Exploring hemp farming as a sustainable agriculture in South Africa, using a social-ecological systems approach

by

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Abstract

Smallholder communities in the rural regions of South Africa are becoming increasingly vulnerable to challenges associated with climate change and socio-economic conditions. This study includes an exploration of hemp (*Cannabis Sativa. L*) agriculture in South Africa, and seeks to evaluate the sustainability of such agriculture, as well as the opportunities for agricultural and socio-economic development possible, through employing smallholder hemp agriculture in South Africa.

The concepts relating to hemp cultivation, sustainable agriculture, and smallholder farming in South Africa, were unpacked, and framed using a social-ecological systems framework. A social-ecological systems approach provides a holistic perspective for understanding the social and ecological factors responsible for driving the establishing of the hemp industry in South Africa, as well as the potential impacts.

To gain a South African perspective of hemp agriculture and the industry I conducted in-depth interviews with six participants, that were carefully selected based on their personal experience in hemp cultivation. A non-participant case study was also used in this study to explore a hemp research trial farm, where soil samples were taken to test for levels of minerals present in the soil. This was then analysed to determine the level of influence the hemp taproot has on the nutrient cycle of the soil.

Results from this study indicated that the ecological benefits of cultivating hemp included the absence of pesticide use, and moderate fertiliser requirements, as well as the aeration and microorganism regeneration characteristics associated with the hemp taproot. The agglomeration of end-uses and industries available through hemp production meets the socio-economic contexts experienced by rural communities in South Africa, due to the economic multiplier effect of

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establishing a hemp industry. Observations at the research trial farm in Riebeek-Kasteel, suggested that hemp does not naturally increase the nitrogen levels in the soil, as studies have suggested, however, methods for enhancing the nutrient flow of soils through hemp cultivation are identified. Smallholder hemp agriculture in South Africa can be viable given the correct conditions, such as climate, access to resources, and guidance. Furthermore, it is highly suggested that smallholder farmers rotate the hemp crop with a nitrogen fixing, winter food-crop, to avoid depletion of soil nutrients, and to meet social drivers such as food and nutrition insecurity.

With the changing of laws surrounding the agriculture of industrial hemp in South Africa and other countries throughout the world, industries such as bio- plastic, biofuel, hemp-based building materials, medicinal cannabis, and the nutrition industry, will begin to drive the development of such agriculture. This study emphasizes the importance of smallholder inclusion in the infant industry, to develop a powerful mechanism for social and agricultural development in the rural regions of South Africa

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Opsomming

Kleinboergemeenskappe in Suid-Afrika se landelike gebiede word toenemend trefbaar vir uitdagings wat met klimaatsverandering en sosio-ekonomiese omstandighede verband hou. Hierdie studie ondersoek die hennep- (*Cannabis Sativa. L*) landboubedryf in Suid-Afrika, en beoog om die volhoubaarheid van sodanige landbou te evalueer, asook die geleenthede vir moontlike landbou- en sosio-ekonomiese ontwikkeling, deur hennep-landbou met behulp van kleinboerdery in Suid-Afrika aan te wend.

Ons voorsien 'n uiteensetting van die konsepte wat met hennepverbouing, volhoubare landbou en kleinboerdery in Suid-Afrika verband hou, en bou die konsepte deur middel van 'n sosiaal-ekologiese stelsels-raamwerk. 'n Sosiaal-ekologiese stelsels-benadering voorsien 'n holistiese oogpunt om die sosiale en ekologiese faktore te verstaan wat vir die aandrywing en daarstelling van die hennep-industrie in Suid-Afrika verantwoordelik is, asook die moontlike gevolge daarvan. Om 'n Suid-Afrikaanse perspektief van hennep-landbou en die industrie te behaal, het ons diepgaande onderhoude met ses deelnemers gevoer, noukeurig gekies as gevolg van hul persoonlike ondervinding met hennepverbouing. 'n Nie-deelnemende gevallestudie is ook in hierdie studie gebruik om 'n proefplaas vir hennepnavorsing te ondersoek, waar grondmonsters geneem is om die teenwoordige mineraalvlakke in die grond te toets. Dit is daarna geanaliseer om die invloedsvlak van die hennep-penwortel op die grond se voedingstofsiklus te bepaal.

Resultate van hierdie studie het aangedui dat die ekologiese voordele van hennepverbouing die afwesigheid van plaagdoder en matige vereistes vir messtof ingesluit het, asook die hennep-penwortel se eienskappe wat verband hou met deurlugting en die vernuwing van mikro-organismes. Die versameling eind-gebruike en industrieë beskikbaar as gevolg van hennepvervaardiging voldoen aan die sosio-ekonomiese aandrywers wat deur landelike

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gemeenskappe in Suid-Afrika ervaar word as gevolg van die ekonomiese vermenigvuldigingseff
ek met die daarstelling van ʼn hennep-industrie. Soos studies aangedui het, dui observasies by die navorsingsproefplaas in Riebeek-Kasteel daarop dat hennep nie die stikstofvlakke in die grond natuurlik verhoog nie, tog is metodes om grond se voedingstofvloei deur hennepverbouing te verhoog, geïdentifiseer. Hennep- landbou met behulp van kleinboerdery in Suid-Afrika kan onder die regte omstandigehede lewensvatbaar wees, soos byvoorbeeld klimaat, toegang tot hulpbronne en leiding. Daarenbowe word dit hoogs aanbeveel dat kleinboere die hennepgewas met ʼn stikstof-vasstellende, winter voedselgewas roteer om te verhoed dat grondvoedingstowwe uitgeput word, en om aan sosiale aandrywers soos voedsel en voeding insekuriteit te voldoen.

As gevolg van die veranderig van wetgewing rondom industriële hennep-landbou in Suid-Afrika en ander lande in die wêreld, sal industrieë soos bioplastiek, hennep-gebaseerde boumateriaal, medisinale cannabis en die voedingsindustrie die ontwikkeling van sodangie landbou aandryf. Hierdie studie betoog dat dit belangrik is om die kleinboer in hierdie nuwe industrie by te reken, om ʼn kragtige meganisme vir sosiale en landbou-ontwikkeling in die landelike gebiede van Suid-Afrika te ontwikkel.

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List of Acronyms and Abbreviations

AMSRS: HortaPharm B.V., Amsterdam, the Netherlands

ARC: Agricultural Research Council

B: Boron

C: Carbon

C: Organic carbon

C3: Deciduous crops and evergreen trees, and woody plants

Ca: Calcium

CA: Conservation Agriculture

CaO: Calcium Oxide

CBD: Cannabidiol

CEO: Chief executive officer

Cl: Chloride

Cl: Chloride

Cmol(+)kg: Centimoles of positive charge per kilogram of soil

Cu: Copper

DESC: Departmental Ethics Screening Committee

DNHSA: Department of National Health South Africa

EEA: The European Environmental Agency

FAO: The Food and Agriculture Organization

Fe: Iron

H2PO: Triple superphosphate

HCO3: Bicarbonate

K: Potassium

KCl: Potassium chloride

LCA: Life-cycle analysis

MEA: The Millennium Ecosystem Assessment

Mg: Magnesium

Mn: Manganese

N: Nitrogen

Na: Sodium

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NH_4NO_3: Ammonium nitrate fertilizer

P: Phosphorous

PAR: Photosynthetically active radiation

PB's: Planetary Boundaries

pH: Potential hydrogen

PPM: Parts per million

REC: Research Ethics Committee

RUE: Radiation-use efficiency

SABC: The South African Broadcasting Corporation

SAHPRA: The South African Health Products Regulatory Authority

SANAS: South African National Accreditation System

SAP: The Forensic Science Laboratory, Pretoria, South Africa,

SES: Social-ecological-systems

SO_4: Sulphate

SOC: Soil organic content SOM: Soil organic matter

THC: Tetrahydrocannabinol

UNODC: The United Nations Office on Drugs and Crime

Zn: Zinc

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Chapter 1: Introduction

1.1) Introduction

The world has entered a precarious era of time coined the Anthropocene, which is characterised by human development and the environmental degradation of ecosystems and associated ecosystem services, on which we heavily depend for current lifestyles (Steffen et al., 2011). Agriculture plays an increasingly important role in current trajectories of our impact on Planetary Boundaries (PB's), which set 'safe operating spaces' for human activity within Earth's system (Steffen et al., 2011). The focus of this study, in terms of such PB's, will centre around an exploration of the capacity the hemp (*Cannabis Sativa L*.) crop has in improving soil quality, and enhancing the resilience of local ecosystem services, as well as whether hemp cultivation is a potential alternative to traditional, subsistence and smallholder agriculture in South Africa.

Agriculture contributes significantly to many of the environmental challenges we currently face, from green-house gas emissions, to water pollution, and overconsumption, and so new forms of agriculture have emerged, such as organic farming, conservation agriculture (CA), which are forms of sustainable farming (Benhin, 2006; Palm et al., 2014; Smith, Kruger, Knot, and Blignaut, 2017). These forms of agriculture recognise the interdependence of 'agri' or land, and 'culture' or cultivar, meaning the interdependence between the soils or lands, and the cultivation or production of the food we need to sustain current lifestyles (Pretty and Bharucha, 2014).

Hemp is a multi-functional, highly versatile crop currently used as a raw material for many traditional and novel industrial applications (Amaducci *et al.*, 2015). A returning interest in the crop stems from relatively low-input, simple cultivation techniques that imply an aligning with sustainable agriculture principles, and the production of sustainable end-use products (Amaducci *et al.*, 2015). The cultivation of hemp can be traced back 10 000 years ago, and is one of the

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oldest cultivated plant species known to man (Amaducci *et al.*, 2015). According to a chemotaxonomic study done by Hillig (2005), the centre of diversity and origin of *Cannabis* is confirmed to be Central Asia, and so the industrial cultivation of hemp is thought to have begun China. The cultivation of cannabis, includes the cultivation of sub-species more generally known as hemp, for fibre (textiles, building materials, for example), seed (hemp seed oil, nutritional food, for example), and flower (cannabidiol/ CBD oils, for example) (Clarke and Merlin, 2013; Duvall, 2016). Marijuana is a different sub- species of the cannabis family, and has been traditionally produced for the psychostimulant ingredient, tetrahydrocannabinol (THC) (Clarke and Merlin, 2013; Duvall, 2016; Thomas and ElSohly, 2016; Chandra, Lata and ElSohly, 2017; Small, 2017). Hemp cultivation in Africa has been practiced for centuries, but African colonial and post-colonial administrations devalued the crops and implemented cannabis controls before most locations around the world (Duvall, 2016).

As one of the oldest plant species to be cultivated, hemp merits academic attention, as some have gone as far as to coin this species a potential ‘saviour crop’ (Coogan, 2016). Many studies, particularly from the global north, have documented the various benefits of cultivating hemp, many of which are ecological, for example, authors have documented the hemp plant species’ capacity to aerate, and regenerate damaged soils. (Linger et al., 2002; Blonder, 2003; Acosta Casas and Rieradevall i Pons, 2005; Leinwand, 2005, 2005; Amaducci, Zatta, Pelatti, et al., 2008; Prade, 2011; Awwad et al., 2016).

However, lacking in the literature is how the cultivation of hemp may impact rural communities, with a focus on enhancing our understating of the main drivers and incentives for growing hemp, as well as the subsequent social benefits of hemp agriculture, particularly in rural South Africa. This study therefore aims to address this gap in knowledge by applying a social-ecological- systems (SES) approach to explore the cultivation of hemp, specifically in South Africa. There is much activity occurring in southern Africa, evident by the number of operational hemp farms and existing industries, for example, Invegrow is an operational hemp

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farm in Malawi, and a thousand hectare hemp farm has recently be initiated in KwaZulu-Natal, South Africa (Coogan, 2016; Sotana, 2013; Mokoena, Funnah and Ngobeni, 2011). Duvall (2016) refers to the United Nations Office on Drugs and Crime (UNODC) in saying that the cultivation of cannabis in Africa, although illegal in many countries, has been practiced for centuries.

Research is needed to identify more sustainable systems for agriculture, as current systems demand ecologically destructive amounts of pesticides, herbicides, and synthetic Nitrogen (N), Phosphorous (P), and Potassium (K) fertilisers (Kremen and Miles, 2012; Laurance, Sayer and Cassman, 2014; Squire et al., 2015; Smith, Kruger, Knot, and Blignaut, 2017). Hence the global movement towards hemp cultivation as a sustainable crop and industry, is in part owed to the many ecological and socio-economic benefits of growing hemp (Van Der Werf, 2004; Leinwand, 2005). The plant species offers numerous direct and indirect ecological benefits and has been used to absorb heavy metals from soils, through a process called phytoremediation (Linger et al., 2002; Angelova et al., 2004). The cultivation of hemp requires relatively low amounts of Nitrogen, Phosphorous, and Potassium (NPK) fertilizers, and the use of pesticides and herbicides is not required for cultivation (Kane, 2000; Mokoena, Funnah and Ngobeni, 2011; Piotrowski and Carus, 2011; Aubin et al., 2015).

Hemp is thought to be a pioneer plant, which are plant species thought to demonstrate the ability to colonise poor-quality soils, and so research into the capacity of the hemp plant species to reclaim ecologically unstable land, is a valuable space for research. In addition, the plant is known to be an incredibly effective weed suppressor, and some farmers have begun to plant hemp amongst their crops to eradicate other weeds (Piotrowski and Carus, 2011). Hemp would also increase biodiversity throughout the farm, as Squire et al. (2015) notes current forms of agriculture greatly reduce the biodiversity of insect and animal species, as well as levels of microorganism activity in the soil, as pesticides, herbicides, fungicides, and NPK fertilizers reduce soil quality and biodiversity.

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As a weed, hemp flourishes given the right environmental conditions, of which conditions also determine the hemp variety selected for production (Belletti, 2007; Amaducci, Zatta, Pelatti, et al., 2008; Piotrowski and Carus, 2011; Prade, 2011; Amaducci et al., 2015). It grows fast, and attracts very little pests and diseases (Van Der Werf, 2004), and could be used as a substitute for the raw material used in many plastic products, as well as being a viable substitute for traditional concrete (Awwad et al., 2016). Hemp is highly suitable for sustainable agriculture (Van Der Werf, 2004), in South Africa, given the country's highly suitable climate (Budden, 2011). Locally, hemp industries would offer agricultural employment, processing plant employment, pharmaceutical opportunities, retail sector employment, skills development, entrepreneurship opportunities, as well as subsidise national imports of hemp and flax products estimated at R120 million annually (Sontana, 2013).

1.2) Purpose of Study

The recent globalisation of *Cannabis Sativa L*. cultivation is a result of the removal of laws prohibiting its cultivation in various parts of the world, due to its medicinal benefits, and the characteristics of its cultivation, that fit into sustainable farming principles (Van Der Werf, 2004; Duvall, 2016). *Cannabis* was recently 'decriminalised' in South Africa, and although it was legalised for consumption in private paces, there are still laws restricting the use and production of cannabis (Minnaar, 2015; Business Insider South Africa, 2018). One may not sell or trade cannabis in South Africa, but it may be cultivated and used privately (Business Insider South Africa, 2018). The Constitutional Court of South Africa ruled in September 2018, that restriction or prohibition of the private use of cannabis was unconstitutional, and an infringement of section 14 of the constitution, in which every South African citizen has the right to privacy (Business Insider South Africa, 2018).

The year of 2019 will be an interesting year for South Africa, as the removal of these laws may give way to new forms of sustainable agriculture, and rural

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communities, specifically those in the Eastern Cape and Kwa-Zulu-Natal may greatly benefit from this high-value, sustainably farmed crop. The removal of these laws also gives way to new spaces for research, as there may be various social, as well as ecological consequences, which have not yet been documented.

In this study a social-ecological systems (SES) approach will be used to study hemp cultivation in South Africa. A SES framework provides a platform to help unpack the ecological and social drivers as well as impact of this industry, and this important in understanding the holistic impact of such an agricultural industry. For example, identifying the prospects of hemp cultivation for environmental restoration of agriculturally degraded land, or as an affordable nutritional food resource for fighting food insecurity in South Africa, is highly valuable for developing our body of knowledge surrounding this agriculture (Leizer et al., 2000; Van Der Werf, 2004; Piotrowski and Carus, 2011; Prade, 2011; Small, 2017).

Conservation agriculture (CA), and sustainable agriculture are approaches that have been applied to agriculture, where ecological principles have been recognised and integrated to improve and sustain productivity, increase profitability, increase employment, enhance food security, manage resource-base more effectively, and conserve agricultural ecology (Smith, H., Kruger, E., Knot, J. and Blignaut, 2017). According to Van Der Werf (2004), hemp will fit into sustainable farming systems, and is agroecologically attractive. Industrial hemp is used in production of over 25 000 products and offers various agroecological benefits and socio-economic opportunities (Young, 2005). Using the SES lens will be highly valuable, as developing a perspective of hemp agriculture, which includes the social and ecological benefits, is a means of developing our body of knowledge of sustainable agriculture in South Africa. This study will identify the viability of smallholder industrial hemp agriculture in South Africa, and this will reflect the social-ecological benefits identified.

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This study will also aim to evaluate the ecological, social and economic suitability of hemp cultivation in the South African smallholder context, paying specific attention to CA principles, because of the long-term sustainability associated with inducing such principles into one's operation. The possibilities of cultivating in areas of poor soil quality, and the cultivating requirements will be identified. This could be a developmental opportunity for many smallholder and subsistence farming communities in South Africa, and potentially those in southern Africa, to transition towards more alternate and sustainable livelihoods.

1.3) Problem statement

The world faces holistic challenges as our biodiversity is depleted, while fresh water supplies run dangerously low in some areas, pollution and overconsumption of non-renewable resources becomes a global trend, and the subsequent effects of climate change are melting the polar ice caps and rising sea levels (The Millennium Ecosystem Assessment, 2005; Folke *et al.*, 2011; Scheffran and Battaglini, 2011). With more relevance to South Africa, and the focus of this study, challenges such as social inequity, which impact rural smallholder communities, will be explored (Baiphethi and Jacobs, 2009; Pienaar and Traub, 2015a; Smith, H., Kruger, E., Knot, J. and Blignaut, 2017)..

In South Africa, socio-economic conditions and climate change are increasingly compromising the capacity of traditional smallholder and subsistence farmers in South Africa, to maintain sustainable livelihoods (Van der Laan *et al.*, 2017). In this context, rural smallholder and subsistence farming is generally characterized by low input, and low output production systems, as well as being mostly unirrigated agriculture (Van der Laan *et al.*, 2017). Smallholders residing in the 'Homelands', which are regions historically marginalized in South Africa, require more sustainable livelihoods, as they become increasingly vulnerable to social ills, such as food and nutrition insecurity, and unemployment (Van der Laan *et al.*, 2017).

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In addition, smallholder farmers in South Africa are becoming increasingly vulnerable to agroecological ills, such as soil erosion, as well as challenges associated with a lack of access to irrigation and agricultural inputs (Van der Laan *et al.*, 2017). Lastly, a lack of access to markets for trade of produce reduces the socio-economic opportunity for smallholder farmers in South Africa, as development in the past has been focused on white-owned commercial agriculture, which has historically dominated the agri-food industry in South Africa (Van der Laan *et al.*, 2017).

This study seeks to evaluate whether the hemp crop could be employed in rural smallholder communities in South Africa, as a means of meeting multiple drivers simultaneously, and as means of providing access to a growing market.

1.4) Rationale for the Study

The rationale for this study is found in the lack of research on hemp in South Africa due to prohibition of the substance tetrahydrocannabinol, found in the cousin species of hemp, marijuana or ‘dagga’ (Mokoena, Funnah and Ngobeni, 2011; Sontana, 2013; Coogan, 2016). Secondly, the world is entering a precarious era in time in which sustainable transitions are necessary for the preservation of our planet (Steffen et al., 2015).

Hemp being the diverse commodity it is, as well as offering various social opportunities and ecological benefits, cultivation of this plant may present a solution to many social-ecological problems, including biodiversity loss, ecological degradation, soil erosion, food insecurity, poverty, and absence of skills development and employment opportunities in South Africa (Mokoena, Funnah and Ngobeni, 2011; Coogan, 2016; Sontana, 2013). There are various factors justifying the need for this study. For example, the need for soil aeration and regeneration in South Africa (Thierfelder et al., 2015), the suitable conditions for hemp cultivation in South Africa (Coogan, 2016), and the

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characteristics of sustainable agriculture, largely associated with hemp agriculture (Van Der Werf, 2004).

Many authors have studied the potential of hemp as a high energy yielding feedstock for biogas and/or biofuels (Kreuger et al., 2011; Prade, 2011; Rehman et al., 2013), which presents South Africa an opportunity to improve the livelihoods of rural communities through combining hemp cultivation with biofuel production, and thus providing sustainable forms of energy for those without. If this is a possibility, then research into hemp cultivation in South Africa is invaluable. This study will clarify perceived realities of hemp farming in South Africa and add to the body of knowledge of hemp cultivation, through a more holistic and ecologically centred approach, which is lacking in associated literature. With farms already in operation in South Africa, it would be valuable to research international literature of the various ecological benefits of hemp cultivation, while engaging with a diverse pool of stakeholders to uncover South African perceptions of both ecological benefits and social opportunities.

Furthermore, a clarification of correct cultivation methods for the South African climatic context would be highly useful for those initiating collaborative farms. According to Sontana (2013) various collaborative, hemp research farms in the Eastern Cape, Western Cape, and Kwa-Zulu-Natal have been initiated but only a few are still operational. The results of these research trials have not been disclosed, and thus exploring the outcomes of such hemp research trials is valuable in building a South African perspective of hemp agriculture and the industry

1.5) Research Design, Methodology and Methods

This is a traditional thesis, consisting of six chapters, and utilizes predominantly qualitative research methods. Through an investigation of available documents, and literature reviews, concepts such as smallholder farming in South Africa, sustainable agriculture, and hemp cultivation will be unpacked. This will contribute to understanding the main drivers behind the establishment of a hemp

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industry in South Africa, however, primary data will be required to build a holistic perspective. And so, this study additionally includes an analysis of six semi-structured interviews, as well as an analysis of a case-study of a hemp research farm in Robertson, in the Western Cape.

Interviews were conducted with a diverse range of stakeholders of the hemp industry in South Africa, to encapsulate the South African perspective of hemp as a sustainable social-ecological system. The case-study was guided by an observation protocol and includes an analysis of soil sample collected from the Robertson farm to test for micro and macronutrients in the soil. The soil sample will be used to identify whether the hemp crop at the Robertson test farm is conserving and effectively cycling macronutrients in the soil.

1.6) Research Objectives

The research objectives of this study, include:

- Understanding the social benefits of smallholder hemp production, as well as the ecological benefits, through the SES lens
- Identifying the drivers behind the establishment of a hemp industry in South Africa
- Understanding the ecological benefits associated with hemp cultivation
- Unpacking the challenges associated with hemp cultivation
- Determining the primary limitations to development of smallholder hemp agriculture in South Africa

1.7) Brief Chapter overviews

Chapter 1

Chapter 1 provides a brief introduction to the purposes and aims of this study and provides background information into the reasons for the advocation of hemp cultivation in such parts of the world, including South Africa. The

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introduction also introduces the research methods used in this study, specifically the research methods associated with the interview analysis, as well as the Robertson farm case-study, and soil analysis. Lastly, Chapter 1 provides a brief indication of what is to be expected in each chapter.

Chapter 2

Chapter 2 presents a thorough literature review, which aims to explore the socio-economic and agroecological drivers behind the development of smallholder agriculture in South Africa, and how this relates to the documented benefits of hemp agricultural industries in other parts of the world. Concepts such as smallholder farming in South Africa, sustainable agriculture, and hemp cultivation are explored. The argument for developing smallholder hemp agriculture in South Africa, will be framed using a social- ecological systems approach to build a holistic perspective of the drivers, benefits, and limitations to establishing viable smallholder hemp agriculture in South Africa.

Chapter 3

Chapter 3 describes the research design and the research methods used in this study, as well as the limitations and ethical considerations. The research methods include semi-structured interviews with diverse stakeholders of the South African hemp industry, and a non-participant observation case-study of a hemp research farm located in Robertson, in the Western Cape.

Chapter 4

Chapter 4 includes an analysis of the interviews to illustrate the main drivers behind the establishment of a South African hemp industry, the ecological benefits as well as the challenges associated with hemp cultivation in South Africa. In addition, Chapter 4 also includes an analysis of the Robertson case-study, which was based on non-participant observation. Lastly, a soil analysis is presented to determine the effect of hemp cultivation on macronutrients levels in soil.

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Chapter 5

Chapter 5 hosts a discussion surrounding the research objectives initially set-out, and draws from the interview analysis, as well as the Robertson case-study and soil analysis. Using the analysis, as well as the preliminary research provided in Chapter 2, suggestions for viable smallholder hemp systems in South Africa and spaces for future research are provided. The discussion aims at providing a broad-scale, holistic perspective of hemp agriculture in South Africa using the SES lens. In addition, Chapter 5 will address the results of the case-study and soil analysis.

Chapter 6

Chapter 6 is a conclusion chapter and summarizes the main findings of the study. This chapter also highlights the spaces for future research.

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Chapter 2: Literature Review

2.1) Rural livelihoods in South Africa

Agriculture has long played a role in providing livelihoods for rural communities in South Africa, however, subsistence and smallholder farming have always been marginalized by the commerce-dominated agricultural sector (Adey, 2007). Due to the role commercial agriculture has played in the South African agri-food system, it is perceived as the predominant model for agricultural success (Adey, 2007). This perception has reduced the emphasis placed on the support of subsistence and smallholder farming, and thus lowered the capacity of agricultural service providers to support the emerging hemp-product market (Adey, 2007).

Predominant success of the commercial farming model has also played a role in driving certain farming practices across all scales, as Adey (2007) notes a lack of alternative, ecological farming practices in rural South Africa, significantly when compared to other African countries. These alternative, ecologically orientated farming practices include crop diversity of multiple varieties, as well as water and soil conservation practices, which are practices unfamiliar to subsistence and smallholder farming landscapes in South Africa (Adey, 2007). Furthermore, ecological farming practices have been seen as synonymous with subsistence farming, and for this reason, such practices have been perceived as inadequate methods for income generation (Adey, 2007).

The Apartheid era has done much to provide challenges in re-addressing the state of rural development in South Africa, due to the policies favouring the development of white owned farms (Adey, 2007). Policies such as the White paper for Agriculture in 1984, for example, further solidified the holding of arable lands by white commercial farmers (Adey, 2007). Unsurprisingly, the land left to Black rural communities, known as the ‘Homelands’, was then, and is to this day located on relatively poor arable lands (Adey, 2007).

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2.1.1) Predominant drivers for social and agricultural development of rural smallholder communities in South Africa

The Bantustans or Homelands, where smallholder communities in South Africa predominantly reside, are held under communal tenure, in which both elements of individual and collective property rights are combined (Adey, 2007). Because of such, access to land in the homelands is dependent on membership to socio-political groups, such as tribal units, and so private ownership of land is not the common mode in this context, however, the production on such land is generally left to individuals who have gained access to such land (Adey, 2007).

In principle, this should translate to a communal area for every household in the community, a plot of arable land for production, and access to property resources, more commonly recognized as grazing lands and local water sources (Adey, 2007). In terms of agriculture and subsequent economic development, Porter and Phillips-Howard (1997) note how the agri-food production system in South Africa, has been designed to support white-owned, commercial farming enterprises. Black farmers residing in the former homelands have greatly struggled to compete with agricultural production supported by an elaborate marketing board system, and publicly regulated support, in terms of credit and agricultural inputs (Porter and Phillips-Howard, 1997).

Van Averbeke and Mohamed (2006) note how the challenge of developing policy that enables smallholder progress from subsistence to commercial scale in South Africa, is generally recognized as creating the necessary conditions to motivate and enable such developmental transitions. However, Van Averbeke and Mohamed (2006) investigated the extent to which smallholders aspire to such agricultural development, and whether this path for smallholder agricultural development, is in fact positive for the such communities. Following the collapse of the Apartheid government, smallholder famers were categorized according to 'subsistence' who make up the largest group, 'commercial' the smallest group,

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and a third group, known as ‘emerging’ farmers (Van Averbeke and Mohamed, 2006).

The term ‘emerging’ is used to denote smallholder farmers in the spectrum ranging from subsistence to commercial, who ‘desire’ to progress and develop their agricultural systems towards the commercial mode of production (Van Averbeke and Mohamed, 2006). And, as mentioned before, this perception held by emerging smallholder farmers in South Africa has shaped resultant development trajectories of smallholder agriculture towards the commercial mode of production. Van Averbeke and Mohamed (2006; 137) note how the three predominant categories represent ‘evolutionary steps on a development trajectory from subsistence farmer, via emerging farmer, to commercial farmer’.

According to the discourse of various contemporary agricultural economists, a successful smallholder farmer is depicted as a ‘highly productive farmer, who actively participates in markets, and earns sufficient cash income, primarily from agriculture, to enjoy a lifestyle that is free of poverty.’ (Van Averbeke and Mohamed, 2006). If smallholders were to proceed along this development trajectory, they would increasingly engage with more commercial, and high-input systems, and produce high outputs, initially (Van Averbeke and Mohamed, 2006). However, these systems have shown to be unsustainable, and environmentally destructive, and so new means of enhancing smallholder productivity, and market inclusion should be sought (Van Averbeke and Mohamed, 2006). In addition, specific climate, natural landscape, and socio-economic contexts unique to different smallholders, should be defined and understood, as such contexts determine different strategies for agricultural development (Van Averbeke and Mohamed, 2006).

The socio-economic landscape for rural communities in South Africa includes several economic activities often engaged with by families in the community (Adey, 2007). Subsistence and smallholder farming are predominant activities, as most of the food consumed by rural communities, is in fact, produced on local

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farms (Adey, 2007). Subsistence and smallholder farming in the context of rural South Africa is often characterized by minimal government support (Statistics South Africa, 2017), and thus low input farming systems, and decreasing levels of produced output (Adey, 2007). And so, poverty and food insecurity are inextricable elements of rural communities in South Africa, as a quarter of all children in rural South Africa are still affected by malnutrition and subsequent stunting (Adey, 2007; Neves and du Toit, 2013; and Calzadilla *et al.,* 2014).

Poverty is the main driver of food insecurity in South Africa, and as unemployment affects nearly 40% of the country, it remains a very real challenge facing both urban and rural communities (Adey, 2007). The Food and Agriculture Organization (FAO) of the United Nations defines food security as; “the access by all people at all times to adequate, safe, and nutritious food for a healthy a productive life” (FAO, 2006: 1). It is importance to meet such needs of vulnerable communities, in both urban and rural regions, due to the regressive cognitive and physiological effects of malnutrition (Engle *et al.*, 2007; Aguero, Carter and Woolard, 2010; Woodhead, 2016; FAO, IFAD, UNICEF, WFP, 2018).

Due to high levels of unemployment in urban South Africa, there exists a common belief that many unemployed are moving back to rural areas, as well as those who have contracted the Human Immunodeficiency Virus (HIV) and are too sick to seek employment (Adey, 2007). High levels of South African citizens have contracted the virus (Kharsany and Karim, 2016), and through returning to family households in rural areas, are placing further pressure on households to generate increasing incomes (Adey, 2007). Small-scale agriculture is often inadequate even at the rural household level, and so other forms of generating income include woodwork, beadwork, craft work, and beer selling, however, many remain in the poverty trap, and require alternative opportunities (Adey, 2007).

Very few smallholder farmers in rural South Africa produce significant incomes through agricultural production alone, and as result, farming is often perceived

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as an occupation for the poor, and according to Adey (2007) the young subsequently have very little interest in farming. Following the collapse of Apartheid, black commercial-scale farming was an exciting enterprise that unfortunately never truly took off, due to limited natural and human resources within the Provincial and National Departments of Agriculture (Adey, 2007). Aiding the failure of black commercial-scale farming was a lack of a coherent rural development plan on both Provincial and National levels, high levels of poverty, and a very inefficient transferal system of arable land (Adey, 2007).

Today, there are approximately 1.3 million smallholder farmers in the former homelands, and 2.9 million households engaging with subsistence and smallholder farming activities (Van der Laan *et al.*, 2017). In the context of rural South Africa, smallholder and subsistence farming is generally characterized by low input, and low output production systems, as well as being mostly unirrigated agriculture (Van der Laan *et al.*, 2017). Unirrigated agriculture in South Africa is common, noticeably by the fact that only 1% of the total 13% of cultivated land is irrigated (Van der Laan *et al.*, 2017). This figure stands far below the average of 21% irrigated agriculture for countries, globally (Van der Laan *et al.*, 2017). However, this indicates a space of interest for development of more sustainable irrigated agriculture in South Africa, whether that interest lies in irrigation systems, diversifying crop varieties, enhanced crop management systems, or all the above. The primary drivers for development of South African smallholder agriculture is, firstly, the unemployment crisis facing communities in rural regions. Secondly, the negative influence of climate change is reducing the capacity of smallholder farming systems to remain agriculturally and economically viable. Lastly, the food insecurity of over 25% of the population, which is expected to grow synonymously with population, is also driving the development of smallholder agricultural production, to meet future food demand (Van der Laan *et al.*, 2017).

Globally, the increase in food production required to meet the demand of 9 billion people with the average North American diet, would require crop land to double,

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even if global agricultural production caught up to the standard North American yield (Van der Laan *et al.*, 2017). If South Africa is to meet the necessary agricultural production required, that production would have to reflect a move towards meeting social drivers across national, regional, and local contexts. Social drivers in rural South Africa include developing opportunities for individuals and communities to create sustainable livelihoods, and these should be seen similarly, as opportunities for rural and agricultural development. Given that the impact of climate change and declining soil fertility rates are circumstances affecting such rural communities the most severely (Benhin, 2006; Calzadilla *et al.*, 2014; Smith, H., Kruger, E., Knot, J. and Blignaut, 2017), strategic solutions that meet the needs of these communities must be sought.

Facing this challenge successfully will require finding innovative ways of farming diverse, higher value crops, specifically for those involved with smallholder farming, significantly because of the large communities that remain dependent on such agricultural production (Adey, 2007; Morton, 2007; Aliber and Hart, 2009; Baiphethi and Jacobs, 2009; Neves and Du Toit, 2013; Tibesigwa and Visser, 2015; Van der Laan *et al.*, 2017). This agriculture would have to then meet the various ecological and agricultural drivers that are currently limiting smallholder and subsistence farmers to produce, as well as reducing dependence on industrial inputs (fertilizer, herbicides, pesticides). To elaborate, such agriculture must be viable considering soil, climate, and agroecological contexts, as well as market opportunities, and subsistence-use, such as fibre, food, fuel, feedstock, and possibly raw medicines (Kern, 2002).

2.1.2) Ecological drivers for the development of sustainable smallholder agriculture in South Africa

Numerous studies have documented ecological drivers that may impact both smallholder and commercial agriculture in South Africa. Below I have summarised a few of these ecological drivers. These drivers are the most articulated in literature pertaining to smallholder farming in South Africa, and the ecological challenges such communities face (Van der Laan *et al.*, 2017). Such

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challenges are fresh-water depletion, salinization, eutrophication, and declining soil fertility, which will be addressed as they indicate the long-term unsustainability of current agricultural practices

2.1.2.1) Fresh water depletion

With a projected population of 82 million by 2035 in South Africa, food production must increase by 100% or more, and irrigation of agricultural land will be essential in meeting such increases in production (Van der Laan *et al.*, 2017). Irrigated agriculture in South Africa utilizes approximately 60% of the total runoff used by all sectors, which equates to just below 40% of total exploitable runoff (Van der Laan *et al.*, 2017). Despite such demand, only 1% of total land is irrigated, and yet this one percent accounts for 30% of total agricultural production by value (Van der Laan *et al.*, 2017).

With increasing demand for water, more pressure is placed on the redirection of water resources away from irrigation, and towards industrial and domestic sectors (Van der Laan *et al.*, 2017). Resultantly, it is estimated that national fresh water supply will be outweighed by national demand for water by the year 2025, which is less than a decade from the time of this study (Van der Laan *et al.*, 2017). Authors have argued solutions to this national crisis are found in the link between science, community, governance, and research (Van der Laan *et al.*, 2017). Furthermore, defining links between modern science and traditional knowledge systems in local contexts, where the challenge exists, is essential to finding solutions in such unique contexts. This could lead to the development of new agricultural industries, which allow for sustainable irrigation management.

2.1.2.2) Salinization

Salinization is commonly expressed as the concentration of dissolved salts, which are classified as non-toxic inorganic constituents at moderate levels,

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however, concentration of such salts can induce toxicity (Van der Laan *et al.*, 2017). Salinization is often caused by increased levels of leakage, and excessive rates of groundwater recharge, which increases levels of salts found in irrigated soils intended for agricultural production (Van der Laan *et al.*, 2017). High levels of salinity in soils often reduces agricultural production, due to the hindering effect such salts have on the capacity of crops to take up water, and therefore grow (Van der Laan *et al.*, 2017).

South Africa's waters constitute inorganic salts such as magnesium (Mg), calcium (Ca), sodium (Na), chloride (Cl), bicarbonate (HCO3), and sulphate (SO4), all of which have increased in concentration over the past decade, noticeably by the increases of such salts recorded in the Crocodile River catchment area (Van der Laan *et al.*, 2017). These levels of salt concentrations, found in 30% of river monitoring sites in South Africa, are deemed unacceptable by the Department of Water Affairs (DWA) (Van der Laan *et al.*, 2017). The regressive effects of salinization are effecting large areas of agricultural soils in South Africa (Van der Laan *et al.*, 2017), and where commercial farms may be more resilient through developing adaption strategies (Smith, H., Kruger, E., Knot, J. and Blignaut, 2017), smallholder and subsistence farmers remain highly vulnerable to such effects. This is a regional ecological driver of the sustainable development of both the commercial and smallholder agricultural sectors, in that both sectors must seek the development of agricultural industries that don't require pesticides, herbicides, or unsustainable irrigation schemes.

2.1.2.3) Eutrophication

Another contributing factor to the increasing risk posed to agricultural landscapes is eutrophication, which is the nutrient overload of chemical elements such as Nitrogen (N), Phosphorous (P), and Potassium (K) in water bodies, and the cause of subsequent negative effects, such as algae blooms (Van der Laan *et al.*, 2017). Algae blooms restrict the amount of sunlight that is required for aquatic fauna and flora, with regards to oxygen levels, and where

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there are deficient levels of oxygen, a hypoxic zone is reported to develop, and renders aquatic life impossible (Van der Laan *et al.*, 2017).

In South Africa, eutrophication has been a major concern, as high levels of dissolved P have been recorded in over 60% of the river catchments throughout the country (Van der Laan *et al.*, 2017). Intensive agriculture remains a primary source of concentrations of Nitrogen (P) and Phosphorous (P), where at least 20% of total Nitrogen fertilizer used in such agriculture finds its way into aquatic ecosystems (Van der Laan *et al.*, 2017). It should be noted that dryland crop production, which is often characterized as a less-intensive system of agriculture, is considered to have a minimal effect on Nitrogen (N) levels found in freshwater (Van der Laan *et al.*, 2017). Due to low levels of Nitrogen fertilizer input, and minimal irrigation, a net 'mining' of soil Nitrogen is reported to occur, and resultantly such agriculture has a very minor impact on eutrophication, especially when such dryland crop production is practiced on deep soils (Harding, 2015; Van der Laan *et al.*, 2017).

We can understand how such chemical elements end up in water bodies if we compare dryland crop production to irrigated, intensive agriculture, where large amounts of pesticides and fertilizers are used, contributing entirely to agricultural runoff (Harding, 2015; Van der Laan *et al.*, 2017). In addition, irrigated systems tend to be more 'leakier' than dryland crops, and thus aids the mobility of chemical elements (Van der Laan *et al.*, 2017). It should be noted that, this identification may not translate to developing dryland crop production systems, as an agricultural solution, although dryland crops are a space for future research, however, it does indicate a need to develop our management of irrigation systems, as well as our management of pesticide, and fertilizer use. Given that smallholder and subsistence farming systems often have little access to agricultural inputs, and are often unirrigated, these systems are thus of great interest for research and development.

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2.1.2.4) Declining soil fertility and the negative effects of land-use change

Soil fertility has been traditionally poor in soils throughout southern Africa, noticeably by the low levels of soil organic matter (SOM) present (Van der Laan *et al.*, 2017). SOM is highly beneficial for crop production (Van der Laan *et al.*, 2017), and so, lack thereof hinders crop growth, further exaggerating the burden of maintaining yields, especially for smallholder and subsistence farmers in the region. According to a study done by Du Preez, Mnkeni and Van Huyssteen (2010) more than half of South African soils contain less than 0.5% organic carbon (C), 38% contain 0.5-2% organic C, and 4% contain higher than 2% organic C.

Although there is an extensive range of soil types, and organic content varies greatly within and between such soil types, climate, vegetation, topography, and soil texture all contribute similarly to defining levels of soil organic content (Du Preez, Mnkeni and Van Huyssteen, 2010). Due to overgrazing, a significant area of rangeland has been subject to declining organic content, primarily organic C (Du Preez, Mnkeni and Van Huyssteen, 2010).

Finally, land use changes have greatly impacted SOM levels in South Africa, leading to soil crusting, and a complete reduction of organic matter in the top few centimetres of surface soil (Van der Laan *et al.*, 2017). Soil crusting effects infiltrability and nutrient supply disproportionately, with specific regards to the layers directly below (Van der Laan *et al.*, 2017). Without consistent production of biomass litter, the surface horizon (directly below topsoil) remains unfertilized, due to a lack of direct nutrient enrichment, delivered by the litter return (Van der Laan *et al.*, 2017). Indirectly, soil crusting prevents nutrient enrichment of the surface horizon through a loss of capacity to trap atmospheric dust, and thus act like a refuge for animals and birds (Van der Laan *et al.*, 2017). Furthermore, areas where natural vegetation exists as year-round perennials must be identified, as farming practices such as fallowing, leave soils bare, and stand vulnerable to raindrop impact, as well as soils after harvest (Van der Laan *et al.*, 2017).

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2.1.3) Sustainable agriculture vs. unsustainable agriculture

All crops require a diverse set of agricultural and ecological inputs to produce viable yields of quality agricultural commodities (Horrigan, Lawrence and Walker, 2002; Roger-Estrade *et al.*, 2010; Francis and Porter, 2011; Gomiero, Pimentel and Paoletti, 2011; Lichtfouse, 2013; Palm *et al.*, 2014; Squire *et al.*, 2015; Thierfelder *et al.*, 2015; Garibaldi *et al.*, 2017; Van der Laan *et al.*, 2017). These inputs are applied through crop management practices, and desired output is dependent on quality and quantity of inputs, as well as use of an appropriate management scheme, which determines how such inputs are utilised (Woods *et al.*, 2010). Traditionally, commercial agriculture has been heavily dependent on fossil-fuel based inputs, as well as unsustainable irrigation systems (Hazell and Wood, 2008; Weis, 2010; Lichtfouse, 2013; Squire *et al.*, 2015; Horrigan *et al.*, 2016).

Fossil-fuels are consumed through multiple dimensions of traditional, commercial agriculture, as well as across spatial dimensions, for example, fossil-fuels are largely consumed during the production of nitrogen fertilizers (ammonia/NH3, and natural gas/CH4), as well as on site through diesel powered cultivators (cultivation technology), and during transport to urban centres (Woods *et al.*, 2010). In addition, the effects of agricultural runoff on regional water sources, and subsequent eutrophication, are primary arguments for those in support of fundamentally changing agricultural systems, so as to create more sustainable agricultural industries (Horrigan, Lawrence and Walker, 2002; Wall and Smit, 2005; Benhin, 2006; Roger-Estrade *et al.*, 2010; Francis and Porter, 2011; Gomiero, Pimentel and Paoletti, 2011; Powlson *et*

l., 2011; Lichtfouse, 2013; Franzel, Kiptot and Lukuyu, 2014; Thierfelder *et al.*, 2015).

To create a sustainable agricultural industry, all agriculture will have to be practiced according to sustainable systems (Rigby and Cáceres, 2001). Sustainable systems have been compared to natural ecosystems, in that their

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components are primarily the result of natural selection (Ewel, 1999). As a system, natural ecosystems tend to be highly productive, conservative of resources, and resistant to pests (Ewel, 1999).

With regards to agriculture, creating sustainable systems may depend on the agriculture of specific crops, and specific crop management that reflects the local culture and natural biome (communities of indigenous species local to natural landscapes) (Ewel, 1999). It must also then subsequently meet local social and ecological drivers, such as food insecurity and depletion of soil fertility (Ewel, 1999).

Although smallholder and subsistence yields are becoming increasingly vulnerable to the effects of climate change and declining soil fertility, these systems are pre-adapted to low-input agriculture (Adey, 2007). In terms of sustainable agriculture, increasing agricultural output, and developing market access are the remaining challenges for those operating such systems, which have been the predominant barriers limiting the development of smallholder farmers in South Africa (Van Averbeke and Mohamed, 2006; Baiphethi and Jacobs, 2009; Pienaar and Traub, 2015a).

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2.2) Agricultural Systems as Social-Ecological Systems

2.2.1) Introduction:

Ostrom (2009) identifies social-ecological systems as the systems in which humanly used resources are embedded. These systems are highly complex systems composed of multiple subsystems and internal variables within such subsystems (Ostrom, 2009). Ostrom (2009) uses the analogy of the human body, which are organisms composed of organs, organs of tissues, tissues of cells, cells of proteins, and so on. For a complex SES, such as a resource system (e.g., a farm) which consists of resource units (e.g., agricultural production), users (e.g., farmers), and a governance system (organizes resources and laws that shape agricultural contexts), such system elements are distinct, and individual, and play different function roles (Ostrom, 2009). At the SES level, it is the interaction between such elements that determines the outcomes, as this lens aims to identify and define the complexity involved in the holistic functioning of our resource systems (Ostrom, 2009).

In relation to smallholder farming, The Millennium Ecosystem Assessment (MEA, 2005) notes how rural communities in low-income countries remain directly dependent on locally productive ecosystems, which provide sources of basic nutrition. In the case of rural South Africa, many communities similarly remain directly dependent of local soil ecosystems, which provide agroecological services to smallholder production (Van Averbeke and Mohamed, 2006).

2.2.2) Social-ecological systems thinking

The concept of social-ecological thinking is increasingly useful in evaluating the relationships shared between social drivers and the ecological functioning of resource systems (Ostrom, 2009). Significantly, because of the effects of poor resource management, changing climates, declining biodiversity, and the declining capacity of ecosystems to provide ecosystem services (Elmqvist *et al.*, 2003; Folke *et al.*, 2004; Oliver *et al.*, 2015). All of which are heavily depended

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on by humanity in coproducing social-ecological services, which provide food, fibre, medicine, and fuel, as well as regulatory services, such as air, and water regulation (Meacham *et al.,* 2016). If we use the SES lens in analysis of agricultural industries, we can note how firstly, a diversity of agricultural industries has had to develop to provide food products and raw material used for industrial purposes, and how secondly; these systems are ecologically unbalanced and unsustainable, hence the necessary transitions now needed to regain such balance (Meacham *et al.,* 2016). The SES lens leads to these conclusions by identifying the need for sustainable management of our social-ecological systems, and resource pools, significantly due to the heavy dependence we place on such systems (Meacham *et al.,* 2016).

In South Africa, high-input systems are perceived as the model for success in the agricultural industry, and so smallholders attempt to develop their farming systems towards these intensified models, instead of seeking alternative means (Pienaar and Traub, 2015a). This perception may be hindering the development of organic farming methods in South Africa, by promoting the use of high input farming methods (Adey, 2007). These systems are providing additional input costs, decreasing yield quality and quantity over time, and promoting agricultures such as maize, wheat, cotton, and tobacco (Kremen and Miles, 2012; Dillon and Dambro, 2017). These agricultural industries are, firstly; associated with competitive markets (Dillon and Dambro, 2017), and are secondly; monoculture-based agricultures, where we should be developing diverse agricultural production systems, according to authors such as Kremen and Miles (2012). Developing diverse production systems induces far better yields, and is increasingly more ecologically sound, in contrast to monoculture production (Kremen and Miles, 2012). In addition, these agricultures require the use of energy- intensive and ecologically destructive, off-farm inputs, such as pesticides, fertilizers, and possibly agricultural machinery (Kremen and Miles, 2012).

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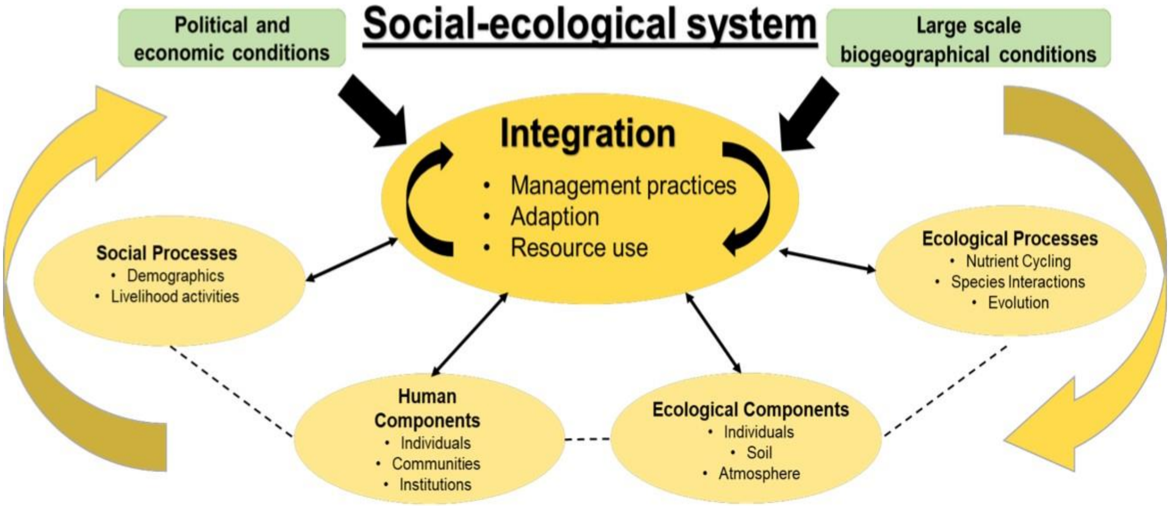

Figure 1: A theoretic conceptualisation of the social-ecological system including social and ecological components (Delport, 2019).

Figure one depicts how successful management of an SES could be induced. However, in terms of smallholder agriculture, overexploitation of soil ecosystems is clear from literature pertaining to industrial agriculture (Horrigan, Lawrence and Walker, 2002; Weis, 2010; Ulrich Hoffmann, 2011) and these systems should not be promoted in regions of South Africa, where agricultural development is targeted. In addition, declining yield production levels translate to higher commodity prices, which are felt most severely by low-income, rural communities, indicating large-scale feedback loops induced through mismanagement of such SES's (Delport, 2019). Ungoverned and under supported SES's exist in abundance throughout the rural agricultural landscape of South Africa, including millions of smallholder communities, who rely on traditional agricultural systems, and the soil ecosystems that support their production (Delport, 2019). Poor farming practices and a lack of capacity to adapt to changing climates are both social-ecological components of a vulnerable smallholder farm, producing negative system outcomes, such as soil erosion at the ecological level, and diminishing livelihood prosperity at the social level (Delport, 2019).

The SES lens contributes through identifying the most sustainable scenario, where agricultural systems for rural smallholders are diverse, rotated crop

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systems, which cultivate successions of indigenous species, and which are farmed according to sustainable, context-based farming methods (Altieri, Funes-Monzote and Petersen, 2012; Pienaar and Traub, 2015a). This is a result of creating a perspective that includes both social and ecological impacts, and through this perspective, one can begin to identify the most sustainable scenario. Therefore, these systems would develop towards becoming low-input, high-output systems, which provide a diversity of food and raw materials for both subsistence purposes, and for smallholder trade.

Some of the greatest drivers for rural development in South Africa is food and nutrition insecurity, including the case of rural communities in the KwaZulu-Natal region who face severe challenges, as children under five are currently experiencing high levels of both stunting, and obesity (Govender *et al.*, 2017). Approximately 2.6 million households in South Africa rely directly on subsistence and smallholder agricultural production, and there are approximately four million smallholder farmers, who operate on 13% of the agricultural land in South Africa, which is thought by authors, such as Pienaar and Traub (2015), to be a valuable space for social, economic, and agricultural development.

2.2.3) Diversifying agricultural production and connecting with traditional knowledge systems

Kremen and Miles (2012) note how diversifying agricultural production increases the integrity of ecosystem services such as soil quality maintenance, pollination, pest control, and nitrogen fixation, as well as carbon-sequestration, surface soil water holding capacity, control of weeds and diseases, climate change resilience, energy efficiency, and crop productivity. Farming systems that offer these benefits should be identified and promoted as strategies towards more sustainable and productive smallholder agricultural systems. Traditional knowledge systems local to a region, include knowledge surrounding the indigenous successions of plant species and their various characteristics, and so here lies the connection between ecosystem science, and traditional knowledge systems (Folke, 2004). In terms of national development, Fine (2014)

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recognizes the development of rural economies as an effective mechanism for reversing urbanization, increasing employment, and driving economic growth through diverse agricultural production.

Developing strategies that address social challenges, such as preserving natural and cultural landscapes, should be guided by an objective of diversifying rural agricultural economies, according to demands of local markets, as well as national and international markets (Naveh, 1998). These are possible strategies for overcoming current social injustices affecting over eight million people in rural South Africa, who have little support from government for adaption strategies (Statistics South Africa, 2017), but possibly hold the capacity to become self-sufficient through agricultural support.

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2.3) Exploring Hemp (Cannabis Sativa L.) Agriculture in South Africa through the SES Lens

2.3.1) Introduction

Hemp is an appraised crop, grown for production of industrial fibre, seed, or cannabinoids (Lu and Clarke, 1995; Ranalli and Venturi, 2004; de Bruijn *et al.*, 2009; Kuddus, Ginawi and Al-Hazimi, 2013; Sausserde and Adamovics, 2013; Johnson, 2014; Spalding, 2014; Schluttenhofer and Yuan, 2017).The family of *Cannabis* originated in central Asia, where two dominant genetical varieties developed in regions localised to India and the Himalayas (Van der Werf, Mathussen and Haverkort 1996). The two dominant strains are commonly known as *Sativa,* which developed in the Himalayan region, and *Indica,* which developed in regions of India (Kuddus, Ginawi and Al-Hazimi, 2013). Werf, Mathussen and Haverkort (1996) refer to Vavilov (1926) who documented the cultivation of hemp occurring throughout multiple geographic and climatic zones, from the Equator to the Polar Circle. *Cannabis* is also reported to be one of the most colonised plant species on Earth, given that it exists on almost every continent, except for Antarctica (Clarke and Merlin, 2013).

Hemp is recognised as possibly one of the oldest non-food crops used by humans, and dates back at least 6000 years (Van der Werf, Mathussen and Haverkort, 1996). Three predominant commodities produced through hemp cultivation include bast-fibre (plant-based fibres), used for paper, sails, rope, and a diverse set of other industrial uses, as well as cannabinoids being the second predominant commodity, and hemp seed being the third (Van der Werf, Mathussen and Haverkort, 1996). Cannabinoids have a psychostimulant effect on the human mind, and so it has been used for spiritual, medical, and recreational activities, while hemp seed has traditionally been produced for its nutrient-rich oils (Van der Werf, Mathussen and Haverkort, 1996). Recently, hemp seed has been recognised as a superfood, and contains a variety of nutrients rare to species of the plant kingdom, and this will be explored later in this section (Whitley, 2017).

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Hemp was a major crop in Russia, North America, and Europe from the sixteenth century to the eighteenth century, primarily for the production of bast- fibre (Van der Werf, Mathussen and Haverkort, 1996). In addition to rope, and sails, garments and fabrics were produced though hemp production, as well as using worn-out hemp fabrics as raw materials in paper mills (Van der Werf, Mathussen and Haverkort, 1996). The industrial cultivation of hemp continued for centuries, however, large-scale agriculture of cotton, tropical fibres, and jute, as well as development of new technologies, which enhanced the conversion of wood to paper pulp, sent the hemp production industry into decline by the nineteenth century (Van der Werf, Mathussen and Haverkort, 1996). In addition, the presence of psychostimulant cannabinoids became a motive for the prohibition of the plant species, and further halted cultivation of Cannabis in many countries, including South Africa (Van der Werf, Mathussen and Haverkort, 1996; Kepe, 2003).

A resurgence of hemp production occurred in North America, and Europe during the Second World War, due to firstly; a recognition of the extremely high rate at which hemp grew, and secondly; the strength of hemp fibre, and the diversity of industrial end-uses (Fine, 2014). However, hemp cultivation had mainly become localised to China, Eastern Europe, and Russia during the nineteenth and twentieth century, and where production of hemp remains a predominant industrial activity (Van der Werf, Mathussen and Haverkort, 1996).

Today, slow increases in hemp seed and bast-fibre production are shown in Figure 2 below, provided by Johnson (2014).

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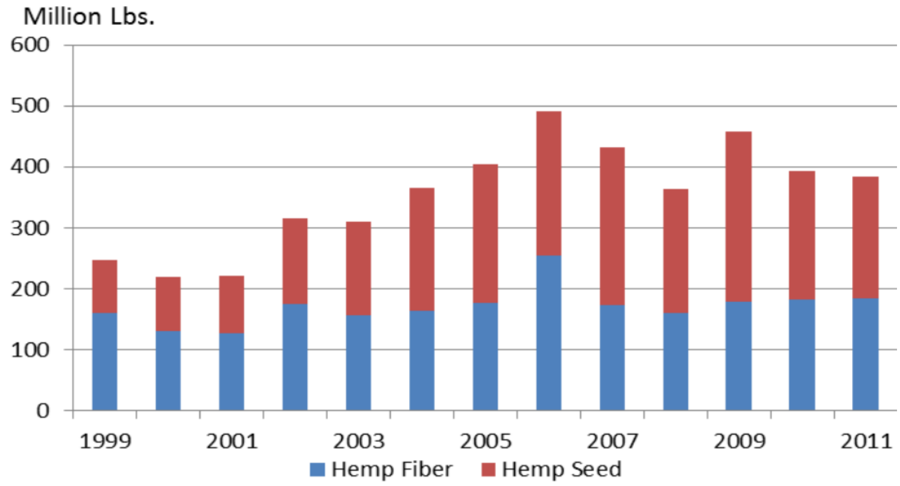

Figure 2: Global growth of hemp seed and fibre production from 1999 to 2011 (Johnson, 2014)

The above figure shows global growth of hemp fibre and seed production, however, this growth has not been consistent, as periods of stability and decline between 2005-2009, as well as 2009-2011 are clear (Johnson, 2014). To define the source of these variations in production growth is a complex task, as many countries, specifically European countries, removed their prohibition of the plant species, which was followed by government subsidization of hemp production (Johnson, 2014). This led to an initial increase in production, which was then coupled by a growing hemp industry in Canada during the end of the twentieth century (Johnson, 2014). The complexity in defining the exact source of this particular trajectory for production growth is found in the political barriers that remain in many countries, and which hinder legal production of hemp (*Cannabis)* (Johnson, 2014).

As a result of such political barriers, global production of hemp is difficult to quantify, and Figure 1 only includes legal production, occurring in regions where prohibitions do not exist. To further define the complexity of such global production growth, a growing awareness of the unsustainable agriculture of commercially cultivated species, such as intensive cotton (*Gossypium L.),* have spurred new interest in crops such as hemp, due to the reported agroecological benefits (Van der Werf, Mathussen and Haverkort, 1996). Today, 27 states in

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the United States, including Hawaii, are conducting pilot trials to evaluate the economic and agronomic viability of what Doug Fine (2015), author of: "Hemp Bound; *Dispatches from the front lines of the next Agricultural Revolution"* notes is already a half-billion-dollar industry in Canada.

Intensive cotton has been criticized by authors of sustainability for its increasingly destructive effects on the environment, including the use of pesticides (used in cycles of up to 20 in a single season), as well as intensive use of irrigation and fertilizer (Van der Werf, Mathussen and Haverkort, 1996). Hemp has been strongly advocated as an effective substitute for cotton, as well as paper, by various authors for a diverse set of reasons (Van der Werf, Mathussen and Haverkort, 1996). These reasons will be explored in this study, as this crop is largely thought to be comparably more sustainable than various other agricultural industries (Lu and Clarke, 1995; Van der Werf, Mathussen and Haverkort, 1996; Luginbuhl, 2001; Amaducci, Zatta, Pelatti, *et al.*, 2008; Prade, 2011; Sausserde and Adamovics, 2013; Adamovičs and Zeverte-Rivza, 2015; Amaducci *et al.*, 2015; Salentijn *et al.*, 2015; Small, 2015).

Furthermore, growing hemp as an annual fibre crop reduces the need to deforest, as well as consuming less energy in conversion to pulp in comparison to wood (Van der Werf, Mathussen and Haverkort, 1996). In addition, hemp contains more lignin content than wood, meaning a wider range of opportunities for non-chlorine bleaching, and production of unbleached pulp are available (Van der Werf, Mathussen and Haverkort, 1996). In terms of sustainable agriculture, hemp is reported to require very modest levels of fertilizer and irrigation, however, one of the more prominent benefits of cultivating hemp, in comparison to most intensive crops, is the minimal amount of pesticide required (Van der Werf, Mathussen and Haverkort, 1996).

Although production of hemp was largely halted in various parts of the world, breeding work in central and eastern Europe, as well as in France and Russia continued to produce enhanced genetical hybrids (Van der Werf, Mathussen and Haverkort, 1996). Such hybrids now offer increased production and fibre

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content, as well as lower psychoactive content, further strengthening its advocacy for industrial development (Van der Werf, Mathussen and Haverkort, 1996).

Reports of higher yields and subsequent ecological benefits of hemp agriculture were documented during the 1980's, where such ecological benefits included the hemp plant's ability to weed suppress and be highly resistant to pests, and thus reduce agricultural dependence on herbicides and pesticides (Van der Werf, Mathussen and Haverkort, 1996). Studies produced during the same time, also suggested the comparable nutrient levels of hemp-seed grain, over crops such as kenaf (*Hibiscus Cannabinus L.*), sugar cane (*Saccharum L.*), or corn (*Zea mays L.*) (Van der Werf, Mathussen and Haverkort, 1996).

Given the agroecological prospects of hemp agriculture, largely documented in pre-liminary studies throughout the 1980s and 1990s, countries such as the Netherlands implemented a comprehensive four-year study, known as the Hemp Research Programme (Van der Werf, Mathussen and Haverkort, 1996). The programme firstly concluded that hemp fibre production for industrial paper mills was profitable for farmers in the Netherlands, as long as an appropriate paper factory was constructed (Van der Werf, Mathussen and Haverkort, 1996). And secondly, the study concluded that hemp production agronomically, was very attractive.

Hemp agriculture should manifestly fit into sustainable farming systems, given its documented agroecological benefits (Van der Werf, Mathussen and Haverkort, 1996; Ranalli and Venturi, 2004; Young, 2005; Amaducci, Zatta, Raffanini, *et al.*, 2008; Rehman *et al.*, 2013; Adamovičs and Zeverte-Rivza, 2015; Salentijn *et al.*, 2015; Tang *et al.*, 2017). This study aims to explore such agroecological benefits, to identify whether such agriculture is viable and sustainable in South Africa, specifically as an alternative livelihood for rural smallholder farmers. And so, cultivation characteristics of hemp agriculture will

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be identified and unpacked, to determine the level of agricultural limitations of introducing such cultivation to rural South African smallholders.

2.3.2) An appraisal of hemp crops' physiological characteristics and possibilities for South Africa

2.3.2.1) Potential complexities to explore

When crops receive their required amounts of nutrients and irrigation, and are not limited by pests, diseases, or other restraints, is an agricultural circumstance in which ideal conditions are said to exist (Van der Werf, Mathussen and Haverkort, 1996). In this circumstance, yield production of dry matter should be proportionate to total photosynthetically active radiation (PAR), captured by the crop canopy (Van der Werf, Mathussen and Haverkort, 1996). Given this climatic phenomenon, areas receiving high amounts of photosynthetically active radiation (visible light between 400-700 nm wavelength) (Ren *et al.*, 2018) are areas of interest, however, crop management and environmental parameters need to be assessed (Van der Werf, Mathussen and Haverkort, 1996). For example, temperature, daylength, and radiation as environmental parameters unique to different agricultural contexts, influence crop management decisions, such as practiced cultivar, sowing and harvesting dates, and plant-per-meter densities (Van der Werf, Mathussen and Haverkort, 1996).

As mentioned previously, date of seed sowing is linked to local environmental contexts, which include unique parameters, and is significantly important in maximizing crop production (Van der Werf, Mathussen and Haverkort, 1996). Although this study aims at exploring agricultural contexts in rural South Africa, it may be useful to examine other cases of hemp production, such as production in the Netherlands. The hemp crop was compared to sugar beet, a highly arable crop under the same climatic conditions of the Netherlands, and this has been included to evaluate the crop performance of hemp (Van der Werf, Mathussen and Haverkort, 1996).

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In this region, temperatures are highest in the months of July and August, however, incoming radiation is greatest during the months of May, June, and July, and so, sowing hemp seed as early as May and June, often leads to poor yield and quality (Van der Werf, Mathussen and Haverkort, 1996). This occurs as early expansion of the canopy is often slow in sub-optimal temperatures, and so sowing of hemp seed must be done in the warmer parts of the year (Van der Werf, Mathussen and Haverkort, 1996). Hemp may be more productive in contexts of warmer climates, significantly if levels of incoming radiation are high year-round.

Base temperatures for leaf appearance is 1 degree Celsius (°C), while canopy establishment rests at 2.5 °C, and for this reason, hemp is similar to a major food-crop produced in North-west Europe- sugar beet (*Beta vulgaris*) (Van der Werf, Mathussen and Haverkort, 1996). The parameters here are useful for possibly understanding when sowing dates would be best given different climatic conditions, as the temperatures provided above stand as base temperatures, indicating optimal growth where incoming radiation is high. In addition, these parameters suggest a strong resistance of hemp to cold weather.

Hemp and sugar beet are similarly spring-sown dicotyledons (Van der Werf, Mathussen and Haverkort, 1996), and here it is important to elaborate slightly on the biological nature of *Cannabis Sativa L.,* which is a predominantly dioecious plant (Small, 2015). Dioecious plants exist naturally as individual female and male plants, which are distinct and inextricably dependent on each other for successful reproduction (Small, 2015, 2017; Thomas and ElSohly, 2016; Chandra *et al.*, 2017). However, hemp also occurs naturally as a monecious plant, where both female and male flowers are found on individual plants, and according to Salentijn *et al.* (2015) such sex expression could alternate yield production, and yield characteristics (seed, flower, and stalk yields). It's interesting to note, that in a pilot trial done by Tony Budden (2013), founder of Hemporium in Cape Town, monoecious hemp varieties were used during trial seasons, as it was assumed bee pollination would not limit quality,

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and quantity of yield production, as monoecious varieties self-pollinate, due to both male and female flowers belonging to individual plants.

Returning to the comparison between hemp and sugar beet, both species share the same base temperatures for leaf appearance (1°C), however, sugar beet develops leaf expansion at 3°C (Van der Werf, Mathussen and Haverkort, 1996). The growth process occurring between sowing date and 50% seedling emergence of hemp, requires a total temperature of 56 degrees over a period of approximately three weeks (°Cd), at a base temperature of 3°C (Van der Werf, Mathussen and Haverkort, 1996). In contrast, sugar beet requires a total of 90 °Cd at a base of 3°C, due to longer growth stages characteristic of sugar beet (Van der Werf, Mathussen and Haverkort, 1996). For canopy closure, hemp would require 340 °Cd at a base of 2.5°C, given an optimal density of 64 plants per square-meter (Van der Werf, Mathussen and Haverkort, 1996). Sugar beet requires a contrasting 500°Cd at a base of 3°C, given an optimal density of eight plants per square-meter, and as a result, hemp establishes itself as a closed canopy far more effectively and resiliently than one of the most arable crops in North-west Europe, given similar conditions (Van der Werf, Mathussen and Haverkort, 1996).

In relation to agricultural landscapes in rural South Africa, sugar beet has been implemented for commercial agriculture in Cradock, in the Eastern Cape, intended as a feedstock for the production of bioethanol fuel (Tomaschek *et al.*, 2012). And so, under similar conditions, hemp should produce yields exceeding that of sugar beet, significantly in rural areas of South Africa, such as those in the Eastern Cape. In addition, sugar beet in the Netherlands is sowed as soon as weather conditions allow, which is usually towards the end of March (Van der Werf, Mathussen and Haverkort, 1996). The same is true for hemp, as both sugar beet and hemp display a resilience to frost, however, sugar beet seedlings are killed around -5°C, while hemp seedlings can survive a short frost of up to -8°C and -10°C (Van der Werf, Mathussen and Haverkort, 1996). When fully established, sugar beet can survive very cold seasons of up to -10°C, while hemp can only survive up to -5°C, however, sowing date for both species remains the

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same, where hemp could be sowed even sooner than sugar beet (Van der Werf, Mathussen and Haverkort, 1996).

Allowing sowing of hemp seed early in Spring, where it can survive possible frost periods, results in a longer period of time for photosynthesis of incoming radiation, and thus maximizing crop growth in such regards (Van der Werf, Mathussen and Haverkort, 1996). In relation to agricultural conditions where hemp can be cultivated in South Africa, regions such as the Eastern Cape, KwaZulu-Natal, and the Western Cape are suggested by the Agricultural Research Council (ARC) of South Africa (ARC, 2014). The Eastern Cape region experiences frost periods between early May and late June, while the frost period in the Western Cape region is between the 20th of May and early July, however, the KwaZulu-Natal region experiences nearly no frost period (Schulze and Maharaj, 2007). In this respect, hemp could be sown relatively early in areas localised to gentle, or absent frost periods, indicating potential for productive hemp cultivation in such areas.

According to research, hemp seed could be sown as early as August, or September in regions of the Eastern Cape, and KwaZulu Natal, however, sowing in the Western Cape region may have to be slightly delayed given particular severity of frost experienced during the winter seasons. The ARC (2014) recommends seed is sowed during the months of October and November. Simulation trials done by Van der Werf, Mathussen and Haverkort (1996) showed that earlier sowing dates allowed for maximum PAR, however, harvesting date played an equally important role in quality and quantity of final yield.

2.3.2.2) Radiation-Use Efficiency

An important concept to introduce is radiation-use efficiency (RUE), which commonly refers to efficiency of dry matter produced per unit of intercepted PAR (Van der Werf, Mathussen and Haverkort, 1996). With regards to hemp, RUE levels are generally lower than most C3 plants (deciduous and evergreen trees, and woody plants) (Van der Werf, Mathussen and Haverkort, 1996). This is generally thought be associated with the loss of dry matter throughout the growing season, due to self-thinning, a natural process of crop shedding, in which large amounts of leaves, stems, and seed naturally fall from the plants (Van der Werf, Mathussen and Haverkort, 1996). This decreases the total surface area in which PAR is converted to energy, lowering hemp's natural RUE, however, lower RUE values have also been thought to be result of large growth respiration, due to synthetization of lignin in the stem (Van der Werf, Mathussen and Haverkort, 1996).

Furthermore, low RUE levels could be additionally associated with growth respiration, due to the synthetization of fats and proteins in the seed (Van der Werf, Mathussen and Haverkort, 1996). This could indicate a positive natural process, as multiple parts of the plant are developed through PAR conversion, and levels of RUE could be misleading. Regardless, areas of high solar radiation, and subsequent PAR, and which are not limited by light diffusion, are areas of interest. South Africa enjoys high levels of solar radiation throughout the country, noticeably by Figure 2 (Solar GIS, 2012).

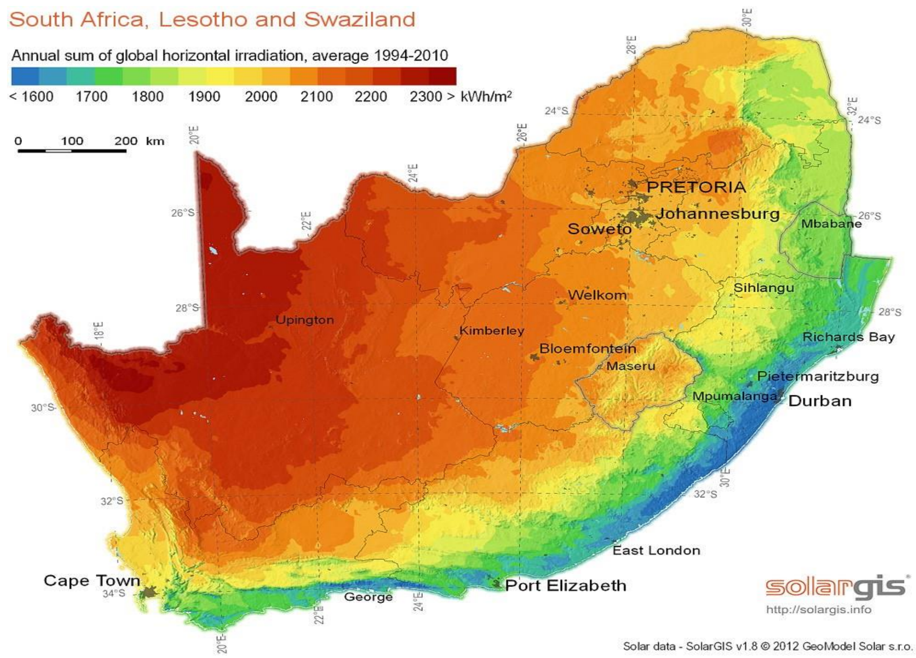

Figure 3: Solar radiation in South Africa, Lesotho, and Swaziland (Solar GIS, 2012)

According to Tsubo and Walker (2005) PAR levels and solar radiation are thought be proportionate, unless there is diffusion of visible light. In addition,

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South Africa receives an average of 2500 hours of sunshine, which translates to average SR levels of between 4.5 and 6.5 watt-hours per square-meter, making the country the third highest receiver of solar radiation in the world (Tsubo and Walker, 2005). Radiation levels in most parts of the country therefore provide ideal conditions for hemp production. This however excludes other important contributing factors such as arable land, access to irrigation and fertilizer remain questionable limitations to production, especially for smallholder and subsistence farmers (de la Hey and Beinart, 2017).

2.3.2.3) Flowering

Flowering of the hemp plant is considered a prominent factor in effecting quality and quantity of crop production (Van der Werf, Mathussen and Haverkort, 1996). This occurs as a result of RUE levels, once again, as multiple studies have corroborated similar results, which suggest low RUE levels are displayed by hemp post-flowering (Van der Werf, Mathussen and Haverkort, 1996). Similarly, these RUE levels are considered a product of lignin synthetization in the stem, and fat and protein synthetization in the seed, as well as significant self-thinning, which is phenomenon in which hemp plants shed dry-matter, such as leaves, seeds, and stalks, and can cause poor crop yields (Van der Werf, Mathussen and Haverkort, 1996). Flowering of the plant is largely associated with harvesting dates, which differ depending on focus of production (fibre, or seed), as well as expressing different flowering characteristics depending on cultivar variety cultured (Van der Werf, Mathussen and Haverkort, 1996).

Flowering has been suggested to be a factor that needs to be included the process of defining crop management practices. This should be based on individual characteristics demonstrated by different hemp varieties.

2.3.2.4) Self-Thinning and Crop Densities

In addition to this appraisal, self-thinning of hemp has been examined, with regards to how crop density may influence the severity of self-thinning (Van der Werf, Mathussen and Haverkort, 1996). It was found that high crop density negatively affected crop development, as individual plants increasingly competed for PAR, which resulted in severe self-thinning, and the death of

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multiple plants throughout the season (Van der Werf, Mathussen and Haverkort, 1996).

RUE levels at high crop densities steadily decline proportionately to the amount of lost plant dry matter, which was proven in two studies done on the effects of crop density on dry matter production (Van der Werf, Mathussen and Haverkort, 1996; Bavec and Bavec, 2006). Both studies concluded, that at a density of 270 plants per square-meter (very high) the rates of self-thinning and plant mortality were high (Van der Werf, Mathussen and Haverkort, 1996; Bavec and Bavec, 2006). This was due to natural competition, in which the bigger plants would out-grow the smaller plants (Van der Werf, Mathussen and Haverkort, 1996; Bavec and Bavec, 2006). At a plant density of 10 plants per square-meter (very low) an unexpected similarity occurred as self-thinning continued, but not as a result of plant mortality (Van der Werf, Mathussen and Haverkort, 1996; Bavec and Bavec, 2006). The cause of self-thinning in this case was merely the excessive amount of shedding, where leaves and branches were lost to dead plant dry matter (Van der Werf, Mathussen and Haverkort, 1996; Bavec and Bavec, 2006).

Although both studies concluded that, at 10 plants per square-meter, and 270 plants per square-meter, the yields were severely affected by self-thinning and plant mortality, however, the suggested crop density differs in fact between both studies (Van der Werf, Mathussen and Haverkort, 1996; Bavec and Bavec, 2006). García-Tejero *et al.* (2014) states, however, that for the production of cannabinoid, hemp crop density optimises production at 10-20 plants per square-meter, while plant density for seed production is optimized at 30-40 plants per square-meter, and for bast fibre production, plant density can range from between 50-75 plants per square-meter. The crop densities provided above are additionally relative to the context of South Africa, as the study that produced such figures was conducted in a Mediterranean, semi-arid climatic context, such as the climate experienced in the Western Cape.

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However, regions of the Eastern Cape and KwaZulu-Natal remain subject to highly diverse climates, consisting of semi-arid, dry sub-humid, and moist sub-humid conditions, noticeable by Figure 3 (Conradie, 2012). In the figure below, the dark brown represents arid terrains, the lighter brown represents semi-arid terrains, the orange represents dry, sub-humid terrains, turquoise represents moist, sub-humid, and blue represents humid, regions (Conradie, 2012).

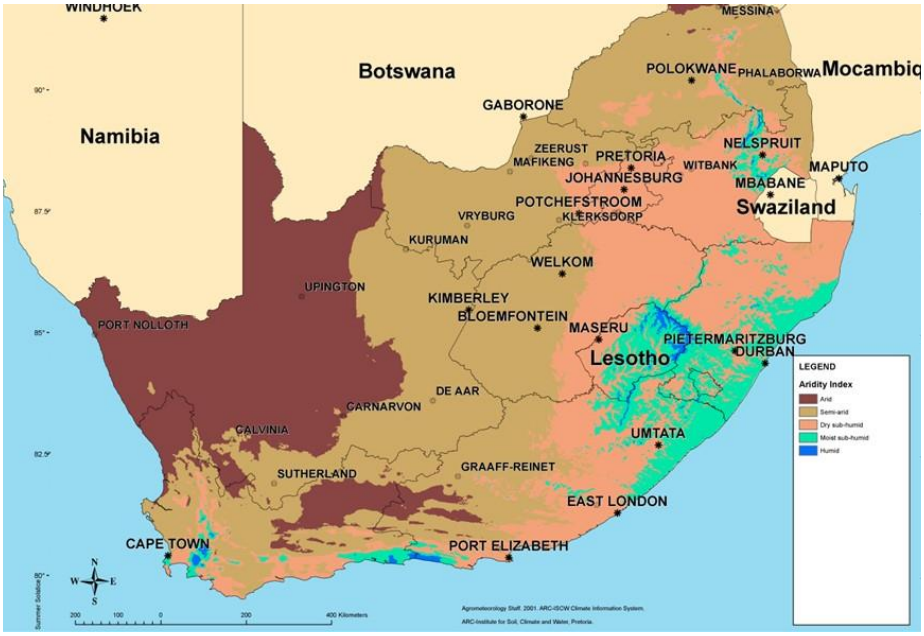

Figure 4: Climatic zones of different regions in South Africa (Conradie, 2012

2.3.2.5) Harvesting Date

The harvesting date for a hemp crop is determined by the focus of crop production (fibre, seed, cannabinoid), and is based on flowering dates (Van der Werf, Mathussen and Haverkort, 1996).

In addition, maximum yields of stem, fibre, and bark have been reached where harvesting date was left to the flowering of male plants, which is the technical maturity of the plant (Bavec and Bavec, 2006). Much research will have to be done before crop management practices, such as sowing date, crop density, flowering period, and harvest date can be optimized. To optimize crop management practices such as those mentioned above, one may even have to trial-season carefully selected varieties, so as to identify the most agriculturally appropriate variety (Bavec and Bavec, 2006). The varieties chosen should be

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based on either local ‘landraces’ (discussed in following section), or varieties that flourish is regions which share similar altitudes, latitudes, and humidity levels (Bavec and Bavec, 2006). Practicing varieties appropriate to climatic contexts is essential in realising the greatest benefits induced through hemp cultivation.

2.3.2.6) Cannabis as a Pioneer species

Cannabis is essentially part of the semi-woody weed family, due to its capacities for phenotypic plasticity, allowing it to adapt effectively in most areas (Small, 2015). Hemp additionally lies within the pioneer plant category (Piotrowski and Carus, 2011), and pioneer plant species hold capacities to be extremely adaptive in humanly modified landscapes, such as smallholder farming landscapes (Dalling 2008). Dalling (2008) defines the term ‘pioneer’ as a plant species which is generally first to colonise newly, or previously modified habitats. The pioneer species are sub-divided into two predominant taxonomic categories, including those that initiate primary succession, and those that are second in succession (Dalling, 2008). Plant species that initiate primary succession of a habitat, also carry a capacity to colonise sites lacking soil organic content (SOC) (Dalling, 2008).

Whether *Cannabis* is a primary or secondary pioneer is unclear, however, Voeks (2014) notes how ‘sun-loving’ *Cannabis* effectively colonises sites before other taxa (groups of multiple organisms), through a comparably low amount of individual *Cannabis* pioneer plants. This may indicate that *Cannabis* is a competitive pioneer species, and different sub-varieties, such as hemp (*Cannabis Sativa L.)* may demonstrate enhanced traits of adaptability and colonisation. With regards to smallholder and subsistence farmers in South Africa, such botanical traits of *Cannabis* indicate its potential agricultural viability and possible agroecological benefits induced, if cultivation of this pioneer is encouraged in such rural farming contexts. The fast-growing, ‘foot- long taproots’, characteristic of hemp (*Cannabis Sativa L.*) enhances this plant species' capacity to resist the negative impacts of drought conditions (Fine, 2014; pg. 67).

2.3.2.7) Cannabis Sativa L. as a landrace in South Africa

Landrace is a term which refers to plant species historically domesticated throughout a region, and which have been traditionally cultured for centuries, or even millennia (Clarke and Merlin, 2016). These selected cultivars or varieties are now a product of a combination of both natural and farmer selection, where originally, motivation to domesticate specific cultivars was based on local climate and human cultural parameters (Clarke and Merlin, 2016). Such parameters motivated early farmers to select the most adaptable and viable cultivars, and through time, these cultivars have become part of the agricultural and natural landscapes prevalent to regions throughout the world (Clarke and Merlin, 2016).

The *Cannabis* family is a culmination of genetically diverse landraces found throughout the globe (Hillig 2005a). The *Cannabis* genus (includes multiple species) which includes species traditionally used for domestication, are similarly found throughout regions from the equator to approximately 60° north of the equator and are found throughout most of the Southern Hemisphere (Hillig, 2005b). With regards to *Cannabis* landraces found throughout regions of South Africa, the table segment provided below documents landraces localised to regions, such as Pietersburg in the Province of Limpopo and the Transkei (Hillig, 2005b).

Table 1: Illustrating *Cannabis* Landraces Prevalent to South Africa (Hillig, 2005b).

Region	Use	Source	Taxation

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Pietersburg	Drug	SAP	*C. Indica C. Sativa, Indica, Indica*
Transkei	Drug	SAP	*C. Indica C. Sativa, Indica, Indica*
Transkei	Drug	AMSRS	*C. Indica C. Sativa, Indica, Indica*
Undisclosed	Drug	DNHSA	*C. Indica C. Sativa, Indica, Indica*

Cannabis landraces have been grown throughout the regions of Limpopo and the Transkei, as well as various undisclosed locations (Table 1, Hillig, 2005b). The denotations; SAP, AMSRS, and DNHSA, refer to the Forensic Science Laboratory, Pretoria, South Africa (SAP), HortaPharm B.V., Amsterdam, the Netherlands (AMSRS), and the Department of National Health, Pretoria, South Africa (Hillig, 2005b). Landraces pertaining to the *Cannabis* family in regions of South Africa, include major sub-varieties, such as *Cannabis Sativa,* the sub-variety in which hemp (*Cannabis Sativa L.)* is categorized, and can be found throughout the regions of South Africa (Hillig, 2005b).

Cannabis landraces can be found multiple regions of the world, including regions of South Africa, Malawi, Zimbabwe, Botswana, Mozambique, Swaziland, and Lesotho (Gastrow, 2003; Kepe, 2003; Mokoena, Funnah and Ngobeni, 2011; Duvall, 2016; Bloomer, 2019). It is recommended that local hemp landraces are identified, and cultivated, as these varieties will demonstrate traits of productivity, pest resistance, and ecosystem conservation (Fukuoka, 1985; Ewel, 1999).

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Using such hemp varieties will enhance soil- ecosystem services, and subsequently reduce dependence on energy- intensive inputs, transforming such systems into productive, sustainable farming systems (Fukuoka, 1985; Ewel, 1999). Landraces in South Africa are thought to be traditionally cultured in Limpopo (Hillig, 2005b), Lesotho (Bloomer, 2019), KwaZulu-Natal (Burns, Jhazbhay and Emsley, 2011), and the Eastern Cape (Kepe, 2003; Mokoena, Funnah and Ngobeni, 2011; Sotana, 2013).

It should be noted that South Africa has become recognised as one of the largest producers of illegal *Cannabis,* which has been mainly produced through smallholders who reside in regions which favour its cultivation, such as Mpondoland, Lusikisiki, the Transkei, and rural areas of the KwaZulu-Natal region (Peltzer and Ramlagan, 2007). Production of such *Cannabis* currently provides livelihoods for smallholders throughout regions of the Eastern Cape, Limpopo, and KwaZulu-Natal (Peltzer and Ramlagan, 2007).

According to Peltzer and Ramlagan (2007) current estimates suggest the total area of land under illegal *Cannabis* cultivation in South Africa is between 1000-1200 hectares (Peltzer and Ramlagan, 2007). The illegal market provides approximately 1.2 million people employment, including 350 000 traditional healers who cultivate the plant themselves, as well as 900 000 *Cannabis* farmers (Preuss, 2019). As mentioned before, predominant *Cannabis Sativa* landraces have been traditionally cultured throughout South Africa, and the greater region of Southern Africa, which is a perspective additionally supported by Peltzer and Ramlagan (2007). The argument here is found in the benefit of supporting traditional and predominant smallholder agriculture of *Cannabis* prevalent to the South African context, which currently supports approximately 1.2 million people (Preuss, 2019).

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2.3.3) The hemp crop as an agricultural system

2.3.3.1) Hemp dual cropping as a potentially productive smallholder agriculture

In terms of how such agricultural systems should be sustainably designed, dual cropping offers production of a diverse set of raw materials, including fibre, shiv/hurd, leaves, flowers, roots, and seeds (Fine, 2014; Budden, 2013, Tang *et al* 2016). Shivs or hurds, are the woody interiors of the hemp stalk, and are becoming increasingly useful agricultural products, used for building material such as 'hempcrete', animal bedding, mulch, and various other by-products (Fine, 2014). These systems have mostly been used to suppress weeds, due to the agroecological characteristic of the hemp plant to do so.

Dual crop systems may be necessary for viable hemp production, at least it is thought in the United Sates perspective (Fine 2014). Hemp dual cropping is entirely possible as a viable system, given the use of a variety appropriate to local altitude, latitude, and humidity levels (Fine, 2014). Such cultivars are thought to exist as different landraces throughout the world, all of which demonstrating diverse traits based on local domestication strategies, and subsequent adaption to local environmental conditions (Kepe, 2003; Hillig, 2005a; Anwar, Latif and Ashraf, 2006; Clarke and Merlin, 2013; Kuddus, Ginawi and Al-Hazimi, 2013; García- Tejero *et al.*, 2014; Salentijn *et al.*, 2015; Small, 2015; Duvall, 2016; Bloomer, 2019).

2.3.3.2) Required inputs for viable hemp agriculture

Purdue University (2015) clarify misconceptions surrounding fertilizer inputs in hemp production, as a common myth believed by many, is the lack of additional nitrogen or potash inputs needed in production. Potash in an agricultural context refers soluble inorganic compounds, which contain Potassium (K), Carbon (C), and Chloride (Cl) (Lockeretz, 1980). Following from seed, agricultural inputs required for hemp farming include macronutrients, such as Nitrogen (N), Potassium (K), Phosphorous (P), Chloride (O), and Calcium Oxide (CaO), as well as Carbon (compost/mulch), if soil organic carbon (SOC) matter is low (Van

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Der Werf and Petit, 2002; Van Der Werf, 2004; Purdue University, 2015). An extensive analysis, provided through multiple studies of hemp agriculture, informs of the reality of such agriculture (Van Der Werf, 2004; Van der Werf and Turunen, 2008; Sotana, 2013; García-Tejero *et al.*, 2014; Purdue University, 2015; Anderson, 2018; Pagnani *et al.*, 2018).

The absence of fertilizer use in hemp cultivation is unfortunately not true, and studies have recommended that 130 kilograms per hectare of nitrogen (N) was necessary for viable production, as well as an approximate 50-80 kilograms per hectare of phosphorous, and 40-90 kilograms per hectare of potash, to keep potassium levels between medium and high ranges (Purdue University 2015). In addition, it was recommended that good Sulphur (S) levels were present at greater than 5000 parts per million (PPM), and Calcium (Ca) levels were not to exceed a rate of 6000 PPM (Purdue University, 2015). Soil type and fertility are important factors to consider, as hemp is grown best in fertile, well-aerated, loamy soils, with a potential hydrogen (pH) of between 6.5 and 7 (Purdue University, 2015). pH refers to the acidity and alkalinity levels found in mediums such as water and soil (Mccauley, Jones and Olson-Rutz, 2017).

However, agricultural inputs involved in the hemp production of a French farm, identified on Table 2, details contrasting quantities to those documented by studies produced in regions such as Indiana, in the United States (Van Der Werf, 2004; Purdue University, 2015). Here, only 75 kilograms per hectare of ammonium nitrate fertilizer (NH4NO3), 38 kilograms per hectare of triple superphosphate (H2PO4), and 113 kilograms per hectare of potassium chloride (KCl), are reported to be used on a French, industrial hemp farm (Van Der Werf, 2004). In addition, Soil fertility levels of 3.5% and higher will indeed yield optimum crop production and is thought to be necessary in developing a viable hemp industry (Purdue University, 2015). However, in other parts of the world, lower fertility levels have reported to bare yields surpassing conventional commercial crops, such as maize, wheat, soybean, and cotton, given the appropriate application of fertilizer, irrigation, and crop management practices (Van Der Werf, 2004).

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2.3.3.3) Pesticide-use

The synthetic chemicals used in conventional agriculture, such as pesticides and herbicides, have regressive effects on human, animal, insect, plant and micro-organism species, and such effects can negatively impact across regional scales (Holzschuh *et al.*, 2007; Beketov *et al.*, 2013). This occurs through leakage into local streams, where both fauna and flora species are vulnerable (Relyea, 2005; Hayes *et al.*, 2006; Beketov *et al.*, 2013), as well as through destructive effects on bee populations, which is limiting regional pollination, and thus flora biodiversity (Holzschuh *et al.*, 2007; Pettis *et al.*, 2012; Sanchez-Bayo and Goka, 2014). In addition, farmers who spray their crops with such chemicals, are subject to negative genetic and epigenetic (non- genetic) influences (Kourakis *et al.*, 1996; Bolognesi, 2003; Patil *et al.*, 2003).

Where smallholder and subsistence farmers gain access to pesticides, the negative health effects of such tend be more severe (Ismael, Bennett and Morse, 2002; Maumbe and Swinton, 2003; Stadlinger *et al.*, 2011; Pedlowski *et al.*, 2012). This occurs due to a lack of awareness amongst smallholder farmers of the toxicity of such chemicals, and this unawareness often leads to subsequent mismanagement of pesticides (Ismael, Bennett and Morse, 2002; Maumbe and Swinton, 2003; Stadlinger *et al.*, 2011; Pedlowski *et al.*, 2012).

Mismanagement of pesticides often translates to farm employees disregarding protective gear and appropriate levels of use, and in addition, the use of ‘cheap’ or low-quality pesticide may be more harmful, due to higher levels of toxicity (Maumbe and Swinton, 2003; Stadlinger *et al.*, 2011; Pedlowski *et al.*, 2012). Significantly, mismanagement of pesticides is common to smallholder farmers in sub-Saharan Africa countries, specifically in the cotton industries of South Africa (Ismael, Bennett and Morse, 2002), and Zimbabwe (Maumbe and Swinton, 2003), as well as the rice industry in Tanzania (Stadlinger *et al.*, 2011).

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No use of pesticides, insecticides, fungicides, or herbicides are reported in hemp agriculture, however, the hemp crop has been reported to display vulnerability to a variety of pests, such as the European borer, grasshoppers, and armyworms in North America (Purdue University, 2015). The crop is also vulnerable to fungal pathogens, commonly referred to as grey and white mould, as well as certain viruses, significantly if grown in succession, or amongst soybean, canola, or sunflower crops (Purdue University, 2015).

Authors have widely advocated the agriculture of hemp, because it requires significantly less use of toxic chemicals, and thus greatly reduces the common negative effects associated, bridging the gap between industrial crop production, and organic farming systems (Jankauskienė, Gruzdevienė and Lazauskas, 2014; Anderson, 2018; Benelli *et al.*, 2018).

2.3.3.4) Hemps' environmental comparability

A study by Van der Werf and Turunen (2008), aimed at defining the environmental effects of hemp and flax textile yarn production. Through a life-cycle analysis (LCA) methodology, it was found that hemp and flax production caused environmental ills when under industrial conditions such as intensive chemical use (Van der Werf and Turunen, 2008). However, the study concluded that the severities of such environmental ills were still to a lesser degree than common crops, and innovation surrounding the energy-efficiency of processing technology, could greatly improve the sustainability of existing, and future hemp industries (Van der Werf and Turunen, 2008).

A study based in France compared hemp production to sunflower, pea, rape seed, maize, wheat, sugar beet and potato production, based on agricultural inputs used, and subsequent environmental effects (Van Der Werf, 2004). The LCA study identified that the hemp crop outperformed the seven other crops in various categories, such as fertilizer requirements, seed requirements for sowing, pesticide-use, agricultural-machinery-use, diesel and natural gas requirements, as well as the total straw dry-matter and grain produced (Van Der

Werf, 2004). To support the ecological sustainability, thought to be associated with hemp agriculture, I refer to Figure 5 (Piotrowski and Carus, 2011; pg. 3) below, which illustrates the comparable 'Biodiversity Friendliness' of the hemp crop, over various other conventional crops.

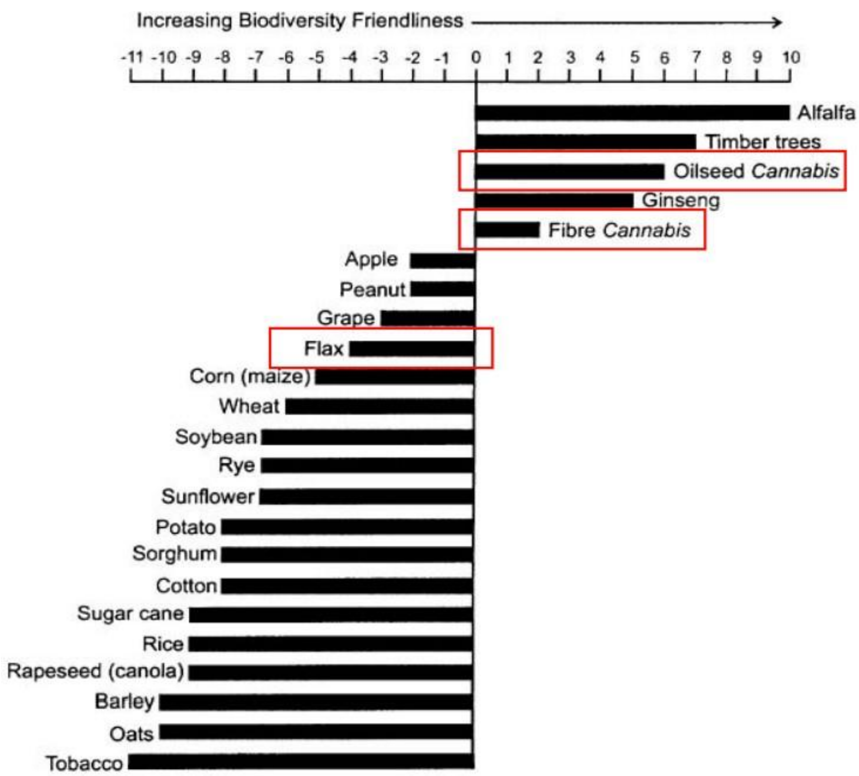

Figure 5: Comparison of selected major crops based on identified levels of 'Biodiversity Friendliness' at the farm-level, and ranges between 1 and 10, indicating levels of unsustainable intensity. (Piotrowski and Carus, 2011)

This is thought to be mostly a product of the low-input agricultural model associated with hemp, as well as the lack of pesticides and other toxic chemicals used in such agriculture (Piotrowski and Carus, 2011).

In addition, The European Environmental Agency (EEA) conducted a study in 2007 to define an environmental comparison of different crops, including hemp,

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which outperformed predominant crops significantly (Piotrowski and Carus, 2011).

Table 2; EEA (2007) environmental comparison of common crops, including hemp, where A represents good practice and C represents poor practice, in terms of the above categories (Piotrowski and Carus, 2011)

	Nutrient depletion	Pesticides	Erosion	Soil compaction	Water consumption	Biodiversity	Agro-biodiversity
Permanent pasture	A	A	A	A	A	A	A
Short rotation coppice (poplar, willow)	A	A	A	A	B	A/B	A
Winter grains	A	A	A	A	A	B	B
Linseed	A	B	A/B	A	A	A/B	A
Hemp	A	A	A/B	A	B	B	A
Alfalfa	B	A	A	A/B	A/B	A/B	A
Grass	B	B	B	A/B	A	B/C	A
Switchgrass	?	?	A	A	A	B	A
Mustard	A/B	B	A/B	A	B	B	A
Sorghum	A	B/C	A	A	A/C	B	B
Wheat	A	B	A	A	B	B/C	C
Sunflower	A/B	B	B/C	A	B	A/B	B
Rapeseed	B/C	C	B	A	0	B/C	A/B
Sugarbeet	B/C	B	C	C	A/C	B	B
Maize	C	C	C	B	A/B	C	B/C
Potato	B/C	B	C	C	C	B/C	C

It is clear from Table 4 (Piotrowski and Carus, 2011; pg. 4) that hemp agriculture can be characterised as a sustainable agriculture, when appropriately practiced, as it displays little negative effects on nutrient depletion, soil erosion, soil competition, and water consumption. In addition, the agro-biodiversity of hemp agriculture has been highly rated in this study (Piotrowski and Carus, 2011).

2.3.3.5) South Africa's rural development spearheaded with smallholder hemp agriculture

In terms of how hemp agriculture can be used to develop smallholder production in South Africa, various social, ecological, and economic challenges faced by rural communities, could be addressed through developing a sustainable industry, that is inclusive of smallholder production. However, regardless of the potential for smallholder hemp production, and the necessary support that will be

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required from provincial and local government for resources and subsidization, such support schemes should already exist to improve the livelihoods of those engaging with smallholder agriculture.
Climate change, and poor farming practices, are reducing the capacity of soil ecosystems to provide the necessary services for the essential production of smallholder and subsistence agriculture (de la Hey and Beinart, 2017). With regards to agronomic attractiveness (productive, low-input crop), and the agricultural context of smallholder and subsistence farmers (vulnerable agricultural landscapes), hemp agriculture presents as a possible means to enhancing smallholder productivity. After production, multiple social drivers experienced throughout such landscapes are met, through providing access to nutrition (hemp seed), agricultural by-products, and raw material applicable to diverse array of industrial end-uses.

Governments in other parts of the world, such as Italy, France, the Netherlands, and Canada, support hemp farmers through knowledge transfer, credit, and subsidization (Fine, 2014). In South Africa, agricultural support is provided to farmers who facilitate commercial-scale agriculture, however, large rural populations in South Africa have little access to the food and non-food commodities produced through this industry (Ortmann and King, 2007; Baiphethi and Jacobs, 2009; Bloomer, 2018).

Governments hold the resources and capacity to support farmers, including both commercial farmers, and smallholder farmers (du Toit, 2017). Creating conditions in which sustainable smallholder agriculture is realised, is not only important for the large rural populations who depend on such agricultural production, but also for the conservation of agricultural and cultural landscapes throughout rural South Africa.

Du Toit (2017) notes how a possible solution to the broader challenges of rural poverty in South Africa, includes land reform, however, a re-orientation of government strategy is required to move away from the tight integration of global value chains. This re-orientation should now move towards a space where the

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creation of a regulatory environment is facilitated (du Toit, 2017). This environment should be created to support the rural informal sector (worth approximately three million rand), as well as ‘local, loose, and socially networked value chains, and, where it is practical, low-input agriculture’ (du Toit, 2017, pg. 6). It’s interesting to note that such a re- orientation of strategy could include the encouragement of hemp cultivation by smallholder and subsistence farmers, as a spearhead for the creation of this regulatory environment.

This is a context in which appropriate conditions are created through a multi-departmental effort of government, and such conditions include the presence of agricultural platforms that aid the sustainable development of possibly the most important agricultural sector, the smallholder and subsistence sector. Through the development of informed, sustainable smallholder agriculture, that reflects local and foreign markets, as well as the development of socially networked value chains, a regulatory environment defined by desired conditions could be created to spur the growth of South Africa’s rural economy.

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Chapter 3: Methodology

3.1) Introduction

According to Kothari (2004) research and scientific methodology are closely related. Research is defined as “an inquiry into the nature of, the reasons for, and the consequences of any particular set of circumstances”, while scientific method closely relates to the logic research agents apply to their different studies within the various branches of science (Kothari, 2004).

This study used a social-ecological system lens to unpack the complexities of hemp cultivation in South Africa. A literature review was used to understand the cultivation of hemp in different regions of the world and identify characteristics of hemp cultivation, to build an argument for its establishment as an agricultural industry in South Africa. This argument was built through identifying the viability of hemp agriculture in the smallholder and subsistence farming contexts of South Africa. The identified viability was based on the characteristics of hemp agriculture, which were identified as sustainable, such as the lack of pesticides required. In addition, the prospect of socio- economic and agricultural development as a result of establishing smallholder hemp agriculture in South Africa, similarly contributed to the argument for the well-suitedness of this agriculture.

The social and ecological drivers that have initiated the cultivation of hemp in South Africa were investigated, as well as the social and ecological impacts. This allowed me to develop a holistic perspective of the positive and negative factors associated with developing smallholder hemp agriculture in South Africa. The social-ecological systems lens also allowed me to identify the impacts/threats to social, ecological, and economic dimensions of rural regions where smallholder hemp agriculture would be practiced in South Africa. Through the extensive literature review presented in Chapter 2, aspects of the cultivation process involved in hemp agriculture, such as pesticide-use, irrigation requirements, the genetical diversity of hemp varieties, fertiliser

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requirements, and system preferences, were identified as focus points for the collection of my primary data. These spaces of research were then used in the construction of my primary research design (Kothari, 2004).

The objectives set out by this study, aimed at identifying, firstly, the drivers behind the establishment of a South African hemp industry, secondly, the ecological benefits of hemp cultivation, thirdly, the challenges associated with hemp cultivation, and lastly, the main limitations associated with developing smallholder hemp agriculture in South Africa. These research objectives then guided both the literature review and interview analysis provided in this study. In addition, the case-study and soil analysis were similarly guided by the research objectives, however, such analyses were focussed on agroecological factors of hemp agriculture in South Africa.

3.2) Limitations

The limitations I encountered in the research process included access to information that related specifically to hemp agriculture in South Africa, as the concept is largely undocumented in publicly accessible sources of information. Much of the empirical research conducted on the topic of hemp agriculture has been conducted in northern hemisphere countries, including the Netherlands, Canada, and the United States. Because of the lack of empirical research conducted in South Africa, I was limited to only the experiences and perspectives of chosen interviewees, who had personal experience in the hemp industry in South Africa.

Secondly, there were challenges associated with applying a social-ecological system approach to this study. This approach provided a holistic perspective, which includes social, ecological, political and economic dimensions. Dealing with such a complex system with variables from multiple disciplines was

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challenging at first, however, as the study continued, this systems' perspective proved beneficial as it provided a holistic view of hemp cultivation.

My own personal limitations were firstly financial, as I wished to observe a hemp trial farm in the Eastern Cape and KwaZulu-Natal regions, where preliminary research had indicated optimum climatic conditions for hemp cultivation in South Africa. In addition, I lacked personal experience in the gathering of primary data, and this could have limited the study in terms of the research design and methods chosen. My personal experience could have also affected the actual gathering of data through the research methods conducted.

Legislation surrounding cannabis cultivation in South Africa remains restrictive of its development, as farmers require a permit from The South African Health Products Regulatory Authority (SAHPRA) to cultivate hemp, and they may only cultivate up to two hectares, currently. As a result of the restrictive regulation of hemp agriculture in South Africa, only organizations such as the ARC and Government agricultural departments are currently farming hemp in South Africa. These operations are mostly evaluation-based, and are similarly restricted to two hectares in size, and so the effect of economies of scale cannot be evaluated. This limitation affected the study directly, as the case study analysed was based on an ARC hemp research farm in Robertson, which was practiced on a quarter-hectare plot.

One of the interviewees included in this study, was targeted specifically because of his involvement with the ARC and the hemp research trials occurring throughout South Africa. However, he made me aware of the fact that the ARC hemp evaluations are still being formulated, and there remain various aspects of the cultivation process associated with hemp agriculture in the South African climatic context, that are unfinalized. As a result of the proceeding evaluations, the interviewee was unable to disclose certain information, which I had deemed as somewhat important to the development of this study.

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My own limitations may have once more limited the study, in that the analysis and discussion hosted in this study is limited to my own experience in the formulation of academic literature, as experienced scholars may have identified further complexity in the argument presented. Lastly, the concept of reflexivity in qualitative research, which Berger (2015) argues is the affect of researchers' social position, such as race, culture, gender, or age, as well their personal experiences and beliefs. My own position in society, as well as my own personal experiences and beliefs may have also limited the study.

3.3) Ethics

Stellenbosch University requires ethical clearance which is done through the Research Ethics Committee (REC), and with specific reference to this study, the Departmental Ethics Screening Committee (DESC). The process was intensive, and many aspects of the research must be disclosed through an application process, in which aspects of the study, such as the research questions and objectives, and research methods are disclosed. The individual(s) conducting the study must put forward their own perceived level of risk associated with the participation of study participants and can range from low to high risk. Risk in this context, relates to the potential emotional, social, physical, legal, ecological, and economic threats posed through conducting the particular study. Risk can also relate to the use of dangerous substances, such as biohazardous substances.

On the 22 of April 2019 the Departmental Ethics Screening Committee (DESC) deemed this study to be of low risk. This was based on the fact that my study posed very little threat to my participants, myself, and my environment.

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3.4) Research Design

This study involves the exploration of concepts such as hemp cultivation, sustainable agriculture, and South African smallholder farming systems. It aims at building a holistic perspective of hemp cultivation in South Africa, and through exploring the nature of such cultivation, and the reasons for its development, as well as the limitations restricting such development, contribute to the body of knowledge surrounding hemp agriculture in South Africa. The research objectives mentioned above demanded a specific approach, and so, to gather data and evidence surrounding such spaces, this study made use of research methods, such as literature surveys, semi-structured interviews, and non-participant case-study observation (Kothari, 2004).

Resultantly, this study made use of a qualitative strategy, as the experiences and knowledge of specifically chosen interviewees provided me with the primary data needed for building a perspective in the South African context (Kothari, 2004). The primary data gathered was then analysed and reformulated to create a narrative that accurately depicted the experiences and perspectives of each of the interviewees. Through identifying the primary drivers, impacts, and limitations perceived by my interviewees, I was able to fulfil the research objectives set out in the beginning of the study.

In addition, through using a case-study and soil analyses, I was able to reinforce the perspectives provided by my interviewees, which centred around the ecological benefits of hemp cultivation, such as the enhancing of micro and macronutrients present in the soil, and the cycling of such nutrients. The results of these analyses aided me in building an argument for the development of hemp agriculture in South Africa, as a sustainable agriculture. My research design was thus based on combining different research methodologies to create a holistic perspective of the drivers, benefits, impacts, and limitations to developing smallholder hemp agriculture in South Africa.

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3.5) Research Methods

The literature survey targeted spaces of research such as hemp cultivation, sustainable agriculture, and smallholder farming systems in South Africa. I made use of online sources such as Google Scholar, JSTOR and the Stellenbosch University online library, which then allowed me to access scientific journals, such as Elsevier. The research collected through the literature survey allowed me to understand the agricultural contexts of smallholder farmers in South Africa, which then allowed me to identify the socio-economic and ecological drivers experienced by such individuals and communities.

3.5.1) Literature Review

A literature survey of hemp cultivation and agricultural industries in other parts of the world, such as Western and Eastern Europe, as well as the United States and Canada, allowed me to explore the positive and negative drivers of hemp agriculture. I could then relate the drivers of hemp agriculture to the socio-economic and ecological drivers experienced by South African smallholder farmers. However, an evaluation of whether hemp agriculture was in fact agriculturally, industrially, and economically viable given the smallholder context in South Africa was also required. To fulfil the research objectives, which closely related to hemp cultivation in South Africa, I utilised a semi- structured interview research method, as well as a non-participant case-study method, because this allowed me to ask questions that were not part of my interview guide.

3.5.2) Interview Analysis

The interviewees chosen for participation in this study, were chosen to represent a holistic perspective of hemp cultivation in South Africa. A diverse pool of interviewees were therefore chosen, for example, Interviewee 1 has ten years of personal experience in both the cultivation and research of hemp agriculture. Interviewee 2 completed an MPhil degree in Sustainable Development in 2016, where she studies the visible and invisible barriers currently restricting the establishment of a South African hemp industry. Interviewee 2 therefore

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provided a view as an experienced researcher in industrial hemp and hemp-based materials.

Interviewee 3 has fifteen years of experience in the African hemp industry and is co-founder and CEO of The Hemporium. The Hemporium is a South African company that trades in hemp-goods, such as hemp-based fabrics, CBD oils, and hemp-based cosmetics, and are also the first to build a house made entirely of hemp raw materials (Budden, 2019). Interviewee 3 also has personal experience in the cultivation process, as he was involved in a

hemp trial farm conducted in Riebeek-Kasteel in the Western Cape Province of South Africa. He is a prominent figure in the hemp industry, and he is popularly referred to as “Mr. Hemp in South Africa’’.

Interviewee 4 is affiliated with the Western Cape Department of Agriculture (WC Dept of Agriculture), and subsequently represented the perception of South African Government-based departments and organizations. He provided the study with various limitations facing the development of a viable smallholder hemp agriculture in South Africa.

Interviewee 5 is the manager of the Agricultural Research Council (ARC)-based hemp research trial located in Robertson, in the Western Cape. He provided the study with a thorough perspective of the conditions required for viable hemp cultivation, as well as the research trial itself, and what has been discovered through such trials so far.

Interviewee 6 is also a member of the ARC who has been highly involved in the various hemp research trials throughout South Africa. He provided the study with a broader perspective of what the ARC hemp trials have discovered. It’s important to note that within the interview analysis, such perspectives were also compared, and through such, I could reinforce the arguments presented in Chapter 2, as well as identify future spaces of research.

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The interview analysis presented in this study aims at creating a diverse perspective of hemp agriculture and the industry in South Africa. It feeds off the semi-structured interviews that was conducted with the six selected participants. Each interviewee contributed a unique experience through the interviews, however, similarities were easily identified, as the interviewees often either had similar views surrounding specific topics or opposing views. To create a narrative, four sub-sections were developed:1) What are the main drivers behind hemp cultivation? 2) What are the ecological benefits of hemp cultivation? 3) What are the challenges associated with hemp cultivation? 4) What are the main threats to communities, current industries, and ecology?

3.5.3) Case-study analysis

The non-participant case-study observation conducted in this study focusses on the hemp research trial located in Robertson, in the Western Cape. I visited the farm on the 26 of September 2019 and observed what was required to cultivate hemp first-hand. This trial hemp farm in located 1.5 hours from Cape Town at 33^{o} 49’’ 42 **S** and 19^{o} 53’’ 05 **E**. The Robertson area is characteristic of wine farms and tourism-based activities. The plot is 0.25 hectares in size and has been used to evaluate various agricultural factors involved in hemp agriculture for the past fifteen years. The plot is surrounded by other research crops of similar size plots, as well as citrus orchards, and south of the hemp research plot is a wetland.

The focus of such evaluations has been the low tetrahydrocannabinol (THC) production of hemp fibre, but more recently, such evaluations have focused on production of high-quality hemp CBD oil. Drip irrigation of a total of 400-500 mm is used during the production of hemp at the Robertson farm, and additional irrigation is used throughout winter. The fertilizer requirements included 150 kilograms per hectare of Nitrogen (N), 80-100 kilograms per hectare of Phosphorous (P), and 60-80 kilograms per hectare of Potassium (K). In addition, Ammonium sulphate or limestone is applied 6 weeks after planting. No use of pesticide or herbicide was observed. Twelve different varieties are

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predominantly cultivated on the Robertson plot, as evaluations have also focused on identifying the best-performing varieties in the climatic context of Robertson, as well as the broader context of South Africa.

The use of agricultural machinery was observed, such as the use of a tractor, intended for the preparation of soils. In addition, a service post-harvest, known as ‘cleaning’, is required to avoid diseases and mould of the harvested raw material. Furthermore, no use of agricultural practices such as mulching, composting, or leaving the fallen green matter in the field post-harvest, was observed. This was then confirmed through the interview with the farm manager of the trial farm, Interviewee 5.

Good soil moisture was present at a depth of 75 cm and the soil was observed to be loamy.

Sowing of seed occurs during the months of October and November and harvesting is done during the months of April and May, the following year.

The following observation protocol was used.

Table 3: Observation Protocol

Agricultural Factors	**Detail**
Location	
Altitude, latitude	
Plot size (ha)	
Agricultural research focus	
Irrigation	
Feeding Requirements	
Pesticide	
Herbicide	
Hemp strain	

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Seed, fibre, or dual crop	
Other required resources and agricultural inputs	
Humidity	
Temperature	
Soil type	
Soil moisture	
Sowing and harvesting date	
Average dry matter yield	
Self-shedding	
Flowering period	
Observed biodiversity; Insect, animal, and plant diversity	
Agricultural pests	
Use of agricultural machinery	
Cultivation process	
Agricultural management practices	
Observed levels of sustainable agriculture	

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Soil sample; Minerals in mg.kg/parts per million (PPM) Organic Carbon (C); as a percentage	

The observation protocol provided for the non-participant case-study, was based on the research objectives of this study, for example, identifying levels of agricultural sustainability requires an analysis of a crop's feeding requirement, in terms of fertilizer, irrigation, pesticides, and herbicides. In addition, indicators of ecologically sound agriculture, such as biodiversity in the soil and surrounding flora were included in the observation protocol. The other factors included in the observation protocol related more to the practices and agricultural systems utilised on the farm. This indicated levels of tillage farming and irrigation management, as well as the use of appropriate harvesting methods and the post-harvest services required, such as cleaning. The protocol analysis also correlated with specific indicators of the Robertson Farm soil analysis.

The Robertson Farm soil analysis required comparisons with various scenarios relating to macronutrient and micronutrient soil profiles of other agricultures, such as vegetable crops, common to smallholders, and corn, a common industrial crop (Hazelton and Murphy, 2019). All crops require specific rates of such nutrients, and without such nutrients, crops are not productive, and so, to provide reference points for a comparative analysis of productive soils, I referred to Hazelton and Murphy (2019). These authors (Hazelton and Murphy, 2019) provide a range of scenarios for soil analysis results and provide application requirements based on 'soil test categories' of very low, low, high, and very high.

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3.5.4) Soil Analysis

A soil sample was taken from the Robertson hemp trial plot, and analysed through a private laboratory, Bemlab, located in Cape Town, South Africa. Bemlab is an accredited testing laboratory through the South African National Accreditation System (SANAS) that specializes in chemical analysis of soil, fruit, leaves, water, and microbiology of water and fruit. For this soil analysis only a chemical analysis of a one-kilogram soil sample from the Robertson farm was required. The chemical analysis included the identification of pH, resistance, Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorous (P) Bray II, Titratable acidity, Stone fraction, Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Boron (B), and Organic Carbon (C).

These micro and macronutrients were targeted for analysis to identify the level of enhancement of the nutrient cycle induced through hemp cultivation at the Robertson Farm. My hypothesis was that there would be low levels of macronutrients and organic fertility, because of the time of soil sample collection. Collection was done four months after harvest, in which the soil is assumed to be at its most depleted. And secondly, I assumed the results of the soil analysis would indicate low levels of organic content, as no use of compost or mulch was observed during my site-visit.

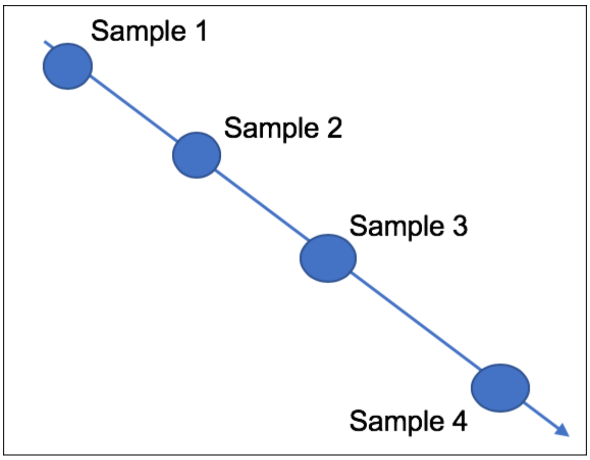

Figure 6: Robertson plot: Soil sample collection scheme

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This collection scheme above illustrates the Robertson plot as a 0.25-hectare area, where the arrow represents the gradient of the plot. Four individual soil samples were collected following the gradient of the plot and are represented by the points labelled; soil sample 1, 2, 3, and 4. Each soil sample was collected equidistant from one another, and at a depth of 75 cm.

Once the samples had been collected, they were combined to create an aggregate of micro and macro nutrients present in the soil at a depth of 75 cm. it should also be noted, that samples 1-4 were all collected on the same date (26/09/2019), and collection was taken after harvest, specifically. A soil analysis of micro and macronutrients present in soil, taken after harvest, indicates levels of crop consumption of nutrients, and thus levels of nutrient depletion. This method aims at identifying the level at which hemp cultivation enhances the flow of nutrients throughout the upper and lower levels of agricultural soil.

3.6) Data

Secondary data is provided through the literature review, while primary data has been provided through the interview and case-study analysis, as well as the soil analysis. The non-participant observation protocol relates to research method, however, data was also received through the soil analysis, provided by Bemlab.

Table 4: Soil analysis results from Bemlab

Soil Analysis Indicators	Detail
Soil Type	Loamy
pH	7.8
Phosphorous (P)-	31 mg.kg/PPM-Bray II (Method of analysis)

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Potassium (K	0.43 cmol(+)kg
Calcium (Ca)-	21.02 cmol(+)kg
Magnesium (Mg	2.56 cmol(+)kg
Sodium (Na)	0.41 cmol(+)kg
Organic content	0.2%

Cmol(+)kg is the centimoles of positive charge per kilogram of soil, which includes the valences and atomic weights of the relative cations. However, conversion from cmol(+)kg to mg.kg/PPM was done to make the results easily comparable. The conversion was done through the formula provided below (Elkins and Elkins, 2019).

Table 5: Conversion formula for cmol(+)kg to mg.kg/PPM

Cation	Divide mg kg^{-1} by this number
Calcium (Ca)	200
Magnesium (Mg)	120
Potassium (K)	390
Sodium (Na)	230
Aluminium (Al)	90

Table 6: Figures after cmol(+)kg to mg.kg/PPM conversion

Before conversion	After conversion to mg.kg/PPM
Potassium (K)- 0.43 cmol(+)kg	167.7 mg.kg/PPM

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Calcium (Ca)- 21.02 cmol(+)kg	4204 mg.kg/PPM
Magnesium (Mg)- 2.56 cmol(+)kg	307.2 mg.kg/PPM

To provide an understanding of the soil analysis results, I created two comparative analyses. The comparative analyses were based on two scenarios which, firstly indicated low levels of macronutrients in soil, and secondly, high levels of macronutrients in soil. This was done to evaluate whether hemp cultivation was providing a positive influence on the soil at the Robertson plot.

The following tables were used to provide a reference point for the levels of micronutrients found in the Robertson soil analysis (Hazelton and Murphy, 2019).

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Table 7: Robertson soil analysis in comparison to scenario of 'low' macronutrients

Macronutrient	Robertson soil analysis	'Low' level scenario of macronutrients (Hazelton and Murphy, 2019)
Phosphorous (P)	31 mg.kg/PPM	2 mg.kg/PPM
Potassium (K)	167.7 mg.kg/PPM	50 mg.kg/PPM
Magnesium (Mg	307.2 mg.kg/PPM	30 mg.kg/PPM
Calcium (Ca)-	4204 mg.kg/PPM	200 mg.kg/PPM

Table 8: Robertson soil analysis in comparison to scenario of 'high' macronutrients

Macronutrients	Robertson soil analysis	'High' level scenario of macronutrients(Hazelton and Murphy, 2019)
Phosphorous (P)	31 mg.kg/PPM	87 mg.kg/PPM
Potassium (K)	167.7 mg.kg/PPM	180 mg.kg/PPM
Magnesium (Mg	307.2 mg.kg/PPM	137 mg.kg/PPM
Calcium (Ca)	4204 mg.kg/PPM	1940 mg

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Chapter 4: Results

Interview analysis

The interviews provided a diversity of perspectives surrounding hemp cultivation, the cultivation techniques involved, the agricultural inputs, the end-use products, the agroecological benefits, and the social-economic drivers that support the establishment of an industrial hemp agricultural industry. Four questions were used to create a meaningful narrative.

1. What are the main drivers behind hemp cultivation?

The diversity of end-use products of hemp, was the first aspect of the industry to motivate Interviewee 1's interest.

Interviewee 1: *"I got to see a diagram, and one in particular, it was a spider diagram of about fifty different uses, from one plant, which grows in 4-6 months, I couldn't believe it."*

The range of uses and by-products associated with hemp agriculture results in the appropriateness of this kind of crop for smallholder farmers in South Africa, significantly because of the access to resources such agriculture allows.

Interviewee 1: *"If you have access to hydrated limestone, which would be the best substance, and then you mix it with the hurd (root bulb of the hemp plant), you can create building materials of high quality, and in doing so, you could teach someone how to build a house. I would think the seed is also very useful, because its highly nutritious, and it can be eaten raw or as a grain. The raw hurd could also be weaved to create crafts or products."*

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Hemp seed has been used in a food-based initiative in South Africa, as the seed is highly nutritious. According to Interviewee 1, they saw ‘incredible’ results, and the children reacted to it in the biggest sense, as he said they were ‘revitalized’.

Interviewee 1: “’*Mamma Micki’ put her entire pension into this soup kitchen, to feed 120 kids and adults soup, and they recognized the nutritional value of adding hemp seed to the soup. Within a few weeks, some individuals had been cleared of tuberculosis.”*

Interviewee 1 was himself involved in a social development initiative, where he managed four kindergartens in Khayelitsha, including approximately 50 children each, and totalling about 200 children.

Interviewee 1: “*There were many kids suffering from ailments largely associated with poor diets, resulting in poor immune systems and susceptibility to various diseases. Through being inspired by Mamma Micki’s soup kitchen, I decided to buy every kindergarten approximately 10 L of hemp seed oil. We put the oil in the children’s soup, or put it on their skin, or gave them a teaspoon in the morning, and we saw some amazing results. The kids were really empowered by the essential fatty acids, omega 6 and 9, and the protein, which they can’t get from anything else, because it’s simply too expensive in these communities.”*

The drought-resistant characteristics of the hemp crop explored in this study, were acknowledged by Interviewee 1, as according to him, hemp is a fairly drought-resistant crop. In addition, Interviewee 1 stated:

Interviewee 1*: “The climate in South Africa allows rural smallholders to rotate various summer and winter crops, significantly because of the low severity of frost periods in most regions throughout the country, in contrast to very northern hemisphere countries, where the soils are frozen over during winter.”*

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In terms of whether research surrounding hemp agriculture and the hemp industry in South Africa is motivating the development and establishment of the agricultural industry, I asked Interviewee 5 if their hemp research trial in Robertson is currently contributing to the development of the legislation surrounding the industrial agriculture of hemp. He noted:

Interviewee 5: "*Because we are parastatal I think it depends on the praise we get from the public itself, there can be change, because these kinds of crops, with these kinds of treatment is very beneficial for the people, but also as a competitive crop, and in adding to the diversity of agricultures, which brings in money."*

To emphasize Interviewee 2's personal drive towards developing both the sustainable interior design industry, as well as the infant hemp industry in South Africa, I refer to what she stated during our interview:

Interviewee 2: "*The tagline for my business is; Design with integrity. I really believe we should be designing lifestyles with integrity, using better materials, for example, using hemp-based fabrics, instead of cotton, or wool. We know this is better, because of the full life cycles of these materials we use in every- day life."*

In the opinion of Interviewee 2, the three major social drivers needed to be met in the rural regions of South Africa, are housing, food, and medicine. She noted that in her opinion, these three major social drivers in rural South Africa, could be met through the practice of one crop. When asking Interviewee 2's opinion of what the future entailed for the hemp industry in South Africa, and whether smallholder farmers will be included, she responded by saying:

Interviewee 2: "*If it takes off, then yes, definitely, especially fibre production for building materials, and industrial processing, as well as seed for the nutrition*

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industry, however, hemp production for CBD may take some technological capacity for the smallholder in South Africa."

In terms of hemp agriculture being a sustainable agriculture, Interviewee 1 said;

"*For a smallholder, this kind of crop can aid you naturally, and build a resistance to climate change, and enhance biodiversity, as well as saving farmers from having to handle toxic chemicals such as pesticides. The seed can be grown for personal consumption, meeting food security directly on the farm, as well as being a useful mulch material, animal feed and bedding. If we had markets for hemp production demand, such as those found overseas, then smallholders would be making over eight times what they do now, compared to wheat."*

With regards to the prospects of smallholder farmers, if the industrial hemp industry was established in the future of South Africa, Interviewee 1 noted how the industry is already being dominated by the commercial sector. However, he suggested the industry be used for empowering people in South Africa. Developing social-economic opportunities in the rural regions of South Africa is thought to be one of the best mechanisms in reducing the urban sprawl, as Interviewee 1 noted:

Interviewee 1: "…*you could even reverse the urban sprawl by developing opportunities in rural regions. From people going from the Eastern Cape, one of the most beautiful places, to shacks in the urban regions, and mostly to find employment and an income, but also because of the lives they see people live through television.*"

With regards to whether hemp is a valuable crop in rotation for smallholder farmers, Interviewee 1 said:

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Interviewee 1: "*I don't want to see monocultures, so the more diverse the agriculture practiced, the better. And here, you have two options, where either hemp is cultivated as a cash-crop, or it used in a horticultural sense, in that the hemp would be used as a natural weed suppressor. But if one had to crop rotate with various grain, herb, vegetable, and hemp, then that would probably be best for smallholders, because given the size of their holdings, they would most likely experience the best of both worlds growing hemp, agriculturally and as a horticulture."*

With regards to the personal experience of Interviewee 5 in the hemp research trial in Robertson, he noted how the climate in South Africa suited the cultivation of hemp, however, regions surrounding Addo Elephant National Park, where hemp research trials are similarly being conducted, offered better conditions for hemp agriculture.

Interviewee 6: *"It's not the same as the Eastern Cape, we have another farm in the Addo region, and hemp grows better in this region because the daylength is longer. Its hotter here in Robertson, it's the same as Oudtshoorn, but daylength is better in Addo."*

In terms of financial drivers, smallholder farmers would be greatly benefiting from hemp CBD production, as Interviewee 6 stated:

Interviewee 6: *"…But also, if we look money-wise, we have discovered through our evaluations that CBD will bring a farmer a better capital gain than the other two crops, currently."*

In addition, legislation surrounding cannabis cultivation and use has recently been reformulated in South Africa, based on constitutionality, according to Interviewee 6. However, Interviewee 6 also stated the recent research trials in South Africa focusing on evaluating the viability of industrial and CBD hemp, are too part of the development of a regulatory framework, which is required for the registration of any agriculture in South Africa.

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2. **What are the perceived ecological impacts of hemp cultivation?**

According to Interviewee 1, the ecological impact of cultivating hemp, occurs through its characteristic taproot, which aerates soils, regenerates soil microorganism activity. Hemp is also recognised as a phytoremediator.

Interviewee 1: "*I believe that we can look to absorbing heavy metals from soils, to reclaim unusable land, as well as cleaning soils heavily laden over years with pesticides and herbicides, such as the Caledon soils. It can also be used to reduce radiation in certain places, such as the Russians, who are using hemp to absorb the radiation in Chernobyl."*

Hemp farming attracts biodiversity of an area, compared to any other farm. Interviewee 1 noted that the diversity ranged from soil-based insects, to winged insects, as well as insects which were predominantly active on the stem and leaf. He emphasized his experience of the bird activity present throughout the farm and referred to what he had learnt during his visit, which was that birds love hemp seed.

Interviewee 1: "…*you start to see the birds returning to feed on the seed, and lots of insects being drawn to the plants, and they restore the micro-biome beneath the canopy.*"

According to Interviewee 1, by removing the use of these chemicals, you ultimately increase the ecological aids induced through biodiversity.

Interviewee 1: "…*this biodiversity is part of how hemp holistically restores soil fertility, as these animals and insects are part of how the natural biome flourishes, and it's something largely forgotten by today's farmers."*

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Interviewee 1 noted that no pesticides, insecticides or herbicides are used in hemp farming, although it is known to be limited by pests such as nematodes and micro-parasites, however, the threat of weeds is eliminated in the farming of hemp.

Interviewee 1: "…*hemp is essentially a weedy plant, it chases the sun faster than other weeds, and thus acts as a natural herbicide."*

Interviewee 2 was also very aware of the lack of pesticides needed in hemp agriculture, as well as what that meant for a farm, and the farmer. Interviewee 2 spoke of the holistic benefits induced through practicing a crop which doesn't require pesticides, or any other toxic chemicals used in most conventional crops today. Taking one of the biggest leaps required for developing a sustainable agriculture, which involves using no harmful chemicals such as pesticides, is seen by Interviewee 2 as highly necessary, and hemp agriculture offers us this opportunity.

In fact, Interviewee 1, 2, 4, and 6 acknowledged the absence of pesticide used in hemp agriculture. Interviewee 5, who is currently the facilitator of the ARC hemp trial farm in Robertson (Western Cape), simply stated;

Interviewee 3: *"No pesticides are registered on hemp."*

Interviewee 3 explained that even with the extreme biodiversity of insects and animals, they noticed certain pests, however, these pests caused no recognizable damages to the crop. He then referred to a popular theory, which posits that the cannabis plant species releases a hormone that influences the behaviour of insects.

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Interviewee 3: *"…there's a theory that the plant releases a hormone that informs insects around the plant, that they are full, so they hang around, but don't really consume anything in the space."*

According to Interviewee 3, if you leave the green matter, such as the leaves and side branches, which fall to the ground quite abundantly throughout the season, then you provide a nutrient litter return to the soil. This allows your soil to be replenished with nitrogen, on which a winter crop could be produced, or prepared for the following season of hemp. He also stated that supplying a litter return of nutrients after each consecutive season also allows the farmer to reduce his/her fertilizer requirement.

Interview 3 noted how he largely believes in the big 'whys' of why we should grow hemp, for example, he strongly advocated it's agriculture, simply because of its vigorous growth.

Interviewee 3: *"…if you are looking at producing hemp fibre, you'll produce at least double per hectare, compared to your normal fibre crops. You can also use the hemp fibre for so many different purposes, that you reduce the need for land for additional crops, and I'm not saying turn hemp into a big monoculture, which dominates everything else, but rather replace the ecologically destructive and resource intensive crops with hemp crops*."

Interviewee 3 also stated that the adaptability of hemp varieties was recognised during the hemp research trial conducted in Riebeek-Kasteel, in that their second-generation harvest was far greater, in terms of biomass yield and quality, in comparison to the first-generation.

Interviewee 3: "*We also saw that it adapts really fast, as we planted some second-generation seeds, and they did a lot better than the first-generation*

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seeds, and from what we know, the plant is very adaptable. You can find it in almost every part of the world, and I'm pretty sure its ability to adapt effectively, is very much why it has been able to colonize most of this planet."

Interviewee 2 too advocated the vigorous growth properties of hemp, and strongly suggested we look towards sustainable land management, through practicing crops that provide the same commodities, or perhaps better-quality commodities, and that require only half the land, and half the resources.

Interviewee 2: "*Currently, the factories use so many chemicals, and large amounts of heat in the production of everyday industrial commodities, such as concrete. Concrete is another comparable industrial product, easily substituted by what we call 'hempcrete'. Now, conventional concrete is ancient material extracted from deep parts of the earth's crust, and is in fact, pure, concentrated carbon. Given our experience of present-day climate change, and the effects of carbon emissions, using concrete to build our future homes and cities, is essentially contributing to that climate change. Through long-term gravitational compression, concrete releases carbon slowly over time, into the atmosphere. Compare this to hemp, where the production of hempcrete involves only the production of a low-input, four-month crop, hydrated limestone, and the know-how. It's safe to say hempcrete is far more sustainable building material than concrete, but more significantly, hempcrete is a carbon sequester, and a really good one."*

Interviewee 2 similarly provided a comparative perspective of the sustainability of hemp industries. She explained that the life-cycle analyses associated with materials such as cotton and wool, which have been compared to the life-cycle analysis of hemp materials, have given insight into the comparable sustainability of hemp industries. This is because the agriculture of hemp which provides the textile-based hemp fabrics, is far more sustainable than the agriculture which produces conventional cotton and wool fabrics. In addition, Interviewee 2 has

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personal experience with the fabrics, and suggests hemp- based fabrics are of far better quality than cotton and wool.

Similarly, when asking Interviewee 2 about her perspective on the influence of hemp agriculture as a tool for reducing crop-land expansion, deforestation, and clearing of wild land, she stated:

Interviewee 2: *"…if you compare it to the production of plastic, which we consume a lot of, and requires the use of materials that are ecologically unsustainable, causing catastrophes like the floating plastic island in the ocean, and the only reason we use it, is because we can make a lot of it for cheap. So many are focusing on materials which can replace plastic, but it has to be something that is ecologically friendly, bio-degradable, and which has the capacity to be produced at very high rates. We know that hemp grows fast, and abundantly, and can be grown in a far more sustainable manner than plastic production. Whether it's the solution to our plastic problem, I'm not sure, but it could definitely halt the expansion of industrial facilities which produce commodities like plastic."*

According to Interviewee 3, in the production of hempcrete (hemp-based concrete), approximately 1.5 tons of Carbon Dioxide is absorbed for every 1 ton of hemp produced during cultivation.

Interviewee 3: *"If you build your house using hemp board, every square foot of wall panelling, roofing, and flooring, will be absorbing around 30 kgs in total of Carbon Dioxide, acting as a carbon sink, and cleaning the air within and around your house. If you use hempcrete, every square foot is absorbing about 100 kgs in total over a period of time.*

Lastly, Interviewee 1 recognised the potential of a rotated, smallholder hemp farm system, as a sustainable social-ecological system, which is economically viable.

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Interviewee 1: "*Bio-plastic, and bio-fuel industries, as well as the carbon tax market may see hemp a lot in the coming future. As a farmer, growing hemp could be done horticulturally to suppress weeds, and improve the nutrient cycle, through aeration, but it could also be grown as a cash crop in rotation, amongst your other winter crops. If grown in rotation, you may find you receive the best of both worlds, horticulturally, and as a valuable crop. Hemp could bring some element of homeostasis to the environment, through attracting various fauna, because you won't be using pesticides."*

3. What are the challenges associated with hemp cultivation?

In terms of access to irrigation and sustainable water management, smallholders may have to transition to contemporary irrigation systems, as Interviewee 1 noted:

Interviewee 1: "…*drip-irrigation, and pivot irrigation systems allow for a far more sustainable management of your water consumption. These systems can be made on the farm, quite simply, or they can be bought for a fair price."*

These systems are really beneficial if one's water supply is becoming increasingly vulnerable to the effects of climate change, as Interviewee 5 noted;

Interviewee 5: *"…water is very important, because hemp needs around 400- 500 mm of water, where tobacco is around 750 mm of water. But three years ago, I brought in the drip irrigation system, and now we save a lot of water, and it's much better than the overheads. And also, because weeds aren't a problem, the drip works much better."*

In terms of the cultivation protocol one follows, Interviewees 1, 3, and 5 all emphasized the importance of crop specification, as the protocols followed

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dramatically differ from one another. The focus of production, whether that be hemp fibre, seed, or CBD determines the protocol used in the cultivation process. For example, Interviewee 1 noted how a hemp fibre crop would probably require more nitrogen, ‘to bulk up the woody stalk’, however, the specific ratios used for application of NPK fertilizer, would depend on the particular variety of hemp. With regards to another aspect of the cultivation protocol which differs between the hemp fibre, seed, and CBD crop, I refer to Interviewee 5 who informed me of how one could dramatically affect the success of your harvest.

Interviewee 5: “…*because of the spacing, for fibre you need a space that’s very close, you need the very thin stem itself, but for the CBD, because you need the side branches, we space at about 30-50 cm for each plant. Between the rows themselves, you need a meter, and by doing this, you’ll get lots of seed and side branches.”*

Interviewee 5 informed me of the natural thinning of the hemp plant, which would occur if not correctly spaced. Natural thinning of the hemp plant causes shedding of its biomass, such as its leaves, stems, and branches, which could dramatically affect the ultimate success of your production.

Interviewee 3 noted how any crop, including, hemp, if practiced season after season, with no recognition of soil conservation, leads to a complete depletion of nutrients found in the soil. For this reason, it’s important to practice a nitrogen fixing winter crop, and so for the smallholder in South Africa, such crops would be based on context-specific conditions. For example, Interviewee 1, 3, and 5 stated that some farmers could use certain bean, split pea, and vegetable crops, as well as legumes. The hemp trial farm in Riebeek-Kasteel facilitated by Hemporium used a crop known as medick, which is part of the legume family, and according to Interviewee 3, this crop effectively regulated the nitrogen levels in the soil.

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In asking if hemp was a relatively easy crop to cultivate, Interview 1 replied;

Interviewee 1: *"I don't have much experience cultivating on a large scale, but from my understanding, it can pretty much grow anywhere, except for the tropics because it doesn't like 'wet feet' (too much water), and polo regions, as its too cold."*

This does not necessarily indicate that hemp will be a viable crop wherever it is grown, and that the ideal conditions for growing industrial hemp, are in fact, quite specific. Interviewee 1 described these conditions:

Interviewee 1: *"You want an alkaline soil with a pH (potential hydrogen relates to levels of acidity) of between 6 and 7. You want it to be a bit loamy, nicely drained, and you want the right sunlight. Hemp is a Phyto-sensitive plant, meaning sensitive to sunlight, and its roots need to enjoy pleasant conditions."*

According to Interviewee 1, 3, and 5, sunlight is incredibly important in cultivating hemp, and genetical diversity of each hemp variety demands its own unique climate conditions, and agricultural treatment For example, varieties which have been developed in the northern hemisphere countries of the world, such as Finland and Canada, are pre-adapted to very long light-cycles, of up to 18-20 hours of light a day. Hemp varieties, which have been developed in the more southern European countries, such as Spain, Italy, and France, are pre- adapted to shorter light-cycles, and according to Interviewee 1, 3 and 5, these conditions are very important to consider when deciding on the right variety for your context.

Interviewee 1: *"…you get some cultivars that like the tropics given the 12-12 hour light cycles, and then you get cultivars like the Fenola, which is from Finland, and they can do long hour light-cycles, where the sun sets at ten pm and then rises at 2 am in the morning, giving you up to 20 hour light cycles! If you have the right conditions, then hemp will grow really effectively."*

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With regards to the physical labour of farming hemp, Interviewee 1, 3, and 5 stated that cultivation can be done through both human labour, or with machinery, and with little technicality. Once a few seasons have been trialled by a farmer, and the farmer has become accustomed to the protocols and the cultivating techniques of hemp, then the process of producing viable yields becomes increasingly less intensive, according to Interviewee 1. In addition, interviewee 1 also stated that once the hemp plant has become acclimatized, in that it influences the soil type, structure and composition, and is in turn influenced by climatic conditions associated with altitude, latitude, humidity, and temperature, the capacity of your hemp crop to produce high quality yields is enhanced greatly.

According to Interviewee 1, the best regions in South Africa to grow hemp, given what we know of the climatic conditions required for the crops' cultivation, are regions such as the Eastern Cape and KwaZulu-Natal.

Interviewee 1: *"Eastern Cape, and Natal jump-out at me. The Western Cape has a Mediterranean climate, and you need specific cultivars, because of the harsh dry summers in the Western Cape, and semi-arid conditions."*

Interviewee 3 stated dual cropping offered various challenges for the farmer, for example, he noted how one would sacrifice either fibre, or seed production, as you would have to make trade-offs during the cultivation process. This is because of the extreme divergence you find in the protocols relating to hemp fibre, seed, and CBD crops, for example, your plant spacing per square-meter is vastly different between all three kinds of hemp crops. Secondly, how you feed the different crops, in terms of NPK fertilizers, differs between all three crops, as well as how you trim the plants given your purpose of production.

In contrast, Interviewee 6 noted how the ARC would suggest the smallholder farmers practice dual hemp cropping.

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Interviewee 6: *"We are currently suggesting that for the smallholder, a multi-purpose variety is used, so the smallholder has some seed, some fibre, and maybe some CBD."*

Interviewee 3: Returning to the cultivation process, there are agricultural methods which can reduce the agricultural inputs required for hemp agriculture. By trimming certain parts of the plant, for example, you can stimulate growth, or development of specific parts of the plant, such as fibre in the stem, seed development, or development of the flower for CBD production. In addition, a farmer will still have access to the plant's by-products after harvest, which can be used as animal feed, animal bedding, soil mulch, and various other uses, and resultantly reduces farming expenses. For the smallholder, there is still business opportunity in producing building materials from the hurd, for example, and various other streams of income could be generated through a resourceful practice of the hemp crop.

According to Interviewee 1 and 3, hemp will grow anywhere, however, it won't grow effectively without the right conditions. But, once you have reconditioned your soil, through either leaving the green matter on the field, or allowing the plant to physically recondition your soil, Interviewee 3 notes how your fertilizer requirements decrease over time. A really important aspect in sustaining the positive ecological and agricultural benefits induced through hemp agriculture, is practicing hemp as a crop in rotation, which Interviewee 1, 3, 5, and 6 all strongly agree with.

Smallholder rotational cropping is too highly suggested by Interviewee 4. He agrees that, there will be a future for an established hemp industry in South Africa, and space for the development of viable, rotated, smallholder hemp and winter food crop systems, which have either access to irrigation, or experience adequate summer rainfall.

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Interviewee 5: *"After we planted the beans, because we rotated on this quarter hectare, from left to right, or right to left, then we saw that there was a big improvement in the height of the plants every year."*

According to Interviewee 6, the research trial in Robertson is still evaluating the fertilizer requirements of hemp CBD crops, however, they have identified the appropriate nitrogen, phosphorous, and potassium (NPK) fertilizer ratios for industrial hemp fibre.

Interviewee 6: *"This is still something we are working on with the CBD, but right now we are using 150 kg per hectare Nitrogen, between 80 and 100 kg per hectare Phosphorous, and then between 60 and 80 kg per hectare Potassium, but this depends on the stage of the crop, so it changes, and you may not have to apply so much if your crop is growing well. But this is not something finalized yet, and it is actually something we are focusing on, is the fertilizer requirement for viable yields. "*

When asking Interviewee 5 if hemp was a heavy feeder in comparison to tobacco, or cotton, he replied:

Interviewee 5: *"No, hemp is light feeder, but climate is very important, because of the daylength, so you look for 16-17 hours of light a day, and water is very important, because hemp needs around 400-500 mm of water, where tobacco is around 750 mm of water. But three years ago, I brought in the drip irrigation system, and now we save a lot of water, and it's much better than the overheads. And also, because weeds aren't a problem, the drip works much better."*

Interviewee 1 and 5 similarly suggest the use of a drip-irrigation system, as large amounts of water can be saved using these novel systems. However, it's important to recognize that smallholders in South Africa may not have access to such irrigation, or the capital to invest into such systems.

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When asking Interviewee 3 about the success of their research project in Riebeek-Kasteel, and the quality of their harvests, he noted:

Interviewee 3: "…*we were growing quite a few different varieties, some performed better than others, but if we were growing just the Ventura, then I reckon we would've gotten a relatively big yield per hectare, but we could only grow about two hectares, because of the regulation. Some of the varieties didn't work, so we lost out with those varieties in terms of a total yield, but I guess we gained the knowledge of what to grow in our context. Also, because it was a trial to examine the vigour of growth of the different varieties, and to see which kind of crop to practice between fibre, seed and dual cropping. If we had continued for a few more years, and identified the best variety, and the best crop to practice, then I'm pretty sure we would've been producing viable yields."*

4. What are the obstacles that prevent you from upscaling hemp cultivation?

A limitation to the development of the industry was provided by Interviewee 4 and relates to the 'expectation' of the hemp crop, and that many people are driving the establishment of the industry through their belief, that hemp is a 'silver bullet' solution to all problems.

Interviewee 4: *"…everyone has this expectation of hemp to be a silver bullet. It's going to solve all our problems. It's going to solve the soil problems. It's going to save people's health. It's going to build houses. We going to make ropes and all these things with hemp. So, there is this expectation, and I personally don't believe in silver bullets*."

Currently, the legislation surrounding hemp agriculture requires the granting of a permit, and this is currently the most restrictive barrier to developing the agriculture of hemp in South Africa, according to all of the Interviewees. The

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same limitation subsequently limits the employment of smallholder hemp agriculture for socio-economic and agricultural development purposes in South Africa. However, Interviewee 5 and 6 noted that the Western Cape Department of Agriculture plan to initiate smallholder hemp agriculture in the Western Cape, in the year 2020, and so, this limitation may not exist in the near future, significantly for smallholder farmers in the Western Cape.

Interviewee 5: *"I am working with the Department of Agriculture here in the Western Cape, and right now, their rural development for smallholders is focused on vegetables, but from next year, they will start with the hemp, because we first need to establish the processing plants."*

Interviewee 4, an important figure in the Western Cape Department of Agriculture, however noted:

Interviewee 4: *"…the first thing is the permit you need, so we don't pay much attention to this. I think there a few other industries, which are showing more promise economically, because of the growth of these industries. These industries would be the blueberry industry, nuts, and citrus, and things like that. This is where farmers can expand without having a narrow regulatory framework to work within, like hemp, so that is why we spend our time more focused on developing these industries."*

Here, Interviewee 4 emphasizes the Department of Agriculture's own limitation in developing the industry in the Western Cape, as there are predominant industries, which are showing more economic promise, in terms of the growth of such industries. In addition, the Department has limited resources, and so they predominantly focus on industries which are not restrained by narrow regulatory frameworks, such as the framework currently associated with hemp agriculture in South Africa.

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According to Interviewee 4, their beliefs may be unjustified given the reality of establishing a viable hemp industry, which is competitive on international markets, and in consideration of the level of technicality involved in the agriculture and industrial processing of hemp.

With specific regards to smallholder hemp agriculture in South Africa, the greatest barrier is the lack of market support, and lack of support in terms of access to seed, agricultural technology, and skill development surrounding hemp agriculture. Interview 4 noted how the cost of irrigation alone dramatically effects the viability of smallholder agriculture, in the Western Cape specifically.

Interviewee 4: *"We know that the water for hemp irrigation will cost between R8000 and R10 000 per hectare, and the farm can be viable, but now we come back to the smallholder who has access to 1.8/2 hectares of land, and that farmer can make R50 000-R60 000 from the hemp crop, but that income must cover all of the expenses involved in production, so will there be money left over for the farmer? Can we blame a smallholder for buying school supplies for his children, instead of paying for his water bill?"*

Interviewee 5 stated that the hemp crop was a competitive crop, in terms of viability, however, he noted that:

Interviewee 5: *"We started CBD two years ago, and our focus was bringing in local smallholders, as well as getting the most out of the crop itself. So, prices for CBD from overseas were used to value the harvest. But compared to production overseas, South Africa can't compete, because we lack the organizations that can process raw material to establish an industry for production and trade."*

In relation to the market for sustainable materials, Interviewee 2, is a sustainable interior designer, and so she seeks out high quality, sustainably produced materials, such as hemp. She notes how in her opinion, the industry is also growing, and the demand for such materials is being recognised in South Africa.

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However, individuals currently have to source their hemp fabrics from China, as she notes the quality produced in China is extremely competitive, and there is still a lot of development needed in South Africa, before the industrial processing is as effective as it is China.

Interviewee 2: "*I have seen the process of producing textiles using flax, a crop often studied with, or in comparison of hemp in the sustainability literature. I saw this through a project sponsored by Government, in which the Centre for Science and Industrial Research (CSIR) trialled the processing of flax for textiles, as I said, and that process was very intensive, in my perspective. Unfortunately, they didn't survive, and mostly because of the unskilled employees who tended to the processing of the material."*

In terms of the potential economic limitations, I refer to Interviewee 4, who noted how many have promoted the establishment of a hemp industry, based on the current value of hemp-based products on overseas markets, however, this is a mistake, because of what he refers to, as the 'Hog-Cycle'.

Interviewee 4: "*The hog-cycle is a cycle studied in agricultural economics, and it describes a recurring scenario where there is a shortage of pig supply, so government-based agricultural departments incentivize farmers to grow pig, and because supply is low, the price of pig is high. So, many farmers now decide to farm pig, but pigs take three years or more to fully mature, and so after three years of tending pig livestock, the market suddenly becomes saturated as a result of the oversupply, because every farmer has been focusing on pig production for the past three years. Now the farmers real income drops far below his expected profit, and there is an oversupply of pig, until there is a shortage again, and this is the hog-cycle."*

It is in Interviewee 4's opinion that, the 'Hog-Cycle' is most likely occurring throughout many hemp markets around the world, including the market in South Africa. Interviewee 3 shared the same opinion as he said that the market for hemp products is becoming dramatically competitive, and this is evident by the

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significant decrease of the value of CBD isolate from $12 000 to $3000, in a single year. Interviewee 4 was very aware of the CBD market, and the varying demand and supply of the product throughout the world, but he again emphasized the effect of the Hog-Cycle, and how many have too recognized the value of producing hemp CBD.

Interviewee 4: "…*we know that with so many people producing it now, that the value will drop dramatically in the future, as supply increases dramatically. So, if we get to a point in South Africa, where the legal constraints are removed, then farmers will make the calculations on these high prices, and it will lead to an oversupply, and as I said, it's not only a local economic trend, it's a global economic trend."*

In contrast, Interviewee 3 stated:

Interviewee 3: *"…it's a good thing (effect of the 'Hog-Cycle') because it means the market is growing, and as a buyer, you don't have to spend reasonably ludicrous prices for the CBD isolate, and then this feeds into social exclusion, because only 1% of the population can afford these products. But if the market does grow through increases in demand and production, then maybe the price drops significantly, and now costs the same amount as a bottle of vitamins. Now our communities have access to, and can afford extremely helpful medicine, and all you need to do is research the medical benefits of CBD, and you will believe in its potential as I do."*

In terms of establishing a viable hemp-based building material industry in South Africa, Interviewee 4 emphasized how the cost of construction using hemp-based materials, would currently be far greater than the cost of conventional building materials.

Interviewee 4: *"…but what are the costs of building that house? And what is the long-term sustainability of those houses?"*

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One's current access to hemp-based building materials is comparably lower to that of conventional building materials in South Africa, and one would have to import such hemp materials. For this reason, using hemp-based building materials in South Africa is currently far more costly than using conventional materials. Interviewee 4 then referred back to the smallholder farmer in South Africa, and noted:

Interviewee 4: "*We must be very realistic when we think about the smallholder farmer, because we know that such farmers earn an average of between R7000-R60 000 per hectare growing things like vineyards, orchards, and vegetables, but we don't know how much of that net profit goes back into the operation of the farm. Because, if you have a reasonable size holding, and you generate surplus profits, then you can easily invest back into the farm operation continuously, including the investment of monetary capital, human capital, and ecological capital, but if you only have one hectare, and R7000 to cover the cost of yours' and your family's livelihood, then you may not have a choice, but to not invest back into your single hectare.*"

These are very real limitations to establishing viable smallholder hemp agriculture, however, they mostly relate to the challenges facing smallholders who are currently practicing conventional crops.

Interviewee 6 provided some insight into the hemp research trials conducted by the ARC in the Eastern Cape and KwaZulu-Natal regions. For example, he noted how irrigation was still required, and evaluations which were based on comparisons between irrigated hemp and dryland (non-irrigated) hemp, in these regions, revealed that dryland systems only produced half that, of what irrigated hemp systems produce on average. Interviewee 6 emphasized the need for irrigation, even if cultivating in areas where summer rainfall is received. However, he did note:

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Interviewee 6: *“Honestly, I wouldn’t recommend that (dryland hemp cultivation) because of the results we have come up with, but in the higher rainfall areas, where say some smallholders receive more than 400-500 mm of summer rainfall, then those farmers can plant hemp as a dryland crop. What we have found is that the crop requires a minimum of 250-270 mm of water, and that is the minimum. So, if there is a smallholder who receives more than this amount of rainfall during the summer season, then those farmers can practice the dryland hemp crop, but as I said irrigation will double your yields, especially if you do not receive a lot of summer rainfall.”*

Returning to Interviewee 4, who elaborated on the alternative building material industry, and who described the limitations government sponsored housing projects have faced, as a result of the perceptions of the involved communities. For example, he informed me of a social development initiative that aimed to provide housing for a community residing in Dysselsdorp, a small town located near Oudtshoorn, in the Western Cape.

Interviewee 4: “*So, instead of brick and mortar, the contractor used ‘sand- sakke’ (sand-bags). You fill a bag with sand, and you stack it, and then you plaster over it. There was nothing wrong with houses, they were strong, well insulated, durable houses, but when the community found out how the houses had been built, immense problems came about. The community members who received the housing deemed it as inferior and began to ask if government/us were discriminating against them, by building them ‘inferior’ houses*.”

Interviewee 4 agrees that alternative building materials are the future of construction, however, he emphasizes the idea, that individuals and communities who have potentially been marginalized, and largely forgotten in the development South Africa, demand conventional housing, such as the brick and mortar housing.

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Interviewee 4; *"…you must be very aware of the communities you are 'pitching' this idea or project to. And then you must make sure they fully understand what the project entails, otherwise somewhere down the line, you will have big problems. You know if you have someone who lives in 'Constantia' who wants to live in an eco-house to reduce his or her carbon footprint, then it is fine, but I think the chances of receiving the same reaction with an individual, or a community in say Khayelitsha, or Dysselsdorp, are much slimmer. I think right now, we need to focus on meeting the basics for these communities, and if they want brick and mortar, then maybe we should look to that first, before we start looking towards these 'eco-houses'."*

Interviewee 6 stated during our interview that 'things' were changing, in terms of the momentum they had recently gained through the research evaluations. And that, organizations such as the South African Health Products Regulatory Authority (SAHPRA), now wish to remove the permit requirement, so farmers throughout South Africa can legally practice the agriculture without initially receiving a permit. However, one currently requires a permit to cultivate hemp in South Africa, as Interviewee 4 noted, and this permit only grants the recipient farmer permission to cultivate hemp up to two hectares in size.

Interviewee 6: *"One thing I wanted to tell you was that, I had a meeting with SAHPRA (South African Health Products Regulatory Authority), to understand the issues they were facing, and what they told me is that, they want farmers to be planting hemp in the near future without having to apply for a permit. But, for that to be done now, hemp needs to be registered as an approved agriculture, because remember, it was illegal not so long ago. So right now, there are many things that need to be evaluated and finalized, and we cannot even suggest to farmers to grow the hemp seed, because it is not registered yet. In the near future, farmers will not have to go through this expensive process of applying for permits, and they will not be restricted to two hectares, because that is currently the limit to the size of a hemp crop in South Africa."*

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Case-study analysis

The observation protocol identified various factors which related to the agricultural practice utilised at the Robertson hemp research farm. For example, moderate levels of fertilizer application were observed, as well as the use of sustainable irrigation systems, such as drip-irrigation systems. Interviewee 5 informed of the large amounts of water saved through using such systems, and such systems may become necessary for farmers who have low access to irrigation, or who experience low rainfall.

Low soil-based insect biodiversity was observed, and this may be due to the fact that there was no vegetative cover available for such soil-based insects, as harvest was four months prior to observation. Another factor which could have influenced the low soil-based insect biodiversity, was the use of agricultural machinery, such as a tractor, which is used to prepare the soil for sowing of the new seed. In addition, wetlands south of the plot would have attracted soil-based and winged insects over the period in which the soils were bare of vegetative cover. Many birds were observed, however, the surrounding crops consisted of citrus orchards, which could have attracted the bird biodiversity.

Throughout my observations I noted a lack of compost and/or mulch-use between the hemp crop in summer and the winter crops, and the practice Interviewee 3 described, in which the green matter of the hemp crop is left in the field to provide a nutrient return, was also not observed. Subsequently, I built an assumption that both the macronutrients and the organic content present in the soils, would be of low levels.

Soil Analysis

Hazelton and Murphy (2019) provide the following soil analysis scenarios, in which recommendations for fertilizer application and agricultural practice are made. These soil analyses have been provided as a comparison for the Robertson Farm soil analysis, to provide insight into the macronutrient profiles

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found at the hemp research farm. The two scenarios used in this analysis identify low and high categories for levels of macronutrients present in soils, and these scenarios will be used to determine the level of influence of the hemp crop on macronutrient conservation and cycling .

The soil analysis provided below, is an example of an agricultural scenario, in which certain applications must be considered for the re-fertilization of soils, as macronutrients are found to be low (Hazelton and Murphy, 2019).

Table 7: Robertson soil analysis in comparison to scenario of 'low' macronutrients

Macronutrient	Robertson soil analysis	'Low' level scenario of macronutrients (Hazelton and Murphy, 2019)
Phosphorous (P)	31 mg.kg/PPM	2 mg.kg/PPM
Potassium (K)	167.7 mg.kg/PPM	50 mg.kg/PPM
Magnesium (Mg	307.2 mg.kg/PPM	30 mg.kg/PPM
Calcium (Ca)-	4204 mg.kg/PPM	200 mg.kg/PPM

The mg.kg/PPM of phosphorous (P) in the above scenario, which is 2 mg.kg/PPM is considered low by Hazelton and Murphy (2019). According to the soil analysis provided by BemLab, the Robertson Farm demonstrates high levels of Phosphorous (P), at 31 mg.kg/PPM.

The following mineral included in the soil analysis provided by Hazelton and Murphy (2019), is Potassium (K). In the provided analysis, Hazelton and Murphy (2019) deem the level of 50 mg.kg/PPM K as low and is thought to require additional application. However, once again, the soil analysis for the Robertson Farm indicates relatively high levels of Potassium (K), at 167 mg.kg/PPM.

Magnesium (Mg) is an essential mineral found in soil, and scenarios where Mg mg.kg/PPM falls below 30, Hazelton and Murphy (2019) recommend application. However, the Robertson farm soil analysis indicates levels of

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Magnesium (Mg) ten-fold that of the scenario provided by Hazelton and Murphy (2019), at 307.3 mg.kg/PPM.

Calcium (Ca) was found to be extremely high at 4204 mg.kg/PPM in the Robertson Farm soil analysis, in comparison to the scenario provided by Hazelton and Murphy (2019), who suggest 60 mg.kg/PPM is low.

Table 8 indicates the levels of macronutrients associated with the category

Table 8: Robertson soil analysis in comparison to scenario of 'high' macronutrients

Macronutrient	Robertson soil analysis	'High' level scenario of macronutrients (Hazelton and Murphy, 2019)
Phosphorous (P)	31 mg.kg/PPM	87 mg.kg/PPM
Potassium (K)	167.7 mg.kg/PPM	180 mg.kg/PPM
Magnesium (Mg	307.2 mg.kg/PPM	137 mg.kg/PPM
Calcium (Ca)	4204 mg.kg/PPM	1940 mg

Here, a scenario is provided where 'high' rates of soil macronutrients are thought by Hazelton and Murphy (2019) to exist. A level of 87 mg.kg/PPM of Phosphorous (P) is thought by Hazelton and Murphy (2019) to be 'high', while the Robertson Farm analysis indicates moderate levels of Phosphorous at 31 mg.kg/PPM.

According to Hazelton and Murphy (2019) levels of Potassium (K) at 180 mg.kg/PPM are considered 'high' and no addition is required, even for a heavy feeding crop, such as corn. The Robertson Farm soil analysis indicates levels of Potassium (K) at a similarly high rate of 167 mg.kg/PPM. Magnesium (Mg) found in soils at a rate higher than 137 mg.kg/PPM is considered high by Hazelton and Murphy (2019). The Robertson Farm analysis indicates

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magnesium (Mg) levels of more than double this rate, at 307.2 mg.kg/PPM. Calcium (Ca), as mentioned before, was found at very high rates in the Robertson Farm analysis, at 4204 mg.kg/PPM. Hazelton and Murphy (2019) suggest in another provided scenario, where calcium (Ca) was found in levels of up to 4080 mg.kg/PPM, that this scenario still relates to the 'high' category.

This soil analysis has been provided to illustrate the positive amounts of macronutrients present in the Robertson hemp research plot and implies the effective macronutrient conservation and cycling of the hemp crop. The diagram below is provided to describe the prospects for agricultural, ecological, and industrial development, and as 'busy' as it may seem, it is the complexity involved with framing hemp agriculture in South Africa, as a social- ecological system, that it is being identified.

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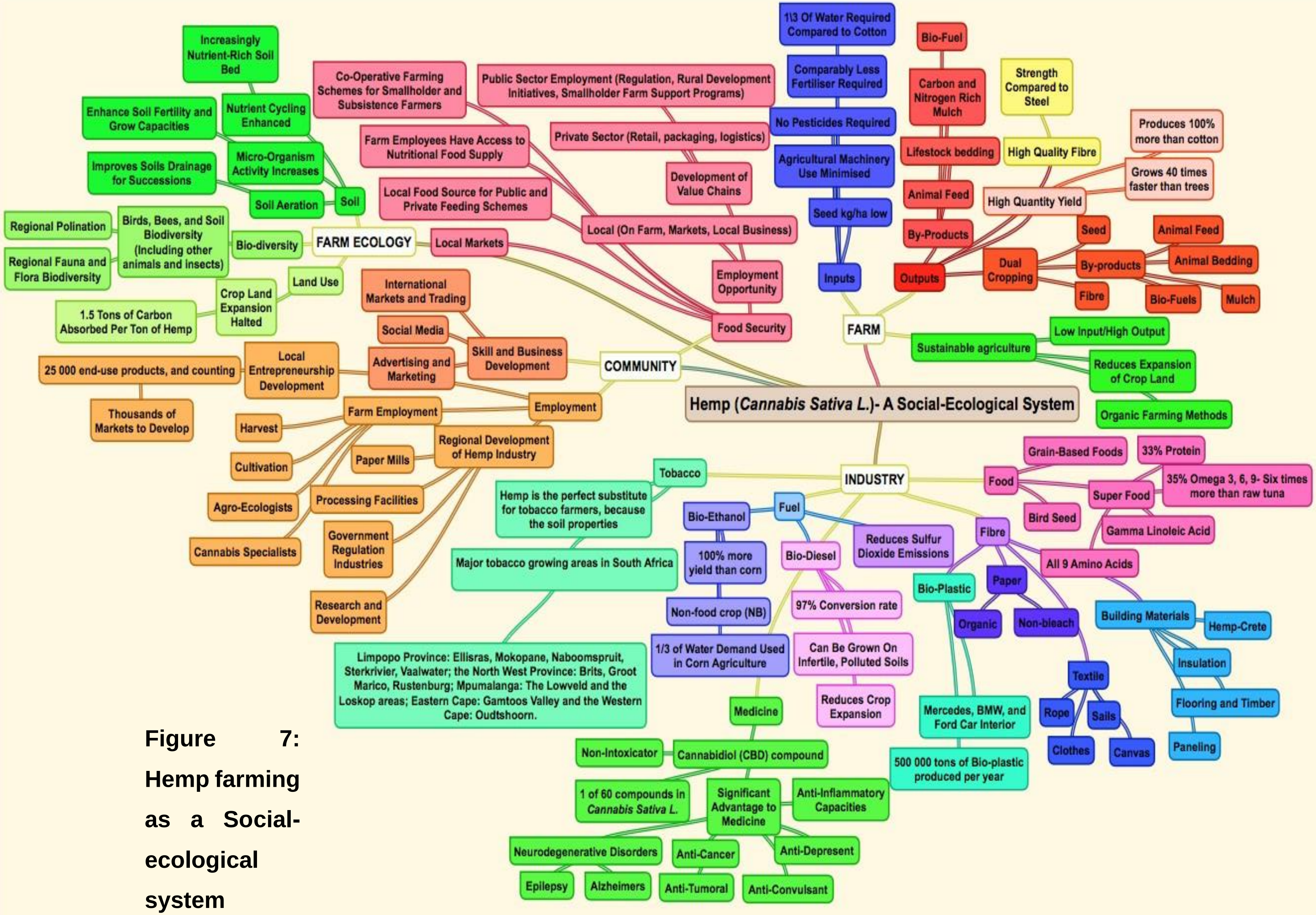

Figure 7: Hemp farming as a Social-ecological system

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Figure 7 provides insight into the various drivers, benefits, and opportunities associated with the developing hemp agriculture and the industry in South Africa. Four predominant dimensions are used to illustrate the holistic impact of developing hemp agriculture, as such impacts are associated with the farm, farm ecology, community, and the industry. On the farm level, agricultural inputs required for viable hemp agriculture are non-intensive, and required irrigation is significantly less in comparison to common smallholder crops, such as cotton. Furthermore, the use of agricultural cultivators can be reduced substantially, as harvesting can be done by hand, given production of hempseed and flower.

Pesticides and herbicides are not required and so smallholder farmers can develop their agricultural systems towards more sustainable forms of agriculture. Through practicing more organic forms of agriculture, smallholder farmers can reintroduce biodiversity into their spaces of production, and as documented previously, the positive ecological impacts of such biodiversity are not only necessary for sustainable agriculture, but highly beneficial for production. The hemp crop has been documented in this study to be a high-yielding crop, in that straw dry matter and seed grain yields surpass that of crops such as corn, maize, sunflower, rape seed, and wheat. Furthermore, according to Interviewee 1 and 3, the crop grows approximately forty-times faster than most trees and harvesting can be done within four and six months. The hemp crop sheds a lot of its biomass throughout its growth stages and leaving this matter in the field is reported to return a nutrient litter, which revitalizes soils of micro and macronutrients. This is an indirect benefit offered to those who practice the crop, and subsequently reduces one’s need for compost or mulch material.

Various by-products are also made available through practicing the hemp crop, for example, the raw materials such as the straw and seed can be used as animal bedding and feed, and the seed can be consumed raw or as a grain by individuals, given the highly nutritious medicinally beneficial properties associated. In addition, the hurd can be used to produce a high quality, bio-

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based concrete, known as hempcrete, given the farmer can access hydrated limestone.

In terms of farm ecology, the hemp taproot effectively aerates soils, and through the length of the taproot, micro and macronutrients are drawn from deep layers of the soil. Through these characteristics, the hemp plant effectively enhances the cycling of micro and macronutrients in the soil and can lead to agricultural scenarios where less fertilizer is required each consecutive season. Through its capacity to aerate, the infiltration of water is enhanced, and thus contributes to restoring soil structure and nutrient flow. Using no pesticides and herbicides during hemp cultivation allows for a reintroduction of biodiversity, significantly in the soil. Soil-based insects similarly enhance the aeration of the soil, while reintroducing microorganism activity allows for increasingly productive soils.

The development of hemp agriculture in South Africa could have potentially regional-scale effects, through reducing the need for additional crop land, as a result of the hemp crop's vigorous growth. In addition, reducing the use of pesticide throughout agricultural landscapes in South Africa, will reduce the negative impacts of salinization, eutrophication, and loss of soil organic matter. Furthermore, introducing hemp agriculture intended for building-materials carbon sequesters during both agricultural production and as bio-based building materials, such as hempcrete and fibre boards.

Developing hemp agriculture in rural communities will allow for a diverse range of socio-economic and industrial opportunities, such as employment on the farm, as well as within the agglomeration of industries possible through such agriculture. Local entrepreneurship could be developed given the diversity of possible end-uses associated with hemp raw material. Skills surrounding the agriculture, industrial processing, and value-adding of hemp-based raw material, could be developed, to provide livelihoods for the many unemployed rural South Africans. In addition, professional careers, such as agroecologists and *Cannabis* specialists could be developed in South Africa to an extent that their skill and

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knowledge is demanded locally and abroad. Furthermore, professional careers associated with post-harvest services, such as ‘cleaning’, could also be developed. As the participants noted previously, processing facilities are already being developed in South Africa, however, there is also space for development of paper mills intended for hemp-based paper production. Developing such industrial facilities will inevitably lead to employment and skill development in South Africa, and because the facilities have to be within a certain distance of the hemp farms, such opportunity will be available to rural communities.

The main industries to be developed as result of hemp agriculture, include hemp-based food, fuel, feed, fibre, and medicine. Fine (2014) notes how hemp fibre can be made into high-quality bio-composites, which can be used in the automobile industry and industries that revolve around producing lightweight, industrial-strength products. The fibre can also be used in the production of high-quality textiles, fabrics, and building materials, all of which are created sustainably, however, the processing technology used in hemp-textile production is currently energy intensive. One of the more promising industries possible through hemp production, is the bioplastic industry, which is a sustainable alternative to the conventional plastic industries, as the plastic is bio-based. Although the hemp-based biofuel industry is recognized as currently unviable, given the inefficiency of the processing technology available, however, both biodiesel and bioethanol can still be produced, and this presents future opportunities for the development of bio-based industries. With regards to bioethanol, only a third of the irrigation required for corn production is required for hemp production, and hemp produces double the yield of corn on average. With regards to biodiesel, hemp displays a 97% conversion rate, and it can be grown on heavily polluted soils.

Lastly, hemp agriculture can meet multiple drivers in rural South Africa, through aiding the development of industries, such as the food and nutrition industry and pharmaceutical industry. Producing hemp seed and flower locally will result in a

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decrease of the price of associated products, such as nutritional supplements and CBD-based pharmaceuticals, which could then become affordable to all South Africans. The positive effects of consuming hemp seed have been largely documented in this study and providing access to such nutrition through development of hemp agriculture and the industry in South Africa is a valuable means of overcoming food and nutrition insecurity in this country.

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Chapter 5: Discussion

Hemp cultivation in South Africa could potentially provide a solution to smallholder farmers, because of the many the social and ecological benefits this crop provides. There are various drivers or motivations that have led to the cultivation of hemp in South Africa, however there are also many challenges that need to be navigated.

Conducting interviews with participants who are involved in the industry, provided a rich understanding of various perspectives of the hemp agriculture and theindustry in South Africa. These interviews suggested that there are many drivers that have led to the establishment of the hemp industry. This includes the wide range of industrial prospects associated with production of hemp-based materials. This a reflection of the hemp crop itself, in that, the hemp crop has been widely documented as a food, feed (livestock-based), fibre, fuel, and medicine crop (Small and Marcus, 2019). Given the context of smallholder farming in South Africa, growing a crop that has the capacity to provide such a diversity of raw materials can be argued as being highly valuable, as some perceive such crops to be the future of farming (Kern, 2002). In addition, rural smallholder communities often have low access to such commodities, and so producing raw material that has value on both the farm and on the markets, is a movement towards developing more sustainable agricultural livelihoods.

Where commodities, such as medicine and nutrition are inaccessible to rural smallholder communities, there is a drive to provide such access, as this scenario represents a social injustice (Govender et al., 2017). The interviews illustrated the positive health benefits of hemp. For example, in 'Mamma Micki's' soup kitchen, adding hemp seed oil to the soup was perceived to aid greatly in individuals being cleared of their tuberculosis. This provides an important contribution to the health- related issues in South Africa. For example, the severe malnutrition of children under the age of five in communities residing in the rural regions of KwaZulu- Natal (Govender *et al.*, 2017), where it is suggested by

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Interviewee 1, 3, 5 and 6 that hemp will effectively grow, due to the well-suited climate in such regions. Leizer *et al.* (2000) notes that the hemp seed contains the full spectrum of essential fatty acids, as well as omega 3 and 6 oils, and also refers to the pharmacological activity identified in their study. The authors identified that the pharmacological activity was related to the presence of linoleic acid (LA), as well as a-linoleic acid (LNA), and the ratio in which they are found. The ratio is reported to stand at 3:1, LA to LNA, and this is thought to be optimal in a nutritional sense (Leizer *et al.*, 2000). The presence of gamma-linoleic acid (GLA), makes hemp seed a 'superior' seed to most, (Leizer *et al.*, 2000; pg., 36). Hemp seeds also contain anticancer, anti-inflammatory, and anti- thrombotic properties induced by the presence of the omega 3 polyunsaturated fatty acids (PUFA). This is an under researched area and there is scope to better understand the holistic benefits of hemp seed consumption. This is especially important for individuals and communities, who have little access to such nutrition and pharmacological products. This is a future space for research.

Hemp cultivation meets multiple drivers experienced by smallholder communities in South Africa, and this becomes especially significant, if we consider the prospects of hempcrete and hemp fibreboards, as well as hemp-based composites (Bedlivá and Isaacs, 2014). Building materials, such as hempcrete and hemp fibreboards, carbon sequester very efficiently, and are very sustainable commodities (Fine, 2014). The sustainability of such commodities stems from the agricultural process of raw hemp material production, which is far less intensive than the process used in conventional building material industries, due to several factors (Fine, 2014). These factors include firstly, growing your raw resources, which carbon sequesters simultaneously, and contributes to the development of bio-based industries (Fine, 2014). Secondly, this agricultural process in particular, is reported to be far more sustainable than most agricultural industries (Van Der Werf, 2004).

Participants suggested that if you grow hemp intended for building materials, then carbon sequestering occurs throughout the agricultural period, as well as the lifetime of the materials. With regards to the processing of hemp raw

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material, one only requires hydrated limestone to produce hempcrete. Fine (2014) echoed this as he found hempcrete to be of very high quality. When one considers the vigorous growth characteristics of hemp, as well as the low-input requirements for its cultivation, it’s logical to argue the possible viability of smallholder hemp farming in South Africa. This is significantly true when we consider the suggestions that smallholders should grow fast-growing crops, to increase the biomatter produced, which should then be used as mulch. Participants felt that you should try leave the green matter in the field after a hemp harvest which ensures a biomatter litter return of nutrients to the soil and is highly suggested for sustainable hemp cultivation.

Participants felt that hemp crop requires a third of the irrigation required in cotton agriculture. Averink (2015) found the same in his study and also found hemp to be a better-quality fabric. In addition, the crop requires no pesticide or herbicide use, and is highly rated by Piotrowski and Carus (2011) as a ‘Biodiversity Friendly’ crop. This relates to ecological drivers, such as developing smallholder agriculture which does not contribute to eutrophication of surrounding ecosystems, destroy biodiversity, or the compromise the health of farmers. On a holistic level, we can note how hemp agriculture could be developed to create agricultural conditions, that promote ecological homeostasis. The hemp crop has also been recognized as an effective weed suppressor, and this crop characteristic may be beneficial to other crops produced in rotation with hemp, as the use of herbicides are decreased.

Based on the irrigation requirements and climatic conditions identified for viable hemp production, regions such as the Eastern Cape and KwaZulu-Natal, where summer rainfall exceeds levels of 400 mm, are highly suggested for smallholder hemp production. Interviewees reinforced this theory, and also noted how the light-cycles in regions such as Addo Elephant National Park, in the Eastern Cape, are similarly well-suited to hemp cultivation. With this in mind, it is suggested that regions which receive over 400 mm of rainfall a year and which experience long light-cycles, are identified, as these regions will be well-suited

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for low-input, high-out hemp agriculture. Given the high rates of solar radiation and photosynthetically active radiation (PAR) received in South Africa, there should be several regions where such low-input, high-output hemp agriculture can be developed (Tsubo and Walker, 2005). In terms of sustainable agriculture, dryland cropping has been found to be far less intensive and relates to zero-tillage farming more closely (Van der Laan *et al.*, 2017).

With regards to the case-study and soil-sample analysis, it was discovered through the report provided by Bemlab, that high amounts of macronutrients were present in the soil of the hemp research trial plot in Robertson, in the Western Cape. Due to the fact that the soil sample was collected post-harvest, when during this time, soils should be at their most depleted rates, I had anticipated low rates of macronutrients, such as Potassium (K), Phosphorous (P), Magnesium (Mg), and Calcium (Ca), as well as low rates of organic matter (OM). However, the results showed that high levels of potassium (K), phosphorous (P), magnesium (mg), calcium (Ca) were present throughout the soil profile. In addition, the samples were collected at the same depth, of 75 cm, and this is was done to produce an indication of whether the hemp crop was enhancing the nutrient cycle, throughout multiple layers of the soil at the Robertson research plot.

The soil analysis highlighted key findings through a comparison with different soil analysis scenarios, provided by Hazelton and Murphy (2019), in which the authors also provided application recommendations for the various scenarios. Through the comparative analysis, the levels of macronutrients, such as Phosphorous (P), Potassium (K), Magnesium (Mg), and Calcium (Ca) present in the soil of the Robertson farm plot, which were all in the ‘high’ category, according to the authors Hazelton and Murphy (2019). In addition, recommendations made by Purdue University (2015), suggested calcium (Ca) levels remain below levels of 6000 PPM, and the Robertson farm soil analysis indicates calcium (Ca) levels of 4204 PPM. These comparisons indicates that

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the hemp crop is effectively conserving and cycling macronutrients in the soil of the Robertson plot, and this is a highly valuable characteristic of a crop.

Low organic matter content was identified through the Robertson Farm soil analysis, and this was especially true when compared with the scenarios provided by Hazelton and Murphy (2019). However, the observation protocol analysis correlated with soil analysis, in the sense that no use of mulch or composting was observed at the Robertson research farm, and so, it was noted that the soil analysis may indicate low organic matter content. This was then validated through the soil analysis, which did in fact indicate low levels of organic matter, at 0.34%. Furthermore, it was recognised that regions in southern Africa are home to soils inherently of poor quality, and it was assumed that low organic matter content would limit the viability of hemp production in South Africa. Preliminary observations (see photographs 1 and 2) indicated the 2018/2019 Robertson research trial harvest was not limited by low organic matter, as these hemp plants were thriving according to Interviewee 5, farm manager of the Robertson trial farm.

Photograph 1 and 2: Bentley Sederstroom (Right) farm manager of the Robertson research farm pre-harvest of 2018/2019.

There are of course many barriers to establishing a viable industry in South Africa, such as the narrow regulatory framework, and permit requirement

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associated with hemp agriculture (Troskie, 2019). In addition, the research trials conducted in South Africa by organizations such as the ARC and The Hemporium, have been restricted to two hectares of hemp production, and so the effect of economies of scale cannot be evaluated (Budden, 2019). Although this may not affect smallholder farming of hemp, due to the generally small size of smallholder plots in South Africa, defining the impact of up-scaling industrial hemp production may be the driver required for motivating development of an appropriate regulatory framework for hemp agriculture in South Africa. This driver may motivate organizations such as the South African Health Products Regulatory Authority (SAHPRA), who are currently considering the removal of a required permit for hemp agriculture in South Africa.

Interviewees that participated in this study and prominent figures in the ARC, noted how the Western Cape Department of Agriculture currently plans to initiate the development of smallholder hemp agriculture in the Western Cape. Furthermore, they emphasized the objective of involving local smallholders in the Robertson hemp research trial, and so organizations such as the ARC and the Western Cape Department of Agriculture have also recognised the potential of employing smallholder hemp agriculture. The South African Broadcasting Corporation (SABC) hosted an interview with individuals such as Dr Thandeka Kunene just after the decriminalization of cannabis use and cultivation in South Africa, in September 2018 (SABC Digital, 2018). She stated that hemp agriculture in South Africa will bring along an ‘industrial, agricultural, and ecological revolution’ (SABC Digital, 2018). After which, she stated this kind of revolution would centre around rotational cropping systems, which include industrial hemp (SABC Digital, 2018).

It’s interesting to note that rotational cropping is highly suggested by the interviewees as well as key figures in the South African hemp industry, such as Dr Thandeka Kunene. It was found through the interview analysis that rotational cropping offers hemp farmers in South Africa various benefits, for example, if a nitrogen fixing, winter food-crop is placed in rotation with hemp, then one’s soils

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are replenished of nitrogen, and the farmer has an additional revenue stream. Producing food-crops throughout winter connects to overcoming food and nutrition insecurity, which is predominant in the rural regions of South Africa (Govender *et al.*, 2017). I refer once again to Dr Thandeka Kunene, who stated that industrial hemp agriculture could be used as a powerful mechanism for overcoming poverty in South Africa (SABC Digital, 2018).

Lastly, it was also argued by Interviewee 4 that the 'Hog-Cycle', an economic trend, in which many invest into an economically promising agriculture, ultimately decreasing the value of that industry over the time, is a trend currently occurring within both the local and international hemp industries. This economic trend is thought to be responsible for the dramatic decreases in value of CBD isolate, from $12 000 to $3 000 per kilogram, however, Interviewee 3 perceives this a positive driver. If the 'Hog-Cycle' is in fact affecting the hemp industry locally and abroad, then it means the industry is developing, and if South Africa continues to develop an established hemp industry, then the price of hemp- based products will resultantly decrease, and subsequently become far more affordable for South African citizens. With regards to hemp seed, which has been identified as a highly nutritious and medicinally beneficial product in this study, providing access to such a product, either through retail or directly through cultivation, is a valuable means of enhancing food and nutrition security in South Africa.

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Chapter 6: Conclusion

The main findings of this study include the comparable sustainability of hemp agricultural industries, which offer numerous opportunities for developing bio-based industries, food and nutrition-based industries, cosmetic industries, and pharmaceutical industries in South Africa. More importantly, by using the social-ecological systems lens, this study identified the various social and ecological benefits induced through smallholder hemp cultivation. These benefits are a result of practicing a low-input, high-output crop, that is rotated amongst nitrogen-fixing winter crops. As the hemp crop requires no pesticide, or herbicide, and requires significantly less irrigation, especially when using sustainable irrigation systems, such as the drip-irrigation system, and requires relatively low amounts of fertilizer, this crop has thus been identified in this study, as potentially viable in the South African smallholder context.

Smallholder farmers residing in regions of South Africa, such as the Eastern Cape and KwaZulu-Natal, where levels of summer rainfall exceed 400 mm, and light-cycles are long, experience ideal climatic conditions for low-input, high-output hemp agriculture. If hemp agriculture is to be established and developed in South Africa, it is highly suggested smallholders in these regions are identified and introduced to sustainable hemp agriculture. This crop can provide multidimensional benefits and opportunities, that relate to both the social and ecological drivers experienced by smallholder households and communities in rural South Africa. This is especially true when one rotates their hemp crop, as two different crops are produced annually, which can include two food-crops, or one food and one non-food, meeting local food security, and providing the smallholder with multiple revenue streams. Raw hemp materials can be processed on the smallholder farm, such as hemp seed oil, which can be pressed and bottled on-farm, and high-quality building materials can also be produced on farm, given the smallholder has access to hydrated limestone. If a hemp industry is established in the future of South Africa, there will be a demand

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for hemp-based building materials, and thus space for market inclusion of smallholder hemp production, and this applies to the agglomeration of industries possible through the development of hemp agriculture.

In term of the ecological benefits of hemp agriculture identified in this study, it was determined through the soil and case-study analysis, that the hemp crop does not necessarily fixate nitrogen in the soil, however, it may enhance the nutrient cycling of macronutrients in the soil. This was determined based on the high levels of macronutrients, such as Potassium (K: 167.7 mg.kg/PPM), Phosphorous (P: 31 mg.kg/PPM), Magnesium (Mg: 307.2 mg.kg/PPM), and Calcium (Ca: 4204 mg.kg/PPM) found to be present in the soil. These amounts represent a high scenario for soils which should at the time of analysis, be of a low amount. Based on the comparative soil analysis, these levels of macronutrients were deemed as high, and Calcium was not found in excess of 6000 mg.kg/PPM. Due to the fact that soil sample collection was done specifically at a time when soils are thought to be at their most depleted, the results indicated that the hemp crop had been efficiently conserving the macronutrients in the soil. A space for future research exists in determining whether the hemp plant’s taproot does in fact enhance the nutrient cycling.

Lastly, the case-study analysis highlighted a key factor identified through the observation protocol, which related to the lack of use of agricultural practices, such as composting or mulching. These practices are also closely related to the practice, in which the hemp green matter is left in the field, to provide a nutrient litter return, which was also not an observed practice at the Robertson research farm. Indicators of such, include low rates of observed soil-based insects, the observed use of agricultural machinery, such as tractors, and the low organic content indicated in the soil analysis. Here lies another space for future research, where the impact of agricultural practices such as composting and mulching on hemp cultivation, as well as the practice described, could be quantified and evaluated.

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Appendices

Appendix A: Electronic Consent Forms

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Dear Mr Sederstroom

My name is Brett Rightford, a student at the Sustainable Institute, in affiliation with the Economic and Management Sciences Department of Stellenbosch University, and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my master's degree in Sustainable Development.

Please take some time to read the information presented here, which will explain the details of this project.

Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

You were approached as a possible participant because of your experience and knowledge with regards to hemp (Cannabis Sativa L.) cultivation and drivers in South Africa, and your participation could greatly benefit the purpose and aims of this study. The purpose of this study is to identify the environmental benefits of hemp agriculture in South Africa. Secondly, to identify the possible social benefits of hemp cultivation, specifically for those in the KwaZulu-Natal and Eastern Cape provinces, and to investigate whether hemp farming could provide a better livelihood for rural communities based in these areas. Lastly, this study aims at exploring the sustainability of hemp agriculture, focusing on the emerging commercial-scale farms.

The interview will take approximately 30 minutes to complete and will contain a combination of questions covering the environmental and social benefits of hemp farming, the farming methods used, and notable characteristics of the agricultural process. There will be no payment for participation, however, any transport costs due to travelling will be compensated for, and food and beverage will be provided. Interviews can be done via cell phone or internet calls.

RIGHTS OF RESEARCH PARTICIPANTS:

You have the right to decline answering any questions and you can exit the survey at any tim reason. You are not waiving any legal claims, rights or remedies because of your participation i If you have questions regarding your rights as a research participant, contact M [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Stellenbosch University https://scholar.sun.ac.za

Your information and response to the survey will be protected by encrypted passwords, and any contribution will only be published with your consent. Interviews will be voice-recorded for accuracy of transcription, and only my Supervisor, Dr Kristi Maciejewski, and I will have access to this data.

If you have any questions or concerns about the research, please feel free to contact the researcher Brett Warwick Bevan Rightford; 0817946653, brightford@gmail.com, and/or the Supervisor, Dr Kristi Maciejewski; krismacski@gmail.com.

To save a copy of this text, either download via email and save to folder, or copy paste-text and transfer to alternative word document. The file is convertible to PDF format.

I confirm that I have read and understood the information provided for the current study.	YES	
	☒	☐
I agree to take part in this survey.	YES	NO
	☒	☐

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Stellenbosch University https://scholar.sun.ac.za

Dear Mr Mokgohloak

My name is Brett Rightford, a student at the Sustainable Institute, in affiliation with the Economic and Management Sciences Department of Stellenbosch University, and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my master's degree in Sustainable Development.

Please take some time to read the information presented here, which will explain the details of this project.

Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

You were approached as a possible participant because of your experience and knowledge with regards to hemp (Cannabis Sativa L.) cultivation and drivers in South Africa, and your participation could greatly benefit the purpose and aims of this study. The purpose of this study is to identify the environmental benefits of hemp agriculture in South Africa. Secondly, to identify the possible social benefits of hemp cultivation, specifically for those in the KwaZulu-Natal and Eastern Cape provinces, and to investigate whether hemp farming could provide a better livelihood for rural communities based in these areas. Lastly, this study aims at exploring the sustainability of hemp agriculture, focusing on the emerging commercial-scale farms.

The interview will take approximately 30 minutes to complete and will contain a combination of questions covering the environmental and social benefits of hemp farming, the farming methods used, and notable characteristics of the agricultural process. There will be no payment for participation, however, any transport costs due to travelling will be compensated for, and food and beverage will be provided. Interviews can be done via cell phone or internet calls.

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Your information and response to the survey will be protected by encrypted passwords, and any contribution will only be published with your consent. Interviews will be voice-recorded for accuracy of transcription, and only my Supervisor, Dr Kristi Maciejewski, and I will have access to this data.

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If you have any questions or concerns about the research, please feel free to contact the researcher Brett Warwick Bevan Rightford; 0817946653, brightford@gmail.com, and/or the Supervisor, Dr Kristi Maciejewski; krismacski@gmail.com.

To save a copy of this text, either download via email and save to folder, or copy paste-text and transfer to alternative word document. The file is convertible to PDF format.

I confirm that I have read and understood the information provided for the current study.	YES	
	☒	☐
I agree to take part in this survey.	YES	NO
	☒	☐

CONSENT TO PARTICIPATE IN RESEARCH

Dear Mr Van Rooyen

My name is Brett Rightford, a student at the Sustainable Institute, in affiliation with the Economic and Management Sciences Department of Stellenbosch University, and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my master's degree in Sustainable Development.

Stellenbosch University https://scholar.sun.ac.za

Please take some time to read the information presented here, which will explain the details of this project.

Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

You were approached as a possible participant because of your experience and knowledge with regards to hemp (Cannabis Sativa L.) cultivation and drivers in South Africa, and your participation could greatly benefit the purpose and aims of this study. The purpose of this study is to identify the environmental benefits of hemp agriculture in South Africa. Secondly, to identify the possible social benefits of hemp cultivation, specifically for those in the KwaZulu-Natal and Eastern Cape provinces, and to investigate whether hemp farming could provide a better livelihood for rural communities based in these areas. Lastly, this study aims at exploring the sustainability of hemp agriculture, focusing on the emerging commercial-scale farms.

The interview will take approximately 30 minutes to complete and will contain a combination of questions covering the environmental and social benefits of hemp farming, the farming methods used, and notable characteristics of the agricultural process. There will be no payment for participation, however, any transport costs due to travelling will be compensated for, and food and beverage will be provided. Interviews can be done via cell phone or internet calls.

RIGHTS OF RESEARCH PARTICIPANTS:

You have the right to decline answering any questions and you can exit the survey at any time reason. You are not waiving any legal claims, rights or remedies because of your participation in t If you have questions regarding your rights as a research participant, contact Mı [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Your information and response to the survey will be protected by encrypted passwords, and any contribution will only be published with your consent. Interviews will be voice-recorded for accuracy of transcription, and only my Supervisor, Dr Kristi Maciejewski, and I will have access to this data.

If you have any questions or concerns about the research, please feel free to contact the researcher Brett Warwick Bevan Rightford; 0817946653, brightford@gmail.com, and/or the Supervisor, Dr Kristi Maciejewski; krismacski@gmail.com.

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To save a copy of this text, either download via email and save to folder, or copy paste-text and transfer to alternative word document. The file is convertible to PDF format.

	YES	
I confirm that I have read and understood the information provided for the current study.	☒	☐
	YES	NO
I agree to take part in this survey.	☒	☐

Stellenbosch University https://scholar.sun.ac.za

Dear Camilla and Tony Budden

My name is Brett Rightford, a student at the Sustainable Institute, in affiliation with the Economic and Management Sciences Department of Stellenbosch University, and I would like to invite you to take part in a survey, the results of which will contribute to a research project in order to complete my master's degree in Sustainable Development.

Please take some time to read the information presented here, which will explain the details of this project.

Your participation is entirely voluntary, and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

You were approached as a possible participant because of your experience and knowledge with regards to hemp (Cannabis Sativa L.) cultivation and drivers in South Africa, and your participation could greatly benefit the purpose and aims of this study. The purpose of this study is to identify the environmental benefits of hemp agriculture in South Africa. Secondly, to identify the possible social benefits of hemp cultivation, specifically for those in the KwaZulu-Natal and Eastern Cape provinces, and to investigate whether hemp farming could provide a better livelihood for rural communities based in these areas. Lastly, this study aims at exploring the sustainability of hemp agriculture, focusing on the emerging commercial-scale farms.

The interview will take approximately 45 minutes to complete and will contain a combination of questions covering the environmental and social benefits of hemp farming, the farming methods used, and notable characteristics of the agricultural process. There will be no payment for participation, however, any transport costs due to travelling will be compensated for, and food and beverage will be provided. Interviews can be done via cell phone or internet calls.

RIGHTS OF RESEARCH PARTICIPANTS:

You have the right to decline answering any questions and you can exit the survey at any tim reason. You are not waiving any legal claims, rights or remedies because of your participation i If you have questions regarding your rights as a research participant, contact M [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Stellenbosch University https://scholar.sun.ac.za

Your information and response to the survey will be protected by encrypted passwords, and any contribution will only be published with your consent. Interviews will be voice-recorded for accuracy of transcription, and only my Supervisor, Dr Kristi Maciejewski, and I will have access to this data.

If you have any questions or concerns about the research, please feel free to contact the researcher Brett Warwick Bevan Rightford; 0817946653, brightford@gmail.com, and/or the Supervisor, Dr Kristi Maciejewski; krismacski@gmail.com.

To save a copy of this text, either download via email and save to folder, or copy paste-text and transfer to alternative word document. The file is convertible to PDF format.

	YES	NO
I confirm that I have read and understood the information provided for the current study	☒	☐
I agree to take part in this survey.	☒	☐

Signed by Camila Budden on behalf of Tony and Camila Budden

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Appendix B: DESC Approval

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Departmental Ethics Screening Committee Report

Ethics application reference number: **SPLSID-2019 – 9412 – B RIGHTFORD**

1) Please argue the ethical risks that are related to the research proposal submitted for review, together with the DESC's proposals on how to avoid or mitigate these ethical risks. *(Rows may be added if space below is limited)*

Any ethical issues that need to be highlighted?	What must/could be done to minimise the ethical risk?
None	

2) Please mark with an X the applicable risk classification assessed for this project:

Minimal risk	
Low risk	x
Medium risk	
High risk	

For definitions of the above risk levels, please consult the DESC guidelines on the DRD-website: DESC Guidelines

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Appendix C: Original Soil Analysis From Bemlab

bemlab
www.bemlab.co.za
part of PathCare group of companies

sanas
T0654

16 Van der Berg Crescent
Gant's Centre
Strand

P O Box 684
Somerset Mall,
7137

Tel. (021) 853-1490
Fax (021) 853-1423

E-Mail admin@bemlab.co.za

Vat Reg. Nr. 4200161414

Certificate of Analyses

Report No.: **GR24902**

Brett Rightford
5 Dixton Road
Observatory

Soil Analyses Report

Date received: 01/10/2019
Date tested: 11/10/2019

Orchard	Lab. No.	Depth (cm)	Soil	**pH (KCl)**	Resist. (Ohm)	**H^+ (cmol/kg)**	Stone (Vol %)	P (mg/kg) **Olsen**	**Bray II**	K mg/kg	Ex. cations (cmol(+)/kg) **Na**	**K**	**Ca**	**Mg**	**Cu** mg/kg	**Zn**	**Mn**	**B**	Fe mg/kg	**C** %	S (Am.acet mg/kg
Robertson ARC Farm	24902		Loam	**7.8**	560		3	**6**	**31**	167	**0.41**	**0.43**	**21.02**	**2.56**	**2.0**	**2.2**	**22.9**	**0.60**	4	**0.20**	20.2

Olsen P will only be reported if the pH >= 7.0 or specifically requested for analyses.
See analyses interpretation for assistance with interpreting the report and relevance of each analyses.
Values in **bold** are ISO 17025 accredited methods.

Statement: The reported results may be applied only to samples received. Any recommendations included with this report are based on the assumption that the samples were representative of the block from which they were taken.
Samples received in good condition.

Base Saturation

Orchard	Lab. No.	Na %	K %	Ca %	Mg %	T-Value cmol/kg	Acid Sat. %
Robertson ARC Farm	24902	1.66	1.75	86.12	10.47	24.41	0.00

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