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CONTEXTUALISING ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS: THE AGRICULTURE SECTOR IN SOUTH AFRICA AS A CASE STUDY THROUGH THE DOUGHNUT THEORY

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Contextualising Environmental And Socio-Economic Impacts: The Agriculture Sector In South Africa As A Case Study Through The Doughnut Theory

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DECLARATION OF MOBILITY

This thesis is the result of the Joint Master's degree in Climate Change and Diversity: Sustainable Territorial Development (CCD-STeDe).

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THESIS APPROVAL

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I, Dr. Lee-Ann Modley as supervisor of the student ____ Léa Zaoui _____________________________________, hereby APPROVE the thesis entitled ______ CONTEXTUALISING ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS: THE AGRICULTURE SECTOR IN SOUTH AFRICA AS A CASE STUDY THROUGH THE DOUGHNUT THEORY___________________________________.

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ABSTRACT

Environmental and social impact assessment is increasingly crucial for any organisation, yet current frameworks often fail to contextualise impacts within socio-ecological systems. This thesis explores the application of Raworth's Doughnut Theory to address this gap, focusing on downscaling the model to local levels while considering interactions between human needs and planetary boundaries. Using South Africa's agricultural sector as a case study, the research employs a distributive justice and sufficientarianism approach to determine the minimum environmental pressures required for ensuring access to a healthy diet. The study aims to assess whether the sector operates within a "Safe and Just Space" and to provide insights for contextualising sustainability impacts that can be adapted across various sectors and businesses. By integrating local socio-ecological contexts into impact assessment, this research contributes to a more comprehensive understanding of sustainability, potentially transforming how businesses evaluate and report their environmental and social impacts.

RÉSUMÉ

La mesure des impacts environnementaux et sociaux par les entreprises et autres organismes est devenue essentielle aujourd'hui. Selon l'EFRAG, un impact d'entreprise se définit comme l'effet d'une entreprise sur l'économie, l'environnement, et les populations, incluant notamment son effet sur les droits humains, en conséquence des activités ou des relations d'affaires de l'entreprise. Les entreprises mesurent ces impacts, qu'ils soient environnementaux ou sociaux. Cependant, ces évaluations sont souvent relatives et auto-référentielles, comparées à des performances passées ou à celles du secteur, soulevant ainsi la question de savoir si ces impacts sont suffisants dans un contexte d'urgence climatique, de dégradation de l'environnement et d'inégalités sociales, définissant ainsi leur réelle contribution au développement durable. Pour une évaluation plus précise, il est nécessaire de situer ces impacts dans le contexte socio-économique et environnemental du territoire concerné. Cette recherche propose d'explorer cette problématique en utilisant le modèle du Doughnut.

Le Doughnut, un modèle économique proposé par K. Raworth en 2012, définit deux frontières à ne pas dépasser : une frontière intérieure, le plancher social, pour les besoins humains de base, et une frontière extérieure, le plafond environnemental, pour la préservation de l'environnement. Le plafond environnemental s'inspire des limites planétaires définies par J. Rockström (2009), englobant neuf seuils écologiques à ne pas franchir pour maintenir la stabilité de la planète. Le plancher social repose quant à lui sur la Déclaration universelle des droits de l'homme, définissant onze dimensions de la vie qui correspondent aux besoins fondamentaux des humains. Cette étude vise à explorer la pertinence et la praticabilité du modèle du Doughnut (Raworth, 2012) en l'appliquant au secteur agricole en Afrique du Sud, afin de déterminer si ce secteur fonctionne dans un espace sûr et juste. Trois objectifs spécifiques guident cette exploration :

Définir l'Espace Sûr et Juste : Établir des seuils environnementaux et sociaux pour le secteur agricole sud-africain, incluant les limites environnementales nationales, les

impacts minimaux nécessaires à la sécurité alimentaire, et les indicateurs de privation socio-économique pour les travailleurs agricoles et la population générale.

- Évaluer les Impacts Environnementaux : Analyser dans quelle mesure les impacts environnementaux réels du secteur agricole s'alignent avec les seuils définis pour déterminer si le secteur reste dans l'espace sûr.
- Examiner la Privation Sociale : Évaluer le niveau de privation sociale dans le secteur agricole en analysant des indicateurs socio-économiques clés liés à la sécurité alimentaire, aux conditions de travail, au bien-être social et à l'égalité des genres, afin de déterminer si le secteur respecte l'espace juste.
- Définir un espace sûr et juste pour une activité économique nécessite de déterminer la part d'espace écologique que cette activité ne doit pas dépasser pour rester dans les limites de durabilité. Cette recherche utilise le principe du suffisantarisme, qui considère que tout individu ne doit manquer d'aucun besoin fondamental en dessous d'un seuil de suffisance défini. Ce principe s'aligne avec le modèle du Doughnut qui promeut cette idée à travers son plancher social.

Dans cette étude de cas, trois seuils environnementaux les plus impactés par la production agricole sont évalués : le changement climatique, l'utilisation de l'eau, et le changement d'usage des sols. Pour chacun d'entre eux, la limite environnementale nationale sud-africaine et la limite environnementale minimale nécessaire pour nourrir la population sud-africaine sont définies à partir de sources secondaires issues de la littérature scientifique. Par ailleurs, des indicateurs socio-économiques permettant d'évaluer le niveau de sécurité alimentaire dans le pays ainsi que les conditions sociales et de travail des employés du secteur agricole sont répertoriés. L'ensemble de ces éléments permet de définir un Espace Sûr et Juste pour le secteur agricole en Afrique du Sud. Ces seuils et indicateurs sont ensuite comparés aux impacts réels du secteur agricole en Afrique du Sud en prenant comme année de référence 2018. Les résultats de cette recherche montrent que pour chacune des dimensions environnementales, le secteur agricole occupe plus de 50% de l'espace environnemental sûr du pays, tout en dépassant significativement le seuil environnemental minimal défini comme nécessaire pour nourrir la population sud-africaine. Par ailleurs, l'analyse des indicateurs socio-économiques montre un niveau d'insuffisance élevé en termes de sécurité alimentaire mais également en termes de conditions sociales et de travail acceptables pour les travailleurs du secteur.

La mise en pratique du modèle du Doughnut et de ses théories associées sur le secteur agricole en Afrique du Sud permet de conclure sur plusieurs considérations techniques et éthiques quant à la pertinence de ce modèle pour la mesure d'impact. D'un point de vue technique, l'interprétation des résultats montre une cohérence avec les réalités sud-africaines, lorsqu'ils sont comparés aux conclusions de recherches précédentes sur le sujet. Cela sous-entend une certaine fiabilité des résultats quantitatifs obtenus après l'utilisation du Doughnut. Cependant, de nombreux défis techniques ont été relevés lors de l'étude de cas. Tout d'abord, la traduction entre les limites environnementales minimales et maximales ainsi qu'avec les impacts réels du secteur peut créer des incohérences si le périmètre de mesure, l'unité ou la description de l'indicateur diffèrent entre ces paramètres. Un temps de recherche important doit donc être consacré à cette étape afin d'assurer la comparabilité entre les données. Ensuite, l'utilisation du suffisantarisme comme principe d'allocation peut rendre difficile l'application de ce modèle à tout type d'activité puisque cette notion issue de la justice distributive se concentre avant tout sur les secteurs essentiels. Ainsi, son utilisation pour la contextualisation d'impacts pour d'autres types d'activités économiques limite l'application du Doughnut selon cette méthodologie. D'un point de vue éthique, le processus de définition d'un Espace Sûr et Juste et l'allocation d'une partie de ce dernier à un secteur en particulier soulève des interrogations sur la définition d'un seuil maximal supplémentaire, visant à limiter l'utilisation de la richesse au-delà de simplement leur impact environnemental, mais aussi sur l'intégration d'autres considérations de justice entre les espèces, entre les générations et entre les territoires. Cette limite éthique est particulièrement visible dans le cas de l'Afrique du Sud, où les réalités agricoles sont fortement marquées par l'apartheid, par exemple.

Pour conclure, cette recherche montre que le modèle du Doughnut est pertinent pour offrir un contexte socio-écologique aux impacts environnementaux et socio-économiques. Néanmoins, il présente de nombreuses limites techniques, notamment en termes d'accessibilité et de précision des données, mais aussi dans le choix du facteur d'allocation, qui soulève d'importantes considérations éthiques.

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AESA - Absolute Environmental Sustainability Assessment

CSRD - Corporate Sustainability Reporting Directive

CSR - Corporate Social Responsibility

EEMRIO - Environmentally-extended multi-regional input-output model

EFRAG - European Financial Reporting Advisory Group

ESG - Environmental, Social, and Governance

FAO - Food and Agriculture Organization (of the United Nations)

GDP - Gross Domestic Product

GRI - Global Reporting Initiative

LCA - Life Cycle Assessment

SADC - Southern African Development Community

SASB - Sustainability Accounting Standards Board

SBTi - Science Based Targets initiative

SDG - Sustainable Development Goals

ZAR - South African Rand

CHAPTER 1. RESEARCH PROJECT

This research focuses on the issue of contextualising impacts within the framework of impact assessment for economic activities. Currently, most impacts are considered in relative terms, without comparing them to the realities of the socio-ecological systems where these impacts occur. In recent years, there has been growing interest in exploring the use of absolute thresholds to compare impacts against environmental and social boundaries. Raworth's Doughnut model (2012), which defines a Safe and Just Space for Humanity—where all individuals can meet their basic needs without exceeding environmental limits—offers a compelling framework to provide a quantitative context to these impacts. Thus, the aim of this research is to explore the relevance and practicality of the Doughnut model for contextualizing the environmental and social impacts of economic activities.

As this is an exploratory study, a case study approach has been chosen to test the application of the Safe and Just Space concept to real impacts of economic activities. The agricultural sector was selected for this case study, as it has a significant environmental footprint while also being a key sector for addressing the essential social need of food security. South Africa presents an interesting study area due to the importance of agricultural land use in the country and the social considerations linked to food security. This chapter aim to present the research project.

1. Aims and objectives

The aim of this study is to explore the relevance and practicality of the Doughnut Model (Raworth, 2012) for impact contextualisation by applying it to the agricultural sector in South Africa and determining the extent to which this sector operates within a defined Safe and Just Space.

Three research objectives are defined:

Objective 1: To define the "Safe and Just Operating Space" for South Africa's agricultural sector by establishing environmental and social thresholds, including national environmental boundaries, minimum impacts required for food security, and socio-economic indicators of deprivation among agricultural workers and the general population.

Objective 2: To assess the extent to which South Africa's agricultural sector's environmental impacts align with the defined environmental thresholds, determining whether the sector operates within the "safe space" by adhering to both upper and lower environmental limits.

Objective 3: To evaluate the level of social deprivation in South Africa's agricultural sector by analysing socio-economic indicators related to food security, working conditions, social well-being, and gender equality, in order to determine whether the sector remains within the "just space" as outlined by the Doughnut model.

2. Problem Statement

As environmental and socioeconomic challenges grow worldwide, regulations, consumer demand as well as environmental, social and governance (ESG) risks along supply chains are pushing companies to embrace sustainable practices and openly disclose their effects on the environment and society (Christensen et al., 2022). Conventional corporate reporting frequently fails to provide a thorough evaluation of an organisation's sustainability performance because it ignores the complex environment in which these businesses operate (Haffar & Searcy, 2018). Investigating frameworks and methodologies that can help successfully contextualise the effects of business activity on their territories is essential to address this issue and put forward a “stronger” sustainability and transformative change.

In 2012, Raworth presented the Doughnut Economics model, which takes a comprehensive approach by imagining a "safe and just space for humanity" between the environmental ceiling and the social foundation. Although this approach has a strong theoretical foundation, it is limited for downscaled applications that can help direct businesses in assessing their sustainability performance, especially from a macro-economic perspective that could be re-applicable through companies and sectors. By offering a way to situate a particular industry on the Doughnut, this research can provide new avenues for the impact assessment of economic activities of a given industry to assess if they are really doing “good enough” in each country/territory. This exploratory research uses a case study approach to investigate the relevance and practicality of the Doughnut model, which appears appropriate as it allows for evaluating *“what is common and what is particular about the case”*, according to Ebneyamini et al. (2018).

To build a robust case study, this research draws on existing methodologies related to the Doughnut model, such as Absolute Environmental Sustainable Assessments (Bjørn et al., 2019), Earth System Justice (Gupta et al., 2023), and Decent living standard and sufficientarianism (Heide et al., 2023). This study aims to apply these theories, intertwined with the Doughnut model, to define a context to environmental and socio-economic impacts of the South African agriculture industry and to then discuss the benefits and limits of this approach. The case study uses the Doughnut Economics framework (Raworth, 2012), the work from Cole et al. (2014) and the studies from Rammlet et al. (2023), to assess whether the agriculture sector in South Africa is operating within a Safe and Just Space and what are its areas of improvement. In particular, this research can provide a deeper understanding of the interactions between environment and social impacts of an activity, beyond socio-economic indicators, by also putting forward justice considerations. Furthermore, by proving a Doughnut Economics model's application for a specific economic sector, this study could provide significant insights to the conversation on the sustainable taxonomy for impact assessment and how justice considerations could be added to the field.

3. **Justification of study**

In January 2023, the European Commission formally endorsed the Corporate Sustainability Reporting Directive (CSRD), with the objective of modernising and fortifying regulations concerning the disclosure of social and environmental data by corporations (European Commission, 2023). This directive introduces a crucial concept: double materiality. In corporate reporting, materiality refers to information that is pertinent, meaning that it has the potential to exert a significant influence on a company, its operations, and its capacity to generate both financial and non-financial value for itself and its stakeholders (Adams et al., 2021). For the first time, in 2019, the European Commission defined double materiality as the consideration of two material perspectives: single materiality, or financial materiality, and impact materiality (Adams et al., 2021). The former focuses on assessing the effects on the company's performance and value, primarily for shareholders, while the latter centres on the reporting of the environmental and social impacts stemming from the company's operations on the external world, affecting a broad spectrum of stakeholders (Adams et al., 2021). This concept has sparked discussions among scholars and professionals. While some criticise it, suggesting that it might only promise the illusion of a more effective ESG reporting, others view it as a paradigm shift that could mitigate greenwashing and elevate sustainability standards within companies (Chiu, 2022; Faber, 2023). According to some experts, the essence of double materiality lies in the reintegration of the company into a collective project, making it accountable for its activities and actions, and, in turn, effectively closing the cognitive loop on risk assessment between the company and its impact on society and the environment (Crona et al., 2021; Rambaud, 2023).

How we measure and understand impacts is key for impact assessment and sustainability reporting as it guides the company along a transformative path towards sustainable development. Impacts can be real or potential, positive or negative, short or long-term, intentional or unintentional, and reversible or irreversible (France Stratégie, 2023). The idea behind assessing impacts is to figure out how a company contributes, whether it is a positive or negative contribution, to sustainable development (France Stratégie, 2023). When we consider double materiality, impacts should ideally be studied in the specific socio-ecological context where the company operates (Haffar & Searcy, 2018). This inside-out approach, promoted by double materiality, takes a closer look at the impacts and risks a company imposes on the external world, which is necessary to assess system value. It calls for the use of fitting indicators based on the context, like the Sustainable Development Performance Indicators suggested by UNRISD (Yi et al., 2022).

Nevertheless, these kinds of indicators are far from being widely adopted by businesses that are just beginning to grasp the concept of double materiality. Haffar & Searcy (2018) argue that because firms only take into account self-referential indicators, such as absolute performance or incremental change, and ignore larger sustainability thresholds, their environmental and social impact evaluations lack direction and context (Haffar & Searcy, 2018). As these disclosures lack an outside reference point that goes outside the company's view, they only offer a partial picture of the sustainability performance of the business. As a result, self-referential reports fail to sufficiently take into account the concept of "sustainability context" and are inward-looking as opposed to outward-looking (Yi et al., 2022). Context-based sustainability emphasises that a company's impacts should exist within a broader framework of sustainability, considering the constraints and standards imposed by the socio-environmental system in which each company operates (Haffar & Searcy, 2018). Contextualising impacts is a move from relative to absolute sustainability, which is theoretically capable of bringing about more transformative change (Haffar & Searcy, 2018). But what underlies the concept of absolute sustainability?

Various frameworks and methodologies have emerged, known as Absolute Environmental Sustainability Assessment (AESA), which aims to determine whether a production or consumption activity can be considered environmentally sustainable in an absolute sense (Bjørn et al., 2018). This assessment involves comparing the environmental pressure of the activity to its assigned environmental carrying capacity defined as *"the maximum sustained environmental interference a natural system can withstand without experiencing negative changes in structure or functioning that are difficult or impossible to revert"* (Bjørn et al., 2018). For instance, Hjalsted et al. (2021) address the challenge of assessing the sustainability of products or companies in absolute terms. According to these authors, an entity can only be considered absolutely sustainable if it stays within its allocated share of the safe operating space, defined by specific environmental capacity limits, such as the Planet Boundaries (Hjalsted et al., 2021). They argue that entities must evaluate whether their efforts to reduce impacts are "good enough" from a strong sustainability perspective, meaning their activities align with planetary boundaries (Hjalsted et al., 2021). Heide et al. (2023) propose that the absolute perspective entails a shift from merely improving to doing what is necessary to meet the needs of both present and future generations within the biophysical limits of the planet. Companies, therefore, require a benchmark or reference level for absolute sustainability as they previously primarily focused on comparing environmental impacts for competitive advantage (Heide et al., 2023). The purpose of AESAs is to assist companies in determining when their products are not just better than alternatives but genuinely "good enough" (Heide et al., 2023). Thus, the concept of carrying capacity and thresholds not to be exceeded is crucial for contextualising impacts. In the case of environmental impacts, current research consistently relies on the Planetary Boundaries defined by Rockström et al. in 2009 and their carrying capacity (Bjørn et al., 2020).

However, implementing planetary boundaries poses a challenge and current research on the application of the Planet Boundaries model to corporate impacts is limited. Since Planetary Boundaries are a global concept, downscaling might be considered unjustifiable or unnecessary (Feretto et al., 2022). Nevertheless, the fact that policies are developed and applied locally, within political borders, has resulted in the creation of many downscaled versions of the Planetary Boundaries and the ability to downscale the boundaries appears necessary to make them operational (Feretto et al., 2022). Bai et al. (2024) assert that they need to be translated for various stakeholders as it can inform target-setting strategies, considering capacity, responsibility, and equity, and involving co-design between scientific entities and other stakeholders. Businesses in particular are major actors of sustainable change and should adopt distributive and regenerative economic models, which address inequalities and marginalisation, encourage more equitable value and opportunity sharing, and ensure that Earth's resources are never depleted but are continuously used within the cycles of the living world (Sahan et al., 2022; Bai et al., 2024).

For the Planetary Boundaries framework started to make his way in ESG reporting. At the corporate level, Li et al. (2022) note that companies are increasingly incorporating planetary boundaries into their strategies as there is growing interest among corporations in evaluating their absolute performance due to growing pressure from shareholders and investors. Li et al. (2022) mention that the Kering Group, in collaboration with the University of Cambridge Institute for Sustainability, promotes the idea that companies should actively work to restore local environmental health by adhering to local boundaries rather than merely focusing on their proportionate share of global boundaries. Also according to Li et al. (2022), L'Oréal is investigating the use of PB-based weighting factors as a crucial tool for prioritisation and Alpro is setting context-specific water boundaries in partnership with WWF. Furthermore, Li et al. (2022) mention how Mars is implementing PB-aligned absolute boundaries for greenhouse gas emissions, water use, and land use and Unilever is examining the complexities of using planetary boundaries to assess their land use, biodiversity, and water-related impacts in collaboration with academic institutions. According to Cranston & Steffen (2019), the instinctive response is to "downscale" them, exploring their implications within the operational scales of a company. Another approach is "upscaling," where the impacts of business activities at local scales are translated into a broader context. By doing so, a benchmark for sectors could be constructed to help identify both laggards and leaders (Cranston & Steffen, 2019).

Nonetheless, scholars agree that Planetary Boundaries and environmental challenges are not the sole thresholds to consider and social justice and what is socially acceptable must also be taken into account (Biermann & Kim, 2020). In response to this, Raworth introduced in 2012 the concept of the Doughnut economy for a just and safe space considering social foundation, in contrast to solely focusing on the safe space defined by planetary boundaries (Sahan et al., 2022). The Doughnut comprises two concentric rings: one for the social foundation, which makes sure that no one is left without the basic needs of life, and the other for the ecological ceiling, which keeps humanity from going over the planetary bounds that protect Earth's life-supporting systems as a whole (Sahan et al., 2022). These limits define a doughnut-shaped area that is socially and environmentally equitable as well as safe, allowing humanity to thrive there (Sahan et al., 2022). The application of the Doughnut Economy has gained attention across various fields, including tourism, public governance, and social impact assessment. For instance, Raworth's Doughnut Economics model has been implemented to rethink tourism destination management, offering a fresh perspective for sustainable tourism development (Hartman & Heslinga, 2022). Moreover, the model has been integrated into public governance strategies, such as in the Danish built environment, aligning with the principles of Circular Economy and Absolute Sustainability (Hansen & Lynge, 2020). Although there is little study on how social and environmental priorities interact, the doughnut image highlights the necessity for them to do so (Ferreto et al., 2022). For Capmourteres et al. (2019), the Doughnut Model could be applied to sustainability assessment as it allows to understand the complex network of possible causalities, synergies, and trade-offs to approach sustainability rather than a collection of individual elements.

Therefore, the interest for the Doughnut in the academic literature demonstrate its appeal as a research framework. To use the Doughnut's thresholds to contextualise the environmental and socio-economic impacts of a company or an activity, one must evaluate all the impacts of a company and then measure the ecological and socio-economic impacts in absolute terms within a given territory to compare them to thresholds set by the doughnut. However, several limitations arise. Firstly, few companies publish the precise set of their environmental impacts that can be evaluated against planetary boundaries. In the context of this research, it seems more appropriate to focus on the scale of a sector and a national territory as the data is more readily accessible and available. The same applies to socio-economic impacts for which there is no absolute social sustainability assessment, as social impacts are poorly understood and defined (Huysentruyt et al., 2022). The concept of a social footprint has been little explored, and the social aspect is often overlooked due to its complexity. One way to think about the social footprint is proposed by McElroy et al. (2008). Instead of questioning whether a company consumes too many resources compared to what is allowed, as in the environmental footprint, the social footprint considers whether the company creates and distributes enough "anthropogenic" capital to ensure the well-being and basic needs of individuals (McElroy et al., 2008). This includes individual capital such as access to food, social capital like health, education, financial networks, and built capital like infrastructures (McElroy et al., 2008). In practical terms, Rao and Min (2017) propose that the Decent Living Standard ensure sufficient provisions to guarantee well-being. This framework outlines a set of universal, essential, and irreducible material conditions necessary to achieve basic human well-being, accompanied by relevant indicators and quantitative thresholds (Rao & Min, 2017).

Finally, environmental and socio-economic impacts, as mentioned earlier, cannot be thought of independently but within a complex system of interactions. In particular, the social footprint of the sector cannot be evaluated based on environmental indicators grounded in science but must be considered in light of the sector’s “expected” role in society, its ability to respond to "anthropogenic" capital flows, and a given context. Previous research has aimed to bridge the gap between ecological ceilings and social foundations, such as the work by Dillman et al. (2021, 2023), who explored the "safe and just space" for urban mobility. They proposed a framework for developing sector-specific sustainable consumption corridors inspired by Doughnut Economics. To integrate social and environmental dimensions, Dillman et al. (2021) utilised the DPSIR (Driver–Pressure–State–Impact–Response) Framework, where 'pressures' refer to the transgression of planetary boundaries and 'drivers' are the external forces stemming from human demand that lead to these pressures. Their research suggests a framework and indicators from existing literature specifically tailored to the mobility sector but does not apply these using actual data for a specific territory. In the context of the agricultural sector, the primary driver is access to food, which creates environmental pressures. From a quantitative perspective, Aleissa & Bashi (2023) argue that these pressures can be expressed in terms of impacts on ecosystem services. They study the minimum environmental impacts necessary to meet the sufficient food needs of a population.

This thesis uses the agricultural sector in South Africa as a case study. The choice of South Africa was influenced by the prior work of Cole (2014), who used the Doughnut Theory to establish a national barometer, defining the country's environmental and social thresholds through a bottom-up approach i.e., by adapting indicators to the country's realities. The selection of the agricultural sector appears pertinent due to its significant environmental impact, its integral role in a country's socio-economic system, and its contribution to the Sustainable Development Goals in the context of the social footprint assessment. Indeed, the agriculture sector in South Africa shows many challenges. The sector represents only 2.4% of South Africa's GDP (Department of Agriculture, Land Reform, and Rural Development of the Republic of South Africa, 2022), while approximately 11.6% of the total households in South Africa reported experiencing hunger in 2021 (Statistics South African RSA, 2022). Simultaneously, the majority of South Africa's land was used for agricultural activities in 2019, accounting for almost 80% of the country's total land area with the land being predominantly categorised as "land under permanent meadows and pastures" (Statista, 2023). These figures highlight the importance to understand to explore what would be a Just and Safe Space for agriculture activities in South Africa and how the sector occupies it.

4. Methodology

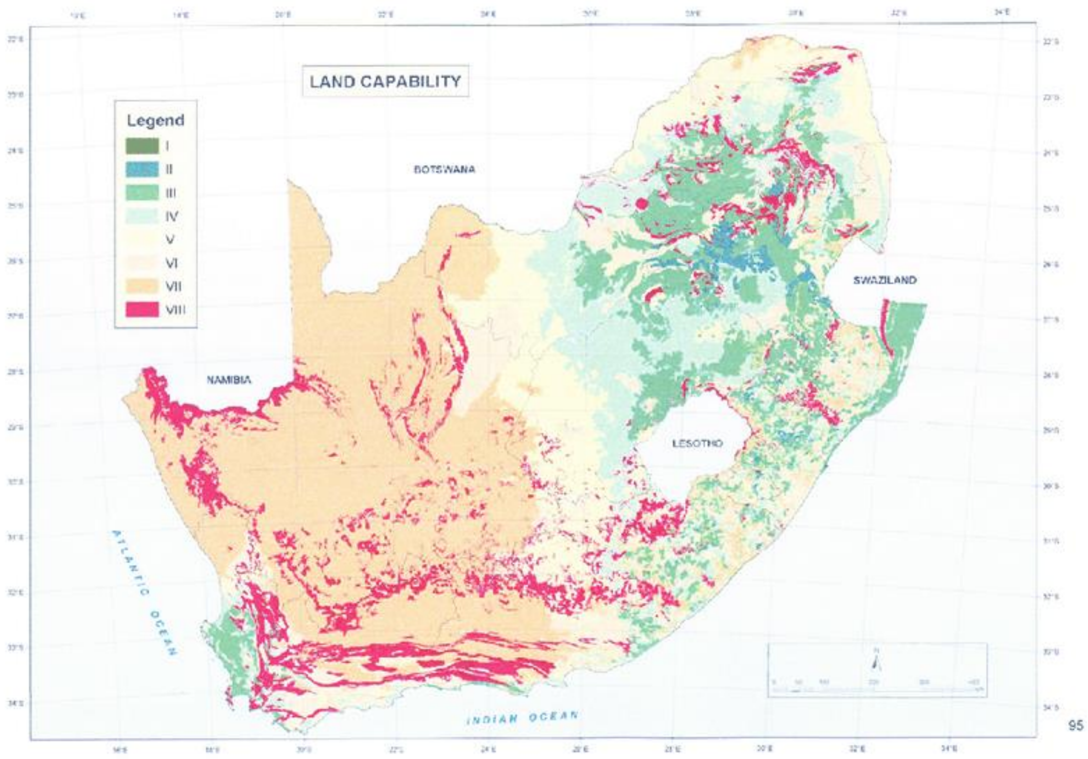
4.1. Study Area

South Africa is located at the southern tip of Africa, with a coastline stretching over 3,000 km (Republic of South Africa, 2022). It begins in the dry area near Namibia along the Atlantic Ocean, goes around the top of Africa, and extends north towards the warmer part of Mozambique along the Indian Ocean (Republic of South Africa, 2022). The country's territory spans latitudinal coordinates from 22°S to 35°S and longitudinal coordinates from 17°E to 33°E, covering an area of 1,219,602 km² (Republic of South Africa, 2022). The landscape includes diverse ecosystems such as bushveld, grasslands, forests, deserts, mountains, clean beaches, and wetlands (Republic of South Africa, 2022).

South Africa is highly vulnerable to climate change and the degradation of the already vulnerable natural environment is exacerbated by the early adoption of conventional agricultural techniques (FAO, European Union, CIRAD, and DSI-NRF Centre of Excellence in Food Security, 2022). The preservation of good agricultural conditions is crucial as, while about one-third of South Africa receives enough rainfall for crop production, only around 12% of the country has fertile soil, and less than 3% of South Africa is considered highly productive land (Goldbaltt, 2008). Hence, most land in South Africa has limited agricultural potential according to Cloete & Olivier (2010). Agricultural land is classified into several categories based on land capability, which refers to "*the most intensive long-term use of land for purposes of rainfed farming, determined by the interaction of climate, soil, and terrain,"* as defined by the

Department of Agriculture, Land Reform and Rural Development (2021). Defined from Class I to Class VIII on the map below, Class I is the most suitable for agriculture but accounts for only a small portion of the country's land. In contrast, the higher classes, which offer less favourable conditions for agricultural production, make up a larger portion of the country's surface area (Cloete & Olivier, 2010).

Figure 1: Map of the South African land capability (Cloete & Olivier, 2010)



South Africa's agricultural economy is divided into a well-established commercial sector, a growing emerging sector, and a mostly subsistence-oriented sector in rural areas. Therefore, agricultural activities vary from intense export production - such as fruits, wine, and field crops - to mixed farming and livestock farming with cattle and sheep (FAO, European Union, CIRAD, and DSI-NRF Centre of Excellence in Food Security, 2022).

The agricultural sector in South Africa raises several socio-economic questions. In terms of GDP, agriculture contributes around 5%, making up a substantial 14% of total merchandise exports (FAO, European Union, CIRAD, and DSI-NRF Centre of

Excellence in Food Security, 2022). While agriculture's direct contribution to the overall GDP is modest, it plays a crucial role in job creation and foreign exchange (Goldblatt, 2008). The commercial agricultural sector has experienced an annual growth rate of approximately 14% since 1970, surpassing the overall economic growth of 14.5% during the same period (Goldblatt, 2008). Despite its economic significance, the agricultural sector's contribution to GDP has been declining. South Africa produces more food than it needs, covering over 75% of the required calories for its people. However, although the country is self-sufficient in food, it maintains a positive trade balance and relies on an importing system and distributing food products (FAO, European Union, CIRAD, and DSI-NRF Centre of Excellence in Food Security). This observation alerts on numerous socio-economic challenges, such as ongoing issues with food and nutrition security with 11.6% of the total households in South Africa reported experiencing hunger in 2021 (Statistics South African RSA, 2022; FAO, European Union, CIRAD, and DSI-NRF Centre of Excellence in Food Security, 2022).

Understanding the environmental and socio-economic impacts of the agricultural sector in South Africa is therefore crucial and assessing the sector's position in the safe and just operating space is essential for effectively addressing challenges. Furthermore, it can serve as a benchmark for any businesses in the agricultural sector operating or sourcing suppliers in South Africa.

4.2. Data collection

To achieve the aim of this study, the first objective is to define the parameters for establishing a "Safe and Just Space" for the agricultural sector in South Africa. Once these thresholds are established, the second and third objective are to assess the actual impacts of the South African agricultural sector within the country. Finally, to determine if these impacts fall within the defined Safe and Just Space, the research is inspired by the Sustainable Quotient framework developed by McElroy (2008) will be used. The Sustainable Quotient is a ratio that measures the sustainability of an impact within a broader socio-ecological context (McElroy, 2008). As defined by Yi et al. (2022), the Sustainable Quotient is:

“A measure of the performance of an organisation. It is expressed in terms of the organisation’s impacts on vital capitals relative to what the standards or sustainability norms must be to ensure the well-being of stakeholders. Actual impacts divided by normative impacts provide a measure of sustainability.

$$Sustainable\ Quotient = \frac{A}{N}$$

Where S = Sustainability performance
A = Actual impacts on carrying capacities of vital capitals
N = Normative impacts on carrying capacities of vital capital”

Capital refers to a reserve or stock of resources that produces a steady flow of valuable goods or services essential for human well-being (Thomas & McElroy, 2016). Ensuring an adequate supply of these essential resources can be considered as sustainable, while depleting or failing to maintain them is considered unsustainable. The types of capital examined in this study, as defined by Thomas & McElroy (2016), include:

- Natural Capital: Resources such as air, land, water, minerals, flora, fauna, ecosystems, and other natural resources that humans and nonhumans rely on for their well-being. This also includes ecosystem services, which are the functions provided by ecosystems that contribute to the well-being of both humans and nonhumans.
- Human Capital: Comprises knowledge, skills, experience, health, values, attitudes, motivation, and ethical aspects of individuals, including their intellectual capital.
- Social and Relationship Capital: Encompasses teams, networks, and hierarchies of individuals collaborating, along with their shared knowledge, skills, experience, health, values, attitudes, motivation, and ethical aspects, including their shared intellectual capital.

To facilitate the use of the many concepts in this research, the sustainable quotient is not mentioned as such in the research, which focuses primarily on evaluating the ratio in question.

To conduct this research, only quantitative data is collected from online secondary sources. The study relies on secondary sources because the target population is the entire population of South Africa, making direct data collection access complex. Existing datasets, previously collected by entities such as government agencies or research organisations, will be used for the study. Wherever possible, the data used is gathered for the year 2018, post-covid, otherwise the most recent available data is chosen.

The data collection includes two sets of data:
- Collecting the data to define the Safe and Just Space of the South African agriculture sector in the country.
- Collecting the data of the actual impacts of the South African agriculture sector to be able to compare them with the thresholds defined by the Safe and Just Space.

4.2.1. Safe and Just Space Data

The first set of data to be collected pertains to the environmental parameters to be studied to define the Safe and Just Space. To focus strictly on the agricultural sector, the study will consider only the environmental dimensions directly influenced by agriculture. The goal is to identify the areas of impact on the planet, essentially what can be considered material i.e., significant for a broad spectrum of stakeholders to maintain a safe space for them (Thomas & McElroy, 2016).

To streamline the selection of impact areas, this research uses the findings of the EAT-Lancet Commission (2019). The EAT-Lancet report is a scientific document that examines the environmental impact of global dietary patterns to propose an alternative diet that ensures healthy nutrition while respecting planetary boundaries (Willett et al., 2019). The Commission focuses on six key environmental dimensions—those most significantly affected by food production and for which there is sufficient scientific evidence to provide quantifiable targets (Willett et al., 2019). These dimensions are climate change, land-system change, freshwater use, nitrogen cycling, phosphorus cycling, and biodiversity loss (Willett et al., 2019). To facilitate the primary aim of this research, which is to explore the relevance of the Doughnut model, only the first three dimensions are examined. Therefore, the environmental indicators studied are as follows:

Table 1: List of environmental dimensions and indicators studied

Environmental dimension	**Indicator**	**Unit**
Climate Change	GHG Emissions	CO_2 equivalent
Freshwater Use	Water Use	Mm^3
Land-use	Crop-land Use	Km^2

For each of these dimensions, this research defines a maximum threshold corresponding to the carrying capacity, which represents the safe available environmental space. Additionally, a minimum threshold is set, defined by an acceptable social baseline of carrying capacity usage necessary to meet basic needs and ensure living standards. To achieve this, two main secondary sources are used:

- The national barometer for South Africa defined by Cole et al. (2014). These findings serve as the national environmental boundaries and are assessed through a bottom-up approach that evaluates each limit based on relevance to South Africa (Cole et al., 2014).
- Research by Rammelt et al. (2022), which defines, for each of the EAT-Lancet environmental dimensions, the environmental impact necessary to meet the dietary needs established by the EAT-Lancet guidelines.

By collecting this data, the Safe Space for the agricultural sector in South Africa is defined.

To establish the Safe and Just Space, socio-economic thresholds for the sector must also be included. To address this, the research considers two types of indicators: those corresponding to external stakeholders of the agricultural sector (i.e., society at large) and those related to internal stakeholders (i.e., the workers within the sector). Two secondary sources are employed:

- The FAO that developed a set of indicators dedicated to food security, based on recommendations from the Committee on World Food Security Round Table on hunger measurement (2011).
- The report commissioned by the International Labour Organisation's Pretoria Office, titled "Farm Workers' Living and Working Conditions in South Africa" by Visser & Ferrer (2015) that explores the social working conditions of the agricultural workforce.

The thresholds for these socio-economic data are primarily quantitative. Based on the concept of a decent living standard, these thresholds indicate whether basic human needs are met. A theoretical quantitative threshold would be either 0% or 100%—assuming no individual should lack basic needs. However, because this threshold does not have academic research to back them, this research relies more on a qualitative assessment, evaluating the level of deprivation and unmet needs for each indicator.

Once all the data is gathered to define the Safe and Just Space, the next step is to collect the actual environmental and socio-economic impacts of the agricultural sector. This collection is essential for comparing these impacts against the thresholds established for the Safe and Just Space.

4.2.2. Environmental and socio-economic impacts of the agriculture sector in South Africa

To collect environmental data on South Africa's agricultural sector, two primary data sources will be used, each chosen based on the scope of the impact assessment. The scope needs to align with the thresholds set to define the Safe and Just Space. The GHG emissions thresholds are measured across the entire supply chain, while other impacts are assessed based on the sector's direct activities. Hence, for each environmental impact, the two sources are:

- The Exiobase Database: This database is employed to assess GHG emissions, as it enables a comprehensive evaluation of the entire supply chain. Exiobase utilises environmentally extended multiregional input-output (EEMRIO) analysis, a method for assessing environmental impacts from a global consumption perspective (Steinmann et al., 2018). The database covers 200 products, offering detailed breakdowns, including 15 product groups for agricultural production. It distinguishes between various livestock species and crop types, each with specific environmental impacts (Steinmann et al., 2018). Exiobase can be accessed and downloaded from: https://www.exiobase.eu/index.php.

- Our World in Data: This open-access database, licensed under Creative Commons BY, compiles data from third-party sources such as the FAO, the World Bank, and various academic studies. It focuses on significant global environmental and societal challenges (Roser, 2024). This source is used to collect data on water impact and land-use impact. The database is accessible at: https://ourworldindata.org/about.

Finally, to collect socio-economic impacts data of the agriculture sector, the same sources specified in the data collection to define the indicators are used to collect the socio-economic impacts.

4.3. Data Analysis

The data analysis aims to compare the actual impacts of the agricultural sector with the defined thresholds of the "Safe and Just Space" for South Africa. This analysis will be conducted in two stages:

1. Environmental Data: The analysis aims to apply the quotient presented earlier to evaluate the environmental impacts. This quotient helps to determine the extent to which the sector's environmental impacts align with or exceed the established safe and just thresholds.

$$Environmental\ Limit\ Quotient = \frac{Agriculture\ Sector's\ actual\ impact}{Environmental\ limit}$$

- For the maximum environmental threshold, if the quotient exceeds 1, it indicates that the sector is operating above South Africa's carrying capacity.
- For the minimum environmental threshold, if the quotient is greater than 1, it suggests that the sector operates above the social foundation necessary to ensure a decent living standard.

The extent to which the sector's use of carrying capacity is above or below these two levels provides a contextual understanding of the impacts.

2. Socio-Economic Data: The analysis can apply a quotient if the threshold is a specific quantitative value, such as a monetary limit for instance. In that case, the quotient used is:

$$Social\ Limit\ Quotient = \frac{Agriculture\ Sector's\ Actual\ Impact}{Social\ Threshold}$$

If the quotient is superior to 1, then the sector impact does not fall below the social foundation boundary. On the contrary, if it is inferior to 1, then the sector does not achieve the required social limit.

However, socio-economic indicators can hold in their definition the idea of deprivation and unmet need. In that case, this study only considers an absolute threshold that may 0% or 100% according to the formulation of the indicator. No ratio is used in that case in order to avoid mathematical issues such as dividing by zero.

4.4. Tools and Resources

- FAOSTAT (https://www.fao.org/faostat/fr/#home)

FAOSTAT provides free access to food and agriculture statistics, including sub-sectors such as crops, livestock, and forestry, for over 245 countries and territories. These data cover all FAO regional groups from 1961 to the most recent available year.

- Exiobase database (https://www.exiobase.eu/).

According to the European Environmental Agency (2019), "EXIOBASE is a global, detailed Multi-Regional Environmentally Extended Supply-Use Table (MR-SUT) and Input-Output Table (MR-IOT). It was developed by harmonising and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry. Subsequently the country supply-use tables were linked via trade creating an MR-SUT and producing a MR-IOTs from this. The MR-IOT that can be used for the analysis of the environmental impacts associated with the final consumption of product groups." EXIOBASE covers 43 countries including South Africa, full trade matrices with insights on which product from which country is exported by which sector to which industry sector in another country. The base distinguishes over 160 industry sectors and 200 product categories by country and covers the relations between industries and countries, not only in monetary value, but also in physical terms. It covers 40 emitted substances, land use, water use and 80 resources by industry (Stadler et al., 2018).

- Our World in Data (https://ourworldindata.org/)

- National Statistics.

- Research papers.

CHAPTER 2. LITERATURE REVIEW

This chapter presents a comprehensive literature review that elucidates the theoretical foundations and methodologies employed in contextualising environmental and social impacts. The review begins by examining why contextualising impact is crucial for developing more holistic and precise impact assessment. In this context, it explores two principal theories: Planetary Boundaries and the Doughnut model, which provide a foundational framework for understanding and contextualising impacts.

Subsequently, the chapter undertakes a critical review of diverse methodologies that apply these theories to impact measurement. This analysis encompasses both the practical applications of these methodologies and their ethical and moral limitations, offering a balanced view of their efficacy and challenges in real-world scenarios.

The final section of the chapter narrows its focus to an in-depth analysis of the agricultural sector in South Africa to feed the case study. This part investigates key scientific studies pertinent to the region and sector, and explores the specific challenges encountered when applying the Doughnut model for impact contextualisation in this unique geographical and industrial context.

1. Stakes and Theories Behind the Contextualisation of environmental and socio-economic impacts

1.1. The need for the contextualisation of environmental and socio-economic impacts

Corporate impact, as defined by the European Financial Reporting Advisory Group (EFRAG), encompasses the various effects a company has on the economy, environment, and society (France Stratégie, 2023). This definition includes both actual and potential impacts, which can be positive or negative, short-term or long-term, and intended or unintended (France Stratégie, 2023). The concept emphasises a company's contribution to sustainable development, as impact assessment has become a crucial component of Corporate Social Responsibility (CSR), now essential in modern business practices (France Stratégie, 2023). The global ISO26000 standard defines CSR as the *“responsibility of an organisation for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour that: contributes to sustainable development, including health and the welfare; takes into account the expectations of stakeholders; is in compliance with applicable law and consistent with international norms and behaviour; and is integrated throughout the organisation and practised in its relationships”* (ISO26000). Thus, the growing interest in impact assessment is driven by stakeholders' expectations for greater transparency regarding CSR and the economic, social, and environmental consequences of business activities (France Stratégie, 2023). Kanpdal et al. (2024) assert that CSR is intimately connected with environmental, social and governance (ESG) impacts and their reporting. While CSR has roots in philanthropic efforts, encompassing a wide range of ethical practices from workforce issues to environmental concerns, ESG, with measurable quantitative indicators, provides a data-driven method for evaluating a company's performance in these domains and represents a move towards greater transparency for CSR (Kanpdal et al., 2024). De Souza Barbosa et al. (2022) found that following ESG reporting can improve a company's reputation, competitiveness, sustainability practices, and diversity. Furthermore, Karwowski & Raulinajtys-Grzybek (2021) noted that implementing CSR initiatives helps reduce ESG-related risks. Thus, the instrumental use of CSR and ESG impacts intertwined has evolved into a strategic approach that interacts with other business strategies, aiming for long-term sustainability and addressing the legitimate needs of various stakeholders (Rodriguez-Gomez et al., 2020).

In response to the growing need for understanding ESG impacts, new corporate reporting regulations have emerged. On a global scale, various frameworks have been developed to address ESG reporting (Bertels & Dobson, 2020). The Integrated Reporting (IR) framework establishes guiding principles and elements governing the content of integrated reports for environmental, social and governance impacts (Bertels & Dobson, 2020). Similarly, the Sustainable Accounting Standards Board (SASB) has developed standards to help publicly listed companies disclose material and decision-useful sustainability information to shareholders and potential investors (Bertels & Dobson, 2020). Concurrently, in February 2012, the South African Code for Responsible Investing (CRISA) was established to familiarise the investor community with ESG issues and emphasise their importance (Chininga et al., 2023). In Europe, the European Union Directive (2014/95/EU) mandated large European entities to produce non-financial reports from 2017. Christensen et al. (2021) argue that such reporting plays a crucial role in influencing corporate behaviour, especially through mandatory reporting as it is more likely to result in real changes than voluntary disclosures by pushing companies to expand and refine their CSR activities. The authors cite for instance societal or stakeholder pressures and peer benchmarking as key drivers for these changes Christensen et al. (2021).

However, current impact reporting faces significant criticism. Arvidsson & Dumay (2021) find ESG information valuable but ambiguous and non-comparable. This issue is further complicated by the large array of voluntary reporting frameworks and guidelines that fragment the practice, often reducing it to a marketing tool according to Rodriguez-Gomez et al. (2020). One of the primary challenges in improving ESG impact reporting lies in defining when an impact can be considered sustainable (Lucarelli et al., 2020). Lucarelli et al. (2020) discuss the EU's efforts to create a classification system to assess a company's environmental sustainability. Introduced in March 2020, the EU Taxonomy aims to evaluate the environmental sustainability of various economic activities. However, this poses a major challenge as it requires extensive ESG-related disclosures from companies and financial market participants (Och, 2020). Adding to this complexity, Berg et al. (2022) highlight significant disparities in how companies' ESG performances are rated, leading to uncertainty about setting clear ESG targets.

Och (2020) suggests that establishing clear definitions and thresholds for environmental, social, and governance aspects of sustainability is crucial for achieving clarity and comparability. Crona et al. (2021) defend this point of view and argue that current frameworks often fail to recognise that companies may exacerbate the very physical risks they are trying to manage, thus contributing to systemic failure. The authors contend that the current approach, based on financial materiality, aligns closely with investor demands for financially-focused assessments but often overlooks complex externalities. Yi et al. (2022) further emphasise this challenge in sustainability reporting. According to these authors, users of sustainability reports often struggle to accurately assess an organisation's position regarding sustainable development, partly because critical issues may be overlooked and because the presented data often lacks context (Yi et al., 2022). Organisations tend to disclose or emphasise their more favourable attributes while downplaying negative ones (Yi et al., 2022). This lack of comprehensiveness is finally underscored by Haffar & Searcy (2018), who critique sustainability reports for not using context-based indicators in reporting ESG performance. Instead, companies rely on self-referential indicators, which ignore broader sustainability thresholds and fail to show how a company's sustainability efforts contribute to broader systemic sustainability (Haffar & Searcy, 2018). Li et al. (2022) note a growing interest in evaluating the absolute performance of operations, driven by shareholder and investor pressure, which involves comparing performance against predefined thresholds.

To address these gaps, various research initiatives advocate for a context-based approach to sustainability. The Embedding Project, for instance, aids companies in incorporating social and environmental considerations into their operational and decision-making processes (Bertels & Dobson, 2020). It helps companies move beyond "what could we do" to addressing "what do we need to do to effectively contribute to the resilience of the environmental, social, and economic systems in which we operate?" according to Bertels & Dobson (2020). Similarly, the UN Research Institute for Social Development has introduced Sustainable Development Performance Indicators (SDPI). These offer an alternative form of ESG reporting by adopting an inside-out perspective, focusing on a company's impacts on the external environment (Yi et al., 2022). This method goes beyond traditional ESG by contextualising these impacts and encouraging companies to set ambitious targets (Yi et al., 2022). Regarding current regulatory frameworks, aside from the Global Reporting Initiative (GRI) - which encourages companies to report on how they contribute to the improvement or deterioration of key socio-ecological issues - and the new Corporate Sustainability Reporting Directive (CSRD) in Europe, few frameworks promote the concept of contextual reporting (Bertels & Dobson, 2020). Finally, global initiatives like the Science-Based Targets initiative (SBTi) are promoting a context-based approach according to environmental limits. The SBTi defines science-based targets (SBTs) that help companies align with Earth's limits and global objectives for equitable human development. For instance, the SBTi is designed to align the company's emissions reduction objectives with climate science requirements for the global economy to reduce emissions by 50% by 2030 and reach net-zero before 2050 (SBTi, 2023). SBTs for nature have also been released as the first step towards comprehensive science-based targets that encompass all aspects of nature: biodiversity, climate, freshwater, land, and ocean (SBTi, 2023).

While the adoption of contextual reporting methods is still in its early stages, it appears crucial for elevating environmental and social impact assessment and ensuring precise impact assessment. However, the high complexity of socio-ecological systems is challenging, and the theories and methodologies underpinning these realities are intricate and have numerous limitations. As presented above, a key area of interest for contextualising impacts and, hence for this research, is the Science Based Targets initiative (SBTi) and its use of Planetary Boundaries, i.e., global environmental limits. Although this framework has become highly popular and has become a reference, it faces many criticisms. For instance, Bjørn et al. (2021) critically analysed the calculation of Science-Based Targets (SBTs). Bjørn et al. (2021) note that although over 500 companies have set SBTs, the methods used for setting these targets are not standardised across guidelines, which raises concerns that some methods may lead to overshooting temperature goals. Taking this critique further, Tilsted et al. (2023) argued that the allocation of science-based targets results in an unjust distribution of burdens. They contend that this approach maintains or even deepens global inequalities by preserving companies' existing share of global emissions going forward, regardless of their historical emissions, capacity to transition, or available resources (Tilsted et al., 2023). Thus, while SBTs represent an internationally adopted methodology for contextualising climate and environmental impacts, the framework appears to lack a social and justice perspective (Tilsted et al., 2023). Despite this limitation, the SBTi remains an interesting starting point for this research as it provides a foundation for exploring these issues and potential areas for improvement in impact assessment methodologies and research is ongoing in order to bridge its methodological gaps (Tilsted et al., 2023). For instance, to address the points of critique of the SBTi, the use of the concept of the Doughnut which adds social foundations to Planetary Boundaries can enable the activation of social resilience alongside environmental considerations. This approach potentially offers alternatives to the injustices present in the SBTi framework and refines this type of methodology for contextualising impacts.

To explore the contextualisation of impacts, this thesis will thus focus on socio-ecological systems from a macro perspective, using methodologies such as those employed by the SBTi, which are grounded in Planet Boundaries. Additionally, it will incorporate the considerations of the Doughnut concept. The subsequent sections will delve into the theories and concepts underpinning the idea of contextualising an impact. It should be noted that this thesis aims to operationalise the Doughnut theory within the framework of corporate impact assessment in the current economic context, thus adopting an anthropocentric perspective. Heide & Gerris (2024) point out that most familiar approaches to environmental sustainability boundaries focus on protecting nature to ensure human well-being, rather than as an end in itself, thereby applying an anthropocentric perspective. Consequently, while acknowledging the diversity of values of nature worldwide, this thesis will consider Earth System Science as a reference point.

1.2. Theories behind the contextualisation of impacts: Planet Boundaries

Earth System Science, as coined by Steffen et al. (2020), provides a crucial framework for comprehending Earth as a single, complex, adaptive system. The Earth System Science is an interdisciplinary approach that integrates traditional scientific fields to offer a comprehensive view of Earth's dynamics, emphasising the influence of life on the planet's chemical and physical processes (Steffen et al., 2020). Earth System Science is based on several transformative concepts (Steffen et al., 2020). A first concept is the Anthropocene, which delineates a new geological era characterised by human impact on the biosphere and climate (Steffen et al., 2020). This concept serves as a unifying framework, linking climate change, biodiversity loss, pollution, and social issues such as high consumption, growing inequalities, and urbanisation (Steffen et al., 2020). Another significant concept derived from Earth System Science is that of tipping elements. These encompass critical components of the Earth System, such as the Amazon rainforest, Boreal forests, and ice floes which exhibit nonlinear relationships and can undergo irreversible changes when certain thresholds are crossed (Steffen et al., 2020). Finally, the Planetary Boundaries framework, also emerging from Earth System Science, connects biophysical insights with policy and governance at the global level. This framework aims to guide the sustainable management of Earth's resources and has gained major interest over the past years (Steffen et al., 2020). Understanding the concept of planet boundaries is paramount for this research.

Rockström et al. introduces the concept of Planetary Boundaries in 2009, following the United Nations Climate Change Conference in Copenhagen in order to provide a new approach to climate change mitigation (Brand et al., 2021). Rockström et al. (2009) examines the transitions between the Holocene era — a period characterised by natural environmental changes where Earth's regulatory systems maintained conditions conducive to human development — and the Anthropocene era, marked by increased reliance on fossil fuels and industrial agriculture (Rockström et al., 2009). These changes create irreversible environmental shifts that are less supportive of human development, leading to the need for the delineation of *"the safe operating space for humanity"* based on the previous conditions of the Holocene (Rockström et al., 2009). Therefore, the Planetary Boundaries framework defines a Safe Operating Space for humanity within the planet's biophysical subsystems or processes (Rockström et al., 2009). Rockström et al. (2009) identifies nine boundaries and thresholds: climate change, biodiversity loss (terrestrial and marine), disruptions to nitrogen and phosphorus cycles, stratospheric ozone depletion, ocean acidification, global freshwater use, land use changes, chemical pollution, and atmospheric aerosol loading. In 2023, across the nine boundaries assessed, six are overshooting their limit (Richardson et al. 2023).

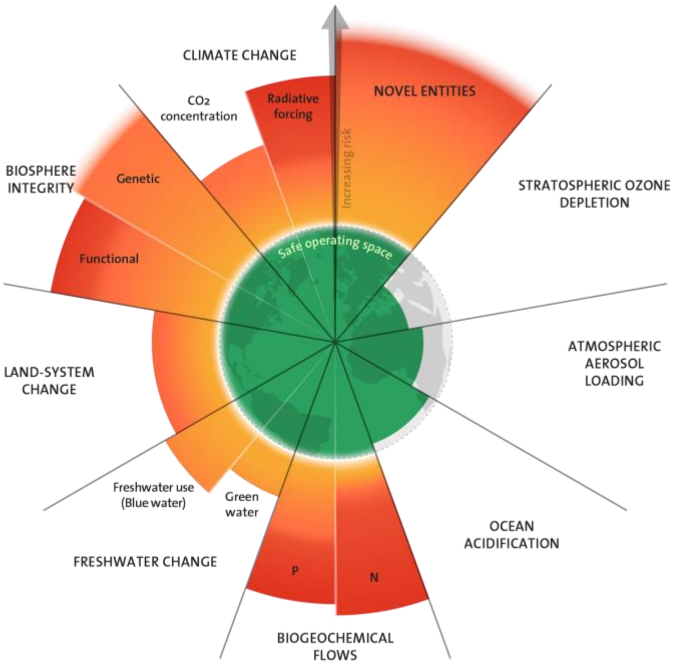


Figure 2: The 2023 update to the Planetary boundaries. Licensed under CC BY-NC-ND 3.0. Credit: "Azote for Stockholm Resilience Centre, based on analysis in Richardson et al. 2023"

More recently in 2023, particularly after the introduction of Raworth's Doughnut concept in 2012 - which is explored in the next section -, Rockström et al. (2023) revisits the concept of planetary boundaries. Their aim is to connect environmental limits with basic human needs, incorporating principles of justice and safety. They propose Earth System Boundaries, a framework designed to maintain the resilience and stability of the Earth system while minimising significant harm to humans from changes in this system. This updated concept includes a dimension of justice, acknowledging that the impacts of Earth system changes vary widely among different social groups and countries (Rockström et al., 2023). This idea that the Earth System and planetary limits cannot be considered in isolation from the complexities of human dynamics is advocated by Steffen et al. (2020). Their approach involves examining projections that span biophysical aspects like climate, while also incorporating insights from social sciences and humanities in order to gain a more comprehensive view of potential futures (Steffen et al., 2020).

Consequently, the focus shifted from solely considering a safe operating space to encompassing a just space as well. This evolution is crucial for integrating considerations of Earth system resilience with human well-being (Rockström et al., 2023). Raworth's Doughnut model and the theories underpinning it endorse this perspective as early as 2012. This thesis now examines the contribution of the Doughnut Model and its advocacy for social foundations in detail, exploring how they contribute to a more holistic understanding of impact contextualisation that encompasses both environmental and social dimensions.

1.3. Theories behind the contextualisation of impacts: Social foundations

Steffen et al. (2020) posit that the Sustainable Development Goals represent a significant evolution in sustainability thinking, integrating human development and equity within a broader Earth System context. For Willberg et al. (2024), the Doughnut largely influenced the creation of the Sustainable Development Goals. This alignment underscores the Doughnut's compatibility with existing global sustainability frameworks, enhancing its potential for widespread adoption and implementation (Willberg et al., 2024). Doughnut Economics is a framework introduced by Kate Raworth in 2012, which offers a potential compass for addressing current global challenges (Sahan et al., 2021). The Doughnut Theory consists of two concentric rings: an inner social foundation and an outer ecological ceiling. This structure visually represents the interdependence between human well-being and planetary health, emphasising that societal progress must occur within Earth's ecological limits (Sahan et al., 2021). Hence, between these boundaries lies a space that is both ecologically safe and socially just, embodying the ultimate goal of sustainable development (Sahan et al., 2021).

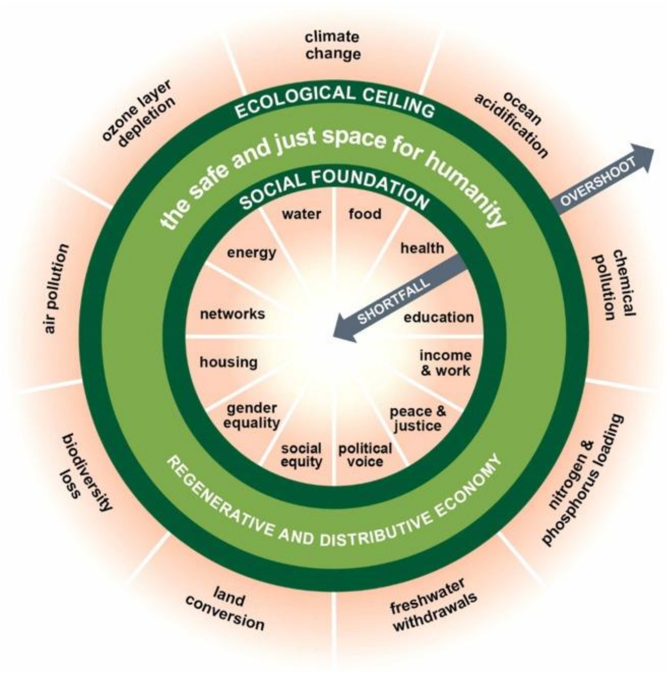


Figure 3: The Doughnut of social and planetary boundaries (Doughnut Economics Action Lab Website, 2024)

Building on this concept, Doughnut Economics advocates for a paradigm shift from the pursuit of endless GDP growth to a more balanced, thriving state (Raworth, 2012). While this idea of balance is not novel and has existed in various cultures for millennia, Raworth (2021) argues that Western societies need to develop new conceptual frameworks to articulate a vision of sustainability that resonates with contemporary challenges. To achieve this balance, the Doughnut promotes two key principles: regenerative and distributive economics (Raworth, 2012). The regenerative aspect calls for an urgent transition to an economy that works within the cycles of the living world, while the distributive aspect aims to address inequality and marginalisation by sharing value and opportunity more equitably (Sahan et al., 2021). These principles directly address the dual challenges of environmental degradation and social inequality, demonstrating the interconnected nature of these issues (Sahan et al., 2021). This perspective aligns with the Decent Living Standard theory proposed by Rao and Min (2017), which emphasises the necessity of providing a "basic minimum" set of goods and capabilities to all individuals to ensure justice within society. This approach advocates for the universal provision of essential resources required for well-being and active participation in society, translating into rights to a decent standard of living. Such a standard encompasses both material and social aspects fundamental to human dignity.

Additionally, the Doughnut concept's approach aligns with the notion of socio-ecological systems, as explained by Leach et al. (2018). This perspective views society and ecosystems as inseparable, co-evolving entities, shifting the sustainability discourse from a static standpoint to one that recognises the dynamic nature of these systems (Leach et al., 2018). Therefore, the Doughnut model identifies two thresholds, environmental and social, that can serve as an impactful basis for reflecting on how to provide context to environmental and social impacts.

In 2016, Häyhä et al. (2016) already note that there is a growing demand to translate the Planetary Boundaries and the Doughnut from a global scale to more localised contexts, including the company level, reflecting a recognition of the need for actionable sustainability frameworks. However, this translation process is challenging due to the complex interplay between different scales and systems (Häyhä et al., 2016). This challenge underscores the need for innovative methodologies that can bridge global concepts with local realities (Häyhä et al., 2016). As the thesis moves forward to review various methodologies for operationalising the Doughnut at a local scale, it explores how these approaches can provide a contextualisation for impacts. This exploration is crucial in developing practical methodology for impact assessment to implement the Doughnut's principles effectively, potentially revolutionising how we approach sustainable development at various scales.

2. Methodologies and their limits: Downscaling the Planet Boundaries and the Doughnut

The aim of this section is to present the methodologies that can be used to apply the Doughnut to local scales, i.e. ‘to downscale’. For planetary limits, the Absolute Environmental Sustainability Assessment already provides a solid research base for the use of these limits at lower scales, but it does have ethical limits for which solutions will also be developed here. This is less the case for social foundations, where no direct quantitative framework exists.

2.1. Methodologies for downscaling Planet Boundaries: Absolute Environmental Sustainability Assessment

Beyond the theoretical framework, various methodologies and practical approaches have been developed to evaluate countries, sectors, products, or cities within the context of Planetary Boundaries (Bai et al., 2024). These boundaries play a crucial role in contextualising environmental impacts, although they were initially designed to monitor and assess the global environmental state rather than for application at smaller, regional levels, as noted by Haljsted et al. (2021). Häyhä et al. (2016) notes that there is a growing demand to translate planetary boundaries from their global-scale perspective to support sustainability decision-making at more localised levels. Recognising the limitations of relative sustainability assessments that merely compare products, nations, or sectors between them, efforts have been made to foster the importance of understanding absolute sustainability (Haljsted et al., 2020). The academic community thus developed various sustainability assessment concepts that consider biophysical or other limits, collectively known as Absolute Environmental Sustainable Assessment (AESA) concepts and frameworks (Li et al., 2021).

AESA provides a framework for evaluating human impacts against regional or global environmental thresholds (Bjørn et al., 2015). This approach examines the production or consumption activities of various entities, including nations, companies, and individuals, to determine whether their environmental pressures fall within sustainable limits (Bjørn et al., 2015). Absolute sustainability, according to AESA, requires entities to remain within their allowable limits within the Safe Operating Space, as determined by quantifiable environmental load limits such as Planetary Boundaries (Haljsted et al., 2020). Central to AESA is the concept of carrying capacity, defined by Bjørn et al. (2020) as *"the maximum persistent impact that the environment can sustain without suffering perceived unacceptable impairment of the functional integrity of its natural systems or, in the case of non-renewable resource use, that corresponds to the rate at which renewable substitutes can be developed"*. This definition underscores the dynamic relationship between human activities and environmental resilience (Bjørn et al., 2020).

In recent years, AESA has gained prominence within the scientific community, with increasing focus on developing absolute impact indicators or establishing connections with absolute benchmarks, as noted by Katzer et al. (2024). In their 2020 study, Bjørn et al. (2020) conducted the first systematic review of AESA methods and their applications, identifying 45 relevant studies globally, written in English in the form of peer-reviewed academic articles, conference proceedings and reports. The 31 case studies they examined span a wide variety of anthropogenic systems, from specific products and companies to the total consumption of nations. For Bjørn et al. (2020), this breadth of application demonstrates the versatility and potential of AESA in addressing sustainability challenges across different scales. Bjørn et al. (2020) thus proposed a framework aiming to provide practitioners with recommendations for selecting and using existing AESA methods, as well as guidance on conducting assessments and communicating results to decision-makers. This review showed that environmental impacts are excessively high in most examined production and consumption activities, indicating that improvements in eco-efficiency have been insufficient to decouple environmental impacts from economic growth (Bjørn et al., 2020).

Most case studies can be characterised as proofs of concept, though some were commissioned by government entities, such as the Dutch or European environment agencies (Bjørn et al., 2020). For instance, Sala et al. (2020) used an AESA approach to evaluate EU consumption, which occupies a significant share of the globally available safe operating space. Sala et al. (2020) evaluates the environmental impacts of the European Union's production and consumption in 2010 using various indicators, comparing these impacts to planetary boundaries from both production and consumption perspectives. Their findings reveal that despite comprising less than 10% of the world’s population, the EU is nearing the point of surpassing global ecological thresholds studied. At the state level, Cole et al. (2014) use a bottom-up stakeholder-engagement approach to determine national-level indicators and boundaries, presenting a national barometer for sustainable development in South Africa. Cole et al. (2014) employ a decision-based methodology to systematically assess environmental and social dimensions, indicators, and boundaries in a consistent and repeatable manner. This bottom-up approach is designed to select the most appropriate criteria for capturing the primary environmental and social concerns in

South Africa (Cole et al., 2014) . Data is sourced from national databases and reports, international databases, and academic literature (Cole et al., 2014). Additionally, expert judgement is obtained through semi-structured interviews with South African experts from various sectors, including national, provincial, and metropolitan government, national research institutes, universities, and international non-governmental organisations (Cole et al., 2014). The study's findings reveal that South Africa exceeds its environmental boundaries in areas such as biodiversity loss, marine harvesting, freshwater use, and climate change, while social deprivation was most pronounced in safety, income, and employment (Cole et al., 2014). At the sectoral level, Chandrakumar et al. (2018) build on previous research to propose an AESA framework for adopting both consumption and production-based accounting to benchmark the climate impacts of the New Zealand agri-food sector against the share of the 2°C carbon budget. At the company level, Wolff et al. (2017) adapted the AESA methodology to assess the compatibility of a company's business practices and its value chain with biodiversity conservation. The study focused on a mass-market retailer, specifically examining the environmental pressures exerted by its food portfolio during the agricultural production phase, over the period from November 2015 to October 2016 (Wolff et al., 2017). The findings highlight that several of these pressures are driving biodiversity loss and are unsustainable, revealing that the pressures associated with the retailer's "average annual food basket" significantly exceeded the sustainable limits of the carrying capacity allocated to food consumption (Wolff et al., 2017). Furthermore, the study identified that a small number of product categories disproportionately contribute to the overall ecological impact (Wolff et al., 2017). For Wolff et al. (2017), these results have important implications for corporate strategies, especially mass-market retailers and their food supply chains, and they also open up new research avenues to further operationalise this assessment approach.

Facing the plurality of methodologies existing in AESA, Bjørn et al. (2020) and Bai et al. (2024) outlined methodological framework to AESA and downscaling Planet Boundaries. Bjørn et al. (2019) proposed five steps for AESA involving defining the activity to be assessed, establishing environmental sustainability objectives such as Planetary Boundaries, translating these objectives into quantified environmental carrying capacities, collecting data, and benchmarking against established targets. In

2024, Bai et al. introduced a structured framework consisting of two stages: transcription and allocation. Transcription involves connecting global environmental thresholds to specific local environmental pressure indicators for precise monitoring and management. The allocation or sharing principle step entails scaling and adjustment to ensure equitable distribution of Earth system budgets across different scales, reflecting local contexts. Bai et al. (2024) analysed 40 research papers and while his recent research illustrates the ongoing efforts to make global sustainability concepts applicable and actionable at more localised scales, the diversity of approaches also highlights the complexity of translating global boundaries to local contexts. Bai et al. (2024) caution against the risk of individual actors cherry-picking methods in translation and subsequent target setting, given the numerous existing sharing principles. The sharing principle is indeed central to using AESA.

The sharing principle represents a ratio that allocates a global quantity of the acceptable carrying capacity to a lower scale, such as an individual, company, or territory (Gondran et al., 2023). This involves identifying socio-economic variables available at both global and local scales that are correlated with the environmental variable under study (Gondran et al., 2023). The choice of this principle can be evaluated from both technical and ethical perspectives (Gondran et al., 2023). Hjalsted et al. (2020) stress the importance of the allocation principle as it serves as the normative foundation for distributing a resource to be shared in the Safe Operating Space. Therefore, it is crucial to thoroughly understand and carefully select these principles. For example, Häyhä et al. (2016) reviewed various principles for sharing the planetary safe operating space, such as Equality (equal rights to ecological space using per capita for instance), Right to Development (a right to an exemption from obligations to countries in development), Sovereignty (allocation proportional to present emissions *i.e* “grandfathering”), Ability to Pay (the greater the capacity to act or pay, the greater is the share in the mitigation/economic burden). Today, equal per capita, grandfathering and final consumption expenditure - representing the demand for a sector or activity - are most commonly used sharing principles according to Hjalsted et al. (2021).

Table 2: Main allocation factors used in AESA according to Hjalsted (2021) and Häyhä et al. (2016)

Allocation Factor	Description	Assumption
Equality	Equal rights to ecological space	All individuals globally have equal rights to access and use ecological space. Allocation is done on a per capita basis, meaning each person receives an equal share of the ecological resources or capacity, regardless of their country of origin.
Right to Development	Right to exemption from obligations for countries in development	Principle that developing countries should be allowed to develop economically and socially without being unduly constrained by environmental restrictions.
Sovereignty	Allocation proportional to present emissions ("grandfathering")	Based on current or historical emissions levels. Sectors that have higher current emissions are allocated more ecological space, essentially allowing those who have used more in the past to continue using a larger share. This method is often criticised for perpetuating historical inequalities.
Ability to Pay	Greater capacity to act or pay results in a lower share of carrying capacity	Allocating a larger share of the carrying capacity to low GDP countries than to high GDP countries, thus favouring poorer and less developed nations.
Final Consumption Expenditure	Allocation based on the final consumption spending of households and entities	Reflects the actual demand and consumption levels by taking into account the spending patterns of households and institutions

The downscaling process of planet boundaries is thus challenging. Li et al. (2021) suggest that studies aiming to operationalise planetary boundaries should focus on identifying context-specific local thresholds that are most relevant to the particular circumstances of the area in question. For Häyhä et al. (2016), the need to manage diverse understandings of scale and interdependence across biophysical and social systems embodied by the sharing principle is highly complex. In fact, Heide & Gjerris (2024) criticise this current use of allocation factors. They argue that most used sharing principles (grandfathering and final consumption expenditure) do not align with the purpose of AESA, as they do not take into account the importance of meeting human basic needs within planetary limits. Heide & Gjerris (2024) call for the integration of the social foundation and environmental ceiling of the Doughnut Economics concept into AESA. Drees et al. (2021) also acknowledge that the Doughnut is a relevant avenue, viewing it as *"a promising step in promoting the importance of social dimensions within the PB discourse."* Hence, rethinking AESA methods to integrate the Doughnut model seem paramount although it poses challenges, as social indicators are complex to measure, and the integration of socio-ecological interactions is complicated (Huysentruyt et al., 2022). Nevertheless, there is a growing interest in integrating social and justice aspects to Planetary Boundaries as shown through the evaluation of Earth System Boundaries by Rockström et al. in 2023. Ferreto et al. (2022) argue that the Doughnut model highlights the necessity of simultaneously integrating social and environmental priorities and represents an opportunity to advance the currently limited research on their interaction. Recent research on this matter provides new insights to better understand the links between these two boundaries.

2.2. Methodologies to link just socio-ecological thresholds

For Drees et al. (2021), the interplay between environmental and social boundaries prompts the question of whether societal well-being and environmental stewardship are conflicting objectives. Capmouteres et al. (2019) also highlight that this interaction suggests a contradictory relationship: exceeding planetary limits can compromise social needs, while individuals lacking basic social provisions may resort to environmentally unsustainable practices. Feretto et al. (2022) and Willberg et al. (2024) explore the intricate interplay between Planetary Boundaries and the Social Foundation, highlighting how environmental pressures and poverty can exacerbate each other. They emphasise that poorly devised environmental policies can inadvertently worsen poverty, underscoring the necessity of maintaining both a Safe and Just operating space for humanity. Therefore, the complex interactions between environmental and societal factors demand attention in both theoretical discourse and practical implementation (Capmouteres et al., 2019).

Recent advancements in statistical models have facilitated the exploration of the links between planetary boundaries and the social foundation, demonstrating the effective utilisation of the Doughnut framework in sustainability assessments (Capmourteres et al., 2019). For example, biophysical and ecosystem service limits can be used as a first step to bridge the gap between the global and local scales (Feretto et al., 2022). Häyhä et al. (2016) also offered a framework for downscaling planetary boundary processes to the scales needed for implementation but that differs from AESA. In translating planetary boundaries into national-level targets, three dimensions should be considered explicitly: biophysical, socio-economic, and ethical (Häyhä et al., 2016). The biophysical dimension deals with the geographical scales of planetary boundary processes and their interactions (Häyhä et al., 2016). The socio-economic dimension addresses the sub-global links created by production and consumption patterns and through international trade (Häyhä et al., 2016). The ethical dimension addresses equity in sharing the global safe operating space and recognising the differences between countries' rights, abilities, and responsibilities (Häyhä et al., 2016).

A way to work on the biophysical and ethical dimensions and work towards socio-ecological thresholds is, for example, through the notion of ecosystem services. For instance, Aleissa et al. (2023) extended the framework of planetary boundaries to include social sustainability by setting a lower limit that must be surpassed to meet basic demands and avoid critical human deprivation. According to Aleissa et al. (2023), this framework represents the ecological ceiling and social foundation in a common unit for various ecosystem goods and services using biophysical models. Similarly, Feretto et al. (2022) consider the definition of ecosystem services crucial in downscaling planet boundaries. Ecosystem services, defined as "the benefits provided by ecosystems that contribute to making human life both possible and worth living" (IPBES), underpin the Safe and Just Operating Space defined by the Doughnut. According to Feretto et al. (2022), both ecosystem services and the Doughnut concept are based on the consideration that economic and social assets are embodied in natural assets, and hence depend on them. The Doughnut represents a balance between social well-being and environmental constraints, achievable by maintaining the ecosystem services provided by nature and ensuring that everyone benefits from them (Feretto et al., 2022). Furthermore, Gupta et al. (2022) adds to this reflection the notion of justice by stating that methodologies to apply the Doughnut must ensure a minimum level of nature’s contributions to people to achieve social foundations is necessary and requires maintaining ecosystem functions on human-dominated lands, freshwater, and marine systems. Guided by the Sustainable Development Goals and international human rights principles, Gupta et al. (2022) posit that everyone should have at least minimum access to food, energy, water, housing and transport necessary for a dignified life or to escape poverty. However, Gupta et al. (2022) also stress that ensuring such minimum access adds significant pressure on the environment unless issues of sharing the remaining resources, risks/harm, and responsibilities are addressed through sustainability practices combined with structural and systemic transformations.

In practice, the choice of the sharing principle can help in finding socio-ecological thresholds. Heide et al. (2023) regret the traditional disconnect between the social foundation and the environmental ceiling within the concept of the doughnut economy in AESA and the choice of the allocation factor. Furthermore, Ryberg et al. (2020) critique the lack of harmonisation in the selection and application of sharing principles in AESA, noting the absence of comprehensive discussions on the normative values and ethics guiding these choices. For instance and as seen previously in this thesis, within the Science-Based Targets initiative framework, Tilsted et al. (2023) explain that all target-setting methods rely on grandfathering which results in an unjust distribution of GHG emissions and maintains or deepens global inequalities. Nonetheless, there are alternative allocation principles that better align with notions of fairness and distributive justice and could be implemented instead (Tilsted et al., 2023).

Recent academic efforts, such as those by Heide & Gjerris (2024), advance methods to implement distributive justice through sufficientarianism. They highlight strategies such as the Fulfilment of Human Needs principle and a bottom-up approach based on Decent Living Standards. Sufficientarian policies are defined as measures and daily practices aimed at reducing the demand for energy, materials, land, and water while ensuring human well-being remains within the planet's ecological limits (Heide & Gjerris, 2024). Sufficientarianism and Decent Living Standard has already been used in various studies. Millward-Hopkins & Oswald (2023) explore models for estimating the minimum energy requirements for providing decent material living standards essential for human well-being in order to achieve a climate-safe, low energy demand future, and universal decent living simultaneously, given the current global inequalities in energy consumption and technological access. They find that global final energy consumption in 2050 could be reduced to the levels of the 1960s, despite a population growth thanks to technological innovation and radical consumption changes (Millward-Hopkins & Oswald, 2023). Francart et al. (2023) propose an approach for sectoral allocation based on sufficientarianism and “decent living” scenarios for the building sector in Denmark linked to housing rights using Millward-Hopkins & Oswald’s research (2023). They found that the housing sector in Denmark should account for 18.8% of the climate change carrying capacity and concluded that ethical allocation based on sufficientarianism and decent living standard should be promoted rather than conserving existing unsustainable paradigms (Francart et al., 2023). Moreover, Willberg et al. (2024) use Doughnut Economics to develop a conceptual framework for accessibility and mobility that incorporates concerns with both social equity and planetary boundaries to achieve decent transport accessibility, essential for reaching activities such as employment, health services, and grocery shops, and study the environmental cost required for certain levels of accessibility. In 2019, the EAT–Lancet Commission developed global scientific targets for achieving human health without exceeding planetary boundaries for Earth system processes (Tulloch et al., 2023). The Commission’s report widely influenced methods, results, or discourse cross-disciplinary research and debate across life sciences, health and medical sciences, and social sciences (Tulloch et al., 2023).

Therefore, these scientific papers show that sufficientarianism and decent living standard are applicable in the context of operationalising the Doughnut to address both the challenge of finding a more ethical allocation principle and successfully connecting environmental and social thresholds. These considerations can also feed the methodologies of the last part of the Doughnut which comprises socio-economic dimensions. Sufficientarianism and Decent Living Standard provide a foundation to better apprehend in practice these indicators.

2.3. Methodologies for socio-economic foundations

Addressing the social dimension presents a significant challenge due to the lack of standardised methodologies and the complexity of linking social and environmental dimensions in practice. Huysentruyt et al. (2022) emphasise the difficulty of establishing a clear framework or consensus on socio-economic indicators and targets. They point out that socio-economic impacts are often poorly understood and defined, resulting in inconsistencies in how companies' social impacts and dependencies are assessed within ESG frameworks. Feretto et al. (2022) also highlight the lack of emphasis on the social aspects within the doughnut model and the absence of a standardised framework for applying the Safe and Just Operating Space.

One perspective for understanding the assessment of socio-economic impacts and their thresholds is through the concept of social and human capital (Baue, 2020). Baue (2020) likens social and human capital to natural capital, where carrying capacity refers to the resources available. However, while environmental thresholds are designed not to be exceeded, benchmarks for social and human capital (also referred to as anthropogenic capital) are set to avoid falling below certain levels (McElroy, 2008). Obligations linked to natural capital involve limiting consumption and production, whereas those related to anthropogenic capital focus on the provision and maintenance of basic needs. This distinction means that in the social domain, norms are defined by the requirements necessary to sustain the beneficial flows of goods and services from anthropogenic capital, ensuring basic human well-being for a defined population (McElroy, 2008). According to the Social and Human Capital Coalitions (2019), social and human capital include networks, shared norms, values, and understandings. Human capital, in particular, refers to an individual’s knowledge, skills, competencies, and attributes. These resources are essential for strengthening societal cohesion, resilience, and business success (Social and Human Capital Coalitions, 2019). Social cohesion is defined as a societal state that seeks to enhance the well-being of all its members, combat exclusion and marginalisation, foster a sense of belonging, build trust, and create opportunities for upward mobility (Social and Human Capital Coalitions, 2019).

Another perspective is to employ the methodologies mentioned earlier to link environmental and social dimensions. This involves the ideas of sufficientarianism and the Decent Living Standard as proposed by Rao & Min (2017). These concepts, typically applied to define environmental thresholds, can also be used to establish social thresholds. Vélez-Henao & Pauliuk (2023) suggest that the Decent Living Standard defines essential services that are preconditions for human well-being, irrespective of sociocultural factors. This framework provides a straightforward, bottom-up approach to understanding the trade-offs between poverty and climate change, while also offering a globally recognised framework to estimate the energy and materials required to achieve the Sustainable Development Goals (SDGs), including the eradication of poverty (SDG 1), zero hunger (SDG 2), good health and well-being (SDG 3), quality education (SDG 4), and reduced inequalities (SDG 10) (Vélez-Henao & Pauliuk, 2023). Thus, the Decent Living Standard offers a clear approach to considering diverse forms of capital.

This aligns with stakeholder theory, which posits that businesses and their activities impact both external stakeholders—such as communities, broader society, and environmental concerns—and internal stakeholders, primarily the company's own workforce (Macassa et al., 2020). For internal stakeholders, various social indicators should be considered, including respect for human and workers' rights, worker safety, fair and equal livelihoods with appropriate benefits, and job creation (Social and Human Capital Coalitions, 2019). Companies also bear responsibilities in areas such as the rights of indigenous peoples, the preservation of cultural heritage, and local land rights. Additionally, fair taxation and legal spending of local taxes are crucial. These factors contribute to social cohesion, influence inequality levels, support sustainable development, and enhance consumer purchasing power and economic demand (Social and Human Capital Coalitions, 2019). Providing fair wages, decent jobs with suitable benefits, preventing discrimination, and reducing the wage gap between the lowest and highest earners are essential for ensuring decent livelihoods for workers and their families. Education on health and safety, skills development, and contributions to communities are equally important (Social and Human Capital Coalitions, 2019). Regarding external stakeholders, food security can be considered as the major societal stake for the agriculture sector to address.

Therefore, this section has presented various impact assessment methodologies, demonstrating how the Doughnut model can be operationalised in practice on a case-by-case basis. Sufficientarianism, at this stage of reflection, emerges as a key concept to integrate into the case study. The agricultural sector is particularly relevant for this study because it directly addresses a basic human need: access to food, which has been the subject of numerous academic studies. This is especially pertinent in South Africa, where millions of households face food insecurity. This case provides a practical lens through which to examine the application of sufficientarian principles and assess their effectiveness in addressing both sustainability and social equity in the contextualisation of impacts. The final part of this literature review will explore insights into the agricultural sector's relevance to the Doughnut model, with particular emphasis on its manifestation in South Africa.

3. Application of the Doughnut and linkage to the agriculture sector in South Africa

This section aims to focus on the chosen case study to first better understand the relationship between the agricultural sector and the Doughnut model. It then presents the environmental considerations related to the agricultural sector in South Africa, followed by the economic considerations.

3.1. The agriculture sector and the Doughnut: general considerations

This section presents the key insights to consider regarding the agricultural sector and its interactions within the Doughnut framework, first by reviewing the sector's impact on environmental boundaries and then by addressing the socio-ecological considerations of the agricultural sector.

3.1.1. Environmental limits of the agriculture sector

The ability of agriculture to reliably supply food and other essential resources to an expanding global population is vital for human survival and related activities. According to Velten et al. (2015), agriculture faces several significant threats, including climate change, biodiversity loss, land degradation, water depletion and pollution, rising production costs, and the decline of rural communities and farms. These challenges undermine agriculture's capacity to fulfil human needs and are intensified by current agricultural practices (Velten et al., 2015).

The idea of sustainable agriculture has emerged as a potential remedy to these issues. Since its introduction in the Brundtland Report of 1987, it has been acknowledged as an integral part of sustainable development. Nevertheless, Velten et al. (2015) contend that the concept of sustainable agriculture is laden with ambiguity, resulting in varied interpretations and methods. This variability underscores the complexity and contentious nature of defining sustainable agriculture, making a single, universal definition impractical due to the need for context-specific adaptations (Velten et al., 2015).

Additionally, Campbell et al. (2017) highlight that agriculture not only poses substantial risks to planetary boundaries but also plays a critical role in strategies aimed at mitigating environmental degradation. They argue that significant transformations throughout the entire food system, including production practices, landscape management, and food consumption, are essential to reduce agriculture's impact on planetary boundaries (Campbell et al., 2017). This comprehensive approach emphasises the interconnectedness of all food system activities, from farming to retail, and their collective effect on environmental sustainability (Campbell et al., 2017).

Given the considerable environmental impact of the agricultural sector, researchers have examined its effects on planetary boundaries. Campbell et al. (2017) investigated this impact and found that agriculture significantly pressures multiple planetary boundaries, extensively altering Earth's systems. For instance, Campbell et al. (2017) noted that agricultural activities greatly influence land-system change, with croplands and pastures occupying approximately 40% of the global land surface. This extensive land use has led to widespread deforestation, particularly in tropical regions, with agriculture being responsible for about 80% of global deforestation. Campbell et al. (2017) also documented the major impact of agriculture on freshwater resources, accounting for the majority of global freshwater withdrawals—around 70% of withdrawals and 84% of human blue water consumption. Additionally, agricultural practices have significantly altered biogeochemical flows, especially nitrogen and phosphorus cycles (Campbell et al., 2017). The sector is responsible for approximately 85% of global anthropogenic nitrogen use, primarily through fertiliser application (Campbell et al., 2017). Similarly, Campbell et al. (2017) reported that over 90% of mined phosphorus is utilised for agricultural fertilisers, accelerating the global phosphorus cycle. The integrity of the biosphere is profoundly affected by agriculture, mainly through land-use change and habitat destruction, leading to significant biodiversity loss and disrupted ecosystem functions (Campbell et al., 2017). They estimated that agriculture is responsible for about 80% of the impact on this boundary. Additionally, Campbell et al. (2017) assessed that agriculture exerts a considerable influence on climate change. When considering the entire food system and agriculturally driven land use change, agriculture contributes approximately 25% of total greenhouse gas emissions, including those from deforestation, livestock production, and various farming practices. They also noted that ocean acidification is indirectly influenced by agriculture through CO2 emissions and nutrient runoff from fertilisers. Although agriculture is not the primary driver, Campbell et al. (2017) estimated its contribution to this boundary's impact to be about 25%. Campbell et al. (2017) found that agriculture's contribution to stratospheric ozone depletion is currently minor, estimated at around 5%, but is expected to grow in the future due to increasing N2O emissions from fertiliser use. They also documented that atmospheric aerosol loading is affected by agriculture through practices like crop residue burning and ammonia emissions from fertilisers, contributing 14-15% of the total impact on this boundary. Regarding novel entities, Campbell et al. (2017) identified agriculture as a significant source of chemical pollution, particularly from pesticide use, although quantifying this impact globally remains challenging. The potential effects of genetically modified organisms in agriculture on this boundary continue to be a subject of ongoing debate, according to Campbell et al. (2017).

The substantial impact of agriculture on planetary boundaries prompts further research aimed at understanding these effects at local scales. Various studies analysed the agricultural sector and planet boundaries through different scales and case studies. Gerten et al. (2020) found that if Planetary Boundaries were maintained without a concurrent shift towards more sustainable production and consumption, current agricultural practices could support only 3.4 billion people. Moreover, up to 48.6% of food is currently produced under conditions that violate planetary boundaries (Gerten et al., 2020). Xian et al. (2023) examined Chinese agriculture to develop an Agricultural Environmental Footprint Index that incorporates various footprint indicators—such as land, water, carbon, nitrogen, and phosphorus footprints—within the framework of planetary boundary theory. Their study highlighted the spatial variations in the environmental impacts of agriculture across China. Similarly, Schulte-Uebbing et al. (2022) downscaled the planetary nitrogen pollution boundary to a regional scale, revealing both the overuse and potential for intensification of agricultural nitrogen, thereby illustrating the disparities between different regions of the world.

3.1.2. Socio-ecological Considerations for the Agriculture Sector

From a social standpoint, the agriculture sector plays a crucial role in ensuring food security. Food security, as defined by the World Bank, involves all individuals having reliable physical and economic access to adequate, safe, and nutritious food that meets their dietary needs and preferences, promoting an active and healthy life. The FAO describes the minimum dietary energy requirement as the threshold caloric intake necessary to sustain a minimum acceptable weight for height. This measure is used to determine the prevalence of undernourishment within a population; individuals whose caloric intake is consistently below this threshold are considered undernourished (Roser et al., 2024). The minimum daily dietary energy per person to maintain health is approximately 1,800 kcal per day per capita, while a sufficient food supply is around 2,500 kcal per capita per day (Vermeulen et al., 2019).

From the perspective of justice, distributive justice in food systems pertains to the equitable distribution of resources, burdens, services, and non-material aspects of life (DeBruin et al., 2023). In food systems, this includes the fair distribution of food security, environmental impacts, and labour-related injustices such as worker exploitation. Distributive food justice acknowledges that certain natural factors, like soil types and water body locations, are unevenly distributed geographically. Since these are not influenced by human actions, they do not typically constitute issues of justice. This concept frames food as a universal human right, tailored to local food cultures to meet dietary needs and preferences for a healthy, active life (DeBruin et al., 2023). Other distributive concerns include food affordability, viable livelihoods for food producers, good working conditions, health and wellbeing, environmental impacts of food production, availability of natural resources for food production, and the capacity to engage in sustainable transitions (DeBruin et al., 2023).

From a socio-ecological perspective, addressing food security involves considering the minimal environmental pressures necessary to meet these needs. Research by Rammlet et al. (2022) assessed the impacts of ensuring minimum food access on critical Earth systems. Aleissa & Bakshi (2023) investigated the environmental limits of meeting food needs without surpassing the ecosystem capacities of nations to provide goods and services, examining whether 178 countries can sustainably meet their needs.

In summary, tackling the complex challenges facing agriculture requires understanding its environmental and social impacts. Sustainable agriculture seeks to balance the necessity of food security with the need to protect planetary boundaries while ensuring social justice throughout the value chain. This thesis aims to use the concept of ecosystem services to link environmental and social issues initially, before focusing more closely on the socio-economic aspects of the agricultural sector. South Africa has been chosen as the study area.

3.2. South Africa and its agriculture sector: socio-economic considerations

According to the OECD (2022), South Africa boasts the most industrialised and diversified economy in Africa, ranking second on the continent after Nigeria in terms of economic size. South Africa has the highest GDP per capita on the continent and is considered an upper-middle-income country (OECD, 2022).

However, persistent income inequality and widespread poverty remain pressing issues. South Africa grapples with a high and enduring unemployment rate, which stands as a significant barrier to poverty reduction (Chininga et al., 2023). Over 55.5% of the population lives in poverty, exceeding the national upper poverty line by approximately 1,335 ZAR in 2021 (Chininga et al., 2023). South Africa's Gini index, a common measure of inequality, was 0.63 in 2014, ranking among the highest globally (World Bank Poverty and Inequality Platform, 2024).

In South Africa, the agriculture, forestry, and fishing sector accounts for approximately 5.4% of the total workforce. The South African agricultural sector is dualistic, consisting of a well-integrated and highly capitalised commercial sector with approximately 35,000 farmers producing about 95% of the agricultural output on 87% of the total agricultural land area (Hawkins et al., 2022). In contrast, the small-scale farming sector comprises around 4 million farmers operating in the former homelands and utilising only 13% of South Africa's agricultural land (Hawkins et al., 2022). Hawkins et al. (2022) note that this population is vulnerable, as most are poor, less educated, and live in rural communities with underdeveloped infrastructure. Wages are also a key socio-economic indicator. In 2023, Minister Thulas Nxesi increased the minimum wage for farmworkers and domestic workers to ZAR 25.42 per hour. To translate this figure in terms of monthly earnings, assuming a standard 40-hour work week, this hourly rate translates to approximately ZAR 4,402.74 per month. The 2023 report of the Global Living Wage Coalition provides updated estimates of family living expenses and living wages for the wine grape growing region of Western Cape Province, South Africa at ZAR 5,354 per month while the Cost of a Basic but Decent Living is ZAR 8,692. This data demonstrates the struggle of farmworkers to earn a sufficient wage to sustain their needs.

South Africa faces significant challenges in ensuring food security, exacerbated by various socio-economic and environmental shocks as highlighted by the SADC (2022). The country struggles with inflation and rising prices of fuel, agricultural inputs, and food products (SADC, 2022). The number of people vulnerable to food insecurity has increased significantly, reaching 14.4 million, nearly a quarter of the country's total population in 2022 (SADC, 2022). Despite these challenges, South Africa continues to meet its national food needs by combining domestic production and imports (SADC, 2022). For example, in 2022, the SADC recorded an estimated maize harvest of 14.723 million tonnes, sufficient to meet demand in both human and animal food markets. The calorie supply of 2,776 kcal/day/capita is above the 2,500 kcal defined by EAT-Lancet but below the global average of 2,959 kcal (FAO).

3.3. South Africa and its Agriculture Sector: Environmental Considerations

According to the Convention on Biological Diversity, South Africa is one of the world's most biologically diverse countries, with a variety of species, high endemism rates, and ecosystem diversity. The country is home to nine biomes, 31 distinct freshwater ecoregions, and three biogeographic zones along its coastline (Convention on Biological Diversity). Despite covering just 2% of the Earth's land surface, South Africa houses 10% of the world's plant species and 7% of its reptiles, birds, and mammals. Endemism rates are as high as 56% for amphibians, 65% for plants, and up to 70% for invertebrates (Convention on Biological Diversity).

However, South Africa is particularly vulnerable to climate change. Over the past five decades, annual temperatures in South Africa have increased by at least 1.5 times the global average rise of 0.65°C (Van der Bank et al., 2017). Climate change impacts various sectors such as health, agriculture, water, and urban areas, potentially creating new societal and economic challenges (Ziervogel et al., 2014). The grassland biome could be severely affected by the encroachment of woody vegetation due to rising temperatures and CO2 levels (Van der Bank et al., 2017). Drought is the most significant natural disaster impacting economic, social, and environmental activities in Southern Africa (Hawkins et al., 2022).

Agricultural production relies on the availability of land with sufficient water, soil resources, and an adequate growing season. South Africa's resources are varied, with only 12% of the total area suitable for crop production, mainly in the east and central parts of the country (Dube et al., 2013). Livestock farming, including game farming, is the main agricultural activity in the more arid areas (Dube et al., 2013). Important regions for wheat and fruit production, often under irrigation, are located in the Western Cape and Northern provinces (Dube et al., 2013). Protected areas, including parks and reserves, are crucial for biodiversity and water resource protection and are significant for the tourism industry, which contributes 8% to the GDP, exceeding agriculture (Dube et al., 2013). Maize, wheat, sunflower, and sugarcane occupy about 75% of the total harvested area of approximately 5.2 million hectares, with maize contributing almost half of this area (Dube et al., 2013). Grapes are the most valuable crop, accounting for 25% of the value, followed by maize at 17%, and then sugarcane, wheat, and potatoes. Maize and wheat are the most consumed food commodities, with beer in third place. In general, grains and cereals remain essential food commodities in the South African agriculture sector (Dube et al., 2013). South Africa remains the largest maize producer in the SADC region (Dube et al., 2013) Water availability remains a significant obstacle to the expansion of agriculture, with nearly 50% of the country's water used for agriculture and about 1.3 million hectares under irrigation (Dube et al., 2013).

The effects of climate change are already apparent, with an increase in pests like aphids, whiteflies, red spiders, and thrips in South Africa (Mutengwa, 2023). Crops are affected by variations in rainfall due to climate change (Van der Bank et al., 2017). Water-related challenges include more frequent floods and droughts (Van der Bank et al., 2017). Tropical cyclones are expected to hit the South African coasts more frequently, bringing heavy rains and causing floods in some northern parts of the country (Davis-Reddy & Vincent, 2017). Reductions in precipitation and the number of rainy days have been observed in certain regions (Davis-Reddy & Vincent, 2017). Despite this, South Africa heavily relies on rain-fed agriculture for food production, with sixty percent of all groundwater and surface water withdrawals used for commercial agricultural irrigation (Hawkins et al., 2022).

In response, South Africa has initiated investments in agricultural adaptation strategies such as crop diversification and the use of stress-tolerant cultivars (Mutengwa, 2023). Research into orphan crops is increasing, providing farmers with opportunities to diversify their crops, including a range of tubers, legumes, cereals, and roots (Mutengwa, 2023). Continuous development of heat- and drought-resistant cultivars is underway to address the country's recurrent droughts and heatwaves (Mutengwa, 2023).

However, there are disparities in climate adaptation, particularly among smallholder farmers who rely on rainfed and manual irrigation and have limited access to the necessary infrastructure or resources (Hawkins et al., 2022). Investments in irrigation infrastructure are more advanced in the commercial sector than in the smallholder sector (Mutengwa, 2023). Smallholder irrigation systems often underperform, resulting in low maize yields averaging less than 3 t/ha, primarily due to inadequate management (Mutengwa, 2023), thus perpetuating inequalities.

To conclude, this section highlights the importance of examining the agricultural sector in the context of research on the relevance and practicality of the Doughnut model, particularly in South Africa. Given its significant environmental impacts and its crucial role in society by ensuring food security, this sector is especially useful for illustrating the interactions between environmental and social dimensions. The choice of South Africa and its specific agricultural realities also presents particularly interesting avenues for exploration.

CHAPTER 3. RESEARCH: THE CASE OF SOUTH AFRICAN AGRICULTURE IMPACTS IN SOUTH AFRICA

The aim of this research is to apply the Doughnut model to a specific economic sector in a chosen country to explore the relevance and practicability of contextualising its environmental and social impacts within the Safe and Just Operating Space (Raworth, 2012). This research chose the agricultural sector in South Africa because the sector is particularly relevant for studying the interactions between environmental and social dimensions. Additionally, South Africa is ecologically megadiverse, has widespread poverty, and experiences extreme inequality (Cole et al., 2014). This heterogeneity provides a stringent test for the Doughnut framework, as noted by Cole et al. (2014). It is expected that this case study highlights the technical and ethical limits of applying the Doughnut model to impact assessment.

To conduct this case study, this chapter first outlines the research framework, detailing the main theories that underpin the study, defining key concepts, and illustrating the relationships between these theoretical constructs and the case study. Next, it introduces the integrated methodology, including the research design, and outlines the process for collecting and analysing both environmental and social data. Finally, the chapter concludes with the case study results though the presentation of the collected data and their analysis that addresses the research objectives.

1. Research Framework

To contextualise the impacts of the agricultural sector in South Africa using the Doughnut model, it is essential to understand the various underlying concepts. These include Planetary Boundaries, the notion of sufficientarism, and key definitions such as the carrying capacity and the Safe and Just Operating Space. Moreover, several studies have specifically applied the Doughnut model to the agricultural sector, demonstrating its relevance and applicability for this case study. Therefore, the aim of this section is to explore the foundational theories that support this case study, highlighting the critical concepts and definitions required for a comprehensive analysis of the contextualisation of the agriculture sector in South Africa. This section finally highlights the relationships between these various theories and concepts and their application to the case study of the agricultural sector in South Africa.

1.1. Theoretical Foundations

To contextualise the impacts, particularly those of the agricultural sector, this research has examined four fundamental studies:

Firstly, Planetary Boundaries, a framework coined by Rockström et al. (2009), outlines the Safe operating limits for humanity concerning the Earth's. It identifies specific Earth-system processes and the critical thresholds that, if exceeded, could result in severe environmental degradation (Rockström et al., 2009). Nine processes were identified where defining planetary boundaries is crucial: climate change, biodiversity loss, disruptions to the nitrogen and phosphorus cycles, depletion of the stratospheric ozone layer, ocean acidification, freshwater use on a global scale, changes in land use, chemical pollution, and atmospheric aerosol loading (Rockström et al., 2009).

Secondly, this research mainly draws from the Raworth's Doughnut Model (2012) which builds on the Planetary Boundaries framework by integrating a social dimension into environmental sustainability. It introduces an inner social boundary that represents the basic needs necessary for human well-being and an outer environmental boundary that should not be surpassed to prevent significant harm to the environment (Raworth, 2012). The area between these two boundaries forms the Doughnut itself which represents the Safe and Just Operating Space where human needs can be met without exceeding the planet's environmental limits (Raworth, 2012). This model was studied by numerous scholars and was specifically applied to South Africa by Cole et al. (2014). In their study, Cole et al. (2014) downscaled planetary boundaries and implemented the Safe and Just Space framework at the national level using indicators tailored to South Africa. Their research presents the current status and trajectory of various indicators for environmental and social priorities, highlighting the country's proximity to environmental thresholds and its progress towards ending social deprivation (Cole et al., 2014).

Furthermore, sufficientarism is a conception from distributive justice that focus on the threshold of sufficiency, meaning the threshold where everyone’s basic needs are answered (Davies, 2023). The concepts of Decent Living Standards by Rao & Min (2017) and Earth System Justice as developed by Gupta et al. (2022) are based on the idea of sufficientarism and form a central foundation for this case study. These concepts build on Raworth’s Doughnut framework by emphasising the justice dimension and translating it into practice through strategies aimed at minimising environmental damage, improving access for disadvantaged populations, and supporting fair transitions (Gupta et al., 2022). They advocate for minimum access to essential resources—such as food, energy, water, housing, and transport—to ensure a decent standard of living and reduce poverty, incorporating the principle of sufficientarism, which holds that everyone should have enough (Gupta et al., 2022). Decent Living Standards helps tackle broader societal issues than just access to basic needs by bridging with the SDGs and provide a framework for social dimensions of the Doughnut (Vélez-Henao & Pauliuk, 2023).

Finally, the EAT-Lancet Commission's Report, "Our Food in the Anthropocene: Healthy Diets from Sustainable Food Systems" (Willett et al., 2019), provides a comprehensive understanding of the impact of food production on Planetary Boundaries, precious for this case study on agriculture. This report sets evidence-based global scientific targets for both nutritious diets and sustainable food production practices (Willett et al., 2019). It defines a Safe Operating Space for food systems and concentrates on six key environmental processes affected by food production: climate change, land-system changes, freshwater use, nitrogen cycling, phosphorus cycling, and biodiversity loss (Willett et al., 2019). For each of these processes, it specifies the minimum shares that can be allocated to food production while still maintaining a healthy diet for the global population by 2050 (Willett et al., 2019).

1.2. Key concepts and definitions

Several key concepts have been derived from these theories and will be used throughout this case study. The Safe and Just Operating Space represents the area within Raworth's Doughnut model and is the focal point of this case study (Raworth, 2012). It refers to the space between the upper environmental limits on resource use and the lower boundary of a social foundation necessary for human well-being (Raworth, 2012). The aim of this research is to define the Safe and Just Operating space for South Africa and assess whether the impacts of the country's agricultural sector fall within these boundaries. To define the Safe Operating Space, it is important to understand the concept of carrying capacity, which Bjørn et al. (2020) describe as the *"maximum sustained impact that the environment can handle without experiencing unacceptable degradation of the functional integrity of its natural systems."* Thus, the carrying capacity represents the upper limit that must not be exceeded to ensure environmental preservation. Moreover, to identify a Safe and Just Operating Space for an economic activity, the carrying capacity must be distributed among all economic activities. This means that the studied activity must be allocated a specific share of the carrying capacity, which should not be exceeded. The allocation principle is used to evaluate how much of the carrying capacity can be appropriately assigned to a lower scale (Gondran et al., 2023). Lavisse et al. (2024) note that the target of distribution is individual human beings, which means that each choice of a sharing principle is fundamentally grounded in distributive ethics. Given the importance of selecting an appropriate ethical sharing principle, this research adopts the concept of Earth System Justice, as articulated by Gupta and aligned with the Doughnut Model as its guiding framework. This approach uses sufficientarism to propose minimum access levels for all individuals as the basis for resource allocation. This provides a foundational threshold based on sufficientarism - the principle that the basic needs of every individual must be met - and serves as an initial step toward contextualising the impacts of the agricultural sector within the Doughnut framework in a manner that is both just and equitable.

Key concepts and definitions need to be specified for the agricultural sector in particular. On the one hand, regarding environmental impacts, it is well established that agricultural production significantly affects planetary boundaries (Campbell et al., 2017). The EAT-Lancet Report (2019) thus examined six environmental dimensions most impacted by food production: Climate Change, Land Use, Freshwater Use, Nitrogen Cycling, Phosphorus Cycling, and Biodiversity Loss. After reviewing various scientific papers, this research chose to focus on the first three dimensions due to considerations of feasibility and data availability.

Table 3: Environmental dimensions studied in the case study and definitions of the variables

Environmental Dimension studied by the EAT-Lancet Report	**Control Variable and unit**	**Definition**
Climate Change	GHG Emissions *in CO_2e*	Greenhouse gases are a group of seven gases that directly impact climate change: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). These gases are measured in CO_2 equivalents and include all direct emissions from agriculture activities (OECD, 2024).
Land-system change	Cropland use *in km^2*	Land use involves all the ways land is managed and utilised, including the activities and inputs applied to different types of land cover. In the context of GHG inventories, land use is categorised into different types, such as forests, cropland, grassland, wetlands, settlements, and others. A land-use change happens when there is a shift from one of these categories to another (IPCC Glossary, 2024).
Freshwater use	Water withdrawal *in Mm^3*	The amount of freshwater taken from surface or groundwater sources is known as freshwater abstraction. Some of this water will evaporate, some will flow back to the same catchment area from which it was taken, and some may end up in a different catchment or flow into the sea (Hoekstra et al., 2011).

On the other hand, in terms of socio-economic considerations, impacts of the agriculture sector can be divided in two categories. Macassa et al. (2020) note that an organisation's commitment to its social responsibilities extends to both external and internal stakeholders. Externally, this responsibility involves addressing the needs of the local community, wider societal issues, and environmental sustainability (Macassa et al., 2020). Internally, the focus is on the organisation's obligations towards its employees, including efforts to improve workplace safety and health, uphold human rights, provide training, ensure equality of opportunity, and promote work-life balance (Macassa et al., 2020). Consequently, the socio-economic dimensions of the agricultural sector can be evaluated on two levels: firstly, food security, which pertains to the entire South African population, external or indirect stakeholders; and secondly, the internal or direct stakeholders, namely the workers within the South African agricultural sector.

According to the 1996 World Food Summit, food security is defined as a state *“when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life."* This definition emphasises that food security is characterised by four fundamental dimensions: access, availability, utilisation, and stability (FAO, 1996). Since this research primarily focuses on the principle of sufficientarism, only the aspects of access and availability are considered in the indicators as a dynamic vision over several years would have been appropriate to assess stability. Furthermore, there are minimum thresholds for kilocalories per day per person to ensure food security. The World Health Organisation (WHO) sets this threshold at 2,100 kcal per day, while the EAT-Lancet report (2019) suggests a limit of 2,500 kcal per capita per day to ensure access to a sufficient and healthy diet (Rammelt et al., 2022). According to Rammelt et al. (2022), the first threshold corresponds to a dignified life beyond mere survival, while the second is considered sufficient to enhance capability, enabling individuals to escape poverty and vulnerability. These thresholds help achieving Decent Living Standard.

Finally, when considering the social impacts of an economic activity, direct or internal impacts, such as those affecting workers, are also taken into account. As Cole et al. (2014) did when defining the South African Doughnut, the concept of deprivation, as defined by the South African Index of Multiple Deprivation (SAIMD), informs this analysis. According to SAIMD (2021), individuals are considered deprived if they *"lack the types of diet, clothing, housing, household facilities, and fuel, as well as environmental, educational, working, and social conditions, activities, and facilities that are customary."* These definitions help in selecting indicators for the agricultural workforce, with the primary focus in this study on working and social conditions.

1.3. Relationships between concepts

By integrating these theories, this research establishes a comprehensive framework to contextualise the impacts of the agricultural sector in South Africa.

The Planetary Boundaries framework helps identify the specific national environmental thresholds for South Africa, representing the upper limits of the country's carrying capacity that should not be exceeded. In contrast, the integration of Earth System Justice, with its sufficientarian approach, allows us to define the lower "acceptable" environmental limit—one that ensures a minimum healthy and sufficient diet for the population. In this research, the sufficientarian principle serves as the allocation factor. Rather than setting a maximum allowable resource use, this principle establishes the theoretical minimum required to meet the essential needs of the population.

The findings of the EAT-Lancet report (2019) are central to this case study, as they operationalise these theories for the agricultural sector by providing specific, actionable guidelines for a planetary health diet. This diet defines the minimum caloric intake necessary for a healthy and sufficient diet while staying within planetary boundaries. The 2,500-kcal limit helps assess the environmental pressures required to achieve this social foundation. Additionally, the work of Rammelt et al. (2022), which translates the EAT-Lancet diet (2019) into minimum environmental pressures for climate change, freshwater use, land-use change, and nutrient cycling (nitrogen and phosphorus), further defines the social foundation, contextualising the sector's environmental impacts.

Furthermore, by recognising that an organisation or economic activity holds responsibilities towards both its internal stakeholders (such as workers) and external stakeholders (the broader society), this research evaluates the social impacts of economic activity. For this, the Decent Living Standards and deprivation levels serve as benchmarks for social thresholds. Applying these concepts allows for the contextualisation of the impacts of South Africa's agricultural sector, emphasising its primary responsibility to ensure access to sufficient and healthy food while minimising pressure on planetary boundaries.

In conclusion, by comparing these minimum and maximum thresholds with the actual impacts of the sector, this approach enables an assessment of how far environmental limits are exceeded and which social limits are unmet. Ultimately, this provides a contextualised understanding of South Africa's agricultural sector within its Just and Safe Operating Space.

Thus, this leads to the establishment of three main research objectives to contextualise the impacts within the Safe and Just Operating Space:

- Objective 1: To define the Safe and Just Operating Space for South Africa's agricultural sector by establishing environmental and social thresholds, including national environmental boundaries, minimum environmental impacts for food security, and socio-economic deprivation indicators for agricultural workers and the general population.
- Objective 2: To assess the extent to which the actual environmental impacts of South Africa's agricultural sector align with the upper and lower environmental thresholds to determine whether the sector remains within the safe space.
- Objective 3: To evaluate the level of social deprivation in South Africa's agricultural sector by analysing key socio-economic indicators related to food security, working conditions, social well-being, and gender equality for agricultural workers to determine whether the sector remains within the just space.

1. Methodology

This section presents the methodology of this case study, first outlining the justification for the research design, then data collection methods used to define a Safe and Just Operating Space for the agricultural sector in South Africa, as well as to determine the actual impacts of the sector. Subsequently, it details the data analysis plan, which allows for the analysis of the collected data, focusing separately on environmental data and socio-economic data.

1.1. Research Design

This study has chosen a case study approach for several reasons:

- Case studies enable exploratory research. As Ebneyamini & Sadeghi Moghadam (2018) state, the case method allows the questions of why, what, and how to be answered with a relatively full understanding. According to these authors, the case study approach is suitable as a research strategy when the topic is broad and highly complex, when there is not a lot of theory available, and when context is very important. It allows the exploration of situations in which the intervention being evaluated has no clear set of outcomes.
- In the context of this research, despite available theory, few practical cases have been conducted using this research framework. The case study, through practical implementation, allows for the identification of concrete limitations and strengths in contextualising the Doughnut model.
- Finally, impact assessment tools can lead to various complexities such as data availability, data transcription, and determining the scope of data to use. Conducting impact assessment in a concrete case more easily raises these points of attention and helps understand their importance.

This case study research design addresses the research objectives by:

- Testing the feasibility of defining a Safe and Just Space through quantitative limits based on real-world data and determining their relevance to the country's realities.

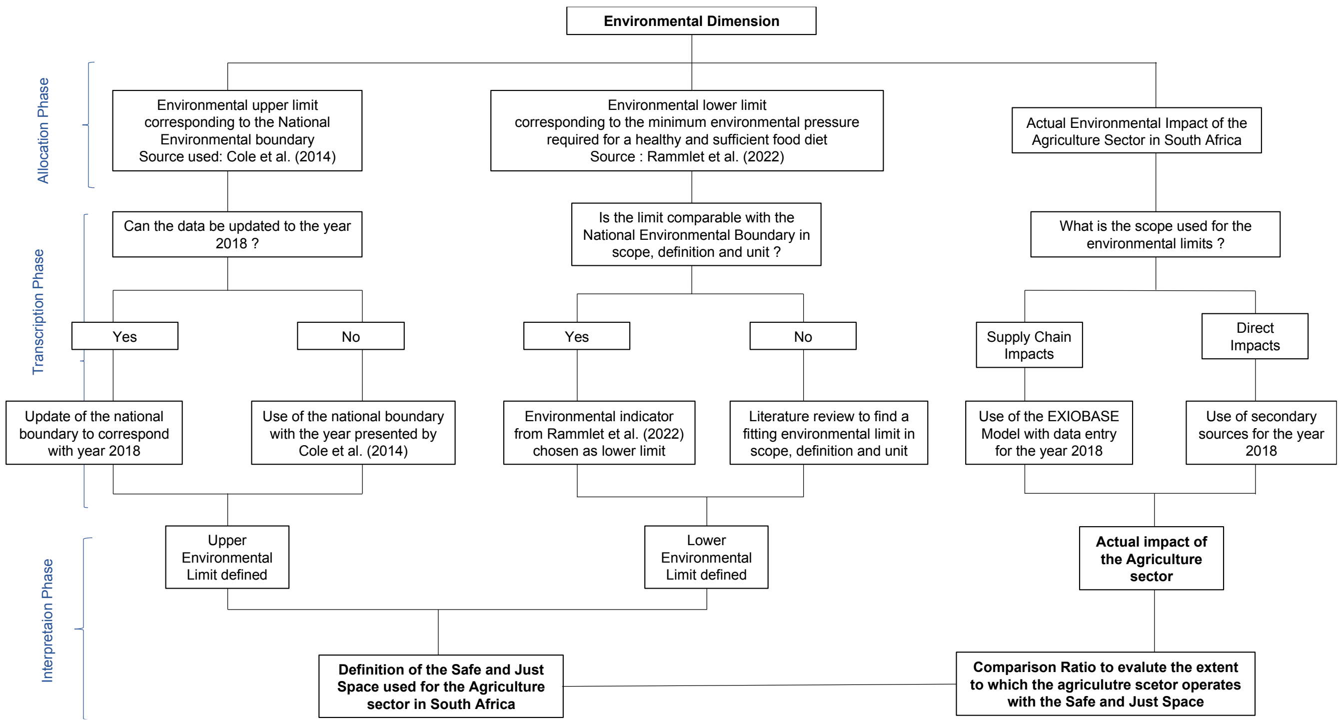
- Exploring the allocation principle that allows for downscaling the Safe and Just Space thresholds to levels such as an economic activity, specifically testing the use of sufficientarianism as an allocation principle in this research.
- Examining the ease of transcription between various data, i.e., their comparability, between the defined threshold data and the agricultural sector's impact data.

Transcription and allocation are two key steps in defining the Just Space, according to Bai et al. (2024). Transcription refers to the process in which an environmental impact, defined as an anthropogenic pressure, is linked to an environmental boundary (Bai et al., 2024). Allocation is the process by which the space defined by the environmental boundary, i.e., the carrying capacity, is divided, allowing a portion to be allocated to a specific economic activity.

The type of data collected is only quantitative from secondary sources through academic literature. Data collection for environmental data is based on two key principles: data availability and the ability to translate between thresholds and actual impacts. This involves considering the scope of impact measurement, which can be either direct (impacts directly related to the agricultural sector in Africa) or indirect, taking into account the broader supply chain impacts. The translation must also account for the indicator being studied and its unit of measurement to ensure that the two sets of data are comparable. The analysis and interpretation of the data—determining whether they fall within the Safe and Just Space—can only be conducted if the data are comparable.

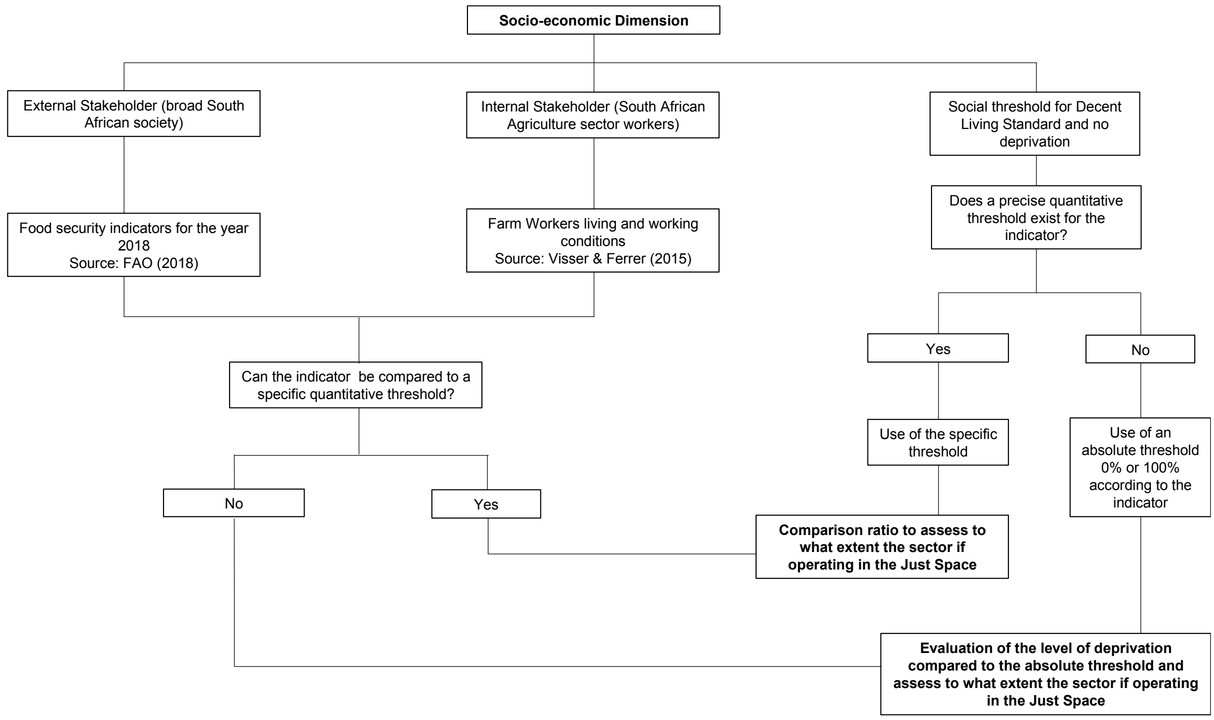
Thus, for the environmental data, the research design is structured as follows:

Figure 4: Research Decision Tree for Environmental Data



The collection and analysis of socio-economic data is more straightforward and follows two considerations. If the socio-economic indicator collected can be identified with a specific social threshold, such as a monetary value, both values must be comparable, particularly in terms of the year, to avoid the effects of inflation. If the socio-economic indicator is already a deprivation measure in itself, then the threshold is an absolute scale from 0 to 100, and no ratio needs to be evaluated to determine whether the social threshold has been met or not.

Figure 5: Research Decision Tree for Socio-economic Data



1.2. Data Collection Methods

This section outlines the types of data collected, the data collection methods employed, and the sources used for both the thresholds of South Africa's Safe and Just Operating Space and the actual impacts of the country's agricultural sector. The year 2018 was chosen for data collection. The main reason is because the study from Rammlet et al. (2022), essential to this study, used 2018 as a reference year to avoid the potential influence of COVID-19 on the agricultural sector, thus eliminating a possible limitation in this study. Moreover, this research considers that selecting 2018 ensures the availability of data, as more recent data may not yet have been updated or published.

However, given the specificity and precision of the data required for this research, it is possible that not all data originates from the same year. In cases where data from 2018 is available, it is be prioritised. If only data from another year is accessible, it will be used, and any temporal discrepancies will be clearly indicated during the data collection process.

1.2.1 Defining the Safe and Just Operating Space

The first objective of this research is to define the boundaries of the Safe and Just Operating Space for the agricultural sector in South Africa. This entails establishing the national environmental limits, which constitute the upper threshold; the lower threshold, determined by the minimum environmental pressures required to ensure an adequate supply of healthy food; and the social dimensions that must be safeguarded, such as the absence of deprivation in working conditions for the sector's workers and food security for the broader society.

To define this Safe and Just Operating Space, three levels of quantitative data, only from secondary sources, must be collected:

1. Data for the National Environmental Limits for South Africa:

Given the availability of data, this thesis focuses on Planetary Boundaries that are recurrently studied in the context of the agricultural sector and where data is available. Therefore, indicators will be collected for the environmental dimension of climate change, land-use and freshwater use. The data will be sourced from secondary data through previous research, particularly the study by Cole et al. (2014), which examined South Africa's Doughnut model using customised indicators that best reflect the country's realities. Where possible, this research will update certain datasets that date back to 2014 or earlier to use more recent data. Because Cole et al. (2014) study is a bottom-up, this approach will help define South Africa's national environmental boundaries, though it is acknowledged that some of the data may not be directly applicable to our study. In such cases, other research will be used to supplement the data on South Africa's environmental limits. Hence, if the current indicators are found unsuitable, this research may seek alternative sources from other authors.

2. Data for the Minimum Environmental Pressures Required for Social Foundation:

These indicators are necessary to ensure a sufficient dietary intake of 2,500 kcal per day for each environmental dimension considered. Data for this purpose will be gathered from secondary sources, drawing on previous scholarly studies. This thesis will particularly rely on prior research from Rammelt et al. (2022) that used the EAT-Lancet Commission's report. Rammelt et al. (2022) explored the environmental pressures involved in ensuring a minimum access of 2,500 kcal. Drawing on this research, these results will be adapted to the South African population to determine the minimal social foundation required.

3. Data for Defining Socio-Economic Indicators for the Agricultural Sector in South Africa:

These indicators must ensure, in absolute terms, that there is no state of deprivation under the Decent Living Standard. The indicators can be categorised into two main groups: internal impacts on the workforce, focusing on working conditions and social benefits nd gender equality among agricultural sector workers; external impacts on the population, particularly concerning food security. To collect socio-economic data, for the first level concerning food security, the FAO has developed a comprehensive set of food security indicators based on recommendations from the Committee on World Food Security Round Table on hunger measurement, held at FAO headquarters in September 2011. The second level of analysis focuses on the conditions of agricultural workers in South Africa, who are direct stakeholders affected by the sector's socio-economic impacts, particularly regarding their well-being. Regarding the working conditions of farm workers in South Africa, the indicators used in this research are derived from a report commissioned by the International Labour Organization's Pretoria Office, titled "Farm Workers' Living and Working Conditions in South Africa: Key Trends, Emergent Issues, and Underlying and Structural Problems" (Visser & Ferrer, 2015).

1.2.2 Determining the actual impacts of the agriculture sector in South Africa

The second and third objectives aim to analyse the actual impacts relative to the Safe and Just Operating Space. After collecting data on the Safe and Just Operating Space, it is necessary to gather data on the actual environmental and socio-economic impacts of the agricultural sector in South Africa to achieve these additional objectives. Initially, this involves collecting environmental data, followed by socio-economic data.

To collect the environmental data, which is quantitative, two methods will be employed:

1. EXIOBASE, an environmentally-extended multi-regional input-output (EE MRIO) model that provides insights into global economic interdependencies and their environmental effects.
2. Secondary data obtained from the free online data platform "Our World in Data", aaggregating data from various reputable sources, such as the World Bank, United Nations, and academic studies, allowing for a comprehensive analysis of trends and patterns over time.

These two types of data sources are used to assess the following impacts:

Firstly, the EXIOBASE model is specifically be used to evaluate the impact of agricultural production on climate. Climate impacts are assessed across the entire value chain, including both direct and indirect effects, such as upstream impacts from suppliers and downstream impacts from buyers. Considering this scope is essential for comparing impacts with the selected thresholds from the national boundary and Rammlet et al. (2022) study. EXIOBASE is a crucial tool for evaluating environmental impacts throughout the value chain as it is designed to link downstream environmental impacts with upstream drivers, allowing for the tracking of commodity footprints across complex supply chains. Developed through EU projects such as EXIOPOL, CREEA, and DESIRE, EXIOBASE offers a comprehensive global EE MRIO database suitable for environmental assessments (Stadler et al., 2018). EXIOBASE includes data from 1995 to 2011, covering 44 countries, including South Africa, and categorises 200 products and 163 industries (Stadler et al., 2018). The EXIOBASE model was used in previous studies to assess the impacts of agriculture. For instance, Donati and Tucker (2022) analysed the environmental impacts and value added generated abroad by the agricultural sector through imported final consumption in the Netherlands. They then compared these impacts with those generated by the agricultural sector in the Netherlands due to exports to other countries. Similarly, Liao et al. (2023) utilised the model to quantify the unsustainable environmental impacts of food systems, indicated by the breach of national-scale planetary boundaries, considering both production and consumption perspectives across 189 countries and regions worldwide.

Secondly, for the other environmental dimensions i.e., freshwater use, land use, and nitrogen concentration, only direct impacts are taking into account meaning the impacts only from the direct production of agriculture. Therefore, EXIOBASE will not be used for data collection; instead, only secondary data sources related to agricultural production will be used, particularly from the "Our World in Data" platform, which compiles data from various sources. The identified secondary sources are:

- The Food and Agriculture Organisation's AQUASTAT database, as processed by Our World in Data for the indicator of agricultural water withdrawals, 2015, measured in m³ per year. Agricultural water is defined in this indicator as the annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes (Aquastat – processed by Our World in Data, 2017).
- HYDE (2023) – with minor processing by Our World in Data (2024) to estimate the total areal land use for agriculture, measured as the combination of land for arable farming (cropland) and grazing in hectares in South Africa.

For the socio-economic data, the impacts corresponding to the collected indicators will be directly extracted from the sources:

- The "Farm Workers' Living and Working Conditions in South Africa: Key Trends, Emergent Issues, and Underlying and Structural Problems" report on farm workers' conditions in South Africa, commissioned by the International Labour Organization's Pretoria Office by Visser & Ferrer (2015).
- The Living Wage for rural South Africa with Focus on Wine Grape Growing area in Western Cape Province by Anker & Anker (2013)
- Statistics results from the FAO available on FAOSTAT

1.3. Data Analysis Plan

The data analysis is conducted in two stages, each of them allowing to answer to the second and the third objective of the research. First, the environmental data are analysed, focusing on the three dimensions under study: climate, freshwater use and land use. This stage involves comparing the data collected for the thresholds of the Safe and Just Space with the actual environmental impact data. The second stage involves analysing the socio-economic indicators, comparing them against a baseline of non-deprivation or complete gender equality.

1.3.1. Environmental Indicators Analysis

The first part of the analysis aims to address the second objective of this research, which seeks to determine the extent to which the environmental impacts of the South African agricultural sector fall within the environmental limits of the Safe and Just Space. To interpret the collected environmental data, the analysis evaluates their position relative to the national environmental boundary as the upper limit and the environmental impact necessary to meet the country's food needs as the lower limit. Depending on how the sector's impacts deviate from each of these limits, it is possible to interpret the deficit or surplus of the carrying capacity space occupied by the sector relative to the thresholds. The balance between these two thresholds helps to understand to what extent environmental impacts could be reduced or increased to meet social needs.

The following equations are used to estimate whether there is a surplus or deficit in relation to each of these limits:

- Upper Environmental Limit for an Environmental Dimension:

$$if \ \frac{Agriculture\ Sector's\ Actual\ Environmental\ Impact}{National\ Environmental\ Boundary} < 1,$$

$$\text{then the economic activity does not exceed the country's national environmental resources.}$$

This equation allows for the assessment of the percentage of the country's carrying capacity used by the agricultural sector. A ratio below 1 indicates that, for the environmental dimension under study, the environmental impact of the agricultural sector does not exceed the national environmental limit. Conversely, a ratio above 1 indicates that the environmental impact of the sector is too high compared to the national limit, meaning that the sector is no longer operating within the Safe Space of the country.

It is important to note that this ratio considers only the concept of the Safe Space and not the Safe and Just Space, as the minimum environmental threshold has not yet been included. Secondly, this ratio uses the national environmental limit as the maximum threshold, rather than a limit specific to the agricultural sector. Therefore, this ratio does not indicate whether the sector operates specifically within the Safe Operating Space for agriculture, since the upper limit chosen represents the entire country. To determine this, it would have been necessary to allocate a specific maximum limit to the sector by distributing the carrying capacity. However, for methodological reasons and to maintain an ethical perspective, this research did not pursue this approach. Nonetheless, the ratio provides insight into the extent to which the environmental impacts of the sector place significant pressure on the country's resources, comparing them against maximum thresholds that should not be exceeded to preserve the country's biophysical and environmental integrity.

- Lower Environmental Limit for an Environmental Dimension for Social Foundation:

$$if \ \frac{Agriculture\ Sector's\ Actual\ Environmental\ Impact}{Minimum\ Environmental\ Pressure\ Required} > 1,$$

$$\text{then the economic activity meets the minimum environmental pressure needed to ensure the social foundation of healthy and sufficient diet.}$$

The purpose of this equation is to determine the percentage by which the agricultural sector in South Africa operates above or below the minimum environmental threshold required to ensure access to a healthy and sufficient diet, as outlined by Rammelt et al. (2022). The higher the percentage above 1, the greater the environmental impacts relative to the minimum threshold. If this percentage is below 1, it theoretically indicates that agricultural production is insufficient to establish the social foundation needed to provide a healthy and adequate diet for the entire population. This ratio provides an idea of how far the production is from reaching the lower limit that is sufficient to feed the population healthily and adequately.

1.3.2. Socio-Economic Indicators Analysis

This second part of the analysis aims to address the third research objective, which is to evaluate the extent to which socio-economic impacts fall within the Just Operating Space of the South African agricultural sector.
As outlined in the data collection section, two main groups of data are to be analysed:

- The impacts on external stakeholders, representing South African society in general and their access to food security;
- The impacts on internal stakeholders, represented here by the workforce of the South African agricultural sector, including gender equality.

To better qualify these results, this research employs the concept of deprivation; that is, if a portion of the population has unmet needs, the indicator falls below the social threshold.

This research considers that, if no specific quantitative social threshold can be defined for the socio-economic indicator i.e., the indicator is intrinsically linked to a deprivation idea, then an absolute threshold is used, set at either 0% or 100%, depending on the indicator. While this may appear to be an ambitious target, the thesis argues that every individual should be able to meet their basic needs. For example, the research assumes that no individuals should experience food insecurity and that every worker should have access to paid sick leave. This methodology allows for a clear assessment of the socio-economic performance of the South African agricultural sector in terms of its capacity to meet basic needs and provide fair conditions for both its workforce and the broader population. By setting absolute thresholds, it becomes easier to determine whether the sector is fulfilling these essential requirements or falling short in certain areas.

If a specific quantitative threshold can be defined, then the ratio is used:

$$\frac{Actual\ Agriculture\ Sector's\ impact}{Minimum\ Social\ Threshold}$$

If this ratio is less than 1, then the sector does not meet the minimum expected social threshold.

However, each of the collected indicators will be compared to this absolute threshold using qualitative analysis, as applying a mathematical ratio can present issues, such as dividing by zero.

3. Results

This section of the chapter aims to present the research findings. These results address the three research objectives defined earlier. First, this section presents all the collected data, including those related to the first objective, which seeks to define the thresholds of the Safe and Just Space, as well as the data for the second and third objectives, which require determining the actual impacts of the agricultural sector in South Africa. Subsequently, this section will present the data analysis, thereby fully addressing research objectives 2 and 3 by comparing the agricultural sector data with the thresholds of the Safe and Just Space to contextualise the impacts within this framework.

3.1. Data collection

Following the guidelines provided in the research design, this section lists all the data collected to address the three research objectives.

3.1.1. Defining the Safe and Just Operating Space

The first research objective is to define a Safe and Just Operating Space for the agricultural sector in South Africa. As outlined in the research design, three levels of data are collected:

- National environmental limits
- Minimum environmental limits to ensure the social foundation

- Socio-economic indicators for both external and internal stakeholders

The following section presents the results of the data collection for defining the Safe and Just Operating Space.

3.1.1.1. South Africa National Environmental Boundaries

Three environmental dimensions are examined in this case study: climate change, freshwater use and land use. The following national environmental limits have been determined:

Climate Change national boundary: For the national safe boundary, Cole et al. (2014) considered the 2010 Required by Science target is 451 MtCO2. This target can be updated to be closer to 2018. In 2021, the country committed to a fixed target for greenhouse gas emissions levels of 398-510 MtCO2e by 2025 according to the Nationally Determined Contributions published by UNDP. The national boundary chosen for this study is therefore 398 MtCO2e per year which is the lower bound of the target.

Freshwater use national boundary: As a national boundary, Cole et al. (2014) chose the consumptive freshwater use by humans; that is, water that is not supplied or allocated by the DWS (Department of Water and Sanitation) and cannot be used, except in rural areas where there is little or no water service provision. Cole et al. (2014) found that in 2014 the total available yield was 14,196 Mm^3 per year. Cole et al. (2014) consider that this total available yield could increase in the future if additional water is imported from neighbouring countries, additional groundwater is accessed, return flows increase, and physical water losses in municipalities are reduced.

Land-use change national boundary: As a national boundary, Cole et al. (2014) considered “acceptable arable land for crop production (class I–III)” of 12.1%. In fact, in 2012, only 25% of land in South Africa was arable and only 12.1% of land was termed “acceptable arable land.” The author's methodological approach employs South Africa's National Land Capability Classification, which categorises land into eight classes (I-VIII) based on environmental risks, terrain, soil quality and climate. By focusing on the 12.1% figure, representing only classes I-III, the author prioritises land inherently more suitable for rain-fed agriculture, aligning with sustainable land use principles. This approach excludes class IV lands, which often require irrigation, acknowledging the interconnection between land and water resource management in South Africa's semi-arid context. The selection of only "acceptable arable land" as a boundary reflects a long-term perspective on agricultural sustainability, discouraging the exploitation of marginal lands more prone to crop failures. This comprehensive methodology emphasises sustainable agriculture, water resource considerations, and long-term viability in determining land use boundaries.

Thus, the data collection for South Africa's national environmental limits is summarised in the table below.

Table 4: South African National Environmental Boundaries studied

Environmental dimension	National environmental boundary	Unit	Scope	Source
Climate Change	398	$MtCO_2e$	Supply Chain	Cole et al. (2014); 2021 Nationally Determined Contributions published by the Government of South Africa for update
Freshwater Use	14,196	Mm^3	Direct	Cole et al. (2014)
Land Use	12.1	%	Direct	Cole et al. (2014)

3.1.1.2. Minimal environmental pressures to ensure food security in South Africa

This section presents the results of the data collection for defining the minimum environmental limits, which correspond to the minimum environmental pressures associated with the production of a healthy and sufficient diet. The EAT-Lancet report considers that a caloric intake of 2,500 kcal, which allows for access to a healthy diet while respecting planetary boundaries, is defined by the following daily diet per person.

Table 5: Planetary Health Diet for 2,500 kcal per person per day according to the EAT-Lancet Report

	Just access level for 2500 kcal a day per capita	
Food groups	**Macronutrient intake grams per day**	**Caloric intake kcal per day**
Whole grains	232	811
Tubers or starchy vegetables	50	39
Vegetables	300	78
Fruits	200	126
Dairy foods	250	153
Beef, lamb, and pork	14	30
Chicken and other poultry	29	62
Eggs	13	19
Fish	28	40
Legumes	75	284
Nuts	50	291
Unsaturated oils	40	354
Saturated oils	11.8	96
Added sugars	31	120
Total		**2 503**

For food, Rammelt et al. (2022) identified the environmental pressures associated with achieving the minimum caloric intake per person per year in the world in 2018. Regarding land use, Rammelt et al. (2022) assessed the land required to produce a healthy mix of food items. However, the national boundary used by Cole et al. (2014) takes into account acceptable arable land specific to South Africa. As a result, these two datasets are not directly comparable, and an alternative minimum environmental threshold must be identified for this dimension.

The only global study addressing this issue is Myers (1998), who determined that the minimum arable land required to sustainably support one person is 0.07 hectares. This threshold is used by United Nations organisations to assess land carrying capacity, according to Fischer. Therefore, the following thresholds per person are used. It should be noted that this data might not consider the 2,500 kcal per day as a threshold, and as such, the figures could be lower than expected for that caloric intake.

Table 6: Minimum Environmental Pressure required required for a sufficient diet per year for the South African population (Myers, 1998; Rammlet et al., 2023)

Environmental dimension	**Climate (tCO_2e cap−1 yr−1)**	**Water—blue (m^3 cap−1 yr−1)**	**Land (ha cap−1)**
Variable definition	GHG Emissions from food production (including the whole supply chain)	Irrigation water required for food production	Minimum Arable Land needed
Environmental Pressure Required for the production of 2,500 according to the EAT-Lancet	1.91	98.23	0.07

To determine the share of environmental pressures necessary to ensure minimum access to food for the population of South Africa in 2018, these values are multiplied by the number of South African inhabitants, which was 57,339,635 in 2018 according to the World Bank. This calculation yields:

Table 7: Minimum Environmental Pressure required for achieving 2,500 kcal EAT-Lancet diet per year for the South African population (Rammlet et al., 2023)

Environmental dimension	**Climate ($tCO_2e\ yr^{-1}$)**	**Freshwater Use ($m^3\ yr^{-1}$)**	**Land Use (ha)**
Environmental dimension definition	Emissions from food production (including the whole supply chain)	Irrigation water required for food production	Arable land required to sustain one person

Environmental pressure required for the production of 2,500 according to the EAT-Lancet	109,314,695	5,632,434,991	40,138

Thus, this table summarises the impacts related to meeting the minimum requirements for access to a balanced diet sufficiently rich in kcal to ensure dignity and capability, thereby addressing the social threshold of the Doughnut while remaining within environmental limits.

3.1.1.3. Socio-economic indicators

This section aims to present the socio-economic data collected. With deprivation being considered the threshold, only the indicators relevant to the research are listed. For each of the indicators mentioned, it is assumed that they should not show any signs of deprivation, and to define a just operating space, they must either be at 0% or 100%, depending on the indicator.

Two groups of indicators are considered. The first group pertains to food security, which corresponds to the inner circle of the Doughnut model and is closely linked to the sharing principle, ensuring sufficient agricultural production for the South African population. This principle represents an indirect stakeholder in terms of well-being within the agricultural sector. The second group addresses the conditions of agricultural workers in South Africa, who, in terms of well-being, are the direct stakeholders affected by the socio-economic impacts of the sector, including work and social conditions such as the living wage but also concerns gender equality between male and female workers. In addition to the other indicators, living wage versus decent living wage can be considered with a monetary threshold. Research by Anker & Anker (2013) has provided significant findings for the South African context. Their studies indicated that, in 2013, the cost of maintaining a basic but decent standard of living for a family was estimated at ZAR 5,120.

Table 8: Socio-economic indicators collected with their social threshold and their sources

Indicator	Social Threshold	Source
Food security (External Stakeholders)		
Prevalence of undernourishment	0%	FAOSTAT
Prevalence of severe food insecurity in the total population	0%	FAOSTAT
Percentage of the population unable to afford a healthy diet	0%	FAOSTAT
Working conditions for the workforce (Internal Stakeholders)		
>45 hrs/week	0%	Visser & Ferrer (2015)
Paid Vacation Leave	100%	Visser & Ferrer (2015)
Paid Sick Leave	100%	Visser & Ferrer (2015)
Maternity Leave	100%	Visser & Ferrer (2015)
Paternity Leave	100%	Visser & Ferrer (2015)
Pension Contribution	100%	Visser & Ferrer (2015)
Medical Aid Contribution	100%	Visser & Ferrer (2015)
No Regular Salary Increase	0%	Visser & Ferrer (2015)
Living Wage	5,120 ZAR	Anker & Anker (2013)
Living Wage gender gap	0%	Visser & Ferrer (2015)

3.1.2. Determining the actual impacts of South African agriculture sector

3.1.2.1. Environmental Impact Assessment

To determine the impact of the South African agricultural sector on South African lands in 2018, specifically the impact of agricultural production, two data sources are employed: EXIOBASE and the Our World in Data website, which aggregate research data from various organisations and scientific studies, particularly regarding the environmental impacts of agriculture. This choice was made to ensure a comparison of the data, including with respect to minimum thresholds. EXIOBASE calculates the entire value chain associated with a given economic activity, whereas the data from Rammlet et al. (2023) only account for the value chain in terms of GHG emissions. For the other three environmental dimensions—freshwater use, land-use, and nitrogen concentration—only direct impacts are considered.

South African Agriculture Sector’s impact on climate change

According to data processed by Our World in Data (2024) from the FAO, the gross value of agricultural production in South Africa amounted to $22.8 billion in 2018. This valuation encompasses the production of primary commodities and their corresponding producer prices, with the value of livestock measured based on indigenous meat production. Accordingly, the following data has been input into the model:

Table 9: Repartition of the gross value production of agriculture products in South Africa in 2018 according to the FAO and corresponding EXIOBASE sector

Item	Value in million USD	EXIOBASE sector name
Apples	453	Cultivation of vegetables, fruit, nuts
Apricots	29	Cultivation of vegetables, fruit, nuts
Asparagus	1	Cultivation of vegetables, fruit, nuts
Avocados	97	Cultivation of vegetables, fruit, nuts
Bananas	202	Cultivation of vegetables, fruit, nuts
Barley	108	Cultivation of cereal grains nec
Beans, dry	69	Cultivation of cereal grains nec
Cabbages	23	Cultivation of vegetables, fruit, nuts

Cantaloupes and other melons	13	Cultivation of vegetables, fruit, nuts
Carrots and turnips	55	Cultivation of vegetables, fruit, nuts
Cauliflowers and broccoli	7	Cultivation of vegetables, fruit, nuts
Cherries	2	Cultivation of vegetables, fruit, nuts
Chillies and peppers, green (Capsicum spp. and Pimenta spp.)	1	Cultivation of vegetables, fruit, nuts
Cucumbers and gherkins	19	Cultivation of vegetables, fruit, nuts
Figs	2	Cultivation of vegetables, fruit, nuts
Grapes	2,124	Cultivation of vegetables, fruit, nuts
Green corn (maize)	417	Cultivation of cereal grains nec
Groundnuts, excluding shelled	34	Cultivation of vegetables, fruit, nuts
Hen eggs in shell, fresh	793	Poultry farming
Lemons and limes	240	Cultivation of vegetables, fruit, nuts
Lettuce and chicory	16	Cultivation of vegetables, fruit, nuts
Maize (corn)	2,248	Cultivation of cereal grains nec
Mangoes, guavas and mangosteens	49	Cultivation of vegetables, fruit, nuts
Meat of cattle with the bone, fresh or chilled	3,441	Cattle farming
Meat of chickens, fresh or chilled	3,631	Poultry farming
Meat of pig with the bone, fresh or chilled	465	Pigs farming
Meat of sheep, fresh or chilled	873	Cattle farming
Mushrooms and truffles	37	Cultivation of vegetables, fruit, nuts
Oats	8	Cultivation of cereal grains nec
Onions and shallots, dry (excluding dehydrated)	195	Cultivation of vegetables, fruit, nuts
Oranges	451	Cultivation of vegetables, fruit, nuts
Other beans, green	12	Cultivation of vegetables, fruit, nuts
Other berries and fruits of the genus vaccinium n.e.c.	18	Cultivation of vegetables, fruit, nuts
Papayas	9	Cultivation of vegetables, fruit, nuts
Peaches and nectarines	161	Cultivation of vegetables, fruit, nuts
Pears	202	Cultivation of vegetables, fruit, nuts
Peas, green	2	Cultivation of vegetables, fruit, nuts
Pineapples	48	Cultivation of vegetables, fruit, nuts

Plums and sloes	43	Cultivation of vegetables, fruit, nuts
Pomelos and grapefruits	177	Cultivation of vegetables, fruit, nuts
Potatoes	586	Cultivation of vegetables, fruit, nuts
Pumpkins, squash and gourds	95	Cultivation of vegetables, fruit, nuts
Quinces	0	Cultivation of vegetables, fruit, nuts
Raw milk of cattle	1,284	Raw milk
Shorn wool, greasy, including fleece-washed shorn wool	677	Wool, silk-worm cocoons
Sorghum	25	Cultivation of cereal grains nec
Soya beans	517	Cultivation of cereal grains nec
Strawberries	23	Cultivation of vegetables, fruit, nuts
Sugar cane	659	Cultivation of sugar cane, sugar beet
Sunflower seed	291	Cultivation of oil seeds
Sweet potatoes	20	Cultivation of vegetables, fruit, nuts
Tangerines, mandarins, clementines	166	Cultivation of vegetables, fruit, nuts
Tea leaves	4	Cultivation of vegetables, fruit, nuts
Tomatoes	191	Cultivation of vegetables, fruit, nuts
Watermelons	17	Cultivation of vegetables, fruit, nuts
Wheat	529	Cultivation of wheat

Greenhouse gas (GHG) emissions, as reported by EXIOBASE, amount to 203.87 MtCO2e.

The GHG impacts are distributed among the studied agricultural sectors as follows:

Table 10: GHG emissions (MtCO$_2$e) from the agriculture production in South Africa in 2018 (EXIOBASE results)

EXIOBASE sector name	GHG emissions in MtCO$_2$e
Cultivation of oil seeds	1.08
Cattle farming	140.05
Cultivation of cereal grains nec	8.96
Cultivation of sugar cane, sugar beet	0.50
Cultivation of vegetables, fruit, nuts	10.71
Cultivation of wheat	2.84

Pigs farming	6.96
Poultry farming	27.84
Raw milk	4.04
Wool, silk-worm cocoons	0.88

South African Agriculture Sector's impact on freshwater use, land-use and nitrogen concentration

The data used to assess the environmental impacts of the South African agricultural sector regarding freshwater use, land use, and nitrogen concentration primarily come from the Our World in Data website, which utilises data mainly from the FAO, as well as academic research. These data have allowed for the evaluation of the direct environmental impacts of the sector on South African territory from a territorial-based production perspective. This means that the impacts are not adjusted for the exports of South African agricultural production to other countries. Consequently, the data do not account for the portion of agricultural production that is actually consumed by the South African population.

The Food and Agriculture Organization's AQUASTAT database, as processed by Our World in Data, indicates that agricultural water withdrawals in South Africa totalled 9.96 billion m^3 per year. This figure encompasses water withdrawn for irrigation, livestock, and aquaculture purposes, including various sources such as renewable freshwater, groundwater, and treated wastewater.

FAO data processed by Our World in Data (2024) reveals that agricultural land use in 2018 encompassed 96.34 million hectares, incorporating both cropland and permanent meadows and pastures. Specifically, arable land, defined as land under temporary crops, meadows, market gardens, and temporarily fallow land, accounted for 9.89% of the total land area.

Table 11: Summary of the actual impacts of the South African agriculture sector in South Africa

Environmental Variable	GHG Emissions	Freshwater Use	Land-use
Unit	$MtCO_2e$	Mm^3	km^2
Scope	Entire supply chain	Direct impacts	Direct impacts
Current impact of the South African agriculture sector in South Africa	204	9,960	40,138

3.1.1.1. Socio-economic impact assessment

This section aims to present the socio-economic impacts of the agricultural sector in South Africa at two levels of analysis. Firstly, it examines the socio-economic impacts affecting South African society as a whole, particularly food security. Secondly, it considers the impacts on the South African workforce, focusing on working conditions and gender equality.

Food Security

The FAO has developed a comprehensive set of food security indicators based on recommendations from the Committee on World Food Security Round Table on hunger measurement, held at FAO headquarters in September 2011. The following data for South Africa is available on the FAOSTAT:

Table 12: Socio-economic impacts for food security in South Africa (FAO)

Indicator	Time Period	Unit	Value
Prevalence of undernourishment	2017-2019	%	5.7
Number of people undernourished	2017-2019	Million	3.3
Prevalence of severe food insecurity in the total population	2017-2019	%	6.9

Percentage of the population unable to afford a healthy diet	2018	%	64.9 (37.2 million South Africans)

Additionally, the data collected from the study by Rammlet et al. (2023) can be included. These data represent the environmental impact required to meet the food needs of the South African population. In this research, they effectively represent the social foundation, as defined by Raworth.

Agriculture Workforce

Working conditions are also part of the socio-economic studied in this research. The data presented here are drawn from a comprehensive report on farm workers' conditions in South Africa, commissioned by the International Labour Organization's Pretoria Office. Titled "Farm Workers' Living and Working Conditions in South Africa: Key Trends, Emergent Issues, and Underlying and Structural Problems," (Visser & Ferrer, 2015). Published in February 2015, the study focuses on the working conditions of farmhands and labourers in the formal agricultural sector, including hunting, forestry, and fishing industries, during the third quarter of 2014. This research provides a detailed snapshot of employment practices, worker benefits, and labour conditions in South Africa's agricultural sector, offering valuable insights into the challenges and inequalities faced by farm workers.

Aspect	Overall	Permanent	Limited Duration	Unspecified Duration	Men	Women
Work Status	100%	51.1%	25.2%	23.6%	Higher	Lower
Written Contracts	-	92%	80.8%	40%	-	-
Modal Work Hours	41-45 hrs/week	-	-	-	41%	47%
>45 hrs/week	-	-	-	-	30%	22%
Paid Vacation Leave	46.4%	75.2%	~15%	~15%	-	-
Paid Sick Leave	35%	58.7%	~10%	~10%	-	-
Maternity Leave	5.6%	-	-	-	-	-
Paternity Leave	1.5%	-	-	-	-	-
Pension Contribution	20.6%	38.6%	<3%	<3%	-	-
Medical Aid Contribution	1.5%	-	-	-	-	-
Direct Salary Negotiation	81.4%	-	-	-	-	-
Union Negotiation	-	9.0%	0.7%	1.1%	-	-
No Regular Salary Increase	-	3.8%	14.7%	14.8%	7.9%	11.3%

Additionally, the net living wage estimated by Anker & Anker (2013) was 3,122 ZAR for farmers in the Western Cape, where most farms in South Africa are located.

Finally, gender equity remains a key socio-economic factor to assess. Share of females in total employment in agriculture, forestry and fishing 47.14% of the workforce. Regarding gender equality, various studies have demonstrated that South Africa exhibits numerous inequalities across all economic sectors, including agriculture. This gender disparity is particularly evident in wage differences between male and female workers.

Research by Visser & Ferrer (2015) provides quantitative evidence of this gender wage gap in South Africa. Their findings reveal a persistent, though gradually narrowing, disparity in earnings between men and women. Specifically, their study found that, on average and with all other factors being equal, women earned approximately 11% less than their male counterparts in 2011. In 2012, the gap decreased slightly, with women earning about 9% less than men. By 2013, the disparity had further reduced, but women still earned 6.2% less than men in comparable positions.

3.2. Data Analysis

Thanks to the data collection, it is now possible to proceed to the data analysis, which is conducted in two stages. First, the analysis of environmental data involves assessing the extent to which the actual impacts of South Africa's agricultural sector align with the two chosen thresholds: the maximum national environmental limit and the minimum environmental pressure necessary to ensure a healthy and sufficient diet, as outlined by the EAT-Lancet dietary guidelines.

3.2.1. Environmental Data Analysis

The aim of this analysis is to evaluate the impact of South Africa's agricultural sector concerning the Safe and Just Operating Space, which is defined by two thresholds: the national environmental limit for South Africa and the minimum environmental limit required to ensure a sufficient and healthy diet of 2,500 kcal per day, as specified by the EAT-Lancet.

To achieve this, two ratios are assessed:

$$\frac{Agriculture\ Sector's\ Actual\ Environmental\ Impact}{Minimum\ Required\ Environmental\ Pressure}$$

$$\frac{Agriculture\ Sector's\ Actual\ Environmental\ Impact}{National\ Environmental\ limit}$$

The following results are obtained:

Environmental Dimension	**Climate Change**	**Freshwater Use**	**Land-use**
Variable	**GHG Emissions**	**Water withdrawal**	**Arable land-use**
Unit	$MtCO_2e$	Mm^3	km^2
Minimum impact necessary for food security in South Africa	109	5,632	40,138
Current impact of the South African agriculture sector in South Africa	204	9,960	114,679.27
National environmental impact limit	398	14,196	147,745.48
Ratio actual impact / minimum impact required	**186%**	**177%**	**286%**
Ratio actual impact / national environmental limit	**51%**	**70%**	**78%**

The first environmental dimension analysed is climate change, with GHG emissions measured in $MtCO_2e$ as the primary indicator. On one hand, the results show that the impacts of the South African agricultural sector are 86% above the minimum environmental threshold needed to ensure a social foundation of 2,500 kcal per day for the South African population. This indicates that the South African agricultural sector meets the requirement to provide a sufficient social foundation as defined by the Just Space of the Doughnut model. On the other hand, the results also reveal that the climate impact, in terms of GHG emissions from the agricultural sector, represents 50% of the carrying capacity defined by the national environmental limit. This means that the emissions from the entire value chain of the agricultural sector already use 50% of the resources available within the country’s Safe Space. Consequently, only 50% of the emissions capacity remains available for other economic activities if the country is to stay within its national environmental boundary. Although the sector operates within the Safe Space of the country, this result does not clarify whether the sector's impact is excessively significant, since the maximum limit has been allocated to the country as a whole, encompassing all its economic activities and not solely the agricultural sector. However, these results provide context for understanding that the agricultural sector contributes significantly to GHG emissions, exceeding the environmental threshold. It is possible to interpret these findings as indicating the need to reduce GHG emissions to free up carrying capacity while maintaining a production level that ensures a healthy and balanced diet, defined as 2,500 kcal per person per day.

The second environmental dimension examined is freshwater use. By analysing the ratio between the actual impact of the agricultural sector on freshwater use, measured by the indicator of water withdrawal, and the minimum environmental threshold for water use necessary to maintain the social foundation for food security, the results show that the agricultural sector exceeds the minimum threshold by 77%. Although the sector meets the basic social foundation requirements, this 77% excess indicates that the sector exerts an undue impact on the available water resources. Moreover, this analysis is supported by the ratio comparing the actual water use to the maximum environmental limit. The findings reveal that the agricultural sector occupies 70% of the carrying capacity for freshwater use, leaving only 30% available for other economic activities. Given that South Africa is a country suffering from droughts and water shortages, these results suggest that the agricultural sector does not operate within a Safe Space for the environment.

The third environmental dimension analysed is arable-land use. The results show that the land allocated to cropland and grazing exceeds the minimum land required to ensure the food social foundation by more than nine times. Furthermore, the comparison between the sector's current impacts and the national environmental maximum limit defined for acceptable arable land reveals that the agricultural sector already accounts for 78% of the limit. This indicates that agriculture occupies a significant position within the land-use environmental dimension. Based on a straightforward analysis of these results, it can be considered that the agricultural sector is overshooting both the maximum and minimum limits.

These findings suggest that the South African agricultural sector is operating beyond social environmental limits across all examined parameters while attempting to meet the fundamentals of food security. For the three environmental dimensions studied, the agricultural sector functions outside the safe space defined by the doughnut model, indicating a significant occupation of the carrying capacity. Although the sector remains within national limits, it is important to consider the contribution of other socio-economic sectors to the achievement of planetary boundaries. Notably, the agricultural sector exceeds the threshold necessary for food security. This raises the need for reflection on how the carrying capacity is utilised for the well-being of South Africans, considering factors such as dietary habits and export demands. In 2020, horticulture emerged as the leading agricultural export product of South Africa, with a value of 5.4 billion U.S. dollars, followed by cereal exports at 1.1 billion U.S. dollars. Additionally, other agricultural products accounted for 931 million U.S. dollars in total exports (Cowling, 2024).

3.2.2. Socio-economic Data Analysis

The results obtained are summarised in the table below.

Table 13: Socio-economic impacts of the agriculture sector compared to the social threshold analysis

Indicator	Current impact	Boundary
Wage	3,122 ZAR	5,120 ZAR
Gender wage gap	6,20%	0%

Work superior to 45 hrs/week		
Men	30%	0%
Women	22%	0%
Paid Vacation Leave	46,40%	100%
Paid Sick Leave	35%	100%
Maternity Leave	5,60%	100%
Paternity Leave	1,50%	100%
Pension Contribution	20,60%	100%
Medical Aid Contribution	1,50%	100%
Direct Salary Negotiation	81,40%	100%
Union Negotiation		
Permanent	9,00%	100%
Limited Duration	0,70%	100%
Unspecified Duration	1,10%	100%
No Regular Salary Increase		
Permanent	3,80%	100%
Limited Duration	14,70%	100%
Unspecified Duration	14,80%	100%
Prevalence of undernourishment	5.7%	0%

Prevalence of severe food insecurity in the total population	6.9%	0%
Percentage of the population unable to afford a healthy diet	64.9%	0%

These figures indicate that the data collected for each indicator does not meet the expected thresholds. None of the socio-economic indicators appear to reach the desired targets. This can partly be attributed to the use of absolute limits, set at 100% or 0% (depending on the indicator's formulation), based on the assumption that well-being should be achieved for the entire population. Additionally, the ratio between the actual wage and the comparison with the decent living wage shows that the current wage is 40% lower than the established threshold. Regarding gender equality, a gap in the wages earned is not be noted.

Overall, in South Africa, most indicators reveal that the workers are affected by unfair working conditions. Regarding food security indicators, it is observed that the prevalence of the population lacking access to sufficient and healthy diets remains in the millions, demonstrating the persistence of food insecurity in the country. Thus, it can be considered that the agricultural sector does not adequately address this dimension. These results highlight the persistent challenges in South Africa's agricultural sector regarding fair working conditions and food security for the population, emphasising the need for substantial improvements to meet the set socio-economic objectives.

3.3. Data Analysis conclusion

The collected data and their interpretation indicate that the agricultural sector in South Africa does not fully align with Safe and Just Space. While agricultural activity occupies a significant position within the country's socio-economic landscape, this analysis does not aim to establish a definitive benchmark for the sector. As a result, it is not possible to determine precisely whether the agricultural sector is meeting its expected objectives or by what percentage it exceeds or falls short in terms of resource consumption.

The findings suggest that the agricultural sector produces more than is necessary to ensure food security within the country. However, this analysis does not account for the specific consumption patterns of South Africans, indicating that a portion of the production is likely destined for export. Thus, while the sector does contribute to national food security, the resources it consumes already occupy a significant share of the country's environmental limits, raising critical questions regarding sustainability.

Moreover, the socio-economic data collected provide insights into the state of food security across the nation. Although the overall production appears sufficient to ensure food security, a portion of the population continues to suffer from undernourishment and lacks access to a healthy and sufficient diet. This situation raises concerns about the equitable distribution of agricultural production.

Finally, the socio-economic indicators also highlight that the working conditions of those directly involved in the agricultural sector, specifically the labour force, fall short of what is necessary to ensure their well-being. For instance, in the Western Cape region, wages are not adequate for agricultural workers to maintain a decent standard of living, and significant gender disparities persist in terms of pay. Additionally, many social benefits are not guaranteed for these workers.

Figure 6: South African agriculture impacts on climate change compared to thresholds

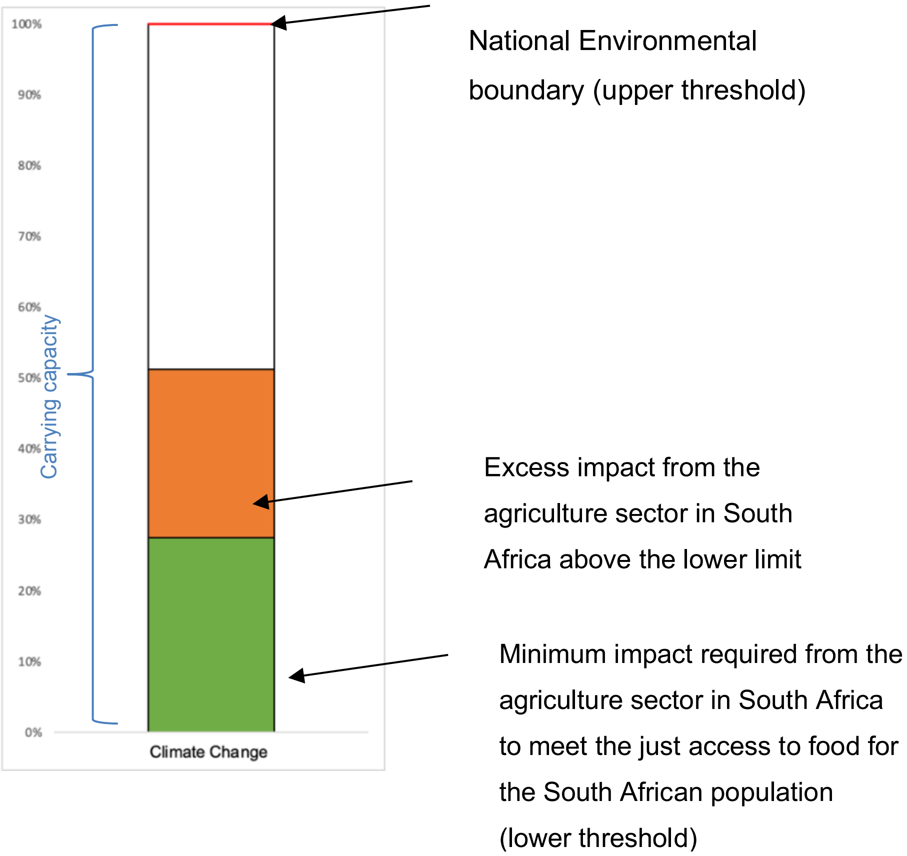


Figure 7: South African agriculture impacts on freshwater use compared to thresholds

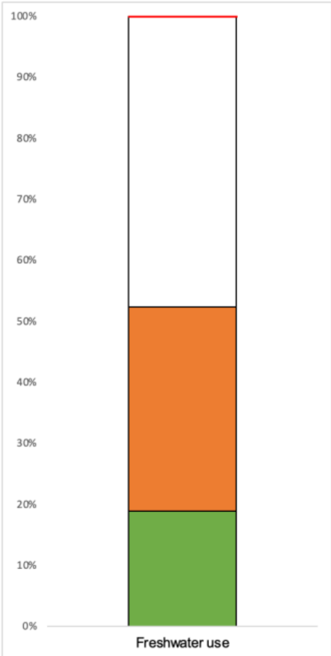
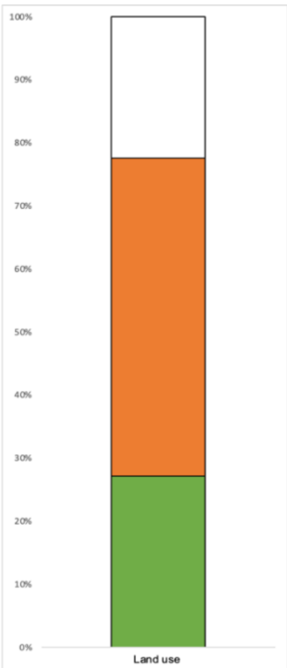


Figure 8: South African agriculture impact on arable land use compared to thresholds



CHAPTER 4. DISCUSSION

This chapter discusses the research findings in relation to the study's objectives and evaluates how these findings align with the aim of the research. The aim of this thesis is to explore whether the Doughnut model serves as a relevant and operational tool for contextualising the environmental and social impacts of an economic activity. The case study of the agricultural sector in South Africa approach is used as an exploratory approach. The case study research framework is divided in three defined research objectives for each step of using the Doughnut model to contextualise an impact. To recap, the three research objectives are:

- Objective 1: To define the Safe and Just Operating Space for South Africa's agricultural sector by establishing environmental and social thresholds, including national environmental boundaries, minimum environmental impacts for food security, and socio-economic deprivation indicators for agricultural workers and the general population.
- Objective 2: To assess the extent to which the actual environmental impacts of South Africa's agricultural sector align with the upper and lower environmental thresholds to determine whether the sector remains within the safe space.
- Objective 3: To evaluate the level of social deprivation in South Africa's agricultural sector by analysing key socio-economic indicators related to food security, working conditions, social well-being, and gender equality for agricultural workers to determine whether the sector remains within the just space.

Applying this methodological approach to a real-world scenario allows to reveal the advantages and limitations of the Doughnut model in impact assessment, which are explored in this chapter.. It is important to note that the application of the Doughnut model discussed here concerns how it is used in this research, primarily based on the principles of sufficientarianism and justice. The discussion is therefore confined to this specific use of the Doughnut model within the context of environmental and social impact contextualisation.

1. Technical considerations

This section examines the technical aspects of using the Doughnut model for impact contextualisation. The discussion begins with an interpretation of the analysis results, comparing them with previous research to assess their consistency with earlier findings. Additionally, this section addresses the technical challenges encountered during data transcription and allocation, particularly those related to the choice of the sufficientarian approach.

1.1. Results interpretation and coherence check

The research findings provide a contextualisation of the environmental and social impacts of the agricultural sector in South Africa. The Doughnut model is applied to evaluate these impacts within the South African agricultural sector. The case study, through Objective 2, demonstrates that the model allows for contextualising results using absolute environmental boundaries, including a maximum national limit and a minimum national limit required to meet the food needs of the South African population. Objective 3, using deprivation indicators (unmet needs compared to an acceptable standard of living), reveals that the agricultural sector operates below the expected social foundation threshold. To confirm the consistency of these quantitative results, this section compares them with other studies to interpret and ensure the coherence of results across different studies.

Regarding climate change, the impact of the agricultural sector is found to be significant, as the results indicate it represents half of the climate's carrying capacity and operates well above the social threshold. This can be explained partly because the results consider the entire supply chain, including upstream and downstream sectors. Additionally, livestock is identified as a major contributor to climate impact, with EXIOBASE results showing that cattle and poultry farming alone generate 167.90 $MtCO_2e$, largely due to the significant use of coal-based electricity production, as indicated by EXIOBASE findings. The production of red meat itself is notably GHG-intensive, emitting 99 $kgCO_2e$ per kg, according to Poore & Nemecek (2018), processed by Our World in Data. Moreover, coal production is highly emissive, being the largest source of GHG emissions in South Africa in 2021, accounting for 83% of total GHG emissions from fuel combustion, as reported by the IEA (2024). Thus, the interpretation of the results aligns with the case study analysis, indicating that the South African agricultural sector does not operate within the Safe Space of South Africa due to significant GHG impact.

Similarly, the results for freshwater use demonstrate that the agricultural sector occupies a significant share of the carrying capacity of this environmental dimension, also operating above a minimum threshold. The findings of this research are consistent with the water footprint data by Pahlow et al. (2015), who estimate that crop production contributes about 75% of the total national water footprint, with maize, fodder crops, sugarcane, wheat, and sunflower seed accounting for 83% of the crop water footprint. Freshwater use is crucial in South Africa for crop production and the general population, as 80% of South Africa is classified as semi-arid to arid, with only 18% being dry sub-humid to sub-humid, thus limiting the potential for crop cultivation, according to Bonetti et al. (2022). In this context, contextualising impacts by commercial agriculture companies could foster a quantitative perspective on sustainable water management in the country. Commercial agriculture production, heavily dependent on irrigation, accounts for approximately 60% of total water withdrawals (Bonetti et al., 2022).

Finally, regarding land use, the contextualisation result is the most significant. The findings show that agriculture occupies nearly all remaining arable land in South Africa, almost twice the minimum area required to ensure the social food foundation. This high result can be explained by the fact that the national limit for arable land is already intrinsically linked to the agricultural sector. As Goldblatt (2011) notes, arable land is scarce, with a large portion dedicated to animal feed. It is important to recall that the minimum environmental limit for land use used in this study is not defined by the 2,500-kcal threshold but rather by a portion of land per hectare, as defined by Myers in 1998. Therefore, this threshold may differ significantly from what would have been found using the 2,500-kcal limit.

Furthermore, the socio-economic indicators chosen for food security reveal that food security is not assured for a portion of the population. Van den Berg and Walsh (2023) note that, at the national level, South Africa is considered food-secure, but there is widespread agreement that household food insecurity remains a serious problem. Chakona and Shackleton (2019) explain that household food insecurity in South Africa is closely linked to household socio-economic status, indicated by income, employment status, and food expenditure. Therefore, total household income is crucial in achieving food security, and with high levels of poverty, it is challenging for most South African households to purchase enough food to feed the entire household (Chakona & Shackleton, 2019). Furthermore, food security is experienced differently across social groups, as shown by Brown et al. (2024), who examine the meaning of food for young people living in urban informal settlements and rural villages in KwaZulu-Natal. Beyond nutrition and sustenance, food also carries significant cultural and social meanings that influence young people's perceptions and experiences of food insecurity (Brown et al., 2024). Gender also impacts the relationship with food insecurity (Brown et al., 2024).

The indicators and data collected on working and social conditions for workers show that minimum rights are not met. This aligns with Devereux's (2020) research on violations of farm workers' labour rights in post-apartheid South Africa. This research indicates widespread non-compliance by employers with labour rights (Devereux, 2020). Many farm workers interviewed have never signed an employment contract and are paid less than the statutory minimum wage (Devereux, 2020). Employers avoid paying full wages, and many do not pay unemployment insurance contributions for their workers (Devereux, 2020). The majority of women surveyed do not have access to toilets while working in vineyards and orchards (Devereux, 2020). Injuries at work often go unreported, so workers do not receive compensation, and many injured workers have to pay their medical bills (Devereux, 2020). Devereux (2020) adds that a high proportion of workers are exposed to pesticides that cause health problems such as skin rashes and breathing difficulties, but farmers rarely provide protective clothing.

Gender equality is also shown in the results which is supported by recent case studies such Mkuna & Wale (2023) who provides a sector-specific evidence of gender inequality in agriculture. Their research, focusing on small-scale irrigation farmers in KwaZulu-Natal, revealed that male farmers earn significantly higher on-farm income than female farmers, with a difference of about R26,788 per cropping season (Mkuna & Wale, 2023).

Thus, the interpretation of the results aligns with the scientific literature, indicating that the methodology employed in this research effectively contextualises impacts and demonstrates a certain level of viability. However, using the Doughnut model reveals several technical limitations, particularly when applied at the corporate level and in implementing the Safe and Just Space.

1.2. Technical Limits

The interpretation of the results, and their comparison with other real-world research, has shown that the Doughnut model facilitates the quantitative contextualisation of results by using absolute limits. However, the case study also highlights several limitations and challenges when attempting to downscale the Doughnut model.

A first technical limit is linked to the nature of the data collected allowing a smooth. transcription between the data of the thresholds and with the actual. Data availability both for the actual impacts but also for the thresholds is concern noted by Turner and Wills (2022) who describe the difficulties involved in adapting the Doughnut model to a local context, particularly concerning data availability—a significant constraint encountered in the case study. To apply this model effectively to impact assessment, an entity studied must have precise knowledge of their environmental and social impacts in the countries where they operate. For example, this approach would require companies to assess their impacts not only in the countries where their products are produced but also where they are consumed, necessitating a detailed understanding of their entire supply chains. In a globalised economy, tracing a company's impacts across its entire value chain is a complex task. One practical solution, employed in the case study, is the Environmentally Extended Input-Output Analysis, which links biophysical resource flows and environmental impacts to the monetary transactions of goods and services through global supply chains (Li et al., 2021). In this research, EXIOBASE model is used to explore the interdependencies between the GHG emissions and economic factors for example. The second data availability challenge regards the need to compare these impacts against environmental limits specific to the country or sector in question. Turner and Wills (2022) considers identifying suitable methodologies for downscaling boundaries a challenge, as boundaries are often global in nature but may have identifiable national or local thresholds. Fanning et al. (2021) are able to partially answer that problem by developing a website that enables the visualisation and comparison of nations' environmental and social progress relative to the Doughnut of social and planetary boundaries for most countries worldwide, suggesting that access to such thresholds is theoretically possible. A final consideration for transcription is the fact that even if data is available, making sure that the scope, the definition of the indicator and its unit fit with the other data collected from the same environmental dimension. Incoherent results might happen if these precautions are not being taken into account. This was the case with the environmental dimension of land use, where the minimum environmental limit had to be adjusted to align with the indicator used by Cole et al. (2014) in their definition of the South African Doughnut.

A second technical limit noted in this research is the allocation process that is not straightforward. To make sure the boundaries are downscaled to fit the local contexts, a major component of this thesis involves the search for an allocation factor that is as fair as. This led to adopting the principle of sufficientarianism as defined by Heide et al. (2023), grounded in the notion of distributive justice and closely linked to ecosystem services. Thus, instead of setting a maximum limit for a specific economic activity, this thesis focuses on proposing a minimum threshold to meet basic human needs, specifically in the context of the agricultural sector, where food security is a primary concern. However, defining a sufficiency limit is challenging because it is an arbitrary standard that is difficult to justify (Davies, 2023). For example, in the case study, the sufficiency threshold for food is set at 2,500 kcal per day, based on the diet defined by the EAT-Lancet Commission. Although there is some consensus around this study, it has faced criticism. Verkerk (2019) critiques the westernisation, simplification, and globalisation of diets, arguing that these trends pose significant challenges for both people and the planet. Verkerk (2019) also consider that this type of diet is made by policymakers and researchers with strong ideological beliefs but little practical experience in diverse ecotypes of nutrition or sustainable agriculture. This lack of practical knowledge means that critical examples, such as resolving autoimmune conditions through specific dietary changes or restoring marginal grasslands by reintroducing livestock, often go unnoticed (Verkerk, 2019). Moreover, Beal et al. (2023) find that this diet presents micronutrient deficiencies which could lead to substantial public health burdens compared to what might be achieved in a fully nourished population. Consequently, rather than prescribing a planetary health diet universally, it might be more effective to recommend locally appropriate diets that meet nutrient needs and adhere to local dietary guidelines, accounting for different cultural contexts and environmental conditions (Beal et al., 2023).

Hence, this reflection prompts a deeper consideration of the ethical issues underlying the definition of thresholds for a Safe and Just Space.

2. Ethical Considerations

Numerous frameworks have attempted to clarify the complexities involved in defining a Safe and Just Space, yet it remains challenging to justify these approaches on a local scale or from an ethical standpoint, particularly when determining which products/economic activity should be allocated a larger share of the carrying capacity. From the beginning of this research, the notion of allocating a portion of carrying capacity to economic activities, and thereby defining a Safe and Just space, has raised significant ethical concerns (Lavisse et al., 2024). The alternative approach of sufficientarianism was selected for its ethical appeal; however, it also represents a substantial barrier to promoting a standardised impact reporting system based on the Doughnut model and planetary boundaries. This suggests that the model may not be universally applicable across all sectors, given the varying impacts and importance of different economic activities to human well-being. Furthermore, this research appears incomplete in its contextualisation of impact. Although the national environmental boundary, a maximum limit, was considered, the search for an allocation factor consistent with the thesis's problem did not succeed in defining a carrying capacity limit for a specific sector, economic activity, or company. Therefore, this initial issue remains unresolved due to this methodological gap, demanding further exploration of this discussion through the lens of justice considerations.

2.1. Classifying Economic Sectors

Davies (2023) argues that sufficientarianism presents a challenge in setting non-arbitrary thresholds. The concept of thresholds involves moral implications: two individuals should be treated differently if one is above and the other is below the threshold, even if their differences are minor (Davies, 2023). This raises questions within this research about how to classify needs and determine which economic products/activity are more essential to humans than others, thus deserving more allocated resources. According to Heide et al. (2023), the philosophical foundation of this issue lies in distinguishing between necessities and luxuries, focusing on meeting essential needs while avoiding excesses that harm the environment. Davies (2023) further examines this by discussing the justification for sufficiency thresholds. He identifies the problem of "expensive tastes," where individuals are not satisfied unless they achieve a quality of life significantly better than what most would consider acceptable (Davies, 2023). Thus, according to Davies (2023), this depends on a concept known as hedonic adaptation—where people adjust their goals and desires to new circumstances, suggesting that focusing on subjective assessments of personal satisfaction might tolerate more inequality than an approach centered on objective goods.

According to Heide et al. (2023), this perspective justifies the approach of sufficientarianism. The current disparity between those lacking basic necessities and those living in abundance underscores the need to prioritize goods that satisfy fundamental needs over luxuries that impose significant environmental impacts (Heide et al., 2023). While human needs are consistent across different contexts, their fulfillment varies based on individual preferences and environmental conditions; beyond a certain point, additional resources do not enhance well-being (Heide et al., 2023). Davies (2023) partially supports this view, arguing that it is not about assuming a uniform view of what constitutes a valuable life but instead focusing on the common requirements necessary for pursuing a range of values, especially in terms of autonomy or freedom. Therefore, Heide et al. (2023) suggest that products should be evaluated based on their capacity to meet essential needs or their tendency to contribute to excessive luxury. On an individual level, ethical decisions regarding desires should consider their environmental footprint and feasibility within a safe operating space (Heide et al., 2023).

Thus, not all sectors are equal, and according to the principle of sufficientarism, sectors that do not serve to meet essential needs and ensure decent living standards should theoretically be allocated less environmental space and should not worsen social inequalities. Therefore, the use of the Doughnut model in the way proposed in this research does not seem suitable for companies operating in non-essential sectors.

2.2. Completing Thresholds with Justice Considerations

The sufficientarianism perspective also raises questions regarding an upper limit. In the case study, only the sufficiency threshold was defined, with no maximum threshold established for the agricultural sector. Consequently, the Safe and Just Operating Space for the sector remains undefined. The question of an upper limit, based on distributive justice, also emerges, underscoring the difficulties in applying a universal framework to sectors with varying roles and impacts.

Hickey (2023) explores the concepts of sufficientarianism and limitarianism, both central to discussions on distributive justice. While sufficientarianism, widely debated in the literature, emphasises ensuring everyone has enough of certain essential goods, limitarianism, a newer concept introduced by Ingrid Robeyns (2022), argues against the moral permissibility of possessing an excessive amount of certain goods, thus setting an upper limit on justifiable resource holdings. Therefore, sufficientarianism establishes a minimum threshold everyone should attain, while limitarianism sets a maximum threshold no one should exceed, effectively delineating permissible resource holdings within these two limits (Hickey, 2023). This framework further allows for recognising varying degrees of ethical transgressions (Hickey, 2023). For instance, if an individual significantly exceeds the upper threshold, their actions are deemed more ethically problematic than if they exceed it by a smaller margin (Hickey, 2023). This reflects the notion that greater excesses raise more significant ethical concerns by diverting resources that could address more urgent needs (Hickey, 2023).

Limitarianism is also supported by Gupta et al. (2023) in their vision for Earth System Justice, emphasising the importance of justice in contextualised impact assessment and acknowledging the socio-ecological realities of impacted territories. Gupta et al. (2022) argue that incorporating justice helps move away from an anthropocentric view towards a more inclusive framework that recognises the rights and needs of non-human entities. The research reframes Earth System Justice to encompass a broader scope by integrating three dimensions of justice: interspecies justice, which stresses ethical obligations towards non-human species and the stability of Earth's systems; intergenerational justice, which focuses on fairness across generations to ensure that future generations have access to the same resources and opportunities as the current generation; and intragenerational justice, which considers equity within the current generation, including international, inter-community, and individual justice (Gupta et al., 2022). This comprehensive approach to justice aims to address not only human well-being but also the health and stability of broader ecological and social systems (Gupta et al., 2022). Therefore, beyond guaranteeing minimum access to resources, as examined in the case study, Gupta et al. (2022) also explain that the upper limit of carrying capacity must be defined by the equitable allocation of remaining resources and responsibilities, addressing key drivers of Earth system change and vulnerability: inequality, overconsumption, and harmful accumulation and investment, using concepts like limitarianism. Lastly, Gupta et al. (2022) emphasise that an equitable allocation of responsibilities regarding harm caused is crucial, as those most affected by negative environmental impacts are often the least responsible for them (Gupta et al., 2022). These three perspectives on justice—interspecies and Earth system stability, intergenerational, and intragenerational—highlight the complexity of defining a space that is truly Safe and Just (Gupta et al., 2022).

Furthermore, Brand et al. (2021) propose a new paradigm shift towards societal boundaries instead of the traditional boundaries offered by the Doughnut. According to Brand et al. (2021), societal boundaries are not determined solely by biophysical processes but instead arise from dynamic social processes, resulting in collectively agreed-upon thresholds that societies pledge to respect. These boundaries address issues such as poverty, inequality, ecological degradation, injustice, subordination, exploitation, resource consumption, and the protection of shared resources and are fundamentally structural, shaped by political frameworks within societies (Brand et al., 2021). Rather than viewing the planet as inherently limited, the concept of societal boundaries calls for seeing it as potentially plentiful, provided that society collectively impose self-restraint and ensure equitable resource sharing among both present and future generations (Brand et al., 2021). This perspective highlights the importance of collective self-limitation, or autonomy, which is understood not as complete independence but as the capacity for self-governance and responsible decision-making (Brand et al., 2021).

2.3. Reflection on the Agricultural Sector in South Africa

These new theoretical contributions on justice suggest that the Safe and Just Space defined for the agricultural sector may not be entirely "safe" or "just," as it overlooks several crucial aspects of justice, history, and culture that a quantitative approach of the Doughnut model may not adequately capture.

For example, in South Africa, agriculture is particularly shaped by the history of apartheid while remaining a significant livelihood factor (Akinyemi & Mushunje, 2019). Commercial agriculture in South Africa was historically state-subsidized and heavily state-regulated, ruled by state interventions that favoured predominantly White commercial farmers to the detriment of their Black workers (Kheswa, 2015). Akinyemi & Mushunje (2019) note that after the apartheid, South Africa had approximately 82 million hectares of white-owned agricultural land and the democratic government pledged to redistribute 24.5 million hectares to previously disadvantaged South Africans, predominantly black residents of the former homelands, by 2014 (Akinyemi & Mushunje, 2019). Hence, a boundary that considers intergenerational justice, as proposed by Gupta et al. (2022), should be taken into account.

Moreover, other societal considerations are often overlooked when the Doughnut is assessed using only quantitative data. Akinyemi & Mushunje (2019) observe that, over the last decade, land has shifted away from farming towards non-agricultural uses such as game farms, golf courses, housing, and holiday estates. Despite this decline in farming activities, land-based livelihoods remain significant in rural areas of South Africa, where alternative employment opportunities are limited (Akinyemi & Mushunje, 2019). Fisher et al. (2024) also highlight this issue, noting that South African smallholders have increasingly disengaged from farming in recent decades, despite the lack of alternative livelihoods and the deepening of rural poverty. This deagrarianisation within South African smallholder communities is part of a broader global phenomenon (Fisher et al., 2024). Furthermore, the growing dominance of powerful agricultural input suppliers and supermarkets, coupled with intense competition for land, has driven smaller farms out of business, leading to farm upscaling and increased agricultural industrialisation (Fisher et al., 2024). Furthermore, Ritchie & Roser (2024) caution that agricultural employment data should be used carefully, as much agricultural employment is informal and unrecorded in many countries, including significant work performed by women and children. Rogan (2019) found that informal employment represents about 24 per cent of total agricultural and non-agricultural employment in the eight major South African metropolitan areas, and around 30 per cent of total employment in the country. In this context, a boundary incorporating intragenerational justice between communities, as proposed by Gupta et al. (2022), could be considered.

An additional environmental consideration is the use of land for agriculture in South Africa. This research considered the use of arable land by agriculture, and the space occupied by the agricultural sector is significant. This finding is particularly relevant when considering agricultural land use in general. Agriculture accounts for approximately 80% of South Africa's land resources, with grazing land amounting to 84 million hectares in 2018 (HYDE 2023, with minor processing by Our World in Data), while Rammelt et al. (2022) allocate only 2,276 hectares in their definition of minimal pressures for a 2,500 kcal diet. Meissner et al. (2013) note that livestock farming in South Africa occupies about 70% of agricultural land. However, Ritchie & Roser (2024) point out that while the FAO attempts to impose standard definitions and reporting methods, complete consistency across countries and over time is not always possible. Therefore, data on agricultural land across different climates may not be directly comparable. For example, permanent pastures differ significantly in nature and intensity between African countries and dry Middle Eastern countries. In South Africa, grazing and livestock is an integral part of rural livelihoods, with communal grazing systems occupying only 17% of the total farming area but sustaining 52% of the cattle, 72% of the goats, and 17% of the sheep.

These reflections highlight the necessity of incorporating more nuanced understandings of justice and equity when defining frameworks such as the "Safe and Just Space," particularly in sectors with complex socio-economic histories like agriculture in South Africa. This raises important questions about the challenges of contextualising impacts within diverse socio-economic realities and the evolving definition of what constitutes sustainability. As Li et al. (2020) point out, these boundaries are not fixed constructs but are subject to change over time, influenced by complex ecological feedbacks. Li et al. (2021) emphasise the importance of a local boundary-defining process that encompasses more than just environmental considerations, addressing competing socio-economic interests from citizens, businesses, society, and the overall health of ecological systems. Public participation is crucial in operationalising the Doughnut model as regional or national commitments that reflect public perceptions of how specific planetary boundaries affect livelihoods since different communities may have varying priorities for their local share of resources (Li et al., 2021). Thus, determining what constitutes a fair and just share of the safe, local operating space is not purely a scientific endeavour but also involves significant ethical and normative considerations (Li et al., 2020).

In conclusion, this chapter has evaluated the research findings in light of the study's objectives, offering insights into the practicality and relevance of the Doughnut model for contextualising environmental and social impacts within the agricultural sector in South Africa. The findings reveal that while the Doughnut model provides a useful framework for assessing impacts through defined environmental and social thresholds, its application also presents several challenges. The technical limitations related to data availability and the complexities of downscaling global planetary boundaries to a local context are significant hurdles. However, the research has demonstrated that the model can be operationalised to provide meaningful insights into sustainability, particularly by adopting a sufficientarian approach to ensure that basic human needs are met.

The chapter also explored the ethical considerations involved in defining a "Safe and Just Space" for economic activities. The notion of sufficientarianism was crucial in determining thresholds for the agricultural sector, yet the research highlighted the need to address additional justice concerns, such as intergenerational and interspecies equity, as well as socio-economic realities shaped by historical and political contexts, especially in South Africa. The use of the Doughnut model must be sensitive to these justice dimensions, and the findings suggest that further refinement is needed to ensure that it can comprehensively address the diverse needs and impacts of various sectors.

In summary, while the Doughnut model offers a promising tool for impact contextualisation, the study identifies both its strengths and areas where further development is required, particularly in refining allocation methods and addressing ethical issues in defining a truly "Safe and Just Space" for sustainable development

CHAPTER 5. CONCLUSION, LIMITS AND FUTURE RESEARCH

1. Conclusion

The aim of this research was to explore the relevance of using Raworth's (2012) Doughnut Model to contextualise the environmental and social impacts of economic activity, using the agricultural sector in South Africa as an exploratory case study. The objectives of this research were to define Safe and Just space of South Africa for the agriculture sector and then assess whether this sector operates within the by studying its environmental impacts in relation to the country's environmental ceiling and its social impacts in comparison to the social floor.

The results of the case study demonstrated that it is indeed possible to use the Doughnut Model to provide context for the impacts of an economic activity. Key findings revealed that the South African agricultural sector represents a significant portion of the carrying capacity in the three environmental dimensions studied: climate change, freshwater use, land use. Regarding the lower environmental floor, the comparison with minimum limits for access to a healthy and sufficient diet showed that the South African agricultural sector produces well above the expected limits to allow South Africans access to such a diet. However, while the South African production is sufficient to fulfil the basic need of access to enough food for its population, the agricultural sector does not meet the social floor of the Doughnut as food security is not ensured in the country. The agriculture sector does not meet the social floor of the Doughnut in terms working and social conditions for the works. Issues such as below-living wages, gender pay inequality, and lack of social privileges for workers persist, indicating that while production is adequate, distribution and access remain problematic, and the sector is failing to meet several aspects of the social floor.

By applying the Doughnut Model to the South African agricultural sector, this research demonstrated its potential as a tool to provide contextual precision in impact assessment of economic activities within ecological and social boundaries. Importantly, it also allowed for a new vision of the role of a business or any organisation in a given society and territory, enabling an understanding of its impact beyond its direct operations. This approach offers a more nuanced understanding of sustainability than traditional relative and auto-referential metrics alone, potentially informing new strategies and models for organisations in the territories where they are present.

However, the various obstacles and challenges encountered in this research demonstrate that while the Doughnut Model provides valuable insights, its application to assessing environmental and social impacts is not straightforward. One significant technical limitation is data availability, as organisations need to understand and measure their impacts across their entire supply chain while being aware of the Doughnut thresholds for each country. Moreover, defining fair and ethical thresholds for the Safe and Just Space is complex and intrinsically linked to notions of justice. This raises important questions about the ability the smooth standardisation of this approach across impact assessment. As the Doughnut model can serve as a useful compass for organisations, this showed that any contextualised impact assessment must be considered from the perspective of environmental and social justice. Thus, integrating justice is crucial for designing stronger targets and modifying them to steer economic policies towards more equitable outcomes, as Gifford et al. (2022) argue. Justice-based targets can offer a starting point for addressing the root causes of consumption, instead promoting market-based mechanisms that perpetuate inequality, limited access, greenwashing, and harm (Gifford et al., 2022).

2. Limits of the research

Despite the valuable insights provided by this research, several limitations are associated with the methodological considerations and the application of the Doughnut model for impact contextualisation.

The primary methodological limitations involve challenges in accessing precise data for complex indicators. The accuracy and quality of studies relying on the Doughnut model heavily depend on the availability and granularity of both impact data and threshold data, which are not always directly comparable. Furthermore, these studies often depend on secondary data sources, necessitating careful attention to ensure that the scope of the measured impacts is accurately understood. Currently, standardization in reporting practices is lacking. However, it is worth noting that regulations on ESG reporting, particularly within the European Union, are becoming more detailed and comprehensive. This trend may enhance access to more robust data within the EU in the future.

Another critical issue relates to the variability in data sources, which can significantly impact the consistency and precision of results. Data often originate from diverse sources with differing methodologies, leading to non-uniform results. For example, the scope of impacts considered may vary substantially between different studies. Defining the scope of analysis is therefore crucial for accurate comparisons. For instance, Climate Watch estimated in 2021 that South Africa's agricultural sector contributed 32.2 $MtCO_2e$ in GHG emissions, representing 6.31% of the country's total emissions. In contrast, EXIOBASE data from this research indicates that the sector produces 200 $MtCO_2e$. Such discrepancies underscore the importance of a consistent approach to defining and measuring impacts to ensure reliable comparisons.

Another major consideration in this research is the distinction between consumption-based and production-based perspectives. According to the Global Carbon Budget (2023), processed by Our World in Data, consumption-based emissions allocate the emissions generated during the production of goods and services to the location where they are consumed, rather than where they are produced. Consumption-based emissions are calculated as production-based emissions minus emissions embedded in exports, plus emissions embedded in imports. This research did not address the consumption-based perspective due to limitations encountered when using EXIOBASE. However, most research on downscaling adopts a consumption-based approach, which is crucial for understanding the full environmental impact and its effects on different countries (Li et al., 2021). Focusing solely on domestic resource use can provide an incomplete picture of environmental and socio-economic impacts, especially as countries increasingly rely on global trade to drive development by sourcing goods and services worldwide (Li et al., 2021). Incorporating a consumption-based perspective that acknowledges global trade connections is vital for a comprehensive understanding of these impacts. Ignoring the role of global trade risks significant biases in understanding and managing planetary boundaries (Li et al., 2021). For example, in 2018, South Africa's territorial-based GHG emissions were 435

MtCO2e, while its consumption-based emissions were 324 MtCO2e (Global Carbon Budget, 2023). The lower consumption-based emissions indicate that South Africa is a net exporter of carbon dioxide. Therefore, evaluating South Africa's GHG emissions impact requires considering both production and consumption perspectives to provide a complete understanding of its environmental impact, especially from the perspective of equitable impact distribution, as most GHG emissions might not be attributable to the South African population.

Another significant limitation of this research is the reliance on the EXIOBASE model, which has inherent constraints. EXIOBASE relies on fixed coefficients and general estimates, offering a static rather than dynamic view of economic and environmental interactions. The model typically uses data from a single reference year and does not account for the evolution of economic variables and their impacts over multiple years. As a result, it fails to capture changes in impact trajectories over time, complicating the assessment of long-term trends or the critical evaluation of a country's direction concerning environmental sustainability and economic development.

Finally, this research did not compare the agricultural products from the EAT-Lancet diet, as used by Rammelt et al. (2022), with the actual agricultural production of the South African agricultural sector. Therefore, some of the agricultural products defined in the EAT-Lancet diet may not be produced in South Africa, meaning the country may need to import them.

3. Areas of future research

Future research is crucial to further explore the contextualisation of impacts within ESG reporting, alongside the application of the Doughnut model.

One avenue for further research would be to test additional case studies across different territories and sectors to deepen the methodological insights proposed in this study. For instance, fully implementing the diverse thresholds of justice as outlined by Gupta et al. (2022), or attempting to apply Brand et al.’s (2021) concept of societal boundaries to a specific case study, could be particularly illuminating. In this regard, Sobkowiak et al. (2023) propose rethinking ecological boundaries through postcolonial studies, ecofeminism, storytelling, or art-based approaches. Further exploration into how businesses incorporate notions of environmental and social justice could also be valuable.

Additionally, it would be insightful to assess more bottom-up applications of the Doughnut model. While this research adopts a macro perspective on the Doughnut, a bottom-up approach may offer a more practical framework for impact assessment. This would allow companies to use the Doughnut as a strategic tool, as envisioned by Raworth (2012). For example, the French sustainable development consultancy, UTOPIES®, suggests that companies use the Doughnut model to contextualise their socio-economic impacts, thus broadening their understanding of their societal contribution beyond purely economic benefits. This approach could better reflect the needs of the countries in which the companies operate by applying country-specific Doughnut models, taking into account local environmental and social challenges to identify key issues within their global value chains. Moreover, the SDPI (Sustainable Development Performance Indicators) could also provide a more tailored, bottom-up approach by offering companies specific indicators aligned with the sustainable quotient to genuinely explore and reflect upon their impacts.

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ANNEXES

Glossary

Absolute Environmental Sustainability Assessment (Hjalsted et al., 2021): Its primary objective is to ascertain the environmental sustainability of anthropogenic systems in absolute terms, encompassing a comprehensive array of impact categories. The assessment framework is designed to evaluate whether such systems operate within the boundaries of environmental sustainability. This approach involves a direct comparison between the environmental impacts generated by an anthropogenic system and the regional or global environmental limits. It offers a means to not only evaluate current environmental performance but also to set tangible targets for achieving sustainability in the future.

Carrying capacity (Bjørn et al., 2020): "The maximum persistent impact that the environment can sustain without suffering perceived unacceptable impairment of the functional integrity of its natural systems or, in the case of non-renewable resource use, that corresponds to the rate at which renewable substitutes can be developed."

Context-based sustainability (Haffar & Searcy, 2018): This concept refers to the broader socio-ecological system within which a company operates, encompassing the thresholds this system imposes on company performance throughout its value and supply chain. In corporate reporting, the principle of 'sustainability context' stipulates that performance disclosures must be reported in relation to these limits. This approach emphasises the importance of evaluating corporate sustainability performance within the context of broader environmental and social boundaries, rather than in isolation or solely against industry benchmarks. By considering sustainability context, companies and stakeholders can gain a more comprehensive understanding of corporate sustainability impacts and progress.

Doughnut Economics (Sahan et al., 2021): Doughnut Economics is a framework introduced by Kate Raworth in 2012, which offers a potential compass for addressing current global challenges. The Doughnut Theory consists of two concentric rings: an inner social foundation and an outer ecological ceiling. This structure visually represents the interdependence between human well-being and planetary health, emphasising that societal progress must occur within Earth's ecological limits. Hence, between these boundaries lies a space that is both ecologically safe and socially just, embodying the ultimate goal of sustainable development.

Earth System Justice (Gupta et al. 2022): Earth System Justice redefines the planetary boundaries and Doughnut model by integrating more detailed justice considerations. It highlights three key forms of justice: interspecies justice and maintaining Earth system stability, fairness between generations (intergenerational justice), and equity within the current generation (intragenerational justice). The framework seeks to balance reducing the risks of global environmental change (safe) with promoting well-being (just), ensuring a fair distribution of nature's benefits, risks, and responsibilities across all people, within boundaries that ensure safe and just conditions for sustaining life on Earth.

ESG impacts (EFRAG): The various effects a company has on the economy, environment, and society. This definition includes both actual and potential impacts, which can be positive or negative, short-term or long-term, and intended or unintended.

Environmentally-extended multi-regional input-output model (EEMRIO) (Stadler, 2018): Environmentally Extended Multi-Regional Input-Output (EEMRIO) models provide a comprehensive methodology for assessing the environmental implications of economic activities within a globalised context. They help bridge the nexus between downstream environmental impacts and upstream economic drivers by tracing commodity footprints through intricate, often globalised, supply chains. EEMRIOs employ input-output tables to derive production functions and allocate environmental externalities to specific economic sectors. The models utilise the Leontief inverse matrix to approximate infinite sums, enabling the capture of cumulative effects throughout complex supply chains. By integrating regional production data with associated environmental costs and international trade flows, EEMRIOs enable the quantification of diverse consumption-based footprints, such as land use, greenhouse gas emissions, and water consumption.

Food security (FAO, 2006): Food security was defined during the 1996 World Food Summit as “Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” According to the FAO, four dimensions need to be fulfilled:

- Food availability refers to ensuring that there is enough food of appropriate quality, which can be obtained through either domestic production or imports, including food aid when necessary.
- Food access focuses on individuals having the means or resources to acquire enough nutritious food. These resources, or entitlements, are shaped by the legal, economic, political, and social systems within their community, which may include traditional rights like access to communal resources.
- Utilisation involves making effective use of food through a balanced diet, access to clean water, proper sanitation, and healthcare, ensuring that individuals achieve a state of nutritional well-being where all their physical needs are met. This highlights the critical role of non-food factors in ensuring food security.
- Stability means that a population, household, or individual must consistently have access to sufficient food. They should not face the risk of food shortages due to sudden events like economic or climate crises, or recurring issues such as seasonal food scarcity. Stability, therefore, encompasses both the availability and access aspects of food security.

Planet boundaries (Rockström et al., 2009): The planetary boundaries framework was developed following the 2009 UN Climate Change Conference in Copenhagen to provide a new approach to climate change mitigation. It examines the transition from the Holocene era, characterised by natural environmental changes supportive of human development, to the Anthropocene era, marked by increased human impact on the environment. The framework aims to define a "safe operating space for humanity" based on Earth's biophysical subsystems and processes. It identifies nine critical boundaries and thresholds:

- Climate change
- Biodiversity loss (terrestrial and marine)
- Disruptions to nitrogen and phosphorus cycles
- Stratospheric ozone depletion
- Ocean acidification
- Global freshwater use
- Land use changes
- Chemical pollution
- Atmospheric aerosol loading

These boundaries represent the limits within which humanity can operate sustainably without causing irreversible environmental damage. The concept provides a scientific basis for understanding and managing human impact on Earth's systems to ensure long-term sustainability.

Sharing or allocation principle (Gondran et al., 2023): This principle provides a method for distributing a global carrying capacity across various scales, from individuals to companies and territories. Its application involves both technical and ethical considerations. This approach is particularly relevant for translating global environmental boundaries, such as planetary boundaries, into actionable targets for smaller entities. From a technical standpoint, it requires identifying socio-economic variables available at global and local scales and correlating them with the environmental factor under study. For instance, population ratios are often used for territorial systems, while the economic sector’s share of total value added can be applied to industrial systems. Ethically, the choice of sharing principle reflects judgments about fairness and justice. While egalitarianism, which allocates based on proportional weight, is most common, alternative approaches like equity can account for historical responsibilities or disadvantages. The flexibility of this framework allows for the use of multiple ratios and adaptation to various contexts.

Sufficientarianism (Timmer et al., 2021): Sufficientarianism is a distributive justice doctrine that aims to 'maximise the number of people who have enough' in any situation. According to this approach, the social objective should not be to achieve equality in the relevant space (income, well-being, opportunities, etc.) but to focus on the threshold that defines what is "enough."

Thresholds or limits (Yi et al., 2022): These thresholds can be either minimum limits, such as labour standards, or maximum limits, like resource use or pollutant emissions. They are defined based on science-based thresholds, such as the 2°C global temperature limit for climate change, or accepted norms and obligations like the Sustainable Development Goals.

Tables

Table 14: Caloric intake required per food groups per capita and for the South African population (Rammlet et al., 2022; Willet et al., 2019)

	Just access level for 2,500 kcal		
Food groups	**Macronutrient intake grams per day (possible range)**	**Caloric intake kcal per day**	**Caloric intake kcal per day for the South African Population**
Whole grains	232	811	46 502 443 985
Tubers or starchy vegetables	50	39	2 236 245 765
Vegetables	300	78	4 472 491 530
Fruits	200	126	7 224 794 010
Dairy foods	250	153	8 772 964 155
Beef, lamb, and pork	14	30	1 720 189 050
chicken and other poultry	29	62	3 555 057 370
eggs	13	19	1 089 453 065
fish	28	40	2 293 585 400
legumes	75	284	16 284 456 340
nuts	50	291	16 685 833 785
Unsaturated oils	40	354	20 298 230 790
Saturated oils	11,8	96	5 504 604 960
Added sugars	31	120	6 880 756 200
Total		**2 503**	**143 521 106 405**

Table 15: Pressure from food social foundation on climate change (Rammelt et al., 2022)

	Just access level for 2500 kcal a day	
Food groups	**kg CO_2e/cap/day**	**kg CO_2e/day for the South African population**
Whole grains	0,40	23 052 414
Tubers or starchy vegetables	0,03	1 528 675
Vegetables	0,17	9 630 650
Fruits	0,19	11 006 458
Dairy foods	0,65	37 198 387
Beef, lamb, and pork	2,16	124 128 383
chicken and other poultry	0,96	54 860 312
eggs	0,17	9 621 402
fish	0,00	-
legumes	0,08	4 586 024

nuts	-0,09	- 5 082 843
Unsaturated oils	0,29	16 564 719
Saturated oils	0,09	4 886 592
Added sugars	0,13	7 511 143
Total (kg CO_2e/day)	5,22	299 492 316
Total (tCO_2e/yr)	1,91	109 314 695

Table 16: Pressure from food social foundation on freshwater use (Rammelt et al., 2022)

	Just access level for 2,500 kcal a day	
Food groups	**Water needed (m^3/cap/day)**	**Water needed (m^3/day) for the South African population**
Whole grains	0,07	4 043 039
Tubers or starchy vegetables	1,07E-03	61 147
Vegetables	0,02	985 995
Fruits	0,04	2 247 152
Dairy foods	0,01	361 149
Beef, lamb, and pork	0,01	446 862
chicken and other poultry	3,44E-03	197 497
eggs	1,08E-03	61 705
fish	NA	NA
legumes	0,01	808 287
nuts	0,09	5 224 246
Unsaturated oils	0,01	672 617
Saturated oils	3,46E-03	198 422
Added sugars	2,15E-03	123 211
Total (m^3/day)	0,27	15 431 329
Total (km^3/year)	0,00	6
Total (m^3/year)	98,23	5 632 434 991

Table 17: Pressure from food social foundation on land-use (Rammelt et al., 2022)

	Just access level for 2500 kcal	
Food groups	**Land needed (ha/cap)**	**Land needed (ha) for South Africa**
Whole grains	0,03	1 573 608
Tubers or starchy vegetables	1,82E-03	104 223
Vegetables	0,01	442 016
Fruits	0,01	412 395
Dairy foods	0,02	1 186 989
Beef, lamb, and pork	0,03	1 468 701
chicken and other poultry	0,01	649 113
eggs	3,54E-03	202 806
fish	NA	NA

legumes	0,04	2 108 610
nuts	0,02	1 118 707
Unsaturated oils	0,01	328 786
Saturated oils	1,69E-03	96 992
Added sugars	2,13E-04	12 223
Total	0,17	9 705 169
Grassland	0,00	2 276
Total Level (ha/cap)	0,17	9 707 445

Table 18: GHG Emissions from South African agriculture sector according to EXIOBASE

Sectors	GHG Emissions ($MtCO_2e$)
Cattle farming	140,05
Poultry farming	27,84
Cultivation of vegetables, fruit, nuts	10,71
Cultivation of cereal grains nec	8,96
Pigs farming	6,96
Raw milk	4,04
Cultivation of wheat	2,84
Cultivation of oil seeds	1,08
Wool, silk-worm cocoons	0,88
Cultivation of sugar cane, sugar beet	0,50