# Exploring the social-ecological drivers and impacts of the blueberry boom in South Africa

by

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## Declaration

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## Summary

Since 2015 there has been a rapid increase in blueberry production within South Africa, with most of the industry focused on exporting the fresh fruit. Despite the recent emergence of the blueberry industry, it contributed over R1 billion in export revenue in 2020. To date, little research has been conducted to understand what is driving the growth in the blueberry industry, what impacts the industry has on the local environment and community and how vulnerable the industry is to external shocks. Because the industry is focused on exports, this study explored the social-ecological drivers and impacts of the industry using the telecoupling framework. The thesis consists of 5 Chapters. Chapter 1 introduces the blueberry industry in South Africa, while Chapter 2 introduces the telecoupling framework, which allows for a combination of qualitative and quantitative methods. In Chapter 3, I analysed interview data with individuals in the blueberry industry using a deductive thematic analysis approach as a qualitative method to investigate the drivers of increasing adoption of blueberry production in South Africa. In Chapter 4, I used a life cycle assessment (LCA) as a quantitative method to analyse the social-ecological impact of the blueberry industry in South Africa. Chapter 5 provides a set of conclusions.

Chapter 3 identified seven key drivers that contributed to the adoption of blueberry farming. These drivers included (1) the perceived profitability due to the high market value of blueberries on the export market, (2) access to start-up capital as loans or investment to afford the high start-up cost of blueberry production, (3) the growing market with an increasing number of blueberry consumers in richer countries, (4) existing or early relationships with exporting companies to gain access to proprietary genetic material, production advice and connections with buyers, (5) the fact that the harvest season of blueberries falls outside the harvest season of other valuable export fruits like citrus, apples and pears which allows farmers to diversify their operation and income, (6) employment opportunities in a mixed operation that allows farmers to keep their best seasonal staff employed throughout the year, and (7) the low risk of theft associated with blueberries due to their delicate harvesting method.

Concerns were raised about the industry's vulnerability to external shocks, but recently observed socio-political and environmental shocks appeared to have had limited impacts to date. National and global lockdown restrictions as a result of the COVID-19 pandemic (2020 – 2021) had minor impacts on farm operations because agricultural production was considered to be an essential service under lockdown regulations. Additionally, the initial hard lockdown in South Africa (23 March 2020 – 1 May 2020) occurred outside the blueberry harvest season that starts in July, which gave farmers time to prepare. The blueberry industry already complied with many of the COVID-19 hygiene requirements, because blueberries are picked by hand and receive no post-harvest treatment before consumption.

Climatic shocks including droughts, early-season rain and hail have had the biggest impacts on the industry. Recent droughts in various areas of South Africa (between 2015 – 2018) forced some farmers to reduce their operation size and to truck water in at an additional cost to meet irrigation needs for blueberries. Abnormal early season rain and hail storms during the picking season in the northern parts of South Africa damaged the fruits and resulted in large yield losses. After civil unrest in two major economic hubs of South Africa (July 2021), Durban and Gauteng, a concern for blueberry farmers surfaced, even though this occurred outside the harvest and export window and had no direct impact on the industry. Concerns were related to the unpredictability of civil unrest shocks and are associated with the time sensitivity of exporting blueberries due to their short shelf life.

The study also found that despite the age of the industry it is already experiencing many changes and facing numerous challenges. The first is increasing competition in South Africa as a result of the industry's rapid expansion as well as increasing competition from other southern hemisphere countries. The increasing supply of blueberries allows buyers to obtain more competitive prices which impacts the profitability of the industry. This is combined with other existing challenges in South Africa, like the increasing cost of essential inputs (fertiliser, fuel, electricity) and inefficient and degrading port infrastructure that often result in export delays, has reduced the profitability of the industry over the last few years. South Africa's current social and economic climate makes it harder for farmers to acquire loans or investments which limits their ability to adopt new technology or expand their blueberry operations. Despite the challenges of the industry, the farmers are, however, optimistic about the future of the industry and are looking at solutions such as precision agriculture, to address some of these challenges.

Chapter 4 used a LCA to explore the social-ecological impacts of the blueberry industry in South Africa and found a variety of impacts. A hectare of blueberries produced in South Africa had the potential to damage (1) population health through increasing the number of years lost to ill-health (measured as disability-adjusted life years), (2) the economy, by increasing the cost required to extract resources in the future (measured as surplus resource cost), and (3) the environment, by contributing to biodiversity loss(measured using species loss potential per annum). The production phase of blueberries contributed to more than 90 per cent of the impact, driven by the use of protective structures (plastic tunnels), fertiliser, agrochemicals and fuel, while packaging and storage were responsible for the remaining impact. While the same pattern was observed for apples, grapes, oranges, pears and strawberries, blueberries had the lowest impact on human health, the economy and the environment in comparison.

In, I also reflected on the potential of the LCA ReCiPe 2016 method (Huijbregts et al., 2017) as a tool to quantify the social-ecological impact of a system within the telecoupling framework. In the end, I found that LCA impacts are restricted to selected environmental indicators that are converted to high level social, economic and ecological impacts. Therefore the LCA alone does not account for all of the impacts and should be combined with other methods such as surveys and interviews to identify the broader impacts. I addressed this limitation of the LCA by including other impacts of the industry that emerged during interviews were discussed. These impacts include both negative and positive impacts such as creating job opportunities, adding to the tourism industry, and decreasing the aesthetic appeal of scenic tourist routes.

In conclusion, the blueberry industry is a well-suited case study to explore the social-ecological drivers and impacts of a commercial superfood industry in Africa using the telecoupling framework, as the production is mainly driven by consumers in faraway places (Europe and Asia).

## Opsomming

Sedert 2015 was daar 'n vinnige toename in bloubessieproduksie binne Suid-Afrika, met die meeste van die bedryf wat op die uitvoer van die vars vrugte fokus. Ten spyte van die onlangse ontstaan van die bloubessiebedryf, het dit meer as R1 miljard se uitvoerinkomste in 2020 bygedra. Tot op hede is min navorsing gedoen om te verstaan wat die groei in die bloubessiebedryf aandryf, watter impak die bedryf op die plaaslike omgewing en gemeenskap kan hê en hoe kwesbaar die bedryf is vir eksterne skokke. Omdat die bedryf op uitvoere fokus, het hierdie studie die sosiale en ekologiese dryfvere en impakte van die bedryf te ondersoek binne die raamwerk wat die sosio-ekonomiese en omgewings interaksies tussen afstand geskeide menslike en natuurlike sisteme gebruik . Die tesis bestaan uit 5 hoofstukke. Hoofstuk 1 stel die bloubessiebedryf in Suid-Afrika bekend, terwyl Hoofstuk 2 die raamwerk bekend stel wat gebruik word om die sosio-ekonomiese en omgewings interaksies tussen afstand geskeide menslike en natuurlike sisteme te studeer, wat dit moontlik maak om ‘n kombinasie van kwalitatiewe en kwantitatiewe metodes te gebruik onder een raamwerk. In Hoofstuk 3 het ek 'n deduktiewe tematiese ontledingsbenadering gebruik as 'n kwalitatiewe metode om onderhouddata met individue in die bloubessiebedryf te ontleed en die dryfvere van die toenemende opname van bloubessieproduksie te ondersoek. In Hoofstuk 4 het ek 'n lewensiklus assessering as 'n kwantitatiewe metode gebruik om die sosiale en ekologiese impak van die bloubessiebedryf in Suid-Afrika te ontleed. Hoofstuk 5 verskaf 'n stel gevolgtrekkings.

Hoofstuk 3 het sewe belangrike dryfvere geïdentifiseer wat bygedra het tot die opname van bloubessieboerdery. Die dryfvere het die volgende ingesluit (1) die waargenome winsgewendheid inverband met die hoë markwaarde van bloubessies op die uitvoermark, (2) toegang tot aanvangskapitaal as lenings of belegging om die hoë aanvangskoste van bloubessieproduksie te dek, (3) uitbreiding van die markruimte met 'n toenemende aantal bloubessieverbruikers in ryker lande, (4) bestaande of vroeë verhoudings met uitvoermaatskappye om toegang te kry tot hulle genetiese eiendom, produksie advies en verhoudings met kopers, (5) die oesseisoen van bloubessies val buite die oesseisoen van ander waardevolle uitvoer vrugte soos sitrus, appels en pere wat boere dan toelaat om hulle bedryf en inkomste te diversifiseer, (6) dit skep werksgeleenthede wat boere in staat stel om hul beste seisoenale personeel deur die jaar in diens te hou, en (7) die lae risiko van diefstal wat geassosieer word met bloubessies as gevolg van hulle delikate oesmetode.

Kommer is uitgespreek oor die bedryf se kwesbaarheid vir eksterne skokke, maar onlangs sosio-politieke en omgewings skokke het tot dusver beperkte impakte gehad. Nasionale en wêreldwye inperkings as gevolg van die COVID-19-pandemie (2020 – 2021) het ‘n lae impak op die plaasbedrywighede gehad omdat landbouproduksie as 'n noodsaaklike diens beskou was tudens die inperkings. Boonop het die aanvanklike streng inperking in Suid-Afrika (23 Maart 2020 – 1 Mei 2020)

buite die bloubessie-oesseisoen plaasgevind wat gewoonlik in Julie begin, dit het boere tyd gegee om voor te berei. Die bloubessiebedryf het reeds aan baie van die COVID-19-higiënevereistes voldoen, omdat bloubessies met die hand gepluk word en geen na-oesbehandeling ondergaan nie voor dit die verbruik bereik. Klimaats skokke insluitend droogtes, vroeë seisoen reën en hael het die grootste impak op die bedryf gehad. Onlangse droogtes het sommige boere gedwing om hulle produksie area te verminder en om water teen 'n addisionele koste in te bring met trokke om aan besproeiingsbehoeftes vir bloubessies te voldoen. Abnormale vroeë seisoen reën en haelstorms gedurende die pluk seisoen in die noordelike dele van Suid-Afrika het die vrugte beskadig en het tot groot opbrengsverliese gelei. Na burgerlike onrus in twee groot ekonomiese kern areas van Suid-Afrika (Julie 2021), Durban en Gauteng, het dit ‘n kommer geword vir bloubessieboere, al het dit buite die oes- en uitvoervenster plaasgevind en geen direkte impak op die bedryf gehad nie. Dis is ‘n bekommer as gevolg van die onvoorspelbaarheid van burgerlike onrus skokke en die sensitiew tydsberekening om bloubessies uit te voer as gevolg van hulle kort raklewe.

Die studie het ook gevind dat ten spyte van die ouderdom van die bedryf dit reeds baie veranderinge ervaar en talle uitdagings in die gesig staar. Die eerste is toenemende mededinging in Suid-Afrika as gevolg van die bedryf se vinnige uitbreiding sowel as toenemende mededinging van ander suidelike halfrond-lande. Die toenemende volume bloubessies stel kopers in staat om meer mededingende pryse te bied aan verskaffers wat die winsgewendheid van die bedryf beïnvloed. Dit in kombinasie met ander bestaande uitdagings in Suid-Afrika, soos die toenemende koste van noodsaaklike insette (kunsmis, brandstof, elektrisiteit) en ondoeltreffende bestuur en agteruitgaan van hawe-infrastruktuur wat dikwels tot uitvoervertragings lei, het die winsgewendheid van die bedryf oor die laaste paar jaar verminder. Suid-Afrika se huidige sosiale en ekonomiese klimaat maak dit moeiliker vir boere om lenings of beleggings te verkry wat hulle vermoë beperk om nuwe tegnologie te bekostig of hulle bloubessiebedrywighede uit te brei. Ten spyte van die uitdagings van die bedryf, is die boere egter optimisties oor die toekoms van die bedryf en kyk hulle na oplossings soos die meer akuraat gebruik van insette om van hierdie uitdagings aantespreek.

Hoofstuk 4 het ek 'n lewensiklus assessering gebruik om die sosiale en ekologiese impakte van die bloubessiebedryf in Suid-Afrika te identifiseer en het daarmee ‘n verskeidenheid van impakte gevind. 'n Hektaar bloubessies wat in Suid-Afrika geproduseer is, het die potensiaal gehad om (1) die bevolkingsgesondheid te beskadig deur byte dra tot die aantal jare wat weens swak gesondheid verloor word (gemeet as ongeskiktheids-aangepaste lewensjare), (2) die ekonomie te beskadig as gevolg van die toenemende koste wat nodig is om hulpbronne in die toekoms te onttrek (gemeet as surplus hulpbron koste), en (3) die omgewing te beskadig deur by te dra tot biodiversiteits verliese (gemeet met gebruik van spesie verlies potensiaal per jaar). Die produksiefase van bloubessies het bygedra tot meer as 90 persent van die impak, dit kan toegeskryf word aan die gebruik van beskermenings strukture (plastiek tonnels), kunsmis, landbouchemikalieë en brandstof, terwyl verpakking en stoor stappe verantwoordelik was vir die minderheid van die impakte. Dieselfde patroon waargeneem is vir appels, druiwe, lemoene, pere en aarbeie, maar bloubessies het die laagste impak gehad op menslike gesondheid, die ekonomie en die omgewing in vergelyking.

In Hoofstuk 4 het ek ook die potensiaal van die lewensiklus assessering ReCiPe 2016-metode (Huijbregts et al., 2017) oorweeg as 'n instrument om die sosiale en ekologiese impak te kwantifiseer onder ‘n raamwerk wat die sosio-ekonomiese en omgewings interaksies tussen afstand geskeide menslike en natuurlike sisteme in ag neem. Op die ou end het ek gevind dat 'n lewensiklus assessering impakte beperk is tot geselekteerde omgewingsaanwysers wat omgeskakel word na saamgevoegde sosiale, ekonomiese en ekologiese impakte. Die lewensiklus assessering alleen neem dus nie al die impakte in ag nie en moet gekombineer word met ander metodes soos opnames en onderhoude om die breër impakte te identifiseer. Ek het hierdie beperking van die lewensiklus assessering aangespreek deur ander impakte van die industrie wat na vore gekom het tydens onderhoude in te sluit. Hierdie impakte sluit beide negatiewe en positiewe impakte in soos die skepping van werksgeleenthede, byvoeging tot die toerismebedryf en die vermindering van die estetiese aantreklikheid van natturskone toeristeroetes.

Ten slotte, die bloubessiebedryf is 'n geskikte gevallestudie om die sosiale en ekologiese dryfvere en impakte van 'n kommersiële supervoedselbedryf in Afrika te ondersoek deur die raamwerk te grbruik wat die sosio-ekonomiese en omgewings interaksies tussen afstand geskeide menslike en natuurlike sisteme in ag neem, aangesien die produksie hoofsaaklik deur verbruikers in ver plekke (Europa en Asië) gedryf word.

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## Preface

This MSc thesis consists of five chapters. The first chapter is an introduction to the focus subject of the thesis, and it aims to provide background information about the connectedness, drivers, and impact of the agricultural industry with a specific focus on cash crops and the blueberry industry. The second chapter is a literature review that explores the existing application and outcomes of the telecoupling framework, which is the conceptual framework used to guide the thesis. The third and fourth chapters have been compiled as individual manuscripts for publication in peer-reviewed journals and as a result, there is some repetition between these two chapters. The last chapter is a conclusion of the overall outcome of the thesis.

Chapter 1: Introduction

Chapter 2: Literature review

The application of the telecoupling framework to date

Chapter 3: Research chapter

Identifying the drivers of the expanding blueberry industry in South Africa

Chapter 4: Research chapter

The impact of blueberry production destined for export in South Africa

Chapter 5: Conclusion

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# Chapter 1: Introduction

## 1.1 Social-ecological agriculture systems

Historically social and ecological components were studied separately in their specific, independent disciplines such as ecology and social sciences. However, the recent acknowledgement that social and ecological challenges are fundamentally interconnected has resulted in the development of social-ecological systems thinking (Folke, 2006; Schoon and van der Leeuw, 2015). This concept considers human societies and the natural environments as interconnected and dependent systems (Biggs et al., 2021a; Folke et al., 2016). A good example of a social-ecological system is the global food system where there is continuous interaction between the human and the natural systems from the point of production to disposal (Allen and Prosperi, 2016). This global system is at the core of human and environmental health and contributes to economies and cultural belonging but food production, distribution and consumption also lead to substantial environmental impacts that often translate into social and economic impacts (Allen and Prosperi, 2016; Oteros-Rozas et al., 2019). Understanding food systems as dynamic and complex social-ecological systems that are affected by a complex array of social and environmental factors (Rivera-Ferre et al., 2013) can help inform strategies to build a more sustainable food system that ensures the future health of the human population and the environment (Oteros-Rozas et al., 2019).

A substantial expansion has been observed in the agriculture industry over the past few decades. Some persistent drivers of the expansion have been rapid human population growth and consumption patterns that have led to an increase in the volume of food required from the agriculture industry. Historically, two key strategies have been used to meet growing global demand: (1) expansion – to increase agricultural area and (2) intensification – to increase yield using technology advances such as fertilizer, chemicals, or genetically modified crops (Hazell and Wood, 2008; Mayer et al., 2015; Zabel et al., 2019). Today it is more common to observe intensification rather than agricultural expansion, due to the declining availability of arable land. Expansion does still occur, but is more commonly observed in poorer countries where intensification is underutilised (Binswanger-Mkhize and Savastano, 2017; Zhang et al., 2021). In such countries, agricultural expansion is responsible for the largest share of land-use changes, converting natural habitats to multi-crop, monocrop, or closed greenhouse systems (Zhang et al., 2021). Agriculture also negatively impacts biodiversity and can reduce the resilience of an environment, making it more vulnerable to shocks like floods and pests (Crist et al., 2017). Although intensification can reduce the extent of land required to produce food, excessive inputs like fertilisers and pesticides can leach into the environment and cause damage to environmental, economic and social systems (Crist et al., 2017; Zabel et al., 2019). Both strategies to expand or intensify agriculture, therefore, have negative social-ecological impacts (Crist et al., 2017; Hazell and Wood, 2008; Mayer et al., 2015; Zabel et al., 2019).

In the past, agricultural land-use change and intensification were driven by local factors such as local demand and climate (Alexander et al., 2015; Meyfroidt et al., 2013). These locally-driven impacts created local feedbacks which made the impacts more apparent to local consumers (Albornoz and Glückler, 2020; Breves and Schramm, 2021; Campbell, 2009; Garrett and Rueda, 2019; Sundkvist et al., 2005) and meant it was simpler to identify those responsible for the impact. However, the growing global food trade network means that increases in agricultural production today are driven by a diverse range of factors such as distant demand (Carlson et al., 2018; Friis and Nielsen, 2017; Garrett and Rueda, 2019; Gasparri et al., 2016; Llopis et al., 2020; Sandström, 2018), increase in disposable income (consumers can purchase more items and are not restricted by local production limitations) (Alexander et al., 2015; Alexsandrowicz et al., 2019; Garrett and Rueda, 2019; Laroche et al., 2020), competitive export prices (consumer destinations that are willing to pay the most) (Baird and Fox, 2015; Castilla et al., 2016; de Castro et al., 2022; Ibarrola-Rivas et al., 2020), production input costs (producer destination that can sell products for the lowest amount) (Castilla et al., 2016; de Castro et al., 2022; Friis and Nielsen, 2017; Garrett and Rueda, 2019; Matlhola and Chen, 2020; Rulli et al., 2019), external investment (Garrett and Rueda, 2019), policies (Baird and Fox, 2015), diet trends (Crenna et al., 2019; Garrett and Rueda, 2019; Gebisa Etea et al., 2017; Pan et al., 2012), etc. These factors make it harder to identify which drivers are responsible for agricultural changes, who receives social-ecological benefits, and who should be held responsible for the negative impacts of the industry (FAO, 2017; Jayne et al., 2017; Jellason et al., 2021). An example of the complex connections between consumer choice, disposable income, trendy diets, and social and environmental impacts is a global diet shift, whereby an increase in income is correlated with an increase in the consumption of meat, dairy, refined grains, fruits, and vegetables (Godfray et al., 2018). The shift in the type of food consumed and preparation method (fast food to meet urbanising workforce demand) has increased the number of individuals that suffer from non-communicable diseases (lifestyle conditions) such as obesity, type II diabetes, and cancer (Fanzo, 2016; Godfray et al., 2018; Pan et al., 2012; Popkin et al., 2012). Another impact observed from this processed carbohydrates and meat-heavy diet shift is the increase in environmental impacts such as a significant contribution to greenhouse gasses and natural habitat destruction as a result of the food types that are consumed (Clark et al., 2019).

## 1.2 Diet changes and superfoods

Health and environmental problems have contributed to a recent diet shift amongst some groups of consumers to increase the consumption of healthy foods such as vegetables and fruits, and decrease the consumption of meats and processed food, to improve human population health and reduce the environmental impacts (Azzurra et al., 2019; Ranganathan et al., 2015). This in turn has given rise to the superfood industry. This industry includes a collection of food items that are known for their high nutrient levels and are thought to have exceptional health benefits (Howatson and Madison, 2017; Loyer, 2016; Meyerding et al., 2018). Superfoods are perceived as food items that are produced in a natural way, grown in pristine, exotic, and remote environments, and are often associated with indigenous people and practices that are considered to be more natural and less harmful to the environment (Loyer, 2016; Meyerding et al., 2018). Therefore, these superfoods are not only perceived as being good for human health but also good for the environment. The superfood industry, as it is known today, started taking off in the late 1980s and early 1990s and has grown to be a multimillion-dollar industry that experienced 15% growth over five years (Loyer, 2016). One of the leading superfood groups are superfruits which are exotic fruit with a high nutritional value such as goji berries, pomegranates, blueberries, noni, etc. Demand for superfruits has increased as a result of trendy diets, like the raw and paleo diets, as well as a general trend for healthier diets in more affluent communities to reduce the incidence of non-communicable diseases (Loyer, 2016; Magrach and Sanz, 2020; Meyerding et al., 2018). However, branding a food item as a superfood immediately increases the price and targets these items towards richer, developed countries. For example, Quinoa, once the staple food of Bolivian people, was labelled as a superfood around 2013 and experienced a dramatic increase in production (area under cultivation tripled since 2000) and price (value per ton has doubled since 2000) (Loyer, 2016). The price increase of quinoa made it inaccessible to local people which forced them to change their traditional diets and they started treating it solely as a cash crop for the export market (Loyer, 2016).

The uptake of cash crops (a crop that is produced solely for its economic value) like superfruits has continuously been identified in developing countries as a means for local, small-scale farmers to increase their income (Alemu and Alemu, 2017; Anderson, 2002; Llopis et al., 2020; Lukanu et al., 2009). These crops are grown predominantly for export to richer countries to obtain the highest prices and improve a farmer's income and food security. Previous research showed that developed countries remain the dominant producers and exporters of staple crops such as wheat, rice, and maize that are essential to provide food security in many developing countries, whereas developing countries have replaced a share of their staple grains with cash crops (Amrouk et al., 2019; Garrett and Rueda, 2019). This reveals that the developing countries are taking on the risk of cash crop production to export these crops to developed countries, while the developed countries maintain the bulk share of the low-risk staple crops (Amrouk et al., 2019).

## 1.3 Origin of blueberries

Blueberries, considered to be a superfruit, originate from North America where indigenous peoples consumed the berries as part of their diet during winter months when other food was scarce (Hummer, 2013). They used the flowers, leaves, and roots of the blueberry plant as a medicine to purify blood, induce labour and as a diuretic. European explorers discovered these valuable berries as early as 1615 and the cultivation of blueberries started in the late 1800s (Hummer, 2013; Kalt and Dufour, 1997). Cultivation expanded to the European continent in the 1930s and blueberries became an ingredient in pharmaceutical and food supplement products for blood vessel disorder and eye conditions (Kalt et al., 1997). Global blueberry production grew from 35 000 tonnes in 1961 to 820 000 tonnes in 2019 (Figure 1.1A). The industry started to experience exponential growth in the 1990s and is still growing each year. Blueberries were first classified as a superfood in 1997 because of their high levels of antioxidants (Bierend, 2019; Hummer, 2013; Tarkanyi et al., 2019), after which the industry started experiencing a boom in volume (Figure 1.1B) and value (Figure 1.1C) of exports. The price per ton of blueberries has been increasing since the 1960s, however, the sharpest increase is also observed after 1997 (Figure 1.1D). This shows that labelling blueberries as a superfood had an enormous impact on the demand and the price of blueberries, especially for consumption in places far from the origin of production. To date, North America and Europe are responsible for 88% of the total blueberry consumption and the United States of America and Canada have been the dominant producers of blueberries (Figure 1.2). However, their share of the global production has slowly started to decrease while other producers like Peru have seen a significant increase in their share of production (Figure 1.2).

## 1.4 The blueberry industry

The high prices obtained for blueberries since 1997 have been an incentive for many farmers across the world to cultivate them, with many farmers in the southern hemisphere cultivating blueberries to fulfil market demand in the northern hemisphere's winter season (Strik, 2007). Blueberry production can now be found on six continents, with Chile becoming one of the largest blueberry producers due to the favourable climatic and soil conditions (Agosin and Bravo-Ortega, 2012; Hancock et al., 2018) while, Peru, another South American country, is fast becoming a major competitor after the rapid expansion of production in recent years (Cosio Borda et al., 2018). The South American and global expansion of blueberries has been facilitated by creating more tolerant varieties that can grow in different climatic conditions (Jimenez et al., 2005; Rowland et al., 2012; Walworth et al., 2012). The majority of blueberries produced in Chile are exported to the USA during the winter season in the northern hemisphere when fresh blueberries are harder to find but remain in high demand (Agosin and Bravo-Ortega, 2012). Similar to the USA, Europe and other northern hemisphere countries don't have sufficient blueberries to meet the demand during their winter season, and as the demand for blueberries grows it opens up the market for more southern hemisphere-based producers, whose harvests occur in the northern off-season.

South Africa is currently the largest producer of blueberries in southern Africa and is experiencing continuous exponential growth in blueberry production. The total blueberry production in South Africa almost tripled over three years starting from 4 127 tons in 2016 to 11 306 tons in 2018 (Figure 3). The land area used to produce blueberries almost doubled over the same period from 1 068 ha to 2 000 ha using a mixture of natural, fallow and cultivated land for the expansion (WCDoA and BerriesZA, 2019). The Western Cape province currently accounts for the majority of the area under blueberry production (60%) followed by Limpopo (15%), North West (10%), and Gauteng (8%) (BerriesZA, 2019). The largest share is produced under shade netting (43%) and in open-air (40%), whereas the remaining 17% are grown in tunnels. Two planting methods differentiate the operations, with 71% of all blueberries grown in soil and the remaining 29% grown in substrate such as peat and coir (WCDoA and BerriesZA, 2019).

The bulk of blueberries cultivated in South Africa is exported to the United Kingdom and Europe to ensure the availability of fresh blueberries when their local blueberries are out of season. In South Africa 72% of blueberries produced between 2013 and 2018 were exported as fresh fruit, 12% were locally sold as fresh fruit, and the rest were processed (WCDoA and BerriesZA, 2019). An overwhelming majority was initially exported to the United Kingdom however, the South African market has diversified over time by exporting to other countries such as the Netherlands, Germany, Ireland, Malaysia, Spain, United Arab Emirates, Saudi Arabia, and others (SARS, 2021). Nevertheless, in 2018 the United Kingdom still accounted for more than half of the fresh blueberry exports from South Africa.

The rapid blueberry expansion is likely driven by the high market value of blueberries on the export market, but the high start-up costs could be a potential hurdle for farmers. This is contradictory to other superfood and cash crop booms that have small start-up costs and allow small-scale farmers to participate in the market (Alemu and Alemu, 2017; Aravindakshan et al., 2020; Bitama et al., 2020; Friis and Nielsen, 2017; Llopis et al., 2020; Lukanu et al., 2009; Zaehringer et al., 2020).

Blueberry production in South Africa is therefore a particularly interesting case to understand the drivers and impacts of a young expanding superfood industry. This thesis explores the social-ecological drivers of blueberry expansion in South Africa as well as the social-ecological impacts of this expansion.

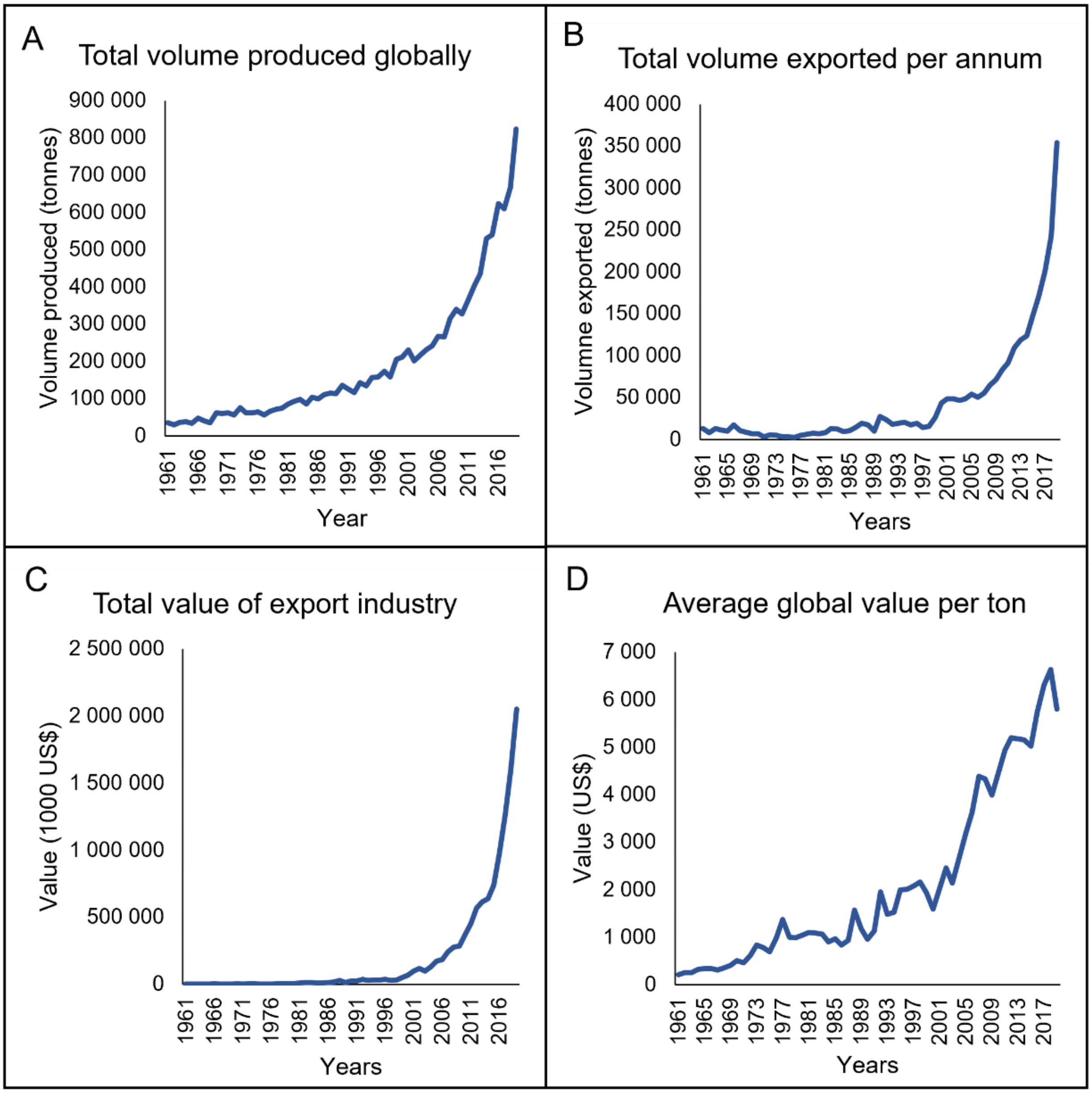


Figure 1.1 An overview of the global blueberry industry between 1961 and 2019 A) total volume of blueberries produced globally per annum in tonnes, B) total volume of blueberries exported per annum in tonnes, C) the total value of the blueberry export industry in US dollars and D) the average global value per ton of blueberries over time (FAO, 2020).

## 1.5 Conceptual framework

The telecoupling framework (Liu et al., 2013) is often used to study social-ecological systems and has been applied to study the trade of agricultural commodities between social-ecological systems at various scales (Ibarrola-Rivas et al., 2020; Liu et al., 2013; Llopis et al., 2020; Matlhola and Chen, 2020; Paitan and Verburg, 2019; Sun et al., 2018). The telecoupling framework is used to understand the socioeconomic and environmental connections between coupled human and natural systems that are geographically or politically separated. This framework has five main components (1) the systems (sending/receiving/spillover), (2) flows (connection between systems), (3) causes (drivers of the telecoupling), (4) agents (influence and partake in the telecoupling), and (5) effects (the impacts of the telecoupling). The sections are described in more detail in Chapter 2.

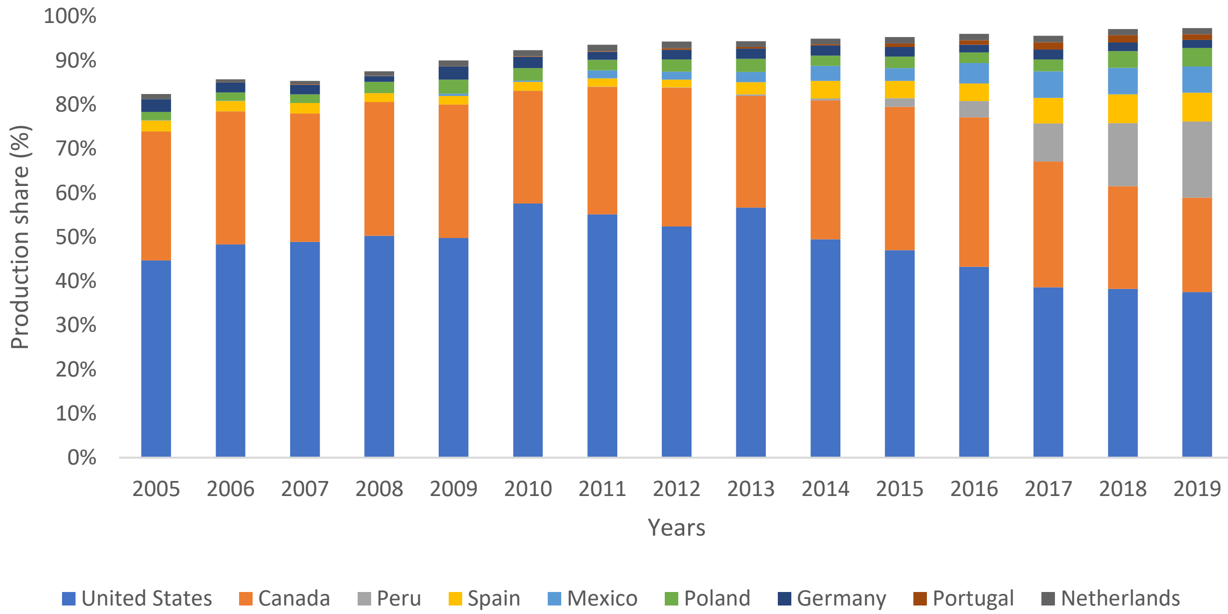


Figure 1.2 The production share of blueberries for the top ten production countries as a share of the total global production between 2005 and 2019 (Tridge)

This is one of a few conceptual frameworks that have been developed in the social-ecological systems field to facilitate a holistic view by combining methods that answer specific questions into a broader framework (Biggs et al., 2021b). These conceptual frameworks exist in the social-ecological systems field because methods from numerous fields have been adopted to study the drivers, flow and impact of trade (Deutch et al., 2021). Despite the growing recognition of the importance of understanding social-ecological connections, most methods separate social and environmental aspects (Guerry et al., 2015). The more commonly used methods focus on individual aspects, for example, the ‘environmental footprint’ approach focuses on a selection of environmental indicators but disregards economic and social impacts (Wiedmann and Lenzen, 2018). Similarly, approaches such as the Multidimensional Poverty Index focus on social dimensions and neglect the environment (Alkire et al., 2014). Used in isolation, these approaches do not allow for a holistic or comprehensive understanding of social-ecological system dynamics (Biggs et al., 2021a; Deutsch and Troell, 2021; Schlüter et al., 2021).

Therefore to overcome these problems this thesis focused on two aspects of the telecoupling framework, the causes and effects of blueberry trade, using the framework as a conceptual framework that recognises both social and ecological dimensions of systems. In this thesis, I explored the causes (drivers) behind the blueberry telecoupling across both systems and I explored the effects (impacts) of the telecoupling in South Africa to understand how distant demand can impact the local community and environment. Here I combine complementary methods (life cycle assessments (LCA) and deductive thematic analysis) throughout this thesis to allow a well-rounded view of the drivers and impacts that the blueberry industry has in a social-ecological system context (Figure 1.3). A qualitative approach was adopted in Chapter 3 in an effort to understand what influenced the decision-makers (farmers and farm managers) to adopt blueberry farming. The data were analysed through a deductive thematic analysis to highlight which agents and causes of the two telecoupled systems are responsible for the expansion of the industry (Figure 1.3). Whereas a combination of a quantitative (life cycle analysis) and qualitative (deductive thematic analysis) approach was used in Chapter 4 to understand the effects of the expanding industry on the economy, people and the environment in South Africa (Figure 1.3). To determine the impacts in the sending system the ReCiPe 2016 LCA method was used because it measures the impact across the economy, human health and environment but these results were supplemented with additional impacts that emerged from the interviews in Chapter 3.

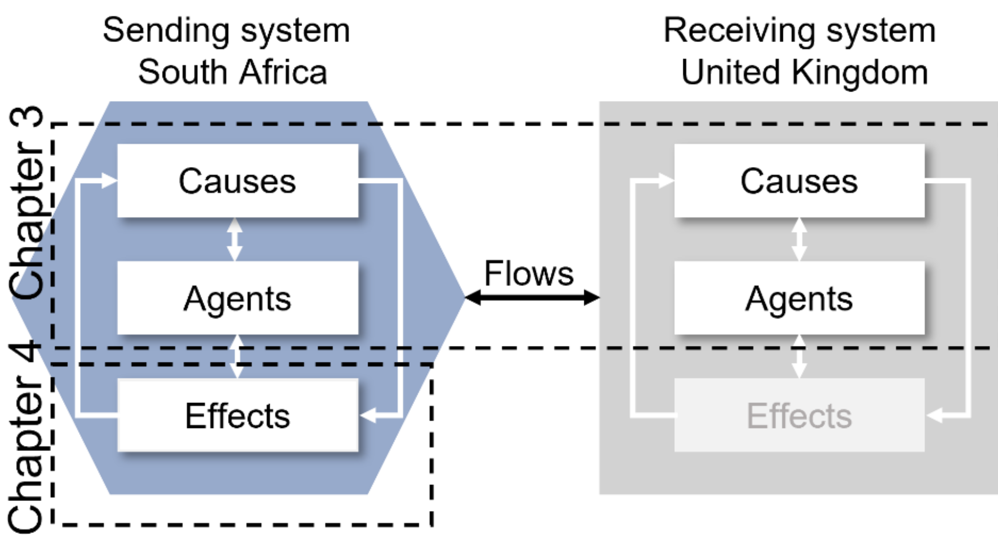


Figure 1.3 Overview of the areas of the telecoupling framework that is explored in the blueberry case study of South Africa per chapter. The thesis focuses on the aspects within the dotted lines. The telecoupling framework distinguishes between sending systems (from where a particular flow originates), receiving systems (to where the flow is directed), and spillover systems (not visualised but referring to systems that experience externalities as a result of exchanges between sending and receiving systems. Chapter 3 focuses on farmers and their motivations to grow blueberries in South Africa (sending system), and the consumers in the UK as a cause for demand (receiving system). Chapter 4 assesses the impacts of blueberries in South Africa as a result.

## 1.6 Problem statement

To study the sustainability of systems in an increasingly connected world, both socioeconomic and environmental factors must be considered (Reyers et al. 2018). Telecoupling has become a useful framework to analyse the impacts of material and non-material flows in terms of a variety of social-ecological factors. However, to date, few studies have used the telecoupling framework to study the impacts on systems in Africa, with the majority of studies focusing on the larger trading countries such as China, USA, Europe, and some South American countries (Figure 1.2) (Carlson et al., 2017; da Silva et al., 2021; Fang et al., 2016; Kapsar et al., 2019; Liu et al., 2015; Sandström, 2018; Sun et al., 2018; Wang et al., 2021; Xiong et al., 2021; Yang et al., 2018; Yao et al., 2018; Zhang et al., 2018). Most trade studies also focus on large agricultural commodities, with smaller cash crops being understudied. Furthermore, when cash crops are studied, the focus has been on adoption by small scale farmers (Baird and Fox, 2015; Carlson et al., 2018; da Silva et al., 2021; Friis and Nielsen, 2017; Godar and Gardner, 2019; Liu et al., 2015; Llopis et al., 2020; Sun et al., 2018; Yang et al., 2018).

South Africa's expanding blueberry industry is an ideal case study because it both fills the gap on telecoupling research by applying the framework to a cash crop in Africa, and by focusing on commercial farmers as opposed to small-scale farmers which is the norm. Furthermore, only a small number of telecoupling studies considered how an external shock can hinder or facilitate the socioeconomic and environmental impacts of a coupling (Carlson et al., 2017; Zhang et al., 2018). Considering COVID-19 in this study provides an opportunity for this research to observe how vulnerable the coupled system is to a particular external shock.

This thesis, therefore, address three gaps: (1) the geographical gap in telecoupling studies in Africa, (2) the drivers and impact of cash crop adoption by commercial farmers in a telecoupled system, and (3) the vulnerability of coupled systems to external shocks. This offers an opportunity to expand on existing telecoupling research, as well as address new ideas under the telecoupling framework.

## 1.7 Research aim and objectives

The overall aim of this thesis is to explore the drivers and impacts of the expanding blueberry trade in South Africa using the telecoupling framework. This will be achieved through five specific objectives:

1. Conduct a literature review on the application of the telecoupling framework to date. (Chapter 2)
2. Identify the social and ecological drivers behind the expanding blueberry industry in South Africa. (Chapter 3)
3. Understand the multidimensional impacts that the expanding blueberry industry has in South Africa. (Chapter 4)
4. Understand how a shock such as COVID-19 can impact the growth of the industry. (Chapter 3)
5. Explore the usefulness of a life cycle assessment methodology that includes environmental, social, and economic measures. (Chapter 4)

# Chapter 2: The telecoupling framework - A review

## 2.1 Introduction

The world is becoming increasingly connected not only through trade and knowledge transfers but also through the transfer of environmental and socioeconomic impacts such as pollution (Matlhola & Chen 2020; Ibarrola-Rivas et al. 2020; Fang et al. 2016 ) and land dispossession (Llopis et al. 2020; Chignell & Laituri 2016; Boillat et al. 2018; Baird & Fox 2015). These connections also emphasize the interconnectedness between social and ecological systems (Berkes & Folke 1998). Despite the growing understanding of these connections, many decisions and policies still assume separate and unconnected social and environmental goals (Guerry et al. 2015). This poses significant challenges for global sustainable development (Hovis et al., 2021; Zeng et al., 2021).

Social-ecological systems offer a useful lens for linking social and ecological systems in a way that recognizes their intertwined nature, focusing particularly on the interactions and feedbacks between the social and ecological aspects of these systems (Reyers et al. 2018). This social-ecological connectivity operates at various scales from local to global, as well as across scales; local connections and interactions are no longer the only factors that influence the development of social-ecological systems in a particular place. For example, demand for materials from faraway places, driven by an increase in global connectivity and shifting global demand, now influences distant places through the trade of agricultural commodities (Liu et al. 2018; Wilting et al. 2017; Lenzen et al. 2012). It is therefore important to improve the understanding of potential direct and indirect social-ecological impacts to achieve sustainable development at local as well as global scales.

A recently developed framework in the social-ecological systems field, telecoupling, address both socioeconomic and environmental aspects of these systems while considering connections that span across large distances. Telecoupling was first introduced by Lui and colleagues (2013), with the intent to use the framework to understand the complex drivers and impacts of interaction between distant coupled human and natural systems. This chapter describes the telecoupling framework and reviews the socioeconomic and environmental drivers and impacts of telecoupled systems from recent publications with a specific focus on trade. The review will also consider dynamics between developed and developing countries by observing the displacement of socioeconomic and environmental impacts as a result of telecouplings. This review is used to illustrate the appropriateness of the telecoupling framework to analyse socioeconomic and environmental drivers and impacts of distant connections as motivation for the application of this framework to investigating the blueberry industry in South Africa.

## 2.2 The telecoupling framework

The telecoupling framework was constructed by combining elements from work on teleconnections which primarily focuses on biophysical flows (Wallace and Gutzler, 1981) and globalisation which primarily focuses on social flows (Sassen, 1998) to create an umbrella framework that can be used to holistically analyse socioeconomic and environmental factors of trade, resource and knowledge flows. Individually these two frameworks only allowed for the analysis of environmental (teleconnections) and socioeconomic (globalisation) impacts of connection between distant places in land systems research. The telecoupling framework is considered well-suited to social-ecological systems research because it connects a diverse range of distant socioeconomic and environmental interactions and the impacts they have (Liu et al., 2019).

The main components of the telecoupling framework are systems, flows, agents, causes and effects (Liu et al. 2013) (Figure 2.1). The framework requires the initial identification of telecoupled systems - i.e. the sending systems that export materials, information etc., and receiving systems, that imports materials or information from the sending system. It also requires the identification of the flow (what is being sent and received) that is responsible for the coupling, such as the flow of goods, knowledge, people, energy or capital.

The systems are mainly predefined coupled human and natural systems that are geographically separated (e.g. country A/country B, or city/rural area) or politically different (e.g. local municipality A/local municipality B or nature reserve/agricultural sector). Systems can exist at a local scale (e.g., municipalities), national/country scale, or global scale. Although systems are classified as either sending or receiving systems in a coupled environment, these can be used interchangeably depending on the flow and direction being analysed (i.e., if there is a two-way connection, a system can be both a sending and a receiving system). An example of a two-way connection is the livestock product trade between Brazil and China where Brazil is the sending system when considering the flow of livestock products but Brazil can also be the receiving system when considering the flow of payment for livestock products (Chung & Liu 2019).

The flow between two systems can also impact other systems, and this particular type of flow is called a spillover - a concept similar to externalities in economics (Liu et al., 2018; Pascual et al., 2017). Flows can also create feedback between sending, receiving and spillover systems that can either hinder or enhance the coupling or potentially even change the flow over time. The flows between sending, receiving and spillover systems are a result of environmental, socioeconomic or other drivers such as demand for goods, which are defined as the cause for a telecoupling. These flows are facilitated by agents which are decision making entities (humans, animals or plants) that can further impact the strength of the telecoupling. The identified flows will most likely have positive or negative socioeconomic and environmental effects within sending, receiving and spillover systems. These effects can be advanced or hindered by changes in the underlying cause of the telecoupling, feedback loops or agents involved in the coupling (Liu et al. 2013).

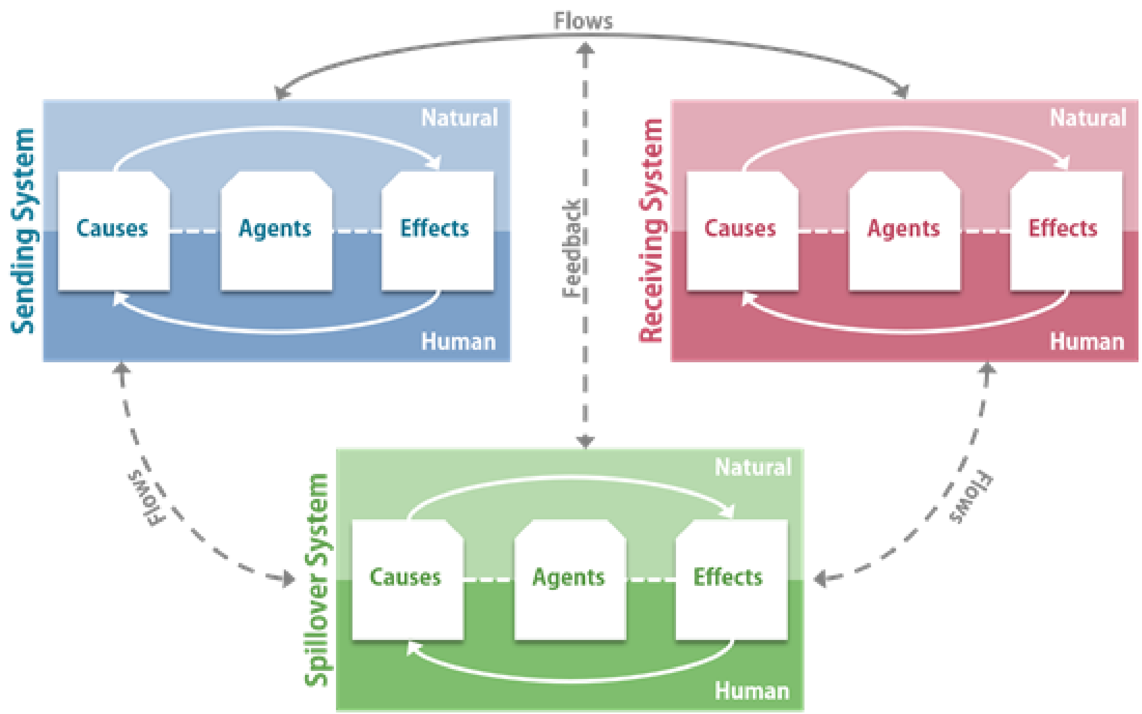


Figure 2.1 A conceptual illustration of the telecoupling framework, created by Liu et al. (2013), which represents the five main elements of the telecoupling framework (systems, flows, agents, causes, and effects) and highlights the coupling between human and natural environments. Systems can be classified as sending or receiving systems dependent on the observed flow and agents and causes are not limited to one system but can span across systems (Liu et al., 2019).

## 2.3 Application of the telecoupling framework

The telecoupling framework can be applied to many types of connections but to date, it has mostly focused on trade as the main connection between systems (Kapsar et al., 2019). The dominant trade commodities that have been investigated are common large scale agricultural commodities including soybean (da Silva et al., 2021; Gasparri et al., 2016; Herzberger et al., 2019; Lenschow et al., 2015; Liu et al., 2018), fish meal and oil (Carlson et al., 2018, 2017), tomatoes (Ibarrola-Rivas et al., 2020), bananas (Friis and Nielsen, 2017) and livestock products (Chung et al., 2019; de Castro et al., 2022; Easter et al., 2018; Zhang et al., 2018). A smaller number of studies have focused on other flows including knowledge (Carlson et al., 2017; Gasparri et al., 2016; Marola et al., 2020), technology (Carlson et al., 2018, 2017), tourism (Liu et al., 2015; López-Hoffman et al., 2017; Zhang et al., 2018), human and other species migrations (Baird and Fox, 2015; Ibarrola-Rivas et al., 2020; López-Hoffman et al., 2017), system shocks (Zhang et al., 2018), water (Chignell and Laituri, 2016; Deines et al., 2015), and ecosystem services (López-Hoffman et al., 2017; Martín-López et al., 2019; Yang et al., 2018).

The scale at which systems are studied using a telecoupling lens varies widely, with some studies only focusing on a single level and other studies analysing systems across multiple levels including combinations of local, national, and international scales (Downing et al., 2021; Kapsar et al., 2019; Schröter et al., 2018). Studies have been conducted across six continents, but the majority of studies are from North America, South America, Asia, and Europe, with China, the United States of America, Brazil, and Laos accounting for a large number of studies (Kapsar et al., 2019). China has the highest number of studies and is considered to be the largest trading nation (Liu et al., 2013). These studies include the analysis of the impact of soybean trade between Brazil and China (da Silva et al., 2021; Liu et al., 2013; Sun et al., 2018; Yao et al., 2018), banana trade between Laos and China (Friis & Nielsen, 2017), water transfer schemes, soil erosion and deforestation within China (Deines et al., 2015; Wang et al., 2021; Zeng et al., 2021), and the impact of tourism, trade and natural disasters on the Wolong Nature Reserve (Liu et al., 2015; Yang et al., 2018; Zhang et al., 2018).

The complexity and scale of telecoupled systems make it hard to address all aspects in a single study. For this reason, while most studies consider the whole telecoupling, they often focus on specific aspects. More comprehensive studies tend to be constructed as a series of papers each with a narrow focus within the telecoupling. A series of studies conducted on different aspects of the Wolong Nature Reserve (Liu et al., 2015; Yang et al., 2018; Zhang et al., 2018) provide an example of an attempt to understand all the impacts of different telecouplings on a single system. A collection of papers that studied the impacts of soybean trade between Brazil, the United States of America and China (da Silva et al., 2021; de Castro et al., 2022; Liu et al., 2013; Sun et al., 2018; Yao et al., 2018) focused more on the impacts and drivers of the specific flow across different systems. More often, studies focus on a single system, agents, socioeconomic causes or effects, or environmental causes or effects. Previous studies have identified a variety of agents involved in the coupling; including local and national governments (Castilla et al., 2016; Chignell and Laituri, 2016; Friis and Nielsen, 2017; Llopis et al., 2020; Matlhola and Chen, 2020), NGO's (Boillat et al., 2018; Chignell and Laituri, 2016), producers (Friis and Nielsen, 2017; Ibarrola-Rivas et al., 2020; Llopis et al., 2020), consumers (Castilla et al., 2016; Ibarrola-Rivas et al., 2020; Matlhola and Chen, 2020), sellers (Friis and Nielsen, 2017; Matlhola and Chen, 2020) and even migratory species (López-Hoffman et al., 2017), who are responding to a range of socioeconomic and environmental drivers. Commonly observed socioeconomic impacts included land grabs (Baird and Fox, 2015; Chignell and Laituri, 2016), displacement of local communities (Boillat et al., 2018; Llopis et al., 2020), urbanisation (Boillat et al., 2018; Chignell and Laituri, 2016; Xiong et al., 2021), decreased food security (Chignell and Laituri, 2016; Easter et al., 2018; Friis and Nielsen, 2017; Llopis et al., 2020) and decreased human wellbeing (Llopis et al., 2020). Commonly observed environmental impacts include land-use changes (Friis and Nielsen, 2017; Garrett and Rueda, 2019; Herzberger et al., 2019; Lenschow et al., 2015; Marola et al., 2020; Rulli et al., 2019), deforestation (Bruckner et al., 2015; Garrett and Rueda, 2019; Lenschow et al., 2015; Xiong et al., 2021) water and soil pollution (Chignell and Laituri, 2016; Ibarrola-Rivas et al., 2020; Matlhola and Chen, 2020; Wang et al., 2021), greenhouse gas emissions (de Castro et al., 2022; Fang et al., 2016; Rulli et al., 2019), biodiversity loss (Ibarrola-Rivas et al., 2020; Lenschow et al., 2015; Yang et al., 2018) and habitat degradation (Baird and Fox, 2015; Bruckner et al., 2015; Liu et al., 2015; Martín-López et al., 2019). This indicates that multiple approaches have been used under the telecoupling framework to answer specific questions about the telecoupling. Similarly this thesis explores different aspects of the telecoupling in Chapter 3 (causes and agents across both systems) and Chapter 4 (impacts within the sending system) to understand the social-ecological drivers and impacts of the expanding blueberry industry. The following sections will focus on the different impacts that have been recorded in studies where the telecoupling framework was applied.

## 2.4 Socioeconomic impacts

Telecouplings are mainly driven by potential socioeconomic benefits, however, these do not always materialise as envisioned. Most studies find that trade has negative socioeconomic impacts on local populations in the sending systems, who are predominantly based in developing countries (Downing et al., 2021). The high demand for affordable products in developed countries causes the displacement of production to developing countries which call for upscaling technology and methods in developing countries to meet demand (Zeng et al., 2021). This shift of production to developing countries is usually accompanied by large-scale land-use change, but more importantly the dispossession and displacement of local people. For example, land dispossession was observed as a result of oil palm production expansion in Indonesia (Rulli et al., 2019) and rubber expansion in Laos and Cambodia (Baird and Fox, 2015) following an increase in trade of these commodities. Large numbers of land concessions sold by the Indonesian government to oil palm farming companies in response to increasing biofuel demand resulted in many locals being displaced (Rulli et al., 2019). Similar land concessions in Laos saw many local people displaced to less suitable terrains, forcing them to farm on steep ravines, whereas Cambodia experienced displacement from land concession and migrant workforces (Baird and Fox, 2015). The industry provided job opportunities for migrant workers instead of the local community which gave migrants the power to purchase local land and displace local communities (Baird and Fox, 2015). However, trade is not the only flow responsible for the dispossession and displacement of local people. Nech Sar National Park in Ethiopia was created to protect the endemic Swayne's hartebeest following information flows from British biologists which led to the eviction of all the local communities in the reserve (Boillat et al., 2018). Similarly, the creation of nature reserves in Madagascar, in an effort to protect biodiversity hotspots in collaboration with conservation and aid agencies in the USA and Switzerland, resulted in restricted access to land for locals (Llopis et al., 2020). Many communities that were displaced remained near the borders which restricted their ability to continue local farming practices (shifting cultivation – a method of rotational farming where natural vegetation is burned to clear the land for temporary cultivation and the land is abandoned after the harvest to allow for the return of natural vegetation ) because of limited land availability after the creation of nature reserves (Llopis et al., 2020). Similarly, water development aid in Ethiopia has indirectly resulted in the displacement of local people to build more dams. Water aid development by local and regional NGOs and aid organisations improved water availability to rural communities by installing taps closer to homes, but this increased the survival rate of children, and with limited work, water, and food available in rural areas, this fuelled urbanisation (Chignell and Laituri, 2016). The increase in urban population placed more stress on already limited water supply and infrastructure which required the construction of new reservoirs and dams upstream displacing local people.

Telecouplings also result in human migration in some instances. The tomato industry in the Netherlands and Spain both relied on foreign labour during the tomato harvesting season (Ibarrola-Rivas et al., 2020). This saw many migrants from nearby countries temporarily or permanently migrating to these areas for employment. The rubber industry has also created opportunities for migrant labour with areas such as southern Laos receiving many migrants from Vietnam and north-eastern Cambodia regions receiving migrants from southern Cambodia (Baird and Fox, 2015). However, in Cambodia, many migrants also bought land from locals either displacing or marginalising local communities while other migrants send the majority of their income home. The flow of money to the migrant place of origin could have other impacts in those places, but also means less money remains in the migrant areas (Baird and Fox, 2015).

Other negative impacts include the poor living conditions of migrants. In Spain and the Netherlands, many migrants linked to the tomato industry were reported to live in poor conditions which means that the tomato trade is indirectly impacting the well-being of migrants (Ibarrola-Rivas et al., 2020). The impact of telecoupling on human wellbeing has also received some attention in a study by Llopis et al. (2020). This study looked at the impact of establishing nature reserves and the farming of cash crops on the wellbeing of local farmers in Madagascar. The results showed that farmers closest to the nature reserve experience a decrease in available land to practice shifting cultivation, restricting their agricultural land and reducing their ability to produce enough food. Alongside soaring inflation rates caused by the cash crop boom, these communities had a significant decrease in wellbeing, although they experienced some positive ecosystem services supplied by the nature reserves. Other communities further away from the protected areas and closer to transport infrastructure experienced an increase in income from cash crop production but this was still lower than the inflation rate. These communities also experienced increased theft and crime within their communities as well as a decrease in community connectivity which had an overall negative impact on their wellbeing (Llopis et al., 2020).

### 2.5 Environmental impacts

In addition to socioeconomic impacts, telecouplings often have negative environmental impacts on systems. Land-use changes as a result of trade flows result in a wide range of impacts. For instance, increasing global soybean demand has resulted in soybean agriculture expansion in Brazil at the cost of forest land (da Silva et al., 2021; Liu et al., 2013; Sun et al., 2018; Yao et al., 2018), leading to habitat destruction and biodiversity loss over time. Similarly, an attempt by the European Union to move to more sustainable energy in the form of biofuel resulted in deforestation in Brazil. However, once the impacts were recognised new policies were established to prevent future deforestation (Rulli et al., 2019). In Laos, many rice farmers converted their gardens and lowland rice paddies to banana plantations as a response to increasing Chinese demand for bananas after political differences with previous providers (Philippines) and China's inability to produce bananas locally due to soil degradation. Banana plantations require heavy chemical input which is degrading fertile soils of Laos and raising concerns about future soil fertility (Friis and Nielsen, 2017). Another example is the increase in demand for tomatoes as a result of the increase in the average European citizen's income and ability to find tomatoes all year round. In a study by Ibarrola-Rivas et al. (2020), they identified two sending systems (the Netherlands and Spain) that produced tomatoes for Germany. The difference between local climates resulted in different cultivation methods, but both experienced major land-use changes with the Netherlands growing tomatoes in greenhouses and Spain in plastic-covered tunnels. Both these methods excluded natural species, but the impacts were most profound in Spain as this occurred in an arid biodiversity hotspot, threatening biodiversity as well as causing plastic pollution and adding to water stress.

Land-use changes do not only occur because of trade. In the Wolong Nature Reserve in China, land-use change was also brought about as a result of the tourism industry (Liu et al., 2015), payment for ecosystem services (Zhang et al., 2018) and an earthquake (Yang et al., 2018). The tourism industry improved the local infrastructure, but this had negative impacts on the environment including habitat loss and fragmentation (Liu et al., 2015). An earthquake that occurred near Wolong Nature Reserve caused major damage to the infrastructure that reduced tourist visits which limited local income and disconnected locals from the outside world emphasising the reliance of the community's wellbeing on these flows (Zhang et al., 2018). This resulted in local farmers struggling to maintain their income because the crops they produced only had a short timeframe to get to markets and the earthquake reduced individuals' ability to reach these markets. This prompted many locals to increase livestock farming which allowed more flexibility in timing to market. However, this had significant negative impacts on the panda habitat due to overgrazing (Zhang et al., 2018). Another land-use change observed in the Wolong Nature Reserve was linked to the flow of payment for ecosystem services from the government to households in the nature reserve called Grain to Green Program (GTGP) which paid farmers to convert their croplands to forestland or grassland (Yang et al., 2018). This land change resulted in positive environmental impacts by improving soil and water retention that also reduces flood risks (Yang et al., 2018).

Other flows such as information flow regarding sustainable policy implementation can also have positive environmental impacts. The Peruvian anchoveta industry benefited from sustainable information flows, such as stock recovery and management plans after the collapse of the anchoveta stocks; this also led to Peru becoming one of the current leaders in sustainable fish stock management (Carlson et al., 2018, 2017). Similarly, information and foreign investment flows have facilitated the creation of nature reserves to decrease negative environmental impacts (Boillat et al., 2018; Llopis et al., 2020).

Other flows were had negative environmental impacts on industries based on the trade of natural materials. High demand for fishmeal and fish oil, improved technology and new knowledge allowed the Peruvian anchoveta industry to harvest ample fish, but poor initial stock management alongside uncontrollable environmental drivers (El Nino) resulted in the collapse of anchoveta fish stock (Carlson et al., 2018, 2017). The industry was lucky to recover with a second wave of information flow that created a more sustainable industry. Loco (false abalone) and abalone trade are closely connected and experienced soaring prices and demand that resulted in a large decline in wild abalone stocks globally. This has given rise to abalone aquaculture, reducing prices at first but later increasing the value of wild abalone which in turn increased poaching of wild sustainably managed loco stocks (Castilla et al., 2016). This shows that even with policies in place a distant driver can change the effectiveness of policies and have severe environmental impacts.

### 2.6 Displacement of socioeconomic and environmental impacts

A common theme detected by telecoupling research has been the displacement of socioeconomic and environmental impact from one system to another. For example, the donkey hide trade between Botswana and China increased inequality in low-income rural farmers. These farmers sold donkeys to middlemen at a very low cost but this sacrificed a key part of their livelihood (Matlhola and Chen, 2020), as donkeys were their main transport and agricultural muscle (Matlhola and Chen, 2020). In addition to these socioeconomic impacts China also built slaughterhouses in Botswana that offered socioeconomic benefits through job creation, but the poor management of run-off and waste disposal resulted in pollution of air and water supply to local people. This was not mitigated by the ban of donkey hide trade but rather opened a black market which resulted in the theft of donkeys from rural farmers further aggravating inequalities (Matlhola and Chen, 2020).

Similarly, the study by Ibarrola-Rivas et al. (2020) found that Germany displaced the impacts of tomato production to Spain and the Netherlands when observing the energy, water, fertiliser, land, and labour inputs causing both environmental and social issues in these producing countries. The study concluded that Germany is experiencing a large resource-saving in comparison to producing similar quantities themselves. This was also apparent in the energy trade of affordable solar power panels as the European Union imported panels from China to meet its own local green energy policies but in return displaces production emissions. The EU over time has added an anti-dumping tax onto the Chinese manufactured solar panels to mitigate environmental impacts making them more expensive than locally produced solar panels, but this has had significant socioeconomic impacts in China (Fang et al., 2016). The observed socioeconomic and environmental impacts caused by telecouplings revealed that all connections had some negative effects. This in turn highlights the need for understanding the potential impacts that may arise and the effective management of these interactions to mitigate impacts in a connected world to ensure a sustainable future.

## 2.7 Conclusion

The review highlights the breadth and depth of research that has been conducted using the telecoupling framework to study socioeconomic and environmental impacts because of distant connections. It shows that the telecoupling framework has been a useful methodology to explore the socioeconomic and environmental factors of a variety of connection types ranging from simple to complex knowledge transfer, migration, and trade connections. The case studies looked at various connections using the framework and the results showed either socioeconomic or environmental impacts or both. The current body of research also demonstrates that different connection types can have similar socioeconomic and environmental impacts. For example, knowledge and trade connections can both result in locals being displaced from land (Baird and Fox, 2015; Boillat et al., 2018; Llopis et al., 2020; Rulli et al., 2019). It also demonstrates changes to a connection could have further impacts such as banning donkey hide trading resulting in theft (Matlhola and Chen, 2020), and tax increases on solar panels lead to a drop in demand which in turn resulted in job losses (Fang et al., 2016).

The review further illustrates that in these distant connections, one country or region tends to benefit while the other is negatively impacted, highlighting the concept of displacing impacts through these connections. This indicates that the power dynamics of distant connections are skewed, and it seems to be skewed to richer, developed countries that displace harmful impacts to poorer, less developed countries (Garrett and Rueda, 2019; Kastner et al., 2011; Sandström, 2018; Zeng et al., 2021). In conclusion, achieving universal sustainable development rather than localized sustainable development requires that the impacts of distant connections should be considered (Downing et al., 2021; Hovis et al., 2021). It is only through understanding socioeconomic and environmental connections to distant places that policies can be put in place to mitigate harmful impacts and encourage positive impacts. The telecoupling framework is an invaluable tool to support this understanding, and thereby help realize a sustainable future.

# Chapter 3: Social-ecological drivers of South Africa's expanding blueberry industry

## 3.1 Abstract

Blueberry production has experienced rapid expansion in South Africa over recent years. This confirms an emerging pattern of African countries adopting cash crops marketed towards distant consumers. This study aimed to identify the drivers of blueberry expansion in South Africa using existing quantitative data gathered from the FAO database, South African Revenue Service (SARS) database, BerrieZA reports, and United States Department of Agriculture (USDA) reports, combined with qualitative data collected through surveys and interviews. Four themes were explored: (1) initial drivers that promoted blueberry production adoption and expansion, (2) the current blueberry industry including the challenges faced by participants, (3) the susceptibility to shocks, and (4) the requirements needed to secure the future of the industry. The interviews highlighted seven drivers of blueberry expansion including the perceived profitability, access to start-up capital, access to an expanding market, relationship with exporters, the ability to diversify income, environmental factors like climate and soil, employment opportunities to maintain key staff, and the low risk of theft. The findings from the interviews and surveys were largely corroborated by existing statistical data, with a few exceptions. This young industry is already facing various challenges like the increase in competition, increase in input cost and the poor condition of export ports that arose during interviews. This study showed that 17 months into the COVID-19 pandemic, respondents experienced no significant direct impact, but it has raised concerns over the dependence on supply chains, import costs and other indirect drivers. Participants noted the potential vulnerability of the industry to other shocks such as droughts and civil unrest. Lastly, participants alluded to increasing research and development investments, precision agriculture and port infrastructure upgrades as improvements that can address the current challenges and ensure the future viability of the industry. Despite challenges, the general belief is that the blueberry industry will persist and keep expanding in South Africa.

## 3.2 Introduction

Blueberries comprise one of the crops that are experiencing the fastest expansion of production in South Africa. Since 2008, the area dedicated to blueberry production in the country grew by an average of 40 per cent per annum (WCDoA and BerriesZA, 2019). This is ten times greater than the growth of the global blueberry industry, which expanded by an average of four per cent per annum between 2008 and 2019 (FAO, 2020). The volume of blueberries produced by South Africa increased from 250 tonnes in 2008 to over 22,000 tonnes in 2020 (USDA, 2020; WCDoA and BerriesZA, 2019) and the value of the industry increased from R 34 million in 2008 to over R 1 billion in 2018 (WCDoA and BerriesZA, 2019). Despite the rapid expansion, South Africa and other southern hemisphere countries such as Chile and Peru still have a limited local market for blueberries, and most of the crop is destined for export (Evans and Ballen, 2017).

Small-scale farmers in developing countries are increasingly adopting and producing cash crops to export to richer, developed countries (Anderson, 2002; Bitama et al., 2020; Lukanu et al., 2009; Zaehringer et al., 2020). Cash crops are those with a high market value grown by farmers for their economic potential and are generally not produced to improve global food security (Loyer, 2016). This can include food crops or non-food crops such as soybeans for biofuel, vanilla for flavouring food, or blueberries as a superfood that forms part of a healthy diet. In many developing countries, governments and Non-Government Organisations (NGOs) are advocating for the adoption of such cash crops to increase the income and food security of local farmers (Bitama et al., 2020; Loyer, 2016). This phenomenon is also commonly observed in African countries that adopt cash crop production to increase income by exporting such crops to developed countries where demand is high. Previous studies have identified three overarching elements that can drive new crop adoption: (1) environmental suitability, (2) social perception, and (3) economic benefits (Hazell and Wood, 2008; Hockett and Richardson, 2018; Inoni et al., 2021; Jayne et al., 2017; Katengeza et al., 2012; Nilsson et al., 2019).

In the past, geography or spatial elements strongly influenced land-use change decisions, however technological advances have substantially reduced the restrictions of geography. Technology allows manipulation of environments and crops themselves, to achieve optimal growth and yield across a range of environments (Alexander et al., 2015; Floros et al., 2010; Henry, 2020; Hettig et al., 2016; Meyfroidt et al., 2013; Miller et al., 2008; Sassenrath et al., 2008; Zelaya et al., 2016). However, environmental factors such as climate still affect decisions and feasibility to grow certain crops, especially in poor areas that do not have access to sufficient technology (Hockett and Richardson, 2018; Mehdi et al., 2018; Nilsson et al., 2019; Paudel et al., 2019; Zelaya et al., 2016). The environmental factors that are often considered include suitable temperature, rainfall, seasonality of rainfall, wind strength, probability of hail, chill hours for the selected crop. Other factors such as high densities of common pests that will result in higher pesticide use or costly infrastructure can discourage farmers from adopting a crop (Nilsson et al., 2019), as would geological factors such as soil composition, slope, and proximity to water (Aravindakshan et al., 2020; Hitayezu et al., 2016; Hockett and Richardson, 2018; Paudel et al., 2019; Zelaya et al., 2016).

Social factors can also influence a farmer's decision to adopt a new crop or expand the existing area of a crop, including demographic factors, land size, farm equipment, household size, and subsistence farming dependency (Aravindakshan et al., 2020; Hettig et al., 2016; Katengeza et al., 2012; Ostwald et al., 2013). Previous research showed that individuals with a higher degree of education are more likely to adopt innovations, such as adopting a new crop earlier, than farmers with lower education levels (Greig, 2009). Similarly, younger farmers are known to more actively seek innovation in comparison to older farmers (Greig, 2009). Land size and available farming equipment can restrict a farmer's ability to adopt new crops, whereas household size has been an important consideration, especially for small scale farmers when crops are labour intensive (Hitayezu et al., 2016; Hockett and Richardson, 2018; Katengeza et al., 2012; Konrad et al., 2018; Nilsson et al., 2019; Ostwald et al., 2013). The farmers' current food security and reliance on sustenance farming can also substantially influence their ability and willingness to adopt new crops. For example, vanilla farmers in Madagascar who are further from markets (more remote) are still heavily reliant on farming rice to ensure their food security and they, therefore, dedicate a smaller area of their farm to vanilla farming than other farmers that are closer to the markets (Llopis et al., 2020).

Economic and institutional factors are also key factors that influence a farmer’s choice. Lukanu et al. (2009) and Malek et al. (2019) observed that the preference for a cash crop was dependent on the reliability of the prices, the accessibility of buyers, and the availability of labour. This notion has been supported by various other researchers (Aravindakshan et al., 2020; Bell and Moore, 2012; Ebanyat et al., 2010; Hettig et al., 2016; Hitayezu et al., 2016; Hockett and Richardson, 2018; Katengeza et al., 2012; Konrad et al., 2018; Mehdi et al., 2018; Nilsson et al., 2019; Ostwald et al., 2013; Tessema et al., 2019). The price of crops on local and international markets, as well as the ease of access to these markets, are some of the most important factors that impact a farmer's choice to adopt a new crop (Aravindakshan et al., 2020; Bell and Moore, 2012; Ebanyat et al., 2010; Hettig et al., 2016; Hitayezu et al., 2016; Hockett and Richardson, 2018; Konrad et al., 2018; Mehdi et al., 2018; Nilsson et al., 2019; Paudel et al., 2019; Tessema et al., 2019). Alongside the price, the input cost such as infrastructure (Mehdi et al., 2018; Ostwald et al., 2013), chemicals (fertiliser, pesticides, herbicides, and fungicides) (Katengeza et al., 2012; Matebeni et al., 2021), labour, water, and transport can impact profitability and attractiveness of new crops (Mehdi et al., 2018; Ostwald et al., 2013).

Farmers also adopt new crops to diversify income that reduces dependency on a single crop or as a response to the decrease in profit of an existing crop (Bell and Moore, 2012; Ebanyat et al., 2010; Konrad et al., 2018). Furthermore, a farmer's debt, access to loans or subsidies can influence their willingness to adopt new crops (Katengeza et al., 2012; Ostwald et al., 2013); farmers with high debt will be less likely to adopt new high-risk crops despite the potential financial gain. Whereas if farmers can easily obtain loans or get subsidies for the specific crop it can encourage them to adopt a new crop. Local or international policies will also determine a farmer's willingness to adopt a new crop (Ebanyat et al., 2010; Hettig et al., 2016; Ostwald et al., 2013; Paudel et al., 2019), for example, if stringent, complex policies are implemented on an existing crop, it can encourage the farmer to search for an alternative crop that is easier to produce and sell to the market.

In addition to these general factors, farmers also consider less common factors such as external shocks and vulnerabilities (Aravindakshan et al., 2020; Konrad et al., 2018; Nilsson et al., 2019). When adopting new crops, farmers may be aware of the potential vulnerability of the crop to shocks such as floods, droughts, or price volatility (Aravindakshan et al., 2020; Konrad et al., 2018; Nilsson et al., 2019). Therefore, if an area is prone to drought, farmers are more likely to adopt drought-resistant crops than water-intensive crops. However not all external shocks are predictable and these are harder for farmers to consider, especially under conditions of global change. Unpredictable factors can include shocks such as the price crash of a commodity (Konrad et al., 2018) or reduced trade due to a global pandemic such as COVID-19. (Aravindakshan et al., 2020; Konrad et al., 2018; Nilsson et al., 2019).

Much of the existing research discussed above focuses primarily on small-scale farmers, with a large share of case studies in Africa and Asia, and only a few studies considering commercial farmers. In 2003, Meyer et al. assessed the potential of blueberry production in South Africa. They found that South Africa has no insect pest of economic importance to blueberries, and the climate of the recommended planting zone, the highveld, is suitable for low chilling varieties. However, despite the suitability of the highveld climate, the majority of blueberry production currently occurs in the Western Cape. Meyer et al. (2003) also noted the potential for export to the European market, as South Africa is geographically well-positioned to export to Europe and can provide blueberries during their off-season. This reflects what is observed in the industry today as the largest share of blueberries produced in South Africa is destined for export, and the biggest share is destined for the United Kingdom.

This chapter explores the social-ecological drivers behind the blueberry expansion in South Africa, using both existing data on prices, export demand, labour requirements and other factors that can have an impact on a farmers' decision to start blueberry farming. Existing statistical data on production, prices, trade and employment were complemented by remote surveys completed by farmers and farm managers to improve the understanding of drivers. This study addresses the gap in current research relating to the drivers behind cash crop uptake by commercial farmers (rather than small-scale farmers). At the same time, the study recognises that the drivers behind agricultural land-use change are complex and do not remain static over time. As stated by Harvey (1966): "geographical patterns are the result of human decision" and are influenced by psychological and sociological drivers. Therefore, this study further also explored the difference in earlier and current motivations to be involved in blueberry farming and considered how an unexpected external shock, such as COVID-19, can drive change in the industry.

## 3.3 Methods

### 3.3.1 Blueberry production in South Africa

The South African blueberry industry represents only a small share of total fruit production and agricultural activities in the country but the industry has undergone rapid expansion to meet growing demand in northern hemisphere countries such as the United Kingdom. Currently, most of the production (60%) occurs in the Western Cape, while Limpopo, North West, and Gauteng are the other three provinces that contribute substantially to production (WCDoA and BerriesZA, 2019) (Figure 3.1). Production is observed in open-air (40%), or under two types of protective structures namely shade netting (43%) or plastic tunnels (17%) (WCDoA and BerriesZA, 2019). Most of the blueberry bushes are planted in the soil (71%) and the remainder is planted into pots of substrate (29%) (WCDoA and BerriesZA, 2019).

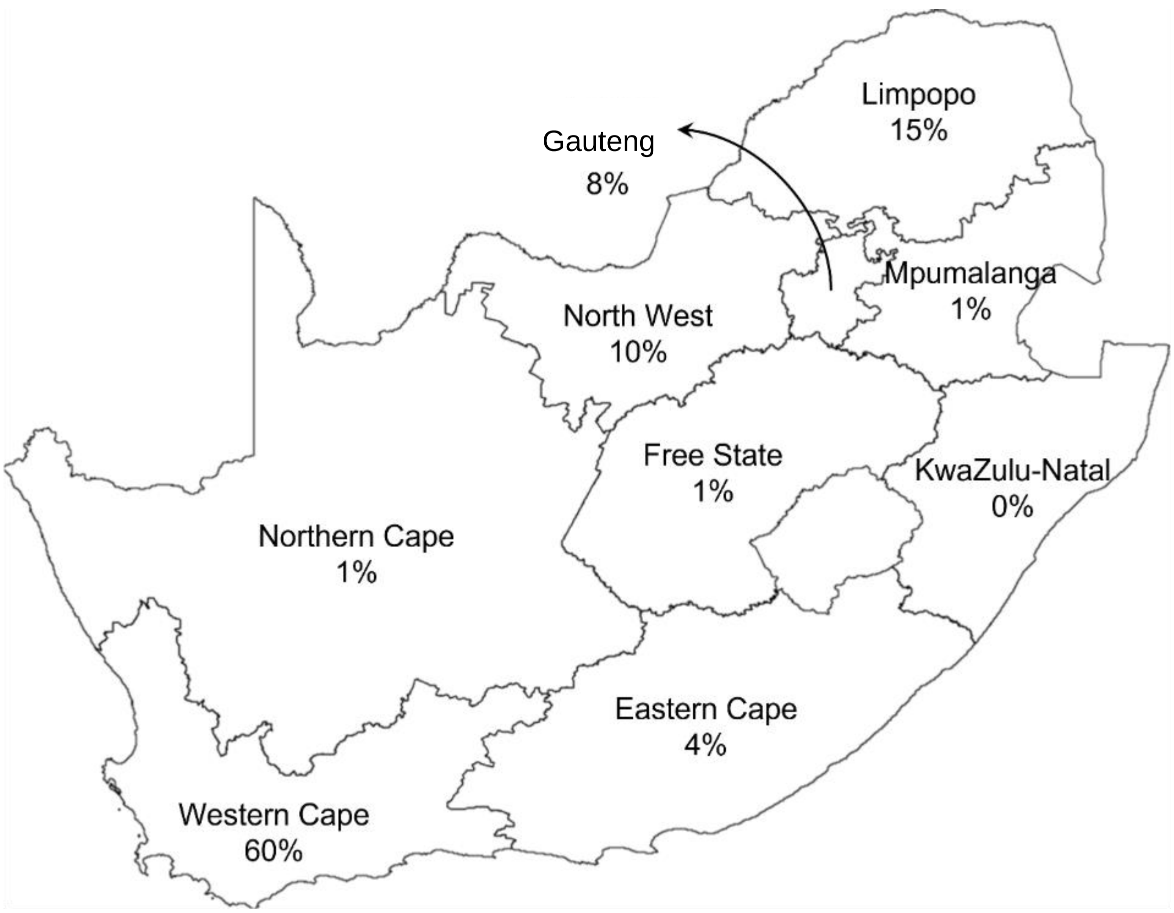


Figure 3.1 Map of South Africa with an indication of blueberry production per province (WCDoA and BerriesZA, 2019). Despite suitability identified in the northern parts of the country (Meyer and Prinsloo, 2003), much of the blueberry production is in the southwest of the country.

In South Africa 22 per cent of the blueberries are accessible to the local market; fresh blueberry consumption accounts for the largest share of local blueberry consumption. This represents a mere 13 per cent of total production in South Africa. The remaining nine per cent of the 22 per cent of South African blueberries accessible to the local market and the small volume of blueberries imported are consumed in processed form (USDA, 2020). Processed blueberries are commonly found in products such as confectionery products, juice, ice creams, and yoghurts. Despite the small share of blueberries intended for the local market, local demand is increasing as a result of an increase in health-conscious consumers and access to the public in supermarkets. Demand was estimated to grow by 26 per cent between 2019 and 2020 (USDA, 2020; WCDoA and BerriesZA, 2019). Overall South African blueberry consumption is still very low (60 grams per person per annum) in comparison to other countries. Globally, North America (the United States of America and Canada) is the largest consumer of blueberries with an average annual consumption of 2 kg per person while blueberry consumption is growing in European and Asian countries (CBI, 2021; Evans and Ballen, 2017). The United Kingdom is the third-largest consumer of blueberries, with an average consumption of 800 grams per annum, while the average European consumes only 200 grams of blueberries per annum (CBI, 2021).

The remaining 78 per cent of South African blueberries are exported fresh to Europe, Asia, and the Middle East as a result of increasing year-round demand for superfoods by health-conscious consumers in these countries (Bierend, 2019; Clark, 2021; Loyer, 2016; Moss, 2021; USDA, 2020). Europe and specifically the United Kingdom imports the largest share (54%) of South African blueberries to meet their consumer demand in the northern hemisphere‘s winter season when fresh blueberries are scarce (Brazelton, 2011; Evans and Ballen, 2017; USDA, 2020; WCDoA and BerriesZA, 2019). Despite the disruption caused by COVID-19, the blueberry industry in South Africa was still able to export a record amount of blueberries in 2020 (IFC, 2021; Meintjies, 2021; USDA, 2020).

### 3.3.2 Data collection

#### *3.3.2.1 Existing statistical data*

Data on the existing South African blueberry industry was obtained from BerriesZA (an industry body that represents berry growers in South Africa) and augmented with data from other sources (FAO, 2020; SARS, 2021; USDA, 2020). This data was not analysed but only used to support survey and interview data. The data included the production volumes and value, export volumes per destination, and employment over time as potential response to the drivers (Addendum A).

### *3.3.2.2 Surveys*

A total of 42 blueberry farms were identified across South Africa using a diverse range of search tools which included general google searches for blueberry farms, identifying farms that belong to the BerriesZA association, farms listed as exporters for export companies, and using the CapeFarmMapper tool (https://gis.elsenburg.com/apps/cfm/). Email addresses were captured from these platforms or the farm websites. The remote survey was conducted after obtaining the required ethical clearance from the Research Ethics Committee at Stellenbosch University (REC-2021-17072). The survey was constructed as a Google Form that captures individual responses to which participants were directed by a link included in a bulk email sent to all identified addresses on the 14th of June 2021 that contained an overview of the project. The survey had three sections, the first section was an overview of the research, ethical approval, and clarification of participant rights and requested consent to use their data. The second section captured demographic information, and the third section was the main data collection section that asked participants their opinion on the influence seventeen potential drivers had on their decision to adopt blueberry farming (Addendum B). These seventeen potential drivers were gathered from existing literature on the blueberry industry in South Africa (including popular articles by CBI (2021) and Clark (2021), the report by WCDoA and BerriesZA (2019) and the paper by Meyer et al. (2003)) and allocated to the appropriate system using the telecoupling framework (Figure 3.2, Chapter 2). Non-respondents were prompted with a follow-up email two weeks after the initial email. All responses were captured between the 14th of June and the 13th of September 2021.

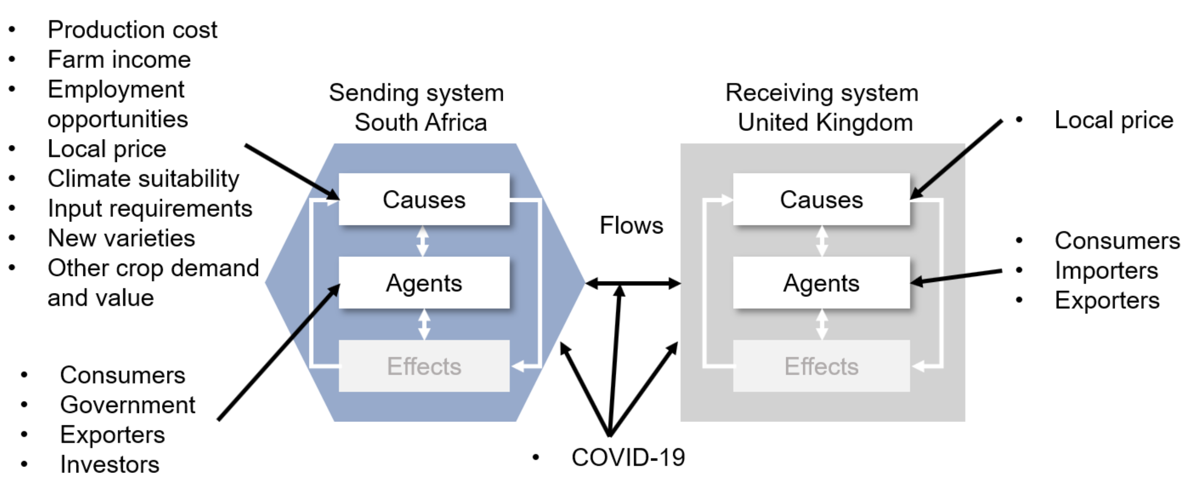


Figure 3.2 Drivers identified from literature mapped onto the telecoupling framework (Chapter 2) (Liu et al. 2013).

#### *3.3.2.3 Interviews*

As a result of the low number of respondents to the survey, additional semi-structured interviews were conducted virtually with participants to get an in-depth understanding of survey responses. During the online survey, participants were asked if they would be willing to engage in further conversation about the blueberry industry; 11 out of the 13 participants indicated their willingness. These eleven participants were invited to a one-to-one semi-structured virtual session as a follow-up on survey response. Four of these participants did not respond to the follow-up conversation invite. A total of seven interviews were completed in line with the interview procedures approved by the Research Ethics Committee at Stellenbosch University (REC-2021-17072). Six of the participants were farm managers or farm owners whereas one participant was a nursery owner. During the interviews, nine guiding questions (0) were used to explore the drivers and current challenges of the blueberry industry building on the survey questions and response. The interviews provided additional context into the current industry as participants expanded answers to include changes in the industry, challenges and future innovations that need to happen. Interviews lasted 1 – 1.5 hours, and were conducted between the 16$^{th}$ of July and 15$^{th}$ of September 2021.

### 3.3.3 Data analysis

The interviews were transcribed in English, and analysed within Atlas.ti version 9 (Scientific Software Development GmbH, 2021). The interview data were analysed using the deductive thematic analysis approach to identify, code, and group the data into four main themes that emerged from the interview data. The first step of the thematic analysis was to familiarise myself with the interview data. This was done by transcribing the interviews and making initial notes after reading through the transcribed interviews. Once the data were imported into Atlas.ti (Scientific Software Development GmbH, 2021) I started coding the data using the seventeen potential drivers explored in the survey to create a collection of phrases from various interviewees that expressed the same opinion. This was done iteratively by reading through the interviews multiple times to code phrases and also add new codes as they emerged from the text. Additional codes were added when new concepts were identified that were considered to be of interest to the study. After many coding interactions, I grouped the codes into four main themes that emerged from the interviews (1) drivers of the industry, (2) challenges that the industry face, (3) the industries vulnerability to shocks, and (4) future innovation that are required to ensure the viability of the industry. Lastly, I reviewed the codes and themes to ensure that I captured all the important data from the interviews. The results of the interview themes were then compared to the survey results and used to elaborate on those results by giving context to the outcomes of the survey. The existing data were also used to supplement identified themes that emerged during the analysis of the interviews.

## 3.4 Results

### 3.4.1 Demographic profile of respondents

There was little variation in the demographic profile of the 13 individuals that completed the survey (Addendum C) and the subset of seven people who were interviewed. All of the participants were white and predominantly male (only one female participant in both the survey and interview). While 8/13 survey participants and 4/7 interview participants were in the age group 40 to 59, 4/13 and 2/7 were in the age group 20 to 39 and only one participant in both the survey and interview groups was over 60 years old. The farms were predominantly located in the Western Cape (6/13 in the survey group and 4/7 in the interview group) and Limpopo (3/13 and 2/7) while two participants from Mpumalanga participated in the survey stage and one in the interview stage. The survey stage also included one participant from Gauteng and one from KwaZulu-Natal. Participants identified their role as farm owners (8/13 and 4/7), farm managers (2/13 and 2/7), nursery owners (2/13 and 1/7), and a project coordinator (1/13). Participants had very similar opinions on the drivers of blueberry adoption in South Africa as discussed in more detail in the following sections.

### 3.4.2 Reason for entering the blueberry industry

#### *3.4.2.1 Income and profitability*

All participants expressed that the potential economic benefits from the blueberry industry were the dominant reason for adopting blueberry farming. Participants were often experiencing financial strain and seeking profitable alternative crops such as blueberries which showed high profitability as a result of soaring prices on the export market between 2012 and 2015 (Figure 3.3). Others were looking at diversifying their income by adding to existing crops on the farm or replacing crops that were experiencing a decrease in profitability. Most participants also noted that the three-year period to obtain a return on investment was a benefit in comparison to other fruit trees that took longer to start generating a profit. One participant was not only involved in blueberry production, but also in a private equity firm that is attempting to develop blueberries as a common assets class of the future because of its economic potential. The firm considers blueberries as a crop that offers the opportunity to change the standard agricultural model through encouraging investment, which is possible because of the high profitability, short turnaround time, and ability to mitigate risks. The idea of using blueberries as a profitable commodity in which to invest was captured by one participant in this quote: *"We think it* *works well with blueberries 'cause of the turnaround time of harvest from development and revenue and it's also an attractive investment opportunity for the corporates."* – Participant 1.

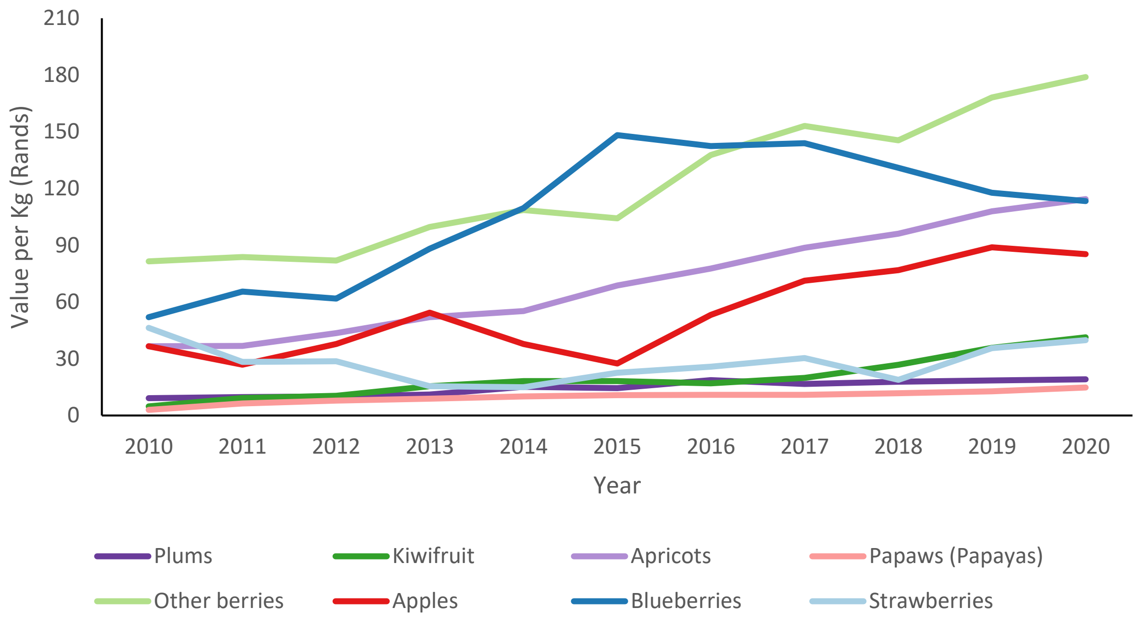


Figure 3.3 The average price obtained for South African fresh fruit on the export market (SARS, 2021). The category of other berries include berries like raspberries, blackberries and mulberries.

Notions around profitability revealed by interview participants were supported by the survey data (Addendum Figure C.1) where all participants agreed that blueberry prices and the ability to increase (13/13) and diversify (11/13) farm income with blueberries were a driver for them to adopt blueberries. Furthermore, the picking season of blueberries falls outside the bulk of other commonly farmed fruit groups (Figure 3.4) which makes blueberries a good alternative to existing crops when considering a mixed operation.

*3.4.2.2 Financial capacity*

All participants expressed that blueberry production is more expensive than other crops and that it is crucial to have sufficient funds to invest in blueberry farming. Therefore, access to loans and investors was essential for blueberry adoption. Participants also expressed that the lack of access to loans and investors could be a limiting factor because of the expensive start-up cost of blueberry production. The following comment by a participant reflects on the high start-up cost of blueberry production today when farmers have to consider replacing older genetics *"our initial planting cost on berries was very similar to apples and pears, so we didn't feel uncomfortable about it, but today's apples and pears are probably somewhere around about half a million (rand) a hectare. Probably the cheapest blueberry* *planting that we can do is somewhere in the region now of R 700 000 or R 800 000 a hectare but the vast majority is now north of two (million rand) because its pots and medium and structures and irrigation, so you know it's changed dramatically over the last five years"* – Participant 2.

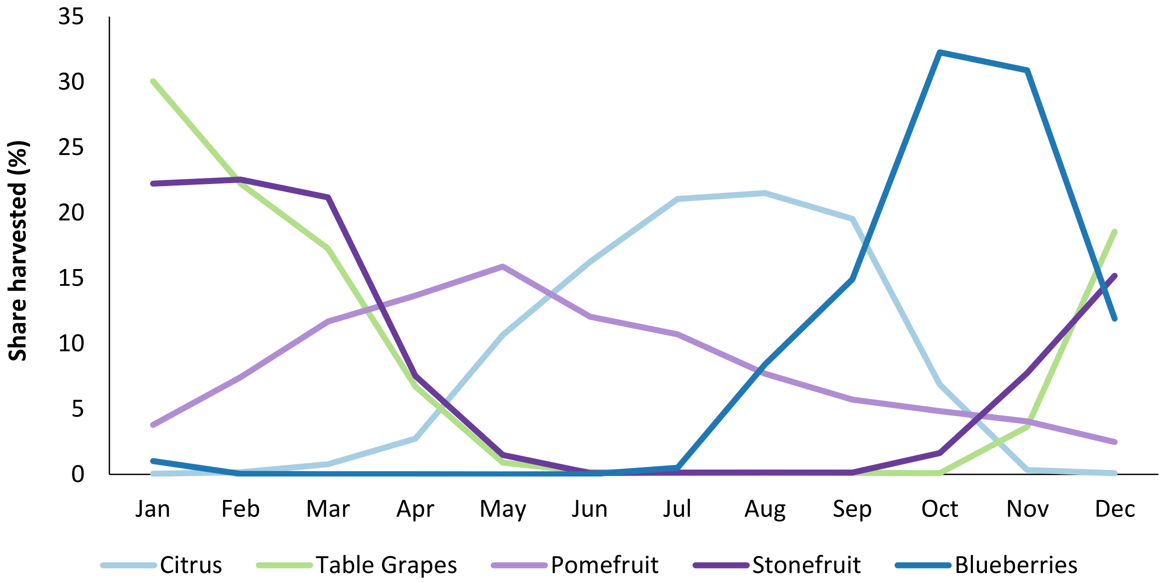


Figure 3.4 The percentage of the total volume of main fruit groups harvested per month in a year in comparison to blueberries (WCDoA and BerriesZA, 2019).

*3.4.2.3 Market demand*

South African blueberries are predominantly produced for the export market, more specifically the United Kingdom and European markets (Figure 3.5). The local market has been steadily growing but is considered to be limited to middle to high-income individuals because of the price of blueberries. The majority of the participants in the survey and interviews stated that growing demand by consumers in Europe is another reason that they were drawn to blueberries. The sentiment for growth is captured by one participant's remarks*: "There's definitely still opportunity in the blueberry industry, there's obviously significant (supply) growth. I mean, we're talking 25 (per cent) plus year on year out of Peru for the last 10 years, and although that's largely focused on the US market, you know they're looking to Europe and obviously to China and you know those markets (consumer demand) are growing at, let's call it somewhere around about 9 or 10% (a year)… So if you look at the growth of blueberries in the UK, you know they're still growing, and they've outstripped raspberries. Now they're the second biggest player in the berry category after strawberries, and we're talking about penetration levels in excess of 50% in the UK, and you compare that to somewhere like France where we've got penetration levels, probably somewhere between 11 and 15%"* - Participant 2.

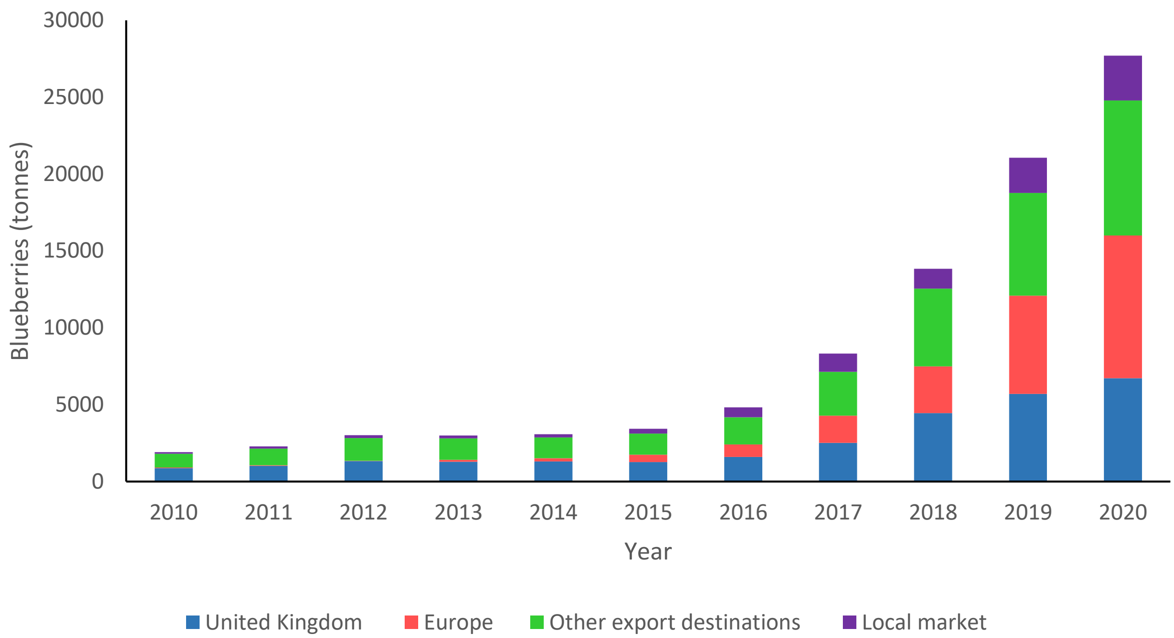


Figure 3.5 Volume of blueberries produced in South Africa per market destination (SARS, 2021; WCDoA and BerriesZA, 2019)

#### *3.4.2.4 Influence of exporters*

Participants mentioned that individuals in the blueberry industry are highly reliant on a relationship or agreement with a blueberry exporting company as they are also the owners of proprietary blueberry varieties, and they provide farmers with the required support and information to get started with blueberries. In the survey, ten participants agreed that communications with exporters influenced their decision to adopt blueberries (Addendum Figure C.1) while, early adopters mentioned in the interviews that personal relationships, network connections, or communications with individuals within these export companies influenced their decision to take up blueberries. In addition, the exporters continuously obtain newer proprietary genetic varieties that are better adapted to the climate in South Africa, which was also considered to be an initial driver of blueberry uptake by some participants. The early engagement with exporters was illustrated by two participants in the following quotes: (1) *"The owner of the farm had a personal connection with an individual in an exporting company and he always tried to be different in the farming industry. This led to the farm being one of the first three farms growing blueberries commercially in South Africa."* - Participant 4, (2) "*To cut a long story short, I eventually came across one exporter and I saw that they had varieties that were low chill varieties and I contacted them… and I said I might have a place that's interesting to you (the exporter) with the low chill varieties, I think would be advantageous to your marketing plan because I would be coming in earlier than you guys down in the Western Cape*." – Participant 5.

*3.4.2.5 Employment opportunities*

Blueberries are considered to be very labour intensive (Addendum Table A.3; Addendum Table A.4) and the employment opportunities it creates were mentioned as another driver of blueberry adoption by a few participants during interviews. The one participant considered employment as a driver because of funding for a specific Environmental, Social and Corporate Governance (ESG) project that aims to reduce unemployment. Blueberry farming offered the opportunity for continuous investment and therefore the chance to scale the model and grow employment opportunities, which were not possible in commonly adopted government and aid organisation job creation and poverty alleviation projects like clinics and schools which have limited employment opportunities and scalability. The following quote shares the participant's thoughts about the role of blueberry farming in the employment project: *“we've got a really nice project we were working with a mine, where they're providing the funding. We (are) rolling out the project and operating it, a blueberry farm, in particular, and the prime objective there is to create employment for a very poor community and high unemployment region 'cause the mine can only employ X amount of people.”* – Participant 1.

Another participant identified it as an opportunity to keep good seasonal staff employed for longer periods throughout the year so that they can maintain their high performing seasonal staff year on year. This is supported by a participant from a mixed farm operation that stated: *“About 80 to 90 per cent of our pickers return, that comes back to the farm. We also have a group that we try and keep once the picking season is over and then they prune until they can harvest again or they prune etc. We try and keep our core group busy for as long as we can, about 10 months of the year and they are mainly the ones with the highest picking speed ”* – Participant 4.

*3.4.2.6 Environmental factors*

The environment plays an important role when considering the establishment of a blueberry farm and all the survey participants somewhat agreed that they consider climatic suitability to be a driver of blueberry production (Addendum Figure C.1). Participants considered access to water as important because they highlighted that blueberries are more water-dependent and intensive than other fruit they have previously produced like mangos and papayas. In that sense, water availability can be a driving factor but also a limiting factor. The regional climate was also considered a driver even though the majority of South Africa’s climatic regions can accommodate the newer varieties of blueberries that do not require any chill hours. Participants from the northern region of South Africa consider their climate to be well suited and therefore an influential driver of uptake because they have a lower risk of rain during the picking season which limits the structural inputs required to mitigate risk (e.g. shade net structures and plastic tunnels), while their warmer spring conditions also allow them to get the optimal price for blueberries as they fall within the early blueberry season when supply is limited (Figure 3.6). One producer in the northern region voiced their environment as a benefit: "*I think (it) is probably one of the best climates in this country for blueberry production and one of the reasons being is you don't need to invest too much money in infrastructure… so we get the rain as you know in the summer which is fine because there's no fruit on the bushes and it's warm and these things just grow.*" - Participant 5.

Less suitable climates like those experienced in the Western Cape do not discourage blueberry uptake as the new varieties are adapted to the temperature. However, the production method is influenced by other climatic factors such as rainfall during the harvest season, lower than optimal temperatures during the early high price windows, and strong winds that can damage blueberry bushes and fruits. In the Western Cape, many farmers, therefore, choose to cover blueberries with shade netting and plastic tunnels to reduce the risk of exposure to these potential weather hazards. This additional infrastructure impacts the start-up and maintenance cost of producing blueberries. Controlling for the risk in the southern region of South Africa was highlighted in the following quote: *"We are about 30% plastic and 70% under shade netting or open. Open-air is a risk in the Cape whereas in the North it is different*" - Participant 4.

Similar to climate, the soil is not specifically a driver of blueberry adoption but rather a driver of the production method. Many of the participants mentioned that soil quality was the most important factor for blueberry production, specifically the drainage qualities. However, these ideal soil conditions can be obtained by manipulating natural soil or planting in pots. Participant 4 stated the need for alternatives such as pots as a result of suboptimal soil: "*Our soil is horrible, which is Western cape soil… So if your soil is good, meaning good drainage soil chemical composition does not matter, then I will plant in soil but we are mainly in pots*".

#### *3.4.2.7 Reduced theft risk*

One participant highlighted that blueberries reduce the amount of risk associated with fruit theft because of their small, delicate nature and the fact that they must be picked individually. This participant expressed that this was a driver of adoption for them because they have previously struggled with fruit theft. The lower theft susceptibility is highlighted in the following quote by the participant: *"A benefit of blueberries against other commodities is that they don't get stolen. A mango, avo, macadamia nut, and citrus, they come and steal bakkie loads full. Blueberries are too difficult to pick and steal at night"* – Participant 6.

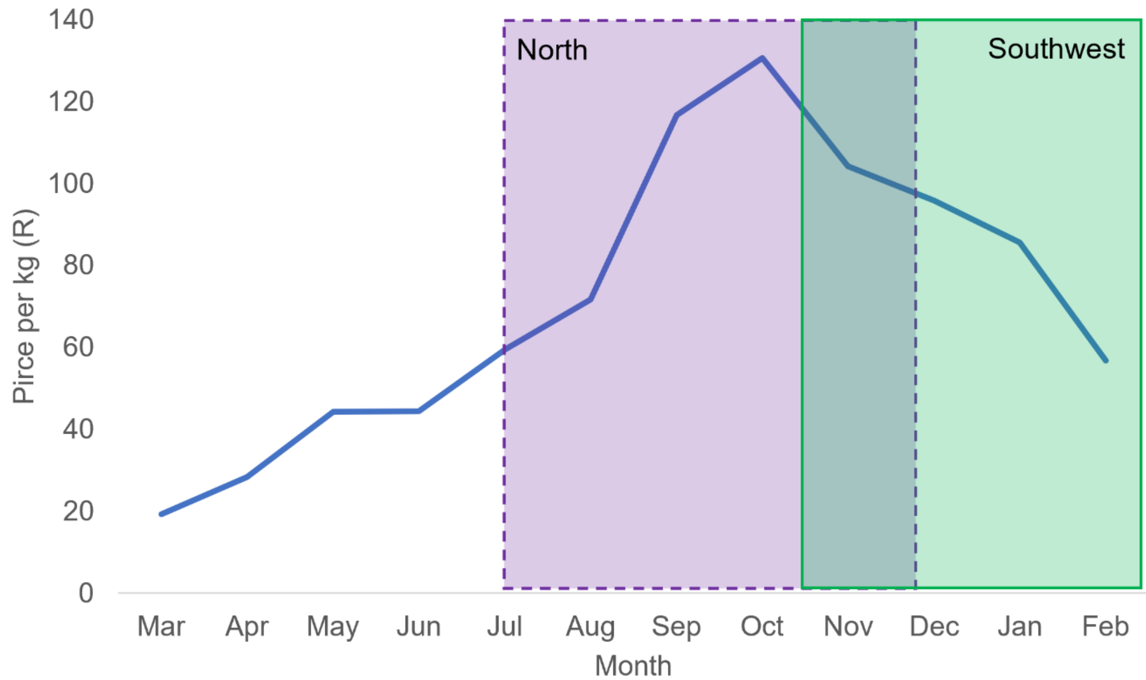


Figure 3.6 The average monthly price obtained for a kilogram of South African blueberries on the export market over the last ten years and the harvest season of the different production areas. Purple represents the estimated harvest season of individuals in the northern area of South Africa while green represents the estimated harvest season for the southwestern area of South Africa.

### 3.4.3 Impact of recent changes in the blueberry industry

The rapid expansion both in terms of land area and yield of the blueberry industry globally and within South Africa has resulted in many changes in the industry since the participants became involved in the industry. All the interviewed participants stated that in the last few years the profitability of the industry has decreased. This is important since profitability was one of the main attractions to the industry for the majority of individuals. Overall participants agreed that the decrease in the profitability can be attributed to the increase in competition locally and internationally from countries like Peru, as well as the increase in cost to develop and maintain a hectare of blueberries in South Africa.  A statement where one participant highlights the change in profitability in the industry: *“there's no doubt that it was more profitable 10 years ago, five years ago. You know, there's more competition, prices stabilized, you've got the Peruvian fruit that comes in”* – Participant 1.

The increase in competition has reduced the price offered to farmers but not the average price for blueberries on the export market, which has increased (Figure 3.3). Participants noted that they are now challenged to optimise their operations and by selecting the best blueberry varieties for their environment and market. Competition has placed added pressure on the quality requirements for blueberries that are destined for the export market, and increased the number of blueberries that are rejected by supermarkets which further cuts into the farmers' profits. The impact of competition on quality standards as alluded to by one participant highlighted: *"You know you can pick eight 18 tonnes a hectare and of that 18 tonnes about 10 to 20% can get rejected on arrival in the UK or Europe"* – Participant 1.

The profitability of the industry is further exacerbated by local challenges faced within South Africa such as the current economy, politics, and infrastructure. The unstable economic environment in South Africa has resulted in lower foreign investment and high inflation rates that lead to an increase in the production cost of blueberries, while the export markets can maintain much lower annual inflation rates. Interview participants all voiced that they are concerned about the current economy and the increasing cost to produce blueberries. This includes the increasing cost of electricity, fuel, and fertiliser in South Africa that are crucial to blueberry production (Matebeni et al., 2021). The following quote shows the increasing input costs experienced by participants: *"the costs of have gone through the roof as well, I mean, I think we were looking at about R 600,000 a hectare including irrigation infrastructure and land prep back in 2013, 2014, 2015, and now you won't get away, and I'm not including irrigation infrastructure because we've got the irrigation infrastructure, just shy of a million rand a hectare"* – Participant 5.

In several interviews, it was raised that competition leads to exporters demanding a minimum farm size of around 20 hectares before individuals can be considered for the market. This substantially increases the initial start-up capital required and limits the number of small-scale farmers that can economically benefit from the industry and often places pressure on farmers to expand sometimes beyond their capabilities. A participant's opinion about the start-up challenges faced by new farmers: *"If you want to get into the industry now you have to start with a minimum of 20 hectares you know first shot so that would make it even more difficult to get in sort of financially. I was lucky to be able to start with only a few hectares and grow from there"* – Participant 7. Additionally, the economy also impacts farmers' ability to obtain the required loans to start or expand blueberry farms which were highlighted in the following quote: *"The farmers are definitely taking strain and they're finding it harder to get finance, places like the land bank, unfortunately, aren't really available to farmers"* – Participant 3.

Political matters such as land appropriation without compensation that is currently being explored in South Africa have been put forward by the majority of participants as a concern regarding the industry. A participant mentioned that this was a constant concern raised by private investors when seeking capital. While another participant emphasises the importance of financial access that is being affected by political matters: *"where the country is in terms of land appropriation, I think the farmers are scared, it's (blueberry farming) really is a significant investment and again to get the financing has really become a problem."* – Participant 3.

Degrading infrastructure, predominantly the sea freight export channels, was also pointed out by all the participants as a concern in general within the agriculture industry, but more so specifically with regards to the blueberry industry because it is an extremely time-sensitive crop. Concerns increased when the prices obtained for a kilogram of blueberries via air freight (which is more expensive than sea freight and road transport) decreased to match prices obtained via cheaper sea freight, which reduced the volume of blueberries exported through more reliable air freight (Figure 3.7). Participants expressed that it is common to experience delays via sea freight during their peak season and one participant expressed that they have experienced delays up to two weeks. Overall, this impacts their time of entry into the market and the quality of the fruits that make it to market which in turn impacts the price they obtain for their blueberries. This quote reflects on the infrastructure challenges faced by the fruit export industry: *"Then the port in Cape Town is falling apart, you can go talk to the citrus farmers when they just came out of the drought, Durban, and Kouga, nothing was working, Cape Town was good then suddenly no of the gantries and cranes were working and then you add a bad cape storm to the mix and you throw covid in there and the ships are not docking."* – Participant 4.

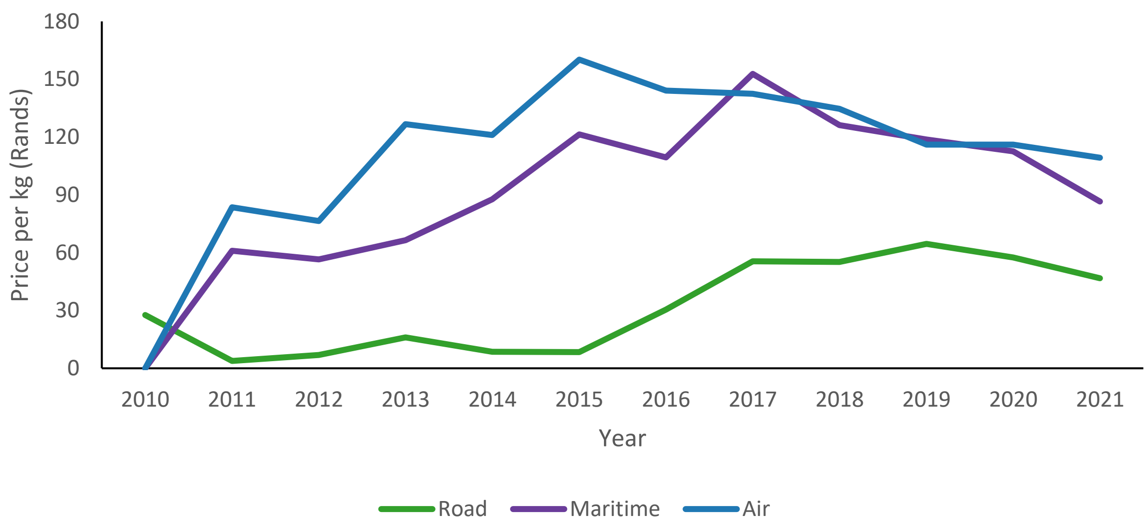


Figure 3.7 The price obtained for exporting a kilogram of blueberries from South Africa via three transport methods between 2010 and 2021 (SARS, 2021)

### 3.4.4 Impact of shocks on the industry

In addition to the ongoing challenges that the industry faces, participants mentioned four shocks that have impacted the blueberry industry: (1) COVID-19, (2) droughts, (3) other extreme weather events like floods and hail, and (4) civil unrest. Of these, COVID-19 was discussed in most detail. In the survey, eleven participants recorded that COVID-19 had no impact on their willingness to expand blueberry operations and one participant indicated that it increased their willingness to expand their operation (Addendum Figure C.2). This provides a view that, at the time of the survey between June and September of 2021, COVID-19 had not radically disrupted the industry and this view was also prominent in interviews among all seven participants. Agriculture, which includes the blueberry industry, was identified as an essential service under the lockdown regulations and therefore it was allowed to operate throughout the COVID-19 period. Participants indicated that they haven't had large COVID outbreaks amongst their staff that could result in a shutdown, and one participant mentioned that they have a backup staff team to minimise disruptions. Additionally, the strict hygiene requirements implemented to pick blueberries also reduced the burden of implementing COVID-19 protocols as the industry already adheres to many of these. The industry mainly operates outdoors within low-density groups but social distancing was a bit harder to achieve. This was addressed by dividing pickers into smaller teams that work together and reducing transport capacity to 50% by doubling the number of trips to transport staff. In the field, pickers could maintain the required social distance, however in workshops and packhouses it proved a bit more challenging. To minimise the risk in these more challenging work environments farmers urged individuals to wear masks at all times, adhere to hygiene protocols and avoid contact with other individuals as much as possible.

The main impacts of COVID-19 were not directly related to blueberry production, but rather indirectly impacted the industry through the increase in transport costs due to a decrease in flights and ships. The bulk of participants in interviews confirmed that their export cost, specifically air freight, increased when COVID-19 restrictions were implemented. Another indirect impact noted by a few of the participants was the increase in costs of importing inputs required for production. This is highlighted by a participant that discussed the price of importing inputs *"we see it on the other side, we plant our products in peat and we do use imported products, and they've absolutely skyrocketed and that's just the cost of cargo."* - Participant 3.

Another participant observed that COVID-19 caused a number of items to have an added surplus charge that also increased their production and export costs. Two participants reflected on a positive impact from COVID-19 related to alcohol restriction during lockdowns which in their opinion improved the productivity of employees on the farm: *"Our staff was more productive because of the alcohol restrictions and I think violence in the labour communities also decreased. In general, I would say they saved a lot of money not spent on alcohol."* – Participant 7.

Besides COVID-19, three other shocks emerged from the interviews. The most common shock that was noted by participants were the droughts in the Western Cape and Limpopo area. Droughts were considered to be an overall concern for the industry and two participants expressed that they had to reduce their blueberry operation because of the limited water they had available during the recent droughts. The one participant also had to truck water in to maintain the already reduced operation and has recently bought a water pipeline that runs over seven kilometres to increase the volume of water available to the farm. One participant reflected on how severe the drought was: "*we have enough water but it was borderline at a stage. We have a strong borehole but three years ago we could see it was struggling. All our dams are now full but it is maybe the exception because a few years ago it was rough."* – Participant 4.

Other extreme climatic events like early rainfall and hail also emerged as a shock that impacted the industry. After the drought, one region experienced extremely high volumes of early rain during their picking season. This abnormal extreme weather event damaged blueberries that were not protected by plastic tunnel structures and reduced the number of picking days which led to a large volume of the blueberry crop being lost. Another participant observed: "*We had a hail event in April, which is something I have never seen before. Yeah, and that took 30% of our crop out, and if we'd had netting, that obviously would have, we wouldn't have lost 30% of the crop… And then last year after, after three very dry seasons, jeepers, we had a rain event at the end of August beginning of September just as we were getting into peak production on one blueberry variety and you know blueberries (are) like grapes when it gets too much water, it just burst*" – Participant 5.

The last shock that emerged from the interviews was the recent civil unrest (riots) that occurred in July 2021 which predominantly affected two provinces (Kwazulu Natal and Gauteng). While these had no direct or indirect impact on the blueberry industry, participants noted that if this event happened during their picking season it could have had a considerable impact on the industry. This was based on the impact these riots had on citrus producers that had to stop picking because they could not export their crop. Considering that blueberries have a much shorter shelf life than citrus, the potential impact would have been substantially more if unrest timing had coincided with the harvest. The following quote relates to a farmer recalling the civil unrest: *"like in Durban with all the strikes and things and the riots that closed the ports in Durban, they're (citrus farmers) experiencing massive negative loss"* – Participant 1.

### 3.4.5 The future of the blueberry industry in South Africa

Improvements required to ensure the longevity and success of the blueberry industry was the final theme that emerged from the interviews. At a high level, it included improving efficiency in the industry, securing sufficient market access, and optimising the role of multinational companies. Becoming more efficient to improve production and improving the export supply chain were the top issues for interviewees, which they have started to address by adopting various new technologies. An example of technology adoption to optimise inputs includes the following: "*we will definitely expand* *like I said earlier, the profit is under pressure but even so there isn't another crop that comes close to it but you will have to be sharper and better. We are considering reducing the number of blueberry plants. From that, if you farm well you can obtain the same yield and a higher net profit because you have less expenses… Because we were one of the first farms our rotation is to replace the older varieties with newer varieties and newer techniques and you consolidate, we got a quote on scales which you put your plants on. So we anyway have around 20 test stations in the field that you every day check you ec drainage, you write everything down that has happened. You have your input from your PC and from the field that is physically drained from the pots. This scale does it for you, it links remotely with your PC or phone. You can see the exact weight of the plant and as it transpires water you can see weight loss, so if it is 500g lighter it needs 500g of water. So that are all functions to be more effective*." -Participant 5.

The other area that needs to be optimised is the export supply chain and two possible ways were suggested by participants. The first is increasing the shelf life of blueberries through developing newer genetic varieties that have an extended shelf life and improving the existing cold chain to reduce quality degradation in the chain. The second is to upgrade infrastructure and optimise export operations to prevent delays. Thereafter the industry needs to ensure that they have sufficient market access to absorb the volume of blueberries being produced. In that sense, South Africa must establish itself in a diversity of markets as a competitive producer of blueberries. However, this responsibility lies with the exporting companies and therefore participants have suggested that these companies need to improve their marketing efforts. A participant also raised that marketing should be done responsibly to avoid price crashes as the industry is growing faster than demand is. One participant expressed the need for exporters to respond to the increase in competition: *" We all agree on that as growers (competition is increasing and marketing needs to improve), typically like I mentioned earlier, the holiday is over. It was very easy to sell blueberries at a high price a couple of years ago, you know, so marketing is a very active role. You have to go out and build relationships, meet people, have people travelling the world to pitch your product as an exporter so you need a specialist fruit salesman."* – Participant 1.

The last factor that emerged as an element that should be considered to ensure a successful blueberry industry is aligning with the market and consumer demand. The blueberry industry needs to consider the sustainability of production methods, as raised by one participant, as consumers are demanding more sustainable food production and the industry needs to align. This can include a range of solutions such as complete biological production or substituting unsustainable inputs like peat for more sustainable alternatives like coir made from coconut husks. The following quote expressed a participant's observation of sustainable adaptations: "*there are farmers that are saying they're not* *going to go the chemical route. They want to do biological farming and there are not many of them… It's all about yield. So if you farm biologically and you can get a 25% higher yield, it is more effort, but at the end of the day, your input costs become cheaper. In fact, and you get a higher yield per hectare, so your utilization of your space is better, so your profit overall profitability will increase*." – Participant 3. Furthermore, participants implied that the local price for blueberries in supermarkets should be lowered in an effort to grow the demand within the local market. One participant also noted that COVID-19 can potentially impact the demand on the local market as it has impacted the South African economy and the buying power of consumers.

Finally, a reflection on the role of the local market in the future of the blueberry industry in South Africa suggests that there may also be scope for improving the local market: *"in South Africa, we are on the way to producing 20 000 tonnes, so roughly 2000 tonnes must go somewhere (other than the export market). The (local) chain stores do not reduce their prices to the end consumer but the farmer's prices decrease and not the chain store. I think we will be able to move much more tonnes in South Africa if the chain stores drop their prices because berries are perceived as unaffordable."* – Participant 4.

## 3.5 Discussion

This study sought to investigate the factors driving blueberry production uptake and expansion in South Africa. Seven drivers were identified as important considerations in entering the industry (1) economic benefits, (2) financial access, (3) market demand, and access, (4) intelligence of export companies, (5) employment opportunities, (6) environmental factors including water, climate, and soil, and lastly, (7) social issues like fruit theft. Despite initial perceived benefits of the industry, participants expressed that the industry is changing at a rapid pace, and they are currently facing many challenges such as increased competition, supply chain problems, reduced prices, and the industry's susceptibility to some shocks. Surprisingly, participants noted that COVID-19 has only had a minor impact on the industry but exposed the industry's reliance on effective supply chain management. In the end, all the participants expressed that they believe that the industry has a strong future in South Africa if these challenges can be addressed.

### 3.5.1 Demographic profile

Although the influence of demographic attributes on participant responses was not statistically analysed due to the small sample size, participants' appeared to express similar opinions on the drivers of the blueberry industry despite differences in their age, gender, or job title. Previous research on cash crop adoption amongst small-scale farmers has observed that younger more educated individuals often adopt new crops earlier than older farmers (Appau et al., 2020; Inoni et al., 2021;

Katengeza et al., 2012), whereas I found early adopters amongst all three age groups. This could be a result of the small number of participants in the study, but is more likely because of their similar demographic profile (apart from age). It is also important to consider that all of the participants operate at a commercial scale (three participants were solely dependent on blueberry production and four farmed a mixture of crops), therefore entry into the industry is not necessarily at the sole discretion of individuals, but could come about as a collective decision made by stakeholders in a commercial operation. In addition to interviewing more farmers, future research can include other stakeholders like farm workers in the interview process to get a better understanding of the broader social impacts (Ibarrola-Rivas et al., 2020; Llopis et al., 2020).

### 3.5.2 Initial drivers of blueberry adoption

The main drivers of blueberry expansion highlighted in this study align with other cash crop studies despite it focusing on commercial operations rather than small-scale farms. This includes the perceived profitability of the cash crop, access to financial support, market demand, and engagement with exporters. Similar to the majority of cash crop adoption studies (Appau et al., 2020; Friis and Nielsen, 2017; Ibarrola-Rivas et al., 2020; Llopis et al., 2020; Tessema et al., 2019), perceived economic benefit was a dominant driver of blueberry adoption. Specifically, the profitability and ability to diversify income through a crop that is predominantly destined for the export market. This finding is in line with the market value and projected income from blueberry production (WCDoA and BerriesZA, 2019). Participants also considered the quick return-on-investment time (3 years) a convincing driver of blueberry adoption which has not been observed in previous research. An individual's financial capacity and access to loans and investment were also considered to be crucial factors when adopting blueberries because of their extremely high start-up cost. This was also observed as an important factor in rural cash crop adoption, however, the capital required was much lower in these instances (Appau et al., 2020; Friis and Nielsen, 2017). Despite the challenges to secure loans within South Africa, the industry has managed to keep expanding through finding private investors or leveraging other avenues to secure start-up money.

Ouédraogo et al. (2016) reported that adopting a new crop, new genetic variety, crop rotation, and the expansion of existing farm operations are positively correlated to new market opportunities. The Centre for the Promotion of Imports from developing countries (CBI) has reported that there is still a large opportunity for blueberry producers as European countries are still experiencing ongoing growth in demand for blueberries; they also reported that Europe's imports grew by 41% between 2018 and 2019 alone (CBI, 2021). This was supported by the majority of the participants, who indicated that demand for blueberries is still increasing. Alongside the growing demand, South Africa is considered to be perfectly situated to produce blueberries for the northern hemisphere because it produces blueberries during the Northern hemisphere winter season when there is a shortage (CBI, 2021; WCDoA and BerriesZA, 2019). South Africa also has a well-established export relationship with Europe and the United Kingdom in particular (BerriesZA, 2019), which makes it an easy market to access for blueberry producers. Demand and existing relationships with Europe and the UK were considered to be stronger drivers of blueberry expansion in South Africa than local market demand that remains low.

The influence of external individuals being exporters or middlemen is a common theme throughout cash crop adoption studies, mainly because the bulk of cash crop studies occur in rural areas where individuals do not have access to all the information (Baird and Fox, 2015; Friis and Nielsen, 2017; Llopis et al., 2020). Even though blueberry production in South Africa occurs mainly at a commercial scale on well-established farms that have access to more information than small-scale rural farmers, export companies were still crucial influencers in the adoption stage. Participants noted that they established the relationship for three main reasons (1) to gain access to proprietary genetic material, (2) as a knowledge source in the start-up stage, and (3) to ensure the producer has access to a viable market for blueberries. Ouédraogo et al. (2016) also observed a positive correlation between adopting high input cost practices and the provision of technical and financial support. Blueberries require extremely high input costs, especially in areas that require protective covers or pots for production, which likely explains the importance of this relationship as a driver of blueberry uptake.

Environmental factors such as climate and soil were commonly perceived as drivers of agricultural uptake. In many small-scale cash crop studies, the climate and environment were one of the most important factors determining crop adoption, including crop switches to more drought-tolerant crops as a result of climate change (Appau et al., 2020; Aravindakshan et al., 2020; Katengeza et al., 2012; Ouédraogo et al., 2016; Tessema et al., 2019). Participants in this study agreed that environmental factors are drivers of blueberry uptake and expansion, but many of the environmental factors can be controlled for by using newer genetic varieties, covering areas with protective structures, and planting in the optimal substrate in pots (Meyer and Prinsloo, 2003; USDA, 2020; WCDoA and BerriesZA, 2019). The importance of environmental factors in influencing crop choice in previous studies could be because previous studies focused on rural communities that do not have the capital or access to knowledge to adopt new technology that combats these constraints. This study suggests that access to technological advances can overcome environmental limitations as blueberries production in South Africa occurs across a diverse range of climates and environments. Nevertheless, environmental factors influenced the production method adopted, as well as the genetic varieties that have been developed (Meyer and Prinsloo, 2003; WCDoA and BerriesZA, 2019). This is further supported by participants highlighting that the optimal environment for blueberries is in the northern region of South Africa, while the majority of blueberry farming is still situated in the Western Cape.

Participants in the blueberry industry also highlighted some unique drivers (not mentioned previously in the literature) that influenced their decision to adopt blueberries (1) employment opportunities and (2) decreased risk of theft. In most cases, high labour demand is seen as a negative when weighing up options for crop production (Aravindakshan et al., 2020; Hettig et al., 2016; Tessema et al., 2019). However, survey and interview participants in this study considered this to be a reason for selecting blueberries (Addendum Figure C.1). Previous research has not highlighted employment opportunities as a driver of cash crop adoption but rather a limiting factor for small scale farmers, as their labour availability is related to their household size or their ability to afford hired labour (Aravindakshan et al., 2020; Hettig et al., 2016; Tessema et al., 2019). Yet, there are examples where cash crops are adopted despite the intensive labour requirements, as in the case of tobacco (Appau et al., 2020) and vanilla production (Llopis et al., 2020). In the case of the South African blueberry industry, employment opportunities were seen as a positive, as the blueberry season is offset from other major fruit crops and managers want to maintain skilled labourers year-round because of the high labour demand and delicate picking required. The industry has also been used as a case study that attempts to address the high levels of rural unemployment in South Africa.

Theft is a continuous problem faced by fruit farmers in South Africa, especially with cash crops like avocados and citrus (Christensen, 2021; Coleman, 2020). This can accumulate to massive losses for cash crop farmers whether they are small scale (Llopis et al., 2020) or large scale (Christensen, 2021; Coleman, 2020) as a result of saleable crop loss, property damage, and the cost of security to minimise theft. Fruit theft is generally associated with high-value crops for resale purposes rather than as a source of food for the thieves (Coleman, 2020; Llopis et al., 2020). Therefore, the notion raised by a participant that the size and difficulty of picking blueberries reduce the risk of theft could be a valuable driver for export-orientated farmers, because it reduces the risk of income loss due to theft and property damage, as well as reduces the input cost required to hire private security.

### 3.5.3 The current blueberry industry in South Africa

Temporal heterogeneity of drivers is observed in many agricultural crop industries due to changes such as price and demand over time (Grote et al., 2021; Munteanu et al., 2014). The blueberry industry is experiencing changes across a number of the identified drivers. Some of the challenges raised by participants during the interviews are related to the maturity of the blueberry industry: (1) decrease in price and (2) increase in competition; while others are common challenges to the whole agricultural sector in South Africa: (3) increasing price of inputs, (4) degrading export infrastructure and (5) access to financial support.

A common observation in cash crop studies is that early spikes in prices attract producers to adopt the cash crop, but as the industry matures prices decrease and stabilise over time (Friis and Nielsen, 2017; Llopis et al., 2020). The increase in the number of producers and the volume of the cash crop produced over time results in a decrease in market price, reducing the income of early adopters that experienced initial high prices due to the scarcity of the commodity. This decrease in price experienced by participants in this study and supported by statistical data can be a result of the maturity of the industry as producers and production volume increase in South Africa. Participants expressed an expectation that competition would increase as the industry expands in South Africa and other markets like Zimbabwe, Peru, and Chile, which could further impact the profitability of operations.

The decreasing value of South African blueberries in combination with the increasing cost of agricultural inputs makes it extremely challenging to achieve the early perceived profitability. The global increase in the cost of key agricultural inputs including fuel, fertiliser, and herbicides, together with the weakening of the Rand has resulted in an enormous increase in input costs for South African farmers (Luckhoff, 2021; Sihlobo, 2021, 2018; Western Cape Government and University of Stellenbosch Business School, 2018). South Africa relies largely on imported agrochemicals, therefore the increase in fuel prices also impacts the transport cost of inputs, and further adds to an increase in input costs (Matebeni et al., 2021; Sihlobo, 2021, 2018). Electricity is another input that is experiencing a rapid increase in price in South Africa, further adding to the input cost required to produce blueberries (Matebeni et al., 2021; Western Cape Government and University of Stellenbosch Business School, 2018). The soaring input costs may reduce the profitability of the blueberry industry and impact the industry's ability to produce blueberries at a competitive price for the export market.

On top of increasing input costs, participants noted that there has been an increase in the cost to transport blueberries to their destination. This comes as a result of increasing fuel prices and inefficiency and degrading of infrastructure at South African ports (Chadwick, 2019; Majola, 2021). The poor conditions of South African ports have resulted in fewer ships docking and more competition for transport which also adds to the price of transport (Majola, 2021). This poses a significant problem for the blueberry industry as the current market value for blueberries is not sufficient to export blueberries via air freight, making the industry reliant on ship freight. Another common problem that occurs as the result of poor port conditions are delays in shipping times; this directly impacts the capacity for exporting good quality blueberries and obtaining the highest price. The majority of participants noted that the price obtained for blueberries is linked to the time of entry into the market.

Delays in shipping can impact the price obtained in two ways (1) the longer waiting period can result in a decrease in the quality of the fruit that reaches the market and (2) it can impact the time of entry to the market and often result in larger volumes being shipped at the same time. These delays can also lead to quality degradation of the blueberries which increases the chance of rejection by the buyer. Producers in the wine and citrus industry in South Africa have reported similar issues with delays in exports due to inefficiencies and poor infrastructure (Chadwick, 2019; Majola, 2021). Munim et al. (2018) reported that the port infrastructure and efficiency for developing countries are crucial to their economic development, while Chang et al. (2014) noted that R1 million shortage in the port sector would result in a 17% deficit of the total annual economy in South Africa.

Participants also noted that access to loans and other funding in South Africa presents a challenge for individuals to fund expansions or optimise their operation by procuring improved blueberry varieties or new technology such as irrigation infrastructure. The continuous exploration of notions like land appropriation without compensation (this bill failed to pass on the 7th of December 2021) in South Africa was raised as a concern as participants noted that it deterred private investment, which further limits individuals' options to access finance (Boshoff et al., 2018; Sihlobo and Kapuya, 2018). The lack of access to loans and financial support was considered to be a limiting factor of cash crop adoption in other studies (Appau et al., 2020; Inoni et al., 2021; Katengeza et al., 2012; Tessema et al., 2019) and could reduce the expansion or increase abandonment of the blueberry production in South Africa. Additionally, exporters now require that individuals cultivate at least twenty hectares of blueberries before they can be represented by exporters. This in combination with the increase in competition, transport and input costs, decreases in market prices, and lack of access to financing can reduce the willingness of new individuals to enter the blueberry industry. It could also lead to current individuals abandoning blueberry production. Nevertheless, all the participants noted that they still consider the industry to be lucrative despite these challenges.

### 3.5.4 Impact of shocks on the blueberry industry

Cash crops and small-scale farmers are considered to be vulnerable to external shocks (Friis and Nielsen, 2017; Rubhara et al., 2020), however, the blueberry industry in South Africa has shown low susceptibility to the shocks based on this study. According to interviewees, COVID-19 simply added to existing challenges like the price and accessibility of inputs, transport associated with poor port conditions, and increasing global production prices. Other studies observed that COVID-19 had a large impact globally on many industries, including agriculture (Pak et al., 2020; Stephens et al., 2020). A study that looked at the initial impact of COVID-19 on agricultural markets in India found that there were initial spikes in commodity prices, but this, as well as supply constraints, considerably decreased within the first month of the lockdown (Varshney et al., 2020). The initial lockdown in South

Africa (26 March to 30 April 2020) occurred outside the picking and export season for blueberries, and the agriculture industry was considered an essential service (Phillip, 2020) which likely reduced the impact of the shock on the industry. This study also focused on blueberry production at a commercial scale. Lopez-Ridaura et al. (2021) found that COVID-19 had a more substantial impact on small and medium scale farming operations in Central America and Mexico, while it had only minor impacts on commercial farms. The industry has also adopted existing policies and procedures related to hygiene practices similar to COVID-19 protocols which minimised operational disruptions (OECD, 2020; Varshney et al., 2020).

This study indicates that droughts are considered to be the shock that has had the worst impact on the blueberry industry in South Africa. Participants noted that blueberry production is highly reliant on consistent water availability throughout the year and drought conditions could damage and kill blueberry bushes. A few participants had to reduce their operation size during these conditions while also procuring additional water from other sources. This is in line with the Western Cape Government (2017) report that stated that the drought will have the largest impact on resource-intensive irrigated crops that are produced for the export market; the impacts included consolidation of production to a smaller number of producers, decrease in income from exports, increasing prices for inputs like water and potential job loss in the supply chain. Irrigated crops in general are highly susceptible to prolonged droughts (Katengeza et al., 2012; Meza et al., 2021; Rey et al., 2017; Western Cape Government, 2017). The blueberry industry has also been impacted by shocks such as early or late season rain, excessive amounts of rain, and hail. These extreme weather conditions have also resulted in reduced yields and damage to many other fruit crops (Beillouin et al., 2020; Vogel et al., 2019). Rainfall outside the normal rain window, specifically during the harvest season can delay the picking of blueberries and result in the perishing of blueberries that cannot be sold to the market (Meyer et al., 2003). Like with many other small bushes, hail can damage the plant and the fruits if it occurs during the harvest season, and also reduce the yield. The increasing frequency of such extreme weather events as a result of climate change can impact individuals' willingness to engage or continue with blueberry production as it will require more infrastructure investment and potentially seeking alternative water sources at an added cost (Meyer and Prinsloo, 2003; Nhamo et al., 2019; Ouédraogo et al., 2016; Vogel et al., 2019).

The last shock that emerged from this study was the recent civil unrest riots in South Africa (9 to 18 July 2021) that disrupted the majority of supply chains to the largest export port in Durban (Mchunu, 2021; Meintjes, 2021). Although this shock had no impact on the blueberry industry, it was raised as a concern during interviews because it impacted other fresh fruit exports like the citrus industry (Meintjes, 2021). Participants said the main reason they weren't impacted is because it happened outside their picking season and if such disruptions occurred within their picking season it could have led to a substantial loss in income due to perishing fruit. It has also been observed that farmers in other African countries suffer severe economic and infrastructure losses because of civil unrest, which poses a significant risk for the sustainability of their agriculture sectors (Maynard, 2015).

### 3.5.5 The future of the blueberry industry in South Africa

For the industry to continue to grow in South Africa, current challenges need to be addressed, and the industry needs to align with global consumer demand for more sustainable products. Improving the efficiency of blueberry production through precision agriculture has been observed to be successful in increasing profitability as well as reducing the environmental impact of production by decreasing the inputs that are required (Balafoutis et al., 2017; Medici et al., 2019). Investment in research and development can also increase the resilience of the blueberry industry to minimise the impacts of shocks and address supply chain issues (Chaminuka et al., 2019; Henry, 2020; Nhamo et al., 2019; Rawat, 2020). Research and development can include creating new varieties with increased shelf life and drought tolerance or alternative treatments to reduce blueberry degradation (Chadwick, 2019; Chang et al., 2014; GAIN Group, 2020; Munim and Schramm, 2018). Similarly, economic investment in improving port infrastructure can reduce the supply chain challenges currently faced by the industry as port infrastructure is a key factor to an export industry's success (Chang et al., 2014; Munim and Schramm, 2018). Thereafter market demand and access are other crucial success factors for export industries (CBI, 2021; Clark, 2021; Ouédraogo et al., 2016). These factors were reiterated by participants as a need that should be addressed by exporters to expand to new and less saturated market areas to ease competition and allow the industry to grow. Lastly, producers also have a responsibility to ensure they align their production practice with consumer demand and preferences, which are increasingly shifting to practices with a lower impact on the environment (TNC, 2020; Zamuz et al., 2021). The effectiveness of new improvements requires further research.

## 3.6 Conclusion

This chapter explored drivers for the rapidly expanding blueberry industry in South Africa, especially the drivers behind commercial cash crop adoption destined for the export market. The initial drivers of the growth in the blueberry industry in South Africa are similar to the drivers of other cash crop industries, with the exception of two drivers: employment opportunities and reduced susceptibility to theft. The young blueberry industry is already facing challenges such as reduced profitability due to the increase in competition, an increase of essential input costs, transport costs and access to loans or investments. Interestingly, the industry was considered to have low susceptibility to shocks like COVID-19 but is expected to be more susceptible to climate and export time delay related shocks. All of the participants have expressed that they are working towards overcoming some of these challenges to ensure the future of the industry in South Africa.

The findings of this study can be used by policymakers to understand the drivers of cash crop adoption in Africa and identify early expansion and production policies that can reduce large scale disruption to the economy and environment as a result of cash crop booms. The results can also be used to explore solutions that will reduce the challenges faced by the blueberry industry and address the industry's vulnerability to external shocks like extreme climatic events. For example, climate-smart approaches can be encouraged and proactively implemented to prevent potential climate change impacts on the industry. But the results should be seen in light of some limitations. The first was the small sample size as a result of COVID-19 restrictions that required participants to complete surveys and interviews remotely. This sample size limited my ability to statistically analyse the difference between individual participants, farms or regions which could be addressed in future research to understand how demographic, geographical or socioeconomic differences can influence the drivers of blueberry adoption. This study was only representative of commercial-scale operations and did not include small-scale operations as these farmers are less likely to be identified through web searches as they might not be affiliated with the BerriesZA association or have a public-facing website. Therefore, it is important that future research also include small-scale operations to understand the differences between these types of operations (e.g., small-scale farms that use royalty-free blueberry bush rather than proprietary genetics used in commercial operations or small-scale farms that focus on the local market as opposed to the export market). Despite these limitations, the few participants represented in this study represent 30% of the 42 contacted.

# Chapter 4: Social-ecological impacts of the blueberry industry in South Africa

## 4.1 Abstract

Crop expansion driven by consumer demand from richer, developed countries are displacing social-ecological impacts from these countries to poorer, developing countries that produce and export these crops. This study applied a life cycle assessment (LCA) to quantify the potential social-ecological impacts of blueberry expansion in South Africa, driven primarily by demand from the United Kingdom. This study quantified the potential impacts on human health, resource scarcity, and biodiversity loss for four stages (production, post-harvest, packaging, and storage) of the blueberry life cycle in South Africa. My results show that displacing a hectare of blueberry production to South Africa will have an impact across the social-ecological system, impacting human health (7,59x10-3 disability-adjusted life years), the economy (236,26 USD of resource surplus cost), and the environment (1,11x10-5 species loss potential per year). The potential impact of blueberries was compared to apples, grapes, oranges, pears, and strawberries that are also commonly produced in South Africa for the export market and found that blueberries had the lowest impact in comparison to these fruits. Our results suggest that producing and exporting apples, grapes, oranges, pears, or strawberries are potentially more harmful than producing and exporting blueberries. The production stage was the largest contributor to the potential impact of blueberries and the other fruits. Overall, the LCA does not account for some key social-ecological impacts such as the social benefit of employment and disturbance of landscape aesthetics that can impact the existing tourism industry. Therefore, in the future LCA results should be used in combination with other methods when quantifying the impacts of a telecoupling.

## 4.2 Introduction

Since the late 20$^{th}$ century, the biomass of food traded globally has experienced a fivefold increase while the trading of food has expanded three times faster than food production, and almost all newly converted agricultural land is also destined for export rather than local markets (Mayer et al., 2015). A major driver of food trade is growing consumer demand in wealthier countries that have experienced an increase in disposable income, allowing them to purchase a larger number of regular, luxury, and exotic food items on a routine basis (Garrett and Rueda, 2019; Gebisa Etea et al., 2017; Jąder, 2020; Mottaleb et al., 2018; Sandström, 2018). Importing food items provides an opportunity to overcome the seasonality of local production cycles, limited land availability, and sub-optimal climatic conditions to meet consumer demand. Differences in production cost (Godar and Gardner, 2019), trade policies, and subsidies (Fang et al., 2016; Friis and Nielsen, 2017; Rulli et al., 2019) can also drive the choice to import food items that can be offered to consumers at a lower price. This allows importing countries with stricter social and ecological policies and regulations to evade local regulation by outsourcing production to areas with less stringent policies and regulations (Balogh and Jámbor, 2020; Fang et al., 2016; Friis and Nielsen, 2017), resulting in social-ecological consequences for the exporting countries (Wiedmann and Lenzen, 2018).

The expansion of agricultural commodity trade across the globe increases the geographical distance between production and consumption (Garrett and Rueda, 2019; Godar and Gardner, 2019). Such geographical distance leads to longer, more complex supply chains, allowing for information such as the production method, chemicals used and farm location to get lost or obscured from the consumer (He, 2018) and creating additional psychological distance between production and consumption (Garrett and Rueda, 2019; Godar and Gardner, 2019). This distance further results in the breakdown of feedbacks that help facilitate just socioeconomic and environmentally sustainable production. Breves and Schramm (2021) and Maiella et al. (2020) observed that psychological distance influences an individual's efforts to reduce their environmental impact as it is associated with their perceived exposure to climate change impacts. Therefore, if production and its impacts are closer to the site of consumption, social-ecological impacts might be more obvious and result in action from the consumer (Sundkvist et al., 2005). Furthermore, Lenzen et al. (2012) showed that international trade is a threat to the survival of many species yet demand for products like coffee and chocolate keeps growing. Therefore, physiological distance can also create a false sense of security of access to commodities by obscuring the vulnerability and state of the distant production areas.

In recent years much effort has gone into the study of social-ecological sustainability of the global food trade. An emerging framework, telecoupling, provides the structure to study the complex social-ecological impacts of trade (Castilla et al., 2016; Easter et al., 2018; Garrett and Rueda, 2019; He, 2018; Herzberger et al., 2019; Ibarrola-Rivas et al., 2020; Llopis et al., 2020; Sun et al., 2018) and is defined as the social-ecological interaction between distant natural and human coupled systems (Liu et al., 2019). The framework does not specify the methodology to quantify the social-ecological impacts, although there are existing methods in the social-ecological systems space that can be applied (Deutsch and Troell, 2021). Some common methods used are physical trade flows (Godar and Gardner, 2019), input-output analysis such as multi-regional input-output analysis (Qasemipour et al., 2020; Wilting et al., 2017), footprint analysis such as environmental footprint (Kissinger and Gottlieb, 2010; Lenzen et al., 2012; Wiedmann and Lenzen, 2018), life cycle assessments (LCA) (Frankowska et al., 2019; Loiseau et al., 2020; Sasaki et al., 2021), and energy return on investment analysis (Galán et al., 2016). These methods can be categorised as material- and energy-flow accounting (MEFA) methods that act as decision support tools for individuals and policymakers (Deutsch and Troell, 2021). Drawing from previous research a LCA approach was adopted in this study as it allowed me to quantify the pollution, waste and other impacts that are externalised by the receiving countries

(Guinée et al., 2011). This is done by converting inputs extraction and usage-related emissions during the different life cycle stages into a measure of the potential impacts related to these life cycle stages which allows for comparison among life cycle stages and between life cycle stages of different products.

I applied the telecoupling framework (Liu et al., 2013) to the South African blueberry industry to assist in identifying the sending (exporting country) and receiving (dominant importing country) systems. Then I analysed the social-ecological impacts of blueberry production in South Africa (sending system) as driven by demand from the United Kingdom (receiving system). Blueberries are a sought-after cash crop known as a superfood associated with health benefits for the consumer. A boom in blueberry production has been observed in southern hemisphere countries to meet consumer demand in the northern hemisphere (WCDoA and BerriesZA, 2019). It is currently the fastest growing agricultural commodity in South Africa and expanded from only 68 hectares in 2008 to over 2000 hectares in 2020 (WCDoA and BerriesZA, 2019). Most blueberries produced in South Africa are destined for export, with the bulk (54%) of the exports going to the United Kingdom (WCDoA and BerriesZA, 2019). The establishment and expansion of blueberry operations in South Africa can lead to negative or positive impacts on the environment and society. These impacts are dependent on numerous factors such as replacement of other crops, inputs required and location, to name a few.

The study has four core objectives: first, to determine the social-ecological impact of the blueberry life cycle of operation in South Africa using a LCA. The second objective was to compare the difference in the social-ecological impact of blueberries with other fruit (apples, oranges, pears, peaches, grapes, and strawberries) that are commonly produced in South Africa. The third objective was to reflect on additional impacts of this superfood industry that emerged from literature and interviews, and the last objective was to reflect on the effectiveness of the LCA methodology to study the social-ecological impacts of a telecoupled system.

## 4.3 Methods

### 4.3.1 Fruit industry

South Africa exports over 60 per cent of the produced fresh fruit (Fruit SA, 2019) which accounts for the largest share of South Africa’s agricultural exports income (Phaleng, 2017). Citrus, pome, and grapes make up the bulk of the fresh fruit exports (95%) while exotic fruits and nuts, which include blueberries, account for less than one per cent of exports (Fruit SA, 2019). As a result, blueberries contribute a small share of the agricultural income however on average a larger percentage (73%) of the total yield of blueberries is exported annually in comparison to the average percentage of all fruit yields that are exported (60%). Crops that are compared to blueberries, such as oranges, apples, and pears, produce almost seven times the volume (kg) of fruit per hectare (Addendum Table E.1) and currently occupy larger areas in South Africa (Fruit SA, 2019). These fruits are also more affordable and accessible to individuals in the low and middle class in South Africa as fresh fruit or as processed products like juice, jams, and dried fruits (van Lin et al., 2018). This could explain the larger local volumes, whereas the high price tag of blueberries means that the consumption is limited to a small percentage of the South African population.

South Africa predominantly exports fresh fruits to Europe, Russia, Asia, and the United Kingdom (Fruit SA, 2019; Phaleng, 2017). In the early stages of the blueberry industry (between 2008 and 2012) almost 85 per cent of all fresh blueberries produced in South Africa were exported to the United Kingdom (BerriesZA, 2019) however as expansion continued, South Africa diversified the blueberry market by diversifying export destinations and increasing supply to the local market (Figure 4.1). Nevertheless, the United Kingdom remains the largest importer of South African blueberries (Figure 4.1). This industry’s growth can be attributed to the increase in global demand for blueberries as well as the high market value of these crops as observed in Chapter 3, these drivers were also observed to be key for cash crop uptake in other regions (Appau et al., 2020; Friis and Nielsen, 2017; Llopis et al., 2020).

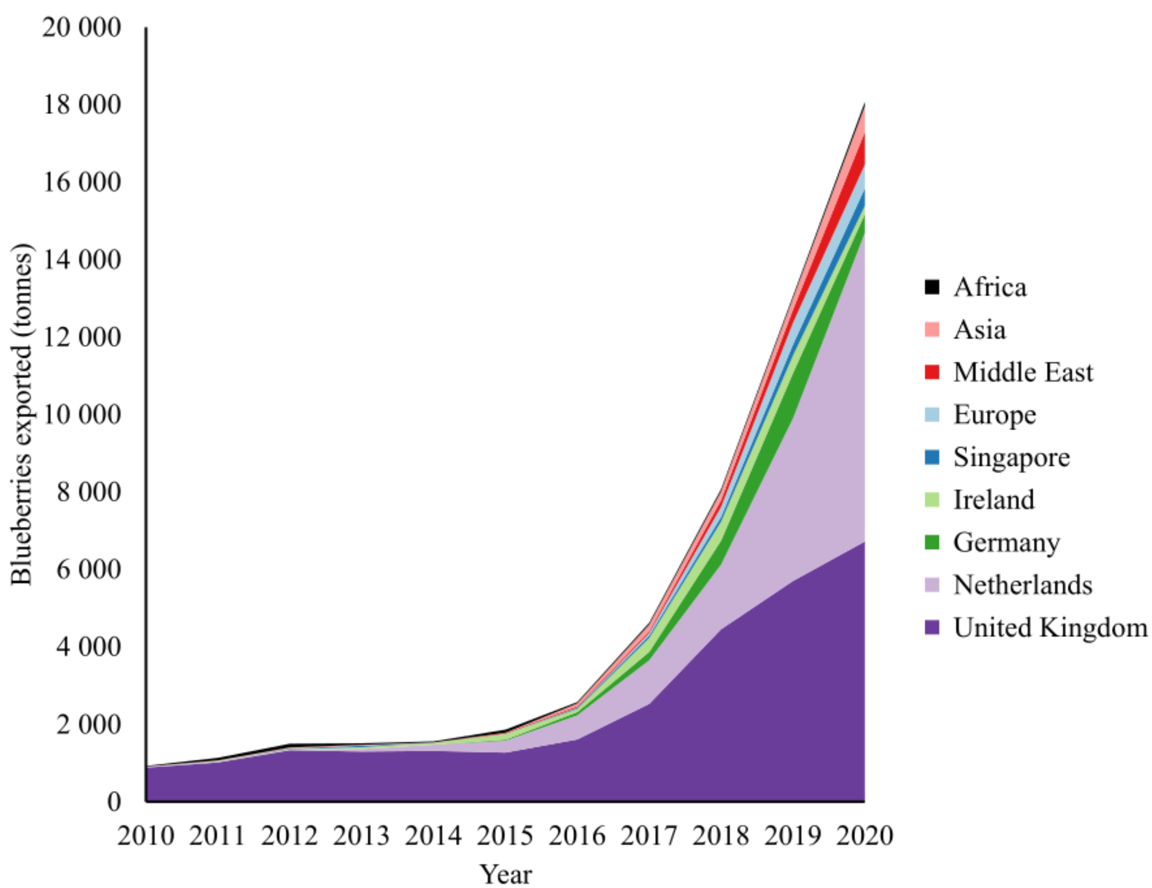

Figure 4.1 The volume of blueberries exported in tonnes per destination from South Africa between 2010 and 2020 (SARS, 2021)

### 4.3.2 Life cycle assessment

Life cycle assessment (LCA) is a structured methodology used to study the social-ecological aspects and impact of any product from the origin of production to the end of life (ISO, 2006a). This includes processes such as the production of raw material, raw material conversion, retail and distribution, consumption, and disposal at end of life. LCA was chosen as it is the only method that uses an internationally defined standard, and it can account for each stage of the life cycle in detail. It also allows for the inclusion of complex supply chains and localisation of potential impacts and has been applied in numerous studies to observe the environmental impact of trade (Beylot et al., 2019; Corrado et al., 2020; Hamilton et al., 2018). Furthermore, it is a well-supported field with open access training material and data resources as well as offering free and easy to learn software solutions such as openLCA. It has also recently seen an expansion in the inclusion of new environmental indicators plus the addition of economic and social indicators (Deutsch and Troell, 2021).

A life cycle assessment consists of four steps (Figure 4.2). The first is to define the goal and scope (spatial scale, environment) of the study as well as assumptions made during the analysis. The second step is to create an inventory of all material and energy flows that are present for each of the life cycle phases, for example, what raw materials are required to produce a product or the amount and type of chemicals needed to manage pests during crop production. The third step is to use an impact assessment method to convert inventory data into defined potential impacts, and to determine the potential impact of the material and energy flows for each phase of the life cycle. The final step is to interpret the results, discuss the identified impacts of the LCA, identify potential problems of the analysis and highlight future improvements for similar studies and the fruit production industry.

To align with global standards, this study used ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b) to guide the methodology of the life cycle assessment (Figure 4.2) which is further described in the following sections.

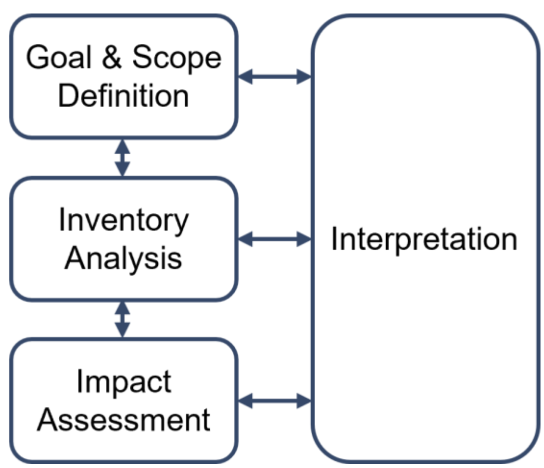


Figure 4.2 Phases of a life cycle assessment (ISO 14040)

*4.3.2.1 Goal and scope*

To address the potential impact of the blueberry telecoupling, I considered the impact of four of the eight phases (production, post-harvest, packaging, and storage) of the blueberry life cycle that occurs before the point of export to limit the impacts to South Africa (sending system). This is illustrated in Figure 4.3 which combines the telecoupling framework (Liu et al., 2013) with the life cycle stages of blueberries. Data were compared to that of selected fruits (apples, grapes, oranges, pears, and strawberries) that are commonly produced in South Africa. The system boundary was constrained to South Africa to identify the potential impacts that occur in the system because of distant demand (telecoupling) driven expansion. The nursery and transport phases were excluded for all fruit because of the lack of available data on nursery production and transport distances in South Africa. The retail to disposal phases was excluded since impacts occur outside South Africa.

The functional unit for this study is the volume (kg) of fruit produced per hectare to allow for comparison of the impact if a hectare of selected fruit is displaced by a hectare of blueberries. Caution should be taken when using results from this study to generalise impacts, as production might differ significantly between different producers, and this study used average data of production methods in South Africa. Further assumptions are made in the study (see more detail in the data section below).

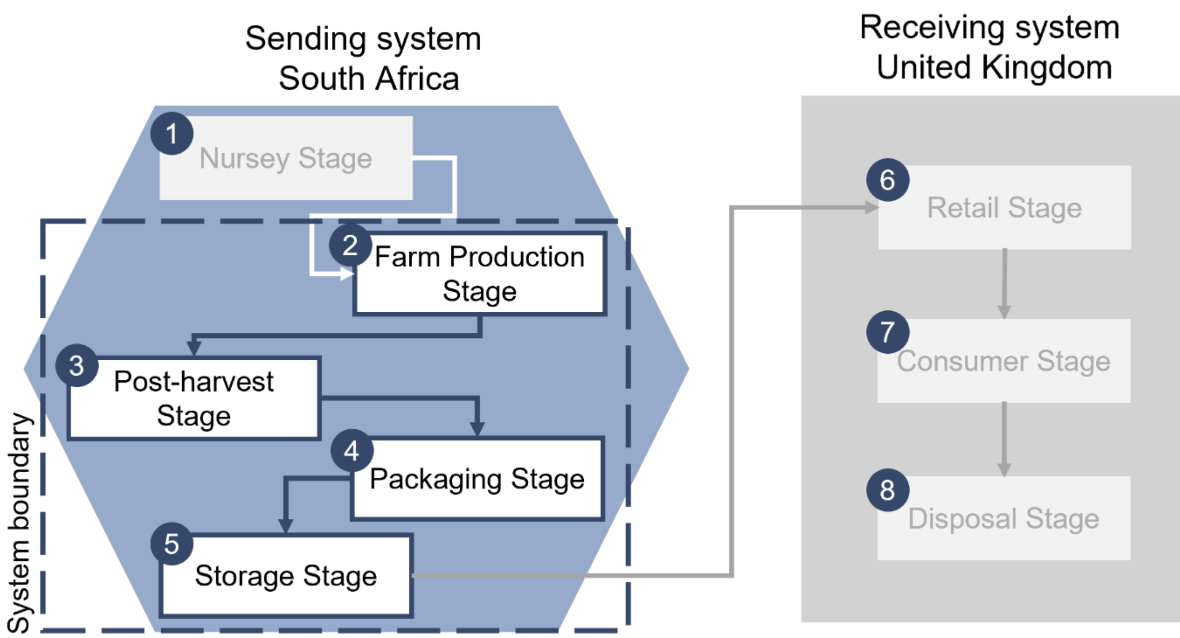


Figure 4.3 An illustration of the South African and the United Kingdom coupled system that includes the life cycle stages of the blueberry supply chain. The illustration indicates in which country each of the stages occurs and highlights the stage that will be considered in this study in white blocks.

### 4.3.3 Life inventory data and assumptions

#### *4.3.3.1 Production stage*

Both primary and secondary data were used to create a comprehensive table of the inputs for the farm production phase of the different crops (Table 4.1). The production stage includes the land-use change per hectare, the water input (blue water – irrigation from the surface and groundwater reservoirs and indirect water use- water that is not used for irrigation but indirectly used in other production processes e.g. to produce chemicals, plastic packaging, etc), fertiliser application, pesticides and fungicide application, energy inputs (diesel required for farm machinery and electricity required for irrigation) and other structural inputs such as plastic tunnels, and wooden trellises specific to each crop. The main data source for crops other than blueberries was the Ecoinvent Database 3.7 (Wernet et al., 2016) (Table 4.1), this database comprises of comprehensive input tables for the life cycle stages of various products that can be used in a LCA but it did not include the water consumption of these fruits. Where possible, South African specific data were selected but for the fruit with no specific South African data available, global averages were used. For blueberry production, the data were collected from three blueberry farmers in South Africa that participated in interviews in combination with data from existing literature. The three participants each completed an Excel spreadsheet that contained a list of inputs with an empty block to insert their quantities, this was completed at their own time. Once all of the spreadsheets have been returned, the average for each input was calculated.

Table 4.1 The inputs and data source used for each of the life cycle stages in the LCA.

<table>
<tr><th>Stage</th><th>Inputs</th><th>Data source</th></tr>
<tr><td rowspan="3">Production</td><td rowspan="3">Land use area<br>Water<br>Fertiliser<br>Pesticide<br>Herbicide<br>Fungicide<br>Fuel<br>Electricity<br>Protective and support structures</td><td>Blueberries: South Africa farmer data supplemented with data from an existing LCA of blueberry production (Aguirre et al., 2012)</td></tr>
<tr><td>Apples, pears, and oranges: Ecoinvent Database 3.7 (South Africa average)</td></tr>
<tr><td>Grapes and strawberries: Ecoinvent Database 3.7 (Global average)</td></tr>
</table>

| | | |
|---|---|---|
| **Post-harvest** | Chemical treatments<br>Water | All fruit: Frankowska et al., 2019 |
| **Packaging** | Polyethene granules<br>Polyethene terephthalate granules<br>Cardboard | All fruit: Frankowska et al., 2019 |
| **Storage** | Chemical treatments<br>Water | All fruit: Frankowska et al., 2019 |

For this study, farm production practices were in line with South African practices which assumes that all fruit except for blueberries and strawberries are exclusively grown in open-air whereas blueberry and strawberry production in South Africa consists of a mixture of open-air (21%), shaded netting (68%) and tunnel (11%) production (WCDoA and BerriesZA, 2019). Due to the lack of available data, this study assumed that the percentage (68% and 11%) of strawberry production under shade netting and plastic tunnels is the same as for blueberry production in South Africa. However, only plastic tunnels were considered in the LCA due to the lack of data about the impacts of shade nets. Another structural indicator considered in the LCA is the wooden trellises used to support larger fruit trees like apples and pears. A further assumption was that all crops are grown conventionally due to the lack of available data on the percentage of crops that are produced organically as well as organic production methods in South Africa. It was assumed that these three farmers production methods represented the average blueberry farm in South Africa. For all the other crops Ecoinvent Database 3.7 data were used which either represent average production in South Africa or average production globally (Table 4.1). Ecoinvent 3.7 uses a kilogram of crop produced as the functional unit whereas the defined functional unit of this study was yield (kg) of fruit produced per hectare. Data were therefore converted to crop production per hectare by multiplying inputs per kilogram by the average kilogram production per hectare in South Africa (Addendum Table E.1).

*4.3.3.2 Post-harvest stage*

For the remaining stages, existing data from a study by Frankowska et al. (2019) was used, as the study included data on the production and processing of fruit destined for United Kingdom supermarkets. The post-harvest stage included water and chemical inputs required to treat fruits after harvesting. A wide range of post-harvest treatments exist and, depending on the final product, might differ based on the processing of crops. However, for this research only post-harvest treatments for fresh fruit were considered. Most fruits are washed after they have been harvested, therefore water used for washing fruit is a key input. For apples and pears, 0,597 l/kg of water (Frankowska et al., 2019) was used to wash a kg of fruit, whereas for the remainder of fruits (excluding blueberries and strawberries) there are no specific data available on the water required. I, therefore, assumed that 0,4 l/kg of water is used for grapes and oranges as is suggested by (Stoessel et al., 2012). Blueberries and strawberries are not washed after harvest, since this can damage the fragile berries and reduce the quality of the product. In addition to being washed, some crops are also treated with chemicals to control for pests and prevent deterioration during the storage and transport stages. Apples, pears, and citrus are treated with pesticides, diphenylamine (apples & pears), and sodium hypochlorite, during the post-harvest stage but due to lack of data on specific pesticides, the general pesticide input within Ecoinvent 3.7 was used for all three crops (Addendum Table E.2). Apples and pears are treated with a calcium chloride solution and grapes are treated with sulphur dioxide to prevent mould (Addendum Table E.2). Blueberries and strawberries also have no post-harvest chemical treatment.

#### *4.3.3.3 Packaging stage*

During this stage, material requirements to produce the standard plastic and cardboard packaging for each fruit were included. For the packaging stage, this study assumed that all packaging is produced and therefore occurs within South Africa. The data published by Frankowska et al. (2019) was used to estimate packaging impacts in line with the United Kingdom consumers' market. I assumed that all fresh blueberries, strawberries, and grapes are packaged in PET punnets and all the remaining fruits (oranges, apples, and pears) are packaged within low-density polyethene (LDPE) bags. In addition, cardboard boxes were assumed to be secondary packaging for all fruit (Ingwersen, 2012). The inputs required to produce the packaging are the same across fruits, however, the quantities differ (Addendum Table E.3). Lastly, the indirect water use for each product was also considered within this stage (Addendum Table E.4).

#### *4.3.3.4 Storage stage*

The average required temperature and duration that fruit is stored before being sent to a retailer was considered for this stage. After post-harvest treatment and packaging, fruits are stored in cold storage facilities to prevent deterioration and to increase fruit shelf life. This study used the storage temperature and storage time for the different fruit from (López Camelo, 2004) as a guide. This was converted to the energy consumption for the storage of each fruit type (Addendum Table E.5) in line with the study done by (Frankowska et al., 2019). In addition to the direct electricity consumption, indirect water use for electricity consumption was also considered (Addendum Table E.4).

### 4.3.4 Impact assessment method

All data were imported into openLCA 1.10.3 software (https://www.openlca.org/) which was used to perform the Life Cycle Impact Assessment (LCIA) using ReCiPe 2016 midpoint and endpoint as the impact assessment method (Table 4.2; Figure 4.4) (Huijbregts et al., 2017). I used ReCiPe 2016 (Huijbregts et al., 2017) as the life cycle impact model because it allows us to determine aggregated overarching values for the social, economic, and environmental impact represented by the three endpoint indicators. ReCiPe 2016 (Huijbregts et al., 2017) converts resource extraction for production and emissions from production flows into measurable potential impact indicators such as the global warming potential that is measured as the volume (kilograms) of $CO_2$ released into the air or the impact on the environment measured as the number of species lost over time due to emissions and land-use change. The method produces two sets of impact results i.e., midpoint indicators and endpoint indicators (see Table 4.2 for list of indicators and individual descriptions). The midpoint indicators represent the primary impact of the inputs used during the life cycle stages and the endpoint represents an aggregation of midpoint indicators to measure the potential damage of the life cycle stages to human health, the environment, and the economy (Huijbregts et al., 2017). For example, when applying chemicals to a crop, the LCA can account for damage caused by resource extraction to produce the chemicals and emissions as a result of chemical application. It then converts the extraction and emissions production flows for inputs into tangible impacts such as potential contribution to climate change, environmental toxicity, etc. It also aggregates a collection of these impacts to show the overall damage to biodiversity, human health, and resource availability related to chemical use that signifies the environmental, social and economic impacts respectively. The potential impact of the different fruit analysed in this study were compared using an impact index described in the next section.

### 4.3.5 Impact index

A simplified index was created for blueberry inputs using the LCA analysis results per midpoint indicator to identify the high impacting inputs and origin of impacts by standardising results to allow for comparison within and between indicators despite the unit. The contribution of inputs to an indicator was converted to a value on a scale of 0 to 10 using the following formula:

Equation 4.1 Formula to determine the impact index

$$y = \left(\frac{x - x_{min}}{x_{max} - x_{min}}\right) \times n$$

Where y is the scaled contribution of the input to the indicator, x is the original contribution of the input to the indicator value, $x_{min}$ is the minimum observed input contribution to the indicator, $x_{max}$ is the maximum observed input contribution to the indicator and n is the upper limit of the rescaled value. The overall rank for an input was obtained by rescaling the data for each indicator and averaging the scores across the indicator. The same method was repeated for the midpoint indicator results of all the fruit to create an index table to compare within and across indicators and to determine which fruit had the largest social-ecological impact.


Figure 4.4 Visual representation of the relationship between midpoint and endpoint indicators for the ReCiPE 2016 impact assessment method (Huijbregts et al., 2017). The colours indicates the grouping of the damage pathways that contribute to each endpoint indicator; damage to human health (purple) as the social impact, damage to the ecosystem (blue) as the ecological impact, and damage to resource availability (green) as the economic impact.

Table 4.2 An overview of midpoint indicators from ReCiPe 2016 with the acronym, unit of measure and a basic definition (Huijbregts et al., 2017)

| | Indicator | Acronym | Unit | Description |
|---|---|---|---|---|
| Midpoint | **Fine particulate matter potential** | FPMP | kg PM2,5 eq | The intake fraction of fine particulate matter due to emissions in the region was determined and expressed in primary PM2.5-equivalents. |
| | **Fossil fuel potential** | FFP | kg oil eq | The ratio between the energy content of a fossil resource and the energy content of crude oil. |
| | **Freshwater ecotoxicity potential** | FET | kg 1,4-DCB | The factor of the potential impact of a chemical is divided by the potential impact of 1,4-dichlorobenzene emitted to freshwater. |
| | **Freshwater eutrophication potential** | FEP | kg P eq | The fate factor for phosphorus emissions to freshwater. |
| | **Global warming potential** | GWP | kg CO2 eq | The total extra radiative forcing (sunlight absorbed by the Earth) integrated over time as a result of the emission of 1kg of greenhouse gasses (GHG) relative to the additional radiative forcing integrated over that same time horizon caused by the release of 1 kg of $CO_2$. |
| | **Human toxicity potential (carcinogenic)** | HTPc | kg 1,4-DCB | The factor of the potential impact of a carcinogenic chemical is divided by the potential impact of 1,4-dichlorobenzene emitted to freshwater. |
| | **Human toxicity potential (non-carcinogenic)** | HTPnc | kg 1,4-DCB | The factor of the potential impact of a non-carcinogenic chemical is divided by the potential impact of 1,4-dichlorobenzene emitted to urban air. |
| | **Ionizing radiation potential** | IRP | kBq Co-60 eq | The collective exposure dose is caused by the emission of a radionuclide. The collective dose is expressed as the total average exposure in Sievert (J/kg body weight) multiplied by the number of people in a population integrated over time. |

| | | | | |
|---|---|---|---|---|
| | **Marine ecotoxicity potential** | MET | kg 1,4-DCB | The factor of the potential impact of a chemical is divided by the potential impact of 1,4-dichlorobenzene emitted to seawater. |
| | **Marine eutrophication potential** | MEP | kg N eq | The fate factor for phosphorus emissions to seawater. |
| | **Surplus ore potential** | SOP | kg Cu eq | The average additional volume of ore to be produced in the future due to the extraction of 1 kg of a mineral resource, considering all future production of that mineral resource relative to the average additional amount of ore produced in the future due to the extraction of 1 kg of copper (Cu), considering all future production of copper. |
| | **Ozone formation potential (environmental)** | OFPe | kg NOx eq | The level of exposure to ozone that vegetation experiences due to emissions in the region is determined and expressed in NOx equivalents. |
| | **Ozone formation potential (human)** | OFPh | kg NOx eq | The intake fraction of ozone by people due to emissions in the region is determined and expressed in NOx equivalents. |
| | **Ozone depletion potentials** | ODP | kg CFC11 eq | The amount of ozone a substance can deplete relative to CFC-11 for a specific time horizon |
| | **Acidification potential** | AP | kg SO2 eq | The fate factor for acidification due to emissions in the grid is determined and expressed in kg SO2 equivalents. |
| | **Terrestrial ecotoxicity potential** | TET | kg 1,4-DCB | The factor of the potential impact of a chemical is divided by the potential impact of 1,4-dichlorobenzene emitted to industrial soil. |
| | **Water consumption potential** | WCP | $m^3$ water consumed | A ratio that measures the volume of water consumed as a portion of the water extracted. |
| **Endpoint** | **Human Health** | HH | Disability-adjusted loss of life years (years) | Measure damage to human health as the number of years that are lost or lived out with a disability due to disease. |

| | | | | |
|---|---|---|---|---|
| | **Natural Environment** | ED | Time integrated species loss (species*year) | Measures damage to the environment as the number of integrated species that are lost per year. |
| | **Resource Scarcity** | RA | Surplus cost ($) | Measures damage to resource availability as the additional cost that is required for future mineral and fossil resource extraction. |

### 4.3.6 Additional impacts

This study also reflected on potential impacts that are not covered by the LCA but which emerged from existing literature and interviews with seven individual stakeholders in the blueberry industry through 60 to 90 minute semi-structured interviews with individuals in the industry to explore the drivers and impacts of the blueberry industry using nine questions (Addendum D). The individuals were identified through a diverse range of search tools which included general google searches for blueberry farms, identifying farms that belong to the BerriesZA association, and farms listed as exporters for export companies. These individuals were then invited to participate in interviews after ethical approval was received by the Research Ethics Applications (REC) committee at Stellenbosch University and voluntarily participated in the interviews. The interviews were transcribed in English, and analysed within Atlas.ti version 9 (Scientific Software Development GmbH, 2021) using a deductive thematic approach. This approach consists of coding phrases that express similar thoughts by reading through the transcribed interviews multiple times until all similar and interesting thoughts from participants are coded. Thereafter these codes were assigned to overarching themes and in this chapter, I only included the theme additional impacts.

## 4.4 Results

### 4.4.1 Midpoint indicator results

#### *4.4.1.1 Blueberries*

The blueberry production stage was the largest contributor across all the indicators (potential impacts) in the study and represented at least 96 per cent of the potential impact per indicator (Figure 4.5). The production stage was the sole contributor to five indicators (Fossil Fuel Potential, Freshwater Eutrophication Potential, Global Warming Potential, Ionizing Radiation Potential, and Surplus Ore Potential) for blueberries. The inputs that contributed the most to the production, as well as the overall impact of blueberries, were the use of plastic tunnels for a portion of production to protect bushes against extreme weather conditions; the use of urea fertiliser to reduce the acidity of the soil to create an optimum growing environment for bushes; the emissions of fuel required to maintain and harvest the blueberries and phosphoric acid and nitrogen fertilisers used to increase the acidity of soil to preferred acidic levels for blueberry production (Table 4.3, Addendum F).

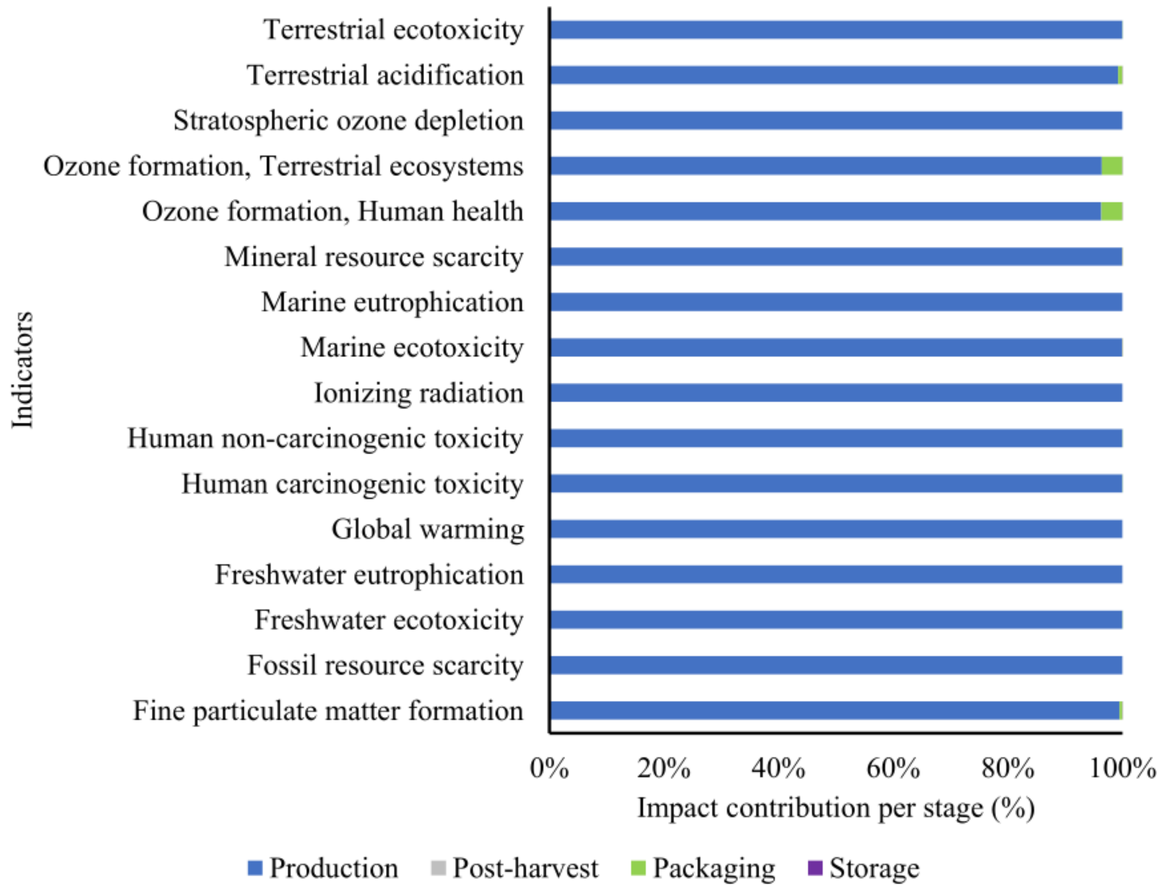


Figure 4.5 Percentage contribution of life cycle stages of blueberries to the social-ecological indicators (Huijbregts et al., 2017). Blueberries don't undergo any post-harvest treatment therefore this stage has no contribution to the overall impact. The packaging stage is only visible for a few indicators and the storage stage is not visible for any indicators because of their small contribution to the impact.

The post-harvest stage had zero impact as blueberries do not undergo any post-harvest treatment due to their fragile nature. The blueberry packaging stage contributed to most of the indicators except for Fossil Fuel Potential, Freshwater Eutrophication Potential, Global Warming Potential, Ionizing Radiation Potential and Surplus Ore Potential however the overall impact as a share of the total impact was small, despite being the second-largest contribution phase (Figure 1.1, Figure 4.5; Table 4.3; Addendum F). This phase's largest contributions were attributed to Ozone Formation Potential (human) (3,7 %) followed closely by Ozone Formation Potential (environment) (3,6 %) (Figure 4.5) while contributions to the remainder of the indicators were negligible. Table 4.3 reveals that the production of cardboard boxes for secondary packaging was the largest contributor during the packaging stage with a particularly large contribution, ranked as the second-largest contribution overall, for Ozone Formation Potential (human and environment). The production of cardboard boxes also contributed to a large share of the total Fine Particulate Matter Potential, Terrestrial Acidification Potential and Surplus Ore Potential during the packaging phase for blueberries.

Table 4.3 A simplified impact index of all the inputs that contribute more than one per cent to an indicator during the life cycle of blueberries on a scale of 0 to 10. The variations of green represent the lowest impacts, yellow and orange variations represent the medium level impacts and the variations of red represent the highest impacts. *Storage stage

| | Production | | | | | | | | | | | | | | Packaging | | | *S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Glass container | Dimethylamine | Electricity | Copper | Diesel | Glyphosate | Lime | Magnesium oxide | Nitrogen fertiliser | Pendimethalin | Phosphoric acid fertiliser | Plastic tunnel production | Potassium fertiliser | Urea fertiliser | Carton board production | PE granulates production | PET granulates production | Electricity |
| Fine particulate matter formation | 1,66 | 6,0E-05 | 0 | 0,87 | 7,46 | 1,07 | 0,02 | 0,12 | 1,97 | 0,05 | 3,31 | 10,00 | 0,20 | 7,68 | 0,87 | 4,9E-04 | 0,02 | 1,4E-04 |
| Fossil resource scarcity | 0,00 | 0 | 0 | 0,03 | 3,89 | 0,67 | 0,01 | 0,03 | 1,34 | 0,07 | 1,63 | 4,09 | 0,16 | 10,00 | 0 | 0 | 0 | 0 |
| Freshwater ecotoxicity | 2,5E-03 | 0 | 2,0E-07 | 7,84 | 8,03 | 1,22 | 0,01 | 0,70 | 3,09 | 0,05 | 4,52 | 10,00 | 0,19 | 6,07 | 3,5E-05 | 2,6E-07 | 5,6E-06 | 4,3E-07 |
| Freshwater eutrophication | 0,04 | 0 | 0 | 5,81 | 7,30 | 6,55 | 0,02 | 0,10 | 2,84 | 0,07 | 8,44 | 10,00 | 0,23 | 6,75 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Global warming | 2,60 | 0 | 0 | 0,07 | 6,79 | 1,20 | 0,02 | 0,28 | 4,33 | 0,10 | 1,66 | 5,40 | 0,31 | 10,00 | 0 | 0 | 0 | 0 |
| Human carcinogenic toxicity | 0,01 | 0 | 1,2E-07 | 0,41 | 3,04 | 0,35 | 4,9E-03 | 0,23 | 0,52 | 0,01 | 7,90 | 10,00 | 0,05 | 1,36 | 3,0E-05 | 1,4E-05 | 1,2E-04 | 3,0E-07 |
| Human non-carcinogenic toxicity | 0,09 | 0 | 3,1E-07 | 5,21 | 10,00 | 0,56 | 4,5E-03 | 0,40 | 1,87 | 0,03 | 1,79 | 5,87 | 0,10 | 3,59 | 1,9E-04 | 8,9E-05 | 7,9E-04 | 1,4E-06 |
| Ionizing radiation | 3,74 | 0 | 0,00 | 0,18 | 7,12 | 4,24 | 0,04 | 0,20 | 2,65 | 0,09 | 3,74 | 10,00 | 0,32 | 9,16 | 0 | 0 | 0 | 0 |
| Land use potential | 0,00 | 0 | 0,00 | 0,14 | 10,00 | 0,57 | 0,01 | 0,03 | 1,16 | 0,02 | 8,49 | 2,78 | 0,17 | 1,86 | 0 | 0 | 0 | 0 |
| Marine ecotoxicity | 0,02 | 0 | 7,4E-05 | 7,86 | 7,41 | 1,08 | 0,01 | 0,66 | 3,11 | 0,05 | 4,59 | 10,00 | 0,20 | 6,45 | 3,8E-02 | 1,6E-02 | 0,14 | 2,6E-04 |
| Marine eutrophication | 1,05 | 0 | 7,9E-08 | 1,84 | 2,94 | 2,50 | 0,01 | 0,04 | 2,45 | 0,93 | 1,69 | 5,62 | 0,12 | 10,00 | 7,4E-06 | 8,0E-07 | 1,0E-05 | 1,8E-07 |
| Mineral resource scarcity | 0,04 | 1,4E-03 | 0 | 1,92 | 5,74 | 1,71 | 2,2E-03 | 0,01 | 2,20 | 0,02 | 8,45 | 10,00 | 0,09 | 2,66 | 0,09 | 1,4E-03 | 0,02 | 4,1E-04 |
| Ozone formation, human | 1,29 | 2,8E-04 | 0 | 0,18 | 10,00 | 0,63 | 0,02 | 0,09 | 1,84 | 0,04 | 1,36 | 2,90 | 0,27 | 3,31 | 4,10 | 2,3E-03 | 0,07 | 6,8E-04 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ozone formation, environment | 1,27 | 2,7E-04 | 0 | 0,18 | 10,00 | 0,63 | 0,02 | 0,09 | 1,81 | 0,04 | 1,36 | 2,99 | 0,27 | 3,34 | 4,01 | 2,3E-03 | 0,07 | 6,7E-04 |
| Stratospheric ozone depletion | 0,04 | 0 | 0 | 0,02 | 0,32 | 0,05 | 1,1E-03 | 4,1E-03 | 10,00 | 0,13 | 0,07 | 0,23 | 0,36 | 0,40 | 0 | 0 | 0 | 0 |
| Terrestrial acidification | 2,60 | 8,9E-05 | 0 | 1,16 | 6,41 | 0,92 | 0,02 | 0,09 | 3,21 | 0,06 | 4,21 | 7,17 | 0,26 | 10,00 | 1,30 | 7,3E-04 | 0,02 | 2,2E-04 |
| Terrestrial ecotoxicity | 0,27 | 0 | 1,5E-06 | 7,33 | 3,88 | 0,76 | 0,01 | 0,03 | 2,73 | 0,04 | 2,42 | 7,43 | 0,33 | 10,00 | 2,8E-05 | 2,0E-06 | 1,8E-05 | 3,1E-06 |
| Water consumption potential | 0,06 | 0 | 2,1 | 0,02 | 0,58 | 0,54 | 0,01 | 0,01 | 0,72 | 0,02 | 3,30 | 1,43 | 0,03 | 10,00 | 0 | 0,11 | 1,61 | 0,91 |
| | | | | | | | | | | | | | | | | | | |
| Average | 0,82 | 1,2E-04 | 0,12 | 2,28 | 6,16 | 1,40 | 0,01 | 0,17 | 2,66 | 0,10 | 3,83 | 6,44 | 0,20 | 6,26 | 0,58 | 0,01 | 0,11 | 0,05 |

The blueberry storage stage contributed to the same indicators as the packaging stage however during this stage all contributions were below one per cent. The consumption of electricity for cooling storage units is the only element that contributes to this stage, and it had the largest contribution to Terrestrial Toxicity Potential and Freshwater Toxicity Potential.

#### *4.4.1.2 Apples, grapes, pears, oranges, and strawberries*

The production phase is also the dominant contributor to the overall impact of apples, oranges, and strawberries, and it was the sole contributor to the same five indicators, as for blueberries. During the production phase fuel and fertiliser, specifically, were also the inputs that contributed the largest share to the other fruits' overall social-ecological impact. Strawberries, like blueberries, do not undergo any post-harvest treatment due to their fragile nature while apples, grapes, pears and oranges undergo different treatments during the post-harvest stage, contributing to their overall impact. During the packaging phase, Ozone Formation Potential (environment) was one of the largest contributors for all the fruit which can be attributed to the common use of cardboard boxes as secondary packaging. Apples, pears and oranges had a lower overall impact during the packaging stage as they are packaged in Low-Density Polyethylene (LDPE) bags rather than Polyethylene Terephthalate (PET) punnets used for blueberries, grapes, and strawberries. Like blueberries, the storage stage contributed less than one per cent to the midpoint indicators for the other fruit however the impact for apples, pears, and oranges during this phase was slightly higher in comparison to blueberries, strawberries and grapes because of their longer storage time.

In summary, the results showed that a hectare of apples had the highest potential social-ecological impact of all the fruits closely followed by pears and oranges (Table 4.4). A hectare of blueberries on the other hand had the lowest potential social-ecological impact but just slightly lower than grapes. A hectare of strawberries had a medium potential impact while having the highest impact for Marine Eutrophication Potential and Ozone Formation Potential (human).

Table 4.4 A simplified impact index of the total potential impact per hecare based on the average yield of fruits for each indicator across the life cycle stages on a scale of 0 to 10. The variations of green represent a low impact, yellow and orange variations represent a medium impact and the variation represent a medium impact and the variations of red represent a high impact. Water consumption was excluded as it was not available for all of the fruit.

| Indicator | Apple | Blueberry | Grape | Orange | Pear | Strawberry |
|---|---|---|---|---|---|---|
| **Fine particulate matter formation** | 9,35 | 0,00 | 1,19 | 10,00 | 8,55 | 4,54 |
| **Fossil resource scarcity** | 10,00 | 0,00 | 1,12 | 9,44 | 9,09 | 6,33 |
| **Freshwater ecotoxicity** | 8,09 | 0,12 | 0,00 | 4,66 | 10,00 | 1,46 |
| **Freshwater eutrophication** | 10,00 | 0,00 | 0,25 | 6,66 | 5,72 | 2,87 |
| **Global warming** | 10,00 | 0,00 | 1,45 | 8,52 | 9,18 | 4,86 |
| **Human carcinogenic toxicity** | 9,64 | 2,89 | 0,00 | 10,00 | 9,07 | 6,44 |
| **Human non-carcinogenic toxicity** | 8,93 | 0,14 | 0,00 | 10,00 | 8,79 | 4,23 |
| **Ionizing radiation** | 8,09 | 0,00 | 0,82 | 10,00 | 7,35 | 4,71 |
| **Marine ecotoxicity** | 9,96 | 0,36 | 0,00 | 7,90 | 10,00 | 7,43 |
| **Marine eutrophication** | 0,11 | 0,00 | 0,09 | 0,12 | 0,09 | 10,00 |
| **Mineral resource scarcity** | 8,93 | 2,58 | 1,80 | 10,00 | 8,11 | 0,00 |
| **Ozone formation, human** | 7,04 | 0,00 | 1,44 | 7,01 | 6,51 | 10,00 |
| **Ozone formation, e** | 10,00 | 0,00 | 2,19 | 9,84 | 9,30 | 5,18 |
| **Stratospheric ozone depletion** | 10,00 | 0,00 | 0,84 | 3,47 | 7,19 | 1,36 |
| **Terrestrial acidification** | 10,00 | 0,00 | 1,52 | 9,31 | 9,11 | 3,40 |
| **Terrestrial ecotoxicity** | 9,60 | 1,46 | 0,00 | 9,03 | 10,00 | 3,27 |
| | | | | | | |
| **Average** | 8,73 | 0,47 | 0,79 | 7,87 | 8,00 | 4,76 |

## 4.4.2 End point indicator results

### *4.4.2.1 Potential impact on human health*

During the production, post-harvest, packaging, and storage stages, blueberries had the lowest potential impact on human health in South Africa compared to the other fruits in this study. This indicator measures the disability-adjusted loss of life years because of emissions to the environment (Huijbregts et al., 2017). The mid-point indicators that contribute to this end point indicator are illustrated in Figure 4.4. I found that Fine Particulate Matter Potential and Global Warming Potential were the two indicators that had the largest potential impact for blueberries and the other fruit while, Human Toxicity Potential (non-carcinogenic) and Human Toxicity Potential (carcinogenic) contributed a smaller share (Figure 4.6). The Ionizing Radiation Potential, Ozone Formation Potential (human) and Surplus Ore Potential only add up to a very small amount of the potential human impact (Figure 4.6).

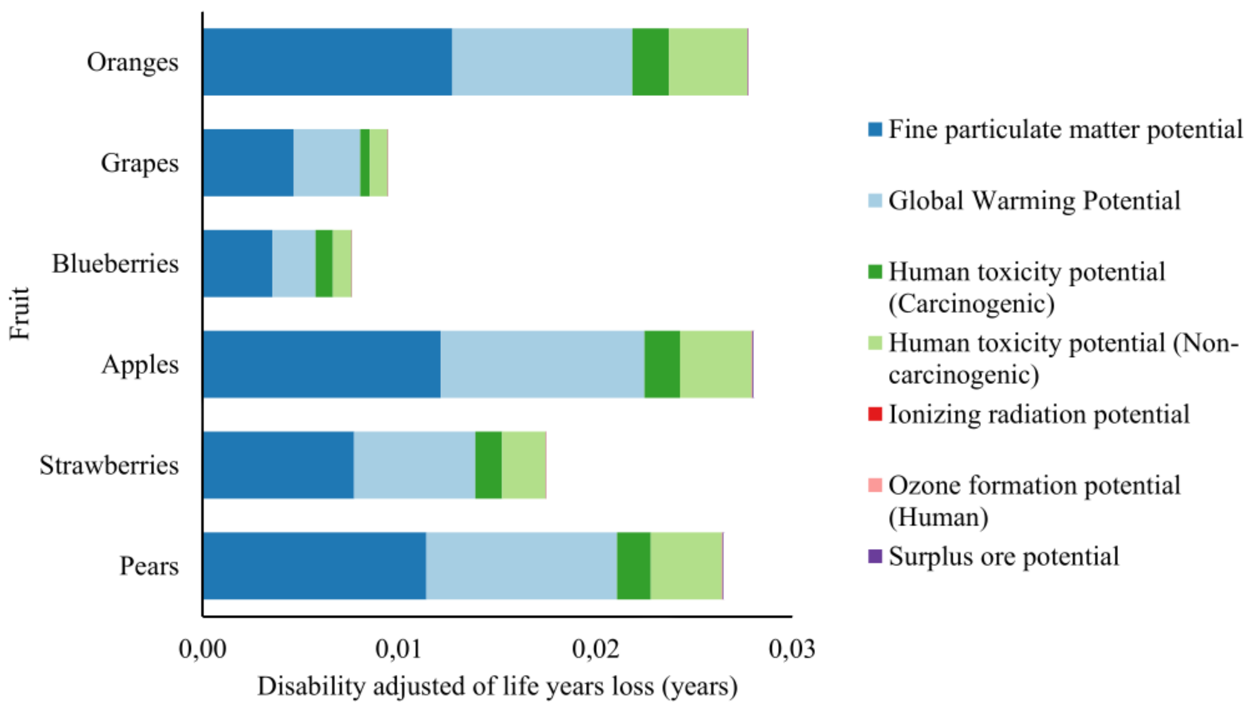


Figure 4.6 The overall potential risk to human health as a collective of mid-point indicators for the selected fruit.

### *4.4.2.2 Potential impact of ecosystem*

The potential damage to the ecosystem is measured as the number of species loss due to activities during the production, post-harvest, packaging, and storage stage of the fruit production in South Africa (Huijbregts et al., 2017). Blueberries also had the smallest potential impact on the environment within South Africa in comparison to the other fruit in this study because it is the fruit with the lowest integrated species loss potential (1,11E-05 species·yr). Overall, the Global Warming Potential indictor contributes the most to all the fruits potential damage to the environment (Figure 4.7). Thereafter Terrestrial Acidification Potential is the second largest contributing indicator while the remainder of the indicators only contributes small percentages (Figure 4.7).

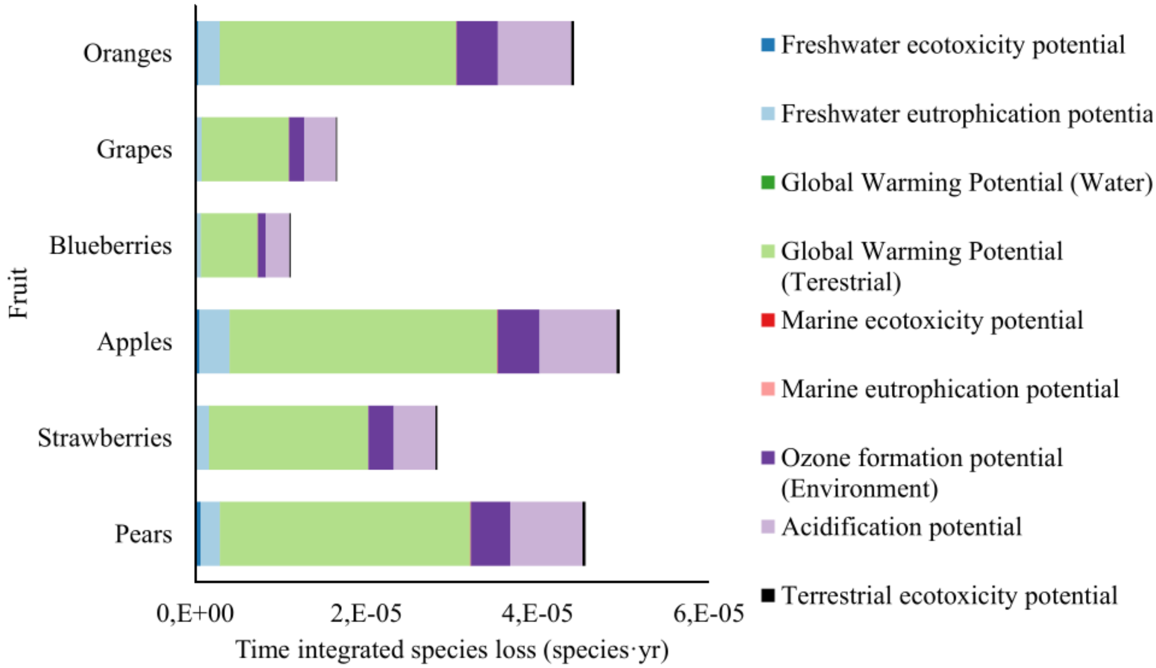


Figure 4.7 The overall potential risk to the environment as a collective of mid-point indicators for the selected fruit. Water consumption was excluded as it was not available for all of the fruit.

#### *4.4.2.3 Resource scarcity potential*

The resource scarcity potential of the fruit is measured as the total surplus cost in dollars for each of the resources used across the four stages of their life cycle (Huijbregts et al., 2017). Again, blueberries had the lowest risk of causing potential damage to the South African economy because of resource scarcity. This indicator was only influenced by two midpoint indicators, Fossil Fuel Potential and Surplus Ore Potential (Figure 4.8). The Fossil Fuel Potential indicator accounts for the bulk of the potential economic damage while the Surplus Ore Potential only contributed a small percentage (Figure 4.8).

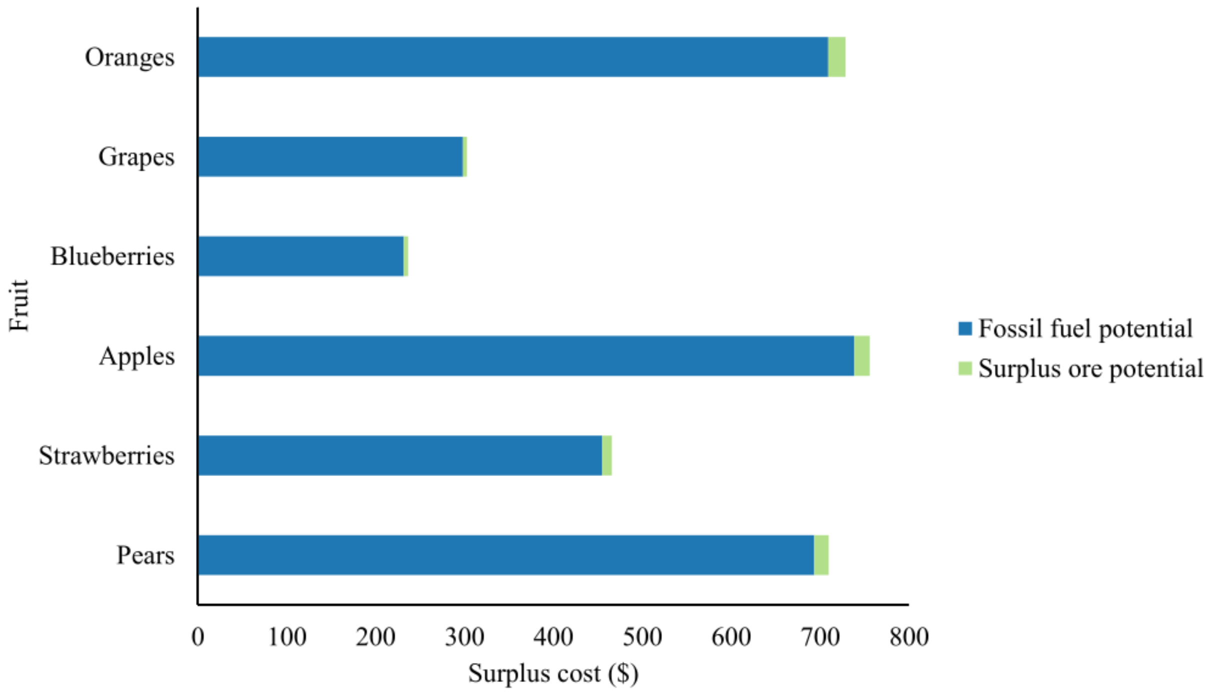


Figure 4.8 The overall potential risk to resource availability as a collective of mid-point indicators for the selected fruit.

### 4.4.3 Additional potential impacts

In addition to the LCA results, I have identified other potential impacts that the blueberry industry can have within South Africa. These potential impacts emerged from existing literature and interviews with individuals in the blueberry industry. Firstly, a few of the participants mentioned that large scale change in land-use change could impact other fruit industries. For example, replacing large areas of apple orchards with blueberries can reduce the local availability of apples and increase the cost of apples. This can reduce the number of common crops available to the local market. One farmer noted in the interviews that blueberries are highly dependent on consistent water supply as they start wilting after a few days whereas other fruit trees can survive long periods without water without causing damage to the trees. The reliance on constant irrigation can add pressure on the water supply especially when water availability is limited. The use of plastic tunnels to produce blueberries has numerous impacts, the first being that it diverts rain from the system for the benefit of the picking season which makes the production of these berries more dependent on irrigation. The tunnels also have the potential to exclude natural biodiversity and this in combination with the use of additional beehives has been observed to negatively impact local pollinator populations. However, the extra beehives can create additional income opportunities through honey production. Furthermore, there are concerns about the impact that plastic tunnels can have on the aesthetic appeal of the environment, this concern was raised by a local municipality in the Western Cape. On the other hand, blueberries can become a tourist attraction as some of the blueberry farms allow the public to come and pick their own blueberries and one farm runs a small farm stall selling blueberry related products on a popular tourist route in Western Cape. Blueberries offer farmers in South Africa the opportunity to increase their income through these value-added services and to generate a high profit obtained from the export market. Blueberries also have one of the highest labour demands per hectare of fruit production in South Africa therefore it creates additional job opportunities in the agriculture sector. Furthermore, farmers have highlighted that the job opportunities created by blueberries favour female employment. Lastly, blueberries are also considered to be a superfood that can provide health benefits to the local population however this is dependent on the affordability of blueberries.

## 4.5 Discussion

### 4.5.1 Key findings

Agricultural activities are responsible for a large share of employment, natural resource consumption, and environmental damage but are crucial to feed the globe and meet consumer demand, making this a key area sector to focus on in the effort to create a more just and sustainable world (Ritchie et al., 2020). The growing social-ecological system research field aims to address sustainability concerns while recognising the interconnectedness between the human and natural environments. Yet, the complexity of the food trade can relieve individuals of their responsibility and make it harder to overcome the sustainability challenges (Friis and Nielsen, 2017; Garrett and Rueda, 2019; Ibarrola-Rivas et al., 2020; Llopis et al., 2020). To address these challenges, the telecoupling framework sits within this space as a conceptual framework to study the impacts of flows (information, people, food, etc.) between two or more social-ecological systems. This study used the telecoupling framework to examine the social-ecological impact of the blueberry supply chain and how it measures up to other commonly produced fruit (apples, grapes, oranges, pears and strawberries) in South Africa using a LCA approach. Indicators suggest that the greatest potential impact of the fresh blueberry supply chain is generated during the production phase while the other phases have minor impacts in South Africa.

Over 90 per cent of the potential impact of the blueberry supply chain in South Africa can be attributed to the production phase because of plastic cover infrastructure, fuel and fertiliser usage (Figure 4.5; Table 4.3). The other fruit had similar results, with the production phase accounting for the largest impact due to fuel and fertiliser usage. These findings correspond with other LCAs that found that the bulk of impacts occur during the production stage of fresh fruit due to the high inputs required (Frankowska et al., 2019; Ingwersen, 2012; Martin-Gorriz et al., 2020). Several studies have found that protective structures (e.g. shade netting, greenhouse) have a much larger environmental impact than open-air agriculture because of the resources and energy required to produce these structures (Cerutti et al., 2015; Frankowska et al., 2019; Khoshnevisan et al., 2013; Yoshikawa et al., 2008). Protective structures are used in blueberry production to protect the plants and fruits against extreme weather conditions like hail and rain during the harvest season, especially in the Western Cape where rain often overlaps with the harvest season, that can damage fruit and delay picking and where open-air production might not always be economically viable. Therefore, most protective structures increase the volume of irrigation required, as natural rain is blocked from the system (Cerutti et al., 2015). Furthermore, fuel and fertiliser usage, prominent drivers of impact in this study, are commonly observed to be a dominant contributor to the impact of fruit production whereas consumption, disposal and packaging are often omitted from studies because of their minor contribution to the overall impact (Cerutti et al, 2015). This study did not consider the water consumption of all the fruit due to the lack of data, therefore this study does not consider the comprehensive impact of water consumption.

The use of secondary packaging stood out as a part of the life cycle that can be improved (Table 4.3) by using alternative secondary packaging such as reusable crates or recycled cardboard boxes. Albrecht et al. (2013) conducted a LCA to compare the social-ecological impact of wooden crates, cardboard boxes and plastic crates as secondary packaging of fresh produce in Europe. They found that cardboard boxes had the highest impacts across all the indicators making reusable crates more favourable. (Koskela et al., 2014) observed that the reuse of plastic crates as secondary packaging for bread delivery reduced the impact of the plastic crate production to be lower than that of non-recycled single-use cardboard boxes, but the weight of the plastic crates and return transport means the impact of reusable plastic crates remains higher than recycled cardboard boxes. These contrasting findings also show how different objectives can impact the outcomes and confirm that the whole supply chain should be carefully considered and optimised when switching to alternative secondary packaging.

Blueberries had the lowest potential risk to human health, species diversity and surplus cost within South Africa when compared to the other studied fruits (Figure 4.6; Figure 4.7; Figure 4.8). This indicates that potentially replacing a hectare of apples, grapes, oranges, pears, or strawberries with blueberries could reduce the overall social-ecological impact of the South African agriculture sector, whereas converting fallow land to blueberry orchards adds to the existing social-ecological impact of the agriculture sector. However due to the variation in inputs used in other studies as a result of variation in production methods I observed a difference in the overall impact of blueberry production between our results and other studies. Therefore, more research is required to determine the comparability of crops in general. The environment, including climatic conditions, are factors that can influence production practice and in South Africa, blueberry production requires protective structures that add to environmental impact, whereas blueberry production in the Netherlands and the United

Kingdom have an overall higher impact due to the use of heated greenhouses as a protective measure against cold winters (Frankowska et al., 2019). Therefore, it can be considered that the social-ecological impact of blueberry production in South Africa is lower than in countries that rely on heated greenhouses during their winter seasons. The limited number of registered chemicals that can be applied to blueberries in South Africa also limits the impact, as farmers have noted that they have to use organic alternatives while other countries might have a larger number of chemicals registered (Blueberry International Organization, 2018). This illustrates the importance of considering heterogeneity in social-ecological systems when creating policies and emphasises the need for heterogenous policies to promote sustainable agriculture (Gaviglio et al., 2017; Lachaud et al., 2017; Xie et al., 2019).

### 4.5.2 Importance of research

Understanding the impacts of inputs and identifying those responsible for the bulk of a fruit's impact is the starting point to improve food supply chain sustainability, (Medici et al., 2020). While overall impacts were deemed lower than other fruits farmed in the region, there are still opportunities to improve the sustainability of blueberry farming by reducing plastic cover, fuel and fertiliser usage. To reduce the use of plastic covers (used against extreme weather conditions and rain during the harvest season), expanded production should be restricted to regions suitable to optimal climatic conditions, such as the highveld, however, this might not be viable in South Africa because of the limited area that offers these conditions (Meyer et al., 2003). A better option for the blueberry industry in South Africa would be to optimise fuel and fertiliser usage in an effort to reduce the impact of the supply chain in South Africa. As suggested by farmers, advances in technology and data science can be applied to optimise the usage of these inputs. This includes technology such as remote sensing and auto-steering to optimise and reduce the volume of fertiliser and agrochemicals which in turn reduce the volume of fuel required (Balafoutis et al., 2017; Medici et al., 2020, 2019). Such technology can also assist farmers to further reduce the impact of blueberry production by optimising the usage of other inputs and can also be valuable to optimise the inputs required during the packaging and storage stage. For example, technological advances can reduce the energy required during the production and packaging stage. Alternative primary and secondary packing, as well as alternative energy sources, can be explored to further reduce the impact of the blueberry value chain in South Africa (Albrecht et al., 2013; Koskela et al., 2014; Medici et al., 2019). A note of caution is that these results do not represent the exhaustive potential impacts of blueberry production as other inputs i.e., plastic pots and shade netting were not included due to the lack of data.

### 4.5.3 Additional impacts

Over the last ten years, more than 80 per cent of South African blueberries were exported annually which is much higher in comparison to apples (49 %), grapes (16 %), oranges (70 %), pears (55 %), and strawberries (7 %) (FAO, 2020) which also produce higher volumes than blueberries (WCDoA and BerriesZA, 2019). If existing orchards are replaced by blueberries, as indicated by farmers, there is a potential to reduce the volume of fresh fruit available to the local market and reduce fresh fruit consumption due to shortages and increased prices (Friis and Nielsen, 2017; Llopis et al., 2020; Loyer, 2016). As observed by Ibarrola-Rivas et al. (2020), another potential negative impact not accounted for in the LCA is the use of plastic tunnels and shade netting that can decrease the aesthetic appeal of the environment for both residents and tourists. This can become important in areas like the Western Cape, which are observing an expansion of emerging blueberry farms with protective structures, and where the economy depends on tourism (Ferreira and Hunter, 2017; WCDoA and BerriesZA, 2019). One farmer mentioned that the local municipality has raised concern about structures on a scenic route to preserve the aesthetic appeal and that farmers must obtain municipal approval before erecting structures on scenic routes as stipulated in Zoning Scheme By-Laws (Drakenstein Municipality, 2018). The environmental damage endpoint indicator was the most comprehensive when considering the impacts of blueberry farming. Still, it only observes water potential and did not account for the water scarcity that is crucial to a water-scarce country like South Africa, and even more so for future agriculture due to the water uncertainties caused by climate change (Nhamo et al., 2019; Zwane, 2019). This indicator also does not consider how the addition of pollinator hives, exclusion by plastic tunnels and chemical usage can impact local pollinator populations and other organisms (Angelella et al., 2021) and can further result in biodiversity loss (Maraveas, 2020). One farmer noted that when they first started farming under plastic tunnels, they experienced a lower pollination rate due to excessive chemical residue that remained on the plants. (Leach et al., 2017) supported this finding as the study detected a higher residue of insecticides on raspberries grown under plastic tunnels.

The current price of blueberries may allow farmers and farm workers to ensure a higher income from the lucrative fruit which can improve overall livelihoods. However, due to the increasing input costs (WCDoA and BerriesZA, 2019), this will rely on the consistency of the high global trade price. The seasonality of the berries also allows farmers and seasonal farm workers on mixed variety farms to increase income security as it provides income in the off season compared to more dominant fruits like citrus and pome (WCDoA and BerriesZA, 2019). Further economic contributions can arise from potential spillover systems, for example, the increase in pollinators required for blueberry production can increase honey production creating economic benefits for South Africa (Nichols Applied

Management Inc., 2019; Rucker et al., 2012). Blueberry farms do have the potential to become alternative tourist attractions that allow the public to pick their own berries and therefore may lead to the expansion of other overflow businesses such as coffee shops for visitors. The labour-intensive nature of blueberries creates more job opportunities than other fruit and can assist South Africa to address increasing numbers of unemployed people (Global Africa Network, 2020; Liedtke, 2021; WCDoA and BerriesZA, 2019). Participants stated that blueberry pickers are almost exclusively females and therefore this industry has the potential to create more opportunities for the vulnerable female population within rural areas. Blueberries sold to the local market can lead to health benefits for local consumers as they contain high levels of antioxidants, phytoflavinoids, potassium and vitamin C which can potentially lower the risk of developing heart disease and cancer (Basu et al., 2010; Kalt and Dufour, 1997). Overall, the impact of the blueberry telecoupling is complex and has the potential to result in several social and economic benefits. Due to their lower input requirements blueberries have the potential to reduce the overall impact on the environment if the blueberry industry replaces existing higher-impact crops. However, blueberries can still have negative social, economic and environmental impacts such as environmental degradation and depleting water sources.

### 4.5.4 Reflection on LCA methodology

LCA lacks the consideration of wider social-ecological impacts and provides long term abstract potential impacts rather than visible impacts to the community. It also lacks the ability to produce uncertainty estimates which means the accuracy of the analysis and data may be questionable. The ReCiPe assessment (Huijbregts et al., 2017) focuses on environmental impacts and converts them to social (damage to human health) and economic (damage to resource availability) indicators. This means the social and economic impacts are limited to the extrapolations of environmental impacts rather than considering a comprehensive list of impacts as expected in a telecoupling framework. Indicators like damage to human health are not specific to the farming population but rather the whole population and can therefore downplay the potential health damage that farmers and farm workers are exposed to due to their proximity to chemical application. Lastly, the level of detailed data required for a LCA is hard to obtain which resulted in many assumptions being made and the use of local and global averages rather than case-specific data. Thus, the LCA masks the heterogeneity of impacts and can potentially lead to policies that are generated as a one size fits all policy.

Despite these limitations, the LCA was the only social-ecological system method that provided an internationally standardised method (ISO, 2006a & 2006b) to measure impacts. This can allow policy makers to make a direct comparison between the sustainability of agriculture supply chains. It was also one of only a few methods that provided an output that represents the social, economic, and environmental impacts, reducing the number of methods required for a study. If used in combination with other tools such as qualitative interviews and surveys that accommodate for its shortcomings (Paitan and Verburg, 2019), LCA can still have a meaningful contribution within the telecoupling framework because it allows comparison between studies and can potentially link inputs or impacts to qualitative results. The high data demand can also be a benefit if data are available per farm to act as a decision-making tool for farmers rather than for generic policies. The inclusion of the full life cycle can provide insights to potential spillover systems by considering upstream and downstream processes, for example, packaging that is produced in another country and the required transport can be included in the analysis. Localised LCA can facilitate better decision-making in telecoupled countries when importing items by comparing the impact of the full life cycle including the different production methods, variation of inputs, proximity to packaging production, trade distance, energy supply, etc. and therefore select the items with the lowest overall impact (Kissinger and Gottlieb, 2010).

### 4.6 Conclusion

This chapter aimed to quantify the impacts of blueberry expansion in South Africa on a series of environmental and socioeconomic outcomes, using a life cycle assessment. Despite its high impact at the production stage, blueberry production is likely to have the lowest impact in comparison to other popular fruits that are produced in South Africa based on the required inputs. The lack of data on the water consumption of the other fruits would be an important factor to add to future research. However, since the LCA only considers limited impacts, it is suggested that future studies should combine the LCA with other methodologies to increase the understanding of the broader social-ecological impacts such as the industries impact on tourism in the Western Cape and the economic contribution of the industry.

The results in this chapter highlight the often-neglected negative impacts of superfoods, which are usually considered to be healthy and good for the environment. These results can therefore be used by policymakers as a guide to create agricultural policies that are more socially, economically and environmentally sustainable for South Africans. Farmers can also use the results as a decision-making tool to identify high impact inputs and address these impacts to align themselves with the change in markets toward more sustainable production. This research, however, was subject to several limitations including the lack of country-specific data on inputs used in the production, COVID-19 restricting my ability to visit farms, farmers restricted by contractual agreements not to disclose input data considered to be proprietary, and using global averages as substitutes for these missing local data. The results from the small sample size and global averages might not be representative of these industries and future research should build on these results by increasing the number of local farms that contribute to the production data in an effort to generate more robust results. A larger sample size or detailed farm-specific data from diverse blueberry farms can also allow researchers to distinguish between the impacts of different production methods as well as different farming regions to produce a comprehensive view of the production methods and regions that generate the lowest impacts. Overall, the detailed data that is required to conduct a LCA resulted in several assumptions that were used in the analysis which could be addressed in the future by including all stakeholders (e.g. pack houses, transporters and packaging producers) involved in the blueberry life cycle to generate a more accurate understanding of the overall impact. Lastly, future research can set out to investigate the additional impacts through surveys and interviews with other stakeholders in the industry to create an in-depth understanding of the broad and complex impacts of a telecoupled industry.

# Chapter 5: Conclusion

## 5.1 Overview

This thesis aimed to explore the social-ecological drivers and impacts of the expanding blueberry industry in South Africa within the telecoupling framework. This offers an opportunity to expand on existing telecoupling research, as well as address new ideas under the telecoupling framework. By conducting this work, I aimed to address three current research gaps: (1) the lack of telecoupling case studies in Africa, (2) exploring drivers and impacts of commercial cash crop farms as opposed to the commonly studied small-scale farms, and (3) improving the understanding of the vulnerability of coupled systems to external shocks. A variety of drivers, challenges and impacts of the telecoupled blueberry industry in South Africa were identified, while also exploring the efficiency of methods that can be used to analyse the drivers and impacts in the telecoupling framework. This chapter contains a summary of the key findings and conclusions of this thesis and reflects on the contribution of the study and recommendations for future research.

## 5.2 Key findings

A variety of methods were adopted to explore the drivers and impacts of the blueberry industry in South Africa. Telecoupling was selected as an overarching framework because it allows the exploration of social-ecological drivers and impacts that are connected to trade and, the method was well suited to the South African blueberry industry that exports the bulk of its production. The literature review (Chapter 2) revealed that the telecoupling framework was commonly used to explore agriculture-related trade between social-ecological systems, but often focused on single aspects such as social impacts (Garrett et al., 2019; Godar et al., 2019; Laroche et al., 2020; Llopis et al., 2020), whereas this thesis used the framework to explore the social-ecological drivers and impacts of the telecoupled system. In Chapter 3 a combination of survey, interview and existing statistical data were used to identify the drivers of the blueberry industry expansion and explore the industry's challenges, vulnerability to external shocks and required improvements. While in Chapter 4 existing and collected data were used to construct a life cycle assessment (LCA) to determine the social-ecological impact of the blueberry industry in South Africa and interview data was used to explore additional impacts not captured by the LCA.

The results from Chapter 3 indicated that both social (profitability and income diversification, access to capital, market demand and access, relationship with exporters, employment potential, and low susceptibility to theft) and ecological (seasonality of blueberries is offset from other major crops, climate, soil quality and access to water) drivers are responsible for the establishment and expansion of blueberry operations, while some drivers like climate and soil quality also influence the selected production methods, which varied slightly between the northern and southern growing regions in

South Africa. This is in line with previous research that also found a diversity of drivers like profitability and climate were responsible for crop establishment and expansion, dependent on the area of adoption (Anderson, 2002; Appau et al., 2020; Hazell and Wood, 2008; Jellason et al., 2021; Lukanu et al., 2009). The results showed that drivers are not only spatially dependent but also temporally dependent, as participants highlighted that the drivers had changed over time as a result of emerging challenges. These included industry-related challenges such as an increase in market-related competition and broader challenges such as deterioration of port infrastructure in South Africa and increasing cost of key agricultural inputs. These identified challenges collectively impact the profitability of the industry and can compromise the viability of the industry in the future.

Several shocks were identified as additional challenges that the industry needs to consider. Thus far the blueberry industry has shown low susceptibility to the impacts of COVID-19 partly due to the timing of the hard lockdown, existing hygiene protocols and designation of the sector as essential, but participants expressed concern regarding the vulnerability of the industry to a variety of shocks such as extreme weather events and civil unrest. The industry's reliance on continuous water access for daily irrigation cycles makes it highly susceptible to droughts. It is also susceptible to other extreme weather events like hail and unexpected early seasonal rain which can damage the fruit during the fruit development and harvest stage. In addition, disruption in the export supply chain as a result of events like civil unrest can have huge consequences during the blueberry harvest season considering the short shelf life of the fresh fruit. Lastly, Chapter 3 identified various improvements that can be implemented by the industry and the South African government to ensure the future viability of the industry, including addressing the current challenges by exploring new market areas to increase their reach and ease competition pressure, utilising precision agriculture and addressing the current economic state of South Africa to stabilise input related costs and improving port infrastructure to minimise export delays. The industry also needs to align with changing consumer demand for more sustainable and transparent agricultural products to remain relevant in the market, specifically considering that blueberries are a superfood.

The impacts of the blueberry industry in South Africa were documented in Chapter 4, which highlighted that up to the point of export (i.e. processes within the South African border including production, packaging and processing), the production stage of a fruit's life cycle is the largest contributor to its social-ecological impact. The large impact during the production stage can be attributed to the use of protective structures (plastic tunnels), fertiliser, agrochemicals and fuel while the other two stages (packaging and storage) were responsible for a much smaller impact. The LCA aggregated the midpoint indicator impacts into three endpoint indicators that showed a hectare of blueberries produced in South Africa had social, economic and environmental impacts with the potential to damage (1) population health through contributing to 7,59x10-3 disability-adjusted life years, (2) the economy, by increasing the cost required to extract resources by US$ 236,26 (surplus resource cost), and (3) the environment, by contributing to biodiversity loss by 1.11x10-5 species loss potential per annum which was lower than the other export fruits that were explored. Although these findings seem to be compatible with other fruit LCA research (Cerutti et al., 2015; Frankowska et al., 2019; Ingwersen, 2012), different impact assessment methods have been used in these studies which impact the comparability of the results. In this thesis, blueberries had the lowest potential impact when compared to the five selected fruits, whereas Frankowska et al. (2019) found that blueberry production in the United Kingdom and other European countries had a higher overall impact than the five selected fruits in this study, mainly due to the use of greenhouses for production to protect bushes from cold winter temperatures. The South African climate allows farmers to produce blueberries without the need to construct or maintain resource-intensive infrastructure which could explain the lower impact of blueberry production in South Africa as observed in this study.

Chapter 4 also revealed that a LCA alone does not account for all of the potential impacts, as additional social-ecological impacts such as creating female employment opportunities in rural areas, reducing the aesthetic appeal of scenic tourist routes and creating berry picking tourism which emerged from interviews with participants during data collection for Chapter 3. This is consistent with social-ecological systems research approaches, that emphasize that social-ecological studies often require multiple methods due to the complex nature of these systems (Biggs et al., 2021b). This thesis further indicates that the bulk of impacts caused by blueberry production in South Africa is driven by distant demand as most blueberries produced in South Africa are exported to European countries. This makes it clear that there is a displacement of impacts from developed countries to developing countries in an effort by developed countries to meet consumer demands elsewhere (Appau et al., 2020; Baird and Fox, 2015; Friis and Nielsen, 2017; Ibarrola-Rivas et al., 2020; Meyfroidt et al., 2013).

### 5.3 Contribution and recommendation of this study

There is a lack of literature available on the blueberry industry in South Africa, and this thesis adds to knowledge about the young emerging industry. The outcomes of this thesis are also significant in gaining insight into the telecoupling of superfood production and consumption within a commercial African context, given the lack of telecoupling and commercial superfood adoption research in Africa. This is crucial in a world where demand for superfoods is increasing especially in developed countries, and developing countries, including countries in Africa, are increasing the production of high-value superfoods to meet this demand (Cernansky, 2015; Clark, 2021; Loyer, 2016; Magrach and Sanz, 2020; Moss, 2021).

A review paper by Jellason et al. (2021) highlights the lack of research into drivers of agricultural expansion, specifically in Sub Saharan Africa. This thesis adds to the understanding of agricultural drivers, particularly in the context of commercial superfood crops, as a diverse range of dynamic drivers emerged from Chapter 3. Understanding agricultural drivers is important to recognise how superfood adoption emerges, changes over time and varies spatially so that policymakers can make informed decisions that are appropriate to the locality of the industry, to avoid large scale disruptions of the local food system and to minimise the risk of environmental damage (Hazell and Wood, 2008; Jellason et al., 2021). Similarly, identifying the social-ecological impacts of the industry is important to inform policymakers and consumers about the impact of the industry and guide them to initiate the promotion of sustainable economic growth and employment opportunities, while limiting the environmental impact of agriculture. Given the image of superfoods as both beneficial to health and the environment, this and similar studies provide evidence about their often neglected negative environmental and social impacts.

Furthermore, identifying those responsible for the social-ecological impacts of the blueberry industry is crucial for policymakers to correctly assign the accountability of impacts and reduce the displacement of social-ecological burdens to developing countries. The LCA results can be used to educate consumers about their impacts and to break down the psychological distance between production and consumption that often absolves consumers of their responsibility (Breves and Schramm, 2021; Kastner et al., 2011; Ruiter et al., 2016; Wiedmann and Lenzen, 2018). The results from Chapter 4 can also be used as a decision-making tool by producers to identify the inputs that have the largest contribution to the social-ecological impact and use it as a guide to reduce these impacts to strive towards a more sustainable industry by addressing high impact areas. This is becoming increasingly important in a market where consumers demand more sustainable produce and transparency about the production methods (Isenhour, 2012; Ranganathan et al., 2015; Zamuz et al., 2021).

The study is valuable to understand the susceptibility of the agricultural industry to external shocks and its dependency on critical systems like port infrastructure and market access as these factors can impact local and distant food security, income and economies. Having knowledge of these shocks can inform actors such as policymakers to plan and respond appropriately to shocks and to reduce the associated risks such as food shortages, price spikes and disruptions in the supply chain (Béné, 2020; Davis et al., 2020; Lunt et al., 2016). In the presence of a global pandemic that has disrupted food chains, the blueberry industry must learn from other industries that were severely impacted and develop responses to similar shocks. This can include policies that prevent food trade disruptions or strategies to utilise the local market and processing facilities in case of trade disruptions to minimise crop losses. Similarly, the industry should understand the potential impact of climatic shocks as South

Africa is expected to experience more frequent extreme climatic events such as droughts and floods as a result of climate change (Nhamo et al., 2019). The higher frequency of these extreme climatic events can lead to massive economic losses for the industry considering the vulnerability of blueberries to extreme weather events like droughts, unexpected rain and hail. Therefore producers should take adequate precautions to protect crops from extreme climatic events like implementing protective covers or procuring additional water sources, however, producers should also consider the social-ecological impact of the precautions. Lastly identifying other potential external shocks, like the recent civil unrest protests observed in Durban and Gauteng in July 2021 that disrupted the export supply chain, can help actors like producers and exporters develop strategies that reduce the industry's susceptibility to such shocks through creating mitigation plans for unpredictable supply chain disruptions.

### 5.4 Limitations and improvements

This thesis was undertaken during the COVID-19 pandemic, which presented a variety of challenges. I was not able to conduct face to face interviews which limited my ability to interview people with sufficient access and knowledge about online interview software such as Zoom, Google Meets and Microsoft Teams. The small sample size gathered in Chapter 3 restricted my ability to undertake any quantitative analysis and it also means that the qualitative data might not be representative of all blueberry farms in South Africa. The homogenous demographic profile of participants and their operations resulted in little variation in response to the survey and interview questions. However, the in-depth interviews used to mitigate the small sample size allowed me to collect rich data by gaining a broader understanding of the industry from the participants and allowing me to ask follow-up questions and clarify responses. Additionally, the small sample size used in Chapter 4 to measure the impact of the blueberry industry might not be representative of all blueberry farmers in South Africa, similarly, using the global average for the production stage of grapes and strawberries could over or underestimate their impact in South Africa. Collecting input data for blueberry production was challenging as some farmers are not allowed to share their input data because of contractual obligations. Future research can build on these initial findings by increasing the sample size to be more robust and representative of the whole blueberry industry. The study also did not account for the full water consumption of all the fruit.

Future research can also build on these results by conducting interviews with individuals like farmworkers who were hard to reach during the pandemic. This can increase the understanding of the broader social-ecological impacts by exploring how blueberry production has impacted local communities, for example, do these communities see an increase in employment and a poverty reduction? Future research can also include broader groups of individuals such as consumers, retailers, related industry actors (e.g. beekeepers and protective infrastructure producers) to understand the spillover impact of the blueberry industry. This research can explore if the industry has resulted in economic benefits for other industries or perceived health benefits to the consumer. It can also engage tourism industries similar to wine routes that have emerged as an area currently engaged in the industry (food-tourism) or conflict with the blueberry industry (because of visual impacts to the landscape) to understand if the blueberry industry is contributing to the tourism industry or negatively impacting tourism in surrounding areas. This could all contribute to recording the micro-level impacts of the blueberry industry in South Africa which would add to the impacts that were identified in Chapter 4 of this thesis. It could also be used to explore individual actors' (such as exporters, retailers, consumers) involvement in the telecoupling in-depth as only a couple of actors (producers, consumers and exporters) were included in this study. This is important to understand how actors' actions can create feedbacks that either enhance or hinder the blueberry industry. Similarly, there is also an opportunity to expand research beyond South Africa and conduct similar research in other developing blueberry industries elsewhere to gain insights into the heterogeneity of drivers and impacts for the different systems.

Although many participants and news articles stated that other fruit crops are being replaced by blueberries, it was hard to determine the extent to which this occurs in South Africa due to a lack of data. Given this, future research can be conducted on this topic to determine the potential for blueberries to replace other fruit and further explore the spillover impact of the blueberry industry on other fruit and crop sectors in South Africa and on the export market. Understanding all of these additional impacts can give insights into the broad and complex impacts of the blueberry industry and add valuable insights on the general impacts of a superfood telecoupling within a social-ecological system. In addition, this type of research can also explore the impact of the expanding blueberry industry on local diets and the nutritional value of these changes.

In this study, some challenges in the industry were raised which included both generic challenges faced by the agricultural industry as a whole and specific challenges faced by the blueberry industry. There is potential for future research to explore these challenges in more detail as well as explore ways to mitigate or address the challenges. This research should focus on the high impact areas like degrading port infrastructure as it not only affects the blueberry industry but the whole agricultural industry. Another key challenge that can be explored in future research is the cost escalation of agricultural input costs and the effectiveness of precision agriculture to optimise inputs and reduce production costs. Then it could also be valuable to explore the saturation point of the European and global blueberry market and how increasing competition will shape the future of the blueberry industry in South Africa. In the same way, future research can look at the likelihood of the industry's exposure to identified shocks and explore potential opportunities to mitigate against these shocks in an effort to improve the resilience of the industry like investing in protective structures or additional water resources to combat extreme climatic events, creating alternative export routes for unexpected disruption the export supply chain and exploring technologies such as better cold chain management or breeding new genetic varieties to improve the shelf life of blueberries. Lastly, future research could use the same combination of methodology (LCA, surveys and interviews) to explore the drivers and impacts of other superfoods in South Africa and compare them to the drivers, impacts and challenges that exist in the blueberry industry. This can be used to advise policymakers on the performance and sustainability of superfood commodities and inform producers about the social, economic and environmental sustainability of different superfood commodities.

### 5.5 Final words

This thesis was able to fill some important knowledge gaps about the blueberry industry in South Africa, particularly in relation to the complex range of drivers and impacts of the industry. The thesis also successfully adds to telecoupling research by illustrating how distant demand can drive local land-use change and impact local industries, specifically in the context of a commercial superfood telecoupling. The main drivers identified in this study are similar to other cash crop adoption studies despite the difference in production scale and included the perceived profitability of the industry, access to capital, technology advancements such as new genetic material, and the climatic suitability of the crop. The study also identified two unique drivers including the lower susceptibility to theft and the employment potential to maintain good seasonal workers. In addition, the study highlighted that drivers change over time which can sometimes even act as negative feedback that discourages adoption, for instance, market competition increases and profitability decreases. The blueberry industry showed some resilience to shocks, however, the interviewees were aware of the vulnerability to shocks and are increasing efforts to improve the resilience of the industry especially to prevent harvest losses due to extreme climatic events and reduce the impact of disruptions in the supply chain. This study found that the largest impact was generated by the production stage of the blueberry life cycle. Given that the blueberry industry is driven by the export market, the study indicates that the United Kingdom and European consumers displace their consumption impacts to South Africa. Blueberries did show a lower potential to cause damage to the environment, economy and people compared to apples, grapes, oranges, pears and strawberries but the results also highlighted variation in production methods and impacts as a result of environmental and financial factors emphasising the importance of creating policies that account for the heterogeneity of the social-ecological system.

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# Addendum A - Existing data

Addendum Table A.1 Existing data of the production, use, export and value of blueberry production in South Africa (BerriesZA, 2019).

| | **Area under blueberry production in South Africa (Hectares)** | **Volume of blueberry production in South Africa (Tonnes)** | **Volume of blueberries consumed locally (Tonnes)** | **Volume of blueberries processed (Tonnes)** | **Volume of blueberries exported (Tonnes)** | **Value of total blueberries exported (Rands)** | **Value per ton of blueberries exported (Rands)** |
|---|---|---|---|---|---|---|---|
| **2008** | 68 | 253 | 59 | 20 | 175 | R 11 773 639 | R 67 370 |
| **2009** | 126 | 465 | 57 | 33 | 634 | R 34 584 629 | R 54 588 |
| **2010** | 234 | 864 | 106 | 60 | 926 | R 48 117 040 | R 51 971 |
| **2011** | 299 | 1108 | 135 | 78 | 1129 | R 73 956 844 | R 65 480 |
| **2012** | 443 | 1641 | 200 | 115 | 1496 | R 92 346 137 | R 61 716 |
| **2013** | 446 | 1652 | 202 | 116 | 1506 | R 132 838 139 | R 88 180 |
| **2014** | 462 | 1710 | 209 | 120 | 1558 | R 170 893 583 | R 109 706 |
| **2015** | 696 | 2577 | 315 | 180 | 2082 | R 275 326 416 | R 132 267 |
| **2016** | 1068 | 4127 | 656 | 902 | 2569 | R 365 910 066 | R 142 416 |
| **2017** | 1640 | 7431 | 1186 | 1623 | 4622 | R 665 269 810 | R 143 933 |
| **2018** | 2000 | 11306 | 1305 | 1918 | 8083 | R 1 057 880 734 | R 130 877 |

Addendum Table A.2 The volume and value per kilogram of blueberries exported from South Africa to their consumption destination (SARS, 2021).

| | 2015 | | 2016 | | 2017 | | 2018 | | 2019 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Country exported to** | **Volume exported (Kg)** | **Value per kilogram of blueberries exported (Rands)** | **Volume exported (Kg)** | **Value per kilogram of blueberries exported (Rands)** | **Volume exported (Kg)** | **Value per kilogram of blueberries exported (Rands)** | **Volume exported (Kg)** | **Value per kilogram of blueberries exported (Rands)** | **Volume exported (Kg)** | **Value per kilogram of blueberries exported (Rands)** |
| **Botswana** | 1049 | R 35 | 6883 | R 32 | 6924 | R 47 | 9173 | R 60 | 9164 | R 55 |
| **Australia** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 |
| **Saint Helena** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 43 | R 176 | 46 | R 122 |
| **Réunion** | 0 | R 0 | 0 | R 0 | 315 | R 95 | 370 | R 112 | 6486 | R 87 |
| **Netherlands** | 307387 | R 155 | 622059 | R 141 | 1129590 | R 146 | 1663961 | R 128 | 4198961 | R 120 |
| **Malaysia** | 4575 | R 147 | 54174 | R 167 | 103433 | R 151 | 214773 | R 150 | 247953 | R 135 |
| **Ireland** | 148172 | R 142 | 81120 | R 138 | 357731 | R 127 | 487421 | R 121 | 456780 | R 117 |
| **United Kingdom** | 1265066 | R 155 | 1609899 | R 142 | 2523702 | R 146 | 4454734 | R 129 | 5701911 | R 114 |
| **Spain** | 2295 | R 143 | 12806 | R 156 | 48749 | R 138 | 230151 | R 124 | 397915 | R 130 |
| **Germany** | 28313 | R 158 | 79626 | R 146 | 218564 | R 166 | 622194 | R 149 | 1169622 | R 110 |
| **United Arab Emirates** | 21679 | R 161 | 32885 | R 200 | 37507 | R 98 | 94294 | R 131 | 179112 | R 123 |
| **Mozambique** | 194 | R 45 | 154 | R 10 | 596 | R 80 | 2925 | R 6 | 211 | R 44 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Malawi** | 3 | R 598 | 204 | R 35 | 313 | R 55 | 185 | R 46 | 71 | R 75 |
| **Lesotho** | 29613 | R 5 | 8130 | R 18 | 4314 | R 36 | 4349 | R 24 | 2650 | R 45 |
| **Namibia** | 1632 | R 52 | 4361 | R 53 | 9679 | R 61 | 9341 | R 63 | 5468 | R 74 |
| **Hong Kong** | 1600 | R 184 | 17749 | R 174 | 63657 | R 136 | 16627 | R 141 | 41926 | R 122 |
| **Italy** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 85978 | R 124 |
| **Mauritius** | 837 | R 101 | 4581 | R 114 | 16540 | R 97 | 25898 | R 97 | 29374 | R 90 |
| **Saudi Arabia** | 0 | R 0 | 1765 | R 69 | 1175 | R 199 | 52260 | R 159 | 104389 | R 178 |
| **Singapore** | 0 | R 0 | 26417 | R 175 | 66055 | R 160 | 125975 | R 167 | 283064 | R 131 |
| **Eswatini** | 897 | R 21 | 706 | R 142 | 823 | R 142 | 1277 | R 166 | 969 | R 160 |
| **France** | 0 | R 0 | 0 | R 0 | 306 | R 136 | 0 | R 0 | 72888 | R 129 |
| **Bahrain** | 0 | R 0 | 0 | R 0 | 1345 | R 21 | 1469 | R 148 | 6012 | R 102 |
| **Kuwait** | 2849 | R 98 | 0 | R 0 | 374 | R 137 | 15330 | R 130 | 25003 | R 183 |
| **Democratic Republic Of Congo** | 588 | R 41 | 0 | R 0 | 0 | R 0 | 67 | R 65 | 110 | R 82 |
| **Qatar** | 1530 | R 16 | 0 | R 0 | 9921 | R 65 | 10465 | R 131 | 23003 | R 128 |
| **Seychelles** | 0 | R 0 | 0 | R 0 | 0 | R 183 | 332 | R 139 | 1257 | R 147 |
| **Uganda** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 |
| **Belgium** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Oman** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 1844 | R 167 | 3882 | R 97 |
| **Philippines** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 |
| **Cambodia** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 510 | R 167 |
| **Thailand** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 |
| **Tanzania** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 100 | R 3 |
| **Maldives** | 0 | R 0 | 12 | R 201 | 1948 | R 118 | 0 | R 0 | 0 | R 0 |
| **Angola** | 376 | R 73 | 5 | R 143 | 5 | R 143 | 0 | R 0 | 0 | R 0 |
| **Zambia** | 219 | R 42 | 1532 | R 24 | 211 | R 89 | 431 | R 76 | 1197 | R 63 |
| **Nigeria** | 2 | R 83 | 0 | R 0 | 0 | R 0 | 1 | R 26 | 11 | R 41 |
| **Kenya** | 2680 | R 21 | 1044 | R 161 | 4533 | R 15 | 943 | R 54 | 11 | R 209 |
| **Zimbabwe** | 36162 | R 7 | 3060 | R 7 | 50 | R 23 | 0 | R 0 | 47 | R 165 |
| **Russian Federation** | 0 | R 0 | 0 | R 0 | 10692 | R 164 | 23958 | R 174 | 5568 | R 172 |
| **Japan** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 1954 | R 89 |
| **United States** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 12271 | R 124 | 0 | R 0 |
| **Israel** | 0 | R 0 | 0 | R 0 | 0 | R 0 | 10 | R 10 | 0 | R 0 |
| **Congo** | 0 | R 0 | 0 | R 5 200 | 0 | R 0 | 7 | R 71 | 0 | R 0 |
| **Cameroon** | 0 | R 0 | 14 | R 129 | 0 | R 0 | 0 | R 0 | 0 | R 0 |
| **Rwanda** | 0 | R 0 | 125 | R 40 | 0 | R 0 | 0 | R 0 | 0 | R 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Vietnam** | 0 | R 0 | 0 | R 0 | 3005 | R 71 | 0 | R 0 | 0 | R 0 |
| **Canada** | 0 | R 0 | 0 | R 0 | 30 | R 73 | 0 | R 0 | 0 | R 0 |
| **Ethiopia** | 60 | R 80 | 0 | R 0 | 0 | R 0 | 0 | R 0 | 0 | R 0 |

Addendum Table A.3 The number of employees per hectare (multipliers) and in total for fruit crops produced in South Africa (FruitSA, 2018)

| | **Multipliers** | | | **Employment Numbers** | | |
|---|---|---|---|---|---|---|
| **Fruit Type** | **Permanent** | **Seasonal** | **Total** | **Permanent** | **Seasonal** | **Total** |
| **Apples** | 0,6 | 0,5 | 1,1 | 14 196 | 13 104 | 27 300 |
| **Pears** | 0,6 | 0,5 | 1,1 | 6 812 | 6 288 | 13 100 |
| **Apricots** | 0,6 | 0,6 | 1,2 | 1 738 | 1 604 | 3 342 |
| **Plums/Prunes** | 0,6 | 0,6 | 1,2 | 3 484 | 3 216 | 6 700 |
| **Peach & Nectarines** | 0,6 | 0,5 | 1,1 | 5 155 | 4 729 | 9 884 |
| **Cherries** | 1,1 | 0,8 | 1,9 | 317 | 251 | 568 |
| **Table Grapes** | 1,1 | 1,1 | 2,2 | 24 180 | 22 320 | 46 500 |
| **Avocados** | 0,6 | 0,1 | 0,7 | 10 422 | 1 158 | 11 580 |
| **Litchi** | 0,6 | 0,1 | 0,7 | 704 | 129 | 833 |
| **Mango** | 0,1 | 0,3 | 0,4 | 867 | 2 169 | 3 036 |
| **Oranges** | 0,1 | 0,4 | 0,5 | 2 323 | 17 082 | 19 405 |
| **Soft Citrus** | 0,1 | 0,5 | 0,6 | 1 146 | 8 423 | 9 569 |
| **Grapefruit** | 0,0 | 0,4 | 0,4 | 365 | 2 685 | 3 050 |
| **Lemons** | 0,2 | 0,3 | 0,5 | 2 885 | 4 423 | 7 308 |
| **Blueberries** | 1,0 | 1,6 | 2,6 | 2 040 | 3 240 | 4 780 |
| **Wine Grapes** | 0,3 | 0,1 | 0,4 | 28 559 | 11 294 | 39 853 |
| **Nuts** | 0,2 | 0,3 | 0,5 | 6 500 | 11 153 | 17 653 |

Addendum Table A.4 The number of individuals employed by the South African blueberry industry between 2013 and 2018 (WCDoA and BerriesZA, 2019)

| Year | Permanent | Seasonal | Packhouse | Supervision | Total |
|---|---|---|---|---|---|
| **2013** | 455 | 723 | 38 | 61 | 1278 |
| **2014** | 471 | 749 | 40 | 63 | 1323 |
| **2015** | 710 | 1128 | 60 | 95 | 1993 |
| **2016** | 1089 | 1730 | 92 | 145 | 3056 |
| **2017** | 1673 | 2657 | 141 | 223 | 4693 |
| **2018** | 2040 | 3240 | 172 | 272 | 5724 |

## Addendum B - Survey layout

Section 1

# Understanding the drivers of blueberry expansion

My name is Michelle Fourie, a student at the Department of Conservation Ecology and Entomology, and at the Centre for Sustainable Transitions and I would like to invite you to participate in my research that will allow me to obtain a masters degree. My research will look at the drivers of blueberry production expansion and impact that blueberry production and trade have on the local environment, economy and wellbeing of people in South Africa. This questionnaire will focus understanding which of the identified drivers influenced your decision to start producing blueberries on your farm and should take about 10 to 15 minutes to complete. I have obtained the required ethical clearance from the ethics committee at the University of Stellenbosch (REC-2021-17072). Your information and response to the questions will be protected by only publishing aggregated data for all participants with no link to individual responses. The stored data will contain identifiable data to allow effective communication with participants, but all data will be stored in a password protected folder that only people directly involved in the research project can access.

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 will have the right to withdraw from the study at any given time which will mean that all information you provided will be deleted and will not be used in the study. If you would like to know more about the study before participating feel free to reach out to me at 17497701@sun.ac.za or on 0827869369.

* Required

Email *

Your email

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

Next

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Section 2

## Demographic Information

The following section consists of questions about your demographic profile.

What is your job title? *

- [ ] Farm Owner
- [ ] Farm Manager
- [ ] Other: ____________

What gender do you identify as? *

- ◯ Female
- ◯ Male
- ◯ Prefer not to say
- ◯ Other: ____________

Which age bracket do you fit into? *

- ◯ 20 - 39
- ◯ 40 - 59
- ◯ 60+

Which ethnicity group are you part of?

- ◯ Asian
- ◯ Black
- ◯ Coloured
- ◯ Indian
- ◯ White
- ◯ Other: ____________

Which province do you farm in? *

- ◯ Western Cape
- ◯ Limpopo
- ◯ Mapumalanga
- ◯ Gauteng
- ◯ Eastern Cape
- ◯ Kwa Zulu Natal
- ◯ Freestate
- ◯ Northern Cape
- ◯ North West

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Section 3

## Understanding the drivers of blueberry expansion

The following section will consist of questions about your participation and decision making regarding blueberry farming.

Why did you choose to start blueberry farming? *

Your answer

What year did you plant your first hectare of blueberries? *

Your answer

How many hectares of blueberries do you currently produce? *

Your answer

Please indicate if each item below influenced your decision to plant blueberries on the below scale. *

| | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| The average price per ton of blueberries | ◯ | ◯ | ◯ | ◯ |
| The export price per ton | ◯ | ◯ | ◯ | ◯ |
| The cost of producing a ton of blueberries | ◯ | ◯ | ◯ | ◯ |
| The ability to increase the farms income | ◯ | ◯ | ◯ | ◯ |
| The high demand in the market for blueberries | ◯ | ◯ | ◯ | ◯ |
| The ability to diversify your income | ◯ | ◯ | ◯ | ◯ |
| The employment opportunities that it offers | ◯ | ◯ | ◯ | ◯ |
| The suitability of your climate for blueberry production | ◯ | ◯ | ◯ | ◯ |

| | | | | |
|---|---|---|---|---|
| The release of newer blueberry varieties | ○ | ○ | ○ | ○ |
| The volume of irrigation required | ○ | ○ | ○ | ○ |
| The quantity of chemicals required | ○ | ○ | ○ | ○ |
| Government advocation for blueberry expansion | ○ | ○ | ○ | ○ |
| Communication with a exporter (e.g. United Exports or BerryWorld) | ○ | ○ | ○ | ○ |
| External investment to support establishing blueberries | ○ | ○ | ○ | ○ |
| A decrease in price of other established fruit on the farm | ○ | ○ | ○ | ○ |
| A decrease in market demand for other established fruit on the farm | ○ | ○ | ○ | ○ |

| | | | | |
|---|---|---|---|---|
| An increase in cost to production of other established fruits on the farm | ◯ | ◯ | ◯ | ◯ |

Has COVID-19 increased of decreased your willingness to expand your blueberry operation? *

◯ Increased

◯ Decreased

◯ COVID-19 had no impact on my willingness to expand my blueberry production

Is there anything else you would like to add?

Your answer

Would you be interested to participate in further conversations with me regarding the impact of blueberry expansion in South Africa? *

◯ Yes

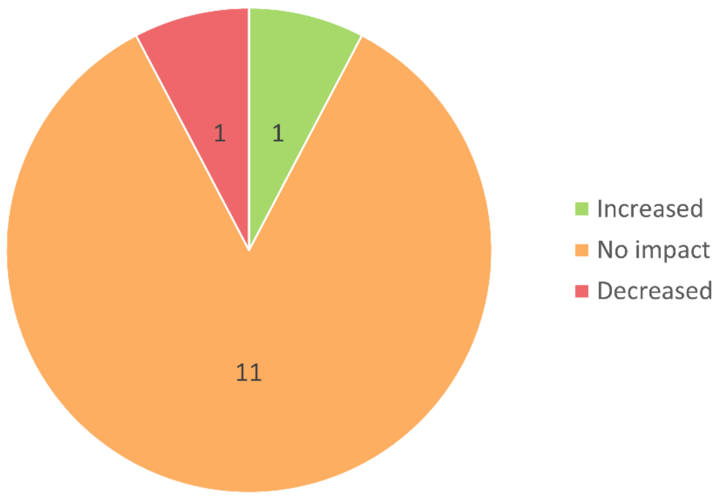
◯ No

# Addendum C – Survey Results

Addendum Table C.1 Demographic profile of participants that responded to the online survey.

| | **Number of participants** |
|---|---|
| **Sex** | |
| Male | 12 |
| Female | 1 |
| **Age group** | |
| 20 – 39 | 4 |
| 40 – 59 | 8 |
| 60+ | 1 |
| **Ethnicity** | |
| White | 13 |
| **Province** | |
| KwaZulu-Natal | 1 |
| Limpopo | 3 |
| Mpumalanga | 1 |
| Western Cape | 7 |
| **Job Title** | |
| Farm owner | 8 |
| Farm manager | 2 |
| Other | 2 |
| **Selected survey language** | |
| Afrikaans | 2 |
| English | 11 |


Addendum Figure C.1 Survey participants' Likert scale responses that show the level of agreement on a variety of suggested drivers for the blueberry industry.




Addendum Figure C.2 Survey participants' responses to the question: Has COVID-19 increased or decreased your willingness to expand your blueberry operation?

## Addendum D - Generic interview questions

- If you know what you know now, would you start or encourage others to start blueberry farming today?
- Will you continue expanding your operation and what is the size limit? Or if not, why not?
- Did you see blueberries as an employment opportunity for seasonal or full-time staff? Has it increased female employment in your opinion?
- Do you consider blueberries to be water or chemical-intensive in comparison to other crops you have worked with?
- What communications did you have with exporters and how did they influence your choice? Are you happy with your export (do you have a good relationship and feel treated fairly?)
- Is the industry as profitable as expected? How do royalties and exporters impact your profitability?
- Which crops on your farm have experienced a decrease in price and demand?
- Which crops have experienced an increase in production cost on your farm? Are you replacing these crops with blueberries?
- What other crops are you replacing with blueberries or how much new land/fallow land have you converted for blueberry production?
- What does your operation look like, shaded/tunnels/open-air & pots/soil, how did this impact your decision when looking at the start-up cost?

# Addendum E - Life cycle assessment

Addendum Table E.1 The average yield per hectare of fruit per annum in South Africa (BerriesZA, 2019).

| Crop | Average production per hectare (kg) |
|---|---|
| **Apples** | 36 287 |
| **Pears** | 33 566 |
| **Blueberries** | 4 990 |
| **Grapes** | 12 193 |
| **Strawberries** | 22 680 |
| **Oranges** | 33 566 |

Addendum Table E.2 Post-harvest inputs per kilogram of crops (Frankowska et al., 2019).

| Crop | Water (l/kg) | Pesticide (mg/kg) | Calcium Chloride (mg/kg) | Sulphur dioxide (mg/kg) | Sodium hypochlorite (mg/kg) |
|---|---|---|---|---|---|
| **Apples** | 0,597 | 25 | 8100 | 0 | 0 |
| **Pears** | 0,597 | 25 | 8100 | 0 | 0 |
| **Blueberries** | 0 | 0 | 0 | 0 | 0 |
| **Grapes** | 0 | 0 | 0 | 3,1 | 0 |
| **Strawberries** | 0 | 0 | 0 | 0 | 0 |
| **Oranges** | 0 | 0 | 0 | 0 | 1300 |
| **Alfalfa** | 0 | 0 | 0 | 0 | 0 |

Addendum Table E.3 Input data for packaging a kilogram of fruit (Frankowska et al. 2019) (Luske, 2010; Ingwersen, 2012).

| Packaging | PE [a] (g/kg) | PET [b] (g/kg) | Cardboard (g/kg) |
|---|---|---|---|
| **PET Punnet** | 3,7 | 53 | 115 |
| **LDPE [c] Bag** | 3,9 | 0 | 6 |

[a] PE - Polyethene

[b] PET – Polyethylene terephthalate

[c] LDPE – Low-density polyethene

Addendum Table E.4 Indirect water demand from various processes (WRAP, 2013b, 2016; CBI, 2016)

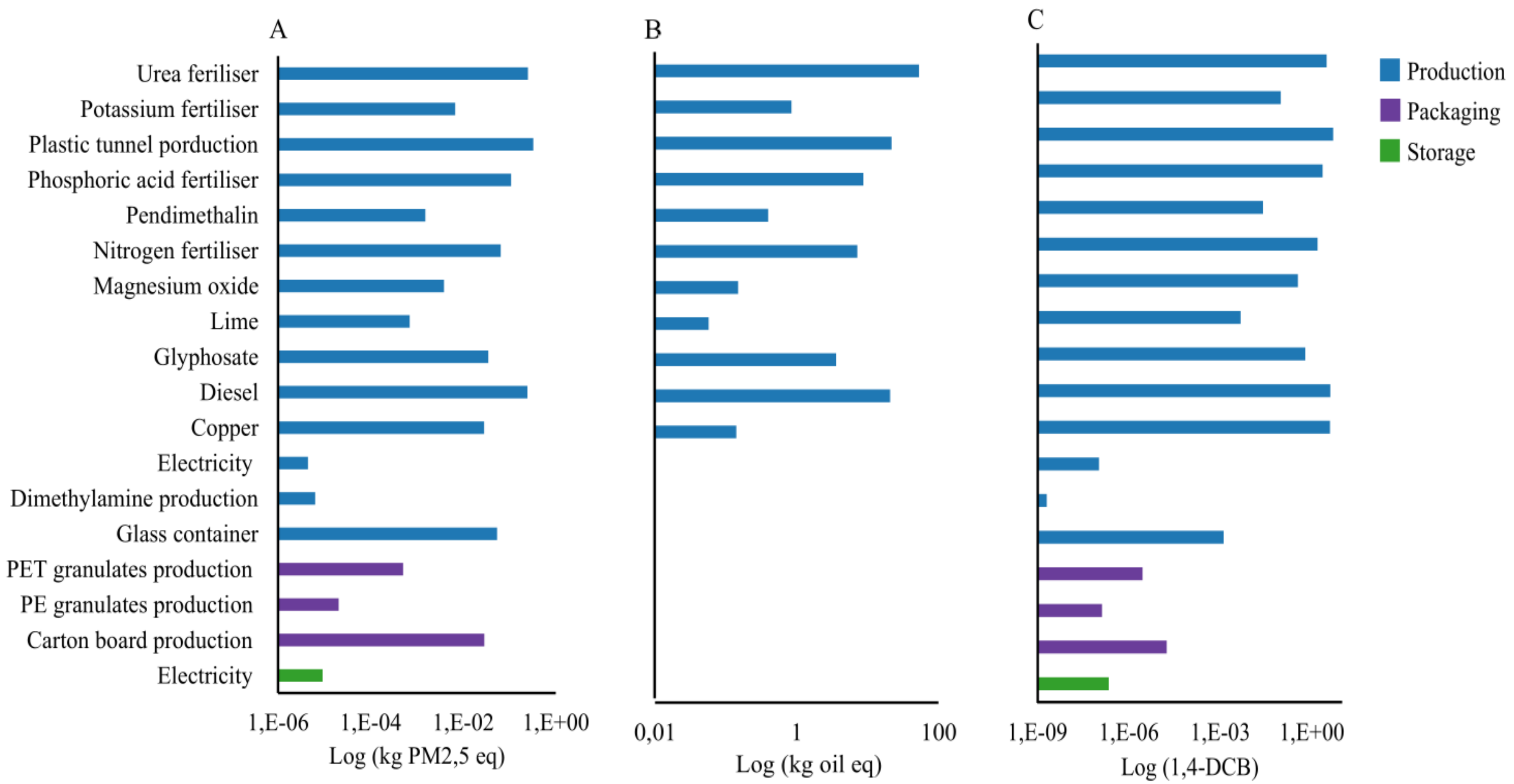
| Water Use | Blue water [a] usage |
|---|---|
| **Electricity (L/MJ)** | 1,9 |
| **PP, PET (L/kg)** | 4,8 |
| **LDPE (L/kg)** | 2,9 |
| **Pesticide (L/kg)** | 15,59 |
| **Sodium hydroxide (L/kg)** | 11,38 |
| **Sulphur dioxide (L/kg)** | 2,33 |

[a] Blue water – irrigation water from surface and groundwater reservoirs (Hoekstra et al., 2011)

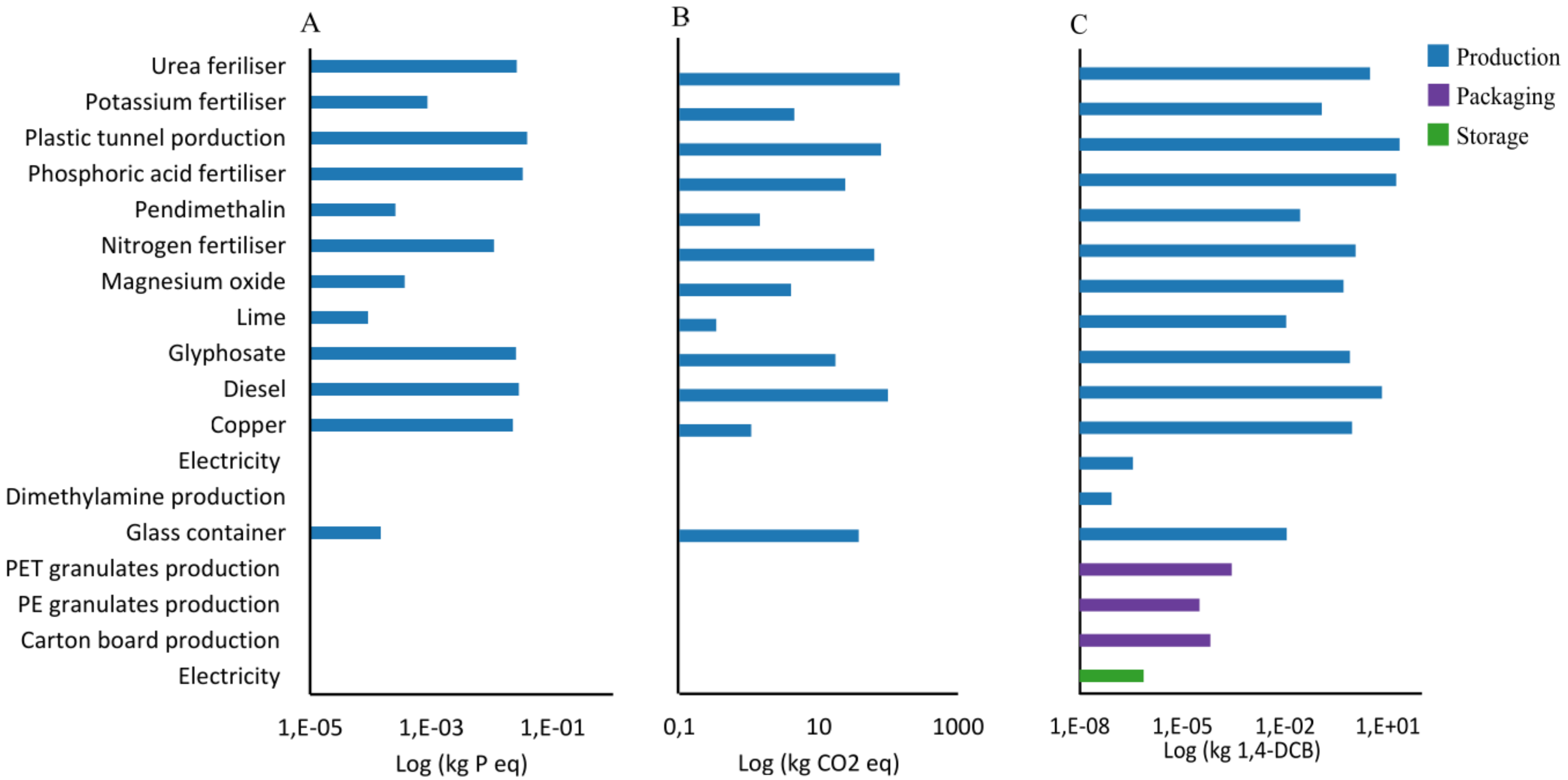
Addendum Table E.5 Average energy consumption of each crop during storage stage based on storage temperature and time (Camelo, 2004).

| Crop | Storage Temperature (˚C) | Storage Duration (days) | Storage energy (MJ/t·day) | Storage energy average (kJ/kg) |
|---|---|---|---|---|
| **Apples** | -1 – 4 | 30 – 180 | 4,1 | 430,5 |
| **Pears** | -1,5 – 0,5 | 60 – 210 | 5,4 | 729 |
| **Blueberries** | -0,5 – 0 | 14 | 5,4 | 75,6 |
| **Grapes** | -0,5 – 0 | 14 – 56 | 5,4 | 189 |
| **Strawberries** | 0 – 0,5 | 7 | 5,4 | 37,8 |
| **Oranges** | 0 - 9 | 56 - 84 | 2,7 | 189 |

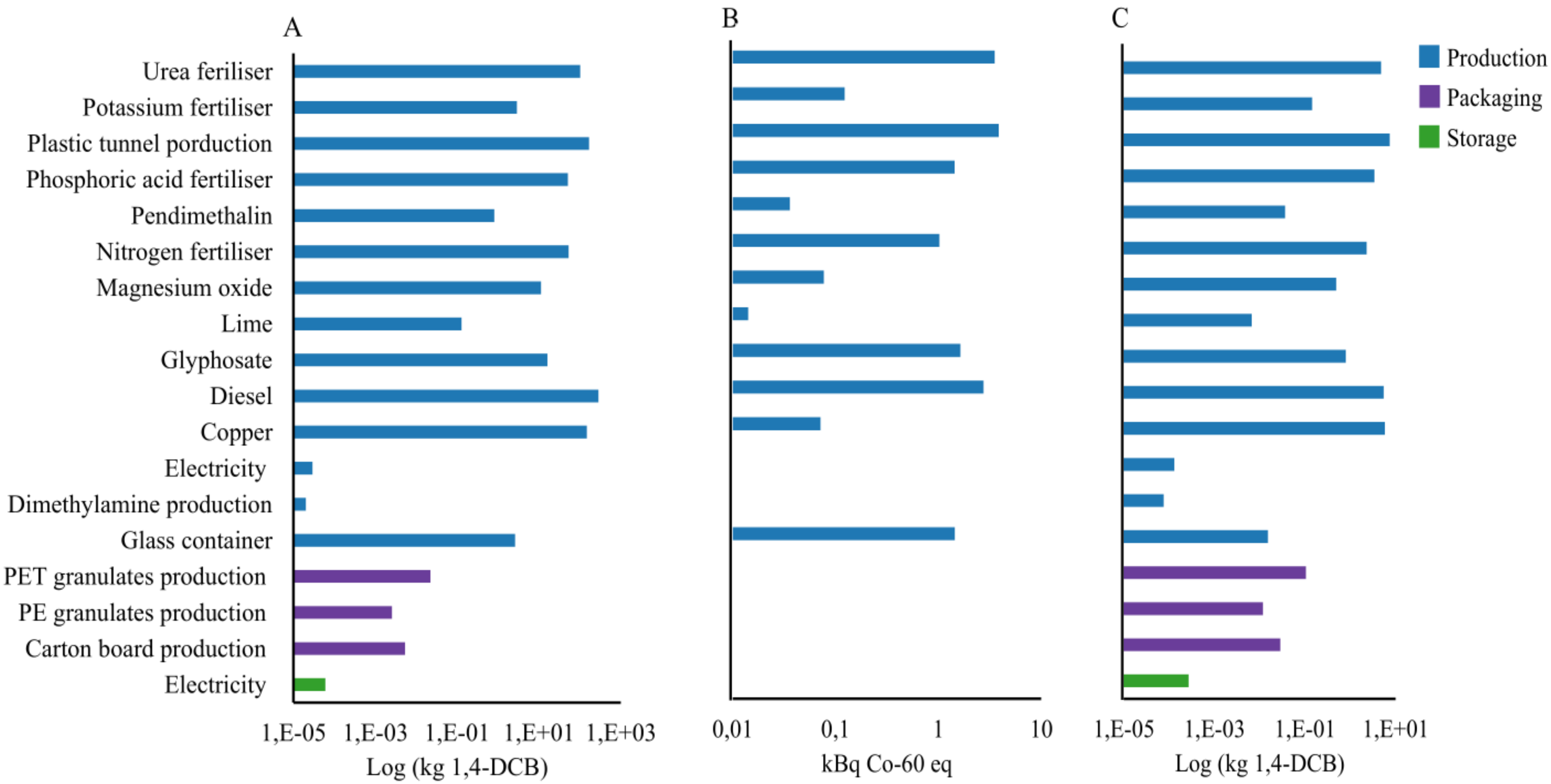
# Addendum F - Detailed results of Midpoint indicators for blueberry life cycle



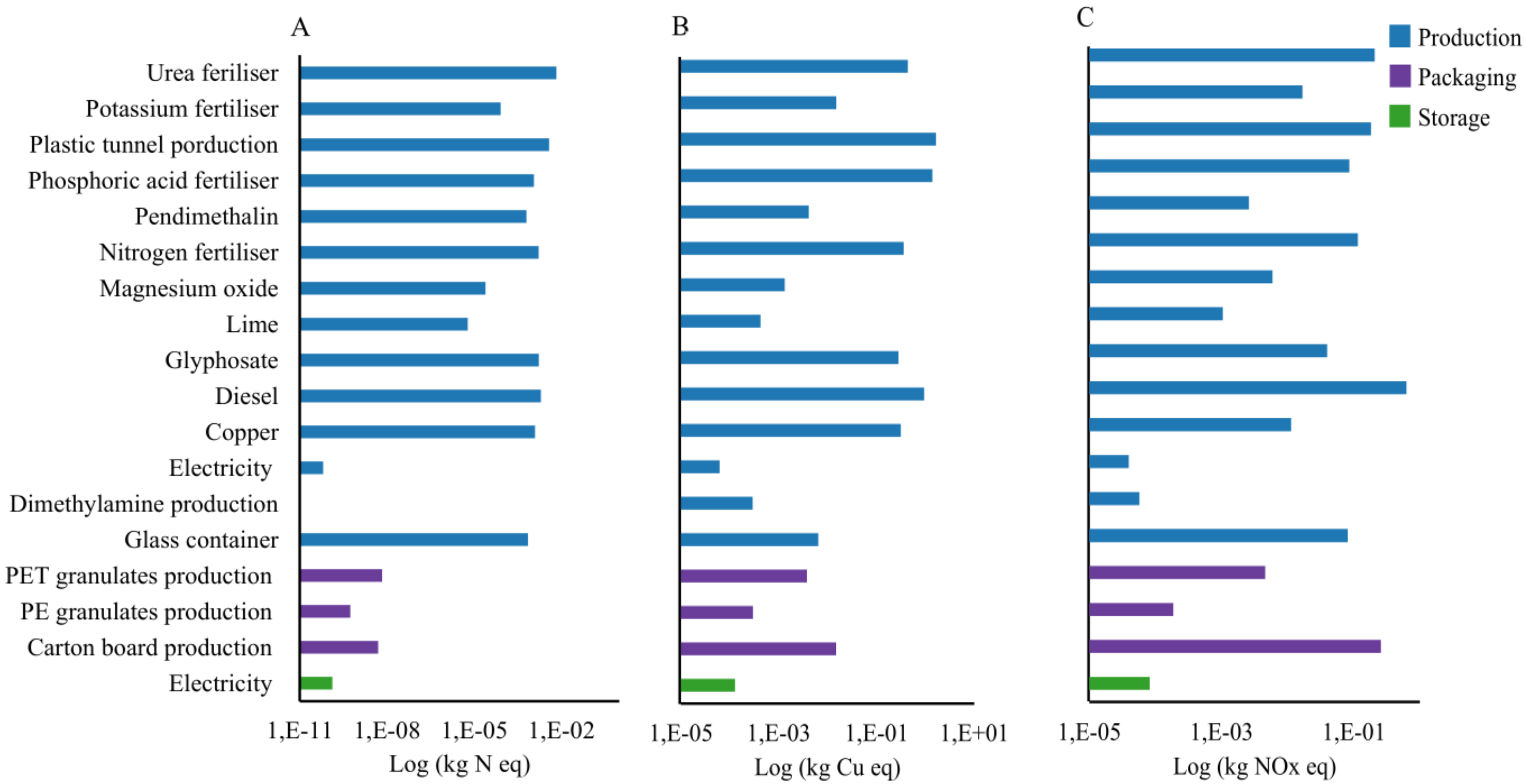

Addendum Figure F.1 The log-transformed value per element contribution during the life cycle of blueberries which accounted for more than one per cent of the overall impact of blueberries A) fine particulate matter potential, B) fossil resource scarcity potential, and C) freshwater ecotoxicity potential.



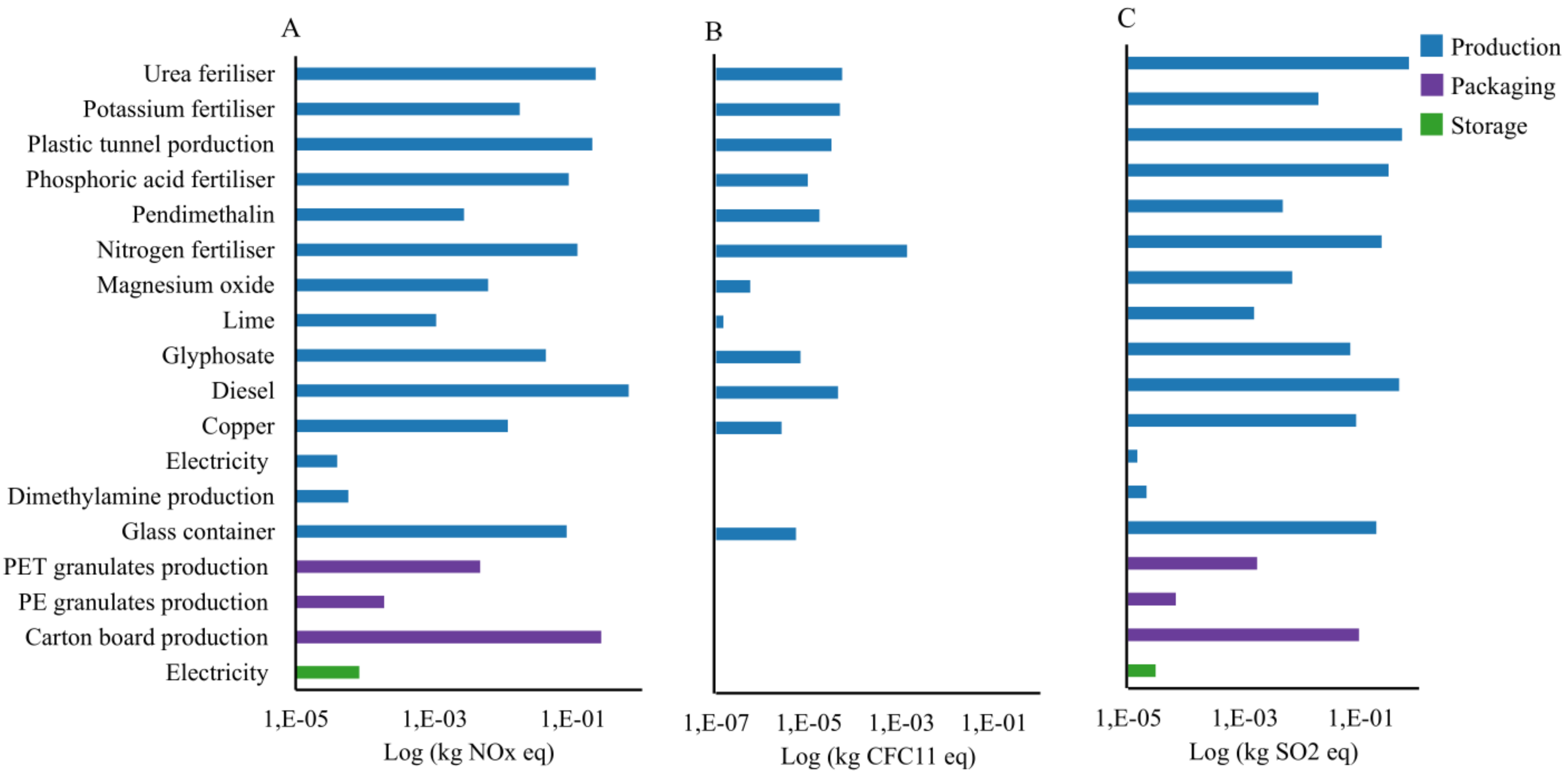

Addendum Figure F.2 The log-transformed value per element contribution during the life cycle of blueberries which accounted for more than one per cent of the overall impact of blueberries A) freshwater eutrophication potential, B) global warming potential, and C) human carcinogenic toxicity potential.



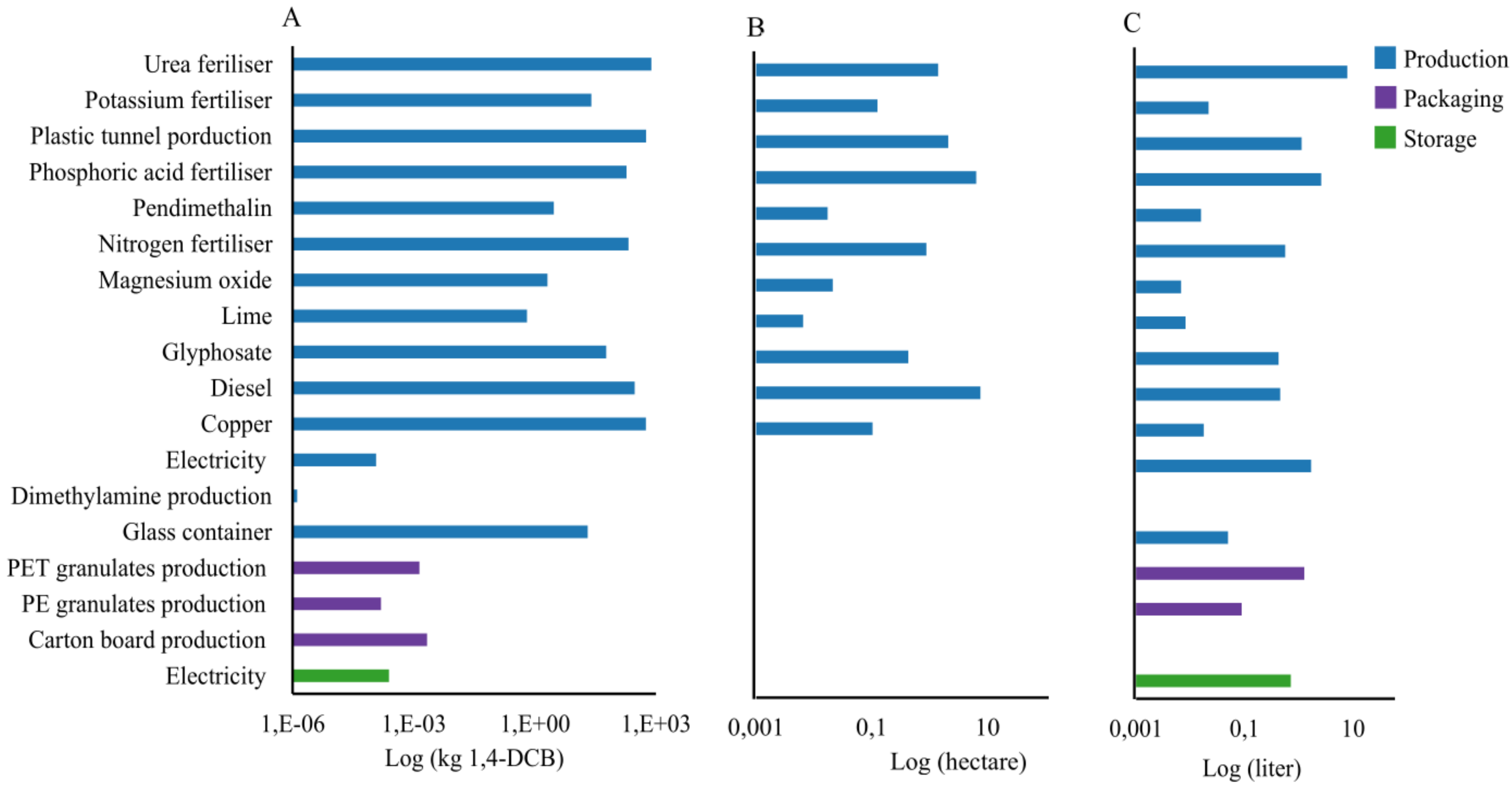

Addendum Figure F.3 The log-transformed value per element contribution during the life cycle of blueberries which accounted for more than one per cent of the overall impact of blueberries A) human non-carcinogenic toxicity potential, B) ionizing radiation potential, and C) marine ecotoxicity potential.




Addendum Figure F.4 The log-transformed value per element contribution during the life cycle of blueberries which accounted for more than one per cent of the overall impact of blueberries A) marine eutrophication potential, B) surplus ore potential, and C) ozone formation (human) potential.




Addendum Figure F.5 The log-transformed value per element contribution during the life cycle of blueberries which accounted for more than one per cent of the overall impact of blueberries A) ozone formation (terrestrial) potential, B) ozone depletion potential, and C) terrestrial acidification potential




Addendum Figure F.6 The log-transformed value per element contribution during the life cycle of blueberries which accounted for more than one per cent of the overall impact of blueberries A) terrestrial ecotoxicity potential, B) land use potential, and C) water consumption potential.