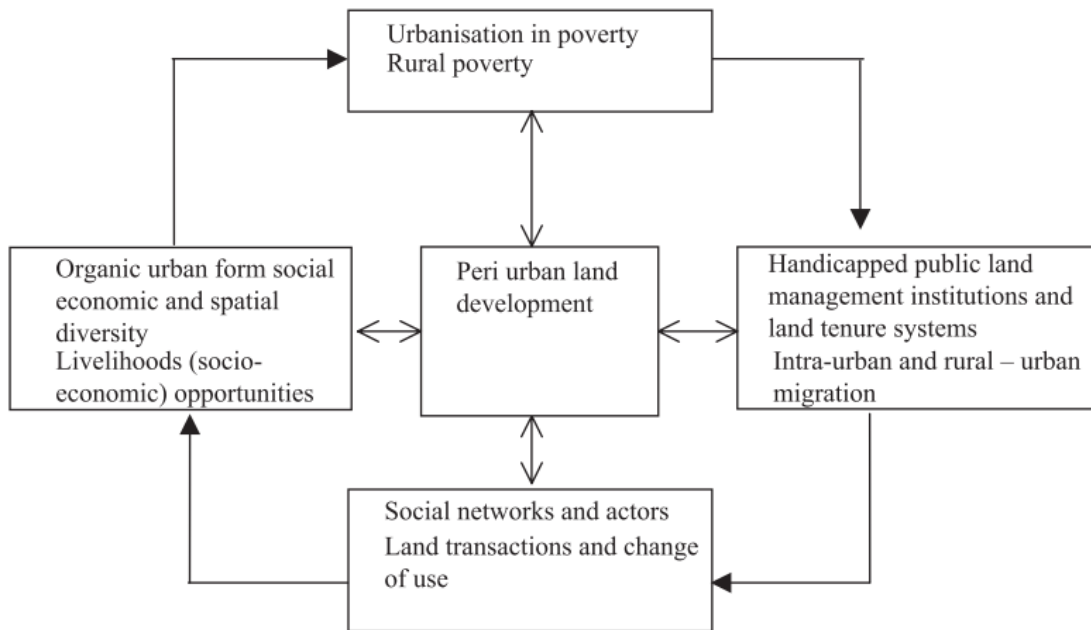


Figure 2-4: Urban morphology surrounding rural and urban poverty

Source: Kombe (2005:129)

Figure 2-4 illustrates how poverty ensures long-term consequences of socio-economic fragmentation and marginalisation, which affects society and physical land configurations. As the intra-urban and rural poor migrate, fragmented community development affects the anthropogenic dimensions that surpass the direct impact in these RPU regions. More understanding of RPU informal settlement regions should be visibly recognised as this research provides a similar view by identifying the potential of GI planning from the influence of RPU informal settlement regions.

Lastly, domestic water use is always a factor for consideration in any settlement infrastructure development. McGregor and Simon (2012:39) describe how waste generation impacts the environment through liquid and solid waste disposal. It requires specific management approaches for different pollutants from multiple sources (domestic, industrial and agricultural). On a settlement scale, domestic water can be “black” water, which is a mixture of feces and water, flushed from WCs (Water Closets) and pour-flush toilets. Or “grey” water, which is the slush from kitchens and bathrooms (Parkinson, 2003:81). “Grey” water has fewer pathogens, having a lower oxygen demand, resulting in less health or environmental threat than “black” water (Parkinson, 2003:81). Informal settlements are classified as “informal”, most commonly due to lack of sewage and water networks. Identifying the potential of GI planning can enable municipalities to deal more strategically with informal household’s water issues and critical habitat regions, at the same time.

2.6 Conclusions

The important lesson from this sections regarding urban, rural and peri-urban regions relation to identifying GI potential from the informal settlement are:

- When defining space the planning dimension is fixed within that space and excluded outside that demarcated space. This can limit the potential identification of GI due to regional scale wherein GI need to function.
- Various scales co-exist between and within urban, rural and peri-urban areas that need to grasp throughout the planning approaches of GI.
- In combining informal settlement and green infrastructures spatial land use planning and management through rural-urban regions, the overall plan needs to collective consider urban, rural and peri-urban regions but can practically be compartmentalized in three separate development regions.

Spatial planning approaches involve GI planning that includes the anthropogenic dimension through informal settlement at a regional scale. This regional scale forces a strategic spatial planning direction that is the most inclusive spatial planning platform regarding complex matters such as GI planning. In a manner, the identification of potential GI planning from RPU informal settlement is appropriately scaled and focused to identify GI planning inclusive to informal settlement influences.

As there is ambiguity towards the spatial planning for the contemporary scale and trend of the informal settlement the following lesion is tailored for identification of potential GI planning orientation. Informal settlements fall under the umbrella of urban sprawl that covers the fast amount of urban to rural regions in a corridor alongside accessible and cheap open space (mostly peri-urban) and natural resources. As Informal settlement stretch through urban to rural regions with high population densification, there is a long-term spatial conflict evolving in spatial land use management and planning and the protection and conservation of green infrastructure. Identifying the potential of GI planning in such societies will potential discourage the poverty cycle. This poverty cycle explained in section 2.5 establish a degraded and fragmented society that diminished land until resource are scared and communities sprawl to further degrade communal land inevitably leaving large land patches over utilized.

CHAPTER 3: GREEN INFRASTRUCTURE PLANNING

Figure 3-1 illustrates the structure of chapter three.

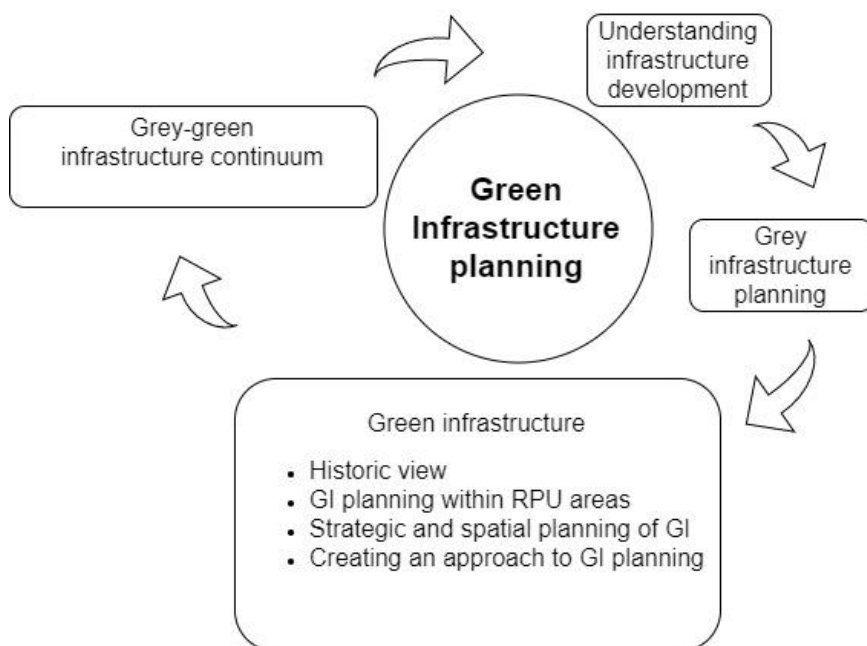


Figure 3-1: Structure of chapter three

Source: Create from Draw (2017)

3.1 Introduction

Allen (2012:21) stated that GI planning is an intermediate scale function to form a bridge between broad landscape-scale networks and site scale activities. Strong spatial planning principles of spatial green asset agglomeration form cluster networks that produce cumulative advantages of ecological corridors. A comprehensive thinking approach through spatial land use planning is further clusters infrastructure planning advantages (Roe *et al.*, 2013:651). Infrastructure planning and development are considered to be the main driver for rural-peri-urban transformation (Gaffney, 2010:9; Tavares *et al.*, 2012:443; Ward, 2003:6). Understanding spatial infrastructure perception, limitations, and integration can potentially contribute to more robust and less vulnerable, co-habitual RPU informal settlements within adjacent environmental regions. Identifying the GI planning potential is but a preliminary step towards such desired ventures, whereas this current study operates in a sub-regional district scale from informal settlement influence.

Conventional infrastructure is also often referred to as “grey infrastructure” (Kruger, 2014:73; Liqueste *et al.*, 2015:269; Spatari *et al.*, 2011:2175). Grey infrastructure has transformed the modern century of urban landscapes, forcing natural environments to adapt or disappear unto the pressure of urban metabolic flows. Human settlements, however, depend on the natural interconnectivity of ecosystems for its livelihood. Thus alone standing and non-strategic

conventional infrastructure can supply the capacity to relieve human settlement demands, but does, unfortunately in no way, sustain the full demand. As such, RPU settlements are characterized by the infrastructure networks of informal settlements to be slum development, roadways, and human movement patterns as the main drivers of separation within natural ecosystem pathways in these areas (Brook & Dávila, 2000:27; De Zeeuw *et al.*, 2011:160; Kombe, 2005:115). Understanding infrastructure relation is key to comprehend the appropriate spatial planning approached needed for informal settlement planning in combination with grey-green infrastructure types.

3.2 Understanding infrastructure development

Spatial ecosystem services define green infrastructure relations (Marchese, 2015:298). Figure 3-2 illustrates various spatially arranged GI planning elements (corridor, links, hubs and core) that create spatial integrity for GI planning (Benedict & McMahon, 2012:13; Hansen & Pauleit, 2014:518; Scott *et al.*, 2013:572). Humans, unlike abiotic and biotic movement, can on a continual basis cross transect boundaries much easier from one biotope (community area) to the next, (EEA, 2015:9; Scott *et al.*, 2013:573). GI planning strategically arranges built space to compliment desired mobility of humans, while sustaining the appropriate integration of required spatial integrity for socio-ecological functionality (Mell, 2015:57). Identifying the potential of GI planning need to comprehend the scale of GI interconnectivity as illustrated in Figure 3-2 rather than be limited to the smaller scale of anthropogenic interconnectivity.

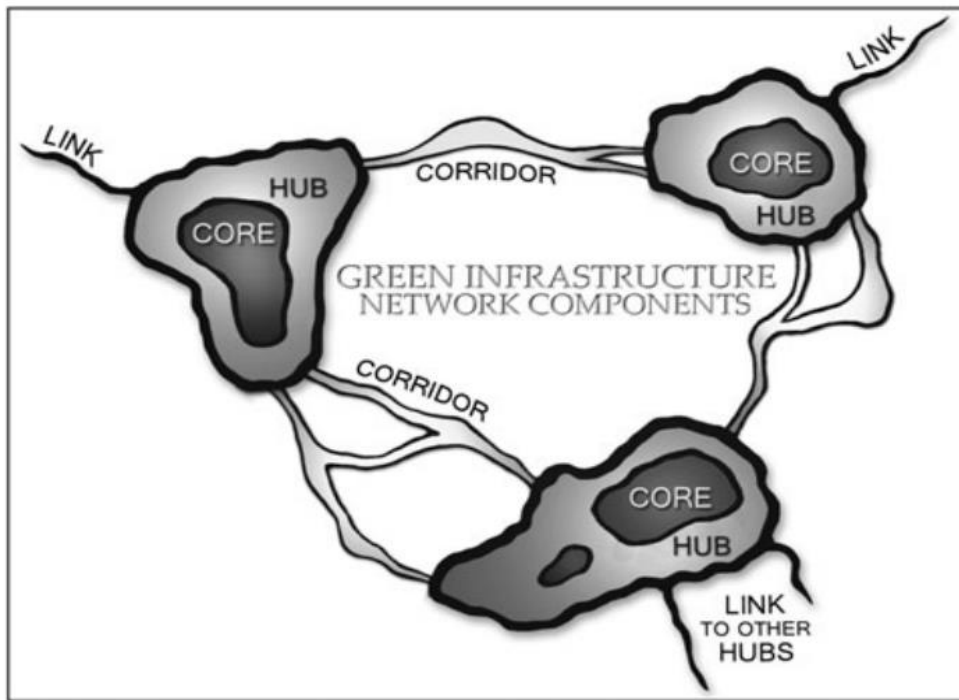


Figure 3-2: A green infrastructure network connects ecosystems and landscapes in a system of hubs, core, corridor, and links

Source: Allen (2012:21)

Interconnectivity of any infrastructure is based on various natural or man-made principle basis. Star (1999:380) explained that infrastructure is seen in the relational property it takes and not the use thereof. Meaning that the relations that are placed together to form infrastructure, define the infrastructure, more than the end result of that specific infrastructure. For example, a municipal water line comes from an infrastructure based on the multi-lateral connections, placement, and planning of numerous dimensional water lines, rather than a single water line connected to a household. Berlant (2016:393) explains infrastructure as the movement or pattern of social form, adding to Star's (1996:380) definition of infrastructure being invisible and in the background, for other kinds of work. It's not a system, structure and never a "thing", but always a flow in a relationship or an infinite regress of relationships (Bateson, 1978:249). Star (1999:381) identified some common principles for defining infrastructure:

- *Embeddedness*: Infrastructure is sunk into and inside of structures, social arrangements, and technologies.
- *Reach or scope*: This may be either spatial or temporal-infrastructure, which has reached beyond a single event or on-site practice.
- *Transparency*: Infrastructure is transparent to use, in the sense that it does not have to be reinvented each time or assembled for each task, but rather invisibly supports these tasks.

- *An embodiment of standards*: Infrastructure taking on transparency by plugging into other infrastructures and tools in a standardised fashion, but modified by the scope of and often modified by conflicting conventions
- *Built on an installed base*: Infrastructure does not grow de novo; it wrestles with the inertia of the installed base while inheriting strengths and limitations from that base.
- *Become visible upon breakdown*: The normally invisible quality of a working infrastructure becomes visible when it breaks. Even when there are backup mechanisms or procedures, their existence further highlights the now-visible infrastructure.
- *Fixed in modular increments, not all at once or globally*: Because infrastructure is big, layered, and complex, and because it means different things to different locals, it is never changed from above.

Relating to the application of these infrastructure principles of Star (1999:381) is well-known, summarized spatial phrase: “Plan regionally and then act locally, to achieve the plan” (Pickett, *et al.*, 2013: vii). Zipperer *et al.*, (2000:680) argue that the previous statement is only an umbrella term for successful regional development, but that further refinement of different land use planning scales needs to integrate into upper planning systems, as necessary.

Strategic placement, alignment, and balancing of bulk service delivery to human settlements, within socio-political and environmental boundaries, is a challenging task for planners (Torres, 2008:27). Infrastructure delivery, as part of settlement planning, should entail an innovative, long-term integration approach (Schäffler *et al.*, 2013:15). Each settlement’s layout, relationships, and spatial dependency are globally different. Either in formal or informal locality (Ingram *et al.*, 2012:395; Pickett *et al.*, 2013:23). Integrating infrastructure principles with social and ecological principles creates a more holistic view of the local and regional trans-lateral spatial application of infrastructure development (Zipperer *et al.*, 2000:687). However, sensitivity is compulsory in the adaptation of infrastructure and ecology, as demand and supply relations for livelihoods differ immensely (Enrique *et al.*, 2015:64; Jones *et al.*, 2016:153). Any counteracting pressure on infrastructure development will have a ripple effect on urban metabolic flows. Such city-wide change of urban metabolism is evidence of a spatial nature: that human settlements depend on strategic infrastructure development inevitably in most facets of everyday life.

Mixed land uses causes the relationships of urban settlements and ecosystems to be highly complex and multifaceted (Rosa & Privitera, 2013:94; Schäffler, 2011:50). The EEA (2015:26) elaborates that spatial patterns are determined through land use intensity, heterogeneity and connectivity (Zipperer *et al.*, 2000:686). Land-uses will accordingly categorize infrastructure allocation whereas land use activities (being relative to infrastructure development) will also change land use types. Strategic planning of land uses and landscape management can assist the adaptability of various land-use tensions regarding community livelihoods and green

infrastructure protection and conservation. Using multi-scalar, mixed land use planning to strategically shift infrastructure development into desired directions is part of the compact urban development or smart growth planning and part of this research (Colding, 2011:231; EEA, 2015:64). The informal settlement consists of mix land use types and by identifying the potential of GI planning from the informal settlement, numerous land uses with associated built infrastructure is included.

3.3 Grey infrastructure planning

Grey (conventional/traditional) infrastructures are man-made services, systems, and networks within built-up society (Harrison *et al.*, 2014:54; Spatari *et al.*, 2011:2174). The planning of roads, sewers, as well as water, drainage and electricity lines are general observances of grey infrastructure that seal landscapes with impermeable, “hard” surfaces (Liquete *et al.*, 2014:8; Schäffler *et al.*, 2013:12). The EEA (2016:26) defines grey infrastructure as the shaping mechanism of the physical layout of urban areas, while determining urban patterns such as the “compactness, sprawl, urban form, urban design, connectivity of streets, mobility patterns, density, urban landscape” as well as “how the city residents live, move and work (e.g. housing, connectivity, mobility, accessibility). The majority of contemporary grey infrastructure development, that is acknowledged, understood and practised throughout settlements, are controlled by humans for humans (Dale *et al.*, 2000:643; Schoeman, 2010:9; UN-Habitat, 2015:2). In identifying the potential of GI include the grey infrastructure as a resource that is required to deliver basic goods and services without compromising the spatial integrity of GI.

Broadly, grey infrastructure deals with urban commons on a continual basis. The UN habitat (2015a:11) states that “urban green commons” are traditionally recognized as “the atmosphere, forests, rivers, fisheries or grazing land“. However, the more modern concepts thereof are linked with public goods, such as public space, marketplaces, public education, health and infrastructure that allows social-economic functionality (Cilliers *et al.*, 2013:694; GVANI, 2011:17; SRC, 2014a:5; Young & McPherson, 2013:70). Barthel *et al.*, (2014:145) elaborates that urban green commons work against privatisation of land, as privatisation lowers the contact between people and nature, and impoverishes the ecological habits and functions. Acknowledging the influence that grey infrastructure has on ecosystem-based infrastructure, and vice versa, is critical for integrating sustainable development thinking on all urban commons (Dale *et al.*, 2000:644; Roe *et al.*, 2013:652).

Grey infrastructure continually interacts with urban ecosystem-based infrastructures (TEEB, 2010b:27). These cross-cut through various land uses in the form of tapping aquifers, stormwater channels, road networks and sewage networks, that expand with urbanising trends (McPhearson *et al.*, 2016:11). Infrastructure development transforms the natural environment in settlements, locking in spatial patterns in rural to urban areas confined for decades afterwards. For example, road-ways occupy a set space, e.g. kerbsides and additional municipal reservoirs for water,

electricity and telecommunication lines (CSIR, 2000b:8-13). Common grey infrastructure types that change spatial ecological patterns associated with human settlement development are illustrated in Table 3-1 (Barthel & Isendahl, 2013:230; Bolund, 1999:295; Brook & Dávila, 2000:30; McPhearson *et al.*, 2016:11).

Table 3-1: Common grey infrastructure types related to GI

Type	Function
Transport	<p>Transport refers to the road, rail, air, sea (ports) and pipelines crossing the full spectrum of the urban metabolism (EEA, 2015:26; NPC, 2011:161). The robustness of infrastructure developments depends on its users and stewards (Hosseini <i>et al.</i>, 2016:49). This is a daunting task if I&AP's (Interested and Affected Parties) do not understand or comprehend the scale, functionality, and spatial interrelationship between transport infrastructures and socioecology (Belanger, 2009:85; Cumming <i>et al.</i>, 2013:1142; limi <i>et al.</i>, 2015:11).</p> <p>As transport networks get “locked-in” with spatial planning, the surrounding environment is forced to adapt or move away from built infrastructures. This is because soils are sealed which prohibits water absorption through hardened landscapes (EEA, 2015:9; Elmqvist <i>et al.</i>, 2013:277).</p> <p>Informal transport infrastructure proceeds from a “de facto” pattern, as people continually travel (EEA, 2015:37). The bottom line when dealing with formal or informal transport networks is that people will to continually move. However, the strategic placing of such movement networks will determine futuristic robust and vulnerability trade-offs of nature and human developmental relationships.</p>
Water	<p>The flow and purification of water involve complex hybrid infrastructures. Made up of natural (green and blue) and built (grey) spaces which create a sensitive planning platform (Demuzere <i>et al.</i>, 2014:107). Basically, blue infrastructure constitutes the spatial planning of the hydrological cycle. This cycle integrates with ecosystems (Barthel & Isendahl, 2012:5; Charles River Watershed Association, 1998:3; Kati & Jari, 2016:537). A close link exists between green-blue infrastructure (Barthel & Isendahl, 2012:8; Hansen & Pauleit, 2014:520; Kati & Jari, 2016:537; Elmqvist <i>et al.</i>, 2013:557). Recognising that blue infrastructure covers areas much larger than the targeted society which it serves is key to the strategic spatial planning thereof.</p>
Sewage	<p>Soltani and Sharifi (2012:126) state that sewage can be recycled in three steps: anaerobic, aerobic and discharging treatments. The last step is placed back into ecosystems and hydrological cycles (MEA, 2005:22). This is a grey infrastructure element which affects the ecosystem-based infrastructure such as wetlands, mangroves, and water catchment boundaries. Such activities (ranging from developing and developed countries application) changes the robust vulnerability trade-off through potential from sewage pollution (Bolund & Hunhammer, 1999:298; Pauleit <i>et al.</i>, 2011:284; Vollmer & Grêt-Regamey, 2013:1543).</p>

Source: Authors creation (2017)

The grey infrastructure types of transport, water, and sewage, which surrounds human settlement infrastructures, will alter spatial sustainability between the demand and supply of human and natural resources. There are various other grey infrastructure types associated with the industry, communication, businesses, and agriculture sectors. These have not been mentioned or discussed because this dissertation is focused on RPU informal settlement areas. This section is not arguing grey versus green infrastructure as bad against good. Rather the strategic placement and functioning of green infrastructure in a dominantly grey infrastructure perception are addressed.

3.4 Green infrastructure

Section 2.3.1. described the GI for this study and define GI unto two definitions being that of Ahern *et al.*, (2014:256) as the “spatially and functionally integrated systems and networks of protected landscapes supported with protected, artificial and hybrid infrastructures of built landscapes that provide multiple, complementary ecosystem and landscape functions to the public, in support of sustainability” and Benedict and McMahon (2012:3) referring to GI as the “interconnected green-space network (including natural areas and features, public and private conservation land, working lands with conservation values, and other protected open spaces) that is planned and managed for its natural resource values and for the associated benefits to human populations”. The following section reflects the historical occurrence of green infrastructure in the context of previously mentioned definitions and thereafter a brief explanation of GI planning in PRU regions will follow.

3.4.1 A historical view on green infrastructure

Based on historical evidence of human development, various GI networks and processes in cities and rural areas can be identified (McPhearson *et al.*, 2016:11). GI has been recorded, dating back to 400 B.C: as man-made alterations of the Amazon’s topography, with thousands of kilometres of raised fields to stand above the seasonally flooded grasslands of the Beni region in Bolivia (Comberti *et al.*, 2015:252). Vast quantities of earth was moved “to create raised agricultural fields, causeways, reservoirs, forest islands, ring ditches, fish weirs, ponds, and other structures—permanently modifying not just the topography of the region but also the hydrology, soil structure and fertility, faunal and floral communities, biodiversity, and local climate” (Comberti *et al.*, 2015:252).

Various cities in ancient times adapted landscape socio-ecological practices, ranging from numerous existing and emerging ecosystems over different geographical boundaries (Qureshi *et al.*, 2010:187). In ancient times, as Amrhein (2014:92) explains, the wondrous gardens of Nineveh (current day Iraq) were strategically aligned with man-made (grey infrastructure) irrigation canals and watercourses from the perennial river flowing through and along the country. Dalley (1993:2) states that these gardens were part of flood control from the Tigris and Euphrates rivers in Mesopotamia. Such gardens were strategically constructed and planned by professional

gardeners for multiple benefits. Ancient biblical evidence explains that, as part of the human need for self-sufficiency, home gardens were mandatory in order to provide food security, possible shelter and other household necessities (Bible, 1611: Jeremiah 29:5).

Mumford (2010:260) explains that in the past, cities from the medieval times to the nineteenth century utilised spatial planning of gardens as strategically located watersheds. These watersheds sustained some livelihood capitals for royal and even the poor, dwellers of society. Mumford (2010:170) emphasizes some critical roles of ecosystems services as man-made habitats to wetlands, functioned as sewage disposal management nodes in numerous city networks throughout history. However, the industrial revolution which diminished green spaces, community dependency, and self-sufficiency, resulted in low resilience from settlement functioning. Living spaces became a breeding ground for pests and diseases and were chained by the effect of sudden social and ecological fragmentation through urbanization (Dale *et al.*, 2000:648; EEA, 2015:46; Young *et al.*, 2014b:2571).

Historical spatial paradigms of GI cited by Barau (2015:286), Kruger (2014:71), and Mell (2014b:34) reference Frederic Law Olmsted and Sir Ebenezer Howard as being fundamentalists of GI thinking. Corridor links of greenways, integrated with conventional (grey) built capacity and services thereof, were some of their ideas (Leita & Ahern, 2002:67). Barau (2015:286) explains how Sir Howard influenced London's food sector by adding community agricultural gardens for food security, while simultaneously improving microclimates, aesthetics, flood control, and air quality. Mumford (1938:112) identified the value of gardens as a response away from the vulnerable times that London faced as a city. Such socio-ecological knowledge was dispersed in landscape utilization as proven by the artefacts, locally adapted organisms, trees, landscape features as well as with written accounts (Colding *et al.*, 2014:449).

GI provide multiple functions to the surrounding areas, evident in various case studies such as the Boston Emerald Necklace 1878 in New York, which were planned in response to the flooding of the Charles River (Kruger, 2014:72). Mell (2014b:10) explains that the Boston Emerald Necklace is now “promoted as a multi-functional greenway addressing sustainable drainage and flood control, tourism, recreation, promotes well-being, increases access to linear mobility features, and supports biodiversity/habitats for migratory birds.” The value of GI planning is more evident in long-term than short-term operation (Andersson *et al.*, 2014:451; McPhearson *et al.*, 2016:12).

Historically government authorities were responsible for managing the transition towards a more sustainable development when faced with humanity's greatest challenges, such as poverty reduction (Connop *et al.*, 2016:2; Folke, 2006:260; Ingram *et al.*, 2012:7). Contemporary landscape is altered by man-made habitats such as gardens and parks covering more than half of a city's green spaces (including private ownership), resulting in issues of ownership and access (Schäffler & Swilling, 2013:247; Young, 2014:2573). It is vital to acknowledge such man-made

habitats as part of the urban fabric for large and small-scale green spaces, for the sake of diversity and to link open spaces (Andersson *et al.*, 2014:446). Barthel (2014:444) argues that “collectively managed urban gardens are contemporary examples of ‘memory workers’ to serve as living protocols for transmitting information about local climate, soils, and moisture regimes related to the crops that thrive in distinctly different localities, as well as about fluctuating populations of organisms important for producing food.”

Contemporary perspectives on GI differ internationally from Europe to the UK and especially from North America (differing in various prerequisites for blue versus green infrastructure) (Liquete *et al.*, 2014:18; Mell, 2014:26). Lee *et al.*, (2015:147) explains that the current urban GI in Asian countries is focused on adapting to climate change, improving the resilience of extreme weather events, enhancing biodiversity and ecosystem services, and improving public health and well-being. Asian cities undertake broad climate change programs, through building a strong commitment to the poor and vulnerable society groups (De Zeeuw *et al.*, 2011:159). From developed to developing countries, throughout ancient times and during the industrial revolution, the evidence is clear that spatial integrity of landscape management has had, and will continue to have, an influence on human livelihoods. The following section will focus more specifically on the integration of GI planning into RPU regions.

3.5 GI Planning within RPU areas

This section aims to identify the linkages between “green infrastructure planning” and “strategic spatial planning in RPU informal settlement regions”. GI is coupled to spatial integrity for adaptation strategies onto any social, political and geographic context (Geneletti & Zardo, 2016:39). In this manner, the complexity of ecosystem services relates to the concept of “green” and the spatial integrity that fits into infrastructure planning, as to form the concept of “green infrastructure planning”. Wamsler *et al.*, (2016:9) explain various strategic planning approaches of GI will constitute GI planning directions. There is a difference thus between GI and GI planning, as this dissertation value GI planning above the mere acknowledgement of green infrastructure without any holistic GI principle application. Figure 3-3 illustrates how GI elements are strategically arranged to become stronger by integrative management as development follows. As time proceeds these elements of Figure 3-3 should move higher to the desired state of spatial integrity through “conserve green infrastructure network”. Identifying the potential of GI planning is a preliminary step to integrate GI planning development as to be labelled “conserve green infrastructure network”.

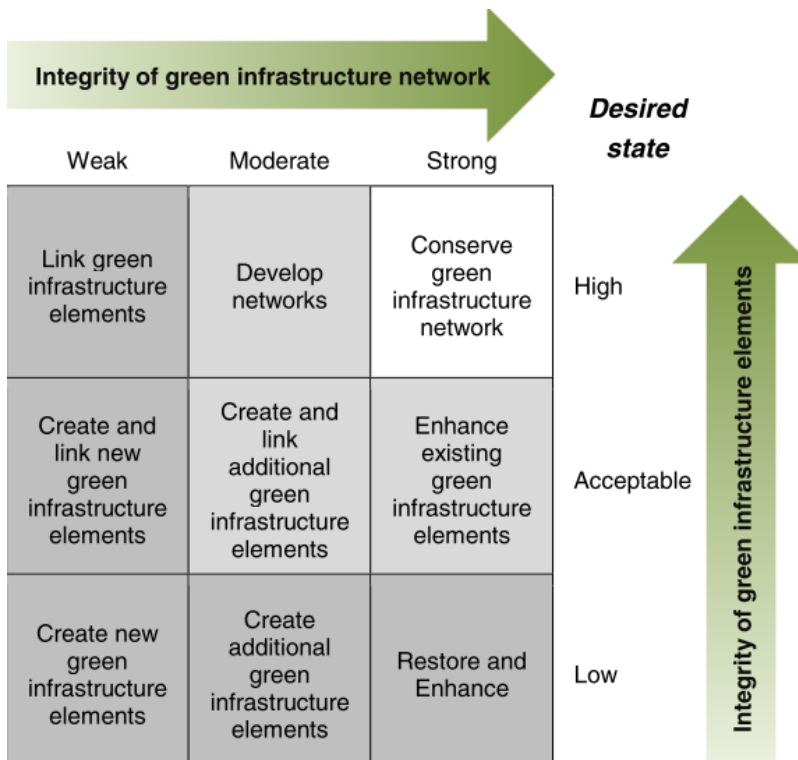


Figure 3-3: Decision support matrix based on the connectivity of the green infrastructure network and the quality of its elements

Source: (Hansen & Pauleit, 2014:523)

In spatial planning terms, Mell (2014a:614) referenced Ian McHarg 1969's landscape thinking to “design with nature” within an urban context. McHarg systematic land-use planning of multiple category maps overlaid onto each other illustrated how GI planning can fit to meet the required complexity of ecological, social and economic functions of society and the environmental relations (Colding, 2011:228). A hierarchy taken by this current study of GI planning is rolled-out by Scott *et al.*, (2013:567) by describing the “Three Ps” framework of Principles, Practices, and Procedures. Table 3-3, provides the necessary aspects for constructing a comprehensive, realistic and practical milieu in order to comprehend GI. Parameters mentioned in Table 3-3 deal with the complexity of understanding the multi-functionality wherein GI exists. This is accomplished by bridging the natural and human dimensions by typologies (Hansen & Pauleit, 2014:526; Madureira & Andresen, 2014:39; Young *et al.*, 2014b:2574). Taking GI planning to “design with nature” this current study focus on GI principles that address the potential conceptualization complexity of GI. These typologies are holistic enough to include other infrastructure types as not to isolate green from grey infrastructure but unify the types of infrastructure into sustainable development directions.

Table 3-2: GI typology adapted for this dissertation theme

Parameters	Sub-categories/definitions/examples	
Setting	Rural, urban, peri-urban, combined (containing elements of both rural and urban landscapes)	
Geographic scale	Regional scale	
Sectors	Agriculture, built environment, energy, fisheries, forestry, health, tourism, transport, urban & regional planning, water, cross-sectoral, nature protection	
Ecosystem habitat	e.g. Arable land, coast, forest, grassland, river, wetland; estuary, recreational, rocky, thicket, tree crops, woodland, artificial water bodies, extractive, settlements	
Objectives	Climate changes adaption and mitigation	Enhancing ecosystem resilience and functioning, support society to adapt to climate change (e.g. natural flood management, coastal protection, green roofs)
	Spatial conservation	Focus on a priority concentrated geographic areas rather than a targeted species group for spatial and integrative planning
	Soil protection	e.g. afforestation, sustainable agriculture, land management
	Quality of life/well-being	e.g. establishing recreational areas, installing green roofs to improve local climate and air quality, creating jobs and promoting rural and regional development
	Sustainable management	Taking actions specifically aiming to improve the ecological quality and permeability of landscapes, therein addressing multiple ecosystem services and functions and adopting a long-term perspective e.g. greenbelt, natural riparian ways.

Source: Adapted from Brown and Everard (2015:65), Naumann (2011b:17), Sinnett *et al.*, (2015:229) and Young *et al.*, (2014:2576).

Building and refining from Table 3-3, Figure 3-4 develops from co-managing resilient planning directions to more long-term urban to rural implementations (Brown & Everard, 2015:63; Laforteza *et al.*, 2013:104). In this dissertation, the potential of GI planning can be linked to Figure 3-4 from the perspective of “city as a social-ecological system”. Although Connop *et al.*, (2015:2) addressed an urban interface, by including ecosystem services like the hydrological cycle implies that rural and peri-urban regions must be incorporated within such a “city” definition for a social-ecological system. This research argues the case that identifying the potential of GI planning need to include the whole rural to urban geographic space as to meet the illustrated “urban green infrastructure” components as illustrated in Figure 3-4.

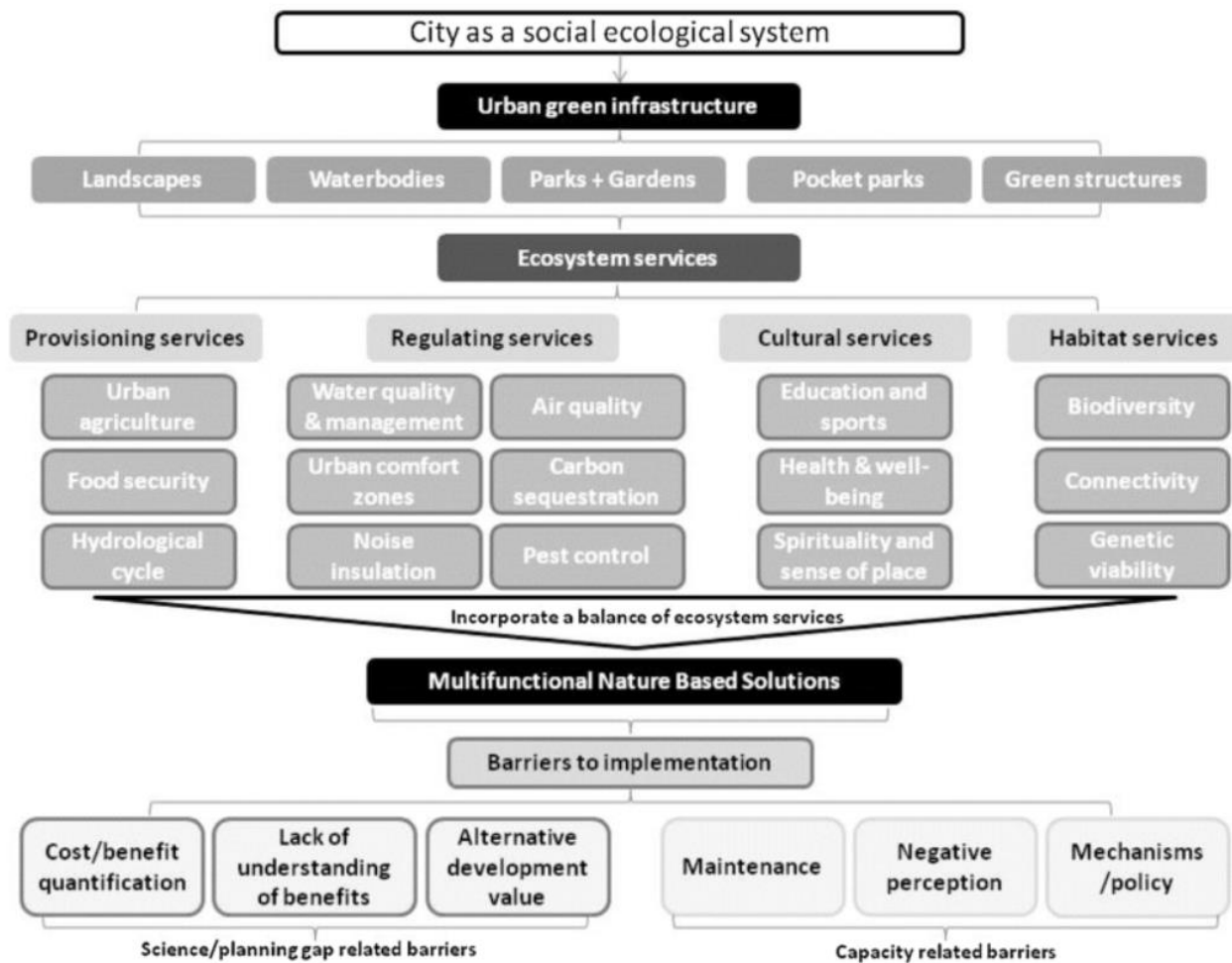


Figure 3-4: A framework for green infrastructure implementation in urban areas

Source: Adapted from (Connop *et al.*, 2015:2)

Dealing with urban green infrastructure as mentioned in Figure 3-4 the society where about the urban boundaries reside bares numerous challenges for GI planning integration. McPhearson *et al.*, (2016:2) argues that as global urbanization is expected to increase in urban populations, from 3.9 to six billion in the year 2045, the additionally demanded infrastructure with the current infrastructure backlogs, will potentially diminish and drain natural resources. This is a problem too great for government responsibility alone. Thus, a massive demand for new infrastructure presents itself wherewith strong socio-ecologically based design, architecture and development planning will need to make way for adaptive governance processes, such as presented in GI planning (Connop *et al.*, 2015:10; McPhearson *et al.*, 2016:2). Moving into GI planning paradigms a strong aspect of strategic and spatial planning is parallel approaches to comprehend and practice.

3.5.1 Strategic and spatial planning of GI

According to the post-2015 development agenda of the UN-Habitat (2013:2), green spaces and vegetation cover, in urban and peri-urban areas, are essential for biological and hydrological balance as well as economic development. Steffen *et al.*, (2011b:740), van Zoest and Hopman

(2014:108) and TEEB (2011b:6) explained that the various ecosystem services that make human life pleasant and possible can be grouped in four categories, namely cultural, regulating, provisioning and supporting services. Dealing with any type of urban to rural planning that influences the natural environment, brings forth a multi-dimensional sensitivity that needs the spatial integrity of the landscape with functional ecosystem services (Barrow, 2006:52; Elmquist *et al.*, 2013:553). By identifying the potential of GI planning the capacity of GI, namely the four categories of ecosystem services, is not identified per se, but the geographic space that these categories and anthropogenic influence function need to be included in the identified potential.

Ahern (2007:270) and Mell (2013:154) recognized the importance of complimentary, multi-functional and scaled spatial planning, connectivity, and spatial patterns. Building on the “Patch-corridor-matrix model” the Mosaic model reflects sensitivity to the spatial integrity view of multi-functional green spaces on earth’s surface as a mesh (mosaic) of different scales and spatial connectivity of natural, semi-natural and man-made regions (Alberti, 2005:170; Frank *et al.*, 2012:30; Goddard *et al.*, 2010:92). Andersson *et al.*, (2014:446) describe mosaics consisting of small-land use patches with high ecosystem heterogeneity from a regional view. Breed *et al.*, (2014:6) and TEEB (2010d:18) argues interconnectivity and interdependencies of socio-ecological landscapes facilitate the flow of energy, materials, nutrients, and species specifically in moulding ecosystem services that should benefit human populations. GI planning strategically realizes such before mentioned interconnectivity and interdependencies of socio-ecological landscapes (Connop *et al.*, 2016:4; Mell, 2014a:619; McPhearson *et al.*, 2016:11; Young *et al.*, 2014:2576).

GI is situated in a common scientific dilemma, as Baud *et al.*, (2015:225) explains. The theoretical debates dominate GI planning discussions, spreading confusion through the global North and South as GI application differs in each sphere. The “lack of knowledge” is a major issue and is the common attribute to spatial planning ambiguity when it comes to GI planning implementation (Jones *et al.*, 2016:154). Baud *et al.*, (2015:232) elaborates that knowledge does not travel properly between different scales of government departments. Identifying the potential of GI planning identifies various levels of municipalities overseeing the identified land uses that require GI planning. In this manner, a strategic identification of the spatial planning to in answering “to who and where should knowledge management be dispersed” receives more clarity through GI planning approaches

Stokols *et al.*, (2013:4) argue when dealing with ecosystem services over different spatial and temporal scales integrative interdisciplinary is required in order to comprehend the socio-ecological landscape priority for strategic spatial planning (Barrette; 2001:79; Naumann *et al.*, 2011a:96). Table 3-6 provides basic ecological and land use principles for urban and rural landscape planning. These principles are holistic enough to include other infrastructure types as not to isolate green from grey infrastructure but unify the types of infrastructure into sustainable development directions.

Table 3-3: Key principles for ecological research and spatial land use decisions

Principle	Explanation	
Connectivity	How spatially or functionally continuous a patch, corridor, network or matrix of concern is	
Content	The structural and functional attributes of a patch where “structure” is the physical arrangement of ecological, physical, and social components, and “function” refers to the way the components interact	
Context	The patch’s location relative to the rest of the landscape as well as the adjacent and nearby land units that are in direct contact or linked to a patch by active interactions.	
Disturbance	The type, intensity, and duration of (natural and anthropogenic) disturbance shape the characteristics of populations, communities, and ecosystems.	
Dynamics	Temporal	How a patch or patch mosaic changes structurally and functionally through time
	Spatial	How a patch or patch mosaic interconnect from spatial scale but is not sensitive to social scales, however, enable general level consideration of the psychological and social benefits as part of a holistic approach
Heterogeneity	The spatial and temporal distribution of patches across a landscape. Heterogeneity creates the barriers or pathways to the flow of energy, matter, species, and information	
Hierarchy	A system of discrete functional units that are linked but operate at two or more scales. Proper coupling of spatial and temporal hierarchies provides a key to simplifying and understanding the complexity of urban landscapes	
Landscape	The size, shape and spatial relationships of land cover types influence the dynamics of populations, communities, and ecosystems.	
Place	Local climatic, hydrologic, edaphic, and geomorphologic factors, as well as biotic interactions strongly, affect ecological processes and the abundance and distribution of species at any one place.	
Species	Particular species and networks of interacting species have key, broad-scale ecosystem-level effects	
Time	Ecological processes function at many time scales, some long, some short; and ecosystems change through time	

Sources: Adapted from (Dale *et al.*, 2000:648; Grimm *et al.*, 2000:579; Putz *et al.*,2000:686)

3.5.2. Creating an approach to GI planning

These sections provide GI principles which will address the dynamic capabilities of an approach to identify the GI planning potential from the influence of RPU informal settlements. Ecology, from human spheres, has four basic principles of natural capital: (1) dependence on solar energy, (2) biodiversity, (3) control of population growth, and (4) cycling of nutrients (Miller & Spoolman, 2009:60). Natural capital has a higher spatial dependency in RPU informal settlements located in less developed countries, in terms of time, species, place, disturbance, and landscape. Such dependency influence land-use decisions in tremendous ways of previously mentioned factors (Putz, 2000:676; Zipperer *et al.*, 2000:686; Schulttz *et al.*, 2015:7374). Applying GI principles for identifying GI planning potential should be aligned with Bohemian's (2002:193) list of ideas, being:

- Make abstractions (thoughts, ideas, and concepts), placed onto land, visible and discernible.
- Make complex, natural processes visible and comprehensible.
- Expose systems and processes that were previously hidden.
- Emphasize the anthropogenic connection with nature.

De Vos (2002:202) and Kumar (2014:17) reference a mix-methods of including quantitative and qualitative research that should be ideal for GI-related planning approaches. This dissertation aims to provide a broad view of GI principles to assist in conceptualizing GI planning and identify GI planning potential for a regional context. GI principles are taken from Hansen and Pauleit (2014:516) and Roe *et al.*, (2013:653) characterize GI planning for adaptive strategic spatial planning to represent the qualitative aspect of this research. The basis of GI planning's principles is given in Table 3-8. However, Table 3-8 does not have enough planning direction carry GI planning potential directly over to local land use planning. GI principles are fundamentally rooted in regional planning directions and require external local application comprehensiveness in dealing with local decision-making processes (Hansen & Pauleit, 2014:519; Roe *et al.*, 2013:668). These principles are holistic enough to include other infrastructure types as not to isolate green from grey infrastructure to create a potential identification that comprehends GI planning and informal settlement complexity.

Table 3-4: GI planning principles identified for purposes of this research

Principles	Description
Approaches addressing green structure	
Holistic, comprehensive, flexible and integrated approach	To the treatment of planning environments (urban, urban fringe and countryside) and targets (nature conservation, social welfare, and economic prosperity). GI may include 'green' parks, gardens, woodland and water bodies, but also linear features and routes such as footpaths, streams and rivers, cycle routes, roadside verges and linear woodlands. Green infrastructure planning considers urban green as a kind of infrastructure and seeks the integration and coordination of urban green with other urban infrastructures in terms of physical and functional relations (e.g., built-up structure, transport infrastructure, and water management system)
Multifunctionality:	The overall structure can fulfil ecosystem service functionality and adaptability. Importantly, the potential for interactions between functions is emphasized. Each of these characteristics though can also be identified as primary objectives of GI, as well as providing multifunctional benefits. This links to sustainability thinking and long-held views that multiple-use landscapes are generally held to be more robust than those with single-uses. This does not necessarily mean a 'more is better' principle should be adopted and there are instances where desirable functions
Connectivity/Linkage:	GI can provide a series of 'nodes' and 'hubs' and corridors which provide physical linkage in the landscape and the opportunity for interactions between different actors in the landscape and within the landscape itself. Connectivity aims to combat fragmentation of habitats and isolation of species to reduce biodiversity losses.
Multi-scale approach:	Green infrastructure planning can be used for initiatives at different scales, from individual parcels to community, regional, and state. Green infrastructure should function at multiple scales in concert
Multi-object approach:	Green infrastructure planning includes all kinds of (urban) green and blue space; e.g., natural and semi-natural areas, water bodies, public and private green space like parks and gardens
The primary importance of green infrastructure:	GI is the first step in a development process; GI should be identified, protected and planned before development takes place. GI is thus considered the fundamental infrastructure in landscape development and consideration of the quality and criticality of such infrastructure is important
Evidence-based approach:	GI planning is based on robust scientific knowledge gained from a number of fields including landscape ecology, land use planning theory and practice and social studies of landscape ecology
Approaches addressing governance process	
Strategic approach:	Green infrastructure planning aims for long-term benefits but remains flexible for changes over time
Social inclusion (partnership and participatory):	A cross-disciplinary approach to practice and theory; achieving GI planning in practice demands the involvement of numerous stakeholders. Many other benefits are seen as accruing from such an approach including empowerment, social capital building, tapping into local knowledge, ownership, and consensus
Transdisciplinarity:	Green infrastructure planning is based on knowledge from different disciplines such as landscape ecology, urban and regional planning, and landscape architecture; and developed in partnership with different local authorities and stakeholders
Long-term approach:	GI planning requires a long-term commitment, with public investment to achieve the potential for addressing sustainability issues through landscape planning, design, and maintenance. The timescale is significant because change is considered an integral part of the landscape which is seen as an ever-changing mosaic and thus management over time for future generations is practically and conceptually important and influenced by sustainability principles.

Source: Adapted from (Hansen & Pauleit, 2014:517; Roe *et al.*, 2013:653)

3.6 Green and grey infrastructure continuum

A grey-green continuum implies combining compatible grey (conventional infrastructure) with green (socio-ecologically sensitive) practices, designs, planning, and management (Claro *et al.*, 2013:8; Norton *et al.*, 2015a:128; Roe *et al.*, 2013:652). Mell (2013:153) argues that a grey-green continuum is parallel-coupled to the success of GI planning. This continuum is the sum of various principles, as illustrated in Annexure five. The practical application of this is illustrated in Annexure four and should be strategically fused into a unified infrastructure system (Mell 2013:153, Roe *et al.*, 2013:653). Figure 3-5 represents a comparison between the possible grey and green infrastructure types within a designated landscape. The aim of grey-green continuums is to depend and integrate towards the optimum delivery of ecosystem services with the lowest cost as possible for long and short-term development. This is accomplished through the human intervention of natural and semi-natural areas and by strategically planning corridors and links in order to relieve or replace the vulnerability of grey infrastructure capacity (Pakzad & Osmond, 2016:69; Tiwary & Kumar, 2014:351). Unlike grey infrastructure, the spatial integrity of GI planning relies equally on the public interaction and behaviour patterns of associated spaces, rather than on the space in itself (Jaffe, 2010:364; Norton *et al.*, 2015:136; Roe *et al.*, 2013:658; Tzoulas *et al.*, 2007:173).



Figure 3-5: Combined grey and green infrastructure solutions
 Source: GPC (2013:34)

The grey-green continuum encourages sustainable landscape development, that meets a functioning infrastructure of visual green (meaning ecological) resource management, integrated with public green spaces (Mell 2013:155). Spatial complexity is amplified when taking ecological engineering into a public space and linking public responsibility to these spaces (Schäffler, 2011:56; Tiwary & Kumar, 2014:351). The grey-green continuum depends on understanding grey infrastructure in trans-disciplinary complexity (Giordano, 2014:483). See Annexure four for a better understanding of this as a vital end to meet the full spectrum of GI planning. Sinnett *et al.*, (2015:228) explain the spectrum of GI's multiple characteristic traits fits into urban-rural spatial planning. These principles flow through the urban transect which varies with landscape transformations, rather than technological, political or socially demarcations (Mell, 2010:56; Scott *et al.*, 2013:574). As the urban transect divide urban to rural areas, by the various environmental

and land use activity types, GI planning has an existing grey-green continuum adaptation through the transect which needs to be organised (ASLA, 2016:1).

Hybrid infrastructure refers to a grey-green continuum that incorporates artificial infrastructure but in regards to protected infrastructure, more emphasis is placed on a demarcated zone of spaces that are defined for conservation and protection. GI, unlike grey infrastructure, expands with time (if appropriate management occurs) to deliver adaptive functionality through ever-changing environments (Mell, 2013:153; Wamsler *et al.*, 2016:8). The complexity of GI, as seen from Brook and Dávila, (2000:14) and Benedict *et al.*, (2012:14), is that, besides the planning framework, the actual geographic dynamics make the planning of GI unique to its location. GI is different and unique in its own right and should be integrated and respected alongside grey infrastructure systems (Claro *et al.*, 2013:7; Mell, 2013:164; Norton *et al.*, 2015:133).

GI planning is built on grey-green continuums for addressing human livelihood demands and supplies while ensuring a close relation with ecosystem services and humans servicing ecosystems, to create a platform for multiple indicators of livelihood quality (Ingram *et al.*, 2012:93; Syrbe & Walz, 2012:87). The UN (2015:1) is moving international commitment and investment directions towards the focus of climate change through the Conference of Parties (COP21) to bring climate change strategies into alignment with local environmental management. Figure 3-6 illustrates the various cycles of activities operating through ecosystems that can be built around the term GI as well. S2E is defined as “actions humans have taken in the past and currently, that modify ecosystems to enhance the quality or quantity of the services they provide, whilst maintaining the general health of the recognized ecosystem over time” (Comberty *et al.*, 2015:247). Services to Ecosystems (S2E) is recognized and supported on a basis of bio-cultural diversity, adaptive management, and sustainable livelihoods. This is similar to the UN’s sustainable development outcomes (UNECA, 2013:90). However, striving to realize S2E, needs a radical reciprocal rethinking to shift spatial planning spheres of ecosystem services delivery towards multi-scale ecological stewardship. Figure 3-6 illustrates such reciprocal environments that strengthen the local scale services of human and nature interactions (Ahern, 2007:268; Grimm *et al.*, 2000:573; Schäffler, 2011:38). Identifying the potential of GI planning is but first steps to engage various communities into a strategic spatial planning platform for grey-green infrastructure planning. Human action can have a positive consequence on the environment. As Comberty *et al.*, (2015:247) describes human cultivation and efforts to enhance ecosystem services (referred to as S2E) should be understood and used in spatial planning regimes.

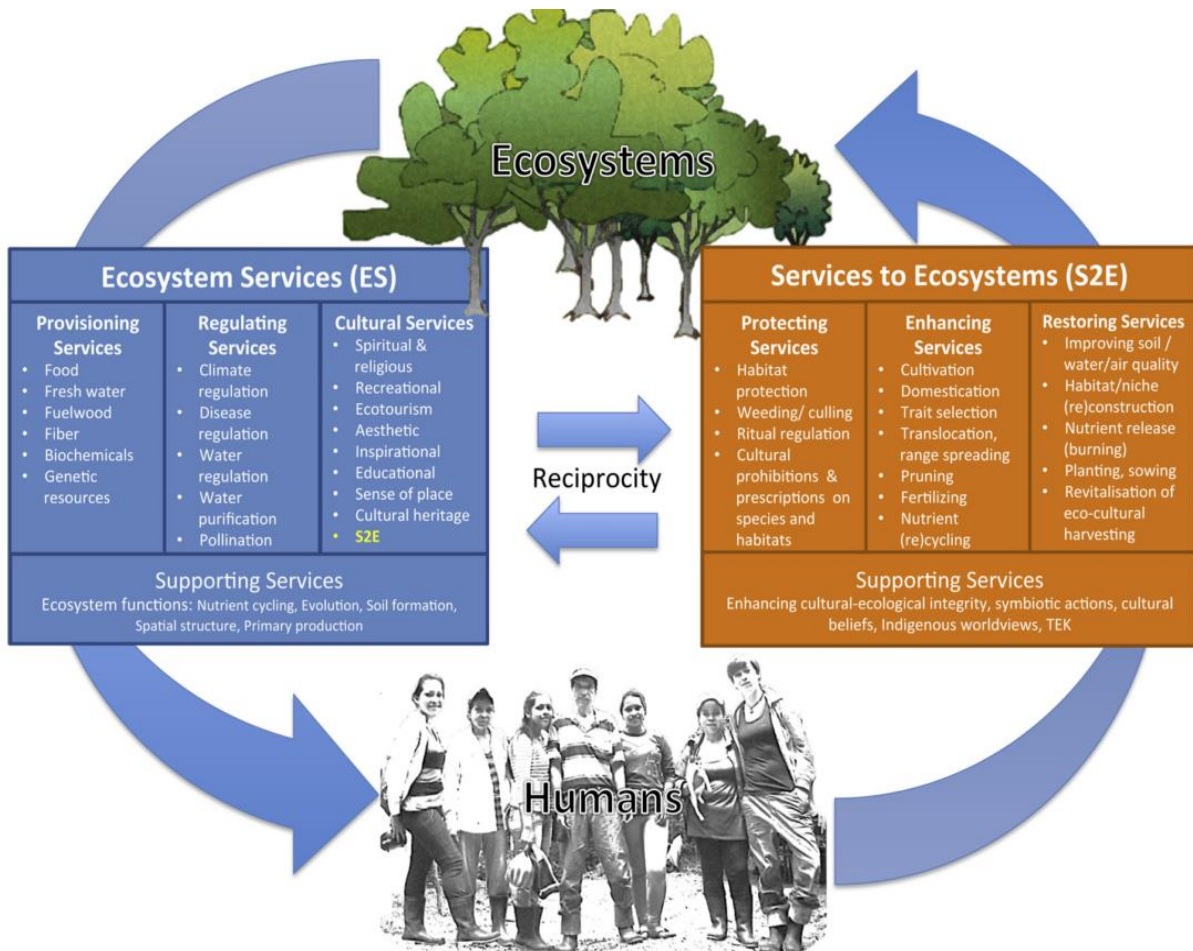


Figure 3-6: The reciprocal system of service to ecosystems (S2E) and vice versa
 Source: Comberti *et al.*, (2015:257)

A historic example of S2E is given by Barthel and Isendahl (2012:3), referencing the socio-ecological resilience of ancient cities (e.g. Constantinople and Maya cities in Central America), as having large spatial alterations created by human activities. Such historical evidence supports lower-level social forms of water and food management that reflect local “social-ecological memories” for transmitting practical knowledge between people across generations (Barthel & Isendahl, 2012:8). This dissertation will not evaluate S2E or socio-ecological memory groups. However such aspects are end results if the potential of GI planning is pursued land use planning scale integration. The identified planning potential of GI needs to consider from out a GI principle perspective the positive influence of humans on ecosystems even in RPU informal settlement context.

3.7 Conclusion

The lessons learned in this section is:

- That GI planning is so multi-functional in service and scale that adaptability is the greatest advantage for GI integration as a concept into other existing and planning infrastructure type.

- GI compliment and harmonize the overall need for infrastructure development on a regional scale as being foundational natural based solutions through man-made grey-green continuum developments
- GI planning truly fits the saying “Think regionally (GI) but act locally (spatial land use management and planning)”

Socio-ecological relationships are vulnerable to the “compact” planning of urban spaces. This is due mainly because such development caters for high-density liveability, rather than environmental stewardship responsibility (Frank *et al.*, 2012:32; Tratalos *et al.*, 2007:308). RPU informal settlement areas tolerate uncontrolled urban sprawl of informal settlements, which is critically changing the landscapes. Reshaping settlement planning demands strategic, guiding principles to integrate infrastructure throughout land-use levels in order to influence settlements in a sustainable manner (Salter *et al.*, 2011:85; UN-Habitat, 2013a:2). GI planning is not an infrastructure replacing development, nor is it working against grey infrastructure. This study thus identifies the potential of GI planning through overarching principles to be inclusive of other infrastructure type and associated land use activities. In this manner, a sub-regional district scale planning approach incorporates the necessary strategic spatial planning element to comprehend the vulnerable socio-ecological relationships of GI in the midst of a dominated anthropogenic influence of informal settlements.

GI planning in this chapter proposed definitions and principles having strong resilience thinking cores, which should be holistically integrated into different spatial land use planning and management scales. Examples of GI is disguised under agricultural, wetland, forestry and other landscape modifications. However, these large-scale long-term projects form part of the patch-corridor matrix that must be collectively incorporated into more effective and efficient strategic spatial planning for ecosystem service delivery at multiple scales throughout various urban to rural scales. Thus identifying the potential of GI planning from informal settlement influence provide a planning approach to further understand and comprehend spatial planning complexities regarding GI planning.

CHAPTER 4: GI PLANNING IN AFRICAN AND SOUTH AFRICAN RPU REGIONS

Figure 4-1 captures the structure of Chapter four.

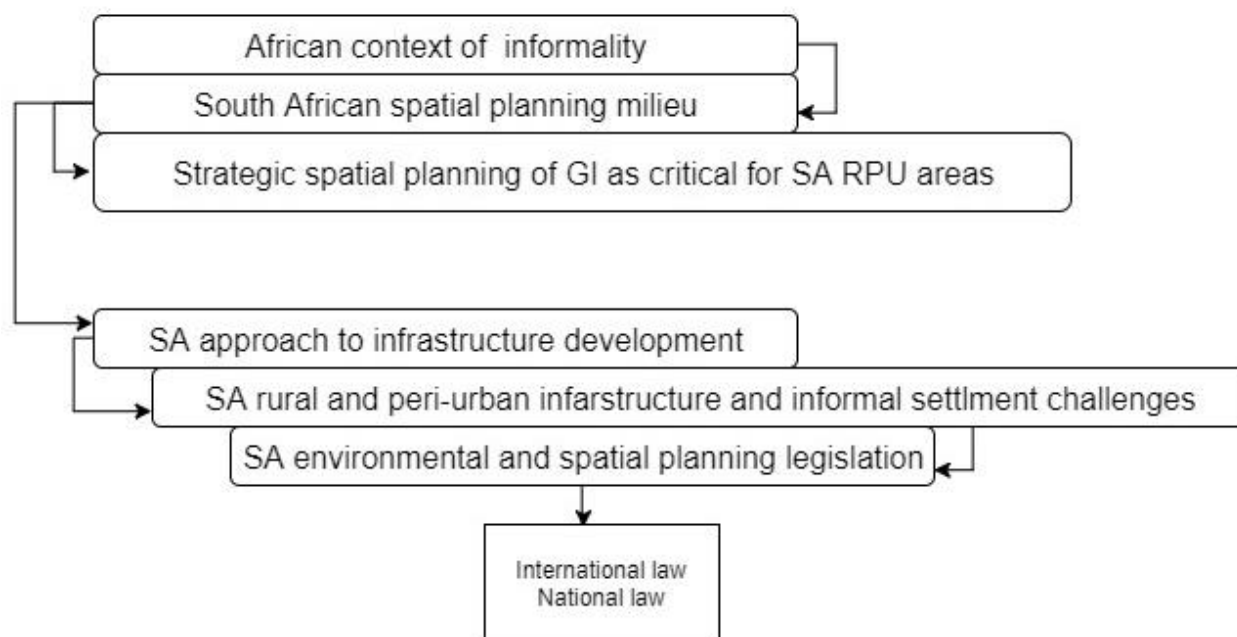


Figure 4-1: Structure of chapter four

Source: Created from Draw (2017)

4.1 Introduction

This chapter addresses the GI planning strategic spatial background within South Africa's environmental and spatial planning milieu. First, an overview of some African countries regarding informal settlement, land use and environmental challenges will be discussed regarding spatial and environmental planning in RPU regions of Africa. This provides the context to further focus on South African context and similarities with the rest of African country examples as to identifying GI planning's potential in RPU informal settlement regions in South Africa that address the socio-geographic spatial planning context.

In South Africa current national and provincial policies directions is creating a platform suitable for nature-based solutions that are sensitive towards spatial land use planning (Cilliers & Cilliers, 2016:11). As with many African countries, the use of infrastructure development differs in particular ways of initiation and development, for example driving climate change propaganda to promote more change to integrate GI planning than local municipal projects (Cilliers *et al.*, 2013:691). This uniqueness of the de facto element of developing countries mixed with numerous international and national legislation provides certain aspects where to GI planning has to be tailored to development success. Recognizing before mentioned developing countries spatial and environmental planning uniqueness, will require an identification of GI planning potential within

RPU regions, as RPU regions dominate African countries much more than compared with developed countries.

4.2 African context and informality challenges

Governments are more concerned with the urban pressures of poverty, unemployment, and access to food, energy, water, sanitation and housing, than the “voiceless” existing green infrastructure (visibly recognized as ecosystem services illustrated in Annexure three) that relieves the urban metabolic pressures (Elmqvist *et al.*, 2013:457). To be a step ahead of foredooming natural or man-made disasters, green infrastructure should offer leverage to uphold and sustain spatial resource management. In less developed countries, Zipperer *et al.*, (2000:676) argue that ecological principles that influence land use decisions being time, space, place, disturbance, and, landscape are factors for consideration when regarding spatial planning interventions. As with any geographic regions globally, the visible patterns to strategically conduct spatial planning for GI is highly influenced by anthropogenic morphology. The government, acting as the main driver of change in African countries, need to identify GI planning potential in RPU regions to visually recognize the areas requiring strategic GI planning.

Urban-rural environmental stability is troubled by resource depletion and pollution, through the abuse and overuse of specific natural, African sources (Duffy, 2006:94; TEEB, 2009:9). This undiversified dependency on energy and material sources decline and weakens abiotic, biotic, and anthropogenic urban to rural metabolisms (Cilliers & Cilliers, 2016:19; McPhearson *et al.*, 2016:8). This contributes to an African phenomenon of increased civil war, caused by natural resource control conflicts (Collier & Gunning, 1999:9). Adding to African challenges is that disasters cripple African countries in energy, housing, transport and food security through annual floods, droughts, earthquakes, landslides and civil strife (Cross & Coombes, 2013:37; UNECA, 2008:8). This creates tension factors that change the urban metabolisms on local to national government levels (Roberts, 2008:523). Especially evident in mixed land use activities (Baud *et al.*, 2015:228; UN-Habitat, 2015:6). Strategically identifying the potential of GI planning in a developing country context will tailor the direction of strategic spatial planning for mitigating before mentioned realities.

The following are African examples of spatial settlement change, influencing natural resource planning and management that mould any given GI planning potential. These examples are taken from North African regions, but similarities to the South African RPU context, are considered.

Tanzania: Hambati (2013:920) explains that there are three stages of informal settlement development, as in-situ slum upgrading, redevelopment and relocations, which depend on the growth phases of a particular informal settlement. Continental land use conflicts occur with ever increasing slum densification and resettlement, but in Tanzania, property rights (security of tenure) through informal channels, are generally not that insecure (Kombe, 2005:133). Thus, early

stages of slum development need to have secure tenure or land ownership; two aspects of informal settlements that should be considered when negotiation for government services and infrastructure provision, should be realized (Smith & Stirling, 2009:40).

African countries have rural populations generally occupied with agricultural sector activities and agglomerates informal settlement dispersions close to road and rail infrastructure (Tavares *et al.*, 2014:167). Tanzania's focus for rural accessibility with adequate transport infrastructure is a government prone investment platform for effective socio-economic growth (limi *et al.*, 2015:17). Continental infrastructure development is highly driven by government transport directions. However, some African governments aligned such direction with the informal cross-border trade, which stimulates its own settlement distribution (UNECA, 2010:302; GCRO, 2014:#26; UN-Habitat, 2015:11-2). Natural resources are seen as a mere commodity, rather than part of life's dependable infrastructure that should be integrated with individual and community environmental stewardship (Steffen *et al.*, 2011:749; Zipperer *et al.*, 2000:677).

Rwanda: Doll's, cited in Ingram *et al.*, (2012:263), evaluation of infrastructure interventions in Rwanda through the scope of poverty meeting ecology, states that energy services and sources channelize spatial settlement dynamics. Doll, cited in Ingram *et al.*, (2012:268), argues that as energy interventions are a daily part of Africa's settlement dynamics, there are different fuel types such as animal dung, fuelwood, charcoal and LPG (Liquid Petroleum Gas) for cooking. Such daily demands reshape the surrounding environment. This is evident from the forest, air, and water quantities and qualities and is especially evident around poor settlements without built infrastructure. Dawson and Martin (2015:64) argues that the basic needs, namely "(1) sufficient food, (2) adequate water, (3) physical and economic security, (4) shelter, (5) fuel for warmth and cooking, (6) physical and mental health and access to medical treatment (including for childbirth), (7) autonomy or freedom of action, and (8) not to suffer from isolation or negative relationships", can be addressed through strategic management of ecosystem services. Dawson and Martin (2015:69) explored socio-ecological reductionism in Rwanda and put forth the notion that local communities' values and practices are not fully recognized in environmental decision-making. This misguides ecosystem definitions and leads to inadequate policies and socio-ecological landscape management directions.

Cross and Coombes (2013:72) state that one of the key building blocks of infrastructure development in Rwanda is the sustainable waste management vision for 2020. Scarlat *et al.*, (2015:1275) illustrate that the energy deficiency in rural Africa is larger in sub-Saharan Africa than in North Africa. This makes alternative energy solutions, such as for waste management, a necessary consideration. Waste will continue to be dumped in Africa. This means the opportunity to convert waste into a resource, while carbon emission schemes are inadequately used in Africa, is a strong trade-off for contemporary energy alternatives (Couth & Trois, 2012:2115). A large portion of green infrastructure fragmentation is coupled to national energy planning interventions.

Such economic drivers determine new or expanding settlement trends, surpassing spatial landscape integrity, to sustain such narrowly focused development dispersions.

Dawson and Martin (2015:62) rate Rwanda as having the highest population density in mainland Africa. A total of 89% of inhabitants depending on small-scale agriculture (Dawson *et al.*, 2016:206). The UNDP (2014:87) groups Rwanda with China and Viet Nam, which went from a very low health care coverage to nearly universal coverage within a decade. As 85% of Rwanda's population is within rural boundaries, close to agriculture activities, the government is heavily involved in reforestation, social equity and using the community to eradicate internal conflict for an all-around higher quality living (Gebauer & Doevenspeck, 2015:99). As with Tanzania, securing property rights enables people's ability to borrow money and create incentives for better housing in Rwanda (Cross & Coombes, 2013:107). The dissertation benefits from Rwanda's concept of the regional planning of strategic resource planning, which simultaneously rebuilds local communities and stabilizes future natural resources to be utilized for decades to come.

Nigeria: Nigeria's capital city, Lagos, has a stretched out periphery that is dominated by informal settlements. This is a common attribute to African capitals. The land is cheaper in peri-urban areas because of unavailable or non-existent basic services and infrastructure facilities (Opoko *et al.*, 2015:121). Posel and Marx (2013:829) conducted a study of circular migration in South African informal settlements, whereby Nigerians, as with many migrants, are less likely to return to the slums with the aim of achieving ownership. A form of ownership, rather than renting or occupying slum houses, proceeds into dual ownership, a common prevalence in poor communities. Slum dwellers do not have high aspirations for a long-term commitment in the informal settlements because poverty dominates these environments (Posel & Marx, 2013:829).

Construction activities on the environment in Nigeria have a negative impact on the excess consumption of resources, materials, energy, landscape changes and depletion of natural resources (Emuze, 2013:17). This norm extends through formal and informal infrastructural development. Nigerian slums are a good example of disorder, regarding environmental degradation and cultural disparity that deals with a lack of ownership or seasonal migration, which never places responsibility on community stewardship for the environment.

It is evident from the previous mentioned African spatial planning examples that challenges in developing countries involve broad public domains interwoven through RPU regions built and natural areas. Interdependent natural corridors that interlink GI spatial integrity are diminished or pressured by such before mentioned African urban sprawl that desperately requires strategic spatial intervention (Cilliers & Cilliers, 2016:26; McPhearson *et al.*, 2016:9). Providing the identified planning potential of GI is a nature-based solution for African urban challenges that should be further practised in a South Africa spatial planning milieu.

4.3 South African spatial planning milieu

Africa is the second largest continent (covering over 30 million sq.km) and has over 1.1 billion inhabitants. Of this 40 % is urban dwellers, but it has fewer persons per sq. km than Asia (the largest continent) which has a “rural” population of over 2.2 billion (GeoHive, 2015:1; Rosenberg, 2010:1). In the last decade, South Africa’s stimulation in rural to urban migration has brought various, urbanizing transformations. Even though the country ranks within a high GDP (Gross Domestic Product) (Posel & Marx, 2013:829; Statistics times, 2015:1). Africa is, however, under pressures of poverty, unemployment, scarce resources, and serious diseases, such as HIV/Aids and malaria. These pressures are hindering social settlement patterns and spatial planning organisation (Cobbinah *et al.*, 2015:22; UNDP, 2015:9; Ward & Kamsteeg, 2006:63).

Transformative forces in developing countries instigate fast growing RPU sprawl. These forces precede from post-colonialism, liberalization, global politics of development, wars, shifting boundaries, chaotic development, and gated communities (Smith & Stirling, 2009:7; Zhao, 2013:573). South Africa’s transformative forces dawned from the pre-1994 apartheid regime, but after more than two decades the spatial fragmentation is still taking it’s socio-economic and environmental toll (Drewes & Aswegen, 2012:25; Du Plessis & Landman, 2002:54; Landman, 2003:11). The following section captures the current infrastructure development in South Africa where GI planning has to be identified in.

4.3.1 South African approach to infrastructure development

The attempt to reconcile the pre-apartheid legacy of marginalizing spatial planning identities was futile. Du Plessis and Landman (2002:54) describe how pre-1994 spatial patterns of racial discrimination, changed the infrastructure distribution dramatically (Schäffler, 2011:70). Historically the socio-political changes of the post-1994 apartheid regime, created a transitional period for exponential growth in South African urban societies, especially in slums (De Jong, 2014:119). Today, after more than a decade has gone by, these pre-1994 spatial separations are expanding with rampant environmental degradations that follow (du Plessis & Landman, 2002:55; Giordano, 2014:485; Schäffler, 2011:80).

Roberts (2002:195) argues that metropolitan areas have expanded to include large parts of peri-urban, rural and tribal land, within city boundaries. A lack of a smart growth or compact planning approach is prevalent on South Africa’s spatial planning scenes (Brown-Luthango, 2010:135; Du Plessis & Landman, 2002:14). South Africa’s abundance in space per capita, is not adequately used to buffer urbanization, but rather accommodates urban sprawl. This develops wasteland uses which burden the demand for extended grey-green infrastructure provisions in a disorganized structural layout (Schoeman, 1999:3; Smith & Stirling, 2009:16). Cilliers *et al.*, (2013:693) elaborates that poor suburbs (a common occurrence in South Africa) have less public green spaces, which results in poor ecosystem service provision when compared to the more

affluent communities. The effect of destructive and marginalized spatial settlement patterns is evident in the majority of city-regions within South Africa.

Giordano (2014:486) elaborates that the post-apartheid national government spheres are neglecting macroeconomic policy and structural adjustment through the unequal distribution of public infrastructure (public transport networks, activities, and modes). This overlooking of regional planning changes local livelihood spaces and opportunities by directing influencing access, mobility, and utility of resources. Disparities in South Africa's households to access public infrastructure are explained by Jaglin (2008:1901) as:

- a) Rigid and centralized municipal delivery systems, that creates backlogs in rapid demographic growth areas.
- b) Inadequate large-scale technology infrastructure, since quick fix solutions cripple financial capacities and exclude low-income, unsophisticated and/or uneducated societies.
- c) Detached spatial linkage of communities 'drivers. Which create "de facto" multiplication of private providers of different, profit and non-profit making, infrastructures.

Rural legislative development, from the South African government, has been stated by Du Plessis *et al.*, (2014:253) as driven mainly by the Rural Development Framework (RDF) and Comprehensive Rural Development Strategy (CRDP). "The RDF establishes a new development support system... consisting of a reformed communal tenure system; a democratised rural administration system; the establishment of a Rural Development Agency (RDA), with a development and a funding component; (MTSF) A Rural Investment and Development Financing Facility (RIDFF); the National Rural Youth Service Corps (NARYSEC); the Animal and Veld Management Programme (AVMP) (consisting of soil rehabilitation, the re-greening of the village space, and the deep congestion of the village space); the revitalisation of the rural towns and villages; and the River Valley Catalytic Programme (RVCP), which is 'a framework for integrating for water planning and management with environmental, social and economic development along the river banks (watershed development)" (Du Plessis *et al.*, 2014:253). In theory, various rural initiatives are set. However, the practical application and implementation of the legislative framework, is an issue in developing countries, with South Africa being no different. Initiating the potential of GI planning in RPU areas can set many of these rural initiatives in motion in order to accomplish sustainable infrastructure development.

Infrastructure development in South Africa has undergone major systematic shifts. Department of Agriculture, Forestry and Fisheries'(DAFF's) Strategic Plan for the period 2013/14 to 2017/18 has been aligned to the national transversal policy framework. This policy framework consists of the National Development Plan (NDP), the New Growth Path (NGP), the Industrial Policy Action Plan 2 (IPAP2) and the decisions of the Presidential Infrastructure Coordinating Commission (PICC). It has four key focus areas, promoting food security, such as smallholder farmers and

cooperatives, agro-processing, access to forestry resources, and access to fisheries (including marine and inland aquaculture) (Du Plessis *et al.*, 2014:252; South Africa, 2015:7). This rural infrastructure investment is streamlined through Strategic Infrastructure Projects (SIP) as presented in Annexure two, such as “storage, transport (roads, branch train lines, ports), irrigation, processing facilities (abattoirs, dairy infrastructure), aquaculture, tourism, hospitals, other public health facilities and nursing colleges” (Giordano, 2014:491). Infrastructure in South Africa is based on “grey” built space, which does not equally value the spatial integrity of GI, to uphold settlement structures surrounding such built spaces. GI planning in RPU areas provides the spatial integrity required in order for infrastructure development to include landscape ecosystem services in protection and conservation planning. To identify the potential of GI planning in RPU areas, will assist in such multi-scaled decision making as being the first step for integrating larger urban development frameworks into strategic environmental plans.

Drewes and Aswegen (2012:27) conclude that South Africa tends to invest infrastructure, usually when a bottleneck is dealt with, due to private sector investment. South African infrastructure development, as with many other developed and developing countries, instigate such investment through economic growth and physical structural change (Cobbinah *et al.*, 2015:26; de Wit *et al.*, 2012:44; SA Cities Network, 2015:67; UNDP, 2014:26). Spatially addressing green infrastructure, as a factor in decision-making, has to compliment or compete within such socio-economic competitive surroundings. Through using the potential of GI planning, the development direction can be intensified to increase competitive advantages of the collective grey-green infrastructure approaches for the overall infrastructure development. However, this current study only identifies the potential of GI planning on a sub-regional district scale regarding the South African background for infrastructure development from RPU informal settlement regions.

4.3.2 South African rural and peri-urban infrastructure and settlement challenges

South African rural households, located in traditional, informal or rural regions, have a close relationship with urban migration. This is either from differing income regions to find employment, or from one metro to the next (Posel & Marx, 2013:820; Richards & Taylor, 2012:7). Such places create pressure on cities ‘natural resources. Especially in metropolitan areas, where informal settlements function as a highway for travelling members of the poor society. When comparing South Africa’s rural development and planning challenges with that of other African countries, similar issues occur regarding settlement challenges such as un-secure tenure systems (Richards & Taylor, 2012:8). With the influence of agriculture, South Africa’s Land Tenure Security Policy for Commercial Farming Areas 2013, focuses on farm dwellers and farm workers ‘relation to land tenure security and land reform rights (Du Plessis, 2014:254). Identifying the potential of an area for GI planning implies that the specific regions will be identified to further investigate issues such as un-secure tenure systems to advance environmental stewardship responsibility to communities having high migration rates.

StatsSA (2016:19) states that South Africa's population account for over 55 million people. As this dissertation deals with informal settlements, the influence of immigration has spiked in 2015. Most of these immigrants come from the Congo, Mozambique or Zimbabwe, and changed informal settlements dramatically (StatsSA, 2016:53). The Census of 2016 illustrates the distribution of household types, the majority being formal dwellings. Almost 13% informal dwellings, 7% traditional dwellings and some, unspecified, dwellings occupy South African borders (StatsSA, 2016:72). These households struggle with water connections, with over 1,7 million households having no access to piped water, and over 45% of South African households with only access to piped water outside their dwelling units (StatsSA, 2016:66). This is evident pressure on municipal service delivery of resource that implies higher dependability on surrounding natural resource. Identifying the potential of GI planning in South Africa can be a spatial planning approach that initiates a nature-based solution to decentralize municipal service delivery in the long term.

Sanitation is another issue in settlements as StatsSA (2016:71) shows that 49.5% of all households only have toilets in the yard, and only 4.9% has a toilet outside the yard. Adding to such waste matters is refuse removal. Municipalities struggle, either because informal settlements and traditional dwellings have their own refuse dumps (mostly illegal) or because, if removed by the municipality once a week, access to the RPU informal settlement road is difficult (StatsSA, 2016:76). Planning for open spaces is a multi-beneficial aspect of humans and nature. The potential of GI planning can lead to further measures as to mitigate such urban pressures through spatial land use scales of grey-green continuums (see Annexure four).

South African rural and peri-urban areas differ from its urban counterpart, especially regarding land use types and the provisioning of basic municipal services to human settlements. Due to weaker infrastructure services provided for informal settlement regions, in rural and peri-urban areas, there is a higher dependency on local natural resources. This weakens the open spaces of rural areas versus those of functional and accessible infrastructure from urban areas. Rural areas have a larger capacity of natural resources than peri-urban areas, but the spatial distribution of rural informal settlement densities, compared to peri-urban areas which are much wider. Identifying the various RPU informal settlement challenges as mentioned before has a major impact on infrastructure development that must be mitigated through spatial and environmental legislation to tailor GI planning into the development process. The following section covers the spatial and environmental planning legislation background for South Africa regarding GI planning

4.3.3. South African environmental and spatial planning legislation

The Constitution (South Africa,1996:1251) states that humans have the right to a "harmonistic environment for current and future generations, that prevent pollution, ecological degradation, promote conservation, secure ecologically sustainable development and use natural resources while promoting justifiable economic and social development". Van der Bank (2012:28) states that

the constitutional mandate for local government is focused on “developmental local government”. The White Paper on local government (1998) describes it as working with citizens and groups, within the community, for sustainable and quality livelihoods. Identified GI planning should in no wise go against countries written Constitution. GI planning is flexible enough to be tailored specifically for a countries context such as with South Africa, without compromising the spatial integrity of GI as a concept.

Strydom and King (2009:22) state that environmental legislation cascades directly from Section 24 of the Constitution (1996) of environmental rights, and indirectly as *inter alia* in the right of access to information and the right to administrative justice. Strydom and King (2009:25) add that most of South Africa's environmental laws and policies, adopted after 1996, explicitly mentions the fact that municipalities, provincial and national authorities, should “join forces across and within the three spheres of government in pursuing these laws' and policies' for sector-specific objectives”. Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA), a national act almost 20 years after the Constitution, is among the few to promote these joined forces in spatial land use planning.

In the following sections, South African legislation will be handled in relation to international, national and local levels. GI, as viewed in this dissertation, has not been integrated into South African multi-governmental structures or legislative frameworks, but occurs partially in South African law. Those pertaining to the planning of wetlands, biodiversity, forestry, agriculture, coastline management, climate change, disaster management, waste management and air quality regulation - to name but a few (see Annexure eight and 11).

4.3.3.1. International law impacting on the South African context

Du Plessis (2008:70) states that instruments of International Law (IL), illustrated in Annexure nine, pertains to “soft law” instruments. These bring guidance through international direction, with an end result of guiding local authorities (municipalities) in the environmental context. The IL instruments, in Annexure nine, were chosen based on their relevance to GI planning, operating in a developing country context. Meaning, various European types of IL has not been included. The IL instrument reflects some of the historic development in South African environmental management as well as spatial planning legislation. Such an overview of IL is given as to provide the planner over the potential of GI planning the South Africa environmental legal direction that shapes South African contextual GI planning application of identified GI planning potential. The following research theme will be used to assess each legislation’s compatibility.

The research theme: GI (as defined in Section 3.5.2 by Benedict and McMahon (2012:3) and Ahern *et al.*, (2014:256)) in rural and peri-urban informal settlements specifically for strategic spatial planning. On the basis of this theme, portions of each law will be referenced and have a direct or indirect contribution to the development of potential GI planning relations in South Africa.

Annexure nine represents IL that has influenced South African environmental management and spatial planning, from various developing and developed country paradigms. Human development and national levels of community equity from individual to settlement products and services were derived from IL (Department of Environmental Affairs and Tourism, 1997:15). The post-apartheid era shows various contributions of the UN to guide sustainable development frameworks in South African legislation. Such legislation is filtered down to the national level, to become more specific to the country's context. National legislation in South Africa has, historically, met various political issues that hindered environmental management with spatial land use planning. The following sections share more detail about national legislation that influences aspects related to the GI planning research theme.

4.3.3.2. National law guiding GI Planning in South Africa

Annexure 10 cites various South African treaties and resolutions of international organisations that have a direct impact on the management of environmental affairs at a national level, as Strydom and King (2009:81) explains. For instance, the “ratification of the Convention on Biological Diversity provided the impetus for the development of a national biodiversity policy and strategy” (illustrated in Annexure 10). Various legislative changes have been institutionalized after the 1994 apartheid era, to try and mitigate past socio-political abuse of legislation. Schoeman (2011:109) portrays applicable environmental management, spatial planning and land use management policies, legislation, and guidelines, which can be used to reflect possible influences for GI planning on local, provincial and national levels. As GI planning covers a broad spectrum of spatial development, each legislative act, policy, or guideline will not be referenced. Further investigation into applicable laws, related to a specific section of GI, is recommended for developing GI planning potential.

The national legislation (NL), as seen in Annexure 10, gave way to various development frameworks that relate to this dissertation theme. To name just a few: the Urban Renewal Programme, Municipal Infrastructure Grant, Reconstruction and Development Programme (RDP), Growth, Employment and Redistribution Strategy (GEAR), and the Integrated and Sustainable Rural Development Strategy (ISRDS) (CWCI, 2006:3; De Jong, 2014:77; Schoeman, 2014:397). The national legislation covers a broad spectrum of development aspects, as pertaining to infrastructure and settlement structures. In other words, the national law can quickly become narrowly focused on a specific development procedure and disregard broader integration. Thus, as promulgated through SPLUMA, South African spatial planning and development are moving towards a more integrated planning direction (Cameron, 2015:12; Cilliers & Cilliers, 2016:38; SA CitiesNetwork, 2015:18).

In regards to South African spatial planning for the environment, NEMA (67 of 1998) reflects the multilateral basis needed in order to regulate the environmental management and development, in ways similar to SPLUMA (2013). NEMA (67 of 1998) has various sub-divisions, such as

National Environmental Management: Protected Areas Act, 2003 (Act 57 of 2003); National Environmental Management: Waste Act, 2008 (Act 59 of 2008); National Environmental Management: Air Quality Act, 2004 (Act 39 of 2004); National Environmental Management: Integrated Coastal Management Act, 2008 (Act 24 of 2008); and National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004). Each of these has specific policies and regulations. New to the legislative framework of NEMA (67 of 1998) is the Environmental Implementation and Management Plan (EIMP) (2015/2020). This plan covers biodiversity and heritage resources, oceans and coastal environmental management, climate change and air quality management, and chemicals and waste management, until 2020 on a national level. Annexure eight is an overview of the policies, acts of parliament, and regulations used in the formulation of the EIMP. Annexure eight gives a good overview of the vast legislation frameworks, operating in South Africa, to plan and manage the environments. Such broad spatial planning and environmental management legislation is mentioned in regards to comprehending the regional scale dynamics applied to identifying the conceptual underpinning of GI planning potential in this current study. The application of NEMA (67 of 1998) and SPLUMA legislation on identified GI potential will need further investigation, not addressed in this dissertation.

Lastly, in view of spatial infrastructure related to the environment, Strydom and King (2009:28) state that empowered by the Infrastructure Development Bill, the PICC SIP's is guided by selected ministers and steering committees as presented in Annexure two. Strydom and King (2009:29) argue the Bill disregards national policy commitments to environmental management and sustainable development, aiming only at the approval of SIP's. This is a troublesome aspect for upholding the spatial integrity of ecosystems within SIP's planned regions. Infrastructure development in South Africa is struggling to achieve a multilateral integrated governmental framework and hopefully, through SPLUMA a more integrated planning process will flow out or prepare the pathway for such developments (Cilliers & Cilliers, 2016:23; SA CitiesNetwork, 2015:28). GI planning potential is but basic steps to enhance SPLUMA's spatial strategic planning directives.

4.3.3.2.1. SPLUMA and GI planning

Du Plessis *et al.*, (2014:237) argue that the underlying idea of the Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA) is to revoke the Development Facilitation Act 67 of 1995 in favour of a uniform management system (Kruger, 2014:94). Although SPLUMA was enacted in 2013, various alterations occurred. For example, Chapter V and VI was unconstitutional and resulted in further publications in the government gazette (South Africa, 2015a:4). Five basic principles underpin SPLUMA's spatial planning and development. Namely, the principle of (a) spatial justice, (b) spatial sustainability; (c) efficiency; (d) spatial resilience; and (e) good administration (Du Plessis *et al.*, 2014:238). The first principle is especially pertinent to the land

reform process. Especially with respect to broadening access to land, both in rural and urban contexts (Du Plessis *et al.*, 2014:238; Ndlela, 2016:49; SA CitiesNetwork, 2015:20).

The change for local municipalities from SPLUMA is referenced by Ndlela (2016:49):

- Section 24 (1) of SPLUMA requires that, within 5 years of SPLUMA's enactment into the law of parliament, each municipality has to adopt a single land use scheme for its entire municipal area. Once this land use scheme is adopted and approved of, the land use scheme will have the force of law and must give effect to Municipal Spatial Development Frameworks (MSDF).
- All landowners, land users, spheres of government, and land developers will be bound by the provisions of this land use scheme.
- Municipalities will be required to establish Municipal Planning Tribunals (comprising of municipal officials and suitably qualified external persons, appointed by Council) to make decisions on land development.
- The Minister of the Department of Rural Development and Land Reform must monitor compliance with these requirements.

Spatial transformation is the main theme in SPLUMA and defines it as creating a platform for “tension-ridden planning-in-motion” that requires reinvention, re-imagination, and exploration“(SA CitiesNetwork, 2015:23). Du Plessis *et al.*, (2014:238) explains that the undertone idea of SPLUMA is to promote all future development frameworks to include persons and areas that were previously excluded (e.g. informal settlements, former homeland areas, and areas characterized by widespread poverty and deprivation). One of SPLUMA's approaches is to formalize the informal areas while protecting prime and unique agriculture lands, and promoting the effective and equitable functioning of land markets (Du Plessis *et al.*, 2014:238). GI planning conceptual underpinning falls in line with SA CitiesNetwork (2015:23) notion to SPLUMA as a multidimensional, open-ended and heterogeneously complex planning approach. The SPLUMA Act of 2013 provides the legislative strong-arm to integrate the potential identification of GI planning derived from the spatial and environmental influences of RPU informal settlement regions.

From the intra-municipal integration view of SDF's, Kruger (2014:95) argues, that the Integrated Development Plans (IDPs), adopted in terms of the Local Government: Municipal Systems Act (32 of 2000), will form the basis of municipal planning. According to the various municipal levels, the emphasis of preparing land use schemes is of utmost importance when addressing various spatial landscapes, infrastructure, and settlement aspects simultaneously (Cameron, 2015:21; Kruger, 2014:958). The Spatial Land Use Management Bill (SPLUMB) provides such a single national framework for spatial planning and land development, as illustrated in Table 4-1.

Alignment of identified GI planning potential will need to be planned and adapted in South Africa to integrate with SPLUMB development directives and multi-lateral municipal planning levels.

Table 4-1: SPLUMA influence on national spatial planning and land development

	National	Provincial	Local
Spatial planning	National SDF Regional SDFs	Provincial SDF	SDF (in line with MSA)
Land uses management	SPLUMA	Provincial Planning Acts	Municipal zoning schemes (wall-to-wall schemes)

Source: Adapted from South Africa (2012:15). SDF (Spatial Development Framework); MSA (Municipal Systems Act); SPLUMA (Spatial Planning Land Use Management Act)

To conclude, SPLUMA functions as a legislative strong-arm to direct from a national spatial planning view development direction that is more interconnected with bottom-up knowledge from local level municipality tribunals (Kruger, 2014:94; SA CitiesNetwork, 2015:46). GI planning needs to be mainstreamed into the South African SPLUMA integration of SDF's and IDP's if identified GI planning potential will have any weight in spatial land use developments. This means municipal planning tribunals, or whoever would delegate the GI planning process, aligned with the SPLUMA system, need to be transparent throughout the whole planning process in all strategic spatial planning matters (CitiesNetwork, 2015:29). National planning approval does not override municipal planning approval through SPLUMA. That puts local contextualization of infrastructure development such as GI planning, within reaching distance (Cameron, 2015:7). As identifying the potential of GI planning is not directly affected from IL, NL or provincial legislation, this study strategically identifies specific regions that should be further studied in the application of before mentioned laws specific to that region spatial and environmental context.

4.4 Strategic spatial planning of GI in SA RPU areas

GI planning spatial integrity aspect provides a strategic planning advantage in order to assist in the spatial reconciliation between humans and nature (Cilliers *et al.*, 2014:260–270; TEEB, 2010d:22). Understanding the strategic spatial planning aspect of GI planning is multi-beneficial on intra-governmental and private levels (Elmqvist *et al.*, 2015:105; Garmendia *et al.*, 2016:3; Naumann *et al.*, 2011a:54). This dissertation has differentiated between infrastructure as a concept versus the understanding of GI, as well as conventional grey infrastructure planning versus GI planning (cross-reference to section 3.6). Converting the potential of GI planning into practical spatial planning elements can mitigate serious challenges prevalent in South Africa, similar to other developing countries RPU areas, such as:

- urban transformation
- the threat to natural resources
- poor health conditions and food security
- Issues with safety and security
- social cohesion
- individual rights
- the poverty rates increase (Barau, 2015:286; Hambati, 2013:920; Kombe, 2005:127; Prain & Lee-smith, 2010:20).

The following aspects present further advantages of strategic spatial planning for GI planning to be used in a South African spatial land use planning context.

- A logical rule is that biodiversity does not attract habitats, but habitats enable functional biodiversity's or not. This makes GI planning fit for spatial resilience development as developing the space before addressing the species (Ahern, 2007:269; Roe *et al.*, 2013:650). By strategically matching ecological landscape capacity to settlement densities, RPU metabolic flows would naturally progress through time and space, fluctuating in quality and quantity between each geographic area (Weber *et al.*, 2006:97). Thus identifying the potential of GI planning provide insight to understanding the scale of potential influence and potential GI space to consider regarding GI planning. South Africa is no different in this matter as GI planning potential through GI planning principles provide enough flexibility to integrate such a planning process.
- Furthermore, rural and peri-urban farmers struggle under labour shortages, due to rural migration into urban economic sectors (with higher wages and living cost) or because of socio-political conflicts (Christoplos *et al.*, 2004:11; Clements *et al.*, 2011:6; Smith & Stirling, 2009:12). These trends are particularly observable among the younger generation, as agricultural livelihoods are regarded as backward and slow income generators (Brook & Dávila, 2000:134). A response to this problem is shifting to less labour-intensive crops, that in turn reduces the diversity and redundancy of resource management in RPU regions (Christoplos *et al.*, 2004:4; SRC, 2014a:11). Such population groups in RPU regions can benefit from socio-economic opportunities through grey-green continuums. Through local resource utilization, GI planning can simultaneously invest in local human livelihood capitals and relieve the vulnerability of the basic services of food, water, shelter and waste management (Milder *et al.*, Ingram *et al.*, 2012:85; Jones *et al.*, 2016:154). This dissertation provides the identification of potential GI planning, to provide better planning direction, in order to mitigate previously mentioned issues.

- Horizontal and vertical interconnectivity as well as the interrelationship of spatial scale is a prime challenge in urban to rural GI planning (Andersson *et al.*, 2014:448, 2013:68 Schäffler & Swilling, 2013:254, Tzoulas *et al.*, 2007:170; Young & McPherson, 2013:68). The large difference that GI planning brings, to strategic spatial planning, is that it takes the human element into consideration through a grey-green continuum (Andersson *et al.*, 2014:445; Mell 2014a:618). RPU areas have high-density neighbourhoods, which fragments and continue to disconnect bioregions because of unplanned built space, especially evident in developing countries (Barbosa *et al.*, 2007:187; De Jong, 2014:10). The adaptation in this current study, achieved through GI planning, is accomplished by the spatial integrity between humans and nature to restructure fragmented RPU interfaces (Benedict *et al.*, 2012:4; Foster *et al.*, 2011:2). The essence of GI planning's adaptive nature for this current study is the integration into RPU areas from a regional planning approach based on human and natural planning elements.
- Addressing RPU regions based on local knowledge is a valuable aspect of proper regional planning in GI planning development. Local knowledge inventories consist of identifying the needs of the community and the environment, in order to harmonize contextual development (Ahern *et al.*, 2014:258; Mayer *et al.*, 2012:58; Mell, 2013:155). GI planning contains numerous spatial assets, each with its own inception of relations. Strategic spatial planning combines the grey-green infrastructures of spatial knowledge inventories, in order to realize dynamic capabilities. These are essential for the beneficial theory of change (Ahern, 2011:341; Benedict & McMahon, 2001:15). Change is imminent when it comes to infrastructure and RPU areas. This places the emphasis on timeless qualities through GI planning.
- GI planning should monitor ecotones (transitional areas between specific ecosystems) and biotope networks, as socio-ecological indicators in RPU regions, to ensure regional planning that fits local contexts. SRC (2014:17) provides a MUD (Management Up-Down) solution: "covering developed and developing countries the driver to enhance green infrastructure come in multiple contextual solutions. Bank loans are given to building projects scoring high on green certification system (Japan), scientist and small fishers agree on vision and voluntary agreement to manage ocean territories (Chile), after a disaster hurricane in 1998 Honduras land management change to the household level leading, to equitable land distribution, and protected forests serving communities to cope with similar flooding 10 years later, and small-scale innovations of rainwater harvesting and conservation, tillage provides bountiful potential increasing on-farm productivity and ecosystem service outputs. Especially where poverty, and high vulnerability to climate change, affect inhabitants (Tanzania) ". Developed and developing countries have existing evidence of regional planning conducted by GI with long-term success.

Table 4-2 illustrates the main concepts in order to understand infrastructure as pertaining to this research. These infrastructure types are not categorized in any manner, however, a progression is stated from human-induced grey infrastructure towards human-induced green infrastructure in the form of green infrastructure planning. Understanding the use of infrastructure types will increase transparency in the development of each infrastructure, a much needed spatial planning element as seen from the South African spatial planning milieu.

Table 4-2: The dissertation infrastructure types and principle application

Infrastructure types	RPU example	Strategic planning principles
Anthropocentric Infrastructure	By humans: <ul style="list-style-type: none"> Built space/products (water canals, electricity lines, vehicles, settlement structures, roads, water pipes, farming equipment, dam walls) People types, skills, and group cohesion 	<ul style="list-style-type: none"> Embeddedness. An embodiment of standards. Built on an installed base Become visible upon breakdown
Ecological infrastructure (purely naturally related)	By nature: A specific landscape focused solely on the ecological value e.g. healthy mountain catchment, river, wetland, coastal dune, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements "in a" landscape.	<ul style="list-style-type: none"> Embeddedness. An embodiment of standards. Built on an installed base Become visible upon breakdown
Green infrastructure	From diverse landscapes by humans: <ul style="list-style-type: none"> Woodlands, dams, artificial waterbodies, field crops, hill crops, gardens across various landscapes From diverse landscapes by nature: <ul style="list-style-type: none"> Adapting soil types, river systems, wetlands, forest, rainfall, the wind, grassland etc. across various landscapes 	<ul style="list-style-type: none"> Time Place Landscape Table 3-8
Green infrastructure planning	By humans: <ul style="list-style-type: none"> Strategically placing infrastructure and green infrastructure to mutually benefit each other and the larger ecosystem sphere surrounding it. Utilizing the cycle in future planning of potential GI planning and determining the expansion thereof to meet the urbanizing needs. To limit the urbanizing growth through strategically built space planning and possible reconfiguration of existing grey to include "green" in a holistic sense of multifunctionality and inter-dependability. By nature: <ul style="list-style-type: none"> Adapting the natural cycles to function e.g. Nitrogen-, phosphor-, hydrological-, sulphur- and carbon cycle; the sun, the moon 	<ul style="list-style-type: none"> Table 3-8

Source: Adapted from (EEA, 2015:37; Dale *et al.*, 2000:648; Du Plessis & Landman, 2002:45; Miller & Spoolman, 2012:66-73; SANBI, 2016:1; Schäffler, 2011:96; Star, 1999:381)

4.5 Conclusion

The following lessons learned from this chapter are:

- African RPU regions cover broad spaces having high population densities commonly structure in relation to informal settlements, which fits ideally the identification of GI planning potential from RPU informal settlement.
- GI planning is not an end-pipe solution for infrastructure development and informal settlement challenges. The need to tailor GI planning approaches that integrate contemporary de facto planning and management may reach a higher degree of acceptability and community management. It's thus crucial to accurately establish the potential of GI planning stemming from such RPU regions to a strategically direct nature-based solution for developing countries urban metabolic challenges.
- South Africa's overall infrastructure development need to decentralize municipal service delivery through nature-based solutions that in the long term is self-regulating. Identifying the potential of GI planning on broad regional scales should be first steps to initiate the higher potential of ecosystem services to be protected and conserved for the sake of the environmental and the communities that depend on such regions.
- South African national legislation of SPLUMA and NEMA need to be tailored parallel in complimenting GI planning integration for South Africa spatial and environmental planning. Identifying the potential of GI planning has to be flexible enough to accommodate legislative directions as well.

CHAPTER 5: METHODOLOGY FOR IDENTIFYING THE POTENTIAL OF GI PLANNING IN RPU INFORMAL SETTLEMENT REGIONS

Figure 5-1 captures the structure of Chapter five.

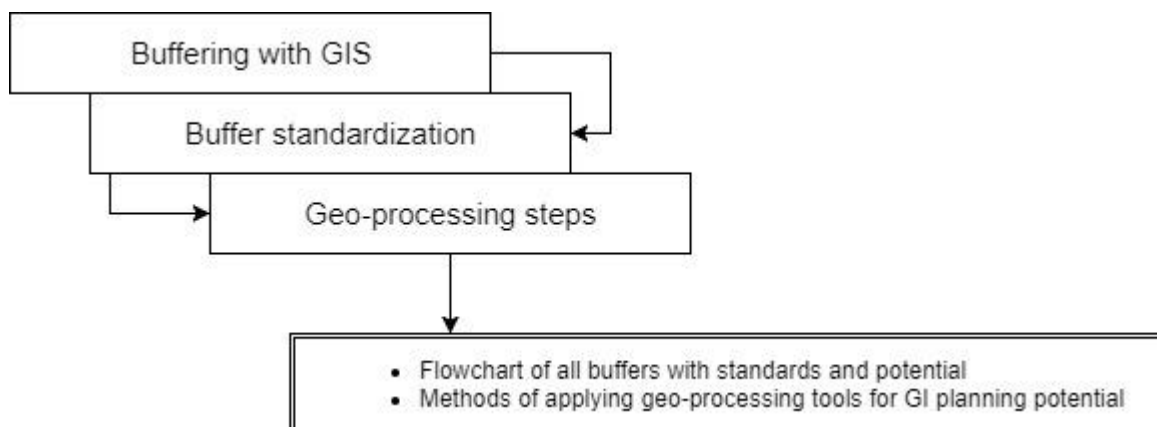


Figure 5-1: Structure for chapter five

Source: Created from Draw (2017)

5.1. Introduction

This dissertation deals with identifying the potential of GI planning based on the potential influence that these informal settlements can have on the requires space to protect and conserve established GI in the case study. The methodology used in this chapter can be duplicated in other developing countries RPU regions. GI differs globally in every geographic unit, and all GI planning principles are holistically applied, as not to narrow the focus solely to, for e.g. specific features of ecological distinctiveness. Constructing a model for each case study of GI planning is essential to grasp the anthropogenic-geographic uniqueness of any planning area.

Modelling land cover is fundamentally interlinked with scientific literature methods to conduct GI planning such as the integration of landscape data in Geographic Information System (GIS) formats (La Greca *et al.*, 2011:2195; Wickham *et al.*, 2010:192). Kambites and Owen (2006:489) acknowledge numerous strategic plans and policies for GI planning, which includes rural buffer tools through GIS to add the overall efficiency of spatial plans. Linking GI planning and GIS is part of most mainstream GI planning practice approaches. However, specific to the site-context numerous local limitation and boundaries will determine GI planning directions (Bobbins & Culwick, 2015:44; Norton *et al.*, 2015b:133; Rosa & Privitera, 2013:105).

Qualitative research also uses in GIS for this research, is defined by ESRI (2016:1) as using data that is classified or shown by category, not by amount or rank (for instance, soil by type or animal by species). Using data for vegetation types, river networks and other open space features brings a qualitative platform whereupon the integration of informal settlement as points represent the quantitative data of this research. The combination of qualitative and quantitative data, to identify

the potential of GI planning in RPU informal settlements, make this study GI planning highly adaptable. The locality of this dissertation is the eThekweni municipality of KwaZulu-Natal. Further geographic, settlement, and infrastructure contexts have been explained in Chapter 4 and Section 6.2.

This research will use the MOSS regions (provided by the eThekweni municipality) against the influence of informal settlement distribution in RPU areas. Note that in this empirical study, the MOSS areas with river networks bears the best resemblance to existing GI in the eThekweni municipality case study. However, the strategic placing and development direction for MOSS areas with river networks is seen as “GI planning” potential and not only as GI. Identifying the potential of GI planning is seen as determining the strategic spatial direction of the current MOSS areas and river networks in relation to the spatial influence of RPU informal settlements.

This chapter deals with the methodology of the case study to identify the potential of GI planning in RPU informal settlement areas of South Africa. The contextual background that is underlying in this empirical investigation, regarding urban-rural concepts, is provided in Section two, green and grey infrastructure descriptions in Section three, and how prepared South Africa is for GI planning, in Section Four. This chapter incorporates a unique approach not commonly observed in GI planning regarding the potential GI identification from RPU informal settlement. The following section elaborates on the purpose of using GIS buffering in the identification of potential GI planning.

5.2. Buffering with GIS

Macfarlane *et al.*, (2015:1) define a buffer zone as “a strip of land with a use, function or zoning, specifically designed to protect one area of land against impacts from another”. Protect does not necessarily mean the exclusion, prohibition or separation of built infrastructure as referred to the multi-beneficial nature of grey-green continuum from GI planning as explained in Chapter three. Wickham *et al.*, (2010:186) argue that a significant area of GI research, is related to the identification and mapping of ecological networks that cross socio-economical networks as well Spatial planning needs a deepening of an ecological fix, which is rooted in GI (Scott *et al.*, 2013:563). Understanding buffers is a fundamental link between taking GI theory to more practical application ventures.

The Nature Conservancy (2015:1) defines ecological buffers as “protected zones established around sensitive or critical areas — such as wildlife breeding or hibernation habitats, streams, and wetlands — to lessen the impacts of human activity and land disturbance.” GI planning utilizes such buffering tools to strategically integrate principles for the effective strategic spatial planning of GI. Buffers have long been used in land-use planning to protect natural resources and limit the impact of land use mixes (Macfarlane *et al.*, 2015:iii). As GI and its associated networks fall into a strategic approach, decisions for conservation, protection, and restoration is built from the

information retrieved from buffer analyses. Defining ecological buffers, which are more specifically used for GI, will not compensate for habitat scarcity and fragmentation, but will help protect the remnant of natural heritage features with associated functions. A spatial character of ecological buffers similar to humans is that ecology function in habitats that crosses urban and rural land uses (Henshaw & Ursic, 2012:5).

Ecological buffers have been labelled as protection zones, vegetation protection zones, or vegetation filter strips. But ecological buffers do not equate to being setbacks, adjacent lands, or critical function zones (Henshaw & Ursic, 2012:5). Jiang *et al.*, (2016:1324) explain that ecological control lines (including ecological red line and ecological buffer zones) with construction land use control lines delineate ecological and urban spaces, respectively. The use of ecological buffer zones is a diversified concept that slots into the larger framework of environmental management.

Ecological buffers are not structures, but the necessary platforms for habitat and ecological connectivity (Bentrup, 2008:49). The assessment of ecological buffer effectiveness is very challenging. Yongzheng *et al.* (2016:26) and Jiang *et al.* (2016:1324) state that ecological control lines are used with rapid urbanization, and these lines function as long-term spaces in managing urban development. Ecological buffer zones function as a spatial tool, to reflect Ecological Importance and Sensitivity (EIS) assessment results, and are based on the Present Ecological States (PES) (Scott-Shaw, 2016:12; Yongzheng *et al.*, 2016:26).

The width of buffers generally differs from fixed, to modified, to variable width, with modified fixed-width being the generally accepted approach in South Africa (Macfarlane *et al.*, 2015:5). De Wit *et al.*, (2012:42) incorporate valuation techniques, for natural hazard regulation, through buffering ecosystem services in order to better understand the capacity of ecosystems in South Africa. Krasny and Tidball (2009:464) discuss social-ecological buffer advantages, for resilience integration of GI planning. But for this dissertation, the goals and objectives are based on buffer standards, directed to landscape vegetation types and informal settlement points.

Several spatial landscape studies have used buffer analysis to determine spatial planning of green open spaces, ecological buffers of human interactions, and buffer zones for natural habitat conservation and protection (Anderson *et al.*, 2012:4; Landman, 2003:29; Schäffler date and page?, Bobbins, *et al.*, 2013:72). Xiang (1996:8) and Mas (2005:79) agree that buffer zones can be cost-effective, and can assist with the rapid assessment of the effectiveness of a protected area. This dissertation uses buffering on district scales, to identify informal settlement influence on the adjacent environment. As this current study evaluates informal settlements 'influence on strategic spatial planning, the generalization of informal settlement and MOSS types only simplifies mapping, but in no way can this current study direct local spatial planning decisions.

5.3. Buffer standardization

This research provides a South African context for identifying the potential of GI planning and informal settlement relation, that is unique to South Africa's spatial planning literature. The inclusion of buffers differs in source references, mainly because GI planning does not have mainstream buffer standards for South African GI typologies. Nor does eThekweni provide enough buffer standards to identify GI potential. External buffer standards were integrated in order to include a wider sense of the influence that informal settlements may have on GI and how different buffers reflect different protection and conservation of GI areas. Annexure 12 provides buffer standards that were not able to be used in this research but be acknowledge as to increase the GI planning complexity. First, the provincial and thereafter the international buffer standards used for this research will be explained.

KwaZulu-Natal is located in a biodiversity hotspot with global importance, making the protection and conservation of fauna and flora essential for the regulation of different authoritative parties (Driver *et al.*, 2015:2; Mclean *et al.*, 2016:9). The eThekweni municipality's Department of Environmental Planning and Climate Protection Department (EPCPD) as well as the provincial Ezemvelo KZN wildlife organization provided buffer standards for certain open spaces (eThekweni Municipality, 2017:105; Ezemvelo KZN wildlife, 2013:14-17; Mclean & Ground, 2016:13; Roberts *et al.*, 2012:173). Table 5-1 illustrates some of these buffer standards, regulated in KwaZulu-Natal regions as these regions relate to GI. Each buffer decision was based on the provided buffer standard, but where a flexible buffer width was given with the minimum and maximum values these values were added together and divided to get an average to use as a buffer standard for this dissertation.

Table 5-1: GI buffer standards found regulated in the KwaZulu-Natal region

Type of open space	Buffer description	Buffer decision	Reference
Critically endangered, endangered or vulnerable forest types	100 m	100m	Ezemvelo KZN wildlife (2013:14-17)
D'MOSS	No development inside D'MOSS	Original shape area	EPCPD (2016:1)
Drainage lines	20m	20m	Ezemvelo KZN wildlife (2013:14-17)
Forest	40m buffer from the canopy dripline	40m	EPCPD (2016:1) Scott-Shaw & Lancelot (2016:21)
Riverine (perennial/Non-perennial)	1:100 year flood line with 20m	20m	Ezemvelo KZN wildlife (2013:14-17)
Rivers and streams	10-40 m	$(10+40)/2=20m$	EPCPD (2016:1)
Drainage	20m	20m	EPCPD (2016:1)
Wetland	30 m	30m	Ezemvelo KZN wildlife (2013:14-17) Scott-Shaw & Lancelot (2016:21)
Major rivers	100	100m	(Escott <i>et al.</i> , 2016)

Source: Adapted from Ezemvelo KZN wildlife (2013:14-17), EPCPD (2016:1) and Scott-Shaw & Lancelot (2016:21)

The inclusion of international buffer standards illustrated in Table 5-2 assisted, in various ways, with the identification of GI planning potential. Firstly, some of these buffer standards provided more insight into different types of GI that needed to be buffered against human influence. Secondly, some types of GI was not fully covered by the KwaZulu-Natal's regulated buffers, but international buffer standards were more effectively addressing the complexity of GI. Lastly, by adding international buffer standards that are scientifically approved illustrated in Table 5-2 that compliments South African buffer data, a better understanding of similarities and differences in buffer standards of similar GI types, is made clear.

Table 5-2: International buffer standards related to green infrastructure

Vegetation type		Buffer description	Buffer decision for case study	References
Wetlands		*31-40 m	$(31+40)/2=35$	Beacon Environmental Ltd (2012:138)
Upland woodlands and forest		*21-30 m	$(21+30)/2=25$	Beacon Environmental Ltd (2012:138)
Flood retention and stream flow regulation		20-70 m	$(20+70)/2=45$	The nature conservancy (2015:5)
Erosion and sedimentation control		15-50m	$(15+50)/2=32$	The nature conservancy (2015:5)
Stream temperature regulation		70m	$70/2=35$	The nature conservancy (2015:5)
Organic matter and large woody debris recruitment		10-100m	$(10+100)/2=55$	The nature conservancy (2015:5)
Riparian forest buffer		46 m	$46/2=23$	Troy and Wilson (2006:441)
Road class	Width buffer (m)	Influence distance(m)	Buffer decision for case study	Reference
A/primary	10	15	15m due to roads not being categorized	McPherson <i>et al.</i> , (2008:70)
B/secondary	8	15		
Other	4	15		
Standard Dimensions, Intensity and Influence Distance for Roads and Highways				

Source: Adapted from Beacon Environmental Ltd (2012:138), McPherson *et al.*, (2008:70), The Nature Conservancy (2015:5) and Troy and Wilson (2006:441)

Table 5-3 contains combined buffer standards to be used to identify the potential of GI planning in RPU informal settlement regions. The identified 30 square meters was proposed by McPherson *et al.*, (2008:70), and due to insufficient data about the spatial plotting of informal settlement residents 'survey, the integration of StatsSA's survey for the average households of 3.8, was used. Multiplying the influence areas of 30 square meter per person with the 3.8 average households from StatsSA, the influence area of 114 square meters, was created. This was applied to the informal settlement household points that were attained in GIS plotting.

Table 5-3: Combined StatsSA with McPherson *et al.*, (2008:70) human influence buffer standard

Population density (terrestrial) influence distance	Rationale
30m ² per person *3.8 household average=114m ² per household	This is an overall view of the impact people activities from population density can potentially have on marine environments. Because the dwellings are household orientated per person impact has been multiplied according to StatsSA (2016:61) stats of 3.8 average households in KwaZulu-Natal.

Source: Adapted from (McPherson *et al.*, 2008:70)

5.4. Geoprocessing steps

In ArcGIS, geo-processing tools were used to conduct the analysis, which identified the potential of GI planning in RPU informal settlement regions of the eThekweni municipality case study. Geo-processing entails single and multilayer analyses of the point, line, and polygon buffers and clips (GIS, 2008:109). Geo-processing overlays methods of intersecting, identity, and clips were used to refine data and buffer layers into representative maps (GIS, 2008:118).

The following section illustrates how buffer standards were applied to the eThekweni municipality case study, giving an overview of different buffering processes and providing the rationale for applying GI planning principles to this case study. The identified GI potential of each buffer type has been presented in Annexure 13. This Annexure is compiled into the following order of a full GI potential map for each buffer used in the case study, including a rural section, and a peri-urban section clearly recognizes RPU informal settlement's influence on different types of GI in the eThekweni case study. To create the identified GI planning potential was performed on the basis of applying GI planning principles, as explained in the following section.

5.4.1. Flowchart of all buffers with standards and potential

As explained in Section 5.3, the buffer types were not custom made to fit the available GIS data. Thus, the different data layers that represent GI in the eThekweni municipality, had to be sorted in order to effectively conduct the buffer analysis. Table 5-4, illustrates the sorted GIS data that was used to buffer the informal settlement and GI types for the potential influence of the informal settlement.

Table 5-4: MOSS layers group to make buffer analysis more effective

MOSS final layer	Included MOSS types
Forest	Woodland, Thicket, Forest
Agriculture	Field crops, Tree crops
Wetland	Freshwater wetland, Freshwater Wetland
Utility	Utility, Recreational
Major rivers	Major rivers, Estuary, Marine
Minor rivers	Minor rivers

Source: Authors creation (2017)

Dealing with buffer types, it can be argued, include only the larger buffer width. However, due to the source data differing from provincial and international standards, the various widths were used to provide a local spatial planner with the opportunity to assess individual informal settlement influences. It is important to note that the method of Figure 5-1 represents the potential identification of GI and not the strategical spatial planning potential, which is needed for GI planning. When the various GI planning principles are applied to this identified GI potential the result will be the identified GI planning potential.

After sorting the various data layers (such as vegetation types, river networks, informal settlement types, and road networks) the various buffer standards, of Table 5-1, 5-2 and 5-3, were applied as illustrated in Figure 5-2, which illustrates the various buffer types along with the various, overlapping buffer widths.

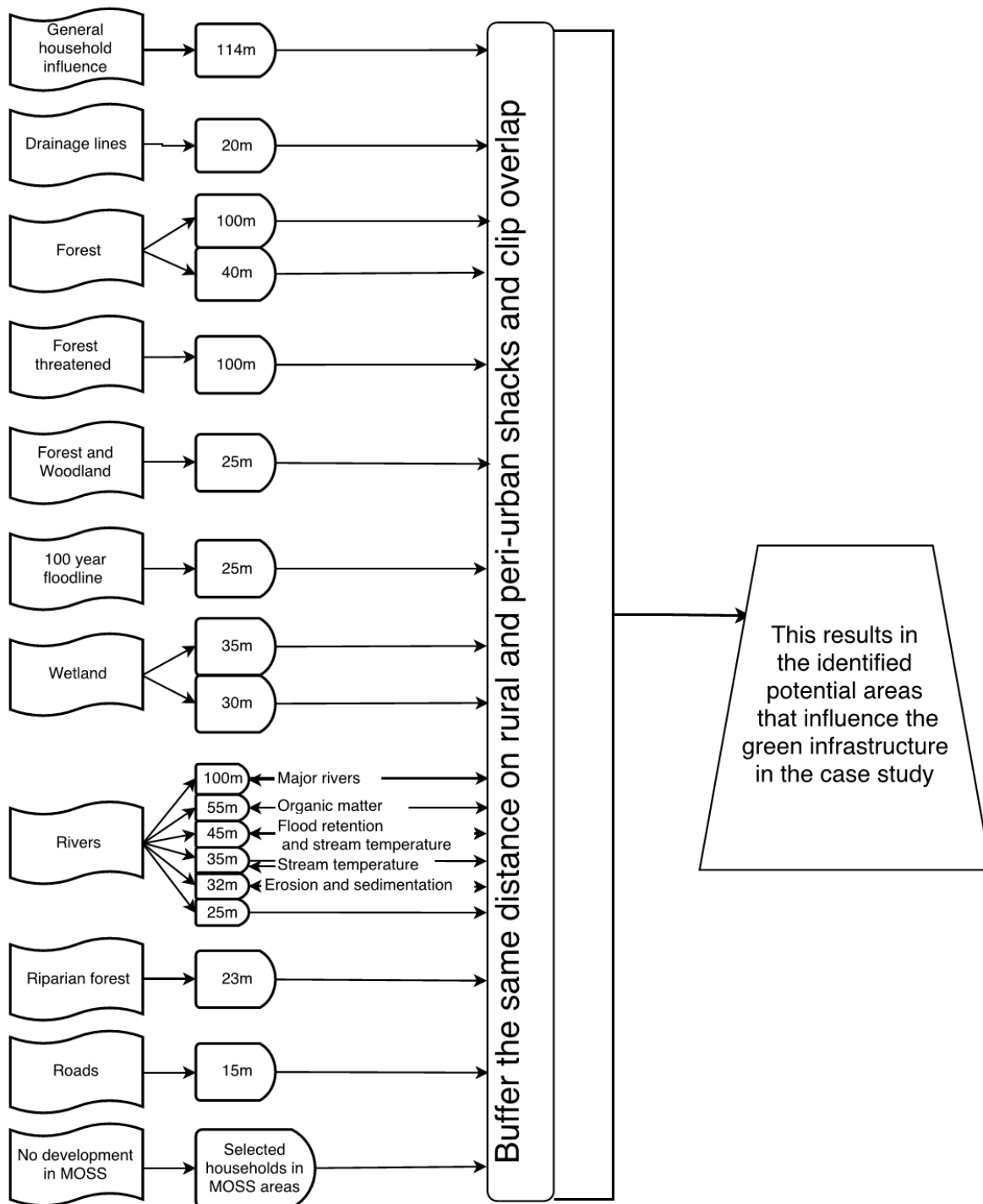


Figure 5-2: Overview of the different buffer approaches and categorized by type
 Source: Created from Draw (2017)

5.4.2. Methods of applying geo-processing tools for GI and GI planning potential

As shown in Section 5.4.1, there are different buffer standards used for this current study. The theme of this dissertation is the potential of GI planning in RPU informal settlements. This means that the potential influence that informal settlements could have had will be buffered by the identified GI in the case study area. As this current study does not evaluate the capacity of GI, only the potential thereof, there is more spatial flexibility in order to integrate GI principles. Eventually, the areas, strategically related to the informal settlement, that have been affected

could be identified and the potential space in the region, that needs conservation and protection, can be strategically understood. This will improve the rationality behind understanding what should be the desired transition steps to get from GI potential to GI planning potential through applying GI planning principles as explained in section 3.5.2.

5.4.2.1. Methods for identifying GI planning potential through the potential RPU informal settlement influence

Identifying GI potential from informal settlements, incorporates the transformation of data into usable units, without compromising the scale dynamics of informal settlement influence. The raw data of informal settlements are, in reality, only represented as points, but to comprehend the informal settlement's influence, the same buffer distance used to protect and conserve several MOSS types is placed on informal settlement points. In this manner, only the overlapping areas of the informal settlement and GI buffers are clipped in order to reflect the influence area, which informal settlements have on the potential GI buffer distances. The linear thinking necessary for the identification of GI potential is provided in Figure 5-3.

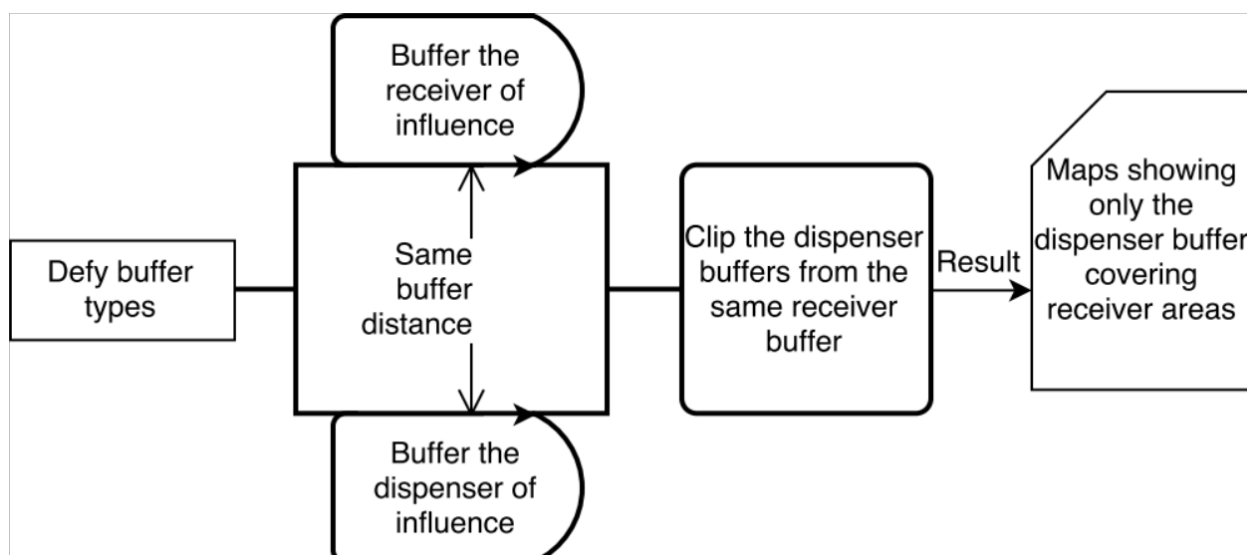


Figure 5-3: The thought process in identifying GI potential

Source: Created from Draw (2017:1)

As MOSS regions are defined as a set of different habitat types that needs to be conserved and protected. The Forest vegetation type will be used as an example of how this dissertation has applied buffer methods. In Figure 5-4, the Forest regions are selected within the case study boundary, however, this map only focuses on a section within the larger Forest area, for more clarity when explaining the methodology.

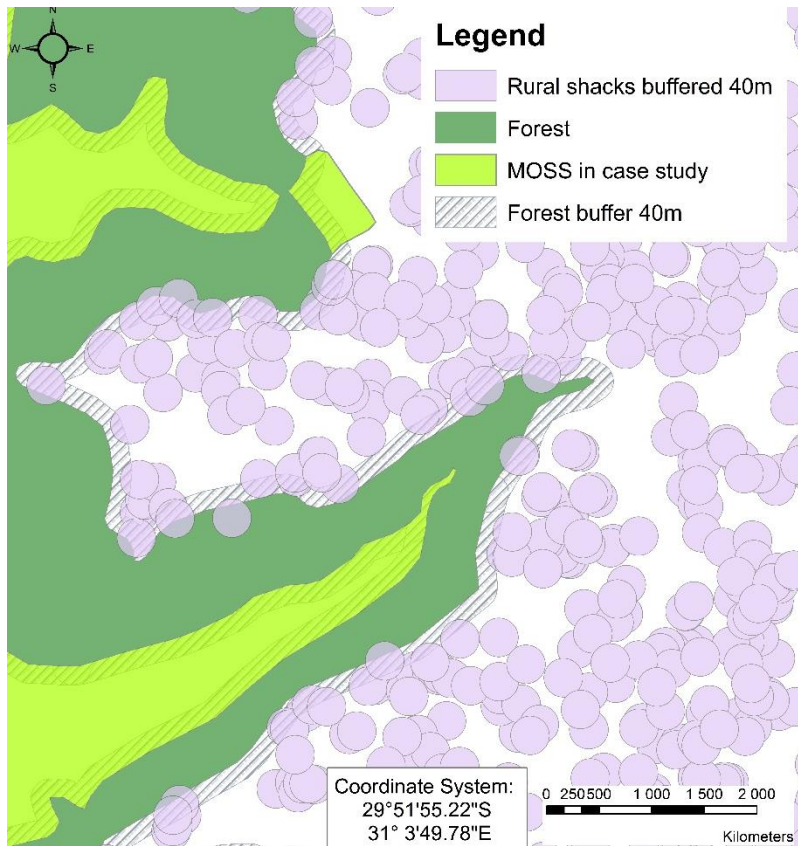


Figure 5-4: Example of Forest 40m buffer with RPU 40 m buffer shack influence unclipped
 Source: Author created through ArcGIS 10.4.1 (2017)

Figure 5-4 describes the first half of the flow diagram, in Figure 5-2, which resembled the buffer method applied to the Forest vegetation type, having a 40m buffer placed around the informal settlements. The following Figure 5-5 illustrates how the overlapping informal settlements that have 40m buffer distances, are taken from Forest's 40m buffer, that has been clipped. The informal settlements in red that are left in Figure 5-5 represent the current GI potential of RPU informal settlement regarding a 40 m Forest buffer influence of GI.

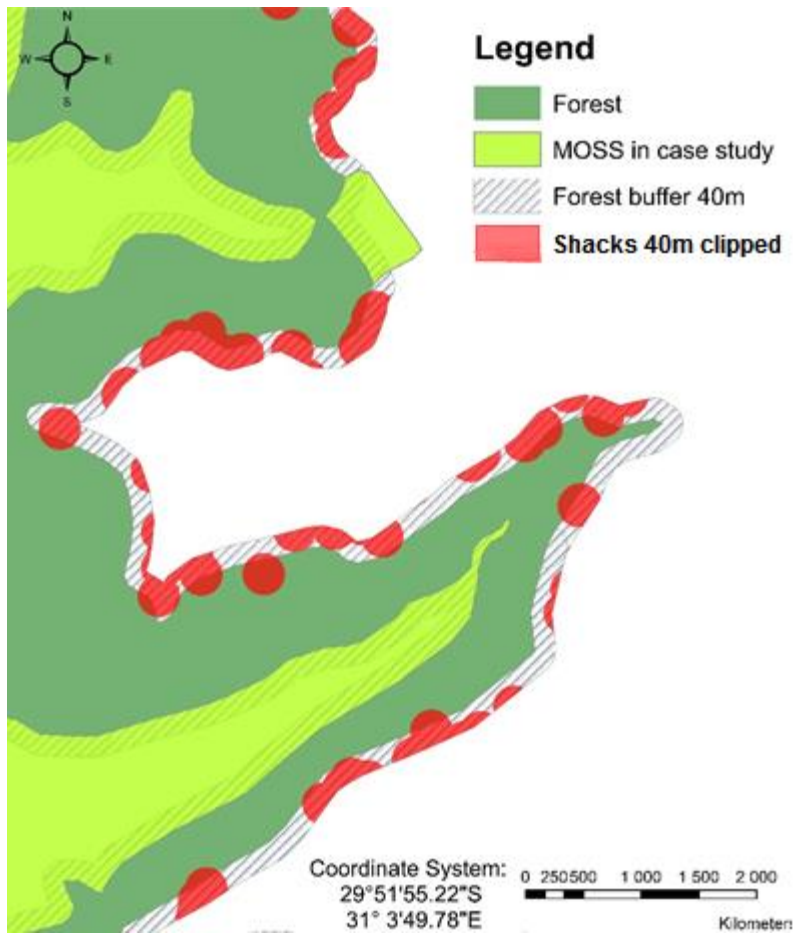


Figure 5-5: Example of Forest 40m buffer with RPU 40 m buffer shack influence clipped
 Source: Author created through ArcGIS 10.4.1 (2017)

Although each defined GI feature is buffered, only the RPU informal settlement buffer was clipped. This was to identify the potential influence of such a development as to meet the theme of this research. This approach is followed for each identified buffer standard type and has been used separately for the identification of potential GI planning of RPU informal settlement influence. The overlapping buffer sizes, which are projected over the same informal settlement (illustrated in Annexure 13 as individual maps), can create conflict with interpretation. Figure 5-6, illustrates the conflict of dealing with different buffer sizes on a single map.

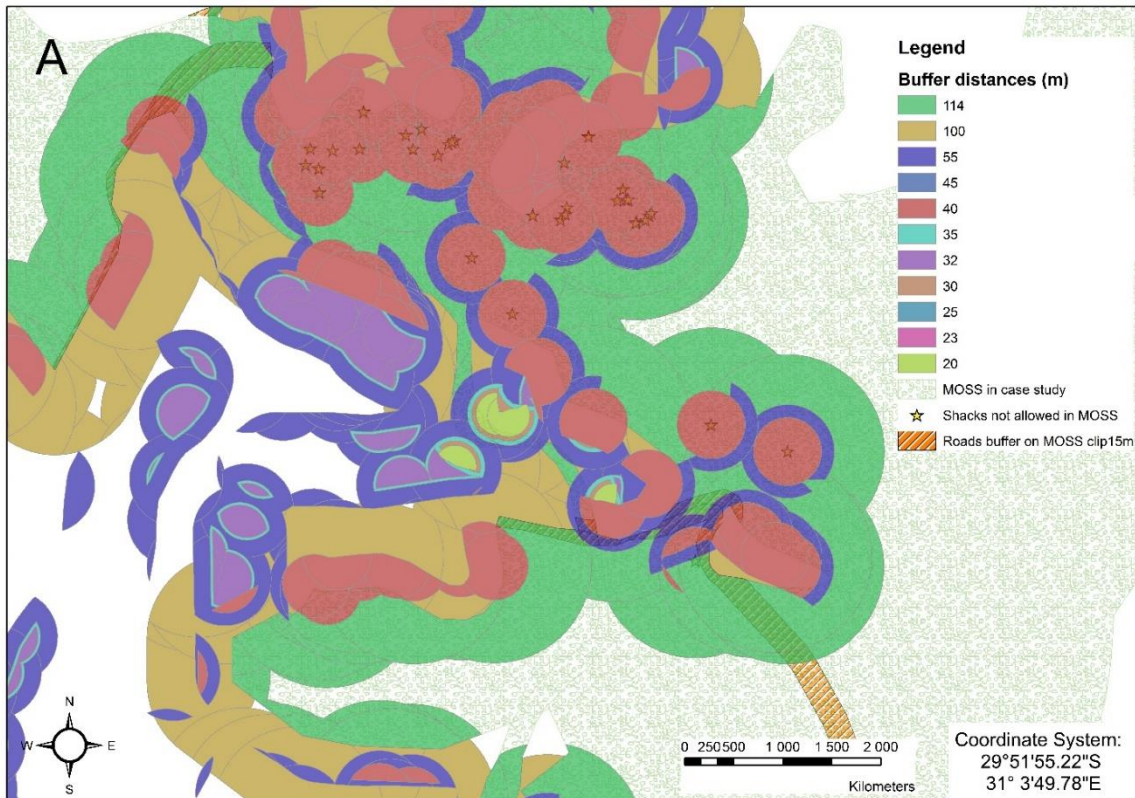


Figure 5-6: (A) Example of all buffer sizes on one map; (B) Generalizing of all buffer distances into a single colour

Source: Author created through ArcGIS 10.4.1 (2017)

Depending on the goal of the interpretation of the buffered area, the influence needs to be separated, combined, or partially combined with discretion. Figure 5-6 (A) illustrates all buffer

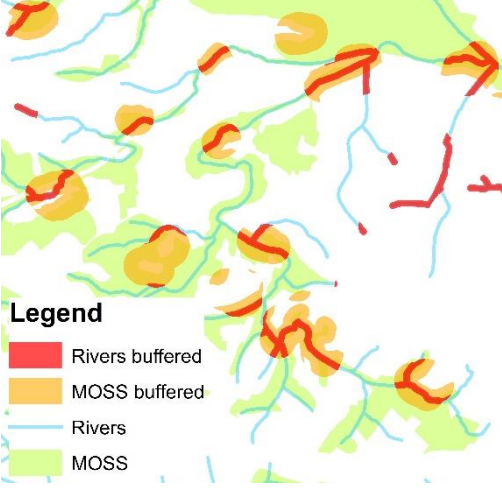
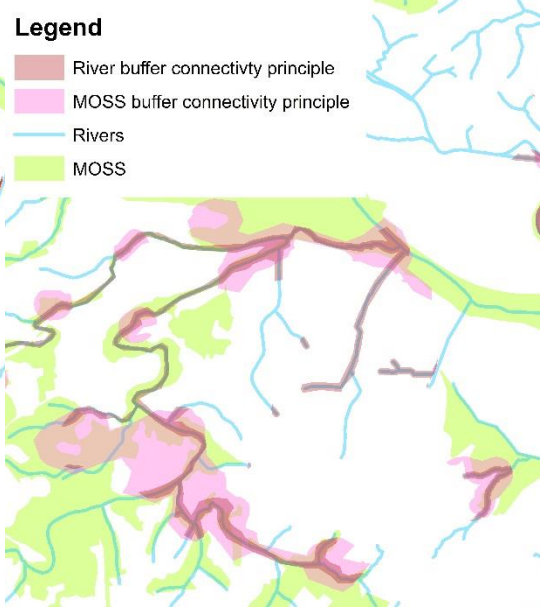
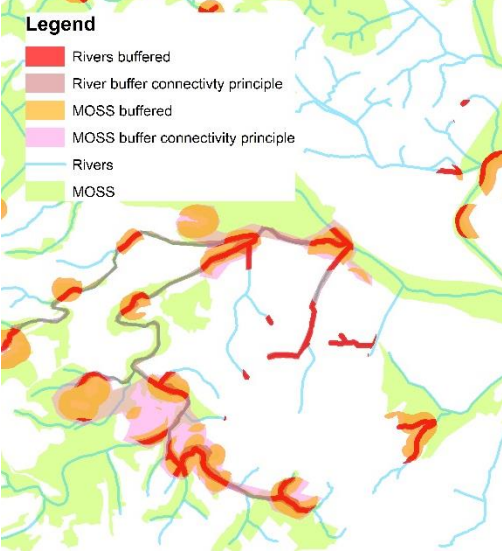
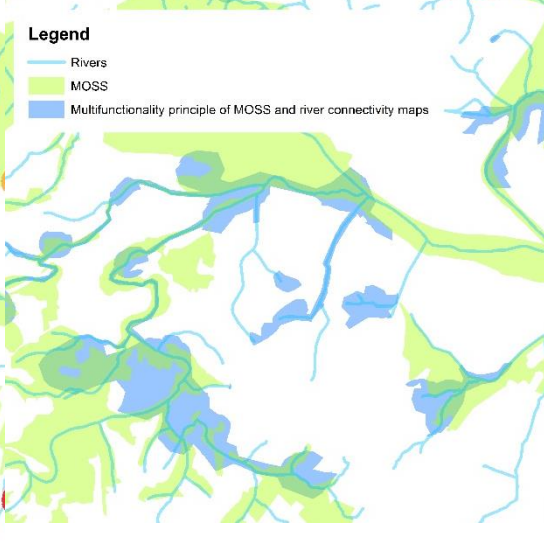
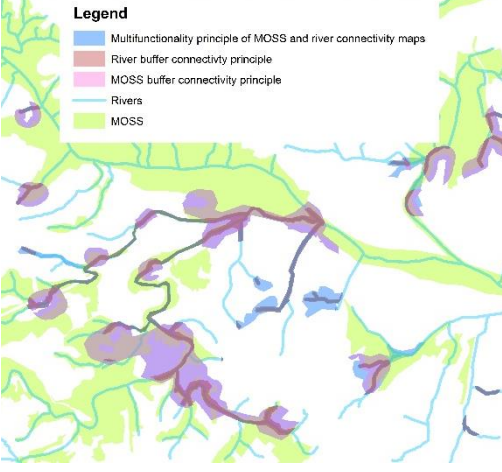
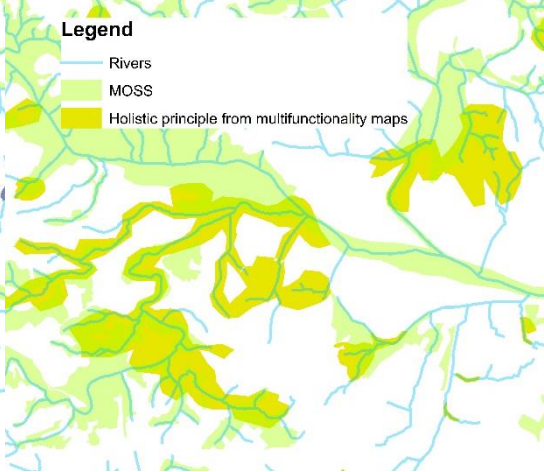
standards that were clipped as per Figure 5-2's flow diagram and was placed on a single map. Many of the influences cannot be seen in Figure 5-6 (B), because of larger buffer sizes overshadowing smaller buffer clips.

Converting such data into a single map generalizes all the buffer sizes. Figure 5-6 (B) is thus misleading if the goal is to understand the complexity of different influence boundaries. Integrating various buffer sizes into multiple maps provide a more effective manner to understand the influences of informal settlements on different GI types, as seen in Annexure 13. However, the aim of this current study is the identification of GI planning potential that functions on a regional scale of interpretation. As the potential, and not the capacity, should be identified, this current study has grouped the identified GI potential together in order to apply GI planning principles on that identified GI potential.

5.4.2.2. Applying GI planning principles method unto identified GI potential to create GI planning potential

Converting GI potential over to GI planning potential includes the transformation of GI potential to strategic spatial maps, which address the necessary spatial integrity through applied GI planning principles. In this manner, the following table (Table 5-5) illustrates the three main spatial principles that were used. Each principle was built upon the other in order to reflect the GI planning potential visually. Table 5-5 illustrates the methods used to identify and apply each principle in the context of the identified GI potential.

Table 5-5: Polygon adaptation method: GI planning principle application to GI potential

Principles	Principle scoping map	Principle applied map
Connectivity	 <p>Legend</p> <ul style="list-style-type: none"> Rivers buffered MOSS buffered Rivers MOSS 	 <p>Legend</p> <ul style="list-style-type: none"> River buffer connectivity principle MOSS buffer connectivity principle Rivers MOSS
Multifunctionality	 <p>Legend</p> <ul style="list-style-type: none"> Rivers buffered River buffer connectivity principle MOSS buffered MOSS buffer connectivity principle Rivers MOSS 	 <p>Legend</p> <ul style="list-style-type: none"> Rivers MOSS Multifunctionality principle of MOSS and river connectivity maps
Holistic, comprehensive etc.	 <p>Legend</p> <ul style="list-style-type: none"> Multifunctionality principle of MOSS and river connectivity maps River buffer connectivity principle MOSS buffer connectivity principle Rivers MOSS 	 <p>Legend</p> <ul style="list-style-type: none"> Rivers MOSS Holistic principle from multifunctionality maps

Source: Authors creations (2017)

Table 5-5 provides the illustration of how GI planning potential is identified through three GI planning principles, namely connectivity; multi-functionality; holistic, comprehensive, flexible and integrated, approach. The GI planning principle maps are built upon each other. In other words, to recognise the identified GI planning potential from the connectivity to the multi-functionality principle, there is a necessary increase in the spatial scale. An increase in spatial scale also occurs when the holistic principle maps are built from the multi-functionality maps. All additional polygons are manually drawn through ArcGIS 10.4.1 to include the strategic spatial rationale of each principle, specific in the context of the identified potential influence of RPU informal settlement.

Figure 5-7 illustrates an example of critical GI planning potential areas that were created through the connectivity principle, as illustrated in the approach of Table 5-5. This is only a portion of a larger map, used to show how the “to rust brown” influence areas of RPU informal settlement have corridors of clusters, and how a polygon was drawn over such major influence corridors. An illustrated high influence of informal settlement area of the ‘spatial distribution of the identified GI planning potential is presented through applying GI planning principles as a methodology.

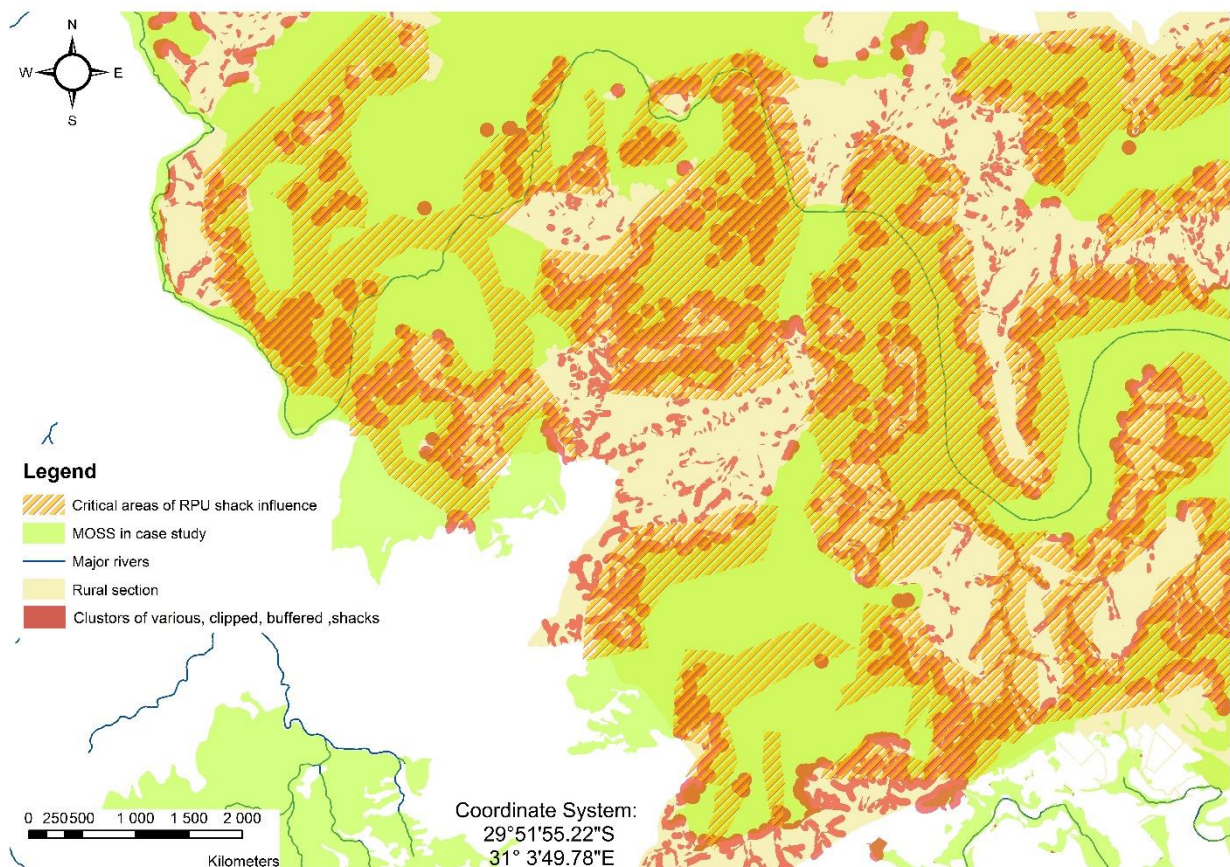


Figure 5-7: Critical RPU informal settlement influence from a connectivity principle viewpoint in the eThekweni municipality

Source: Author created through ArcGIS 10.4.1 (2017)

Figure 5-7 represents only a section of the entire maps that will be seen as the potential of GI planning in the eThekweni municipality case study. The linear thinking behind creating GI planning potential maps is illustrated in Figure 5-8. After creating these 36 maps (in Annexure 13) all the connectivity maps were merged into one final connectivity principle map, drawn from GI potential. Each individual influence, as illustrated in Annexure 13, was used to create the connectivity maps whereupon the multi-functionality principle was applied in order to produce the multi-functionality map. Thereafter, the final stage to integrate connectivity and multi-functionality maps were merged into one map. The holistic principle was applied to this merged map, in order to illustrate the largest spatial influence to be strategically integrated with GI planning principles. Finally three maps were created; namely, the connectivity, the multi-functionality, and holistic GI planning principle maps.

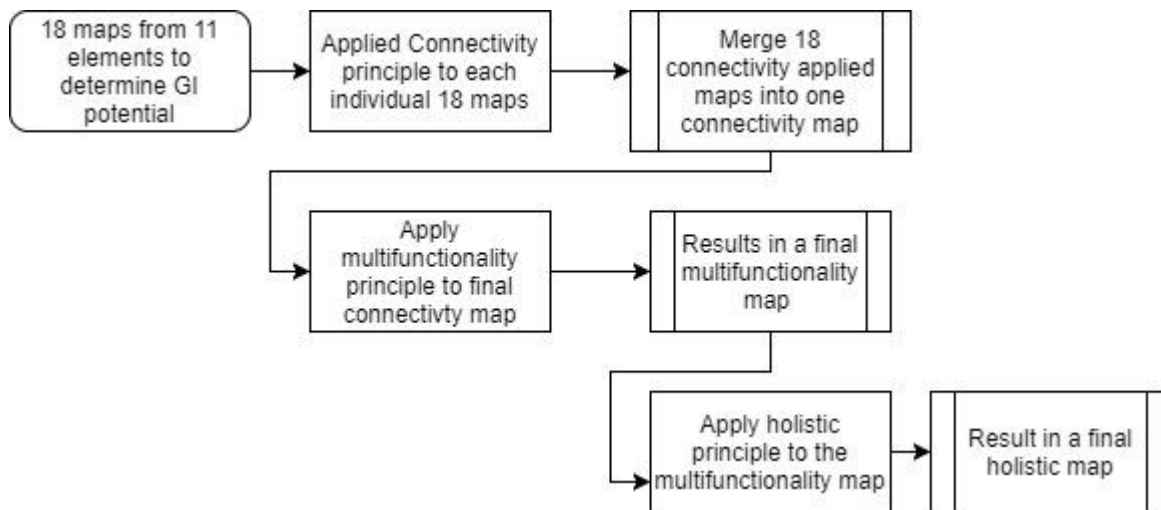


Figure 5-8: Linear thinking of the applied GI principle maps

Source: Author created online in Draw (2017)

5.5. Conclusions

Lessons learned from this section is:

- Data has to come from local resources of GI buffers and informal settlement influences but needs to be flexible enough to adapt to strategic spatial planning.
- GIS modelling provides adequate tools for a methodological process to identify GI planning potential from quantity data of informal settlement households against qualitative data of vegetation types and GI planning principles.
- The methodology in itself is limited due to incomplete data of the contextual influence of specific informal settlement influences of the eThekweni municipality against the specific buffer standards of the KwaZulu Natal GI regions.

SECTION B: EMPIRICAL STUDY

Chapter 6: Identifying GI potential in eThekweni municipal RPU informal settlement areas

Figure 6-1 captures the structure of Chapter six.

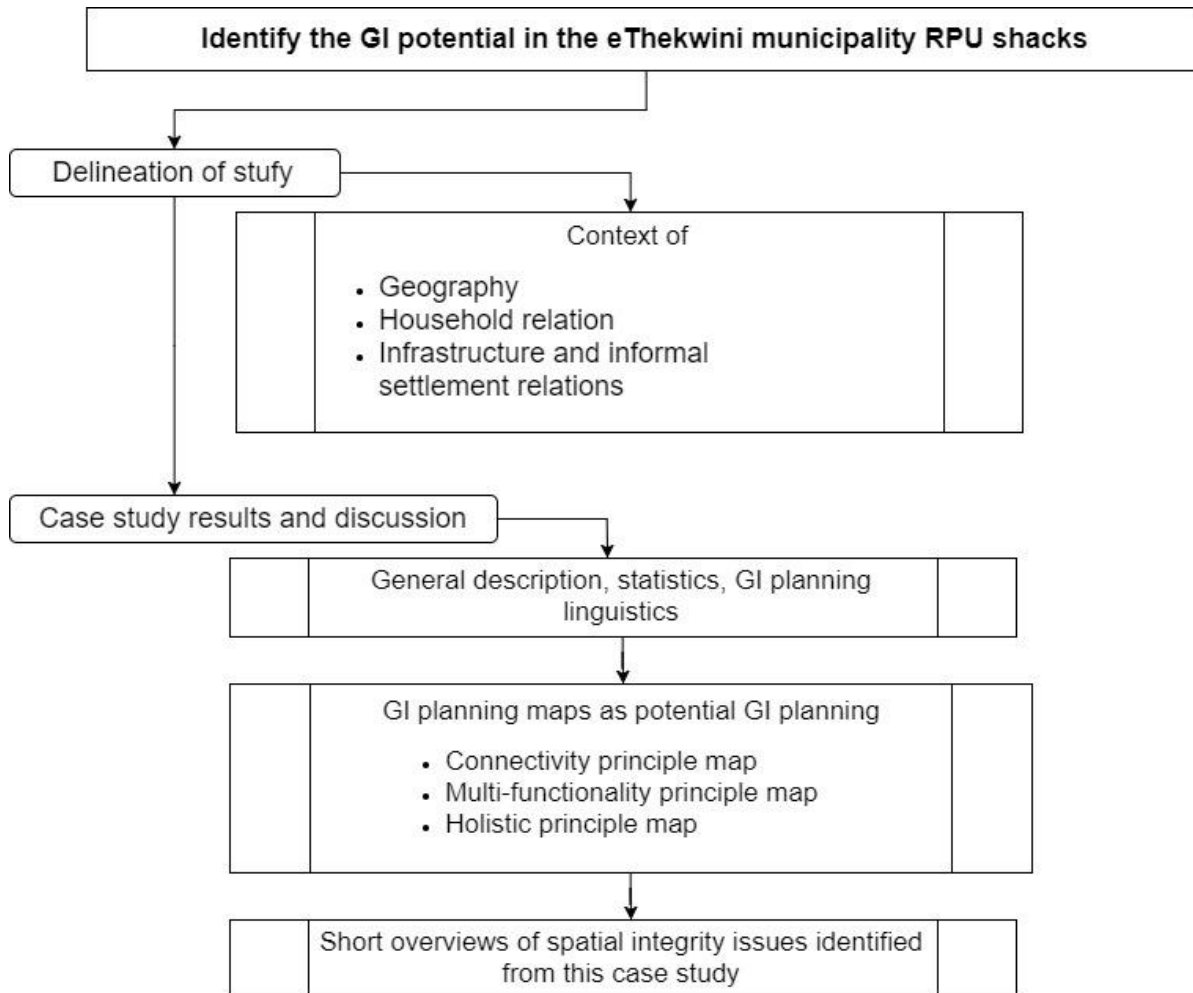


Figure 6-1: Structure of chapter six

Source: Created from Draw (2017)

6.1. Introduction

South Africa's global status is that of a developing country due to the poverty, unemployment, crime and infrastructural backlogs (ASSAf, 2014:22; UNECA, 2013:20). The current expansion of national economic activity is recognized spatially with five metropolitan municipalities out of nine provinces located in coastal (Western-Cape, Eastern Cape, KwaZulu-Natal) and inland (Gauteng and Free State) regions (SAHO, 2016:1; South African Government, 2016:1). In the same occurrence, as many African countries, the exponential increase of urban sprawl has widely dispersed from metropolitan areas into the rural boundaries of each mentioned province (Meyer, 2013:90). This has made tremendous landscape alterations, evident in ecosystem service delivery and habitat transformation (ASSAF, 2014:229; Andersson *et al.*, 2012:2). South Africa's

formal built space and informal activity corridors have, historically, undergone numerous planned and unplanned interventions, with GI planning being a most recent development venture.

South African literature differs on how to conceptualize and employ “GI”. SANBI (2017:1) states that “ecological infrastructure “refers to the natural function of ecosystems, and functions as a component when defining GI. The common challenges, when defining infrastructure, is not to separate a functioning system from the platform from wherein it functions because this will collapse the integrity of the system itself. South African institutions portray ecological infrastructure as focusing more on the function of ecosystem service that crosses over various spaces and boundaries, while GI focuses on open spaces such as parks, gardens or environmentally friendly components of built infrastructure (SANBI, 2017:1). As explained in Section 3.5, the complexity of GI conceptualization needs to be fully harnessed as not to oversimplify the planning process or to separate natural landscapes spatial integrity.

The nearest terminology that resembles similar aspects of GI (as defined in this dissertation) from the eThekweni municipality, is called “ecological infrastructure”. It is spatially applied on a regional scale (eThekweni municipality, 2014a:1). Durban municipality functions in the greater eThekweni municipality, and has adapted GI planning through Durban Metropolitan Open Space System (D'MOSS) (Environmental Management Department, 2016:1). An eThekweni municipal newspaper, Palmnut post (2002:2), states that D'MOSS has existed from 1982 as green corridors linking, with core conservation regions, placing GI activity in the eThekweni municipality as one of the earliest GI planning ventures that happened in KwaZulu-Natal. The following section describes the delineation of this case study.

6.2. Delineation of the study

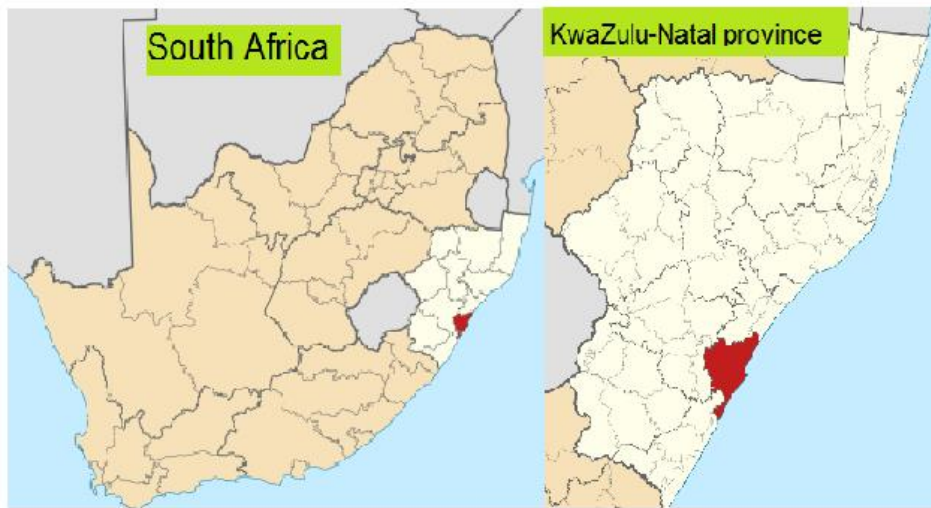
A metropolitan’s municipality fits the criteria for regional planning of GI within a single authoritative planning unit. Approaches to GI planning is evident in various metropolitans in South Africa, such as in Ekurhuleni, Tshwane (Gauteng), Cape Town (Western Cape) and eThekweni (KwaZulu-Natal) (Cilliers & Cilliers, 2016:26; Culwick *et al.*, 2016:33; Harrison *et al.*, 2014:2). KwaZulu-Natal has widespread informal and traditional dwellings, with habitats containing a rich biodiversity surrounding these dwellings (HDA, 2013:9; Mclean & Ground, 2016:27). The eThekweni municipality was thus purposefully selected for identifying the potential of GI planning in RPU informal settlement regions.

The eThekweni municipality has a long and strong legislative background surrounding the use of ecological landscapes. In the eThekweni municipality, Durban stands out as one of the first municipalities in a developing country to have an adaptation plan for building urban resilience (Cilliers & Cilliers, 2016:20). The eThekweni metro is involved in the global commitment to sustainable urban development solutions and climate change ventures. One of these noteworthy directions is the Urban NEXUS. It guides stakeholders to “identify and pursue possible synergies

between sectors, jurisdictions, and technical domains, so as to increase institutional performance, optimize resource management, and service quality” (ICLEI, 2016:1). ICLEI (2014:2) explains that the Urban NEXUS case study, in the eThekweni metro at Mariannhill landfill, provides means to promote biodiversity awareness and to reap additional educational benefits from the community. This is accomplished through a conservancy and gas-to-energy plant inside the landfill. A second noteworthy direction, according to Aldo (2013:7), is that local municipalities are not getting adequate guidance and finances from metropolitan-level planning, but that Durban has been chosen by the 100 Resilient Cities, pioneered by the Rockefeller Foundation (100RC), to formulate a Resilience Strategy (100RC, 2015:1). The eThekweni municipality (2016:1) states that phase two, of the planning steps of their resilience strategy, is completed. This strategy faces challenges of Durban resilience development, such as ageing infrastructure, coastal flooding, disease outbreak, drought, heat waves, rainfall flooding, rising sea level and coastal erosion (100RC, 2015:1; Roberts *et al.*, 2012:169). The eThekweni municipality argues that the case of “ecological infrastructure” is missing critical elements in the resilience development of Durban’s urban to rural space (eThekweni municipality, 2014a:1). The eThekweni municipality has the past, current, and potential future for GI planning integration in mind.

Cilliers and Cilliers (2016:27) state that Durban’s MCPP initiated the “Community Based Adaptation Plans (CAPs), the Durban Climate Change Partnership (DCCP), the Green Roof Pilot Project, Low Carbon Durban Research Project, Luganda School Water Harvesting and Micro Agricultural Water Management Technology, Buffelsdraai and Inanda Mountain Reforestation Projects, Community-Ecosystem Based Adaptation Program and integrated climate protection and biodiversity planning work-streams to focus on ecosystem-based adaptation”. Urban to rural, inland and coastal influence of GI planning, has a long way to go for resilience development to reflect on formal and informal settlement infrastructures (e.g. water, electricity, sanitation, housing, transportation and open space). This dissertation acknowledges these active development procedures, in the eThekweni municipality, as moving to a deeper ecological paradigm, as illustrated in Annexure 11.

The eThekweni metro includes the Durban municipality (having the largest land cover, but not the largest MOSS coverage, as is the case in the rural west of eThekweni metro, due to the urban built space) and other commonly known coastal municipalities, such as Umhlanga Rocks and Amanzimtoti. Figure 6-2 illustrates the case study boundaries in the bottom view of the layout, and how the northern part of eThekweni was chosen. This division was made based on the sufficient distribution of informal settlements in RPU areas, which are surrounded with adequate regional MOSS coverage to investigate the potential of GI planning. RPU areas are chosen based on the eThekweni municipality’s GIS layers to define urban and rural land use. Choosing the northern region for the case study, the following wards were demarcated (wards from the eThekweni municipality were chosen from 2-3, 8-16, 18-63, 92, and 101-102 to be used in this case study).



Legend

- Case study area: RPU regions
- MOSS (Metropolitan Open Space Ssystem)
- Dams
- Wards

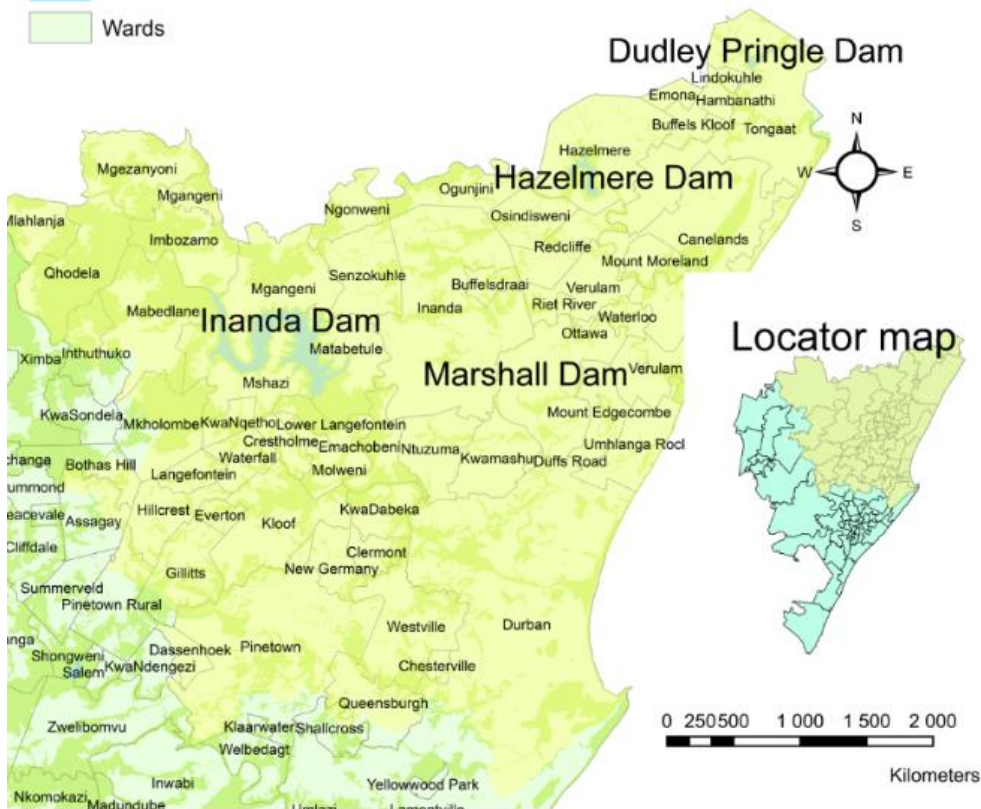


Figure 6-2: Locator map of eThekweni municipality case study region

Source: Adapted from Wikimedia Commons (2010:1), (Top- left and right) and the Author (Bottom)

The following Figure 6-3 illustrates the continental view of the KwaZulu-Natal provincial location of the case study. KwaZulu-Natal is the only South African province that borders three other countries (Mozambique, Swaziland, and Lesotho) while having a coastline. Politically, socially and naturally KwaZulu-Natal is one of South Africa’s most dynamic provinces.



Figure 6-3: Continental and national view of the case study in the KwaZulu-Natal province
Source: Africam (2014)

6.2.1. Geographic context

Strydom and King (2009:101) explain that South Africa is one of 17 recognized mega-diverse countries (those which host the majority of the world's fauna and flora species) but only comprising of less than 1% of the earth's land area. South Africa is home to nearly 10% of the world's plant and animal species: 8% of world's bird species, 5% of world's reptile species, and 5.5% of the world's insect species (Stevens *et al.*, 2015:2; Strydom & King, 2009:101). South Africa has unique habitats and a very high biodiversity that should receive the necessary attention for protection and preservation. Strydom and King (2009:101) state that “according to the most contemporary assessment of South Africa's ecosystems, 40% of terrestrial ecosystems, 57% of river ecosystems, 65% of wetland ecosystems, 43% of estuarine ecosystems, 58% of coastal and inshore ecosystems and 41% of offshore ecosystems are threatened”. The urban built space in South Africa impends to further increase such statistics, accomplished by urbanization and urban sprawls. These aspects can be potentially mitigated in RPU regions through this dissertation potential identification.

The eThekweni metro includes three major biomes, namely the Grassland, Savanna and the Indian Ocean Coastal Belt. Figure 6-4 illustrates South Africa's diversity in the form of a biome map (Mucina & Rutherford, 2006:570). These different biomes with their diverse landscape features have a strong factor in land use development activities. As informal settlement regions tend to sprawl, the spatial integrity of biomes is put under pressure by such human-built environments. PSSe (2016:1) points out that other African countries only have an average of between three to four biomes, compared to South Africa's nine

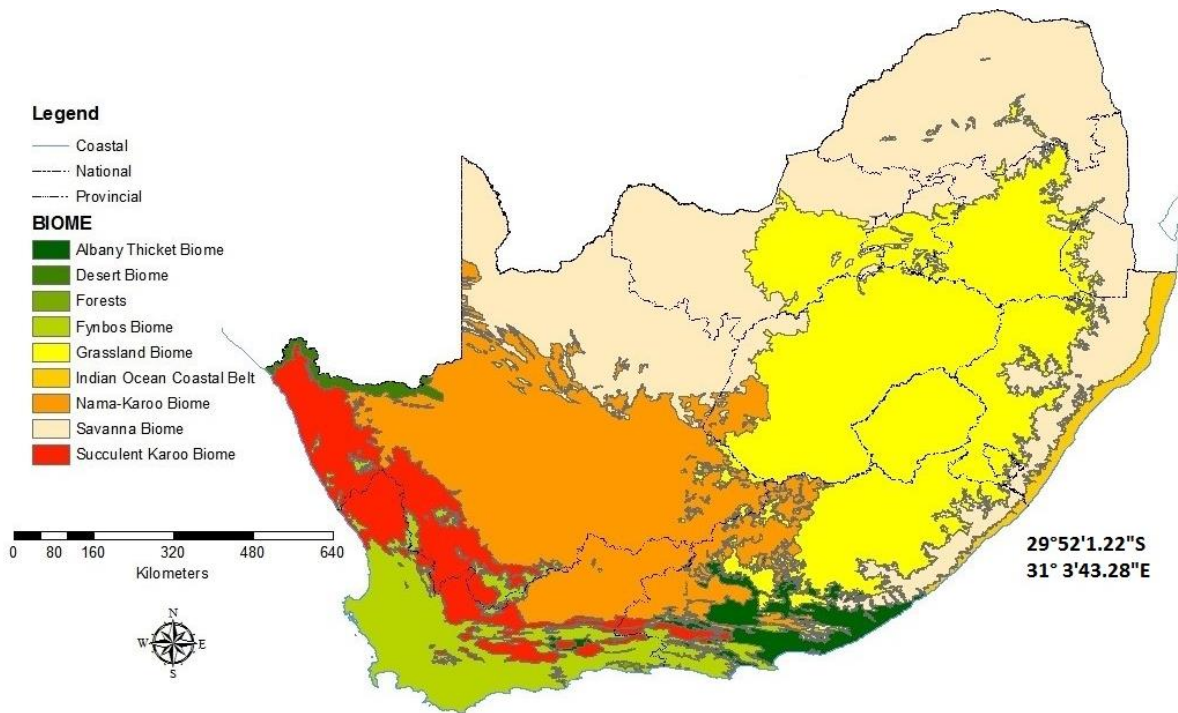


Figure 6-4: Map of South African biomes

Source: Adapted from ArcGIS 10.4.1. (2016) and Mucina and Rutherford (2006)

Mucina & Rutherford, (2006:570) state that the Indian Ocean coastal belt is part of a distinct subtropical region that has more or less open thornveld, with numerous and extensive patches of forest. This climate receives between 819 and 1272 mm rainfall per year, but has an evaporation roughly between 1490 mm per annum, and can be as high as 1833 mm near the Empangeni region (Mucina & Rutherford, 2006:572). Rocky outcrops are very frequent and dramatic scarps, krantzies, and deep canyons are typical accompanying geomorphological features of this landscape (Mucina & Rutherford, 2006:572). Areas such as Maputaland, many water-rich environments, e.g. coastal lagoons and extensive swamps, show a high groundwater table (Mucina & Rutherford, 2006:572). Another biome in the eThekweni municipality is the Savanna Biome. It has a seasonality of precipitation and (sub) tropical thermal regime, with strong summer rainfall (Mucina & Rutherford, 2006:442). The KwaZulu-Natal sandstone bioregion crosses the eThekweni metro region (Mucina & Rutherford, 2006:511).

Evidently, fragmentation of the eThekweni municipality's spatial integrity occurs throughout the entire municipal boundary, affecting the spatial interconnectivity of conservation and protection areas (Environmental Management Department, 2016:3). The Ezemvelo KZN Wildlife is a provincial level organization that manages ecosystems that goes beyond political boundaries (eThekweni municipality, 2016:88). Figure 6-5 illustrates threatened ecosystems, with some being critically endangered. To include GI planning is not to isolate a specific ecosystem type, but to include the collective advantages of different ecosystem corridors which are under threat.

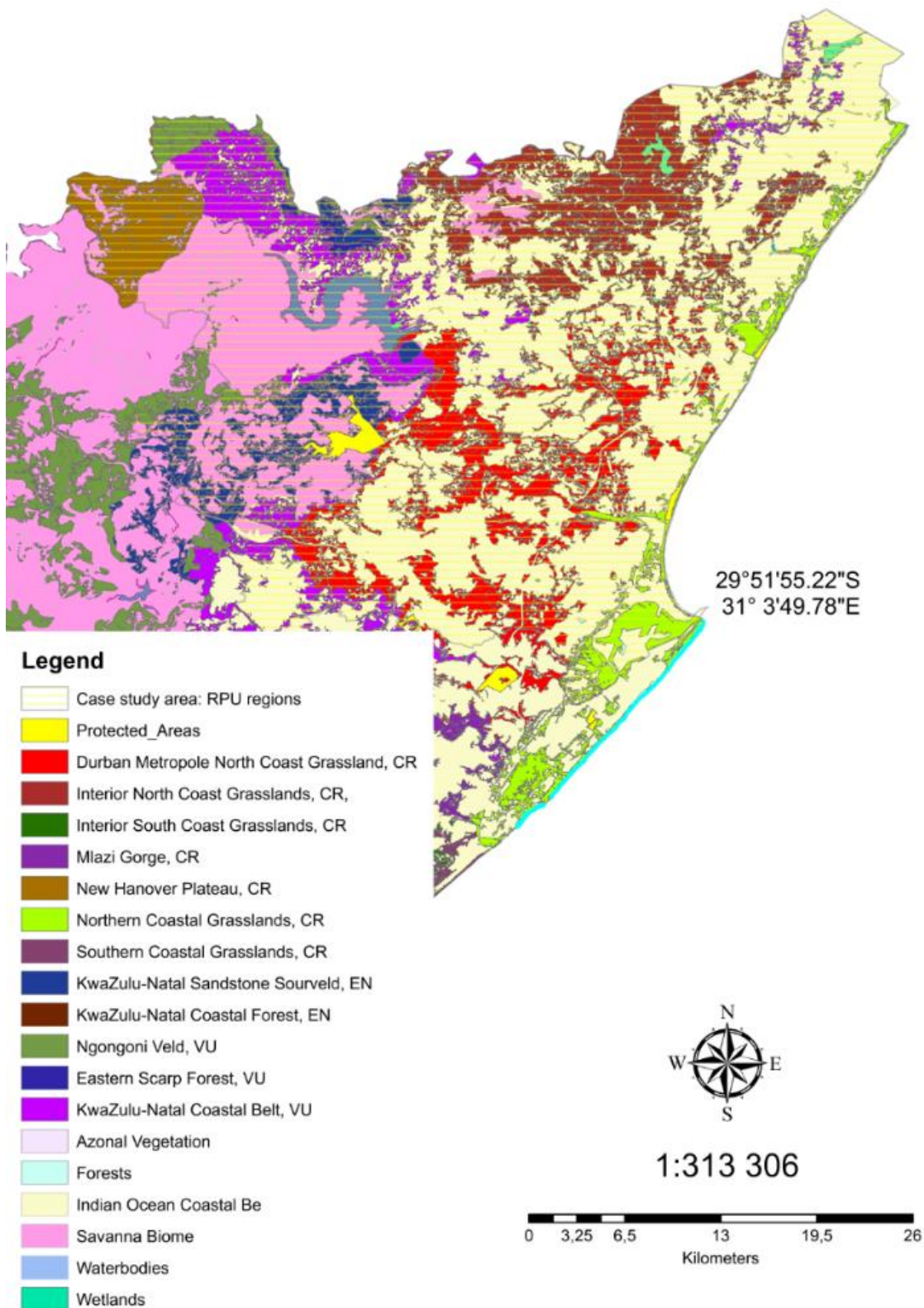


Figure 6-5: Threatened vegetation ecosystem of eThekweni municipality (northern side) (CR-critical endangered; EN-endangered; VU –vulnerable)

Source: Adapted from ArcGIS 10.4.1. (2016) and Mucina and Rutherford (2006)

Figure 6-6 illustrates the various MOSS areas applicable to the case study. The eThekweni metro municipality has subdivided these areas according to its prominent vegetation and landscape

activity types. Mucina & Rutherford (2006:511) makes the point that intensive grazing threatens the conservation of certain vegetation types, such as protected grassland types.

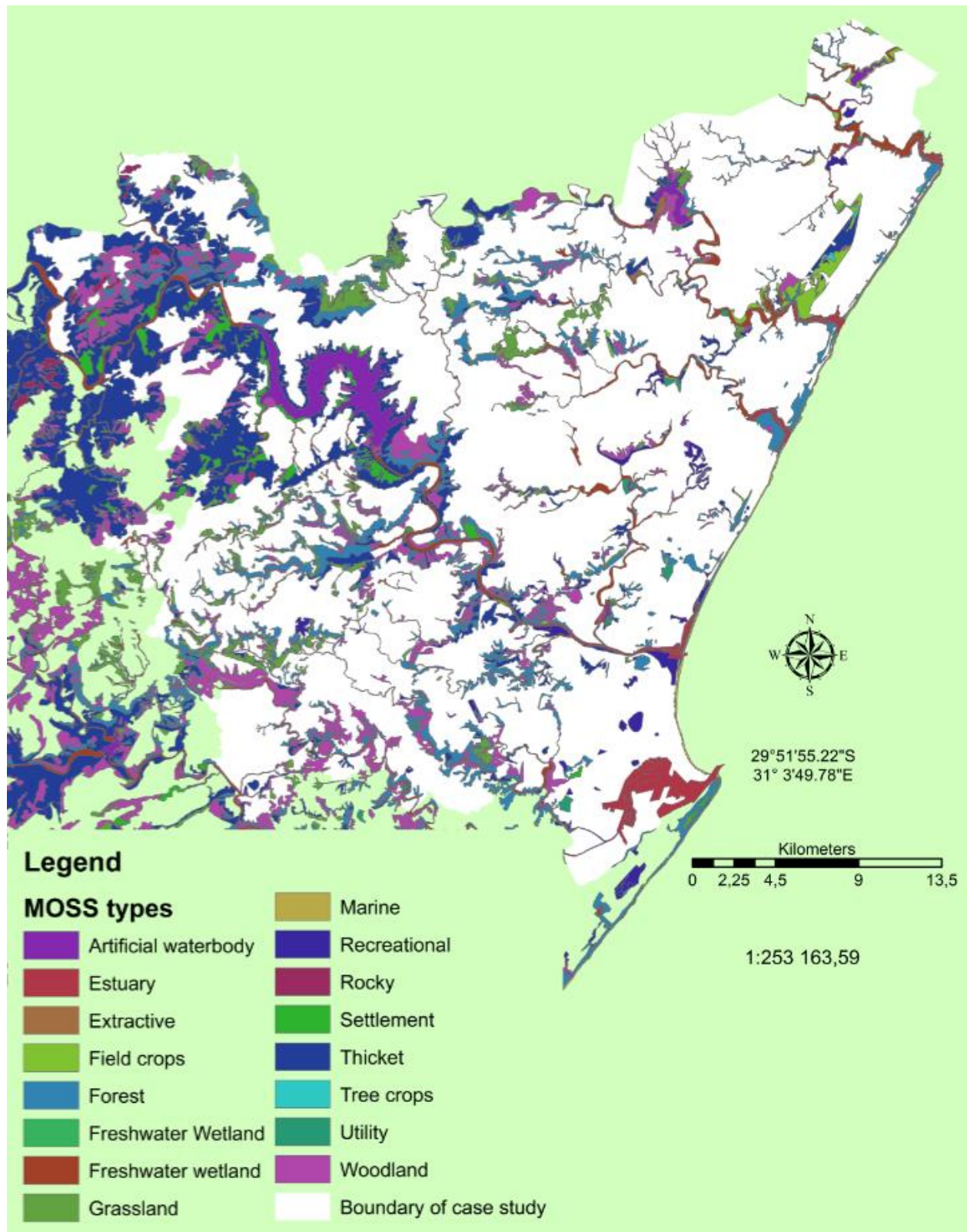


Figure 6-6: MOSS types of eThekweni (Northern side)

Source: Adapted from ArcGIS 10.4.1. (2016) and Mucina and Rutherford (2006)

6.2.2. Household context

Rural populated nodes, as set by political boundaries, are mostly located in KwaZulu-Natal and the Eastern Cape. In 2011 StatsSA (2011:15) stated that nearly 27% of South Africa's population resides in these declared rural nodes. This does not account for the rural and peri-urban dwellers situated in urban nodes throughout the country. StatsSA (2016:18) points out that over 63% of KwaZulu-Natal's population is under the age of 29, with black Africans being the largest population group. Citizens occupying informal settlements in rural and peri-urban parts of the case study are predominantly black African dwellers with diverse cultural traditions. Some of these traditions can alter landscape ecology, for e.g. no-fence grazing activities.

Anderson *et al.*, (2012:2) explain that transforming informal settlements into formal housing is a key development challenge in South Africa. StatsSA (2016:56) shows that KwaZulu-Natal has the second largest distribution of households in the country. It also has an average of 3.8 persons per household. The main challenges facing the municipalities, from households 'perspective, are (StatsSA, 2016:61):

- Lack of safe and reliable water supply
- Lack of or inadequate employment opportunities
- Cost of electricity
- Inadequate housing
- Violence and crime

Informal settlements can be seen as the "missed by" or "poorly serviced" of basic municipal infrastructure (EMM, 2002:3, HDA, 2013:6; Moselane, 2015:27). Thus the term "informal settlement units" are shacks and traditional housing units, that have a variety of self-constructed basic infrastructure services (e.g. water by a bucket system, sewage by pit latrines, electricity by solar power or generators, and roadways by gravel or self-constructed pathways) (Du Plessis & Landman, 2002:32; HDA, 2013:32; Opoko *et al.*, 2015:125).

Settlements of peri-urban regions are different by urban location. It is commonly located on patches of open land that is, generally, adjacent to some type of public infrastructure, especially main transport routes (Torres, 2008:5; Zhao, 2013:572). Peri-urban settlements have, unlike rural settlements, an abundance of formal settlements and built space within close proximity. However, peri-urban settlements lack basic infrastructure services and that is what classify these settlements as informal (Smith & Stirling, 2009:17).

The influence of informal settlements has not been widely studied, and even less so in collaboration with GI buffer methodology, from programs such as ArcGIS. The following section deals with the geographic, household, infrastructure context of eThekweni, and the relation thereof

to the informal settlements. Thereafter this section will provide a brief overview of the legislative background of the case study.

6.2.3. Infrastructural and settlement relations

The following facts were not taken from information provided by the eThekweni municipality, but can be a reference from provincial similarities to this metropolitan municipality region. StatSA (2016:68) presents KwaZulu-Natal as having almost 541,000 households without safe drinking water. There are 25% less agricultural households in KwaZulu-Natal, from 2011 to 2016. This shows a potentially higher impact of rural-urban migration (StatsSA, 2016:86). As seen in the geographic context of KwaZulu-Natal's diverse vegetation types on fertile soils, various agricultural activities occur from household parcels, such as livestock production, poultry production, and vegetable production (StatsSA, 2016:89). Households participate in farming activities in the backyard, farmland, communal land, school, church, and other organizational land activities (StatsSA, 2016:89). With all this local activity occurring in households, from rural to urban areas, it is clear that households without water infrastructure would have to depend on nearby water bodies. This places pressure on the spatial integrity of the quality of the water resources of surrounding habitats.

Pillay and Pahlad (2014:175) conducted public perception studies of green spaces in the South Durban areas, stating that the evidence from community observation showed that green spaces are eroding and creating an "ecological amnesia" to what services and disservices of nature can provide through community landscapes. Urban sprawl, throughout the case study, covers difficult landscapes that continually complicate transport networks, electricity, as well as water and sanitation provision. When looking at rural and peri-urban areas for this case study, there were more informal dwellings of shacks and slums occurring in peri-urban areas, and more traditional housing structures in the rural regions (Google earth pro, 2016).

GIS layers, provided by the eThekweni municipality (2016:1), were used in regards to various built infrastructure relations for the case study, such as electricity provision, which is minimally distributed in RPU areas. A lack, of such infrastructure, places pressure on surrounding natural resources, such as firewood, which is used for heat and energy, while promoting deforestation. However, not slum development only, but also industrial economic demands, add to the concern (MEA, 2005:4; Smith & Stirling, 2009:7; Tengö & UNs-CBD & SRC, 2014:34). Main transport networks are tar roads that deteriorated so that only gravel is left or self-proclaimed road networks, through informal and traditional settlement movement patterns (Google earth pro, 2016). Gravel roads undergo higher erosion rates that fragment functionality of settlements and environments.

6.2.4. Legislation context

South African provinces differ in spatial planning dynamics because these provinces have specific legislation. The specific legislation covering the KwaZulu-Natal province will not automatically and

totally apply to other provinces. When considering other provinces, such as the Gauteng or the Western Cape, which has well-established metropolitan areas, the South African governance structure differs in environmental and land use management laws and by-laws provincially. There is thus national legislation that provides some aligning direction for provincial and local municipalities. Only in this last decade, there has been a national plan, as explained in Annexure eight, for more comprehensive strategies to depend on local municipal integration.

Table 6-1 deals with planning legislation that revolves around KwaZulu-Natal, before and after the abolishment of apartheid, as well as to the first democratic election in 1994, but it is still applicable today. There is a rationale behind taking a historical approach to the environmental and spatial land use legislation of KwaZulu-Natal for this case study (in the form of Table 6-1). If GI planning is going to meet the practical implementation, according to its coherent definition, the parties involved with planning will have to understand various GI related legislation that existed in South African history and that has led up to this contemporary adaptive, planning integration. Just as identifying the potential of GI planning is only the first step for mainstreaming the GI concept into South African policy frameworks, so this view on the legislation is an example for future planning parties to address the fundamental factors necessary in order to understand the more holistic scheme of GI planning implementation in the context of other South African provinces.

These laws, mentioned in Table 6-1, have impacted, directly and indirectly, on various settlement and infrastructure developments. Local municipal laws and by-laws have changed the spatial integrity of KwaZulu-Natal. Several of these laws have been repealed by SPLUMA 2013, these will be indicated in Table 6-1. GI planning potential is not a project-planning approach, but rather a regional path that needs regional environmental understanding as well as an understanding of the provincial legislation as pertaining to spatial planning for long-term GI planning integration. Proving a catalogue of KwaZulu-Natal's legislation provides future planning parties with the ability to scope legislation to be more integrated and refined when it comes to environmental and spatial land use planning. Legislation needs to be shaped to follow a more strategic adaptation approach.

Table 6-1: Summary of planning legislation in KwaZulu-Natal

Nationally administered land development and planning legislation	
1970	Subdivision of Agricultural Land Act No. 70 of 1970
1977	National Building Regulations and Building Standards Act 103 of 1977
1995	Development Facilitation Act 1995, No. 67 of 199 (repealed, to a certain extent, by SPLUMA, 2013)
1997	KwaZulu-Natal Nature Conservation Management Act 9 of 1997
2000	National Land Transport Transition Act, No. 22 of 2000
2008	KwaZulu-Natal Planning and Development Act No. 6 of 2008
National environmental legislation	
1989	Environment Conservation Act No. 73 of 1989
1997	Water Services Act No. 108 of 1997
1998	National Environmental And Management Act (NEMA), No. 107 of 1998
1998	National Water Act No. 36 of 1998
1999	National Heritage Resources Act No. 25 of 1999
1999	World Heritage Convention Act No. 49 of 1999
2004	National Environmental Management: Biodiversity Act No. 10 of 2004
Provincially administered legislation	
1927	Black Administration Act, 1927 (Act No. 38 of 1927)
1949	Town Planning Ordinance No. 27 of 1949
1967	Physical Planning Act No. 88 of 1967 (remnants retained through Act 125 of 1991)
1967	Removal of Restrictions Act No. 84 of 1967 (repealed by SPLUMA, 2013)
1984-1987	Black Communities Development Act No. 4 of 1984 and R 1897 R 1897 /1986
1990	KwaZulu Amakhosi and Iziphakanyiswa Act No. 9 of 1990 and Amendment Act No. 5 of 1995
1991	Less Formal Township Establishment Act No. 113 of 1991 (repealed by SPLUMA, 2013)
1991	Physical Planning Act No. 125 of 1991 (repealed by SPLUMA, 2013)
1992	KwaZulu Land Affairs Act No. 11 of 1992
1992	KwaZulu-Natal Nature Conservation Act 29 of 1992
1992	Transkei Environmental Conservation Decree 9 of 1992
1994	KwaZulu-Natal Ingonyama Trust Act 3 of 1994 as amended by (of a similar name) 9 of 1997
1997	KwaZulu-Natal Heritage Act, No. 10 of 1997
1997 & 1999	KwaZulu-Natal Nature Conservation Management Act No. 9 of 1997 and KwaZulu-Natal Nature Conservation Management Amendment Act. 5 of 1999
2001	KwaZulu-Natal Provincial Roads Act No. 4 of 2001
2003	KwaZulu-Natal Land Administration Act No. 3 of 2003
2013	Spatial Land Use Management Planning Act

Source: CER (2016:1) and Berrisford (2005:1) Highlighted acts have been repealed by SPLUMA 2013

The eThekweni municipal MOSS system is aimed at protecting areas that have a high biodiversity value with associated ecosystem services, by creating an interconnected system of open spaces (Roberts, 2010:401). Roberts *et al.*, (2012:174) explains that D'MOSS covers more than 80 000 hectares and, in 2003, had a value of R3.1 billion per annum (for the 63,115 hectares back then). Freedman (2014:567) uses the *Le Sueur v eThekweni Municipality* case as an example to explain how the legislative authority of the local sphere (an aspect missing in Constitutional planning) has dealt with conservation and protection of the “environment”, as part of municipal planning. In 2000, the eThekweni Municipal Council adopted a resolution that amended its town planning scheme through the Durban Metropolitan Open Space System (D'MOSS). In order to achieve this goal of environmental conservation and protection through D'MOSS, a municipal by-law had to ensure that the conservation regulation of land, within a D-MOSS area, may not be developed without first obtaining an environmental authorization in terms of the municipality's town planning schemes. Even with this authorization, the land may only be developed according to strict controls, aimed at protecting the ecological goods and services that the land provides (Freedman, 2014:584). This reflects an authoritative adaption to land use regulation in preparation for GI planning legislative authority in local development regions.

However, this regulated MOSS system created conflict with private landowners. These parties argued that the constitution did not make provision for municipal councils to declare if the environment is to be protected or not, for it fell outside the local municipal jurisdiction, according to the Constitution (Freedman, 2014:584). SPLUMA has finally fulfilled the judgement, as mentioned by Freedman (2014:585): “municipalities are in the best position to know, understand and deal with issues involving the environment at a local level, and also because municipalities have historically always exercised legislative responsibility over environmental affairs as a part of municipal planning.” GI in South Africa is built on established MOSS, in and around city centres, in different forms and types. However, integrating these different types of MOSS into a strategic spatial plan, suited for local municipal planning systems, depends on broader provincial and national legislative municipal planning powers.

Another view of legislative issues, when engaging municipal planning systems in order to advance environmental processes for more sustainable development, is illustrated in Figure 6-7, which argumentatively initiates various combined water and land development policies into developing platforms in the KwaZulu-Natal province. Figure 6-7 visualizes the national-to-provincial “red tape” in South African legislation, with the responsible institutions as well as existing strategies and programs that are hurdles for progressive GI planning adaptation. Any I&AP involved with mainstreaming GI planning in South Africa has to take note of Figure 6-7 with regards to basic knowledge of provincial inputs concerning multi-governmental integration which surrounds the management and planning of natural resources.



NWA	National Water Act	DWA	Department of Water Affairs
MCAA	Multilateral Competent Authority Agreement	DAC	Department Of Arts and Culture
WSA	Water Services Institutions	DAFF	Department of Agriculture, Forestry, and Fisheries
NHRA	National Heritage Resources Act, 1999	DEARO	Department of Agriculture, Environmental Affairs and Rural Development of KwaZulu-Natal province
CARA	Conservation of agricultural resources acts 43 of 1983	DEA	Department of Environmental Affairs SANBI
NFA	National Forests Act	SANBI	South African National Biodiversity Institute
NEMA	National Environmental Management Act	EKZNW	Ezemvelo KZN Wildlife
ECA	Environment Conservation Act (73 of 1989)	AMAFA	Heritage KwaZulu Natali
NEMBA	National Environmental Management: Biodiversity Act		
NEMPA	National Environment Management Protected Act		
NEMA	National Environmental Management Act		
NCMAA	unknown		
NCO	unknown		
HA	Health act		

Figure 6-7: Key legislation covering natural resources in KwaZulu-Natal

Source: Global Water Partnership (2015:2)

6.3. Results and discussion of the case study

This section applies the methodology and results, explained in Section five. An overview will provide further data, related to the case study, whereupon the buffer methodology was applied. A brief summary of various statistics, regarding the case study results, will also be given. As GI

from informal settlements only reflects on the areas inside protected and conserved buffers which are altered by human activities, this section focuses on GI planning potential as the strategic spatial integration via GI planning principles from identified GI potential.

6.3.1. General description

In regards to the potential of GI, there is a higher efficiency to planning and managing land where humans have not yet built (Alberti, 2005b:170; Bolund & Hunhammer, 1999:297; Torres, 2008:14). As seen from Figure 6-8, the spatial distribution of settlements, with none to poor basic infrastructures, are more concentrated into pockets of high-density areas in peri-urban regions than the broad rural distribution around Inanda dam, for instance. However, the environment surrounding rural and peri-urban areas differ. The latter is more concentrated in urban built space. This does not only disturb but replaces green with grey infrastructure, making habitat preservation and management difficult, since there is no required space to manage (Allen, 2012:18; Smith & Stirling, 2009:28). Rural settlements are more simplistic to rehabilitate, and are in close relation and dependency to the raw natural ecosystem and natural habitats, compared with peri-urban areas (Alberti, 2005:179, TEEB, 2009a:7).

The first aspect was to define where the rural areas and the peri-urban areas were, within the demarcated eThekweni municipality case study. Informal dwelling units, plotted by the eThekweni municipality's (2016:1) GIS inventory, assisted in separating the spatial distribution between rural and urban informal settlements. Urban land uses determined peri-urban informal settlements and rural land uses determined rural informal settlements. Figure 6-8 represents the newest data from 2011, depicting rural and peri-urban informal/traditional dwelling units. Various structural changes could have occurred over the past five years, and would not be accounted for. In the rural region, the spatial distribution is much broader compared to the peri-urban areas. However, taking the concentration into account, the peri-urban informal settlement corridors also have intense pockets of household densities, similar to the rural areas.

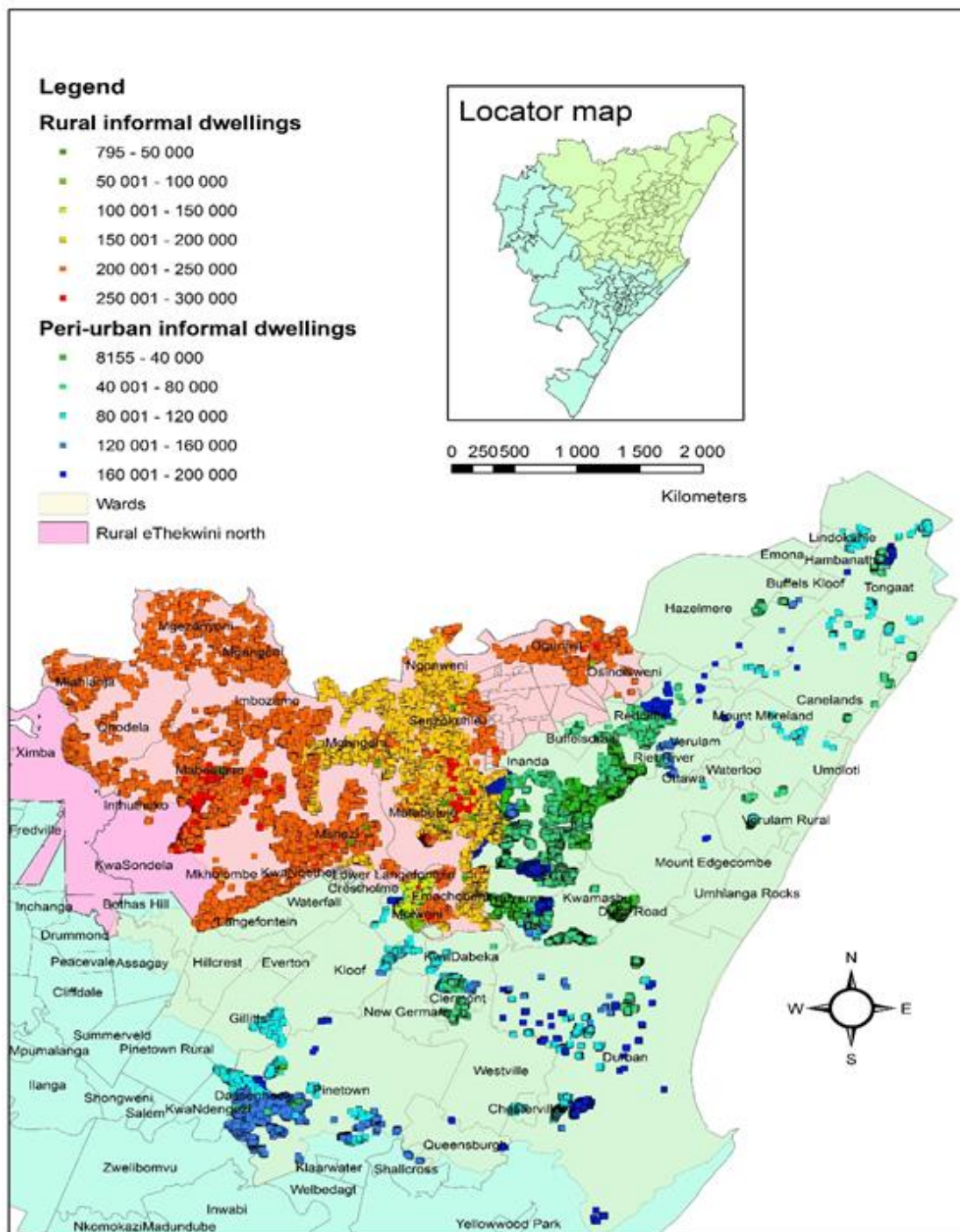


Figure 6-8: Rural and peri-urban informal settlement in eThekweni northern wards
Source: Adapted from ArcGIS 10.4.1. (2016)

The informal settlement dwelling units were generalized as to have the same potential influence on MOSS types than in any area; not remarkably separating rural from peri-urban areas. Population density has been shown to multiply the influence that settlements have on natural resources. This dissertation, however, only used settlements as units, and did not regard population density per square meter (Allen, 2003:138; Gómez-Baggethun & Barton, 2013:236; McPherson *et al.*, 2008:62). Such scientific research performed on land use planning scale would

have to be conducted on a local and project scale and was not integrated into this regional view of identified GI potential.

Figure 6-9 illustrates that the eThekweni municipality has, over the years, established the current MOSS. Polygons, in red, reflect MOSS added in 2016. The eThekweni municipality (2016a:1) explains that D'MOSS types are not a land use zone, but a layer which is legally enforceable. This destination provides more flexibility for existing land use policies and land use activities to be managed. As MOSS is traced closer to the coastal (East) regions (seen in Figure 6-9) there is a smaller concentration of interconnected MOSS, mainly due to an increase in urban built space.

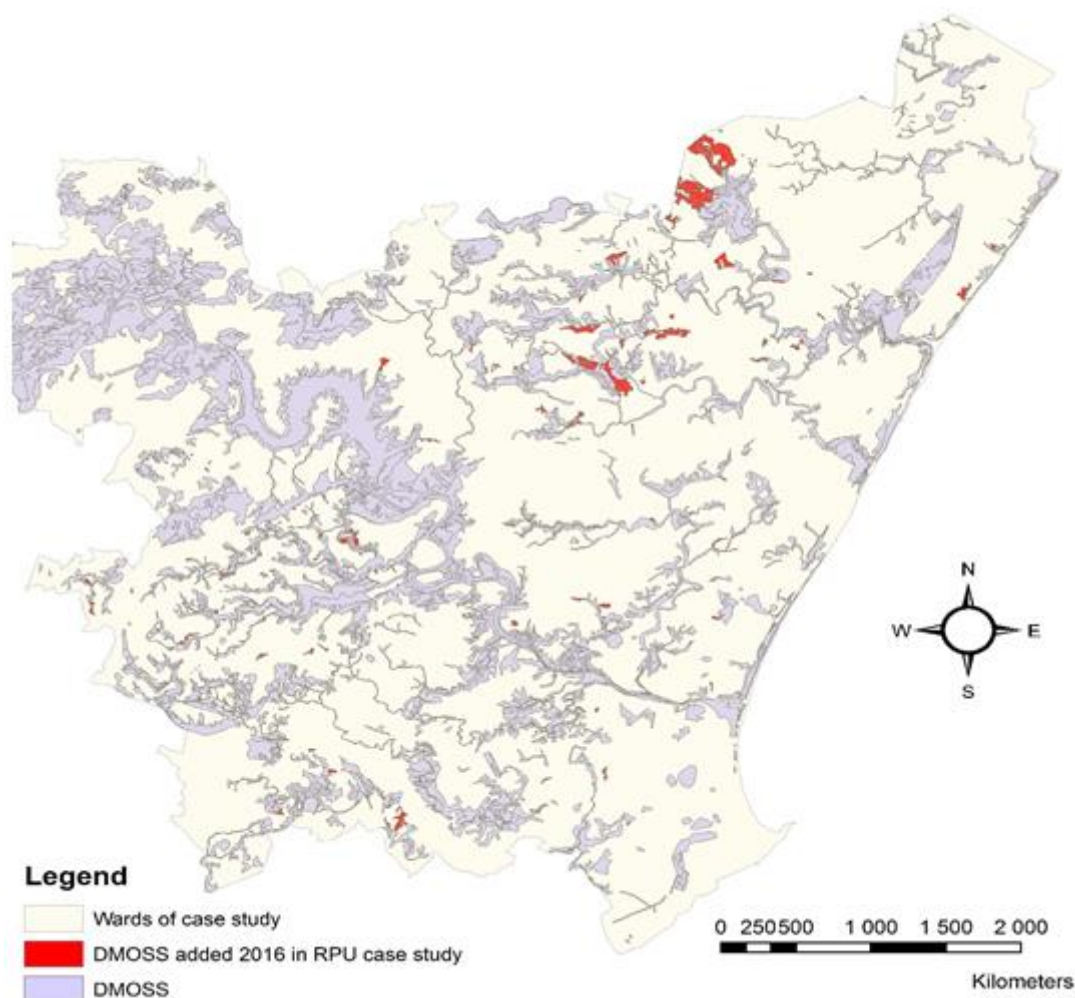


Figure 6-9: Entire MOSS coverage by the case study demarcation

Source: Adapted from ArcGIS 10.4.1. (2016)

Figure 6-10, illustrates the difference between rural and peri-urban MOSS areas. Determining rural from peri-urban settlements are based on the different land use types, as demarcated by the eThekweni municipality in archived GIS inventories. The MOSS, in Figure 6-10, is limited to the case study and there are various other MOSS distributions throughout the entire eThekweni metropolitan area. This separation merely illustrated the larger spatial occurrence of MOSS in rural areas, similar to the distribution of informal shacks in the rural area compared to peri-urban area.

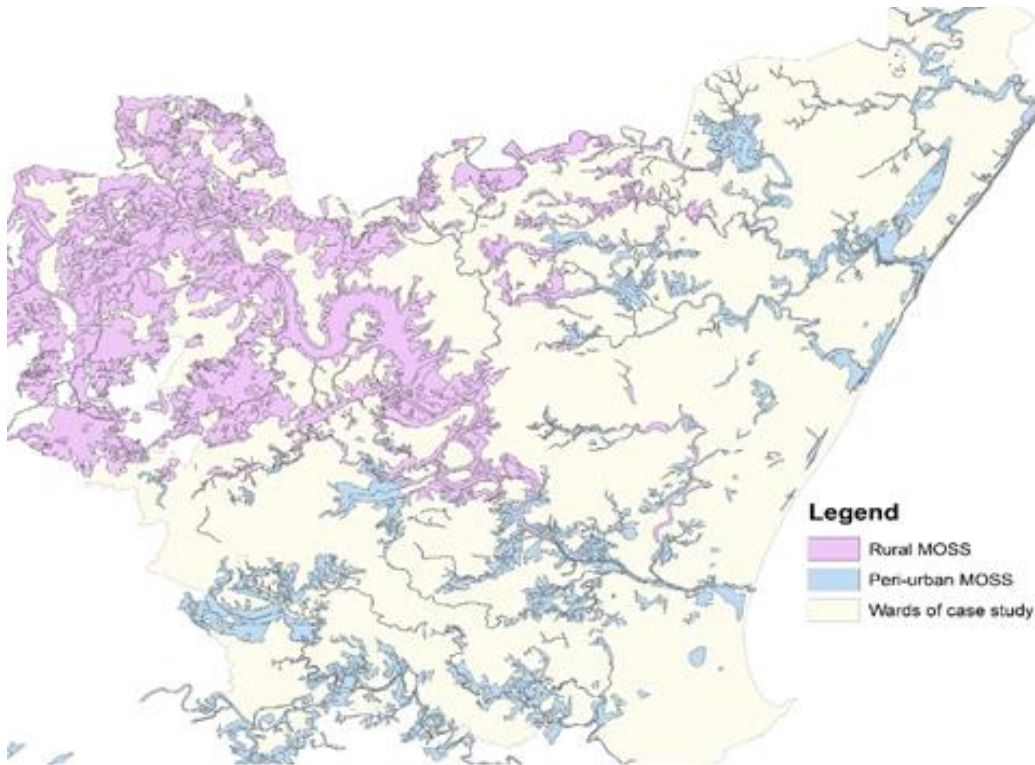


Figure 6-10: Different rural and peri-urban MOSS in the case study demarcation
 Source: Adapted from ArcGIS 10.4.1. (2016)

Although rivers had been planned separately from GI through some GI scientific literature, dealing with GI and separating it from rivers would not be logically correct (Barbati *et al.*, 2013:37; Liqueste *et al.*, 2014:17; Dunn, 2010:53). Water is a key link to the cycle of natural systems. Fauna and flora, on the other hand, does not play an intrinsic part in the hydrological cycle (Kati & Jari, 2015:537; MEA, 2005:2; TEEB, 2010d:21). For this current study, the aspect of GI was taken from the combined presence of MOSS and perennial river networks. In this manner, the buffer zones, as illustrated in Annexure 13, were also focused on the human influence barrier on rivers, as buffered from informal settlement regions. Figure 6-11 illustrates the various river networks used for this current study.

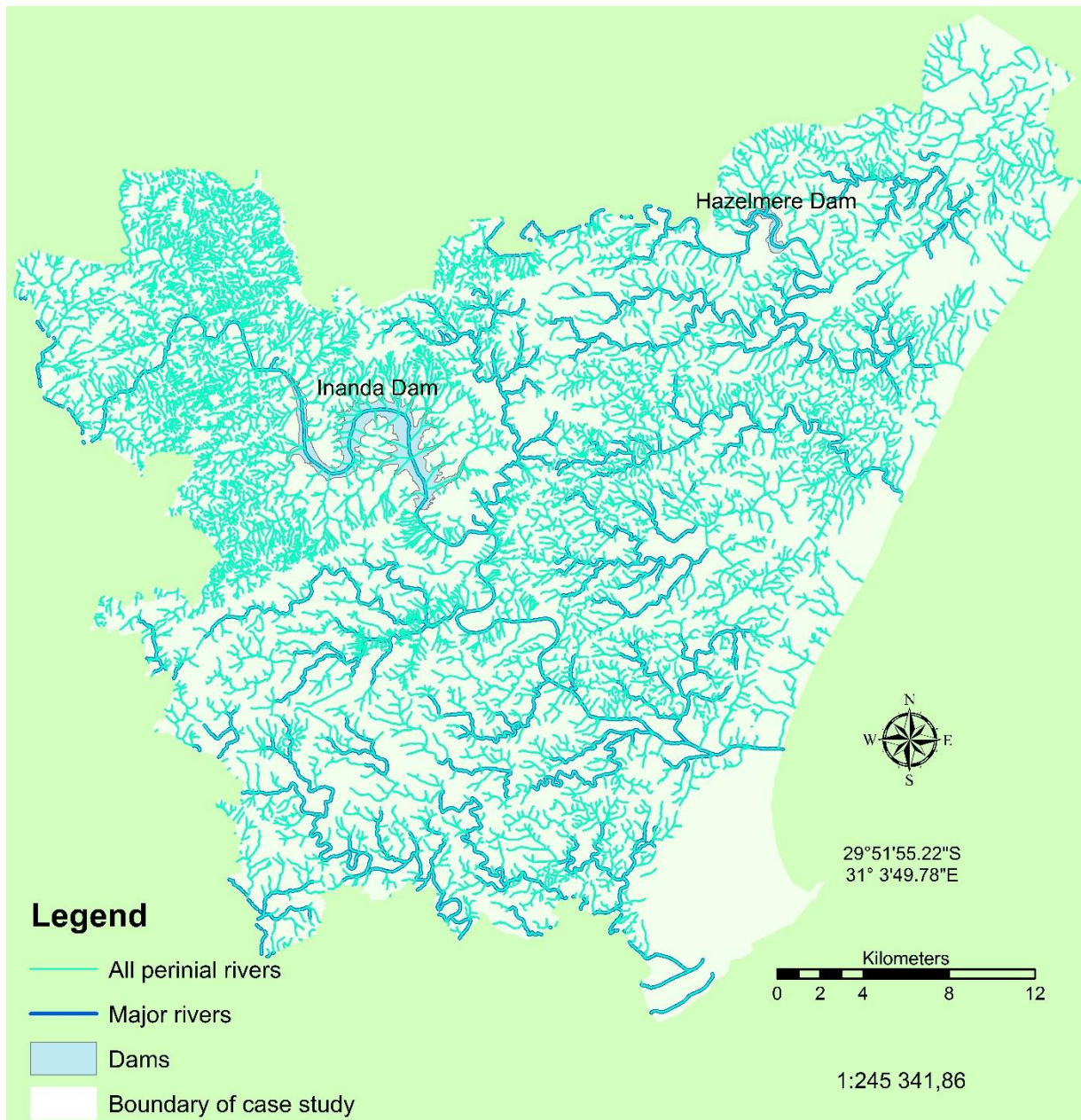


Figure 6-11: Perineal rivers in the case study
 Source: Adapted from ArcGIS 10.4.1. (2016)

6.3.2. Statistics

The statistical figures showcased in this section were calculated from drawn maps in ArcGIS 10.4.1. Each of the statistics targets certain aspects regarding the influence of informal settlements on GI potential, or the identified GI potential that is under pressure from informal settlement influence.

In regards to the social dispersion throughout the case study, out of the total RPU informal settlement households (in the form of units in ArcMap) 38 037 were rural and 103 966 peri-urban. The number of RPU dwelling units that influenced some type of GI potential buffer type was 82 824 units (more than 50%). This implies that approximated 58% of the total selected RPU informal settlement areas, potentially directly influences GI throughout the case study. There were

also 2128 illegal RPU household units (equal to about 1.5% of the total number of informal settlements) that directly expand into established MOSS areas. Subtracting the informal settlements, that expand into buffer areas, from those that expand only into MOSS areas, 56,5% of informal settlements operate within protected and conserved buffer spaces (namely identified GI potential areas). RPU informal settlements, thus, have a major influence on adjacent natural spaces.

An assumption is drawn from the statistics in Section 6.2, as presented in the geographic, household and infrastructure context sections, show that a large percentage of the informal settlement houses black South Africans that depend on backyard farming. This type of household is also situated in regions with small to none basic municipal infrastructure and services. Such rural households, thus, rely heavily on the surrounding natural resources. And these natural resources are, in many cases, protected and conserved MOSS regions, as well as buffer areas required by scientific literature to protect and conserve certain natural elements.

6.3.3. Buffer influences from informal settlements on MOSS and river networks

This section is dealt with in Annexure 13 as it includes several maps which reflect the identified potential of GI from the case study. It does, however, not reflect the GI planning potential of the study, but rather illustrates individual buffer influences from informal settlements, projected on MOSS and river networks. Only when these individual buffer sets were combined and GI planning principles were applied to the maps, was the GI planning potential identified (illustrated in Section 6.4.2).

The maps in Annexure 13 can be used to understand what the potential influence, from informal settlement patterns on different MOSS and river networks in certain areas, maybe. The focus, as proposed by the theme of this current study, is the identification of the potential of GI, rather than the capacity of GI. In this manner the different maps are provided of each buffered informal settlement's influence, to ensure that the reader understands the spatial distribution and scale dynamics that the informal settlements could possibly have on MOSS and river networks.

The maps in Annexure 13 do not provide any type of interpretation of the identified GI potential. This is because this current study is aimed at the GI planning potential that includes GI planning principles. Further investigation, in order to convert the GI potential into GI capacity, would provide more accurate data so that a contextual analysis of the influence, that informal settlements have on the demarcated GI regions, could be conducted.

6.3.4. GI planning linguistics

There is a barrier in the communicative process of applying GI principles across different disciplines. This is due to a lack of spatial knowledge management of the same or similar principles (Baud *et al.*, 2013:6, 2015:226). To fully comprehend the potential of GI planning, an attempt was made to clear up the possible ambiguity regarding GI as a concept. Table 3-6 was

created to assist in the evaluation of this complex term, ensuring transparency with the use of GI planning principles, across trans-disciplinary viewpoints. Figure 6-12 explains the methodical layout used in the formation of Table 6-3

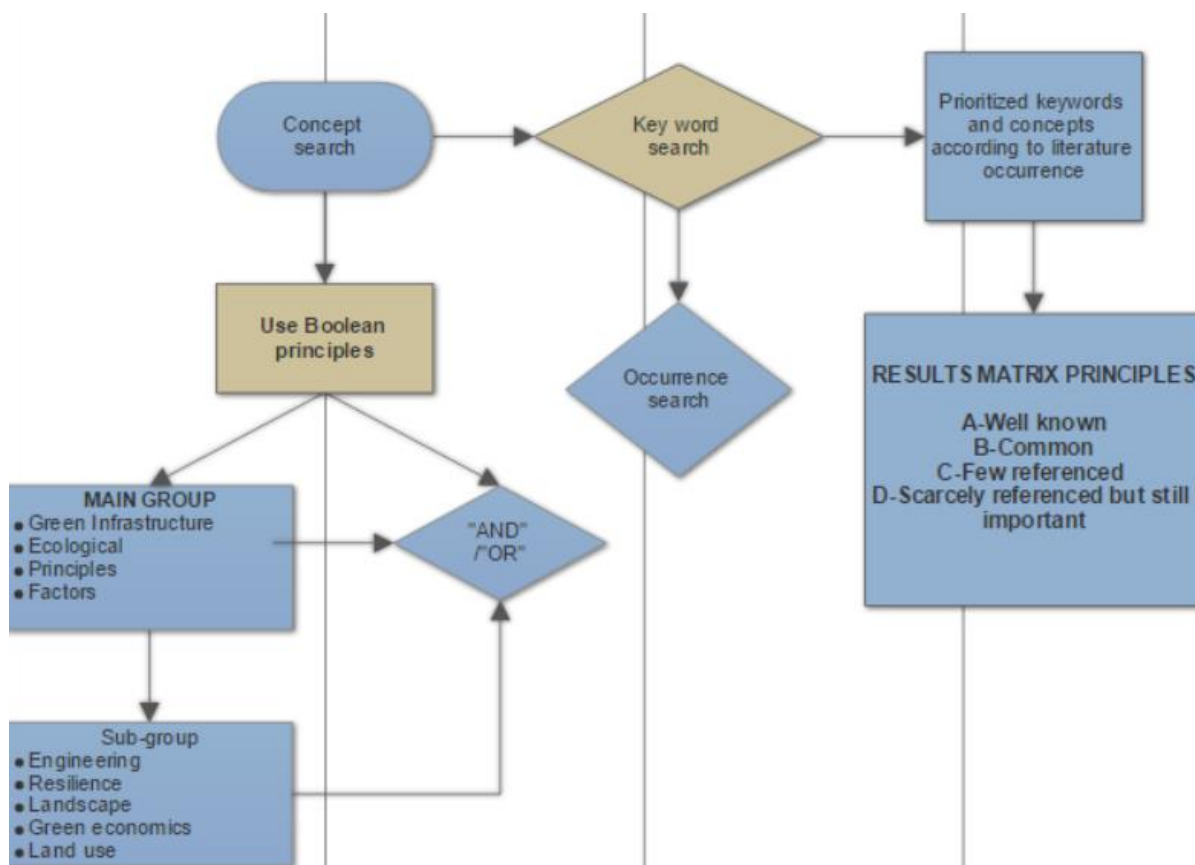


Figure 6-12: Flow chart of the methodology behind Table 3-8 GI principle formulation

Source: Authors creation

Collecting scientific literature for GI linguistic research as illustrated in the methodology of Figure 6-12 a “concept search” method was used. GI planning is thus the concept and the search process is described as follows. This method combines Boolean principles of “and” and “or” to refine the literature taken from different scientific search engines (Felipe, 2008:657; Giunchiglia *et al.*, 2009:4). Secondly, refining the gathered literature, a “keyword search” method was used, wherein the occurrence of main and sub-group keywords, especially revolving around the word “principle”, was established (de Felipe *et al.*, 2008:656; Webber, 2010:2). Lastly, counting the number of principal occurrences, a fourth level hierarchical grouping was created to divide the principles into four high to low referenced groupings. Alphabetical sorting was done within each group. Figure 6-12 illustrates the methodological process beginning at the left and moving to the right.

Classification of Table 6-3 was ranked by taking the most acknowledged principle, with the most literature occurrence, as the 100% benchmark. The rest of the identified principle accounts were matched to that benchmark (the occurrence of that “most cited principle”) and then converted to a percentage. This was done to see where to classify each principle in the order the principle occurred through various literature references. The given, general percentage categories are

“well-known“ (A), “common“ (B), “low acknowledgement“ (C) and “scarcely referenced but still important“ (D). According to these categories, only acknowledged principles, from a mixture of literary source engines, were used. These search engines include Google Scholar, Google, and EBSCOhost. Lastly Table 6-2 illustrates the classification of GI linguistics presented in Table 6-3.

Table 6-2: Percentage categorization of GI-related terminology in scientific literature in Table 6-3

Categories of popularity	Percentage articles in reference to all the identified acknowledged principles
A- Well-known,	75-100%
B-Common	50-75%
C-Low acknowledgment	25-50%
D-Scarcely referenced but still important	0-25%

Source: Authors creation (2017)

Table 6-3 is basically the prioritized linguistic surrounding GI planning. This is a broad view of the different communicative concepts and keywords used to describe principles related to GI planning. Table 6-3 will provide a higher communicative development between the various trans-disciplinary fields that are involved in the potential identification of GI planning. Table 6-3 was only prioritized to illustrate the occurrence of principles that exist in scientific literature and does in no manner reflect a hierarchy for GI principles, in order of importance or value for identifying the potential of GI planning in RPU informal settlement regions.

Table 6-3: Leading principle linguistics of green infrastructure planning prioritized into well-known (A), Common (B), Low acknowledgement (C) and scarcely referenced but still important (D)

Prioritised numbering	Principles as given by leading authors towards GI planning relation	Authors
A1.	Accessibility,	(Mell, 2014a:613)
A2.	Communicative and social- inclusive process	(Hansen & Pauleit, 2014:517)
A3.	Connectivity between/across urban locations	(Elmqvist <i>et al.</i> , 2013:565) (Mell, 2014b:3)
A4.	Design and plan green infrastructure before development	(Benedict & McMahon, 2002:18)
A5.	Integration (holistic, comprehensive and flexible approach)	(Hansen & Pauleit, 2014:517; Roe <i>et al.</i> , 2013:653)
A6.	Landscape pattern and process (ecological network concept)	(Ahern, 2007:3)
A7.	Linkage is key	(Benedict & McMahon, 2002:18)
A8.	Multi-functionality and interconnection of green spaces	(Hansen & Pauleit, 2014:517) (Pauleit <i>et al.</i> , (2011: 273)
A9.	Multi-scaled approach	(Ahern, 2007:3)
A10.	Planning	(Mell, 2010:36)
A11.	Sustainability	(Mell, 2014a:613)
B1.	A critical public investment	(Benedict & McMahon, 2002:18)
B2.	Biodiversity	(Mell, 2010:36)
B3.	Context	(Elmqvist <i>et al.</i> , 2013:565)
B4.	Cooperation and learning	(Elmqvist <i>et al.</i> , 2013:565)
B5.	Delivery of multiple benefits simultaneously to humans and nature	(Mell, 2014b:3) Mell, 2010:129)
B6.	Diverse range of investment options	(Mell, 2014b:3)
B7.	Focus of the key stakeholders and community involvement	(Kambites & Owen, 2006:488) (Pauleit <i>et al.</i> , 2011: 273)
B8.	Framework for conservation and development	(Benedict & McMahon, 2002:18)
B9.	Habitat	(de Groot <i>et al.</i> , 2002:395 references by Young <i>et al.</i> , 2014:2573) (MEA, 2005:15)
B10.	Holistic approach /understanding of systems and their supporting capacity (Geographical, Political, and Functionally)	(Kambites & Owen, 2006:488; Mell, 2014b:3)
B11.	Information collation and analysis (baseline data)	(de Groot <i>et al.</i> , 2002:395 references in Young <i>et al.</i> , 2014:2573; Kambites & Owen, 2006:488; Mell, 2010:204)
B12.	Integrated approach to investment in urban (and urban-rural interface) environments	(Mell, 2014b:3)
B13.	Is grounded in sound science and land-use planning theories and practices	(Benedict & McMahon, 2002:18)
B14.	Learning by doing’.	(Kato & Ahern, 2008:549)
B15.	Long-term and strategic approach to the investment and management of urban environmental resources base	(Mell, 2014b:3) (Roe <i>et al.</i> , 2013:653) (Benedict & McMahon, 2002:18) (Mell, 2010:36)
B16.	Management actions as experiments.	(Kato & Ahern, 2008:549)
B17.	Monitoring being the key.	(Kato & Ahern, 2008:549)
B18.	Native species	(Elmqvist <i>et al.</i> , 2013:565)
B19.	Promotion of cross-boundary implementation	(Mell, 2014b:3)
B20.	Providing different ecosystem service categories (provisioning regulating, supporting and cultural)	(Pauleit <i>et al.</i> , (2011: 273) (MEA, 2005:15), (TEEB, 2010c:18)
B21.	Spatial distribution/coverage	(Mell, 2014b:3)
B22.	Systems thinking	(Elmqvist <i>et al.</i> , 2013:565)
C1.	Adapting to climate change	Mell 2013:154
C2.	Change	(Elmqvist <i>et al.</i> , 2013:565)
C3.	Different kinds of knowledge	(Elmqvist <i>et al.</i> , 2013:565)

C4.	Diversity	(Elmqvist <i>et al.</i> , 2013:565)
C5.	Experimentation and evidence-based approach	(Elmqvist <i>et al.</i> , 2013:565) (Roe <i>et al.</i> , 2013:653)
C6.	Green infrastructure initiatives engage diverse people and organizations, obtaining input from representatives of different professions and sectors	(Mell, 2010:129)
C7.	Leadership	(Elmqvist <i>et al.</i> , 2013:565)
C8.	Mainstream	(Elmqvist <i>et al.</i> , 2013:565)
C9.	Multi-object approach	(Hansen & Pauleit, 2014:517)
C10.	Planned comprehensively	(Benedict & McMahon, 2002:18)
C11.	Production	(de Groot <i>et al.</i> , 2002:395 references in Young <i>et al.</i> , 2014:2573)
C12.	Respect for the site	(Kambites & Owen, 2006:488)
C13.	Strategic landscape management practices adopted by practitioners	(Mell, 2013:154)
C14.	Sustainable landscape policy	(Mell, 2013:154)
C15.	Synergies	(Elmqvist <i>et al.</i> , 2013:565)
D1.	Assessments of landscape fragmentation	(Mell, 2010:110)
D2.	Capital negotiations	(Mell, 2010:110)
D3.	Contextualization by transdisciplinarity and collaboration needs conception, design, implementation and maintenance phase	(Scott <i>et al.</i> , 2013:571) (Hansen & Pauleit, 2014:517)
D4.	Local distinctiveness	(Kambites & Owen, 2006:488)
D5.	Obtain sources of sustainable funding	(Kambites & Owen, 2006:488)(Mell, 2010:204)
D6.	Participatory and partnership approach	(Roe <i>et al.</i> , 2013:653)
D7.	Planning for the protection and enhancement of GI assets and functions should precede the allocation of land for development (GI is fundamental infrastructure planning)	(Scott <i>et al.</i> , 2013:571)
D8.	Primary importance (the first step is GI)	(Roe <i>et al.</i> , 2013:653)
D9.	Promote economic regeneration	(Mell, 2010:36)
D10.	Reconcile urban habitats with their natural analogues	(Elmqvist <i>et al.</i> , 2013:565)
D11.	Several plans/experiments at once for fast learning.	(Kato & Ahern, 2008:549)
D12.	Should be funded up-front as primary public investments, using the full range of available financing options	(Mell, 2010:129)
D13.	Social norms and perceptions	(Mell, 2010:110)
D14.	Spatial disparities	(Mell, 2010:110)
D15.	To achieve adequate data	(Kato & Ahern, 2008:549)

Source: Authors compilation (2017). Principles are alphabetically ordered and colour coded according to labelling.

Annexure five deals with the principles of ecosystems, climate change adaption, the ecological design process, landscape approach, agricultural production, environmental conservation, green engineering and economics, and resilience. Annexure five provides a proper view of green and grey infrastructure disciplines and explains how Table 6-3's GI planning linguistics is used in trans-disciplinary fields. The result was that various, specific ecosystem elements and site-specific requirements, were not evident by the GI planning linguistics of Table 6-3. However, the general and majority of trans-disciplinary principles have been covered in Table 6-3. This will assist any planning team that would want to develop the potential of GI planning into land use planning scales as to achieve higher efficient and effective planning integration.

Prain and Lee-smith (2010:19) explain that the aspect of “dialogues” highlights the micro-level interactions, negotiations, and shifts in ideas as crucial support for macro-level policy integration. In this manner, the crucial social capital gain will ensure the degree of association, trust, mutual confidence and social interaction that characterize planning relationships (Prain & Lee-smith, 2010:19; UNECA, 2013:17). Table 6-3 provides more direction in clear communication of social capital to comprehend the complexity of GI planning approaches. This dissertation provides the potential of GI planning in RPU informal settlement areas on a regional planning scale via the principles provided in Table 3-8 and increases in comprehensiveness through the principle integration in Table 6-3.

Thus, the highest effective and efficient planning with the principles would be to understand which principles of Table 3-8 and Table 6-3 complement each other, specific to the spatial planning landscape dynamics. In this manner, after the potential of GI planning is determined using Table 3-8, the correct application of Table 6-3’s principles can be linked to the appropriate land use planning scale dynamics. This will equip the planning teams who will further refine the potential of GI planning to land use planning scales (e.g. sub-regional and local scales) in order to know which GI planning principles to focus on, as well as the linguistics surrounding such spatial planning approaches.

Lastly, with regards to understanding the application of the GI planning principles, drawn to GI potential, Table 6-4 was created. This table combined the main GI planning principles, from Table 3-8, with the GI linguistic synonyms that occur in scientific literature in relation to GI planning. Providing a larger vocabulary to a fairly new terminology, within landscape ecology as well as the strategical regional planning on the areas of informal settlement influence, supplies a larger context to understanding the spatial dynamics in this methodology. In dealing with the eThekweni case study, the holistic principle drawn from the potential of GI did not match each synonym used from Table 6-3. Since this current study is limited to spatial geo-anthropocentric data, capacity is not focused but rather the potential and informal settlements are isolated from the anthropocentric influence on GI. Table 6-4 provides a larger vocabulary, necessary for the reader to comprehend the spatial dynamics of each given GI principle.

Table 6-4: GI related principles of Table 6-3 synonym with main GI planning principles from Table 3-8

Main words/principles	Synonymous words/principles
Holistic, comprehensive, flexible and integrated approach	Design and plan green infrastructure before development, Integration (holistic, comprehensive and flexible approach), Planning, Sustainability, Framework for conservation and development, Holistic approach /understanding of systems and their supporting capacity (Geographical, Political, and Functionally), Learning by doing, Systems thinking Sustainable landscape policy
	A4, A5, A10, A11, B8, B10, B14, B22, C14
Multifunctionality:	Multi-functionality and interconnection of green spaces, Production, Synergies
	A8, C11, C15
Connectivity/Linkage:	Connectivity between/across urban locations, Landscape pattern and process (ecological network concept), Linkage is key, Biodiversity, Habitat, Native species, Spatial distribution/coverage, Diversity, Respect for the site, Assessments of landscape fragmentation, Reconcile urban habitats with their natural analogues
	A3, A6, A7, B2, B9, B18, B21, C4, C12, D1, D10
Multi-scale approach:	Multi-scaled approach, Promotion of cross-boundary implementation
	A9, B19
Multi-object approach:	Providing different ecosystem categories (provisioning regulating, supporting and cultural), Multi-object approach
	B20, C9
The primary importance of green infrastructure:	Planned comprehensively, Planning for the protection and enhancement of GI assets and functions should precede the allocation of lands for development (GI is fundamental infrastructure planning), Primary importance (the first step is GI)
	C10, D7, D8
Evidence-based approach:	Information collation and analysis (baseline data), Is grounded in sound science and land-use planning theories and practices, Management actions as experiments, Experimentation, and evidence-based approach, Local distinctiveness, Several plans/experiments at once for fast learning, To achieve adequate data
	B11, B13, B16, D4, D11, D15
Strategic approach:	Accessibility, Context, Delivery of multiple benefits simultaneously to humans and nature, Monitoring being the key, Adapting to climate change, Mainstream, Strategic landscape management practices adopted by practitioners, Spatial disparities
	A1, B3, B5, B17, C1, C8, C13, D14
Social inclusion (partnership and participatory):	Communicative and social- inclusive process, A critical public investment, Cooperation and learning, Focus of the key stakeholders and community involvement, Leadership, Participatory, and partnership approach, Social norms, and perceptions
	A2, B1, B4, B7, C7, D6, D13
Transdisciplinarity:	Different kinds of knowledge, Green infrastructure initiatives engage diverse people and organizations, obtaining input from representatives of different professions and sectors, Contextualization by transdisciplinarity and collaboration needs conception, design, implementation and maintenance phase
	C3, C6, D3,
Long-term approach:	Diverse range of investment options, Integrated approach to investment in urban (and urban-rural interface) environments, Long-term and strategic approach to the investment and management of urban environmental resources base, Capital negotiations, Obtain sources of sustainable funding, Promote economic regeneration, Should be funded up-front as primary public investments, using the full range of available financing options
	B6, B12, B15, D2, D5, D9, D12

Source: Authors creation from Table 3-8 and Table 6-3

6.3.5. Identifying rural and peri-urban GI planning potential from informal settlement influence

The following sections deal with the identified GI planning potential from RPU informal settlements in the eThekweni municipality region. Applying the methodology, explained in Section 5.4, the following maps and tables explain the conversion of GI potential as seen in Annexure 13, towards GI “planning” potential. Integrating the GI planning principles application provides the strategic spatial understanding of the influence of informal settlements in RPU regions.

As seen in Table 3-8, the first three principles (namely connectivity, multi-functionality and the holistic principle) encapsulate the spatial planning principles of the other mentioned principles. In this manner, the following sections examine the identified GI planning potential, at the hand of the three principles which incorporates the spatial principle understanding altogether. In viewing the three principles of Section 6.3.4.1 unto Section 6.3.4.3 will provide the full view of GI planning potential in the case study. Thereafter a snapshot collage of various planning approaches, regarding the identified GI planning potential, is given to assist in the interpretation and spatial planning direction for the identified GI planning potential.

An important aspect to consider is technical rationalizing of the GPS placement of every polygon line on the following GI planning principle maps. The GI principles are only principles in itself, providing no definite guideline, standards, requirements or limitation as to the implementation or design of the GI potential. Thus, applying GI planning principles to merely remain “potential” suits the identification of GI planning potential from GI principles to fit the dynamic geo-anthropocentric context of this case study. It is in this regard that the potential GI planning maps are not fixed polygons but were created dependent on the spatial influence of informal settlements across MOSS and river networks, in order to conform to strategic spatial potential tools that the spatial planner can integrate to realistically protected and conserved GI spaces contextually.

6.3.5.1. Connectivity principle

The potential, illustrated in the following figures, are the integrated influence from individual buffers (as illustrated in Annexure 15) that has been merged, into GI planning maps, along with the GI planning principle of Connectivity. Figure 6-13 illustrates the RPU potential of GI planning by a connectivity principle application. Thereafter, Table 6-5, cross values the use of the connectivity principle in light of other GI principles in order to evaluate the spatial integrity of the potential GI influences on the case study.

The connectivity principle is the smallest built GI planning polygon, amongst the illustrated GI planning principles in this case study. Applying the connectivity principle is drawn from the identified GI potential polygons that are within a close proximity to each other. Through ArcGIS, additional polygons were created between and around the influence polygons to enhance connectivity specific to each region's required contextual interrelation of spaces between MOSS, water networks and identified RPU influences. Strengthening the connectivity of spaces to further

protect and preserve, beyond the identified GI potential, in a connectivity principle produced constructive GI planning potential.

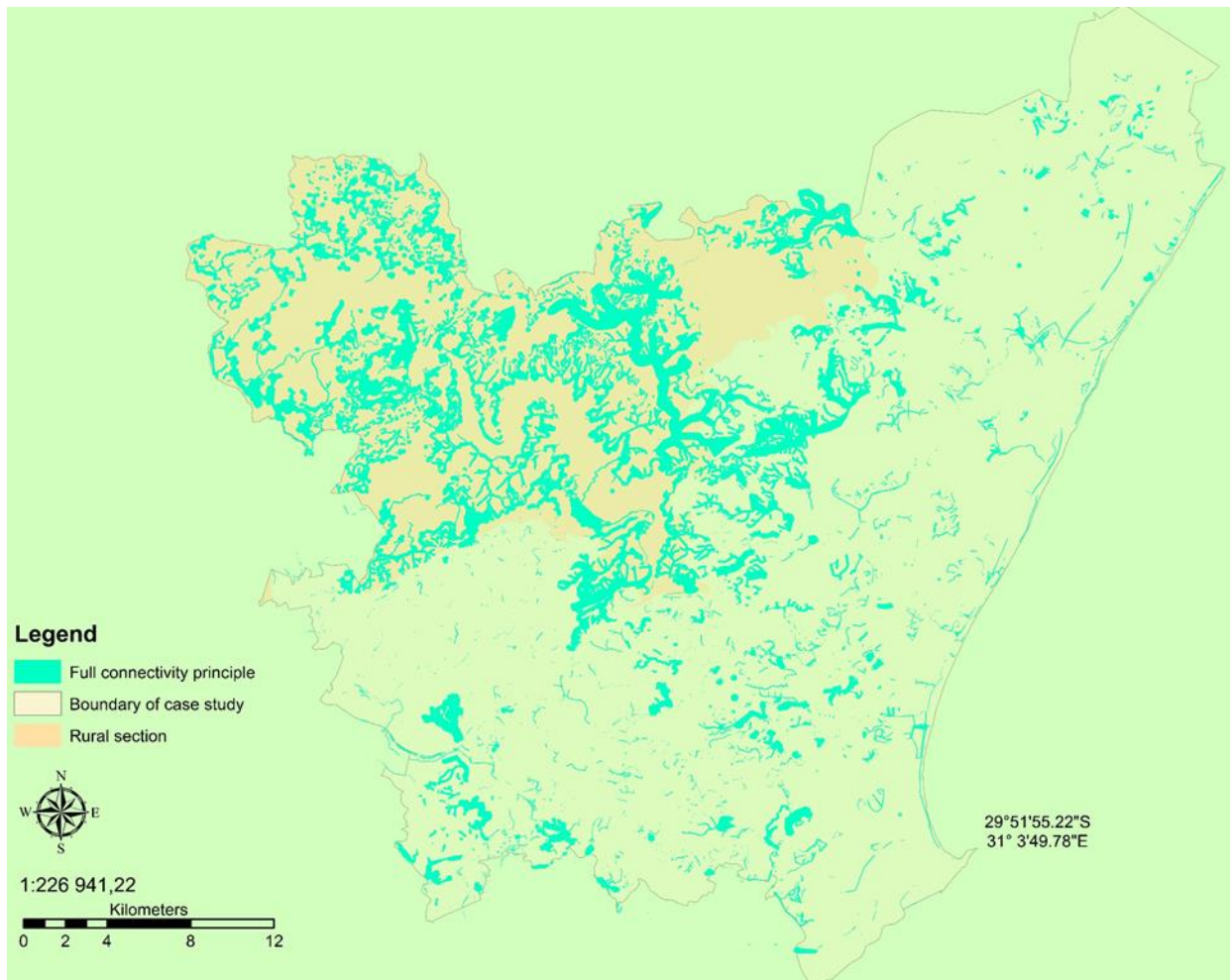


Figure 6-13: Full connectivity principle for GI planning potential in the case study region
Source: Authors creation from ArcGIS 10.4.1 (2017)

Table 6-5: Connectivity principle applied for GI planning potential understanding

GI principles	Status and rationale regarding GI planning principles
Approaches addressing green infrastructure structure in a connectivity sense	
Holistic, comprehensive, flexible and integrated	<p>Status: Low</p> <p>Rationale: There is a higher spatial connectivity of influence from informal settlements in the rural regions compared to those in the peri-urban areas. This causes comprehensive spatial planning to have a low degree of connectivity, for protecting MOSS and river networks, which is prevalent in rural areas. In this manner, the spatial connectivity is not holistically and flexibly manageable in order to counteract possible informal settlements' influence in either rural or peri-urban area.</p>
Multifunctionality	<p>Status: Low</p> <p>Rationale: From a connectivity viewpoint, the spatial influence has a larger impact in rural areas, due to the fact that more GI exists in those areas. The peri-urban areas have less MOSS, due to larger fragmentation of MOSS regions by built-up development. Thus, the critical green space, in peri-urban areas, are also under threat by informal settlements' influence. This makes the continuity of multi-functionality a scarce occurrence in rural and peri-urban areas. Especially by way of green spaces forming a spatial network of infrastructure patch-corridors.</p>
Connectivity /Linkage	<p>Status: Low to moderate</p> <p>Rationale: Rural connectivity of GI spaces are few. Peri-urban areas already have much less MOSS spaces than rural areas. The influence of informal settlement regions, being located closer to urban areas, disregards habitat and species' diversity in MOSS and river regions, more than with rural boundaries.</p>
Multi-scale approach:	<p>Status: Principle partially achieved</p> <p>Rationale: The use of MOSS, rivers, roads and informal settlement distribution across local and district scale boundaries, incorporates a multi-scale approach. From a connectivity viewpoint, the scale can be taken down to vegetation types; fauna and flora territory for sustainable natural development of resilient ecosystem views.</p>
Multi-object approach:	<p>Status: Principle partially achieved</p> <p>Rationale: The combined inclusion of rivers, with grassland, road networks, and dwelling units covers a broad spectrum of objects used in a single approach. The integration of humans and nature is limited by the spatial potential capacity of the planning approach as well as the available data. More natural and built-up elements can add deeper and specific value to convert potential into usable units in order to analyze and predict more accurate spatial planning approaches.</p>
The primary importance of green infrastructure:	<p>Status: Principle partially achieved</p> <p>Rationale: To identify the potential of GI is a crucial part of the first steps for GI planning. However, this dissertation only covers the potential. Further studies, surrounding the capacity of GI through the case, are needed for adequate decision-making processes. From a connectivity viewpoint, the identified buffer elements reflecting the potential GI in the case study region can be advanced through geological, hydrological, fauna and flora refinement of buffered elements, specific toward designated biome regions. Further, GI planning approaches can further incorporate a human factor from more built elements of anthropogenic demand and supply the effects on natural systems. This could add value to the connectivity of influence, specific to case study regions. As GI includes natural and anthropogenic elements, across natural boundary scales, this connectivity principle focuses on GI as having primary importance.</p>

Evidence-based approach:	<p>Status: Low</p> <p>Rationale: Robust scientific evidence, for this dissertation, stretched as far as the incorporation of provincial and international literature, with regards to defying buffer standards for the GI planning approach. Further studies in the analysis of the capacity of the potential for GI planning, will add to the necessary evidence-base background in order to conduct proper decision-making processes. The data used for ArcGIS was dated until 2011 for informal settlements. As the influence is a large determinant of the identification of potential, such data needs to be newly sourced, before decision making of spatial development can proceed.</p>
Approaches addressing governance process of GI in a connectivity sense	
Strategic approach:	<p>Status: Principle potentially achieved</p> <p>Rationale: As the eThekweni municipality has authoritative power over established MOSS regions, the identified potential is realistically broadened by including river networks. The influence of informal settlements is prone to migration. Neither does it promote a fixed capacity. It fluctuates, thus, the study presents only the influence as potential. The strategic element of rural and peri-urban human and natural elements provide the spatial integrity of GI scaling and is not limited to grey infrastructure scales. Various human influences of informal household activities, with associated roads and drainage development, are matched against various water and vegetation buffer standards. The spatial integrity is advanced, in the sense that various anthropogenic and natural elements are fused into a singular model of GI potential to be principally interpreted. This provides the necessary flexibility for the spatial planner to channel desired elements, while having a larger spatial reference of GI, to plan and compare with. Strategically, that would be bottom-up spatial planning, as individual bottom influences are arranged in a top view in order to harness the context required for GI scales.</p>
Social inclusion (partnership and participatory):	<p>Status: Incomplete</p> <p>Rationale: The involvement of stakeholders were not incorporated when identifying the potential of GI planning in this case study. Neither were local nor district municipal input is taken into account when refining the potential of GI to be used for GI planning principle integration. This current study only used the eThekweni municipality's GIS raw data, and have by no means included the data of officials or researchers involved with the KwaZulu-Natal region's GI.</p>
Transdisciplinarity:	<p>Status: Incomplete</p> <p>Rationale: As this is only a desktop study, identifying the potential of GI planning in the eThekweni region, the only trans-disciplinary aspects of this current study were mixing different buffer standards, from local and international literature. Further integration of various eThekweni municipalities, specific to each region, would be able to provide local, up-to-date information on informal settlements' influence. Local municipalities would also be able to point out various habitat and ecosystem particularities to focus on, in the GI potential determination and, especially, the GI planning potential integration.</p>
Long-term approach:	<p>Status: Principle potentially achieved</p> <p>Rationale: The scale dynamics were performed with diverse geographic regions, having a vast amount of integrated informal settlement household influence crossing different municipal boundaries. If planning should alter the elements (if appropriately provided) on the projected scale, the only logical success would be found in long-term approaches.</p>

Source: Authors creation (2017)

6.3.5.2. Multifunctionality principle

The following GI planning principle application (to GI potential) is the multi-functionality principle. Figure 6-14 presents a larger interconnected corridor space compared to the one in Figure 6-13. Spatial integrity is addressed more in this GI principle, having a larger spatial scale, because it reflects the definition of GI to a deeper extent.

As explained in Chapter five, the method of building the maps for the multi-functionality principle is based on the previous maps drawn (from the connectivity principle). Multi-functionality argues the case for larger interconnectivity of strategic green spaces to form an interdependent patch-corridor-matrix of spaces. This map illustrates a larger platform in order to protect and conserve against the influence of informal settlement activities, with the purpose of building the resilience for the identified potential, regarding the spatial integrity to sustain GI.

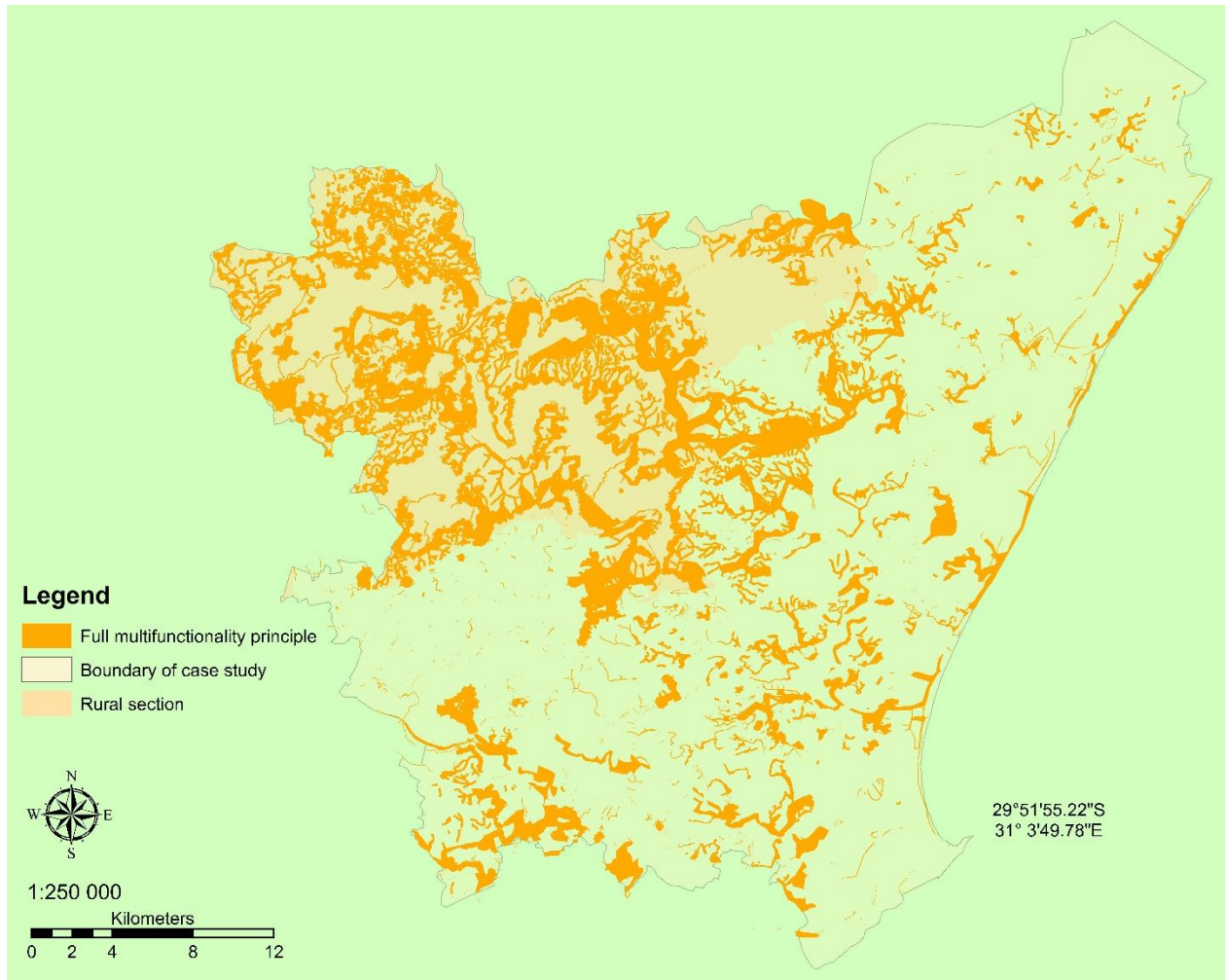


Figure 6-14: Full multifunctionality principle for GI planning in the case study region

Source: Authors creation from ArcGIS 10.4.1 (2017)

It is clear from both the connectivity and multi-functionality figures that, although the rural areas cover less ground space than peri-urban areas, the highest degree of informal influence is spatially arranged in the rural regions. The peri-urban area has a larger spatial fragmentation of MOSS spaces than within rural boundaries, making the scattered influence of RPU areas a serious concern for the spatial integrity of peri-urban regions. Table 6-6 illustrates the multifunctionality principle.

Table 6-6: Multifunctionality principle applied for GI planning potential understanding

GI principles	Status and rationale regarding GI planning principles
Approaches addressing green infrastructure structure in a multifunctionality sense	
Holistic, comprehensive, flexible and integrated approach	<p>Status: Low</p> <p>Rationale: Unique to this case study, in dealing with multi-functionality, is the relation of river networks and MOSS regions that are highly dependent on each other. This currently results in broad spatial coverages around dams, major rivers, wetlands, and estuaries. These spaces cover more ground, than the connectivity principle's application maps, in order to meet a larger dependency on a holistic, comprehensive, but still flexible, GI planning approach (for multi-functionality).</p> <p>Applying a comment from the connectivity principle to the multi-functionality view: There is a higher spatial connectivity of influence from informal settlements in the rural regions compared to those in peri-urban areas. This causes comprehensive spatial planning, to protect MOSS and river networks, which is widespread in rural areas, to have a low degree of connectivity. In this manner, the spatial connectivity is not holistically and flexibly managed to counteract possible informal settlement influence, in either rural or peri-urban area.</p>
Multifunctionality	<p>Status: Low</p> <p>Rationale: Multi-functionality is more visible in the rural boundaries, to counteract the spatial broad influence of informal settlement and, especially, at the centre of the peri-urban areas. There is a larger functionality which is dependent on major rivers, wetlands, dams, and estuaries in the RPU regions. Multi-functionality has to be adapted for larger existing GI spaces which exist outside the selected MOSS and river networks in order to include a larger reality of natural resource multi-functionality.</p> <p>Applying a comment from the connectivity principle to the multi-functionality view: The spatial influence has a larger impact in rural areas, due to the fact that more GI exists in those areas. The peri-urban areas have less MOSS, due to larger fragmentation of MOSS regions by built-up development. Thus the critical green space in peri-urban areas is also under threat by informal settlement influence. This makes the continuity of multi-functionality, by green spaces, to form a spatial network of infrastructure patch-corridors, in rural and peri-urban areas, a scarce occurrence.</p>
Connectivity/Linkage	<p>Status: Low to moderate</p> <p>Rationale: The connectivity of polygons are expanded around the influence of informal settlements that are based on the connectivity principle maps. In this manner, the added spaces taken from the connectivity principle were adapted to include a larger multi-functionality of multiple data layers. These data layers were of human (transport networks, sewer lines, household activity) and natural elements (river networks, vegetation types including those under threatened status). In this integrated view, the added connectivity was supplementary to the multi-functionality principle's maps. Which was not the case for the connectivity principle's maps, which only focused on the potential GI influence that was spatially distributed.</p> <p>Applying a comment from the connectivity principle to the multi-functionality view: Rural connectivity of GI spaces are few. Peri-urban areas already have much fewer MOSS spaces compared to rural regions. The influence of informal settlement regions are located closer to urban areas and, thus, disregards habitat and species' diversity in MOSS and river regions, even more than in rural boundaries.</p>
Multi-scale approach:	<p>Status: Principle partially achieved</p> <p>Rationale: Applying a comment from the connectivity principle to the multi-functionality view: The use of MOSS, rivers, roads, and informal settlement distribution, across local and district scale boundaries, incorporates a multi-scale approach. From a connectivity viewpoint, the scale can be taken down to vegetation types as well as fauna and flora territory for sustainable natural development of resilient ecosystem views.</p>

Multi-object approach:	<p>Status: Principle partially achieved</p> <p>Rationale: Applying a comment from the connectivity principle to the multi-functionality view: The combined inclusion of rivers, with grassland, road and road networks, as well as dwelling units, cover a broad spectrum of objects used in a progressive planning approach. The fusion of human and natural elements is limited by the spatial potential capability of the planning approach and available data. More natural and anthropocentric elements could add deeper and more specific value, in order to convert potential into usable units, in order to analyze and predict more accurate spatial planning approaches.</p>
The primary importance of green infrastructure:	<p>Status: Principle partially achieved</p> <p>Rationale: The multi-functionality principle adds to the GI essence, with more predominance than with the connectivity principle maps. In this manner, a larger platform, for GI to build landscape ecological resilience, is provided through a larger and more strategic extension of the interconnected space in order to protect and conserve GI in this case study. This is only in reference to the potential and does in no way provide the capacity of GI. In other words, GI through the multi-functionality principle provides a larger platform to perform more extensive spatial planning.</p> <p>Applying a comment from the connectivity principle to the multi-functionality view: From a connectivity viewpoint, the identified buffer elements, which reflect the potential GI in the case study region, can be advanced throughout geological, hydrological, fauna and flora refinement, depending on the designated biome region.</p>
Evidence-based approach:	<p>Status: Low</p> <p>Rationale: Applying a comment from the connectivity principle to the multi-functionality view: Robust scientific evidence for this dissertation stretched as far as the incorporation of provincial and international literature with regards to defining buffer standards for the GI planning approach. Further studies, in the analysis of the capacity of the potential for GI planning, will add to the necessary evidence-base background in order to conduct proper decision-making processes. The data used in ArcGIS dated until 2011 for informal settlements. As the influence is a large determining factor for the potential identification, such data needs to be newly sourced before decision making of spatial development can proceed.</p>
<p>Approaches addressing governance process of GI in a connectivity sense</p>	

<p>Strategic approach:</p>	<p>Status: Principle potentially achieved Rationale: Spatial strategic planning better into the multi-functionality principle than into any other GI principle. The case study reflects the strategic comprehensiveness of developing GI, where the source of influence is the pivot point, rather than the established natural hotspots of species diversity or certain fauna/flora niches. Multi-functionality is thus based. It is also strategically identified in light of the influence informal settlements have on generalized, established GI. This is to manage and mitigate the spatial impact-potential of settlement sprawl, against the space required in order to protect and preserve identified GI. The dynamics of spatial strategic planning, through the multi-functionality principle, incorporates numerous sprawl of informal settlement influences against diverse vegetation types and river networks. The multi-functionality maps, thus, created larger polygon spaces compared to the potential of GI influence maps (presented in Annexure 13) or the illustrated connectivity principle maps (of Figure 6-13). Applying a comment from the connectivity principle to the multi-functionality view: As the eThekweni municipality has authoritative power over established MOSS regions, the identified potential is realistically broadened by including river networks. The influence of informal settlements is prone to migration. Neither does it promote a fixed capacity. It fluctuates, thus, the study presents only the influence as potential. The strategic element of rural and peri-urban human and natural elements provides the spatial integrity of GI scaling and is not limited to build grey infrastructure scales. For example, various human influences of informal household activities, with associated roads and drainage development, are matched against various water and vegetation buffer standards. The spatial integrity is advanced, in the sense that various anthropogenic and natural elements are fused into a singular model of GI potential. Which is to be principally adapted, resulting in GI planning potential. Strategically, that would be bottom-up spatial planning, as individual bottom influences are arranged in a top view in order to harness the context required for GI scales.</p>
<p>Social inclusion (partnership and participatory):</p>	<p>Status: Incomplete Rationale: Applying a comment from the connectivity principle to the multi-functionality view: The involvement of stakeholders are not incorporated to identify the potential of GI planning in this case study. Neither is the local, nor the district municipality's input taken into account when refining the potential of GI that is to be used for GI planning principle integration. This current study only used the eThekweni municipality's GIS raw data, and have by no means included the data of officials or researchers involved with the KwaZulu-Natal region's GI.</p>
<p>Transdisciplinarity:</p>	<p>Status: Incomplete Rationale: Applying a comment from the connectivity principle to the multi-functionality view: As this is only a desktop study, identifying the potential of GI planning in the eThekweni region, the only trans-disciplinary aspects of this current study were mixing different buffer standards, from local and international literature. Further integration of various eThekweni municipalities, specific to each region, would be able to provide local, up-to-date information on informal settlements' influence. Local municipalities would also be able to point out various habitat and ecosystem particularities to focus on, in the GI potential determination and, especially, the GI planning potential integration.</p>
<p>Long-term approach:</p>	<p>Status: Principle potentially achieved Rationale: Applying a comment from the connectivity principle to the multi-functionality view: The scale dynamics were performed with diverse geographic regions, having a vast amount of integrated informal settlement household influence crossing different municipal boundaries. If planning should alter the elements (if appropriately provided) on the projected scale, the only logical success would be found in long-term approaches.</p>

Source: Authors creation (2017)

6.3.5.3. Holistic principle

A GI planning principle that incorporates an interconnected vision from the influence of informal settlements to a long-term regional strategic planning approach, is the holistic principle. The “holistic principle” is shortened from the full reference of the “holistic, comprehensive, flexible and integrated approach”. It was shortened in order to simplify the map presentation and description. The holistic principle map methodology (presented in Chapter five) adds ArcGIS layers to the connectivity as well as the multi-functionality maps. In this way, fuller strategic spatial maps can be created for long-term integration of areas, in order to potentially protect and conserve the spatial integrity of natural systems.

The holistic principle has been divided into two maps in order to more effectively illustrate the dynamic capabilities of this applied GI planning principle. Figure 6-15 portrays the first part of the holistic principle, drawn from the previous connectivity and multi-functionality principle maps, and presents roads and rivers that are not strategically placed.

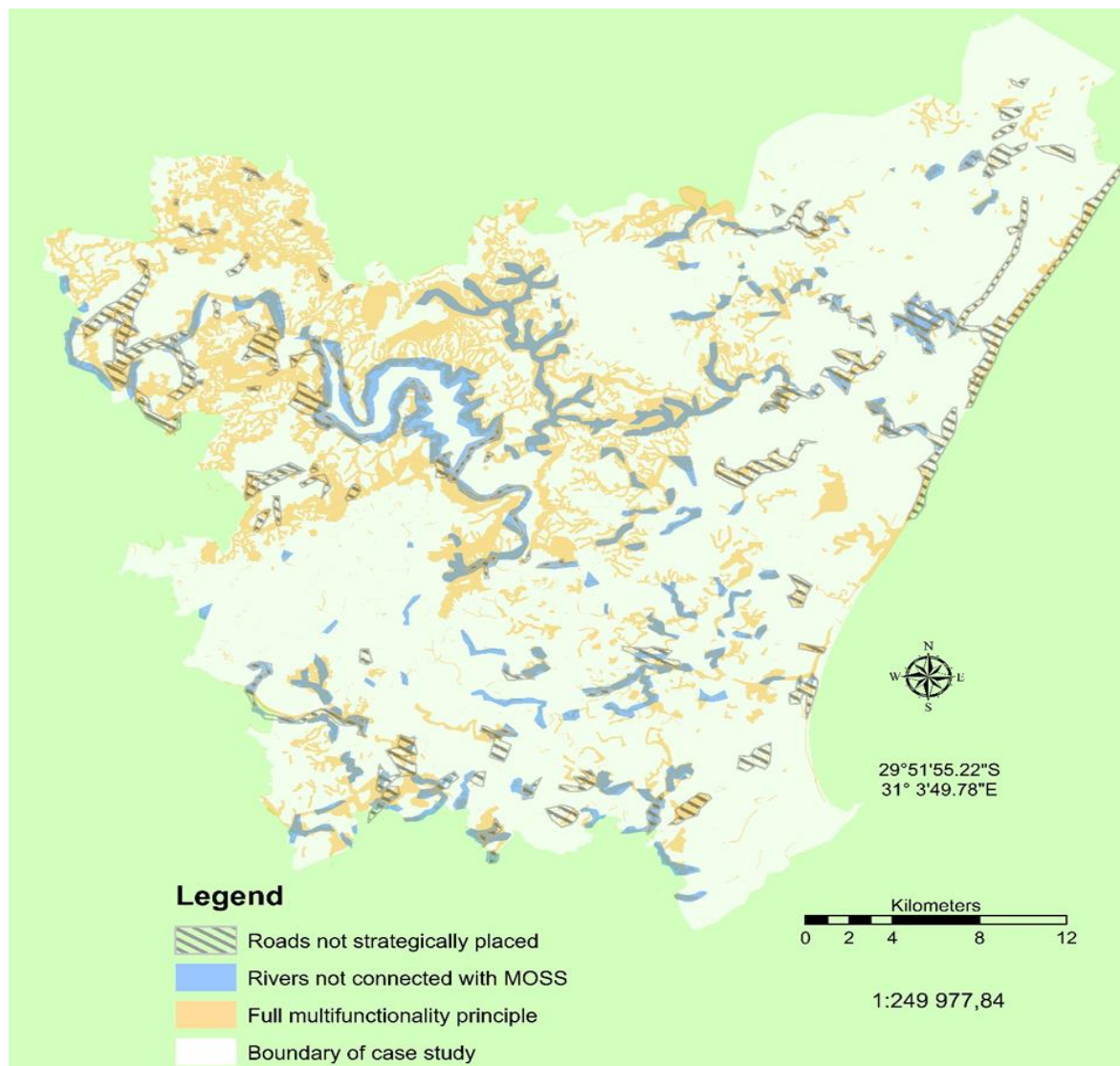


Figure 6-15: Full holistic principle for GI planning in the case study region (part one)

Source: Authors creation from ArcGIS 10.4.1 (2017)

The second part of the holistic principle is presented in Figure 6-16 and shows the various open spaces that need a high degree of security. The established MOSS spaces have low spatial connectivity, as well as the overall/general spaces that can be included to potentially increase the strategic spatial integrity of the case study. These spaces were drawn manually in ArcGIS 10.4.1., as interpreted from the holistic GI planning principle. Including the multi-functionality principle within the holistic principle maps, adds to the contextual underpinning to create the polygons in the applied manner.

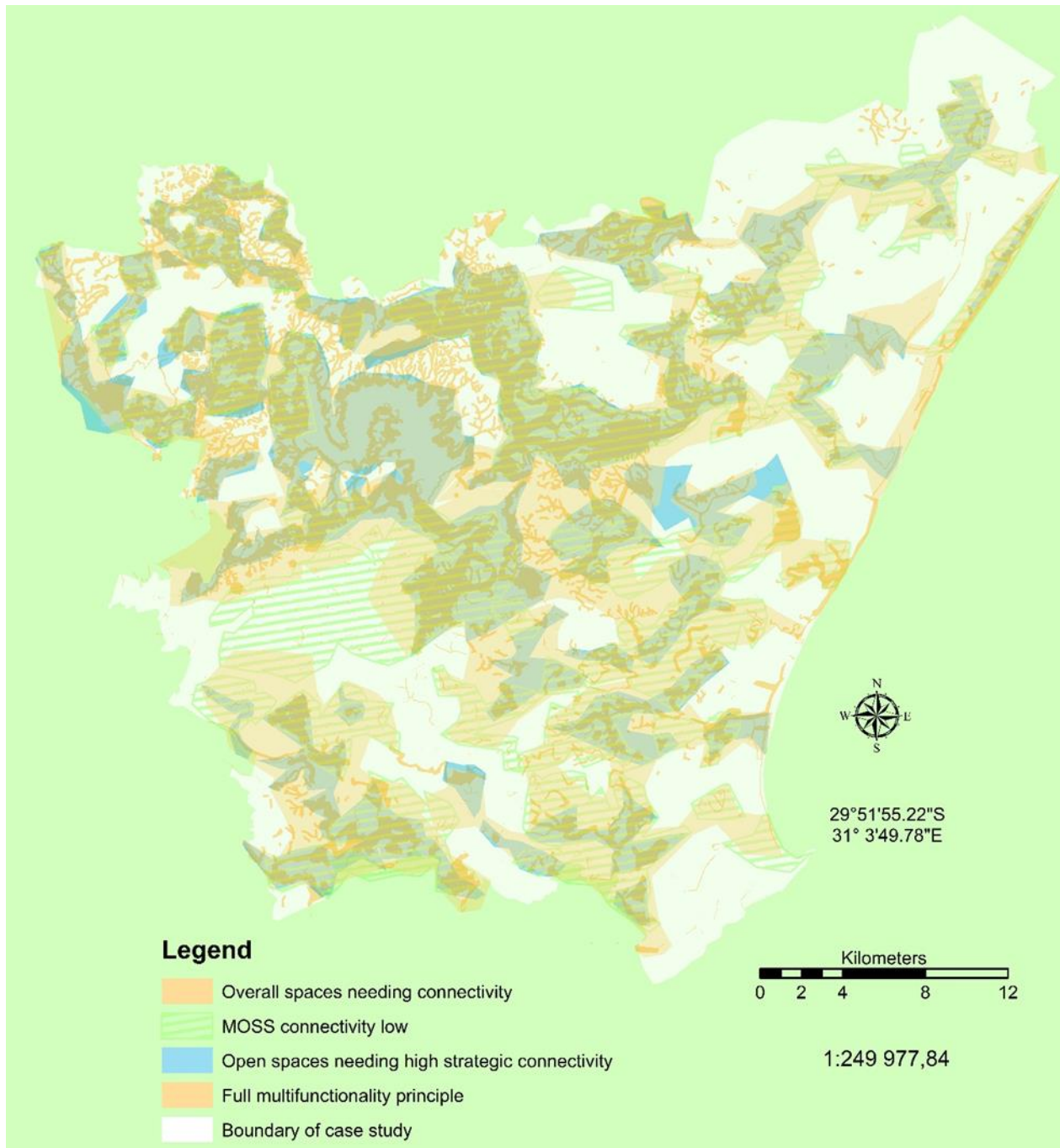


Figure 6-16: Full holistic principle for GI planning in the case study region (part two)

Source: Authors creation from ArcGIS 10.4.1 (2017)

The following table, Table 6-7, values the holistic GI planning principle against the other recognized GI planning principles; similar to what has been done to the connectivity and multi-functionality GI planning maps (Table 6-5 and 6-6). However, specific to the holistic principle maps, unlike with the connectivity and multi-functionality principle maps, is the scale variation of the corridor patterns of potential GI planning. The rationale differs in the holistic principle due to larger scale dynamics.

Table 6-7: Holistic principle applied for GI planning potential understanding

GI principles	Status and rationale regarding GI planning principles
Approaches addressing green infrastructure structure in a connectivity sense	
Holistic, comprehensive, flexible and integrated approach	<p>Status: Low</p> <p>Rationale: (Figure 6-15) The holistic strategic placement of established roads cut through pristine boundaries of MOSS and river networks which could potentially disrupt the spatial integrity of GI in the case study.</p> <p>(Figure 6-16) The spatial integrity of GI flows from an interconnected, valuable green space continuity. This figure illustrates how informal settlement influence has created pockets of MOSS and river networks that, potentially, need more established protected and conserved spaces in order to ensure long-term livability of these natural systems within these predominately human-built areas.</p>
Multifunctionality	<p>Status: Low</p> <p>Rationale: (Figure 6-15) Since the classification of roads are not taken into consideration, the activity of a road is generalized so that potential can be identified. As the polygon areas illustrate, the variously visible intrusions of transport networks, through the case study's GI, is larger MOSS spaces divided into smaller sections, that decrease landscape ecological aspects (such as biodiversity niches and successful migration patterns of fauna and flora). The identification of potential roads and rivers are not spatially or strategically protected or placed and does not include land use planning scale of natural and human dynamic capabilities, the multi-functionality is limited to a general conclusion.</p> <p>(Figure 6-16) Rural areas have a larger need for spatial connectivity in order to address the multi-functionality from those regions informal settlement influence. Peri-urban areas have fewer MOSS spaces and more compact informal settlement influence which reflect less spatial connectivity, than in rural areas. However, the overall spaces that need to be connected and spaces of river networks where MOSS connectivity is low, occur more in the peri-urban areas, due to river networks that are not spatially integrated into the eThekweni municipality's established MOSS layers.</p>
Connectivity/Linkage	<p>Status: Low</p> <p>Rationale: (Figure 6-15) Rural regions have a larger influence on informal settlements, more established MOSS, and include the Inanda dam with its associated river networks. This causes the influence of transport networks and unconnected river networks to have a higher potential to be strategically integrated. This does not mean the connectivity in peri-urban areas is in a better state. It means that working with the limited data, the peri-urban spatial planning dynamics are more concerned with pockets and burst of informal settlement influence that needs to be mitigated from roads and unconnected river networks.</p> <p>(Figure 6-16) Strategic spatial connectivity can be better rationalized in Figure 6-16 than in Figure 6-15. This connectivity is more focused on the potential river and MOSS networks that flow from rural and urban areas over larger land space. In this manner, the illustrated lack of spatial connectivity and poorly recognized MOSS spaces, equates to a low connectivity principle, in both rural and peri-urban areas, derived from the influence of informal settlements.</p>

Multi-scale approach:	<p>Status: Principle partially achieved</p> <p>Rationale: (Figure 6-15) The scale aspect built on the scale inclusion of the multi-functionality principle, is broadened through the strategic spatial arrangement of roads and river networks collectively. Thus, the individual suffered from a visible 1:10 000, unto a collective buffer from a visible view of 1:200 000 scales, is taken with the holistic principle. (Figure 6-16) Similar scale dynamics of Figure 6-15 are incorporated into Figure 6-16. However, the rationale to create polygon layers from the identified potential of informal settlement influence is much larger than with any other previously applied GI planning principle. The established MOSS and full river networks in a holistic GI planning principle map make it much larger.</p> <p>This principle is partially achieved because the GIS data can be increased to include various other influence spheres on land use planning scale which influences GI planning.</p>
Multi-object approach:	<p>Status: Principle partially achieved</p> <p>Rationale: (Figure 6-15) It builds upon the object dynamics of the multi-functionality principle. The focus of this figure rests on the un-strategic placement of transport networks and identified river networks (not spatially included) to be protected and conserved and observed from the spatial distribution of informal settlement influence.</p> <p>(Figure 6-16) This table is built from the multi-functionality principle object as well and is more focused on the collective arrangement of strategic spatial green and blue infrastructure. In this manner, the space drawn around the various objects, include a regional view of nature and human elements.</p> <p>This principle is partially achieved based on the missing human influence objects, e.g. domestic waste patterns, which have not been incorporated into the influence of GI planning of this case study.</p>
The primary importance of green infrastructure:	<p>Status: Principle poorly achieved</p> <p>Rationale: As the terminology of GI takes a broad spectrum of semi-natural, naturally built, and management elements into consideration, the scope of GI contained in the eThekweni case study of potential GI planning, is incomplete. This is mainly due to a lack data about the full influence that informal settlements have in the sub-regional district scale of the case study.</p>
Evidence-based approach:	<p>Status: Low</p> <p>Rationale: Similar to the connectivity and multi-functionality principles, the evidence for the case study was received from the eThekweni municipality (as ArcGIS data). Various standards for the buffers are taken from international and provincial literature. The illustrated polygons, as seen in the holistic principle, are created through individual observation of the created data and was strategically drawn. Group dynamics of trans-disciplinary planning, that is familiar with the eThekweni district, should be included in the polygon creation of the GI planning principle, to increase the evidence-based rationale for the maps.</p>
Approaches addressing governance process of GI in a connectivity sense	
Strategic approach:	<p>Status: Principle potentially achieved</p> <p>Rationale: The essence of the holistic principle application, is to advance the strategic spatial plotting of GI, in the form of MOSS and river networks spaces. These were, either, not formally demarcated as a protected and conserved region, or, the space between established MOSS and river networks needed bridging polygon spaces to uphold potential spatial integrity. Figure 6-13 reflects the road and river networks that need more strategic protection and conservation. Figure 6-14 gives a more of a view of the collective strategic placement of MOSS spaces that needs adaption and additional areas to consider for inclusion into the established MOSS layers.</p> <p>As the scale is based on a sub-regional district level, the strategic plotting of individual buffer influences was incorporated by the buffering of influences. This buffering process uses literature standards that have not been tailored to the individual buffer's geo-anthropocentric context. Further addition, to the strategic approach, can be the use of units to measure the value of various natural and human-built elements. This will provide the bridge, to move from the potential of capacity GI planning to ensure more accurate spatial land use planning capabilities.</p>

Social inclusion (partnership and participatory):	<p>Status: Incomplete</p> <p>Rationale: Similar to the connectivity and the multi-functionality principle, the social inclusion of private and public sector contributions to the creation of the potential GI has not been done. This is merely a potential identification from limited data, a part of GI from parts of the anthropocentric influence, namely, the rural and peri-urban informal settlements.</p>
Transdisciplinarity:	<p>Status: Incomplete</p> <p>Rationale: Applying a comment from the multi-functionality principle to the holistic view: This is only a desktop stud identifying the potential of GI planning in the eThekweni region. The only trans-disciplinary aspects of this current study were mixing different buffer standards from local and international literature. Further integration of various eThekweni municipalities, specific to each region, would provide local, up-to-date information on informal settlement influence. Local municipalities would also be able to point out various habitat and ecosystem specifics to focus on, in the GI potential determination and, especially, the GI planning potential integration.</p>
Long-term approach:	<p>Status: Principle potentially achieved</p> <p>Rationale: The fundamental scale dynamics of the holistic principle truly values a long-term spatial land use planning approach, in order to constructively address the identified potential as presented in this case study. Changing established land uses involves an intensive, long chain of planning steps in the private and public sectors' planning paths. A potential GI planning approach has no fundamental influence in decision-making plans, if there has not been a capacity GI planning direction merged with the local IDP, UDP SDF, EMF and other spatial planning frameworks (established by a South African municipal planning system). The closest planning direction, as directed through municipal planning frameworks in the holistic GI planning principle approach, is such as is presented in Annexure 8: Environmental Implementation and Management Plan of 2016 (EIMP). Such types of policy frameworks use SPLUMA 2013 as a strong-arm to enforce the spatial land use planning approaches. If the potential of GI planning has any chance of being converted into a capacity development planning approach through SPLUMA 2013, then GI planning needs to be an integral part of the planning directive of spatial planning development scales, such as the EIMP 2016 (Annexure eight).</p>

Source: Authors creation (2017)

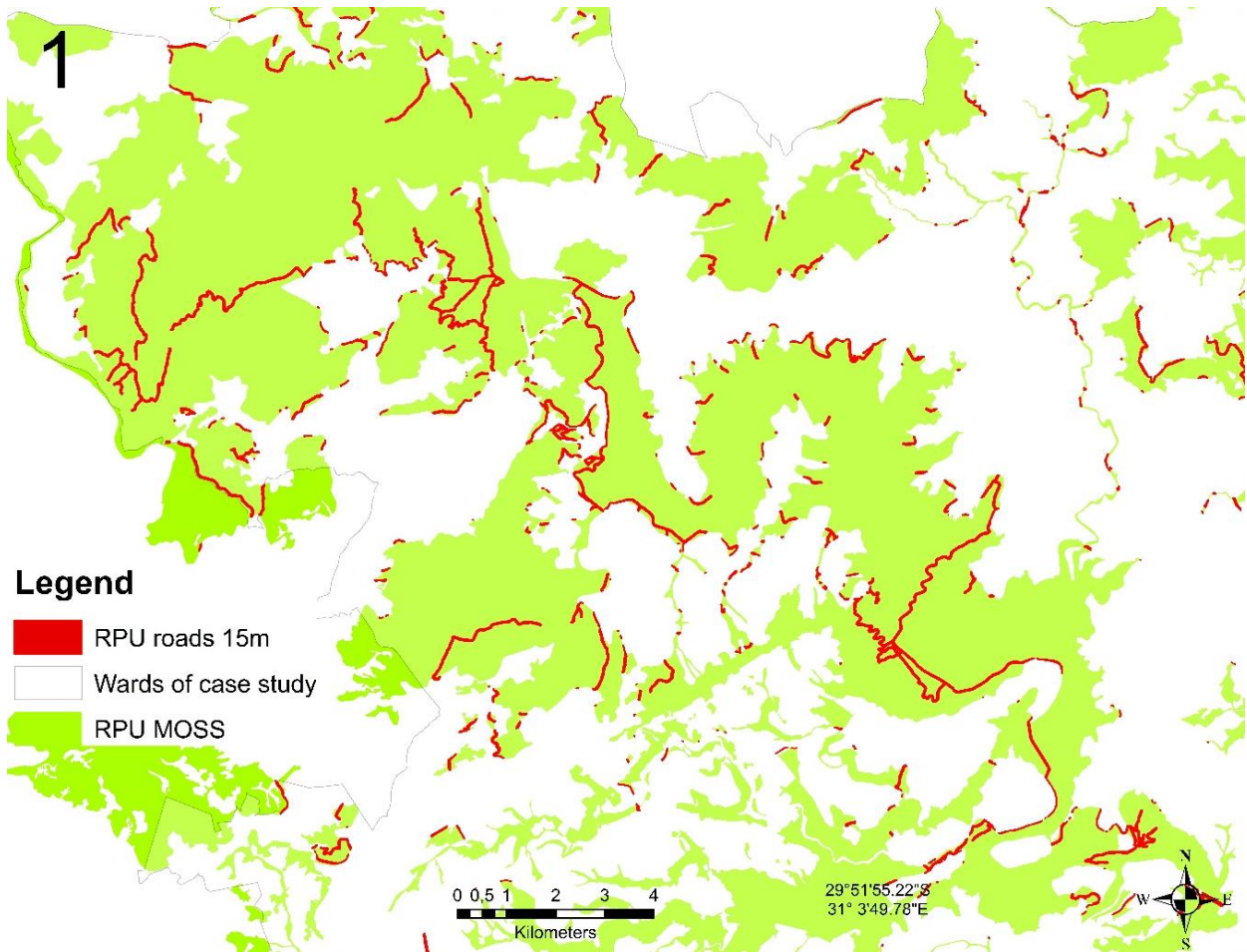
To conclude, the information presented in the previous table (Table 6-7) is only a GI principle evaluation of the potential of GI planning, and does in no way give plotting direction for spatial planners to change land use planning, based purely on the provided maps (illustrated in this case study regarding the eThekweni region). The following section deals with the possible outflows that such data could create and that can be used by spatial planners to integrate into land use planning aspects (as presented in Annexure one and Annexure four).

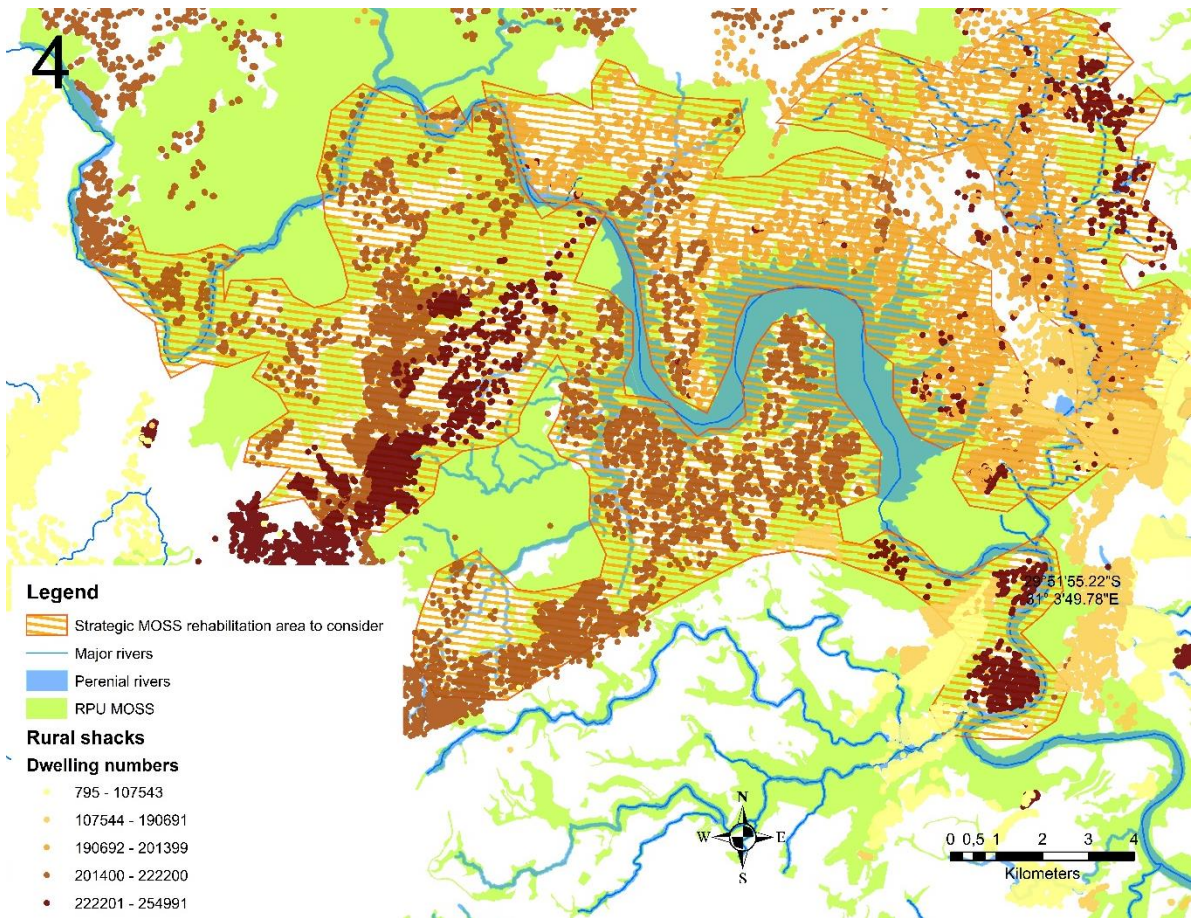
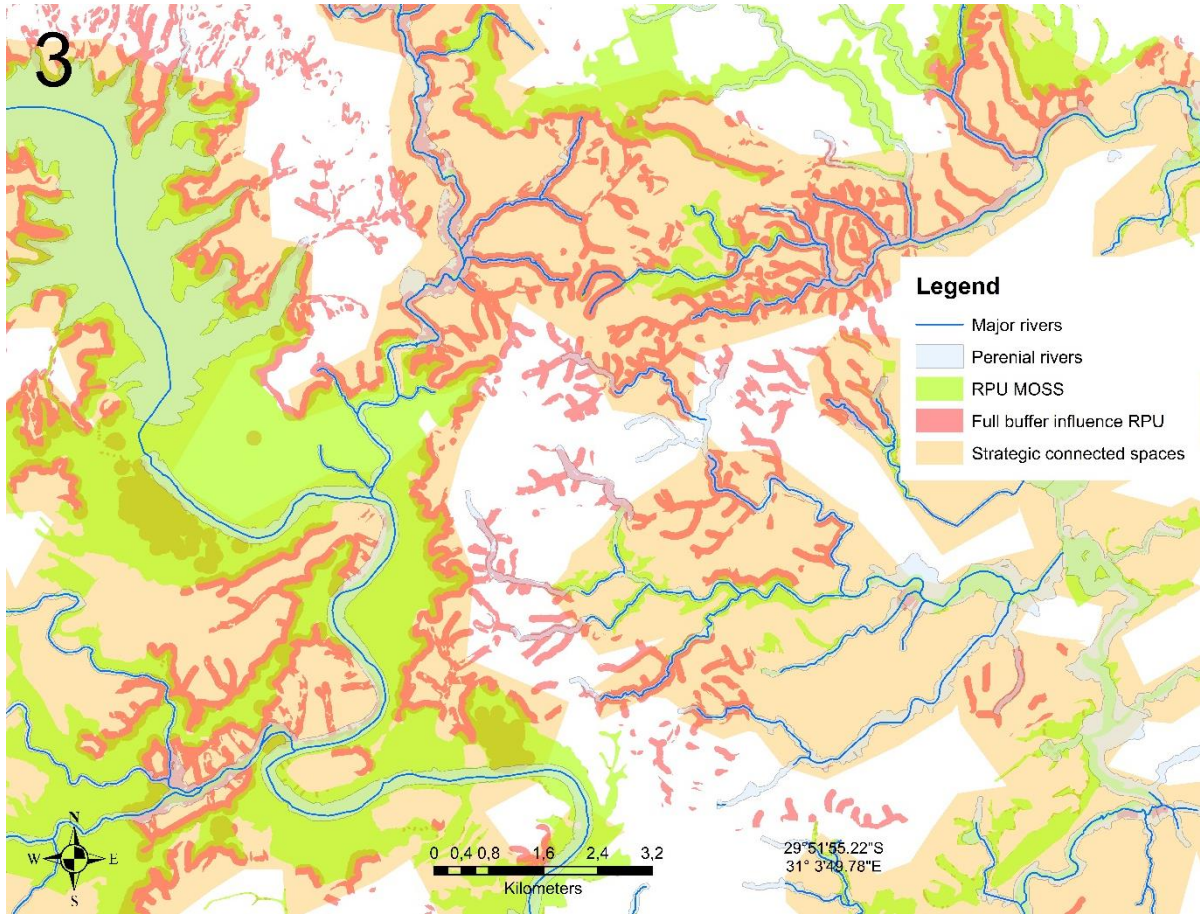
6.3.5.4. Short overviews of spatial integrity issues identified from this case study

This section deals with different approaches that spatial planners can employ to further investigate the various aspects of how informal settlement patterns can influence GI as well as different suggestions. The following issues will only be briefly presented in a snapshot view of Figure 6-17, and only identifies a possible approach from the identified GI potential:

1. Roads that split open spaces into smaller fragmented spaces, discourage the continuity of ecosystem services and put pressure on habitat regions which rely on the spatial continuity potential for the functioning of the ecosystem (see Annexure three on ecosystem services).
2. Drainage lines potentially fragment habitat landscapes which could discourage biodiversity niches and should be strategically placed in different grey-green continuum ways, through alternative solutions. This is especially important in sensitive habitats, for e.g. wetlands.

3. Large open spaces are not strategically interconnected with smaller open spaces and vice versa. Such connection could withstand the pressure of informal settlement sprawl through the identified GI potential. The pressure can stem from the depletion of natural capital, caused by a neighbouring community's dependency on wood and water resources, or human waste disposal in wetlands, or sensitive biodiversity hotspots.
4. The spatial distribution of informal settlements around MOSS types and river networks create a spatial barrier for habitat and biodiversity functioning. Such influence areas must be strategically buffered, especially the most valuable habitat regions and biodiversity pathways, in order to preserve and protect it from unsustainable anthropogenic transformation.
5. Overlapping the current MOSS with the potential GI, and then adding the threatened vegetation types, can advance the strategic GI planning, created of new MOSS layers, that could advance the spatial integrity of the region.





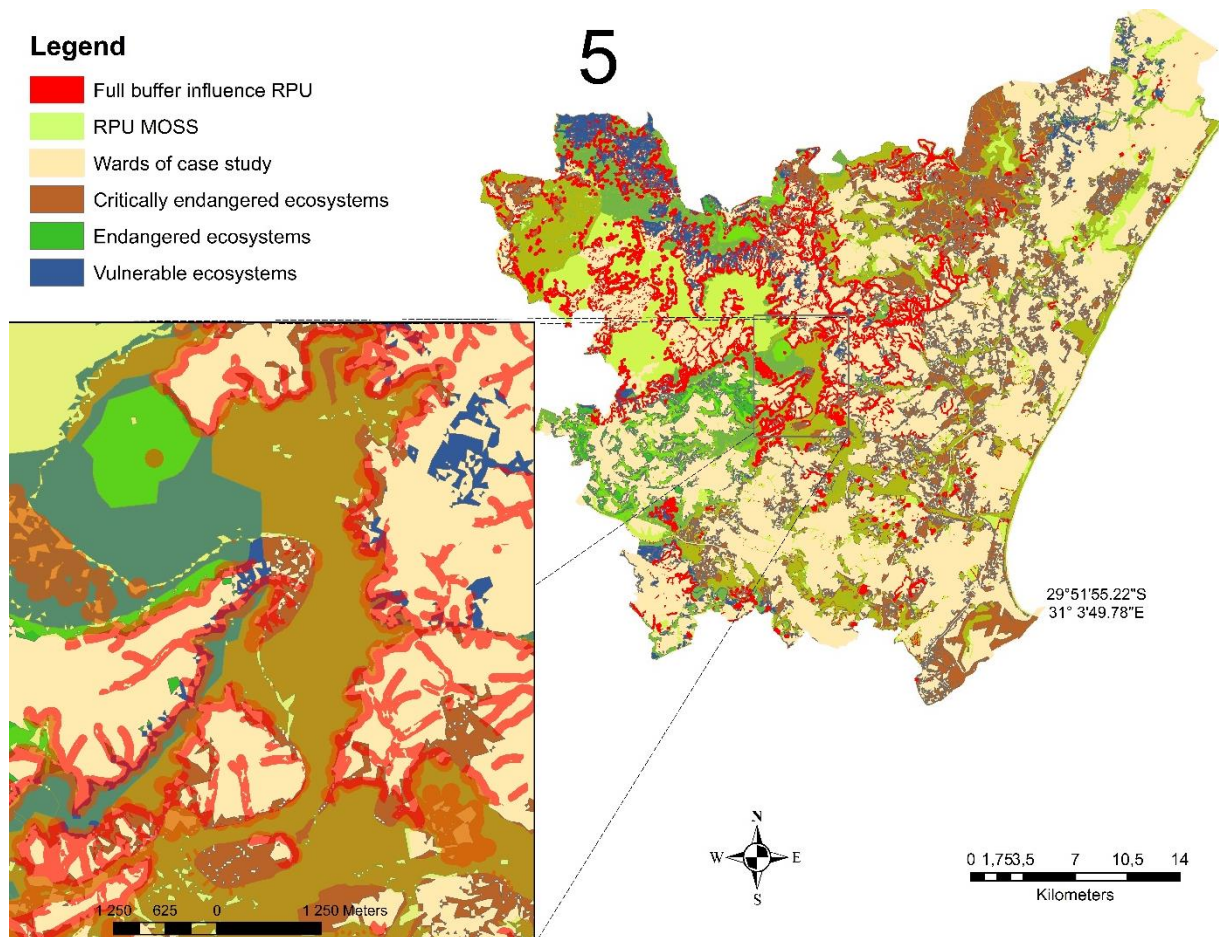


Figure 6-17: Five point short overview for further usage of the identified GI potential from RPU shacks: (1) Un-strategic roads that influence MOSS multi-connectivity; (2) Potential conflict from drainage line placement; (3) Strategic connection areas from shack influences; (4) Strategic MOSS rehabilitation areas from informal settlement hotspots and (5) MOSS areas lacking interconnectivity from threatened ecosystem areas

Source: Authors creation through ArcGIS 10.1.4 (2017)

Furthermore, using a land use planning scale instead of a regional planning scale approach, the following could potentially occur:

- i. Understanding the broad space necessary for GI's potential functioning, GI planning identifies urban sprawling patterns, which need to be increased in compact development ventures of areas strategically reserved for GI planning (holistic principle integration). Thus, providing strategically long-term, grey infrastructure for these communities, will potentially protect and conserve the potential GI.
- ii. Annexure 13 provides individual buffer sets, of different elements, influencing the determination of GI planning potential. The GI potential of Annexure 13, can be used to further investigate the individually identified GI potential, from RPU informal settlements. For instance, this could be achieved by applying GI planning principles to an individual buffer set, in order to produce identified GI planning potential from that individual influence.

The various snapshot presentations, in Figure 6-17, need further investigation by a trans-disciplinary planning team, with regards to the identified GI potential. Incorporating spatial plans and designs, on land use planning scales, can be advanced by looking at Annexure one and Annexure four, while Annexures six unto 12, provides more of a spatial and environmental policy integration. Such plans and designs are thus built on the sustainable paradigm of Annexure 11 while minding the view of the function of Annexure three (ecosystem services). The short overview of this section has not incorporated the above-mentioned Annexure since this current study only identifies, and does not develop, the GI potential from informal RPU settlement influence.

6.4. Conclusion

South Africa has a diverse mixture of people, nature, history, and spatial and environmental legal frameworks. Within this richness of diversity, various specific attributes unique to South African areas, are fading away as time proceeds (Du Plessis & Landman, 2002; UNECA, 2008; Stevens *et al.*, 2015:24). Some of these elements that are quietly disappearing are the spatial integrity of landscapes that uphold ecosystem services. Various international and national legislation are promulgating aspects of human health, sustainable development, equity, and other such resilience development features. However, local development integration is a major concern in South African environmental management and spatial planning development (Roura-pascual *et al.*, 2009:1603).

Lessons learned from this sections chapter is that:

- Specific informal settlement regions have the potential influence to fragment and diminish certain vegetation types and river networks spatial integrity on a metropolitan municipality scale
- A holistic view of certain vegetation types and river networks should be targeted for further investigation regarding protection and conservation ventures such as legalizing more MOSS land uses
- Specific transport networks can potentially separate and bulwark habitat functionality to be further investigated
- Vast open spaces should be more strategically integrated with smaller open spaces in and around urban regions to potentially interconnect high-value vegetation types and specific river network functionality from potential informal settlement influences
- By possessing the potential GI maps various opportunities to strategically plan for endangered and threatened vegetation types from the influence of informal settlement regions can be further investigated in specific regions as identified

The South African distribution of informal settlements are mostly made up of shacks or traditional housing (that is more spread out through rural areas) and increasingly densified toward resourceful areas of coastal, forests, dams and rivers regions (eThekweni municipality, 2013:2). From municipal survey data of informal settlements in the eThekweni region, the majority of settlements lack working septic tanks, electricity or water connections. These are commonly associated with poorly insulated homes or shelters. Such basic infrastructure provision is critical for preserving the natural infrastructure surrounding settlements since human activity depletes resources much faster than nature can replenish itself. The areas identified in this study are prime regions to further investigate the integration of basic infrastructure and services.

**SECTION C: CONCLUSIONS AND
RECOMMENDATIONS**

Chapter 7: Research conclusions

Figure 7-1 captures the structure of Chapter seven.

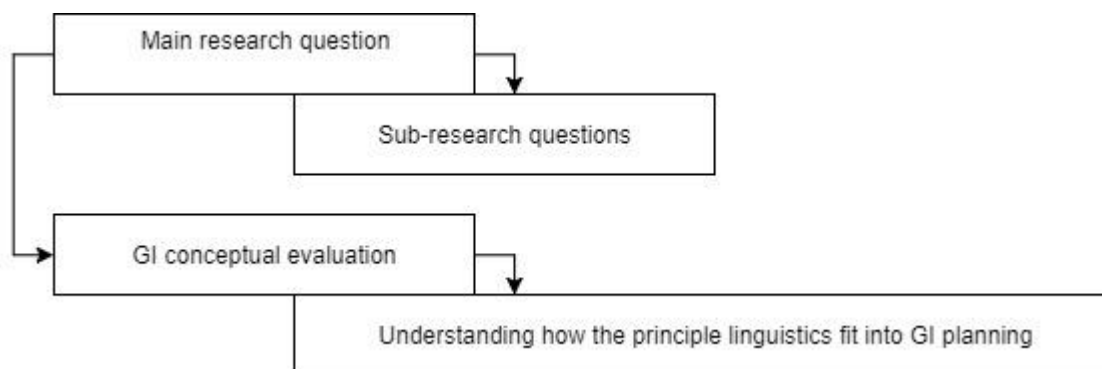


Figure 7-1: Structure of chapter seven

Source: Created from Draw (2017)

7.1. Introduction

This research identified the potential of GI planning by applying GI planning principles on a sub-regional district scale, in rural and peri-urban informal settlement regions (as defined in Section 2.2). Throughout RPU regions, informal settlements (described in Section 2.4 and 2.5) dominate vast spatial development patterns, crossing numerous types of vegetation and river networks (as outlined in the case study in Section 6.2). Understanding the platform that defines urban, rural and peri-urban spatial planning concepts, will influence the potential planning for GI (evident in Section 2.3 and Chapter three).

South Africa's spatial planning and legislative context for determining the potential GI planning in RPU informal settlement areas, were derived from environmental and spatial planning legislation (mentioned in Section 3.4 and illustrated in Annexure eight, nine, 11 and 12). The legislative framework presented in this research does not have a direct influence on identifying GI planning potential from a sub-regional district perspective, but provide the direction where to such potential need to be further tailored to. However, the inclusion thereof provides a historic, current and potential future indication of how the identified GI planning potential, should be aligned. Sections 6.2 and 6.3 showcase the identification of GI planning potential in the KwaZulu-Natal province.

The methodology used to determine the potential of GI planning from RPU informal settlements was focused on the eThekweni municipality in the KwaZulu Natal province of South Africa. In that case study, MOSS and river networks represented GI, whereas the influence of informal settlement points was buffered in order to identify the potential of GI. Building upon the identified GI (as illustrated in Annexure 13), GI planning principles provided the strategic spatial planning aspect to convert the identified GI potential into the identified GI planning potential as explained in Chapter five and elaborated in Chapter six.

7.2. Hypothesis

GI planning can be applied in rural and peri-urban informal settlement regions following specific GI principles on a sub-regional district scale as can be indicated by the case study of the eThekweni municipality in South Africa.

This hypothesis has been met for the case study and a reflection for the South African context of identifying GI planning potential from RPU informal settlements on a sub-regional district scale.

7.3. Accordingly, this chapter provides answers to the research questions captured in Chapter one.

7.3.1. Main research question

a. What is the potential of GI planning in rural and peri-urban informal settlement regions, as perceived from a sub-regional district scale?

An objective of this research was to determine the potential of GI planning on a sub-regional district scale in RPU areas, as described in Section 6.2. Using such a metropolis-level planning approach in the eThekweni municipality the potential of MOSS and river networks have been integrated with the human factor of RPU informal settlement influences. Section 5.4 explains the methodology of using GIS to identify MOSS and river networks as established GI types that are influenced by potential RPU informal settlement area influences. All identified potential of GI is illustrated in Annexure 13, showing a rural, peri-urban and a full coverage map of identified GI potential. However, applying GI planning principles (described in Section 3.5.5) provided the flexibility to match the identified GI planning potential within a sub-regional district scale. This main GI planning potential is presented in Section 6.3.5.

Converting the identified GI potential inside a sub-regional district scale, covered numerous established MOSS types and included perennial river networks in order to address the complexity of GI multi-functionality. The sprawl of informal settlement points is represented by RPU informal settlements, and by applying the same buffer width of each GI types on every informal settlement point, various overlaps of buffer spaces provided the potential of GI planning potential (illustrated in Annexure 13). Although the GIS data is limited, it was enough to address potential GI and transform the potential influence of informal settlements across the sub-regional district in order to strategically identify GI planning through applying GI planning principles. Three of the GI planning principle list of Table 3-8 was used to identify the GI planning potential from RPU informal settlements. In this manner the three principles of connectivity, multi-functionality and the holistic principle covered enough of the GI concept over to identify the potential of GI from informal settlements.

7.3.2. Sub-research questions

a. How are urban, rural and peri-urban areas defined and related to GI planning?

Spatial planning is better focused in urban than rural areas when there is a defined concept of spatial boundaries and detailed land use data. Section 2 elaborates on each of the terms and uses as it relates to regional planning interlinking with these regions to reflect the influence of the potential of GI planning in RPU areas. Regional planning is based on land use divisions as this study separated informal settlements based on the spatial location between urban and rural areas. This research used informal settlement patterns, as explained in Section 2.4 and 2.5, as an influence on established GI space within the boundaries of urban, rural and peri-urban regions. Using strategic spatial planning through GI principles in Section 3.5.5, the potential of GI planning is thus based on the demarcation of urban-rural land use types but covers sub-regional district regions as delineated in Section 6.2. Strategic spatial planning grasps the spatial integrity of various regions' natural and human development within GI planning, which is then organized within the spatial boundaries of urban, rural and peri-urban regions.

b. How were GI planning potential determined as part of the strategic spatial planning from RPU informal settlement regions?

One of the objectives of this research was to use GI planning principles to determine the potential that GI planning holds for RPU regions. GI planning principles provide the strategic spatial planning flexibility that is needed to satisfy the spatial integrity of GI. Applying GI principles (explained in Section 3.5) within RPU informal settlement regions establishes a spatial planning platform for strategic spatial planning. When applying GI planning principles at a sub-regional district level, it will not compromise the spatial integrity (identified in Section 2.3.1) of human settlements when addressing the potential multi-functionality of GI planning. The identified GI planning potential from Section 6 does not elaborate on all the theoretical elements of GI as a concept (explained in Section 3) due to the limitations of RPU informal settlement influence.

The methodology for identifying the potential of GI planning came from the use of spatial data into an ArcGIS 10.4.1 modelling platform. The informal settlement represented as points were buffered with the same distance of each identified GI type distance to protect and conserve that area. The informal settlements buffers that overlapped with the various GI type buffers were clipped as the identified GI potential for this study. Using ArcGIS further, the identified GI potential maps were adapted by manually adding polygon features to satisfy three different GI planning principles. In this manner, a strategic spatial planning approach was created to convert identified GI potential into GI planning potential through the use of GI planning principles in ArcGIS.

c. What South African environmental and spatial planning legislation relates to the potential of GI planning and RPU informal settlement areas?

Section four deals with South African legislation while Section 6.2 briefly explains provincial legislation and SPLUMA contextualization for GI planning in RPU informal settlements. The international legislation that compliments GI planning relations that were adapted for South Africa is presented in Annexure nine. Annexure 10 presents the national environmental and spatial legislation that illustrates two separate fields of integrated environmental law such as NEMA and SPLUMA. De Visser and Poswa (2017:20) argues that local municipal by-laws are envisaged relationally by provincial legislation in KwaZulu Natal but this is not the case in all provinces. This provides a stronger integration for SPLUMA into municipalities such as eThekweni Municipality so as to create a platform to plan for an informal settlement that could benefit from this study's identified GI planning potential.

d. What is the identified potential of GI planning in the metropolitan case study of the eThekweni municipality?

The eThekweni municipality case study is situated within a metropolitan region that operates on a sub-regional district scale, as illustrated in Section 6.2. Identifying the potential of GI does not automatically result in GI planning, as explained in Section 3.5 Complexity of the GI concept. The influence of RPU informal settlements provided the space wherein the potential of GI was identified, and this space is seen as the identified GI potential, as illustrated in Annexure 13. When transforming this space into GI planning potential, it will require the integration of GI principles as was applied in Section 6.3.5. Because of this, operating within the metropolitan scale is the best-suited approach. This enables a diverse spatial distribution of RPU informal settlements while incorporating the scale within extensive regions that captures habitats for potential ecosystem service functions.

Table 7-1 is adapted from Table 3-3, to illustrate the typologies addressed in this study and various exclusions. The limitations of this study concerns GI planning potential within RPU informal settlement regions on a sub-regional district scale that could not reflect all GI typologies in identifying the potential. In Table 7-1 the orange represents the “fully addressed typologies”, yellow represents “briefly addressed typologies” and the white sections represent “unaddressed typologies”.

Table 7-1: GI typology adapted for this research theme (the orange represents the “fully addressed typologies”, yellow represent “briefly addressed typologies” and the white sections represent “unaddressed typologies”)

Parameters	Sub-categories/definitions/examples	
Setting	Rural, urban, peri-urban, combined (containing elements of both rural and urban landscapes)	
Geographic scale	Regional scale	
Sectors	Agriculture, built environment, energy, fisheries, forestry, health, tourism, transport, urban & regional planning, water, cross-sectoral, nature protection	
Ecosystem habitat	e.g. Arable land, coast, forest, grassland, river, wetland; estuary, recreational, rocky, thicket, tree crops, woodland, artificial water bodies, extractive, settlements	
Objectives	Climate changes adaption and mitigation	Enhancing ecosystem resilience and functioning, aid society to adapt to climate change (e.g. natural flood management, coastal protection, green roofs)
	Spatial conservation	Focus on a priority concentrated geographic areas rather than a targeted species group for spatial and integrative planning
	Soil protection	e.g. afforestation, sustainable agriculture, land management
	Quality of life/well-being	e.g. establishing recreational areas, installing green roofs to improve local climate and air quality, creating jobs and promoting rural and regional development
	Sustainable management	Taking actions specifically aiming to improve the ecological quality and permeability of landscapes, therein addressing multiple ecosystem services and functions and adopting a long-term perspective e.g. greenbelt, natural riparian ways.

Source: Brown and Everard (2015:65) Naumann (2011b:17), Sinnott *et al.*, 2015:229; Young *et al.*, (2014:2576)

GI typologies provide an organized guideline to evaluate the GI potential that has been identified in this research. However, the parameters are not a checklist, but similarly to the GI principles, it guides GI planning direction. This typology will also be able to adapt to any geographic context. In this manner, the flexibility of GI planning is to be applied to any society and natural region since GI typologies and GI principles provide a transparent direction for GI planning development. This research, however, provides a strategic spatial planning outlook from a sub-regional district scale,

purely based on the potential, and not the capacity, for GI planning. It is for this cause that Table 7-1 has certain GI typologies not fully acknowledged and some not addressed.

Chapter three explains GI as a concept, whereas Section 4.2 and 4.3 provide the South African background to illustrate the need for such a concept, in spatial land use and in environmental management. The inefficiency of the attempt to mainstream GI into spatial land use practices is prevalent in the various principles related to GI planning. These principles, as presented in Table 6-3 and Annexure five, stems from the multi-disciplinary dealings with GI. Table 7-2, provides a view of scale that overlaps the GI planning scales (adapted from Table 2-2) and with the GI principles (of Table 6-3). The GI planning linguistics of Table 6-3 were integrated into Table 7-2 in order to provide the scale variation on GI principle application. When dealing with the potential of GI planning the complexity of GI as a concept, needs to be organized and managed along with GI typologies, to realize such potential for specific human and natural relations and scale.

Table 7-2: Scales applicable to spatial planning

Scales	GI principle linguistics
Regional	A 1,5,9,11/ B 10, 12, 13, 15, 19, 20/ C 1, 7, 10, 14/ D 5
Metropolitan area	A 2, 3, 8/ B 1, 6, 8, 21, 22/ C 3, 6, 8, 13/ D 2, 7, 9, 14, 15
District	A 4, 6/ B 4; 7. 16, 17/ C 5, 9, 11, 15/ D 3, 8, 10, 11, 12
House/block	A 7, 10/ B 2, 3, 5, 9, 11, 14, 18/ C 2, 4, 12/ D 1, 4, 6, 13

Source: Authors created (2017)

Relying on the principle linguistics of GI creates various planning aspects to consider and understand. These aspects are stated in Table 7-3, through a SWOT analysis. This analysis evaluates GI planning linguistics in order to understand the various dynamics of strategic spatial planning, for GI planning as a concept. This evaluation is also addressed in a different manner in Annexure six. Annexure six resembles various developing and developed countries, having different integration of GI. The evaluation of Table 7-3 can resolve some ambiguity as to why there is an imbalance in GI planning adaptability in various countries.

Table 7-3: A SWOT analysis of GI planning linguistics

Strengths	Weakness
<p>GI planning principles integrated from Table 6-3 and Annexure five provide a strong reference to guide GI planning direction to meet the dynamics of GI as a concept. Aligning the GI definition with the GI linguistics provide a more transparent understanding of the terminology surrounding GI and the uses thereof.</p>	<p>The GI conceptual understanding accumulates various human and natural elements into a single process. Such complexity can create ambiguity in the development and the integration of GI linguistics. Thus the method of interpretation of GI linguistic with GI planning principles has to adapt towards a socio-ecological resilience development. The lack of mainstreaming a GI planning concept adds to such weakness in the strategic spatial planning application.</p>
Opportunities	Threats
<p>Green infrastructure is a fairly new terminology that is pooled into a mainstreamed planning approach associated with resilience development, climate change strategies, social-ecological systems (SES) and various adaptive planning practices to harmonize human and nature co-development. The GI principle proposes insight into disciplines from established spatial and environmental planning and management types. Such integration opportunities can potentially increase the mainstreaming of GI planning as a conceptual into private and public sectors.</p>	<p>Misinterpreting the terminology surrounding GI planning can coherently mislead the eventual development of GI to be a retrofitting of green spaces in urbanized areas as rather compliment strategic spatial multifunctionality of natural and built infrastructure co-development. GI linguistics is only supplemental to the underpinning of GI as a concept and the planning thereof. Establishing GI planning without acknowledging the potential of humans on nature and vice versa will marginalize, isolate, fragment and possibly destroy the spatial integrity of long-term ecosystem services from GI.</p>

Source: Authors creation (2017)

7.4. Conclusion

Acknowledging GI as an integral part, rather than a sub-division of infrastructure typology, is of critical value in strategic spatial planning. The overview of this research determined the potential of GI planning as dependent on the conceptual framework of infrastructure, GI and GI planning as elaborated on in Sections 2 and 3. The main research question and sub-questions have been evaluated from theoretical and empirical studies.

Table 7-4, provides the strengths, weaknesses, opportunities, and threats of this research's theoretical and empirical conclusion. This table also provides an overview of the "knowledge gaps" which this research has addressed as well as lists further research challenges that can be questioned in GI planning literature.

Table 7-4: A SWOT analysis covering this research in regards to the identified potential of GI planning in RPU informal settlement regions.

Strength
<p style="text-align: center;">Theory</p> <ul style="list-style-type: none"> • Sub-regional district scale with GI principles provides effective assessment for the potential of GI planning from RPU informal settlement influence. • Underpinning the GI as a concept through GI principles guidance allows GI planning to achieve a higher strategic spatial planning approach. • GI planning does not replace grey infrastructure but integrates into multiple spatial planning scales for multifunctional spatial planning applications in rural and peri-urban settlement regions. • Spatial integrity is made more visible, comprehensible and usable through potential identification of GI. • May potentially change the urban morphology strategic spatial planning and management direction to mitigate urban-rural poverty and natural resource degradation. <p style="text-align: center;">Empirical</p> <ul style="list-style-type: none"> • Established data for MOSS and river networks through GIS, enabled an integrative advantage for the strategic spatial planning of GI on a sub-regional district scale. • Buffering informal settlement units provided an influence sphere to predict and plan for spatial land use management from established informal settlement districts. • GI principles and linguistics provided flexible guidance to analyze a regional perspective of socio-ecological landscape management.
Opportunity
<p style="text-align: center;">Theory</p> <ul style="list-style-type: none"> • Various spatial scales can flow out of the potential of GI planning to adapt to various spatial land use planning approaches. • Identifying the potential of GI is a step towards “designing with nature” that creates space for innovative spatial planning approaches as seen in Section 6.3.5.4. • Creating the possibility for timeless qualities in spatial land use planning can create landscapes to be reinterpreted and rediscovered over time. • This research potential can decentralize government pressures to deliver basic infrastructure through strategic natural resource management. • The potential of GI planning identifies various MOSS types and river networks to be further analysed for higher integrative biocapacity planning against informal settlement patterns in RPU regions. <p style="text-align: center;">Empirical</p> <ul style="list-style-type: none"> • GI potential provides a visible landscape direction to further expand on the strategic spatial planning of other urban-rural spatial planning dynamics. • South African municipalities can advance GI planning principles into the environmental management and spatial planning spheres to address the challenges of informal settlement patterns against natural resources. • The potential of GI gives way to more integrative (existing and new) national, provincial and local legislation for informal settlement planning through strategic bioregions. • Identifying the MOSS and non-MOSS types in RPU regions as part of GI planning is a stronger nature-based solution for identifying potential GI planning.
Weakness
<p style="text-align: center;">Theory</p> <ul style="list-style-type: none"> • Land use planning scales of spatial and temporal dynamics are not integrated into the strategic spatial planning potential • Regional planning of GI potential cannot target specific GI to an informal settlement in the same capacity and locality as grey infrastructure <p style="text-align: center;">Empirical</p> <ul style="list-style-type: none"> • By generalizing all MOSS types and the influence of informal settlement units the integration of unique human and natural capacities to change the potential of GI planning is not acknowledged.

- GIS data that has not been updated especially of MOSS types and informal settlement units and the various barriers specific to that region will produce a too broad potential of GI planning direction.
- Regional planning of grey infrastructure is scaled by human activities and regional planning by green infrastructure is scaled by bioregion patterns. Thus the incorporation of grey infrastructure detail could not be seen in the regional planning of GI planning potential and needs to be integrated into land use spatial planning scales.

Threats

Theory

- This research abides by the strategic spatial land use planning and does not integrate the capacity of ecosystem services on sub-regional district scales. This will be a misguided direction to follow in land use spatial planning scales because ecosystems will not be incorporated to reflect the required biocapacity in relation to local RPU informal settlement demand and supply.
- This research potential of GI planning cannot be applied to the urban regions directly, as formal settlement regions and other land use activities can influence GI planning potential and have not been integrated.
- Other metropolitan areas outside the eThekweni municipality, that does not have established MOSS planning will first need to get provincial and local legislation up to date with GIS and remote sensing of MOSS types before the required potential can be strategically planned and integrated into land use spatial planning systems.

Empirical

- South African local municipalities should not think that this potential of GI planning is a fixed area of planning direction for decades to come. This was only the potential influence of South African informal settlement patterns on MOSS types in a regional planning sphere. The potential will expand with added GIS data and the interpretation of GI planning principles can have different rationales with different planning teams. This whole potential is only a guideline of how to address the potential of GI planning in RPU settlement regions specific and should not be duplicated in city-dynamic outside of what was stated in this research.

Source: Authors creation (2017)

Urban to rural environmental landscapes are highly shaped by the joint infrastructure development throughout urban metabolic systems. Such metabolic systems are directed by regulating land use planning directions that transform regional environments collectively. This research argues that by determining the potential of GI planning in RPU informal settlement regions sustainable development approaches and strategic landscape management can be strengthened in order to mutually benefit human livelihoods as well as the spatial integrity of natural systems.

Chapter 8: Research recommendations

Figure 8-1 captures the structure of Chapter eight.

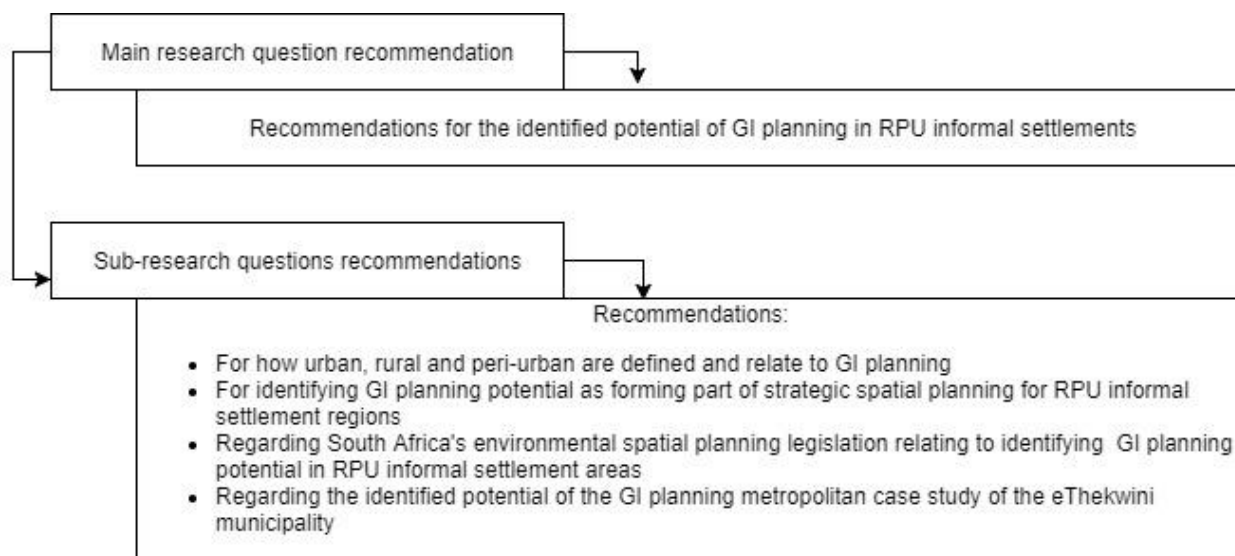


Figure 8-1: Structure of chapter eight

Source: Created from Draw (2017)

8.1. Introduction

This chapter provides recommendations concerning the identified potential of GI from the influence of RPU informal settlement areas. The recommendations deal with spatial boundaries of urban-rural regions, strategic spatial planning for GI, and South African GI planning based on a local case study setting.

Throughout this research, a desktop study presented the necessary conceptualism of GI, potential GI planning, and the principles needed for strategic spatial planning from RPU informal settlement influences. Mell (2010:264) and Laforteza *et al.* (2013:106) argues for a similar view to this study, in that GI planning is an integrated planning approach to conduct spatial landscape and land use management for long-term, socio-ecological resilience development (Cilliers & Cilliers, 2016:21). However, recommendations for this research's questions does not provide the solutions of GI planning, but rather a platform for further research direction.

The South African GI planning recommendations, of this research, are based on theoretical and empirical information, as well as the information gathered in Annexure 1 to 15. Therefore, this research does in no manner fully address the complexity of GI as a concept. The following recommendations are based on the research questions captured in Chapter 1 and should be considered a point of departure for GI planning, based on identified GI potential in RPU informal settlement regions.

8.2. Core planning recommendation

8.2.1. Recommendations for the identified potential of GI planning in RPU informal settlement regions, as perceived from a sub-regional district scale

Based on this research it is recommended that all spatial planning approaches should incorporate reciprocal thinking; and that although presented in a systematic linear structure, spatial thinking needs to loop back in order to increase transparent planning processes (Glasson *et al.*, 2012:5). The identified GI planning potential is flexible enough for the spatial connectivity, accessibility, integration and scale element to be integrated into a singular system. Such integration promotes a reciprocal planning approach that meets the complex spatial planning concept of GI.

As informal settlement regions sprawl through RPU regions, the need for a strategic spatial planning approach, such as GI planning, is recommended through this research in order to promote livelihood assets. Identifying the potential of GI planning from the influence of RPU informal settlement regions is only one aspect of identifying the GI planning potential on a metropolitan scale, as well as spatial connectivity of bio-regions and river catchment areas. Because a sub-regional district scale has been chosen for this research, the various variables of bio-regions and river catchment areas with human settlement regions can be potentially incorporated into the GI development trajectory.

A recommendation for government bodies and authorities is to use environmental policy tools to “bulldoze” and prepare the necessary way for local municipal adoption of GI development trajectories, such as integrated urban-agro design (focused on urban food security) (Lee *et al.*, 1999:3). A bottom-up resource management approach captures ecosystem service boundaries beyond socio-political boundaries in order to cause local municipalities to have more nature-based solutions in spatial planning directions (Milani, 2006:43). Environmental management and spatial land use laws as well as by-laws, for rural and peri-urban informal settlements, are recommended to be tailored in the scope of GI planning’s spatial integrity and GI planning principles.

8.3. Planning recommendations based on sub-research questions

8.3.1. Urban, rural and peri-urban areas related to GI planning should be well defined

Performing spatial planning that interconnects throughout the entire urban transect is a complex planning approach. When comparing the inhabitants of rural areas there is a closer relation to the agricultural sector, compared to that of lower labour diversity in peri-urban dwellers (Dawson *et al.*, 2016:204; UN-Habitat, 2015:3). Peri-urban neighbourhoods have a high level of migration, as seen in Latin America, due to various necessary but undesirable circumstances (Allen, 2003:139; Kombe, 2005:128; Torres, 2008:16). Rural to peri-urban communal land depends on the functionality of socio-ecological infrastructure. Such a type of infrastructure has local contextual spatial integrity (an interconnected hierarchy) that requires adequate functioning habitats for

ecosystem services (Bergsten & Galafassi, 2014:10; TEEB, 2010c:106; Tiwary & Kumar, 2014:351). It is recommended that the urban transect should be studied based on the metabolism of the natural and human resources, that comprehend GI planning complexity of inclusive anthropogenic dimensions.

Unlike humanly built infrastructures, ecosystems, structures, and networks have the capacity to naturally regenerate itself over a time-space continuum (Naumann *et al.*, 2011:9; Teeffelen *et al.*, 2014:66). The aim of nature-based infrastructure is to interdepend and integrate the delivery of ecosystem services through the human intervention of natural and semi-natural areas. This should be done through strategically planned corridors and links to relieve or replace the vulnerability of grey infrastructure capacity (Pakzad & Osmond, 2016:69; Tiwary & Kumar, 2014:351). Looking at the sheer number of definitions that exists in literature for GI, it is difficult to pin down only one definition to a contextually defined area (Madureira & Andresen, 2014:38; Ahern *et al.*, 2014:256; Benedict *et al.*, 2012:1). It is thus important to understand the complexity of infrastructure relations so that the concept of GI in spatial planning is fully comprehended. GI planning fits into the strategic spatial integrity being the core theme for GI, especially if planned and delivered appropriately (Hostetler *et al.*, 2011:371; Tiwary & Kumar, 2014:351).

Strategically developing spaces to have simultaneous benefits in human-dominated environments are challenging in any geographic site (Faucette, 2012; GVANI, 2011:83). A common example, when dealing with GI planning, is to use trees to provide an indicator for investing in GI planning. Foster *et al.*, (2011:23) argues American case studies have shown the establishment cost per tree is between R767-R7675, maintenance cost per tree between R230-R997 and mature trees' annual net economic benefits per tree between R460-R1381. Consequently making the return rate on a tree approximately R23-R46 for every Rand invested (and to dollar conversion 2016-03-19). This current study will not conduct a GI asset evaluation in the case study, but acknowledges the value of expanding on GI assets priorities, to increase the potential for long-term GI planning development. Further refinement through fine-scale spatial planning needs to cluster activities in order to increase the polarisation of GI development on city levels, as to reach the identified potential.

The impact that RPU informal settlement regions have in nature is difficult to evaluate.. The vulnerability from hazards is a common occurrence within informal settlement regions (Abbott, 2002:321; UN-Habitat, 2015:8-5; Weakley, 2013:6). Adding to this vulnerability trend, informal settlements have a “chaotic” (chaotically ordered) practice, where slums “don’t wait for the government to upgrade for them (informal settlements). They (informal settlements) let the government find them (informal settlement communities) along the way – if ever they (local municipalities) decide to come along (see the re-blocking case of Joe Slovo, Cape Town)” (Utveckling, 2013:8). Identifying the potential of GI from informal settlement regions provide a platform to address disaster management, informal settlement restructuring, and protection of strategic open spaces in a single spatial planning approach. It is thus recommended that further

research on GI planning divisions, between urban, rural and peri-urban areas, should be conducted from the influence of the Anthropocene, as presented with this research's focus on identifying informal settlement influence for GI planning potential through buffer types.

Cornelius (2016:14) points out that the majority of such knowledge, in developing countries, revolve around urban agriculture (for food and nutrition security) as this should be starting points in local GI development. Informal settlements can learn from structured urban gardening platforms, while transforming ecological landscape planning, at the same time (Bendt *et al.*, 2013:28). Strategic spatial planning can broaden the base of local ecological knowledge. All the while broadening the planning and management of socio-ecological infrastructure brings forth social capital in the form of environmental stewardship. Environmental stewardship aligns with strategic settlement planning towards landscape resilience, through innovation, adaptive management and social learning (Taylor *et al.*, 2013:1450). It is recommended that the areas identified from the potential of GI planning, in this research, should be further investigated for decentralization based on “memory groups” pertaining to socio-ecological knowledge and characteristics of environmental stewardship.

Rosa and Privitera (2013:97) document the effectiveness of using high-resolution orthophotos associated to each land use type. Engaging communities and governance in participation platforms, that are simplified through technology, is an acknowledged best practice aspect in numerous GI case studies (Bergsten & Galafassi, 2014:4; Liqueete *et al.*, 2014:17; Liqueete *et al.*, 2015:273; Mell, 2010:87). Table 8-1, provides various planning tools that cover urban, rural and peri-urban regions which can be used for GI potential identification. Since GI consist of various elements to be studied, e.g. decentralization, identification of strategic planning etc., the planning tools of Table 8-1 can provide a wide variety of information and modelling in order to tailor local context planning. Annexure one is an extension of Table 8-1 that reflects on various spatial planning mechanisms for GI development.

Table 8-1: Planning tools associated with governing urban biodiversity and ecosystem services

Tools and approaches	Description	Scale of action	Cross-referencing
Satellite images	Satellite images that cover larger areas and are then combined with high-resolution images in order to inform management	Local-regional	(Schäffler <i>et al.</i> , 2013:204; UN-Habitat, 2013:a)
Indicators monitoring ecosystem change	Indicators on different levels, in order to set targets, as well as measure and monitor ecosystem state over time.	Local-regional	(Claro <i>et al.</i> , 2013:46; Madureira & Andresen, 2014:39)
Biotope Area Ration	Using Biotope Area Ratio (BAR) or Biotope Area Factor (BAF) to map surface types.	Local-regional	(Abunnasr, 2013:87; Ahern <i>et al.</i> , 2014:258; Elmqvist <i>et al.</i> , 2015:190)
Scenario development	Developing scenarios to better inform processes pertaining to planning and stakeholders. For e.g. using multi-criteria evaluation.	Local-regional-global	(Gill <i>et al.</i> , 1998:116; Kousky <i>et al.</i> , 2013:3565; Tiwary & Kumar, 2014:352)
Ecological footprint analysis	Ecological footprints can track progress, provide early warning, support setting targets, and drive positive policy change.	Global	(Andersson <i>et al.</i> , 2014:451; Gómez-baggethun & Barton, 2013:235; Harrison <i>et al.</i> , 2014:67; Schäffler, 2011:45)
Knowledge management system	Regional ecological knowledge databases, which update regularly in order to better inform planning.	Regional	(Baud <i>et al.</i> , 2013:8, 2015:227; Kato & Ahern, 2008:549)

Source: Adapted from Elmqvist *et al.*, (2013:564).

When dealing with data inventories (also referenced in Annexure seven), governments should follow the guidelines of De Wit (2012:39) as well as that of Gómez-Baggethun and Barton (2013:235) in order to corroborate information inventories from a bundle of ecosystem services. Table 8-2, illustrates the various environmental components that need to be further researched so that more comprehensive potential of GI planning in urban-rural regions, can be ensured. This research reflects the influence of informal settlements, based on buffer widths taken from various literature. An example would be: if more accurate data were to be taken from Table 8-2, regarding this research's influence of RPU informal settlement regions, a higher strategic spatial planning potential could be determined.

Table 8-2: Environmental components and impact indicator example to further identify GI planning potential information inventory

Environmental component	Impact indicators (examples)
Air quality	the area containing pollutant concentration in each air quality class number of people affected in each class area of sensitive ecosystems affected
Noise	the area affected in each class of noise level number of people by noise level class uses/sensitive species affected by noise level class
Surface water	number of surface water flows disrupted volume (length)/water quality class number of affected people/users vulnerable/sensitive species affected
Groundwater	area/groundwater recharge rate area/groundwater contamination risk class
Soil	occupied area in each soil quality class rate of soil loss by erosion area affected by contamination risk
Biological populations, communities, and habitats	affected area of natural value (classified areas, biotopes) number of protected species affected fragmentation and changes in habitat size
Socioeconomic Impacts	travel time (accessibility) employment agricultural production forestry production mineral resources affected

Source: Adapted from Antunes and Santos (2001:517).

Thus, a multi-method approach is highly recommended in order to address the research quality as well as the quantity complex systems to uphold the socio-ecology integrity through GI planning (Connop *et al.*, 2015:2; Liqueete *et al.*, 2015:269; Mell, 2010:95; Pakzad & Osmond, 2015:70 Tiwary *et al.*, 2016:210). In terms of the influence that informal settlements have, and any other anthropocentric development regarding this matter. Such a green perspective addresses the urban metabolic, that underpins the influence on GI planning potential, more comprehensively. It is recommended that a green perspective is further investigated and incorporated into GI planning potential identification.

8.3.2. GI planning potential should be identified in order to form part of the strategic spatial planning for RPU informal settlement regions

It is recommended that the identified GI planning potential is further explored with regards to decentralising resource dependency in human settlements by strategic spatial planning. TEEB (2009a:2) argues that decentralisation should be pushed by local authorities, who are the best agents for change in the environmental sector relations, being managers of substantial budgets, having strong executive power in short command structures, and operating at grass root level. A level of decentralisation with numerous units and sub-units – also known as modularity – reduces

risk within the system and prevents negative change from flowing too quickly from one component to another (Harrison *et al.*, 2014:13).

Decentralisation promotes redundancy planning that has more synergies with a polycentric governance system than that of a monocentric governance system (SRC, 2014a:6 Identified GI planning indicates a variety of region elements to be strategic, spatially adapted. This could potentially lead to higher redundancy of resource provision for human and the natural habitat preservation. GI planning is thus a catalyst for stronger modularity, not only from an ecosystem service perspective but as a pressure-releasing mechanism for governmental resource delivery (if planned and managed efficiently and effectively).

Another motivation for GI as redundancy planning is that RPU areas in developed and developing countries are well suited for GI planning integration when it comes to large-scale implementation (SRC, 2010c:3; Hălbac-Cotoară-Zamfir, 2009:290). An example of such GI scale planning is explained by Felson *et al.*, (2013:883) by using the well-known case of Mayor Bloomberg's New York City planning (NYCPlan). The NYCPlan allocated urban forestry experiments into an urban aesthetic and functional space, investing \$313 million over 10 years into the New York City Department park design. Schäffler *et al.*, (2013:15) state that New York GI planning will save taxpayers \$1.5 billion, and reduce combined sewer outflows to 17.9 billion gallons a year (compared to 19.9 billion achieved through grey infrastructure approaches). Elmqvist *et al.*, (2013:371) explain that the NYCPlan for 2030 addressed urban forestry goals through 132 specific initiatives ranging from "improved bicycle and pedestrian facilities, grants and liability provisions for contaminated land remediation, enhanced waste recycling and to new regulations for energy efficiency in existing buildings" (Benedict & McMahon, 2002:8; Dunn, 2010:51; Saroop & Allopi, 2015:14).

It is necessary to use multiple options in order to identify the best management practice direction for prioritising tailored project initiatives, such as with the NYCPlan, yielding the highest grey-green continuum benefits with the lowest long-term capital cost (Barrow, 2006:48; Brown & Everard, 2015:65; Travers *et al.*, 2013:8; Young *et al.*, 2014a:2581). In like manner, the identified GI planning potential is recommended as a redundancy planning approach with long-term and large-scale planning potential. The focuses of this research were informal settlements as functioning in a developing country context. It is thus recommended that the identified GI planning potential should be further investigated in developing countries in order to compare the influence of informal settlements and the existing GI planning potential on large sub-regional district scales.

It is also recommended that the identified GI planning potential should be further researched from the perspective of full cycle systematic planning, as provided in the following example: New York's governmental CCEDCP (refer to Figure 8-2 for meaning) planning framework of the NYCPlan, is a transparent overview of the stages and challenges roughly pertaining to GI planning. The GI planning team needs to keep continual "contact" with the roll-out of each planning stage, in private

and public sectors (refer to Figure 8-2). As seen in Figure 8-2, behind each planning stage is comprehensive pre-planning, pilot initiatives, as well as ample provision directions for the final application. This “behind the scenes” scoping and screening is the necessary push factor that enables high potential GI planning to be a success. The pre-management and scenario planning, evident from Figure 8-2, for GI integration, can be a multiplier factor used to aid in the slow payback period of potential benefits of GI assets (Hansen & Pauleit, 2014:525; Spatari *et al.*, 2011:2176). All this planning, programming, setting up and arranging contact sessions, in addition to any other social-inclusive activity of all involved disciplines in economic, political, environmental, and administrative spheres, can and should be done, as far as possible, before capital cost is calculated (Demuzere *et al.*, 2014;113 Flynn & Traver, 2013:10). Barriers, thus, to GI planning from a socio-political viewpoint should not be underestimated, which means that institutional and legal frameworks, from an inter-municipal collaboration, should shape and compliment the GI planning process (Bergsten & Galafassi, 2014:2; Brown & Everard, 2015:65).

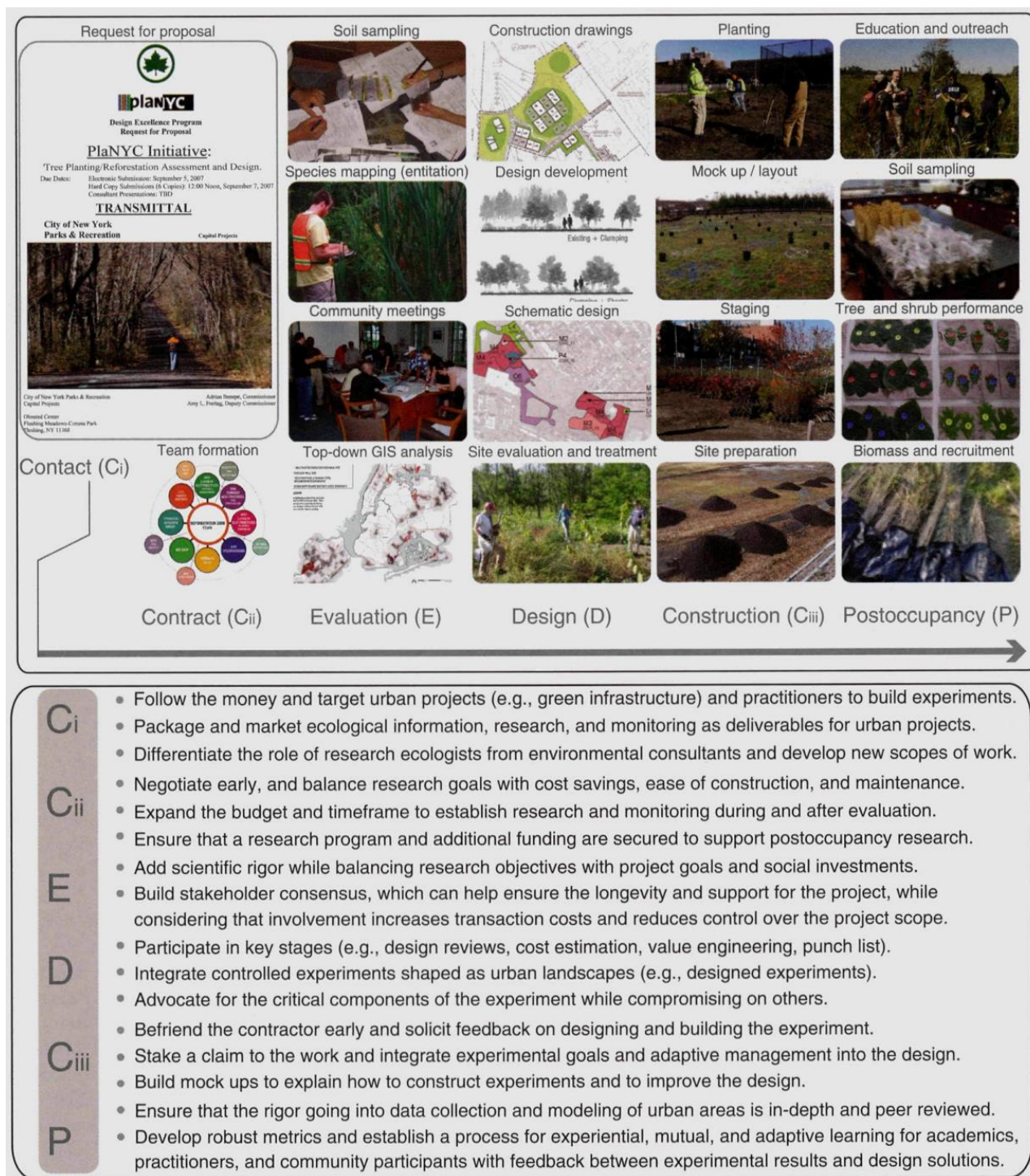


Figure 8-2: An overview of the New York City Afforestation Project (NY-CAP) process with general recommendations for involving research ecologists in urban green infrastructure project Source: Felson *et al.*, (2013:886)

The following recommendations concern strategic spatial planning for RPU informal settlements, as to create a planning sphere that compliments GI planning adaptation. Dunn (2010:55) highlights spatial planning ventures from leading cities. These cities revised stormwater regulations in order to emphasize the importance of on-site retention and treatment as well as to explicitly state a preference for GI approaches. For example, Seattle has a “Green Factor Ordinance” that allows structures, such as green roofs, to fulfil a requirement within commercial

structures, residential structures, and parking lots pertaining to a certain achievement in “green factor” accreditation (Dunn, 2010:55). Some local governances have placed a building and design standard, in commercial, industrial and residential developments, to meet the criteria as set out in the Leadership in Energy and Environmental Design (LEED) standard (Kruger, 2014b:71). Du Toit (2013:3) explains that green-certified building owners and developers benefit from free publicity and press while having return market values depending on the land-use type and socio-economic and political structure.

Kruger (2014b:107) comments that leading states in America, starting in 2005 with a Green Permit Program, linked sustainable practices with green economics and business projects. This enhanced the quality of life for the local residents. Developers and building owners could choose various green building practice inclusions, from a green “menu” that was provided by the local authorities (Kruger, 2014b:163). It is suggested that further investigation is necessary to tailor standards and programs as LEED, a green menu, and green factor accreditation throughout rural and peri-urban settlement regions. This will cause a definite change in the identification of GI planning potential through RPU region settlements and open spaces.

8.3.3. South Africa’s environmental and spatial planning legislation should consider the potential of GI planning in RPU informal settlement areas

A prominent recommendation is that GI planning should be mainstreamed into the South African private and public sector, through relevant legislative frameworks. This proceeds from development capacities that are dependent on government and private sector's commitment to international organizations and donor agencies, which assist in GI-related funding developments (Baud *et al.*, 2015:225; Cobbinah *et al.*, 2015:28).

The UN-Habitat (2015a:5) states that effective planning for resilience relies on understanding local and regional variation in vulnerabilities to hazardous climate, health, and economic impacts. A recommendation pertaining to South African GI planning, is to construct legislative frameworks that incorporate public and private sector involvement based on shaping land use regulations in order to mitigate climate change hazards and vulnerabilities throughout human settlement regions. Thus, the recommended inclusion of private and public sectors through legislation of local municipal law and by-laws into nature-based solutions (such as GI planning) is required for mainstreaming GI in South Africa.

South African legislation of SPLUMA and NEMA have changed the direction of spatial planning instruments. De Visser and Poswa (2017:17) agree that SPLUMA deals with “unplanned” (informal) communal land through local municipal by-laws. It is recommended that the potential for GI planning should be aligned with SPLUMA and NEMA's spatial planning, from national to local municipal levels. This research evaluated South African, and the KwaZulu-Natal, spatial and environmental legislation in order to illustrate a history of spatial land use, environmental management, and current impacts of informal settlements in rural and peri-urban regions. GI

planning would be equivalent to combining the environmental management of NEMA with the systematic and strategic spatial land use planning of SPLUMA, to produce strategic GI planning in South Africa.

The EEA (2015:50) explains that, as part of setting GI planning into mainstream application, “natural assets, urban forms, land use patterns, heritage elements and stocks (existing parts of the urban fabric such as buildings and infrastructure)” must be adapted towards resilience development (Andersson *et al.*, 2014:446; Rosa & Privitera, 2013:96). Working on the basis of conventional infrastructure, it is recommended that in order for GI to function, planning, design, and budget frameworks has to flow through time and spaces in similar fashion as with grey infrastructure systems (Benedict & McMahon, 2006:15; Harrison *et al.*, 2014:69 Kruger 2014b:69; Schäffler & Swilling, 2011:15). Grey infrastructure has established guidelines, such as International Organization for Standardization (ISO) 9001 and 14001 guidelines, EIA’s and Environmental Management Strategies (EMS), all of which include human and environmental settings (Abunnasr, 2013:1; Yahya, 2010:3).

Environmental management systems enhance policy and guideline platforms for the socio-ecological sensitive strategic spatial planning of urban to rural areas (Benedict & McMahon, 2002:22; Roe *et al.*, 2013:660). Figure 8-3 illustrates the difference between an EMS platform with and without proposed GI planning, and different spatial tools and the degree of integration thereof. It is thus recommended that the identified GI planning potential should be further advanced to align with the South African EMS platform, adapted specifically for GI; that is, legalized, in a similar fashion, as the EIMP of Annexure eight.

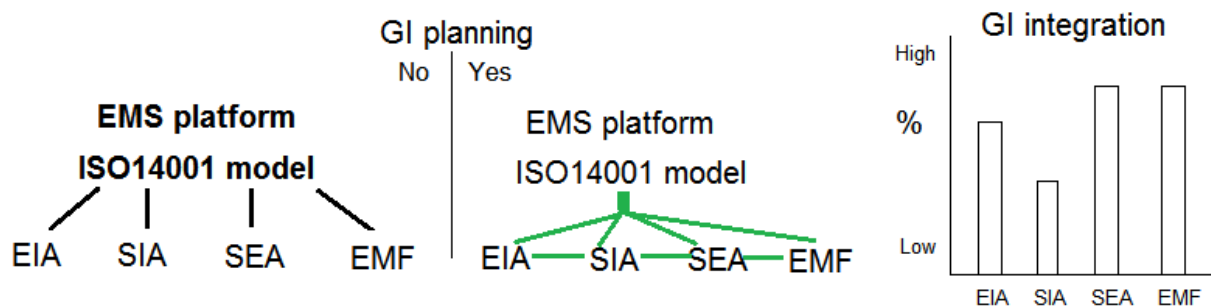


Figure 8-3: A scenario layout of GI planning change and capacity dependency of spatial programs in a South African Environmental Management System (EMS) using different assessments, namely: Environmental Impact Assessment (EIA), Social Impact Assessment (SIA), Strategic Environmental Assessment (SEA), Environmental Management Framework (EMF), and Green Infrastructure (GI).

Source: Authors compilation (2017)

Luck *et al.*, (2012:1027) argue that, as global governances are integrating closer to environmental inclusive platforms, an increasingly globalised economy, privatization of public assets, government deregulations and economic rationalism, stimulates decentralisation of government

structures. Using GI planning from a top-down perspective to align bottom-up mechanisms, such as synchronized EMS for GI development, is a critical milestone on the path to addressing the identified GI planning potentials spatial integrity in South Africa. Various EMS models exist, such as the well-known ISO 14001 international standard used in several cross-sectoral fields related to GI planning (Campos *et al.*, 2016:453; Rendell & McGinty, 2004:5). The adaptability of GI planning as a mechanism to enhance EMS compliance models, need to be a priority in South African spatial planning paradigms. Elmqvist *et al.*, (2013:705) illustrated this point with the Critical Biodiversity Index (CBI) success of Yokohama, a Japanese local municipality promoting resilience development of biodiversity-related activities through the environmental management provided by the ISO 14001 model. It is thus recommended that tailored ISO models are further investigated for the identification of GI planning potential. Especially complimenting the South African context as depicted in this research case study of eThekweni Municipality.

Scott *et al.*, (2013:565) and Goldstein *et al.*, (2012:7568) explain how mainstreaming ecosystem services would alter various land-use dynamics, and would attract economic, legal and cultural approaches. Teeffelen *et al.*, (2014:65) explain that the challenge lies in identifying policy instruments that can govern land use change from economic development, with a small to none net biodiversity loss, in terms of landscape capacity. Since environmental related spatial planning practices still differ internationally, the approach to GI planning's adaptation with current policy as well as its implementation interface needs to be sensitive, so that vital GI principles will not be compromised (Cobbinah *et al.*, 2015:20; Vollmer & Grêt-Regamey, 2013:1543). GI planning principles are prone to resilience development through incubating socio-ecological resilience thinking for local land use policy and management (Bobbins & Culwick, 2015:39; Brown & Everard, 2015:62; Mell, 2010:13; Syrbe & Walz, 2012:87). It is thus recommended that the identified GI planning potential in RPU areas provide ideal regions for pilot projects to further investigate policy instruments for integrating GI planning principle spatial planning approaches.

The full operational capacity of GI planning across regions tends to flow slowly over years, even decades. Thus, it is recommended, that South African municipalities should follow leading municipalities, such as eThekweni, into the best practices for nature-based solutions (Mell, 2014:618; Young *et al.*, 2014b:2579). Developed and developing countries' policy orientation need to align international socio-ecological systems as early as possible, in order to direct local municipal by-laws. This is to provide a comprehensive, but flexible, adaptation for GI planning integration (Dunn, 2010:54; UN-Habitat *et al.*, 2015:5; Madureira & Andresen, 2014:48).

Established frameworks, pertaining to GI planning potential, that should further investigate, are those practised by the eThekweni Municipality (2012:36) as being that of Spatial Development Frameworks (SDF), Spatial Development Plans (SDP), Local Area Plans, and Functional Area Plans. The eThekweni Municipality (2017:208) 2016/17 IDP review reflects that the SDF represents a 20+ year plan that incorporates legislative transformation and compliance. Which

also suits the long-term integration of GI planning adaptation. Municipalities, such as the eThekweni municipality, is a guide for other South African municipalities to adapt to more strategic spatial planning approaches, that have long-term effectiveness, through socio-ecological inclusive legislative transformation.

8.3.4. Practical planning recommendations based on the identified potential of the GI planning metropolitan case study of the eThekweni municipality:

8.3.4.1. Related to theory delineating the empirical study

McLean *et al.*, (2016:81) state that in the Durban Systematic Conservation Plan (SCP) the utilization of D'MOSS is fundamentally rooted in advancing the spatial integrity of local bio-regions throughout numerous municipal plans, frameworks and study projects. This research provided additional strategic spatial planning on the influence of RPU informal settlements in order to complement the current vision and practice of the eThekweni municipality's D'MOSS utilisation. It is recommended that, as McLean *et al.*, (2016:81) argue, the current spatial tools, legislated through the National Environmental Management Biodiversity Act (NEMBA), 2004 (Act 10 of 2004), provide municipal scale plans that align with the hierarchy of South African environmental management and spatial land use plan, frame, assessment etc.

Thus, it is also recommended that unto this study of identified GI planning potential from RPU settlement, there should be further investigations regarding what degree adaptation of this research is needed in order to complement the eThekweni municipality's spatial planning approach.

A recommendation for the identified potential of GI planning, from this research, is that this potential must be planned along with climate change adaptation plans, and also need to be converted into manageable validated units. Climate change adaptation, mitigation, and urban regeneration are driven by ecosystem-based approaches, a well-known theme internationally regarding environmental management and spatial planning (Bobbins, 2014:5.; Foster *et al.*, 2011:33; Gebauer & Doevenspeck, 2015:99; Munang *et al.*, 2013:3; Norton *et al.*, 2015a:136; Roberts *et al.*, 2012:182). GI moves supportively under the umbrella of climate change adaptation as a key pillar in the spatial dynamics of the socio-ecological development. Gill *et al.*, (1998:117) and Roberts *et al.*, (2012:182) address GI within urban morphology types (UMT's)(e.g. farmland, woodland, transport, residential, retail, etc.) by using town planning and urban management tools to protect and utilize GI assets. Acknowledging GI planning results in assets utilisation, within an appropriate spatial planning scale, impact, and continual expansion capacity, which strategically compliments the local patch-corridor-matrix of landscape planning for climate change adaptation strategies.

Giordano's (2014:481) South African based research states that the capacity of market mechanisms and technological improvements (the strong-arm of socio-ecological modernisation)

must address environmental challenges. Unlike financial systems, there is no fixed socio-ecological “inflation rate” that can quantify or qualitatively change the value of green assets autonomously. This is because socio-ecological development hangs in the balance of ever-changing natural processes and cycles (Cumming *et al.*, 2013:1140; Wilkinson, 2011:152; Young *et al.*, 2014a:2581). Attempting to socio-economically value green assets, it is proposed that a continual, adapting valuation assessment needs to appreciate spatial interconnectivity, as well as the accumulative, exponential growth across the identified GI planning potential, intersect (Wilkinson, 2011:152). This is recommended in the eThekweni municipality case study in order to steer GI planning potential towards GI planning development.

Schäffler and Swilling (2013:255) recognize that there are unofficial cultures of private and public powers that can, and should, stimulate and distribute GI. Rethinking citizen engagement with infrastructure systems, in order to be co-constructors of their service delivery (ecological and municipal), is vital to efficient and for effective GI planning to be applied within the eThekweni municipality. Ahern (2011:343), Cilliers *et al.*, (2013:691), Kato and Ahern (2008:556) as well as Roberts *et al.*, (2012:172) agree that GI is prone to a learning-by-doing method; advancing to localization of diversifying preparedness through building upon local, evidence-based GI practices. It is thus recommended that the identified GI planning regions of the eThekweni municipality, need to focus on private and public sectors to further investigate the influence of RPU informal settlements on nature and adapt buffer width to meet the context of each geographic site.

The following recommendation focuses on the identified potential of GI planning regions with that of associated societies which should integrate into participation studies. Related to empirical study

It is recommended that when identifying the potential of GI planning potential the following points raised adapted from Baptiste *et al.*, (2015:2) should be addressed in a GI planning empirical study:

- What is the lack of understanding and knowledge of what GI is, as well as the benefits it provides
- Identify the deficiency of data that demonstrate benefits, costs, and performance
- Address insufficient technical knowledge and experience to identify GI planning adequately
- Determine the lack of design standards and the best management practices for that specific GI planning approach in that contextual region

This recommendation revolves more around the methodology of this research and the integration of more GIS data inventories (as mentioned in Annexure seven). Chang *et al.*, (2012:496) state that technological applications, such as GIS software, increase effective and accurate planning within grey-green infrastructure development within a Mosaic model. The UN-Habitat (2015b:5) explains that mapping actors, associated assets, knowledge, available tools, policies, and other

means of implementation will strengthen the capacity of actors and actions to address the gaps between urban and rural development. Governments can utilise knowledge transformation in the expansion of digitisation and communication technology, such as GIS systems (e.g. administrative databases, real-time monitoring with GPS) and interfaces with citizens through open-access platforms (e.g. Google Earth) (Baud *et al.*, 2015:226). Commercialisation of information is a recognised international market, which is cheaper than a decade ago and accessible to various income groups via the internet. Digitisation and spatialization of knowledge management, in anthropogenic dimensions, make complex urban-regional, socio-ecological planning more effective in land use planning, reduces inequalities, and prioritises basic service improvements (Baud *et al.*, 2015:231). Thus, it is recommended, that more GIS-based data inventories should be integrated when it comes to using informal settlement influences and GI elements to identify the potential of GI planning through private and public sector involvement in the eThekweni Municipality region.

The Northern Virginia Regional Commission (2010:47) proposed steps and models that can be aligned with the identified potential of GI planning in the RPU informal settlement regions of the eThekweni Municipality. This recommendation is to be considered with the integration of the practical application table of Annexure one while functioning within the sustainable paradigms and models indicated in Annexure 11.

The following recommendations regard the de facto planning component in developing countries that should be integrated into the identifying of GI planning potential. Formalised and systematic organisation of informalities is seen, in many sectors, as barriers to de facto trade and land use development. This spatial complexity deals with trade-offs, which are fundamental concepts in spatial planning end solutions, by prioritising and categorising socio-ecological and economic capitals, when it comes to reaching mutual agreements.

Table 8-2 is a simplified presentation to assist in understanding developing countries' spatial planning categorisation of authoritative influence, and a possible layout to follow thereupon. The recommendation is to use such outlines, as provided in Table 8-2, by taking the identified GI planning potential further into the various community divisions which integrate with land use and local de facto anthropocentric activities.

Table 8-2: Showing spatial planning categorization for developing countries for specific planning areas (yes = green and no = red)

	Private	State/Public	Community/Tribal	De facto
Land uses	Green	Green	Green	Red
Development type	Green	Green	Green	Green
Property values	Green	Green	Red	Red
Social indicators	Green	Red	Red	Red
Access to services	Green	Green	Red	Red
Land governance/ spatial data	Green	Green	Green	Red
Enclosures	Green	Green	Green	Green
Plot sizes	Green	Green	Green	Green
Market activity	Green	Green	Green	Green
Planning services	Green	Green	Red	Red
Social mix	Green	Green	Green	Green
Disasters/ conflicts	Red	Red	Red	Red

Source: Adapted from To *et al.*, 2011:2

Lastly, the recommendations regarding GI planning principles, used in this dissertation, have the capacity to be further investigated when it comes to infrastructure development of South Africa. Especially, regarding the impact thereof on the identification of GI planning potential. Giordano (2014) states various integration steps that are needed to link GI planning with current infrastructure development, derived from the National Planning Commission (NPC) as released by the National Development Plan Vision 2030 (NDP). Various GI related projects can be paralleled with SIP's (as presented in Annexure two) to slowly integrate GI principles for strategic spatial planning in schematic development ventures regarding the potential of GI planning. Recommendations for projects directed towards GI planning potential should be aligned with Naumann *et al.*, (2011a:3) concerning factors that enable GI projects, as well as Baptiste *et al.*, (2015:2) concerning points that can hinder GI projects.

The following bullets depict the above mentioned enabling factors:

- Acquiring sufficient knowledge and evidence
- Adopting a cross-sectoral approach and involving appropriate experts accordingly
- Ensuring sufficient financing, including accounting for monitoring and maintenance activities
- Embracing partnerships
- Building on, and being comprehensive with, established policy frameworks, spatial planning initiatives, and wider strategies for land management
- Raising public and political awareness and support, while also facilitating stakeholder involvement

8.4. Conclusion

Every single village to metropolitan regions will have some form of existing GI, planned or not, implying ecosystems are part of all life on earth (Alberti, 2005:169; Rockström *et al.*, 2009:12). The recommendations of this chapter lie between spaces and infrastructure that reflects the complex synergies that can be drawn from GI planning (Daniel *et al.*, 2012:8816; Liqueite *et al.*, 2014:48). Without spaces, GI would not exist and without the spatial infrastructure, strategically planned and managed by the human influence, the required spatial integrity throughout urban-rural regions cannot be achieved (Cilliers *et al.*, 2013:684; Schäffler & Swilling, 2013:247). Various recommendations mentioned in this chapter forms part of the transforming process, striving to turn unknown, but ever-present socio-ecological systems into visible, manageable units in strategic spatial land use planning. Having the identified potential of GI planning creates more opportunities to advance strategic spatial planning for RPU informal settlement through the adaptation of GI planning principles.

Applying GI planning principles to identified GI incorporates a planning platform for various recommendations concerning strategic spatial planning approaches on a sub-regional district scale. In regards to the environmental management and spatial land use legislation of South Africa, there is an international alignment for spatial planning approaches, such as GI planning (refer to Annexure nine and 10). However, there are recommendations that need to be further investigated for the collaboration of informal settlement planning, in the strategic spatial perspective of GI planning. In South Africa, there is a critical spatial planning need to incorporate a sub-regional district planning approach to the planning of RPU informal settlement regions, derived from nature-based solutions as GI planning.

Recommendations made in this chapter have provided various methods that could be used to advance certain aspects of GI planning, as it pertains to this dissertation title. The recommendations have by no means covered the full spectrum of grey-green-blue infrastructure types as this study has various limitations as described in chapter one. This dissertation identified the potential of GI planning in RPU regions in order to comprehend the potential of informal settlement influence can have for the strategic spatial planning of GI.

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ANNEXURES

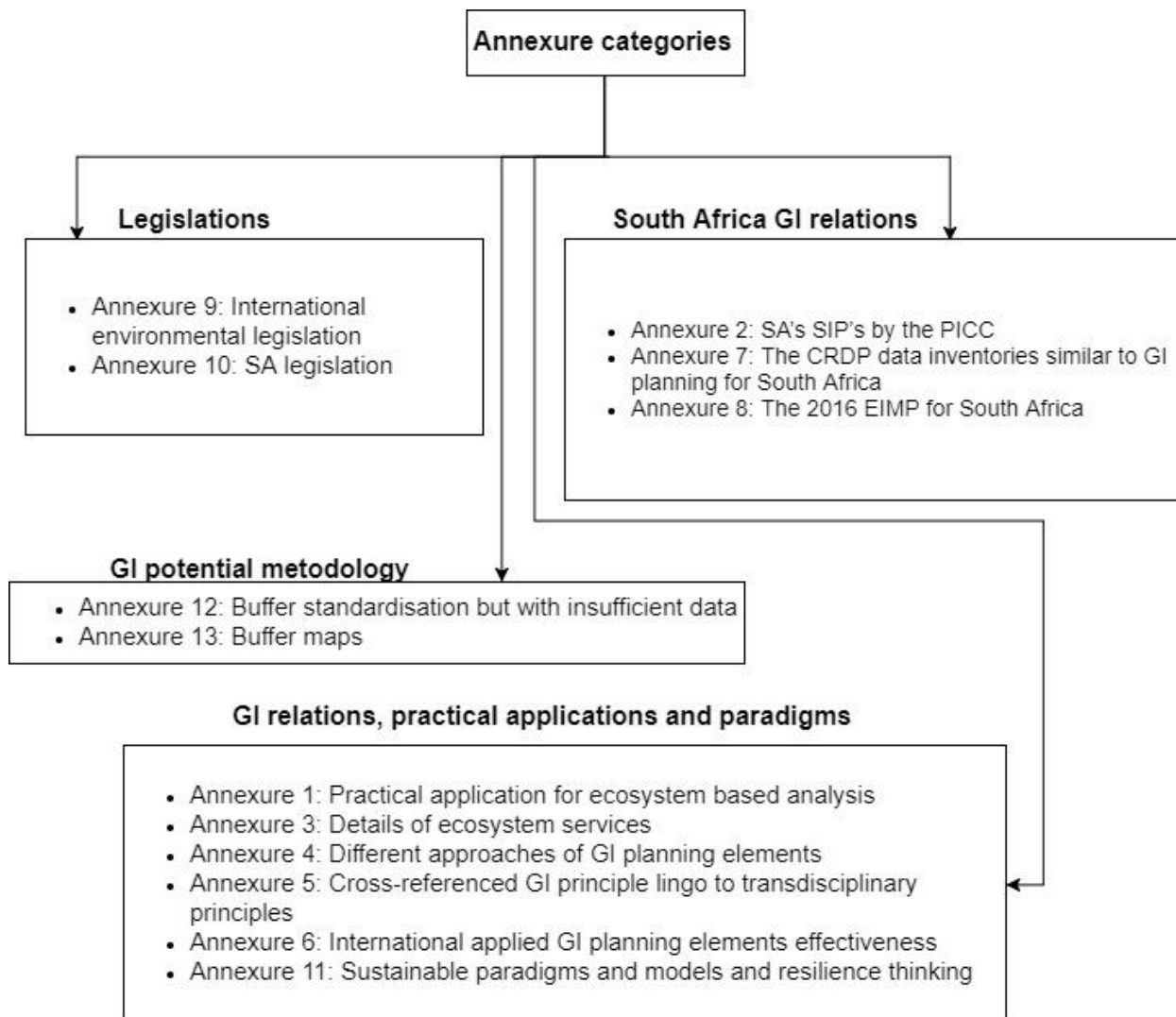


Figure A-1: Annexure categories

Source: Authors creation (2017)

Annexures main relation to chapter divisions

Annexure one	Annexure two	Annexure three	Annexure four	Annexure five
Chapter 6.3.5.3.- 6.3.5.4. 8.3.1; 8.3.4.2.	Chapter 4.3.1; 4.3.3.2.; 8.3.4.2.	Chapter 2.3.1; 4.2.; 6.3.5.4.	Chapter 3.6; 4.3.2.; 6.3.5.3- 6.3.5.4.	Chapter 3.6; 6.3.4; 7.3.2.d.
Annexure six	Annexure seven	Annexure eight	Annexure nine	Annexure 10
Chapter 7.3.2.d.	Chapter 8.3.1; 8.3.4.	Chapter 4.3.3; 4.3.3.2.; 6.2.4; 6.3.5.3; 7.1; 8.3.3.	Chapter 4.3.3.1; 7.3.2.c.	Chapter 4.3.3.2. 7.3.2.c.
Annexure 11	Annexure 12	Annexure 13		
Chapter 6.2; 6.3.5.4; 8.3.4.2.	Chapter 5.3.	Chapter 5.4; 5.4.2.1-5.4.2.2; 6.3.1; 6.3.3; 6.3.5; 6.3.5.2.; 6.3.5.4. 7.1; 7.3.1.a; 7.3.2.d.		

Figure A-2: Annexures main relation to chapter divisions

Source: Authors creation (2017)

Annexure 1: Practical application for ecosystem-based analysis

The information presented in Annexure one has not been included in the main research study as this information is supplemental to analysing various elements of GI planning that is outside the scope of this research theme. This Annexure one should be taken into recognition with the identification of GI planning as to identify GI planning potential in such a manner not to exclude future integration of Annexure one ecosystem-based analyses tools.

Moving away from a paperweight national “green policy and guidelines layout” to a locally known development framework is a goal for current GI planning development (Roe *et al.*, 2013:651). Conducting **reverse cost analyses** the value of ecosystem services are based on two aspects: the accurate value of continual grey infrastructure provision and the cost of these services. Then as green infrastructure penetrates the ecologically related economy, the reduced cost can be addressed as the value green assets is substituting grey infrastructure services (Baptiste *et al.*, 2015:2; Schäffler, 2011:14; Schäffler & Swilling, 2013:254; Spatari *et al.*, 2011:2175). This is not the ideal valuation approach but a stepping stone to mainstreaming GI planning. The following Table 1-1 is a further summary of nature-based solutions to be researched for GI planning.

Table1-1: Summary of Annexure by Travers *et al.*, (2013:53-97) presenting the practical application options for ecosystem-based adaption

Annexure and page (p)	Title	Quantity of tools and resources	Website references (Y=yes & N=no)
A1, p 55.	Tools and toolkits for climate change risk screening	22	Y
A2, p 58.	Examples of application of climate risk screening tools	15 (with sub-sections of project/application)	Y
A3, p 60.	Ecosystem services “CHECKLIST”	4 (According to TEEB reports)	Y
A4, p 62.	Tools and resources for establishing the value of ecosystem services	12	Y
A5, p 64.	Selected resources on identifying impacts to ecosystems	5 resources only	Y
B1, p 66.	Resources for adaptation options analysis	10	8/10 Y
B2, p 68.	Overview of adaptation technologies aligned to impact areas and ecosystem services	6 Impact areas with 32 Adaptation technologies	Y (extended on p 81)
B3, p 82.	Sample evaluation criteria and scale for adaptation options analysis	Taken by Criteria; Scale and Option evaluation	N
C1, p 84.	Guidelines for programming design and monitoring and evaluation	4 resources 10 countries with resources	Y
C2, p 86.	Resources that aid in linking activities to outcomes	10 resources and guides	9/10 Y

C3, 88.	p	Ecosystem-based indicators	6 resources	Y
D1, 96.	p	Resources outlining an adaptive approach to ecosystem management	7 resources	6/7 Y

Source: Adapted from Travers *et al.*, (2013:53-97)

Annexure 2: SA's SIP's by the PICC

The information presented in Annexure two has not been included in the main research study as this information support the spatial planning background for South Africa but functions outside the scope of this research theme. This annexure two should be taken into recognition with the identification of GI planning potential because the research theme of this study combines South African infrastructure and RPU informal settlement relation and Annexure two is supplemental to that relational understanding.

Ndlela (2016:46) states that the Presidential Infrastructure Coordination Commission (PICC) was established to:

- Coordinate, integrate, and accelerate implementation;
- Develop a single common National Infrastructure Plan that will be monitored and centrally driven; Identify who is responsible and hold them to account;
- Develop a 20-year planning framework beyond one administration to avoid a stop-start pattern to infrastructure roll-out.

Table 2-1: The following table summarizes the SIP's (Strategic Infrastructure Projects) of the PICC.

Strategic Infrastructure Projects	Main infrastructure's
1. Unlocking the northern mineral belt with Waterberg as the catalyst	Rail, water pipelines , energy generation and transmission infrastructure, green urban development , industries (mining)
2. Durban – Free State – Gauteng logistics and industrial corridor	Logistics and transport
3. South-eastern node and corridor development	Dam, irrigation , rail, port, industries (sinter and smelter)
4. Unlocking the economic opportunities in North West Province	Roads, rail, bulk water and water treatment , transmission infrastructure, industries (mining, agriculture , tourism, and beneficiation)
5. Saldanha-Northern Cape development corridor	Rail and port, industrial development zone, mining
6. Integrated municipal infrastructure project	Roads, water , electricity and sanitation
7. Integrated urban space and public transport program	Public transport, human settlement , economic and social infrastructure
8. Green energy in support of the South African economy	Green energy, biofuel
9. Electricity generation to support socio-economic development	Electricity generation capacity
10. Electricity transmission and distribution for all	Transmission and distribution network
11. Agri-logistics and rural infrastructure	Storage, transport (roads, branch train-line, ports), irrigation , processing facilities (abattoirs, dairy infrastructure), aquaculture, tourism
12. Revitalization of public hospitals and other health facilities	Hospitals, other public health facilities, nursing colleges
13. National school build program 14. Higher education infrastructure	Schools

15. Expanding access to communication technology	Lecture rooms, student accommodation, libraries and laboratories, ICT connectivity Fibre networks, broadband coverage, analogue broadcasting (TV)
16. SKA and MeerKAT	Radio-telescope
17. Regional integration for African cooperation and development	Transport, water and energy
18. Water and sanitation infrastructure	Water and sanitation access at household level

Notes: Words in bold is directly involved with green infrastructures

Source: Adapted from Giordano (2014:491) and Ittmann *et al.*, (2013:11)

Annexure 3: Details of ecosystem services

The information presented in Annexure three has not been included in the main research study as this information support specific ecosystem services that implies a capacity identification and not potential identification as within this studies research theme. This annexure three should be taken into recognition with the identification of GI planning potential GI is more comprehended when recognizing the intrinsic value that GI can produce but simultaneously the potential space such natural complexity needs to function in.

Developing GI, especially, in the long run, will have various socio-economic capital and spatial costs that can double when mismanaging or ignoring spatial planning directions of, predictable and unpredictable, potential GI ecosystem disservices (Foster *et al.*, 2011:23; Jaffe, 2010:360). Hostetler *et al.*, (2011:370) note the importance of resource distribution with regards to certain questions. “For instance, who will manage these resources, or what is the budget and time-frame of resource planning?” Although the spatial scale whereupon this dissertation identifies GI potentially is too large for determining the spatial cost, it is highly recognized that GI ecosystem disservices need to be included in land uses spatial planning scales for GI planning potential (Felson *et al.*, 2013:888; O’Brien *et al.*, 2017:240).

Contemporary urban planning has advanced GI disservices through handling green spaces only as a “fill in the gap” step (Benedict & McMahon, 2012:3). Ecosystem disservices are a stumbling block and barrier to many GI application schemes, mainly due to misinterpretation, poor communication, or a well-known fact without appropriate solutions (Dou *et al.*, 2014:2816; Dunn, 2010:57; Foster *et al.*, 2011:33). Cilliers *et al.*, (2013:683) argues that natural systems have several costly ecosystem disservices. These include “financial costs (e.g. pruning, damage to urban infrastructure), social nuisance (e.g. allergenic pollen, safety hazards from tree fall), and environmental costs (e.g. alteration of nutrient cycles, production of volatile organic compounds) which all impact negatively on human well-being”. Table 3-7 provides various disservices from ecosystem service sub-categories which can create conflict arenas.

Table 3-1: Ecosystem disservices in the different ecosystem service categories

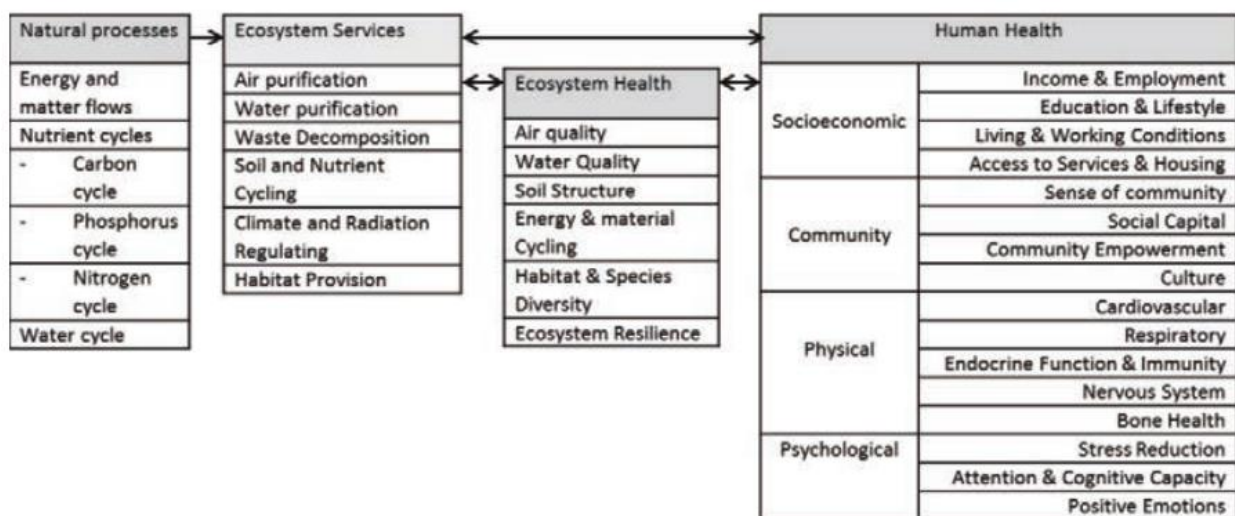
Ecosystem service sub-category	Disservice of the sub-category
Provisioning	e.g. invasive alien species, nuisances (e.g. leaves in autumn or bird excrements)
Regulating	e.g. urban heat island, water run-off, poisoning
Supporting	e.g. eutrophication, excess soil nitrates (soil) erosion
Cultural: ecosystem to society	e.g. annoyance, sounds, smells, fear, time-related factors, cost-related factors, increase stress and crime rates
Cultural: society to ecosystem	e.g. disturbance, extinction

Source: Adapted from (Beumer & Martens, 2014:98; Cornelius, 2016:86)

The vulnerability of GI ecosystem disservices is high in RPU areas because of ecosystem service reductionism and lack of spatial knowledge management (Gómez-Baggethun & Barton, 2013:241). Marshall and Farahbakhsh (2013:998) argue that systems thinking aims to escape reductionism, adding to the worth of GI planning being rooted in the integrative science of socio-ecological systems on infrastructural levels (Naumann *et al.*, 2011:6; Ojea, 2015:42; Syrbe & Walz, 2012:81; Travers *et al.*, 2013:9).

Pakzad and Osmond (2016:74) use ecological, health, socio-cultural and economic indicators to determine the scope of value that GI provides. This is accomplished through ecosystems services to human health and ecosystems in itself, as illustrated in Table 3-2. Taking GI planning's private and public scale and multi-functionality of nature and human dimensions into consideration, GI planning supports a holistic regional planning integration (Syrbe & Walz, 2012:87). This dissertation uses the potential of GI planning, created by strategic principles, to give spatial planning direction in RPU informal settlement regions. If pursued it will affect the aspects mentioned in Table 3-2.

Table 3-2: GI contribution to ecosystems and human health through ecosystem services



Source: Adapted from Pakzad and Osmond (2016:74)

The following Table 3-3 describes the typology and description of the four categories of ecosystem services.

Table 3-3: Typology and description of the four categories ecosystem services

❖ Provisioning services (Is ecosystem services that describe the material or energy outputs from ecosystems. Examples are food, water and other resources)		
Typology	Description of how the ecosystem service functions	Additional types of examples. Added colour coding of RPU and settlement relationship (Green=strong; Orange=moderate; Yellow= poor)
1. Food	>Condition for growing food >Managing agro-ecosystems >Wild foods of forest underestimated	Food (e.g. fish, game, fruit) Water (e.g. for drinking, irrigation, cooling)
1. Raw Materials	>Gives diversity for construction and fuel >Derived from wild and cultivated plant species	Raw Materials (e.g. fibre, timber, fuelwood, oil, fodder, fertilizer) Nutrient and material cycling (e.g. Biogeochemical process, geomorphology process)
2. Freshwater	>Part of global hydrological cycle >Vegetation and forest influence quantity local water availability	Genetic resources (e.g. for crop-improvement and medicinal purposes)
3. Medicinal resources	> Plants as traditional medicine > Raw materials pharmaceutical industry > All ecosystems potential source of medicine	Medicinal resources (e.g. biochemical products, models & test-organisms)
		Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)
❖ Regulating services (are the services that ecosystems provide by acting as regulators e.g. regulating the quality of air and soil or by providing flood and disease control)		
Typology	Description	Additional types with examples. Added colour coding of RPU and settlement relationship (Green=strong; Turquoise=moderate; Yellow= poor)
4. Local climate and air quality regulation	> Tree gives shade and forest influence rainfall and water availability local and global >Through photosynthesis oxygen release and carbon and other pollutant are sunk	Air quality regulation (e.g. capturing (fine) dust, chemicals, etc.) Food control (e.g. water and nutrient regulation/dispersal) Climate regulation (incl. C-sequestration, influence of vegetation on rainfall, temperature etc.)
5. Carbon sequestration and storage	More plant exists more greenhouse gasses are stored. The reciprocal relationship between biodiversity and ecosystem growth is critical for ecosystem types as C-sequestration.	Moderation of extreme events (e.g. storm protection and flood prevention) Regulation of water flows (e.g. natural drainage, irrigation and drought prevention)
6. Modernization of extreme events	Create natural buffers against extreme events and natural hazards that can harm society and the environment e.g. coral reefs and mangroves at the coast and wetland and trees on slopes inland.	Waste treatment (especially water purification) Erosion prevention Maintenance of soil fertility (incl. soil formation)
7. Waste-water treatment	A natural buyer against disaster doubles sometimes as a natural filter system as wetlands have shown. Pathogens are eliminated, decreasing nutrients and pollution.	Pollination Biological control (e.g. seed dispersal, pest and disease control)

8. Erosion prevention and maintenance of soil fertility	Vegetation cover mitigates land degradation and desertification. Thus enhancing plant growth and agriculture and building a stable environment for other ecosystem services.	noise mitigation
9. pollination	Is essential for the development of fruits, vegetables and seeds while animal pollination (mainly insect, some birds and bats) is needed for the majority global leading food crops.	
10. Biological control	Birds, bats, flies, wasps, frogs and fungi all act as natural controls. Ecosystems regulate pests and diseases through the activities of predators and parasites.	
❖ Habitat or Supporting services (Include the non-material benefits people obtain from contact with ecosystems. Example is included aesthetic, spiritual and psychological benefits.)		
Typology	Description	Additional types with examples. Added colour coding of RPU and settlement relationship (Green=strong; Orange=moderate; Yellow= poor)
11. Habitats for species	Provides the livelihood capitals needed for living and reproduction. Ecosystems are dynamic for each species lifestyle local or migration.	Maintenance of life cycles of migratory species (incl. nursery service) Maintenance of genetic diversity (especially in gene pool protection)
12. Maintenance of genetic diversity	Genetic diversity is the variety of genes between and within species populations. Genetic diversity distinguishes different breeds or races from each other thus providing the basis for locally well-adapted cultivars and a gene pool for further developing commercial crops and livestock. Some habitats have an exceptionally high number of species which makes them more genetically diverse than others and are known as 'biodiversity hotspots'	
❖ Cultural services (Include the non-material benefits people obtain from contact with ecosystems. Examples include aesthetic, spiritual and psychological benefits)		
Typology	Description	Additional types with examples. Added colour coding of RPU and settlement relationship (Green=strong; Orange=moderate; Yellow= poor)
13. Recreation and mental and physical health	Releasing energy through humans and animals outside is healthy physically and mentally.	Opportunities for recreation & tourism Information for cognitive development (e.g. Socio-ecological memory, and tertiary education)
14. Tourism	The diversity of tourism tailored to changing geographic areas is a well-known national income of many countries. Eco-tourism is socio-	Sense of well being




	economically because of the educational influence.	Inspiration for culture, art and design Spiritual experience Aesthetic information
15. Aesthetics appreciation and inspiration for culture, art and design	Biodiversity, ecosystems and natural landscapes have influence humanity from the beginning of creation, recorded and revolved in transdisciplinary fields of society.	Education in primary and secondary school Sense of place
16. Spiritual experience and sense of place	Specific forests, caves or mountains are considered sacred or have a religious meaning to certain groups of society, as in socio-economic dimensions as well.	




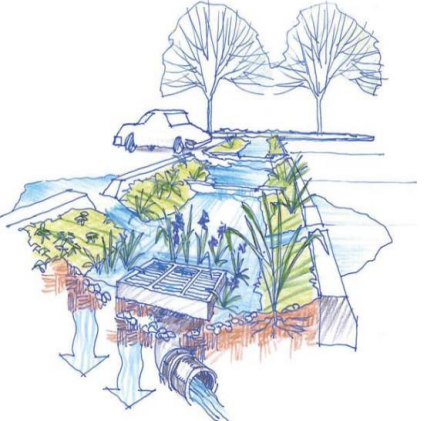

Source: (Alberti, 2005:175; Barrow, 2006:239; Cilliers *et al.*, 2013:681; Andersson *et al.*, 2014:449; European Commission, 2012:19; Daniel *et al.*, 2012:8813; Elmqvist *et al.*, 2013:217; MEA, 2005:40; TEEB, 2010c:18, 2010d:21; Turok, 2015:4) Take not that the colour coding was based on ecosystem types quantity relation in research literature related to rural and peri-urban related planning dimensions.


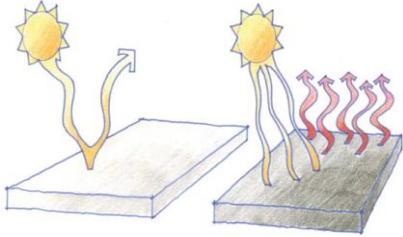



Annexure 4: Different approaches of GI planning elements


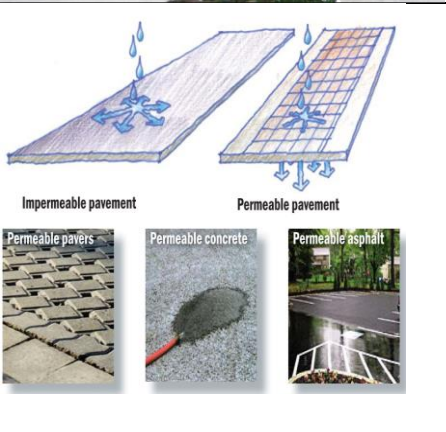

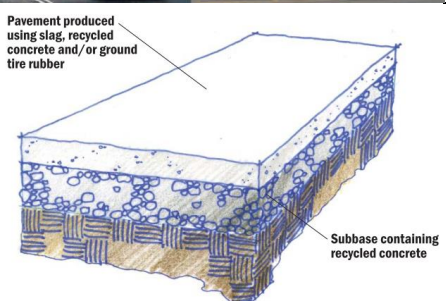


The information presented in Annexure four has not been included in the main research study as this information supports a grey-green continuum overview of designing and management examples functions outside the scope of this research theme. This annexure four should be taken into recognition with the identification of GI planning potential as to identify GI planning potential inside a built environment that should be inclusive towards such information described in Annexure four.

Table 4-1 Individual approaches of GI planning elements on different planning scales






Individual application	Description and theme	Illustration of application	Authors
<p>Working with building/sites (Landowner incentives provide the necessary motivation at the building and site level, in particular for existing properties. Guidelines and changes in building code can require or simply enable implementation during new construction. For larger developments, site plan reviews standards and negotiations can be used to encourage landowners to consider green infrastructure.)</p>			
Cisterns/ rain barrels	A rain barrel or cistern is a container used to collect and store rainwater from a building roof for various uses including irrigating plants. It can also funnel water from the roof into storage tanks to be used for drip irrigation and filtered for use in washing machines		RPA (2012:5) (Daley & Byrne, 2007:28)(Dunn, 2010:51)
Downspout disconnection	Downspouts/gutters discharging directly to stormwater system rerouted to rain gardens or stored in cistern		RPA (2012:5)
Green roofs and green walls	A "green roof" is a roof that is partially or completely covered with plants. A green roof system includes waterproofing, a drainage system, soil and plants. Green roofs can be installed on most flat roofs and are well-suited to garages, provided that they are constructed to accommodate the structural load. Green walls are similar to green roofs just vertically aligned with specifically tailored plant species and design requirements		RPA (2012:5)(Daley & Byrne, 2007:30)




<p>Minimize impervious coverage</p>	<p>Site design reduces paved surfaces to maximum extent possible and/or employs porous pavement</p>		<p>RPA (2012:5)</p>
<p>Rain gardens and biofilters</p>	<p>A rain barrel or cistern is a container used to collect and store rainwater from a building roof for various uses including irrigating plants.</p>		<p>RPA (2012:5) (Daley & Byrne, 2007:28)</p>
<p>Soil and plant quality control e.g. mulching or organic waste</p>	<p>The aspect of using the external input to enhance soil and plant resilience. Such as using mulch to increase soil moisture and reduce weed growth. Organic mulch can even control septoria leaf spot and that green mulch controls nematodes.</p>		<p>(Brook & Dávila, 2000:77.)</p>
<p>Working with neighbourhoods/public spaces (streets, plazas, parks, playgrounds, and parking lots) Municipalities can lead by example by showcasing the range of green infrastructure techniques that justify incentives and mandates. These investments can familiarize planning, zoning and public works staff and their private sector colleagues with the maintenance, installation and best practices technique</p>			
<p>Bioswales and vegetated swales</p>	<p>A bioswale or a vegetated swale is a shallow trench or shoulder landscape with native plants used to slow the speed of surface runoff and allow stormwater to infiltrate back into the ground instead of flowing directly into storm sewers.</p>		<p>RPA (2012:5)</p>
<p>Cool surfaces and paints</p>	<p>Alternate roof types, paint, and shade tree coverage cool stormwater and reduce evaporation.</p>		<p>RPA (2012:5)</p>

<p>Green facades</p>	<p>Green facades are climbing plants grown up a wall directly or on a trellis or similar structure set away from the wall. Unlike green walls, green facades are a realistic option for widespread urban GI implementation because of lower installation and maintenance costs.</p>		<p>(Elmqvist <i>et al.</i>, 2013:102) (Norton <i>et al.</i>, 2015:132)</p>
<p>High albedo pavement</p>	<p>High albedo pavement material is light in colour and reflects sunlight away from the surface. With less sunlight absorbed by pavement, less heat is radiated by the pavement. High albedo pavement, therefore, reduces the urban heat island effect. This reduces cooling costs, helps the survival of urban vegetation, and improves air quality, which can help reduce the symptoms of some respiratory diseases.</p>		
<p>High-performance streets</p>	<p>Streetscapes minimize pavement and include porous pavement, curb cuts, bioswales and/ or enhanced tree pits.</p>		<p>RPA (2012:5)</p>
<p>Increase vegetation cover and native species</p>	<p>Thereby filtering airborne pollutants, offsetting urban heat island effects, up to taking carbon, and reducing the heating and cooling demands of buildings.</p>		<p>(Dunn, 2010:47)</p>
<p>Naturalized detention</p>	<p>Naturalized detention is an area used to temporarily store stormwater on site and slowly release it at a controlled rate. These areas are intended to look and function as native wetlands and include native plants growing both above and below the normal water level.</p>		<p>(Daley & Byrne, 2007:33)</p>

<p>Non-motorized transport</p> <ul style="list-style-type: none"> • Bicycle infrastructure 	<p>Excluding vehicle, transportation not only reduces the ecological footprint of motor vehicles but improve social cohesion of humans and nature. Providing safe, secure and strategic bicycle pathways can be double with other transport related GI planning for multiple benefits.</p>		<p>(Harrison <i>et al.</i>, 2014:70)</p>
<p>Porous pavement</p>	<p>Permeable pavement has pores or openings that allow water to pass through the surface and percolate through the existing subsoil. Permeable pavement comes in the form of permeable asphalt, permeable concrete, and permeable pavers. In areas where soils do not drain freely, permeable pavement can be used in combination with subsurface drainage systems, like pipe underdrains or stormwater infiltration trenches to slow runoff and reduce stress on the combined sewer system.</p>		<p>RPA (2012:5)</p>
<p>Public transport infrastructure</p>	<p>Light rail, rapid bus routes, strategic sub-station design is part of making resource efficient capital flows within urban to rural areas. An interconnection of GI assets can be incorporated to complement the ecosystem system services transport infrastructure influence and uses.</p>		<p>(Harrison <i>et al.</i>, 2014:70)</p>
<p>Recycled construction material</p>	<p>Recycled concrete aggregate can be used in the concrete mix and as a base beneath surface paving. Also, slag, a by-product of steel production, can be used as a component of the concrete mix, reducing industrial waste. Ground tire rubber can be used in porous asphalt and reclaimed asphalt pavement in non-porous asphalt.</p>		<p>(Daley & Byrne, 2007:12)</p>
<p>Renewable electric vehicles</p>	<p>Drifting slowly to solar power and biodiesel vehicles places less pressure on the virgin material to produce electricity and fuel, becoming a more environmentally friendly business, a critical driver needed for environmental stewardship paradigm acceptance.</p>		<p>(Harrison <i>et al.</i>, 2014:70)</p>
<p>Trees and enhanced street tree pits/boxes</p>	<p>Tree canopies, roots and tree pits facilitate stormwater infiltration and detention and helps cools runoff</p>		<p>RPA (2012:5)</p>

Working with landscapes/ townscape
(watersheds, towns and counties)
(Public and private investments in conservation, master plans, zoning ordinances, environmental review processes and land management can promote green infrastructure at the municipal or landscape scale.)

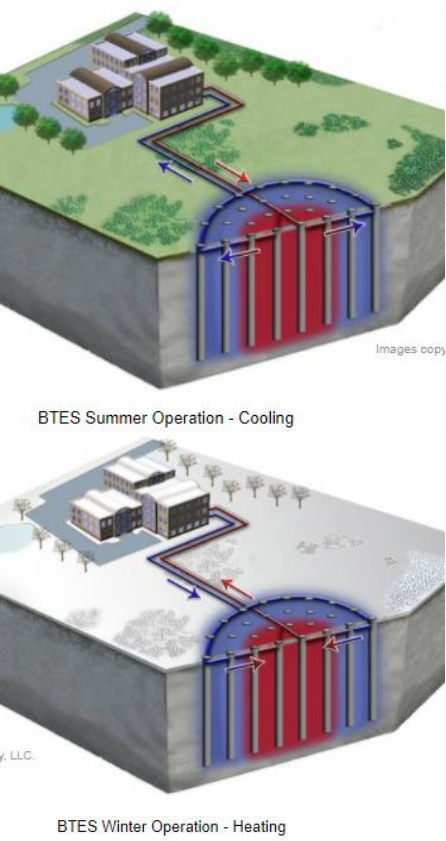
<p>Conservation subdivision</p>	<p>Create smaller building lots and/or concentrate construction and pavement in specific building envelopes. The balance of land placed in conservation status.</p>		<p>RPA (2012:6)</p>
<p>Forest, farm, and rangeland best practices</p>	<p>Best management practices to minimize erosion. This can advance additionally pollination, pest regulation and seed dispersal through diver's biodiversity inclusion.</p>		<p>RPA (2012:6) (Elmqvist <i>et al.</i>, 2013:183)</p>
<p>Land conservation</p>	<p>Conserved land through easement and fee simple acquisition maintain groundwater infiltration and reduce peak runoff events.</p>		<p>RPA (2012:6)</p>
<p>Master plan and zoning</p>	<p>Zoning may allow a city to prioritize areas for different purposes with varying building densities and regulations of human activity, ensure protection of areas valuable to ES provision, and plan their linkages</p>		<p>RPA (2012:6)</p>
<p>Nutrient retention</p>	<p>Is done by adding coarse woody debris, constructing in-channel gravel beds, and increasing the width of vegetation buffer zones and tree cover</p>		<p>(Elmqvist <i>et al.</i>, 2013:183)</p>

Steep slope and erosion controls	Limit erosion and downstream sedimentation		RPA (2012:6)
Urban agriculture	Community gardens for poverty reduction; enhancing food security, nutrition and economic status. Urban gardens can also be a food security mechanism, be important learning arenas and reduce the ecological footprint of cities		
Wetlands, stream corridors (man-made and restored), and floodplain ordinances	More urbanized wetlands, known as "pocket wetlands" has a higher GI value asset rating than similar context wetland in low-human populated areas.		RPA (2012:6) (Dunn, 2010:60)


Retrofitting

(low carbon infrastructure)

In its own respect, these applications are not GI. But if strategically laid-out on an infrastructural GI planning integrating style then it can be included to be part of GI assets.

Borehole thermal energy storage (BTES)	Using hydraulic drilling technology combined with water piping system, the heat energy stored in the earth by the sun in the day is absorbed through the vertical pipes and pumped into the building structure by night.		(Harrison <i>et al.</i> , 2014:70)
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Composting	Kitchen scraps, yard waste and even some paper products can be placed into an inexpensive composting bin to decompose. With very little maintenance, the waste will soon break down into a rich, organic material that can be mixed directly into the garden soil or used as fertilizer for trees and shrubbery. Not only does composting save space in our garbage trucks and landfills, but its product also provides a nutrient boost to poor urban soils.		(Dunn, 2010:50) Daley & Byrne, 2007:24)
Dark sky compliant alley light fixture	Reduces light pollution from the site. Reduces glare and provides better light uniformity • White light produced by metal halide fixtures has a high “colour rendition index” and therefore allows people to perceive colour more accurately		(Daley & Byrne, 2007:12) (Figure from Daley & Byrne, 2007:12)
Drip irrigation system	A water conserving technique which doubles also by placing nutrient-infused water directly into roots of the plant, being more economic and stimulating more growth.		(Dunn, 2010:50)
Recycling	Recycling products like glass, plastic, and metal containers is a simple and inexpensive way to reduce waste hauled to landfills while saving energy and natural resources. This can be converted to resources of GI assets in either waste prevention unto pollution or waste utilization e.g. organic waste to compost or methane gas as a renewable energy source.		(Daley & Byrne, 2007:24)
Solar water heating and solar energy systems	Photovoltaic systems convert sunrays into usable energy cell that can be stored in a battery capacity. This solar energy is used to less grid electricity needed to heat up geysers and depending on the panels size, inverter and battery system there are various scales of solar potential usages.		(Harrison <i>et al.</i> , 2014:70)

Wind turbines	Using wind to rotate blades that produce kilowatt energy has been implemented in various scales and locations. Not only can this lower the need for national energy supply but drive other green technology promoting GI planning development e.g. anaerobic digesters supply agroecosystem.		(Dunn, 2010:50)
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Source: Own compilation and pictures taken from BIL (2017), Gallet (2010), Container gardening (2011), Daley & Byrne (2007), Davra networks (2015), Energy and Gold LTD (2017), Flickr (2015), Garden adventures (2013), GBA (2017), Getly Images (2017), Langrock (2010), MAG (2015), Pinterest (2017), RPA (2012), Trusted clothes (2016) and Underground energy (2009)

Annexure 5: Cross-referenced GI principle lingo to transdisciplinary principles

The information presented in Annexure five has not been included in the main research study as this information support the GI planning linguistics that functions outside the scope of this research theme. Annexure five should be taken into recognition with the identification of GI planning potential because the research theme of this study combines is built on integrating GI planning principles into a natural and urban anthropogenic region. Annexure five thus provide further insight into the understanding and interlinkage that GI planning principle has in other related disciplines.

Table 5-1: Principles for ecosystem-based approached towards climate change adaption

Principles	Direct and indirect link of Table 6-7 GI principles
Maintain and increase ecological resilience	
conserve range and ecological variability of habitats	B10; D9
conserve range and ecological variability of species	B21
maintain existing ecological networks	A6; A4
create buffer zones around high-quality habitats	NONE
take prompt action to control the spread of invasive species	B21
Accommodate change	
understand change is inevitable	C2
make space for the natural development of rivers	C4; C9;C15
make space for the natural development of coasts	C4; C9;C15
establish ecological networks through habitat restoration	C4; C9;C15
establish ecological networks through habitat creation	A6; A4
aid gene flow	NONE
consider the role of species translocation	B21
consider the role of ex-situ conservation	NONE
develop the capacity of institutions to cope with change	C2
develop the capacity of administrative arrangements to cope with change	NONE
develop the capacity to learn from experience	B19; C7; D11
respond to changing conservation priorities	B9
Develop knowledge and plan strategically	
undertake vulnerability assessments of biodiversity	NONE
undertake vulnerability assessments of ecosystem goods and services	D1
undertake scenario planning	C13; D11
implement no regrets actions	NONE
pilot new approaches	B11
monitor outcomes of new approaches	B20
identify potential (cross-sectoral) win-win solutions	NONE
ensure cross-sectoral knowledge transfer	C5
monitor actual impacts of climate change	C1
research likely future impacts of climate change	NONE
improve understanding of the role of biodiversity in ecosystem services	B1
research knowledge gaps with stakeholder participation	B8
Integrate across all sectors	
integrate adaptation and mitigation measures	C2
integrate adaptation policy across relevant economic sectors	B11; C18

integrate adaptation practice across relevant economic sectors	D8
build and strengthen partnerships	C3; B8
raise awareness of benefits of the natural environment to society	B5; B6; B10; B12; B24; B25; D4
Take practical action now	
conserve and restore existing biodiversity	A6; D5; D7; D9
conserve protected areas	D8
conserve high-quality habitats	D8
reduce sources of harm not linked to climate	NONE
use existing biodiversity legislation	NONE
use existing biodiversity international agreements	NONE

Source: Authors compilation from Naumann *et al.*, (2011:122)

Table 6-2: The ecosystem approach principles, closely related to all socio-ecological systems thinking

1. Principles	Direct and indirect link of Table 2-3 GI principles
1. The objectives of management of land, water and living resources are a matter of societal choices.	A2; B11; C3; D2; D12
1. Management should be decentralized to the lowest appropriate level	none
1. Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.	C11; C12; D3; D9
1. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context.	B17; C10; C13; D8; D12
1. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.	C19; D11
1. The ecosystem must be managed within the limits of their functioning.	A6; A7; C17; D7; D10
1. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.	A9; B26; C10; D14
1. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.	B17, B18
1. Management must recognize the change is inevitable.	C2
1. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.	B9; B11
1. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.	B12; C5
1. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.	B15; C8; D3

Source: Authors compilation from Brown and Everard, (2015:62) and CoBD (2004:1)

Table 6-3: The ecological design process principles

Principles	Direct and indirect link of Table 2-4 GI principles
Solutions grow from place	B3; B22; D5; D7
Ecological accounting informs design	A4; A6; A7; B6; B23; D7
Design with nature	A6; B11; B13; B17; C1; C16; C18; D7; D10
Everyone is a designer	A2; B4; B5; B8; B14; C3; C8; C17; D3; D13
Make nature visible	B8; C3; C8; D4; D5

Source: Authors compilation from Van Der Ryn and Cowan (2009:72)

Table 6-4: Principles to secure long-term development potential of biodiversity with a summarized description

Principles		Direct and indirect link of Table 2-3 GI principles
i. No net loss:	Loss of irreplaceable biodiversity must be avoided. Another biodiversity loss has to be compensated for (in quality and quantity).	D7; D9
i. The precautionary principle:	Where impacts cannot be predicted with confidence, and/or where there is uncertainty about the effectiveness of mitigation measures, be cautious and risk-averse. Employ an adaptive approach (several small steps instead of one big step) with safety margins and continuous monitoring (see also The Precautionary Principle Project, www.pprinciple.net/).	A4; B11; B16; B20; B27; C1; C2; C7; C10; D3; D9
i. Participation:	Different groups or individuals in society have a stake in the maintenance and/or use of biodiversity. Consequently, valuation of biodiversity and ecosystem services can only be done in negotiation with these stakeholders. Stakeholders	A2; B4; B5; B8; B14; C3; C8; C17; D2; D3; D13
i. Local, traditional and indigenous knowledge is used in impact assessment to provide a complete and reliable overview of issues pertaining to biodiversity.	Views are exchanged with stakeholders and experts. While physical drivers of change (such as hydrological changes) can be modelled by experts, impacts are 'felt' by people and are location specific (for	A2; A5; B1; B12; B15; D1; D2; D3; D5; D13

Source: Authors compilation from TEEB (2010c:120)

Table 6-5: The principles associated with Landscape approach (for major actors on how agricultural production and environmental conservation is integrated at landscape scales).

Principles	Direct and indirect links of Table 2-3 GI principles
Continual learning and adaptive management.	B4; B16;B19; D11
Common concern entry point	A2; B8; B4; B14; C3; C13; C19;D6;D14
Multiple scales.	A9;
Multi-functionality	A8
Multiple stakeholders	B8; C8; D3
Negotiated and transparent change logic	C10; C13
Clarification of rights and responsibilities	NONE
Participatory and user-friendly monitoring.	B20
Resilience	NONE
Strengthened stakeholder capacity	C8

Source: Authors compilation from Sayer *et al.*, (2013:8351)

Table 6-6: Principles needed to incorporate ecology in land use planning (ecological principles deal with time, place, species, disturbance, and the landscape.)

Principles	Direct and indirect links of Table 2-3 GI principles
I.Examine impacts of local decisions in a regional context,	B3; D3; D5
I.Plan for long-term change and unexpected events,	B17; B18; C2
I.Preserve rare landscape elements and associated species,	A6; B15; D1;
V.Avoid land uses that deplete natural resources,	A6; B15; D1; D7
V.Retain large contiguous or connected areas that contain critical habitats,	A3; A6; B2; B9; C9;
I.Minimize the introduction and spread of non-native species,	B21
I.Avoid or compensate for the effects of development on ecological processes, and	NONE
I.Implement land-use and management practices that are compatible with the natural potential of the area	A6; B15; D1; D7

Source: Authors compilation from Dale *et al.*, (2000:648)

Table 6-7: Principles for slow adaption in landscape planning

Principles	Direct and indirect links of Table 2-3 GI principles
i) Time-sensitive activity	NONE
ii) Heterogeneous and dynamic landscape-moving target	B11; C17
iii) Short time frames to plan with political and other deadlines	B11
iv) Fear of failure/liability, reluctance to accept uncertainty.	B19; C7; D3; D11
v) Unsupportive institutional setting, and complex and competing for social values and interests.	A4; C8; C10; C11;C13; D3
vi) Lack of agreement on clearly stated goals.	B8; C5; D2
vii) Lack of data, monitoring expertise, tradition and culture.	A2; A10; B4; B5; B8; B12; B14; B16; B17; B20; B27; C3; C5; C8; C19; D2; D3;
viii) Lack of scientifically-based guidelines.	B11; B12; B15; B20; C10; C13

ix)	Lack of successful precedents/models.	B11; C8; C13; C17
x)	Transdisciplinary approach not widely understood or practised.	C8; D3

Source: Authors compilation from Kato & Ahern (2008:549)

Table 6-8: Principles of green engineering

Principles	Direct and indirect links of Table 2-3 GI principles
I) Designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible.	NONE
II) It is better to prevent waste than to treat or clean up waste after it is formed.	NONE
III) Separation and purification operations should be designed to minimize energy consumption and materials use.	C14
IV) Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.	A1; A4; A5; A8; C10; C11; C12; C13; C14; C19; D5; D6; D8
V) Products, processes, and systems should be “output pulled” rather than “input pushed” through the use of energy and materials.	A1; A3; A11; B7; C19; D12
VI) Embedded entropy and complexity must be viewed as an investment when making design choices on recycling, reuse, or beneficial disposition.	B11; C10; C13
VII) Targeted durability, not immortality, should be a design goal.	B17; B18; C17; D4; D7; D9
VIII) Design for unnecessary capacity or capability (e.g., “one size fits all”) solutions should be considered a design flaw.	B3; D5; D7
IX) Material diversity in multicomponent products should be minimized to promote disassembly and value retention.	B27; C7; C8; C12; C16; D3; D10
X) Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.	A3; A6; A7; A8; A9; A10 ;A11; B2; B7; B11; B20; B26; C6; C9; C10;C13; C19; D3; D9; D14
XI) Products, processes, and systems should be designed for performance in a commercial “afterlife”.	D2; D12
XII) Material and energy inputs should be renewable rather than depleted.	B11

Source: Authors compilation from Anastas and Zimmerman (2003:96)

Table 6-9: Principles of green economics

Principles	Direct and indirect links of Table 2-3 GI principles
1. Focusing on the primacy of use value, intrinsic value, and quality: This is the fundamental principle of the green economy as a service economy, focused on end-use, or human and environmental needs.	A8; B6; B7; B14; B17; B27; C8; D8; D12
1. Following natural flows: As society becomes ecological, political and economic boundaries tend to coincide with eco-system boundaries. It becomes bioregional.	A1; A3-9; B2; B9; B13; B17; B22; B26; C17; C18; D7; D14
1. Useful waste: In nature, there is no waste, as every process output is an input for some other process.	NONE
1. Elegance and multi-functionality: Problem-solving strategies that develop multiple gains and positive side effects from any one set of actions.	A8; B6; B13; B23; C5; C13
1. Appropriate scale and linked scale: Every regenerative activity has its most appropriate scale of operation. Integrates design across multiple scales.	A1; A3; A5; A6; A7; A9; B22; B26; C9; C10; C13; D14
1. Diversity: Applies to all levels (diversity of species, of ecosystems, of regions), and to social, as well as the ecological organization.	B7; B13; C6; C8; D3; D13
1. Self-reliance, self-organization, self-design: Self-reliance is not self-sufficiency, but facilitates a more flexible and holistic interdependence.	B27; C19
1. Participation and direct democracy: Conversely, ecological organization and new information or communication technologies can provide the means for deeper levels of participation in the decisions that count in society.	B12; B27; C3; C5; C11; C12
1. Human creativity and development: Social, aesthetic, and spiritual capacities become central to attaining economic efficiency and become important goals in themselves.	B3-5; C3; D5
1. The strategic role of the built environment, the landscape, and spatial design: The greatest efficiency gains can often be achieved by a simple spatial rearrangement of system components.	A6; A8; A9; B2; B11; B13; B15; B22; B26; C17; D9; D14

Source: Authors compilation from Milani (2006 43) and Cilliers (2010 25)

Table 6-10: Cluster summary greening principles as the undertone of GI planning

Principles	Direct and indirect links of Table 2-3 GI principles
Integrate	A5; B13; C9
Future price of carbon compliant with potential impacts of environmental climate change	C1; C2
Technology innovation	NONE
Minimize	NONE
Carbon emission	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Energy use	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Air pollution	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Water pollution	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Soil pollution	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Water use	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Land use	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Biodiversity destruction	A11; B6; B10; B12; B24; B25; C18; C19; D4; D10
Maximize	NONE
Synergetic efficiencies	C19
Protection ES	A6; B1; B9; B10; B23; B24; B25
Restoration ES	A6; B1; B9; B10; B23; B24; B25

Source: Authors compilation from (Giordano, 2014:483)

Table 6-11: Principles for building resilience in socio-ecological systems

Principles	Direct and indirect links of Table 2-3 GI principles
Broaden participation	A2
Encourage learning	B4; B16; D11
Foster complex adaptive systems thinking	B11;B27
Maintain diversity and redundancy	C6
Manage slow variables and feedbacks	B17; B19
Promote polycentric governance systems	None

Source: Authors compilation from SRC (2014a:2; 2014b:4)

Table 6-12: Summary of the various tables used from transdisciplinary fields integrated into the GI planning concept

Table number	Title of table	Keywords
6-1	Principles for ecosystem-based approached towards climate change adaption	ecosystem-based climate change adaption
6-2	The ecosystem approach principles, closely related to all socio-ecological systems thinking	ecosystem approach socio-ecological systems
6-3	The ecological design process principles	ecological design process
6-4	Principles to secure long-term development potential of biodiversity with a summarized description	secure the potential of biodiversity
6-5	The principles associated with Landscape approach (for major actors on how agricultural production and environmental conservation is integrated at landscape scales).	landscape approach agricultural production environmental conservation
6-6	Principles needed to incorporate ecology in land-use planning (ecological principles deal with time, place, species, disturbance, and the landscape.)	ecology land-use planning
6-7	Principles for slow adaption in landscape planning	adaption

		landscape planning
6-8	Principles of green engineering	green engineering
6-9	Principles of green economics	green economics
6-10	Cluster summary greening principles as the undertone of GI planning	greening principles
6-11	Principles for building resilience in socio-ecological systems	resilience socio-ecological systems

Source: Authors compilation (2017)

Annexure 6: International applied GI planning elements effectiveness

The information presented in Annexure six has not been included in the main research study as this information support the effective and efficient application of GI typologies internationally whereas such studies functions outside the scope of this research theme. This annexure six should be taken into recognition with the identification of GI planning potential to comprehend the international difficulty of unequal GI typology integration. This the potential identification of GI planning should be conducted in a manner to not hinder GI typology integration.

Table 6-1 represents the various GI elements operating in developed and developing countries at different levels. The colour green shows the extensive progress of GI mostly inside urban areas ranging in elements from sustainability, multifunctionality, accessibility and connectivity. The red colours show the weakest progress and even given that developed countries have an advantage of GI over developing countries, financial funding is a concern everywhere.

Table 6-1: Cross-evaluation of green infrastructure elements against different countries application (Green – extensive, Amber – moderate, Red – weak general applications).

GI Principle	UK	USA	Europe	Asia	Australasia
<i>Sustainability</i>	Green	Amber	Green	Amber	Amber
<i>Multi-functionality</i>	Green	Green	Green	Amber	Green
<i>Accessibility</i>	Green	Green	Green	Amber	Red
<i>Connectivity</i>	Green	Green	Green	Amber	Green
<i>Social Benefits</i>	Amber	Amber	Amber	Amber	Amber
<i>Ecological Benefits</i>	Amber	Amber	Green	Amber	Amber
<i>Economic Benefits</i>	Amber	Red	Amber	Amber	Red
<i>Ecosystem services</i>	Amber	Amber	Amber	Amber	Red
<i>Scaled</i>	Amber	Amber	Amber	Amber	Red
<i>Integrated policy</i>	Amber	Amber	Amber	Amber	Red
<i>Holistic planning approach</i>	Amber	Red	Amber	Red	Amber
<i>Water management</i>	Amber	Green	Amber	Red	Amber
<i>Engineered</i>	Red	Amber	Amber	Amber	Amber
<i>Climate Change</i>	Amber	Amber	Amber	Amber	Amber
<i>Co-ordinated</i>	Amber	Amber	Amber	Red	Red
<i>Funding</i>	Red	Red	Red	Amber	Red
<i>Long-term values</i>	Amber	Amber	Amber	Red	Red
<i>Urban</i>	Green	Green	Green	Green	Green
<i>Rural</i>	Red	Green	Amber	Red	Red
<i>Government policy</i>	Red	Red	Red	Amber	Amber
<i>Regional/local policy</i>	Amber	Amber	Amber	Red	Amber
<i>Government led</i>	Red	Red	Red	Amber	Amber
<i>Regionally/locally led</i>	Amber	Amber	Green	Red	Red
<i>Advocacy policy</i>	Green	Green	Green	Red	Amber
<i>Advocacy led</i>	Green	Green	Green	Red	Red

Source: Mell (2014a:614)

Developing countries have weaker general applications regarding GI than compared with developed countries. The majority of weak applications regarding GI is within the middle section of Table 4-1 that is also seen in the majority of GI planning principles from Table 6-2.

Annexure 7: The CRDP data inventories similar to GI planning for South Africa

The information presented in Annexure seven has not been included in the main research study as this information advances GI data inventories that functions outside the scope of this research theme. This annexure seven should be taken into recognition with the identification of GI planning potential because a limitation of this research is quality data inventories and thus the current identification of GI planning potential in RPU settlement should include such specific data inventories and planning steps as mentioned Annexure seven.

Table 7-1: The CRDP planning approach and similarity of GI planning data inventories for South Africa

Steps	Proposed planning approach
Step 1	Capturing basic cadastral data including: <ul style="list-style-type: none"> • boreholes, • buildings, • contours, • property boundaries, • infrastructure services, • heritage, • forests, • wind pumps and signboard
Step 2	Compiling a draft settlement plan including: <ul style="list-style-type: none"> • Demarcation of stands based on existing fences/boundaries • Numbering of stands • Infilling of open spaces to create additional stands • Stands for community facilities based on needs identified • Environmental aspects • Proper street layout based on acceptable design norms
Step 3	Formulating public participation process including: <ul style="list-style-type: none"> • Presentation of a settlement layout plan to the rural community involved for approval • Request permission from the community to conduct a land use survey/express and households questionnaires
Step 4	Conduct a detailed land use and infrastructure survey physically on the ground to verify and confirm land use.
Step 5	Designing and conducting a detailed questionnaire including households, age, gender, marital status, employment status, education status, disability status, and income status, source of income, mode of transport, employment institutions, migration status, farming experience, housing and infrastructure service. Conduct workshop with questionnaire facilitators to arrange the process of data collection
Step 6	Needs analysis and interpretation by means of settlement layout plan and the questionnaire conducted in every household Create status quo including individual, household and community needs
Step 7	Involving external professional expert such as: <ul style="list-style-type: none"> <input type="checkbox"/> Environmental specialists <input type="checkbox"/> Geologists <input type="checkbox"/> Civil engineers
Step 8	Schedule meeting to involve other Councils of Stakeholders to discuss the implementation plan based on the needs identified

Source: Adapted from Moselane (2015:149)

Annexure 8: The 2016 EIMP for South Africa

The information presented in Annexure eight has not been included in the main research study as this information support the spatial planning background for South African legislation towards a regional planning scope of GI planning types of integrated management strategies and frameworks that function outside the scope of this research theme. This annexure eight should be taken into recognition with the identification of GI planning potential because the EIMP 2016 is evidence of South African legislation to be acceptable for a GI planning strategy. This provides a priority to identify the GI planning potential whereas this study has been dedicated to exactly that purpose.

Table 8-1: Environmental Implementation and Management Plan of 2016 (EIMP) policies, acts of parliament and regulations as a representative of GI planning legal comprehensiveness in South Africa

INTEGRATED ENVIRONMENTAL MANAGEMENT	
Policies	
	White Paper on Environmental Management, 1998
	National Framework for Sustainable Development, 2008
	National Strategy for Sustainable Development (NSSD), 2011,
Acts of parliament	
	National Environmental Management Act (NEMA), 1998, (Act No. 107 of 1998)
	National Environmental Management Amendment Act, 2003 (Act No. 46 of 2003)
	National Environmental Management Amendment Act, 2004 (Act No. 8 of 2004),
	National Environment Laws Amendment Act, 2008 (Act No. 44 of 2008),
	National Environmental Management Amendment Act, 2008 (Act No. 62 of 2008)
	National Environment Laws Amendment Act, 2009 (Act No. 14 of 2009)
Regulations	
	National Environmental Management Act, 1998 (Act No. 107 of 1998) Protected Areas Act: Admission of Guilt Fines, 2011,
	Environment Impact Assessment (EIA) Regulations, 2010
	Environmental Impact Assessment Regulations (Listing Notice 1 of 2010),
	Environmental Impact Assessment Regulations (Listing Notice 2 of 2012)
	Environmental Impact Assessment Regulations (Listing Notice 3 of 2012),
	Environmental Management Framework Regulations, 2010,
	Regulations Relating to Qualification Criteria, Training and Identification of, and Forms to be used by, Environmental Management Inspectors, 2006,
	Regulations for the Establishment of a Designated National Authority for the Clean Development Mechanisms, 2005,
	Regulations Relating to Identification of Environmental Management Inspectors, 2005 by Regulations controlling the use of vehicles in the coastal zone, 2001
BIODIVERSITY AND HERITAGE RESOURCES	
Policies	
	White paper on conservation and sustainable use of biodiversity, 1997,
Acts of parliament	

	World Heritage Convention Act, 1999 (Act No. 49 of 1999)
	National Environmental Management: Protected Areas Amendment Act, 2009 (Act 15 of 2009)
	National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004)
	National Environmental Management: Protected Areas Act, 2003 (Act No. 57 of 2003),
	National Environmental Management: Protected Areas Amendment Act, 2004 (Act No. 31 of 2004)
Regulations: Under National Environmental Management: Protected Areas Act, 2003 (Act No. 57 of 2003)	
	Regulations for the Proper Administration of Nature Reserves, 2012
	Regulations for the proper Administration of the Knysna Protected Environment, 2009
	Regulations for the Proper Administration of Special Nature Reserves, National Parks and World Heritage Sites, 2005
Regulations under: National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004)	
	CITES Regulations, 2010
	Threatened or Protected Species (TOPS) Regulations, 2007
	Regulations for bioprospecting, access and benefit-sharing, 2008
OCEANS AND COASTAL ENVIRONMENTA MANAGEMENT	
Policies	
	White Paper for Sustainable Coastal Development in South Africa, 2000
Acts of parliament	
	National Environmental Management: Integrated Coastal Management Act, 2008 (Act No. 24 of 2008)
	Sea Shores Act, 1935, (Act No. 21 of 1935)
	Sea Birds and Seals Protection Act, 1973 (Act No. 46 of 1973)
	Dumping at Sea Control Act, 1980 (Act No. 73 of 1980)
	Sea Fishery Act, 1988 (Act No. 12 of 1988)
	Antarctic Treaties Act, 1996 (Act No. 60 of 1996)
	Marine Living Resources Act, 1998 (Act No. 18 of 1998)
	Prince Edward Islands Act, 1948 (Act No. 43 of 1948)
Regulations under: National Environmental Management: Integrated Coastal Management Act 24 of 2008:	
	Regulations for the control of use of vehicles in the Coastal Areas (No. R. 496 of 2014)
Regulations under: National Environmental Management: Integrated Coastal Management Act 24 of 2008:	
	Regulations for the management of public launch site (No. R. 497 of 2014)
Regulations under: Sea shore Act, 1935 (Act No. 21 of 1935):	
	General regulations, 1955
Regulations under: Dumping at Sea Control Act, 1980 (Act No. 73 of 1980):	
	Regulations made in terms of section 8 of the Act, 1988,
Regulations under: Antarctic Treaties Act, 1996 (Act No. 60 of 1996):	
	Regulations made in terms of section 6 of the Act, 1997,
Regulations under: Marine Living Resources Act, 1998 (Act No. 18 of 1998):	
	Regulations for the management of the Amathole Marine Protected Area
	Regulations for the management of the Table Mountain Marine Protected Area
	Regulations for the management of the Aliwal Shoal Marine Protected Area
	Regulations for the management of the Pondoland Marine Protected Are
	Regulations for the management of the Bird Island Marine Protected Area,

	Regulations for the management of the Still Bay Marine Protected Area,
	Regulations to manage boat-based whale-watching and protection of turtles,
	Regulations for the management of white shark cage diving,
CLIMATE CHANGE AND AIR QUALITY MANAGEMENT	
Policies	
	White Paper on National Climate Change Response, 2011
Acts of parliament	
	National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004),
	South African Weather Service Act, 2001 (Act No. 8 of 2001)
CHEMICALS AND WASTE MANAGEMENT	
Policies	
	White Paper on Integrated Pollution and Waste Management, 2000
Acts of parliament	
	National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)
Regulations under: Environment Conservation Act, 1989 (Act No. 73 of 1989)	
	Waste Tyre Regulations, 2008
	Regulations under section 24(d) of the ECA
	Regulations regarding waste disposal sites, 1994
	Regulations for the prohibition of the use, manufacturing, import and export of asbestos and asbestos-containing materials, 2008
	Noise control regulations in terms of section 25, 1992

Source: Adapted from South Africa (2016:22)

Annexure 9: International environmental legislation

The information presented in Annexure ten has not been included in the main research study as this information support the international alignment of spatial and environmental legislative background for South Africa but functions outside the scope of this research theme. This annexure ten should be taken into recognition with the identification of GI planning potential because the research theme of this study is based on a South African case study that is regulated by such legislation. Identifying the potential of GI planning should be aligned with such legislation concerning the environment, land uses and RPU informal settlements.

Table 9-1: International law regarding environmental management

Year	The Law	Keywords related to research theme
1948	Universal Declaration of Human Rights	Apply diplomatic and moral pressure on governments that violate their position such as public service delivery and environmental infrastructure by local government (Du Plessis, 2008:70).
1958	Four Geneva Conventions	Covers right on the territorial sea, contiguous zones, continental shelf, fishing and conservation of the living resources of high seas, and the high seas in its whole.
1966	International Covenant on Economic, Social, and Cultural Rights	Right to adequate standard of living for the family and to enjoy the highest standard of physical and mental health (Du Plessis, 2008:70).
1966	International Covenant on Civil and Political Rights	Every human being has the inherent right to life and that it should be protected by law (Du Plessis, 2008:72).
1971	RAMSAR-Conventions on Wetlands of International Importance	Conservation and protection of terrestrial biodiversity especially waterfowl habitats through a broad definition of "wetland". This convention is currently guided by the Strategic Plan 2016-2024 in South Africa (Strydom and King, 2009:106).
1972	Stockholm declaration from The UN conference on the Human Environment	Built-up environment and natural elements are essential to personal well-being and to the enjoyment of basic human rights and the right to life itself. Achievement of the environmental goals will demand the acceptance of responsibility by citizens and communities and that local and national governments will bear the greatest burden for large-scale environmental policy and action within their jurisdictions (Du Plessis, 2008:72).
1973	Convention on International Trade In Endangered Species Of Wild Fauna And Flora (CITES)	South Africa has followed on this framework by NEMBA (see Annexure 8) as CITES appendices of species regarding export regulations is framed by domestic schemes (Strydom and King, 2009:107).
1979	Migratory Species	A distinction between categories of species is given whereby the countries hosting the species migratory pattern should protect such listed species (Strydom and King, 2009:107).
1982	The Nairobi declaration adapted from UNEP's Action plan launched at	An interrelationship between the environment, development, population growth and urbanisation, but management, assessment, and cooperation were required. In this respect, the plight of the developing countries was central to the

	Stockholm declaration 1972	international environmental problem (Strydom and King, 2009:159).
1982	The 1982 World Charter For Nature	The natural environment in the context of nature conservation and protection.
1985-1989	OECD approaches	Constitutes an Environmental Checklist for Development Assistance and application of the polluter pay principle (Strydom and King, 2009:160).
1987	United Nations World Commission on Environment and Development (WCED) Report on Sustainable Development (Brundtland Report)	The environmental challenge in an urban context and proposes legal principles for environmental protection and sustainable development. An emphasis on sparking innovation to bridge national to local level environmental planning to sustain adequate human livelihood capitals (Du Plessis, 2008:79).
1989	Basel Convention	Prevention, transparency, and liability in regards to waste issues (Strydom and King, 2009:149).
1989	The Convention on the Right of the Child	The highest attainable standard of health, including measures to combat disease and malnutrition through the provision of adequate food and clean drinking water, taking into consideration the dangers and risks of environmental pollution (article 24).
1991	Convention on Environmental Impact Assessment in a Transboundary Context, Espoo	That parties take all appropriate and effective measures to prevent, reduce and control significant adverse transboundary environmental impact from proposed activities (Strydom and King, 2009:984).
1992	Agenda 21	Comprehensive planning for sustainable development in covering different aspect e.g. waste management, social capitals etc. (De Jong, 2014:56, Strydom & King, 2009:132).
1992	Convention on Biological Diversity	The concept of sustainable development and the precautionary and preventive principles (Strydom and King, 2009:183).
1992	Rio Declaration on Environment And Development	The anthropocentric rationale for environmental protection and sustainable development, effective environmental legislation and that environmental standards, management objectives and priorities and indigenous people and their communities, as well as other local communities, have a vital role in environmental management and development because of their knowledge and their traditional practices (Du Plessis, 2008:72).
Post-1994 (The era of a democratic republic of South Africa)		
1995	<i>Copenhagen Declaration</i> (World Summit on Social Development)	Put people at the centre of development to 'fulfil their responsibility for present and future generations by ensuring equity among generations and protecting the integrity and sustainable use of the environment strengthening of local communities and groups with common concerns' ability to develop their own organisations and resources and to promote policies relating to social development (Du Plessis, 2008:74).
1996	Local agenda 21:	The policy-making concept at the local level for local authorities construct, operate and maintain economic, social and environmental infrastructure, oversee planning processes, establish local environmental policies and regulations, and assist in implementing national and sub-national environmental policies (Du Plessis, 2008:82).
1997	United Nations Framework Convention	The concept of sustainable development and the precautionary and preventive principles (Strydom and King,

	on Climate Change 1992 supplemented by the Kyoto Protocol in 1997.	2009:183). A refinement of clearer goals and commitments was adopted by the Kyoto Protocol signed in 1997.
1998	Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention)	Establishing environmental rights further (Du Plessis, 2008:74).
1999	Declaration of Bizkaia on the Right to the Environment	Right to the environment cannot be exercised unless sufficient quality information is available, everyone has the right, individually or in association with others, to enjoy a healthy, ecologically balanced environment. Public authorities are accordingly responsible for the protection, conservation, restoration if necessary and prevention of the detonation of the biosphere, geosphere, hydrosphere and atmosphere; the rationale, sustainable use of natural resources; the promotion of patterns of production and consumption which are conducive to sustainable development and the integration of environmental protection (Du Plessis, 2008:74).
2000	United Nations Millennium Declaration (Millennium Development Goals)	Environmental stability for future generation by the current legal and government bodies (Du Plessis, 2008:75).
2000	Earth Charter	Challenges and vision of sustainable development, and the principles by which sustainable development to achieve. Calling for the right, <i>inter alia</i> , to potable water, clean air and safe sanitation and the right of all to a natural and social environment supportive of human dignity, bodily health and spiritual well-being (Du Plessis, 2008:75).
2002	The Johannesburg World Summit On Sustainable Development	Reaffirms that sustainable development requires long-term perspectives and broad-based participation in policy formulation, decision-making, and implementation at all levels (Du Plessis, 2008:76).
2003	The Beijing Declaration Of The Second Global Environment Facility Assembly	Providing financial resources to achieve global benefits in four areas: biodiversity; climate change; international waters; and ozone layer depletion while focusing on other areas as land degradation and persistent organic pollutants (Strydom & King, 2009:160).
2007	The UN Declaration on the Rights of Indigenous Peoples	Equal right to the enjoyment of the highest attainable standard of physical and mental health and that states shall take the necessary steps with a view to achieving progressively the full realization of this right. To maintain and strengthen their distinctive spiritual relationship with their traditionally owned or otherwise occupied and used lands, territories, and water.

Source: Adapted from South Africa (2005:8), Strydom and King (2009:126) and Du Plessis (2008:70)

Annexure 10: SA legislation

The information presented in Annexure ten has not been included in the main research study as this information support the spatial and environmental legislative background for South Africa but functions outside the scope of this research theme. This annexure ten should be taken into recognition with the identification of GI planning potential because the research theme of this study is based on a South African case study that is regulated by such legislation. Identifying the potential of GI planning should be aligned with such legislation concerning the environment, land uses and RPU informal settlements

Table 10-1: A few of the national law regarding South Africa environmental management and spatial planning

Year	Abbreviation	The law
1996	Constitution	Constitution no. 108 of 1996
1996	Green paper	Green paper on Environmental policy for South Africa
1997	UDF	Urban development framework
1997	RDF	Rural development framework
1997	Whitepaper	White paper on environmental management policy for South Africa
1997	Whitepaper	White paper on the conservation and sustainable use of South Africa's biological diversity
1997	Whitepaper	White paper on South African land policy
1997	NWA	National Water Act no. 36
1997	HA	Housing act no. 107
1998	NEMA	National Environmental Management Act
1998	Whitepaper	White paper on environmental management policy
1998	Whitepaper	White Paper On Local Government
2001	Whitepaper	White Paper On Spatial Planning And Land Use Management
2000	SEA	Guideline Document: Strategic Environmental Assessment In South Africa
2000	NLTT	National Land and Transportation Transition Act No. 22
2001	Whitepaper	White Paper On Spatial Planning And Land Use Management
2006		Planning For Open Space, Sport And Restoration Act
2002	DA	Disaster Management Act No. 52
2003	MFM	The Municipal Finance Management Act No.56
2003	NSDP	National Spatial Development Perspective
Biodiversity path		
2004	NSBA	National Spatial Biodiversity Assessment
2005	NBSAP	National Biodiversity Strategy and Action Plan
2008	NPAES	National Protected Areas Expansion Strategy
2008	NBF	National Biodiversity Framework
2011	NBA	National Biodiversity Assessment
2006	NSDF	National Spatial Development Framework
2013	SPLUMA	Spatial Land Use Planning Act

Source: Cilliers (2014:48), South Africa (1996:1241), South Africa (2016:4), Schoeman (2014:397), Strydom and King (2009:102) and Tlokwe City Council (2013:13)

The Centre for Environmental Rights (CER) summarized South African legislation having a large influence in environmental related spatial planning, as is listed in Table 11-2. This historic view of legislation influencing the land use planning and environmental management is centralized on green infrastructure separated from the grey built space. Legislation on international and national levels does not have a distinctive grey-green continuum integration in South African legislation.

Table 10-2: Short summary of legislation influencing land use planning, over South African history

Year	Legislation
1970	Subdivision of Agricultural Land Act No. 70 of 1970
1970	Mountain Catchment Areas Act 63 of 1970
1998	National Forests Act No. 84 of 1998
1999	World Heritage Convention Act 49 of 1999
1999	National Heritage Resources Act 25 of 1999
2000	Local Government: Municipal Systems Act No. 32 of 2000
2003	National Environmental Management: Protected Areas Act No 57 of 2003
2007	Astronomy Geographic Advantage Areas Act No. 21 of 2007
2008	National Environmental Management: Integrated Coastal Management Act No. 24 of 2008
2013	Spatial Planning and Land Use Management Act, 2013
2014	Special Economic Zones Act, No. 16 of 2014
2014	Infrastructure Development Act No, 23 of 2014
2016	Draft Preservation and Development of Agricultural Land Bill

Source: Adapted from CER (2016:1)

Annexure 11: Sustainable paradigms, models and resilience thinking

The information presented in Annexure twelve has not been included in the main research study as this information support environmental management models and paradigms that function outside the scope of this research theme. This annexure twelve should be taken into recognition with the identification of GI planning potential because understanding GI planning from the perspective of environmental models and paradigms presented in Annexure twelve provides a holistic comprehension of such a spatial planning approach.

Table 11-1 is an explanation of various international best practice views on environmental management models and paradigms. Such views are important to comprehend how legislation should be formalized and what end result spatial development should aim at. Each of the last phases and paradigms has shown in Table 13-1 illustrates a holistic, resilient and need for a detailed end result of the intended model. GI planning principle is similar as to attain such end result application, however, as seen in Table 13-1 the pathway to that end result is a complex legislative and development process phases and paradigm shifts.

Table 11-1: Environmental management models and paradigms

Model	Phase 1	Phase 2	Phase 3	Phase 4	
Road to sustainability	From pollution control to prevention	Product stewardship improved—recover, re-use and recycle	Cleaner technologies	Sustainable vision	
Natural capital	Increasing productivity of natural resources used in the production processes	Closed loop systems with no waste or toxicity	Change the business model from products to services	Reinvest in natural capital to restore, sustain and expand the planet's ecosystems	
Sustainability learning curve	Legal compliance	Beyond compliance	Eco-efficiency	Sustainable development	
Model	Paradigm 1	Paradigm 2	Paradigm 3		
Raufflet's three-dimensional model, 2006	Incremental reduction of environmental input and output impacts	Adaptive redesign of organizational behaviour patterns to mimic ecosystem functioning	Radical transformation of the entire production and consumption patterns		
Model	Paradigm 1	Paradigm, 2	Paradigm 3	Paradigm 4	Paradigm 5
Colby's five paradigms of environmental management in development	Frontier economics	Environmental protection	Resource management	Eco-development	Deep ecology

Source: Strydom and King (2009:11)

Glassman (2012:198) explains the noosystem in the following manner:

“The noösphere is an emergent “space” for development of autonomous project communities that allows human intellect to guide our perceptions of events and of the built environment, and to actually participate in defining and redefining these events and places over time. The noösphere is a complex, uniquely human system of activity where individual minds use mediational tools to engage in the transfer of information and problem-solving activities.”

Barrett (2001:82) says the noösphere is the “the sphere of mental (human) activities influencing the biosphere, whereas natural science is defined as any of the sciences (e.g. physics, chemistry, or biology) that deal with the matter, energy, and their interrelations and transformations”. Both Barrett (2001:83) and Glassman (2012:203) argues the importance of biophysical science for the intellectual basis towards transdisciplinary planning, management, policy, education and various scientific fields. Barrett (2001:82) emphasises the ecosystem dynamics as the incubator of influence reflecting many transformations of noösphere, a strong similarity within GI planning also.

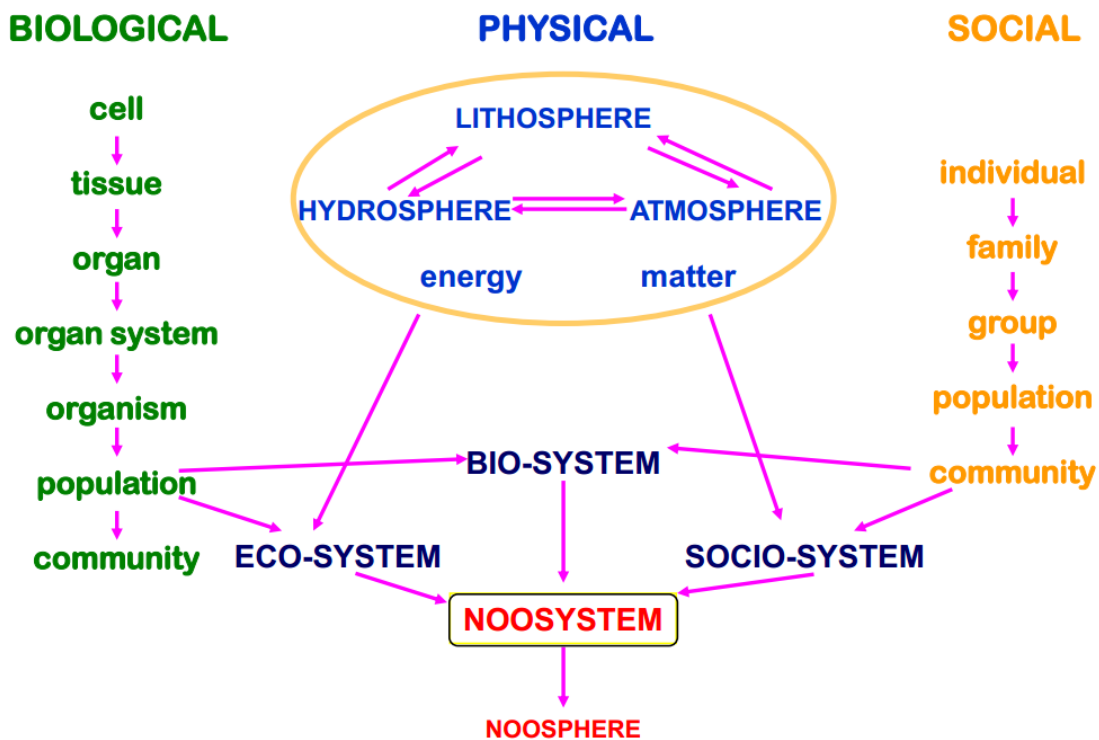


Figure 11-1: The noosystem

Source: Retief (2015a:2)

Steffen *et al.*, (2011b:740), van Zoest and Hopman (2014:108) and TEEB (2011b:6) explain the various ecosystem services that make human life pleasant and possible, can be grouped in four categories of services (water retention, psychological restoration from stress, biomass production etc.). The ecological dimension is but a small part of the noosystem that produces the noösphere,

this is a modern link to close the ecological cycle towards integrative science as seen in Figure 11-1. According to the UN-Habitat (2013:2) post-2015 development agenda, green spaces and vegetation cover in urban and peri-urban areas are essential for biological, hydrological balance and economic development.

Taking the element of the noosystem (in Figure 11-1) to the integrative science of a noösphere (in Figure 11-2) a strong adaptive nature behind planning, development, managing and follow-up principles can be recognised. GI planning is a multi-scale social-ecological memory (addressed in Andersson *et al.*, (2014:449)) of planning frameworks within the noösphere, meeting strategic goals of the ecological and integrative science (as seen in Figure 11-2). GI planning can thus form the part of the tools needed to close the ecological cycle inside the sustainable development of human livelihoods. GI planning's ecological-economics creates the platform to boom ecological and integrative science development (Boyd & Banzhaf, 2007:625; Fisher *et al.*, 2009:649).

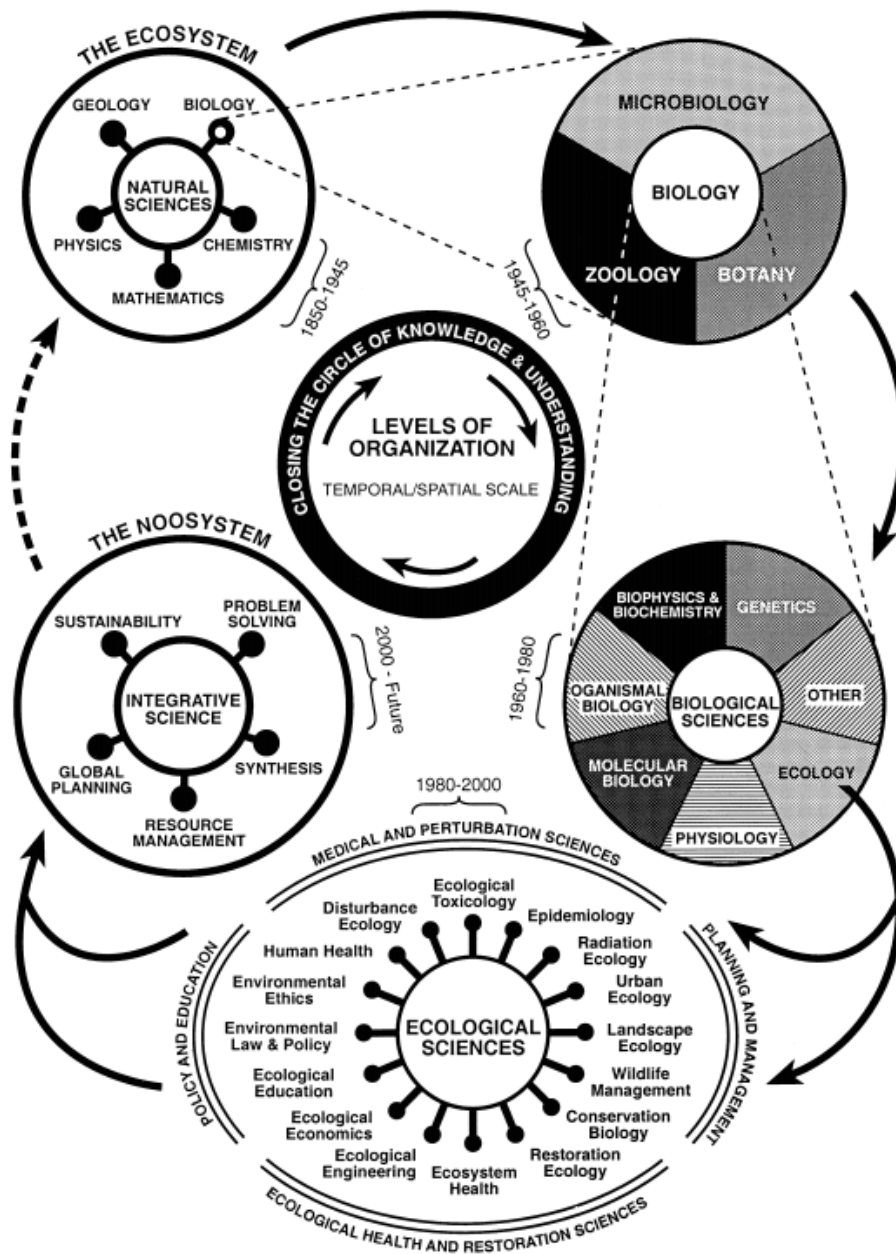


Figure 11-2: A historical perspective (1850–2000) depicting the evolution of ecology and the ecological/environmental sciences.

Source: Barrett (2001:81)

A ground-breaking conceptual underpinning for GI planning integration is resilience thinking. Folke (2006:260) explains that resilience provides an overarching framework that present integrative science in a guiding and organising platform. The aim with GI planning and resilience thinking is to broaden the sense of readiness for sudden shocks, risks, uncertainties or surprises as dealing with such a complex system (Foster *et al.*, 2011:32; Pakzad & Osmond, 2016:70; Schäffler & Swilling, 2013:247). Resilience thinking provides the necessary reality for GI planning integration into various transdisciplinary and multiple government planning levels.

Infrastructure that is based on natural elements, in and around built-up regions has to incorporate resilience thinking to achieve necessary spatial integrity between nature and nature as well as between men with nature (Cilliers & Cilliers, 2016:44; Connop *et al.*, 2015:3; Pakzad & Osmond, 2016:73. Xu *et al.*, (2012:7928) states that viewpoints are formed by categorising infrastructure into engineering systems (e.g. water-energy nexus), ecological infrastructure, ICT, socio-economic (e.g. banking, finance) and social network infrastructure. Resilience thinking affects every aspect of GI planning, thus the potential of GI planning includes resilience thinking as to incorporate GI principles to established GI potential from the potential of RPU informal settlement influence.

As exempted by the UN-Habitat (2015b:5) the urgent need to bridge knowledge and capacity gaps, in relation to crucial urban and territorial challenges, is part of resilience thinking. These include “climate change, safety and security, disaster resilience, ecosystem connectivity, green infrastructure, food security, health, diet, and nutrition”. Resilience thinking aims for the practical management of regional ecosystems and global sustainability, if vertical integration between regional and local level infrastructure and horizontal adaptation of urban to regional transects integrates (Carpenter *et al.*, 2012a:135; Haider *et al.*, 2015:5). GI planning establishes socio-ecological system relations so that, through redundant strategic planning, resilience thinking can ensure spatial integrity. “Documenting and disseminating inspiring experiences, tools, practices and strategies in urban-rural linkages in collaboration with research institutions, academia, civil society and policy-makers can assist in developing capacity, address development challenges and strengthen linkages between areas“(UN-Habitat, 2015:5). Identifying the potential of GI planning from anthropogenic influences such as RPU informal settlements are but first steps of resilience thinking in GI planning.

Harrison *et al.*, (2014:16) states that by matching essential development goals with resilience, as a way to think and act in that conceptual relationships produce more sustainable, achievable goals (Quinlan *et al.*, 2015:9). The SRC (2014a:3) states resilience is the capacity of a system to deal with change and continue to develop, while resilience thinking investigate how interacting systems of people and nature or socio-ecological systems, are best managed so that sustainable and resilient supply of essential ecosystem services which humans depend on, is ensured (TEEB, 2010c:14). RPU areas are disengaged in connection, links, and corridors from socio-ecological systems, critically needing resilience thinking. Providing the potential for GI planning provides the first steps to further investigate strategic spatial planning direction from macro to micro level urban and regional planning ventures.

Building on the dynamic connectivity of, as McPhearson *et al.*, (2016:8) states, “ecology of and for cities”, there exist a need to diversify general community resilience into contextual resilience, tailored to local environmental conditions. This should produce higher redundancy of adaptive and transformative coping strategies (Andersson *et al.*, 2014:448; Elmqvist & McDonald, 2013:736). Barthel (2014:429) determines that resilience thinking is similar to the resilience

function of the human immune system. It reflects historic exposure to pathogens, building memories of past exposures of disturbances, which accumulate in gene pools of a given species and progressively reflect responses of the past and adapting to new disturbances. Understanding human biology can simplify the understanding of socioecology. Figure 11-3 illustrates the vein network of a human heart (top left) and hand (top right), which serves to illustrate how similar hierarchical networking can be pictured (to the bottom image) as socio-ecological networks of water and open space (as in the example of Durban). There are similar hierarchical flow networks in each of these pictures. However, the optimal functioning of every system depends on the full spectrums spatial integrity of each network relations. The hand will function less if the nervous system is disconnected from a specific finger's blood vessels. In the same manner, open space systems depend on large networks of small rivers, above and below ground levels, to sustain habitats and species diversity. The finger is part of the hand, the hand connects to the arm and the arm to the body. If the hand is cut off from the body, the body does not die, but would struggle to perform daily tasks and would be handicapped onwards. In a similar manner, open space networks, as small it may seem to the transect boundaries, need to be spatially linked to the regional sphere to ensure spatial integrity or it would suffer the loss of valuable ecosystem services in different spatial and temporal scales. Identifying then GI potential makes visible the invisible networks to understand the resilience thinking within GI planning and the GI principles thereof.

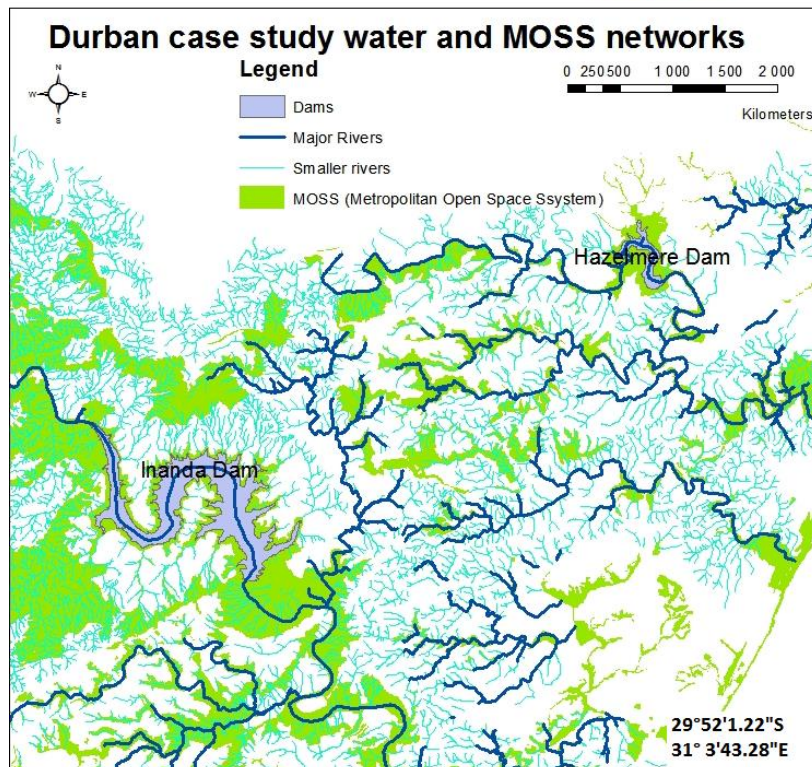
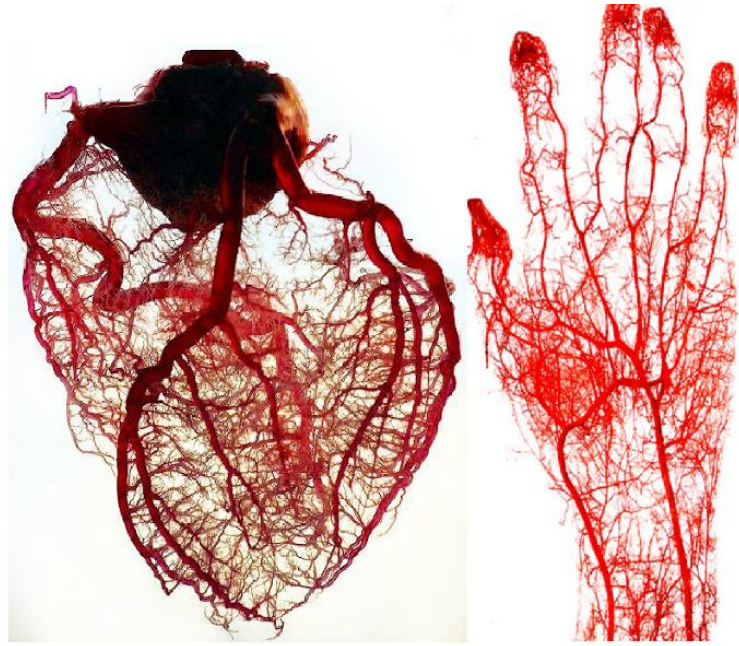


Figure12-1: Vein networks of the heart and hand compared with water and MOSS (Metropolitan Open Space System) network in the case study

Source: Authors creation (2016), adapted from WPCCGG (2009:19), Google images (2016:1) (top-left) and Paternity (2009:1)(top-right)

Harrison *et al.*, (2014:22) match planning based on resilience thinking with ecology, which is rooted in a social setting. In other words, strategic spatial planning flows through the lens of society, a socio-ecology system itself, to integrate critical social science (Davoudi & Strange, 2009:306). A social aspect that fences in spatial knowledge management is the “knowledge gap” which is evident in classifying and assigning value to ecosystem services, disaster management

and spatial agriculture management (Brook & Dávila, 2000:70; Gómez-baggethun & Barton, 2013:237; Ingram *et al.*, 2012:387; Rockström *et al.*, 2009:113). Resilience thinking challenges such knowledge gaps to integrate thinking that include diverse perspectives and impact analysis, for decision-makers to find optimal and adaptive solutions (Cilliers *et al.*, 2014:265). Felson *et al.*, (2013:884) explain that the gap in ecological knowledge falls into design and construction of grey-green infrastructure. Primarily addressing factors of infrastructure cost, durability, maintenance, safety, and aesthetics. Sustainable grey-green infrastructure development should harness formal and informal nodes of resilience thinking (ranging from local to professional people), as participatory “memory groups” engaging in ecosystem management (Schäffler & Swilling, 2013:248). Identifying the potential of GI planning from potential RPU informal settlement influences provide an integrative map showing various regions to target. Such target zones relate to specific people groups, communities and certain local municipalities that should receive integrate knowledge management about everyday practices that enhance a GI planning development perspective from the bottom up planning and development.

Annexure 12: External buffer standards but with insufficient data for this current study

The information presented in Annexure thirteen has not been included in the main research study as this information support the buffer standards but could not be used due to certain limitations of this research case study and not enough data could be gathered to conduct buffer standard to further define GI potential. This annexure thirteen should be taken into recognition with the identification of GI planning potential because not all GI types were addressed in this research and more specific buffers standards tailored for that specific environment should be gathered. Annexure thirteen provides different buffer types to consider for further identification of GI planning potential.

The following tables are buffers that have been used in previous case studies from literature. In the eThekweni municipality and

Table 12-1: Wetlands, rivers and FEPAs (freshwater ecosystem protected areas) and steepland buffer width

Wetlands, rivers and FEPAs(freshwater ecosystem protected areas)	100m
Steep land	Land steeped 1:3 considered undeveloped

Source: Taken from Mafela and Teixeira-Leite (2015:13) and EPCPD (2016:1)

Table 12-2: Buffer standards of settlement aspects influencing the environment

Population density (marine) influence distance			
Population Density (marine) (m)	Direct influence(marine) (m)	Indirect influence(marine) (m)	Rationale
1-99	500	4000	This is an overall view of the impact people activities from population density can potentially have on marine environments. As this is a potential estimate there is no critical zone of impact gives as a further project to regional level analysis will be needed (Antunes & Santos, 2001:518).
100-299	1000	5000	
300-599	1000	5000	
600-999	1000	5000	
1000-1999	1500	5000	
2000-3499	1500	5000	
3500-5499	1500	5000	
5500-7999	1500	5000	
8000+	1500	5000	
Sewage			
Sewage seepage	Influence distance (m)	Rationale	
0-25 pit latrines/km2	500	Due to the fluidity of sewage, pollution distribution can easily transfer from one area to the next through groundwater channels, if the latrine isn't sealed off. Such pollution called "black water" has high pathogens and high oxygen demand making the water unable to serve living organism effectively, and can cause a health hazard (Parkinson, 2003:81).	
25-50 pit latrines/km2	2000		
50-500 pit latrines/km2	5000		
500-5000 pit latrines/km2	10000		
>5000 pit latrines/km2	20000		

(Mcpheerson *et al.*, 2008:70)

Table 12-3: River and air quality distances that are influenced by human activities

Element	Distance (m)	Reason
Rivers	1000	As this current study evaluates the strategic spatial planning principles of GI, the operational level has to use an analysis that covers vast landscapes. This analysis uses water and air quality buffer standards at large scale.
Air quality	2500	

Source: Vollmer and Grêt-Regamey, (2013:1544); Antunes & Santos, (2001:523)

Table 12-4: Buffer widths of different taxa

Taxa type	Buffer description
Songbirds	45m -90m for breeding recommendations, but riparian buffers more 201m may retain some forest interior songbirds
Mammals	150m-305m and based on wind patterns, adjacent land use and surrounding vegetation
Amphibians and reptiles	90m-165m but a high degree of variance is found
Fish and aquatic invertebrates	10m-100m
Reptiles	30-60m
mammals	10 riparian buffers
Songbirds	Please refer to article
Mammals	150m-305m and based on wind patterns, adjacent land use and surrounding vegetation
Amphibians and reptiles	30-95 m
Fish and aquatic invertebrates	30m with many additional designs
Amphipods and Isopods	25m while proposing erosion control lines and professional guidance on pre-harvest planning
Mussels, crayfish and snails	Propositions unique to all Please refer to article
Butterflies and moth	Specie niches Please refer to article
Stoneflies, Dragonflies, and Caddisflies	Specie niches Please refer to article
Beetles	Please refer to article
Vascular and Nonvascular Plants	Please refer to article

Source: Adapted from Warrington *et al.*, (2017:107)

Table 12-5: Barriers of different land uses against human impact

Type vegetation units	Barrier distance against human influence (m)	Rationale
Forest	1000	These distances are given to show the robustness of various landscapes to human influence. The moment when water is involved the influence of humans is amplified as water capacity increase.
Agricultural lands and other lands	750	
Wetlands and water reservoirs	500	
Artificial barrier lands	250	
Rivers	1	

Source: Adapted from Chang (2012:495)

Annexure 13: Buffer maps

The information presented in Annexure fourteen has not been included in the main research study as this information only reflects GI potential without the integration of GI planning principles. This annexure fourteen should be taken into recognition with the identification of GI planning potential because without this potential identification, GI planning principles would not be strategically applied.

100 Threatened forest types 100m

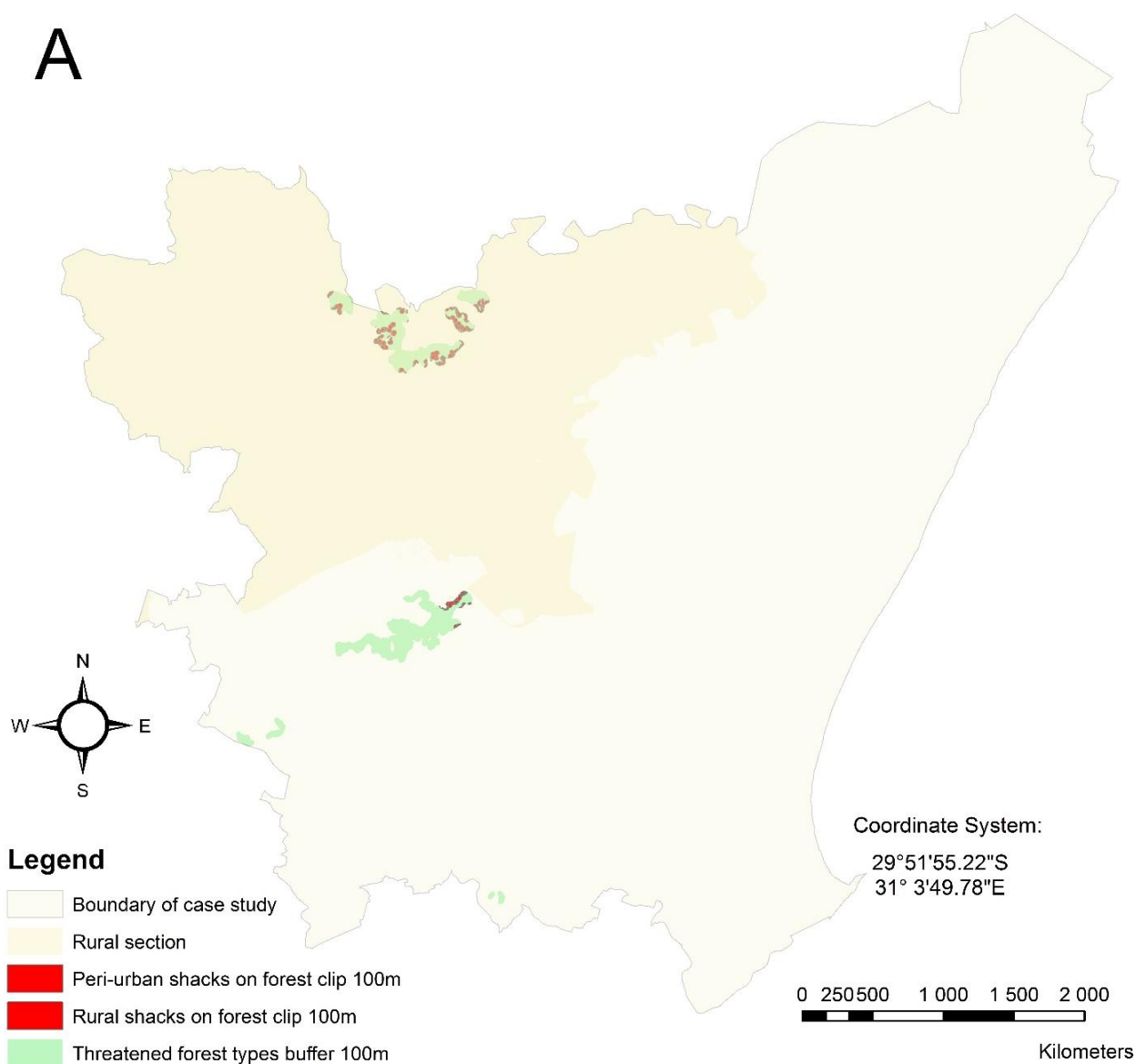


Figure 15.1. Threatened forest types A (overview); B (rural view) and C (peri-urban view)
Source: Authors compilation through ArcGIS 10.4.1 (2017)

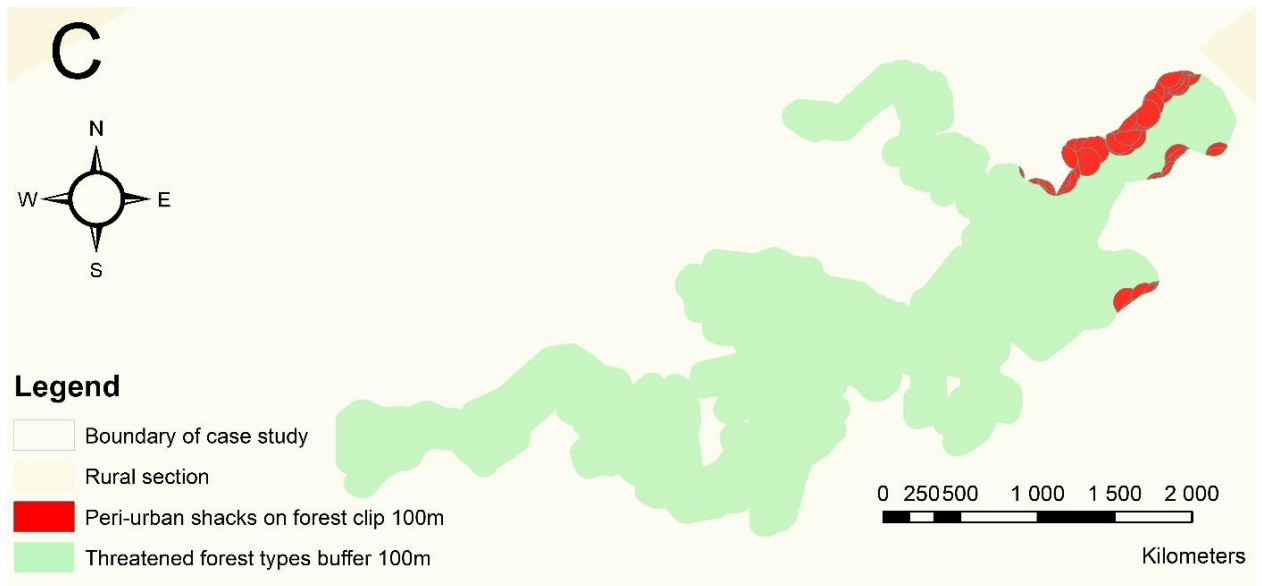
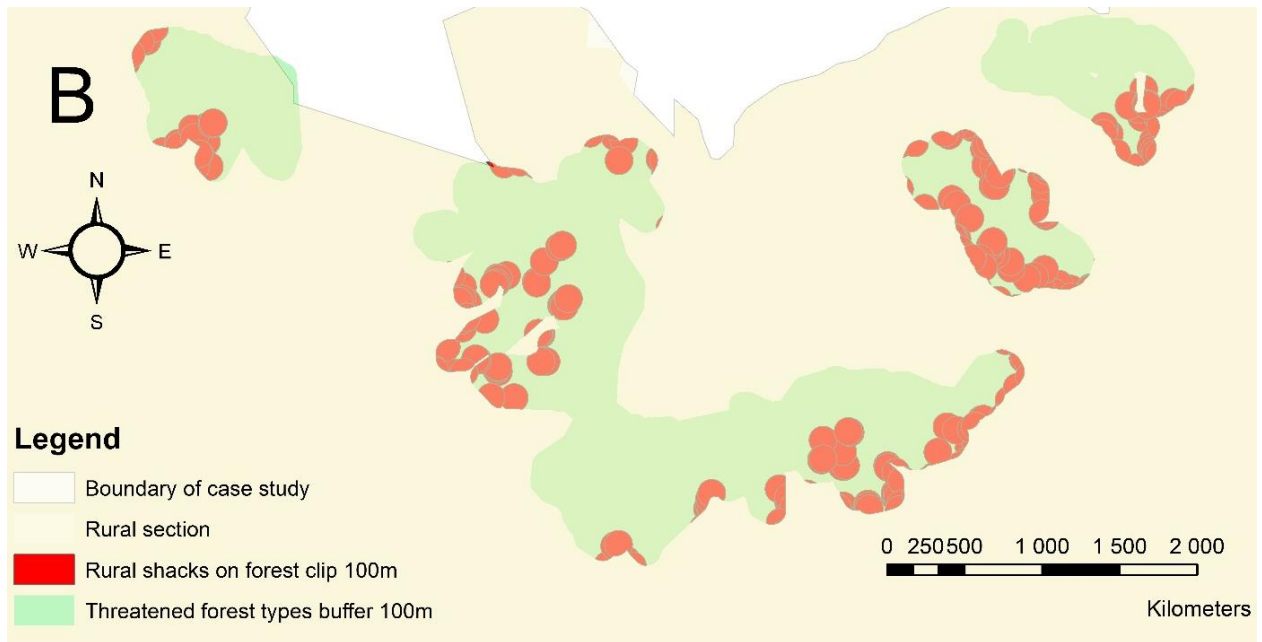
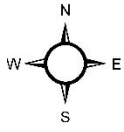


Figure 15.1. Threatened forest types A (overview); B (rural view) and C (peri-urban view)





Source: Authors compilation through ArcGIS 10.4.1 (2017)

100-year flood zone 25m

A



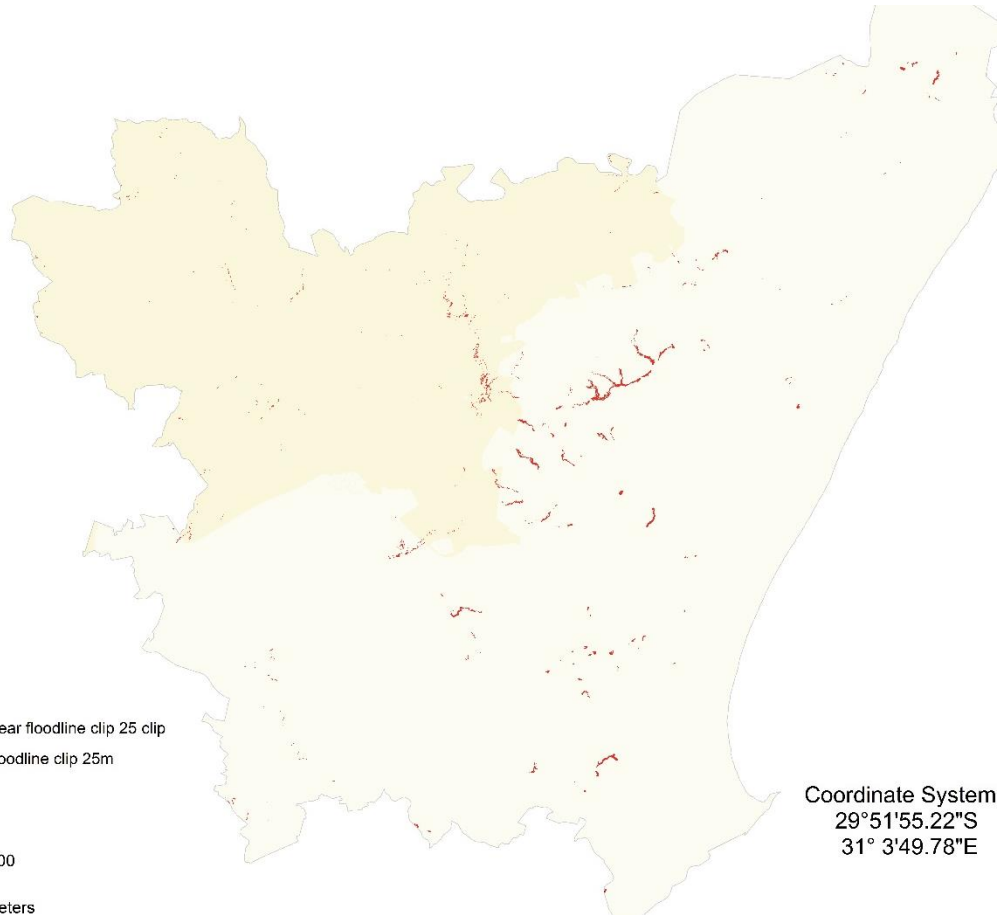
Legend

-  Boundary of case study
-  Peri-urban shacks on 100 year floodline clip 25 clip
-  Rural shacks on 100 year floodline clip 25m
-  Rural section

0 250 500 1 000 1 500 2 000



Kilometers



Coordinate System
29°51'55.22"S
31° 3'49.78"E

Figure 15.2. 100-year flood zone 25m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

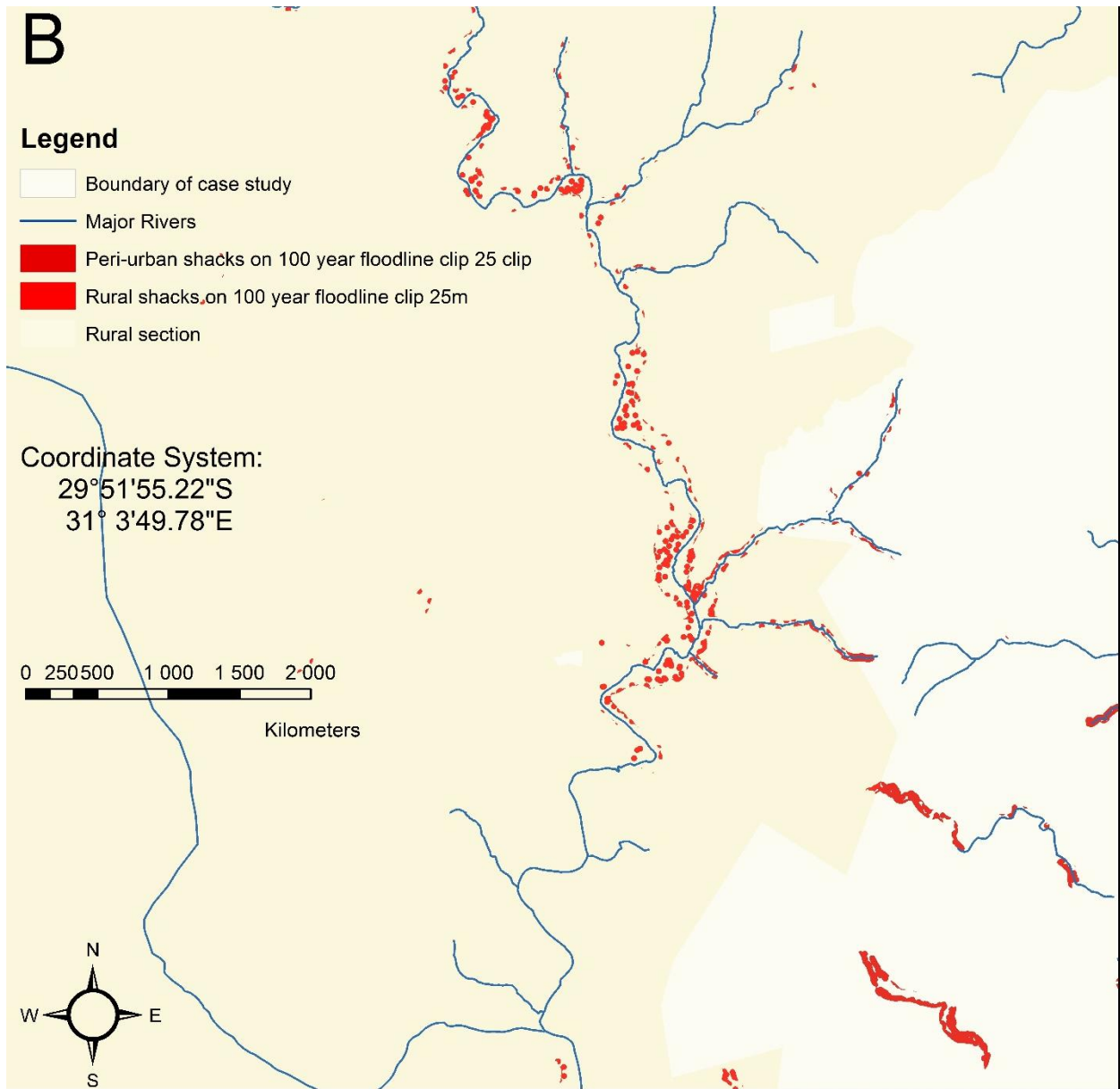


Figure 15.2. 100-year flood zone 25m A (overview); B (rural view) and C (peri-urban view)
 Source: Authors compilation through ArcGIS 10.4.1 (2017)

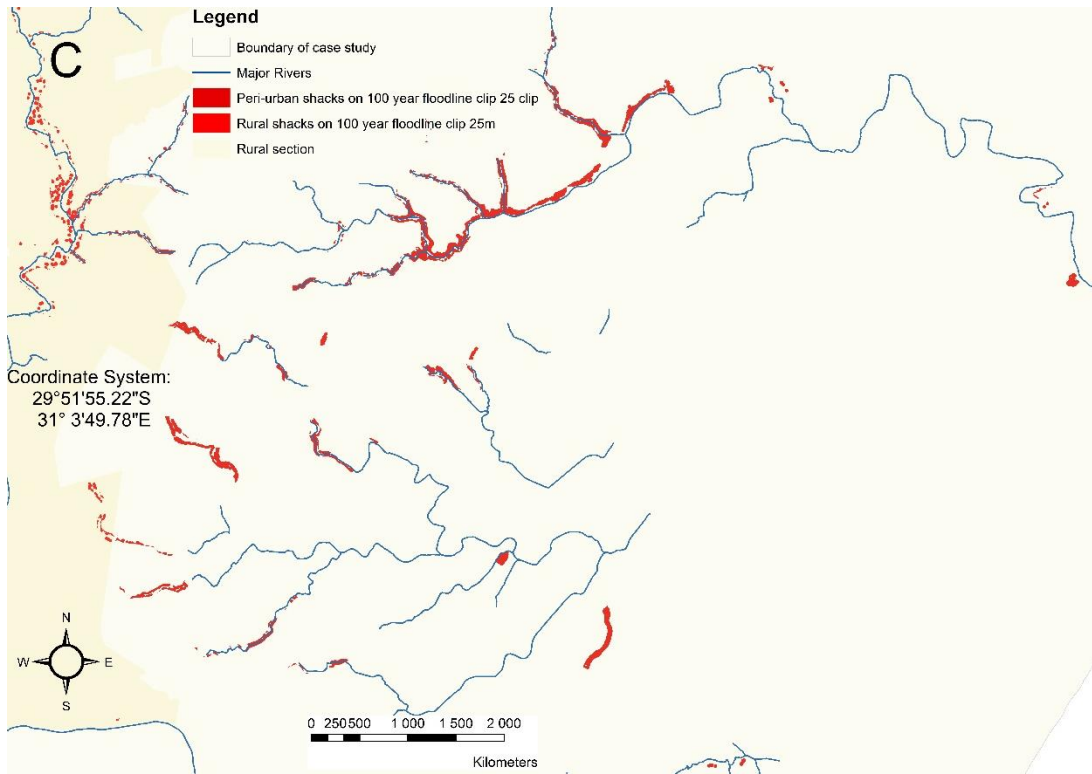


Figure 15.2. 100-year flood zone 25m A (overview); B (rural view) and C (peri-urban view)
 Source: Authors compilation through ArcGIS 10.4.1 (2017)

MOSS influence 114m

A

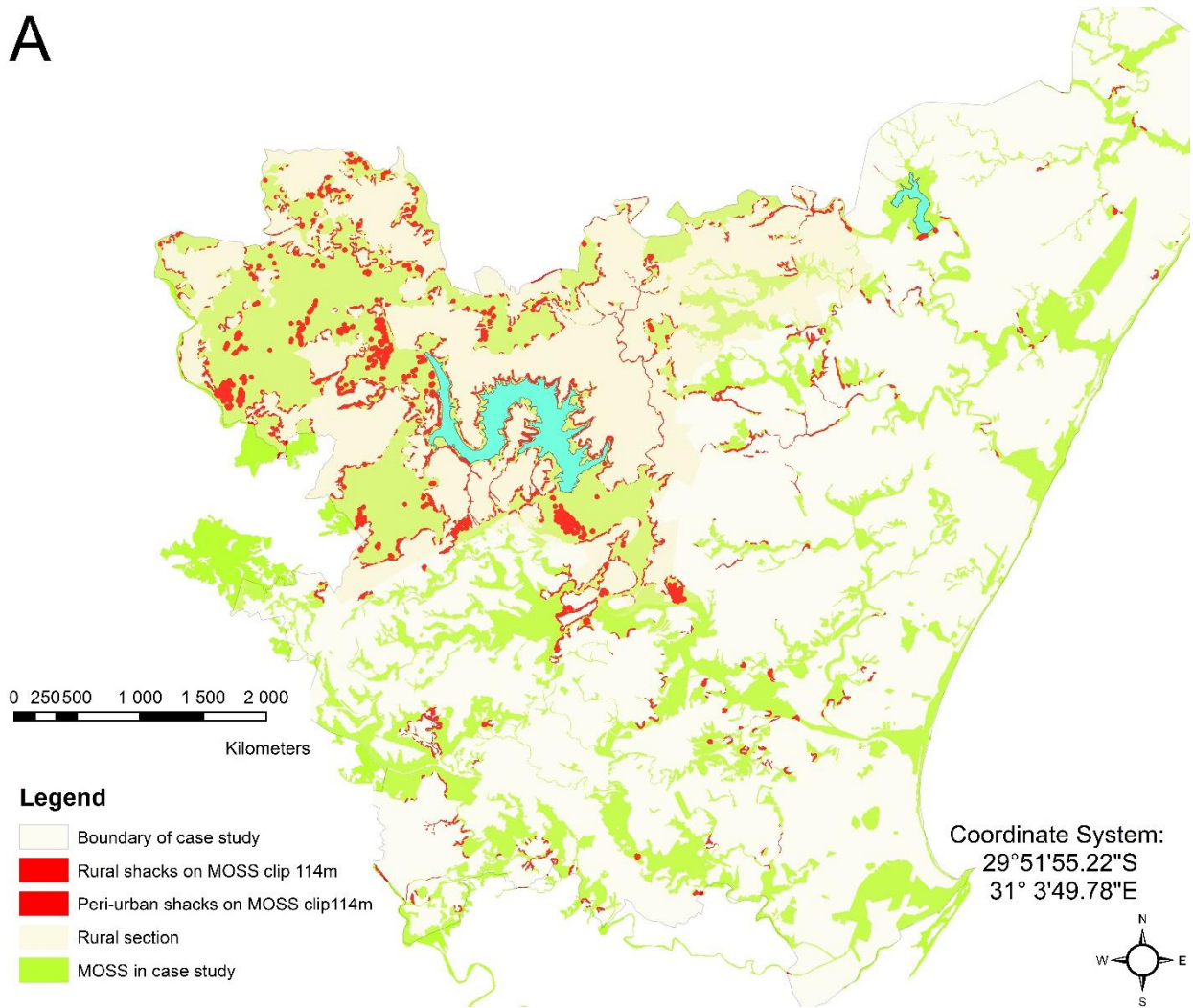


Figure 15.3. 114m MOSS influence A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

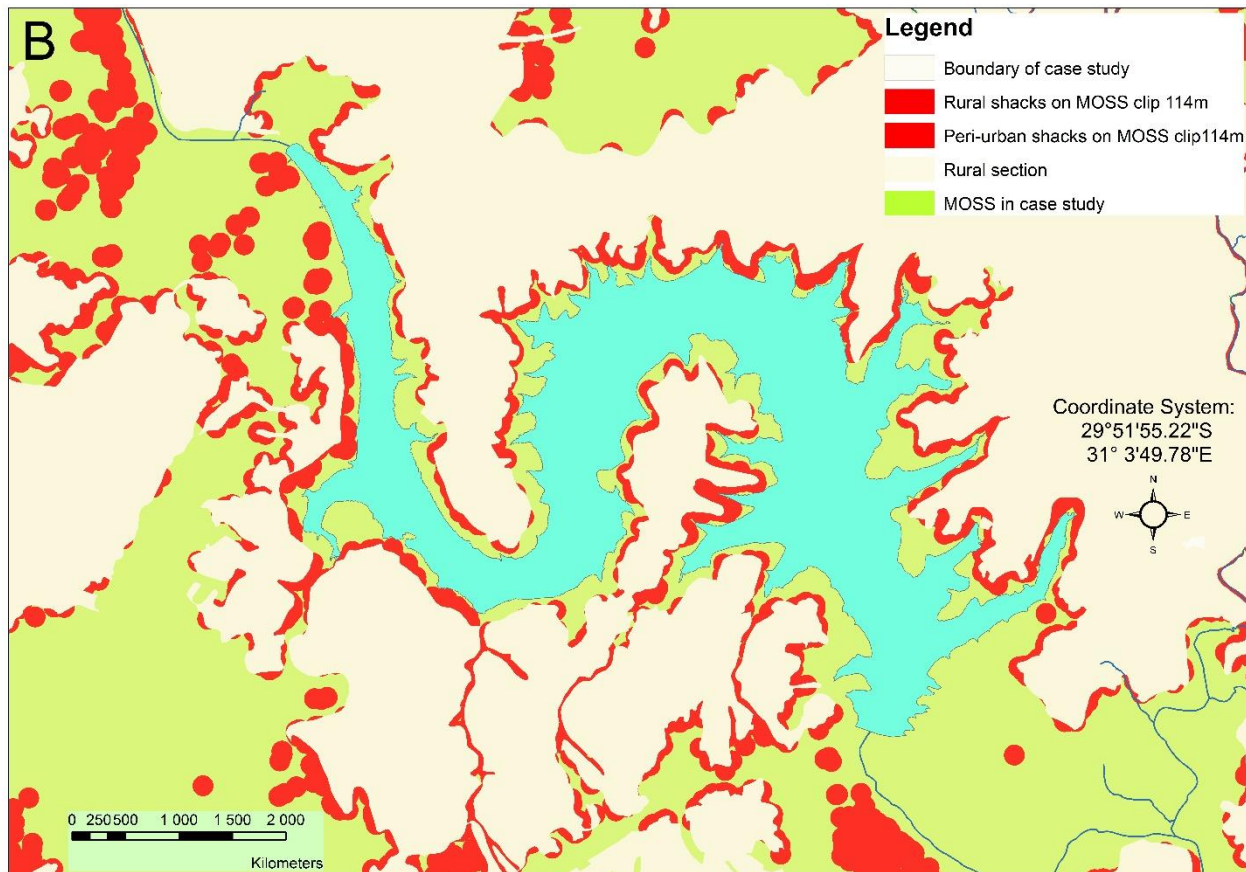


Figure 15.3. 114m MOSS influence A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

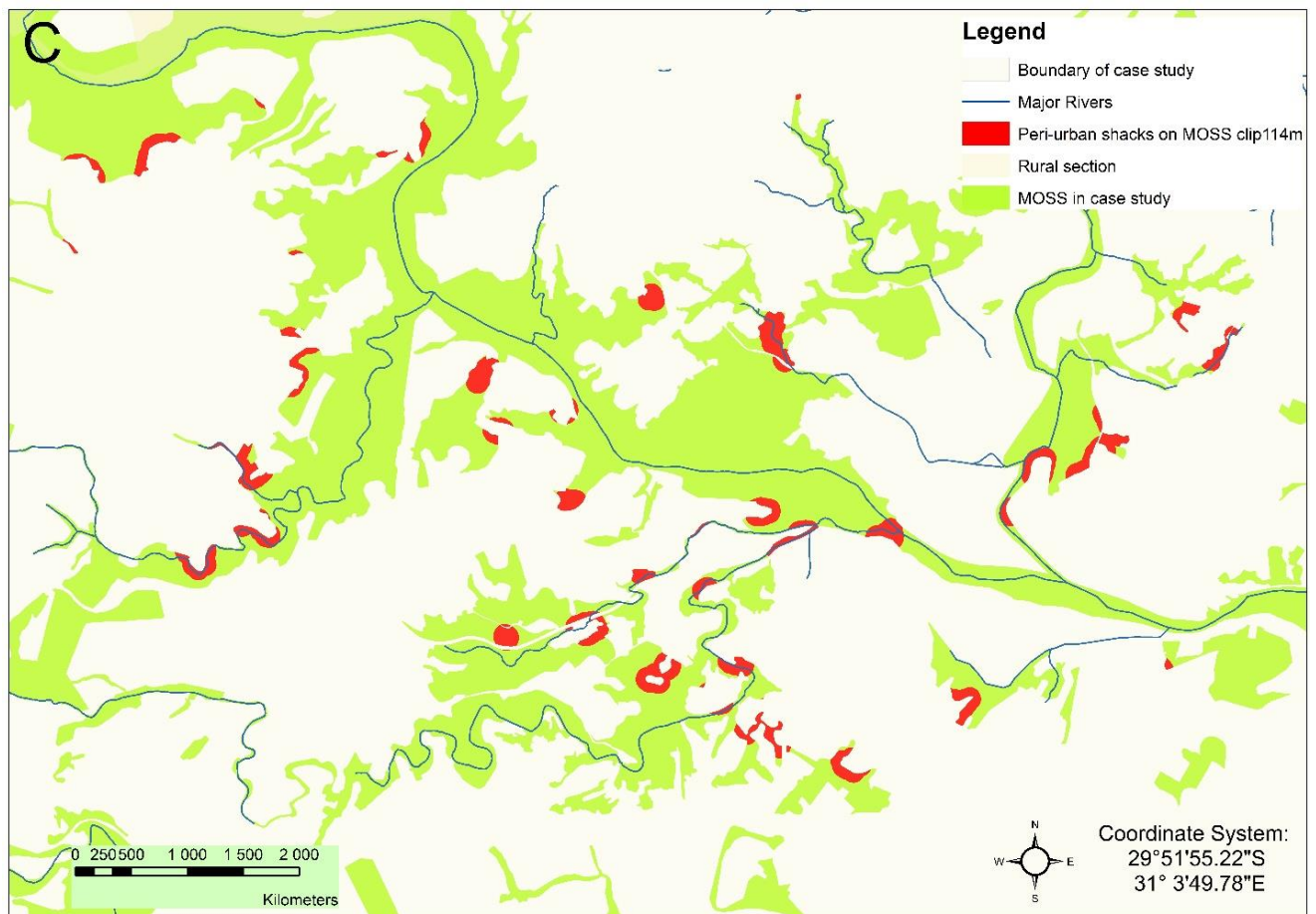


Figure 15.3. 114m MOSS influence A (overview); B (rural view) and C (peri-urban view)
 Source: Authors compilation through ArcGIS 10.4.1 (2017)

Drainage lines 20m

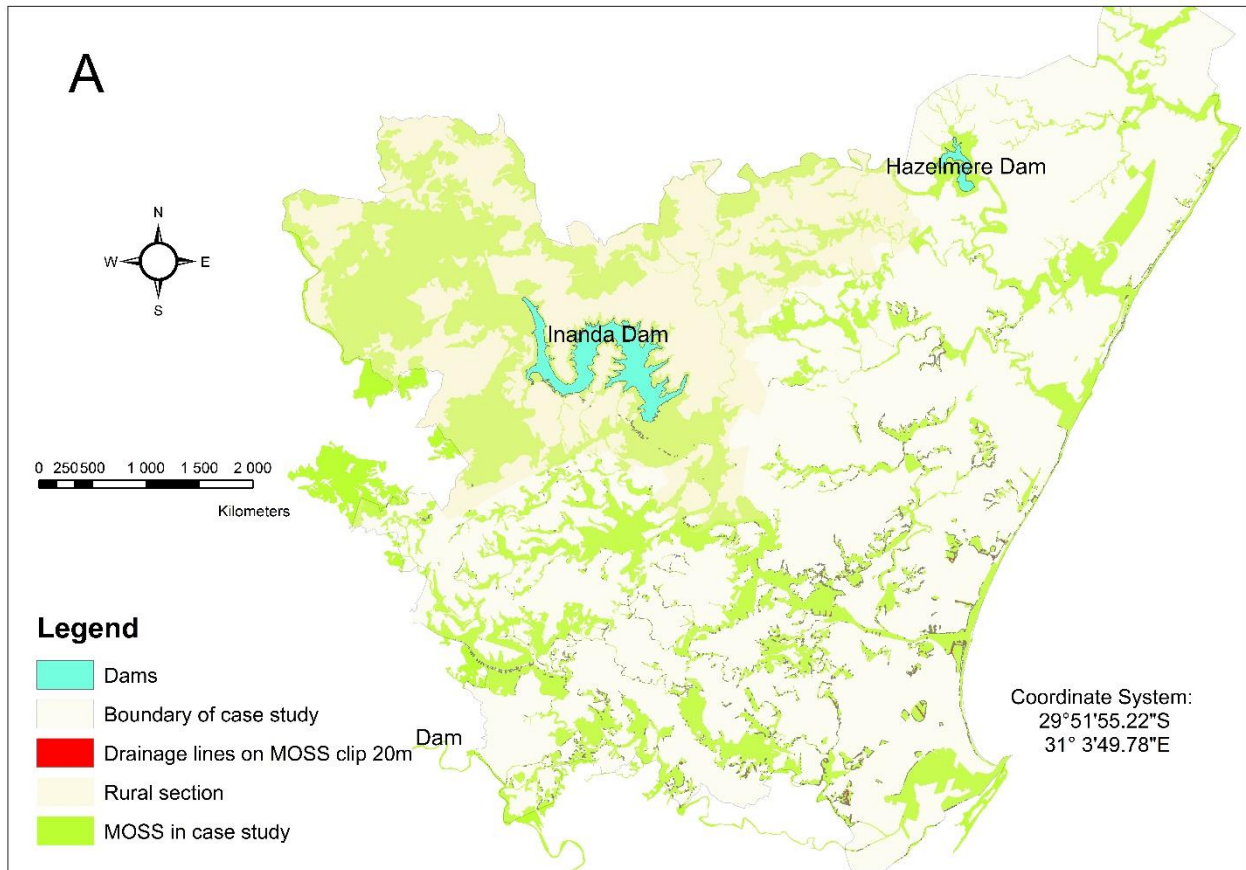


Figure 15.4. Drainage lines A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

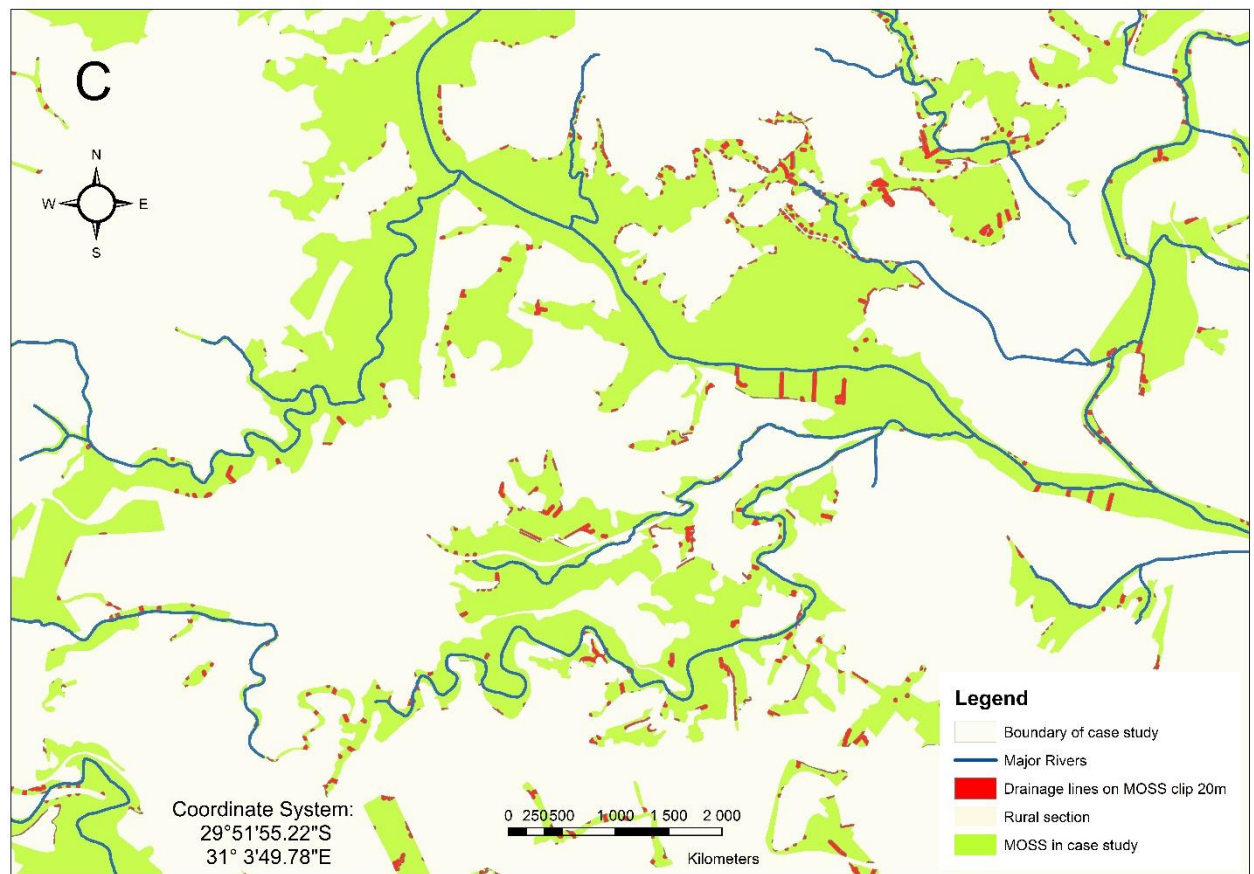
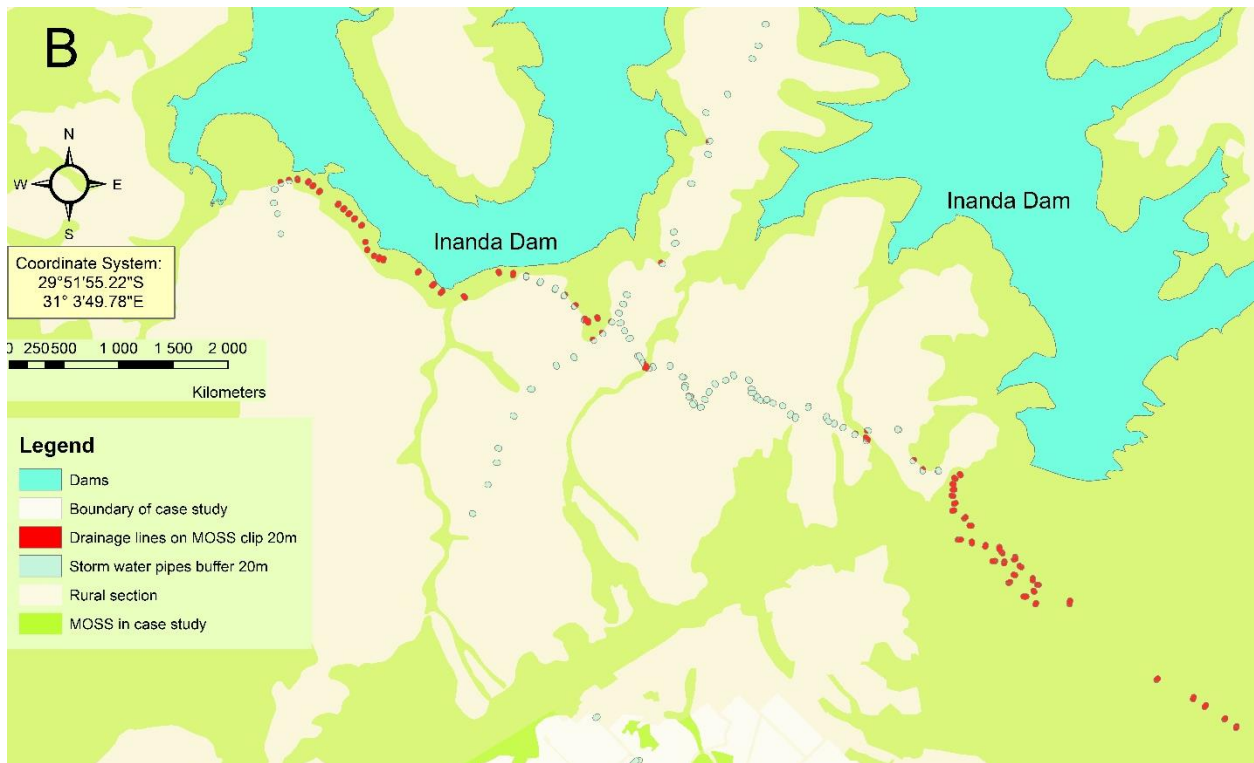


Figure 15.4. Drainage lines A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

Erosion and sedimentation 32m

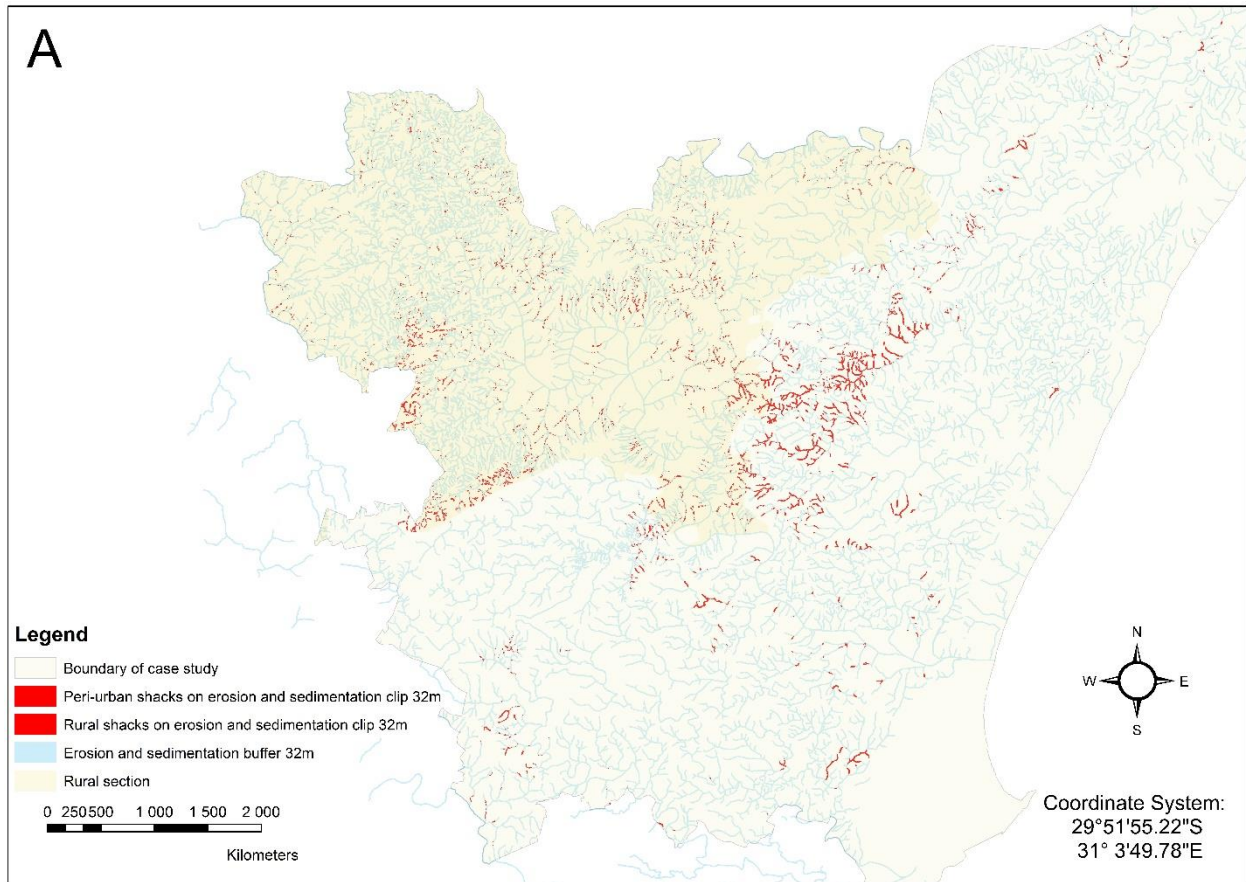


Figure 15.5. Erosion and sedimentation 32m A (overview); B (rural view) and C (peri-urban view)
Source: Authors compilation through ArcGIS 10.4.1 (2017)

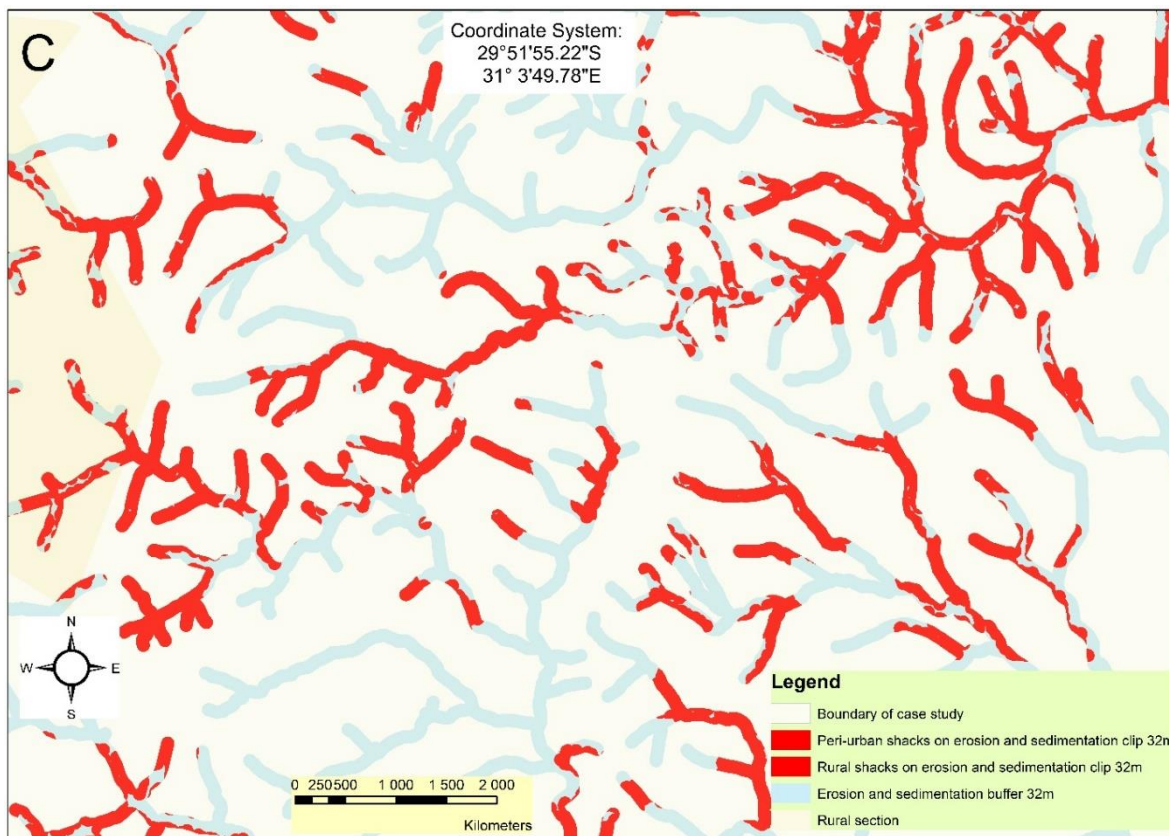
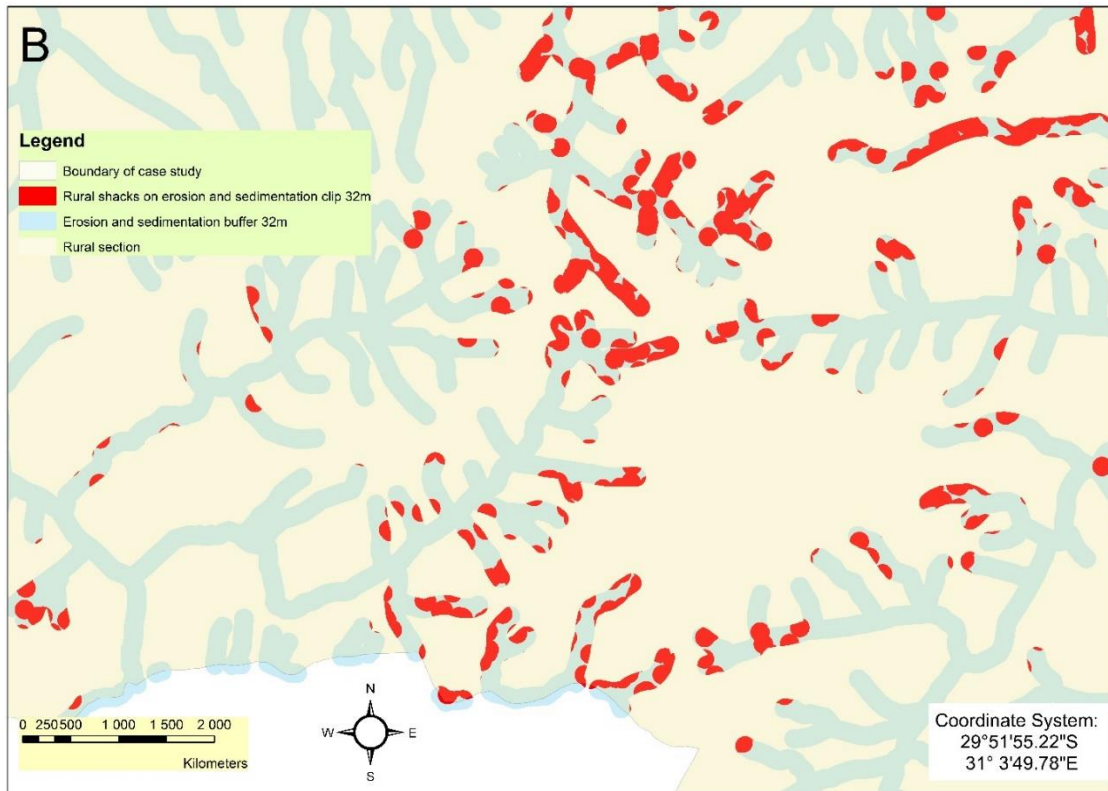


Figure 15.5. Erosion and sedimentation 32m A (overview); B (rural view) and C (peri-urban view)
 Source: Authors compilation through ArcGIS 10.4.1 (2017)

Flood retention 45m

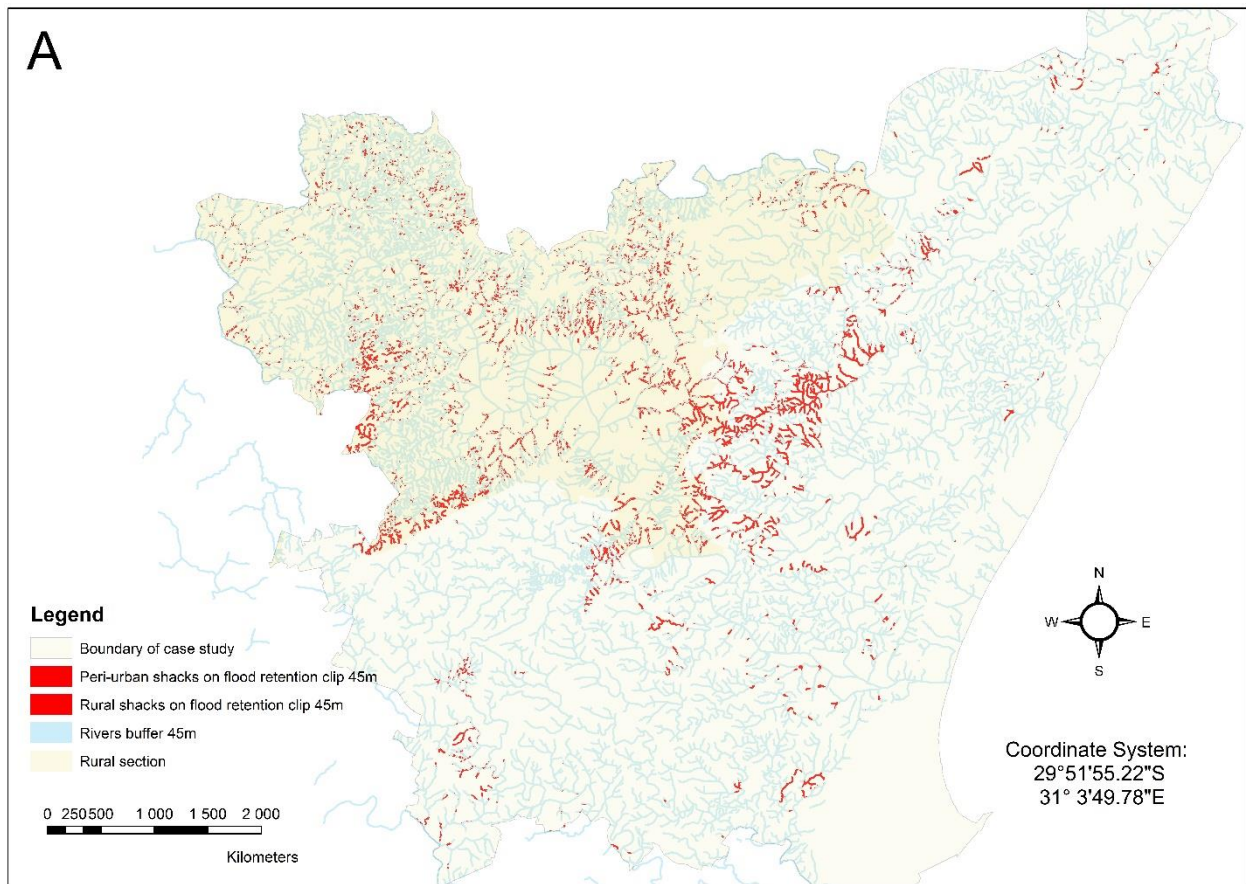


Figure 15.6. Flood retention 45m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

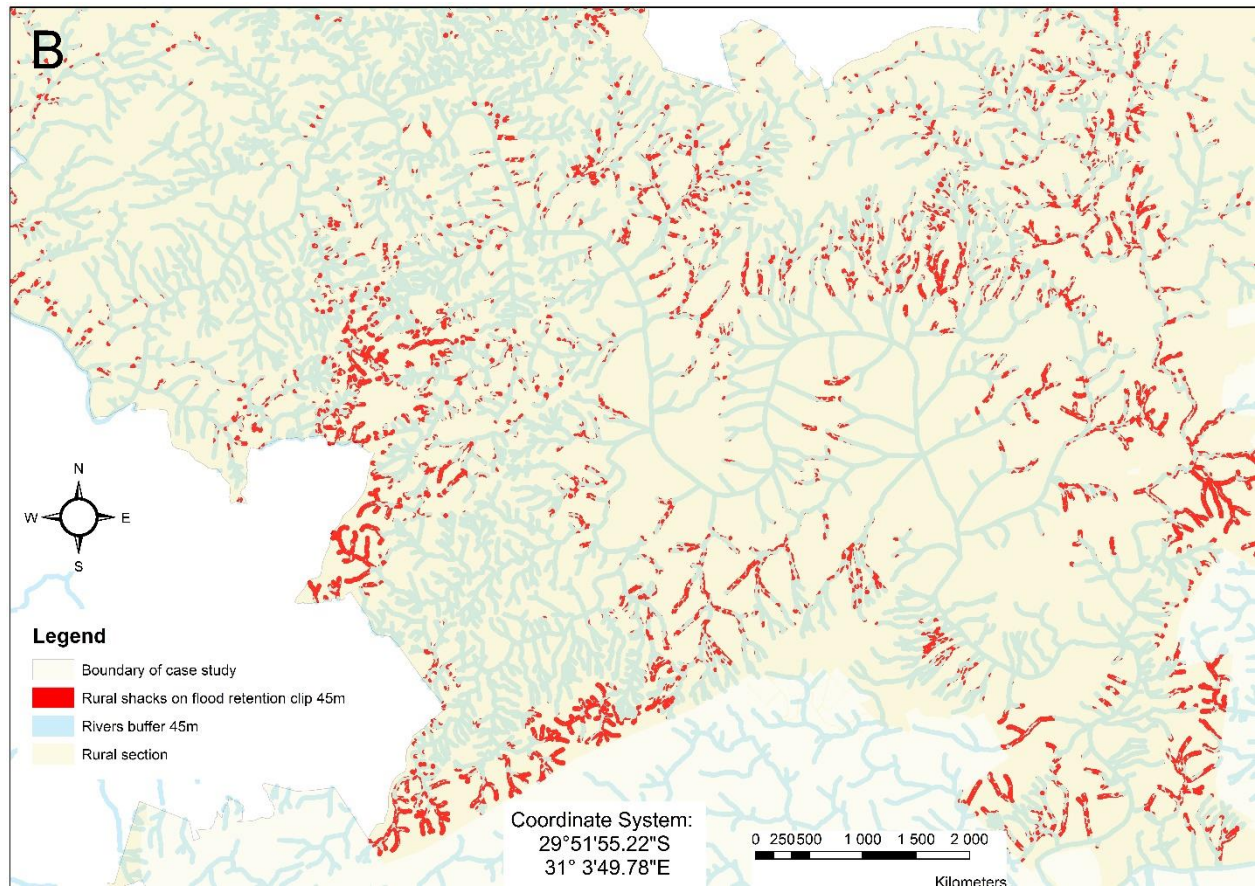


Figure 15.6. Flood retention 45m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

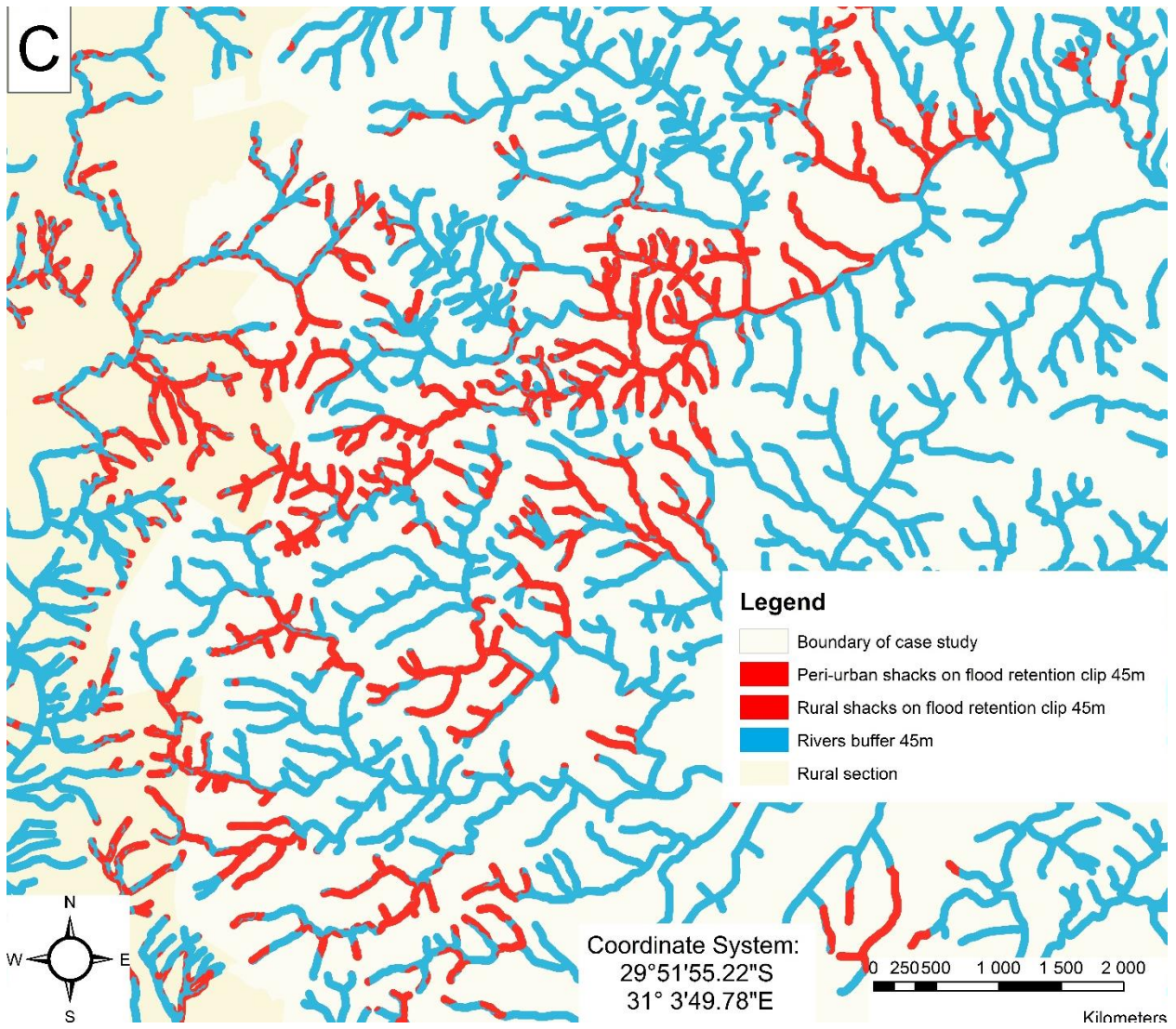
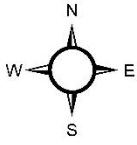


Figure 15.6. Flood retention 45m A (overview); B (rural view) and C (peri-urban view)





Source: Authors compilation through ArcGIS 10.4.1 (2017)

Forest 40m

A



Legend

-  Boundary of case study
-  Peri-urban shacks clip 40m
-  Rural shacks on forest clip 40m
-  Rural section



Coordinate System:
29°51'55.22"S
31° 3'49.78"E

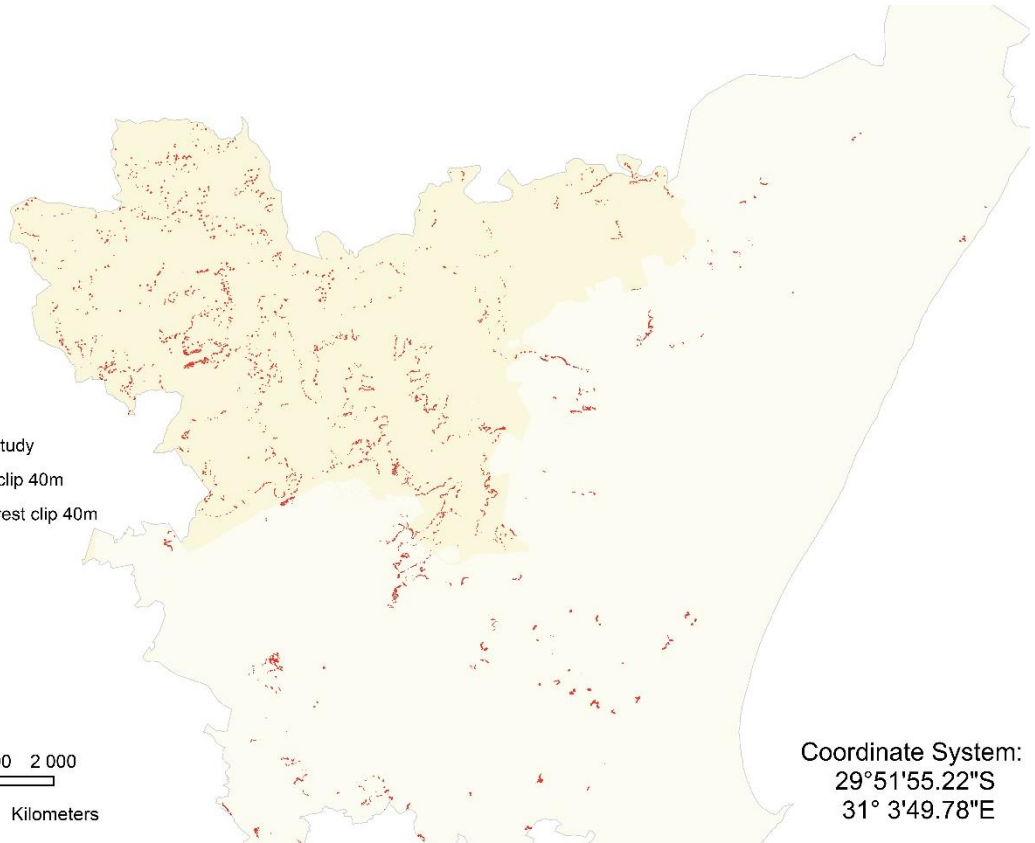


Figure 15.7. Forest 40m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

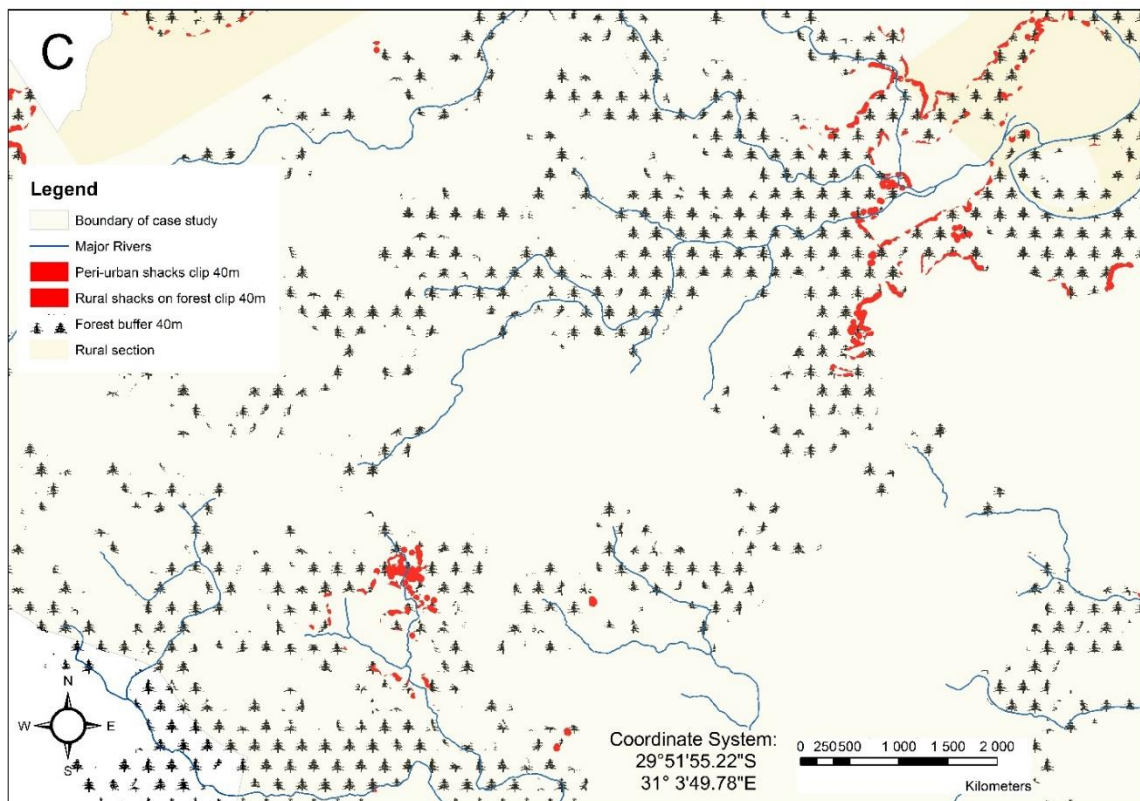
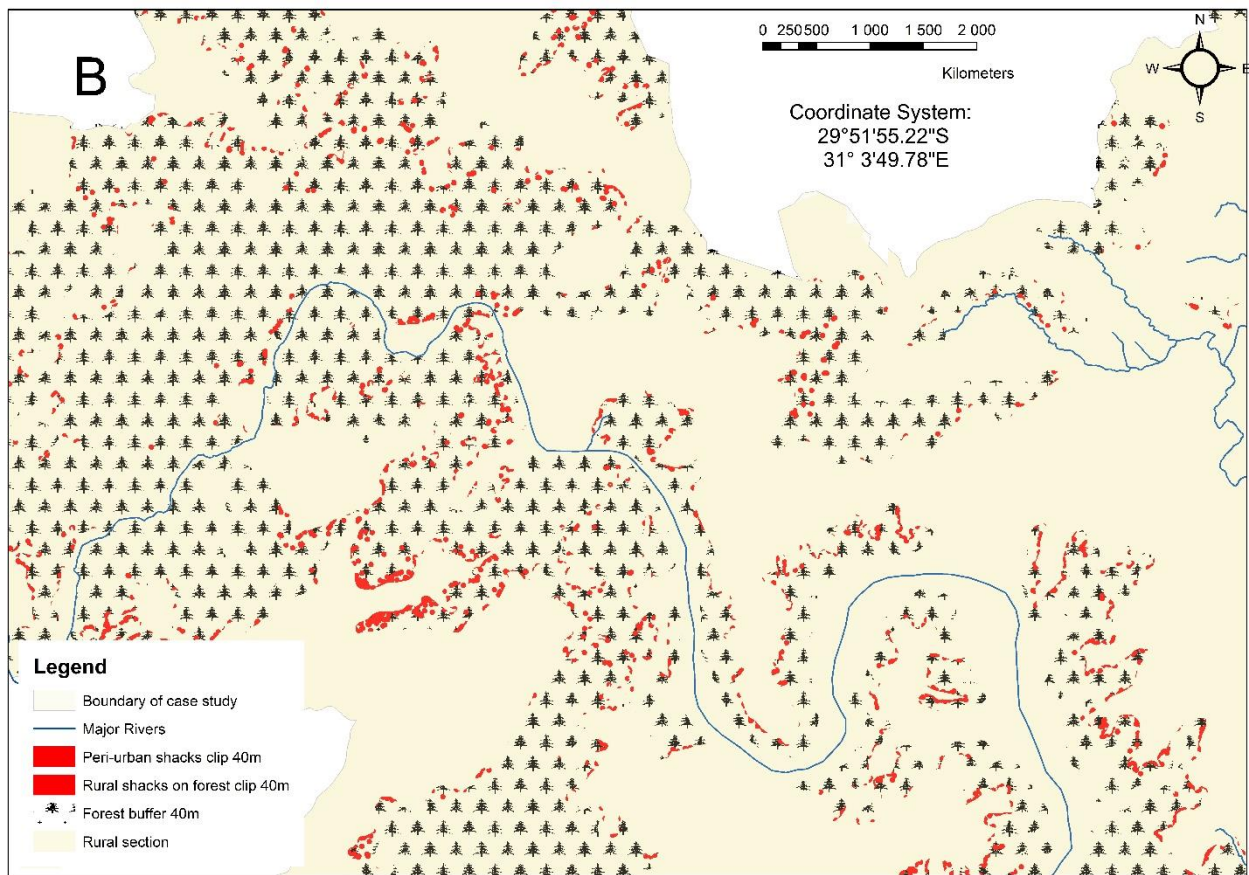


Figure 15.7. Forest 40m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

Forest 100m

A

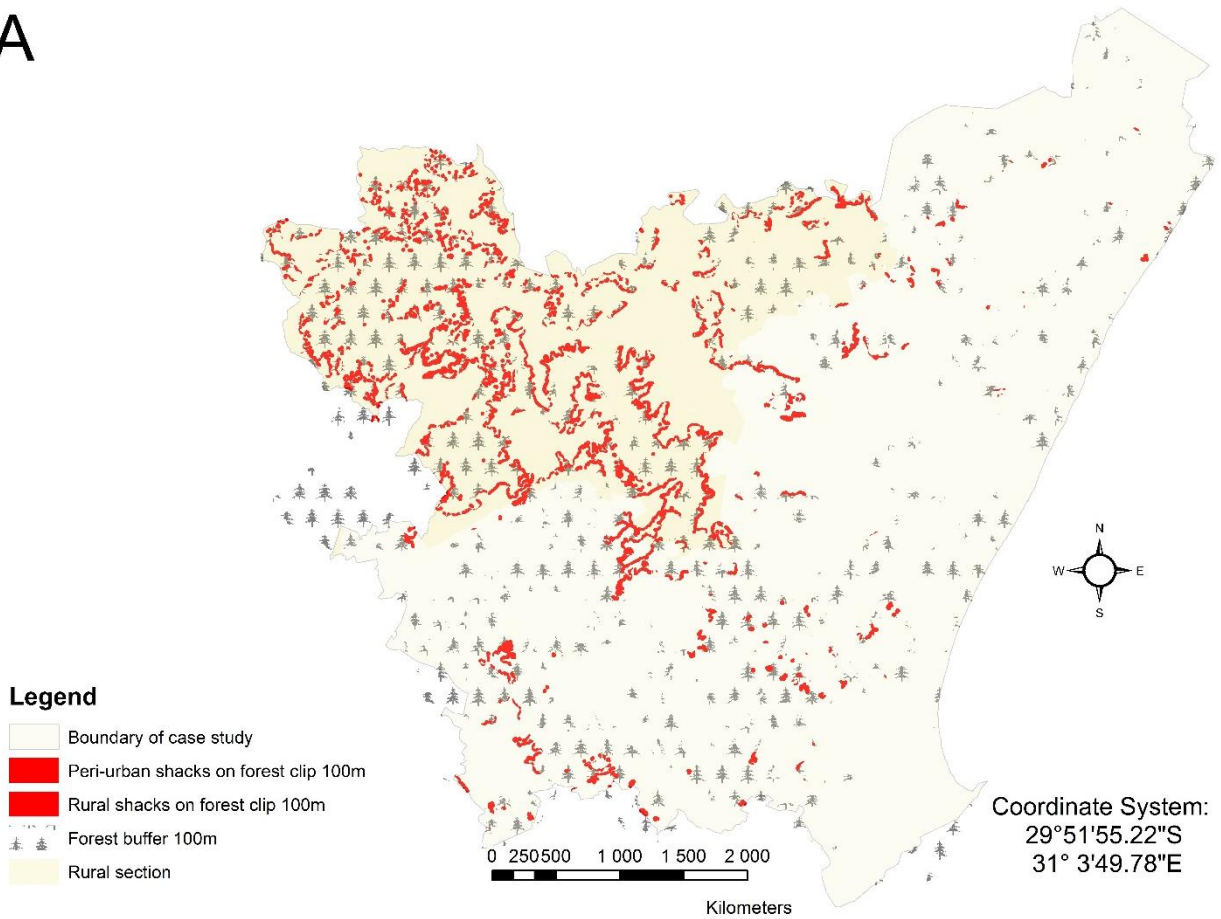


Figure 15.8. Forest 100m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

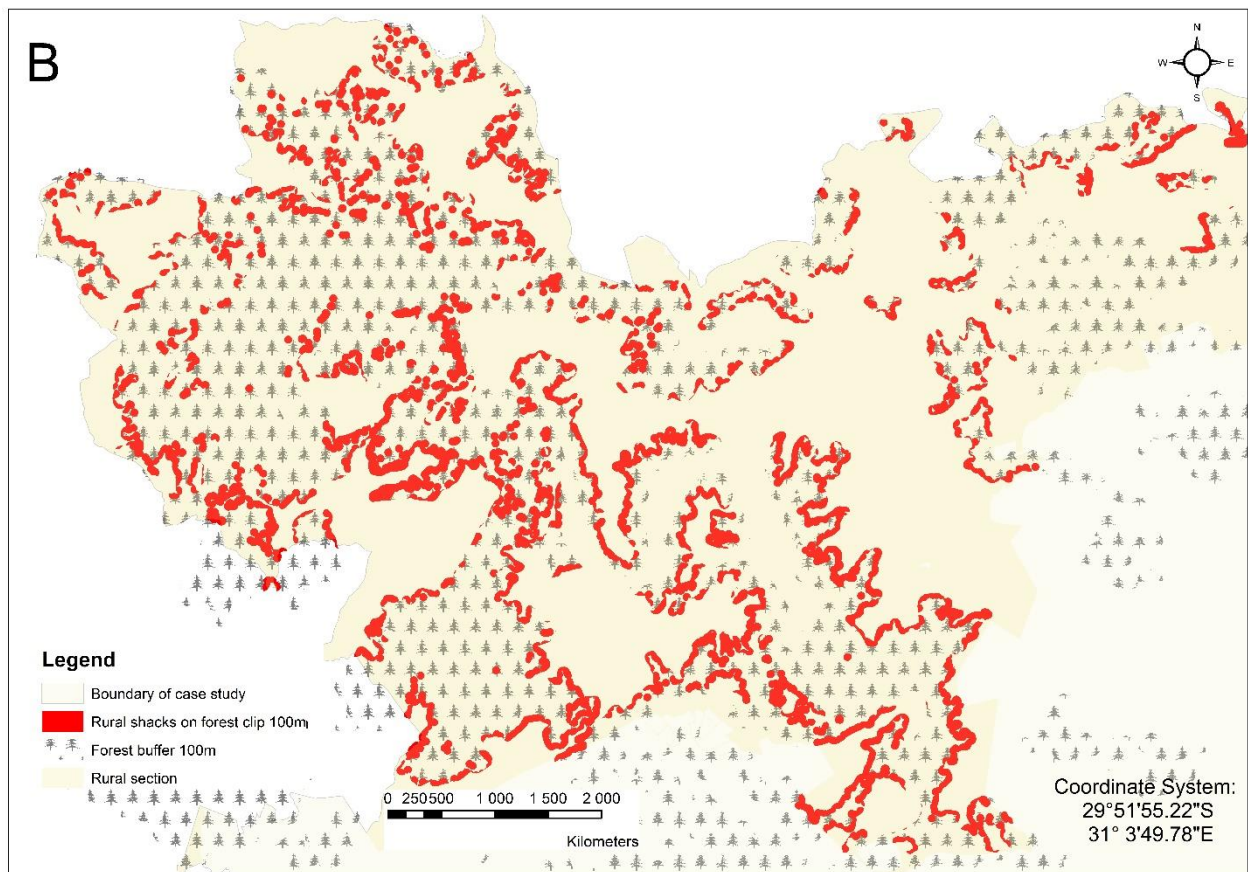


Figure 15.8. Forest 100m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

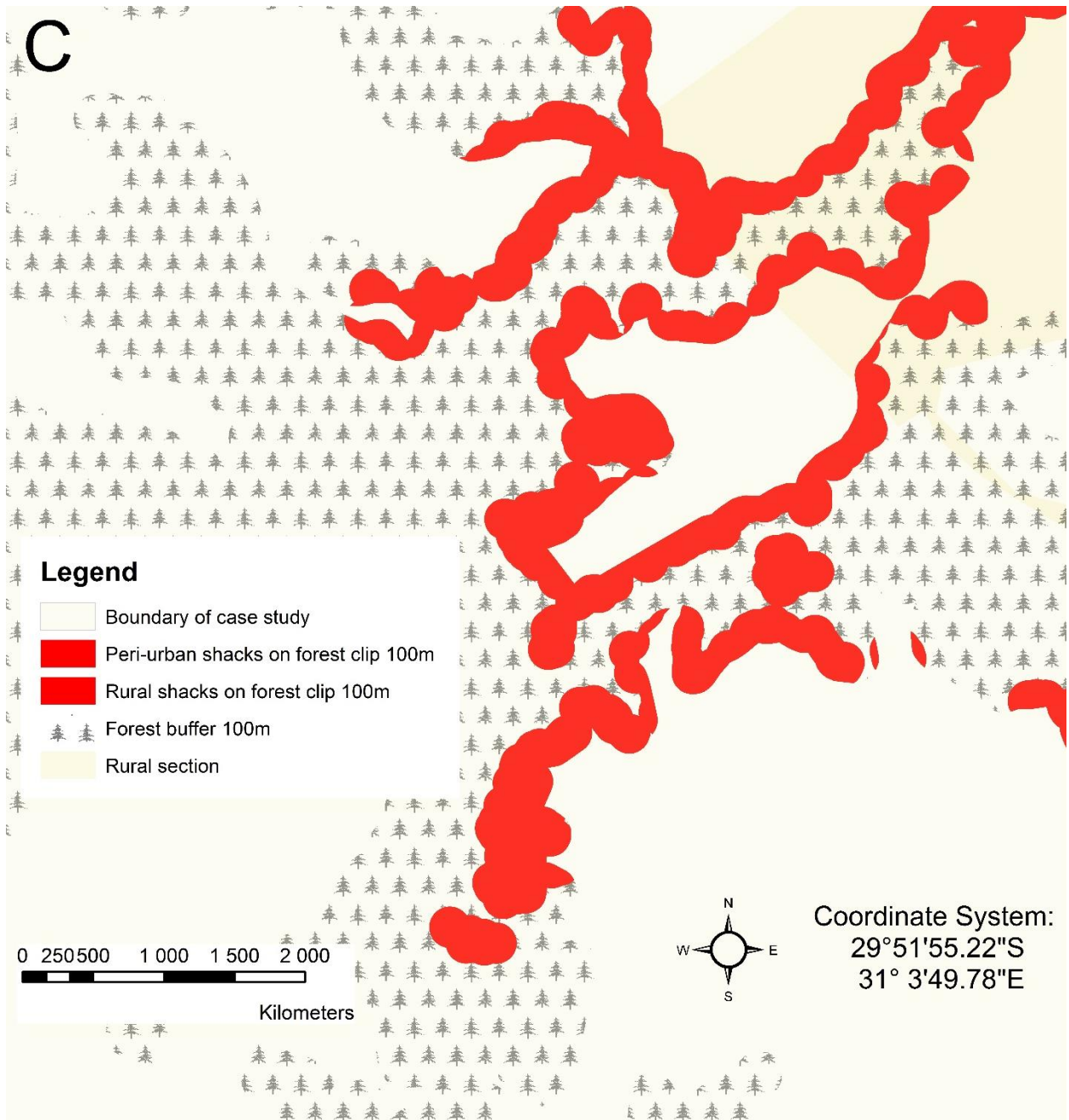


Figure 15.8. Forest 100m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

Forest and woodland 25m

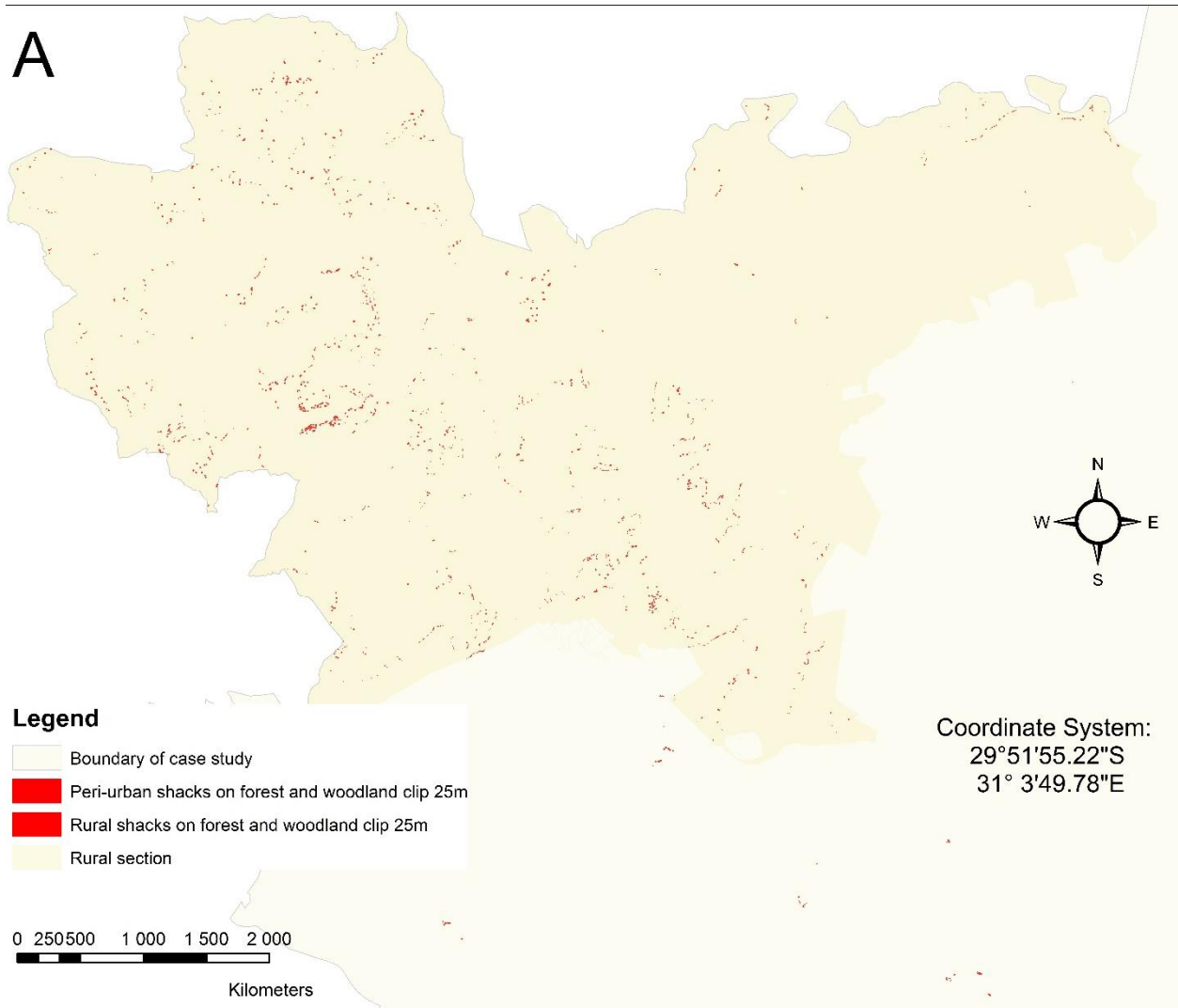
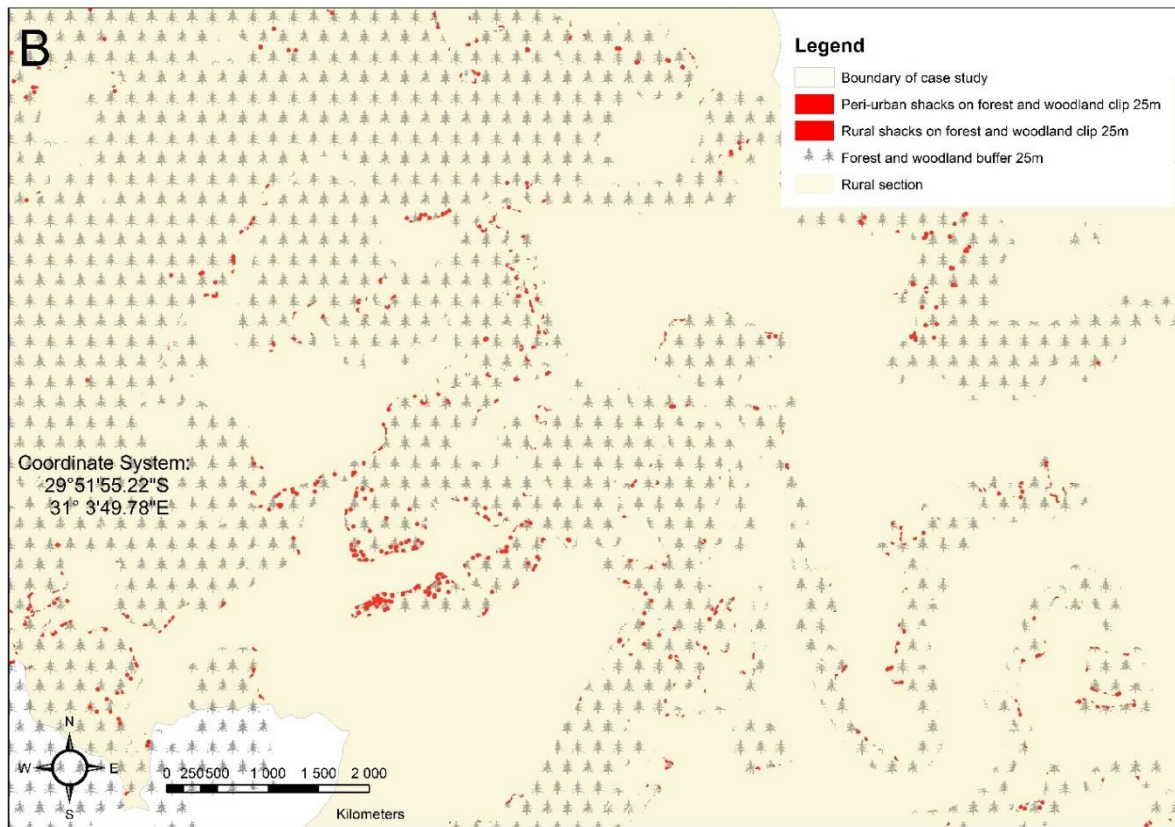


Figure 15.9. Forest and woodland 40m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)



Figure

15.9. Forest and woodland 40m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

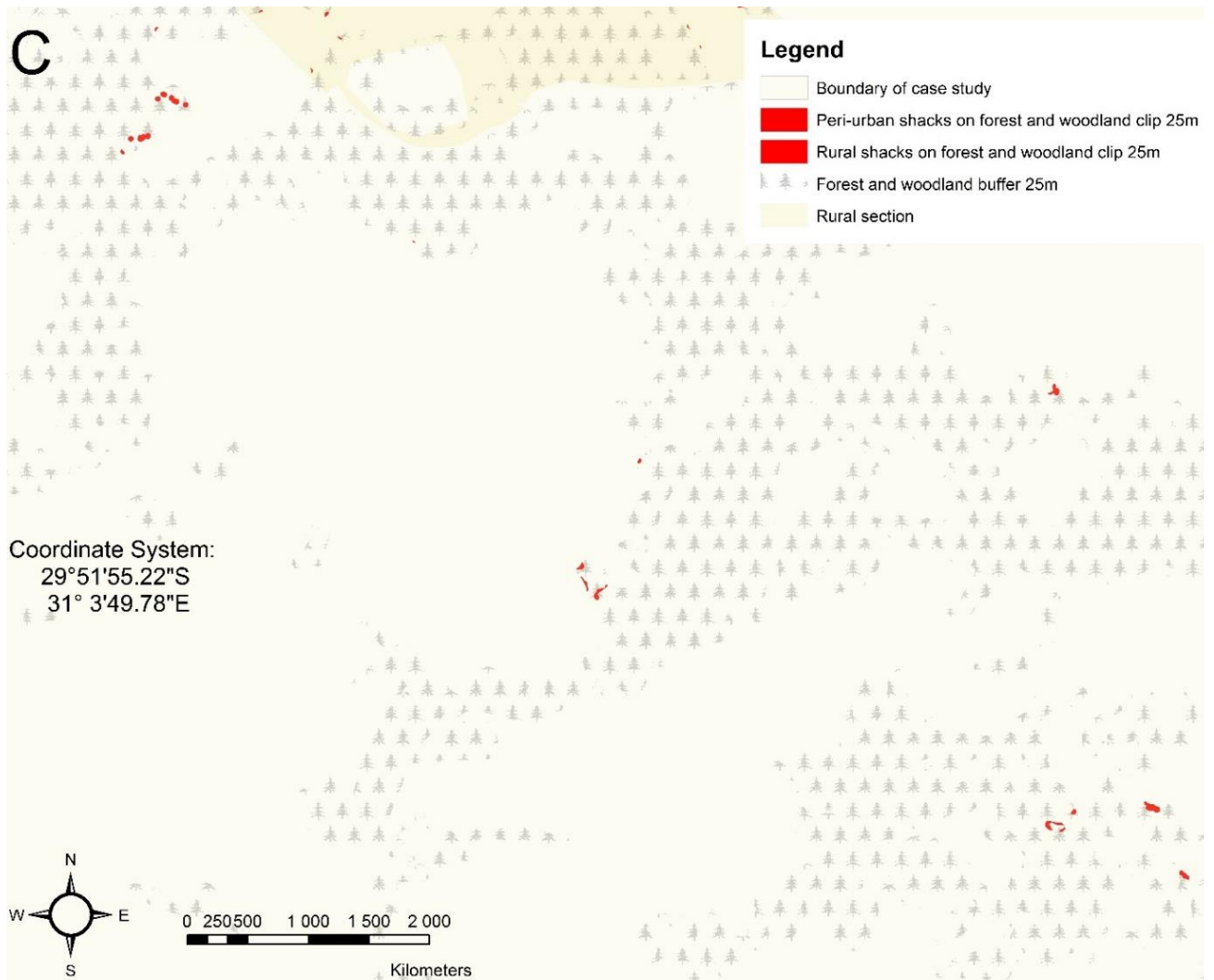


Figure 15.9. Forest and woodland 40m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

No development in MOSS

A

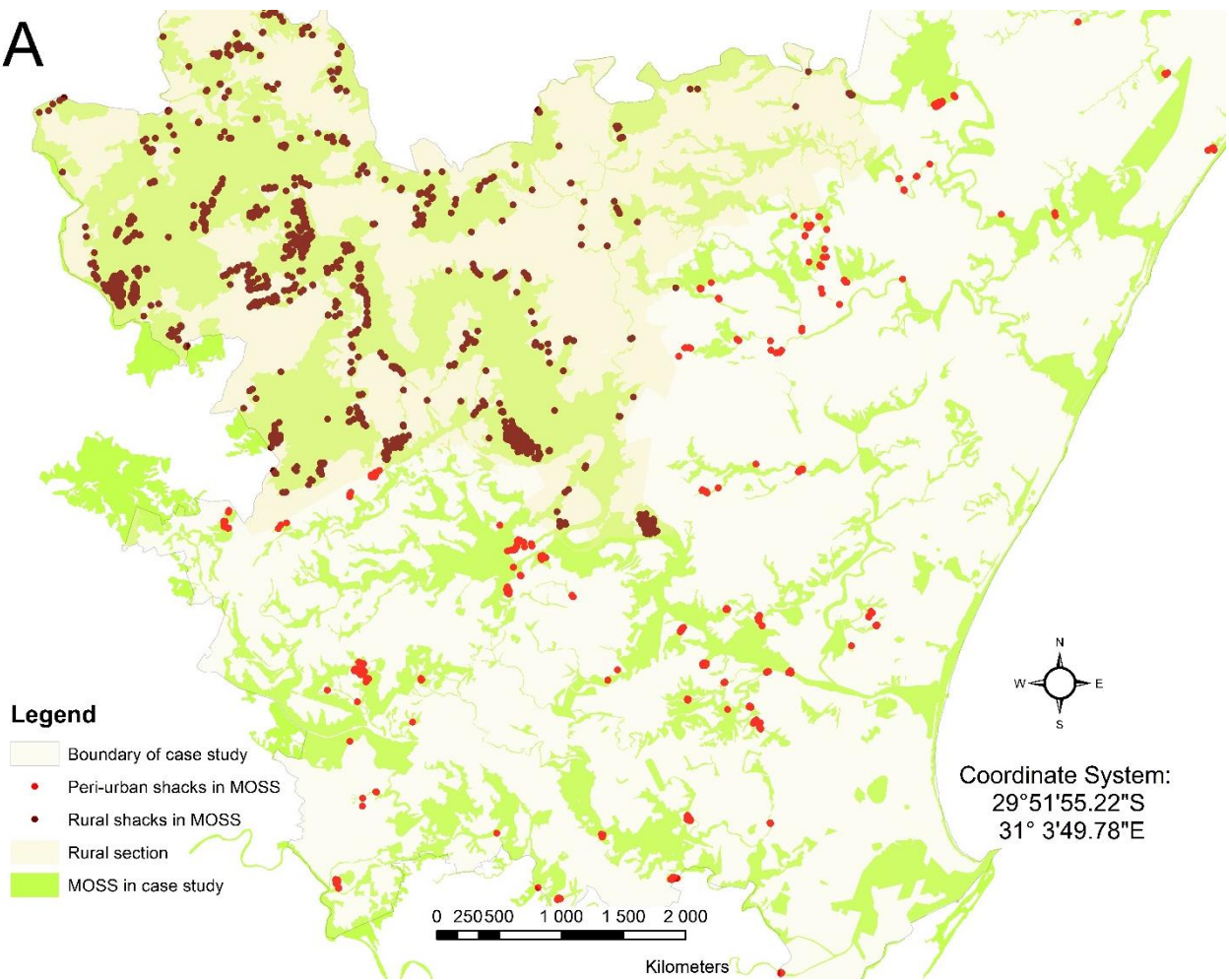


Figure 15.10. No development in MOSS A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

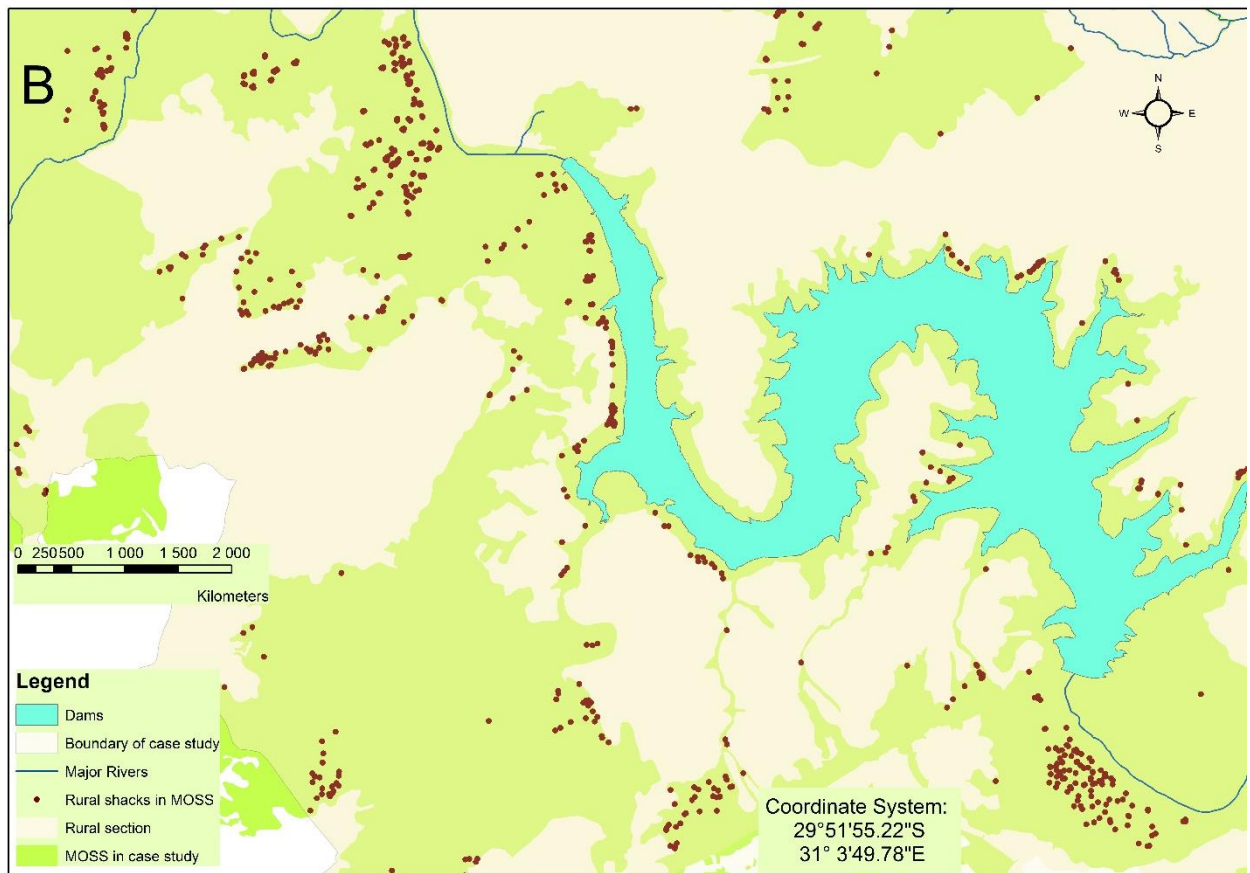


Figure 15.10. No development in MOSS A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

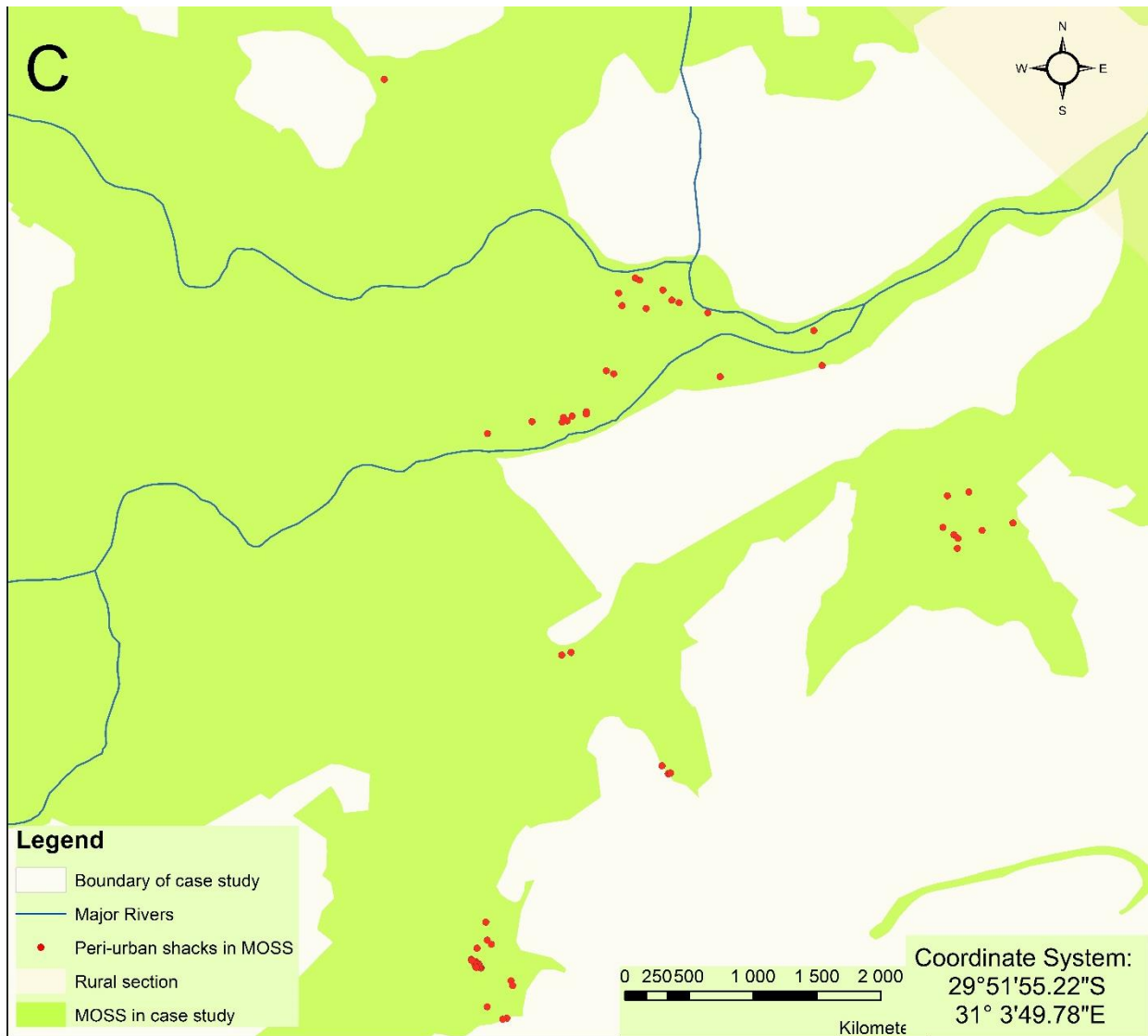


Figure 15.10. No development in MOSS A (overview); B (rural view) and C (peri-urban view)
Source: Authors compilation through ArcGIS 10.4.1 (2017)

Organic matter 55m

A

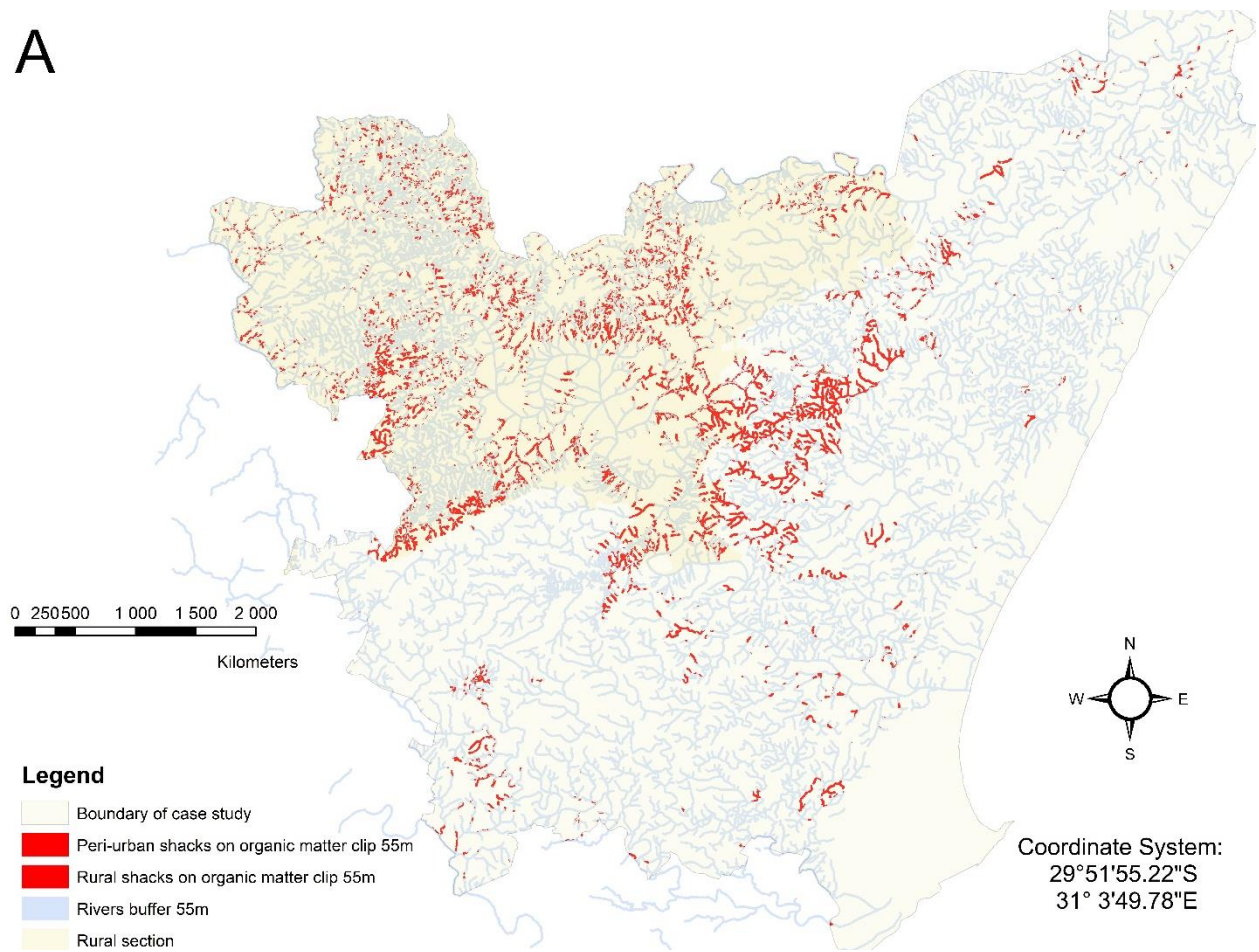


Figure 15.11. Organic matter 55m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

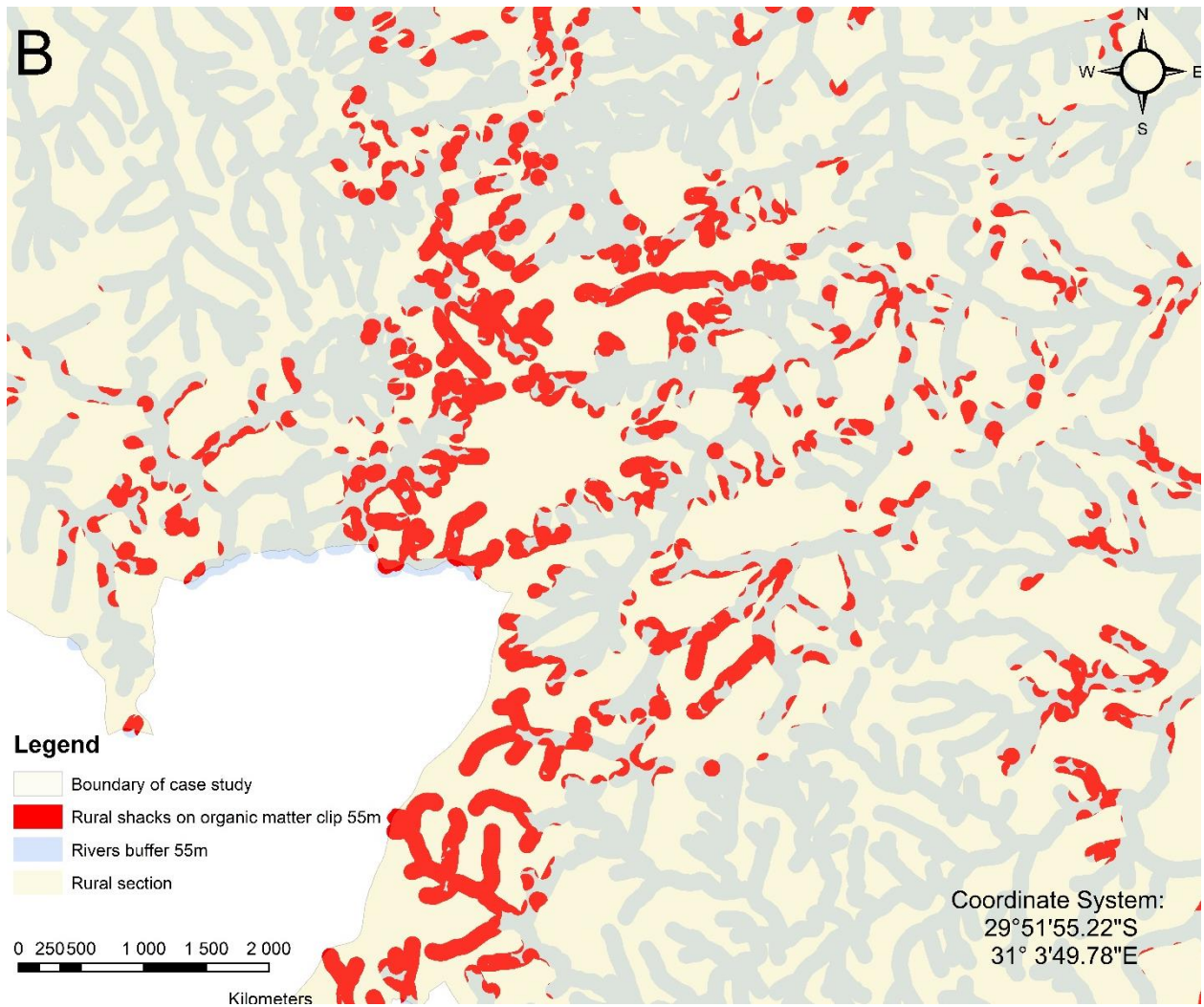


Figure 15.11. Organic matter 55m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

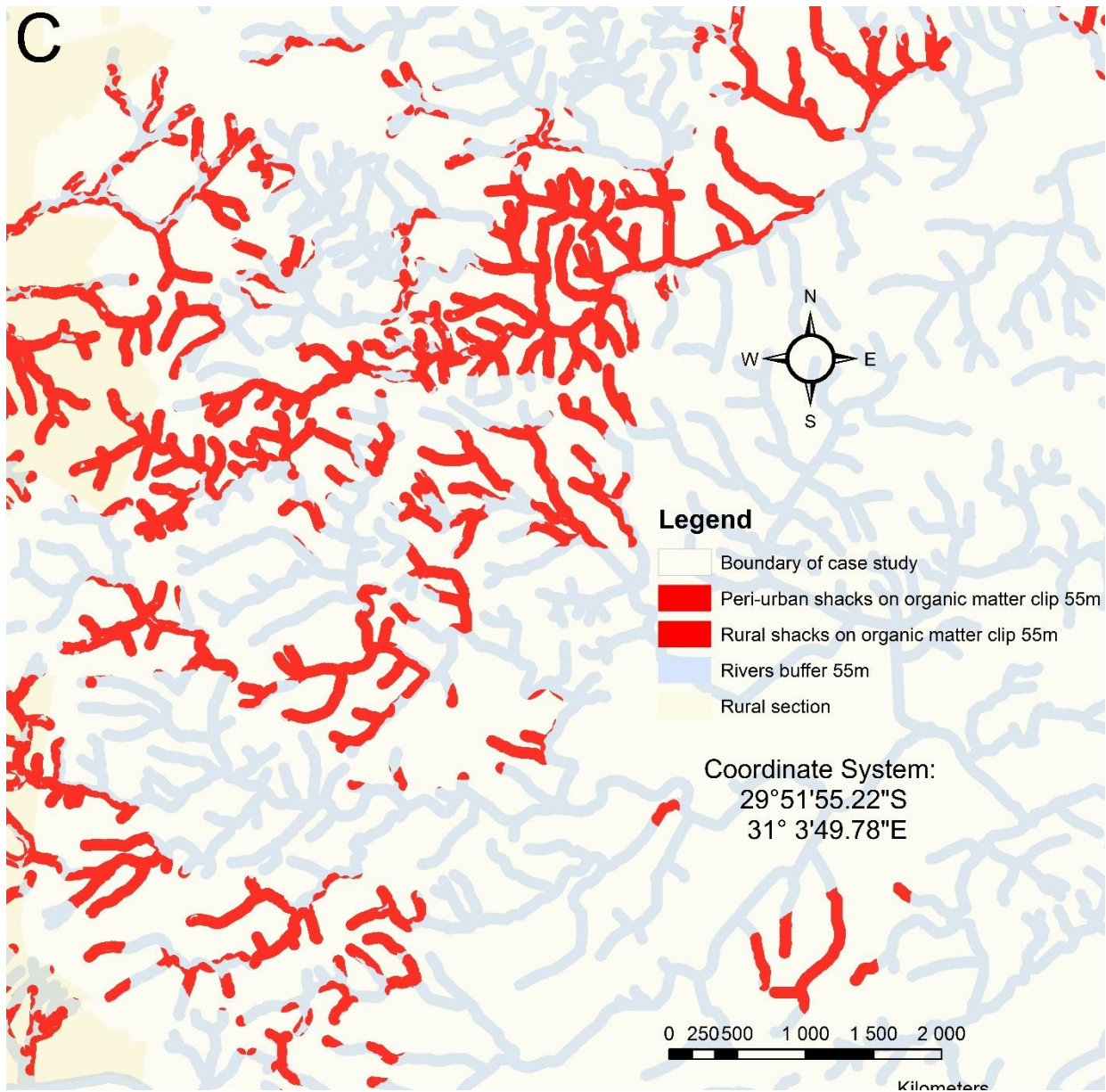


Figure 15.11. Organic matter 55m A (overview); B (rural view) and C (peri-urban view)
 Source: Authors compilation through ArcGIS 10.4.1 (2017)

Riparian forest 23m

A

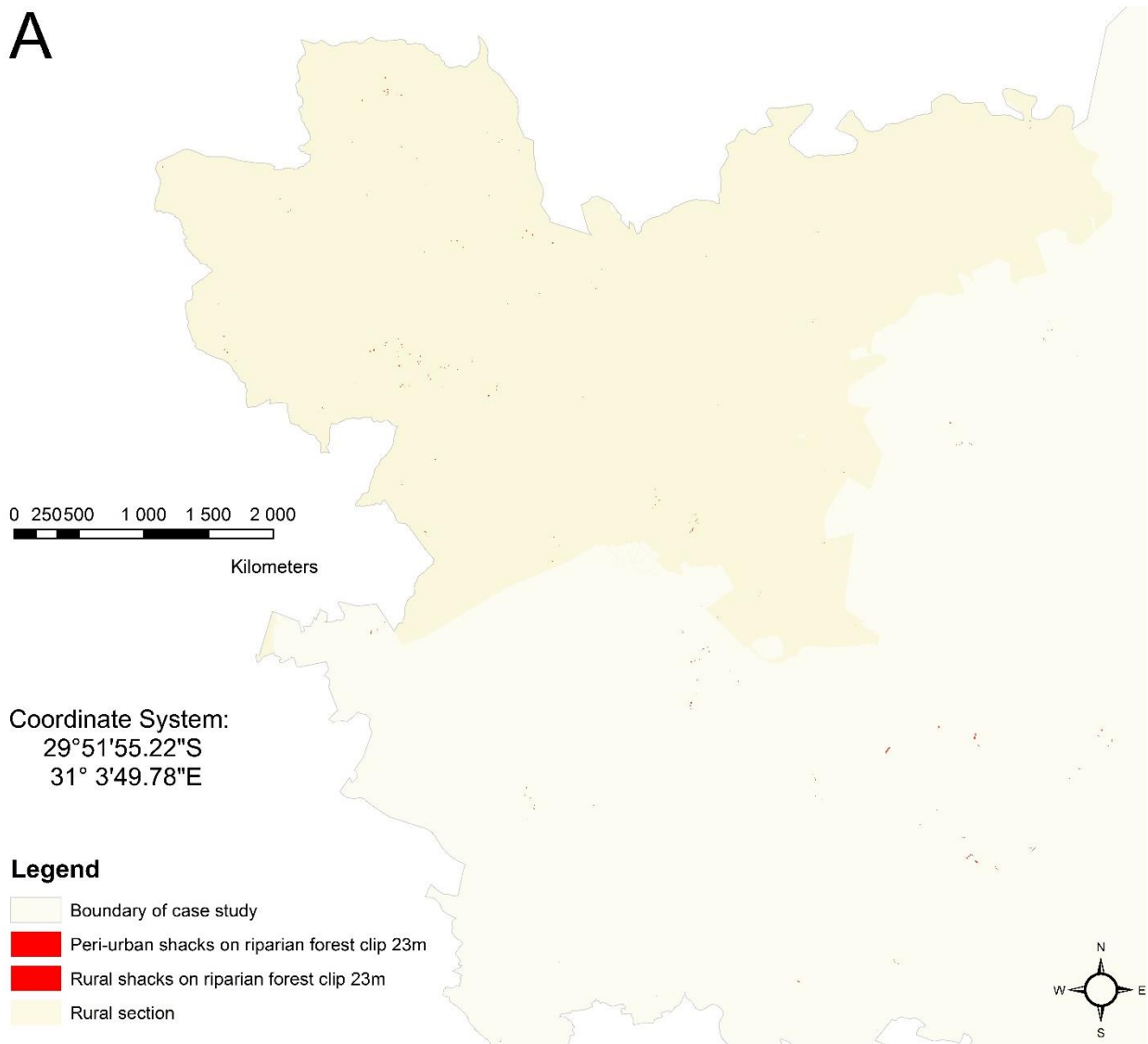


Figure 15.12. Riparian forest 23m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

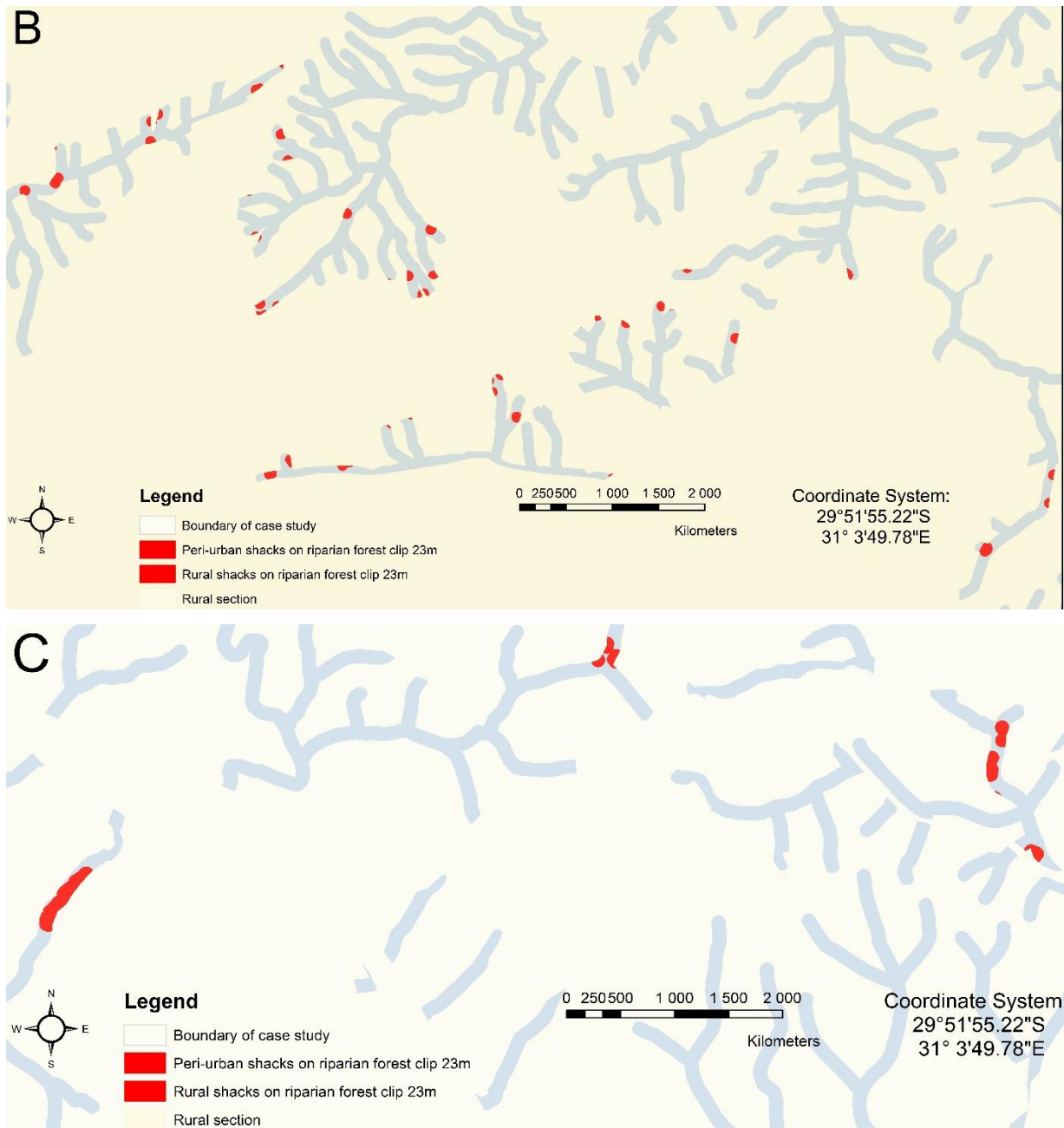


Figure 15.12. Riparian forest 23m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

Roads 15m

A

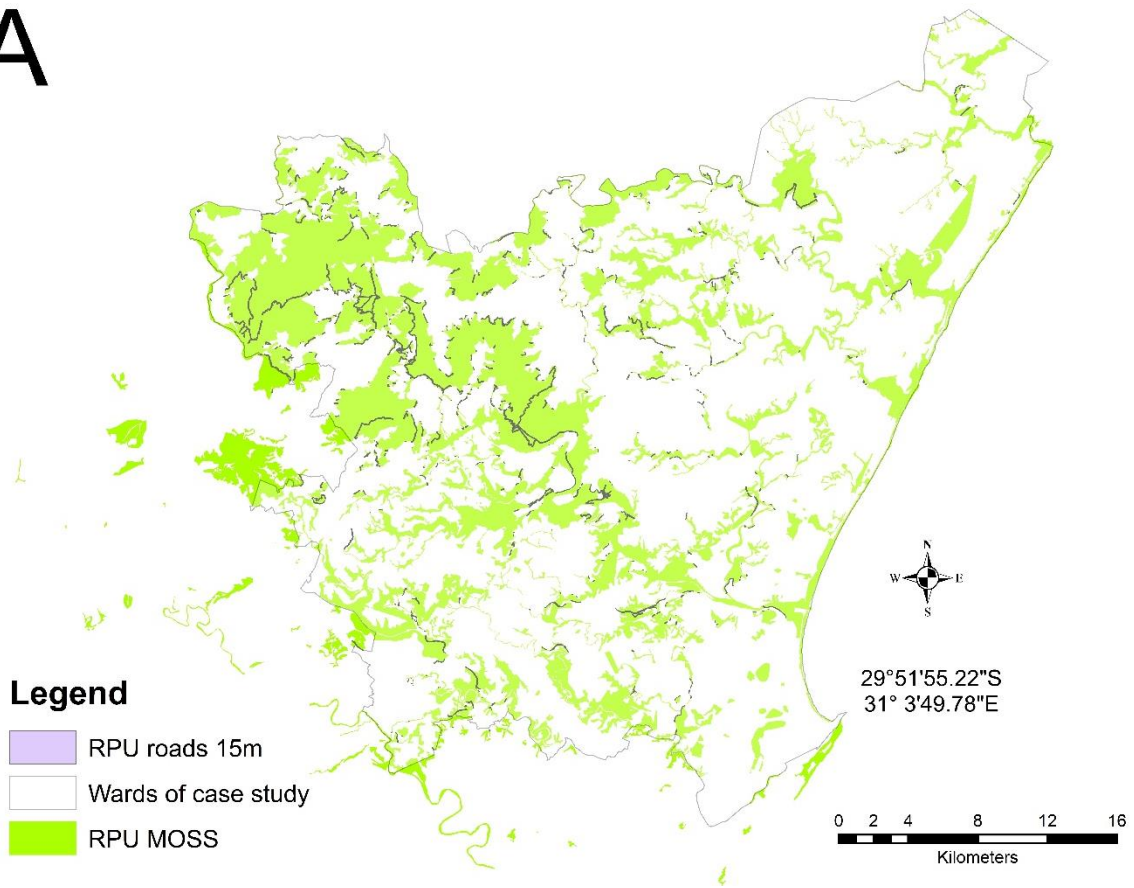


Figure 15.13. Roads 15m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

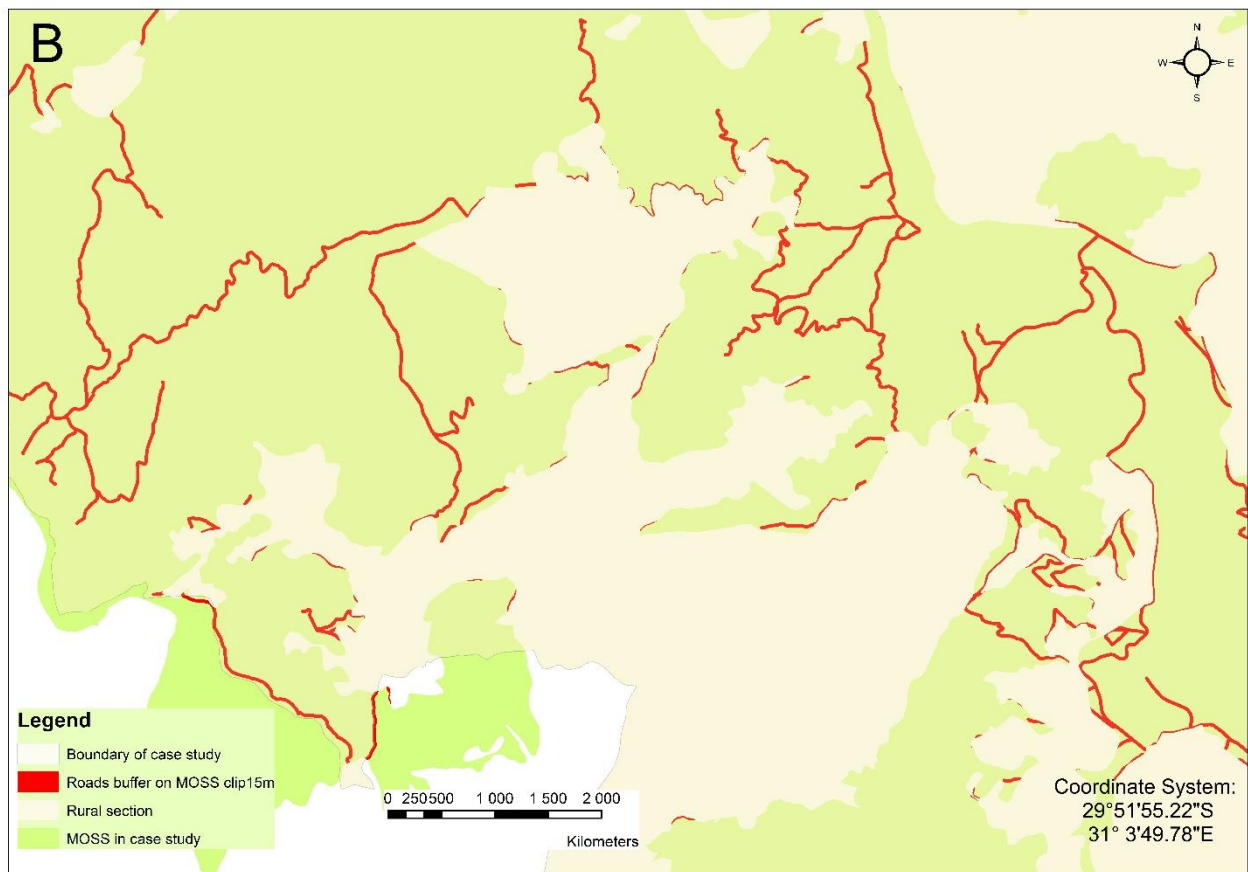


Figure 15.13. Roads 15m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

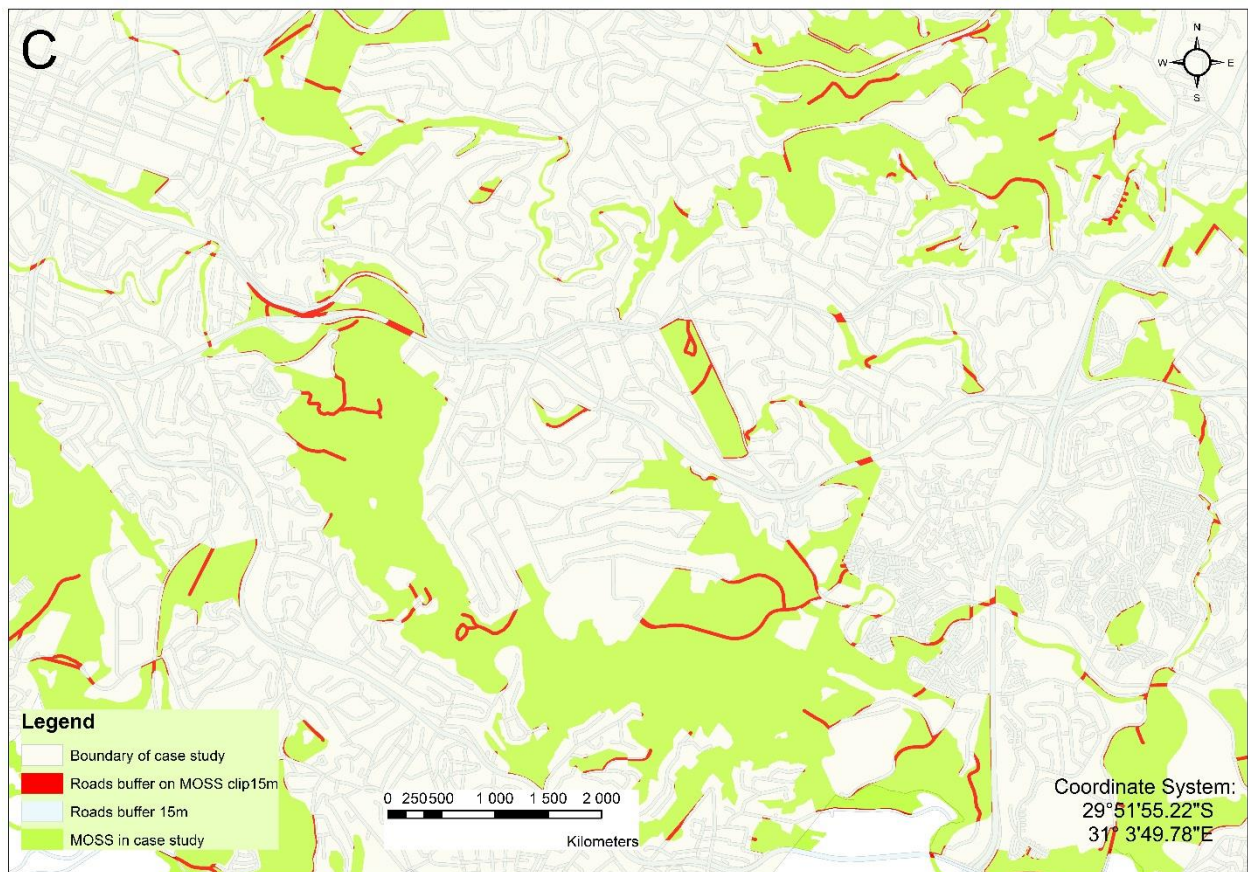


Figure 15.13. Roads 15m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

Stream temperature 35m

A

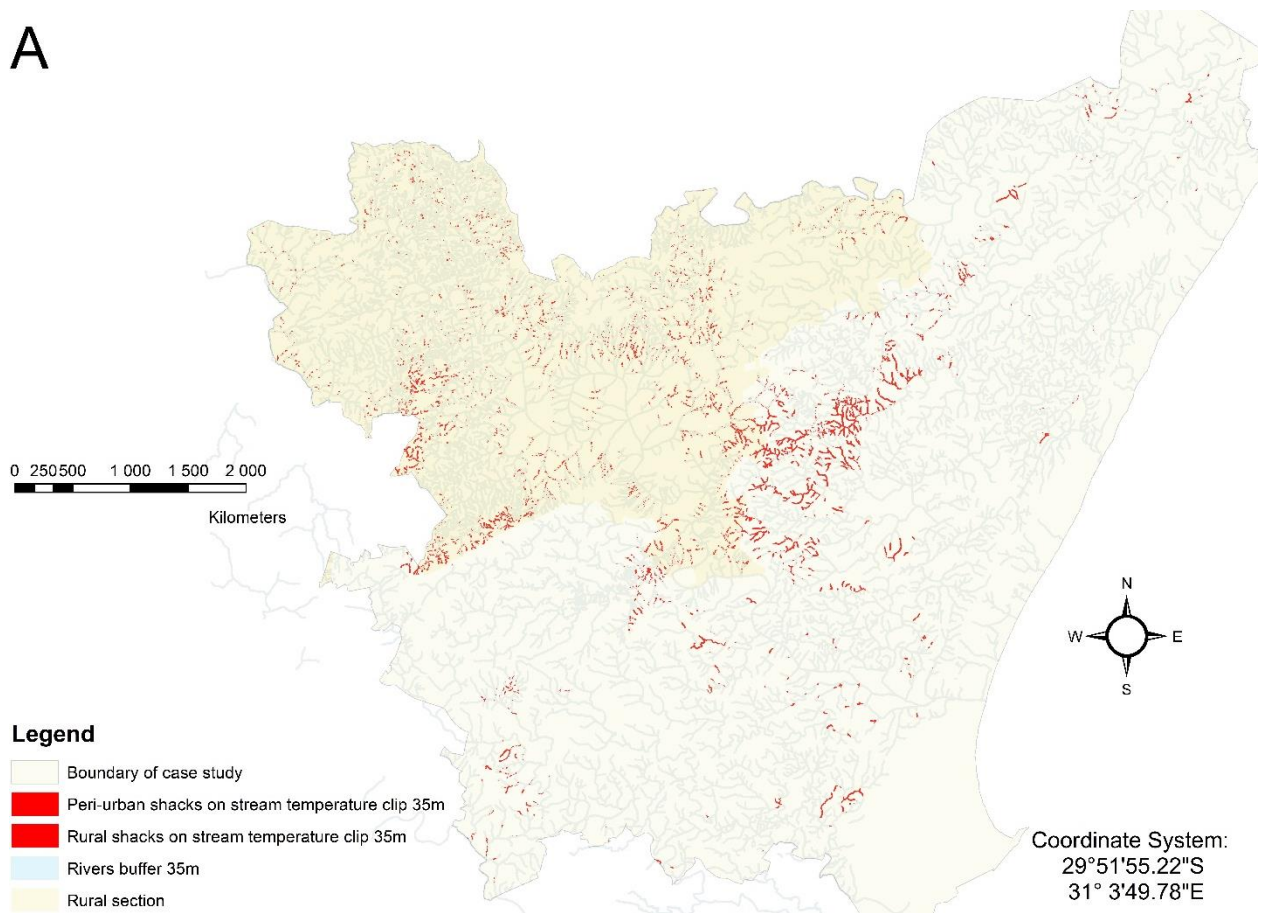


Figure 15.14. Stream temperature 35m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

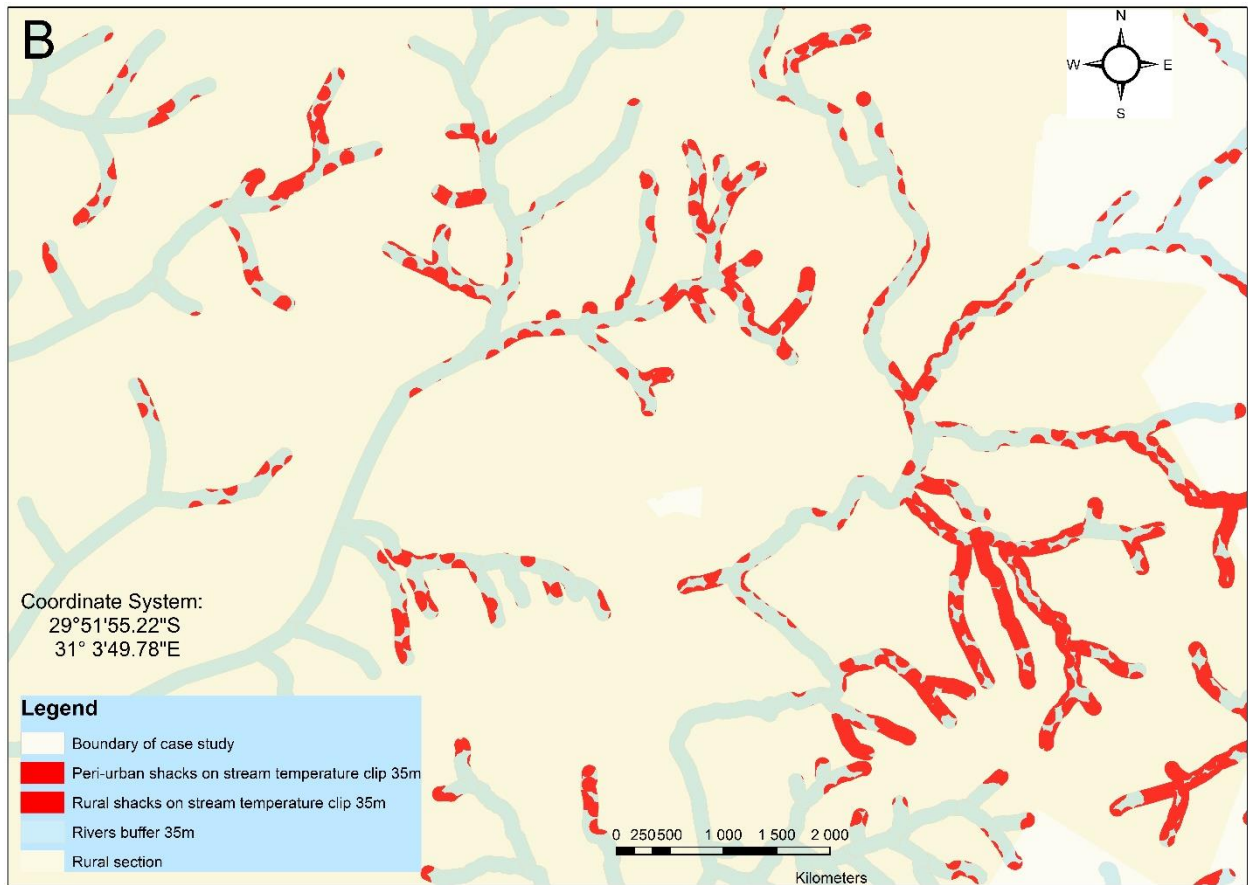


Figure 15.14. Stream temperature 35m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

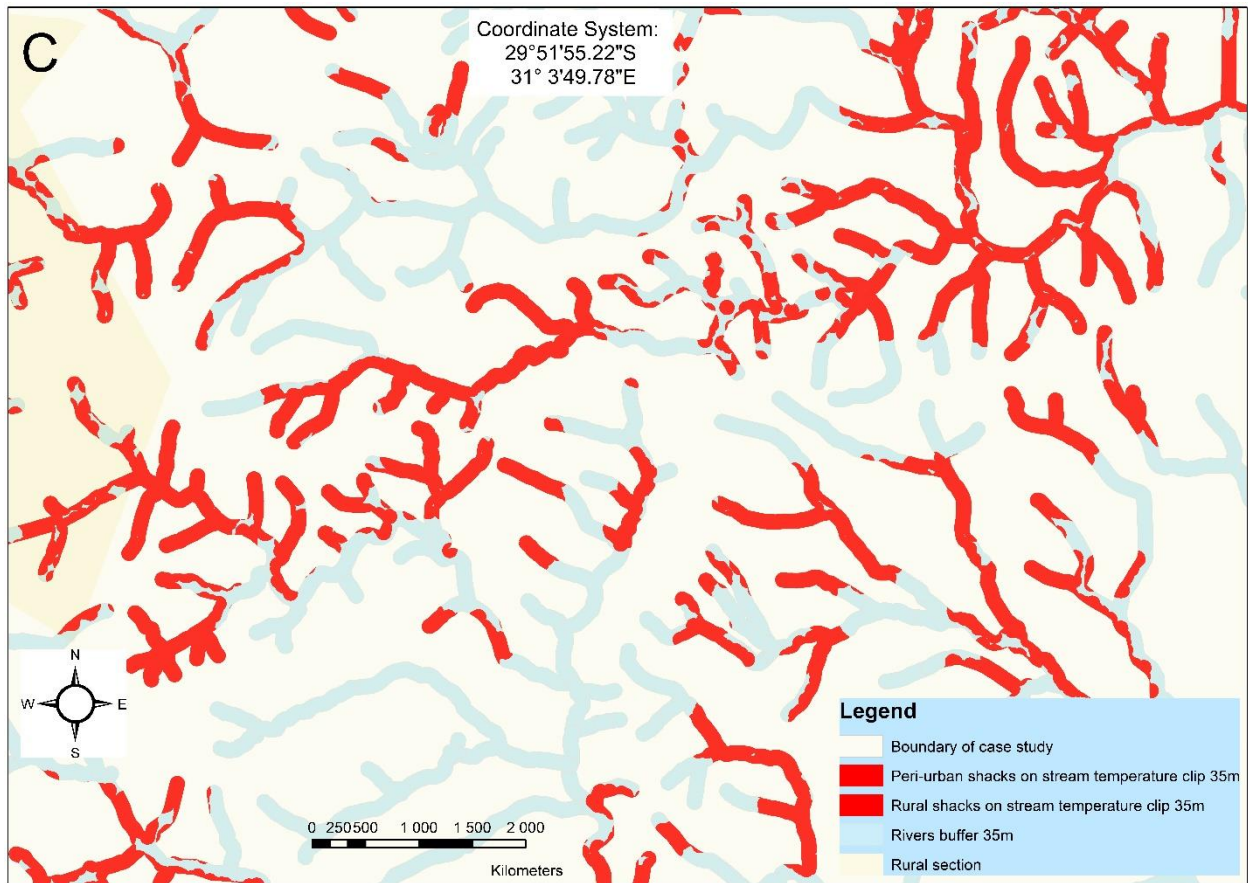


Figure 15.14. Stream temperature 35m A (overview); B (rural view) and C (peri-urban view)
Source: Authors compilation through ArcGIS 10.4.1 (2017)

Wetland 30m

A

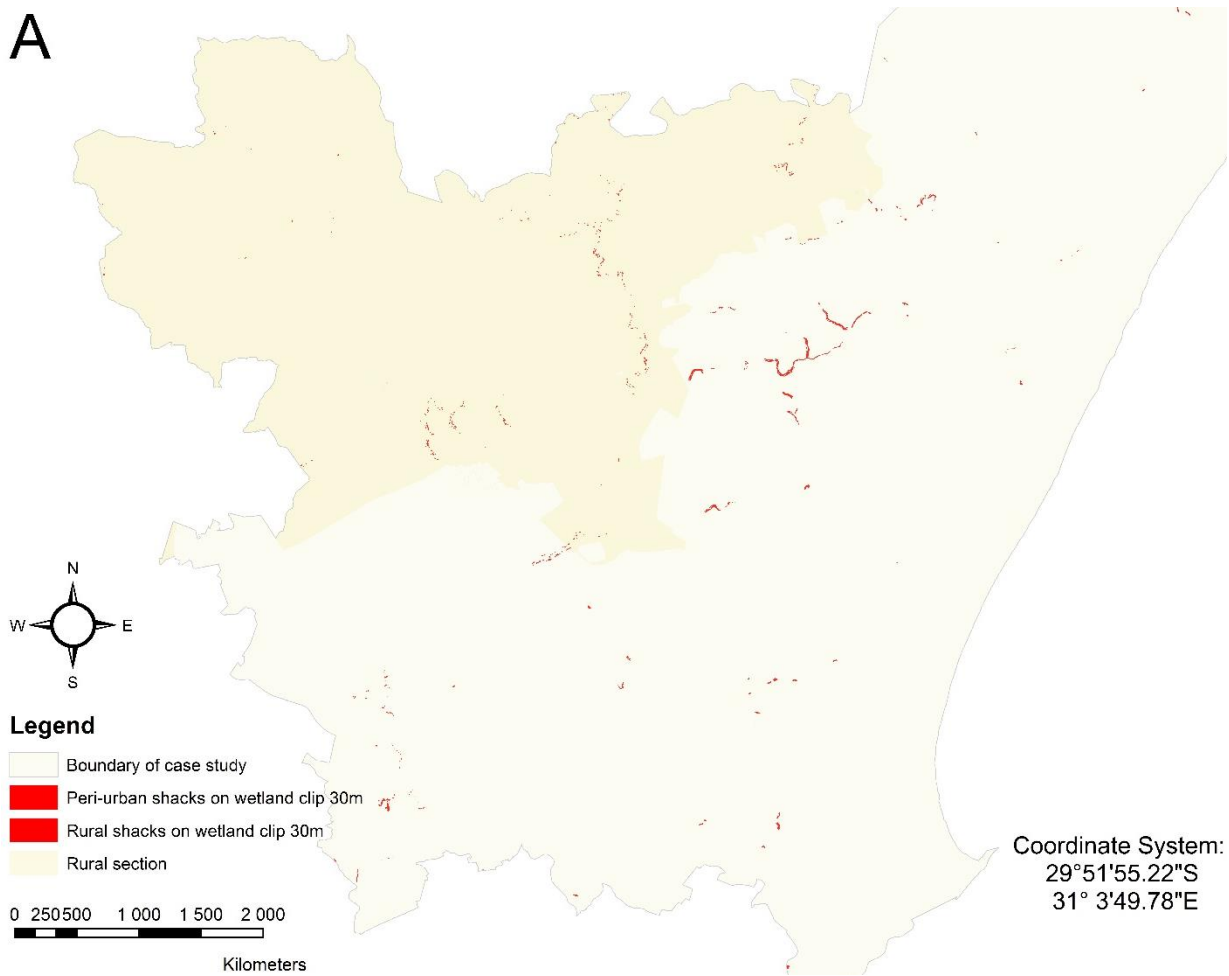


Figure 15.15. Wetland 30m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

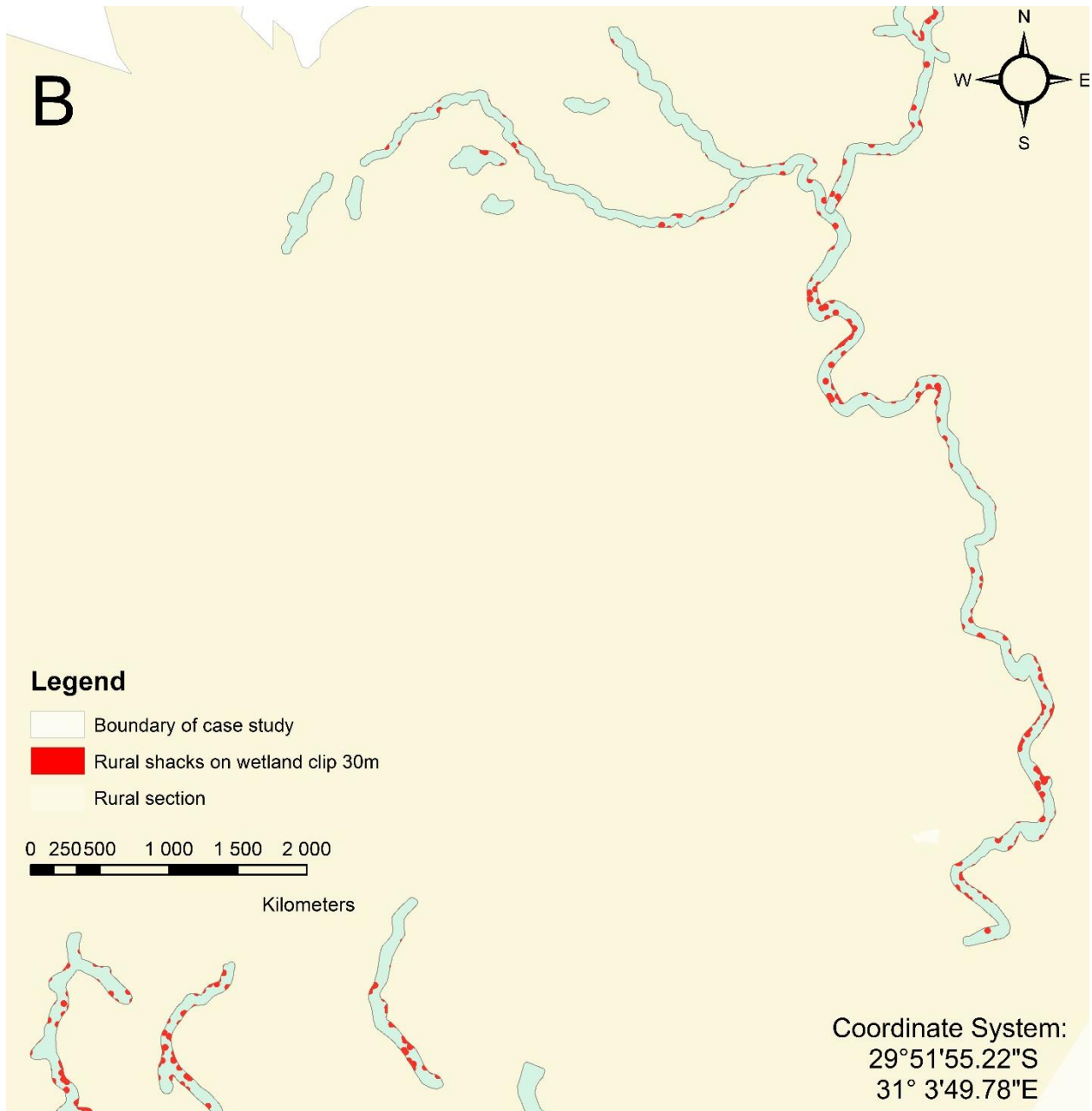


Figure 15.15. Wetland 30m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

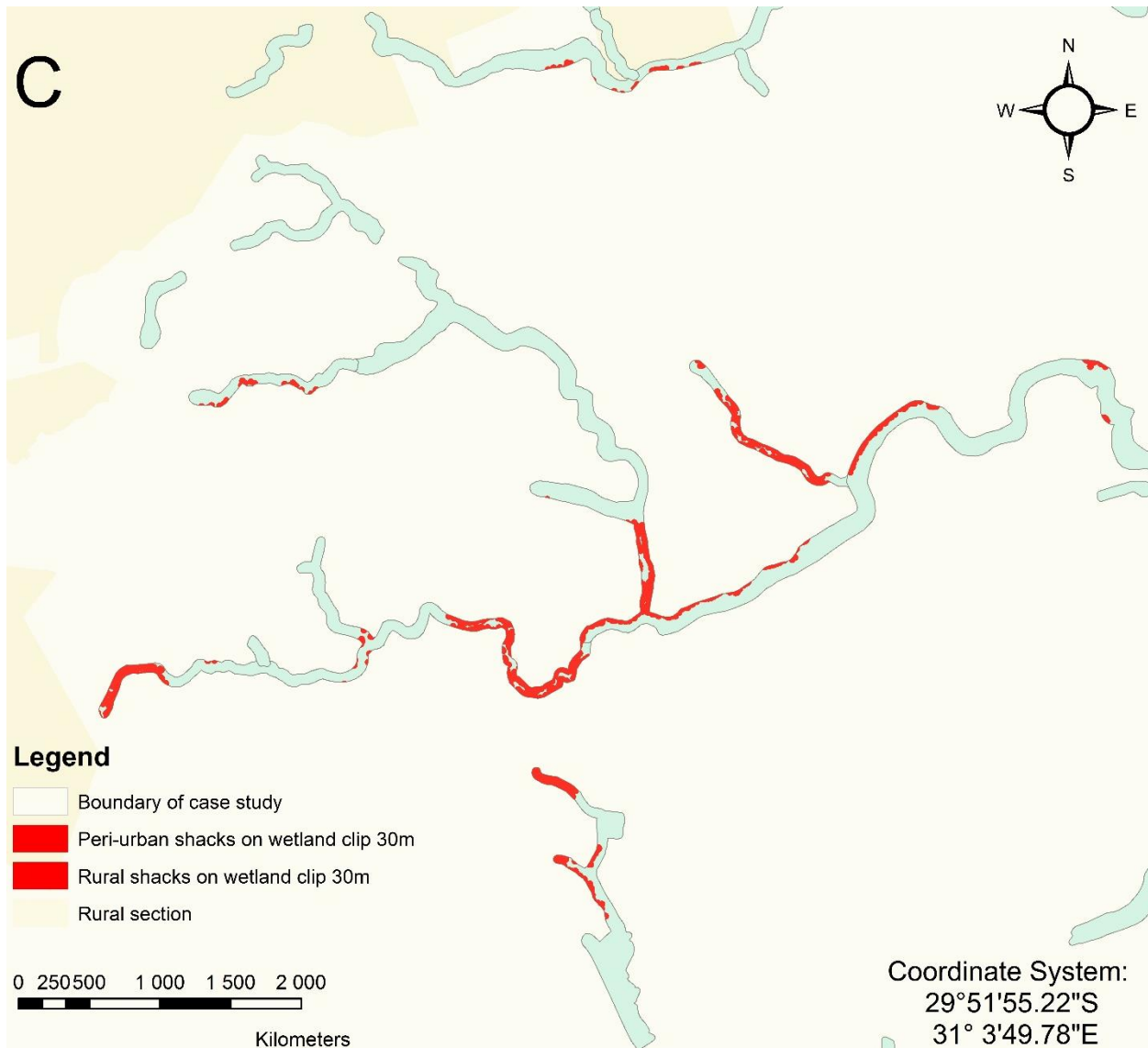


Figure 15.15. Wetland 30m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

Wetland 35m

A

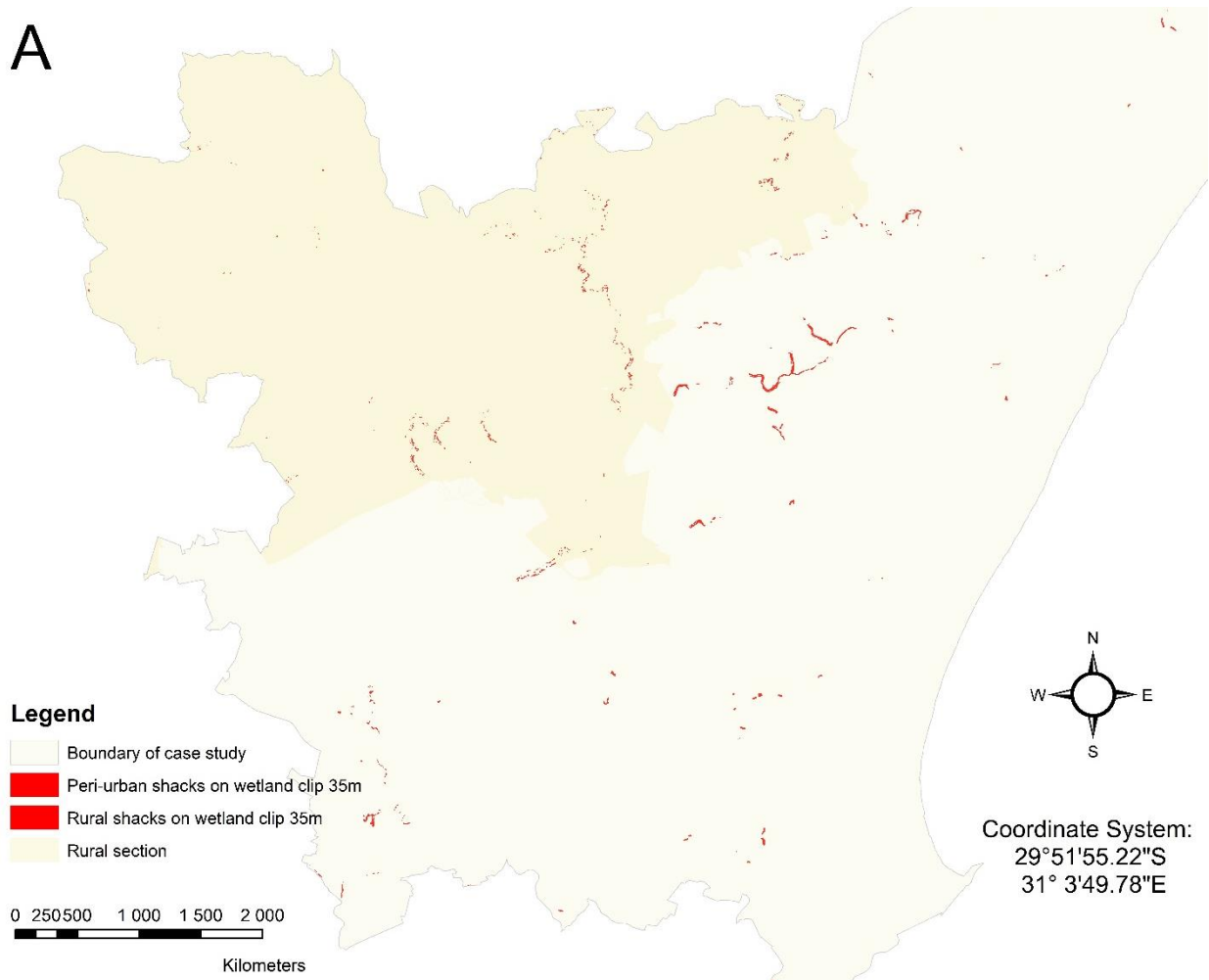


Figure 15.16. Wetland 35m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

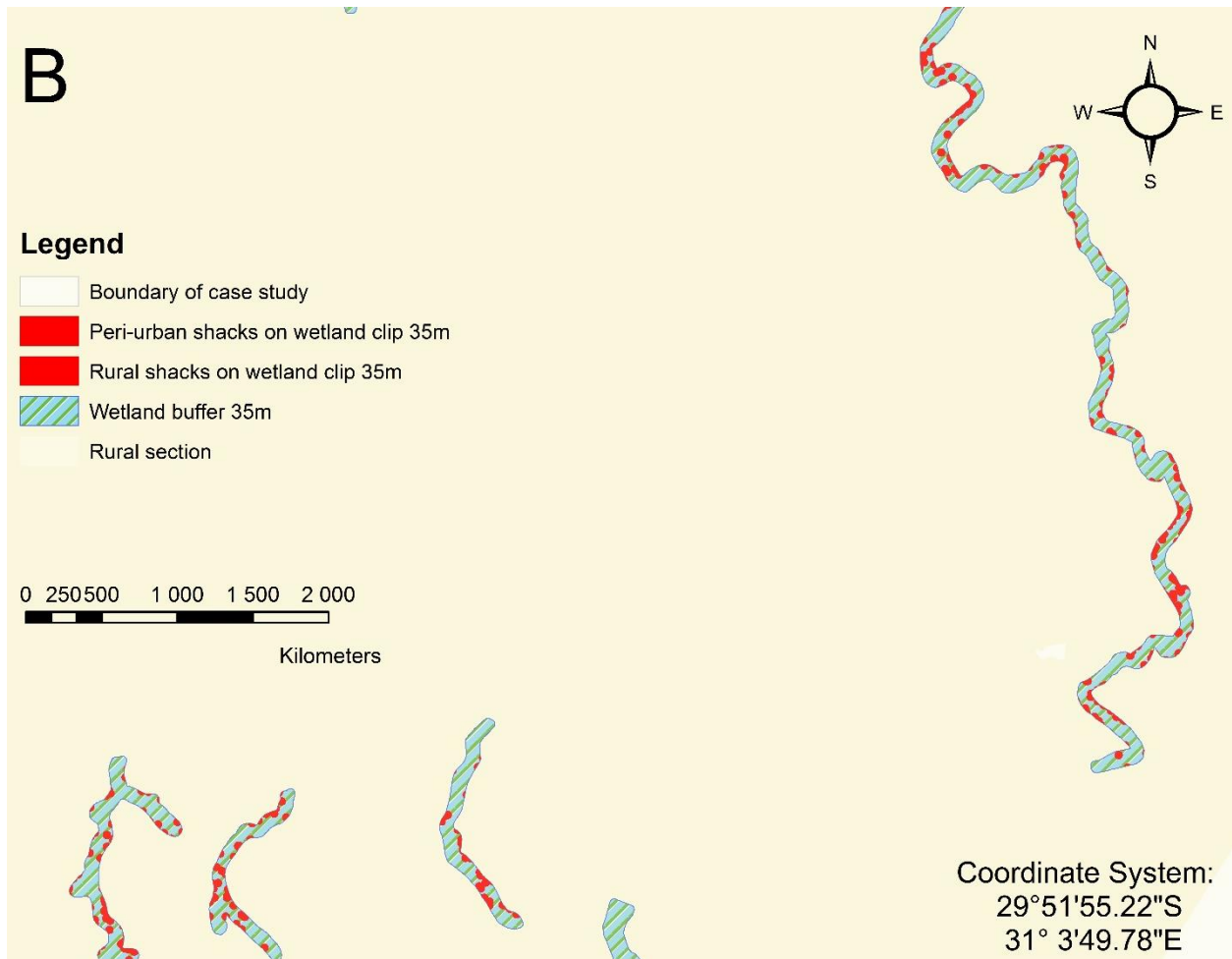


Figure 15.16. Wetland 35m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

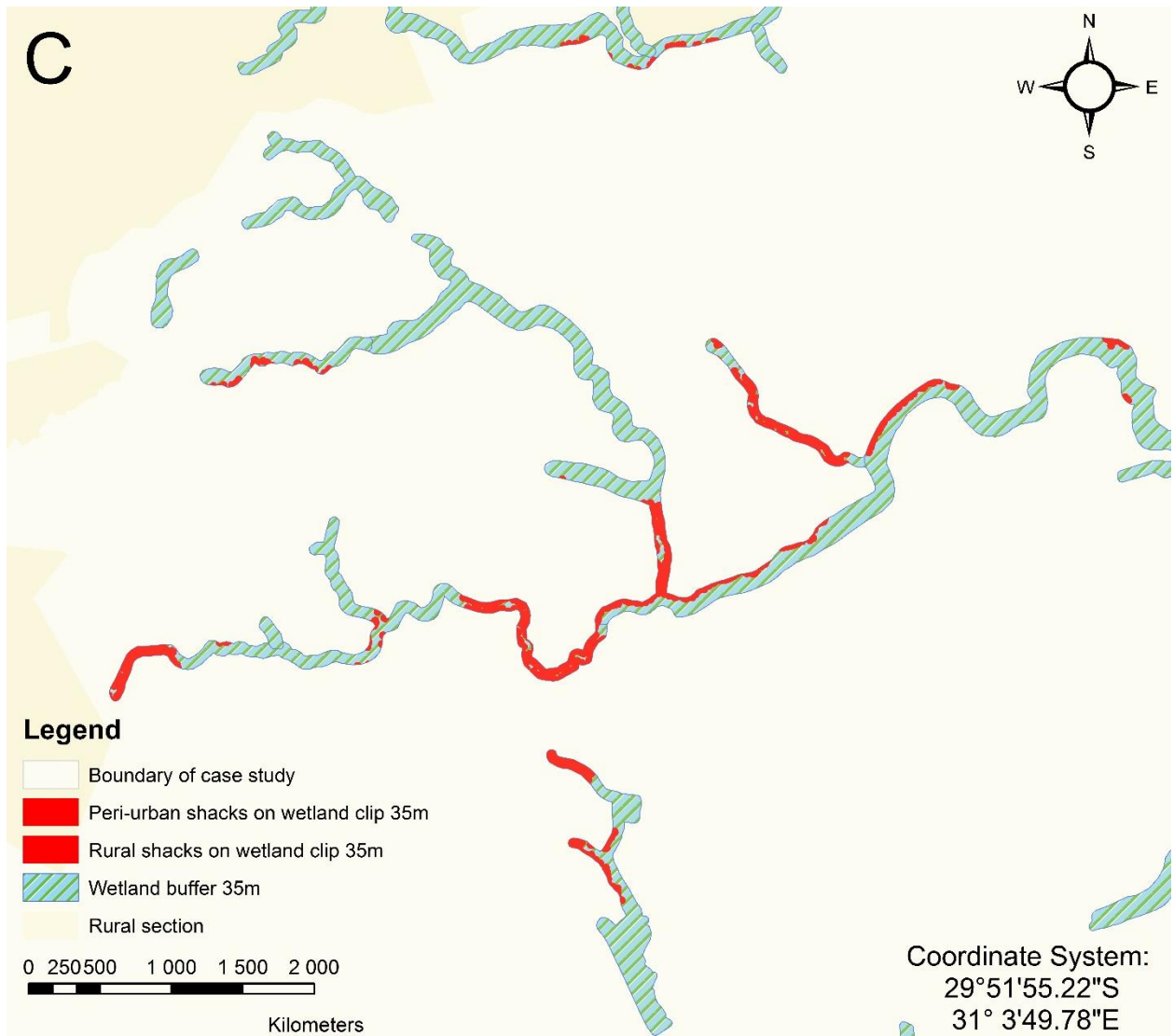


Figure 15.16. Wetland 35m A (overview); B (rural view) and C (peri-urban view)

Source: Authors compilation through ArcGIS 10.4.1 (2017)

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