A COMPARATIVE KNOWLEDGE MAP OF PHD RESEARCH IN RELATION TO PRIORITY ENVIRONMENTAL ISSUES IN SOUTH AFRICA

by

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Declaration

I Unine van den Berg hereby declare that the thesis Title: A COMPARATIVE KNOWLEDGE MAP OF PHD RESEARCH IN RELATION TO PRIORITY ENVIRONMENTAL ISSUES IN SOUTH AFRICA, which I hereby submit for the degree of Doctor of Philosophy Environmental Management at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution.

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Abstract

The content, nature and characteristics of South African PhDs in environmental management are unknown. It is not clear what the research themes or trends between 1998 and 2017 were, and if the strategic research themes that are important for South Africa (included in legislation, policies and plans) were taken into consideration. The PhDs and the strategic driver documents were compared to establish if there is any alignment between the two. There is no synthesised document that compares the current body of knowledge, in the form of PhDs, to that of the key strategic drivers that South Africa ascribes to, which in turn may guide future research needs and identify niche research areas. The study aimed to establish the level of alignment between South African environmental management and science PhD knowledge production and priority environmental issues in South Africa. The philosophy that underpinned this research was interpretivism, which involves a researcher to interpreting elements of a study and focusing on meaning, which mostly only materialises at the end of the study. The method used for this study was a systematic literature review and content analysis. The data, in this case completed PhDs, were manually examined, and then, to ensure objectivity, the text-mining software program, Leximancer, was used for further analysis. A comparative knowledge map was then generated from the data analyses as a strategic tool to support knowledge translation to address the future priority research areas that needs to be addressed. The results of the study indicated that research mostly focused on biodiversity, habitat and resources, and social environmental aspects relating to the people of South Africa. Two major issues that did not receive much attention was the waste and greenhouse gas and the green or low carbon economy, renewable energy themes. In terms of the government documents, the Biodiversity Act and Air Quality Act were well represented. Many PhDs addressed aspects in the themes that were identified from the State of the Environment reports. The aspects identified by a report from Kok and Pietersen from 1999 and the NDP 2030, received less coverage in the completed PhDs. This study identified research gaps that need to be explored to ensure that PhDs are relevant to the development goals of South Africa, as stipulated in the strategic environmental documents. It is recommended that prospective PhD students consider the national environmental strategic drivers and objectives when considering research themes, especially the NDP 2030. This will ensure that greater alignment is achieved between

the knowledge production of PhD studies and the strategic environmental goals, legislation, policies and plans for developing the country.

Acknowledgements

Dankie U en almal.

Abbreviations and acronyms

ASSAf	Academy of Science of South Africa
AQA	Air Quality Act
BAO	Belief-Action-Outcome
CAES	College of Agriculture and Environmental Sciences
CC	Climate change
CHE	Council of Higher Education
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DHET	Department of Higher Education and Training
ECA	Environmental Conservation Act
EIA	Environmental Impact Assessment
HEI	Higher Education Institutions
HEQC	Higher Education Quality Committee
ICMA	Integrated Coastal Management Act
NDP	National Development Plan 2030
NEMA	National Environmental Management Act
NMU	Nelson Mandela University
NPHE	National Plan for Higher Education
NRF	National Research Foundation
NQF	National Qualifications Framework
NWU	North West University
RU	Rhodes University
SAEO	South Africa Environment Outlook
SARChI	South African Research Chairs Initiative
SAQA	South African Qualifications Authority
SEMAs	Specific Environmental Management Acts
SETA	Sector Education and Training Authority
SOER	State of Environment or Outlook Reports
UCT	University of Cape Town
UJ	University of Johannesburg
UF	University of Fort Hare

UFS	University of the Free State
UKZN	University of KwaZulu-Natal
Unisa	University of South Africa
UP	University of Pretoria
US	University of Stellenbosch
UV	University of Venda
UWC	University of the Western Cape
Wits	University of the Witwatersrand
WMA	Waste Management Act

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Chapter 1 – Introduction

1.1 Background

Sustainable development issues can be traced to the 1972 United Nations Conference on the Human Environment held in Stockholm. The concept of environmental management and sustainable development only later became mainstream by two events that had global consequences and further increased the awareness of how unsustainable development was having a negative effect on the well-being of both the Earth and human beings. The first was the publication of the document "*Our Common Future*", in 1987, which stated that life on Earth, was being threatened by the rapid deterioration of the Earth and that influential political action was needed (Department of Environmental Affairs and Tourism (DEAT), 2004:6). The second event was the Conference on Environment and Development in 1992, held by the United Nations, which is more commonly known as the Rio Earth Summit (DEAT, 2004:6).

The United Nations adopted the Millennium Declaration in 2000, whereby member states agreed to meet common responsibilities that would lead to better international relations for the benefit of the Earth. One of these obligations was to manage natural resources in accordance with sustainable development principles. In 2002, the World Summit of Sustainable Development was held in Johannesburg, which established a Plan of Implementation, although this plan seems not to have been implemented (Strydom & King, 2015:iv). This World Summit held in Johannesburg brought international environmental issues to the fore in South Africa as well.

South Africa had some environmental legislation in place as early as 1956. This included legislation that covered the control of drinking water, which was governed under the Water Act No. 54 of 1956, pollution, under the Atmospheric Pollution Prevention Act No. 45 of 1965, and the protection of animals through the Animal Protection Act No. 71 of 1962. The general environment of South Africa was further protected under the Environmental Conservation Act (ECA) No. 73 of 1989.

In 1996, South Africa adopted a new Constitution, with Section 24 providing for the protection of the environment. Subsequently, in 1998, the National Environmental

Management Act (NEMA) No. 107 of 1998 gave effect to Section 24 of the Constitution (Strydom & King, 2015:v). Under the auspices of NEMA, five Specific Environmental Management Acts (SEMAs) have been promulgated to ensure the proper management of biodiversity, protected areas, air quality, coastal areas, and waste. The heightened international awareness and promulgated legislation made the management of the environment pertinent in the mind of scholars and government officials. The environmental agenda started to feature in local and international development plans and frameworks. The intensified focus on the urgent need to both care for, and raise awareness around, environmental destruction has led to the rise of a study field environmental management.

Scholars across a number of disciplines furthered the inclusion of environmental management studies into curricula (Strydom & King, 2015:iii). That said, in South Africa, the environmental management field of study was mostly incorporated within the various geography departments of South African tertiary education institutions.

South Africa has 26 public tertiary education institutions, which are divided into three categories: nine universities of technology, six comprehensive universities and eleven traditional universities (De Jager & Frick, 2016:443). The first university to formalise the incorporation of environmental management into geography was the University of the Witwatersrand, which attached the name 'Environmental Studies' to the Geography Department in the 1950s (Visser, Donaldson & Seethal, 2016:72). In 1973, the University of Cape Town followed by establishing a Chair of Environmental Studies and in 1985 the department changed its name to the Department of Environmental and Geographical Sciences.

The Geography Department of the University of KwaZulu-Natal included in 1988 the word 'environment' in their department's name (Visser *et al*., 2016:172). In 1989, the name Environmental Studies appeared in the name of the Geography department at Unisa. Since the merger between Unisa and Technikon South Africa in 2004, an independent, fully-fledged environmental sciences department was established at Unisa.

In the 1990s, most other traditional and comprehensive South African universities followed suite (Visser *et al*., 2016) (Table 1.1). Diplomas and degrees were awarded in an array of disciplines, and postgraduate studies including PhD dissertations or theses.

Table 1.1: Inclusion of environmental management/science/studies at South African universities.

1950 – 1970's	1980's	1990's	2000's
University of the Witwatersrand (1950s)	University of KwaZulu-Natal (1988)	Walter Sisulu University (1990s)	University of Limpopo (2002)
University of Cape Town (1973)	University of Fort Hare (1980s)	University of Durban –Westville (1990s)- (Now included in the University of KwaZulu-Natal)	University of Zululand (2002)
	Unisa (1989)	Potchefstroom University for Christian Higher Education (1990) (post- merger with three other institutions now known as University of the North-West)	University of Pretoria (2002)
		University of the Free State (1991)	
		Rand Afrikaans University (1994) (post-merger with two other institutions now known as University of Johannesburg)	
		University of Venda (1995)	
		University of the Western Cape (1995)	
		University of Stellenbosch (1995)	
		Rhodes University (1998)	

(**Source**: Adapted from Visser *et al*., 2016).

This background triggers interest in the question as to whether a PhD in environmental management/sciences/studies truly reflects national, environmental, strategic and niche areas to the benefit of South African society, the needs of the profession and, more importantly, the environment.

The overall picture of the content regarding PhDs in environmental management/sciences/studies is unclear, as the major themes and trends of research post the introduction of environmental legislation in 1998, are unknown. The

government of South Africa has promulgated environmental-related legislation and subscribed to national and international development plans.

1.2 Rationale

The first port of call to establish the novelty of this research was a search on the South African National Research Foundation's (NRF) NEXUS database. The terms, "systematic literature review" and "environmental" were used to search for keywords. A total of 1884 results were found but only one masters study relating to the type of research proposed in this study. This particular master's study, done by Van der Linde (2003) (through the University of Johannesburg), focussed on the publishing of environmental management/sciences/studies orientated research by geographers in South Africa between 1996 and 2001. Brereton, Kitchenham, Budgen, Turner and Khalil (2007:571) indicated that this type of content analysis research has also been done in other disciplines, especially the medical, social, education, and information systems profession. PhD research undertaken in the field of environmental management, by South African universities between the years 1998 and 2017 has not been analysed and compared to environmental legislation, surveys, plans and government documentation.

The rationale for this study is to extract the critical, priority, environmental management research topics from selected strategic documents, and to conduct a comparative analysis of environmental management related PhD research completed between 1998 and 2017. If a disparity between environmental priorities and completed PhD research is found, this study will contribute to a potential alignment between priority issues and research foci. This will indicate, and may avert research to continue to explore, research priority topics that are not in the interests of the country, the continent of which it is part, and, ultimately, the environment. If alignment is attained, the study will still be significant, as it will indicate that research in the environmental management domain is focusing on the correct aspects that may only be of benefit to the country and its people.

1.3 Research Problem and Research Questions

A philosophical discussion usually prevails with regards to 'what' or 'who' should guide research. Should it be government or researchers themselves? Governments are signatories to international treaties, is subsidising PhD research and using taxpayer's money to do so. There is numerous literature that states that taxpayer's money is wasted if research is done that may not be in the interest of the country and its people. However, the possible notion that government documents could be weak, and that academic freedom should prevail is acknowledged so governments should not set the research agenda for all research endeavours.

The perpetual conundrum between the autonomous role that researchers have to focus on under-researched fields and conducting research to drive policy development, and the role that researchers have to conduct research in response to strategic government direction is acknowledged. There would and should be both research in response to strategic direction as well as research that drive policy reform as research is at the forefront to discover and drive emerging issues.

Further, in the case of research in the environmental management field, it can be argued that this field is an applied field that deals with real world problems and research is therefore expected to demonstrate real world relevance and alignment with societal issues.

This research is not advocating that research should only use government themes to conduct research, but merely that it is an important matter that must be investigated to test the alignment of PhD with government priorities. The purpose of the research is to identify research gaps in terms of the legislation, documents, and plans of government to assist South Africa and Africa to reach its goals as per the NDP 2030 and the Agenda 2063.

The research problem under investigation is therefore that the content, nature and characteristics of South African PhDs in environmental management are unknown. It is not clear what the research themes or trends were between 1998 and 2017. The

environmental research themes that are of strategic importance to South Africa, which are included in legislation, policies, plans and goals, must be explored and determined.

The PhDs and the strategic driver documents must be compared, to establish if there is any alignment between the two. There is no synthesised document that compares the current body of knowledge, in the form of PhDs, to that of the key strategic environmental drivers that South Africa ascribes to, which in turn may guide future research needs. It is unclear what environmental management research is focusing on, and if the research is making a significant contribution to the environmental management study field of the country. The primary research question that will guide this study is subsequently stated as follows:

“How well are the contributions of South African environmental management/sciences/studies PhDs aligned towards addressing priority environmental issues in South Africa?”

The study aims to establish the priority environmental issues in South Africa. The level of alignment between environmental management/science/studies PhDs and the identified priority environmental issues in South Africa, are investigated. The following objectives are identified to operationalise the aimed research:

1. To interrogate the national environmental management policies, plans and goals for South Africa in order to extract priority environmental issues and transform these into strategic research themes.
2. To systematically analyse the nature and characteristics of South African PhD research in environmental management/sciences/studies between 1998 and 2017.
3. To critique comparable alignment of PhD research done in environmental management/sciences/studies with the identified strategic research themes in government documents.
4. To develop a comparative knowledge map where the knowledge contributions of South African PhDs in environmental management/sciences/studies will be aligned to the identified strategic research themes.

This knowledge map will then be interrogated to address the following research questions:

1. What is the level of alignment between the PhD focus areas and the strategic research themes?
2. Which strategic research themes have not been covered by the related PhD research?
3. What are the research gaps that should receive priority in future PhD studies in terms of the identified strategic research themes?

The significance of this study is indicated as follows: It is currently not known if research in environmental management is supporting environmental legislation or the development plans of the country. The research will indicate what focus areas the PhD research currently covers in the domain of environmental management in South Africa. The investigation will highlight areas that have been over-researched, not been researched much, or those areas which have been completely neglected.

This study intends to report on a systematic literature review and content analysis of PhD dissertations completed between 1998 and 2017 in the field of environmental management, to ascertain the major themes and any trends, which in turn will be compared to strategic drivers, legislation, reports and plans, to determine alignment among them and future research needs. This study can establish whether the PhD research in South Africa is aligned with past, present and future environmental themes and trends.

A comparative knowledge map will then be generated from the analysed data, as a strategic tool to support knowledge translation, in order to address where future priority research needs should be addressed. The rationale of this knowledge map is to interrogate this as a knowledge asset to identify critical knowledge that is worthwhile for future research endeavours. As such, it is possible to capitalise the knowledge which future generations should research as a priority gap area. In order to structure the research, the study was decided to be delineated as can be seen in the following section.

1.4 Delineation of Study

Research needs to be delineated to make sure that the study has boundaries and stays focussed on the research problem and the scope of the study. The PhD degrees, and the nature and content of the identified documents that will be used, as well as the time frames for the study, are the main concerns that need to be delineated.

The themes and niche areas found in legislation and other relevant literature, such as the Kok and Pietersen survey report (1999), State of Environment or Outlook Reports and development plans, will be compared to PhD studies. The PhDs that will be included would only have been done by students at the eleven traditional and six comprehensive South African universities (Table 1.1), focused only on South Africa in environment-related research, and supervised within these environmental sciences/study/management departments. PhD studies done on South Africa by other international universities will not be considered for this research, as this research wants to establish if South African institutions are considering direction-giving documents. This exclusion will ensure that the study can establish if the PhD research in South Africa is aligned with past, present (Research Question 1) and potential future (Research Question 3) environmental themes and to highlight the gaps or research themes (Research Question 2).

Doctoral degrees that were undertaken at departments that offer environmental degrees relating to environmental issues between 1998 (the inception date of NEMA) and 2017, will be analysed. The study, from here on forward, when referring to the data, (the PhDs) will refer to 'environmental studies', which will include environmental management, environmental studies and environmental science. It is necessary to have one description, as the environmental departments at different universities award degrees in all three sub-disciplines.

A further issue of clarification is the interchangeable use of the term ‘dissertations’ and ‘thesis’ at different institutions. In this document, ‘dissertations’ will be used to describe a master’s degree and a ‘thesis’ the PhD study. Only PhD studies at the different universities will be investigated, irrespective of whether it is called a ‘dissertation’ or ‘thesis’. Master’s degrees will not form part of this research, as the South African

Qualifications Authority (SAQA) level descriptors only expect PhD research to create new research concepts and new knowledge or practice (SAQA, 2012).

In terms of legislation, only the NEMA and its SEMAs will be used for this study, as it includes the themes and aspects that are deemed important for the environment of South Africa. The National Development Plan 2030 (NDP) does include agriculture under the environmental section, but this will not be investigated or included in the research, as agriculture is treated as a separate discipline at universities.

Other statutes, such as the National Water Act No. 36 of 1998, the National Forest Act No. 84 of 1998, the Marine Living Resources Act No. 18 of 1998 and the Mineral and Petroleum Resources Development Act No. 28 of 2002 will not be considered for the study. The NEMA encompasses these aspects in its principles and in the SEMAs. The discussion regarding the delineation of this research, highlights the limitations of the study.

1.5 Limitations to the Study

Stability, reproducibility and accuracy influence reliability when conducting a qualitative analysis of content (Weber, 1990:120). Reliability problems may occur out of the uncertainty of the meaning of words, definitions, or coding rules (Weber, 1990:118). The understanding of the coding rules by the researcher may change over time, which can lead to subtle changes in meaning, but great unreliability at the end (Weber, 1990:123). Elements of the data may be related to several categories, which could affect the coding and categorisation (Elo & Kyngäs, 2007:113). Coding fatigue may set in, and mistakes in the coding may occur as the process proceeds (Weber, 1990). If the data is reduced too much, the integrity of the data can be lost (Elo & Kyngäs, 2007:123). Only one researcher will determine the coding, categories and themes.

Subjectivism and excessive interpretation by the researcher can stand in the way of a successful analysis (Elo & Kyngäs, 2007:114). By placing too many items into one category is also a threat to the research; therefore, methods of validity and inter-reliability will be used to offset the possible influence of the limitations stipulated above.

Methods of validity and inter-reliability that will be used include the verification of PhDs with the universities where the degrees were awarded. The PhDs will, in addition to manual examinations, further be text-mined by the software program Leximancer. Details on these methodological aspects will be discussed in Chapter 3.

Not all government documents containing legislation, policies, national and international plans and goals will be used, but only those deemed the most appropriate for the research, and to create a comparative knowledge map.

Another limitation of the study is that environmental-related research can take place in other disciplines such as engineering and microbiology, for instance. Such disciplines are not part of the sampling scope of this study. It is also possible that a student can register and enrol from a non-South African University and conduct research on South African environmental aspect. This is also not part of the scope for this study. As with every research project that is undertaken, any ethical issues need to be specified.

1.6 Ethics

According to Leedy and Ormrod (2013:104), ethical matters can be categorised in four categories: protection from harm, voluntary participation, privacy, and honesty with other professional colleagues. Most of these categories are aimed at protecting living beings when collecting and analysing data and reporting on findings. The data for this study will be collected and analysed by using a systematic literature review method. It is not foreseen that living beings would be caused harm or that their privacy would be intruded upon. All documents that will be used in the data collection process are in the public domain, and therefore do not require access permission.

Anonymity need not be ensured. It is common practice to analyse the information which is in the public domain, such as scholarly articles, research which is found on the Nexus database, Google, and in open library sources. For example, the library websites open to the public in institutions such as the University of Johannesburg (UJ), the University of Cape Town (UCT), the University of South Africa (Unisa), the University of KwaZulu-Natal (UKZN), etc. Analysis of Higher Education institutions

(HEI) research practices is compared, classified, ranked and rated, with the institutions' names attached. Table 1.2 lists articles in which this is common practice:

Table 1.2: Example of articles in which the names of institutions are mentioned.

Mouton, and Valentine (2017). **Specifically, page 7.**
De Jager and Frik (2016). **Specifically, page 447.**
Sandham and Retief (2016). **Specifically, page 456.**
Visser (2016). **Specifically, page 42-43.**
Bozkurt, Kumtepe, Kumtepe, Aydin, Bozkaya, and Aydin (2015). **Specifically, page 18.**
Sinha and Macri (2002). **Specifically, page 142-145.**
Caffarella (1999). **Specifically, page 8.**

(**Source**: Own).

As the study will rely on interpreting the data, honesty and transparency are essential, and objectivity must be present throughout the study. The findings of the study must not be biased to guarantee that the research question will be answered. Paraphrasing, as well as acknowledging sources and authors, will avoid plagiarism by further using the Harvard referencing system.

The research was submitted to the Ethics Committee of the College of Agriculture and Environmental Sciences (CAES) for consideration, and approval was granted with the following reference number: 2017/CAES/152. The remainder of the document will be structured according to the chapter layout, below.

1.7 Chapter Layout

Chapter 1 – Introduction

In this chapter, the research idea was introduced and developed. Motivation for the study was formulated and explained. The research problem, research question, aims and objectives were articulated. Chapter 1 further outlined what can be expected in the rest of the dissertation (Mouton, 2001:122).

Chapter 2 – Literature Review

This chapter starts with a discussion of the professional, policy, national and theoretical context of the study (Plowright, 2011:8). The policy and national contexts deal with the history of the environmental agenda and related documents, as well as Higher Education in South Africa. Under the theoretical context discussion, an overview of what literature has been included in the study and the theories that are related and form the basis for the research, is given. Definitions of key aspects and concepts are deliberated upon.

Chapter 3 – Research Design and Research Methodology

The research philosophy and research design are described and discussed in Chapter 3. The research methods, consisting of the data sampling and collection are included and deliberated upon. The data that was collected consists of a description of the universities in South Africa that produced PhD research in environmental studies between 1998 and 2017, and the actual PhDs found in the institutional repositories of the universities. The data also includes government documents as set out in Chapter 2. The automated text-mining process of Leximancer, and the outputs created, are explained and reflected on. Reliability, research bias, verification and the limitations of the research can further be found in this chapter.

Chapter 4 – Analysis, Results, and Findings of the PhDs

The aim of Chapter 4 is to establish the content and nature of the two hundred and fourteen (214) PhDs at the different universities. Before the analysis could be done, the context of the government documents had to be determined. Once the context was known, the government documents were examined to create themes and aspects, and then placed in a table. A manual analysis of the PhDs was executed, followed by using text-mining, with Leximancer, to ensure credibility. Datasheets were generated, that indicated the results of both the manual and the Leximancer process. The information of the PhDs in the datasheets was counted, categorised, and transferred to the table that consisted of the government document themes and aspects. The results

uncovered main themes. Once the information of the PhDs was known, an alignment with the government documents could be executed.

Chapter 5 – Alignment of PhDs and Comparative Knowledge Map

In Chapter 4, the detail of each PhD was determined. In this chapter, the alignment of each PhD with the government documents is done. The details of the PhDs are matched with aspects in a government document, analysed, counted and discussed. A summary and illustration in the form of a comparative knowledge map is developed from the results of chapters 4 and 5. A brief explanation to describe what the comparative knowledge map illustrated, is inserted. The combination of all the PhDs done in South Africa each year, from 1998 to 2017, under the themes and aspects of the government documents, is discussed. Research gap areas are identified and highlighted.

Chapter 6 – Synthesis, Recommendations and Conclusion

The results of the analyses in chapters 4 and 5, and the resultant comparative knowledge map, are discussed in Chapter 6. The results are related back to the fundamental theories, research method and literature review. This concluding chapter ensures that the research aim, and objectives have been reached, and the research questions answered. The findings are linked and related to the literature review and the theory (Mouton, 2001:124).

The research questions and the achieving of objectives are declared. The significance and importance of the study are highlighted. Recommendations, in terms of further future research, and possible identification of research areas in environmental management, are made in this final chapter.

Chapter 2 – Literature Review

2.1 Introduction

This study aims to establish if the content, nature and characteristics of South African PhDs in environmental studies, which is unknown, is aligned with priority environmental areas of the South African government. The two main concepts that must be kept in mind throughout this study are the environmental documents of South Africa and PhDs done in and about South Africa. These two concepts and the research study itself needs to be placed in context. The discussion of contexts is helpful and ensures an understanding of perspectives that are actively part of this particular research (Plowright, 2011:10). For that purpose, the five contexts of Plowright (2011) are used.

Plowright (2011:8) distinguish between five contexts on which research are based. The literature review will follow these five contexts: the professional, organisational, policy, national and theoretical contexts. When discussing the professional and organisational context of the study, the employment background of the researcher is considered.

The theoretical context, as stated by Plowright (2011), offers the conceptual framework for the study. In the first part of the theoretical context section, the literature of studies that employs similar methods, are included. In the second part of the theoretical context section, supporting ideas and theories fundamental to the research are explained. Theories that were considered will only be mentioned briefly. The two theories – the complexity theory, and the Belief-Action-Outcome (BAO) Framework, deemed fundamental to the research, are discussed, and their relation to this research emphasised.

The chapter concludes with an overview and justification of the national and policy context relating to the main concepts: environmental documents of South Africa, and PhDs done in the environmental management field. When discussing the national and policy context, two of the main constructs – the environment, and Higher Education in South Africa – will be deliberated upon by focusing on the history, policies and legislation. A motivation as to why certain documents were included in the study, is

given after each of the discussions regarding the environment and Higher Education in South Africa. Figure 2.1 provides an overview of the chapter layout and the different contexts of the study:

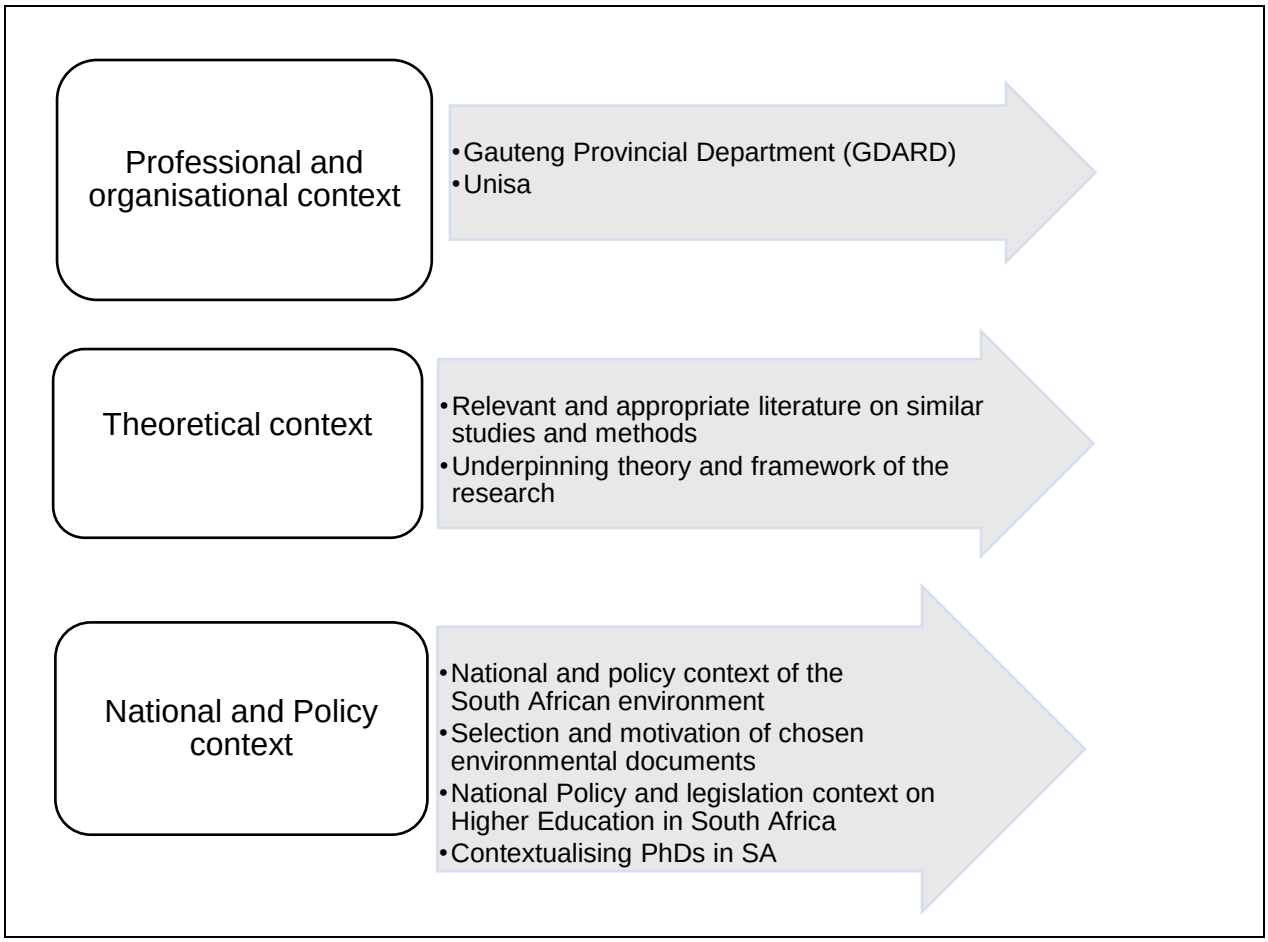


Figure 2.1: Overview of the chapter layout and contexts of study. (**Source**: Own).

2.2 Professional and Organisational Context

The employment and professional history form part of the professional and organisational context of this study. The professional and organisational context offer the background of the researcher and provide the reader with a professional perspective of an organisation. The inclusion of these two contexts creates an awareness of any biases that the researcher might have as a result of previous experiences or attitudes towards the chosen research (Plowright, 2011:10). The researcher of this study has worked in the Gauteng Provincial Government Department (Gauteng Department of Agriculture and Rural Development – GDARD) concerned with the environment, for twelve years. During this twelve-year period,

numerous pieces of environmental legislation, regulations, reports and development plans were produced, in which the researcher participated. The review and recommendations with respect to proposed developments, and the NEMA regulations, were also part of the researcher's job description. The researcher then took employment as a lecturer in the Department of Environmental Sciences at the University of South Africa (Unisa).

Unisa is an open distance education institution with approximately 400 000 students enrolled from 130 countries. It is the largest university in South Africa and on the African continent, as well as the oldest in South Africa, celebrating its hundred-and-forty-fifth year of existence in 2018 (Association of Commonwealth Universities, 2016:1). Unisa was founded in 1873 as the University of the Cape of Good Hope and received a Royal Charter in 1877 (Singh & Liang, 2010:21). During the early history of Unisa, it was only an examining agency for the Oxford and Cambridge universities. In 1946, it became a distance education university (Singh & Liang, 2010:21).

In 2004, Unisa merged with the Technikon SA and the distance education component of Vista University (Singh & Liang, 2010:21). Unisa operates in terms of the Higher Education Act No. 101 of 1997 and is accredited by the South African Department of Higher Education and Training (DHET), the South African Council on Higher Education (CHE) and the South African Qualifications Authority (SAQA) (Unisa, 2018a:1). The university has different colleges; of interest to this specific research is the College of Agricultural and Environmental Sciences (CAES). Within this college, the Department of Environmental Sciences is positioned where research in environmental studies is done.

It is in the interests of the Department of Environmental Sciences (Unisa), and all other departments that offer environmental management, that researchers know what the research trends are in environmental management and environmental sciences. The alignment of the research with legislation and other government documents, is in the national developmental interest, and of importance to the quality of the environment for future generations. The discussion above gives context to the specific interest in this research. When deciding on the research topic, the theoretical context was

investigated. This is done to ensure that other studies of this nature exist, and what theories are underlying the research.

2.3 Theoretical Context

The theoretical context of the conceptual framework of the study includes relevant and appropriate literature on similar studies and methods in the studied discipline and that of other disciplines. The conceptual framework further underpins the ideas and theories on which the research is based (Plowright, 2011:12).

2.3.1 Relevant and appropriate literature on similar studies and methods

At a meeting in October 2013, with regard to PhD degrees in Africa, funded by the National Research Foundation (NRF) and the Carnegie Corporation of New York, an agreement was reached that Africa needs more PhDs to produce more high-level skills to support their growing economies. The National Development Plan of South Africa further prioritised an increase in doctoral degrees from 1 876 in 2012 to 5 000 by 2030 (Cloete, Mouton & Sheppard, 2015:2). A key issue may be an excess of PhD students in the market, and the fact that a vast number of these students find it difficult to transfer their skills to the employment market (Cloete *et al*., 2015:5). The alignment of PhDs with the country's development goals were not clear.

Mouton (2010:67) asked the question whether scientists pursue research that is in line with a country's priorities, or if it is of minor concern. Keeping in mind the differences between research fields, the results of his enquiry indicated that a significant percentage of students, in sub-Saharan countries agreed that their work was aligned with the development plans of their country. The percentage of students that agreed with the statement in the field of arts and humanities was 75%, 87% for economics and management, and 83% in the sciences (Mouton, 2010:67).

Environmental management falls within the category of sciences, which had an 83% agreement that students do take into consideration their countries' developmental goals. The number specifically for environmental management in South Africa has not been determined. A number of similar studies have been undertaken in the rest of the

world to determine what PhD research focuses on, even though different methods were used.

Bilotta, Milner and Boyd (2014:68) explored the use of a Cochrane systematic review to inform environmental policies. The study method of systematic reviews initially intended to only examine the efficiency of healthcare treatments and is known as a Cochrane Collaboration (Bilotta *et al*., 2014:68). There was a belief that a systematic review was only relevant to the field of medicine. The existence and work of the Cochrane Collaboration prompted the development of another systematic review body – the Campbell Collaboration, and, within this body, the Collaboration for Environmental Evidence (CEE). The research by Bilotta *et al*. (2014) discovered that in 2014, worldwide, over sixty (60) systematic reviews were conducted in the environmental field (Bilotta *et al*., 2014:74). They noted that society is on the verge of an evidence transformation pertaining to environmental management, but that researchers and their new contributions are needed. The CEE further proposed a five-year plan to promote and conduct the use of systematic reviews in the environmental sector. The use of systematic reviews in the environmental field can ensure inclusive and reproducible summaries of evidence, which in turn can guide policy decisions (Bilotta *et al*., 2014:74). Other disciplines have also conducted similar research initiatives on international, national and South African level.

On an international level, Kantorski (1995) studied string education in the music discipline. The purpose of his study was to analyse the content of doctoral research between 1936 and 1992, relating to string education. He stated that the identification and analysis of trends in research could disclose students' interests and provide perspective for refining future research. The content analysis highlighted frequencies of topic areas and research methodologies. After completion of the study, he could reveal study areas that were under-researched, and areas that had the most research (Kantorski, 1995:293). Caffarella (1999) did another international study on doctoral degrees about education in the specific field of educational technology.

A content analysis of educational technology doctoral degrees from 1977 to 1998 was undertaken (Caffarella, 1999). The major research themes, how the themes and methodologies have changed over time, the research trends, and emerging trends,

were explored. Caffarella (1999:483) stated that studies like these lead to a better understanding of doctoral research and the changing nature of the field. The addition of new technology into the world changes the nature of the research. An example of this is that in the late seventies research dealt with film and video, but more current studies dealt with computers. Research follows new developments (Caffarella, 1999:490). This study further identified research methodologies that were used over the years. It could be seen that the methods used in the early years were mainly comparison studies.

Clark (1983), as cited by Caffarella (1999:483), wrote about the problems of comparative studies, which sparked a debate on the challenges of this method, whereafter the amount of comparison studies diminished. Experimental studies also made way for more qualitative methodologies. Caffarella (1999) also compared 2 689 PhD dissertations, completed at 55 universities in the United States (USA), on educational technology. Research on doctoral degrees in the Honours education field were also deemed important, and a review was carried out by Holman and Banning (2012).

International doctoral degrees on Honours education (1987-2011) were explored. Holman and Banning (2012) studied the general attributes, thematic subjects and topics, and whether the findings have been published, and were sought by using a qualitative meta-study bounded framework with a content analysis approach. An inductive coding strategy was followed. Each dissertation abstract was allocated a subject and topic code, which lead to a thematic structure. Peer debriefing and consensus was used to ensure trustworthiness of the coding process. As per the study by Caffarella (1999), this study also examined the methodologies that were used in the PhD degrees and the institutions where it was generated. It was noted that comparative analysis was incorporated, and more quantitative methods were utilised. There were six (6) subject codes identified, and sixteen (16) related topic codes were included through a comparative analysis of the dissertation abstracts (Holman & Banning, 2012:48). The field of education is not the only field that conducted international research reviews using a content analysis method. The tourism field conducted similar research as can be seen from a study done by Chan and Hsu (2016).

Chan and Hsu (2016) wanted to identify international trends and research themes in environmental management, as part of their tourism study. They did a content analysis of articles relating to environmental management listed on Google Scholar between 1993 and 2014. The first thirty (30) pages of research results were used to compile a list of major themes. The study revealed that a variety of themes relating to sustainable development were prevalent, as well as environmental policy and strategy planning. Carbon foot printing, environmental management systems, green marketing and advertising, supply chain management, people's attitudes and behaviour and the influence of stakeholders on a company, were also themes that have been studied and published the most (Chan & Hsu, 2016:906). Researchers also focus on aspects on a national level in their own countries. Reviews done in Turkey, Finland, Spain and the USA are discussed in the following paragraphs.

Erdogan (2015) researched trends in problem-based learning in Turkey between 2002 and 2013. A content analysis was employed to study learning- and research domains, research designs, subject groups, group sizes and the length of treatments. Masters and doctoral degrees were included, to obtain data. The main purpose of the study was to develop a framework that would identify research trends. A dissertation classification form was developed to extract the data, which is similar to the method discussed in this proposal. The form was examined by colleagues and experts, and then applied to a sample of dissertations to establish reliability. The results of the trial were discussed to obtain consensus, after which the final version was applied to the entire data set. The data was analysed by using an electronic database SPSS20 (Erdogan, 2015:310).

Bozkurt *et al*. (2015) did another study in Turkey on researched trends in the Turkish distance education field. The benefit of their study was that research trends were identified, and a research agenda could be set. They further compared their findings with the global perspectives on current trends to establish similarity.

A focus of nursing education research in Finland was done to describe the field between 1979 and 2014 (Vierula, Stolt, Salminen, Leino-Kilpi & Tuomi, 2016). The constructs that were included in the study were methods, study informants, validity, reliability and ethics. The unit of analysis comprised sentences and paragraphs

conveying the purpose and aims of the dissertations, which were later categorised into 'sub' and 'main' categories. The study revealed the topics that were extensively researched and those that were under-researched. The data collection method that was used the most often was surveys and interviews. The study could also calculate that nursing education research needed more research outputs, as it only covered 12.3% of all dissertations done, in relation to other research areas in the nursing and caring sciences (Vierula *et al*., 2016:151).

Doctoral degrees in public relations in Spain between 1965 and 2004 were examined by Xifra and Castillo (2006), to establish the level of theory development in the discipline. The subjects that were considered included the growth of the discipline, the universities, language, gender, and topics. The dissertation used for the study was coded by two independent coders to ensure inter-coder reliability and agreement. The study revealed that theory-building related dissertations were insignificant and needed attention. The study by Xifra and Castillo (2006:307) also indicated that the political and administrative context of Spain in the early years, under dictatorship, could be seen in the themes of early dissertations. Horton and Hawkins (2010:383) stated that the result of their content analysis on social work dissertations in the USA highlighted the need for a paradigm shift to transform the social work curriculum. Content analysis was not only done on PhD dissertations, but also on research articles.

A study on the research trends in science education analysed research articles published in specific journals from 2013 to 2017. The study established what the main research topics were in the journals, and the research preferences of the researchers who wrote in the journals. The changing trends could be seen, and the declining topics were highlighted in this study (Lin, Lin, Potvin, & Tsai, 2018:367). An investigation of studies and articles done in the Reverse Logistics and Closed Loop Supply Chain Management (RL&CLSCM) research areas and published in the International Journal of Production of Research (IJPR) from 2013 to July 2017, was completed. The study followed a content analysis approach to identify the articles and then their characteristics. The content analysis managed to classify the papers into main categories and sub-categories, after which an identification of the papers' attributes could be done. The content analysis revealed research gaps that could be used for further research (Kazemia, Modak & Govindan, 2018).

A study by Lindebaum, Brown and Al-Amoudi (2020) inspected the extent to which neuroscience in management adhered to the ethical consequences, and in which studies ethical aspects were recognised, and in which ones not. This study was used to provide proof and to refute claims made by other authors. New opportunities in studying ethical and practical aspects in neuroscience were opened with this research.

South African researchers have also conducted systematic reviews on doctoral degrees. Cloete *et al*. (2015:27) established that Garbers (1960), as part of his doctoral study, produced the first systematic analysis of doctoral graduation trends in South Africa for the period 1920-1957. The aim of Garbers's PhD was to determine the percentage of students who continued with postgraduate studies up to doctoral level, and if the skills were enough for the country's needs, and to compare his findings with those of international universities. More field-specific studies in South Africa then followed. Such studies included the field of accounting and tourism.

De Jager and Frick (2016) conducted a study to determine a profile of accounting doctorates produced in South Africa between 2008 and 2014. The total number of doctorates, their attributes or sub-disciplines, and supervisory capacity, were studied. The public institutional repositories of four research-intensive universities were scrutinised, after which the trends were defined, and a comparison made between the four universities. The challenges experienced during the search of the repositories included aspects such as the date of upload onto the repository having no significance to the graduation date, some records not having the full-text available, or the database being incomplete. Discipline-specific investigations between universities provide an understanding of the nature and context of doctorate degrees at these institutions, which will be of interest to academics and prospective students alike (De Jager & Frick, 2016:440). As stated above, the tourism field also conducted review research on research done by students in the tourism field.

Visser (2016) probed the production of student tourism research by students in South Africa. The number, themes and general trends in tourism research since 1960 were investigated by doing an NRF Nexus search of masters and doctoral degrees. The number of degrees awarded per year, per university, per discipline category, broad themes and local focus, could be determined with the study. This study enabled the

tourism discipline to focus on areas and themes needed for future research. The use of systematic reviews in the environmental field is not that common (Bilotta *et al*., 2014:70).

The above literature review highlights the fact that a study of this kind in the environmental field of South Africa has not yet been done. It also provides guidance on how to conduct research of this nature, and the value that such research has for the respective disciplines. The first part of the contextual theory is completed by the discussion of studies that looked at research topics, designs, data collection, abstracts, and analysis techniques. The second aspect of the theoretical context is theories that are foundational to the research.

2.3.2 Underpinning theory and framework of the research

Theory is built on reliable knowledge or facts to explain a process or phenomena (Schafersman, 1997:1). It is a summary and combination of what knowledge is available and known in a specific field. Theories are a reduction of knowledge to basic ideas, which indicates fundamental patterns and relationships. This enables participants in a specific field to use the same common terminology (Moore, 1991:1).

Theory further guides research to determine what is not known. "*Research not grounded in theory is wasteful"* (Moore, 1991:2). Theory is an analytical tool that guide initiatives of finding knowledge and facts rather than the reaching of goals (McMurray, 1995:131). To theorise is also to generate a body of knowledge, and to rise above direct concerns to what is more enduring (Thomas, 2007:46; Moore, 1991:2).

Several theories were considered to offer a theoretical base for this research, which included general systems theory, chaos theory, the complexity theory, and the Belief-Action-Outcome (BAO) theory. After scrutinising and comparing theories, only two were chosen. The two that were chosen to form the framework are the complexity theory and the Belief-Action-Outcome (BAO) theory. These two will be discussed after the other theory's rejection is justified.

Ludwig von Bertalanffy suggested the general systems theory in 1936, which states that real systems are open for interaction, and that the merging with other systems can lead to the attainment of new things that change continually (Heylighen & Joslyn, 1992:1). His focus was to unite science once again, and not to reduce an entity or system to parts. The general systems theory focusses on the arrangement and relations of the parts that connect them as a holistic system. The organisation of the parts defines the system, but it is independent of the elements (Heylighen & Joslyn, 1992:1). Systems thinking firstly strives to explain the ideal future, after which the theory will outline strategies to reach its goal. The nature of this current research study, however, uses the changing potential of the present, to seek what can be altered, without assuming what the end destination or goal will be (Blignaut, 2013:1).

Even though the general systems theory has the same terminology as the complexity theory, the general systems theory defines that systems aspires to a state of equilibrium (Hammond, 2003:113). The systems theory states that humans are part of a stable and homogeneous system, and that everything can be explained through theories, which makes the general systems theory more linear (Finegood *et al*., 2015:1).

The general systems theory is therefore not chosen as the fundamental framework for this research, and where the difference between the general systems theory and complexity theory starts. The complexity theory includes the terms ‘uncertainty’ and the ‘non-linearity of systems’. The system theorists further state that it is possible to stay outside the system, whereas the complexity theorists see themselves as part of the system. The systems theory describes systems as predictable, and that uncertainty can be controlled through knowledge (Mariotti, 2014:1). The complexity theory, as will be seen later, acknowledges uncertainty and attempts to deal with uncertainty, so is the chaos theory as well. The chaos theory states that one needs to expect the unexpected, which is truer for this research.

Chaos theory is seen as complicated information rather than the absence of order. The origins of the chaos theory can be drawn back to Henri Poincaré in 1890 and Sonya Kovalevskaya in 1889 (Wang, 2009:1). Chaotic systems are very much influenced by preliminary conditions that result in immensely different outcomes. As it

is not possible to know all the initial circumstances and details of a system, it is difficult to foresee the outcome of the system. Minor errors in the measuring of systems will be amplified at the end, which makes any expectation unusable. Chaotic systems do have limits and do not increase endlessly (Dhillon & Ward, 2003:7).

The chaos and complexity theories are at times considered as the same theory, which they are not. The chaos system endeavours to understand how a simple system can change in an unexpected manner, which can be more related to this research (Warren, 2013:1). The research reported in this thesis is based on the complexity theory, as it focusses on a complex system where multiple parts interact to emerge into an unexpected order (Warren, 2013:1).

The chaos theory is concerned with time, as well as a few factors and their values, while, the complex systems theory is more concerned with space, the structure, the underlying forces of complex systems and the relations with their environment (Glogowski, 2010:1; Bar-Yam, 2011:1). The chaos theory is located in the discipline of mathematics, whereas the complexity theory is found in science itself (Smitherman, 2004:10). Although the chaos and complexity theories are both theories regarding dynamic, non-linear systems, the chaos theory is a quantitative study and the complexity theory a qualitative study (Kernick, 2004:14). For this research, the complexity theory with its complex system approach is identified and discussed next.

2.3.2.1 Complexity Theory

A complex system has mutually linked elements and is a balanced and a functioning unit. Complexity, as a parameter, is to measure something. It measures the number of elements, the degree of interconnectivity, the adaptation of elements and the diversity of the elements (Colchester, 2016:5). As connectivity increases, the relations between the elements increase. The greater the diversity between the parts, the more complex and abstract the models will be to capture common features (Colchester, 2016:8). A systems model does not only indicate how the elements are related, but also the functioning connection between them. The parts are interconnected and capable of adaptation. In this systems approach, actions lead to reactions, and the equally related elements will change in direct proportion to the change. External and

internal influences cause a chain reaction and response, resulting in change in the system and a final product (Hugo, Viljoen & Meeuwis, 1997:3).

The complexity theory is a multi-agent systems theory, where all the elements have the potential and opportunity to be dominant, depending on the conditions and rules as set out in the beginning of the process (Peter & Swilling, 2014:1598). The characteristics of these complex systems are that they are interdependent, interactive, interconnected, nonlinear, adaptive and self-organising (Colchester, 2016:6). The discussion will start with the environment as a complex system.

2.3.2.1 (i) The environment as a complex system

The natural environment is an example of a complex system. The environmental system is an open system where matter and energy flow between the elements and systems (Hugo *et al*., 1997:3). When studying the natural environment, a holistic systems model approach is necessary. The environment and its ecosystems have many living beings and functions that are interdependent. All the living species, their habitats and the natural cycles are interdependent on one another and they interact with each other to achieve a collective result. It is not a static, but a living, functioning and highly complex unit. A change in one area will have an effect on the entire system (McGinnis & Ostrom, 2014). Destruction always brings about a series of catastrophes, and not only one catastrophe (Goudie, 2019:3). As the elements of the natural environment are also interactive, they are influencing each other, allowing for a two-way flow of input and responses (Hugo *et al*., 1997:3).

The ecosystems, related species and the natural environmental cycles are further interconnected. Due to the high interconnectedness of the living elements and their environments, they are modelled as networks, which also includes the relations between the nodes. The parts of the system and the networks for the systems are further acting and reacting on and to one another via their relations (Hugo *et al*., 1997:4; Colchester, 2016:54).

In complex systems such as the natural environment, the cause and effect are not directly related any more. Non-linearity of a system is an effect caused by multiple

parts that are interacting with each other, and the output can be greater than the sum of the parts. The interacting and interconnections of the non-linear system display discrepancy between the input and output because of the complex interconnections in the system itself (Holdscshlag & Ratter, 2016:82). The disproportionate input into the complex environmental system can make the environment extremely fragile or forceful (Colchester, 2016:6). One cause can have multiple, unpredictable effects, and a small fluctuation can have major significance (Mazzocchi, 2008:12). The interactiveness and interconnectedness of the species, physical and biological processes and cycles of Earth and any subsequent changes and non-linear reactions affects the system and urges the system to adapt.

Adaptation is the adjustment or ability of a natural or human system to react to a response in the environment, and to adapt with a response that changes the environment. Adaptation can lead to the mitigation of damage or the emergence of opportunities. Adaptation implies preparedness for immediate, direct, or indirect environmental changes and uncertainty (Morin &, Orsini, 2020). For adaptation to occur there needs to be a regulatory mechanism in the system. Input or change to the environment and its elements leads to adaptation and changes that display complex behaviour and structures (Colchester, 2016:37). These structures can create new strategies or modify existing strategies that can adapt to change (Mazzocchi, 2008:12). Complex systems can adapt to change, but there are thresholds, that if exceeded, can fundamentally change the system (Holdscshlag & Ratter, 2016:82). These adaptations and environmental changes are not yet fully understood by humankind.

The adaptive renewal cycle by Holdschlag and Ratter (2016:82) proposes four phases of adaptive change. The first phase is the exploitation phase where growth and exponential change occurs. The second phase is that of conservation, where energy and matter are consolidated, and flexibility is reduced. The third phase is rapid and includes the collapse or destruction of the system. The last phase entails restructuring, renewal and the commencement of a new cycle. The start of a new system signifies the resilience of the system (Holdschlag & Ratter, 2016:82). As the system adapts to the change, the system self-organises, and new patterns and outputs emerge.

Within this interactive and interconnected complex system, that can adapt to change, there is no centralised coordinator, and the system organises itself. It only needs simple rules to generate complex results (Nunn, 2007:97). Self-organisation in a system is the spontaneous appearance of order out of chaos because of interactions between components that were initially independent (Colchester, 2016:44). When different parts, or many components, and their interactions amongst each other form a stable pattern of relationships, a self-organising structure will appear (Cleveland, 1994:10). Examples of self-organisation are crystallisation or turbulence (Nunn, 2007:97). Figure 2.2 represents the elements of the environment as a complex system. To make matters more complex, humans and their developments are also creating their own complex systems.

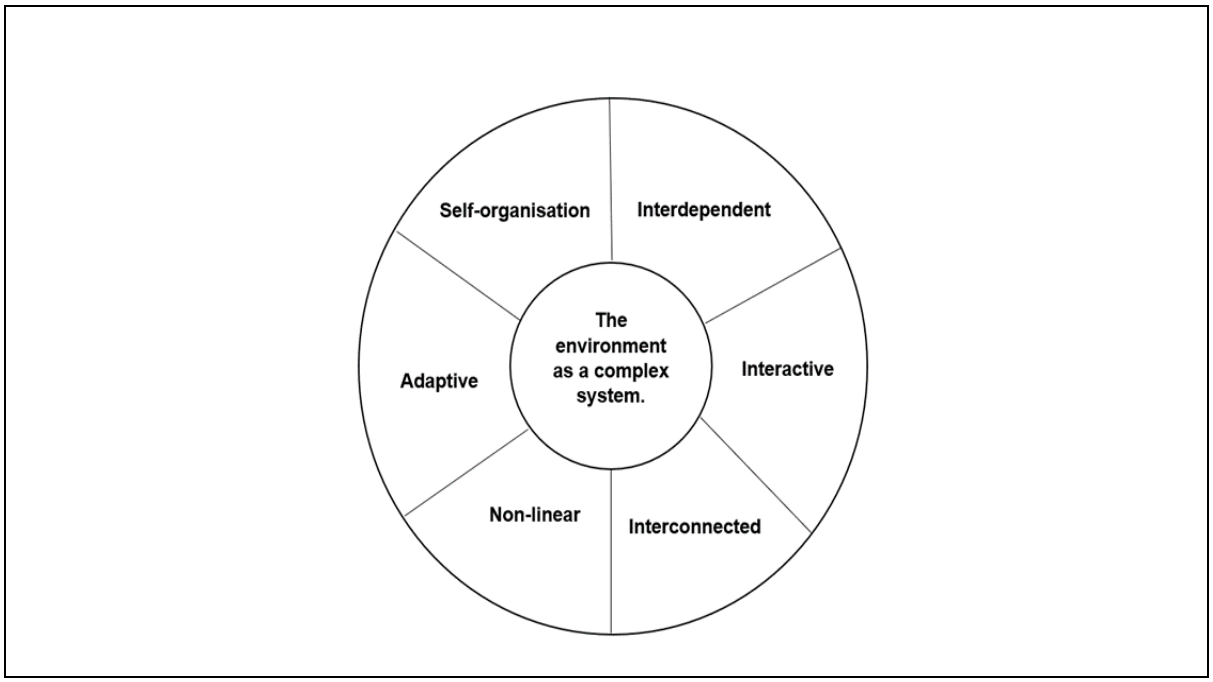


Figure 2.2: The elements of the environment as a complex system. **(Source**: Own).

2.3.2.1 (ii) Human development as complex systems

The world of today is different from the linear world of cause and effect, that Isaac Newton lived in (Colchester, 2016:14, 33). Today's world is more connected, with more universal challenges to which modern science does not have all the answers. Science, mathematics, and engineering provided humans with knowledge and techniques to manage and change the Earth (Arias, Balaguera, Gaitan-Angulo, Lis-Gutierrez, Viloria & Chacin, 2018:1, 2). Devices to store, transform and transport matter and energy are

developed. Humans are creating new systems and networks such as roads, rail networks, communication networks, infrastructure, and more. The storage and processing of data, the development of land, sea, air and space travel are all valuable developments (Arias *et al*., 2018). These human developments are interdependent, interactive, interconnected, non-linear, adaptive and self-organising, and together with the natural environment, makes up a different complex system. Human development has the same characteristics as the environment when considered as a complex system. Human development has also influenced and brought about unexpected and unintended costs for ecosystems, and as a result for humans as well (Arias *et al*., 2018:2).

2.3.2.1 (iii) Human influence on the environment

Humans are ecologically dominant and, on a daily basis, change and affect the environment, either positively or negatively. Evidence is mounting that humanity is influencing the functions of the environment to such an extent that it is threatening the resilience and threshold of the Earth (Steffen *et al*., 2018:8252). Major trends that are of global concern are climate change or global warming related, desertification, deforestation, loss of biodiversity, waste and the scarcity of natural resources (United nations Environment Programme (UNEP), 2019; Mondal, 2020:1).

The introduction of novel entities in the form of a new substance or modified life forms can have detrimental effects on the Earth as a system. Humans are continually doing experiments on a global scale, without taking into consideration experience and results from previous experiments (Steffen *et al*., 2015:7). Some of the damage caused by humans include climate change, deforestation, and species loss to name a few (Meadows, Randers & Meadows, 2005:86). The impact of humans on the interdependent and interconnected complex nature of the environment can cause deleterious effects, which may include the failure of biological systems.

2.3.2.1 (iv) Environmental impacts in complex systems

Humans have an ability to influence the environment of which they form part of, but they cannot disregard the limitations and boundaries of natural laws (Hugo *et al*., 1997:4, 5). Humans and their environment are also constrained by these boundaries (Mazzocchi, 2008:13). The Earth’s boundaries and laws must be respected, to avoid

the Earth becoming an inhospitable place to reside in (Steffen *et al*., 2015:1). One of the basic laws of ecology is that everything is connected to everything, and not one thing in nature should be changed, as unexpected changes will occur (Goudie, 2019:2). The second law of energy states that the use of energy and matter changes the energy and matter from a high quality to a lower quality (Steffen *et al*., 2018:8253). The disregard of natural laws and exploitation of the Earth's matter and energy is essentially impacting on the environment and causing humans and ecological systems to change in an unanticipated and unknown manner.

These impacts influence the natural environment systems that used to work without any interference from humans. The man-made impacts affect the complex environmental system as the impacts from humans are interdependent, interactive and interconnected with the environment. Changes in one sub-level can influence the function of the Earth on the entire system level (Steffen *et al*., 2015:2). These changes and destruction also threaten their own livelihood (Hugo *et al*., 1997:4). Humans and the natural environment both react to external factors and modify their environment to meet their own needs, due to the continuous interactions between them. Humans that are the causes of change in complex systems are connected to natural systems through feedback (Holdschlag & Ratter, 2016:82). The ideal would be negative feedback, where the status quo remains. The human caused degradation of the environment is positive feedback and leads the system to move away from the ideal and to destabilise (Galvani, Bauch, Anand, Singer, & Levin, 2016).

In addition to the above, no future predictions can be made concerning the full impact and change inflicted by humans on the environment that they are dependent and connected to. As humans and the environment are both complex systems and part of a complex system, no one has sufficient knowledge to measure all crucial parameters or to fully understand all the complex ecological cycles (Meadows *et al*., 2005:139). This is also reflected in the social-ecological system (SES) framework by McGinnis and Ostrom (2014).

The social-ecological system (SES) framework developed by McGinnis and Ostrom in 2014 is one of the tools mostly used to address the complexity and linkage of social-ecological systems (Palomo & Hernandez-Flores, 2019). The increasing interest in

solving specialised environmental problems are declining to make way for the notion that social and ecological systems are linked (Vogt, Epstein, Mincey, Fisher & McCord, 2015). The tool was developed to assist the problems that arose when studies were undertaken based on human-environment interactions. The aim of the framework was to provide a shared vocabulary and logical linguistic structure that can enable students from different academic disciplines with the same interest in sustainability and where they all encounter the same problem of analysing complex systems at multiple scales (McGinnis & Ostrom, 2014). The SES framework has first tier components that include resources systems, resource units, governance systems and actors that is found around action situations (Vogt *et al.,* 2015). The action situations are where the components interact and any inputs into the system are transformed into outcomes. The SES framework can be deemed as an entire system, but external stimuli from the components of the ecological or social system can change and affect any component of the SES. These changes may not be seen immediately, or the change can be on a small or large scale (McGinnis & Ostrom, 2014). Due to this fact, it is also not possible to manage all the impacts that are arising as the world is being developed and a new complex system is created.

2.3.2.1 (v) Managing impacts within the newly developed complex system

Humanity impacted and provided input into the environmental system, even though it is an unpredictable complex system. Humans have changed the complex system of the environment by its impacts. As the environment is a complex system, it will adapt to the impacts and change by self-organising into a new system. As humans realised that they are changing a system that was functioning well, they started to manage the impacts by mitigation and rehabilitation. However, by doing this they are changing the complex environmental system again, in fact it is constantly changing with each mitigation and rehabilitation action. For example, trying to conserve wildlife resources by fencing in animals and vulnerable ecosystems in wildlife parks and reserves, causes major changes in the behaviour of ecosystems trying to adjust to the fenced conditions within which they are being managed for their very survival. Governments as managing agents of countries, have further endeavoured to manage the impacts imposed on the environment.

2.3.2.1 (vi) Humans acting as managers of environmental impacts

The creation of these new systems leads to an attempt by humans to try and manage the new system within the initial functional environmental system where the impact of humans was not present. Humans then try to compensate for the impacts caused on the environment with responses such as legislation, regulations, environmental reports, development plans and research. These documents are all an attempt to anticipate and manage possible impacts within the newly developed complex system of the human-changed environment. Legislation relating to the South African environment includes the Constitution and the relevant regulations found in the NEMA and SEMAs. Figure 2.3 provides a graphical representation of what has been discussed to this point, in terms of the interactions between humans and their environment, subsequent to the discussion of the elements of the environment as a complex system being interdependent, interactive, interconnected, non-linear, adaptive and self-organising:

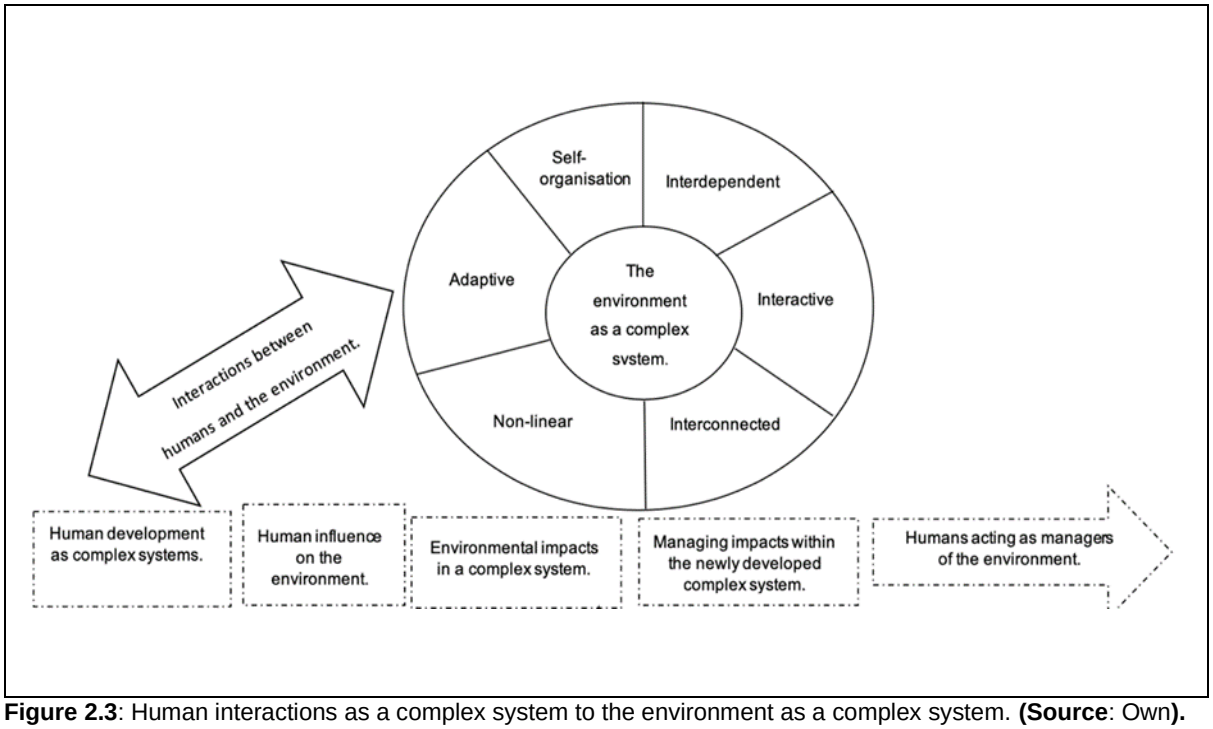


Figure 2.3: Human interactions as a complex system to the environment as a complex system. **(Source**: Own**).**

The interactions of human development, in itself a complex system, necessitated the need to manage human behaviour and their impacts on the environment due to the feedback and impact that humans have on the complex natural environment. As a

result, humans and governments have developed legislation, regulation and development plans to better manage the environment in a sustainable way.

These described parts are seen as foundational to understanding the underlying facets of this research. As discussed in section 1.3 this study aims to determine the alignment of South African environmental management/sciences/studies PhDs with national environmental management policies, plans and goals for South Africa. PhD topics are in themselves not centrally coordinated, however, which also makes PhD topics self-organised, and patterns will emerge from the bottom up.

2.3.2.1 (vii) An analysis of niche focus areas

South African legislation, regulations, environmental reports and development plans are documents that frame the management and mitigation efforts required as a result of the human interactions as a complex system within the complex system of the environment. These documents are developed as a result of the observed and researched effects that the human interactions have on the environment. When analysing these documents, niche focus areas can be identified as the priority environmental concerns for the environment by the South African Government. It can be assumed that such identified priority areas should be phenomena that require better understanding in order to better manage and mitigate the influence of human interactions on the environment. The purpose of research is to investigate phenomena to better understand them.

2.3.2.1 (viii) Self-organised PhD topics with no central coordinator

This process of deciding on a research study can be seen as daunting, chaotic and complex, and is driven by context. Contexts wherein students make decisions for their research are personal and professional, organisational, policy, national or theoretical (Plowright, 2011:8). The professional and personal context are the personal interests of students and their work environments. In the organisational, policy and national context, a student may choose to research a particular organisation, policy or country. With regard to the theoretical context, a student needs to start a search for literature relevant to the anticipated study. The literature search will assist in defining what exactly the constructs, theories and ideas of the research will be (Plowright, 2011:12). The different constructs that students discuss within their research can be seen as

interconnect elements from which organisation and order may emerge. The emergence of order out the preliminary literature search, to a researchable topic is also typical of the elements of complexity theory as already discussed.

2.3.2.1 (ix) Patterns emerge from the bottom up

A feature of a complex system is emergence, which occurs in layers. These patterns and structure of order emerge from the bottom up (Colchester, 2016:6). Elements interrelate and form combined wholes that interact with each other to form larger wholes. The elements still maintain their own independence and functions and is not controlled by the system itself (Glogowski, 2010:1). At each level of a system, both integration and independence are present on their own level and with those levels above and below. Systems on a given level are combinations of systems from the previous level. The emergence of new patterns or order from change and adaptation is almost impossible to predict (Colchester, 2016:38; Nunn, 2007:99).

The particular form of a complex system is the pattern that arises due to the interaction between the elements that make up the system with a bottom-up design. The outcome or shape of the system can, therefore, not be predicted. For this reason, the alignment between PhD studies and national priority environmental issues are investigated in hindsight, due to the self-organising nature of the selection of PhD topics. Figure 2.4 graphically depicts the conceptualisation of this entire discussion in terms of complexity theory.

Colchester (2016:18) further states that systems thinking focusses on the whole system and not the individual parts or elements. The elements in the system includes the PhDs and the identified environmental government documents; hence, the PhDs will not be analysed individually for quality, etc., but rather their contribution to the entire environmental management field. The study will rely on systems thinking, which is not the breaking down of the different elements to understand it better, but rather, a building from the bottom up to better understand the entire system. The bottom-up design of this research will start with no structure to new information. This study is interested in the connectivity between the elements, more than the elements themselves, which makes the complexity theory a suitable choice as underlying theory

2.3.2.1 (x) Uncertainty

Encompassing all the above is that there is no knowledge available to make causal connections between an event and the processes on different levels of a hierarchy mostly due to the non-linearity (Arias, *et al*., 2018:2). The interactions and resulting adaptations in a complex system make it unmanageable to calculate and predict the imminent form of the system. As complex systems are unpredictable, it is not probable to predict what structure will emerge from any set of rules - it is the result of actions and not of any design. The only way to determine the structure of the system is to let the system play it out by itself (Cleveland, 1994:19). The uncertain is therefore certain.

This uncertainty also holds true for the interaction between elements in the environment itself, between man and the environment, and subsequently this research, the PhDs, and priority environmental issues of the South African government.

The appropriateness of the complexity theory to the environmental management field and this study is that the theory fundamentally provides a link between ecological and socio-economic systems (both being complex systems) that affect each other (Peter & Swilling, 2014:1595). The complexity theory provides a framework that can assist in the integration of natural science and human social science methodologies (Peter & Swilling, 2014:1598). These interactions between human and environment systems are one of the core relationships and fundamentals of environmental management research.

The complexity theory is the appropriate theory to support the study, as this research will provide a more holistic view of the PhD environmental management field through the self-organisation of elements and the emergence of new patterns and models, as provided for by the complexity theory, and in this case the PhDs, and their function as a whole compared to identified needs and niche areas in South African environmental government documents. The complexity theory is, however, not the only theory significant to this study as the beliefs that people have towards the management of the environment also influence their decisions regarding the environment. For this reason, the Belief-Action-Outcome framework, as a theory, is also applicable to this research.

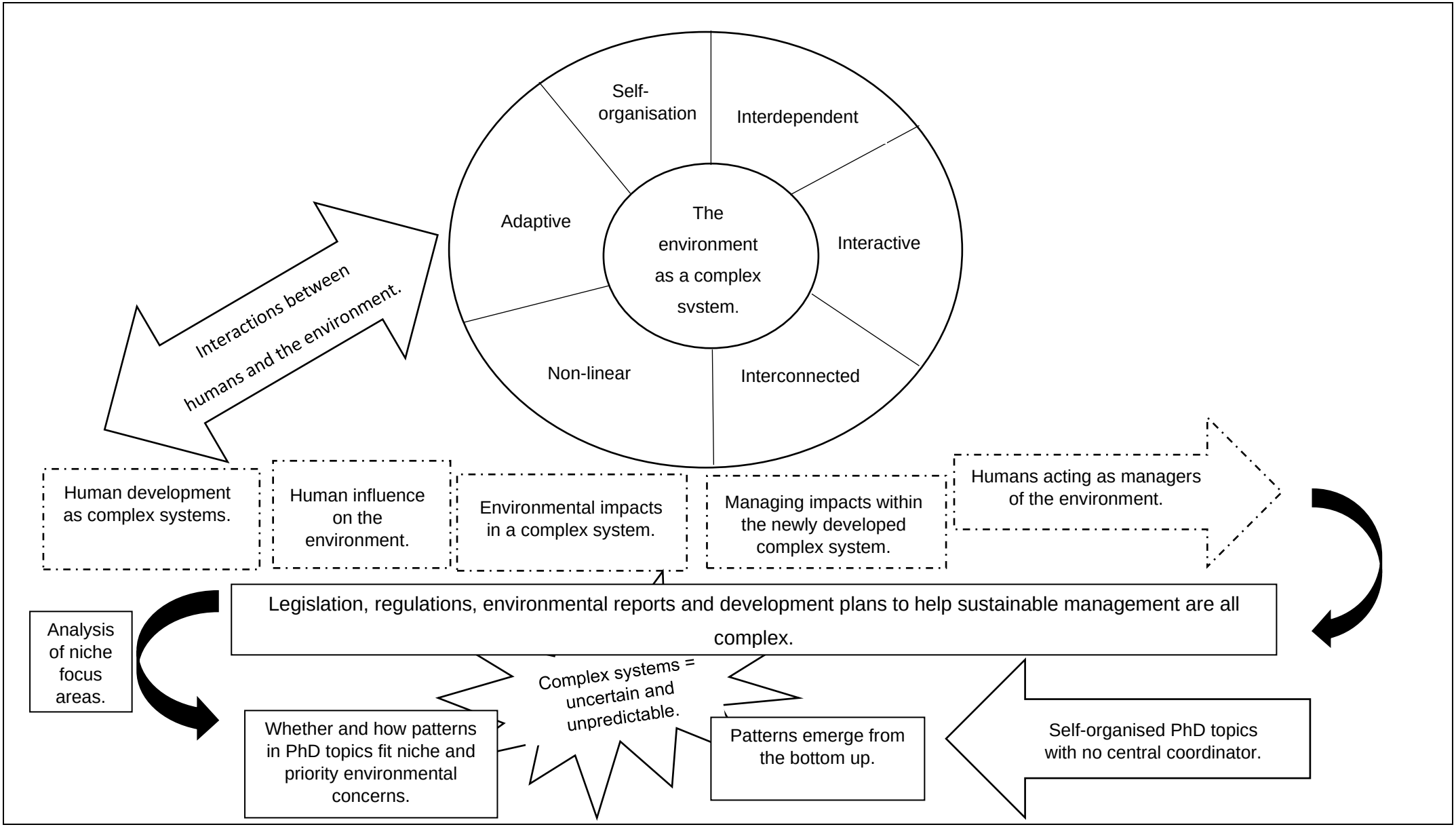


Figure 2.4: The complexity theory as underlying theory to this study. (**Source:** Own).

2.3.2.2 The Belief-Action-Outcome framework

The Belief-Action-Outcome (BAO) framework is designed to include the forming of behaviour through beliefs, the links between intentions and actions as well as instruments that describe outcomes - all in the context of environmental sustainability (Degirmenci & Recker, 2016:2). The BAO framework links societal structures and organisational structures with environmental beliefs, sustainability actions and social and organisation behaviour (Melville, 2010:4; Degirmenci & Recker, 2016:2).

The BAO framework is mainly used to explore and describe the belief formation of individuals and organisations about the environment. The BAO framework states that belief formation is how the beliefs about the environment is established by society or an organisation (Degirmenci & Recker, 2016:2). The beliefs of an individual or organisation about the environment translate into actions that affect the behaviour of the social system or the behaviour of an organisation (Molla, Abareshi & Cooper, 2014:131; Degirmenci & Recker, 2016:2). Behaviour is the outcome of a belief, and action can appear on a macro- or micro- level.

The macro-level is an organisation or social system, and the micro-level is the individual itself. Individuals link the social structure with the behaviour of the social system, which are both macro-level variables (Degirmenci & Recker, 2016:2). Links are further proposed between the influence social and organisational contexts (macro-level) have on the beliefs of individuals (micro-level) and an organisation about the environment, and the influence their beliefs have on sustainability actions and behaviours (Molla *et al*., 2014:131).

The BAO framework has three main links between society, environment and organisations (macro-level constructs) and the individual (micro-level constructs). On the micro-level the BAO framework indicates how the sustainability beliefs of an individual turns into actions and behaviours. The macro- and micro- level indicates that the structures of society and an organisation have an effect on the beliefs of the individual (Molla *et al*., 2014:131).

Figure 2.5, below, illustrates the above discussion in more detail. The social structure wherein people find themselves influences the beliefs of people about the environment

(Links 1) and their beliefs lead to actions (Link 2) and then the behaviour of the social system (Link 3). The social system includes the social, natural, individual and corporate constructs. The organisational structure also influences the environmental beliefs of the organisation (Link 1). The beliefs lead to the actions of an organisation (Link 2), and then to the behaviour of the organisation (Link 3). Link 4 demonstrates that the societal structure can influence the behaviour of the social system, and that the organisational structure can influence the behaviour of an organisation on a macro-level. The organisational structure can, however, also influence the behaviour of the social system, and the societal structure can influence the behaviour of the organisation (Link 5) (Melville, 2010:4).

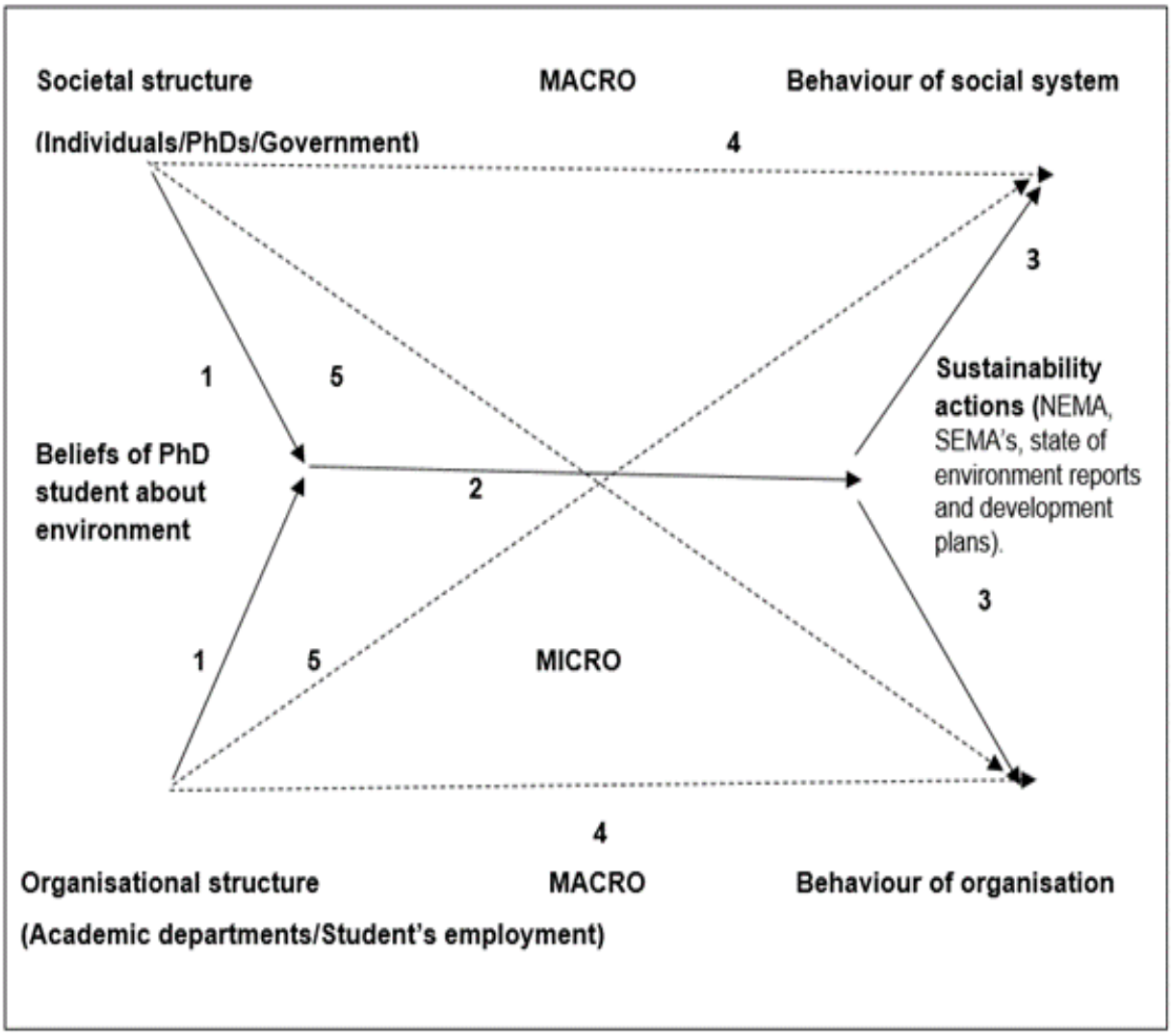


Figure 2.5: Belief-Action-Outcome Framework adapted for this study. **(Source:** Adapted from Melville, 2010:6).

The Belief-Action-Outcome (BAO) framework in short assumes that societal and organisational structures can form an individual's beliefs about the environment and that it can lead to sustainability actions. These actions can in turn form the behaviour of the social system and the organisation (Molla *et al*., 2014:131).

In assessing the appropriateness of the BAO framework to the field of environmental management – and this study, specifically, it is seen that the Brundtland report, world summits, global treaties, etc., are societal structures that formed beliefs about the environment and action formation on a macro- level. These events changed the belief on a micro-level (individual) as well, and individuals became more aware of their environment and their own impact thereon. Hence, the outcome of these beliefs, actions and behaviours of the social system led to the establishment of the environmental management discipline and subsequently the topic choices for the PhD studies.

The BAO framework states that environmental sustainability comprises of human behaviour and contexts in terms of social, organisational and environmental contexts. As can be seen from the complexity theory discussion above, humans are affecting the environment, and at the same time attempting to manage the environmental issues that arise.

The BAO framework provides a method to a link between the micro- (individual) level and the macro- (societal and organisational) level (Gholami, Sulaiman, Ramayah & Mola, 2013:432). This study takes a macro-micro-level approach to see if there are links between the beliefs and actions of government (priority areas identified by governments) as the organisational structure (macro-level) and the individual or PhD students and their beliefs, actions or studies (micro-level).

In this study, the PhD students in environmental management and the government represent the societal structure. The influence of societal and organisational contexts in which PhD candidates work and study impact on the beliefs and attitudes op PhD students pertaining to the environment (Melville, 2010:10). Students who choose to do research in environmental management also had certain beliefs concerning the environment and that their research will contribute or lead to sustainability actions and

behaviours for the environment. The PhD study was the action that they took, and this may have an output on the social system behaviour or the behaviour of an organisation – in this case, the host academic departments of the PhD students, as well as their places of employment. The BAO framework provides a manner to determine whether the contributions of South African PhDs in environmental studies are aligned with addressing the priority environmental issues of the South African government.

The government, also part of the societal structure, further has beliefs and actions associated with the environment, hence their actions and interventions. These actions can include the development of sustainable competencies and pollution preventions strategies (Zeng, Fu & Ouyang, 2018:3). Their beliefs lead to the identification of certain priority areas that they deem important through the NEMA, SEMAs, state of environment reports and development plans. The government, which does not function in isolation, also need to adhere to international treaties and development plans.

The BAO framework also opened more levels and connections between the beliefs of society, organisations, their actions and behaviours for research ideas that students may explore in choosing a research topic for their PhDs (Melville, 2010:2). The organisational structure, – in this case, the environmental management academic departments and respective workplaces of the PhD students, are not only responsible for forming beliefs about the environment, but the action forming process of the BAO framework also requires that beliefs be changed, and behaviour affected on a macro- and micro-level.

The above theoretical context discussed the theory and framework that is underpinning this study. A further aspect that needs to be placed in context is the national and policy contexts of the South African environment and the Higher Education sector. These two contexts provide background and information for the two most important constructs of this study, namely the environmental documents and the PhD studies.

2.4 National and Policy Context

This study draws on government policy and documents and would therefore need to be placed in a policy and national context (Plowright, 2011:11). Taking policies into consideration provides a perspective on the issues that are important for this study. Policy is expressed and implemented in different manners. It can include principles, acts, regulations, reports and statements (Rossouw & Wiseman, 2004:134). The national context provides awareness and information on the location, culture, and history (Plowright, 2011:12). This study will therefore address the policy and national context at the same time, for both the environment and Higher Education in South Africa. The environmental policies and legislation that is believed to be relevant to the study will be discussed in the subsequent section.

2.4.1 National and policy context of the South African environment

South Africa had a centralised government system, prior to 1994, with no transparency in decision-making, and was racially based in all service areas (Rossouw & Wiseman, 2004:132). Environmental policymaking did not include the broader public in the process, and stakeholder engagement was only done with technical experts in the field. Public participation, if done, comprised of consultation with conservation organisations and the distribution of information.

Along with the rising of a democratic government, the environmental policy dialogue also changed. This change in policy now included social and economic aspects. The development of policies was seen as a priority between 1994 and 2004 as South Africa had a new government. The goal of the South African government's environmental policy was to inform the public, organs of state and government agencies of its objectives, and how to achieve those objectives (Ferreira & Lloyd, 2009:192). Table 2.1 provides an overview of legislation, government documents and the year that it was promulgated or published.

Table 2.1: Environmental Management legislation and government documents of South Africa.

Year	Legislation promulgated and government documents published
1995	The Consultative National Environmental Policy Process (CONNEPP).
1997	The Constitution of South Africa, with Section 24 including environmental rights.
	The Green and White Papers on Environmental Management Policy.
	The NEMA Regulations
1998	The National Environmental Management Bill in 1998 and Act (NEMA)
1999	First State of the Environment Report (SOER)
2003	Specific Environmental Management Acts (SEMAs)
	SEMA: National Environmental Management: Protected Areas Act 57 of 2003
2004	SEMA: National Environmental Management: Biodiversity Act 10 of 2004
	SEMA: National Environmental Management: Air Quality Act 39 of 2004
2006	South Africa Environment Outlook (SAEO)
2008	SEMA: National Environmental Management: Integrated Coastal Management Bill 2008
	SEMA: National Environmental Management: Waste Act (WMA) 59 of 2008
2012	National Development Plan 2030 – Chapter 5
2015	Agenda 2063 with Aspiration 1 goal 7
2016	Second South Africa Environment Outlook (SAEO)
2018	Integrated Coastal Management (ICMA) regulations instated.
2019	Specific areas are promulgated under the Protected Areas Act.
2020	NEMA Regulations Amendment is still being undertaken.

(**Source**: Own).

The introduction of environmental issues within the Constitution paved the way for the first national environmental policy process. The Consultative National Environmental Policy Process (CONNEPP) generated discussion documents in 1995, the Green and White papers on Environmental Management Policy in 1997, and the National Environmental Management Bill in 1998, which led to the National Environmental Management Act (NEMA) that was published on 27 November 1998.

The development of environmental policy in South Africa was at first a principle-based framework that included the National Environmental Management Act (NEMA) and the rule-based procedural legislation – for example, the NEMA Environmental Impact Assessment (EIA) regulations in 1997 (Rossouw & Wiseman, 2004:135). Linked to NEMA were issue- and resource-focussed sectoral policies such as the Specific Environmental Management Acts (SEMA). The first SEMA was published in 2003 and dealt with the management of protected areas that paid attention to the conservation of soil, biodiversity, and water.

Specific areas, such as the Protea marine area, Addo Elephant Park and the Robben Island marine area were declared protected areas in May 2019, under the Protected Areas Act. In 2004, the National Environmental Management Air Quality Act 39 of 2004 was promulgated, as well as the National Environmental Management Biodiversity Act 10 of 2004 that aims to protect plant and animal biodiversity. The National Environmental Management: Integrated Coastal Management Act (ICMA (2008) promotes coastal conservation and intends to use resources found in the coastal zone in a social, economic and ecological sustainable manner. In 2018 the regulations for the latter Act were instated (DEA, 2020).

In the same year, the National Environmental Management: Waste Act (WMA) 59 of 2008 was published, to manage waste in South Africa (Rhodes University, 2017:1). The Department of Environmental Affairs and Tourism (DEAT) further introduced supportive documents and guidelines for integrated environmental management (Rossouw & Wiseman, 2004:135). As the environment and regulatory aspects are changing, and new environmental issues are constantly arising, the amendment of environmental legislation is necessary. In 2018, the National Environmental Management Laws Amendment Bill, set out by the Department of Environmental Affairs (DEA), was under discussion (Parliamentary Monitoring Group, 2018).

The institutional framework for environmental policy was not well defined, as different departments and different tiers of government had the same mandates and interests that overlapped (Rossouw & Wiseman, 2004:132). Additionally, this process was undermined once again by the lack of public consultation and the failure to develop a National Environmental Strategy and Action Plan (NE&AP), which would have had appropriate government structures, detailed strategies, action plans, targets and time frames (Rossouw & Wiseman, 2004:133). The NEMA Regulations or EIA Regulations were enforced in 1997, before the NEMA was enacted.

The NEMA Regulations should have been driven by sustainable principles, but are now determined by administrative needs, due to the wrong sequence of promulgation. The NEMA Regulations were supposed to be the way in which the NEMA were given effect (Rossouw & Wiseman, 2004:138). Even though the environmental policy and legislation were based on democratic principles, implementation and compliance are

lagging and not enforced (Rossouw & Wiseman, 2004:131). The environment of South Africa is not only included in the Constitution and subsequent legislation, but also in national plans.

In 2012, South Africa adopted the National Development Plan (NDP) that provided a long-term perspective on how all citizens can have a decent standard of living by 2030 (Corporate Governance Traditional Affairs, 2018:1). It also provides ways in which the different sectors can reach the goals as set by the plan. Chapter 5 of the NDP was dedicated to environmental aspects. Besides the fact that South Africa has policies, legislation and plans, the country ascribes to international treaties and agendas. Two of them are the 1992 Rio Earth Summit and the African Union's Agenda 2063.

During the 1992 Rio Earth Summit, the United Nations requested national governments to compile State of the Environment Reports on a regular basis, so that environmental information and data would be available to make informed decisions. Such reports afford a country and its people the opportunity to see the bigger picture of a nation's performance in terms of its responses to change, and to evaluate whether human interventions and management actions are effective (Department of Environmental Affairs (DEA), 2016:1). South Africa heeded the call and had since produced three reports. The first National State of the Environment Report (SOER) was completed in 1999, and another two, known as the South Africa Environment Outlook (SAEO) followed in 2006 and 2016.

The other international document that is important for this study is Agenda 2063. The African Union's Agenda 2063 document is a fifty-year vision and action plan that sets the same goals and identifies the same priority areas for Africa – and South Africa that is a member of the African Union. There are seven aspirations, and the environmental section of Agenda 2063 can be found in Aspiration 1: Goal 7 section (African Union Commission, 2015b:62). The environmental goals of Agenda 2063 are linked with the sustainable development goals of the United Nations (African Union Commission, 2015a:1). Even though South Africa has plans and agendas in place, it is still connected to the world and its environmental issues.

The word population is currently at approximately 7.2 billion people and 250 million are added every day. Even though the population is growing, 66% of the world's population are starving or are malnourished. Natural resources are depleted, degraded, and overused (Pimentel & Burgess, 2018:313).

The environment of South Africa is in no way different from that of the world. The second South Africa Environment Outlook (SAEO) stated that the South African environment is in a state of decline (DEA, 2016:3). South Africa is one of the forty driest countries in the world and receives less than 500mm rainfall on average in a year (Meisner, Steyn, Moyo, Shadung, Masangane, Nohayi & Jabobs-Mata, 2018).

South Africa attempted to keep up with the developed world by means of mining and this has led to environmental degradation. Natural resources are becoming scarcer, and exploration is venturing into new areas that are less accessible. To sustain these ventures, costs are increasing along with social and environmental degradation. As in the rest of the world, climate change and adaptation are considered a threat to the South African environment (Bega, 2018:1). Based on the national and policy context provided for the South African environment, the following documents are believed important to include.

The documents that will be included in this research provides a past, present and future view, 1998 to 2063, of the environmental issues that are apparent for the wellbeing of the South African environment and its inhabitants. As can be seen in Figure 2.6, the legislation and the identified documents span from 1998 to 2063.

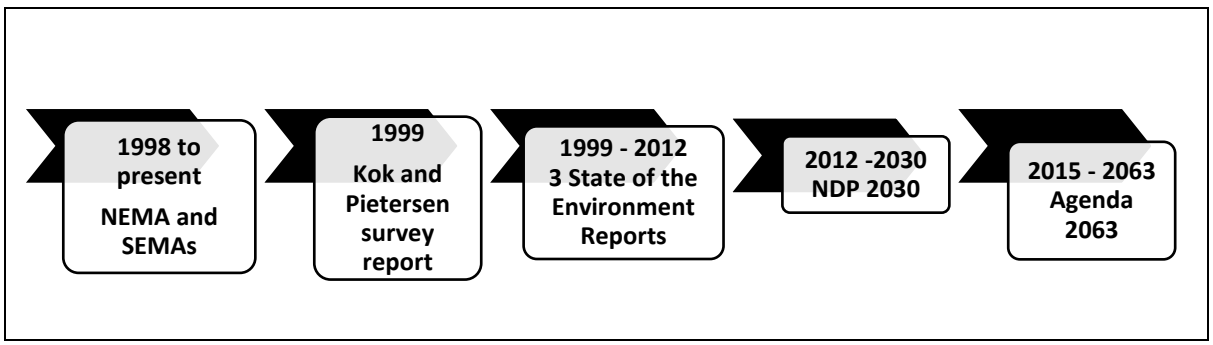


Figure 2.6: Identified environmental legislation and documentation from 1998 to 2063. (**Source**: Own).

The Kok and Pietersen (1999) survey report will be used as this provides past information on what was seen as important by the government for the environment in 1999. The three State of the Environment Reports will shed light on the actual status and challenges the environment faced between 1999 and 2012. The National Development Plan – 2030 (published in 2012) and the Agenda 2063 documents (released in 2015) are included in the study, as it states what the future direction of the government, and Africa as a whole, is at present.

The selection of the environmental-related South African legislative documents will highlight and include the past, present and future themes and trends in environmental management, as South Africa aspires to a clean, healthy, living environment for all. It is important that there must be a conjunction between what the country deems necessary for the wellbeing of their citizens, and that of research, in order to aid the fulfilment of the government's goals and the Constitution.

Section 24 of the Constitution wants to provide a clean and healthy environment. This is given effect by the NEMA (1998), and includes all aspects of the environment, the land, water atmosphere, micro-organisms, animals and plants. The principles of NEMA also stipulate that environmental management must be socially, environmentally, and economically sustainable (South Africa, 1998:8).

There are further several SEMAs that address more specific issues such as the Biodiversity Act, the Protected Areas Act, the Integrated Coastal Management Act (ICMA), the Air Quality Act and the Waste Management Act (WMA) (Figure 2.7). The NEMA with its SEMAs provide guidance and contain the themes and aspects that are deemed important for the management of South Africa's environment. Thus, NEMA with its SEMAs must be taken into consideration when conducting research on environmental management in South Africa.

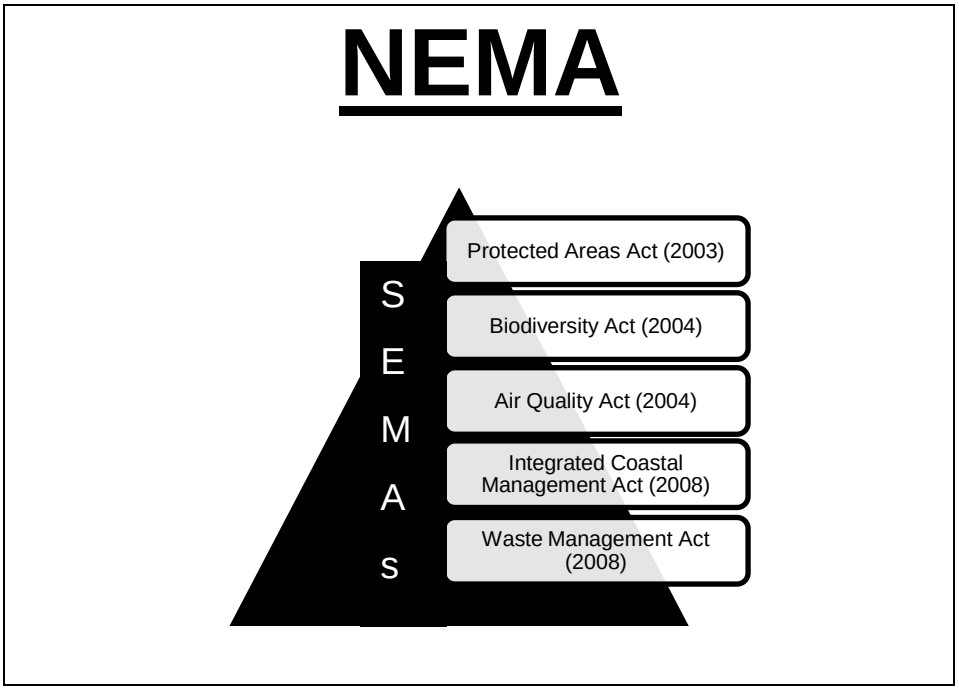


Figure 2.7: Specific environmental management acts (SEMA's) under the auspices of NEMA. (**Source**: Own).

The NEMA and its SEMAs embrace the past and the future themes of the environment that will be used for the research.

With further relevance to the past, the State undertook a survey, in 1999, to determine future environmental research needs (Kok & Pietersen, 1999:1). Kok and Pietersen's (1999:1) survey report on Environmental Management identified long-term research and technology needs in environmental management. The Kok and Pietersen report does not indicate PhD focus areas, but rather what research in environmental management were deemed important. Table 2.2 represents the research priority topics that were believed to be important and should have received research funding from 1999 onwards (Kok & Pietersen, 1999:18).

This document will be compared to the PhD research outputs that has been done between 2000 and 2017 to establish whether PhD research was aligned to the identified research themes suggested by this South African document. The comparison will further indicate if documents that guide research, created by government, are taken into consideration in selecting research priority topics for PhD research, and to what extent completed research are aligned to these priority areas.

Table 2.2: The Top 10 suggested research priority topics to receive research funding.

Rank-order position	Topic description
1	Development of environmentally appropriate technologies to promote a thriving mariculture industry.
2	Development of bioprocessing of organic waste to yield useful chemical and enzymatic products.
3	Widespread use of indigenous pharmacopoeia, food and fibre sources.
4	Development of strategies and technologies to reduce the social impacts of drought.
5	Widespread use of water-efficient and drought-resistant plants including indigenous resources.
6	Widespread use of biotechnology solutions for the clean-up of contaminated land and water.
7	Widespread use of sustainable packaging technologies.
8	Significant use of design centres to support industry with regard to waste minimisation and clean technologies.
9	Development of environmental entrepreneurship training and support systems.
10	Development of capacity within industries to use one another's waste products as source materials within the industrial ecology paradigm.

(**Source**: Adapted from Kok & Pietersen, 1999:18).

These problems were further highlighted in the publication of South Africa's first National State of the Environment Report in the same year. The publication of State of the Environment Reports by national governments was a request from the United Nations during the Rio Earth Summit in 1992 (Department of Environmental Affairs (DEA), 2016:1).

The second report was published in 2006, under the name the South Africa Environment Outlook (SAEO). The third report was the Second South Africa Environment Outlook (SAEO) which was completed in 2012, but only published in 2016 (DEA, 2016:ii) (Figure 2.8):

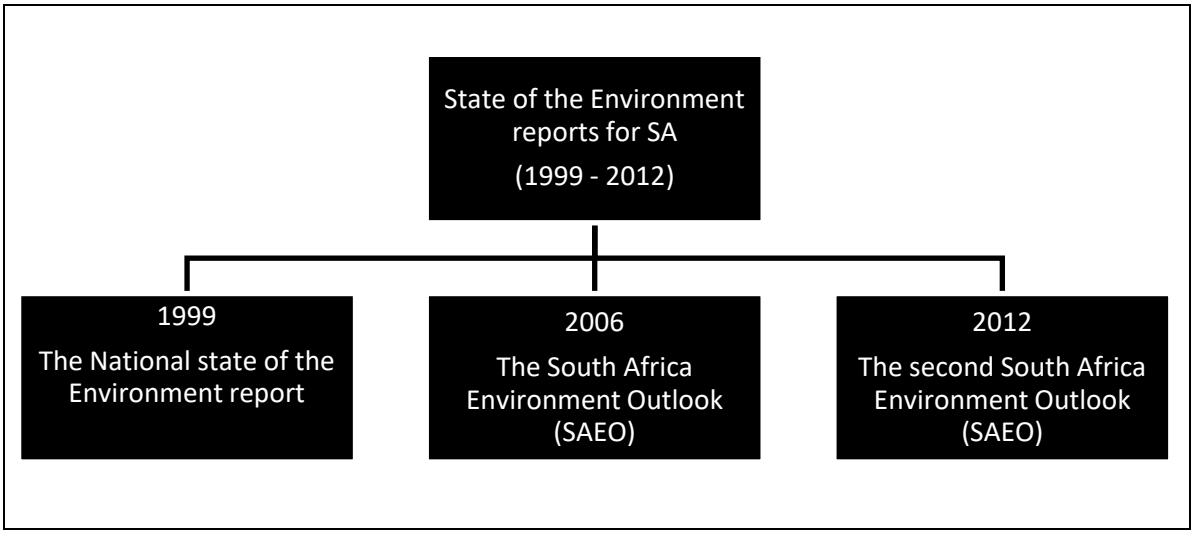


Figure 2.8: Timeline for the publishing of State of the Environment reports. (**Source**: Own).

The themes of the first SOER in 1999 that were deemed important to report on were the state of habitats, biological resources, physical resources, chemical processes and the people of South Africa (demographics) (Ballance & King, 1999:18). The 1999 SOER also suggested that the main response to environmental change was the signing of international agreements, the promulgation of national laws and policies, as well as awareness and education (Ballance & King, 1999:28).

The second report, in 2006, The South Africa Environment Outlook report (SAEO), stated that the major environmental priorities were the quality and availability of water, climate change, human vulnerability, and loss of biodiversity and ecosystem functioning. The SAEO 2006 further reported on the findings and the state of the environment in terms of environmental governance, land, biodiversity, inland water, marine and coastal resources, atmosphere, human vulnerability and settlements (DEAT, 2006:iii). The responses that were suggested in this report were implementation and enforcement of policies, laws and strategies, accessible and consistent information, increased local authority capacity and joint responsibility (DEAT, 2006:15).

The third report, the Second SAEO in 2012, conducted an impact mapping exercise. The document depicted and provided key emerging issues and areas where action is needed, as well as an implementation framework that aimed to improve the state of the environment over time. The key issues that arose were water, land degradation,

greenhouse gas emissions and non-renewable resources (DEA, 2016:27). The options for actions included food-water-energy-nexus, renewable energy and changing the energy mix, the green economy and ecological infrastructure (DEA, 2016:28). The framework in the document with the key issues for action can also be used as an indicator to ascertain if they were or are taken into consideration when conducting environmental PhD research. Environmental reports and frameworks, however, cannot be realized in isolation, and should be reflected in international development plans, related to South Africa, and national development plans. By 2020, the third draft of the South Africa Environment Outlook that was due in 2018, had not yet been published. The SOER 2018 draft incorporates the same environmental issues as the previous reports (Energy Governance South Africa (EGSA), 2018).

The South African National Development Plan (NDP) – 2030 (National Planning Commission, 2012a:14) has set to eradicate poverty and to reduce inequality by setting enabling goals with critical actions. The environment and the related issues are included in Chapter 5 of the NDP (National Planning Commission, 2012a). Chapter 5 of the NDP identifies key points, a vision for 2030, steps towards the vision and the phasing of strategies to reach the targets. The executive summary of the NDP has nine objectives and six actions for 2030 in order to meet the targets that they want South Africa to meet, related to the environment and its people (National Planning Commission, 2012b:57). It is deemed imperative that these targets, objectives and themes be compared to PhD research from 2012 to see if the research incorporated these themes. Further, if the alignment between PhD research and the NDP is not established, it will not be known if research is contributing to what society needs and if PhD research will assist the country in meeting the 2020 and 2030 targets of the NDP. Even further in the future is the African Union's, Agenda 2063.

The African Union created Agenda 2063, which is a 50-year plan and strategic framework for growth, sustainable development, and global strategy to augment the use of Africa's resources to the advantage of all Africans (African Union Commission, 2015d:2). This document is included, as South Africa is a signatory to the African Union. Agenda 2063 has seven aspirations of which a "*prosperous Africa based on inclusive growth and sustainable development*" is Aspiration 1. Under Aspiration 1, there are seven goals, of which Goal 7 is related to the environment and climate. Under

the goal of environmentally sustainable and climate resilient economies and communities there, Agenda 2063 has six environmental priority areas (African Union Commission, 2015b).

The Agenda 2063 document sets goals and identifies priority areas for Africa and South Africa – also a member of the African Union. The Agenda 2063 document identifies possible future research themes and niche areas that are aligned with future priorities or plans that are deemed necessary for the environment of Africa and South Africa. Along with providing the context of the environment, another important construct of this research is the Higher education sector in South Africa.

2.4.2 National Policy and legislation context on Higher Education in South Africa

The changes introduced with the inception of the new democratic government also brought about similar changes in the education sector (Table 2.3).

Table 2.3: Timeline for policy and legislation of Higher Education in South Africa.

National policy and legislation of Higher Education in South Africa	
1959	The Extension of University Education Act (Act No. 45 of 1959)
1995	White Paper on Education and Training in a Democratic South Africa: First Steps to Develop a New System South African Qualifications Authority (SAQA)
1996	The National Education Policy Act (NEPA) (Act 27 of 1996) National Commission on Higher Education (NCHE) Education White Paper 3
1997	Higher Education Act (Act 101 of 1997)
1998	Council of Higher Education (CHE) and the Higher Education Quality Committee (HEQC)
2001	The National Plan for Higher Education (NPHE)
2002-2005	Mergers of higher education institutions.
2008	National Qualifications Framework Act (No. 67 of 2008) and National Qualifications Framework (NQF)
2009	Department of Higher Education and Training (DHET) established
2018	National skills development plan.
2020	A new Sector Education and Training Authority (SETA) Landscape implemented.

(**Source**: Own).

The Extension of University Education Act No. 45 of 1959 provided for separate universities for different races (Makobela and Mlambo, 2017:780). Since the abolishment of the 1959 Act, the development of policy, legislation, and regulations to provide direction of the higher education sector was developed.

The fundamental policy framework from the Ministry of Basic Education in 1995 was the “White Paper on Education and Training in a Democratic South Africa: First Steps to Develop a New System” (South Africa Yearbook, 2016:134). The framework for the new policy, legislation and regulations were then guided by the principles of the National Commission on Higher Education (NCHE) in 1996 (Luescher, 2016:63). The legislation that the NCHE steered in 1996 included both the Education White Paper 3 and the Higher Education Act 101 of 1997.

The National Education Policy Act (NEPA) 27 of 1996 gave effect to the policies and assigned responsibilities to the Minister of Education in terms of legislation and monitoring. The NEPA also provided guidance for the relationships between the national and provincial authorities (South Africa Yearbook, 2016:134). The Department of Education (DoE) was then responsible for all education, including higher education and the Department of Labour was now responsible for training outside higher education (Lange, 2017:35).

The Department of Labour raised concerns regarding the poor skills base of the human resources section in the South African labour sector. Prior to 2008, it was also not mandatory to register a private higher education institution (Luescher, 2016:86). In 1995, the South African Qualifications Authority (SAQA) was established in terms of the South African Qualifications Authority Act No. 58 of 1995 (SAQA, 2018:1). The key task of SAQA was to create a National Qualifications Framework (NQF) (Luescher, 2016:32). The NQF was reviewed in 2001, and the SAQA Act was replaced with the National Qualifications Framework Act No. 67 of 2008. However, neither the SAQA nor the NQF was abolished.

The NQF was refined by the NQF Act, and now included ten NQF levels for secondary and tertiary qualifications, of which the PhD is at level ten (South Africa Yearbook, 2016:134). The NQF, further, had to attain outcomes-based qualifications, irrespective

of, and independent from the institutions that provided the qualification (Lange, 2017:36). The advances of external monitoring also led to the development of the Sectoral Education and Training Authorities (SETAs), which are accredited by SAQA. In 2020, a new SETA landscape were proposed and introduced. Another external quality assurance body, the Council of Higher Education (CHE) and the Higher Education Quality Committee (HEQC) an external body outside of the government, was established in May 1998. The CHE is tasked to ensure quality, as well as to undertake programme accreditation and institutional audits (Luescher, 2016:30).

The National Plan for Higher Education (NPHE) followed in 2001. Subsequently, Higher Education formally accepted the legislated frameworks, as well as the Language Policy, the National Qualifications Framework (NQF) and the Higher Education Qualifications Sub-Framework (HEQSF). The NPHE announced the merger of institutions and their new names (Luescher, 2016: 38). Between 2002 and 2005, the merger of thirty-six public Universities and Technikons created new Higher Education institutions (Luescher, 2016:38). Before the mergers took place, there were 300 private unregulated higher education institutions that caused concern, based on the quality of their qualifications (Luescher, 2016:6). Currently there are twenty-six public universities and more than one hundred private institutions. In 2009, the Department of Higher Education and Training (DHET) was created as a separate entity (Luescher, 2016:34). It is important to be aware of the national and policy context of Higher Education in South Africa as this will shed more light on why PhDs are chosen for this study.

2.4.2.1 Contextualising PhDs in SA

In this section, the history, challenges and demands of doctorate education are discussed. The motivation for people wanting a PhD, and how they choose their topics and titles, form part of this section. Further to this, an overview of environmental studies at South African universities is provided.

2.4.2.1 (i) History of doctorate education

The Doctor of Philosophy had its origins form the Latin Philosophiae – a postgraduate degree bestowed on students by universities. The title ‘PhD’ came from the Greek that means “Teacher of Philosophy”, but it does not refer to the field of philosophy only

(Gokhale, 2018:2). It is more in accordance with the original Greek, meaning “love of wisdom”. In medieval Europe, the PhD was initiated to act as a licence for teaching at universities and was only established in the early 1800s as a research degree in Germany. The German universities, offering PhDs, started to appeal to foreign students – American students in particular. Yale University started to produce PhDs in 1861, which led to Canada in 1900, and the United Kingdom (UK) in 1917, to follow suit. In the United States of America, the PhD degree consists of undertaking advanced level taught courses and academic research. In the UK, Europe and Australia, the degree is entirely research based (Gokhale, 2018:2). Irrespective of the different research cultures, a PhD comprises critical investigation, collection, sorting and analysis of information, in order to create new knowledge (Gokhale, 2018:3).

Doctoral education is changing and adapting worldwide. At the centre of the change is the pressure to increase the number of doctoral degrees. Countries are using the PhD to establish themselves as a knowledge society, or to gain a competitive advantage in the knowledge economy on a global scale. Governments have therefore encouraged the increase in doctoral degrees at universities (Bao, Kehm & Ma, 2016:524). The goal for South Africa is that 75% of all academic staff must have a PhD by 2030. Universities in countries such as Kenya, Nigeria and Senegal even stipulated that all their lecturers must have a PhD within a prescribed period (Mohamedbhai, 2020).

2.4.2.1 (ii) Challenges in doctoral education

The International Association of Universities (IAU) and the Catalan Association of Public Universities (ACUP) during discussions in 2012, identified main challenges that prohibit the creation and promotion of doctoral education. The shortage of funding for students and institutions, institutional capacity, poor supervision, and lack of academic freedom and international information networking are identified as challenges. Cloete *et al*. (2015:9) identified two other main challenges: the weak link of the PhD research to industry, and the lack of awareness to national needs that resonates with this research.

The production of doctorates is affected by dropout and low completion rates, which is seen as inefficient. This means that only around 50% of all students enrolling for a PhD will complete the degree (Cloete *et al*., 2015:22).

In African higher education institutions, doctorate research face challenges such as shortage of funding, poor quality supervision, weak linkages to industry, a lack of international information sharing, among others. To address these challenges there need to be strategies in place that include innovative methods and enhanced data collection methods (Cloete *et al*., 2015:9). The quality of doctorates needs to be improved by better supervision competencies, planned and controlled evaluation systems, and flagship institutions. Government needs to ensure that they support research through funding, by providing incentives. Networking must also be enhanced to increase the sharing of good practises (Cloete *et al*., 2015:9).

In the 1990s, the discussion in higher education in South Africa also revolved around access and equity. This was to address the racial and gender disparities (Cloete *et al*., 2015:15). Irrespective of the challenges, the demand for doctorates is increasing.

2.4.2.1 (iii) Demand for doctorates

The traditional role of a PhD was to deliver future academics; however, from 1990 onwards, the focus has since shifted, and the PhD is now playing a major role in the knowledge economy. As stated previously, the South African government, by means of the National Development Plan (NDP), aims to increase doctoral studies to 100 PhDs per one million of the population (5000 doctorates) by 2030. There has been a steady increase in PhD students in South Africa since 2008, perhaps due to a new funding formula that was instated in 2005 (Van Schalkwyk, Mouton, Redelinghuys & McKenna, 2020:2). Africa, including South Africa, needs more doctorates for African development (Cloete *et al*., 2015:2)

In 2010, the Academy of Science of South Africa (ASSAf) undertook a study on how to meet the demands of high-level skills in an emerging economy. The study revealed that more PhD studies are needed and provided proposals on how this could be achieved. The quality and significance of PhDs must not, however, be compromised by quantity (Mohamedbhai, 2020).

2.4.2.1 (iv) Demand to increase efficiency, quality and significance

In the effort to increase PhD's the quality of the PhD became a concern. The Education White paper of 1997 had no discussion on methods that propose how to assess the quality of PhDs, and no university, offering doctorate degrees has undergone a quality review by the CHE (Cloete *et al*., 2015:104). The CHE suggested that universities should retain their own quality assurance, stating that the CHE would only review the effectiveness of the university and validate the monitoring thereof. In February 2017, the CHE launched the National Reviews of Doctoral Studies, which consist of self-evaluation reports that are interrogated and validated by trained peer reviewers during site visits (Harley, 2020).

Cloete *et al*., (2015:61) defines efficiency as when the systems in place retain students and allow for students to progress from first year degree levels to PhD degrees within acceptable time frames. The system is further efficient if academic staff with PhDs produce more graduates with PhDs. Cloete *et al*., (2015:106), propose a framework that differentiates between seven dimensions of quality. The measurement to determine the quality are the doctoral candidate, the doctoral programme, the doctoral supervisor, the supervision process, the doctoral graduate, the thesis, and the journal paper originating from the thesis.

Investment into higher education by governments and the public, is done because they believe that it creates social and individual benefits, and a strategy for economic development (Mohee, Mhlanga, Wittfoth, Vilakati & Makuku (2020). Taxpayers therefore need to benefit from the value and contributions of PhD research (Van Schalkwyk *et al.,* 2020:1). The finding by the ASSAf report, that South Africa needed more PhDs to enhance the link with national competitiveness in the global knowledge economy, led to more incentives for institutions, but the quality was compromised (Maree, 2012:1).

Most concerning was the significance of the PhD and not more PhDs. Significance is one of the major reasons why published research is not taken seriously by practitioners or policymakers. The categories of significance are practical, theoretical, emotional and personal significance. Practical significance is the practical, real-life application of the findings of applied research, whereas theoretical significance is the

finding of a new insight or understanding into a familiar or old problem (Maree, 2012:12). Emotional significance of research may cause new feelings or emotions towards others or oneself, and personal significance is when the research has a close and personal link with the researcher (Maree, 2012:11). Creswell (2014:27) also mentions that worthwhile research adds to the body of research in a discipline, gives a voice to underrepresented people, or helps to address social injustices. The choosing of topics and titles is therefore an important aspect in the journey to a PhD.

2.4.2.1 (v) How topics and titles are chosen

The choosing of a topic and the formulation of a title that is achievable and unique may be a difficult undertaking. The choosing of a topic usually starts with a broad subject. The broad subject is determined by observing phenomena, consulting the opinion of an expert, and the reading of literature to see what has been done in the specific research area. The broad subject area is then narrowed down to a definite research question (Maree, 2012:20). Advice and comments from colleagues, authorities within the discipline and academic advisors may be requested, to establish whether the title and project is researchable or would have important consequences (Creswell, 2014:27). A suitable topic and title will provide further motivation to a student to enrol for and complete a PhD. There is currently no centralised coordinator that guides the choosing of a topic and this is very much a self-organising aspect of a complex system (section 2.3.2.1 (viii)). A student can, however, consult in South Africa the NEXUS database of the National Research Foundation (NRF), to assist them in choosing a topic. The NEXUS database has provided information on PhDs in all fields of science, since 1919. The database supports the sharing of research data and aids students in the decision-making process of a topic and research study (NRF, 2020a:1).

2.4.2.1 (vi) Motivation to do PhDs

The factors that influence students concerning where to enrol for their doctorates are the relationship with the academic supervisor, the academic reputation of the university and the availability of job opportunities, funding or bursaries (Cloete *et al*., 2015:46; Wiegerova, 2016:126). PhDs are done to receive a higher degree that may improve career opportunities by obtaining higher positions in the workplace or to change careers (Creswell, 2014:27; Mouton 2001:5; Wiegerova, 2016:126).

Mouton (2001:4) provides reasons on why students are motivated to undertake postgraduate studies. One of the reasons students may choose to do a PhD is that they want to gain specialised knowledge to become a recognised expert in a specific research area, or to start an academic career. Another reason that Mouton (2001) offers as a motivation, is that prospective students are curious, and others do not want to be bored anymore and will therefore start to study further. Wiegerova (2016) divides the motives into two large groups, external and internal. External motivation includes the realisation of someone else's ideas or obtaining a financial income without experience, where the internal motivations are, for example the desire to be a researcher or to extend their student life (Wiegerova, 2016:127). The family life of a student and the student's own conviction to complete a PhD are further factors that WIegorva (2016) highlights as motivation.

A PhD study in South Africa requires a learner to demonstrate "*expertise and critical knowledge in an area at the forefront of a field and the ability to conceptualise new research initiatives and create new knowledge or practice*" (South African Qualifications Authority (SAQA), 2012:12). The PhD is further considered new or innovative by peers and it needs to make a noteworthy contribution to the field (Van Schalkwyk *et al*., 2020:1). The contribution must be "*original and at the frontiers of a discipline or field*" (Council of Higher Education (CHE), 2013:40). Thus, PhDs are a significant source of information to study trends in any field as PhDs create, distribute and disseminate scientific information (Bozkurt *et al*., 2015:1). PhDs may be an early indicator of the status of a body of knowledge and can create a platform for further research that is relevant to the goals, objectives, and vision of a field of study (Xifra & Castillo, 2006:303). Kok and Pietersen (1999:20) suggested that South Africa plan research and technology development, in order to meet the environmental impediments of the next century.

2.5 Chapter Summary

The literature review was done using the five contexts of Plowright (2011). By using these contexts, a clearer idea was provided that demonstrates the viewpoint where the study idea originated. The discussion of previous studies using similar methods gave an enhanced motivation for this study. The theoretical framework on which the

research is based, contributed to the explanation of the process and phenomena. The national and policy contexts of the two constructs relating to this research were set and a further motivation was given as to why the particular environmental documents and the PhDs degree were chosen. As the background and contexts of this study and its main constructs are clarified, the methodology of the research can now be discussed.

Chapter 3 – Research design and Research methodology

3.1 Introduction

As the research question has been formulated and the context of the research discussed, decisions regarding the type of data, data collection methods and data analysis can commence (Plowright, 2011:7). However, as with all research, the research design and methodology needed to be clarified to ensure that research rigour of research is maintained. For this reason, an overall view of the research method is provided, followed by a step-by-step discussion on how data was collected to reach the research objectives and answer the research questions. With all research however, the research was also based on a research philosophy that forms part of the research design discussion.

3.2 Research Design

There are three ways to critically review research philosophy of which one is epistemology. Epistemology is the way a researcher views the world, and this will influence the research strategy and methods (Mason, 2014:52). Epistemology is concerned with the study of the nature of knowledge; it is about the way one knows things, or how something can be known, as well as the view of a researcher as to what constitutes valid and acceptable knowledge (Saunders, Lewis & Thornhill, 2012:132; Maree, 2012:70). In this instance the researcher was the instrument who conducts the research. The nature of a research philosophy indicates the type of philosophy that will be followed in the research (Creswell, 2014:6).

Research philosophy relates to the development of knowledge and the nature of that created knowledge in a particular field (Saunders *et al*., 2012:127). It is a belief system regarding the approach to which data should be collected, analysed and utilised (Davison, 1998:31). The philosophy that underpinned this research was interpretivism, which is an attempt to interpret the world around one. Interpretivism involves a researcher interpreting elements of a study and focusing on meaning, which mostly only materialises at the end of the study (Dudovskiy, 2016). The focus is on the details of a situation, the reality behind the details, and subjective meanings that stimulates

actions (Saunders *et al*., 2012:140). More specifically, the interpretivist philosophy aligned with the objectives of this research. A content analysis of the nature and characteristics of South African PhD research in environmental studies was firstly done, followed by an interrogation of legislation, policies, plans and strategic goals.

Further, linked to the philosophy is the research approach that was, in this case inductive. The research reasoning was of an inductive nature, as the data moves from the specific to the general (Elo & Kyngäs, 2007:109). An inductive approach involves the collection of data to explore the phenomenon, after which themes and patterns are identified, then a discussion of the data analysed follows, and finally the creation of a framework (Saunders, *et al.,* 2012:144). This inductive approach was followed for this research, commencing with collecting data and then creating a theory – or, in this instance a comparative knowledge map. To give effect to the research approach, the research required a methodological choice and a time horizon.

The methodology for the research was a qualitative study that utilised a systematic review, and, specifically, a mapping review or systematic map using a content analysis process to analyse existing literature. A systematic review collects all existing evidence on a specific discipline so that a research question can be answered. A systematic review, when done correctly, should have objectives and a methodology that can be replicated. It needs to identify all the evidence or data that is available by using a thorough search plan. The validity of the findings of the data that will be used must be assessed. Further, the findings of the systematic review should be synthesised in a systematic manner (Bakker, 2020).

A mapping review, or systematic map, is used to categorise and map existing literature pertaining to a specific topic. This mapping review identifies gaps in research literature that in turn can generate new reviews or further research. A mapping review offers policymakers and researchers a clear way on how to narrow down policy or practice review questions, and whether to undertake in-depths reviews or only sub-set reviews (Grant & Booth, 2009).

The time horizon was cross-sectional, as the research made comparisons at a single point in time, between the years 1998 and 2017. The following section on research

methods took the above into consideration when the method of how the objectives of this research were achieved and how the research questions were answered, was given.

3.3 Research Methods

As mentioned in the research design section, the content analysis research method was chosen for this research. The analysis of content is a qualitative approach, which began in the 19th century. In the1950s Siegfried Kracauer reasoned that text loses meaning through reduction to words by using a quantitative approach (Priest, Roberts & Woods, 2002:36). The use of content analysis refines words into less, content-related categories (Elo & Kyngäs, 2007:108). This method makes extrapolations from data to their context, to provide knowledge and new insights and a guide to action (Elo & Kyngäs, 2007:108).

A content analysis uses many words or texts to classify it into smaller content categories where it is presumed that the words or texts have a similar meaning in the categories (Weber, 1990:118). A systematic review process was followed, which had eight steps as per Bakker (2020) and was included in three phases (Figure 3.1). The systematic review process starts with a research question or step 1 (section 1.3). In the preparation phase, a research protocol (step 2) was developed that includes decisions on sampling (section 3.3.1). A literature search was then conducted (step 3) to select and collect the data (step 4) (section 3.3.2), which was then verified by the universities (section 3.6). The research protocol included all the PhDs done in South Africa, based on South African environmental issues, that were found in various departments of environmental research in Higher Education Institutions (HEIs), between 1998 and 2017. In the organising phase, the collected data was appraised (step 5) and ordered, so that the data could be extracted (step 6) and analysed (step 7) (section 4.2 & 4.3). The Leximancer software program was additionally used to analyse data by text-mining concepts and themes, which lead to the creation of theme maps (section 3.3.3). The use of the Leximancer software ensured reliability and objectivity in the analysis process. The final phase was reporting the results and action phase, which included the interpretation (Step 8), findings, discussion of results and drawing conclusions. The findings and results were categorised and interconnected to

create a comparative knowledge map that can lead to research ideas. These agendas initiate change, and further benefits the wellbeing of South Africa's environment and citizens (Creswell, 2014:200; Bakker, 2020).

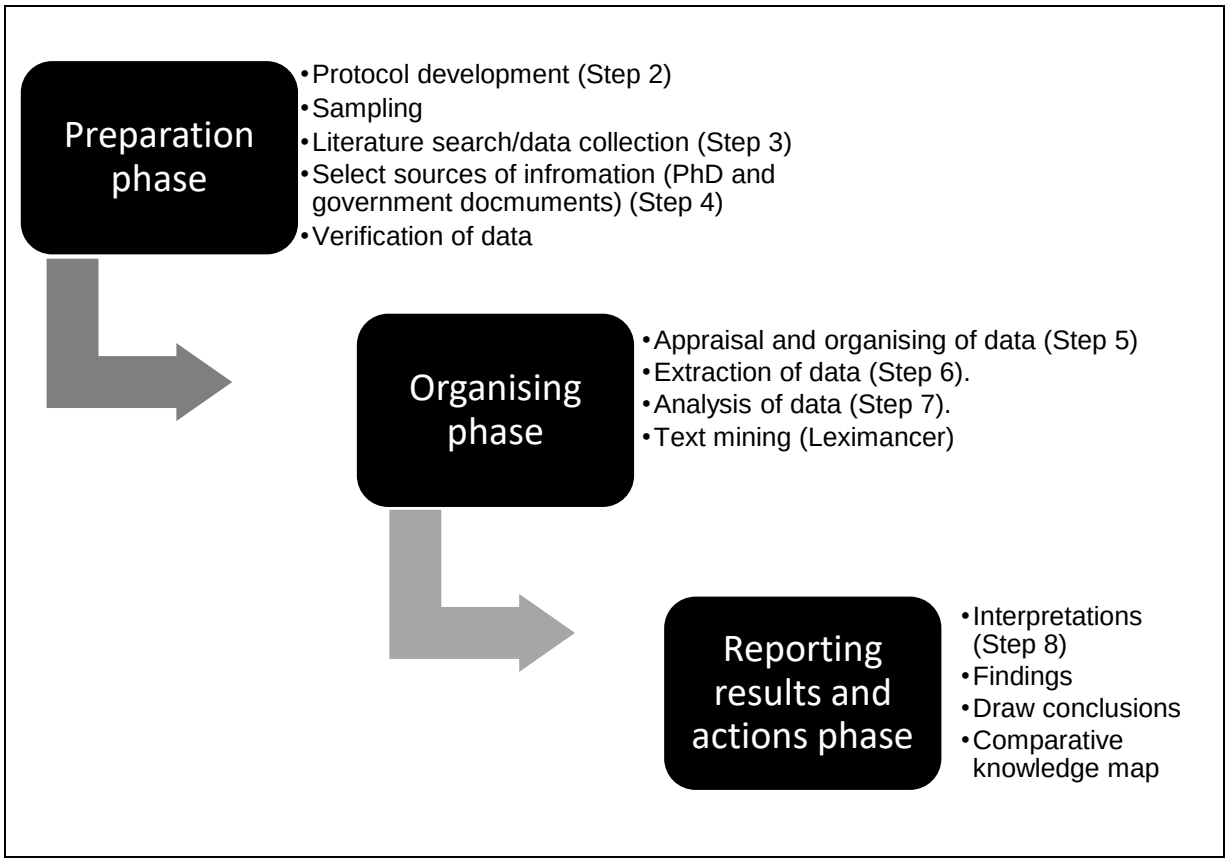


Figure 3.1: The content analysis review process for this research. (**Source**: Adapted from Weber, 1990; Elo & Kyngäs, 2007:110; Brereton *et al*., 2007:572; Plowright, 2011:17; Bakker, 2020).

3.3.1 Data sampling

The intended research aimed to include all the PhDs done in South Africa, based on South African environmental issues that were found in various departments of environmental research in Higher Education Institutions (HEIs), between 1998 and 2017. Table 1.1 reflected the seventeen institutions that were included for this study. The sampling was therefore a census, intentional and purposeful (Maree, 2012:73).

This research, including the documents containing the national environmental management legislation, policies, national and international plans, and goals that are important for South Africa, also made use of purposive sampling, as these documents were viewed to produce the most important information about the phenomena that was studied (Table 2.1 and section 2.4). The sampled documents adhered to the

protocol for inclusion in this study, as discussed in Section 2.4. In terms of data collection, these documents are specified and further discussed in section 3.3.2.1.

3.3.2 Data collection

Data was collected for a content analysis review process that was systematic, and where measures were applied to ensure that the process was objective (Leedy & Ormrod, 2013:149). The purpose of a content analysis review process is to identify certain characteristics within a body of knowledge. A specific section in the environmental management body of knowledge was identified and, in this case, it was the research priority topics in South African PhD research in environmental management, sciences and studies between 1998 and 2017 and related legislation, policies, plans and goals.

3.3.2.1 National environmental management documents

The first objective was to interrogate the national environmental management legislation, policies, plans and goals for South Africa in order to extract strategic research themes. Government documents that were motivated for inclusion in the study were retrieved to give effect to the first objective of this research:

- The SEMAs of NEMA
- The Kok and Pietersen (1999) survey report on Environmental Management
- The three State of the Environment Reports (SOER & SAEO)
- The National Development Plan – 2030
- African Union’s Agenda 2063

All the above documents, except the Kok and Pietersen (1999) survey report on Environmental Management, were found on the government websites (Table 3.1). A copy of the Kok and Pietersen (1999) survey report was found in the Unisa library. Once all the data were collected, it was manually analysed.

Table 3.1: Government documents and government websites.

Government document	Website
The NEMA and the SEMAs	https://www.environment.gov.za/legislation/actsregulations
The three State of the Environment Reports (SOER & SAEO)	https://www.environment.gov.za/otherdocuments/reports
The National Development Plan – 2030	https://www.gov.za/issues/national-development-plan-2030
African Union's Agenda 2063	https://au.int/en/agenda2063

(**Source:** Own).

The second objective of the research was to systematically analyse the nature and characteristics of South African PhD research in environmental studies between 1998 and 2017. This was done by scrutinising the institutional repositories of the universities. These institutional repositories were found in the online libraries of the respective universities. The list of PhDs at each university was send to the Heads of Departments for verification of the information that was collected.

The websites of the universities were also visited to acquire a better understanding of each department. An overview of environmental studies at South African universities could then be formed. The following section provides a brief overview of environmental studies at the seventeen traditional and comprehensive public tertiary education institutions that forms part of this research. The research focus areas, research chairs, research centres and the number of PhDs per university are highlighted. The South African Research Chairs Initiative (SARChI) is an initiative of the Department of Science and Technology but is managed by the National Research Foundations (NRF) with the purpose to strengthen South Africa's ability to produce quality research and students and quality innovation (NRF, 2020b:1). The latest SARChI list was compiled by the NRF in 2018, and the chairs are discussed under each of the relevant departments.

3.3.2.2 University of Cape Town (UCT)

The name of the environmental department at the University of Cape Town (UCT) is the Department of Environmental and Geographical Science. This department at UCT has produced twenty-six PhD studies that fall within the parameters of this study (University of Cape Town (UCT), 2018:1). However, after several attempts (emails and

phone calls) over the verification period of 12 months, the PhDs were not verified by the department.

The UCT has four chairs as per the NRF SARChI 2018 list, that relate to environmental studies. They are Climate Change, Environmental and Social Dimensions of the Bio-Economy, Marine Ecology and Fisheries, as well as Ocean Atmosphere Modelling (NRF, 2018). UCT does not have a centre of excellence tied to environmental management, but has interdisciplinary hubs or research institutes, which include the Climate Systems Analysis Group (CSAG), the African Centre for Cities (ACC) and African Climate and Development Initiative (ACDI) (University of Cape Town (UCT), 2020:1).

3.3.2.3 University of Fort Hare (UF)

The environmental section is found within the Faculty of Science and Agriculture. The Geography and Environmental Science department of the University of Fort Hare has produced one PhD between 1998 and 2017, and this was verified by the Head of Department. The other PhDs were done in Geography. Only the one PhD that related to environmental studies was included in the study. When verification of the data was done, it was conveyed that there are more Master level students at the institution. The university has several research initiatives and chairs, but they are not directly linked to environmental management (University of Fort Hare, 2018:1; NRF, 2018).

3.3.2.4 University of the Free State (UFS)

At the University of the Free State, the Centre for Environmental Management is located in the Faculty of Natural and Agricultural Sciences. Nine PhDs have been awarded at the centre during the demarcated time of this study (University of the Free State, 2018b:1). This was verified by the Centre for Environmental Management itself. One PhD could not be located in full text for analysis purposes, and hence was not included. This university does not have a research chair linked to environmental management (NRF, 2018). Only short courses and postgraduate degrees in environmental management are offered, and the focus is on corporate environmental management. The short courses concentrate on wetlands and Geographical Information Systems (GIS) (University of the Free State, 2018a:1).

3.3.2.5 University of KwaZulu-Natal (UKZN)

The environmental department is found in the School of Agricultural, Earth and Environmental Sciences at the University of KwaZulu-Natal. This department has awarded thirty-five PhDs in Environmental Sciences between 1998 and 2017, where the study area was South Africa-focussed (University of KwaZulu-Natal 2018). The Head of Department verified the list containing the PhDs done at their institution, but only information after 2011 could be verified. All the PhDs in the institutional repository (Doctoral Degrees, Environmental Science) were, however considered, and included in this study. A focus area is Energy and Technology for Sustainable Development. This unit focusses on renewable and alternative energy systems and technologies that include solar, wind and biofuels. This research focus area hosts two SARChI research chairs, namely, the Ecosystem Health and Biodiversity in KZN and the Eastern Cape and the Land Use Planning and Management Chair (NRF, 2018).

3.3.2.6 University of Limpopo

The Geography and Environmental Studies department is within the School of Agricultural and Environmental Sciences, where no PhD study could be located within the departments' repository (University of Limpopo, 2018a:1). Verification could not be obtained. Environmental Chemistry is one of the research focus areas at the university, one research chair could be found on the 2018 list of NRF research chairs: Ecosystem Health: Monitoring and Managing the Health Resilience of the Limpopo River Basin (University of Limpopo, 2018b:1; NRF, 2018).

3.3.2.7 North West University (NWU)

Environmental studies are offered at the Department of Geography and Environmental Studies and the Unit for Environmental Sciences and Management in the Faculty of Natural and Agricultural Sciences. The unit is the administrator of PhD degrees. The sub-programs within the unit are climate change, air quality and impacts; aquatic ecosystem health; biodiversity and conservation ecology; ecological interactions and ecosystem resilience; environmental management; integrated pest management; geology soil science, and spatial planning and implementation (North West University, 2018a:1). Thirty-nine PhDs were done between 1998 and 2017 (North West University, 2018b:1). This could however not be verified as the Promotion of Access to Information Act No 2 of 2000 (PAIA) of South Africa was invoked upon the verification request and

denied on the basis of "*the work involved in processing the request would substantially and unreasonably divert the resources of the public body".* There are also no SARCHI research chairs related to the environment (NRF, 2018).

3.3.2.8 University of Pretoria (UP)

Environmental studies at the University of Pretoria can be found in the Centre for Environmental Studies, Faculty of Natural and Agricultural Sciences (University of Pretoria, 2018a:1). No SARChI research chair linked to environmental studies could be identified (NRF, 2018). They have two research projects, the Lubombo trans-frontier sustainable livelihoods project, that promotes biodiversity conservation, and the Mariepskop long-term observation site, that monitors climate change. Ten PhDs relating to environmental studies were found and verified by the Head of Department (University of Pretoria, 2018b:1).

3.3.2.9 Rhodes University (RU)

Rhodes University has two SARChI research chairs associated with environmental studies (NRF, 2018). They are Marine Ecosystems and Resources, as well as Interdisciplinary Science in Land and Natural Resource Use for Sustainable Livelihoods. The university website does not indicate specific research focus areas, but rather the characteristics that an area must display (Rhodes University, 2018a:1). The environmental science department has several research projects that include sustainable land management, energy saving in South African households, sustainable services from the ecosystem and urbanisation and its impacts on the use of natural resources in Africa (Rhodes University, 2018b:1). Fifteen PhD degrees were bestowed on students from 1998 to 2017 (Rhodes University, 2018c:1). When verification was done, the Head of Department indicated that one of his PhD students were not on the list but verified the remaining 15 PhDs. That specific PhD did not pertain to South Africa and hence not included in the research.

3.3.2.10 University of Stellenbosch (US)

Environmental Studies is in the Faculty of Arts and Social Sciences, and more specific within the Department of Geography and Environmental studies (University of Stellenbosch, 2018a:1). One SARChI research chair, Sociology of Land Environmental and Sustainable Development, could be found on the NRF list, that has

relevance to environmental studies (NRF, 2018). The Head of Department, through the provision of graduation lists from 1937 to 2019, indicated that thirty-one PhDs were completed. However, from the thirty-one degrees only eleven had relevance to environmental studies. The list received from the Head of Department included PhD studies not done about South Africa, or they related to Geography. A further two PhDs were not included in the study, as it was submitted in Afrikaans, which is not compatible with analysis on Leximancer. These two PhDs also pertained more to geography. The institutional repository of this university was used to collect the eleven electronic copies of the PhDs for the study (University of Stellenbosch, 2018b:1).

3.3.2.11 University of the Western Cape (UWC)

The Faculty of Arts is home to the Department of Geography, Environmental Studies and Tourism. No PhD degrees have been awarded and this has been verified with the Head of Department (University of the Western Cape, 2018:1). According to the 2018 NRF list of SARChI research chairs, there are no research chairs that are relevant to environmental management (NRF, 2018).

3.3.2.12 University of the Witwatersrand (Wits)

There are two schools at the University of the Witwatersrand that were responsible for the sixteen environmental management related PhD degrees (University of the Witwatersrand, 2018a & b:1). The one is the School of Animal Plant and Environmental Sciences, where animals and plants are mostly the focus of the research (University of the Witwatersrand, 2018c:1). The other is the School of Geography, Archaeology and Environmental Studies, where the research focus area is more of an archaeological nature (University of the Witwatersrand, 2018d:1). On the list of SARChI research chairs, the university holds many chairs, with one directly related to environmental studies, namely Global Change and Systems Analysis (NRF, 2018). Both schools provided information for the PhD verification process. A digital full-text copy of one PhD could not be located. The author was requested for such a copy but could not be provided and subsequently does not form part of the study. Hence only fifteen PhDs were used for the research.

3.3.2.13 University of Johannesburg (UJ)

Environmental studies are situated in the Department of Geography, Environmental Management and Energy Studies, Faculty of Science. Their research strength is environmental management and they have produced seventeen PhDs (University of Johannesburg, 2018a:1 & 2018b:1), which was verified by the Head of Department. The university does not have a research chair that is connected to environmental studies (NRF, 2018).

3.3.2.14 Nelson Mandela University (NMU)

This university does not have a dedicated department that offers environmental studies. They only have a School of Environmental Sciences that host's agriculture, botany, zoology and geosciences (Nelson Mandela University, 2018a:1). It does however also have a sustainability research unit that promotes sustainability and resilience of social-ecological systems (Nelson Mandela University, 2018b:1). The NMU has four SARChI research chairs. An Earth Systems Science, Marine Spatial Planning, Shallow Water Ecosystems and SA-UK Bilateral Chair in Food Security is located at this university (NRF, 2018). The institutional repository was searched to identify PhDs that are relevant to environmental studies and six could be found (Nelson Mandela University, 2018c:1). These six PhDs were awarded in Environmental Geography and was verified by the Head of Department by means of graduation lists between 1998 and 2017.

3.3.2.15 University of South Africa (Unisa)

The School of Environmental Sciences offers PhD degrees in both environmental sciences and environmental management. A total of twenty-seven degrees have been awarded within the study period and scope (Unisa, 2018c:1). The verification of the PhDs was done by means of graduation lists provided by the Graduations department at Unisa. The NRF list (2018) indicates that there are no SARChI research chairs associated with environmental studies at Unisa. One of their research focus areas and groups are research in environmental pollution, ecotoxicology, and remediation studies (Unisa, 2018b:1).

3.3.2.16 University of Venda (UV)

The School of Environmental Sciences at the University of Venda was established in 1995. The school has eight departments and programmes in Environmental Sciences, Environmental Management, Earth Sciences, Hydrology, Water Resources and Mining and Environmental Geology (University of Venda, 2018b:1). To date, four PhD degrees were bestowed on candidates falling within the parameters of the study (University of Venda, 2018a). Only one of the PhDs was available as an electronic copy and was found on Google. The other three are only displaying the first four pages. This is due to the fact that only the first four pages of each of the PhDs were scanned for the institutional repository, but the university library. Attempts were made to borrow the three PhDs through inter library loan. However, the University of Venda library does not lend out their PhDs. No verification could be obtained that these are the only four PhDs, even though attempts were made to do so. The university has a SARChI research chair with the name of Biodiversity Value and Change in the Vhembe Biosphere Reserve (NRF, 2018).

3.3.2.17 Walter Sisulu University

The Faculty of Natural Sciences hosts the Department of Biological and Environmental Sciences (Walter Sisulu University, 2018:1). The department does not offer a PhD degree in environmental studies hence no PhD degrees could be found within the institutional repository (Walter Sisulu University, 2018:3).

3.3.2.18 University of Zululand

The Faculty of Arts indicated that a PhD in environmental studies is not catered for (University of Zululand, 2018a:1), and the Faculty of Science and Agriculture does not make provision for such a degree (University of Zululand, 2018b:1).

In total from all the above-mentioned Higher Education Institutions, two hundred and fourteen (214) PhDs were recorded and verified at traditional and comprehensive public tertiary education institutions that falls within the ambit of the research scope, and between the years 1998 and 2017 (Table 3.2):

Table 3.2: A summary of SARChI research chairs and the number of PhDs per university.

	University	SARChI research chair	PhDs in Environmental Studies
1	University of Cape Town	4	26
2	University Fort Hare	0	1
3	University Free State	0	8
4	University of KwaZulu-Natal	2	35
5	University of Limpopo	0	0
6	North West University	0	39
7	University of Pretoria	0	10
8	Rhodes University	2	15
9	University Stellenbosch	1	11
10	University of the Western Cape	0	0
11	University of the Witwatersrand	1	15
12	University of Johannesburg	0	17
13	Nelson Mandela University	4	6
14	University of South Africa	0	27
15	University of Venda	1	4
16	Walter Sisulu University	0	0
17	University of Zululand	0	0
		Total:	**214**

(**Source**: Own).

3.3.3 Data Analysis

The PhDs that were sourced digitally as the dataset for this study was firstly analysed manually to establish the content thereof. After that, a text mining tool, Leximancer, was used. The results of both the processes were recorded in a datasheet. The link to the datasheets can be found in Chapter 4: section 4.3. Leximancer is a Computer Assisted Qualitative Data Analysis Software (CAQDAS) program that is used to text-mine the content of documents. It is a piece of concordance software and an automated lexicographic tool that visually displays the text-mined content of documents (Finneran, 2018:35; Hyndman & Pill, 2018:297). The text is coded automatically after it is analysed, by allocating categories in a multi-dimensional space (Van Lill & Marnewick, 2016:2). It uses a statistics-based algorithm that mines textual data and extracts concepts (Samuel, Conçeição & Martin, 2018:2; Sotiriadou, Brouwers, & Le, 2014: 219). The program processes textual documents by defining

contextual associations of words trough term occurrence information. The term occurrence information entails nouns and verbs and their co-occurrence, positions, and frequencies.

Leximancer indicates the frequency of words in text, their connection with each other and their spatial proximity. Leximancer automatically starts by identifying seed words. Seed words are words that most frequently appear in the text. The seed words are then the starting point for defining the concepts. A concept is a collection of seed words that usually *"travel"* together in written text (Thomas, 2014:236). As the program learns more, the seed words are updated, and a thesaurus is created for each concept. The program scans blocks of text and attempts to provide definitions for concepts by identifying the co-occurrence of words within documents (Leximancer, 2018:11).

The data is then used to make two decisions: the most recurring used concepts and the relationship between them (Thomas, 2014:236). The concepts are then grouped together into higher-level themes. The themes are therefore a collection of the concepts that are located together and have a relationship in the text data (Leximancer, 2018:9).

As the co-occurring concepts are combined into themes, the themes are used to create concept maps that show the scale of connections between the concepts and the degree the concepts appear close to each other in the documents that are being analysed (Hyndman & Pill, 2018:297). On the concept map, there are 'bubbles', grey dots and lines. The 'bubbles' on the concept map represent the themes. The name of the theme is derived from the concept most highly connected to the other concepts or most central in meaning within the bubble. It is not the most frequently appearing concept. The name of the 'bubble' can be changed manually by the researcher. These 'bubbles' on the concept maps are heat coloured, according to the colour wheel, which means that most relevant themes are hot colours such as red or yellow and least relevant themes are cold colours such as green or purple (Thomas, 2014:241; Leximancer, 2018:12). The grey dots on the concept map indicates the concepts. The size of the dot provides an indication of the frequency of the co-occurrence of words, the relation between the concepts and their prominence in the data. Leximancer allows the researcher to set the thematic size of the concept map. This means that the size

of the ‘bubbles’ or theme will change, for example if the thematic size is 50%, six themes will be visible on the concept map. At 55%, four themes can be seen, and at 100%, usually only one or two themes are seen on the concept map (Harwood, Gapp, Stewart, 2015:1035). The identified concepts, however, remains the same, and will only be included in the larger or smaller themes.

The lines on the concept map between the concepts, connects the concepts and provide a pathway between the related concepts. What must be noted, however, is that the distance between the dots does not mean that the concepts are more closely related or connected to each other (Leximancer, 2018:15). As Leximancer only identifies concepts and generates a concept map, the researcher must still interpret the concepts and provide a deeper meaning, in the context of the relevant discipline.

Leximancer therefore changes documents into words, concepts, themes and concept maps (Figure 3.2), and thereby provides a way to view textual data in a visual format. This allows for the relationship between concepts to be visually read (Finneran, 2018:35). The Leximancer maps for each PhD was done and included as datasheets in Chapter 4.

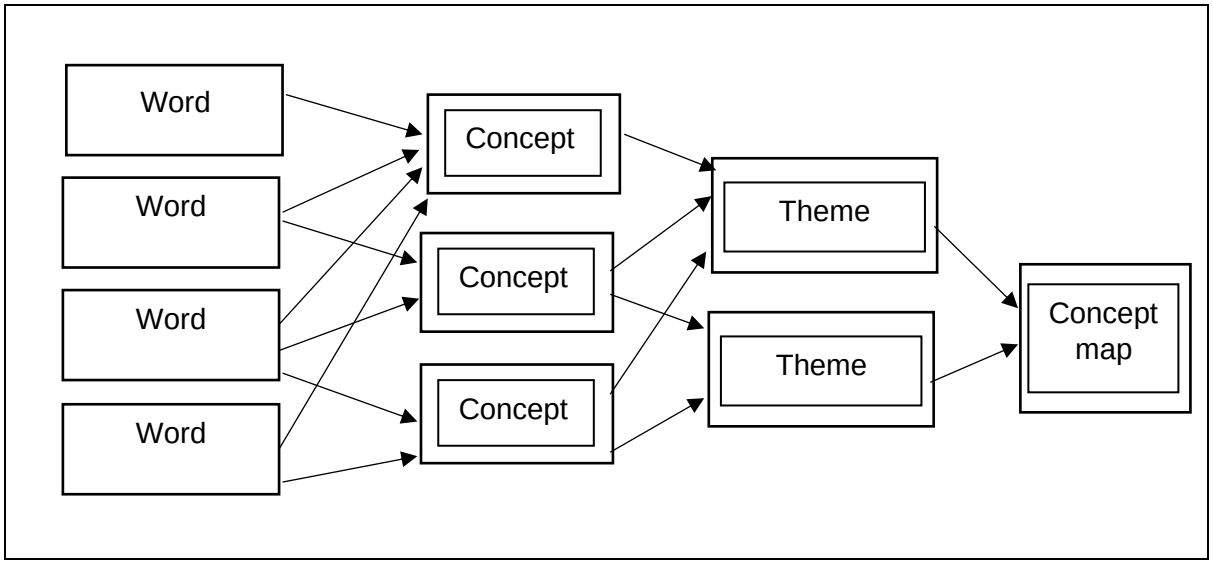


Figure 3.2: Process of text into words, concepts, themes and concept maps as done by Leximancer. (**Source**: Hyndman & Pill, 2018:297).

Sotiriadou *et al.* (2014) explain that Leximancer is useful when textual data is studied in an attempt to discover important factors. If a set of factors or a model is used to

analyse data, Leximancer is not that useful. This research does not have a set of factors but is interested in discovering important factors. Leximancer was therefore used for this research to create concept lists and theme maps. The concept lists and themes were extracted automatically from the text, according to the relationships between concepts and the frequency of when the related term and concepts appear in association to each other in the documents. A spatial and relational analysis was therefore carried out. After the concept maps were created by Leximancer, the focus turned to the gaining of meaning and interpretation of the concept maps. The goal of creating themes was to afford a method of describing the phenomena and the generation of new knowledge (Elo & Kyngäs, 2007:111). Themes that were identified with Leximancer could then be interpreted further to find meaning of the content of the PhDs, which in turn enabled the achievement of the research objectives.

The PhDs were imported into the Leximancer text-mining software. The default concept analysis was firstly run to determine any apparent concepts that were related to each other – for instance, 'sea level' and 'rise', or 'climate' and 'change'. The software program has a stop list of words to avoid listing common words, for instance articles, as concepts. However, words such as figure, data, chapter, results, etc., were removed manually from the concept list, as Leximancer created themes on the concept map for these words since they appeared so many times within the texts of the PhDs. The main reason for removing the seed words were that they would clutter the concept map with unnecessary information. Plural seed words and synonyms were merged, as well to ensure that the words did not form similar and unnecessary themes. The words that were merged and deleted were recorded in datasheets when each concept map was generated. More detail on the datasheets will be disclosed in Chapter 4.

Not all words were necessarily merged, as for instance ‘change’ as a concept could be related to another concept, and it cannot be assumed that it was always linked to ‘climate change’. Even though the seed words were removed or merged, the main concepts relating to the seed words still showed on the concept map. The removal also did not have any bearing on the outcome of the concepts or themes generated. Concept maps were created to provide a more holistic visual representation for all sampled PhDs per university.

After reading the five government documents, the key points of each document and the themes were identified, and all combined under main categories and aspects. Leximancer was not used for the five government documents. The names and environmental aspects of the documents were deemed more important than the content of the entire document. An ordinal scale was used to arrange the data in order by using a table (Maree, 2020). Once the PhDs and the relevant government documents were analysed and major strategic categories identified, attention was given to Objective Three (3).

Objective Three of the research is to critique a comparable alignment of PhD research done in environmental management to the strategic research themes. After the PhD themes relating to research done in environmental studies and the strategic research categories and aspects, were identified from the legislation, policies, plans and goals in South Africa, a comparison for alignment could be done.

Concept maps of each PhD per individual university were compared to categories and aspects of the government documents. This comparison was done to establish what the main research theme of each PhD, was and whether the research outputs were aligned to the five government documents, as well as whether the PhDs were taking government legislation and plans into consideration.

These comparisons will assist in identifying focus areas that were not covered by the PhD research, and to recognise potential gap areas in alignment with systematic mapping reviews (Grant & Booth 2009). This identification of themes and gap areas will further assist in creating a comparative knowledge map where the knowledge contributions of South African PhDs in environmental studies will be aligned to strategic research themes as per Objective Four.

Knowledge maps can be used to support the translation of knowledge, or as a decision tool that can assist in conveying knowledge and actions. Knowledge mapping assists in the comprehension of how knowledge flows, and what the gaps are. One definition of knowledge mapping is *"an association of items of information, preferably visual, where the association itself creates new, actionable information"* (Ebener, Khan, Shademani, Compernolle, Beltran, Lasang & Lippman, 2006: 636). Another definition

states that it is the process, method and tool used for analysing knowledge, to discern meanings and then to further visualise and highlight the important features (Ermine, Boughzala & Tounkara, 2006:129).

A knowledge map provides information that can be transferred and presented in a way that a non-illustrative method will not be able to do. Knowledge maps enhance the value of critical knowledge (Ermine *et al*., 2006:129). The result of a knowledge map is that the sharing of information is easier, and a more assimilated investigation of a large amount of data or information can be captured, that may not be possible in a table or a piece of text (Ebener *et al*., 2006:636). A knowledge map is concrete, tactical and makes implicit knowledge graphical and more visual. Knowledge mapping assists with the inquiry of difficult processes, and therefore plays an important role in knowledge translation (Ebener *et al*., 2006:640). The knowledge map assists in discovering where the knowledge is located, as well as the use and value of the knowledge (Ermine *et al*., 2006:130).

The process to create a knowledge map consists of five steps, namely acquiring-manipulating-, storing-, processing- and visualising data (Ebener, et al., 2006:637). A knowledge map that is created by following this process must adhere to a visual framework. The visual framework has four perspectives: the function of the map, the knowledge type, the recipient, and the visualisation type (map, image, or diagram) (Ebener *et al*., 2006:636). To create the comparative knowledge maps, the manual analysis and the concept maps generated by Leximancer, for the PhDs, was interrogated, tallied, and compared to the categories and aspects of the government documents. This indicated whether the PhD research incorporated strategic government themes, and whether research is aiding the environmental vision and goals of South Africa.

The comparative knowledge map was then interrogated to address the research questions and acted as a comparison between the critical environmental management government documents and research foci covered by the PhDs. This comparative knowledge map indicated the location of knowledge, the value of knowledge and presented the findings of a large amount of data in a visual format. This map indicated the gaps in environmental studies research, which in turn could transfer this

knowledge into action plans for future PhD research. In creating the knowledge map, reliability and research bias were kept in mind throughout the research process.

3.4 Reliability

Campbell, Quincy, Osserman and Pedersen (2013:295) stipulated three types of reliability: stability, accuracy, and reproducibility. Stability is achieved if the results of the content analysis review does not vary over time and can be achieved by coding the same content more than once in the same category (Weber, 1990:120). Accuracy is where a coding system is already established, and further systems are developed and compared to it (Campbell *et al*., 2013:295). Coding fatigue could lead to inaccurate data at the end of the process. Coding fatigue that sets in and leads to errors in the manual coding process, was avoided by using the text-mining tool. Reproducibility deals with the issue whether different coders will arrive at the same data. To ensure reliability it is important not to modify the meaning of codes when involved in the process of coding. The data must continually be compared with the codes and the initial meanings (Creswell, 2014:303).

Leximancer provides reliability in terms of stability and reproducibility (Penn-Edwards, 2010:264; Harwood *et al.,* 2015:1032). The use of the Leximancer software ensured that the data analysis remained objective and that the same results could be arrived at, irrespective of the number of times the text-mine process was repeated. The study searched for the appearance of certain words and therefore objectivity is enhanced (Leedy & Ormrod, 2013:149). Reliability was enhanced by demonstrating the link between the results and the data (Elo & Kyngäs, 2007:112).

The validity parameters of Leximancer, ‘stability, reproducibility, face, correlative, and functional validity’ were found methodologically sound (Penn-Edwards, 2010:264). The manual evaluation of the sampled PhDs provided a second layer of reliability as the results of the Leximancer process and the manual process corresponded with each other.

3.5 Research Bias

With qualitative research there is always the possibility that the research can be subjective. As this research is qualitative in nature, bias for this study need to be discussed. To avoid research bias, the software program Leximancer was used along with manual examinations, which decreased the research bias.

Leximancer was developed to have a more global perspective when identifying themes and concepts. This increases objectivity and decreases any preconceptions or any prior inclinations that the researcher may have during the collection of data or the manual content analysis (Harwood *et al*., 2015:1032).

The themes themselves were also not decided upon or altered externally by the researcher. The name of the theme was derived from the most connected concepts within the 'bubble' of the Leximancer concept map, but can be changed manually by the researcher, which was not done. Default settings for the program were not changed, and manual interventions of Leximancer were avoided, to ensure that the research bias are decreased.

An advantage of a content analysis literature review is that inaccuracies associated with interactions between the researcher and subjects are circumvented (Mouton, 2001:166). By using the Leximancer text-mining program to analyse data and the interpretation of findings, the subjectivity of the researcher is minimised (Thomas, 2014:235). Further advantages, in terms of research bias and the application of a text-mining software program include reproducibility, the reduction of large pieces of data, the enhancement of systematisation, and transparency of the research process (Crofts & Bisman, 2010:183). The automatic nature of the Leximancer program removes research bias (Penn-Edwards, 2010:263).

3.6 Verification

The PhD data lists that were gathered for the universities were verified with the respective Heads of Departments. In certain instances, Heads of Departments referred the data lists to the graduation sections for further verification. Verification of

the findings by Leximancer was done by including the manual analysis of the data in addition to using the software program.

3.7 Limitations

As Leximancer is a concept mapping tool, it affords creating meaning and connections, and to synthesise data in a distinctive manner. Concept mapping entails an effective process in identifying concepts and depicting connections between the concepts. It can deal with a large amount of data, – in this case, two-hundred and fourteen (214) PhDs in a fast manner. It enables research to study an entire topic in its entirety (Samuel, *et al*., 2018:1).

Leximancer does not, however, identify style, tone or nuances of the text, as it only scans the syntactic properties of text (Penn-Edwards, 2010:264). The lexical analysis done by Leximancer is blind in nature, as it does not group concepts that are linked to each other (Harwood, Gapp & Stewart, 2014:1040). Examples of this are ‘remote and sensing’, ‘climate and change’, as well as ‘sustainable and development’. Sotiriadou *et al*. (2014) argue that the use of a software package such as Leximancer tends to alienate the researcher from the data. They found that a researcher had to read the passage again to understand and verify why Leximancer selected a certain concept or theme. This alienation was mitigated in this study through the manual analysis and verification of the data.

According to Samuel *et al*. (2018:2), a textual analysis may overlook key concepts and the reliability of Leximancer decreases if multi-word concepts are introduced. Leximancer states that it can perform an automatic analysis, but it was found that the user still needs to examine the default findings. A significant amount of time was spent on discovering what the sensitivity of findings were when the settings were changed, before a final concept map was created (Biroscak, Scott, Lindenberger & Bryant, 2017:229).

3.8 Chapter Summary

The chapter described the research design with the associated philosophy. The research methods that were used to answer the research question were discussed in a step-by-step manner, to ensure that all the objectives were handled. A brief overview of the data analysis software, Leximancer, was provided, to describe how the concept maps were created. In Chapter 4, the PhDs from universities will be analysed. Datasheets for each PhD will be produced by using Leximancer and a manual analysis. The government documents will be discussed, and research themes identified.

Chapter 4 – Analysis and Categorisation of PhDs Research

4.1 Introduction

The intention of Chapter 4 is to describe the findings of the analysis done on the data derived from the PhDs, and to establish research themes through categorisation. The two hundred and fourteen (214) PhDs were individually scanned and analysed manually to examine the content of each PhD. They were also analysed by Leximancer to ensure that the manual process was credible. In every instance, the results of the university's PhDs and the Leximancer results were interpreted and deliberated upon. The main themes of both processes were then tabulated in datasheets, compared and discussed. The main themes that emerged from the text-mining analysis were then categorised and placed in themes derived from the strategic government documents.

To analyse and categorise the PhD data, the context of the five government documents were discussed to provide context and meaning. The five government documents (the SEMAs, the Kok and Pietersen survey report (1999), the three State of the Environment reports, the NDP 2030 and the Agenda 2063) were manually scrutinised. The main environmental themes were identified by the documents themselves, so no interpretation was needed. Similar aspects from the government documents were grouped together and a theme was then chosen to best represent the grouped aspects. After the main themes were extracted, similar aspects from the different documents were then placed in Table 4.5 under overarching main themes (presented later in Table 4.5).

4.2 Context of the Five Government Documents

The context of the identified themes in the government documents was hence discussed to ensure that an aspect in the document is clear, correctly interpreted, labelled and categorised.

4.2.1 The SEMAs of NEMA

The Specific Environmental Management Acts (SEMAs), the Biodiversity Act, the Protected Areas Act, the Integrated Coastal Management Act, the Air Quality Act, and the Waste Management Act have regulations on how to manage the aspects identified in each of the Acts. The names of the Acts are mostly self-explanatory, but more context is provided below.

The National Environmental Management: Protected Areas Act No. 57 of 2003 (South Africa, 2004b) describes the different kinds of protected areas, such as provincial protected sites or World Heritage Sites. The Act gives effect to the declaration and management of protected areas, the administration of the Act, and any offences and penalties associated with protected areas.

The National Environmental Management: Biodiversity Act No. 10 of 2004 (South Africa, 2004a) explains the establishment, powers and duties of the South African National Biodiversity Institute (SANBI). It stipulates the operating procedures of the Board and financial matters. Biodiversity planning and monitoring is dealt with in the Act. There is a section on protection of threatened or protected ecosystems and species, as well as the trade in threatened or protected species that are listed. Species and organisms posing potential threats to biodiversity; for example, alien and invasive species, as well as genetically modified organisms, are discussed. Bioprospecting, access and benefit-sharing for all people are aspects that are covered, along with permits, appeals, offences and penalties (South Africa, 2004a).

The National Environmental Management: Integrated Coastal Management Act No. 24 of 2008 (ICMA) (South Africa, 2008a) elaborates on the coastal zone. It defines coastal public property, the coastal protection zone, coastal access land, and control of coastal waters. Boundaries of coastal areas are established, and management of estuaries are discussed. The Act provides for institutional arrangements, coastal management programmes, protection of coastal resources, marine and coastal pollution control, appeals and enforcement.

The National Environmental Management: Waste Act (WMA) No. 59 of 2008 (South Africa, 2008b) provides strategy, norms, standards and measures. Waste management measures include the following:

- Priority waste areas
- Reduction, re-use, recycling and recovery of waste
- Waste management activities
- Storage, collection and transportation of waste
- Treatment, processing and disposal of waste
- Industry waste management plans
- Contaminated land

The Waste Act further offers guidance on licensing of waste management activities, waste information systems, compliance and enforcement including appeals.

The National Environmental Management: Air Quality Act No. 39 of 2005 (South Africa, 2005) presents a national framework as well as national-, provincial- and local standards. Institutional and planning matters are presented that includes the:

- National Air Quality Advisory Committee
- Appointment of air quality officers
- Air quality management plans
- Contents of air quality management plan

In the Air Quality Act, measures for priority areas are declared and managed. Controlled emitters and fuels are identified, along with measures in respect of dust, noise and offensive odours. The process of licensing and listed activities, offences and penalties, are stated. Cross-boundary international air quality management is further identified and managed (South Africa, 2005).

4.2.2 The Kok and Pietersen survey report (1999)

Kok and Pietersen (1999) conducted a two-phase survey with participants from organisational affiliations such as the government, Higher Education institutions, industry, labour, NGOs and research councils. The first phase of the survey was to obtain the views of participants regarding opportunities and constraints of environmental management topics. The second phase of the survey was aimed at

obtaining consensus of the identified topics by the participants. The result of the study suggested and identified topics (Table 4.1) that should be considered for research and development funding in South Africa.

Table 4.1: The Top 10 suggested research priority topics that were to receive research funding.

Rank	Topic description
1	Development of environmentally appropriate technologies to promote a thriving mariculture industry.
2	Development of bioprocessing of organic waste to yield useful chemical and enzymatic products.
3	Widespread use of indigenous pharmacopoeia, food and fibre sources.
4	Development of strategies and technologies to reduce the social impacts of drought.
5	Widespread use of water-efficient and drought-resistant plants including indigenous resources.
6	Widespread use of biotechnology solutions for the clean-up of contaminated land and water.
7	Widespread use of sustainable packaging technologies.
8	Significant use of design centres to support industry with regard to waste minimisation and clean technologies.
9	Development of environmental entrepreneurship training and support systems.
10	Development of capacity within industries to use one another's waste products as source materials within the industrial ecology paradigm.

(**Source**: Adapted from Kok & Pietersen, 1999:18).

4.2.3 South African State of the Environment Reports

South Africa produced three State of the Environment Reports (SOER). The names of the two latest dated documents, 2006 and 2012, are the "South Africa Environment Outlook" report (SAEO), but still report on the same state of the environment issues. These reports indicated the state of the environment in 1999, 2002 and 2012. Each of these reports identified specific ecosystem components, environmental priorities or key issues that needed to be addressed to ensure a more sustainable and a healthier environment. The priority and key issues chosen and listed in Table 4.2 are confirmed by the draft of the new SAEO report (EGSA, 2018:8).

The 1999 SOER identified ecosystem components. These components were habitats, biological resources, physical resources, chemical processes and people (Table 4.2). The report stated that the components and their vital functions need attention to sustain the environment of South Africa. Under the habitat component the rapid expansion of human settlements and activities that lead to the loss of habitat, is discussed.

The biological resources component explains that a high proportion of South Africa's resources (fauna and flora) are listed as threatened, and that fish species are commercially exploited. Water, collection of wood biomass and soil degradation are included in the physical resource's component. When looking at the chemical process's component, aspects such as waste, greenhouse gases, water (freshwater and coastal waters) and soil contamination by various pollutants were included.

The people of South Africa component deliberate on the demographics, poverty, unemployment, education, and health services (Balance & King, 1999). This component was a major theme (Social-People of SA theme) of the research. Considering the broad spectrum of the research the Social-People of SA theme itself is very broad. This theme was therefore divided into three sections, communities, health, and food security issues.

Table 4.2: The major themes provided by the SOER and SAEO's.

The National State of the Environment Report (SOER) 1999 **Themes**	**The South Africa Environment Outlook (SAEO) 2006** **Themes**	**The Second South Africa Environment Outlook (SAEO) 2012** **Themes**
Habitats (loss of habitat due to human activities)	Loss of biodiversity and ecosystem functioning (aquatic systems)	Land degradation (loss of habitat due to human activities)
Biological resources (species are threatened and exploited). Physical resources (Water, wood biomass and soil degradation)	Water availability and quality	Non-renewable resources (water and minerals) Water (availability and quality)
Chemical processes (waste, greenhouse gases, contamination of water and soil)	Climate change (weather patterns, sea level rising, impacts on humans and economy)	Greenhouse gas emissions (coal fired power stations and higher traffic volumes)
People of SA (demographics, poverty, unemployment, education and health)	Human vulnerability (AIDS pandemic, food security, access to services and poverty)	Sustainable mining

(**Source**: Own).

In the SAEO done in 2006, the major environmental priorities were water availability and quality of water, climate change, loss of biodiversity and ecosystem functioning and human vulnerability (Table 4.2). The water priority only addressed the concerns surrounding the availably and the quality thereof.

Climate change as an identified priority elaborated on the effects of climate change such as weather patterns, sea level rising and impacts on humans and the economy. Environmental change and environmental hazards, the AIDS pandemic, food security, access to services, poverty and coping capacity all fall under the human vulnerability priority. Loss of biodiversity and ecosystem functioning described that aquatic ecosystems in South Africa are affected the most. Wetlands, river ecosystems and marine ecosystems are severely threatened. Biodiversity and habitat loss share the same concerns as stated in the 1999 SOER (DEAT, 2006).

Key issues or 'tipping points' were identified by the second South Africa Environment Outlook (SAEO) (2012). One of the key issues, and the most important – water, is once again related to in terms of availability and quality. The context of the 'tipping point' land degradation is similar to the SOER (1999) component of habitats. The report states that greenhouse gas emissions are a critical issue as it will increase with the commissioning of the Medupi and Kusile coal-fired power stations, a new liquid fuel refinery and higher traffic volumes. When the report stated non-renewable resources, it considered water and mineral resources (DEA, 2012).

4.2.4 National Development Plan (NDP) 2030

Only the sections of the National Development Plan (NDP) 2030 that refer to the environment were used, and this could be found in the fifth chapter of that document. From an environmental perspective, the NDP 2030 states that there are several related challenges that the country needs to address, and these were included as the first five points in Table 4.3. The objectives and actions identified by the executive summary of the document were slotted under the challenges.

The last two points in Table 4.3 were not challenges but were recognised as additional points that were not mentioned as challenges but could be found under the actions and objectives as well (National Planning Commission, 2012b:47 & 64).

Table 4.3: Main environmental themes in the National Development Plan, 2030.

Main themes extracted from the National Development Plan – 2030
1. Protect and sustain the natural environment and ecosystems. • A set of indicators for natural resources to inform policy. • A regulatory framework for conservation and restoration of protected areas. • A target for the amount of land and oceans that needs to be under protection.
2. Enhance resilience of people and the economy towards climate change. • Disaster preparedness for extreme climate events, establishment of climate change centre. • Sea level rise.
3. Extract minerals in a sustainable manner.
4. Reduce greenhouse gas emissions. • Greenhouse gas emissions, carbon pricing mechanisms, zero emission buildings.
5. Improve energy efficiency. • Energy efficient buildings that meet building standards of the South African National Standard 204, and more use and stimulation of renewable energy.
6. Reduction of waste to landfill.
7. Investment and research into new agricultural technologies and adaptation strategies.

(**Source**: National Planning Commission, 2012b).

4.2.5 Agenda 2063

Table 4.4 indicates the aspiration, goal and the priority areas as stipulated by Agenda 2063. The first two priority areas deal with the aspects sustainable land use management of agricultural land, coastal and marine areas should be preserved, all national parks are protected, biodiversity should be conserved, and that genetic diversity of species are maintained.

The water security priority area contains aspects of rainwater harvesting and recycled wastewater for agricultural and industrial use. Farmers must practice climate-resilient production systems, air quality standards, reduction of fossil fuels use, emission levels from land use and deforestation, and natural disaster preparedness. These all fall under the fourth priority area.

Priority area six includes issues such as the raising of share of renewable energy, energy smart buildings, and urban transport that must have low emissions operating on renewable energy.

Table 4.4: Agenda 2063 aspirations, goal and priority areas related to the environment.

Aspiration 1	Goal	Priority areas
1 A prosperous Africa based on inclusive growth and sustainable development.	1/7 Environmentally sustainable and climate resilient economies and communities.	• Sustainable natural resource management • Biodiversity conservation, genetic resources and ecosystems • Sustainable consumption and production patterns • Water security • Climate resilience and natural disasters preparedness • Promote renewable energy

(**Source**: African Union Commission, 2015 b).

In Table 4.5, all the acts of the SEMAs, research priority topics, components, tipping points, environmental themes and priority areas in the strategic government documents, are listed.

Similar issues found in the documents were identified and classified together. Thereafter, the aspects (which better describes each theme) were grouped under the themes that were named to best represent the content of the grouped aspects.

Table 4.5: Government document aspects grouped and placed under similar themes.

Themes	Aspect in government document	ID number of PhD*	Total in each theme*
Protected areas	Protected areas (SEMA)		
	Protect and sustain natural environment (Indicators, integrated framework and the number of areas under protection) (NDP)		
Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)		
	Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)		
	Sustainable Natural Resource Management (Agenda 2063)		
Coastal	Coastal management (SEMA; Agenda 2063)		
	Thriving mariculture (Kok & Pietersen)		
Waste	Waste management (SEMA)		
	Zero waste, reduction and clean technologies (SOER, 1999; NDP; Kok & Pietersen)		
	Waste usage between industries (Kok & Pietersen)		
	Bioprocessing of organic waste (Kok & Pietersen)		
Social-People of SA	Social impact of drought (Kok & Pietersen)		
	Environmental Entrepreneurship training (Kok & Pietersen)		
	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)		
	Use of indigenous pharmacopoeia food and fibre sources (Kok & Pietersen)		
Water	Clean-up technology for contaminated water (Kok & Pietersen)		
	Use of water efficient plants, rainwater harvesting, wastewater recycling (Kok & Pietersen; Agenda 2063)		
	Water quality, security and quantity (SAEO, 2006; 2012; Agenda 2063)		
	Contamination of water by pollutants (SOER, 1999)		
Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	Greenhouse gas emissions (NDP; SOER, 1999; SAEO 2012)		
	Low carbon economy and carbon pricing (NDP)		
	Sustainable packaging (Kok & Pietersen)		
	Energy efficient and zero emission buildings and transport (NDP; Agenda 2063)		
	Sustainable consumption and production patterns (Agenda 2063)		
	More use of renewable energy (Agenda 2063; NDP)		
Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)		
	Climate resilience – impacts on humans and the economy (Agenda 2063, SAEO, 2006)		
	Natural disasters preparedness (Agenda 2063; NDP)		
	Sea level rise (SAEO, 2006; NDP)		
Mining	Sustainable mining and minerals (NDP; SAEO, 2012)		
	Non-renewable resources – minerals (SAEO, 2012)		
Soil/Agriculture	Contamination of soil by pollutants (SOER, 1999)		
	Investment and research into new agricultural technologies (NDP)		
	Clean up technology for contaminated land (Kok & Pietersen)		
Air	Air quality (SEMA)		
* The columns remain empty in this table but are populated in Tables 4.6-4.18.			

(**Source**: Own).

4.3 Analysis of PhDs per University

The following section describes the content analysis of the PhDs completed in the field of environmental management/sciences/studies. The PhDs were numbered, and manually scrutinised to determine the content thereof by mostly reading the title, abstract, acronyms, keywords, Chapter 1 and paragraph headings. The Leximancer text-mining program was then used to analyse the entire full text of each PhDs, to verify and corroborate the findings of the manual search. Identified terms were then collected through these two processes, and collated.

The PhDs were first studied, before concepts were removed from the automated concept list of Leximancer. When the individual PhDs were uploaded into Leximancer, unnecessary words (examples provided in section 3.3.3 and below) were removed or merged. Words that were removed or merged did not represent a significant concept.

Words that may not be of significance but were closely related to main concepts and the theme of the PhD, were also not removed. These words were, further, only removed after the PhD were investigated to ensure that the name or word was not of any significance in the research. The removed words can be seen in the datasheet for each PhD. Leximancer also keeps words that are deemed important for some reason, even if the word was removed manually. This manually removed word of significance would still be included by Leximancer in the thematic map – the reason being the number of times the word is found in the PhD. Such words would include ‘South Africa’, or the name of an author, government or title of legislation. If the word or words were not removed, they would clutter the map and indicate more relevant themes as less significant.

The words that were merged was when both the singular and plural form of a word were identified as a concept, or one word was typed in italics for example community; communities; *communities*. Surnames of authors were removed. Words that were repeated many times such as table, figure, data, during, use, etc. were removed. The datasheet indicates the words that were either merged or removed for every individual PhD that was imported into the Leximancer programme. The maps then did not indicate all the merged or removed words. This was also done to display clearer maps

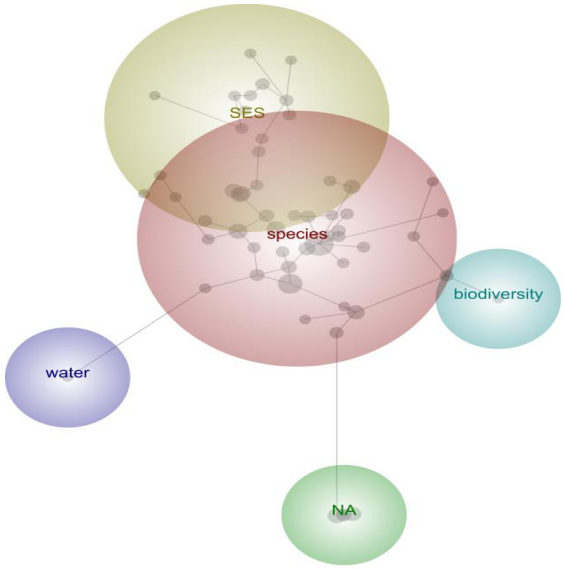
with only significant themes. The main themes on the concept maps reflected on what aspects were mostly written about in each PhD, at each university. A datasheet for each PhD was developed to illustrate this process, see an example in Figure 4.1. The rest of the datasheets for each PhD, per university, can be found at the following electronic link:
https://drive.google.com/drive/folders/1V2NyblbuITHjyq0tygSD2AAVJ0MEU04D?usp=sharing

The left side of the datasheet contained the title of the PhD, an identifier number, keywords, acronyms and terms classified from the PhD. It would then continue with the Leximancer process, where the words removed or merged were indicated and the thematic maps illustrated. The concepts related, and that made up the themes on the thematic map, and the ranked concepts, were then displayed in the last column.

The thematic maps found in the datasheet were set at 50% as explained in section 3.3.3. The size percentage of the themes does not affect the identified concepts; it just makes the map neater and more readable. No important information is lost, as the concepts remains the same. The main theme on the map indicates what the study is about. The main themes and concepts identified by Leximancer were compared with the content and terms identified by the manual search conducted for each of the PhDs. From this process, each PhD and its identifier number, would be allocated to an aspect in one or more of the government documents themes as per Table 4.5.

A PhD could deal with two or more aspects, and with the corresponding identifier number the PhD can be found in more than one theme. The numbers in the table, under each government document, below, is the identifier number (from the datasheet) of each PhD at a university. The identifier number was placed into respective, corresponding themes in the tables of each university. As the results were discussed the identifier number (example from Figure 4.1 is University X 1) and a short

Figure 4.1: Example of a datasheet. (**Source**: Own).

PhD number, title, acronyms, keywords, Identified terms	Words removed or merged	Theme map	Concepts and themes per Leximancer
University X 1: Plant diversity patterns of domestic gardens in five settlements of South Africa **Keywords:** Plant diversity patterns, domestic gardens, garden management, socio-economic status **Acronyms:** NA - Natural areas DG - Domestic garden SES - Socio-economic Status RV - Road verges **ID terms:** contribution that different domestic gardens and specie richness, make. to the overall diversity of an urban or rural settlement and the difference between gardens and SES	**Removed:** figure, table **Merged:** area/areas; garden/gardens		Name-Like Count Relevance DG 1653 100% NA 779 47% Potchefstroom 617 37% RV 306 19% Concepts Count Relevance gardens 1123 68% species 973 59% settlements 470 28% areas 443 27% urban 382 23% diversity 326 20% Theme: species Concepts: species, gardens, richness, sample, test, settlements, results, areas, Potchefstroom, diversity, types, different, total, index, significant, indigenous, natural, alien, urban, plant, composition, sampled, based, cultivated, values, number, study, management, recorded, South Africa, ornamental, plants, use, land, vegetation, trees Hits: 4198 Theme: NA Concepts: NA, DG, RV, IG Hits: 1975 Theme: SES Concepts: SES, socio-economic, data, status, classes, determine, floristic, used, gardening, participants, activities, variables, income, services, analysis Hits: 1249 Theme: biodiversity Concepts: biodiversity Hits: 79 Theme: water Concepts: water Hits: 69

description of the PhD was included under each theme, to ensure easy cross referencing between the datasheets and the theme tables. After the manual scanning and Leximancer process, Annexure 1 was compiled to provide detail of what each PhD entails per university. Under the university, in Annexure 1, each PhD with its corresponding number, as in the datasheet, is placed in themes. Each of the PhDs includes a short description of what the PhD entails. It must be noted that the description in Annexure 1, is not the title.

4.3.1 University of Cape Town (UCT)

The University of Cape Town (UCT) produced twenty-six (26) PhDs. Two of the four SARChI research chairs (climate change, marine ecology and fisheries) were represented. PhDs mostly concentrated on the 'social-people of SA' theme of the combined government documents. Eight (8) PhDs were placed in the 'social-people of SA' theme. These PhDs dealt with communities and small-scale fisheries, flooding in informal housing areas and public participation in the local environment. Food security was grouped under the 'social-people of SA' theme as per the SOER and two SAEO's, and studies on wheat and maize production are listed here. The PhD on wheat also studied the climate change impacts on dryland winter wheat and can therefore be found under two themes.

The 'climate change and natural disaster' theme housed six (6) PhDs and was the second highest number. The impact of climate change on water, small towns, soil, rooibos tea and wheat, was covered. The assessment of potential changes of the wind climate as a result of climate change, and the improvement of climate model predictions and model transferability to provide knowledge on regional effects of climate change, received attention.

One (1) PhD, a theoretical framework on the social construction of nature and that of environmental justice in a provincial nature reserve, was placed under the 'protected areas' theme. Soil degradation and soil loss was indicated by the SOER 1999 as a physical resource, and thus included in the 'biodiversity, habitat and resources' theme; hence, the reason why climate change may impact on soil loss and soil erosion, can be found here. Insights into the paleo-ecology of lowland fynbos was inserted in the 'biodiversity, habitat and resources' theme.

The coastal theme had three (3) PhDs respectively that dealt with aspects related to a thriving mariculture and more specifically small-scale fisheries compliance and governance systems or processes.

Water also had three (3) PhDs that studied the maintaining of key functions of water resources, safe and secure water, and the collective risks within a catchment for sustainable use of water. The 'greenhouse gas, low carbon- or green economy and renewable energy' theme and 'soil/agriculture' theme both had one (1) PhD each. The study on the wind climate was done to see if renewable wind energy was possible and, was placed in the renewable energy aspect and under the 'climate change' theme. Soil is also found in the 'soil/agriculture' theme, but the PhDs found under this theme is more related to agricultural activities and the contamination of soil. One of the aspects in the 'soil/agriculture' theme derived from the NDP is new agricultural technologies. In this regard' a PhD was done to see if the role of seasonal forecasts plays a role in the management decision process of maize farmers. A total of eight (8) PhDs were not placed into any theme. To see the detail of each PhD in each theme, refer to Annexure 1. Table 4.6 summarises the above-mentioned PhDs and indicates the themes that they fall in:

Table 4.6: University of Cape Town (UCT) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Cape Town (26 PhDs)	Protected areas	Protected areas (SEMA)	UCT 5	1
	Biodiversity, Habitat and Resources	Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UCT 2, 20	2
	Coastal	Thriving mariculture (Kok & Pietersen)	UCT 10, 22, 23	3
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	UCT 10, 13, 19, 22, 23, 24, 25, 26	8
	Water	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	UCT 4, 8, 17	3
	Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	UCT 1, 2, 7	6
		Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	UCT 15, 18, 25	
	Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	More use of renewable energy (Agenda 2063; NDP)	UCT 1	1
	Soil/Agriculture	Investment and research into new agricultural technologies (NDP)	UCT 13	1

(**Source**: Own).

4.3.2 University of Fort Hare (UF)

The one (1) PhD that was completed at Fort Hare concentrated on environmental management in military activities. The PhD entailed the perceptions of staff on environmental management, and tests such as heavy metal pollutants in water and soil. Satellite imagery was further analysed to explore land cover change. This PhD was placed under the 'biodiversity, habitat and resources' theme and more specific that of Agenda 2063. Table 4.7 tabulates this information:

Table 4.7: University of Fort Hare PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Fort Hare (1 PhD)	Water	Contamination of water by pollutants (SOER, 1999)	FH 1	1
	Soil/Agriculture	Contamination of soil by pollutants (SOER, 1999)	FH 1	1
	Biodiversity, Habitat and Resources	Sustainable Natural resource Management (Agenda 2063)	FH 1	1

(**Source**: Own).

4.3.3 University of the Free State (UFS)

The University of the Free State completed eight (8) PhDs, and mainly in three (3) themes, 'biodiversity, habitat and resources', 'water', as well as 'climate change and natural disaster' (Table 4.8). The link between arthropod diversity in a new crop and bordering a natural environment landscape, and the integration of disaster risk reduction and climate change adaptation strategies for wetlands management was seen as habitat related and was therefore placed in the habitat aspect.

The latter PhD regarding the wetland, was also placed in the 'climate change and natural disaster' theme. In the biodiversity aspect, a strategy on human predator conflict management (HPCM), specifically the black-backed jackal and caracal conflict, was included. The extensive transformation and loss of biodiversity in a grassland biome can also be found in the biodiversity aspect.

The 'water' theme contained four (4) PhDs that dealt with a prototype water assessments method, water quality monitoring, periphyton as indicator of water-quality and an assessment for the quantity, quality, use and rehabilitation of water resources at catchment and national level.

Table 4.8: University of the Free State (UFS) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of the Free State (8 PhDs)	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	UFS 1, 5	4
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UFS 2, 3	
	Water	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	UFS 4, 6, 7, 8	4
	Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	UFS 1	2
		Natural disasters preparedness (Agenda 2063; NDP)	UFS 1	

(**Source**: Own).

4.3.4 University of Kwa-Zulu Natal (UKZN)

At the University of Kwa-Zulu Natal thirty-five (35) PhDs were completed as indicated in Table 4.9. Their two research chairs, Ecosystem Health and Biodiversity in KZN and the Eastern Cape and the Land Use Planning and Management Chairs, were well researched, as can be seen by the 'biodiversity, habitat and resources' theme as well as the 'protected area' themes that are well represented by the research conducted there. The 'biodiversity, habitat and resources' theme had the most PhDs, and seventeen (17) were documented. 'Mining' and 'soil/agriculture' as themes had no PhDs represented from UKZN.

The 'protected areas' theme was covered by six (6) PhDs. Five PhDs studies were carried out under the Protected areas SEMA. The PhDs studied the impacts of eco-tourism on two World Heritage sites and the effective management of protected areas. The other was about a national park, conservancies, private game parks, stewardship practises at an environmental precinct, and integration of protected areas with their surrounding landscapes.

The 'biodiversity, habitat and resources' theme included the following: commercial forest management, forest plantation health and causes of wetland erosion were placed under loss of biodiversity and ecosystems. The distribution and quality of grass species, biodiversity strategies that identify threats and benefits, the conservation of biodiversity, estuary invertebrates, as well as tree survival and tree growth on landfill soil also fell in this theme. Erosion of soil linked to main roads was placed under this theme as soil degradation falls in the physical resource's aspect of the SOER,1999. A

framework identifying the social and ecological variables in natural resource-based development, rangeland degradation assessment and management, and the managing of communal rangelands, was placed in the resource aspect.

A total of ten (10) PhDs were also done in the; social-people of SA; theme. Their emphasis was on the impact of communities related to eco-tourism, environmental precincts, conservancies and private game parks. Further, were the role of an agency in a women's craft group, the development of a Human Activity System (HAS) model, land restitution involving conservation, and the implementation of renewable energy in marginalised communities and, seen as aspects of significance.

The PhD regarding renewable energy were also placed in the 'greenhouse gas, low carbon- or green economy and renewable energy' theme. A PhD developed and evaluated an educational game that included HIV/Aids, tuberculosis, malaria and cancer, as it was an issue in the 'social-people of SA' theme.

Solutes and solute retention of a wetland, and the external costs of wastewater discharge of organisations, were determined and was identified in the 'water' theme. 'Greenhouse gas (GHG) and Low Carbon- or Green Economy' were represented by PhDs on carbon stocks of forest biomass, impacts of elevated CO_2 on grass, and the influence of air quality management on greenhouse gas emissions in creating a low carbon city.

'Climate change' as a theme reflected that three (3) PhDs wrote about the effect of climate change on wetlands, the risks, management and adaptation to sea level rise, as well as the integration of climate change into air quality management plans. Relating to the air quality matter, this theme had two (2) PhDs: a method for the delineation of air quality management areas, and the integration of climate change into local air management plans. One PhD was completed under the 'coastal management' theme and looked at sea level rise, and coastal erosion along the Southern African coastline.

No PhD work were done in the 'waste', 'mining' or in the soil/agriculture' themes and four (4) PhDs were not allocated to any theme. These were dealing with public-private

partnerships (PPPS), Corporate Social and Environmental Reporting (CSR) and the development of census output areas in South Africa. It further included perceptions and impacts of violence and crime in residential areas and organisational culture as a determinant of response to change in a conservation agency. It was further noted that remote sensing was used as a tool in seven of the PhDs. The aspects of each PhD are in Annexure 1. Table 4.9 below provides an overview of the PhDs in their respective themes:

Table 4.9: University of Kwa-Zulu Natal (UKZN) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Kwa-Zulu Natal (35 PhDs)	Protected areas	Protected areas (SEMA)	UKZN 4, 5, 6 24, 34	6
		Protect and sustain natural environment (Indicators, integrated framework and the number of areas under protection) (NDP)	UKZN 18	
	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	UKZN 2, 19, 20, 22	17
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UKZN 1, 4, 5, 16, 21, 25, 29, 32, 33	
		Sustainable Natural Resource Management (Agenda 2063)	UKZN 3, 11, 26, 30	
	Coastal	Coastal management (SEMA; Agenda 2063)	UKZN 12	1
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	UKZN 4, 5, 6, 9, 10, 17 18, 28, 34, 35	10
	Water	Water quality, security and quantity (SAEO, 2006; 2012; Agenda 2063)	UKZN 2, 15	2
	Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	Greenhouse gas emissions (NDP; SOER, 1999; SAEO, 2012)	UKZN 7, 16, 31	4
		More use of renewable energy (Agenda 2063; NDP)	UKZN 17	
	Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	UKZN 20, 31	3
		Sea level rise (SAEO, 2006; NDP)	UKZN 12	
	Air	Air quality (SEMA)	UKZN 27, 31	2

(**Source**: Own).

4.3.5 North West University (NWU)

The North-West University (NWU) had thirty-nine (39) completed PhDs. When viewing Table 4.10, it is apparent that a large number of PhDs done at the NWU fell within the ‘water’ theme, followed by the ‘biodiversity, habitat and resources’ theme.

The ‘protected areas’ theme included two (2) PhDs. A PhD dealing with a spatial development framework for a world heritage site, was placed under the SEMA aspect, and a PhD relating to an Environmental Management Framework (EMF) was placed under the NDP 2030 aspect. The ‘biodiversity, habitat and resources’ theme included nineteen (19) aspects from PhDs. In this theme, PhDs were done on biological control of leafminers, the effect of maize on plants and insects, plant species richness in urban areas, a synthesis of socio-ecological systems dynamics, the Brenton blue butterfly, biodiversity surveys on macroinvertebrates, evaluation of the biodiversity legislation, effects of per fluorinated chemicals on fish and birds’ eggs and microbial communities. Under the sustainable natural resource management aspect two (2) PhDs could be inserted. These two (2) PhDs pertained to rangeland management.

The ‘waste’ and ‘coastal’ themes had only one (1) PhD each that was related to them. In the ‘social-people of SA’ theme there were three (3) PhDs, but one PhD (identifier number NWU 14) were found in the community (impacts of mining on a community) and health aspects (the dose to members of the public from radioactive effluents on humans) and were placed under each aspect. This then equalled to four aspects. The content of the other PhDs that corresponded with human vulnerability focused on the potential of non-crop plant species to control nematodes on tomatoes and leafy vegetables.

PhD studies focussing on water overall amounted to eighteen (18). The quality of water was mostly completed, and accounts for eleven (11) PhDs. Use of diatoms, *Enterococcus spp.* or microbial communities as water quality indicators, effective removal of algae, determining concentrations and values of toxic parameters, protection of groundwater, a groundwater monitoring system and decision-making model, effects of deep level mining on groundwater all made up the PhDs in the ‘water’ theme.

The contamination of water by pollutants included four (4) PhDs that dealt with persistent organic pollutants in water, polycyclic aromatic hydrocarbons in aquatic ecosystems, exposure routes of per fluorinated chemicals and water soluble inorganic ionic concentrations. Three (3) PhDs, meeting the clean-up technologies for contaminated water criteria, were recorded, and it studied improved algae removal

efficiencies, inclusion of bacterial community structures (as an indicator of anthropogenic disturbances in freshwater) into biomonitoring programs and mining rehabilitation methods, and clean-up technologies for water.

The ‘soil/agriculture’ theme totalled nine (9) PhDs that fitted in this theme. Investment and research into new agricultural technologies aspect, as per the NDP, had five (5) PhDs. The contamination of soil by pollutants referred to two (2) PhDs that engaged aspects such as the concentrations of persistent organic pollutants in soil, and soil ecological risk assessments. Clean-up technology for contaminated land highlighted two (2) PhDs in this aspect and refer to the rehabilitation of coal mining soil and advanced clean up technologies for soil.

No PhD research was done in the ‘greenhouse gas (GHG), the low carbon economy, green economy, renewable energy’, ‘climate change’ and ‘natural disaster and energy’ themes.

Mine remediation and rehabilitation, mining clean-up technologies and post mining effects on groundwater were found in three (3) PhDs and fell in the mining ‘theme’. The four (4) PhDs in the ‘air’ theme for example concentrated on the monitoring levels of toxic metals in the air, the current state of air quality in a megacity, coal-fired air quality emissions management and assessment of atmospheric trace metals.

One (1) of the PhDs relating to environmental control officers did not fit into any of the government document themes. The themes are listed in Annexure 1 with the PhDs that fell within them.

Table 4.10: North West University (NWU) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
North West University (39 PhDs)	Protected areas	Protected areas (SEMA)	NWU 29	2
		Protect and sustain natural environment (Indicators, integrated framework and the number of areas under protection) (NDP)	NWU 3	
	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	NWU 2, 8, 10, 32	19
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	NWU 1, 2, 5, 6, 9, 10, 15, 19, 22, 26, 30, 33, 39	
		Sustainable Natural Resource Management (Agenda 2063)	NWU 12, 22	
	Coastal	Coastal management (SEMA; Agenda 2063)	NWU 30	1
	Waste	Waste management (SEMA)	NWU 23	1
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	NWU 14 (community) NWU 17, 25 NWU 14 (health)	4
	Water	Clean-up technology for contaminated water (Kok & Pietersen)	NWU 11, 13, 27	18
		Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	NWU 7, 11, 13, 15, 21, 24, 29, 31, 33, 35, 36	
		Contamination of water by pollutants (SOER, 1999)	NWU 5, 26, 32, 34	
	Mining	Sustainable mining and minerals (NDP; SAEO, 2012)	NWU 14, 27, 31	3
	Soil/Agriculture	Contamination of soil by pollutants (SOER, 1999)	NWU 5, 37	9
		Investment and research into new agricultural technologies (NDP)	NWU 10, 17, 18, 25, 37	
		Clean up technology for contaminated land (Kok & Pietersen)	NWU 4, 27	
	Air	Air quality (SEMA)	NWU 16, 20, 28, 34	4

(**Source**: Own).

4.3.6 University of Pretoria (UP)

PhDs were mostly done in four (4) themes where the ‘social-people of SA’ theme included the most. The five (5) PhDs in the ‘social-people of SA’ theme concentrated on local livelihoods, rural poverty and expectations of a community relating to corporate social responsibility.

The impact of climate change on tomato production and health specially malaria is in both the ‘social-people of SA’ and ‘climate change’ themes. Other issues in the ‘climate change’ theme included responsiveness of fauna to climate change events and the distribution of Citrus Black Spot (CBS) under current and future climates.

‘Biodiversity, habitat and resources’ theme had three (3) studies that focussed on avian species diversity and the relationship between a community and land degradation or biodiversity. The ‘water’ theme’s PhD was done on water management failures as a result of a misunderstanding of social-ecological system. One PhD that studied ecotourism trails to facilitate environmental education was not placed in any theme. Five (5) PhDs did not go through the Leximancer process, as they were PDF secured documents. These documents were only scanned manually. They are indicated in the datasheets. The themes and the PhDs within them are seen in Table 4.11:

Table 4.11: University of Pretoria (UP) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Pretoria (10 PhDs)	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	UP 9	3
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UP 3, 7	
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	UP 6, 7, 8, 9, 10	5
	Water	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	UP 5	1
	Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	UP 4	4
		Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	UP 1, 6, 8	

(**Source**: Own).

4.3.7 Rhodes University (RU)

The one SARChI research chair (Marine Ecosystems and Resources) did not have any PhDs completed in the ‘coastal theme’. The Interdisciplinary Science in Land and Natural Resource Use for Sustainable Livelihoods) were, however, well represented in the form of completed PhDs. The ‘biodiversity, habitat and resources’ theme comprised of six (6) PhDs. Ecosystem services in a biosphere reserve context and the better use and management of landscapes and species for fuelwood, brushwood and kraal posts was captured in the habitat loss aspect. The biodiversity aspect of this theme looked at alien-invaded riparian systems, river floodplain rehabilitation approaches and the restoring of plant invaded landscapes. Food security in the ‘social-people of SA’ theme accommodated changes in household food security and the impact of HIV and AIDS on household food security. Other aspects in the ‘social-people of SA’ theme that can be found in the ten (10) PhDs were climate change and

communities, indigenous people and their value of natural resources, livelihoods poverty alleviation and management, asbestos contamination, education, as well as the role of natural resource products, including the contribution of non-timber forest products to livelihoods.

'Climate change' and 'natural disaster' along with the soil/agriculture themes equally had one (1) PhD. The one PhD examined the municipal planned climate change adaptation and the implications for community-based adaptation, and the other PhD in the 'soil/agriculture theme', environmental asbestos contamination in soil. Also see Table 4.12 below:

Table 4.12: Rhodes University (RU) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
Rhodes University (15 PhDs)	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	RU 1, 10	6
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	RU 3, 7, 9, 10	
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	RU 2, 4, 5, 6, 8, 11, 12, 13, 14, 15	10
	Climate Change and Natural Disaster	Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	RU 12	1
	Soil/Agriculture	Contamination of soil by pollutants (SOER, 1999)	RU 5	1

(**Source**: Own).

4.3.8 University of Stellenbosch (US)

The research chair, Sociology of Land Environmental and Sustainable Development were well represented in the PhDs. Only four (4) PhDs out of the eleven (11) could be placed in themes. An implementation model for Integrated Coastal Management Act (ICMA) was placed in the 'coastal management' theme. The impact of climate change on human health within the context of disaster management can be found in the 'climate change' and 'social-people of SA' theme. The two (2) PhDs in the 'social-people of SA' theme were about informal settlement upgrading and the effect of governmentality on women's social networks, and the other one the impact of climate change on human health.

Military integrated environmental management was inserted under the 'biodiversity, habitat and resources' theme (see Table 4.13). The other seven (7) PhDs that were not placed under any of the themes covered determined land use planning, impact on heritage resources, attitude of military personnel towards the environment, and planning or development around airports.

Table 4.13: University of Stellenbosch (US) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Stellenbosch (11 PhDs)	Coastal	Coastal management (SEMA; Agenda 2063)	US 10	1
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	US 3, 5	2
	Climate Change and Natural Disaster	Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	US 3	2
		Natural disasters preparedness (Agenda 2063; NDP)	US 3	
	Biodiversity, Habitat and Resources	Sustainable Natural Resource Management (Agenda 2063)	US 4	1

(**Source**: Own).

4.3.9 University of the Witwatersrand (Wits)

'Climate change and natural disaster' theme comprised of seven (7) PhDs and may be linked to the Global Change and Systems Analysis research chair. In the 'climate change' column of Table 4.14, the aspects of reducing climate change impacts on biodiversity loss, savanna and grassland were addressed, and is also inserted under the 'biodiversity, habitat and resources' theme. An evaluation of landfill gas generation and emission rates from landfills can be found here as well. The natural disaster preparedness aspect included two (2) PhDs. These two can also be found in the 'climate change' theme column. The negative impacts on agricultural production due to natural disasters, and the integrating current policy efforts in drought disaster-risk reduction were the aspects dealt with in these PhDs.

The following five (5) PhDs are accounted for in the 'social-people of SA' theme: the role of social capital in community game reserves and the role discursive power and environmental justice played in the pollution and the subsequent destruction of an area, were looked at. The health risks of BTEX and people's perceptions on domestic coal combustion, are two areas that received attention, however, another PhD (Wits 11) dealing with a rotational wood harvesting scheme in selected rural communities,

was placed in the ‘social-people of SA’ theme and in the ‘biodiversity, habitat and resources theme’.

The’ air quality’ and ‘greenhouse gas emissions’ themes shared two PhDs: the measurement of NO_2 over the Highveld, and the evaluation of landfill gas generation and emission rates from landfills. The latter PhD is also found in the ‘waste’ theme. The ambient air quality over a major industrial and urban area, and the people’s perceptions on domestic coal combustion were finalised in the ‘air’ theme. The following three themes had only one (1) PhD: ‘waste’, ‘water’ and ‘mining’. The PhD in the ‘waste’ theme evaluated landfill gas generation and emission rates from landfills. An integrated and sustainable water resource monitoring framework fell in the ‘water’ theme.

Recording the mining industry’s efforts to develop scientifically sound and replicable methods of mine waste rehabilitation, was placed in the ‘mining’ theme. The engagement of an environmental centre with the discourse of sustainable development, did not fit into a theme.

Table 4.14: University of the Witwatersrand (Wits) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of the Witwatersrand (15 PhDs)	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	Wits 6	4
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	Wits 3, 6, 11	
		Sustainable Natural Resource Management (Agenda 2063)		
	Waste	Waste management (SEMA)	Wits 9	1
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	Wits 2, 8, 11, 12, 13	5
	Water	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	Wits 14	1
	Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	Greenhouse gas emissions (NDP; SOER, 1999; SAEO, 2012)	Wits 1, 9	2
	Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	Wits 3, 4, 5, 6, 9	7
		Natural disasters preparedness (Agenda 2063; NDP)	Wits 4, 5	
	Mining	Sustainable mining and minerals (NDP; SAEO 2012)	Wits 10	1
	Air	Air quality (SEMA)	Wits 1, 7, 9, 13	4

(**Source**: Own).

4.3.10 University of Johannesburg (UJ)

At the University of Johannesburg, the ‘air’ theme included seven (7) of the seventeen (17) PhDs (Table 4.15). The focus ranged from the development of a new trace gas retrieval scheme for air quality monitoring, cost-effective and accurate mobile emissions inventories, to emissions from informal domestic stoves, coal-fired power plants and industries. One (1) PhD examined whether the critical loads from acidic deposition would exceed the carrying capacity of the natural environment. Some of the PhDs combined air quality with mining activities and health aspects. These PhDs investigated wind erosion models and wind emissions from mine tailings and ash storage facilities as well as the factors contributing to the degradation of air quality and health, and the effect of mine tailings on health risks to nearby communities, due to respirable airborne mine tailing material.

The ‘social-people of SA’ theme encompassed five (5) PhDs. The students looked at the best way to achieve low carbon energy access in low-income households, and also the perceptions of communities and the impacts of mines. One study combined the perceptions of the community on the cumulative effect of coal mining and disaster preparedness and is therefore found in both the ‘social-people of SA’ and the ‘natural disaster preparedness’ themes.

The other PhD in the mining theme examined a collaborative sustainability model for the mining industry. The hydrological responses of water quality associated with land cover changes is seen in the water theme. The climate change PhD observed the integration of energy security, economic growth, and global warming.

The following four (4) PhDs were not categorised and placed in themes. These dealt with the influences of transport infrastructure on urban development and mobility; oil dependency; the feasibility of using satellite data to research the sea surface temperature; and the use of supply chain management to improve the efficiency and effectiveness of GIS units.

Table 4.15: University of Johannesburg (UJ) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Johannesburg (17 PhDs)	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	UJ 1, 4, 7, 11, 16	5
	Water	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	UJ 8	1
	Climate Change and Natural Disaster	Climate change or climate change centre SAEO, 2006; NDP)	UJ 9	2
		Natural disasters preparedness (Agenda 2063; NDP)	UJ 4	
	Mining	Sustainable mining and minerals (NDP; SAEO, 2012)	UJ 10, 16	2
	Air	Air quality (SEMA)	UJ 1, 2, 3, 11, 12, 13, 17	7

(**Source**: Own).

4.3.11 Nelson Mandela University (NMU)

The NMU has four research chairs, but no PhDs relating to them could be established. Most of the PhDs done at the Nelson Mandela University (NMU) were categorised and inserted in the 'biodiversity, habitat and resources' theme (Table 4.16). One PhD (identifier number NMU 4) was seen twice in the 'biodiversity, habitat and resources' theme, because it dealt with biodiversity and soil as a physical resource. Soil erosion, soil loss, land degradation and the impact of an invader plant on soil moisture flux, as well as assessing soil carbon and carbon dioxide fluxes, were studied. The latter also fell in the greenhouse gas emission aspect. Subtropical forest was analysed specifically to quantify subtropical forest changes over time, and to monitor carbon stocks in a subtropical thicket, where the last also is seen in the greenhouse gas emission aspect.

Table 4.16: Nelson Mandela University (NMU) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
Nelson Mandela University (6 PhDs)	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	NMU 3	7
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	NMU 1, 2, 4, 4, 5, 6	
	Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	Greenhouse gas emissions (NDP; SOER, 1999; SAEO, 2012)	NMU 3, 6	2
		Low carbon economy and carbon pricing (NDP)		
		Sustainable packaging (Kok & Pietersen)		
		Energy efficient and zero emission buildings and transport (NDP; Agenda 2063)		
		Sustainable consumption and production patterns (Agenda 2063)		

(**Source**: Own).

4.3.12 University of South Africa (Unisa)

Under the ‘soil/agriculture’ theme, the NDP identified that the investment and research into new agricultural technologies is of importance. PhD studies in this theme looked at the control of red spider mites (RSM) on tomatoes, the evaluation of a renewable protein supplement for low-quality forages for sheep, antibiotic-free animal production by adding nucleotides to improve intestinal health of calves and the effects of high dietary levels of fibrous feeds on growing pigs fed maize-soybean diets.

Wetland indicators and wetland delineation is in the ‘protected areas’ theme. The co-existence of Vervet monkeys and legalising the international trade in rhino horn for a possible effect on rhino poaching, were positioned in the ‘biodiversity, habitat and resources’ theme.

Agricultural waste residues that can be used for lignocellulolytic enzyme production can be located in the bioprocessing of organic waste aspect. This is the only PhD from all environmental studies PhDs in South Africa that explored this topic as per the Kok and Pietersen (1999) survey report.

With regards to the food security side in the ‘social-people of SA’ theme, PhDs concentrated on the control of mites on tomatoes, the occurrence of mycoflora in rice plants and seeds, arsenic content in various foods with special emphasis on rice and the perceptions of communities on urban agriculture and its impact on food provisioning. The only PhD from all the PhDs done in South Africa in environmental studies that could be categorised in the ‘use of indigenous pharmacopoeia food and fibre sources’ aspect as per the Kok and Pietersen survey report, evaluated the potential of indigenous plants for commercial beverage production. The vulnerability section in the ‘social-people of SA’ theme conducted studies on new anti-TB drugs, biomarkers for bilharzias, gene markers for dermal disorders including skin cancer and antibiotic resistance of *E. coli*. The services aspect in the ‘social-people of SA’ theme explored an effective public participation process and the perceptions of a local community on their participation in wildlife conservation, ecotourism, and ‘social-people of SA development’ to enhance private sector-community collaboration.

The ‘greenhouse gas, low carbon or green economy and renewable energy’ theme had two (2) PhDs that conducted studies on green procurement practices in municipalities and energy efficiency in selected guest houses.

Green procurement practices in municipalities were placed in the ‘climate change’ theme along with the response of the coal mining sector to climate change adaptation. Two (2) PhDs combined agriculture and climate change. The one explored the impact of climate change and adaptation on cattle and sheep farming and the other on farmers perceptions relating to climate change and agricultural production.

Four (4) PhDs were not placed in any theme. Mechanisms to help smaller accommodation establishment (SAEs) overcome the barriers to implementing sustainable tourism, and applications of meteorological satellite products, are two of them. Studies on thermal springs, in particular to classify the springs according to an international standard, and to investigate the diverse uses of thermal springs as possible tourism centres, did not find a place in Table 4.17:

Table 4.17: University of South Africa (UNISA) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of South Africa (27 PhDs)	Protected areas	Protect and sustain natural environment (Indicators, integrated framework and the number of areas under protection) (NDP)	Unisa 22	1
	Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	Unisa 22	3
		Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	Unisa 4, 7	
	Waste	Bioprocessing of organic waste (Kok & Pietersen)	Unisa 11	1
	Social-People of SA	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	Unisa 1, 3, 10, 12, 14, 15, 19, 21, 23, 27	11
		Use of indigenous pharmacopoeia food and fibre sources (Kok & Pietersen)	Unisa 24	
	Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	Energy efficient and zero emission buildings and transport (NDP; Agenda 2063)	Unisa 16	2
		Sustainable consumption and production patterns (Agenda 2063)	Unisa 2	
	Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	Unisa 2, 6	4
		Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	Unisa 17, 18	
	Soil/Agriculture	Investment and research into new agricultural technologies (NDP)	Unisa 1, 8, 20, 25	4

(**Source**: Own).

4.3.13 University of Venda (UV)

As mentioned in Chapter 3, only one (1) of the four (4) PhDs were available in full text; however, the titles were available and therefore placed in themes. The PhDs, as per Table 4.18, is in the ‘mining’, ‘water’ and ‘biodiversity, habitat and resources’ themes. The PhD that had the full text was the remediation of acid mine drainage using magnesite and clay composite and is in the ‘mining’ theme.

The assessment of the efficiency of wastewater treatment facilities and the impact of the effluents on surface water and sediment, similarly the evaluation of community water quality monitoring and management practices, are in the ‘water’ theme. Ant diversity across an elevational gradient; functional versus taxonomic perspectives, is found in the first theme of Table 4.18. The research chair (Biodiversity Value and Change in the Vhembe Biosphere Reserve) was not reflected in the PhD research.

Table 4.18: University of Venda (UV) PhDs placed under themes of government documents.

	Themes	Aspect in government document	ID number of PhD	Total in each theme
University of Venda (4 PhDs)	Biodiversity, Habitat and Resources	Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UV 4	1
	Water	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	UV 2, 3	2
	Mining	Sustainable mining and minerals (NDP; SAEO, 2012)	UV 1	1

(**Source**: Own).

4.3.14 PhDs not placed under any theme

No PhDs were recorded at the Walter Sisulu University, University of Limpopo, University of Zululand and University of the Western Cape; hence no analysis or results tables were done. Thirty (30) PhDs could not be placed into any theme (Annexure 1). This in no way implies that these PhDs did not research important environmental issues.

4.4 Themes Covered by Universities

A summary of the themes covered by universities can be seen in Figure 4.2. In this figure, the following universities – UKZN, UFS, NWU and NMU, the ‘biodiversity,

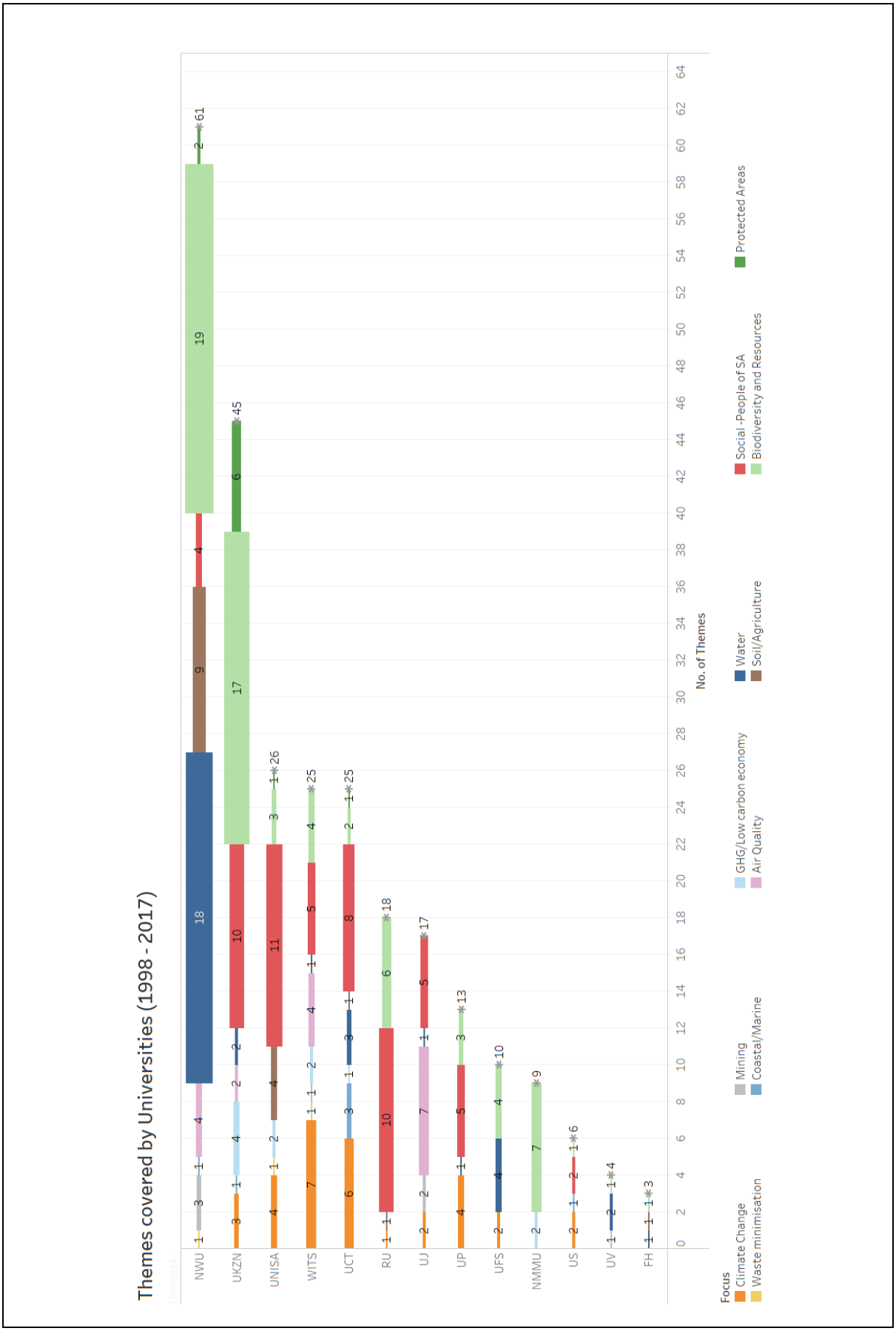


Figure 4.2: Summary of themes covered by universities. (**Source**: Own).

habitat and resources' theme had the most completed PhDs recorded. It is noticeable that at each of these six universities (UCT, UP, RU, US, Unisa and UKZN) the greatest number of PhDs fell in the 'social-people of SA' theme. PhDs at Wits were mostly contained in the 'climate change' theme and at UJ it was the 'air' theme. PhDs that had water as a focus area was mostly found at NWU, UFS, UCT and UV in this order. The NWU and UKZN were also the two universities with the most completed PhDs in environmental studies (relevant to this study) in South Africa.

4.5 Themes and Aspects Covered

The analysis of all the PhDs done in environmental studies in South Africa was undertaken in section 4.3. In this process, the PhDs of each university were categorised according to the theme and aspect that it addressed. This was to get a clear sense of what the details of the sampled PhDs entailed. The identified themes were colour coded as per Figure 4.3. This colour scheme was used throughout this research when the themes were illustrated.

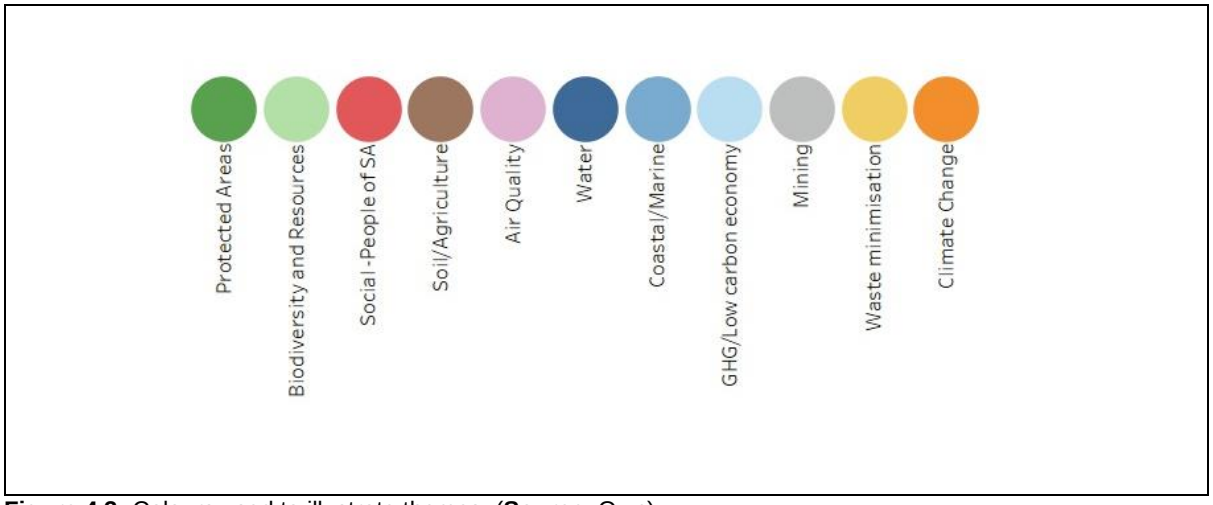


Figure 4.3: Colours used to illustrate themes. (**Source**: Own).

The under-researched themes (table 4.19) and under-researched aspects (Table 4.20) are indicated by using a natural classification break based on the data that was received. These breaks and colour coding are indicated by Figure 4.4.

0 PhDs	1-5 PhDs	6-11 PhDs	12-60 PhDs

Figure 4.4: Colour scale used to highlight theme. (**Source**: Own).

From the summary in Table 4.19, the number of PhDs done at each university, in each theme and under the aspects, were tallied. The total in each theme is seen in the last column. The data analysis indicated that the most PhD work were done in the ‘biodiversity, habitat and resources’ theme (68 aspects in PhDs) and is highlighted by the colour light green, followed by the ‘social-people of SA’ theme (60 PhDs) in red.

The ‘water’ theme had thirty-three (33) aspects in PhDs, in dark blue, and the ‘climate change ‘theme featured thirty-one (31) indicated in orange. The ‘protected’ areas theme (10) is shown in dark green, ‘soil/agriculture’ (16) in brown and the ‘air’ (17) in pink.

The ‘greenhouse gas and low carbon- or green economy and renewable energy’ (11) theme is presented in turquoise, the ‘coastal’ theme (6) is light blue, ‘waste’ (3) mustard and ‘mining’, with seven (7) themes, are in grey.

The second-last column shows the total amount of PhDs per aspect. As can be seen, coloured white, in Table 4.19, eight (8) aspects did not have any PhDs included under them. Most of the aspects, fifteen (15), indicated in light purple, had between one to five PhDs.

Protected areas, sustainable natural resources management, greenhouse gas emissions, climate resilience, sustainable mining and minerals and investment and research into new agricultural technologies as aspects are in a darker purple and have between six (6) and eleven (11) PhDs, respectively.

The following aspects – habitat loss, loss of aquatic ecosystems; biodiversity, biodiversity conservation, biological and physical resources; social-people of SA; water quality, security and quantity; climate change or climate change centre and air quality had between twelve (12) and sixty (60) PhDs in their respective aspects and is depicted with the darkest purple. There is, further a theme, at the bottom, that indicates that thirty (30) PhDs could not be inserted under any theme or aspect.

Table 4.19: Summary of all PhDs analysed and placed under themes and aspects.

Themes	Aspect in government document	Total per university	Total/aspect	Total/ theme
Protected areas	Protected areas (SEMA)	UCT (1); UKZN (5); NWU (1)	7	10
	Protect and sustain natural environment (Indicators, integrated framework and the number of areas under protection) (NDP)	UKZN (1); UNISA (1); NWU (1)	3	
Biodiversity, Habitat and Resources	Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	UFS (2); UKZN (4); NWU (4); UP (1); RU (2); Wits (1); UNISA (1); NMU (1)	16	68
	Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UCT (2); UFS (2); UKZN (9); NWU (13); UP (2); RU (4); Wits (3); UNISA (2); NMU (6); UV (1)	44	
	Sustainable Natural Resource Management (Agenda 2063)	FH (1); UKZN (4); NWU (2); US (1);	8	
Coastal	Coastal management (SEMA; Agenda 2063)	NWU (1); US (1); UKZN (1)	3	6
	Thriving mariculture (Kok & Pietersen)	UCT (3)	3	
Waste	Waste management (SEMA)	NWU (1); Wits (1)	2	3
	Zero waste, reduction and clean technologies (SOER, 1999; NDP; Kok & Pietersen)		0	
	Waste usage between industries (Kok & Pietersen)		0	
	Bioprocessing of organic waste (Kok & Pietersen)	UNISA (1)	1	
Social-people of SA	Social impact of drought (Kok & Pietersen)		0	60
	Environmental Entrepreneurship training (Kok & Pietersen)		0	
	People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	UCT (8); UKZN (10); NWU (4); UP (5); RU (10); US (2); Wits (5); UJ (5); UNISA (10)	59	
	Use of indigenous pharmacopoeia food and fibre sources (Kok & Pietersen)	UNISA (1)	1	
Water	Clean-up technology for contaminated water (Kok & Pietersen)	NWU (3)	3	33
	Use of water efficient plants, rainwater harvesting, wastewater recycling (Kok & Pietersen; Agenda 2063)		0	
	Water quality, security and quantity (SAEO, 2006; SAEO, 2012; Agenda 2063)	UCT (3); UFS (4); UKZN (2); NWU (11); UP (1); Wits (1); UJ (1); UV (2)	25	
	Contamination of water by pollutants (SOER, 1999)	FH (1); NWU (4)	5	
Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy	Greenhouse gas emissions (NDP; SOER, 1999; SAEO, 2012)	UKZN (3); Wits (2); NMU (2)	7	11
	Low carbon economy and carbon pricing (NDP)		0	
	Sustainable packaging (Kok & Pietersen)		0	
	Energy efficient and zero emission buildings and transport (NDP; Agenda 2063)	UNISA (1)	1	
	Sustainable consumption and production patterns (Agenda 2063)	UNISA (1)	1	
	More use of renewable energy (Agenda 2063; NDP)	UCT (1); UKZN (1)	2	
Climate Change and Natural Disaster	Climate change or climate change centre (SAEO, 2006; NDP)	UCT (3); UFS (1); UKZN (2); UP (1); Wits (5); UJ (1); UNISA (2);	15	31
	Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	UCT (3); UP (3); RU (1); US (1); UNISA (2);	10	
	Natural disasters preparedness (Agenda 2063; NDP)	US (1); UFS (1); Wits (2); UJ (1)	5	
	Sea level rise (SAEO, 2006; NDP)	UKZN (1)	1	
Mining	Sustainable mining and minerals (NDP; SAEO, 2012)	NWU (3); Wits (1); UJ (2); UV (1)	7	7
	Non-renewable resources – minerals (SAEO, 2012)		0	
Soil/Agriculture	Contamination of soil by pollutants (SOER, 1999)	FH (1); NWU (2); RU (1)	4	16
	Investment and research into new agricultural technologies (NDP)	UCT (1); NWU (5); UNISA (4)	10	
	Clean up technology for contaminated land (Kok & Pietersen)	NWU (2)	2	
Air	Air quality (SEMA)	UKZN (2); NWU (4); Wits (4); UJ (7)	17	17
No category	PhDs that were not placed in any theme or aspiration found in the government documents.	UCT (8); UKZN (4); NWU (1); UP (1); US (7); Wits (1); UJ (4); Unisa (4)	30	30

(**Source**: Own).

The above data analysis provided details of what each PhD was about and under what theme, according to particular aspects, it could be categorised.

The aspects, in white, that received the least attention were waste, social impact of drought, use of water efficient plants, environmental entrepreneurship, carbon pricing, mechanisms, sustainable packaging and minerals as a non-renewable resource.

4.6 Identified Under-Researched Themes and Aspects

After the analysis of the PhDs and the summary thereof were completed, under-researched themes and aspects emerged as indicated in Table 4.20. The under-researched themes are ‘waste’ with three (3) PhDs followed by the ‘coastal’ (6 PhDs), ‘mining’ (7 PhDs), ‘protected areas’ (10 PhDs), ‘GHG, low carbon, green and renewable theme’ (11 PhDs), ‘soil/agriculture’ (16 PhDs) and ‘air’ (17 PhDs).

The aspects that did not have any PhDs relating to them are zero waste, reduction and clean technologies, social impact of drought; environmental entrepreneurship training; use of water efficient plants, rainwater harvesting, wastewater recycling; low carbon economy and carbon pricing; sustainable packaging, and mining of non-renewable resources – minerals.

Aspects that only had one (1) PhD were bioprocessing of organic waste, energy efficient and zero emission buildings and transport; sustainable consumption and production patterns, use of indigenous pharmacopoeia food and fibre sources and sea level rise.

Table 4:20: Under-researched themes and aspects.

Theme: Aspect in government document	Total per university	Total/aspect
Waste: Zero waste, reduction and clean technologies (SOER, 1999; NDP; Kok & Pietersen)		0
Waste: Waste usage between industries (Kok & Pietersen)		0
Social-people of SA: Social impact of drought (Kok & Pietersen)		0
Social-people of SA: Environmental Entrepreneurship training (Kok & Pietersen)		0
Water: Use of water efficient plants, rainwater harvesting, wastewater recycling (Kok & Pietersen; Agenda 2063)		0
GHG, Low Carbon, Green & Renewable: Low carbon economy and carbon pricing (NDP)		0
GHG, Low Carbon, Green & Renewable: Sustainable packaging (Kok & Pietersen)		0
Mining: Non-renewable resources – minerals (SAEO, 2012)		0
Waste: Bioprocessing of organic waste (Kok & Pietersen)	UNISA (1)	1
GHG, Low Carbon, Green & Renewable: Energy efficient and zero emission buildings and transport (NDP; Agenda 2063)	UNISA (1)	1
GHG, Low Carbon, Green & Renewable: Sustainable consumption and production patterns (Agenda 2063)	UNISA (1)	1
Climate Change & Natural Disaster: Sea level rise (SAEO, 2006; NDP)	UKZN (1)	1
Social-people of SA: Use of indigenous pharmacopoeia food and fibre sources (Kok & Pietersen)	UNISA (1)	1
Waste: Waste management (SEMA)	NWU (1); Wits (1)	2
GHG, Low Carbon, Green & Renewable: More use of renewable energy (Agenda 2063; NDP)	UCT (1); UKZN (1)	2
Soil/Agriculture: Clean up technology for contaminated land (Kok & Pietersen)	NWU (2)	2
Protected areas: Protect and sustain natural environment (Indicators, integrated framework and the number of areas under protection) (NDP)	UKZN (1); UNISA (1); NWU (1)	3
Coastal: Coastal management (SEMA; Agenda 2063)	NWU (1); US (1); UKZN (1)	3
Coastal: Thriving Mari-culture (Kok & Pietersen)	UCT (3)	3
Water: Clean-up technology for contaminated water (Kok & Pietersen)	NWU (3)	3
Soil/Agriculture: Contamination of soil by pollutants (SOER, 1999)	FH (1); NWU (2); RU (1)	4
Water: Contamination of water by pollutants (SOER, 1999)	FH (1); NWU (4)	5
Climate Change & Natural Disaster: Natural disasters preparedness (Agenda 2063; NDP)	US (1); UFS (1); Wits (2); UJ (1)	5
GHG, Low Carbon, Green & Renewable: Greenhouse gas emissions (NDP; SOER, 1999; SAEO, 2012)	UKZN (3); Wits (2); NMU (2)	7
Mining: Sustainable mining and minerals (NDP; SAEO, 2012)	NWU (3); Wits (1); UJ (2); UV (1)	7
Protected areas: Protected areas (SEMA)	UCT (1); UKZN (5); NWU (1)	7
Biodiversity, Habitat and Resources: Sustainable Natural Resource Management (Agenda 2063)	FH (1); UKZN (4); NWU (2); US (1)	8
Climate Change & Natural Disaster: Climate resilience – impacts on humans and the economy (Agenda 2063; SAEO, 2006)	UCT (3); UP (3); RU (1); US (1); UNISA (2);	10
Soil/Agriculture: Investment and research into new agricultural technologies (NDP)	UCT (1); NWU (5); UNISA (4)	10
Climate Change & Natural Disaster: Climate change or climate change centre (SAEO, 2006, NDP)	UCT (3); UFS (1); UKZN (2); UP (1); Wits (5); UJ (1); UNISA (2);	15
Biodiversity, Habitat and Resources: Habitat loss, loss of aquatic ecosystems (SOER, 1999; SAEO, 2006; SAEO, 2012)	UFS (2); UKZN (4); NWU (4); UP (1); RU (2); Wits (1); UNISA (1); NMU (1)	16
Air: Air quality (SEMA)	UKZN (2); NWU (4); Wits (4); UJ (7)	17
Water: Water quality, security and quantity (SAEO, 2006; SAEO 2012; Agenda 2063)	UCT (3); UFS (4); UKZN (2); NWU (11); UP (1); Wits (1); UJ (1); UV (2)	25
Biodiversity, Habitat and Resources: Biodiversity conservation, Biodiversity, Biological and physical resources (Agenda 2063; SEMA; SOER,1999)	UCT (2); UFS (2); UKZN (9); NWU (13); UP (2); RU (4); Wits (3); UNISA (2); NMU (6); UV (1)	44
Social-people of SA: People of SA and Human vulnerability (AIDS, poverty food security and services) (SOER, 1999; SAEO, 2006)	UCT (8); UKZN (10); NWU (4); UP (5); RU (10); US (2); Wits (5); UJ (5); UNISA (10)	59
No category: PhDs that were not placed in any theme or aspiration found in the government documents.	UCT (8); UKZN (4); NWU (1); UP (1); US (7); Wits (1); UJ (4); Unisa (4)	30

(**Source**: Own).

4.7 Chapter Summary

This chapter started with a discussion on the context of the strategic environmental government documents. The PhDs were then analysed manually, as well as by using a text mining tool. After the analysis of both sets of documents the PhDs were placed into the corresponding themes and aspects relating to environmental management government documents of South Africa. The details of the PhDs and main themes were established in this chapter and the under-researched areas pointed out. The next chapter will discuss the alignment of the PhDs, with the government documents. More detail will be provided, to specify what PhDs were done in terms of each of the strategic environmental government documents.

Chapter 5 – Alignment of PhDs and Comparative Knowledge Map

5.1 Introduction

In Chapter 4, each PhD was analysed, and the details thereof placed under aspects and in themes. The themes were made up of combined aspects found in the SEMAs, research priority topics, components, tipping points, environmental themes, and priority areas of the government documents (Table 4.5). Chapter 4 therefore dealt with the analysis of the PhDs and the themes that emerged. Chapter 4 has not yet, however, indicated the alignment between PhDs and the government documents. Chapter 5 therefore provides an analysis of the alignment between the sampled PhDs done in environmental studies in South Africa and the identified strategic government documents, and the subsequent comparative knowledge map.

The values or numbers of PhDs counted for each strategic document do not add up to a total, as one PhD can be counted and found in more than one strategic document grouping, because aspects were combined. This meant that even though 184 PhDs were relevant to the specifications of this study, 262 more aspects in government documents were addressed by the PhDs. A list of the PhDs, with specific details, were placed under the corresponding government documents. This list can be found under Annexure 2.

5.2 PhDs that did not Align with any Theme in the Government Documents

A total of thirty (30) PhDs did not align with any of the government documents and could subsequently not be placed under any theme or priority area. The research topics involved urban space planning and development, competing urban development, development of census output areas, violence and crime in residential areas, land use planning around airports, gated developments, and the effect of apartheid on the spatial form. Further, weather patterns, oil dependency, environmental education, military environmental literacy, ecotourism to facilitate education, human impact on heritage resources, thermal springs, independent environmental control officers, corporate social and environmental reporting, satellite

products and data, and the efficiency and effectiveness of GIS, were also not placed according to identified government documents' aspects and themes.

5.3 Results of the Alignment Analysis between the PhDs and SEMA

In the previous chapter, the Acts were explained, and context provided (section 4.2). Once the main aspects of the SEMAs were obtained, it was used to identify themes and the related PhDs were grouped accordingly (Table 4.19). Figure 5.1 indicates that forty-six (46) issues in PhDs that aligned with the aspects that could be found in the five (5) SEMAs. The PhDs with their corresponding number can be found in Annexure 2.

Of all the SEMAs, the aspects from the Biodiversity Act and Air Quality Act displayed the best alignment with research conducted in seventeen (17) PhDs each. In the Biodiversity Act there is a section on the protection of threatened or protected ecosystems. The PhDs found in this section studied the ecology of lowland fynbos, loss of grassland biome, and quantifying subtropical forest changes. Benefit-sharing for all people is a section of this Act and PhDs relating to the impacts of eco-tourism on heritage sites, a biodiversity stewardship practice, a legal framework for the conservation of biodiversity, benefit sharing in social-ecological systems, biodiversity and local livelihoods and rural poverty and land degradation, were classified in this section. The protection of the Brenton blue butterfly and the legalising of international trade in rhino horn were two protected species that were addressed. Potential threats to biodiversity from alien species, invasive species and genetically modified organisms were written about in PhDs, and hence placed under this Act.

The Air Quality Management Act offers measures for controlled emitters, fuels dust, noise and offensive odours are provided. PhDs corresponding with this Act included delineation of air quality management areas and plans, air quality monitoring, and accurate mobile emissions inventories. The role of mines, landfill gas, domestic coal combustion and coal-fired power stations, and their effect on air quality and health, were used as study topics for PhDs.

The Protected Areas Act designates the different kinds of protected areas, and how they should be protected as per the law. Seven (7) PhDs aligned with the issues regarding a provincial nature reserve, world heritage sites, spatial development frameworks and management effectiveness research on protected areas.

Only two (2) out of the two hundred and fourteen (214) PhDs aligned with the Waste Management Act – more specifically that of emission rates from landfills, and compliance with minimum national standards in municipal waste management systems. The Integrated Coastal Management Act (ICMA) had three (3) PhDs that focussed on an evaluation of the Act itself against different aspects such as marine harvesting and protection. The other PhDs that aligned with the ICMA were the implementation of a model for integrated coastal management, and coastal erosion.

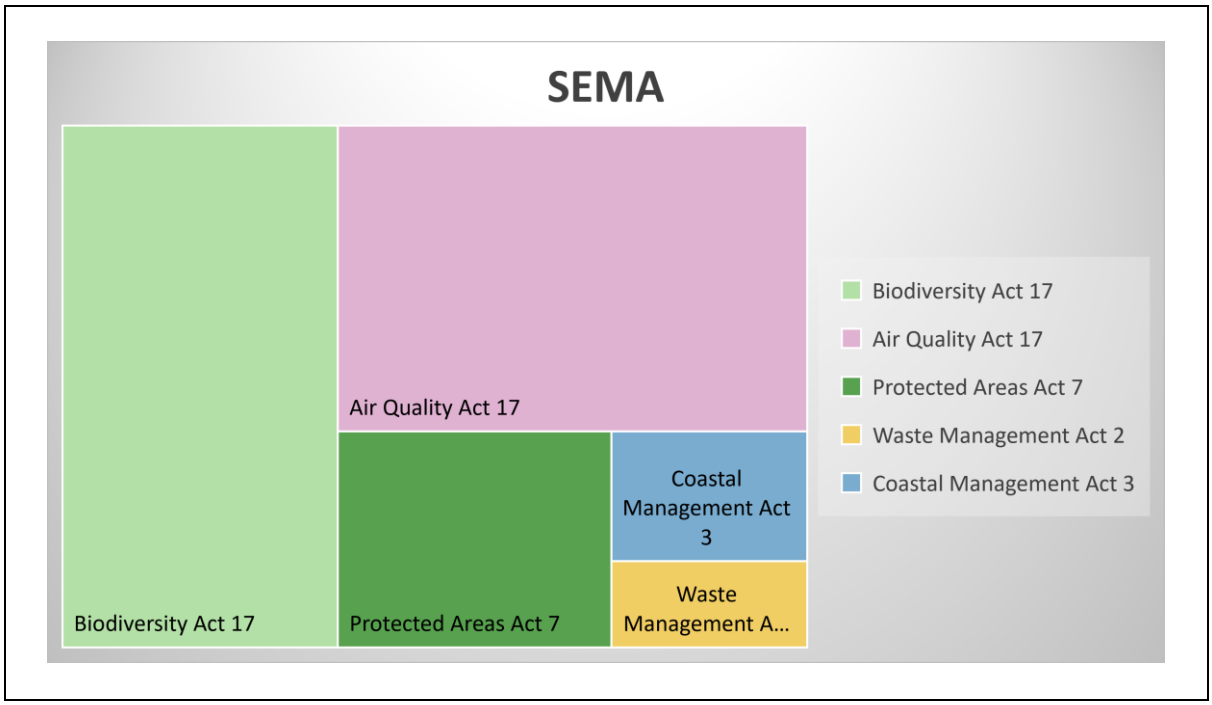


Figure 5.1: The number of issues in PhDs aligning with each SEMA. (**Source**: Own).

5.4 Results of the Alignment between PhDs and the Kok and Pietersen Report

The Kok and Pietersen survey report (1999) did not have many PhDs that aligned with it. Only ten (10) PhDs aligned with the report. In the Kok and Pietersen report three (3) PhDs aligned with the highest ranked topic – environmentally appropriate technologies to promote a thriving mariculture industry. Here the focus of the PhDs

was on small scale fisheries compliance and a customary marine resource governance system.

The second highest ranked topic of the Kok and Pietersen report aligned with one (1) PhD that investigated agricultural waste residues that can be utilised for lignocellulolytic enzyme production. The topic that ranked third dealt with pharmacopoeia and, had one (1) PhD that evaluated the potential of indigenous plants to become commercial beverages. The sixth ranked topic has a two-fold focus as it included the biotechnology for the clean-up of both contaminated water and soil. For the clean-up of water, the three (3) PhDs looked at improved algae removal and the robust monitoring technique to establish the impact on bacterial communities and clean up technologies. The two (2) PhDs that dealt with the clean-up of soil involved advanced clean-up technologies for soil, and the rehabilitation of coal mining soil. The topics that ranked fourth, fifth, seventh, eighth, ninth and tenth as per Table 4.1, had no PhDs that aligned with them.

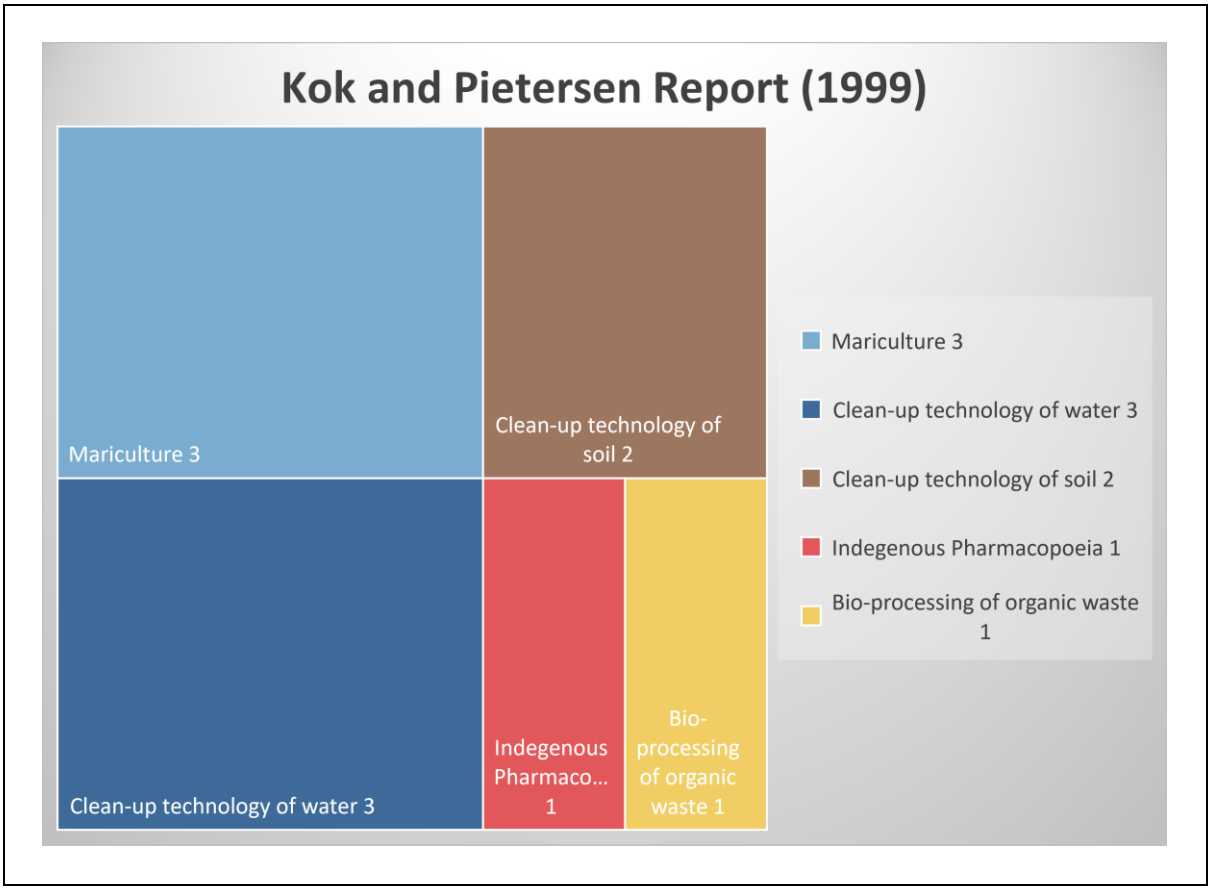


Figure 5.2: The number of aspects in PhDs aligning with the Kok and Pietersen survey (**Source**: Own).

5.5 Results of the Alignment Analysis between PhDs and the SOER/SAEOs

The three State of the Environment reports dated 1999, 2006, 2012, and the research attention that the reports received, can be seen in Figure 5.3. Some PhDs can be found in more than one SOER/SAEO.

5.5.1 State of the environment report (SOER) dated 1999

The SOER 1999 had five themes and aligned with hundred and thirty-five (135) PhDs. Habitat, loss of biodiversity and ecosystems are aspects in the SOER document of 1999, with sixteen (16) PhDs placed under it. The habitat loss aspect aligned with PhD research on habitats such as wetlands, natural grasslands, savanna, forests, a biosphere reserve and subtropical thickets. The impact of humans on fish, birds and insects were further explored.

The PhDs done on the physical and biological resources aspects of the 1999 SOER, were placed in their own themes. The PhDs done in the Biodiversity Act, SEMA section, only covered threatened or protected species and ecosystems, and amounted to thirty-four (34). Under the SOER 1999 theme, all species, threatened and exploited, were considered and included. The PhDs of the Biodiversity Act can thus also be found in the ‘biological resources’ theme and will therefore not be repeated. PhDs that examined aquatic macroinvertebrate, micro-organism biodiversity, juvenile fish, the black-backed jackal, bird eggs, the Vervet monkey, specie richness in domestic gardens and reducing climate change impacts on biodiversity, were further incorporated under this theme.

The ‘physical resources’ theme in the SOER 1999 aligned with ten (10) PhDs, and covered the aspects, water, soil and wood biomass. No PhDs relevant to water were included in this section, seeing that there is a ‘water’ theme that will be discussed as part of the SOER 2006, and can then be read with this section. Loss of soil, soil erosion (due to climate change and tar roads), land transformation and concentration of pollutants measured in soils were placed in the physical resources theme. Further, the impact of invader plant on soil moisture flux and soil carbon, carbon dioxide fluxes and the better use of species for fuelwood, brushwood and kraal posts were included.

Chemical processes in the SOER comprised of waste, greenhouse gases and the contamination of water and soil by pollutants. No PhD was done on waste. Seven (7) PhDs that aligned with the greenhouse gases (GHG) comprised of carbon dioxide fluxes in soil, monitoring of carbon stocks, elevated CO_2 on a grassland community, the measurement of NO_2 over the Highveld, and the role that an air quality management plan could play and its influence on greenhouse gas (GHG) emissions. Concentration of pollutants, atmospheric trace metals and water-soluble ionic species, heavy metal pollutants, polycyclic aromatic hydrocarbons (PAHs) and levels of persistent organic pollutants in water were added under contamination of water theme. The contamination of soil as a theme of the 1999, SOER encompassed four (4) PhDs that addressed heavy metal pollutants in soil, concentration of pollutants measured in soils, asbestos contamination in soil and soil ecological risk assessments of soil pollutants where ants are potential indicators.

Fifty-nine (59) PhDs aligned with the SOER 1999 'social-people of SA' theme. These PhDs dealt with social issues such as governance systems, local livelihoods, communities, poverty, food security, health, education and conservation areas. In terms of health HIV/AIDS, tuberculosis, bilharzias, malaria, *E.coli.* and cancer received attention. In the food security section, PhDs investigated various aspects of maize, wheat, rice and tomatoes. In terms of household food security, the impact of HIV and AIDS on household food security, changes in household food security and perceptions of communities with regards to community urban agriculture, were studied.

5.5.2 South Africa Environment Outlook report (SAEO) dated 2006

Seven themes were captured out of the SAEO 2006, and hundred and fifty-six (156) PhDs aligned with them. The 'greenhouse gas' (7 PhDs) 'loss of biodiversity' (34 PhDs) and 'human vulnerability' (59 PhDs) themes will not be discussed again as this was already done, above, when dealing with the SOER 1999. Annexure 2 also indicates where the subsequent data can be found. In the 'loss of biodiversity' and 'aquatic systems' themes, only the PhDs found in the aquatic systems is deliberated on, as the 'loss of biodiversity' was done in 'the biological resources. In the 'aquatic systems' theme the five (5) PhDs concentrated on wetlands and freshwater aquatic environments.

Assessing the wind climate for renewable energy potential and to improve climate model predictions and model transferability to compare Regional Climate Models (RCM) were PhDs that were placed in the weather patterns section of the 'climate change' theme. The effect of climate change on soil, agricultural production, biodiversity and wetlands was researched. The fifteen (15) PhDs in this theme also housed the response of the coal mining sector to climate change adaptation, landfill gas generation, and emission rates from landfills, plus the integrating policy efforts, energy security, economic growth and global warming. The 'sea level rising' aspect associated with the 'climate change' theme had one (1) PhD.

The 'climate resilience' aspect consists of the impacts of climate change on humans or the economy, and an alignment with ten (10) PhDs was established. Impacts of climate change on agricultural production, rooibos, wheat, citrus fruit, tomatoes, small towns, health, cattle and sheep as well as municipal planned adaptation and the implications for community-based adaptation, were investigated and can be located in this theme.

The 'water' theme of the SAEO 2006 aligned with twenty-five (25) PhDs. Studies considered for this theme researched the monitoring or assessment of water quantity, -quality, -security, -use, -management and the rehabilitation of water resources at catchment and national level. Water assessment methods and water monitoring included the use of bio-indicators such as periphyton, bacteria and diatoms. Wastewater treatment facilities, on-site sanitation systems and wastewater discharge additionally received attention.

5.5.3 South Africa Environment Outlook report (SAEO) dated 2012

Most of the themes in the SAEO 2012 were discussed in the previous two sections related to the state of the environment. PhDs that aligned with the themes in the 2012 SAEO amounted to fifty-five (55). The only one that was not deliberated on was 'sustainable mining'. Here the seven (7) PhD students explored a collaborative sustainability model for the mining industry, mining rehabilitation methods, clean-up technologies and remediation post-mine closure. The perceptions of residents on mines, and exposure of the public to radioactive effluents, as well as existing exposure situations from mines were also captured in the 2012 SAEO. The previous three

reports indicated the state of the environment in 1999, 2006, 2012 and key issues that needed to be addressed.

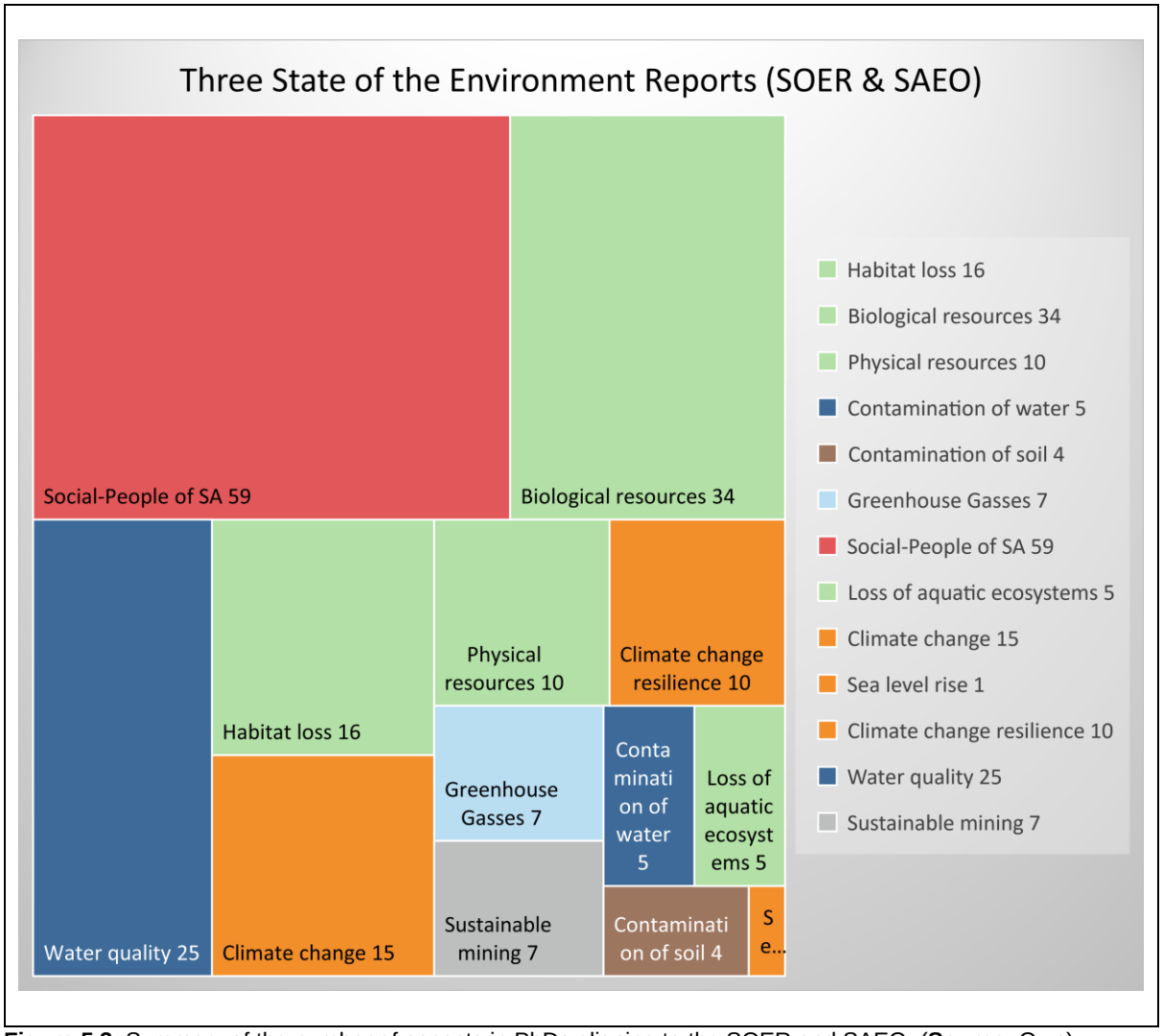


Figure 5.3: Summary of the number of aspects in PhDs aligning to the SOER and SAEO. (**Source**: Own).

The future direction and plans of South Africa must also be considered and this was done in the NDP 2030.

5.6 Results of the Alignment Analysis between the PhDs and the NDP 2030

Figure 5.4 illustrates the finding of the thirty-five (35) aspects in PhDs, after the alignment analysis of the PhDs in comparison to the themes of the NDP was done. Indicators and regulatory frameworks in the 'protected areas' theme was found in the Protected Areas Act and the NDP. Wetland indicators, Environmental Management Frameworks (EMF) and Spatial Development Frameworks (SDF) formed part of this grouping, in terms of the three (3) PhDs completed. Disaster preparedness for extreme

climate events were captured in five (5) PhDs. The studies concentrated on disaster risk reduction strategies for wetlands, impacts on agricultural production due to natural disasters, drought disaster-risk reduction, and disaster preparedness based on the perceptions of the community on the cumulative effect of coal mining on communities.

Energy efficiency in selected guest houses aligned with the energy efficient buildings aspect of the improve energy efficiency theme. The use of more renewable energy, also in this theme, were reflected in two (2) PhDs: impact of the implementation of renewable energy in marginalised communities, and a study of the wind climate to establish the use of renewable energy.

Investment in, and research into, new agricultural technologies and adaptation strategies that were conducted, were recorded in ten (10) PhDs that were centred around the use of seasonal forecasts, feeding experiments, genetically modified maize and non-target insects, integrated nematode control strategies and ants as indicators of soil pollutants. The establishment of a climate change centre, carbon pricing mechanisms, zero emissions and the reduction of waste to landfill did not have any PhDs that could be placed under these aspects. Not many PhDs could relate to the NDP 2030, as illustrated in Figure 5.4; however, the Agenda 2063 had more touchpoints between their aspirations and the PhDs:

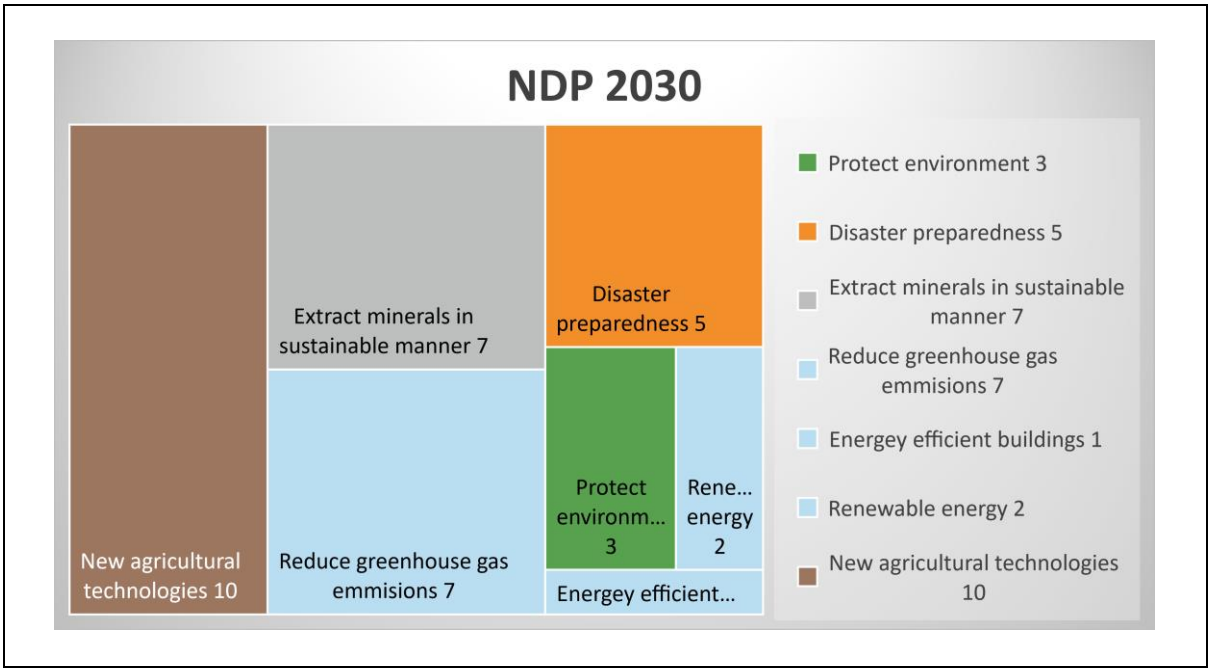


Figure 5.4: The number of PhDs done under the NDP. (**Source**: Own).

5.7 Results of the Alignment Analysis between the PhDs and the Agenda 2063

Priority areas in the Agenda 2063 that involved the most of the eighty-eight (88) aligned PhDs, were biodiversity conservation and water security. Figure 5.5 indicates that climate resilience and sustainable resource management contained between ten (10) and eight (8) PhDs. Most of the priority areas were discussed above. In the sustainable natural resource management priority area, an emphasis on rangelands was revealed, that ranged from a monitoring system for rangeland degradation, the assessment of the quality of the rangeland, the communal management thereof, management treatments and an evaluation of selected soil properties in semi-arid communal rangelands. Natural resource-based development and military integrated environmental management were put in this priority area, along with the focus on rangelands. Green procurement practices in municipalities was the only PhD that could be placed in the sustainable consumption and production pattern area of Agenda 2063, as indicated in Figure 5.5:

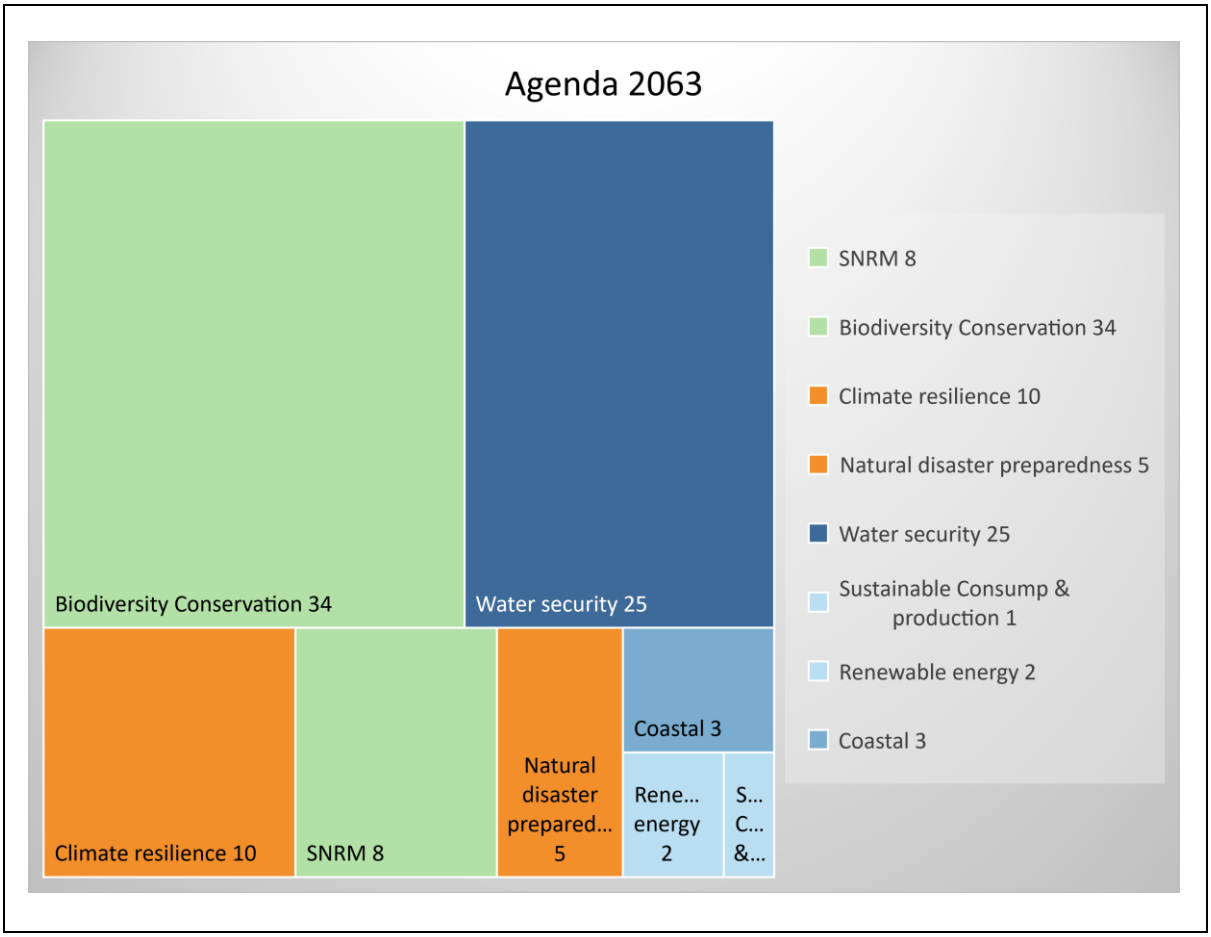


Figure 5.5: The number of PhDs done under the Agenda 2063. (**Source**: Own).

5.8 Summary of the Alignment between PhDs and the Government Documents

Table 5.1 and Figure 5.6 demonstrate that the themes of the SAEO 2006 and the SOER 1999 were well aligned with PhD research. Agenda 2063 and the SAEO 2012, were also well aligned in terms of PhD numbers. A possible reason for this is the publication dates of these documents compared to the publication dates of the PhDs.

The fact that the students select topics or research problems from the environment, that are topical and relevant, and the fact that the government is geared to highlight the topical environmental concerns, are well reflected in the alignment of the PhDs to government documents. The 'human vulnerability' or 'social-people of SA', 'water security' and 'biological resources' had the most PhDs that connected with these themes.

Climate change and resilience, land degradation, biodiversity, air quality and habitats followed. If looked at the SEMA section, it is recognised that some of the Acts received more attention than others.

Table 5.1: Summary of the alignment between PhDs and the government documents.

Government documents	Total number of aligned or non-aligned PhDs
SEMAs	46 PhDs or 21.4%
Kok and Pietersen survey	10 PhDs or 4.6%
SOER 1999	135 PhDs or 63%
SAEO 2006	156 PhDs or 72.8%
SAEO 2012	55 PhDs or 25.7%
NDP 2030	35 PhDs or 16.3%
Agenda 2063	88 PhDs or 41%
Non-aligned PhDs	30 PhDs or 14%

(**Source**: Own).

Figure 5.6 Illustrates a breakdown of the number of PhD aspects in government documents:

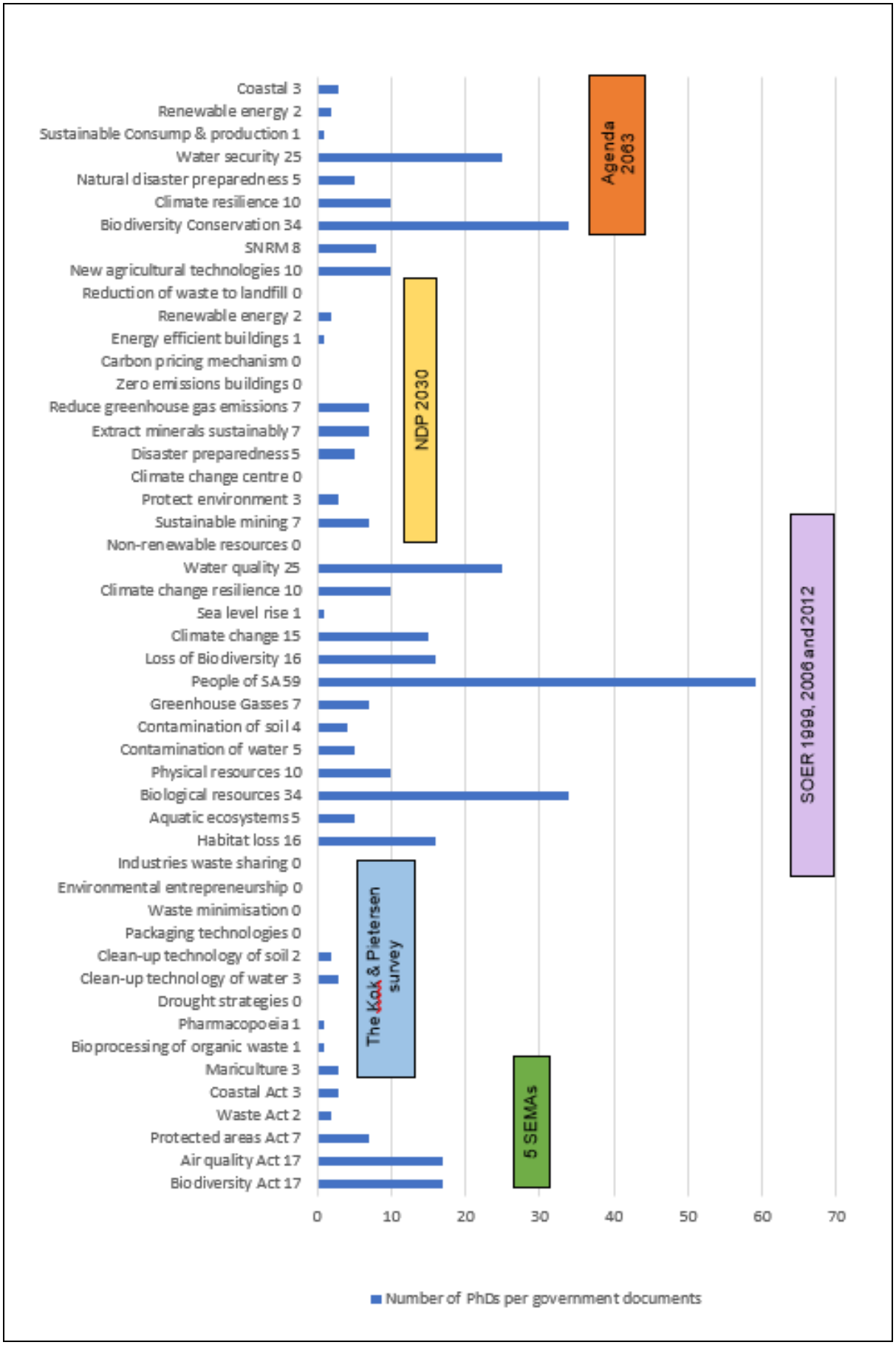


Figure 5.6: Number of PhD issues in government documents. (**Source**: Own).

With the results of the alignment analysis, potential research gap areas for future research in environmental management were discovered, that gave an indication of what themes and aspects were dealt with extensively and which received less to no attention.

5.9 Trends and Gaps in Environmental Research

The analysis done in Chapter 4 on the PhDs completed at universities, indicated themes and aspects that were under-researched (Table 4.20). Even though the themes of Table 4.19 may indicate that many PhDs were completed in a specific theme, some aspects in that theme showed no alignment, and were highlighted more in this chapter when the PhDs were aligned with each aspect of a government document. The ‘social-people of SA’, ‘water’ and ‘climate change’ and ‘natural disaster preparedness’ are such themes.

The alignment of PhDs to the respective strategic government documents (section 5.3 to 5.7) revealed which aspects in the government documents themselves were not researched – or under-researched. These aspects, seen as research gaps, or potential research ideas were captured in Table 5.2. For this chapter and section, the classification was the number of PhDs between 0 and 11 – the same as used in Chapter 4; therefore, if a government document aspect related to 10 or more PhDs, it was not included in Table 5.2.

The research gap table shows an overview of ideas that may be used for future research, and includes ideas such as protected areas, coastal management, waste, water and climate change, to mention a few.

Table 5.2: Research gaps or research ideas.

Research gaps or potential research ideas
• Protected areas as per the Protected Areas Act. • Protect and sustain the natural environment by developing indicators, integrated frameworks and an increase of areas under protection.
• Coastal management as per the ICMA. • Development of environmentally appropriate technologies to promote a thriving mariculture industry.
• Waste management as per the WMA. • Zero waste, reduction of waste and clean technologies. • Waste usage between industries. • Bioprocessing of organic waste.
• Environmental Entrepreneurship. • Development of strategies and technologies to reduce the social impacts of drought. • Use of indigenous pharmacopoeia food and fibre sources.
• Clean-up technology for contaminated water. • Use of water efficient plants, rainwater harvesting, wastewater recycling. • Contamination of water by pollutants. • Aquatic ecosystems.
• Greenhouse gas emissions. • More use of renewable energy. • Energy efficient and zero emission buildings and transport.
• Low-carbon economy and carbon pricing. • Sustainable packaging. • Sustainable consumption and production patterns.
• Climate change centre. • Natural disasters preparedness. • Sea-level rise.
• Sustainable mining and minerals. • Non-renewable resources – minerals.
• Contamination of soil by pollutants. • Clean up technology for contaminated land. • Investment and research into new agricultural technologies and adaptation strategies.

(**Source**: Own).

5.10 The Comparative Knowledge Map

Chapter 4 and the above sections 5.1 to 5.9 dealt with the analysis of PhDs, in terms of PhDs from a university focus perspective and the alignment between the government documents and PhDs. The comparative knowledge map is a culmination of Chapter 4 and the first part of Chapter 5. In the following section, the comparative knowledge map (Figure 5.7) is discussed. It will display the PhDs completed per year, by focus area (the focus area represents the themes as found in Table 4.19), related

to a government document. It also illustrates where the focus and the issues of PhD research in environmental studies were, and where gap areas arose.

The knowledge map reads like a matrix, with the top row indicating the total number of PhDs completed per year. The column to the extreme right indicates the frequency of terms covered by the number of PhDs per focus area (second-to-right column). The icons indicated in this column represents the government documents aligned with the PhDs conducted. The bottom row provides an indication of the government documents and icon in the year of publication of these documents. The shading of purple in the content area of the matrix is representative of the number of PhDs that align with a specific theme in a specific year. The dark purple blocks indicate where the PhD research was focussed on the most, and as the purple colour fades it is an indication of gaps or under-researched areas. In the purple area, under each year, the number of issues in PhDs per focus area and from which government documents it was derived can be seen.

The sixteen (16) blocks with a number in them, but no symbol, means that the PhD did not align with any documents, as the PhD was finalised before the publication of the government documents. This is still important data to have, as it is pertinent to see which PhDs related to which government documents, even before those documents were published. A PhD topic that has alignment to a government document that was published prior to the government document's own publication, still shows alignment to the strategic direction, and shows potential influence on the government documents. One such PhD was completed at UKZN in 1998 regarding protected area outreach programmes: a critical evaluation of the Kruger National Park. Others focussed on the disaster preparedness aspect of the NDP 2030; two (2) PhDs on water, that were before the publication of the SAEO 2006, and two (2) PhDs on the Integrated Coastal Management Act, completed before 2008. Since 2008, a growth and steady rise in PhD research was noticeable.

Between 1998 and 2005, PhD completions varied between one and nine a year. In 2015 and 2016, almost forty (40) PhDs were completed each year. The columns under each year from 2000 to 2017 mostly indicate that PhDs focussed on 'biodiversity, habitat and resources' or the theme' social-people of SA'. The protected areas, mining,

coastal and the greenhouse gas, low carbon- or green economy and renewable energy focus areas all showed a decline from 2015.

Looking at the trends holistically' further' per focus area, the biodiversity, habitat and resources focus area were well researched. Six government documents were included in the biodiversity, habitat loss and resources focus area. In the last three years of the study period, nine (9) PhDs per year, in this focus area, were concluded, as seen in the darkest purple blocks. The 'social-people of SA' focus area were the second most and were deemed important by three government documents. The 'social-people of SA' focus area had a peak of eleven (11) PhDs completed in 2016 and have the darkest purple blocks.

The 'water' and 'climate change' and 'natural disaster' focus areas both showed a steady increase from 2013. In 2011, the most PhDs, five (5), were completed in the 'climate change' theme that was an aspect in the SAEO 2006. In 2007, and between 2014 to 2016, the 'climate change 'theme became even more prominent. The 'water' focus area had a peak of eight (8) PhDs in 2015.

The air quality focus area demonstrated a high level of alignment. This is probably related to the fact that it is tied to legislation, while some of the other documents are strategies. However, the 'protected areas' focus area, the 'waste' focus area and the 'coastal' focus area, even though they are pieces of legislation, still showed low levels of alignment, and indicated the biggest research gap and potential for increased research that can be focussed on. These gaps or under-researched themes were also highlighted in section 4.6.

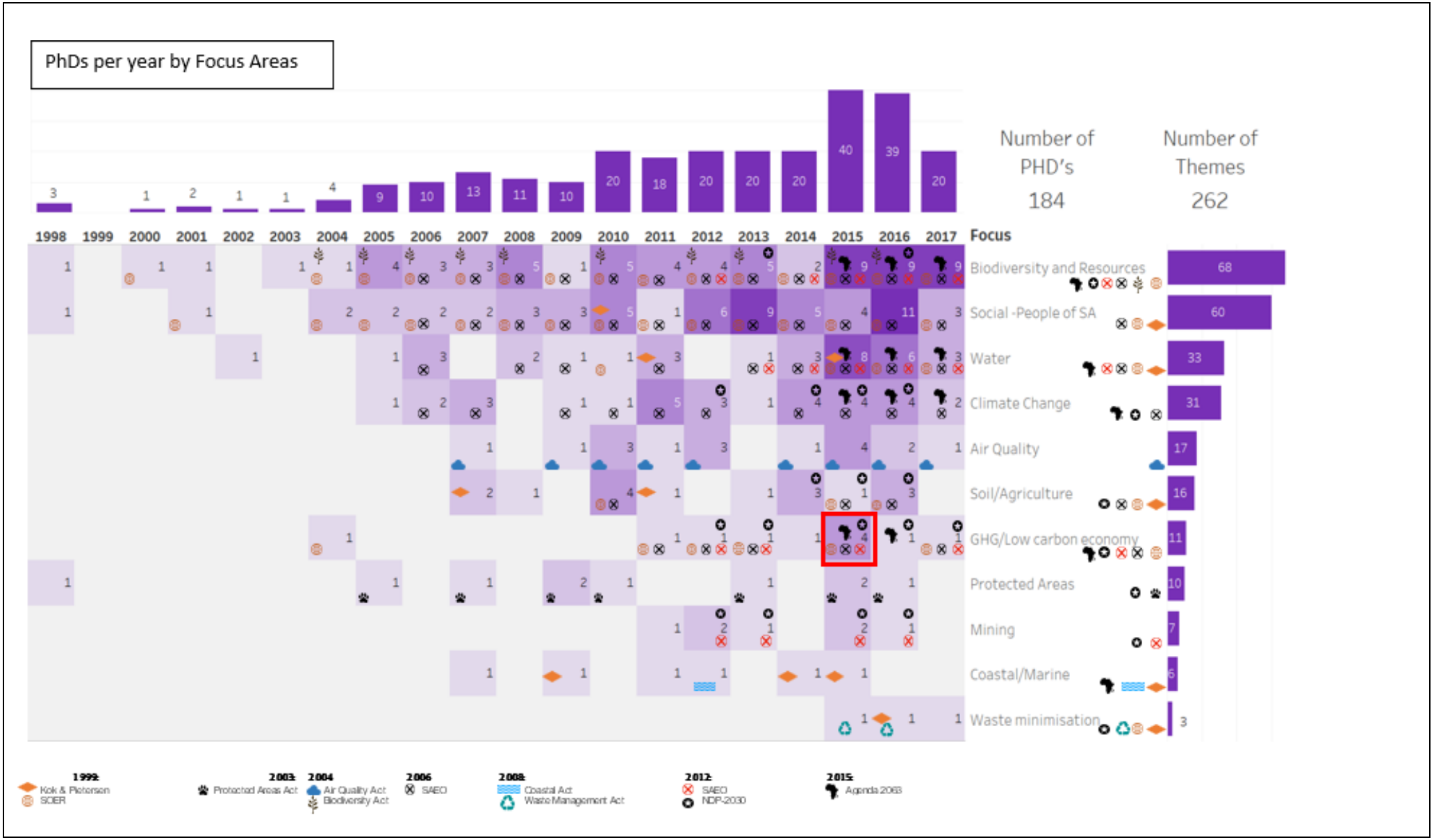


Figure 5.7: Comparative knowledge map. (**Source**: Own).

The example highlighted in the knowledge map represents 4 PhDs that were completed in 2015 in the greenhouse gas and low carbon economy. These PhDs align with SOER (1999), SAEO (2006), SAEO (2012), NDP2030 (2012) and Agenda 2063 (2015

5.11 Chapter Summary

An alignment analysis of the PhDs in relation to the strategic government documents were carried out in this chapter. A comparative knowledge map was developed to visually display the results of chapters 4 and 5. Possible gap areas or future PhD research focus areas that address and contribute towards the strategic environmental themes set by the South African government, were identified. The following chapter will elaborate on the relationship between the results, the theory, and the literature review.

Chapter 6 – Synthesis, Recommendations and Conclusion

6.1 Introduction

This chapter provides a discussion on the analysis done in both Chapter 4 and 5 and the subsequent comparative knowledge map. This discussion will synthesise the research strategy and indicate how the findings are related to the theories and literature that was discussed, as well as how the findings have addressed the research objectives.

This chapter will conclude the thesis with a discussion on the significance, and limitations of the study, the recommendations, and future research. At the start of this research, it was not known whether the contributions of South African PhDs in environmental studies were aligned with priority environmental issues or strategic driver documents, in South Africa, and addressing those issues. Research concerning the focus areas of environmental studies, PhD research, between 1998 and 2017, and the alignment with any of the South African government's environmental aims and objectives, has not been done previously. The strategic research themes that are included in legislation, policies, plans and goals, were explored and identified. The PhDs and the strategic driver documents were compared, to establish whether there was any alignment between the two. This study both determined the nature and characteristics of the PhDs and the government documents and made comparisons through an alignment process.

6.2 Synthesis

Subsequently, a summary of the research aims and answers, how it was achieved, and what it meant for the research, is discussed.

Objective 1: To interrogate the national environmental management policies, plans and goals for South Africa in order to extract priority environmental issues and transform these into strategic research themes (section 4.2).

This objective was attained by firstly identifying national environmental management government documents. The extraction of priority environmental issues was made

easy as the documents highlighted the environmental issues themselves. Once all these issues were known, similar issues from the different documents were grouped together, and named, to best represent the group and, thereafter the strategic research themes. By interrogating the South African environmental management strategic documents, it became clear what policies, plans, goals and environmental issues were deemed important by the government, for a sustainable future.

Objective 2: To systematically analyse the nature and characteristics of South African PhD research in environmental management/sciences/studies between 1998 and 2017 (section 4.3).

Research objective 2 was reached by investigating the institutional repositories of universities to gather PhDs that fell within the scope of this study. All 214 PhDs related to the study were manually scanned and text-mined by using Leximancer. By doing this, the nature and characteristics of South African PhD became known, and affirmation was received that students' choices were not controlled by a central co-ordinator but self-regulated. This knowledge gave a holistic view of past PhD research and possible ideas for future research.

Objective 3: To critique comparable alignment of PhD research done in environmental management/science/studies to the identified strategic research themes (section 5.3).

Objective 3 was accomplished by the alignment of PhDs in environmental management/sciences/studies with the strategic research priorities and aspects identified in the government documents. The alignment process revealed which PhD research aligned with the aspects found in strategic government documents and uncovered possible research gaps.

Objective 4: To develop a comparative knowledge map where the knowledge contributions of South African PhDs in environmental management/science/studies will be aligned to the identified strategic research themes (Chapter 6).

Based on the alignment analyses and subsequent results of chapters 4 and 5, objective 4 was achieved. The comparative knowledge map illustrated the themes, aspects, trends and research gap areas. Several under-researched themes and

aspects were identified along with more prolifically researched areas (‘biodiversity, habitat and resources’ and ‘social-people of SA’ themes). These two themes are the main role players, as previously indicated by the SES framework. The realisation of the objectives made it possible to answer the main and other research question.

Research question 1: What is the level of alignment between the PhD focus areas and the strategic research themes? (section 4.4)

The first question was answered, and the level of alignment between the PhD focus areas and the government strategic themes was established. The answer to this question is that PhDs focussed and aligned mostly with the following themes as found in government documents: ‘social-people of SA’, their vulnerability and social issues, biological resources and biodiversity conservation. Many of the PhDs did not align with any aspects in the government documents, and alignment therefore appeared to be low. Linking to this, 14% of the PhDs could not be placed in any of the themes that is deemed important by the government. Greater alignment was found in aspects that are legislated, but exceptions to this were also noticed in terms of the Protected Areas Act and the Waste Act.

Research question 2: Which strategic research themes have not been covered by the related PhD research? (section 5.8)

The second question could be answered and strategic research themes, that were not covered once the alignment was completed, were seen in sections 4.6, 5.9 and the comparative knowledge map (Figure 5.7). These themes specifically were ‘greenhouse gas, low carbon or green economy and renewable energy’, ‘mining’, ‘coastal’ and ‘waste’. These were themes and aspects that were mentioned in several government documents but displayed little alignment.

Research question 3: What are the research gaps that should receive priority in future PhD studies in terms of the identified strategic research themes? (section 4.6 & 5.9)

The research themes and aspects that should receive priority in future PhD studies, in terms of the identified strategic government research themes, are exhibited in the identified research themes tables (Table 4.19 and 4.20) and in the comparative knowledge map (Figure 5.7). Prospective PhD students may be able to obtain

research ideas for future research, that are in line with government plans to benefit the sustainable development of South Africa, in the mentioned tables and figure. A point that needs to be kept in mind is that government documents are 'living documents' that are subject to change and amendments. PhD studies can equally influence government document in their role of developing new knowledge. The gap and research areas may therefore change, along with changes in the developmental goals and environmental foci of the country. This study may identify research gaps that are relevant at this point in time, but it can be less important in future. Other priority areas will develop due to the dynamic nature of ecosystems and human impacts on the environment.

6.3 Motivations of Students to do a PhD Discussion

The complexity theory states that one needs to expect the unexpected, which is true for this research. At the onset of this study, it was not clear what to expect, or that two themes or focus areas from the government documents would align more than others with the completed PhDs as per the comparative knowledge map (Figure 5.6). From the eleven themes, seven themes did not show much alignment. This finding is reaffirmed, as the contexts wherein students make decisions for their research are personal, policy, national or theoretical, the relationship with the academic supervisor, the academic reputation of the university and the availability of job opportunities, funding or bursaries (Plowright, 2011; Cloete *et al*., 2015; Wiegerova, 2016).

Research efforts, funding and taxpayer money may therefore not be well spent, as PhD research was in some instances not aligned with the plans and projects for prosperity in South Africa as found in environmental management strategic government documents (Van Schalkwyk *et al.,* 2020). As further seen in the BAO framework, the social structure wherein people find themselves influences the beliefs of people about the environment.

The action forming process of the BAO framework also requires that beliefs be changed, and behaviour affected on a macro- and micro-level. If the beliefs of the students are changed, research efforts and resources could be directed towards national environmental goals and plans that may lead to a healthier environment for

all South Africans. If students could be made aware, and if they believe that their PhD study choices could assist the South African government in reaching its environmental goals on a micro-scale, the actions or outputs of their PhDs may have greater effect on the sustainable actions and goals that the government wants to achieve. For future PhD students to be able to do this, the nature of the current body of knowledge must be known, hence the development of the comparative knowledge map.

6.4 The Comparative Knowledge Map Discussion

Erdogan (2015) created a framework map that identified research trends, and Hollman and Banning (2012) a thematic structure, after both executed a content analysis research method. This research also developed a comparative knowledge map, but the design thereof was not clear at the start of the research. Self-organisation is the spontaneous appearance of order out of chaos, because of the interactions between elements. The self-organisation of the elements resulted in the appearance of a stable pattern. As complex systems are unpredictable, it was not probable to predict what structure would emerge from any set of rules – it is the result of actions, and not of any pre-design.

In a complex system, patterns emerge from the bottom up when the interrelations between elements form a whole and the interactions between wholes interact to form larger wholes. This is the reason why Chapter 4 was done first, to establish what the content of PhDs were (Table 4.19) and what universities were focussing on – one whole. As the alignment was done, in Chapter 5, between the PhDs and the government documents, another whole emerged (Figure 5.6). These two wholes (Figure 4.19 and Figure 5.6) then interacted with each other to form a larger whole – the comparative knowledge map (Figure 5.7). The comparative knowledge map therefore emerged as a result of actions, when the system played itself out, and not by any predetermined design. The alignment process of PhDs and government documents and the subsequent comparative knowledge map uncovered results for further discussion.

6.5 Alignment of PhDs, Universities and Government Documents Discussion

The core relationships and fundamentals of any environmental management research are the interactions between human and environment systems. Humans and their developments influence and impact on the environment, and the environment then reacts in an unpredictable and uncertain manner. The complexity theory and the social-ecological system (SES) framework developed by McGinnis and Ostrom (2014), essentially provided a link between ecological and socio-economic systems that affects each other. The interaction between humans and the environment could thus be studied together, as they form a relationship. This was confirmed by Strydom and King (2015), who that stated that students from different disciplines incorporated environmental management studies into their curricula. The complexity theory therefore offered the framework to assist with the integration of natural science and human social science methodologies and elements.

The intention of the research was to identify and compare patterns that emerge from the non-centrally coordinated and self-organised PhD topics to the patterns that may emerge from themes that need to be managed through legislation, regulations, environmental reports and development plans. As the complexity theory underlaid this study, a more holistic view of the PhDs completed in the environmental studies field resulted. The complexity theory, as a parameter, measures the number of elements, the diversity of the elements, the degree of interconnectivity and interdependency of elements. This study was more interested in the connectivity between the elements, than the elements themselves. Once the interconnectivity and interdependency between the elements were recognised, the diverse content of the PhDs was organised and aligned with themes of government documents, and order emerged as seen in the themes table (Tables 4.19 and 4.20) and the comparative knowledge map (Figure 5.7).

The study revealed the number of elements – that is the PhDs, the diversity amongst the PhDs, and the interconnectivity between them. These elements (PhDs) interconnected with each other, as they are studies that focus on the same issue – the environment. Not only did all the PhDs display interconnectivity, but they also interconnected and revealed interdependency with the themes and the aspects of the

strategic environmental government documents. Patterns and themes from the PhDs did emerge, and most of the PhDs could be placed in themes which were determined by the government documents.

Some PhDs (16) aligned with an aspect in the government documents but were done before the date of the publication of the government documents. A PhD that has alignment with a government document that was published prior to the government document's own publication, still shows alignment to the strategic direction, and shows potential influence on the government documents. Because PhDs are supposed to make a new contribution, the PhDs that precede the government documents are potential influencers on the inclusion of that topic in the strategic direction of the government documents. By including this aspect as part of the knowledge map, the potential for cross pollination of the creation knowledge to a strategic decision is demonstrated. It also emerged that thirty (30) PhDs did not relate to any aspect of the government documents. It is important to note that the individual PhDs, or elements still maintain their own independence and functions and is not controlled by the system itself.

When the analysis of individual PhDs was completed, it was seen that PhD topics addressed more than one issue, and do not focus on one issue. This is confirmed by Vogt *et al*. (2015), when they state that there is a decline in interest to solve specialised environmental problems, and the new notion is that social and ecological systems are linked. The PhDs do not only focus on one aspect, but the elements in the PhDs are interactive, interdependent, and interconnect with each other. This could be seen when the alignment analysis revealed that even though 184 PhDs were applicable to this study, 262 aspects were recorded, because one PhD could be found in two or more themes. The non-linear character of the complexity theory confirmed this as well. The complexity theory states that when elements interact, it leads to a greater output, that is greater than the sum of the parts, and more, that any element can be dominant.

The 'biodiversity, habitat and resources' and the 'social-people of SA' themes were the two most dominant themes throughout most of the years and at most universities, as seen in the Table 4.19 and Table 4.20, and the comparative knowledge map (Figure 5.7). This additionally highlights the interaction and interconnectedness between

humans and the environment, as illustrated by the complexity theory and the SES framework (2014) (section 2.3.2.1 (iv). Seeing that the natural environment and humankind are both a crucial part of environmental management, it can be assumed that this trend will be continued.

When the PhDs and the different universities were further analysed, it became known that some universities had NRF, SARChI research chairs (section 4.3). The research chairs were compared with the nature of the PhDs at the universities that had chairs. It emerged that some PhDs were aligned with the SARCHI research chair of the institution for example, UKZN (section 4.3.4), Rhodes (section 4.3.7) and Wits (section 4.3.9). The UCT has four SARChI research chairs (climate change, marine ecology and fisheries) and two were represented. The research chairs (Biodiversity Value and Change in the Vhembe Biosphere Reserve) were not reflected in the University of Venda PhD research, but there were not many completed PhDs. At other universities, their research chair focus areas were not mirrored in their completed PhDs. A reason could be that master's degrees and academic journal articles may focus more on the research chair facets. What also emerged from the analysis was the under-researched aspects in government documents.

The 'greenhouse gases, green- or low carbon economy and renewable energy' theme were cited in five (5) of the seven (7) government documents, but only eleven (11) PhDs were completed that referred to this matter. The Kok and Pietersen (1999) survey report, which provided research direction, focused solely on future research and funding in environmental management pertaining to South Africa, and was the document that did not align with many PhDs (section 5.4). The NDP 2030, a key planning document for South Africa, was also not well aligned with PhD research.

Mouton (2010:67) states that 83% of students, in sub-Saharan countries claimed that their work was aligned with the development plans of their country. The result of this study calculated that this statement may not be representative for environmental management research in South Africa, as the number of PhDs that aligned with the NDP 2030 were only 35 out of the 214 PhDs – or 16.3%. However, it must be noted that the NDP 2030 were only published in 2012, and the number of PhD research studies aligning to this document may change as time pass. As Lindebaum *et al*.

(2020), used a content analysis approach to refute claims made by others, the results of this research may also refute the claim that students align their research work with the NDP 2030 of South Africa.

This analysis established that some of the themes of government documents may not be fully represented in PhDs, and that the country's priorities are not addressed by PhD research, even though Mouton (2010) indicates the importance thereof. This analysis further revealed research gap areas and the trends in environmental studies PhD research – the same as what Bozkurt *et al.* (2015), did in the Turkish distance education field.

6.6 Trends and Gaps in Environmental Research

Systematic mapping reviews and content analysis studies, done by Caffarella, (1999) and Lin *et al.* (2018), revealed research trends and gaps in a specific research discipline. By following the same content analysis research method (section 2.3.1), this study also discovered gaps and trends. Table 4.20 as well as the comparative knowledge map (Figure 5.7), revealed trends, under-researched themes, aspects, and possible research gaps or ideas, just as the studies by Bozkurt *et al*. (2015) and Lin *et al.* (2018) could.

Environmental management commenced with the promulgation of legislation in 1998. However, the UKZN included the word environment in their departmental name as long ago as 1988 and produced the first PhDs in 1998. The one PhD focused on the change of freshwater inflow on juvenile fish and the other on an evaluation of outreach programs in the Kruger National Park. Once again, the connection between humans and biodiversity can be seen in these early first two PhDs. During the time span of the study, a gradual increase in PhD numbers could be seen as, demonstrated in the comparative knowledge map.

The comparative knowledge map further illustrated that, after 2008, an increase in the finalisation of PhDs occurred. This may be linked to the new PhD funding formula that was instated in 2005 and the rise of PhDs in South Africa since 2008, as stated by Van Schalkwyk *et al*. (2020). Even with the increase in PhDs certain gaps arose.

In Chapter 4, research themes were shown that emanated from the content analysis of the PhDs. Aspects (Table 4.20) including coastal, mining, waste, greenhouse gases, green- or low carbon economy and renewable energy, that were mentioned in several documents, could only be found in a small number of the completed PhDs. The waste aspect was mentioned in four of the seven strategic documents. The waste issue was however under researched as only three (3) PhDs were completed from 2008 to 2107. Zero waste to landfills, reduction of waste, clean technologies and waste usage between industries were not addressed, yet UNEP (2019) sees waste as a major challenge for the global environment. Waste as a priority matter is confirmed in the SOER 1999, the Kok and Pietersen Report, the NDP 2030 and legislation – as captured in the Waste Act.

The most dominant global environmental issues created by humans, as believed by Mondal, (2020:1) and UNEP (2019), are climate change or global warming related, desertification, deforestation, loss of biodiversity, waste and the scarcity of natural resources. This is the same as the aspects that were found in the government documents. Even though the Kok and Pietersen survey (1999) and the first SOER (1999) were completed in 1999, most of the aspects are still relevant, and comparable to the issues today in 2021. The comparative knowledge map further indicated that the climate change theme gain momentum, in terms of finalised PhDs since 2011. Research may thus follow new technology and new developments as conveyed by Caffarella (1999). The increased use of renewable energy as new technology can assist with the issues brought about by climate change.

Renewable energy was only represented by two (2) PhDs, completed in 2015 and 2016. However, this theme could be found in both the NDP 2030 and the Agenda 2063. The analyses of PhDs and themes of the main planning document of South Africa, the NDP 2030, also indicated that the alignment was not well proven.

A gap area is therefore the themes of the NDP 2030, which must be considered more often when PhD topics are chosen. This is necessary, seeing that the NDP 2030 and the Agenda 2063 are both planning documents for the future direction and development of a sustainable environment for South Africa.

The systematic mapping review and content analysis discovered research gaps for a research agenda, just as Visser (2016) asserts that after a content analyses, future research gaps could be identified. Chapter 4 (section 4.6) discovered under-researched aspects and themes. Further, Chapter 5 (section 5.9), and the comparative knowledge map, identified gaps that may be future research ideas. Kazemia *et al*. (2018) states that if gaps are identified new research to transform a discipline and PhD research, is needed. Research is not static, but a living and complex unit that can undergo adaptation as per the complexity theory.

6.7 Adaptation and Change Discussion

After Horton and Hawkins (2010) completed their content analysis, they highlighted the need for a paradigm shift to transform or to adapt the social work curriculum. The complexity theory provides for the ability of a system to adapt. Adaptation is the ability of a system to react to a response in the environment, and to adapt with a response that can lead to change of the environment. As the system adapts to the change, the system self-organises, and new patterns and outputs emerge. The new information that this study discovered, may be a regulatory mechanism in the system that can lead to adaptation followed by change.

The comparison and subsequent gap research areas (section 4.6 & 5.9) that were identified, necessitates adaptation of PhD research choices. The adaptation will lead to change, where PhD research ideas may be more aligned with government plans and goals. Not only is adaptation important, but also the beliefs that people have towards the management of the environment. The motivations of why students choose to do a PhD as mentioned by Plowright (2011); Cloete *et al*. (2015) and Wiegerova (2016) needs to be considered when any change is anticipated or expected.

6.8 Limitations of the Final Study

This section will discuss the aspects that the results could not reveal, as well as any limitations. The main limiting issues that were encountered related to the subjectivity of the research method, the capabilities of the software verification of data form NWU and the future use of the results.

This research only did an alignment, and not an appraisal of the content. The results were in no way an indication of the relevancy of all the 214 PhDs to the environmental management field. The under-researched themes and aspects and the identified research gaps in this research, also arose from the alignment process, and is not a representation for the entire field of environmental management or body of knowledge.

The focus of this study was to only indicate the alignment and significance of PhDs in environmental studies research, relative to environmental government documents. It was beyond the scope of this study to determine alignment with other non-environmental related government documents to see where the PhDs that did not align to the sampled documents would fit – such as tourism strategies for instance.

A limitation could be the replicability of the classification of the aspects in the government documents and the PhDs. The approach to sort the PhDs and content of the government documents is a subjective task that requires judgement. Another researcher may come up with a different number of themes or different themes. Leximancer software removed some of that researcher bias, however, and is recommended for any such further research to support in the identification of word frequency and theme development, although the limitations of Leximancer has to be kept in mind as indicated next.

At the commencement of the study, the Leximancer text mining software would have been the only method that would be used to analyse the data, without researcher interference. As the tool was used, it became clear that the tool would produce unrelated concepts that had to be removed, to provide a clearer picture of the data. This may make the replicability of the research difficult, as another researcher could remove more, less or different words. The words that were removed in this study were included in the datasheets, to allow for transparency in this issue. Leximancer could further not be used as a tool on its own as initially assumed, because human clarification was still needed. This manual and automated process complimented each other in the end, and themes and gaps could be discovered.

Even though the under-researched themes and aspects or gaps were highlighted, there is no assurance that universities or students will include the areas in their research agendas. It may, however, still assist students when they need to decide on a research topic for their PhDs. It will further aid the government's objectives and plans in managing the South African environment in a sustainable manner.

It would have been preferable if the PhDs, up to 2020, could have been included in this study. The time span did not allow sufficient time to see whether the aspects of Agenda 2063 were incorporated to a greater extent after 2017. The results indicated a rise in the number of PhDs as the years progressed, and it would have been valuable to see whether the trend continued and whether other themes such as climate change or renewable energy increased. This was not possible, as the release of completed PhDs on the university repositories takes time. The verification process also took a year, which made it difficult to extend the period of this study. The non-verification of the PhDs from the NWU is also seen as a limitation to the study. From these limitations, suggestions for further research could be recommended.

6.9 Recommendations

The aim of this research was to create a comparative knowledge map that suggests research gaps which could provide future research ideas that are aligned with the legislation, research reports, and state of the South African environment reports and plans. The findings and results of this study propose research topics, and therefore a research agenda for future research may be set. The analysis done in this research suggests that further research should focus on the themes of waste, coastal, mining, protected areas, sustainable, greenhouse gases and green- or low carbon economies, and renewable energy.

Over and above the research gaps that were identified in chapters 4 and 5 and by means of the comparative knowledge map, recommendations for future research, flowing from this research, can be suggested. The same process can be applied to the completed master's degrees seeing, that these studies are usually the forerunner of PhD studies. The master's studies might reveal more diverse themes and topics, and could reveal interesting trends and patterns, in terms of alignment with government

documents and university research chairs. Not only should the master's degrees be evaluated but environmental research articles and other disciplines or fields that includes environmental issues, could also be investigated.

This study provided research gaps and under-researched areas when PhDs and government documents were compared. As stated in Chapter 5, (Section 5.10) PhDs completed before the government documents were published, showed potential influence and direction on potential new government documents. A study can also be done to research policy gaps and the influence that research may have on future government documents.

This study only focussed on PhD research over a 19-year period. A study that can be considered in the future is to investigate environmental management research published in national and international journals, that pertain to environmental management and the environment of South Africa. Environmental issues are further linked and included in other disciplines and fields, such as economics, engineering, education, etc., and can also be researched as a whole. The growth of the environmental management/sciences/studies discipline – research methods, language, gender, topics and alignment with SARChI research chairs, could be researched, based on journal article research. The 'social-people of SA' theme revealed a broad research spectrum with many related aspects. For future research, breaking up this theme into smaller sub-themes would make sense to better reveal those details that are potentially now hidden by this too large a theme.

Comparisons of the findings concerning the nature of PhDs at the different universities, could be compared with those of international universities or the global perspectives on current trends, to establish possible similarities. The suggested research must, however, take cognisance that the environment itself, human impact on the environment, developmental goals and the discipline changes and are all dynamic fields and systems.

A finding that may indirectly be derived from this study is that PhD topics are related to the students' personal preference within the environmental management domain. This study did not investigate decision-making processes or preferences, however,

and a valuable study could be to determine how students and supervisors choose topics and judge the potential contribution of the PhD to the body of knowledge. Their willingness to consciously consider the use of themes and aspects from government documents in their planning for their PhD research can be investigated.

Coupled with the recommendations discussed above, further research is needed to establish the quality, significance, impact and influence of PhDs research on national developmental and strategy, in terms of environmental matters. The significance of this research will, hence, now be discussed.

6.10 Significance and Importance of Study

The alignment processes provided information on PhDs at universities, research gaps, ideas for more PhD research of significance, and efficient resource use. No such study has been done, and the systematic literature review research method for environmental management issues is encouraged by international authors.

Bilotta *et al*. (2014) emphasised the use of systematic reviews in environmental management. This PhD study used this method, and therefore joined other researchers to adhere to the call in increasing the use of systematic reviews in environmental research. When the literature review was conducted, no such study could be found that has been done in the past, specifically not in South Africa. The results of the study could be of interest to academics, past and prospective PhD students, policy makers and public servants in the environmental management fields.

This study provided an understanding of the nature and content of PhDs in environmental studies at the different universities in South Africa. It could be revealed what PhDs at universities are concentrating on. If this study was not done, the focus areas, themes or trends of PhD research in environmental studies, done in South Africa, might have remained unknown, and there could be missed opportunities to concentrate on research efforts that focus on the needs of the South African environment. This research therefore provides a strategic approach to closing identified research gaps. If more PhD research is conducted on the aspects of the government documents, it might support the achievement of environmental priorities

in South Africa. Furthermore, when novel PhD research contributes to future strategic direction in South Africa, the mutual influence of two sources of knowledge on each other is acknowledged.

Although the NDP 2030 states that more PhD research is needed in South Africa, quality and significance of PhDs must never be compromised by quantity. This research and the results may provide research ideas to increase PhDs that is of current and not-so-distant future significance. If the process of acquiring a suitable topic and title is made easier, by using this document, it may provide further motivation to a student to enrol for, and complete, a PhD. If more PhDs could be aligned to the country's developmental and national interest, greater sustainable development could be achieved in an era of increasing limited resources.

The importance of this study may be that resources and funding for research will be more directed to aspects that is important for the environment of South Africa. The comparative knowledge map further offers a holistic, visual representation, not only of possible research gaps, but also where funding or resources could be channelled to fill such gaps.

6.11 Conclusion

This research commenced with the perception that it was not known what PhD research in environmental stduies in South Africa were focussing on, and if it was aligned to the government's aim and objectives for the environment. The content analysis of the PhDs revealed that the PhDs did not consider all the aspects equally that are found in the plans and agendas of the government. A substantial number of PhDs did research in the 'biodiversity, habitat and resources' and 'social-people of SA' themes. Other aspects were under-researched, or not researched at all. From this research it can be derived that, as time passes, there is greater alignment between government documents and chosen PhD research topics, although there are still some evident gaps.

Even when the government of South Africa initiated the Kok and Pietersen (1999) survey where environmental research areas were stipulated and funding was

provided, little alignment with the PhDs could be seen when comparing topics to this source. This could have led to missed opportunities and government funding. A change in one area may influence the global system, just as the 1972 United Nations Conference on the Human Environment and the “Our Common Future” document in 1987, may have triggered global efforts and heightened international awareness amongst scholars, even from different disciplines and governments. In the same way will any other major similar event trigger new foci and niche research areas.

The aspects of the South African environmental management government documents focus on the same dominant global environmental issues. If there could be even more alignment between PhD research and the government documents, global issues may then also be addressed at a national level. A small change on national level in a complex system such as the environment, can lead to a major difference on a global scale? If not now, when?

“In a gentle way, you can shake the whole world” – Mahatma Gandhi.

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Annexure 1:

Details of each PhD, including their identifier number (that responds to the datasheet) and year when completed at each university.

University of Cape Town (UCT)

Protected Areas:

- UCT 5: Theoretical framework on the social construction of nature and that of environmental justice in a provincial nature reserve (2009)

Biodiversity, habitat and resources:

- UCT 2: How climate change may impact on soil loss and soil erosion. (2005)
- UCT 20: Insights into the paleo-ecology of lowland fynbos, the nature of paleo-environmental change. (2013)

Coastal:

- UCT 10: Conceptual framework for understanding and addressing small-scale fisheries compliance. (2010)
- UCT 22: How structural and micro-political power dynamics constrain the possibilities for democratic small-scale fisher representation and participation in fisheries governance processes. (2015)
- UCT 23: Describe and understand the customary marine resource governance system of this community and its relationship to living customary law. (2014)

Social-People of SA:

Communities:

- UCT 10: Conceptual framework for understanding and addressing small-scale fisheries compliance. (2009)
- UCT 19: The extent, nature, and impact of flooding in informal and subsidised housing areas. (2013)
- UCT 22: How structural and micro-political power dynamics constrain the possibilities for democratic small-scale fisher representation and participation in fisheries governance processes. (2015)
- UCT 23: Describe and understand the customary marine resource governance system of this community and its relationship to living customary law. (2014)
- UCT 24: How the local municipality manages flood risk in one of their high-risk informal settlements. (2016)
- UCT 26: An evaluation of community-based Environmental initiatives - public participation in the local environment. (2006)

Food security:

- UCT 13: Seasonal forecasts amongst commercial maize farmers and food security. (2008)
- UCT 25: The potential range of climate change impacts on dryland winter wheat production. (2013)

Water security:

- UCT 4: Collective risks within a catchment for sustainable use of water. (2014)
- UCT 8: Evapotranspiration (ET) is fundamental to save and secure water. (2013)
- UCT 17: Horizontal cooperation in regional socio-ecological systems for maintaining key functions of the water resources. (2014)

Climate change and natural disaster:

- UCT 1: Exploring the wind climate of South Africa for renewable energy and climate change. (2015)
- UCT 2: Climate change may impact on soil loss and soil erosion. (2005)
- UCT 7: Improve climate model predictions and model transferability as a new approach for systematic process-based inter-comparison of Regional Climate Models (RCM)s. (2010)

Climate resilience:

- UCT 15: Implications of climate change for Rooibos production and distribution. (2015)
- UCT 18: The interrelationship between “water, climate change and small towns. (2007)
- UCT 25: The potential range of climate change impacts on dryland winter wheat production. (2013)

Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy

Energy:

- UCT 1: Exploring the wind climate of South Africa for renewable energy and climate change. (2015)

Soil/Agriculture:

New agricultural technologies:

- UCT 13: Seasonal forecasts amongst commercial maize farmers and food security. (2008)

No category:

- UCT 3: A cultural approach to reading Durban's urbanity.
- UCT 6: Improve the understanding of the environments and climate dynamics using evidence from palaeosols.

- UCT 9: Improve chronology and Palaeoenvironments and carbon dating of sediment in river.
- UCT 11: The response of an atmospheric general circulation model (OCM) to a reduction in Antarctic sea-ice extent and rainfall in South Africa.
- UCT 12: Spatial analysis learning programme.
- UCT 14: Qualitative forecasts of extreme precipitation using a computationally inexpensive methodology.
- UCT 16: The developmental use of urban land should be ethical, fair and promote social justice. Land development, restitution, and distribution.
- UCT 21: The product and process of shaping urban space that serves as the locus for the symbolic framing of culture.

University of Fort Hare (FH)

Water (1); Soil/Agriculture (1); Biodiversity, habitat, resources (1):

- FH 1: attitudes and perceptions towards considerations and incorporation of environmental issues into military activities and heavy metal pollutants in water and soil. (2016)

University of the Free State (UFS)

Biodiversity, habitat and resources:

Habitat loss:

- UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management. (2016)
- UFS 5: The link between arthropod diversity in a new crop and bordering natural environment landscape. (2015)

Biodiversity:

- UFS 2: Human predator conflict management (HPCM) strategy black-backed jackal and caracal conflict. (2013)
- UFS 3: Extensive transformation and loss of biodiversity in a grassland biome. (2006)

Water:

- UFS 4: prototype environmental water assessment methodology. (2011)
- UFS 6: Water quality monitoring and its application. (2005)
- UFS 7: A study on periphyton as indicator of water-quality. (2015)
- UFS 8: To assess the quantity, quality, use and rehabilitation of water resources at catchment and national level. (2002)

Climate change and natural disaster:

Climate change:

- UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management. (2016)

Natural disaster:

- UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management. (2016)

University of Kwa-Zulu Natal (UKZN)

Protected areas:

Protected areas (SEMA):

- UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites. (2005)
- UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. (2015)
- UKZN 6: The proliferation of Private Game Parks in South Africa and related issues of privatised concentration of natural resources. (2010)
- UKZN 24: Social systems analysis in management effectiveness research on protected areas. (2007)
- UKZN 34: Protected area outreach programmes: A critical evaluation of the Kruger National Park. (1998)

Protect and sustain natural environments (NDP):

- UKZN 18: Perceptions of the conservancy (community-based conservation areas) concept. (2013)

Biodiversity, habitat and resources:

Habitat loss:

- UKZN 2: Non-limiting solutes and the processes of solute retention in a wetland system. (2008)
- UKZN 19: Forest structural attributes and soil nitrogen under forest canopy can be estimated using foliar chemical proxies. (2012)
- UZN 20: Rethink previous views that human impacts are solely responsible for wetland gully erosion and the provision of a rationale for including physical processes and climate change as factors. (2011)
- UKZN 22: Remote sensing techniques to accurately detect and map T. Peregrinus damage, an assessment that is critically needed to monitor plantation health. (2016)

Biodiversity conservation:

- UKZN 1: Remote sensing applications involving C3 and C4 grass species or communities. (2013)
- UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites. (2005)
- UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. (2015)
- UKZN 16: Elevated CO_2 caused early sprouting, early flowering and delayed senescence of the C4-dominated grassland community. (2004)
- UKZN 21: Managing change in a conservation agency organization. (2005)
- UKZN 25: The consequences of change in freshwater inflow for juvenile fish which utilise estuaries as nurseries. (1998)
- UKZN 32: Ecological aspects of vegetation at landfills. (2015)
- UKZN 33: Benefit sharing in social-ecological systems - relationship between the resource, resource users and regulatory instruments. (2015)

Physical resources (SOER 1999):

- UKZN 29: Soil erosion associated with impacts of main tar roads. (2014)

Resources (Agenda 2063):

- UKZN 3: Resilience and social-ecological systems in natural resource-based development. (2015)
- UKZN 11: Rangeland degradation monitoring system for sustainable rangeland management. (2011)
- UKZN 26: Communal rangeland management: A rotational resting system for communal cattle grazing. (2011)
- UKZN 30: Rangelands grassland management treatments practised. (2016)

Coastal:

- UKZN 12: Sea level rise and coastal erosion recommendations for adaptation measures. (2012)

Social-People of SA:

Communities:

- UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites. (2005)
- UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. (2015)
- UKZN 6: The proliferation of Private Game Parks in South Africa and related issues of privatised concentration of natural resources. (2010)
- UKZN 9: The role of an agency in the empowerment process for rural women crafters. (2010)

- UKZN 10: Critical systemic engagements with rural development and nature conservation organizations. (2004)
- UKZN 17: Factors impacting the implementation of renewable energy in marginalised communities. (2016)
- UKZN 18: Perceptions of the conservancy (community-based conservation areas) concept. (2013)
- UKZN 28: Learners learn through interaction with their environment and that knowledge construction is based on previous life experience (HIV/AIDS, tuberculosis, malaria and cancer). (2004)
- UKZN 34: Protected area outreach programmes: A critical evaluation of the Kruger National Park. (1998)
- UKZN 35: Land restitution and conservation: Social capital in a community. (2013)

Water:

- UKZN 2: Non-limiting solutes and the processes of solute retention in a wetland system. (2008)
- UKZN 15: Triple bottom line accounting for the chemical manufacturing sector: External costs due to wastewater discharge. (2015)

Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy:

- UKZN 7: Reliable information on forest stand volume, above-ground biomass (AGB) and carbon stocks. (2015)
- UKZN 16: Elevated CO2 caused early sprouting, early flowering and delayed senescence of the C4-dominated grassland community. (2004)
- UKZN 31: The role that the AQMP could play in support of creating a low carbon resilient city through its influence on greenhouse gas (GHG) emissions. (2011)

Energy:

- UKZN 17: Factors impacting the implementation of renewable energy in marginalised communities. (2016)

Climate change and natural disaster:

Climate change:

- UKZN 20: Rethink previous views that human impacts are solely responsible for wetland gully erosion and the provision of a rationale for including physical processes and climate change as factors. (2011)
- UKZN 31: The role that the AQMP could play in support of creating a low carbon resilient city through its influence on greenhouse gas (GHG) emissions. (2011)

Sea level rise:

- UKZN 12: Sea level rise and coastal erosion recommendations for adaptation measures. (2012)

Air quality:

- UKZN 27: Methodology for the delineation of the boundaries of air quality management areas. (2010)
- UKZN 31: The role that the AQMP could play in support of creating a low carbon resilient city through its influence on greenhouse gas (GHG) emissions. (2011)

No category:

- UKZN 8: The relationship between neoliberalism and the negotiation of competing urban development imperatives in public private partnerships.
- UKZN 13: Improved corporate social and environmental reporting.
- UKZN 14: Development of census output areas.
- UKZN 23: Perceptions and impacts of violence and crime in residential areas.

North West University (NWU)

Protected areas:

- NWU 3: Effectiveness, quality and implementation of Environmental Management Frameworks (EMF). (2015)
- NWU 29: The role of geohydrology in the determination of a spatial development framework of a world heritage site. (2009)

Biodiversity, habitat and resources:

Habitat loss:

- NWU 2: Effect of maize on plants and insects. (2017)
- NWU 8: Time lags in the response of temperate natural grasslands to urbanization and the factors driving these changes. (2015)
- NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. (2010)
- NWU 32: Determine the levels of twelve POP in fresh water, sediment and waste streams, freshwater fish, as well as birds' eggs nesting in aquatic environments. (2017)

Biodiversity:

- NWU 1: Biological control of leafminers on plants by fungi or parasites. (2013)
- NWU 2: Effect of maize on plants and insects. (2017)
- NWU 6: Contribution that different domestic gardens and specie richness make

to the overall diversity of an urban or rural settlement. (2017)

- NWU 9: Ecological factors (ants) influencing the survival of the Brenton blue butterfly. (2009)
- NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. (2010)
- NWU 15: Decline in water quantity and quality determine the aquatic macroinvertebrate biodiversity. (2016)
- NWU 19: Organic pollutants in selected wild and domesticated bird eggs. (2010)
- NWU 26: The potential exposures of humans and wildlife (fish and birds) to the 16 priority Polycyclic Aromatic Hydrocarbons (PAHs). (2017)
- NWU 30: A legal framework for the conservation of biodiversity. (2007)
- NWU 33: The use of diatoms as bioindicators of water quality and the aquatic micro-organism biodiversity or loss thereof. (2006)
- NWU 39: Phospholipid fatty acid (PLFA) analysis to characterise microbial communities' discrepancies. (2016)

Physical resources (SOER 1999):

- NWU 5: Concentration of pollutants measured in soils and sediments. (2010)
- NWU 22: Evaluation of selected soil properties in semi-arid communal rangelands. (2007)

Resources (Agenda 2063):

- NWU 12: Rangeland quality assessment and management. (2015)
- NWU 22: Evaluation of selected soil properties in semi-arid communal rangelands. (2007)

Coastal:

- NWU 30: A legal framework for the conservation of biodiversity (marine harvesting, marine protection and marine pollution). ((2007)

Waste:

- NWU 23: The extent of compliance with minimum national standards in municipal waste management systems. (2015)

Social-People of SA:

Communities:

- NWU 14: Determination of the dose to members of the public from radioactive effluents (gaseous and liquid) and existing exposure situations from mines. (2016)

Food security:

- NWU 17: Plant-parasitic nematodes (PPN) causing damage to tomatoes and integrated nematode control strategies. (2013)

- NWU 25: Association and impact of nematodes on weeds and leafy vegetables with reference to Meloidogyne. (2016)

Health:

- NWU 14: Determination of the dose to members of the public from radioactive effluents (gaseous and liquid) and existing exposure situations from mines. (2016)

Water:

Clean-up technology:

- NWU 11: Improved algae (hirundinella cell) removal efficiencies and final water with good aesthetic quality. (2015)
- NWU 13: Bacterial community structures might provide a good indicator of anthropogenic disturbances in freshwater systems and may be incorporated into biomonitoring programs. (2015)
- NWU 27: Mining rehabilitation methods and clean-up technologies for soil and water. (2011)

Water quality, security and quantity:

- NWU 7: Evaluation of the applicability of diatom-based indices as bioindicators of water quality. (2008)
- NWU 11: Improved algae (hirundinella cell) removal efficiencies and final water with good aesthetic quality. (2015)
- NWU 13: Bacterial community structures might provide a good indicator of anthropogenic disturbances in freshwater systems and may be incorporated into biomonitoring programs. (2015)
- NWU 15: Decline in water quantity and quality that determine the aquatic macroinvertebrate biodiversity. (2016)
- NWU 21: Enterococcus spp. In surface water systems and their importance in water quality assessments. (2016)
- NWU 24: Estimation of trends in groundwater resources in a river catchment. (2016)
- NWU 29: The role of geohydrology in the determination of a spatial development framework. of a world heritage site. (2009)
- NWU 31: Geohydrological consequences associated with the post-mine closure flooding of dewatered dolomitic karst aquifers. (2015)
- NWU 33: The use of diatoms as bioindicators of water quality and the aquatic micro-organism biodiversity or loss thereof. (2006)
- NWU 35: Methodology for environmental decision-making based on a complex environmental water management problem. (2011)
- NWU 36: Methodology and decision-making tool to assist in the evaluation of site suitable on-site sanitation systems. A water quality study. (2006)

Contamination of water by pollutants:

- NWU 5: Concentration of pollutants measured in soils and sediments. (2010)
- NWU 26: The potential exposures of humans and wildlife (fish and birds) to the 16 priority Polycyclic Aromatic Hydrocarbons (PAHs). (2017)
- NWU 32: Determine the levels of twelve POP in fresh water, sediment and waste streams, freshwater fish, as well as birds' eggs nesting in aquatic environments. (2017)
- NWU 34: Assessment of atmospheric trace metals and water-soluble ionic species at two regional background sites. (2015)

Mining:

- NWU 14: Determination of the dose to members of the public from radioactive effluents (gaseous and liquid) and existing exposure situations from mines. (2016)
- NWU 27: Mining rehabilitation methods and clean-up technologies for soil and water. (2011)
- NWU 31: Geohydrological consequences associated with the post-mine closure flooding of dewatered dolomitic karst aquifers. (2015)

Soil/Agriculture:

Contamination of soil by pollutants:

- NWU 5: Concentration of pollutants measured in soils and sediments. (2010)
- NWU 37: Soil ecological risk assessments of selected soils where ants are potential indicators of soil pollutants. (2014)

Investment and research into new agricultural technologies:

- NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. (2010)
- NWU 17: Plant-parasitic nematodes (PPN) causing damage to tomatoes and integrated nematode control strategies. (2013)
- NWU 18: the development and status of resistance of Busseola fusca (Lepidoptera: Noctuidae) to Bt maize. (2010)
- NWU 25: Association and impact of nematodes on weeds and leafy vegetables with reference to Meloidogyne. (2016)
- NWU 37: Soil ecological risk assessments of selected soils where ants are potential indicators of soil pollutants. (2014)

Clean-up technology of soil:

- NWU 4: Rehabilitation of coal mining soil. (2007)
- NWU 27: Mining rehabilitation methods and clean-up technologies for soil and water. (2011)

Air:

- NWU 16: Determine the concentration levels of toxic metals (Cr, Ni, V, and Pb) of air particulate matter in mining areas. (2016)
- NWU 20: In-depth modelling study to assess the current state of air quality within a megacity. (2012)
- NWU 28: Impacts and control of coal-fired power station emissions. (2015)
- NWU 34: Assessment of atmospheric trace metals and water-soluble ionic species. (2015)

No category:

- NWU 38: Understanding independent Environmental Control Officers: learning from major construction projects.

University of Pretoria (UP)

Biodiversity, habitat and resources:

Biological resources:

- UP 3: Characteristics of avian species diversity response to abiotic environmental variables and land transformation. (2000)
- UP 7: Biodiversity and local livelihoods. (2006)

Habitat loss:

- UP 9: Rural poverty and land degradation. (2001)

Social-People of SA:

Communities:

- UP 7: Biodiversity and local livelihoods. (2006)
- UP 9: Rural poverty and land degradation. (2001)
- UP 10: The impact of industry on the environment and expectations of the community relating to corporate social responsibility (CSR). (2013)

Food security:

- UP 6: Impact of climate change and variability on tomato production. (2014)

Health:

- UP 8: Impact of climate on health, specifically Malaria. (2016)

Water:

- UP 5: Water management failures have resulted from a misunderstanding of social-ecological system. (2006)

Climate change and natural disaster:

Climate change:

- UP 4: Responsiveness of South African fauna to climate change events. (2006)

Climate resilience:

- UP 1: The geographical distribution of Citrus Black Spot (CBS) under current and future climates. (2006)
- UP 6: Impact of climate change and variability on tomato production. (2014)
- UP 8: Impact of climate on health, specifically Malaria. (2016)

No category:

- UP 2: Ecotourism trails to facilitate environmental education.

Rhodes University (RU)

Biodiversity, habitat and resources:

Habitat:

- RU 1: Ecosystem services in a biosphere reserve context. (2017)
- RU 10: The better use and management of landscapes and species for fuelwood, brushwood and kraal posts. (2008)

Biological resources:

- RU 3: Restoration of alien-invaded riparian systems. (2012)
- RU 7: Efficiency and effectiveness of restoring plant invaded landscapes. (2012)
- RU 9: River floodplain rehabilitation approaches. (2016)

Physical resources (SOER 1999):

- RU 10: The better use and management of landscapes and species for fuelwood, brushwood and kraal posts. (2008)

Social-People of SA:

Community:

- RU 2: Learning governance and livelihoods: transition toward adaptive co-management to be initiated under resource poor conditions. (2001)
- RU 8: Curriculum implementation process regarding natural resource management (NRM) education in a poor rural education context. (2009)
- RU 11: The role commercialisation of natural resource products plays in the efforts to reduce poverty and vulnerability. (2005)
- RU 12: municipal planned climate change adaptation and the implications for community-based adaptation. (2015)

- RU 13: Indigenous people, livelihoods, and natural resource values. (2011)
- RU 14: Enhance the quality and relevance of university education through implementation of Environmental Education and sustainability. (2009)
- RU 15: The contribution of non-timber forest products to rural livelihoods and their price determination. (2016)

Food security:

- RU 4: Changes in household food security, nutrition and food waste. (2017)
- RU 6: The impact of HIV and AIDS on household food security and food acquisition strategies. (2008)

Health:

- RU 5: Communities suspected of environmental asbestos contamination. (2010)

Climate change resilience and natural disaster:

- RU 12: municipal planned climate change adaptation and the implications for community-based adaptation. (2015)

Soil/Agriculture:

Contamination of soil by pollutants:

- RU 5: Environmental asbestos contamination in soil. (2010)

University of Stellenbosch (US)

Biodiversity, habitat and resources:

Resources:

- US 4: Military integrated environmental management. (2015)

Coastal:

- US 10: An implementation model for Integrated Coastal Management (ICMA), within the South African context. (2011)

Social-People of SA:

Community:

- US 5: Informal settlement upgrading and the effect of governmentality on women's social networks. (2013)

Health:

- US 3: The impact of climate change on human health in the Western Cape, within the context of disaster management. (2007)

Climate change resilience and natural disaster:

- US 3: The impact of climate change on human health in the Western Cape, within the context of disaster management. (2007)

No category:

- US 1: The effect of apartheid on the spatial form, administrative functions, economic disparities, and social composition.
- US 2: Land use planning around airports by employing two aircraft noise prediction models.
- US 6: Theoretical framework that describes and explains forces that drive the location and mix of airport-centric developments.
- US 7: Conserving rock art as a meta-tourism resource in post-modernism context.
- US 8: To determine the military environmental literacy (MEL) (attitude, behaviour and knowledge regarding the environment in which the military operate) of the members of the South African Army (SA Army).
- US 9: Investigated gated developments in non-metropolitan locales.
- US 11: The human impact on heritage resources.

University of the Witwatersrand (Wits)

Biodiversity, habitat and resources:

Biodiversity:

- Wits 3: Reducing climate change impacts on biodiversity. (2015)
- Wits 6: Land cover and climate change threats to savanna and grassland. (2017)

Habitat loss:

- Wits 6: Land cover and climate change threats to savanna and grassland. (2017)

Resources:

- Wits 11: The implementation of a rotational (coppice) wood resources harvesting scheme in selected rural communities. (2017)

Waste:

- Wits 9: Evaluate landfill gas generation and emission rates from landfills. (2016)

Social-People of SA:

Community:

- Wits 2: The role of social capital in promoting sustainable governance in co-managed community game reserves. (2017)
- Wits 8: Discursive power played a major role in the pollution and subsequent destruction of Steel Valley. (2012)
- Wits 11: The implementation of a rotational (coppice) wood resources harvesting scheme in selected rural communities. (2017)
- Wits 13: Domestic coal combustion: People's perceptions and indoor aerosol monitoring. (2007)

Health:

- Wits 12: The concentrations and health risks of BTEX monitored at a diesel-refuelling bay. (2015)

Water:

- Wits 14: An integrated and sustainable water resource monitoring framework. (2017)

Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy:

GHG emissions:

- Wits 1: Measurement of NO_2 over the Highveld. (2015)
- Wits 9: Evaluate landfill gas generation and emission rates from landfills. (2017)

Climate change and natural disaster:

Climate change:

- Wits 3: Reducing climate change impacts on biodiversity. (2015)
- Wits 4: Negative impacts on agricultural production due to natural disasters due to increasing climate variability and climate change. (2014)
- Wits 5: Integrating current policy efforts in drought disaster-risk reduction, climate change adaptation and sustainable development. (2011)
- Wits 6: Land cover and climate change threats to savanna and grassland. (2017)
- Wits 9: Evaluate landfill gas generation and emission rates from landfills. (2017)

Natural disaster preparedness:

- Wits 4: Negative impacts on agricultural production due to natural disasters due to increasing climate variability and climate change. (2014)
- Wits 5: Integrating current policy efforts in drought disaster-risk reduction, climate change adaptation and sustainable development. (2011)

Mining:

- Wits 10: Recording the mining industry's efforts to develop scientifically sound and replicable methods of mine waste rehabilitation. (2013)

Air:

- Wits 1: Measurement of NO_2 over the Highveld. (2015)
- Wits 7: Characterise sources and ambient air quality over major industrial and urban area. (2016)
- Wits 9: Evaluate landfill gas generation and emission rates from landfills. (2017)
- Wits 13: Domestic coal combustion: People's perceptions and indoor aerosol monitoring. (2007)

No category:

- Wits 15: Engagement of an environmental centre with the discourse of sustainable development.

University of Johannesburg (UJ)

Social-People of SA:

Community:

- UJ 1: Effect of gold mine tailings on health risks to nearby community due to respirable airborne tailing material. (2012)
- UJ 4: Perceptions of the community on the cumulative effect of coal mining on communities. (2012)
- UJ 7: Best way to achieve low carbon energy access in low-income households. (2014)
- UJ 16: Perceptions of residents on mine and the impacts of the mine and how to make it more sustainable. (2012)

Health:

- UJ 11: Factors contributing to the degradation of air quality and the consequent health, environmental and the economic effect of pollution. (2012)

Water:

- UJ 8: Hydrological responses of water quality associated with land cover changes. (2014)

Climate change and natural disaster:

Climate change:

- UJ 9: Integration of energy security, economic growth and global warming. (2009)

Natural disaster preparedness:

- UJ 4: Hazard assessment and disaster preparedness: perceptions of the community on the cumulative effect of coal mining on communities. (2012)

Mining:

- UJ 10: Collaborative sustainability model for the mining industry. (2012)
- UJ 16: Perceptions of residents on mine and the impacts of the mine and how to make it more sustainable. (2012)

Air:

- UJ 1: Effect of gold mine tailings on health risks to nearby community due to respirable airborne tailing material. (2012)
- UJ 2: Wind erosion models and wind emissions from mine tailings and ash storage facilities. (2014)
- UJ 3: Development of a new trace gas retrieval scheme for IASI measurements for air quality monitoring on a regional scale. (2010)
- UJ 11: Factors contributing to the degradation of air quality and the consequent health, environmental and the economic effect of pollution. (2012)
- UJ 12: Acidic deposition from coal fired power plants and industries and if the critical loads will exceed the carrying capacity of the natural environment. (2010)
- UJ 13: Cost-effective and accurate mobile emissions inventories. (2009)
- UJ 17: Smoke emissions from informal domestic stoves. (2015)

No category:

- UJ 5: Influences of transport infrastructure on urban development and mobility.
- UJ 6: Oil dependency: Geo-political, Geo-economic and Geo-Strategic considerations.
- UJ 14: The feasibility of using satellite data to research the sea surface temperature, structure and oceanic features.
- UJ 15: The use of supply chain management to improve the efficiency and effectiveness of GIS units.

Nelson Mandela University (NMU)

Biodiversity, habitat and resources:

Habitat:

- NMU 3: Monitoring carbon stocks in a subtropical thicket. (2012)

Biodiversity conservation:

- NMU 4: Impact of the invader plant on soil moisture flux. (2008)

- NMU 5: Quantify subtropical forest changes over time, perform species discrimination. (2015)

Physical resources (SOER 1999):

- NMU 1: Soil erosion and sediment source dynamics. (2011)
- NMU 2: Investigate land degradation, land use trends and model the spatial patterns of soil loss and predict future land use. (2010)
- NMU 4: Impact of the invader plant on soil moisture flux. (2008)
- NMU 6: Assessing soil carbon and carbon dioxide fluxes under different vegetation cover conditions. (2013)

Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy:

Greenhouse gas:

- NMU 3: Monitoring carbon stocks in a subtropical thicket. (2012)
- NMU 6: Assessing soil carbon and carbon dioxide fluxes under different vegetation cover conditions. (2013)

University of South Africa (UNISA)

Protected environment (NDP 2030):

- Unisa 22: Wetland indicators and wetland delineation. (2016)

Biodiversity, habitat and resources:

Habitat loss:

- Unisa 22: Wetland indicators and wetland delineation. (2016)

Biodiversity (SEMA):

- Unisa 7: Legalising international trade in Rhino horn and the possible effect on rhino poaching. (2016)

Biological resources:

- Unisa 4: Vervet monkey troops and co-existence. (2009)
- Unisa 7: Legalising international trade in Rhino horn and the possible effect on rhino poaching. (2016)

Waste:

Bioprocessing of organic waste:

- Unisa 11: Agricultural waste residues can be used for lignocellulolytic enzyme production and that antagonistic invasion by some fungi in co-cultures can increase production of one or more enzymes. (2016)

Social-People of SA:

Food security:

- Unisa 1: The control of mites on tomatoes. (2016)
- Unisa 10: The occurrence of mycoflora in rice plants and rice seeds and their negative impact. (2013)
- Unisa 12: Visual analytical decision support tools on arsenic content in various foods with special emphasis on rice. (2014)
- Unisa 15: Perceptions of community gardeners, residents, environmental health practitioners and Town Planners with regards to community urban agriculture and its impact on food provisioning to citizens. (2014)
- Unisa 24: Evaluate the potential of indigenous plants for commercial beverage production. (2010)

Health:

- Unisa 14: Plant species contain antimicrobial compounds that may lead to new anti-TB drugs. (2016)
- Unisa 19: Bilharzias - biomarkers of common environmental diseases. (2013)
- Unisa 23: Antimicrobial activities of selected medicinal plants against pathogenic isolates and bacteria resistance. Antibiotic resistance and E. coli. (20100
- Unisa 27: Gene markers that may explain the mechanisms of arsenic-induced dermal disorders including skin cancer. (2012)

Community:

- Unisa 3: Effective public participation process in two megaprojects. (2016)
- Unisa 21: The perceptions of local community on their participation in wildlife conservation, ecotourism and social development to develop a new model for enhanced private sector-community collaboration and communication for sustainability. (2016)

Greenhouse Gas, Low Carbon- or Green Economy and Renewable Energy:

Sustainable consumption and production:

- Unisa 2: Green procurement practices in municipalities. (2014)

Energy efficient buildings:

- Unisa 16: Energy efficiency in selected guest houses. (2015)

Climate Change and Natural Disaster:

Climate change:

- Unisa 2: Green procurement practices in municipalities. (2014)
- Unisa 6: Response of the coal mining sector to climate change adaptation. (2016)

Climate resilience – impacts on humans and the economy:

- Unisa 17: Impact of climate change and adaptation on cattle and sheep farming. (20110

- Unisa 18: Climate change and agricultural production – farmers perceptions. (2012)

Soil/Agriculture:

Investment and research into new agricultural technologies:

- Unisa 1: The control of mites on tomatoes. (2016)
- Unisa 8: Effects of high dietary levels of fibrous feeds, of supplementation with Roxazyme® G2 (RX), on growing pigs fed maize-soybean diets. (2014)
- Unisa 20: The evaluation of Leucaena Leucocephala (lam) de wit: a renewable protein supplement for low-quality forages for sheep. (2007)
- Unisa 25: Antibiotic free animal production by adding of feed supplements such as nucleotides to improve intestinal health of calves. (2015)

No category:

- Unisa 5: Applications of meteorological satellite products and the development of a new convection indicator, called the Combined Instability Index (CII).
- Unisa 9: Framework and mechanisms to help smaller accommodation establishment (SAEs) overcome the barriers to implementing sustainable tourism.
- Unisa 13: Classify the springs according to International Society of Medical Hydrology and Climatology (ISMH) standards for balneology.
- Unisa 26: To investigate the diverse uses of thermal springs as possible tourism centres.

University of Venda (UV)

Mining:

- UV 1: Remediation of acid mine drainage using magnesite and clay composite. (2015)

Biodiversity, habitat and resources:

- UV 4: Ant diversity across an elevational gradient; functional versus taxonomic perspectives. (2015)

Water:

- UV 2: Evaluation of community water quality monitoring and management practices, and conceptualization of a participatory model. (2016)
- UV 3: Assessment of the efficiency of Wastewater Treatment Facilities and the Impact of the Effluents on Surface Water and Sediment. (2016)

Annexure 2:

Details of PhDs aligned with the various strategic government documents.

Results of the SEMA analysis

Summary:

The number of PhDs done under each SEMA

SEMA	Number
Protected Areas Act: UCT 5; UKZN 4; 5; 6; 24; 34; NWU 29.	7
Biodiversity Act: UCT 20; UFS 3; UKZN 1; 4; 5; 16; 21; 33; NWU 9; 10; 30; RU 3; 7; 9; NMU 4; 5; Unisa 7.	17
Integrated Waste Management Act: Wits 9; NWU 23.	2
Integrated Coastal Management Act: NWU 30; US 10; UKZN 12.	3
Air Quality Management Act: UKZN 27; 31; NWU 16; 20; 28; 34; Wits 1; 7; 9; 13; UJ 1; 2; 3; 11; 12; 13; 17.	17

Details:

SEMA	Number
Protected areas Act • UCT 5: Theoretical framework on the social construction of nature and that of environmental justice in a provincial nature reserve • UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites. • UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. (2015) • UKZN 6: The proliferation of Private Game Parks in South Africa and related issues of privatised concentration of natural resources. (2010) • UKZN 24: Social systems analysis in management effectiveness research on protected areas. • UKZN 34: Protected area outreach programmes: A critical evaluation of the Kruger National Park. • NWU 29: The role of geohydrology in the determination of a spatial development framework of a world heritage site.	7
Biodiversity act • UCT 20: Insights into the paleo-ecology of lowland fynbos, the nature of paleo-environmental change. • UFS 3: Extensive transformation and loss of biodiversity in a grassland biome. • UKZN 1: Remote sensing applications involving C3 and C4 grass species or communities. • UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites.	17

• UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. • UKZN 16: Elevated CO_2 caused early sprouting, early flowering and delayed senescence of the C4-dominated grassland community. • UKZN 21: Managing change in a conservation agency organization. • UKZN 33: Benefit sharing in social-ecological systems - relationship between the resource, resource users and regulatory instruments. • NWU 9: Ecological factors (ants) influencing the survival of the Brenton blue butterfly. • NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. • NWU 30: A legal framework for the conservation of biodiversity. • RU 3: Restoration of alien-invaded riparian systems. • RU 7: Efficiency and effectiveness of restoring plant invaded landscapes. • RU 9: River floodplain rehabilitation approaches. • NMU 4: Impact of the invader plant on soil moisture flux. • NMU 5: Quantify subtropical forest changes over time, perform species discrimination. • Unisa 7: Legalising international trade in Rhino horn and the possible effect on rhino poaching	
Waste • Wits 9: Evaluate landfill gas generation and emission rates from landfills. • NWU 23: The extent of compliance with minimum national standards in municipal waste management systems.	2
Coastal • NWU 30: A legal framework for the conservation of biodiversity (marine harvesting, marine protection and marine pollution). • US 10: An implementation model for Integrated Coastal Management (ICMA), within the South African context. • UKZN 12: Sea level rise and coastal erosion recommendations for adaptation measures.	3
Air • UKZN 27: Methodology for the delineation of the boundaries of air quality management areas. • UKZN 31: The role that the AQMP could play in support of creating a low carbon resilient city through its influence on greenhouse gas (GHG) emissions. • NWU 16: Determine the concentration levels of toxic metals (Cr, Ni, V, and Pb) of air particulate matter in mining areas. • NWU 20: In-depth modelling study to assess the current state of air quality within a megacity. • NWU 28: Impacts and control of coal-fired power station emissions. • NWU 34: Assessment of atmospheric trace metals and water-soluble ionic species. • Wits 1: Measurement of NO2 over the Highveld.	17

• Wits 7: Characterise sources and ambient air quality over major industrial and urban area. • Wits 9: Evaluate landfill gas generation and emission rates from landfills. • Wits 13: Domestic coal combustion: People's perceptions and indoor aerosol monitoring. • UJ 1: Effect of gold mine tailings on health risks to nearby community due to respirable airborne tailing material. • UJ 2: Wind erosion models and wind emissions from mine tailings and ash storage facilities. • UJ 3: Development of a new trace gas retrieval scheme for IASI measurements for air quality monitoring on a regional scale. • UJ 11: Factors contributing to the degradation of air quality and the consequent health, environmental and the economic effect of pollution. • UJ 12: Acidic deposition from coal fired power plants and industries and if the critical loads will exceed the carrying capacity of the natural environment. • UJ 13: Cost-effective and accurate mobile emissions inventories. • UJ 17: Smoke emissions from informal domestic stoves.	

Results for the Kok and Pietersen (1999) survey report

Summary:

The number of PhDs done as per the Kok and Pietersen survey report (1999) (Author's own, 2020).

Rank	Topic description	Number
1	Development of environmentally appropriate technologies to promote a thriving mariculture industry. UCT 10; 22; 23.	3
2	Development of bioprocessing of organic waste to yield useful chemical and enzymatic products. Unisa 11.	1
3	Widespread use of indigenous pharmacopoeia, food and fibre sources. Unisa 24.	1
4	Development of strategies and technologies to reduce the social impacts of drought.	0
5	Widespread use of water-efficient and drought-resistant plants including indigenous resources.	0
6	Widespread use of biotechnology solutions for the clean-up of contaminated land and water. Land: NWU 4; 27. Water: NWU 11; 13; 27.	Land 2 Water 3
7	Widespread use of sustainable packaging technologies.	0
8	Significant use of design centres to support industry with regard to waste minimisation and clean technologies.	0
9	Development of environmental entrepreneurship training and support systems.	0
10	Development of capacity within industries to use one another's waste products as source materials within the industrial ecology paradigm.	0

Details:

Rank	Topic description	Number
1	Development of environmentally appropriate technologies to promote a thriving mariculture industry. • UCT 10: Conceptual framework for understanding and addressing small-scale fisheries compliance. • UCT 22: How structural and micro-political power dynamics constrain the possibilities for democratic small-scale fisher representation and participation in fisheries governance processes. • UCT 23: Describe and understand the customary marine resource governance system of this community and its relationship to living customary law.	3
2	Development of bioprocessing of organic waste to yield useful chemical and enzymatic products. • Unisa 11: Agricultural waste residues can be used for lignocellulolytic enzyme production and that antagonistic invasion by some fungi in co-cultures can increase production of one or more enzymes.	1
3	Widespread use of indigenous pharmacopoeia, food and fibre sources. • Unisa 24: Evaluate the potential of indigenous plants for commercial beverage production.	1
4	Development of strategies and technologies to reduce the social impacts of drought.	0
5	Widespread use of water-efficient and drought-resistant plants including indigenous resources.	0
6	Widespread use of biotechnology solutions for the clean-up of contaminated land and water. Land • NWU 4: Rehabilitation of coal mining soil. • NWU 27: Mining rehabilitation methods and clean-up technologies for soil and water. Water • NWU 11: Improved algae (hirundinella cell) removal efficiencies and final water with good aesthetic quality. • NWU 13: Bacterial community structures might provide a good indicator of anthropogenic disturbances in freshwater systems and may be incorporated into biomonitoring programs. • NWU 27: Mining rehabilitation methods and clean-up technologies for soil and water.	Land 2 Water 3
7	Widespread use of sustainable packaging technologies.	0
8	Significant use of design centres to support industry with regard to waste minimisation and clean technologies.	0
9	Development of environmental entrepreneurship training and support systems.	0
10	Development of capacity within industries to use one another's waste products as source materials within the industrial ecology paradigm.	0

Results of the three (3) State of the Environment Reports (SOERSs)

Results for the SOER 1999

Summary:

SOER 1999 and the related PhDs (Author's own, 2020).

The National State of the Environment Report (SOER) 1999	
Themes	**Number**
Habitats (loss of habitat due to human activities) UFS 1; 5; UKZN 2; 19; 20; 22; NWU 2; 8; 10; 32; UP 9; Unisa 22; RU 1; 10; Wits 6; NMU 3.	16
Biological resources (species that are threatened and exploited) UCT 20; UFS 2; 3; UKZN 1; 4; 5;16; 21; 25; 32; 33; NWU 1; 2; 6; 9; 10; 15; 19; 26; 30; 33; 39; UP 3; 7; Wits 3; 6; Unisa 4; 7; RU 3; 7; 9; NMU 4; 5; UV 4.	34
Physical resources as per the SOER – water, wood biomass and soil degradation UCT 2; UKZN 29; NWU 5; 22; NMU 1; 2, 4, 6; RU 10; Wits 11.	10
Chemical processes (waste, greenhouse gases, contamination of water and soil by pollutants) Greenhouse gases UKZN 7; 16; 31; Wits 1; 9; NMU 3; 6.	7
Chemical processes (waste, greenhouse gases, contamination of water and soil by pollutants) Contamination of water FH 1; NWU 5; 26; 32; 34.	5
Chemical processes (waste, greenhouse gases, contamination of water and soil by pollutants) Contamination of soil FH 1; NWU 5; 37; RU 5.	4
Social-people of SA (demographics, poverty, food security, unemployment, education and health) Community: (38) UCT 10; 19; 22; 23; 24; 26; UKZN 4; 5; 6; 9; 10; 17; 18; 28; 34; 35; NWU 14; UP 7; 9; 10; RU 2; 8; 11; 12; 13; 14; 15; US 5; Wits 2; 8; 11; 13; UJ 1; 4; 7; 16; Unisa 3; 21. Food security (11) UCT 13; 25; NWU 17; 25; UP 6; RU 4; 6; Unisa 1; 10; 12; 15, Health (10) NWU 14; UP 8; RU 5; US 3; Wits 12; UJ 11; Unisa 14; 19; 23; 27	59

Details:

The National State of the Environment Report (SOER) 1999 **Themes**	
	Number
Habitats (loss of habitat due to human activities) • UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management.	16

• UFS 5: The link between arthropod diversity in a new crop and bordering natural environment landscape. • UKZN 2: Non-limiting solutes and the processes of solute retention in a wetland system. • UKZN 19: Forest structural attributes and soil nitrogen under forest canopy can be estimated using foliar chemical proxies. • UKZN 20: Rethink previous views that human impacts are solely responsible for wetland gully erosion and the provision of a rationale for including physical processes and climate change as factors. • UKZN 22: Remote sensing techniques to accurately detect and map T. Peregrinus damage, an assessment that is critically needed to monitor plantation health. • NWU 2: Effect of maize on plants and insects. • NWU 8: Time lags in the response of temperate natural grasslands to urbanization and the factors driving these changes. • NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. • NWU 32: Determine the levels of twelve POP in fresh water, sediment and waste streams, freshwater fish, as well as birds' eggs nesting in aquatic environments. • UP 9: Rural poverty and land degradation. (2001). • Unisa 22: Wetland indicators and wetland delineation. • RU 1: Ecosystem services in a biosphere reserve context. • RU 10: The better use and management of landscapes and species for fuelwood, brushwood and kraal posts. • Wits 6: Land cover and climate change threats to savanna and grassland. • NMU 3: Monitoring carbon stocks in a subtropical thicket.	
Biological resources (species that are threatened and exploited) • UCT 20: Insights into the paleo-ecology of lowland fynbos, the nature of paleo-environmental change. • UFS 2: Human predator conflict management (HPCM) strategy black-backed jackal and caracal conflict. • UFS 3: Extensive transformation and loss of biodiversity in a grassland biome. • UKZN 1: Remote sensing applications involving C3 and C4 grass species or communities. • UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites. (2005) • UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. • UKZN 16: Elevated CO_2 caused early sprouting, early flowering and delayed senescence of the C4-dominated grassland community. • UKZN 21: Managing change in a conservation agency organization. (2005) • UKZN 25: The consequences of change in freshwater inflow for juvenile fish which utilise estuaries as nurseries. • UKZN 32: Ecological aspects of vegetation at landfills.	34

• UKZN 33: Benefit sharing in social-ecological systems - relationship between the resource, resource users and regulatory instruments. (2015) • NWU 1: Biological control of leafminers on plants by fungi or parasites. • NWU 2: Effect of maize on plants and insects. • NWU 6: Contribution that different domestic gardens and specie richness make to the overall diversity of an urban or rural settlement. • NWU 9: Ecological factors (ants) influencing the survival of the Brenton blue butterfly. • NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. • NWU 15: Decline in water quantity and quality determine the aquatic macroinvertebrate biodiversity. • NWU 19: Organic pollutants in selected wild and domesticated bird eggs. • NWU 26: The potential exposures of humans and wildlife (fish and birds) to the 16 priority Polycyclic Aromatic Hydrocarbons (PAHs). • NWU 30: A legal framework for the conservation of biodiversity. • NWU 33: The use of diatoms as bioindicators of water quality and the aquatic micro-organism biodiversity or loss thereof. • NWU 39: Phospholipid fatty acid (PLFA) analysis to characterise microbial communities' discrepancies. • UP 3: Characteristics of avian species diversity response to abiotic environmental variables and land transformation. • UP 7: Biodiversity and local livelihoods. • Wits 3: Reducing climate change impacts on biodiversity. • Wits 6: Land cover and climate change threats to savanna and grassland. • Unisa 4: Vervet monkey troops and co-existence. • Unisa 7: Legalising international trade in Rhino horn and the possible effect on rhino poaching. • RU 3: Restoration of alien-invaded riparian systems. • RU 7: Efficiency and effectiveness of restoring plant invaded landscapes. • RU 9: River floodplain rehabilitation approaches. • NMU 4: Impact of the invader plant on soil moisture flux. • NMU 5: Quantify subtropical forest changes over time, perform species discrimination. • UV 4: Ant diversity across an elevational gradient; functional versus taxonomic perspectives.	
Physical resources as per the SOER - wood biomass and soil degradation • UCT 2: How climate change may impact on soil loss and soil erosion. • UKZN 29: Soil erosion associated with impacts of main tar roads. • NWU 5: Concentration of pollutants measured in soils and sediments. • NWU 22: Evaluation of selected soil properties in semi-arid communal rangelands. (2007) • NMU 1: Soil erosion and sediment source dynamics. • NMU 2: Investigate land degradation, land use trends and model the spatial patterns of soil loss and predict future land use.	10

• NMU 4: Impact of the invader plant on soil moisture flux. • NMU 6: Assessing soil carbon and carbon dioxide fluxes under different vegetation cover conditions. • RU 10: The better use and management of landscapes and species for fuelwood, brushwood and kraal posts. • Wits 11: The implementation of a rotational (coppice) wood resources harvesting scheme in selected rural communities.	
Chemical processes (waste, greenhouse gases, contamination of water and soil by pollutants) Greenhouse gases • UKZN 7: Reliable information on forest stand volume, above-ground biomass (AGB) and carbon stocks. • UKZN 16: Elevated CO_2 caused early sprouting, early flowering and delayed senescence of the C4-dominated grassland community. • UKZN 31: The role that the AQMP could play in support of creating a low carbon resilient city through its influence on greenhouse gas (GHG) emissions. • Wits 1: Measurement of NO2 over the Highveld. • Wits 9: Evaluate landfill gas generation and emission rates from landfills. • NMU 3: Monitoring carbon stocks in a subtropical thicket. • NMU 6: Assessing soil carbon and carbon dioxide fluxes under different vegetation cover conditions.	7
Chemical processes (waste, greenhouse gases, contamination of water and soil by pollutants) Contamination of water • FH 1: attitudes and perceptions towards considerations and incorporation of environmental issues into military activities and heavy metal pollutants in water and soil. • NWU 5: Concentration of pollutants measured in soils and sediments. • NWU 26: The potential exposures of humans and wildlife (fish and birds) to the 16 priority Polycyclic Aromatic Hydrocarbons (PAHs). • NWU 32: Determine the levels of twelve POP in fresh water, sediment and waste streams, freshwater fish, as well as birds' eggs nesting in aquatic environments. • NWU 34: Assessment of atmospheric trace metals and water-soluble ionic species at two regional background sites.	5
Chemical processes (waste, greenhouse gases, contamination of water and soil by pollutants) Contamination of soil • FH 1: attitudes and perceptions towards considerations and incorporation of environmental issues into military activities and heavy metal pollutants in water and soil. • NWU 5: Concentration of pollutants measured in soils and sediments. • NWU 37: Soil ecological risk assessments of selected soils where ants are potential indicators of soil pollutants. • RU 5: Environmental asbestos contamination in soil.	4
Social-people of SA (demographics, poverty, food security, unemployment, education and health) Community • UCT 10: Conceptual framework for understanding and addressing small-scale fisheries compliance.	59

• UCT 19: The extent, nature and impact of flooding in informal and subsidised housing areas. • UCT 22: How structural and micro-political power dynamics constrain the possibilities for democratic small-scale fisher representation and participation in fisheries governance processes. • UCT 23: Describe and understand the customary marine resource governance system of this community and its relationship to living customary law. • UCT 24: How the local municipality manages flood risk in one of their high-risk informal settlements. • UCT 26: An evaluation of community-based Environmental initiatives - public participation in the local environment. • UKZN 4: Impacts of ecotourism in the St. Lucia and the uKhahlamba Drakensberg heritage sites. • UKZN 5: An assessment of a biodiversity stewardship practice, the open space management and the impact on local communities, ecosystems and adjacent property. • UKZN 6: The proliferation of Private Game Parks in South Africa and related issues of privatised concentration of natural resources. • UKZN 9: The role of an agency in the empowerment process for rural women crafters. • UKZN 10: Critical systemic engagements with rural development and nature conservation organizations. • UKZN 17: Factors impacting the implementation of renewable energy in marginalised communities. • UKZN 18: Perceptions of the conservancy (community-based conservation areas) concept. • UKZN 28: Learners learn through interaction with their environment and that knowledge construction is based on previous life experience (HIV/AIDS, tuberculosis, malaria and cancer). • UKZN 34: Protected area outreach programmes: A critical evaluation of the Kruger National Park. • UKZN 35: Land restitution and conservation: Social capital in a community. • NWU 14: Determination of the dose to members of the public from radioactive effluents (gaseous and liquid) and existing exposure situations from mines. • UP 7: Biodiversity and local livelihoods. • UP 9: Rural poverty and land degradation. • UP 10: The impact of industry on the environment and expectations of the community relating to corporate social responsibility (CSR). • RU 2: Learning governance and livelihoods: transition toward adaptive co-management to be initiated under resource poor conditions. • RU 8: Curriculum implementation process regarding natural resource management (NRM) education in a poor rural education context. • RU 11: The role commercialisation of natural resource products plays in the efforts to reduce poverty and vulnerability. • RU 12: municipal planned climate change adaptation and the implications for community-based adaptation.	

- RU 13: Indigenous people, livelihoods and natural resource values.
- RU 14: Enhance the quality and relevance of university education through implementation of Environmental Education and sustainability.
- RU 15: The contribution of non-timber forest products to rural livelihoods and their price determination.
- US 5: Informal settlement upgrading and the effect of governmentality on women's social networks.
- Wits 2: The role of social capital in promoting sustainable governance in co-managed community game reserves.
- Wits 8: Discursive power played a major role in the pollution and subsequent destruction of Steel Valley.
- Wits 11: The implementation of a rotational (coppice) wood resources harvesting scheme in selected rural communities.
- Wits 13: Domestic coal combustion: People's perceptions and indoor aerosol monitoring.
- UJ 1: Effect of gold mine tailings on health risks to nearby community due to respirable airborne tailing material.
- UJ 4: Perceptions of the community on the cumulative effect of coal mining on communities.
- UJ 7: Best way to achieve low carbon energy access in low-income households.
- UJ 16: Perceptions of residents on mine and the impacts of the mine and how to make it more sustainable.
- Unisa 3: Effective public participation process in two megaprojects.
- Unisa 21: The perceptions of local community on their participation in wildlife conservation, ecotourism and social development to develop a new model for enhanced private sector-community collaboration and communication for sustainability.

Food security

- UCT 13: Seasonal forecasts amongst commercial maize farmers and food security.
- UCT 25: The potential range of climate change impacts on dryland winter wheat production.
- NWU 17: Plant-parasitic nematodes (PPN) causing damage to tomatoes and integrated nematode control strategies.
- NWU 25: Association and impact of nematodes on weeds and leafy vegetables with reference to Meloidogyne. (2016)
- UP 6: Impact of climate change and variability on tomato production.
- RU 4: Changes in household food security, nutrition and food waste.
- RU 6: The impact of HIV and AIDS on household food security and food acquisition strategies.
- Unisa 1: The control of mites on tomatoes.
- Unisa 10: The occurrence of mycoflora in rice plants and rice seeds and their negative impact.
- Unisa 12: Visual analytical decision support tools on arsenic content in various foods with special emphasis on rice.
- Unisa 15: Perceptions of community gardeners, residents, environmental health practitioners and Town Planners with regards to community urban agriculture and its impact on food provisioning to citizens.

Health • NWU 14: Determination of the dose to members of the public from radioactive effluents (gaseous and liquid) and existing exposure situations from mines. • UP 8: Impact of climate on health, specifically Malaria. • US 3: The impact of climate change on human health in the Western Cape, within the context of disaster management. • RU 5: Communities suspected of environmental asbestos contamination. • Wits 12: The concentrations and health risks of BTEX monitored at a diesel-refuelling bay. • UJ 11: Factors contributing to the degradation of air quality and the consequent health, environmental and the economic effect of pollution. • Unisa 14: Plant species contain antimicrobial compounds that may lead to new anti-TB drugs. • Unisa 19: Bilharzias - biomarkers of common environmental diseases. • Unisa 23: Antimicrobial activities of selected medicinal plants against pathogenic isolates and bacteria resistance. Antibiotic resistance and E. coli. • Unisa 27: Gene markers that may explain the mechanisms of arsenic-induced dermal disorders including skin cancer.	

Results for the SAEO 2006

Summary:

SAEO 2006 and the related PhDs (Author's own, 2020).

The South Africa Environment Outlook (SAEO) 2006	
Themes	**Number**
Loss of biodiversity and aquatic systems Aquatic ecosystems: UFS 1; UKZN 2; 20; NWU 32; Unisa 22. The loss of biodiversity PhDs have been listed in row 2 of the SOER 1999 table.	5 34
Climate change (weather patterns, impacts on humans and economy): UCT 1; 2; 7; UFS 1; UKZN 20; 31; UP 4; Wits 3; 4; 5; 6; 9; UJ 9; Unisa 2; 6;	15
The greenhouse gas PhDs have been listed in row 4 of the SOER 1999 table.	7
Sea level rise and climate change had only one (1) PhD: UKZN 12.	1
Climate resilience - Impacts of climate change on humans and the economy: UCT 15; 18; 25; UP 1; 6; 8; RU 12; US 3; Unisa 17; 18.	10
Water availability and quality: UCT 4; 8; 17; UFS 4; 6; 7; 8; UKZN 2; 15; NWU 7; 11; 13; 15; 21; 24; 29 31; 33; 35; 36; UP 5; Wits 14; UJ 8; UV 2; 3.	25
Human vulnerability (AIDS pandemic, food security, access to services and poverty) The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the last row of the SOER 1999 table.	59

Details:

The South Africa Environment Outlook (SAEO) 2006 Themes	
	Number
Loss of biodiversity and aquatic systems • UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management. • UKZN 2: Non-limiting solutes and the processes of solute retention in a wetland system. • UKZN 20: Rethink previous views that human impacts are solely responsible for wetland gully erosion and the provision of a rationale for including physical processes and climate change as factors. • NWU 32: Determine the levels of twelve POP in fresh water, sediment and waste streams, freshwater fish, as well as birds' eggs nesting in aquatic environments. • Unisa 22: Wetland indicators and wetland delineation. The loss of biodiversity PhDs have been listed in the SOER 1999, biological resources.	5 34
Climate change (weather patterns, impacts on humans and economy) • UCT 1: Exploring the wind climate of South Africa for renewable energy and climate change. • UCT 2: Climate change may impact on soil loss and soil erosion. • UCT 7: Improve climate model predictions and model transferability as a new approach for systematic process-based inter-comparison of Regional Climate Models (RCM)s. • UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management. • UKZN 20: Rethink previous views that human impacts are solely responsible for wetland gully erosion and the provision of a rationale for including physical processes and climate change as factors. • UKZN 31: The role that the AQMP could play in support of creating a low carbon resilient city through its influence on greenhouse gas (GHG) emissions. • UP 4: Responsiveness of South African fauna to climate change events. • Wits 3: Reducing climate change impacts on biodiversity. • Wits 4: Negative impacts on agricultural production due to natural disasters due to increasing climate variability and climate change. • Wits 5: Integrating current policy efforts in drought disaster-risk reduction, climate change adaptation and sustainable development. • Wits 6: Land cover and climate change threats to savanna and grassland. • Wits 9: Evaluate landfill gas generation and emission rates from landfills. • UJ 9: Integration of energy security, economic growth and global warming. • Unisa 2: Green procurement practices in municipalities. • Unisa 6: Response of the coal mining sector to climate change adaptation.	15
The greenhouse gas PhDs have been listed above in the SOER 1999 table.	7
Sea level rise and climate change had only one (1) PhD • UKZN 12: Sea level rise and coastal erosion recommendations for adaptation measures.	1
Climate resilience - Impacts of climate change on humans and the economy	10

• UCT 15: Implications of climate change for Rooibos production and distribution. • UCT 18: The interrelationship between “water, climate change and small towns. • UCT 25: The potential range of climate change impacts on dryland winter wheat production. • UP 1: The geographical distribution of Citrus Black Spot (CBS) under current and future climates. • UP 6: Impact of climate change and variability on tomato production. • UP 8: Impact of climate on health, specifically Malaria. • RU 12: municipal planned climate change adaptation and the implications for community-based adaptation. • US 3: The impact of climate change on human health in the Western Cape, within the context of disaster management. • Unisa 17: Impact of climate change and adaptation on cattle and sheep farming. • Unisa 18: Climate change and agricultural production – farmers perceptions.	
Water availability and quality • UCT 4: Collective risks within a catchment for sustainable use of water. • UCT 8: Evapotranspiration (ET) is fundamental to save and secure water. • UCT 17: Horizontal cooperation in regional socio-ecological systems for maintaining key functions of the water resources. • UFS 4: prototype environmental water assessment methodology • UFS 6: Water quality monitoring and its application • UFS 7: A study on periphyton as indicator of water-quality • UFS 8: To assess the quantity, quality, use and rehabilitation of water resources at catchment and national level. • UKZN 2: Non-limiting solutes and the processes of solute retention in a wetland system. • UKZN 15: Triple bottom line accounting for the chemical manufacturing sector: External costs due to wastewater discharge. • NWU 7: Evaluation of the applicability of diatom-based indices as bioindicators of water quality. • NWU 11: Improved algae (hirundinella cell) removal efficiencies and final water with good aesthetic quality. • NWU 13: Bacterial community structures might provide a good indicator of anthropogenic disturbances in freshwater systems and may be incorporated into biomonitoring programs. • NWU 15: Decline in water quantity and quality that determine the aquatic macroinvertebrate biodiversity. • NWU 21: Enterococcus spp. In surface water systems and their importance in water quality assessments. • NWU 24: Estimation of trends in groundwater resources in a river catchment. • NWU 29: The role of geohydrology in the determination of a spatial development framework. of a world heritage site. • NWU 31: Geohydrological consequences associated with the post-mine closure flooding of dewatered dolomitic karst aquifers.	25

• NWU 33: The use of diatoms as bioindicators of water quality and the aquatic micro-organism biodiversity or loss thereof. • NWU 35: Methodology for environmental decision-making based on a complex environmental water management problem. • NWU 36: Methodology and decision-making tool to assist in the evaluation of site suitable on-site sanitation systems. A water quality study. • UP 5: Water management failures have resulted from a misunderstanding of social-ecological system. • Wits 14: An integrated and sustainable water resource monitoring framework. • UJ 8: Hydrological responses of water quality associated with land cover changes. • UV 2: Evaluation of community water quality monitoring and management practices, and conceptualization of a participatory model. • UV 3: Assessment of the efficiency of Wastewater Treatment Facilities and the Impact of the Effluents on Surface Water and Sediment.	
Human vulnerability (AIDS pandemic, food security, access to services and poverty) • The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the last section of the SOER 1999 table.	59

Results for the SAEO 2012

Summary:

SAEO 2012 and the related PhDs (Author's own, 2020).

The Second South Africa Environment Outlook (SAEO) 2012	
Themes	**Number**
Land degradation (loss of habitat due to human activities) Habitats (loss of habitat due to human activities). The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the first row of the SOER 1999 table.	16
Non-renewable resources - minerals	0
Greenhouse gas emissions (coal fired power stations and higher traffic volumes). The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the fourth row of the SOER 1999 table.	7
Water (availability and quality). The list of PhDs is the same as in the SAEO 2006 and will therefore not be repeated. See the second last row of the SAEO 2006 table.	25
Sustainable mining: NWU 14; 27; 31; Wits 10; UJ 10; 16; UV 1.	7

Details:

The Second South Africa Environment Outlook (SAEO) 2012 Themes	
	Number
Land degradation (loss of habitat due to human activities) Habitats (loss of habitat due to human activities) • The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the first row of the SOER 1999 Table.	16

Non-renewable resources - minerals	0
Greenhouse gas emissions (coal fired power stations and higher traffic volumes) • The greenhouse gas PhDs have been listed above in the SOER 1999.	7
Water (availability and quality) • The list of PhDs is the same as in the SAEO 2006 and will therefore not be repeated. See the second last row of the SAEO 2006 table.	25
Sustainable mining • NWU 14: Determination of the dose to members of the public from radioactive effluents (gaseous and liquid) and existing exposure situations from mines. • NWU 27: Mining rehabilitation methods and clean-up technologies for soil and water. • NWU 31: Geohydrological consequences associated with the post-mine closure flooding of dewatered dolomitic karst aquifers. • Wits 10: Recording the mining industry's efforts to develop scientifically sound and replicable methods of mine waste rehabilitation. • UJ 10: Collaborative sustainability model for the mining industry. • UJ 16: Perceptions of residents on mine and the impacts of the mine and how to make it more sustainable. • UV 1: Remediation of acid mine drainage using magnesite and clay composite.	7

Results for the NDP 2030

Summary:

Number of PhDs completed under main themes of the NDP 2030 (Author's own, 2020).

Main themes extracted from the National Development Plan – 2030	Number
1. Protect and sustain the natural environment and ecosystems. A set of indicators for natural resources to inform policy. A regulatory framework for conservation and restoration of protected areas. A target for the amount of land and oceans that needs to be under protection: (NWU 3; UKZN 18; Unisa 22.	3
2. Enhance resilience of people and the economy towards climate change. Disaster preparedness for extreme climate events: UFS 1; US 3; Wits 4; 5; UJ 4. Establishment of Climate change centre.	5 0
3. Extract minerals in a sustainable manner. The list of PhDs is the same as in the SAEO 2012 and will therefore not be repeated. See the last row of the SAEO 2012 table.	7
4. Reduce greenhouse gas emissions. Greenhouse gas emissions The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the fourth row of the SOER 1999 table. Carbon pricing mechanisms Zero emission buildings.	7 0 0
5. Improve energy efficiency.	

Energy efficient buildings that meet building standards of the South African National Standard 204: Unisa 16. More use and stimulation of renewable energy: UCT 1; UKZN 17.	1 2
6. Reduction of waste to landfill.	0
7. Investment and research into new agricultural technologies and adaptation strategies. UCT 13; NWU 10; 17; 18; 25; 37; Unisa 1; 8; 20; 25.	10

Details:

Main themes extracted from the National Development Plan – 2030	Number
1. Protect and sustain the natural environment and ecosystems. A set of indicators for natural resources to inform policy. A regulatory framework conservation and restoration of protected areas. A target for the amount of land and oceans that needs to be under protection. • NWU 3: Effectiveness, quality and implementation of Environmental Management Frameworks (EMF). • UKZN 18: Perceptions of the conservancy (community-based conservation areas) concept. (2013) • Unisa 22: Wetland indicators and wetland delineation.	3
2. Enhance resilience of people and the economy towards climate change. Disaster preparedness for extreme climate events. • UFS 1: The integration of disaster risk reduction and climate change adaptation strategies into wetlands management. • Wits 4: Negative impacts on agricultural production due to natural disasters due to increasing climate variability and climate change. • Wits 5: Integrating current policy efforts in drought disaster-risk reduction, climate change adaptation and sustainable development. • UJ 4: Hazard assessment and disaster preparedness: perceptions of the community on the cumulative effect of coal mining on communities. • US 3: The impact of climate change on human health in the Western Cape, within the context of disaster management. (2007) Establishment of Climate change centre.	5 0
3. Extract minerals in a sustainable manner. • The list of PhDs is the same as in the SAEO 2012 and will therefore not be repeated. See the last row of the SAEO 2012 table.	7
4. Reduce greenhouse gas emissions. Greenhouse gas emissions • The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See the fourth row of the SOER 1999 table. Carbon pricing mechanisms Zero emission buildings.	7 0 0
5. Improve energy efficiency.	

Energy efficient buildings that meet building standards of the South African National Standard 204. • Unisa 16: Energy efficiency in selected guest houses. More use and stimulation of renewable energy. • UCT 1: Exploring the wind climate of South Africa for renewable energy and climate change. • UKZN 17: Factors impacting the implementation of renewable energy in marginalised communities.	1 2
6. Reduction of waste to landfill.	0
7. Investment and research into new agricultural technologies and adaptation strategies. • UCT 13: Seasonal forecasts amongst commercial maize farmers and food security. • NWU 10: Determine through feeding experiments, the effects of Genetically modified Bt maize on selected non-target Lepidoptera, Coleoptera and Diptera species that occur in maize agro-ecosystems. • NWU 17: Plant-parasitic nematodes (PPN) causing damage to tomatoes and integrated nematode control strategies. • NWU 18: the development and status of resistance of Busseola fusca (Lepidoptera: Noctuidae) to Bt maize • NWU 25: Association and impact of nematodes on weeds and leafy vegetables with reference to Meloidogyne. • NWU 37: Soil ecological risk assessments of selected soils where ants are potential indicators of soil pollutants. • Unisa 1: The control of mites on tomatoes. • Unisa 8: Effects of high dietary levels of fibrous feeds, of supplementation with Roxazyme® G2 (RX), on growing pigs fed maize-soybean diets. • Unisa 20: The evaluation of Leucaena Leucocephala (lam) de wit: a renewable protein supplement for low-quality forages for sheep. • Unisa 25: Antibiotic free animal production by adding of feed supplements such as nucleotides to improve intestinal health of calves.	10

Result for the Agenda 2063

Summary:

Number of PhDs per priority area of the Agenda 2063 (Author's own, 2020).

Aspiration 1: A prosperous Africa based on inclusive growth and sustainable development.	
Goal1/7: Environmentally sustainable and climate resilient economies and communities.	
Priority areas	**Number**
Sustainable natural resource management: FH 1: UKZN 3; 11; 26; 30; NWU 12; 22; US 4.	8
Biodiversity conservation, genetic resources and ecosystems. The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See row 2 of the SOER 1999 table.	34
Coastal The list of PhDs is the same as the Integrated Coastal management Act (ICMA).	3

Climate resilience. The list of PhDs is the same as in the SAEO 2006 and will therefore not be repeated. See row 5 of the SAEO 2006 table.	10
Natural disasters preparedness. The list of PhDs is the same as in the NDP 2030 and will therefore not be repeated. See row 2 of the NDP 2030 table.	5
Water security. The list of PhDs is the same as in the SAEO 2006 and will therefore not be repeated. See the second last row of the SAEO 2006 table.	25
Sustainable consumption and production pattern: Unisa 2.	1
Promote renewable energy. The list of PhDs is the same as in the NDP 2030 and will therefore not be repeated. See row 5 of the NDP 2030 table.	2

Details:

Aspiration 1 A prosperous Africa based on inclusive growth and sustainable development.	
Goal1/7 Environmentally sustainable and climate resilient economies and communities.	
Priority areas	**Number**
Sustainable natural resource management • FH 1: Attitudes and perceptions towards considerations and incorporation of environmental issues into military activities and heavy metal pollutants in water and soil. • UKZN 3: Resilience and social-ecological systems in natural resource-based development. • UKZN 11: Rangeland degradation monitoring system for sustainable rangeland management. • UKZN 26: Communal rangeland management: A rotational resting system for communal cattle grazing. • UKZN 30: Rangelands grassland management treatments practised. • NWU 12: Rangeland quality assessment and management. • NWU 22: Evaluation of selected soil properties in semi-arid communal rangelands. • US 4: Military integrated environmental management.	8
Biodiversity conservation, genetic resources and ecosystems. The list of PhDs is the same as in the SOER 1999 and will therefore not be repeated. See row 2 of the SOER 1999 table.	34
Coastal • NWU 30: A legal framework for the conservation of biodiversity (marine harvesting, marine protection and marine pollution). • US 10: An implementation model for Integrated Coastal Management (ICMA), within the South African context. • UKZN 12: Sea level rise and coastal erosion recommendations for adaptation measures.	3
Climate resilience • The list of PhDs is the same as in the SAEO 2006 and will therefore not be repeated. See row 5 of the SAEO 2006 table.	10
Natural disasters preparedness	5

• The list of PhDs is the same as in the NDP 2030 and will therefore not be repeated. See row 2 the NDP 2030 table.	
Water security • The list of PhDs is the same as in the SOER 2006 and will therefore not be repeated. See the second last row of the SOER 2006 table.	25
Sustainable consumption and production pattern • Unisa 2: Green procurement practices in municipalities.	1
Promote renewable energy. Promote renewable energy. The list of PhDs is the same as in the NDP 2030 and will therefore not be repeated. See row 5 of the NDP 2030 table.	2

No category

Summary:

PhDs that were not placed in any category (Author's own, 2020).

No category	Number
UCT 3; 6; 9; 11; 12; 14; 16; 21; UKZN 8; 13; 14; 23; NWU 38; UP 2; US 1; 2; 6; 7; 8; 9; 11; Wits 15; UJ 5; 6; 14; 15; Unisa 5; 9; 13; 26.	30

Details:

- UCT 3: A cultural approach to reading Durban's urbanity.
- UCT 6: Improve the understanding of the environments and climate dynamics using evidence from palaeosols.
- UCT 9: Improve chronology and Palaeoenvironments and carbon dating of sediment in river.
- UCT 11: The response of an atmospheric general circulation model (OCM) to a reduction in Antarctic sea-ice extent and rainfall in South Africa.
- UCT 12: Spatial analysis learning programme.
- UCT 14: Qualitative forecasts of extreme precipitation using a computationally inexpensive methodology.
- UCT 16: The developmental use of urban land should be ethical, fair and promote social justice. Land development, restitution and distribution.
- UCT 21: The product and process of shaping urban space that serves as the locus for the symbolic framing of culture.
- UKZN 8: The relationship between neoliberalism and the negotiation of competing urban development imperatives in public private partnerships.
- UKZN 13: Improved corporate social and environmental reporting.
- UKZN 14: Development of census output areas.
- UKZN 23: Perceptions and impacts of violence and crime in residential areas.
- NWU 38: Understanding independent Environmental Control Officers: learning from major construction projects.

- UP 2: Ecotourism trails to facilitate environmental education.
- US 1: The effect of apartheid on the spatial form, administrative functions, economic disparities, and social composition.
- US 2: Land use planning around airports by employing two aircraft noise prediction models.
- US 6: Theoretical framework that describes and explains forces that drive the location and mix of airport-centric developments.
- US 7: Conserving rock art as a meta-tourism resource in post-modernism context.
- US 8: To determine the military environmental literacy (MEL) (attitude, behaviour and knowledge regarding the environment in which the military operate) of the members of the South African Army (SA Army).
- US 9: Investigated gated developments in non-metropolitan locales.
- US 11: The human impact on heritage resources.
- Wits 15: Engagement of an environmental centre with the discourse of sustainable development.
- UJ 5: Influences of transport infrastructure on urban development and mobility.
- UJ 6: Oil dependency: Geo-political, Geo-economic and Geo-Strategic considerations.
- UJ 14: The feasibility of using satellite data to research the sea surface temperature, structure and oceanic features.
- UJ 15: The use of supply chain management to improve the efficiency and effectiveness of GIS units.
- Unisa 5: Applications of meteorological satellite products and the development of a new convection indicator, called the Combined Instability Index (CII).
- Unisa 9: Framework and mechanisms to help smaller accommodation establishment (SAEs) overcome the barriers to implementing sustainable tourism.
- Unisa 13: Classify the springs according to International Society of Medical Hydrology and Climatology (ISMH) standards for balneology.
- Unisa 26: To investigate the diverse uses of thermal springs as possible tourism centres.

Annexure 3:

Ethics clearance certificate

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 18/11/2019

NHREC Registration # : REC-170616-051
REC Reference # : 2017/CAES/152
Name : Mrs U Van den Berg
Student #: 58532722

Dear Mrs Van den Berg

Decision: Ethics Approval Renewal after Second Review from 01/12/2019 to 30/11/2020

Researcher(s): Mrs U Van den Berg
vdberu@unisa.ac.za

Supervisor (s): Prof M Mearns
Martie.mearns@gmail.com; 082-923-2343

Working title of research:

A comparative knowledge map of strategic research priorities in environmental management for South Africa

Qualification: PhD Environmental Management

Thank you for the submission of your progress report to the UNISA-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is renewed for a one-year period. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

Due date for progress report: 30 November 2020

*The **low risk application** was **reviewed** by the UNISA-CAES Health Research Ethics Committee on 02 November 2017 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

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2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:
The reference number ***2017/CAES/152*** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
Tel: (011) 670-9391

Prof MJ Linington
Executive Dean : CAES
E-mail: lininmj@unisa.ac.za
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Annexure 4:

Turn-it-in receipt

turnitin

Digital Receipt

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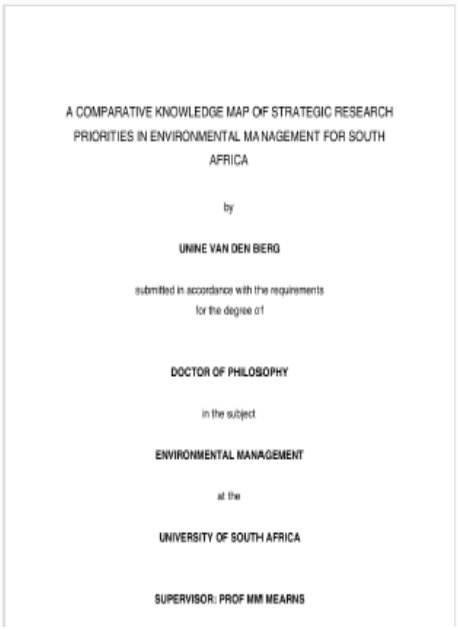


A COMPARATIVE KNOWLEDGE MAP OF STRATEGIC RESEARCH PRIORITIES IN ENVIRONMENTAL MANAGEMENT FOR SOUTH AFRICA

by

UNINE VAN DEN BERG

submitted in accordance with the requirements for the degree of

DOCTOR OF PHILOSOPHY

in the subject

ENVIRONMENTAL MANAGEMENT

at the

UNIVERSITY OF SOUTH AFRICA

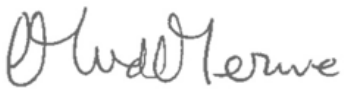
SUPERVISOR: PROF MM MEARNS

Annexure 5:

Language editing certificate

11 January 2021

I, Marlette van der Merwe, hereby certify that both the text and list of references of the doctoral thesis titled "A comparative knowledge map of strategic research priorities in environmental management for South Africa" by Unine van den Berg, have been edited by me, according to the Harvard referencing method as required by the Department of Environmental Sciences, University of South Africa.



Marlette van der Merwe

BA (English) HDipLib (UCT)