Assessing Measures for Agroecological Competitive Advantage

by
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Abstract

The evaluation of agroecological farming practices is a subject of current interest in the field of sustainable agriculture. While agroecology has gained attention as a potential solution for sustainable food systems, assessing its economic performance relies on measuring its competitive advantage. Traditional metrics, including Total Factor Productivity (TFP), Private Cost Ratio (PCR), Profit Margin (PM), and Return on Assets (ROA), are commonly used to evaluate competitive advantage in various sectors, but their applicability to agroecological farming remains unclear.

This master's thesis explores the applicability of traditional competitive advantage measures when applied to agroecology principles within the agricultural sector. The study applies the Analytical Hierarchy Process (AHP) to two Delphi panels to assess agroecological principles' priority and competitive advantage measures' alignment. Results indicate soil health as the most crucial agroecological principle, closely followed by fairness and biodiversity. Total Factor Productivity (TFP) emerges as the preferred measure of agroecological competitive advantage, followed by Profit Margin (PM) and Production Cost Ratio (PCR).

While TFP is favoured, it presents limitations such as data requirements and the inability to capture certain externalities. The study underscores the need for new measures aligned with agroecology's holistic nature and acknowledges limitations, including the inclusive and context-specific nature of agroecology.

This master's thesis contributes to the discourse on agroecological competitive advantage, emphasizing the importance of reevaluating traditional measures within the context of agroecology. It underscores the potential for sustainable agricultural practices to reshape competitive strategies, ultimately fostering a more resilient and equitable food system.

Uittreksel

Die evaluasie van agro-ekologiese boerderypraktyke is 'n onderwerp van huidige belangstelling in die veld van volhoubare landbou. Terwyl agro-ekologie aandag gekry het as 'n potensiële oplossing vir volhoubare voedselsisteme, berus die assesserings van sy ekonomiese prestasie op die meet van sy kompeterende voordeel. Tradisionele metriese, insluitend Totale Faktorproduktiwiteit (TFP), Privaat Koste Verhouding (PCR), Winsmarge (PM), en Rendement op Bates (ROA), word algemeen gebruik om kompeterende voordeel in verskeie sektore te evalueer, maar hul toepaslikheid vir agro-ekologiese boerdery bly onseker.

Hierdie meestersgraad tesis ondersoek die verenigbaarheid tussen konvensionele maatstawwe van kompeterende voordeel en die beginsels van agro-ekologie binne die landbousektor. Die studie maak gebruik van die Analitiese Hiërargieproses (AHP) analise, waar twee Delphi-panele uitgevoer word om die prioriteit van agro-ekologiese beginsels en die belyning van kompeterende voordeelmaatstawwe te assesseer. Resultate dui aan dat grondgesondheid die belangrikste agro-ekologiese beginsel is, gevolg deur regverdigheid en biodiversiteit. Totale Faktorproduktiwiteit (TFP) kom na vore as die verkose maatstaf vir agro-ekologiese kompeterende voordeel, gevolg deur Winsmarge (WM) en Produksiekosratio (PKR).

Terwyl TFP voorkeur geniet, het dit beperkings soos datavereistes en die onvermoë om sekere eksternaliteite te komunikeer. Die studie beklemtoon die behoefte aan nuwe maatstawwe wat in lyn is met die holistiese aard van agro-ekologie en erken beperkings, insluitende die inklusiewe en konteks-spesifieke aard van agro-ekologie.

Hierdie meestersgraad tesis dra by tot die diskoers oor agro-ekologiese kompeterende voordeel en beklemtoon die belangrikheid van die heroorweging van tradisionele maatstawwe binne die konteks van agro-ekologie. Dit beklemtoon die potensiaal vir volhoubare landboupraktyke om kompeterende strategieë te hervorm, wat uiteindelik 'n meer veerkragtige en regverdige voedselstelsel bevorder.

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Glossary of Terms

Agricultural practice: a collection of activities to apply to a farm to produce agricultural products.

Agricultural systems: an assemblage of components that are united by some form of interaction and interdependence, and which operate within a prescribed boundary to achieve a specified agricultural objective on behalf of the beneficiaries of the system (McConnell & Dillon, 1997).

Agroecology: a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems (Barrios et al., 2020).

Agroecosystem: communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fibre, fuel, and other products for human consumption and processing (Maes et al., 2018).

Agroecologically managed farming system: An integrated farming approach that simultaneously applies ecological and social principles to the design and management of sustainable agroecosystems.

Competitive advantage: The above industry manifested ability of a farm to manage agroecological competencies that that meet needs of consumers while earning at least the opportunity cost of resources employed.

Competitiveness: the analytical framework that addresses how nations or enterprises manage their competencies to achieve prosperity or profit (Garelli, 2012).

Conventional Agriculture: a modern farming approach characterized by intensive input use, mechanization, monoculture, and a strong emphasis on commercialization for economic gain (Paarlberg & Paarlberg, 2001; Epule & Chehbouni, 2022).

Farming system: A farming system is the combination of decisions made by a farming household, including the activities related to crops and livestock. It involves transforming land and labor into

List of Abbreviations

AHP – Analytical Hierarchy Process.

CI – Consistency Index.

CR – Consistency Ratio.

DRC – Domestic Resource Cost ratio.

FAO – Food and Agriculture Organization.

HLPE – Higher Level Panel of Experts on food security and nutrition.

IFPRI – International Food Policy Research Institute.

IPCC – Intergovernmental Panel on Climate Change.

NM – Net Margin.

NRB – Natural Resource-Based view of the firm.

OECD – Organisation for Economic Cooperation and Development.

PAM – Policy Analysis Matrix.

PCR – Private Cost Ratio.

PES – Proactive Environmental Strategy.

PM – Profit Margin.

RI – Random Index.

ROA – Return on Assets.

SDG – Sustainable Development Goals.

TAPE – Tool for Agroecology Performance Evaluation.

TAX – Total Asset Turnover.

TFP – Total Factor Productivity.

UN – United Nations.

1 Introduction

1.1 Background

There is a growing consensus that modern-day food and fibre systems are failing at delivering their desired outcomes on food security, nutrition, and environmental impact (FAO, 2019, 2020; Vermeulen et al., 2012). This is despite the agricultural sector being poised as a means to achieve the United Nations (UN) Sustainable Development Goals (SDG). Specifically, SDG 2 and SDG 13. SDG 2 aims to “End hunger, achieve food security and improved nutrition, and promote sustainable agriculture,” while SDG 13 urges to “Take urgent action to combat climate change and its impacts”. After a decade of steady decline, the number of hungry people in the world has slowly increased several years in a row to around 820 million people (FAO, 2019). Furthermore, food production is by far the largest driver of biodiversity loss, water, and land use and contributes up to a quarter of climate change impacts (IPCC, 2019; Poore & Nemecek, 2018; Tamburino et al., 2020). This not only questions the sustainability of current methods of mainstream commercial agricultural systems, but it also challenges the entire notion of competitiveness within the agricultural sector – especially competition for finite resources. Adding to these are fast-changing consumer perceptions and preferences which present a complex and interrelated global system in need of fundamental change to avoid self-destruction.

Over the past decade, agroecology has been promoted as a more sustainable approach to food production and consumption systems. Agroecology is a holistic and integrated approach that simultaneously applies ecological and social principals to the design and management of food systems in an effort to make these more resilient (Francis et al., 2008; Wezel et al., 2009; Gliessman, 2018; Barrios et al., 2020).

Agroecology is a multidisciplinary concept combining concepts of ecology, sociology and economics and has been applied in three distinct ways. As a scientific discipline, agroecology is the study of agroecosystems which are ecological systems modified and managed for human food production. Agroecology is the study of farming practices and principals designed to enhance the resilience and ecological, socioeconomic, and cultural sustainability of farming systems.

Agroecology is also the basis of the bioeconomy, providing a new outlook on the interactions between agriculture, the environment and society (Wezel et al., 2009; Silici, 2014).

The Food and Agriculture Organization (FAO) of the United Nations (UN) have recently defined 10 distinct elements of agroecology:

1. recycling,
2. efficiency,
3. diversity,
4. synergies,
5. resilience,
6. co-creation of knowledge,
7. human and social values,
8. culture and food traditions,
9. responsible governance and
10. circular and solidarity economy.

In contrast, the dominant or conventional agricultural paradigm emphasizes the following elements (Paarlberg & Paarlberg, 2001; Epule & Chehbouni, 2022):

1. Input intensity
2. Mechanization of labour
3. Monoculture and
4. Commercialization of agriculture.

Agroecology is a distinct alternative from the conventional paradigm and is favoured by its proponents because: 1. It promotes diversified and resilient food production. 2. It protects the environment by reducing environmental footprints due to its minimal dependence on external inputs. 3. It is easily accessible by marginalized farmers since it is less dependent on external inputs (Epule & Chehbouni, 2022).

Farmers, being the primary producers, play a pivotal role in agroecological transitions as they manage and control the agroecosystem. Transitioning to an agroecologically managed farming system should be supported by evidence that there is an inherent benefit of this approach when compared to conventional farming systems. The term “competitive advantage” was first used by Micheal Porter in the 1990’s and has been used in agricultural economics and strategic management to describe firms who achieve superior returns relative to their competitors. Competitive advantage is proposed in this study as an economic framework to evaluate the performance of agroecological farms. However, competitive advantage has traditionally been studied on conventional farming systems. As a result, the associated measurement techniques have been adapted to account for benefits and cost structures of conventional farm systems. Therefore, this master's thesis explores the compatibility between conventional measures of competitive advantage and the principles of agroecologically managed farms.

1.2 Purpose of the Study

Agroecologically managed farming systems have been gaining attention over the recent years as a potential solution to the transformation to more sustainable food systems. However, this transition needs to be supported by evidence that agroecological principles allow for the design and management of an economically competitive farming strategy. Competitive advantage is a key component of the financial performance of any firm. Traditional measures of competitive advantage, including Total Factor Productivity (TFP), Private Cost Ratio (PCR), Profit Margin (PM), and Return on Assets (ROA), are commonly used in agricultural economics to evaluate the economic efficiency and profitability of farming operations. However, when applied to agroecologically managed farming systems, which prioritize sustainability, biodiversity, and ecological resilience, their effectiveness becomes unclear.

TFP measures the efficiency of input utilization in agricultural production (Bernolak, 1997; Van Beveren, 2012). In agroecologically managed farming systems, which often involves diverse and complex ecological interactions, TFP may not adequately capture the benefits of sustainable practices like crop rotation, agroforestry, or organic farming. These practices may contribute to long-term soil health and biodiversity but might not be fully reflected in TFP calculations.

Private Cost Ratio (PCR): PCR assesses a farm's ability to pay domestic resource costs (Monke & Pearson, 1989). Agroecologically managed farming systems may incur different resource costs due to its emphasis on sustainable practices, such as reduced chemical inputs or investments in biodiversity conservation. Traditional PCR may not account for these unique cost structures.

Profit Margin (PM): PM measures profitability. Agroecologically managed farming systems often focus on long-term environmental benefits, which may not yield immediate financial returns. Consequently, relying solely on PM may not accurately represent the overall success of agroecological enterprises.

Return on Assets (ROA): ROA evaluates the returns generated from invested assets (Dehning & Stratopoulos, 2002). In agroecological farming, assets may include ecological investments like pollinator habitat or soil-building practices, which may not yield immediate financial returns but have long-term ecological benefits.

This study assesses the suitability of these traditional measures of competitive advantage to measure the performance of agroecologically managed farming systems.

1.3 Research question and objectives

"What is the ability of traditional measures of competitive advantage to assess the performance of agroecological farming enterprises?"

This study attempts to answer the research question via the following objectives:

1. Synthesize the literature on agroecology to define and understand agroecologically managed farming systems.
2. A literature review on the measures of competitive advantage to identify potential measures of competitive advantage for agroecologically managed farming systems.
3. Using the AHP-Delphi method to assess the suitability of traditional measures for agroecological farms.

1.4 Methodological Approach

This study used the AHP method as the primary methodological approach to answer the research question. The AHP is a multicriteria decision analysis tool that uses pairwise comparisons and expert opinions to derive priorities of alternatives in multilevel hierarchical decision problems (Saaty, 1988). The AHP was structured as two-level hierarchy with criteria defined as farm-level principles of agroecology and the alternatives being farm-level measures of competitive advantage. The objective of the AHP was to select a suitable measure of competitive advantage for agroecologically managed farming systems. The criteria for the analysis were derived from the literature review on the principles of agroecology. The measures were also identified from the established literature on measures of competitive advantage.

The Delphi Method was used in the AHP analysis to derive expert opinions. The AHP was conducted on two levels. The first level evaluated principles of agroecology as criteria for a competitive advantage strategy using a multidisciplinary Delphi panel. The second level evaluated traditional measures of competitive advantage based on their ability to account for each respective principle. This was done using a Delphi panel with experts in agricultural economics and agribusiness management. The results were analysed and aggregated using the aggregation of individual priorities method.

1.5 Chapter outline

This thesis comprises five chapters that collectively investigate the intersection of agroecology and competitive advantage within the agricultural sector. Chapter 2 delves into the comprehensive literature review, exploring the evolution of agriculture, the emergence of agroecology, and the fundamental principles of agroecological farming. It also examines traditional measures of competitive advantage in agriculture, laying the theoretical foundation for the subsequent analysis. Chapter 3 details the research methodology, encompassing data collection methods, analytical tools like the Delphi panels and the Analytical Hierarchy Process (AHP). The results of this study are presented in Chapter 4. The study concludes with a discussion of the results, study limitations and recommendations for further study.

2 Literature review

In recent years, there has been a growing focus on agroecology as a potential catalyst for the transformation of food systems, offering solutions to the ecological and social challenges associated with industrial agriculture. Concurrently, the exploration of competitiveness has remained a subject of keen interest among agricultural economics scholars for the past four decades. Most researchers refer to agroecology as a multidisciplinary science, incorporating economic, ecological, and social concepts. Given this perspective, competitive advantage is proposed as the appropriate economic framework for this study. Thus, this literature review aims to identify a framework for the analysis and measurement of the competitive advantage of agroecological farms.

2.1 Agroecology

The origin of Agroecology can be traced back to the early 20th century when Benzin (1928) first used the term to describe ecological methods in research on crops or plants. Since then, Agroecology has evolved into a multidisciplinary concept combining ecological and social aspects to the management and study of food systems (Barrios et al., 2020). The spatial scale of Agroecology has also expanded from the farm to incorporate the agroecosystem and entire food systems.

The evolution of the definition of Agroecology has consequently seen its use vary by authors in this field. The resulting research over the past eighty years has resulted in multiple definitions, applied at various levels of scale across multiple disciplines. At its narrowest, Agroecology is a more environmentally and socially sensitive approach to agriculture. And at its widest, Agroecology is a social movement, involving all actors in the food system, that can solve modern crises such as malnutrition, food security and climate change. This can be seen as a “wholistic” and “prescriptive” use of the term Agroecology because it implies features about society and the environment that go well beyond the farm level (Altieri, 1995).

Thus, it is important to identify an operational definition for agroecology to aid the synthesis of a framework that can accurately measure and analyse the competitive advantage of farms that practice agroecology. It is equally important to understand the concepts and principles that are central to agroecology. This allows for an accurate understanding of the benefits and costs associated with agroecology which then can be translated to its effects on competitive advantage.

2.1.1 The definition of agroecology

The concept of agroecology is derived from two sciences, ecology, and agronomy. This can be seen in the etymology of the word agroecology which is derived from the suffix “agro” and the root word “ecology”. The word ‘agroecology’ first emerged in the 20th century when Benzin (1928, cited in Wezel et al,. 2009, p504), used it to describe the use of ecological methods in research on commercial crop production. In the 1950s, Tischler (1950, 1953, 1959, 1961, cited in Wezel et al., 2009, p504) published several articles in which he used the term ‘agroecology’. His research primarily focused on pest management and the interactions of insects and plant protection in agricultural and non-cultivated landscapes.

Between the 1930s and 1960s, several studies related to agroecology were published, even though the word agroecology was not used in the title. For example, the German zoologist Friederichs (1930) published a book on agricultural zoology and ecological/environmental factors in plant protection, which was similar in approach to that of Tischler. Another important book on agroecology was published by the U.S. agronomist Klages (1928), whose article in 1928 may be one of the first papers dealing with agroecology without using the term (Klages,1928, cited in Baker & Klages, 1942). He analysed the ecological, technological, socioeconomic, and historical factors influencing crop production. At the end of the 1960s, the French agronomist Hénin (1967) defined agroecology as being ‘an applied ecology to plant production and agricultural land management’, which is like Benzin’s definition (Hénin, 1967, cited in Wezel & Soldat, 2009, p.9). The Italian scientist Azzi (1956) defined ‘agricultural ecology’ as the study of the physical characteristics of the environment, climate, and soil, in relation to the development of crops. However, he did not include entomological aspects in his analysis. The foundation of his work was already laid 30 years before (Azzi, 1956).

These early scientists in agroecology were rooted in the biological sciences, particularly zoology (Friederichs, 1930) and agronomy and crop pathology (Klages, 1928, 1942; Benzin, 1928, 1935). Their research was applied at the lowest spatial level, focusing on the interactions between commercial crop production on the field and the natural environment.

During the 1970s, the concept of agroecology started to expand as a distinct science while maintaining the biological aspects applied by prior scientists in the agronomic field. Agroecology gained momentum and scientific interest in this period partly due to the emergence of ecologist movements. These movements were concerned with the atomistic and mechanistic approach of conventional agricultural scientists. Conventional agriculture has been concerned primarily with the effect of soil, animal, or vegetation management practices on the productivity of a particular crop, applying a perspective that emphasises a target problem. This narrow approach often carries unintended secondary consequences that are often ecologically damaging or carry high social costs (Altieri, 1995). It is within this context that the study of agroecology gained momentum in the 1970's. Agroecological studies in this era emphasised indigenous agriculture and highlighted the strategies implemented by indigenous people through traditional practices that served as an alternative to the rural development strategies of the time (Hecht, 1995).

It was in this period that the concept of agroecosystems was suggested by Odum, (1969), who describes it as the resultant interactions between the endogenous biological and environmental aspects of agriculture and exogenous economic and social factors of a particular agricultural system (Altieri, 2010). In other words, agroecosystems are ecosystems modified by humans for food production (Conway, 1987). During this period, agroecology emerged as a distinct conceptual framework to study agroecosystems (Wezel et al., 2009). The definition of Agroecology was expanded to farm management practices that protect natural resources, with guidelines that promote sustainable Agroecosystems. Conway (1987) further describes the four properties of agroecosystems as trade-offs between, 1) sustainability, 2) productivity, 3) stability and 4) equitability.

This second period in the evolution of agroecology expanded the spatial dimension beyond the farm level to agroecosystems as well as incorporating the socioeconomic dimensions to the study of agroecology. Gliessman (1985), highlighted the complex feedback mechanisms which determine agricultural production which is a result of interactions between technological, ecological, and socioeconomic components of farm decision-making. Altieri (1995), highlights factors such as labour availability, access to credit, subsidies, perceived risk, price information, family size and access to other forms of livelihood are crucial to understanding farmer behaviour and agronomic choices. This shows that the human component is equally important as the soil and ecology of the farming system as they design and manage resources to extract food from the system.

The definition of agroecology was once again expanded, in the early 2000's, beyond farm practices and agroecosystems to the entire food system. This includes the entire agricultural supply chain encompassing all actors involved in the production, distribution, and consumption of food. Francis *et al*., (2003), argue that a narrow focus on agroecological production methods at the farm level does not sufficiently deal with the complexity of modern-day food systems. Furthermore, Francis et al., (2003) define agroecology as "the ecology of food systems" emphasising a systems approach in the design and management of ecological and socially sustainable food systems (Francis, et al., 2003).

Only recently have authors advocated for holistic approaches to the study of agroecology, advocating for the study as a science, agricultural practice, and a social movement (Wezel et al., 2009). As a science, agroecology can be seen as an integrated study of the ecology of food systems, taking into consideration economic, social, and environmental aspects. As a practice, agroecology is the study of improving agricultural production methods by harnessing the natural environment and creating favourable synergies between the biological and economical components of agroecosystems (Silici, 2014). Finally, agroecology has been identified as a social movement encompassing all actors in the food system, that can provide an alternative viewpoint to solving modern crises such as malnutrition, food security and climate change (Gliessman, 2018). Furthermore, agroecology is an interdisciplinary study, incorporating aspects of economics, sociology, and ecology into the mix.

Based on the literature, an applicable operational definition for agroecology at the farm level should incorporate the following aspects: 1) the agroecosystem, 2) ecological concepts, 3) social concepts, and 4) systems dynamics.

Barrios et al., (2020) define agroecology as "a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems." This definition incorporates all the aspects at the broader food systems level. This definition is adapted in this study to provide an operational definition of agroecology at a farm level. Agroecologically managed farming systems are defined in this study as "*a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agroecosystems*".

2.1.2 The Agroecosystem

The term agroecosystem and farming system have been used to describe agricultural activities undertaken by humans. The food system describes the greater system that includes agricultural production, processing, marketing and consumption within a geographic region or country (IFPRI, 2022). The agroecosystem can be defined at various scales up to a food system level. However, this section focuses on agroecosystems at the individual farm level.

The term 'agroecosystem' was first used by Odum (1969), to describe the system of biotic and abiotic factors that interact in a farm environment to produce food. These abiotic and biotic factors are interdependent and interact to cycle nutrients and energy. An agroecosystem is an open system in which inputs are received from external sources and outputs are transferred to external systems. The function of agroecosystems is to move energy through the components towards a certain (man-made) goal. This is controlled through input modification and pervasive feedback loops (Altieri, et al., 1995). This contrasts natural ecosystems where there is neither set goal, feedback nor input modification (Caldwell, 2020).

When natural ecosystems are modified into agroecosystems, there is a clearly defined biophysical boundary between them (Conway, 1987). Although the basic ecosystem functions (competition, predation, and herbivory) remain, they are now regulated by humans through agricultural functions such as harvesting, cultivation and pest control. Humans play a key role in the functioning of an agroecosystem as they define the goal of the system (Conway, 1987; Caldwell, 2020). Conway (1987) identifies this goal as "increased social value" which is defined as a function of the output of goods or services produced by the agroecosystem, their relationship to human happiness and their allocation amongst the human population. This adds another level of complexity to the system as it incorporates a socioeconomic dimension. A simple diagram of an agroecosystem at the field or farm level is presented below using a maize farm as an example.

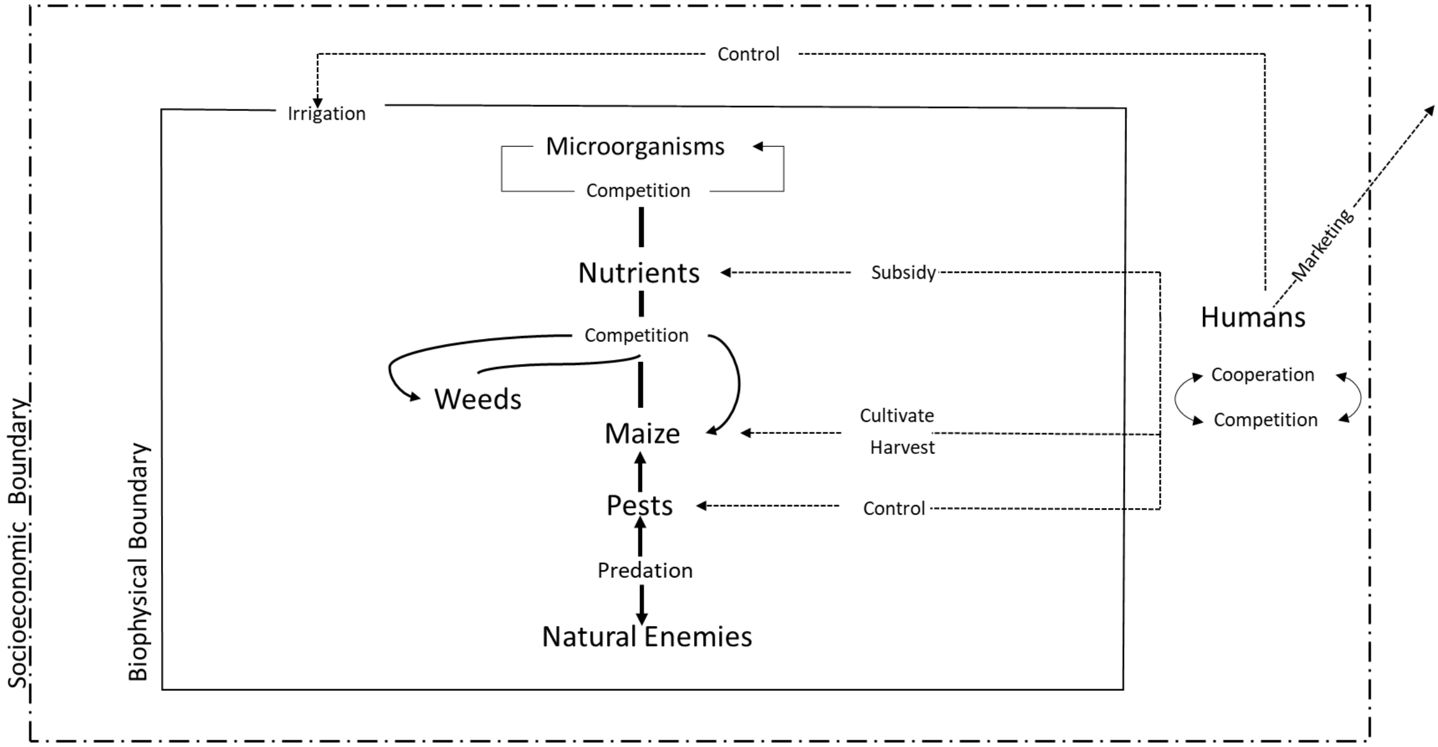

Figure 2.1: The Structure of an Agroecosystem (Adapted from Conway, 1987)

The figure above presents an example of biotic and abiotic factors that might be found in a maize monoculture agroecosystem. Biotic factors include microorganisms, crops, weeds, pests, and predators. Abiotic factors include non-living factors such as sunlight, water, and nutrients. Humans modify the natural ecosystem through agricultural functions within the biophysical boundary to produce a target crop. The target crop interacts with the factors within the biophysical boundary and is subject to competition for nutrients from other plant species and predation by pests. Humans control this by management of pests and subsidising nutrients and water. The choices of agricultural functions undertaken by humans are affected by several socioeconomic factors within and outside of the socioeconomic boundary of the agroecosystem. Factors inside the boundary include the level of competition and cooperation by other humans. Factors outside include market prices, access to credit, governmental policy, and subsidies(Odum, 1969; Conway, 1987).

The structure of an agroecosystem is unique to its region and is determined by the resultant local variations in climate, soil, economic structure, cultural relations, and history. Although each farm is unique in its local agroecosystem, many share similar properties which can be grouped as agricultural systems or region-specific agriculture. Grigg (1974) and Norman (1979) identify several of these systems. These are 1) Shifting cultivation systems, 2) Semi-permanent rainfed cultivation systems, 3) Permanent rainfed cultivation systems, 4) Arable irrigation systems, 5) Perennial crop systems, 6) grazing systems, 7) Systems with regulated ley farming.

These systems are always changing in response to ecological, environmental, and socioeconomic conditions present (Grigg, 1974; Norman 1979, cited in Altieri et al., 1995). This can include factors such as resource availability, environmental degradation, political change and so on. These changes are reflected in farmers' choices in the type and intensity of the agricultural system. The table below provides some examples of the determinants of a particular agroecosystem.

Table 2.1 Determinants of Agroecosystems (adapted from Altieri et al., 1995)

Type of Determinant	**Example**
Physical	Temperature. Radiation Rainfall Soil conditions Gradient Land availability
Biological	Cropping patterns Crop rotation Insect pests Soil microbiology Plant and animal disease
Socioeconomic	Population density Social organization Labour availability Economic (prices, markets, capital, and credit availability) Cultivation implements. Degree of Commercialization Technical assistance
Cultural	Indigenous Knowledge Beliefs Ideology Gender issues Historical events

Agroecosystems are a complex interaction between internal and external biological, socioeconomic and environmental processes. The goal of agroecosystems is to produce social value. Conway (1986) argues that the analytical techniques of classical welfare economics are inadequate in measuring the performance of an agroecosystem and suggests that an assessment should be made on four key system properties that contribute to the goal. These are productivity, efficiency, stability, and sustainability.

2.1.3 Elements of Agroecology

Agroecology has been gaining attention over the recent years as a potential pathway for transformation to a sustainable food system. In 2014, the UN Food and Agricultural Organisation launched the International Symposium on Agroecology for Food Security and Nutrition. This symposium aimed to define elements of agroecology that can serve as an analytical framework for member countries to engage in this area. The result of this 4-year investigation was the 10 Elements of Agroecology. These 10 elements are interlinked and aim to provide a robust framework that can be adapted to local contexts to facilitate policy-making that supports the shift to agroecological food systems. The following section describes these elements.

These elements are:

1. recycling,
2. efficiency,
3. diversity,
4. synergies,
5. resilience,
6. co-creation of knowledge,
7. human and social values,
8. culture and food traditions,
9. responsible governance and
10. circular and solidarity economy.

2.1.3.1 *Element 1: Diversity*

Diversity is used as an umbrella term that covers the concepts of biodiversity, diversity of farm activities and diversity of knowledge systems. Biodiversity refers to the distribution of species of plants, animals and microorganisms interacting in an agroecosystem (Altieri, 1999; Cash, et al., 2003). Agricultural systems that are more biodiverse can make greater contributions to the stability and variety of ecological functions that sustain food production and other ecosystem services such as pollination, biological pest and disease control and soil health (Zhang, Ricketts, Kremen, Carney & Swinton, 2007; Power, 2010; Renard & Tilman, 2019). Diversity of farm activities can provide a "buffer" to external risks such as uncertain markets or policy environment as well as changing environmental conditions. This is because different types of crops and livestock respond differently to environmental conditions and can provide alternate sources of income and livelihood to farmers (Kremen & Miles, 2012). Diversity of knowledge can be seen as the sharing of knowledge by all actors in the food system including other farmers, institutions and businesses and is closely related to element 2, co-creation of knowledge. The FAO states that diversity is a precondition to agroecological transitions, particularly in the context of global change.

2.1.3.2 *Element 2: Co-creation and sharing of knowledge.*

In the realm of agroecology, co-creation and sharing of knowledge, practices and scientific innovations play a key role in the decision-making of farmers (Barrios et al., 2020). Through the fostering of co-creation of knowledge, agroecology can encourage transdisciplinary collaboration allowing for the

integration of knowledge from diverse perspectives including traditional and indigenous knowledge, related to agricultural biodiversity and management practices, as well as practical insights from both male and female farmers and traders with regards to local markets. Agroecology based on the co-creation of knowledge and multistakeholder discourse allows for socially robust solutions to be developed taking into consideration the local context and realities (Scholz & Steiner, 2015; Bendito & Barrios, 2016).

2.1.3.3 *Element 3: Synergies*

Agroecology recognises the need to capitalise on greater than additive or synergistic interactions between components in the agroecosystem. This can be at the field level (e.g., Benefits of intercropping species of legumes and cereals), the farm level (e.g., the positive impacts of organic matter management on soil health) or at the ecosystem level, (e.g., biodiversification impacts on biological pest and disease control). The design of agroecological systems should emphasise diverse and synergistic systems to harness the multiple benefits of component interactions (Barrios et al., 2020).

2.1.3.4 *Element 4: Efficiency.*

Efficiency is an emergent property in the design of agroecological systems through the careful design and management of diversity and synergies between system components (Barrios et al., 2020). Resource-use efficiency can be increased by transitioning from input-intensive systems to knowledge-intensive systems. Agroecological transitions should foster resource-use efficiencies as well as ecological efficiency. Resource-use efficiency refers to a greater output per unit of input whereas ecological efficiency refers to the increased output per unit of environmental cost (Keating, et al., 2010). Agroecological systems should reduce the need for external inputs such as synthetic fertilizers by enhancing biological processes found within the agroecosystem. This can lead to increased incomes and returns to factors of production for farmers (Altieri, Funes-Monzote & Petersen, 2012; van der Ploeg, et al., 2019). Assessment of efficiency gains through agroecological practice should take place at the whole farm level or ecological level as opposed to an individual component level (Alvarez et al., 2014; Alomia-Hinojosa et al., 2020).

2.1.3.5 Element 5: Recycling.

Recycling is central to efficient agroecological production as it replaces the concept of waste and pollution and makes new biological resources available for food production (Barrios et al., 2020). This can be in the form of closing nutrient cycles at the farm level by turning agricultural wastes into compost and improving soil health. Recycling can also be applied at the regional food system level between the various actors. For example, food wastes and processing by-products such as biochar can be recycled back into soils, fed to animals, or used in biogas production. Recycling can lead to lower economic and environmental costs of production and improve farmers' dependencies on external inputs through closing of energy and nutrient cycles and reducing waste. Thus, increasing the autonomy of farmers and reducing their vulnerability to external shocks

2.1.3.6 *Element 6: Resilience.*

Resilience is defined as ‘the capacity of a system to absorb disturbance and reorganize while changing to still retain essentially the same function, structure, identity, and feedback. Agroecology supports a diversified community of organisms to allow the ecosystem to self-regulate when there are pest and disease outbreaks. These diversified agroecological systems are usually more resilient to extreme weather events. Through the diversification of crop and animal species, agroecological transitions enhance socioeconomic resilience. This is because farmers are less dependent on a single crop which can be affected by external market and climatic conditions. Agroecology also reduces farmers' reliance on external inputs by promoting the practice of recycling and efficiency through enhancing biological processes.

2.1.3.7 *Element 7: Human and social values.*

Agroecology places a strong emphasis on human and social values such as dignity equity and inclusion. These relate to the Improved livelihoods dimension of the SDG(Wezel et al., 2014). Human and social values contribute to improved social capital and collective action by putting the needs of those who produce, distribute and consume food at the centre of food systems. This bottom-up approach can provide a new outlook for socially sustainable rural development, empowering people to become their own agents of change.

2.1.3.8 *Element 8: Culture and food traditions.*

Historically, culture and food traditions have played an important role in the type of agriculture conducted in a certain area. Agroecology aims to go back to these roots by supporting local cultures and food traditions by providing a variety of food in line with the local context(Altieri, 1995; Dumont, Vanloqueren, Stassart & Baret, 2016). Local people also have region-specific knowledge that makes the best use of the natural resources in the area. Culture and food traditions play a pivotal role in the creation of a food system that supports food security and nutrition while maintaining the health of ecosystems and their agrobiodiversity(Tomich et al., 2011).

2.1.3.9 *Element 9: Responsible governance.*

The shift towards sustainable agriculture and food systems through agroecological means necessitates the creation of effective and innovative policies, institutions, and markets that facilitate and encourage transformative change, as noted by Caron et al., (2018). Responsible governance from institutions and governments should support the shift to agroecological food systems by embodying accountable, transparent, and inclusive governance mechanisms. These mechanisms at different scales support niche markets by legitimising agroecological produce thus rewarding farmers that support the protection and enhancement of biodiversity and ecosystem services.

2.1.3.10 *Element 10: Circular and solidarity economy.*

It is understood that the circular and solidarity economy plays a vital role in reconnecting producers and consumers, while also presenting innovative solutions for achieving Sustainable Development Goals(De Boer & Van Ittersum, 2018; Schroeder, Anggraeni & Weber, 2019). Within the context of agroecological transitions, it is important to prioritize recycling, shorter food chains, and the promotion of local markets and economic development to increase the resilience of rural communities, sustain the incomes of food producers, and encourage fair prices for consumers(Schipanski et al., 2016; Feliciano, 2019). The principles of the circular economy can also be applied to address global food loss and waste challenges by enhancing recycling, shortening food value chains, and increasing resource-use efficiency (Ghisellini et al. 2015; FAO 2019). As such, responsible governance and the promotion of the circular and solidarity economy should be key goals in agroecological transitions, creating an enabling environment that fosters social, economic, and environmental sustainability.

Transitioning to agroecological-based food systems requires participation from all actors in the food system. This includes producers, distributors, consumers institutions and governments. The 10 Elements of Agroecology outlined by the FAO provide a framework for policy design to support this transformation. Producers can be targeted with policy promoting the elements, diversity, human and social values, synergies, and recycling. These elements can be implemented on-farm and are in direct control of farmers. It is equally important for institutions and governments to create an environment that is conducive to change by implementing elements such as co-creation and sharing of knowledge, recycling, human and social values, culture and food traditions, responsible governance as well as circular economies in policymaking. Furthermore, agroecological transitions should be adapted to the local context and needs of consumers. The efforts of transitions will be in vain if consumers don't recognise the ecological, and social, benefits that food products produced agroecologically have over conventional methods. The result of applying these elements are efficiency and resilience of the entire food system.

What these elements lack is a clear pathway to transitioning to agroecological food systems. The High-Level Panel of Experts (HLPE) addressed this by synthesising a list of 13 principles of agroecology that are aligned and complimentary to the 10 elements of agroecology. The 13 principals differ from the 10 elements as they are formulated as actionable normative and causative statements. This allows all food system actors to identify direct entry points of engagement to implement through practice. The 13 principals exclude resilience and efficiency as they are the outcomes of agroecological food systems. The 13 principals also make a distinction between biodiversity and economic diversity.

These principles are:

1) Recycling,

2) Input reduction,

3) Soil Health,

4) Animal health,

5) Biodiversity,

6)Synergy,

7) Economic diversification,

8) Co-creation of knowledge,

9) Social values and diets,

10)Fairness,

11) Connectivity,

12) Land and natural resource governance,

13) Participation

These 13 principles of agroecology are described in table 2.2 below.

Table 2.2 The 13 Principles of Agroecology Adapted from Wezel. et al., (2015). FI, field; FA, farm Agroecosystem; FS, Food System.

Principle	Description	Scale Of Application	Correspondence to FAO elements
1)Recycling	use local renewable resources and close nutrient cycles as far as possible	FI, FA	Recycling
2)Input Reduction	reduce or eliminate dependency on purchased inputs	FA, FS	Efficiency
3)Soil Health	enhance soil health and functioning particularly by managing organic matter and enhance soil biological activity.	FI	Diversity, Synergies and Resilience
4)Animal Health	ensure animal health and welfare	FI, FA	Resilience
5)Biodiversity	maintain and enhance biodiversity of species and maintain overall agroecosystem biodiversity	FI, FA	Diversity
6)Synergy	enhance positive ecological interaction, integration, and complementarity between components of the agroecosystem.	FI, FA	Synergies
7)Economic Diversification	diversify farming income opportunities	FA, FS	Diversity, Circular and Solidarity Economy
8)Co-creation of Knowledge	Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange	FA, FS	Co-creation and Sharing of Knowledge
9)Social Values and Diets	Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diet	FA, FS	Human and Social Values, Culture and Food Traditions
10)Fairness	Support dignified and robust livelihoods for all actors engaged in food systems	FA, FS	Human and Social Values
11)Connectivity	Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.	FA	Circular and Solidarity Economy
12)Land and Natural Resource Governance	Strengthen institutional arrangements to improve, including the recognition and support of family farmers, smallholders and peasant food producers	FA, FS	Responsible Governance
13)Participation	Encourage social organisation and greater participation in decision-making by food producers and consumers	FS	Human and Social Values

Table 2.2 above summarizes the 13 principles, its corresponding elements, and the scale of application. These principles, like the elements, can be applied at various scales with different actors responsible for each. Given that farmers and their participation are central to the adoption of agroecology, the following table clusters these 13 principles to on-farm and off-farm groups. This will help identify areas where farmers are directly in control and can apply the given principle.

Table 2.3: The 13 Principles of Agroecology, Clustered into On-farm, and Off-farm Groups.

Criteria	**Principle**
On-farm	1) Recycling 2) Input Reduction 3) Soil Health 4) Animal Health 5) Biodiversity 6) Synergy 7) Economic Diversification 10) Fairness
Off-farm	8) Co-creation of Knowledge 9) Social values and Diets 11) Connectivity 12) Land and Natural Resource Governance 13) Participation

Like the 10 elements of agroecology, certain principles apply directly to farmers. It is important to note that agroecology involves the holistic application of all these principles (Barrios et al., 2020; Wezel et al., 2020). The principles clustered in the off-farm category do require farmer participation and benefit from the synergistic interaction of on-farm principles. However, these principles require some form of engagement from the other actors in the food system. Co-creation of knowledge refers to multistakeholder discourse sharing information from diverse sources and creates an enabling environment for agroecology (Scholz & Steiner, 2015; Bendito & Barrios, 2016). It facilitates the awareness of the other principles and signals actors to engage with them. For example, social values and diets can be promoted through multistakeholder discourse, including indigenous communities, consumers, academic institutions, and food producers (Wezel *et al.*, 2014). When consumers become aware of the ecological and social benefits associated with agroecology, it signals producers to cater to those needs by adopting the on-farm principles (van der Ploeg *et al.*, 2019). The same can be implied with connectivity, they require consumer participation or an enabling environment. Land and resource governance directly refers to policy that supports institutional arrangements to improve, including the recognition and support of family farmers, smallholders, and peasant food producers (Wezel, Herren, *et al.*, 2020). Participation also refers to social organisation and multistakeholder discourse.

On the contrary, the principles clustered in the on-farm criteria can be directly actioned by farmers. They refer to a set of management practices that farms can apply directly to their farm or business operations. The following section describes the principles and provides examples of practices farmers can implement.

2.1.4 Principles of Agroecology

2.1.4.1 *Principle 1: Recycling*

Recycling refers to the closing of nutrient cycles on-farm and the recycling of biomass. This can be done through the management of crop and livestock integration and composting of crop and animal wastes (Sorathiya, Fulsoundar, Tyagi, Patel & Singh, 2014). An example of recycling through crop and livestock integration is utilizing manure as a direct application of compost on fields. Manure can also be recycled in a bioreactor to produce methane on the farm for their energy needs. Farmers can also graze livestock on harvested fields allowing for animals to clear wastes and compact soil. Composting of crop wastes can be done in the open air and applied to soils directly. Another method is to ferment harvest wastes and apply them as a liquid fertilizer.

2.1.4.2 *Principle 2: Input reduction*

Farming based on agroecology principles aims to reduce the reliance on external inputs, specifically chemical inputs, through the management of biological processes on farm. Practices of this principle are closely related to principles such as recycling, soil health, synergy, and biodiversity. Through maintenance of the agroecosystem and creating favourable synergies between the components of the farming system, farmers can reduce the number of external inputs required (Altieri, 1995).

2.1.4.3 *Principle 3: Soil Health*

Soil health refers to the functioning of the soil ecosystem in the field. Farmers should maintain and improve the functioning of the soil ecosystem which directly affects the soil fertility (Pulleman, et al., 2012; Miner, Delgado, Ippolito & Stewart, 2020). The first step to achieve this is to conduct comprehensive soil tests. This allows farmers to understand the soil profile within the context of the local agroecosystem. This allows for farm-specific treatments to be applied such as microbial treatments and fertilizer applications. Some examples of general soil health practices include mulching and compost application. These practices help maintain the soil ecosystem by preventing dry soil and adding organic matter. However, soil heath is context specific and different practices should be applied based on the local soil profile (Kibblewhite, Ritz & Swift, 2008).

2.1.4.4 *Principle 4: Animal Health*

Animal health is an important aspect of livestock production in agroecology. Agroecological practices aim to integrate livestock into crop production as well as allowing livestock to exhibit their natural behaviours(Dumont et al., 2013; Sorathiya et al., 2014). Management practices include integrated disease and pest control, rotational grazing, balanced feeding, provision of adapted housing, animal hygiene, preference for traditional breeds and mixed grazing of different livestock.

2.1.4.5 *Principle: 5 Biodiversity*

Biodiversity is a central aspect of agroecology and refers to the variety of living organisms in an agroecosystem, including plants, animals, and microorganisms. Maintaining biodiversity is important for promoting ecological balance, resilience, and productivity in agroecosystems(Altieri, 1999). This can be done through crop diversification, agroforestry, and natural habitat management. Conservation agriculture practices like minimal tillage, cover cropping and mulching can also help to preserve soil biodiversity(Altieri, 1999).

2.1.4.6 *Principle 7: Economic Diversification*

Economic diversification is an important aspect of agroecology that seeks to promote sustainable livelihoods and reduce dependence on a single crop or commodity. Economic diversification can help farmers reduce their exposure to market volatility and risks associated with climate change(Barrios et al., 2020; Wezel et al., 2020). Economic diversification can be realised through crop diversification and livestock integration. Farmers can also diversify incomes through value-adding processing on the farm, direct to consumer marketing and agro-ecotourism.

2.1.4.7 *Principle 10: Fairness*

Fairness is a fundamental principle of agroecology that emphasizes social justice, equity, and democratic decision-making in agricultural systems. Fairness in agroecology recognizes the importance of ensuring that all stakeholders, including farmers, workers, and consumers, can participate in decision-making processes that affect their lives and livelihoods (Barrios et al., 2020). Farmers can practice fairness by ensuring worker rights such as fair wages, safe working conditions and participatory decision making. Other practices include gender equity and fair-trade certification schemes.

2.1.5 Economic Studies of Agroecological Farms

Scopus is comprehensive database of peer-reviewed academic articles by Elsevier. Scopus contains over eighty million documents across 240 disciplines and is considered one of the main academic databases(Chadegani et al., 2013) .

A search for the term agroecology on this database reveals over five thousand articles. Of those, about a fifth mentioned the word 'economic' in their abstract, title or keywords. This shows that the economic component of agroecology has been stressed by scholars in this field. This is supported by influential scholars on agroecology such as: Altieri, 1995; Hecht, 1995; Francis, 2003; Wezel, 2009 and Gliessman, 2018. who all stress the multidimensional performance of agroecology consisting of social, environmental, and economic components.

However, there are few studies dealing with the socioeconomic performance of agroecology. Of these agroecology studies, only 134 documents deal with measuring the economic performance of agroecology. Further only ten of these documents are classified as economic studies. Furthermore, most of these studies agronomic studies deal with the economic costs and benefits associated with a applying a single principle of agroecology. This is akin to the atomistic approach and Newtonian thinking which is dominant in modern-day scientific thinking. For example, Plénet, *et al.,* (2023), compare four different types of peach orchard systems and the effect of chemical input reduction on the profitability of the orchard. They base their analysis on several indicators related to the profitability of the commodity(peaches) alone (Plénet et al., 2023). This ignores holistic nature of agroecology and the synergistic interactions between components in the agroecosystem.

A review of the socioeconomic performance of agroecology by D'Annolfo *et al*., (2017) referenced seventeen studies that follow the same approach of studying the associated economic effects of applying a single principle on a single commodity. They further highlight that the extant literature does not address the holistic nature of agroecology and reflects experimental conditions rather than farm conditions (D'Annolfo, Gemmill-Herren, Graeub & Garibaldi, 2017a).

The Tool for Agroecology Performance Evaluation (TAPE) was developed by FAO partners to evaluate farmer transitions to an agroecological approach. This tool aimed to provide a tool that can measure the multidimensional performance of agroecology and its ability to contribute to sustainable food systems. This tool is comprehensive in accounting for the economic, social, and ecological performance of agroecological farms. The economic component consists of measures of production efficiency, costs and profitability associated with the agroecosystem (Mottet et al., 2020). While this is a comprehensive economic component, on its own, the tool was designed without a theoretical framework that guides the understanding of these variables.

The theory of competitiveness and competitive advantage is proposed as a theoretical framework that can guide the socioeconomic analysis of agroecological farms. This is further explained in section 2.2 below.

2.2 Measuring the Competitive Advantage of Agroecological Farms

Firstly, it's important to differentiate between comparative advantage, competitive advantage, and competitiveness. Comparative advantage is a theory developed by David Ricardo that attempts to understand how resources are allocated between industries in an open economy. Comparative advantage is based on the opportunity cost of production in one industry over another(Warr, 1994). The theory suggests that countries will produce and export products that have a lower opportunity cost of production, i.e., less costly in domestic resources and import those with a higher opportunity cost of production. Competitiveness is a theoretical framework developed by Michael Porter that attempts to understand how firms or countries achieve prosperity or profit (Stonehouse & Snowdon, 2007). Competitive advantage is achieved when firms or countries can achieve superior returns relative to its competitors(Bhawsar & Chattopadhyay, 2015b).

Competitiveness at an enterprise level is the capability of a firm to fulfil two purposes: 1) the needs of consumers and 2) profit (Bhawsar & Chattopadhyay, 2015). Porters seminal work on competitive advantage states that competitive advantage is realised through offering products and services at a higher perceived value or through reducing costs relative to competitors(Porter, 1997; Stonehouse & Snowdon, 2007). Porter's work laid the foundation of competitive advantage thinking. Further studies highlighted the importance of timing and commitment level when entering a market as crucial components of competitive advantage (Ghemawat, 1986; Lieberman & Montgomery, 1988). Hamal and Prahalad emphasise the importance of competing for a future position in the market (Hamel & Prahalad, 1990). There has also been extensive literature on the link between competitive advantage and a firm's capabilities and resources (Ulrich & Lake, 1991; Hart, 1995). This is only a small sample of the extensive literature on competitive advantage over the past fifty years. Multiple researchers have added their own interpretations from different viewpoints when dealing with competitive advantage.

Sigalas and Pekka Economou (2013), found that there are multiple interpretations of competitive advantage that there is no agreement in a single clear and unambiguous definition. They further argue that the definitions used by researchers can be classified into two streams. The first, describes competitive advantage in terms of performance whereas the second stream describes competitive advantage in terms of its determinants. This definitional problem resulted in obscurities of its operational definition. Hence, measurement techniques have also varied depending on the operational definition employed. These include efficiency measures, trade-based measures, productivity measures, profitability measures etc. These are mostly concerned with three areas: 1) Competitive Performance, 2) Competitive Potential and 3) Management Process (Buckley et al., 1988). However, there exists paucity in a single measure that encompasses all aspects of competitiveness.

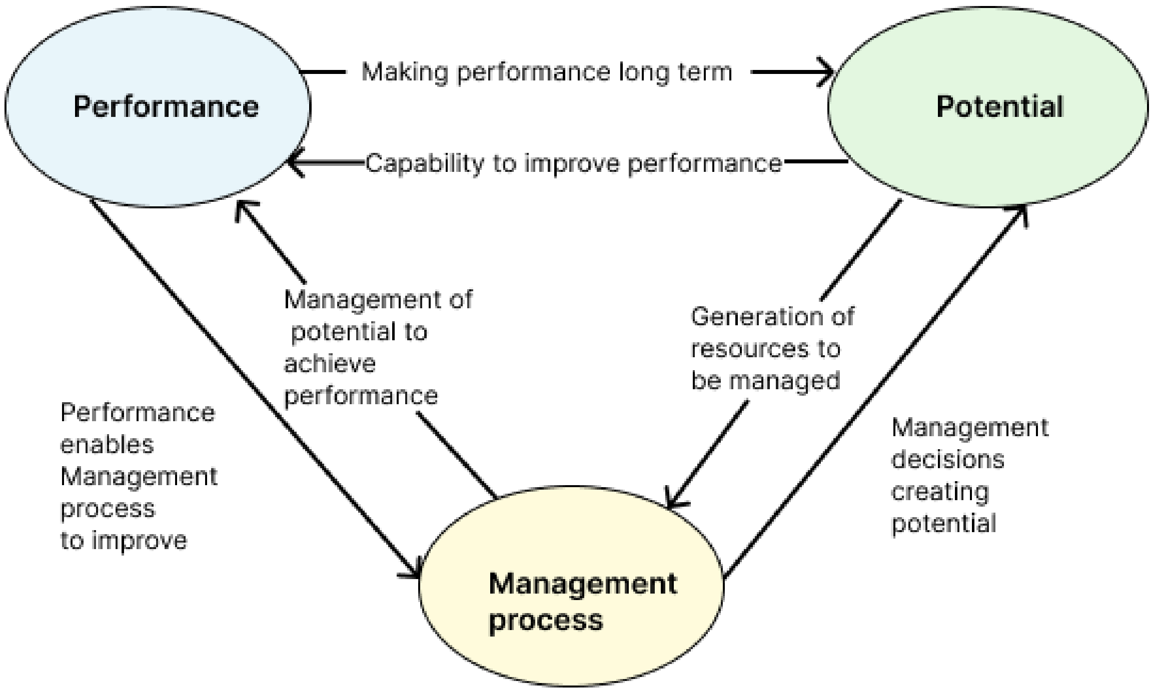

Figure 2.2 The interrelationship between measures of competitiveness. (Buckley et al., 1988)

The 3 P's framework by Buckley *et al.,* (1988), categorises measures of competitive advantage into three interlinked categories. Namely: Competitive performance, Competitive potential, and Management process. They argue that these can be seen as stages in the development of competitive advantages. Potential measures describe inputs into the firm. Performance measures analyse the outcome of business operations and management process measures the management of the firm.

The environmental issues associated with industrial production didn't go unnoticed for long by competitiveness researchers. The Natural Resource Based (NRB) view of the firm is a theory proposed by Hart (1995) that predicts that the future of firm competitiveness will be based on its ability to manage environmentally sustainable competencies. This is supported by Porter and van de Linde (1995), who argue that environmental sustainability is another innovation pathway. Businesses are faced with pressure to innovate in this direction from competitors, consumers, rising costs of resources as well as environmental regulation. Therefore, well-structured environmental regulation will give firms competitive advantage in local and outside markets as environmental standards spread to other markets (Porter & Van Der Linde, 1995).

This has become ever more prevalent in recent years as firms face pressure from all aspects. Consumers are becoming more aware of the environmental costs associated with their consumption (Winston, 2014; Eweje & Sakaki, 2015; Rahman, Mele, Lee & Islam, 2021). The costs of finite resources like fuel, fertilizer and other inputs have been increasing and has seen immense pressure from global crises like Covid19 and the Russia Ukraine war (Workie, Mackolil, Nyika & Ramadas, 2020; Ben Hassen & El Bilali, 2022). There has also been an increase in countries adopting environmentally friendly policy. Mostly notably the Paris agreement on climate change signed by UN members and the EU green deal on climate change and sustainable development (Verschuuren, 2016; Wrzaszcz & Prandecki, 2020). At the same time, competitors are also developing their own sustainability and eco-innovation strategy. This makes eco-innovation and progressive environmental strategy (PES) an appealing strategy to pursue for firms (Tsai & Liao, 2017).

According to Russo & Fouts, (1997), companies that adopt PESs focusing on eco-innovation are more likely to seize opportunities. These companies recognize that committing to sustainability can lead to competitive advantages by establishing themselves as pioneers in eco-innovation(Hart, 1995; Porter & Kramer, 2006). Moreover, effectively utilizing PES allows companies to attribute an eco-label to their products, enhancing their credibility in terms of environmental features (Stefan & Paul, 2008). Consequently, customers perceive these features and increasingly prefer such companies. Further, firms with PES, actively identifying and evaluating environmental trends, are more likely to foster innovation and gain a competitive edge by setting industry standards and creating barriers to entry for competitors (Khanna, Deltas & Harrington, 2009). Furthermore, firms that voluntarily invest in environmental initiatives beyond regulatory requirements are more likely to meet social expectations and generate additional profits(Ervin, Wu, Khanna, Jones & Wirkkala, 2013). Aligning business practices in a socially acceptable manner enables stakeholders and the wider public to perceive benefits from a company's activities (Eweje & Sakaki, 2015), thereby ensuring the legitimacy of its operations.

Given the social and environmental importance of food systems, eco-innovation and PES are of particular importance to agri-food firms. Farmers, being the primary producers in the food system, are crucial to the sustainability of the system. This is because the sustainability of the entire system begins with farmers. Therefore, farmers can gain competitive advantage through eco-innovation and PES (Campos, 2021).

Given the above, competitive advantage is defined in this study as:

"The above industry manifested ability of a farm to manage agroecological competencies that that meet needs of consumers while earning at least the opportunity cost of resources employed."

This definition is based of the NRB view of the firm and recognises the need for firm resources and core competencies (Hamel & Prahalad, 1990; Hart, 1995; Sigalas & Pekka Economou, 2013). This definition also recognises that competitive advantage is a relative concept that manifests in the above industry performance of the firm(Stonehouse & Snowdon, 2007; Sigalas, Pekka Economou & B. Georgopoulos, 2013; Bhawsar & Chattopadhyay, 2015b). This also allows for the measurement of competitive potential and performance in terms of profitability and productivity of the firm relative to its competitors (Buckley, Pass & Prescott, 1988). Research into management processes is reliant on qualitative methodology as opposed to quantitative methodologies presented below. However, qualitative methods alone are not sufficient in the measurement and analysis of competitive advantage. This is because competitive advantage is a relative term and measurement techniques fundamentally rely on the strength of comparison between the firm and its competitors (Buckley *et al.*, 1988). Therefore, this study focuses on quantitative measures of competitive advantage. More specifically, productivity and profitability measures. This can be seen as the "fruits" of management activity. The following section outlines six measures of competitive advantage that can be applied at a firm level.

2.2.1 Productivity measures

The productivity of a firm is closely related to its competitiveness. Productivity refers to the amount of output produced per unit of input over a certain time. Productivity measures can be used for either ex-ante measurement of the performance of the firm or ex-post measurement of the potential of the firm performance. Measurement techniques include the Private Cost Ratio (PCR), Domestic Resource Cost Ratio (DRC) and Total Factor Productivity (TFP).

2.2.1.1 *Private cost ratio (PCR)*

The private cost ratio (PCR) is a ratio used in the Policy Analysis Matrix (PAM analysis to measure the competitiveness of a firm. The PAM is a methodology used to assess the incentives of firms and industries and the impact of policy decision on these incentives at each level (Monke & Pearson, 1989). The PAM consists of two accounting identities. The profit identity states that revenue of the firm is equal to the revenue minus the costs. The second identity measures the divergences between the observed parameters and the same parameters under free market conditions. Thus, measuring the effect of policy on the profitability of firms (Monke & Pearson, 1989).

The PAM can also be used to measure and compare the competitive advantage of firms. Private profitability is calculated by subtracting the costs of inputs from revenues. can be used to measure the competitiveness of the firm given current technology, input and output prices and policy. Private profits greater than zero indicates that the firm is competitive as the firm can earn more than the opportunity cost of resources employed. Private profitability less than zero indicates that the firm is not competitive.

The PCR is closely related to private profitability. The PCR measures the productivity of the firm by indicating how much they can pay domestic factors of production and remain competitive. The PCR is calculated by dividing domestic factor costs by the value added (difference between revenue and tradable inputs). The formula for the PCR is given below.

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$$PCR = \frac{\sum a_{ij} p_k^p}{Y_i^p P_i^p - \sum a_{ij} P_j^p} \tag{2.1}$$

$\sum a_{ij} p_k^p$= Cost of domestic factors at private prices; $Y_i^p P_i^p$= Revenue at private prices.

$\sum a_{ij} P_j^p$ = Cost of tradable inputs at private prices.

A PCR less than one indicates that the firm is competitive as the value-added outweighs the resource cost. A PCR greater than one indicates that the cost of resources is more than the value added and that the firm is uncompetitive. The PCR is advantageous over private profitability as it allows for comparison of different firms producing different commodities by employing a ratio as the unit of analysis(Monke & Pearson, 1989).

Both the PCR and Private Profitability are used to measure competitive potential of a firm as the PAM measures the impact of policy on the firm. However, several studies use these measures to compare the competitive performance of firms. Adegbite, et al. (2014), uses the PCR to measure and compare the competitiveness of crown and sucker techniques of pineapple production in Nigeria. Oluyole, Agbeniyi & Ayegbonyin, (2017) use private profitability and the PCR to compare the competitiveness of three cashew cropping systems in Nigeria. Namely, solo cashew production, cashew and arable crops, and cashew and tree crops.

2.2.1.2 *Domestic resource cost ratio (DRC)*

The DRC is a ratio used to measure the comparative advantage of producing a particular good (Monke & Pearson, 1989). The DRC is a measure of the relative efficiency of domestic production by comparing the opportunity cost of domestic export production with the value added by exporting the product(Frohberg & Hartmann, 1997). The DRC is calculated by dividing the cost of non-traded inputs (in domestic shadow prices) by the value added of producing the same good. The formula for the DRC is shown below.

$$DRC_i = \frac{\sum_{j=k+1}^{n} a_{ij} P_j^D}{P_j^B - \sum_{j=1}^{k} a_{ij} P_j^B} \qquad \textbf{(2.2)}$$

$\sum a_{ij}\, p_j^D$= Cost of domestic factors at shadow prices; P_j^B= Border price of commodity.

$\sum a_{ij} P_j^B$ = Cost of tradable inputs at border prices

The numerator of the DRC is the sum of the cost of non-traded inputs valued at its respective domestic opportunity cost. The denominator is product price less tradable input costs at border prices. A DRC less than 1 indicates that a firm is has comparative advantage in production of the particular good as the value added is greater than the opportunity cost of production. Vice versa(Frohberg & Hartmann, 1997).

The DRC can be calculated using enterprise budgets and the PAM (Monke & Pearson, 1989; Tweeten, 1992). It can also be aggregated to industry level. However, the units used in the numerator and denominator must be the same. Which is usually expressed per hectare, per bushel or per kilogram(Tweeten, 1992).

The major challenge to calculating the DRC is the determination of the appropriate local shadow prices for non-tradable inputs such as land, labour, and capital. The shadow price is determined by the opportunity cost of the return to the respective resource based in their best alternative use in the domestic economy. From an agricultural perspective, this may be rental income forgone for land. For labour, the wages of similar type jobs in non-farm employment can be used. These would then be adjusted to the appropriate free market price, free from any policy distortions (Tweeten, 1992).

The DRC has also been criticized for producing biased results. Master's and Winter Nelson (1995) show that the DRC often shows firms with high levels of non-tradable input use are inefficient. They further add that results can vary based on the researcher's distinction between tradable and non-tradable inputs. Finally, the input output data required may be difficult to acquire (Masters & Winter-Nelson, 1995).

2.2.1.3 *Total factor productivity (TFP)*

Total factor productivity is a measure of efficiency. It measures the rate at which inputs such as labour, capital and are converted to outputs (Bernolak, 1997; Van Beveren, 2012). TFP can be measured at a firm, industry, and economy wide level. TFP has been widely used as an industry level measure of competitiveness along with partial productivity measures like labour productivity and unit labour costs (Siudek & Zawojska, 2014). Partial productivity measures use a single input in the calculations as opposed to TFP which includes multiple inputs. TFP captures the residual output that cannot be explained by changes in the measured inputs. This can be related to factors like, technology, managerial skills and other intangible factors that enhance or impede productivity growth. Thus, TFP measures competitive advantage(Bernolak, 1997; Woodford, Greer & Phillips, 2003; Siudek & Zawojska, 2014). TFP and its associated productivity measures are often applied in the dynamic framework. The changes in the measure are the focus of investigation. Thus, TFP can be used as an ex-post measurement of competitive potential of a firm due to a change in a factor as well as an ex-ante measure of competitive performance over time.

It's important to note that TFP measures the real changes in physical quantities of output. If sales volumes increase but input use also increases, it is not necessarily a TFP increase (Bernolak, 1997). TFP improvement means an increase in production of good or service per (physical) input used. TFP analysis is normally conducted at industry and country level however some have attempted this analysis at firm level(Ondrej & Jiri, 2012; Gal, 2013) . TFP can be calculated using simple ratios or via econometric analysis (Van Beveren, 2012). The most common ratio methods include, Solow residual, data envelopment analysis and growth accounting (Ball & Norton, 2002). The most common econometric analysis includes stochastic frontier analysis and ordinary least square residual analysis (Gal, 2013). The methodology of each is not the focus of this study. However, Gal (2013), provide a detailed breakdown of methods and calculations using the OECD-ORBIS database (Gal, 2013). The key takes away is ratio methods relate output to the weighted sum of inputs and econometric methods rely on estimation of a production function. Finally, the fundamental relationship that TFP measures can be represented by the equation below.

$$TFP = \frac{Total\ Output}{Sum\ of\ inputs} \tag{2.3}$$

When TFP is applied in a dynamic framework, the changes in TFP over time are the focus of investigation normally proceeded by analysis of the elements or components and their effect on the observed change. Measuring TFP accurately is challenging due to data limitations, measurement errors, and the complexity of capturing all relevant factors that influence the firms TFP growth (Siudek & Zawojska, 2014).

Various factors have been analysed in literature including, technology change, environmental policy, and R&D. Dias Avila and Evenson (2016), use the growth accounting method to calculate the trend in TFP for the agricultural sectors in developing countries from 1961-1980 and 1981-2001. They then statistically test the growth rates with technological capital indexes. Their results show that TFP performance is strongly related to technological capital growth (Dias Avila & Evenson, 2010). Ramanathan and Song both combine environmental factors into the production function with other factors like labour and capital. This allows the study of ‘green’ TFP and sustainability factors like green policy that can influence it (Ramanathan, 2005; Song, Bian, Zhu & Nan, 2020).

2.2.2 Profitability measures

Profitability considers the income, costs of variable inputs, costs of factors of production to measure the efficiency of a firm. Profitability is a precondition for competitive advantage. This is because firms that earn a profit are naturally competitive as they can cover the costs of resources employed and meet the demands of consumers. Competitive advantage is present when firms can achieve superior profitability relative to its competitors. Thus, the measurement of profitability can be used as a measurement of competitive advantage. Profitability measures measure the ex-post-performance of the firm and is primarily associated with accounting measures. These include the profit margins and return on assets.

2.2.2.1 *Profit Margin*

Gross margin calculations have been used to compare the costs of production and revenues across firms to indicate which enterprise has a competitive advantage. The gross margin refers to the total income derived from the enterprise minus variable costs of production incurred by the enterprise. The formula for calculating the gross margin is given by Lipsey et al (2004).

$$GM = R - TVC \qquad \textbf{\textit{(2.4)}}$$

The production of goods is unfeasible when total variable costs are greater than revenues. Therefore, gross margin is a measure of performance of the firm. A firm with a gross margin greater than zero is considered competitive. The higher the gross margin, the greater the level of competitiveness. A farm with a negative gross margin is not considered competitive. Firms have competitive advantage when their gross margin is higher than that of competitors.

Gross margins can be expressed as an amount per unit of output or the most limiting resource. For example, farm enterprises can express gross margins per hectare of land or per unit of labour. This aids comparison between firms as the margins are normalized to indexed values that can be easily compared and are based on detailed cost break downs which can provide insights into why some firms are not competitive.

The calculation of gross margins requires revenue and cost data of the firm(s). The recording of this data can differ between firms. For example, the treatment of joint outputs and the differentiation between variable costs and quasi-fixed costs. Accurate comparisons can only be made if the data is of similar quality between firms.

The net margin is similar to the gross margin as it can be used compare the revenues and costs of production between firms. However, the net margin encapsulates not only direct production costs but also a comprehensive spectrum of expenses ranging from overheads to interest payments and taxes. The general formula is given by equation 2.5 below.

$$NM = R - TVC - TFC \tag{2.5}$$

The net margin is equal to firm revenue minus total fixed and variable costs. By encompassing these broader financial considerations, net margin provides a more accurate representation of the overall financial well-being of agricultural enterprises, thus contributing to a more holistic understanding its competitive positioning. Like the gross margin, the net margin relies on accounting data of the firm and can be normalized to a limiting factor.

The net margin and gross margin are usually analysed in combination. Kibiego, (2015), use the gross margin and net margin to analyse the competitiveness of three smallholder milk production systems in Kenya. They also normalize these indicators to a litre of milk produced. Their results show that free grazing systems had the highest gross margin and net margin compared to zero grazing and semi-grazing systems. Implying competitive advantage. Their results further show that profitability of milk production (Kshs/liter) reduced with intensification due to the higher feed and labour costs in more intensive systems (Kibiego, Lagat & Bebe, 2015).

2.2.2.2 Return on Assets

Return on assets (ROA) is a financial ratio that measures the efficiency of asset utilization by relating it to the net profit generated for the firm(Bernolak, 1997). The ROA provides insight into how effective a firm's investments to assets are at generating net profit. The ratio is commonly decomposed into its 'primary ratios'. Namely, the net profit margin (NM) and total asset turnover (TAX). This is known as DuPont analysis after Dupont who popularised its use (Dehning & Stratopoulos, 2002). ROA can be calculated by the set of equations below.

$$ROA = NM * TAX \qquad \textbf{(2.6)}$$

Or

$$\frac{NP}{TA} = \frac{NP}{Sales} \times \frac{Sales}{TA} \qquad \textbf{(2.7)}$$

From the equations above, ROA is equal to the product of the profit to sales ratio (NM) and total asset turn over (TAX). These two ratios capture the effects of efficiency and profitability of the firm. Dehning & Stratopoulos, (2002) argue that lower production costs and increased quality are accounted for by the profitability component, the NM ratio. Increased efficiency is accounted for by TAX. In addition, increased efficiency is accounted for by profitability measures to the extent that fixed costs are a component of cost of goods produced. Therefore, these measures can used to measure firm competitive advantage as a ROA higher than competitors implies greater profitability and efficiency of the firm (Dehning & Stratopoulos, 2002).

Bauman et al., (2018) study the relationship between farm market participation and financial performance for farms across the United States. They use the ROA as the measurement variable which allows firms to be clustered into quartiles based on their performance (Bauman, Thilmany McFadden & Jablonski, 2018). Shadbolt, (2012) uses the ROA to study the differences in competitive advantage strategy for dairy farmers over 4 years in New Zealand. Their study shows that capital intensive dairy farmers are more vulnerable to market conditions than pastoral farmers as they fail to maintain asset efficiency when market prices decline(Shadbolt, 2012) .

2.3 Conclusion

The concept of agroecology is not a new one. It originates from the early 1900's where scientists used the term to describe the study of ecological methods of crop production and protection at the farm level. Since then, the scope of agroecology has grown to include agroecosystem studies and socioeconomic studies of food systems at an expanded temporal level. At its core, agroecology is a multidisciplinary study incorporating ecological and socioeconomic dimensions into the study and management of food systems.

In line with this, the operational definition for agroecology used in this study is adapted from Barrios et al (2020) and is defined as: *'a holistic and integrated approach that simultaneously applies ecological and social concepts to the design and management of sustainable agroecosystems."*

The concept of the agroecosystem is central to the study of agroecology. An agroecosystem describes the system of abiotic and biotic components, modified by humans, that interact in an environment to produce food. The type and productivity of an agroecosystem is determined by multiple factors which include physical, biological, socioeconomic, and cultural factors.

The 10 elements of agroecology outlined by the FAO provide a framework for member countries of the UN to design policy that supports the transition to agroecological food systems. These 10 elements are broad criteria that indicate the focus of transition efforts. These elements are interrelated and need to be applied at farm, community, and policy levels to facilitate this transition envisioned by the FAO. However, farmer participation is key to transitioning to agroecological food systems.

This makes the 10 elements of Agroecology too broad for direct farmer engagement. Elements such as diversity, recycling, synergies, and human and social values can be applied at the farm level. The elements efficiency, and resilience are emergent properties of the entire food system. The elements culture and food traditions and circular economies necessitate consumer participation. If consumers recognise that food produced within a local context has a higher perceived value, then circular economies and culture and food traditions become important value attributes that farms can capitalize on. The remaining elements, responsible governance, cocreation and sharing of knowledge as well as circular and solidarity economy are concerned with policy action. **Therefore, the 10 elements of agroecology cannot serve as an agroecology framework for farmers.**

This study addresses this by using the 13 principles of agroecology identified by the HLPE. The 13 principles are preferred over the 10 elements as they are specific and actionable. Furthermore, the principles were clustered into on-farm and off-farm groups. This reduces the spatial dimension of the principles to the farm level where farmers can directly apply them.

The on-farm principles that were identified are: 1) Recycling, 2) Input Reduction, 3) Soil Health, 4) Animal Health ,5) Biodiversity, 6) Synergy, 7) Economic Diversification, 10) Fairness.

Farmers are central to agroecological transitions and there should be an inherent benefit when transitioning to an agroecological approach compared to their existing methods. This study uses principles of agroecology as a form proactive environmental strategy (PES). PES refers to a set of voluntary practices a firm invests in beyond regulations and will only be adopted by firms if there is a benefit associated with it. Extensive studies have shown that firms can get a competitive advantage by implementing progressive environmental strategies. Government subsidy also plays an important role in environmental innovation by providing incentive for firms to adopt progressive environmental strategies. **Given the ecological and social importance of farms, the principles of agroecology can be used as a competitive advantage strategy for farmers.**

While numerous studies have highlighted the financial benefits of agroecological practices over conventional agriculture, the application of agroecology as a competitive advantage strategy for farmers remains unexplored (D'Annolfo, Gemmill-Herren, Graeub & Garibaldi, 2017b) . To investigate this hypothesis, the study establishes an operational definition of competitive advantage and identifies five measures from existing literature: Private Cost Ratio (PCR), Domestic Resource Cost (DRC), Total Factor Productivity (TFP), Profitability, and Return on Assets (ROA).

While it is possible to categorize the benefits of these principles into three groups: cost savings, price premiums, and ecosystem services, these principles operate synergistically to generate benefits, and their relative importance remains unknown. Additionally, the capacity of each measure to accurately account for each principle needs assessment. To address these questions, the study employs the Analytical Hierarchy Process method, as discussed in Chapter 3.

3 Methods

This chapter presents the analytical framework and method for testing current measures of competitive advantage suitability to account for agroecological principles.

The research question that guides this chapter are further broken down into the following:

“To what extent does PCR, DRC, TFP, Profit margin and ROA account for agroecological principles?”

3.1 Introduction

This study used the AHP analysis to answer the research questions. The AHP is a decision-making methodology developed by Saaty, (1987). It uses pairwise comparisons and expert opinions to derive ratio scales of judgement in multilevel hierarchic structures (Saaty, 1988). The AHP is one of the most widely used tools used by decision makers and is favoured because it uses this hierarchal structure to structure and solve complex problems (Hartwich, 1999).

The purpose of the AHP is to evaluate several alternatives with respect to several criteria. This is done by structuring the problem hierarchy tree with the alternatives at the base, criteria in the middle and the objective on the top (Hartwich, 1999). The decision maker then carries out pairwise comparisons to determine overall priorities for ranking alternatives. The AHP also checks for inconsistencies in judgment (Saaty, 1987).

The AHP analysis can be broken down into 6 steps (Hartwich, 1999). These steps are used in this study as the methodological framework and is described in this chapter. An additional section is also provided to outline the data collection procedure and methodology used for checking consistency. These 6 steps are:

1. Defining the problem,
2. Selecting units of evaluation,
3. Identifying a set of alternatives,
4. Identifying a set of relevant criteria,
5. Developing the hierarchical structure,
6. Collecting information and eliciting local and global priorities.

3.2 Defining the problem.

The current market and environmental conditions make agroecology a potential competitive advantage strategy for farm enterprises. However, competitive advantage is a relative term. Thus, competitive advantage can only be present when measured relative to competitors.

Measuring competitive advantage can be done in several different ways and is dependent on the definition used. Through literature review an operational definition of competitive advantage for agroecological farms was synthesised. Agroecological competitive advantage is defined in this study as: "*The above industry manifested ability of a farm to manage competencies that facilitate environmentally sustainable activities that meet needs of consumers."*

Given this definition, five suitable measures were identified. These being: Private Cost Ratio (PCR), Domestic Resource Cost (DRC), Total Factor Productivity (TFP), Profitability and Return on Assets (ROA). However, the ability of these measures to accurately account for agroecological farms has not been tested.

Therefore, the objective of this AHP analysis is to select a suitable measure of competitive advantage for agroecological farms.

A measure of competitive advantage can benefit multiple stakeholders specifically in the areas of implementation, evaluation, and control of agroecology-based strategies. For farmers, measurement is important to evaluate the performance of the farm relative to competitors as well as to identify competitive agroecological farming practices that they can transition to. Agribusiness and development organizations need to improve their measurement and assessment methods to detect these agroecological costs and benefits as they become increasingly important(Dumont *et al.*, 2016). This also applies to other stakeholders interested in agroecology such as government, institutions, and NGO's.

3.3 Designing and selecting units of evaluation.

The literature review in chapter two reveals that agroecology can be defined by 13 inter-related principles. Evaluation of agroecological systems can take place different levels. Farmers, being the primary producers, are the focus of this investigation. More specifically the farm enterprise and its immediate agroecosystem. Economic analysis of the farming enterprise is necessary to understand the incentives and costs associated with agroecology. Competitive advantage was chosen given that it is a framework investigates business prosperity. Measurement techniques were selected as the unit of evaluation because competitive advantage is a relative term that necessitates comparison with competitors (Buckley *et al.*, 1988). Furthermore, the synergies and interactions between principles of agroecology are accounted for (transformed) to the farm enterprise's prosperity. This makes competitive advantage an appropriate framework for economic analysis of agroecosystems.

3.4 Identifying a set of alternatives

Agroecology is an alternative to conventional agriculture which offers different incentives. Comparing these systems requires a method that accurately represent the costs and benefits associated with each system. Competitive advantage is chosen as it recognises market conditions and government policy as incentives in decision making (Warr, 1994; Porter & Van Der Linde, 1995). The quantitative aspect allows different systems to be compared by employing a single unit of analysis (Buckley *et al.*, 1988). Therefore, measures of firm level competitive advantage are chosen as the alternatives.

In chapter 2, five measures of firm level competitive advantage were identified. Namely, Private Cost Ratio (PCR), Domestic Resource Cost (DRC), Total Factor Productivity (TFP), Profitability and Return on Assets (ROA). These measures, besides DRC, serve as the alternatives for this analysis.

DRC is excluded because it is a measure of comparative advantage. Some analyses do use the DRC and its inverse, in combination with other measures to measure competitive advantage(Frohberg & Hartmann, 1997). However, the DRC fundamentally compares the opportunity cost of the domestic component of production with the value added (at border prices) (Monke & Pearson, 1989). This is comparative advantage (see section 2.2).

A description for the remaining four alternatives is given in table 3.1 below. These measures can be applied at different spatial levels and differ in areas such as: data requirements, benefits measured, scale of application etc. It is important to note that these measures were identified based on the definition of competitive advantage used in this study.

Table 3.1 Measures of Firm-Level Competitive Advantage

Measure	Definition	Level of Analysis	Formula
Private Cost Ratio (PCR)	• The ratio of domestic factor costs to value added in a farming system. • Measures the competitiveness of agricultural system by showing how much it can afford to pay factors of production while maintaining profits. • Used to compare the competitiveness of different agricultural systems and the effect of policy on its competitiveness. (Monke & Pearson, 1989)	Firm	$PCR = \frac{Cost\ of\ domestic\ factors}{\text{Revenue} - \text{Cost of tradable inputs}}$
Total Factor Productivity (TFP)	• The ratio of output to that of all inputs. • Measures efficiency and efficacy of production. • Typically used in a dynamic framework measuring changes in TFP over time. (Bernolak, 1997; Van Beveren, 2012)	Firm, Industry, Country.	$TFP = \frac{Total\ Output}{Labour + Capital\ input}$
Profit Margin	• Gross margin (GM) is total income minus variable costs of production Lipsey et al (2004). • used to compare the costs of production and revenues across firms to indicate which enterprise has a competitive advantage. • Can be normalized to limiting factor like labour or land. • Net margin (NM) is gross margin less directly allocatable fixed cost (Kibiego *et al.*, 2015) .	Firm, Industry	$GM = R - TVC$ $NM = R - TVC - TFC$
Return on Assets (ROA)	• The income returned for every dollar of assets employed. • Can be decomposed into the product of net profit margin (NM) and total asset turnover (TAX). • These measure the profitability and efficiency respectively. • Can be used to compare firms and their performance (Dehning & Stratopoulos, 2002).	Firm	$ROA = NM * TAX$

3.5 Identifying a set of relevant criteria

Agroecology at a farm level can be represented by 8 inter-related principles as described in section 2.1.4. These principles are used as the criteria for the analysis. The principal "synergy" was omitted as it is an outcome of the interactions between the components of the agroecosystem. Leaving the remaining 7 as criteria for the AHP.

Furthermore, the criteria are used at a single level with no aggregation to sub criteria. This is because agroecological principles are inter-related and "overlap" in sub- criteria. The single level further helps distinguish the principles from each other.

3.6 Developing the hierarchal structure

This step involves arranging the problem into its hierarchical structure. This analysis uses a three-level structure with four alternatives at the bottom, and seven criteria at the second level. The overall goal of the analysis is represented at the top level of the hierarchy. Figure 3.1 below shows the hierarchical structure of this analysis.

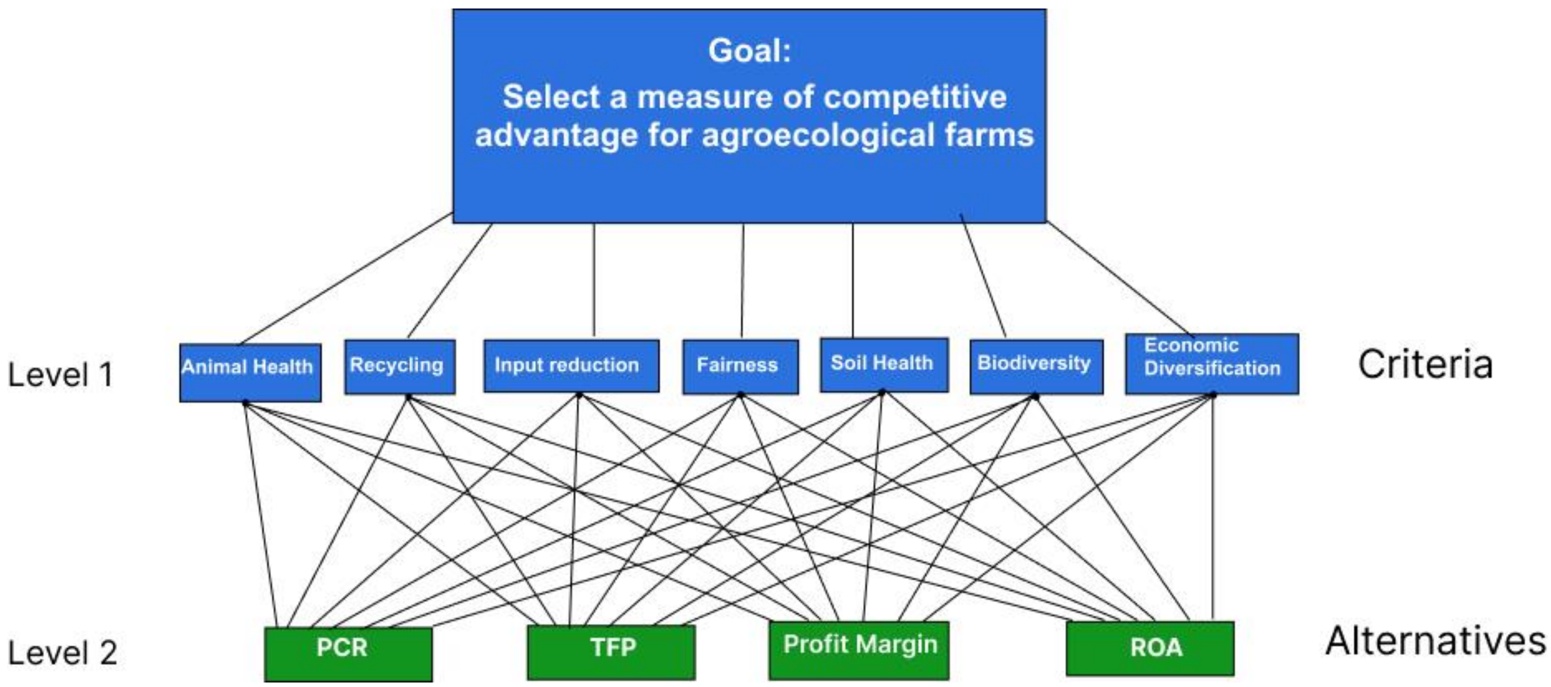

Figure 3.1 Hierarchical structure of AHP analysis

3.7 Data collection

The next step is to evaluate the alternatives as well as criteria by making pairwise comparisons. Both were done using the Delphi method. The Delphi method is a method of structured group communication that is effective in eliciting a collective view from individuals on complex problems (Mahajan, Linstone & Turoff, 1976). This method is an iterative questionnaire procedure with controlled feedback to a group of panellists who have the relevant knowledge and experience in dealing with the topic(Thangaratinam & Redman, 2005). This method is favoured as it can lead to cohesion and ownership of decisions amongst individuals in a diverse group. It was also designed to avoid counterproductive group dynamics by allowing panellists to re-appraise their views considering the group responses(Thangaratinam & Redman, 2005; Skulmoski, Hartman & Krahn, 2007).

The Delphi method is popular among researchers and has been applied in various fields such as medicine, engineering, policy making, etc… As early as 1976, Mahajan, Linstone & Turoff noted the difficulty of attempting to define the Delphi method as one would immediately encounter a study that violated that definition. Given this, there is no single prescriptive approach that exists.

Mahajan, Linstone & Turoff, (1976), did however, give the following general characteristics of the Delphi method. These are: feedback of individual contributions of knowledge, assessment of group judgement, some opportunity for individuals to revise their views and some degree of anonymity of individual responses.

One of the considerations is the number of rounds to conduct. This study used a three-round procedure for both panels. According to Skulmoski et al., (2007) this is the minimum number of rounds to conduct for the Delphi method. The first round consisted of a pre-designed questionnaire given to panellists. The second round consisted of a panel discussion where the aggregate results of the study were presented. After which, the panellists were given the same questionnaire as a final re-evaluation phase.

Another consideration of the Delphi method is the selection of panellists. Many studies have referred to their panellists as “experts”. The use of the word expert is obscure and open for interpretation (Goodman, 1987; Mullen, 2003). This study refers to participants as panellists. Panellists were selected based on their knowledge and experience in the respective fields. This study uses two Delphi panels with each having their own respective panellists. The selection criteria are described below.

3.7.1 Delphi panel on Agroecology

This panel was used to evaluate the criteria in the AHP analysis. I.e., the seven principles of agroecology. This panel can be considered multidisciplinary as prospective panellists were chosen based on their knowledge and experience in food systems. Participants included farmers, academics, institutional representatives, NGOs, and agroecology farmers. Panellists who dealt with sustainable agriculture and agroecology were given preference. A total of ten prospective panellists were contacted with a response rate of 80%. However, due to the availability of participants, only four participants participated in this panel.

The first round of this panel consisted of a prepared questionnaire that required panellists to make pairwise comparisons of criteria. All 7 criteria were compared, giving a total of 21 comparisons. Panellists were contacted and interviewed individually. The criteria were evaluated based on their relative importance to the competitive advantage of agroecological farms. The second round was a panel discussion where the aggregate results of the first round were presented. After which, participants were given an opportunity to re-evaluate their answers. The full questionnaire can be found in the appendix below.

3.7.2 Delphi panel on Measures of Competitive Advantage

This panel was used to evaluate the alternatives of the AHP analysis. This panel follows the same three round structure as the previous panel but shifts the focus on to measures of competitive advantage. These measures are derived fields of economics and strategic management and applied in Agricultural Economics and Agribusiness management. Participants were selected based on their knowledge and experience in these fields. Preference was given to participants who had experience in agroecology, sustainability, and competitive advantage. A total of 20 participants were contacted with a response rate of 65%. Most of the participants were academics, one was from government, and another was from industry. Due to the availability of participants, the final panel consisted of 7 participants.

The first-round questionnaire of this panel required participants to evaluate the 4 alternatives with respect to each criterion. All alternatives were compared pairwise. Giving a total of 42 comparisons. The second and third round followed the same as the delph panel on agroecology. Both panels used the same consensus method and aggregation process. Hence, they will be explained together in the sections below.

3.7.3 Delphi Consensus Process

The Delphi method was initially used a method to gain group consensus although this is not always the case. Some may argue that the Delphi method is designed to force consensus by the way the questionnaire is designed, or results analysed. Mullen, (2003) argues that whether consensus should be sought depends on the aim of the panel. Since this panel is used to evaluate agroecological principles, consensus was not sought in both panels. The reasoning behind this is the fact that agroecology promotes multistakeholder discourse bringing in diverse perspectives. To force consensus would neglect contesting perspectives of panellists.

Instead, this study used simple statistical tests to check the variations in distribution of answers.

The variance of each answer was calculated by: $\sigma^2 = \frac{\sum(x_i-\mu)^2}{n}$

Where $\sigma^2 = variance\ of\ population \quad n = number\ of\ panellists$

$$\sum(x_i - \mu)^2 = sum\ of\ squared\ differences\ of\ population \ \ \text{(Weiss, 2008)}$$

A variance threshold of 40% was set for both panels. If a question had a variance over the threshold, it was flagged. Those questions were then presented to the panellists in the second round of the Delphi panel. The results of the third round were used as the results. These were aggregated using the method described below.

3.8 Calculation of Local and Global Priorities

The following section describes the procedure used to calculate the priorities for the AHP analysis. The pairwise comparisons from the Delphi panels described in the previous section were used as the data for the analysis. Firstly, it is important to describe the scale used for the comparisons.

This study used a verbal scale for comparisons. These are then translated into intermediate values from the fundamental scale described by Saaty and Vargas (2012, p.6). This is then used for the calculation of priorities. Table 3.2 below provides an example of the questionnaire format.

Table 3.2: Pairwise Questionnaire Format with Corresponding Scale Values

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred	
Alternative 1	3	2	1	1/2	1/3	Alternative 2

Table 3.2. shows the format of pairwise comparison questions used for both panels. The numbers in the first row are numerical values assigned to the corresponding verbal scale in

the column heading. These values are used to derive the weightings of alternatives in the AHP. Panellists were given five options of comparison. Alternatives were compared from the middle value with values on the left indicating preference of Alternative 1 and vice versa. Thus, giving five possible answers for each question.

These are:

1. Alternative 1 is most preferred.
2. Alternative 1 is more preferred than alternative 2.
3. Both alternatives are equally preferred (No preference)
4. Alternative 2 is more preferred than alternative 1.
5. Alternative 2 is most preferred.

It is worth considering some of the critiques of the fundamental scale and AHP. The fundamental scale in AHP is based on a nine-point semantic scale and are treated as judgements on a ratio scale. Belton, (1986), argue that judgements made on the semantic scale do not fulfil the requirements for ratio judgements. They further add that the limitations of a 1-9 scale and its semantic associations impose unnatural restrictions on judgements(Belton, 1986). For example, a value of 7 on the semantic scale represents demonstratable stronger preference of alternative. Is “demonstratably” strong, stronger than strong?

In response to this, this study modified some of the techniques of the AHP. Firstly, the upper limit of the fundamental scale of comparisons was reduced from 9 to 3. This aids comparisons by reducing the scale of comparisons thus reducing unnatural judgements. Secondly, this study used the verbal ratio scale and a pairwise comparison questionnaire which was explained to panellists in each round of the Delphi panel. Thus, preference of an alternative over another can only be expressed in three ways, equal preference, preferred, and absolute preference.

3.8.1 Aggregation of Preferences

The next step is to aggregate preferences and construct pairwise comparison matrices. This study uses the aggregation of individual priorities method. This method calculates pairwise comparison matrices for all participants and then aggregates the individual priority vectors to derive a group priority vector. This is preferred over the aggregation of individual preference method as the full analysis is conducted on each participants answer allowing for more representative results. Furthermore, each participant’s answer is weighted equally in the aggregation process. Thus, the procedure described below was applied to all participants to derive individual priority vectors which were then aggregated using the arithmetic average.

3.8.2 Calculation of local priorities

Firstly, a 7x7 matrix (A) was created for criteria. The entries in the upper triangle in this matrix (a_{ij}) represents the relative preference of criteria i over j. The lower triangle matrix was calculated by finding the reciprocal values of the top triangle.

$$A = \begin{Bmatrix} \frac{a_1}{a_1} & \frac{a_1}{a_2} & \frac{a_1}{a_n} \\ \frac{a_2}{a_1} & \frac{a_2}{a_2} & \frac{a_2}{a_n} \\ \frac{a_n}{a_1} & \frac{a_n}{a_2} & \frac{a_n}{a_n} \end{Bmatrix} \quad \textbf{(4.1)}$$

Where: $A = \{a_{ij}\}_{n \times n}$ and $a_{ji} = 1/a_{ij}$ with i, j = 1,2, . . .n.

The next step is to normalize A by dividing each entry by its column sum. This yields a new matrix $\bar{A}$. The entries ($\bar{a}$) in this matrix were calculated using equation 4.2.

$$\bar{a} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad \textbf{(4.2)}$$

The priority vector was obtained by averaging across the rows of matrix $\bar{A}$. This is also known as the principal eigen vector in mathematics. Its entries are denoted by W and were calculated using equation 4.3. The sum of all CW should equal one since it is normalised.

$$W_i = \frac{\left[\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \ldots + \cdots \frac{a_{ij}}{\sum_{j=1}^{n} a_1}\right]}{n} \quad \textbf{(4.3)}$$

This procedure was done once for comparison of criteria for all participants. The results were then aggregated to give the local group priority vector (CW). This shows the relative importance or weight of each criterion.

$$CW = \begin{Bmatrix} CW_1 \\ \vdots \\ CW_n \end{Bmatrix} \quad \textbf{(4.4)}$$

For the alternatives, a 4X4 matrix(B) was constructed for 4(m) alternatives for each criterion. The entries in the upper triangle in this matrix (b_{ij}) represents the relative preference of alternative i over j. The lower triangle matrix was calculated by finding the reciprocal values of the top triangle.

$$B = \begin{Bmatrix} \frac{b_1}{b_1} & \frac{b_1}{b_2} & \frac{b_1}{b_m} \\ \frac{b_2}{b_1} & \frac{b_2}{b_2} & \frac{b_2}{b_m} \\ \frac{b_m}{b_1} & \frac{b_n}{b_2} & \frac{b_m}{b_m} \end{Bmatrix} \text{`} \qquad \textbf{(4.5)}$$

Where: B= $\{B_{ij}\}_{m \times m}$ and $b_{ji} = 1/b_{ij}$ with i, j = 1,2, . . .m.

The same calculations described in equations 4.2 and 4.3 were applied to B to derive the priority vector for alternatives (AW) for each criterion. An entry in this matrix is referred to as v and is calculated by equation 4.6 below.

$$v_j = \frac{\left[\frac{b_{ij}}{\sum_{j=1}^{m} b_{ij}} \ldots + \cdots \frac{b_{ij}}{\sum_{j=1}^{m} b_1}\right]}{m} \qquad \textbf{(4.6)}$$

This procedure was conducted seven times for each participant, comparing the four alternatives with respect to each criterion. The same aggregation procedure was conducted yielding a total of 7 group priority vectors (AW), one for each criterion. This shows the relative preference of each alternative with respect to each criterion.

3.8.3 Calculation of global priorities

The final step in this analysis to select the best measure of competitive advantage for agroecological farms. This was done by applying the weights of criteria to the alternatives to derive the overall preference of alternatives. The seven priority vectors described above are assembled to form the final matrix of priorities (V).

$$V = \begin{Bmatrix} AW_{11} & AW_{12} & AW_{1n} \\ AW_{21} & AW_{22} & AW_{2n} \\ AW_{m1} & AW_{m2} & AW_{mn} \end{Bmatrix} \qquad \textbf{(4.7)}$$

This was multiplied by the priority vector of criteria (CW) to derive the final ranking of alternatives.

$$\begin{Bmatrix} AW_{11} & AW_{12} & AW_{1n} \\ AW_{21} & AW_{22} & AW_{2n} \\ AW_{m1} & AW_{m2} & AW_{mn} \end{Bmatrix} \times \begin{Bmatrix} CW_1 \\ \vdots \\ CW_n \end{Bmatrix} = \begin{Bmatrix} Overall\ rank\ for\ 1 \\ \vdots \\ Overall\ rank\ for\ m \end{Bmatrix} \qquad \textbf{(4.8)}$$

3.9 Checking for consistency.

In the AHP consistency is defined in the following way:

Definition: the matrix A is said to be consistent if: $A(a_i, a_j)A(a_j, a_k) = A(a_i, a_k)$.

A fully consistent matrix, I.e., one with $a_{ik} = a_{ij}a_{jk}$., will have a maximum eigenvalue (λ) equal to the size of the matrix (n). Inconsistencies can be measured by the discrepancies between n and the maximum eigenvalue (λ).

The maximum eigenvalue is a mathematical term that describes the maximum value scalar value associated with the eigenvector of the matrix. This involves solving multiple simultaneous equations to $\sum_{j=1}^{n} a_{ij} v_j = \lambda w_i$ and is out of the scope of this study. A more detailed explanation can be found in(Saaty, 1987) . This study instead used the following formula to estimate the maximum eigenvalue for each matrix.

$$\lambda\, max = \frac{\sum_{j=1}^{n} W_i * a_{ij}}{W_i} \quad \textbf{(4.9)}$$

Where n= size of matrix,

$\lambda\, max$ is given by the matrix product of the weights of the matrix and the corresponding preference divided by the relevant weight. This was calculated for all criteria and alternatives. I.e., All a and b using their respective CW and AW. The consistency index number then can be calculated using equation 4.10 given by Saaty & Vargas, (2012, p9).

$$\mathrm{CI} = \frac{\lambda \max - n}{n-1} \quad \textbf{(4.10)}$$

CI measures the degree of consistency of judgments by comparing it's $\lambda\, max$ with that of a fully consistent matrix. To ease comparison, the consistency ratio, (CR) was calculated by dividing the consistency index number by random index number derived from a matrix of the same size. This is shown in equation 4.11.

$$CR = \frac{CI}{RI} \quad \textbf{(4.11)}$$

The CR gives the absolute measurement of consistency. The comparative random index numbers for 3 ≤ n ≤ 10 are given by Saaty and Vargas, (2012, p9), and shown in table 3.3 below.

Table 3.3: Comparative CR for Random matrices (Saaty and Vargas, 2012, p9).

Size of Matrix (n)	3	4	5	6	7	8	9	10
Comparative Value	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The CR is compared to a consistency threshold set by the decision maker. This study used a threshold of 15%. This is above the recommended threshold of 10% by Saaty. However, this is done to allow some variation in the diverse preferences of panellists.

3.10 Conclusion.

To make a good decision, the decision maker must know and define: the problem, the need and purpose of the decision, the criteria and sub criteria to evaluate the alternatives, the alternative actions to take, and stakeholders and groups affected. The AHP guides decision making by providing a quantitative method to evaluate alternatives. In this chapter, the AHP was applied to find the best measure of competitive advantage for agroecological firms.

The AHP fundamentally consists of the following processes:

1) Hierarchical decomposition of the problem.

Hierarchical decomposition served as the foundation of this approach. By breaking down the complex issue of competitive advantage and agroecology into an organized hierarchy of criteria, sub-criteria and alternatives, the aim was to enhance the transparency of the decision problem. The structure used was a two-level hierarchy with measures of competitive advantage as the alternatives and principles of agroecology as the criteria The hierarchical structure is outlined in Figure 3.1.

2) Pairwise comparison of elements.

The pairwise comparison process was pivotal in quantifying the relative importance of criteria and sub-criteria within the established hierarchy. Expert opinions played a crucial role in establishing priority scales through pairwise comparisons. The collected judgments were translated into numerical values, enabling the derivation of weighted scores that reflected the significance of each criterion relative to others. This step facilitated the prioritization of alternatives based on expert insights, contributing to more informed decision-making. A detailed breakdown can be found in section 3.8.

3) Eigen vector solution to derive priorities of elements.

The estimation of the principal eigenvector was the culmination of the AHP methodology. Through mathematical computations involving the eigenvalue and eigenvector of the decision matrix, the weights for each criterion and each alternative with respect to each criterion were calculated. This procedure provided a coherent representation of the relative importance of different criteria, allowing for their aggregation and the identification of the optimal choice among alternatives.

The consistency check is used in the AHP to assess the accuracy and reliability of the pairwise comparisons. This is done by comparing the maximum eigenvalue with the size of the matrix (n). The Consistency Ratio (CR) is used to measure the degree of inconsistency of the matrix and is compared to a predefined threshold. This study used a threshold of 15%

The Delphi method was used to inform decision makers when assigning the relative weights to alternatives and criteria. The Delphi is a method of structured group communication that is effective in eliciting a collective view from individuals on complex problems (Mahajan et al., 1976). The Delphi method was used to evaluate both criteria and alternatives in this study.

The Delphi panel on principles of agroecology consisted of 4 panellists, with experience and knowledge in the discipline of agroecology and sustainable agriculture (see section 3.7.1). The Delphi panel on measures of competitive advantage consisted of 6 panellists with knowledge and experience in agricultural economics and agribusiness management (see section 3.7.2 .) Both panels consisted of three rounds. The first round consisted of a pairwise comparison questionnaire. The respective questionnaires can be found in the appendix below. The second round consisted of a panel discussion where the aggregate results of the first round were presented. The final round was a re-evaluation questionnaire. The results of the final round were used for the AHP analysis and were aggregated using the aggregation of individual priorities method (see section 3.8.1).

One criticism of the AHP is the idea of rank reversal of original preferences when changing criteria and alternatives. Rank reversal refers to the situation when the addition of a new alternative that does not change the of outcomes on any criteria, leads to a change in the ranking of alternatives in the AHP (Belton & Stewart, 2002). This is due to the new alternative changing scores differently for each criterion. Belton and Stewart, (2002), argue that this criticism is of little significance. They further add that the weights should change with the addition or deletion of a new alternative in a manner that compensates for changes in scaling. Therefore, the entire evaluation procedure should be conducted again when alternatives are changed.

In this way, the methodology outlined in this chapter can serve as a stepwise procedure for evaluating alternatives with respect to agroecological principles. Agroecological principles serve as the criteria for the analysis, with the goal of the analysis determining the relevant alternatives. This will also determine the criteria for panellists for the Delphi method. The Delphi panel enriches the analysis by providing diverse perspectives from panellists. This is the exact procedure carried out in this study. The literature review confirmed that agroecology can be used as a competitive advantage strategy. The decisionmaker chose to focus on measurement of this phenomena and identified four measures. These measures were subsequently tested using the AHP analysis. The results of which are presented in chapter 4 below.

4 Results

The following chapter presents the results of the analysis of the study. Two Delphi panels were conducted. The first addressing the criteria (Principles of Agroecology) and the second addressing the alternatives (Measures of Competitive Advantage). Keeping true to the definition of Delphi panel, all panellists are kept anonymous in the results. The results were then analysed using Microsoft Excel.

The aggregation procedure conducted was the Aggregation of Individual Priorities Method. This means that equations (3.1 - 3.6) were conducted for each panellist, before aggregation of individual priority vectors. These aggregate results are described below.

4.1 Local preference of criteria.

These local preferences are derived from the final questionnaire of the Delphi panel on Agroecology conducted on the 25th of July 2023. The local preference vector of each participant was aggregated to give the final weights/rankings of criteria. Figure 4.1 illustrates the ranking and respective weight for each criterion.

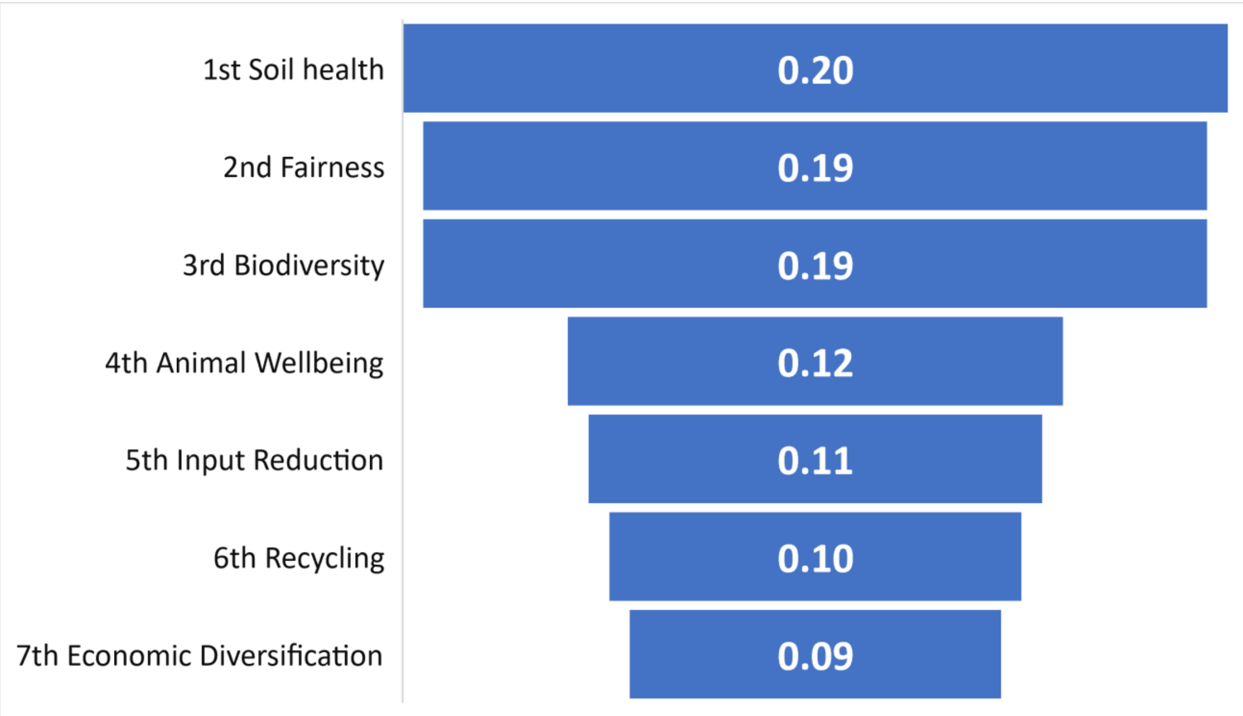

Figure 4.1: Ranked Importance of Agroecological Principles as Competitive Advantage Strategy for Farms.

Figure 4.1 shows that soil heath is the most preferred principle with a weight of 0.20. This is closely followed by fairness and biodiversity with both having a weight of 0.19. The least preferred principle was economic diversification (0.09), followed by recycling (0.10), input reduction (0.11) and animal wellbeing (0.12).

4.1.1 Consistency.

The group consistency ($\lambda\, max$) was calculated by the arithmetic average of individual consistency values ($\lambda\, max$) for panellists. The consistency ratio threshold was set at 15%. Table 4.1 shows the results of the consistency calculations for criteria.

Table 4.1: Consistency of Criteria.

Average group consistency ($\lambda\, max$)	CI	N	RI	CR
7.44	0.07	7	1.35	5%

CI Refers to the Consistency index number and N represents the size of the comparison matrix. The Consistency Ratio (CR) is calculated by quotient of CI and RI, the equivalent CI for a random matrix of size N. From table 4,1, it is evident that the group judgments are consistent with a consistency ratio of 5%.

4.2 Local Preference of Alternatives

The local preference, (or scores) of alternatives was derived from the final questionnaire of Delphi panel on Measures of Competitive Advantage conducted on the 22nd of August 2023. The individual scores for alternatives with respect to each criterion was aggregated to derive the overall scores for alternatives.

For the consistency calculations of these judgements, the same aggregation procedure was followed as described for criteria judgements. The size of the comparison matrix(N) is equal for all seven comparisons. Therefore, they share the same comparative random index number (RI), 0.89. The results below are presented for each criterion.

4.2.1 Principle 1: Recycling

The local priority vector for alternatives concerning recycling represents the preferences of measures by panellists to account for the given principle. Table 4.2 presents the aggregate priority vector for recycling.

Table 4.2: Preference of Measures for Recycling.

Measure	Score	
TFP	0.32	
PCR	0.27	
PM	0.27	
ROA	0.15	
Average group consistency	**CI**	**CR**
4.26	0.09	10%

The measures are ranked in descending order based on their score. Therefore, table 4.2 reads as follows: For recycling, TFP is the most preferred measurement technique with a score of 0.32. PCR and PM are tied as the second most preferred with a score of 0.27. ROA is the least preferred with a score of 0.15. Aggregate group judgements were within the consistency thresholds of this analysis, with a CR of 10%.

4.2.2 Principle 2: Input reduction

TFP (0.34) was the most preferred measure for input reduction, followed by PCR (0.27) and thirdly, PM (0.15). ROA (0.25) was the least preferred measure with a score of 0.14. Table 4.3 shows the scores of measures for input reduction.

Table 4.3: Preference of Measures for Input Reduction.

Measure	**Score**	
TFP	0.34	
PCR	0.27	
PM	0.25	
ROA	0.14	
Average group consistency	**CI**	**CR**
4.15	0.05	6%

Table 4.3 also shows the consistency ratio of the group judgements. This comparison had a CR of 6% which is within the threshold of 15%.

4.2.3 Principle 3: Soil Health

For soil health, TFP (0.34) was the most preferred measure of competitive advantage. Both PCR and PM were the second most preferred measure scoring 0.23. The least preferred was ROA (0.20). Table 4.4 provides the scores for alternatives with respect to soil health.

Table 4.4: Preference of Measures for Soil Health.

Measure	**Score**	
TFP	0.34	
PCR	0.23	
PM	0.23	
ROA	0.20	
Average group consistency	**CI**	**CR**
4.16	0.05	6%

The consistency ratio for this component of the analysis is 6%, within the threshold of 15%.

4.2.4 Principle 4: Animal Wellbeing

For animal wellbeing, PM was the most important preferred measure, with a score of 0.31. TFP was the second most preferred measure. Both ROA and PCR were the least preferred with a score of 0.22. Table 4.5 summarizes these results.

Table 4.5: Preference of Measures for Animal Wellbeing.

Measure	**Score**	
PM	0.31	
TFP	0.24	
PCR	0.22	
ROA	0.22	
Average group consistency	**CI**	**CR**
4.12	0.04	5%

Table 4.5 further provides the average consistency for the group. The consistency ratio for this component was 5%.

4.2.5 Principle: 5 Biodiversity.

Both TFP and PM were considered most preferred measures by panellists. They both scored 0.28 respectively. ROA was the second most preferred with a score of 0.23. The least preferred measure was PCR, scoring 0.22. The results of which are summarised in Table 4.6 below.

Table 4.6: Preference of Measures for "Biodiversity".

Measure	**Score**	
TFP	0.28	
PM	0.28	
ROA	0.23	
PCR	0.22	
Average group consistency	**CI**	**CR**
4.11	0.04	4%

From table 4.6, the consistency ratio is 4%. This mean the group judgments are consistent and within the consistency threshold.

4.2.6 Principle 7: Economic Diversification.

With respect to economic diversification, PM is the most preferred measure among panellists. This is followed by TFP and ROA with a tied score of 0.21. PCR is the least preferred with a score of 0.20. The results are summarised in table 4.7.

Table 4.7: Preference of Measures for "Economic Diversification".

Measure	**Score**	
PM	0.38	
TFP	0.21	
ROA	0.21	
PCR	0.20	
Average group consistency	**CI**	**CR**
4.33	0.11	12%

Table 4.7 shows that this criterion has the highest consistency ratio of the analysis at 12%. This is still within the threshold of 15% and results are still considered consistent.

4.2.7 Principle 10: Fairness.

Table 4.8 summarises the results of the comparison of alternatives with respect to fairness.

Table 4.8: Preference of Measures for Fairness.

Measure	**Score**	
TFP	0.32	
PCR	0.27	
PM	0.24	
ROA	0.17	
Average group consistency	**CI**	**CR**
4.14	0.05	5%

From table 4.8, it is evident that TFP is the most preferred measure of competitive advantage, with a score of 0.32. PCR is the second most preferred with a score of 0.27. ROA is the least preferred measure with a score of 0.17. The results are consistent with a consistency ratio of 5%.

The results presented above describe the relative priority/weight of each agroecological principle. Aswell as the most preferred measure of competitive advantage with respect to each criterion. This is summarised in Table 4.9 below.

Table 4.9: A summary of local priorities in the AHP analysis

Principle	Weight	Most Preferred Measure	Score
Soil Health	0.20	TFP	0.34
Fairness	0.19	TFP	0.32
Biodiversity	0.19	TFP/PM	0.28
Animal Wellbeing	0.12	PM	0.31
Input Reduction	0.11	TFP	0.31
Recycling	0.10	TFP	0.32
Economic Diversification	0.09	PM	0.38

However, the overall most preferred measure of competitive advantage is still unknown. This is the final step of the AHP, and the results are presented in the section below.

4.3 Overall Preference of Alternatives

The aggregate group priority vectors for alternatives were arranged into the final matrix. This is shown in Table 4.10.

Table 4.10: Final Matrix of AHP Analysis

Final Matrix	Recycling	Input reduction	Soil health	Animal Wellbeing	Biodiversity	Economic Diversification	Fairness
PCR	0.27	0.27	0.23	0.22	0.22	0.20	0.27
TFP	0.32	0.34	0.34	0.24	0.28	0.21	0.32
PM	0.27	0.25	0.23	0.31	0.28	0.38	0.24
ROA	0.15	0.14	0.20	0.22	0.23	0.21	0.17

The entries in this matrix are formatted with a 3-colour scale. With respect to each column, scores in the upper quartile are represented by shades of green. Scores in the lower quartile are shaded in red. And the median values are represented by shades of yellow. Therefore, column one reads as follows: With respect to recycling, TFP was the highest scoring measure, PM and PCR are the second highest and ROA has the lowest score. This was then multiplied by the priority vector of criteria (see Figure 4.1) to give the final ranking of alternatives. This is shown by Figure 4.2 below.

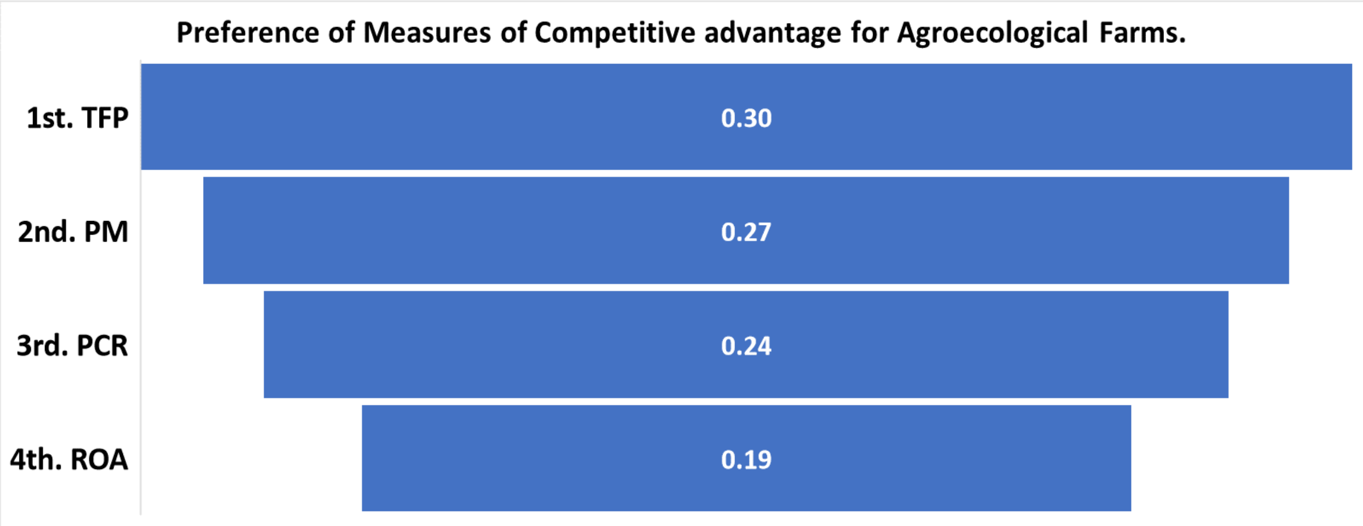

Figure 4.2: *Preference of Measures of Competitive Advantage for Agroecological Farms.*

From figure 4,2, according to the judgements of experts, the most preferred measure of competitive advantage for agroecological farms is TFP (0.39). This is followed by PM (0.27), PCR (0.24) and ROA (0.19). The results are summarised in the section below.

4.4 Summary of Results

The results show that panellists considered soil health the most important agroecological principle with a criteria weight of 0.20 (see Figure 4.1). This is closely followed by fairness and biodiversity with a tied weight of 0.19.

The least preferred criteria were economic diversification (0.09), Input reduction (0.10) recycling (0.11) and animal health (0.12). The consistency ratio (CR) was used in the analysis to check the reliability of the aggregate group judgements. The CR value for criteria was 5% which is below the set threshold of 15%.

The second level was used to evaluate measures of competitive advantage based on their ability to account for each agroecological principle. The results showed that panellists considered Total Factor Productivity (TFP) as the best measure of agroecological competitive advantage as it scored highest in all criteria except economic diversification and animal wellbeing.

Profit Margin (PM) was considered the second most preferred, scoring highest in animal wellbeing, economic diversification, and biodiversity. Return on Assets (ROA) was the least preferred measure, scoring the lowest in all criteria except economic diversification (See Table 4.9: A summary of local priorities in the AHP analysis).

The CR value for all 7 comparisons were all within the predefined threshold of 15% and ranged from 4% to 12%. Given this, the overall preference of alternatives are as follows. TFP is the most preferred measure of agroecological competitive advantage, scoring 0.3 overall. The second is PM with a score of 0.27. This is followed by PCR (0.24) and lastly ROA (0.19). (See Figure 4.2).

5 Discussion & Conclusion.

The following chapter discusses and concludes the study and is arranged as follows. The first section discusses the results of the study. Section 5.2 discusses the limitations of the study. The chapter concludes with recommendations of parameters to consider when developing a new measure of competitive advantage.

5.1 Discussion

The objective of this study was to assess the ability of traditional measures of competitive advantage to assess agroecological farms. The literature review was used to understand the theory of agroecology as well as to understand its application as a competitive advantage strategy at a farm level. Through the literature review, it is evident that the 10 elements of agroecology initially proposed in this study are too broad for farm application. This is because these elements were designed to assist policy making that aids agroecological transitions. Given this, the 13 principles of agroecology by the HLPE (2019) were used as the set of criteria that define agroecologically managed farm systems. These principles are preferred over the elements as they are designed as normative and actionable statements that can be directly related to practice. To reduce the spatial scale of the principles to the farm level, the 13 principles were reduced to 7 endogenous farm principles. These are: 1) Recycling, 2) Input reduction, 3) Soil Health, 4) Animal wellbeing, 5) Biodiversity, 6) Economic Diversification, 7) Fairness.

These 7 agroecological principles can be seen as components in a Proactive Environmental Strategy (PES). Farms that implement PESs concentrating on eco-innovation are more likely to take advantage of opportunities, claim Russo & Fouts (1997). These businesses understand that by positioning themselves as eco-innovation leaders, a commitment to sustainability can result in competitive advantages (Hart, 1995; Porter & Kramer, 2006). Additionally, by using PES properly, farms can give their products an eco-label, boosting their legitimacy in terms of environmental qualities (Stefan & Paul, 2008). Customers recognize these qualities as a result and are choosing these businesses more frequently. Further, farms with PES are more likely to promote innovation and achieve a competitive edge by establishing industry standards and creating barriers to entry for rivals (Khanna, Deltas & Harrington, 2009). Furthermore, farms who spend voluntarily in environmental projects above and beyond legislative requirements are more likely meet social expectations and generate additional profits (Ervin, Wu, Khanna, Jones & Wirkkala, 2013). Aligning business practices in a socially acceptable manner enables stakeholders and the wider public to perceive benefits from a company's activities (Eweje & Sakaki, 2015), thereby ensuring the legitimacy of its operations. Therefore, the principles of agroecology can be used as a competitive advantage strategy for farm enterprises.The results of the first panel suggest that soil health is the most important principle of a competitive agroecological strategy. Soil health refers to the functioning and fertility of the soil ecosystem of the farm. Soil health is crucial to the functioning of the entire agroecosystem as it is the living medium that supports all life (Pulleman, et al., 2012; Miner, Delgado, Ippolito & Stewart, 2020). Without proper soil health, most crop-based cultivation systems will fail. Proper management of soil health can enhance the productivity of the farm, improve resilience, and provide ecosystem services to the environment. Soil health also helps generate synergistic benefits with the other principles.

The second most important principles were biodiversity and fairness, with a tied score. This result directly relates to the ecological and social aspects of agroecology. It is interesting to note that fairness was equally preferred to biodiversity by participants. The consensus was that fairness is a precondition to competitive advantage in agroecology. The reasoning behind this is that fairness is an umbrella term that covers fair treatment of humans within the immediate agroecosystem. Therefore, fairness incorporates tangible social standards like fair wages, and humane working conditions, as well as intangible attributes like co-operation, mobilization of resources and leadership (Barrios et al., 2020). Participants also cited social standards becoming minimum requirements for export markets. For Biodiversity, participants suggested that it is one of their main criteria to define a farm as agroecological. Furthermore, some form of biodiversity is needed to mobilize other principles such as soil health, animal health and economic diversification. The biodiversity of the farm also directly contributes to the synergistic interactions between the principles.

The difference between the highest-scoring principles and second second-highest is only 0.01. This directly relates to the interconnected nature of these principles. Therefore, it is suggested that these three principles be viewed holistically as the most important principles of agroecology. The four lowest ranking principles we also separated by 0.01 respectively but separated from the third highest ranking principles by 0.07. Therefore, they can be considered the least preferred principles. The least preferred principles were economic diversification, input reduction, recycling, and animal health (see Figure 4.1). Economic diversification was the lowest-scoring principle. The panellists viewed economic diversification as the “last step” to transitioning to an agroecological approach. Panellists preferred to implement biological and social principles on farm before diversifying income. Input reduction and recycling were the second least preferred. While these principles are important, they tend to be difficult to define because they are interrelated with the other principles. For example, composting farm wastes promotes soil health but also reduces inputs and is a form of recycling. Animal wellbeing was the fourth-ranked principle. Panellists viewed animal wellbeing as an important principle but not as important as soil health. This is because agroecology promotes integrated farming practices where crop wastes are recycled into animal feed and animals are free to graze. Therefore, it can be argued that soil health determines animal health.

The results of the second Delphi panel show that TFP is the overall most preferred measure of agroecological competitive advantage. Followed by, PM, PCR and ROA. Recent literature also supports TFP being a suitable measure for agroecological competitive advantage (Hoang & Coelli, 2011; Ait Sidhoum, 2023; Baráth & Fertő, 2023). This is because TFP holistically measures changes in real output including that which cannot be explained by inputs (Sinclair et al., 2019, p. 11). Using physical quantities, as opposed to monetary value, allows analysts to quantify changes in the actual volume of agricultural outputs, such as crop yields or livestock production, in relation to the inputs used, like land, labour, and capital. It also allows for inputs, like soil characteristics and climatic conditions, and outputs, like pollution and other externalities that cannot be financially valued to be considered in the analysis.

In contrast, the other three measures are all financial measures, considering only monetary value in their calculations. While this is a limitation of the measures, it can be argued that superior financial profitability is the outcome of a competitive advantage strategy. Thus, measures like PM, PCR and ROA are still valid albeit only 'partially' assessing the financial performance of the farm.

From the results, it can be suggested that TFP is a suitable measure for agroecological competitive advantage. However, the extent to which each principle is accounted for depends on the analyst's choice of input factors and spatial scale. For example, a study assessing the impacts of biological principles of agroecology on TFP may not account for the contribution of social principles. The overall benefits will be present in the changes in physical quantities of output (Bernolak, 1997). However significant contributors may be "hidden" through exclusion in the analysis. The second methodological consideration is the choice of an appropriate spatial scale. Just as agroecosystems can extend across regions and even countries, the associated benefits can do the same. Therefore, changes in TFP may only become significant at a certain spatial level. TFP is mostly applied at an industry or regional level due to its data requirements which might be more accessible at this level.

Overall, this study highlights the need for new measures of competitive advantage based on agroecological principles. Additionally, there are several limitations of this study. This is further discussed in the sections below.

5.2 Limitations

While the results of this study indicate TFP as the overall best measure of agroecological competitive advantage, there are several limitations to this measure. One potential drawback of TFP is its large data requirements. It relies heavily on the accuracy and availability of data, making it sensitive to data quality issues (Siudek & Zawojska, 2014). Moreover, it doesn't account for changes in the quality of inputs or outputs, such as variations in the nutritional content of crops (Kryszak, Swierczy Nska & Staniszewski, 2023). Additionally, TFP may not capture certain externalities, like environmental costs or social benefits, which are increasingly important in the context of agroecology.

Furthermore, this study can be considered as a partial analysis of agroecological competitive advantage covering only the economic aspects. There exists an entire literature body on biological and social indicators of farm performance. These can be integrated into competitive advantage measurement to provide a holistic analysis of agroecosystems.

It's important to note that agroecology is context-specific and needs to be adapted to the local context. Therefore, one limitation of this study is the number and choice of panellists used in this study. The first panel on agroecology consisted of four panellists only. All were based in the Western Cape, South Africa. Two of which were farmers. One was an academic and the other was a representative of a sustainable agriculture institution. While this panel is diverse in knowledge, the sample size is small, and diversity can further be improved. The second panel consisted of six panellists with expertise in economics and business management. This panel does have a higher sample size, but it shares the same diversity issue as the first panel.

This study recognizes several limitations in its approach to measuring agroecological competitive advantage. Firstly, the relatively small sample size and limited diversity of panellists may have influenced the outcomes. Secondly, the study acknowledges the context-specific nature of agroecology and the need for adaptability to local conditions. While these limitations are acknowledged, they underscore the broader methodological challenges in measuring agroecological competitive advantage.

5.3 Recommendations for further study.

The measures employed in this study are limited in scope, focusing exclusively on the economic dimension of agroecology performance. This observation prompts the proposal for future research to construct comprehensive composite indicators suitable of presenting the competitive advantage of agroecological principles. These measures should encompass not only the economic aspect but also incorporate biological and social dimensions. It is crucial to acknowledge that measuring agroecological competitive advantage is a multifaceted task, as indicated by the author's suggestions. Consequently, this section culminates the study by offering guidance on establishing specific parameters for the development of a fresh approach to measuring agroecological competitive advantage.

Firstly, the development of a composite measure should employ a system thinking approach. Systems thinking involves examining agroecosystems as interconnected and dynamic entities, acknowledging that changes in one part of the system can have far-reaching effects throughout. By adopting a system thinking approach in competitive advantage research, one can better understand the complex relationships between various components of agroecosystems, such as soil health, fairness, biodiversity, and the external environment. Using this approach, the researcher should attempt to explain the relationship between economic, biological, and social measures of competitive advantage.

Secondly, the most preferred principles should then be used as the parameters to choose the appropriate measures for the composite measure. Conway, (1987) suggests that agroecological performance should be measured by four criteria. Namely, productivity, stability, sustainability, and equitability. The first criterion is satisfied by the traditional economic measures of competitive advantage. While the other three components relate to biological and social performance. This can be used to formulate an adequate composite measure of agroecological competitive advantage using locally derived principles.

Thirdly, the priority of principles of agroecology should be derived from the local context of the study and seek to capture the diverse perspectives of the local community in the area. For example, a study analysing the competitive advantage of an agroecology farm in the Phillipi horticultural zone should have different priorities when compared to an agroecological farm in the Klein Karoo. Therefore, researchers should find panellists with specific knowledge in that area and conduct a Delphi panel like the one described in section 3.1. Moreover, panellists can be clustered into relevant groups, such as academics, local communities, farmers, institutions, and government. A study by Veisi, Liaghati & Alipour, (2016) provides an example of an AHP analysis of agroecological principles where this was done.

All the measures can be used as economic measures of competitive advantage and future research should focus on integrating ecological and social performance measures into composite farm-level competitive advantage measures. This holistic view of the farm is advantageous as it recognises the role of biological and social components in the success of the farm. Furthermore, the measure should incorporate the four levels as suggested by Conway (1987). This recognises the multifunctionality of the farm within its immediate agroecosystem. I.e., a competitive farm would need to be productive, stable, ecologically, and socially sustainable and equitable. As suggested prior, the choices of measures would need to be selected based on the local context of the farm.

Therefore, an example of a future research objectives based on these results can be the following:

- *"Is soil health a suitable parameter for measuring the competitive advantage of agroecological farms in region X?",*
- *"Is fairness a suitable parameter for measuring the competitive advantage of agroecological farms in region X?",*
- *"Is biodiversity a suitable parameter for measuring the competitive advantage of agroecological farms in region X?".*

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7 Appendix

7.1 Delphi Questionnaire on Agroecology

Delphi Panel Questionnaire: Phase 1

Thesis Title: Assessing Agroecological Elements as Competitive Advantage of Commercial Agricultural Enterprises

Primary Researcher: Naicker KN (21633738@sun.ac.za)

Supervisor: Dr Willem De Lange (wjdel@sun.ac.za)

Introduction

The aim of this panel is to identify the key principles of agroecology that contribute to competitive advantage for farms, and to rank these principles in order of importance. Your expertise in agricultural economics, farming, ecology, and agribusiness management is highly valued and will contribute to the success of this study. The results of this study will be used to inform an Analytic Hierarchy Process (AHP) analysis, which will be used to determine the relative importance of the identified principles as competitive advantage strategies for farms as well as measures that account for these agroecological principles.

Please read through the background of the study to contextualize yourself with the principles of agroecology. After which, you will be required to rate and compare pairs of principles based on their relative importance as competitive advantage strategies for farms.

Please note that aim is to determine preferences and consequently there is no real "correct/incorrect" answer. Your participation is entirely voluntary, and your responses will be kept confidential. The information collected will be used for research purposes only and will be reported in aggregate form.

Glossary of terms

See

Glossary of **Terms**

Background of Study

There is a growing consensus that modern day food and fibre systems are failing at delivering their desired outcomes on food security, nutrition, and environmental impact (Vermeulen *et al.*, 2012; FAO, 2019, 2020). This is despite the agricultural sector being poised as a means to achieve the United Nations (UN) Sustainable Development Goals (SDG). Specifically, SDG 2 and SDG 13. This not only questions the sustainability of current methods of mainstream industrial agricultural systems, but it also challenges the entire notion of competitiveness within the agricultural sector – especially competition for finite resources. Adding to these are fast changing consumer perceptions and preferences which presents a complex and interrelated global system in need for fundamental change to avoid self-destruction.

Agroecology has been gaining attention over the recent years to potentially transform food systems and solve the ecological and social problems associated with industrial agriculture. The FAO recently outlined the 10 Elements of Agroecology as a framework for member countries to transition to agroecological food systems and the HLPE identified 13 principles of agroecology that can be implemented when transitioning to agroecology-based food systems. These principles are intended to serve as a guide for all actors in the food system to redesign business practices.

This is particularly important to farmers, the primary producers in the food system. Adopting these elements and principles require farm management and activities to be redesigned in an ecological and social sustainable way (Barrios et al., 2020). These principles can also serve as a competitive advantage for farmers. The natural resource based (NRB) view of firm competitive advantage defines competitive advantage as the ability of firms to manage competencies that facilitate environmentally sustainable economic activity. Competitive advantage can be realized through lowering costs, pre-empting competitors, and securing the future position of the business (Hart, 1995; Porter & Van Der Linde, 1995). Therefore, these principles can be used as strategy for farmers to gain competitive advantage.

This study uses the 13 principles of agroecology as the framework of practices farmers can use to farm agroecologically. These principles are a set interrelated management practices that farmers can adopt (Wezel, Gemmill Herren, Kerr, Barrios, Luiz, Gonçalves & Sinclair, 2020). This study identified 7 principles of agroecology that can be applied at farm level. These are: 1) Recycling, 2) Input Reduction, 3) Soil Health, 4) Animal Health ,5) Biodiversity, 7) Economic Diversification, 10) Fairness. A brief description of the chosen principles and examples of practices associated with each is provided below.

Principle 1: Recycling

Recycling refers to closing of nutrient cycles on-farm and recycling of biomass. This can be done through management of crop and livestock integration and composting of crop and animal wastes (Sorathiya *et al.*, 2014). An example of recycling through crop and livestock integration is utilizing manure as a direct application compost on fields. Manure can also be recycled in a bioreactor to produce methane on the farm for their energy needs. Farmers can also graze livestock on harvested fields allowing for animals to clear wastes and compact soil. Composting of crop wastes can be done in the open air and applied to soils directly. Another method is to ferment harvest wastes and apply them as a liquid fertilizer.

Principle 2: Input reduction

Farming based on agroecology principles aims to reduce the reliance on external inputs, specifically chemical inputs, through the management of biological processes on farm. Practices of this principle are closely related to principles such as recycling, soil health, synergy, and biodiversity. Through maintenance of the agroecosystem and creating favourable synergies between the components of the farming system, farmers can reduce the number of external inputs required (Altieri, 1995).

Principle 3: Soil Health

Soil health refers to the functioning of the soil ecosystem in the field. Farmers should maintain and improve the functioning of the soil ecosystem which directly affects the soil fertility (Pulleman *et al.*, 2012; Miner *et al.*, 2020). The first step to achieve this is to conduct comprehensive soil tests. This allows farmers to understand the soil profile within the context of the local agroecosystem. This allows for farm specific treatments to be applied such as microbial treatments and fertilizer applications. Some examples of general soil health practices include mulching and compost application. These practices help maintain the soil ecosystem by preventing dry soil and adding organic matter. However, soil heath is context specific and different practices should be applied based on the local soil profile (Kibblewhite *et al.*, 2008).

Principle 4: Animal Health

Animal health is an important aspect of livestock production in agroecology. Agroecological practices aim to integrate livestock into crop production as well as allowing livestock to exhibit their natural behaviours(Dumont *et al.*, 2013; Sorathiya *et al.*, 2014). Management practices include integrated disease and pest control, rotational grazing, balanced feeding, provision of adapted housing, animal hygiene, preference of traditional breeds and mixed grazing of different livestock.

Principle: 5 Biodiversity

Biodiversity is a central aspect of agroecology and refers to the variety of living organisms in an agroecosystem, including plants, animals, and microorganisms. Maintaining biodiversity is important for promoting ecological balance, resilience, and productivity in agroecosystems (Altieri, 1999; Koohafkan, Altieri & Holt Gimenez, 2012). This can be done through crop diversification, agroforestry and natural habitat management. Conservation agriculture practices like minimal tillage, cover cropping and mulching can also help to preserve soil biodiversity.

Principle 7: Economic Diversification

Economic diversification is an important aspect of agroecology that seeks to promote sustainable livelihoods and reduce dependence on a single crop or commodity. Economic diversification can help farmers to reduce their exposure to market volatility and risks associated with climate change (Barrios *et al.*, 2020a; Wezel, Gemmill Herren, *et al.*, 2020). Economic diversification can be realised through crop diversification and livestock integration. Farmers can also diversify incomes through value-adding processing on the farm, direct to consumer marketing and agro-ecotourism.

Principle 10: Fairness

Fairness is a fundamental principle of agroecology that emphasizes social justice, equity, and democratic decision-making in agricultural systems. Fairness in agroecology recognizes the importance of ensuring that all stakeholders, including farmers, workers, and consumers, can participate in decision-making processes that affect their lives and livelihoods (Barrios *et al.*, 2020a). Farmers can practice fairness by ensuring worker rights such as fair wages, safe working conditions and participatory decision making. Other practices include gender equity and fair-trade certification schemes.

Questionnaire

The following is a pairwise comparison of the principles of agroecology. Please indicate which principle you consider more important to the competitive advantage of agroecological farms.

	Most important	Preferred importance	Equal Importance	Preferred importance	Most important		Comments
Recycling: "closing nutrient cycles and recycling biomass on-farm."						Input Reduction	
						Soil Health	
						Animal Health	
						Biodiversity	
						Economic Diversification	
						Fairness	
Input Reduction: "Reduce reliance on externally sourced synthetic inputs."						Soil Health	
						Animal Health	
						Biodiversity	
						Economic Diversification	
						Fairness	
Soil Health: "Improve and maintain functioning of soil ecosystem."						Animal Health	
						Biodiversity	
						Economic Diversification	
						Fairness	
Animal Health: "Maintain healthy livestock and integrate crop and livestock systems."						Biodiversity	
						Economic Diversification	
						Fairness	
Biodiversity: "maintenance of a variety of living organisms in agroecosystem."						Economic Diversification	
						Fairness	
Economic Diversification: "diversify farm income"						Fairness	

7.2 Delphi Questionnaire on Measures of Competitive Advantage

Delphi Panel Questionnaire : Phase 1

Thesis Title: Developing a measure of competitive advantage for agroecological farms.

Primary Researcher: Naicker KN (21633738@sun.ac.za)

Supervisor: Dr Willem De Lange (wjdel@sun.ac.za)

Introduction

This questionnaire ranks measures of competitive advantage based on their ability to account for principles of agroecology Your expertise and experience will be used in an Analytic Hierarchy Process (AHP) analysis which rank the importance of agroecological principles as competitive advantage of farms.

Please read through the background of the study to familiarize yourself with the competitive advantage measures and agroecological principles. You will be requested to rank the 4 measures of competitive advantage based on their ability to account for each agroecological principle.

Please note that aim is to determine preferences and consequently there is no real “correct/incorrect” answer. Your participation is entirely voluntary, and your responses will be kept confidential. The information collected will be used for research purposes only and will be reported in aggregate form.

Glossary of terms

See

Glossary of **Terms**

Study Background

There is a growing consensus that modern day food and fibre systems are failing at delivering their desired outcomes on food security, nutrition, and environmental impact (Vermeulen *et al.*, 2012; FAO, 2019, 2020). This is despite the agricultural sector being poised as a means to achieve the United Nations (UN) Sustainable Development Goals (SDG). Specifically, SDG 2 and SDG 13. This not only questions the sustainability of current methods of mainstream industrial agricultural systems, but it also challenges the entire notion of competitiveness within the agricultural sector – especially competition for finite resources. Adding to these are fast changing consumer perceptions and preferences which presents a complex and interrelated global system in need for fundamental change to avoid self-destruction.

Agroecology has been gaining attention over the recent years to potentially transform food systems and solve the ecological and social problems associated with industrial agriculture (Francis *et al.*, 2003; Tomich, Brodt, Ferris, Galt, Horwath, Kebreab, Leveau, Liptzin, Lubell, Merel, Michelmore, Rosenstock, Scow, Six, Williams & Yang, 2011b; Gliessman, 2016). The Food and Agricultural Organization (FAO) recently outlined the 10 Elements of Agroecology as a framework for member countries to transition to agroecological food systems and the High-Level Panel of Experts on Food Security and Nutrition (HLPE), identified 13 principles of agroecology that can be implemented when transitioning to agroecology-based food systems. These principles are intended to serve as a guide for all actors in the food system to redesign business practices (Wezel, Herren, *et al.*, 2020).

This is particularly important to farmers, the primary producers in the food system. Adopting agroecology requires farm management and activities to be redesigned in an ecological and social sustainable way(Barrios *et al.*, 2020a) . Agroecology can also serve as a competitive advantage for farmers. The natural resource based (NRB) view of the firm defines competitive advantage as the ability of firms to manage competencies that facilitate environmentally sustainable economic activity. Competitive advantage can be realized through lowering costs, pre-empting competitors, and securing the future position of the business (Hart, 1995; Porter & Van Der Linde, 1995). **Therefore, agroecology can be used as strategy for farmers to gain competitive advantage.**

Based on this, the primary research question is as follows: "1) What is the relative importance of agroecological principles as competitive advantage strategy for farm enterprise's."

The second research question deals with measurement of competitive advantage. The study combines the NRB view of competitiveness with the views of Sigalas & Pekka Economou (2013), and Bhawsar and Chattopadhyay (2015) to operationalize a definition for agroecological farms. Competitive advantage is defined as: "The above industry manifested ability of a farm to manage competencies that facilitate environmentally sustainable activities that meet needs of consumers".(Hart, 1995; Sigalas & Pekka Economou, 2013; Bhawsar & Chattopadhyay, 2015a)

The second research question is as follows. "To what extent do current methods of assessing competitive advantage account for agroecological principles?"

The competitive advantage of agroecological firms can be measured in several ways and is mainly in concentrated in two streams: competitive potential and competitive performance. This study identified 4 measures of competitive advantage through literature review. (A brief description of each is provided in the section below.)

This study uses the AHP analysis to answer these research questions. The AHP analysis is a form of multicriteria decision making analysis invented by Saaty, (1985). AHP is used to evaluate alternatives based on a set of criteria. The first part of the AHP is to rank the principles(criteria) based on their relative importance to the competitive advantage of agroecological farms. This panel forms part of the second part of the AHP where the measures(alternatives) are ranked based on their ability to account for agroecological principles(criteria).

The table below gives a description of the four chosen measures of firm level competitive advantage. Also provided is the level of analysis the measure can be used in and a general formula for each. The measures are as follows: 1) Private Cost Ratio (PCR), 2) Total Factor Productivity (TFP), 3) Profit Margin, and 4) Return on Assets (ROA).

Measure	Definition	Level of Analysis	Formula
Private Cost Ratio (PCR)	The ratio of domestic factor costs to value added in a farming system. Measures the competitiveness of agricultural system by showing how much it can afford to pay factors of production while maintaining profits. Used to compare the competitiveness of different agricultural systems and the effect of policy on its competitiveness.	Firm	$PCR = \frac{Cost\ of\ domestic\ factors}{\text{Revenue} - \text{Cost of tradable inputs}}$
Total Factor Productivity (TFP)	The ratio of output to that of all inputs. Measures efficiency and efficacy of production. Typically used in a dynamic framework measuring changes in TFP over time.	Firm, Industry, Country.	$TFP = \frac{Total\ Output}{Labour + Capital\ input}$
Profit Margin	Gross margin(GM) is total income minus variable costs of production. used to compare the costs of production and revenues across firms to indicate which enterprise has a competitive advantage. Can be normalized to limiting factor like labour or land. Net margin (NM) is gross margin less directly allocatable fixed cost.	Firm, Industry	$GM = R - TVC$ $NM = R - TVC - TFC$
Return on Assets (ROA)	The income returned for every dollar of assets employed. Can be decomposed into the product of net profit margin (NM) and total asset turnover (TAX). These measure the profitability and efficiency respectively. Can be used to compare firms and their performance.	Firm	$ROA = NM * TAX$

Questionnaire.

The following questionnaire requires you to rank the 4 measures of competitive advantage based on their ability to account for each agroecological principle. These principles can be seen as interrelated components in a holistic agroecological strategy. There are 13 principles of agroecology however only 7 principles were chosen because they can be applied at a farm level and farmers can directly engage with them.

There are multiple goals for a farm applying an agroecological strategy. These include efficiency, resilience, synergy and social equity and justice as well as profitability and productivity. You will notice that the principles below are interrelated, and the benefits of the system lie within the synergies created by the interactions between them. However, applying one of these principles still can be entry point to an agroecological approach.

A brief description of each principle and its application at the farm level is provided below. Following is a pairwise comparison of the measures of competitive advantage. Please indicate which measure you consider to best account for the respective principle. You may also provide no answer for any of the questions.

Principle 1: recycling

Recycling refers to closing of nutrient cycles on-farm and recycling of biomass and waste. This can be done through management of crop and livestock integration and composting of crop and animal wastes (Sorathiya *et al.*, 2014). A strategy based on recycling should focus on recycling key nutrients from the farm and its surroundings. Thus, decreasing the amount of external nutrients needed. Financially, this relates to lowering input costs and improving profitability (Sorathiya *et al.*, 2014; De Boer & Van Ittersum, 2018). It can also relate to improving efficiency as fewer external inputs are necessary for the same output.

<u>Question 1:</u> With respect to recycling, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for recycling when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	

PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Principle 2: external input reduction

Practices of this principle are closely related to principles such as recycling, soil health, animal health, synergy, and biodiversity. Through maintenance of the agroecosystem, farmers can reduce the number of external inputs required (Altieri, 1995). This component of an agroecological strategy should reduce input costs while also improving the resilience of the farming system by reducing the reliance on external inputs (van der Ploeg *et al.*, 2019).

Question 2: With respect to input reduction, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for input reduction when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	
PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Principle 3: soil health.

Soil health refers to the functioning of the soil ecosystem in the field. Farmers should maintain and improve the functioning of the soil ecosystem which directly affects the soil fertility (Pulleman *et al.*, 2012; Miner *et al.*, 2020). The soil fertility component of an agroecology-based strategy should focus on improving the quality and quality of yields as well as reducing the number of chemical inputs required to maintain soil fertility (Barrios *et al.*, 2020a).

<u>Question 3:</u> With respect to soil health, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for soil health when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	
PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Principle 4: animal wellbeing

Animal wellbeing includes animal health. Animal health is an important aspect of livestock production in agroecology. Agroecological practices aim to integrate livestock into crop production as well as allowing livestock to exhibit their natural behaviours(Dumont *et al.*, 2013; Sorathiya *et al.*, 2014). Management practices include integrated disease and pest control, rotational grazing, balanced feeding, provision of adapted housing, animal hygiene, preference of traditional breeds and mixed grazing of different livestock. Strategies focused on this principle should focus on quality management of livestock and price premiums for their produce (Wezel, Herren, *et al.*, 2020).

<u>Question 4:</u> With respect to animal wellbeing, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for animal health when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	
PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Principle: 5: biodiversity

Biodiversity is a central aspect of agroecology and refers to the variety of living organisms in an agroecosystem, including plants, animals, and microorganisms. Maintaining biodiversity is important for promoting ecological balance, resilience, and productivity in agroecosystems (Altieri, 1999; Koohafkan *et al.*, 2012). This can be done through crop diversification, agroforestry and natural habitat management. Conservation agriculture practices like minimal tillage, cover cropping and mulching can also help to preserve soil biodiversity. Biodiversity is closely linked to linked to soil health, input reduction and economic diversification. Biodiversity in agroecology-based strategy should improve resilience, reduce input costs and improve soil fertility (Barrios *et al.*, 2020a).

<u>Question 5:</u> With respect to biodiversity, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for biodiversity when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	
PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Principle 7: economic diversification

Economic diversification is an important aspect of agroecology that seeks to promote sustainable livelihoods and reduce dependence on a single crop or commodity. Economic diversification can help farmers to reduce their exposure to market volatility and risks associated with climate change (Barrios *et al.*, 2020a; Wezel, Gemmill Herren, *et al.*, 2020). Economic diversification can be realised through crop diversification and livestock integration. Farmers can also diversify incomes through value-adding processing on the farm, direct to consumer marketing and agro-ecotourism. An economic diversification strategy should focus on entering and growing in niche markets for differentiated products, thus improving whole farm profitability and resilience.

Question 6: With respect to economic diversification, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for economic diversification when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	
PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Principle 10: fairness.

Fairness is a fundamental principle of agroecology that emphasizes social justice, equity, and democratic decision-making in agricultural systems. Fairness in agroecology recognizes the importance of ensuring that all stakeholders, including farmers, workers, and consumers, can participate in decision-making processes that affect their lives and livelihoods (Barrios et al., 2020). Farmers can practice fairness by ensuring worker rights such as fair wages, safe working conditions and participatory decision making. Other practices include gender equity and fair-trade certification schemes.

Question 7: With respect to fairness, please compare the measures as preferred measures of competitive advantage. I.e., which of these measures best account for fairness when measuring competitiveness?

	Most Preferred	More Preferred	Equally preferred	More Preferred	Most Preferred		Reasoning
PCR						TFP	
PCR						Profit Margin	

PCR						ROA	
TFP						Profit Margin	
TFP						ROA	
Profit Margin						ROA	

Final comments: