SUSTAINABILITY OF THE SMALL-SCALE TEA PROCESSORS IN KENYA

GATIMBU KARAMBU KIENDE

A THESIS SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN BUSINESS ADMINISTRATION IN THE UNIVERSITY OF EMBU

APRIL, 2019

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

Signature…………………………… Date………………

Gatimbu Karambu Kiende
Department of Business and Economics
D860/143/2015

This thesis has been submitted for examination with our approval as the University Supervisors

Signature…………………………… Date………………

Dr. Maurice Juma Ogada
Department of Business Studies and Economics
Taita Taveta University

Signature…………………………… Date………………

Dr. Samuel Kariuki
Department of Business and Economics
University of Embu

Signature…………………………… Date………………

Professor Nancy Budambula
Department of Biological Sciences
University of Embu

Signature…………………………… Date………………

Dr. Felix Kipchirchir Ngetich
Department of Land and Water Management
University of Embu

DEDICATION

With love

To

Eng. Alexander M. Gatimbu

My father. My cheerleader. My Hero

ACKNOWLEDGEMENT

First, I am grateful to the **Almighty God** for blessing my life with so many gifts and opportunities that are much more than I deserve, and for carefully and timely planning my life and for being there by my side every step of the way.

I express my sincere and heartfelt gratitude to my mentors Dr. Maurice Ogada and Dr. Felix Ngetich for their advice, time, patience, expertise, technical and moral support. Thank you for boosting my confidence level and having faith in my capabilities. More so, thank you for your encouragement when I felt so lost. I am deeply grateful to Prof Nancy Budambula and Dr. Samuel Kariuki for their invaluable comments, guidance, and encouragement.

I am grateful to the University of Embu (UoEm) for partially funding my research. I am thankful to the UoEm members of management and community at large for providing an enabling environment to complete my study. In particular, I appreciate the Vice-chancellor, Prof Daniel Mugendi Njiru, for his moral support and encouragement throughout my study. For that, I am most grateful.

I would like to thank the National Research Fund (NRF), Kenya, for funding this research. I am grateful to the Kenya Tea Development Agency (KTDA) management, staff, and farmers for their feedback and patience to my many questions. Special recognition and appreciation go to the late Mr. Mutai M'Imanyara and Mr. Paul Ringera for their invaluable help. I am grateful to Dr. Bowa Kwach and Dr. Paul Kiprono for facilitating data access. I am indebted to Prof. Hung-Jeng Wang (National Taiwan University) and Prof Daniel Campbell (USEPA) for their invaluable suggestions. Special mention to my colleagues Njoroge Maara and Rogers Ochenge for their friendship, help and the numerous discussions/panel beatings we had at the PhD room, UoN. I am also grateful to the following: Dr. Nthakanio, Dr. Kakai, Dr. Ngumo, Jared, Saina, Serem, Muchiri, Musau, Othuon and Susan. Special mention to my friend William.

I acknowledge my loving parents, Eng. Alexander Gatimbu and Mrs. Lydia Gatimbu, for my life achievements so far. Without their dedication, effort, support, care and love, I could have never made it this far. I specifically thank my mother for being my prayer warrior. Her prayers have always kept me on track. For dad, “I thank you for believing in me and most for always being there and ever constant in my life.”

TABLE OF CONTENTS

DECLARATION .... **ii**
DEDICATION .... **iii**
ACKNOWLEDGMENT .... **iv**
TABLE OF CONTENTS .... **vi**
LIST OF FIGURES .... **ix**
LIST OF TABLES .... **x**
LIST OF APPENDICES .... **xii**
ACRONYMS AND ABBREVIATIONS .... **xiii**
OPERATIONAL DEFINITION OF TERMS .... **xiv**
ABSTRACT .... **xv**
CHAPTER ONE 1
GENERAL INTRODUCTION 1
1.1 Background of the Study 1
1.2 Statement of the Problem 4
1.3 Justification of the Study 5
1.4 Objectives of the Study 6
1.5 Research Questions 6
1.7 Conceptual framework 7
1.8 The scope of the Study 8
1.9 Limitations of the Study 8
1.10 Research philosophy 8
1.11 Organization of the Thesis 9
CHAPTER TWO 10
ENVIRONMENTAL EFFICIENCY AND PROFITABILITY OF THE SMALL-SCALE TEA PROCESSORS IN KENYA 10
2.1 Introduction 10
2.2 Literature Review 10
2.2.1 Theoretical literature 11
2.2.2 Empirical literature 14
2.2.3 Overview of literature 16

2.3 Methodology 17
2.3.1 Research Design.. 17
2.3.2 Analytical framework.. 18
2.3.3 Empirical model specification... 20
2.4 Data and descriptive statistics 21
2.5 Results and discussion 23
2.6 Summary, Conclusion and Policy Implications 36
2.6.1 Introduction... 36
2.6.2 Summary 36
2.6.3 Conclusion 37
2.6.4 Policy implications.. 38
CHAPTER THREE 40
TECHNICAL EFFICIENCY AND PROFITABILITY OF THE SMALL-SCALE TEA PROCESSORS IN KENYA 40
3.1 Introduction.. 40
3.2 Theoretical Framework 40
3.2.1 Empirical literature.. 42
3.2.2 Overview of literature 44
3.3 Methodology 45
3.3.1 Research Design.. 45
3.3.2 Estimation of Technical Efficiency... 45
3.3.3 Technical Efficiency Model.. 46
3.4 Data sources, analysis and Descriptive Statistics............................... 49
3.5 Regression results and discussion 54
3.6 Summary, Conclusion and Policy Implications 62
3.6.1 Introduction... 62
3.6.2 Summary 62
3.6.3 Conclusion 63
3.6.4 Policy Implications 64
CHAPTER FOUR.. 65

INTEGRATED EMERGY AND ECONOMIC EVALUATION OF THE TEA PROCESSORS IN KENYA. 65
4.1 Introduction 65
4.2 Literature review 65
4.2.1 Empirical literature 68
4.3 Methodology 69
4.4 Study Area and Data 72
4.4 Results and Discussion 75
4.4.1 Emergy input structure 75
4.4.2 Economic Viability 78
4.5 Summary, Conclusion and Policy Implications 82
4.5.1 Introduction 82
4.5.2 Summary 82
4.5.3 Conclusion 82
4.5.4 Policy Implication 83
CHAPTER FIVE 84
SYNTHESIS, CONCLUSION AND RECOMMENDATIONS 84
5.1 Synthesis 85
5.2 Conclusion 87
5.3 Recommendation 87
REFERENCES 89
APPENDICES 100

LIST OF FIGURES

Figure 1.1 Conceptual framework on sustainability of small-scale tea processors 8
Figure 2.1: Percentage distribution of efficiency levels for the 54 small-scale tea factories in Kenya for period 2012–2016 26
Figure 2.2: Environmental efficiency trend for the 54 small-scale tea factories in Kenya for the period 2012–2016 27
Figure 2.3: Average environmental efficiency of small-scale tea processors per Region for period 2012–2016 28
Figure 3.1: Frequency distribution of technical efficiency of the small-scale tea processors in Kenya, 2012–2016 59
Figure 4.1: Emergy diagram for the small-scale tea processors in Kenya.......................75
Figure 4.2: Aggregates structure of the Emergy inputs for the small-scale tea processors in Kenya, 2012–2016 (/ha/yr). 78
Figure 4.3: Aggregates structure of the economic inputs for the small-scale tea processors in Kenya, 2012–2016 (unit/ha/yr) 79

LIST OF TABLES

Table 2.1: Descriptive statistics for input and output variables for 54 small-scale tea processors in Kenya, 2012 to 2016 24
Table 2.2: Kruskal Wallis test for Environmental Efficiency of small-scale tea factories per Region 28
Table 2.3: Dunn test for Pairwise comparison of Environmental Efficiency of small-scale tea processors in Kenya per Region for the period 2012–2016 29
Table 2.4: Summary statistics showing the determinants of environmental efficiency for small-scale tea processors in Kenya (2012–2016) 29
Table 2.5: Tobit regression of determinants of Environmental Efficiency for small-scale tea processors in Kenya (2012–2016) 30
Table 2.6: Descriptive statistics of variables for small-scale tea processors in Kenya for period 2012–2016 31
Table 2.7: Pairwise correlation of variables for small-scale tea processors in Kenya for period 2012–2016 32
Table 2.8: VIF variables for small-scale tea processors in Kenya for period 2012–2016...33
Table 2.9: Mean Environmental Efficiency and profitability of the small-scale tea processors in Kenya for the period 2012–2016..33
Table 2.10: Random Effect Model results for small-scale tea processors in Kenya for the period 2012–2016 35
Table 3.1: Descriptive statistics for small-scale tea processors in Kenya for the period 2012–2016...51
Table 3.2: Results of tests of hypotheses for small-scale tea processors in Kenya 52
Table 3.3: MLE Regional stochastic frontiers estimates for East and West of Rift Valley small-scale tea processors in Kenya, 2012–2016..55
Table 3.4: Technical efficiency derived from the Region-specific frontiers for the small-scale tea processors in Kenya, 2012–2016..57
Table 3.5: Input elasticities of the small-scale tea processors in Kenya, 2012–2016......59
Table 3.6: Estimated parameters for the metafrontier of the small-scale tea processors in Kenya, 2012–2016 59

Table 3.7: Summary statistics of Regional efficiency measures for the small-scale tea processors, 2012–2016 61
Table 3.8: The Pearson Correlation Coefficient between Profitability and Technical Efficiency for small-scale tea processors, 2012–2016 61
Table 4.1: Emergy Indices and ratios used for evaluating small-scale tea processors in Kenya, 2012–2016 74
Table 4.2: Emergy Indices and ratios for the small-scale tea processors in Kenya, 2012–2016 (/ha/yr). 77
Table 4.3: Economic inputs to and outputs from for the small-scale tea processors in Kenya 2012-2016 (Ksh/ha/yr) 81

LIST OF APPENDICES

Appendix 1: Region one emergy analysis table for small-scale tea processors in Kenya, 2012–2016 100

Appendix 2: Region two emergy analysis table for small-scale tea processors in Kenya 2012-2016 101

Appendix 3: Region three emergy analysis table for small-scale tea processors in Kenya 2012-2016 102

Appendix 4: Region four emergy analysis table for small-scale tea processors in Kenya 2012-2016 103

Appendix 5: Region five, emergy analysis table for small-scale tea processors in Kenya 2012-2016 (/ha/yr). 104

Appendix 6: Region six, emergy analysis table for small-scale tea processors in Kenya 2012-2016 (/ha/yr). 105

Appendix 7: Region seven, emergy analysis table for small-scale tea processors in Kenya 2012-2016 (/ha/yr). 106

Appendix 8: Region one economic inputs and outputs (ha/yr) 107

Appendix 9: Region two economic inputs and outputs (ha/yr) 108

Appendix 10: Region three economic inputs and outputs (ha/yr) 109

Appendix 11: Region four economic inputs and outputs (ha/yr) 110

Appendix 12: Region five economic inputs and outputs (ha/yr) 111

Appendix 13: Region six economic inputs and outputs (ha/yr) 112

Appendix 14: Region Seven economic inputs and outputs (ha/yr) 113

Appendix 15: Research Permit 114

ACRONYMS AND ABBREVIATIONS

CFU	:	Continuous Fermentation Units
CPDA	:	Christian Partners Development Agency
CSP	:	Corporate Social Practice
DEA	:	Data Envelopment Analysis
EE	:	Environmental efficiency
FP	:	Financial Performance
FUMs	:	Factory Unit Managers
GDP	:	Gross Domestic Product
KEPSA	:	Kenya Private Sector Alliance
KTDA	:	Kenya Tea Development Authority
ROA	:	Return on Assets
SFA	:	Stochastic Frontier Analysis
SMF	:	Stochastic Meta Frontier
TE	:	Technical Efficiency
TGR	:	Technology Gap Ratio
WBCSD	:	World Business Council for Sustainable Development
WCED	:	World Commission on Environment and Development

OPERATIONAL DEFINITION OF TERMS

Emergy An environmental accounting method that addresses the issue of environmental and economic sustainability by quantifying the total amount of natural resources that nature dissipates and the total amount of economic resources that are paid out to produce a product.

Inefficiency Amount by which actual (observed) output falls short of maximum possible output.

Sustainability Efficiency in the use of resources.

Small Scale tea processors KTDA managed factories that buy tea from smallholder farmers whose average land size is approximately 0.27 ha

Technical efficiency Ability of a firm to achieve a higher level of output given similar levels of inputs.

Sustainable development The Brundtland Commission's original definition was paraphrased as "meeting the needs of the present generation without endangering the ability of future generations to meet their needs (WCED, 1987).

ABSTRACT

The tea industry remains vital for export earnings, employment creation and GDP growth. These processors, however, are experiencing a persistent rise in their cost of production. They have pursued sustainability initiatives to scale down production costs. However, the outcome of such initiatives has not been measured. This study thus sought to determine the sustainability of the small-scale tea processors in Kenya. A pragmatic paradigm research philosophy was adopted. All the 54 factories were considered for the study. Primary data entailed interviews with Key Informants. Secondary data was obtained from factory documents and reports, peer-reviewed publications and grey literature. Data Envelopment Analysis was used to compute the environmental efficiency scores. Tobit regression was applied to determine the influential factors of firm variation in environmental efficiency. Stochastic Frontier Analysis was used to determine the technical efficiency scores, as well as determinants in a one-step estimation equation. A Meta-technical efficiency method was used to establish regional efficiency estimates. Finally, Emergy methodology was used to assess the ecological/economic sustainability of these processors. In sum, the thesis contributes to both literature and methodology. Results showed that the tea processors were environmentally inefficient, recording a mean efficiency index of only 49%. Factories have the ability, therefore, to reduce 51% of detrimental environmental inputs without compromising output. Fortunately, efficiency was on an upward trajectory, rising from 29.4% in 2014 to 36.8% in 2016. Further, environmental efficiency affected the profitability of these processors. Results showed a negative effect of environmental efficiency on profitability. Worth noting, 81.3% of factories that had good environmental performance (0.8-1.0) had low profitability, ranging from -0.25% to 1.23%. Factories that were environmentally efficient had a 0.7% lower chance of being profitable. For the second objective, the technical efficiency level derived from the regional frontier was 76%, while that from the meta-frontier was 74%. The technological gap ratio was 97%. Thus, input costs could be reduced by 24% without compromising the potential output. The overall persistent inefficiency for the pooled sample was about 20%, with a residual inefficiency of about 5%. This implies that structural and managerial aspects were involved in the greater inefficiency of the small-scale tea processors. No significant relationship between technical efficiency and profitability was observed. For the third objective, the total Emergy for the purchased non-renewable resources was 93.4%, purchased renewable resources registered 6.3%, and renewable resource was 0.3%. Results showed that the small-scale tea processors relied heavily on purchased non-renewable resources, hence rendering the processing sub-system ecologically/economically unsustainable. The results further showed that the small-scale tea processing sub-systems were profitable, with an average economic output/input ratio of about 2.5. The policy implication of these findings is that the government should offer incentives for the adoption of improved environmental technologies. For example, offering a tax subsidy for new technologies adopted should be considered. For the small-scale tea processors' management, they should seek alternative sources of finance that are cheaper or negotiate for better terms of borrowing with the financiers. In addition, the processors might consider automating some factory processes and incorporate the use of renewable energies, for example, solar power and gasifiers. Further, they may consider issuing a green instrument that simultaneously reduces the cost of capital and ecological impact.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background of the Study

Over the decades, sustainability has become a near daily discussion in the business community (Eweje, 2011). The generation of new markets for sustainable products or cost savings realised through reduced resource consumption within the manufacturing process are examples of opportunities that arise within the context of sustainability. Three primary motivations that drive sustainability in manufacturing firms are competitiveness, legitimation, and ecological responsibility. Efficiency is not only applicable to increasing resource productivity in manufacturing, but also to the creation of new goods and services that enlarge consumer value while maintaining or reducing environmental inputs (Schrettle, Hinz, Scherrer, & Friedli, 2014). With many critical natural resources and ecosystems services being either scarce or under pressure, achieving sustained economic growth requires the absolute decoupling of the production of goods and services from their environmental impacts. This means sustainably consuming environmental resources by improving the efficiency of resource consumption and adopting new production techniques and product designs (Everett, Ishawaran, Ansaloni, & Rubin, 2010).

The World Business Council for Sustainable Development was formed by businesses to assist with the development of business strategies that contribute to sustainable development. Sustainable development implementation became an instant task for businesses, since they are a core part of modern society (WBCSD, World Business Council for Sustainable Development, Council, & Development, 2010). Organisations should be able to implement sustainable resolutions since they have the financial backing, technological know-how and institutional capacity (Obeng & Agyenim, 2015). The sustainability challenge has become increasingly important in the manufacturing sector. This is because global warming and the finiteness of essential resources have prompted different stakeholder groups to adjust their expectations of firms (Schrettle et al., 2014).

Since manufacturing processes are energy intensive and consume significant amounts of resources, manufacturing firms are embedded into the sustainability challenge. Factory moves toward achieving sustainable manufacturing are eco-efficiency improvements and are resource consumption reduction driven. This allows them, therefore, to mitigate negative economic, social and environmental impacts (Davé, Oates, Turner, & Ball, 2015).

Sustainability therefore involves accounting for the physical flow of materials, energy inputs and products, including waste outputs in physical units. This input-output analysis is facilitated by using the accounting principle of double entry and transparency (Ngwakwe, 2012). Hence, there is a need to contribute to the ongoing sustainability debate and ascertain whether the small-scale tea processors should pursue sustainability initiatives, and in what dimensions. Specifically, the present study examines three sustainability dimensions: environmental efficiency, technical efficiency, and Emergy evaluation to provide answers for the persistent rise in production costs. It reports on the empirical findings regarding the small-scale tea processors under the management of Kenya Tea Development Agency (KTDA).

The Kenya Vision 2030 framework identifies the manufacturing sector, and especially the agro-processing industry, as one of the critical drivers for realising a sustained annual Gross Domestic Product (GDP) growth of 10% (Ndicu, 2015). The manufacturing sector has high but untapped, potential to contribute to employment and GDP growth (Government of Kenya, 2013). The average growth percentage of the manufacturing sector has continued to decline, from 4.3% in 2012 to 3.6% in 2016 (KNBS, 2017). The processing of food products mainly drives the sector's growth. Stagnated growth has been caused by poor performance in processing (KNBS, 2017).

Kenya's agriculture sector is made up of six sub-sectors; industrial crops, food crops, horticulture, livestock, fisheries, and forestry. Industrial crops contribute 17% of Agricultural GDP and 55% of agricultural exports (Republic of Kenya, 2010). Among the industrial crops, tea is the highest foreign exchange earner, contributing 26% of all foreign exchange earnings and 4% of the GDP by 2010(Tea Board of Kenya, 2010). The tea sub-sector employs approximately 10% of the population (Kagira, Kimani, & Githii, 2012).

Tea is grown and partially processed in rural Kenya, thus promoting rural infrastructure. Tea production covers an estimated land area of 203,000,000 hectares (KNBS, 2015). The tea industry is divided into two separate sectors, the large-scale sector (plantations) and the small-scale sector. Multinationals such as Unilever Tea own the plantation sector, while local smallholder growers comprise the small-scale sub-sector. The small-scale tea sub-sector accounts for about 63% of the Kenyan tea production (KNBS, 2015). The smallholders have an average landholding size of 0.27 ha (Owuor, Kavoi, Wachira, & Ogola, 2007) per farming household. They are spread throughout the country, and they sell their tea through tea factories that are managed by the Kenya Tea Development Agency (KTDA) (Tea Board of Kenya, 2011).

A myriad of challenges faces the small-scale tea sub-sector. Among them are production-related challenges, management agency challenges, local market-related challenges, regulatory challenges, and international market-related challenges. Of interest are the production-related challenges, and more specifically, production costs. Production costs include human input costs (labour costs), capital input costs (fixed and overhead manufacturing costs), material costs(raw materials, water, and packaging bags), power and energy costs (electricity, wood fuel, petrol, diesel, gas, and furnace oil); miscellaneous costs (administrative expenses and insurance) and welfare costs (Dutta & Nath, 2015). Tea production costs have been rising over the years, as discussed by Owuor,(2011); Kimathi & Muriuki, (2013); CPDA (2008), and this phenomenon motivated the present study to inquire into the sustainability of these processors empirically.

Producer prices have shown a linearly increasing trend over the years (FAOSTAT, 2015). This is in spite of the efforts made to contain the escalating costs. There is a need, therefore, to determine the efficiency of these processors regarding resource use and the drivers of efficiency.

The factory cost of tea production in Kenya is USD 0.28 Kg^{-1} (Kagira *et al*., 2012). This compares poorly with neighbouring countries such as Rwanda, Uganda, and Tanzania, where the costs of production are USD 0.11 Kg^{-1}, USD 0.22 Kg^{-1}, and USD 0.22 Kg^{-1}, respectively (Kagira *et al*., 2012).

In the past, KTDA has put measures in place to increase eco-efficiency, as well as reduce the cost of tea production (KEPSA, 2014). In the quest to increase production efficiency, the company introduced Continuous Fermentation Units (CFU) at all factories. The result was greater consistency in the quality of made tea, giving a production that is more efficient, with a lowering of labour costs, since a single CFU replaced almost 40 workers. To reduce energy costs, KTDA ventured into the development of own, small hydropower plants and converted boiler fuel consumption from diesel to wood fuel. Unfortunately, this raised the demand for wood, which forced KTDA to implement the wood energy project to provide a sustainable source of wood fuel for the factories. At the same time, tea prices have shown a decelerated increase over the years due to an increase in global tea production (supply) and changing consumer preferences. Such developments have resulted in the collapse of tea industries in countries like South Africa (Kagira et al., 2012) and pose serious challenges to the future growth and direction of the tea industry in Kenya. If this trend continues, the major question for the small-scale tea stakeholders and policymakers would then be whether the tea enterprise would be attractive and sustainable. Whether the afore-mentioned initiatives within the small-scale tea processors have resulted in any value gain, remains an empirical question.

1.2 Statement of the Problem

The persistent rise in production costs has been a major concern of the small-scale tea processors. Sustainability initiatives have been pursued by these processors to ensure efficiency in the use of resources (KEPSA, 2014). Such measures include the introduction of CFUs to increase production efficiency, the development of efficient boilers and fans to reduce energy costs, and starting a wood fuel project. Despite all these efforts, the cost of production has persistently been on the rise (KTDA, 2015). This possibly points to inefficient use of production resources, especially the biophysical units (labour, machinery, materials, and energy). Such inefficiency has the potential of impacting both profits and the environment negatively. Thus, it is imperative to examine three critical aspects of these business units: their environmental efficiency and how that correlates with profitability; their technical efficiency; and their ecological sustainability.

1.3 Justification of the Study

Various studies on the performances of the small-scale tea processors in Kenya have been conducted (Ng'ang'a, 2011; Kimathi & Muriuki, 2013; Owuor, 2011; Kaimba & Nkari, 2014). These studies measured performance using profitability ratios only. The present study has assessed their performance using efficiency and profitability constructs, to elucidate the paradox behind the persistent rise in production costs. Previous studies employed sampling techniques hence did not give an adequate understanding of the entire small scale tea industry in Kenya. Furthermore, none of these studies specifically and exclusively focused on environmental efficiency, technical efficiency, and ecological/environmental sustainability. Moreover, most efficiency and Emergy evaluation studies have concentrated in Asia and Latin America (Ortega, 2005; Hong & Yabe, 2015; Zeng, Lu, Campbell, & Ren, 2013). It is worth noting that the rising cost of tea production is a global phenomenon. Hence, a comprehensive understanding of the sustainability of tea production is imperative. This study sought to supplement the previous efforts by offering credible empirical findings on whether sustainability measures should be pursued, and in what dimensions. The study sought to contribute to both literature and the methodology for policy implication, which would help in reducing production costs for the small-scale tea processors in Kenya.

1.4 Objectives of the Study

The broad objective of this study was to determine the sustainability of the small-scale tea processors in Kenya. The specific objectives were:

a) To determine the effect of environmental efficiency on the profitability of the small-scale tea processors in Kenya.

b) To determine the relationship between technical efficiency and profitability of the small-scale tea processors in Kenya.

c) To assess the ecological/economic sustainability of the small-scale tea processors in Kenya.

1.5 Research Questions

To achieve the above objectives, the study sought to answer the following research questions**:**

a) What is the effect of environmental efficiency on the profitability of the small-scale tea processors in Kenya?

b) What is the relationship between technical efficiency and profitability of the small-scale tea processors in Kenya?

c) What is the ecological and economic sustainability of the small-scale tea processors in Kenya?

1.7 Conceptual framework

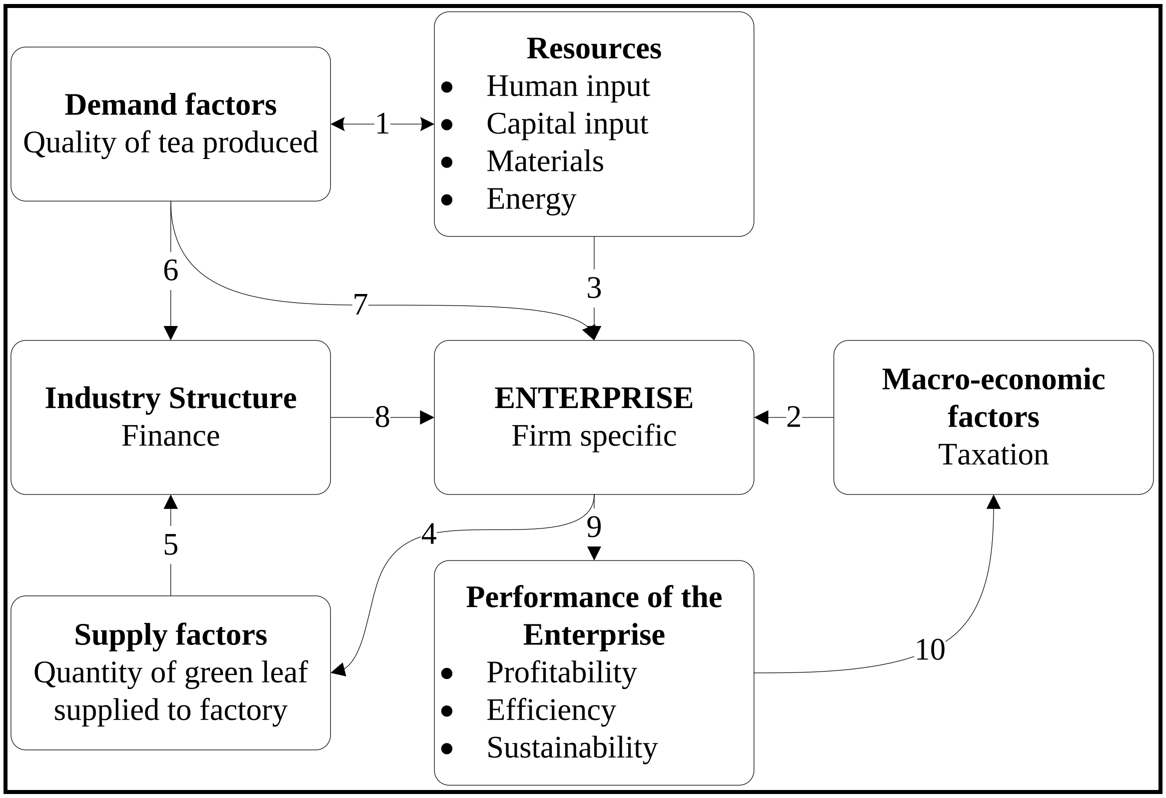


Figure 1.1: Conceptual framework on the sustainability of small-scale tea processors (Source: Author's conceptualization).

Performance of the small-scale tea processors is influenced by three key factors: macroeconomic factors, demand factors, and industry structure. These factors are mutually interactive and affect the enterprise in the following ways: quality and availability of resources are related to the national economy, its infrastructure, and other macroeconomic factors (1); Macroeconomic factors determine the organization of an enterprise as an economic subject (2); Production resources needed for tea production (3); Resources, in combination with technologies and firm-specific factors for production of final output (4); Firm-specific factors influence development of the sector (5); demand factors are clients, both legal and physical entities, who create demand for the tea produced by the processor (6); and Demand by customers is a basis of small-scale tea firm performance (7). Buyer perception of the quality of made tea plays a key role in firm performance. It is based upon the amount, price and quality of tea produced. Enterprise depends on transformations and development of the industry (8). Finance costs play a vital role in the efficiency and performance of these factories. Enterprise performance depends on whether an enterprise can combine, organise and manage resources (9). Achieved results of the performance return to the national economy through taxes and duties, thus influencing fulfilment of the state's functions and business environment (10).

1.8 The scope of the Study

The study covered all 54 small-scale tea processors under the management of KTDA in Kenya, covering a span of five years (2012–2016). The study area encompassed fifteen counties namely; Kiambu, Murang'a, Nyeri, Kirinyaga, Embu, Meru, Tharaka Nithi, Bomet, Kericho, Nandi Nakuru, Kisii, Nyamira, Kakamega and Trans Nzoia. The study focus was placed on the evaluation of environmental efficiency, technical efficiency, and ecological and economical environmental sustainability.

1.9 Limitations of the Study

The study was limited to the 54 small-scale tea processors in Kenya. Accordingly, a generalisation of the findings should only relate to, or apply to, the tea sub-sector.

1.10 Research philosophy

The philosophical underpinning of this study was the pragmatism paradigm. The study focused on gaining an understanding of the paradox behind the persistent rise in production costs and subsequently describing the implications for policy. Emphasis was placed on the research problem, and appropriate approaches were used to understand and address the problem (Creswell, 2013). This philosophy allowed the researcher to think of the approach as a continuum, rather than as opposite positions. That is, at some points the knower and the known had to be interactive, while at others, one may more easily stand apart from what was being studied (Saunders, Lewis, & Thornhill, 2013). The choice of pragmatism as a philosophical basis for this research was made because of the mixed method research approach adopted.

1.11 Organization of the Thesis

To meet the objectives of the study, each research objective was addressed in its chapter as an independent essay, complete with literature review, methodology, data analysis, results, and conclusion. Consequently, the rest of this thesis unfolds as follows: Chapter Two reviews literature on environmental efficiency and measures the environmental efficiency of small-scale tea processors in Kenya, using the Data Envelopment Analysis (DEA) approach. It further measures the determinants of EE using a Tobit regression. Chapter Three discusses the conceptualisation and measurement of TE. It proceeds to measure the TE of small-scale tea processors in Kenya, using the Stochastic Frontier Analysis (SFA) approach, before establishing the determinants of TE among these processors and making policy inferences. Chapter Four examines the literature on integrated Emergy and economic evaluation of the production system before estimating Emergy indices. Policy implications are inferred. Chapter Five synthesizes the overall study and wraps up the thesis.

CHAPTER TWO

ENVIRONMENTAL EFFICIENCY AND PROFITABILITY OF THE SMALL-SCALE TEA PROCESSORS IN KENYA

2.1 Introduction

This chapter responds to the first objective of the thesis. It synthesises the literature on environmental efficiency and profitability and discusses the theoretical and analytical models used before analysing environmental efficiency and profitability. Further, the chapter discusses the results and provides policy ramifications.

2.2 Literature Review

The advances in technology during the last few centuries have been accompanied by extensive environmental destruction. Concerns about the effective management of the ecosystem have intensified in the development trajectories of many economies (Mir & Rahaman, 2011). Global economic growth is currently encountering extreme threats of natural resource depletion. Hence, corporate environmental performance has become a top priority, worldwide. Resource scarcity and increasing operating costs have been identified as reasons for the increased business focus on sustainability (Chofreh, Goni, Shaharoun, Ismail, & Klemes, 2014). With growing environmental legislation and mounting popular concern for the environment and the quality of life, there has been increasing recognition made of the importance of good environmental performance, especially concerning the reducing of environmental disamenities generated as outputs of the production of goods and services. For this reason, the impact of policy on environmental efficiency needs to be identified (Nissi & Rapposelli, 2005).

Industrial production accounts for a large portion of environmental pollution in many countries (Worrell, Allwood, & Gutowski, 2016). Thus, pursuing increased productivity at reduced levels of energy consumption and environmental degradation is becoming increasingly important (Chang, Zhang, Danao, & Zhang, 2013). This is in the wake of the biosphere presenting signs of its incapacity to absorb more residues and pollutants; therefore, emphasising efficiency in the use of resources (Almeida, Madureira, Bonilla, & Giannetti, 2012). This has provided momentum to research environmental efficiency (Zhang, Fang, Wu, & Ward, 2016). The production objective of eco-efficiency is to expand desirable outputs while reducing inputs (such as labor and energy) and undesirable outputs (Long, Zhao, & Cheng, 2015).

The tea industry is one of the primary consumers of energy and has been blamed for contributing to environmental degradation. In Kenya, the demand for energy has been growing at a rate of 6% annually, primarily driven by investment in the manufacturing sector (Kamande, 2014). The industry is heavily dependent on energy for tea withering and drying, and for running machinery. Energy costs account for 30% of factory production costs, which causes a significant impact on the environment (Wal, 2008). For example in Kenya, one kilogram of the dry tea is estimated to cause around 12 kg of carbon dioxide equivalent emissions (Azapagic, Bore, Cheserek, Kamunya, & Elbehri, 2015). Elsewhere, in Malawi, results showed that a kilogram of the dry tea is estimated to cause between 2.51 to 5.41 kg of carbon dioxide (CO_2) equivalent emissions, and consumes between 4.19 to 6.33 kg of green leaf and 0.42 to 1.08 kWh of electricity (Taulo & Sebitosi, 2016). The resulting environmental impact includes global warming (88%), acidification (6%), eutrophication (2%) and human toxicity of about 1% (Taulo & Sebitosi, 2016). Major greenhouse gases emitted by the tea industry include carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (N_2O), carbon monoxide (CO), sulfur dioxide (SO_2) and non-methane volatile organic compounds (NMVOC) (Taulo & Sebitosi, 2016).

2.2.1 Theoretical literature

Environmental issues influence both costs and incomes and have a direct influence on the economic success of a firm (Schaltegger & Synnestvedt, 2002). The conservative wisdom is that environmental protection comes at an additional cost, which may erode a firm's competitiveness (Huang, Wong, & Yang, 2014). Proponents of a “win-win” argument argue that good environmental performance often constitutes an underlying profit opportunity (Porter & Van der Linde, 1995). The mixed empirical evidence reveals the complex contextual factors that are considered in making decisions about environmental initiatives (Siddique & Sciulli, 2018).

The link between environmental and economic performance has been widely debated, resulting in a body of literature that is both mixed and inconclusive. One view is that improved EP may cause extra cost for a firm and thus reduce profitability. Another view holds that improved EP would induce cost savings and increase revenue, as well as economic performance (Pintea, Stanca, Achim, & Pop, 2014). The relationship between CS and CFP has been argued and found variously to be positive (Hart &Ahuja 1996; Cesar, Guimar, & Nodari, 2015), insignificant (Kamande & Lokina, 2013), and negative (Delmas, Nairn-birch, & Lim, 2015; Friedman 1970). Although previous studies have resulted in contradictory conclusions, many studies reviewed do report a positive association between Corporate Social Performance (CSP) and Financial Performance (FP). The positive correlation between CSP and FP that emerges from the literature, albeit interesting, does not warrant a causal interpretation (Francoeur, Makni, & Bellavance, 2009). The majority of the studies have focused on corporate social performance, which is a multi-dimensional construct that includes environmental performance (EP) (Bouslah, M’Zali, Turcotte, & Kooli, 2009). Furthermore, a generalizable, unidirectional relationship applicable to all organisations in all situations does not exist (Alshehhi, Nobanee, & Khare, 2018). These findings of positive, negative or neutral associations stem from conceptual, operationalisation and methodological differences in the definitions and measurement of environmental performance (Bouslah et al., 2009).

Two competing theories attempt to describe the impact of sustainability on corporate financial performance: value creating and value destroying (Alshehhi et al., 2018). These theories are linked to the influence (positive, negative, or neutral) and the causality (direction) of the relationship. The value-creation approach theorises that firm risk is reduced with the adoption of environmental and social responsibility. In contrast, the value-destruction theory predicts that companies engaged in environmental and social responsibility lose focus on profitability, and instead pursue pleasing stakeholders at the expense of shareholders. As with the value-destruction theory, the trade-off theory suggests a negative relationship when resources are channelled towards less profitable sustainable activities (Wang &Wei, 2014).

A positive relationship is explained in the Resource-Based View (RBV) Theory and Stakeholder Theory. Natural Resource-Based Theory (NRBT) stipulates that firms that secure resources and develop capabilities, for example in waste minimisation, will ultimately gain a competitive advantage (increased productivity and efficiency) in the face of environmental challenges (Siddique & Sciulli, 2018). Accordingly, NRBT asserts that the adoption of process-focused pollution prevention, such as eco-efficiency, to reduce wastes can reduce environmental impact and simultaneously improve firm performance through cost reduction (Huang et al., 2014). In legitimacy theory, organisations seek legitimacy from their stakeholders for economic, social and political backing (Low & Umesh, 2014). The legitimacy of the relationship is predicated on the fact that stakeholders have capital that can be either lost or gained, depending on the actions of the organisation (Mir & Rahaman, 2011). Furthermore, a firm's survival depends on its ability to accommodate the sometimes conflicting demands and values of its stakeholders (Buccina, Chene, & Gramlich, 2013). In stakeholder theory, fulfilling the requirements of stakeholders contributes to financial performance (Alshehhi et al., 2018).

The NRBT also affirms that certain firm capabilities cannot be substituted (Hart & Dowell, 2011). This theory also asserts that firms that secure resources and develop capabilities, for example in waste minimisation, will ultimately gain a competitive advantage (increased productivity and efficiency) in the face of environmental challenges (Siddique & Sciulli, 2018). Accordingly, NRBT asserts that the adoption of process-focused pollution prevention, such as eco-efficiency, to reduce wastes can reduce environmental impact and simultaneously improve firm performance through cost reduction (Huang et al., 2014).

The small-scale tea processors in Kenya are, therefore, faced with the dilemma of keeping profits up while at the same time requiring resource and emission reductions. It is apparent that improving environmental efficiency should be a fundamental reform strategy. The literature on the environmental efficiency of the small-scale tea processors remains scanty. Furthermore, the empirical literature on the comprehensive analysis of the relation between environmental efficiency and profitability is scanty. Given the popularity of CSR research as a suitable replacement for total sustainability, the environmental dimension is underplayed (Alshehhi et al., 2018). Focusing on the small-scale tea industry in Kenya and on Environmental Performance (EP) as a measure of corporate social performance (CSP), this study analysed the relationship between EP and FP.

The scarcity of literature on the effect of environmental efficiency on firm performance justified the need for this study and the proposal of the hypotheses. Based on the above, the premise is that environmental sustainability limits the strategic alternatives for firms, forcing firms to forego revenue-boosting activities and thus face declines in profitability.

2.2.2 Empirical literature

Using a Slacks-Based Measure Data Envelopment Analysis (SBM-DEA) model, (Chang, 2013) analysed the environmental efficiency of ports in Korea to estimate the potential CO_2 emission reduction by ports in the country. Labour, capital and energy were used as the major inputs of the port sector. Cargo tonnage and vessel tonnage were handled as desirable outputs, and CO_2 emissions were handled as an undesirable output. It was found that Korean ports are deemed economically inefficient, but environmentally efficient when considering economic and environmental performances simultaneously.

Zeng et al. (2010) used a Structure Equation Model (SEM) to analyse the overall positive impact of cleaner production on business performance on 125 Chinese industries. Their results indicate a positive impact of cleaner production on a firm's business performance. Further, Zeng et al. (2010) documented the fact that the cleaner production activities of a low-cost scheme give a more significant contribution to financial performance as compared with non-financial performance, while the cleaner production activities of a high-cost scheme give a more significant contribution to non-financial performance, as compared with financial performance.

Kamande (2010) analysed the technical and environmental efficiency of Kenya's manufacturing sector. The study incorporated environmental concerns in the technical efficiency analysis and used the SFA method. The results indicated that the environmental efficiency measure is negative, implying that the firms were environmentally inefficient. The findings suggest that a gain in efficiency is achieved by firms when environmental concerns are incorporated into their business objectives. The study by Kamande (2010) used four environment dummy variables to determine environmental efficiency. The present study has used environmental metrics that are not linked to financial indicator**s** to determine environmental efficiency and hence link them to profitability.

Zhang, Fang, Wu, and Ward (2016) adopted anon-radial DEA model with a Slacks-based measure to analyse the environmental efficiency of 16 listed cement enterprises in China for the period 2008–2013. The Author's selected 16 Chinese firms and used panel data for the period 2008–2013. Their results suggest that enterprise size and property structure are key determinants of environmental efficiency. Furthermore, increasing production concentration and decreasing the share of government investment could improve the firm's environmental efficiency. The findings also suggest that the effective monitoring of pollution products can improve environmental efficiency quickly. As in most of the previous studies on environmental efficiency, the sample size is small. This restricts its applicability to other sectors.

Mandal and Madheswaran (2010) analysed the environmental efficiency of the Indian cement industry (macro level) from 2001 to 2004. A 'sequential frontier' for each year, using a single output and four inputs for the production function, was constructed. Efficiency levels varied across states and years. Estimates of environmental efficiency depended on how they modelled pollution, whether as an input or as an undesirable output. However, the results showed the same trend. The focus of their study was at the macro level and incorporated a single undesirable output. Their results may not be generalizable at the micro level. The present study incorporated multiple undesirable outputs and performed a second stage analysis to determine influential factors of environmental efficiency.

In Kenya, Kamande and Lokina (2013) examined the linkage between the profitability of firms, measured by Return on Assets (ROA), and environmental performance, measured by eco-efficiency and an Environmental Management System (EMS) for panel data. The ROA was considered the dependent variable and the EE scores as the predictor variable. Eco-efficiency was measured as the value of output per unit of environmental effects. Water, fuel oil and electricity were considered environmentally detrimental inputs. The estimation results reveal that the eco-efficiency of water, fuel oil, and electricity had no significant impact on the profit of a firm. The results suggest that there is no potential gain to be achieved in the profitability of the firm by improving eco-efficiency in resource use. The present study used DEA to estimate environmental efficiency, and then after that, to determine its effect on profitability.

In South Africa, Nyirenda, Ngwakwe and Ambe (2013) examined the impact of environmental management practices on the financial performance of a South African mining firm. Multiple regression was employed and regressed against three environmental management practices of carbon reduction, energy efficiency and water usage. The results showed there is no significant relationship between the variables. This lends credence to the view that environmental management practices are driven mostly by a desire to abide by regulations and by a moral obligation to use environmental management practices to mitigate climate change impacts.

2.2.3 Overview of literature

From the studies examined, it is evident that limited empirical work has been done on environmental efficiency in the non-agricultural sector in emerging economies. The literature on environmental efficiency remains scanty in Kenya, and Africa in general.

Most studies have been conducted in Asia and mature market economies such as the USA and Europe, where environmental awareness is at a high level. Empirical evidence of the environmental efficiency of small-scale tea processors remains scanty. The present study contributes to the literature in several ways. First, it extends prior studies of the relationship between CSP and Financial Performance (FP) by focusing on environmental performance and utilising a Random Effects Model on a 5-year panel dataset of the small-scale tea processors in Kenya. Second, the study is probably the first documented to investigate the link between environmental efficiency (EE) and FP of the small-scale tea processors in Kenya. By providing a comprehensive and methodologically sound examination of these critical issues, this study has addressed existing gaps in knowledge. This study used quantitative biophysical input and output data, unlike most studies that have relied on the perceptions of respondents to measure environmental constructs. Quantitative data, if available, is preferable (Testa et al., 2014). The present study employed econometric models, based on panel data. Much of the documented research has applied cross-sectional data in the analysis of factors influencing eco-efficiency, which has resulted in the neglect of temporal effects. Specifically, a Random effects model was adopted, unlike previous studies that adopted descriptive analysis, content analysis or survey instruments (Martínez-Ferrero, García-Sánchez, & Ruiz-Barbadillo, 2018).

2.3 Methodology

This section examines the research design and the empirical models used to achieve the first objective of the study as specified in Chapter One – to determine the effect of environmental efficiency on the profitability of the small-scale tea processors in Kenya.

2.3.1 Research Design

This was a non-experimental study and relied on a quantitative analysis of firm-level panel data for the period 2012–2016 for all the 54 small-scale tea processors in Kenya. The analysis was done in three steps. The first step involved estimating the EE scores by the use of Data Envelopment Analysis. The second step involved a Tobit regression for determinants of firm-level EE. The third step involved using a random effects model for establishing the relationship between EE and profitability. Multicollinearity and model diagnostic tests were conducted.

2.3.2 Analytical framework

The study used Data Envelopment Analysis (DEA). This was motivated by the fact that the small-scale tea processors face the same unspecified technology and operational characteristics that define the set of their production possibilities. DEA, a nonparametric approach, was considered appropriate for an environmental efficiency assessment (Tian, Zhao, Mu, Kanianska, & Feng, 2016). Its strength lies in its ability to incorporate multiple inputs and outputs, unlike the Stochastic Frontier approach. An input-orientation DEA was used because the tea processors have powers to control their inputs, rather than their outputs. The Charnes, Cooper and Rhodes (CCR) model use a linear programming method to evaluate the relative efficiency of multiple-input-multiple-output decision-making units (DMUs), without the need for presetting the weight of variables (Chen et al., 2015). The producer problem is to minimise the inputs used, given the outputs required (Eq. 1 and Eq. 2). If there are n DMUs, each of which has m inputs and s outputs, the efficiency score of a DMU is obtained by solving the following model proposed by Charnes et al., (1978). The model is converted to the CCR Model, as given by equations 2.1 to 2.4 (Cooper et al., 2000):

θ^{*}= min θ

Subject to

$$\sum_{j=1}^{n} v_{jX_{ij}} \leq \theta x_{io},\ i = 1,2 \ldots m; \qquad 2.1$$

$$\sum_{j=1}^{n} v_j\, y_{rj} \geq y_{ro},\ r = 1,2 \ldots s; \qquad 2.2$$

$$\sum_{j=1}^{n} v_j = 1 \qquad 2.3$$

$$v_j \geq 0,\ j = 1,2 \ldots n; \qquad 2.4$$

where DMU represents one of the n DMUs under evaluation and x_{io} and y_{ro} are the ^{i}th input and ^{r}th output of DMU respectively.

Since θ= 1 is a feasible solution to (1.2), the optimal value to (2.1), $\theta \leq 1$. If $\theta = 1$, then the current input level cannot be reduced (proportionally), indicating that DMU is on a frontier. If $\theta < 1$, then DMU is dominated by the frontier. θ represents the (input-oriented) efficiency score of DMU.

The relative performance of each DMU (processor) is evaluated in reference to the frontier. This indicates how much each input can be radially reduced to produce an efficient outcome. The main advantage of DEA in this context is that it allows for the assessment of the EE of the small-scale tea processors not only internally, but also by external benchmarking, thus providing new and different perspectives on potential improvements. Another advantage of DEA in this respect is its ability to compute EE scores with inputs and outputs in their natural physical units, without having to normalise them into some common metric. DEA, a nonparametric approach, is considered appropriate for environmental efficiency assessment (Tian et al., 2016). Its strength lies in its ability to incorporate multiple inputs and outputs. By calculating an efficiency score, this method allows the assessing of an entity's DMU capability in converting inputs into outputs. It is considered inefficient when a score below 100% is achieved. This comparison also allows the determination of both input and output targets corresponding to an efficient operation (Moutinho, Madaleno, & Robaina, 2017). EE was analysed using input-oriented Constant Returns to Scale (CRS) Data Envelopment Analysis (DEA) with the undesirable output. The undesirable outputs were transformed using the method of multiplicative inverses (1/bad outputs).

The second stage in efficiency analysis was intended to explore the relationship between firm-level environmental efficiency and other variables that were likely to influence it. These factors were neither inputs nor outputs of the production process, but rather firm-level characteristics. The stage was not only meant to identify the explanatory variables, but also to verify the consistency of the DEA results (Cooper, 1999). DEA scores lie between zero and one. In actual sense, the zero observed is only relative to the firm(s), which exhibit(s) the best practice in the sample. They may not be true zeros. Thus, the Tobit model, as recommended by Cooper (1999), was found appropriate for the second step analysis.

2.3.3 Empirical model specification

To determine the effect of environmental efficiency on financial performance, EE is regressed in the subsequent model to test the hypothesis. The analytical model used was as specified in Equation 2.5.

$$ROA_{it} = \beta_0 + \beta_1\, lnEE_{it} + \beta_2 lnS_{it} + \beta_3\, lnA_{it} + \beta_4 lnC_{it} + \beta_5 G_{it} + \beta_6\, ln\, L_{it} + \beta_7 R_i + \mu_{it} \qquad (2.5),$$

Where ROA_{it} denotes Return on Asset, β are vectors of coefficients to be estimated. EE_{it} is the environmental efficiency score that is time-invariant, S denotes the size of firms, A denotes the firm age, C denotes the capital intensity of firms (Depreciation/sales), G denotes the percentage growth of firms (annual change in sales/sales), and L denotes the leverage of firms (Total Debt/Total Assets). R is the Region dummy, while μ_{it} is the stochastic error term, uncorrelated with the regressors. Random Effect models assume that μ_{it} is not correlated with the research variables in each time interval; hence, the presence of heteroscedasticity was not tested.

Return on Assets (ROA) is a standard accounting measure that represents the profitability of a firm with respect to the total set of resources, or assets, under its control (Karagiorgos, 2010). It reflects the earnings before interest, divided by total assets. The ROA demonstrates how efficiently a firm generates profit per unit of production (Delmas et al., 2015). ROA acknowledges a firm's pollution intensity indirectly via the efficiency of its use in producing earnings (Busch & Hoffmann, 2011). Pre-tax ROA avoids distortions introduced by differences in financial leverage and tax laws (Kupiec & Lee, 2012). ROA, as a proxy for profitability, has been used by (Kamande & Lokina, 2013; Delmas et al., 2015). Panel data helps smooth the effects of managerial manipulation and disparate accounting policies (Gatimbu & Wabwire, 2016).

The present study followed, among others, Haque and Ntim, (2018) in selecting certain firm characteristics as control variables. The control variables taken into account were firm size, leverage, factory age, growth, and capital intensity. Controlling for these factors improves precision and isolates the effect of EE on FP. Financial variables control for sources of firm-level heterogeneity (Elsayed & Paton, 2005; King & Lenox, 2002).

Size controls for economies of scale and pollution propensity. Firm size is an important control variable because larger firms may have more significant resources for social investments and attract greater pressure to engage in CSP, as compared with small firms. It was measured by taking the natural log of the total number of employees. Leverage (a proxy for risk) was measured as the ratio of total debt to total assets. Factory age accounts for variation in experience in tea processing. Growth was measured as the annual percentage change in revenue and controls for variations in production (King & Lenox, 2002). Capital intensity was measured as the ratio of capital used to sales generated.

2.4 Data and descriptive statistics

A census method was adopted for the study. All the 54 small-scale tea factories in Kenya were considered for this study, for the period 2012–2016. The factories are spread across the country and span fifteen counties, namely Meru, Tharaka Nithi, Embu, Nyeri, Murang'a Kericho, Bomet, Nandi, Kirinyaga, Nyamira, Uasin Gishu, Kisii, Kiambu, Kakamega, and Transzoia. Primary and secondary data were collected from each of the 54 factories. Data were collected from both primary and secondary sources. Primary data entailed conducting interviews with key informants. Experienced farmers (ten farmers from each Region) and key industry players were considered for the interviews. Secondary data obtained involved 5-year information on factory inputs and outputs. This study considered the conventional inputs, aggregated into four categories – materials, energy, capital and labour. Input variables were greenleaf tea (Kgs), electricity (Kwts), firewood (m^3), depreciation (Ksh), and the number of employees. Process waste (Kgs), level of GHG emission (Kgs), and wastewater (Kgs) were considered as the undesirable output variables. The undesirable outputs were measured using metrics adopted from Azapagic et al., (2015).

Output and input variables were chosen based on the characteristics of the tea industry. Wastewater, waste gas and solid waste are mostly used to measure the environmental efficiency in manufacturing industries (Zhang et al., 2016). The output variables included were; process waste, level of GHG emissions, and wastewater. The output variables were measured using metrics adopted from (Azapagic et al., 2015). The input variables included were greenleaf intake (Kgs), electricity (Kwts), firewood (m^3), depreciation (Ksh) and the number of casual employees.

2.5 Results and discussion

The absolute amounts of inputs and outputs from the 54 small-scale tea processor showed an upward trend between 2012 and 2016 (Table 2.1). The mean values in depreciation, wastewater, CO_2 emissions, greenleaf intake, process waste and electricity suggest that input resource use, as well as wastes generated by the tea processors, varied among the processors. The mean values of firewood and the numbers of casual staff suggest that their use is similar across the processors. Generally, there is increased use of environmental input resources, as well as increased production of undesirable outputs throughout the observations made.

Table 2.1: Descriptive statistics for input and output variables for 54 small-scale tea processors in Kenya, 2012 to 2016

		depreciation	firewood	electricity	greenleaf intake	casual staff	CO_2 emission	process waste	water waste
2012	Mean	29.2	160	2.46	16.80	94	3.40	0.25	18.70
	Std dev	13.2	7.43	1.11	6.60	48	1.33	0.10	7.33
2013	Mean	30	20.6	2.81	20.80	97	4.16	0.31	22.90
	Std dev	13.2	8.89	1.17	7.93	50	1.59	0.12	8.77
2014	Mean	32.4	19.75	2.66	20.90	85	4.15	0.31	22.80
	Std dev	14.6	8.78	1.00	8.20	36	1.65	0.12	9.10
2015	Mean	31.9	16.92	2.44	19.40	75	3.88	0.29	21.30
	Std dev	14.8	8.15	1.10	8.92	31	1.81	0.13	9.95
2016	Mean	33.9	19.48	2.77	22.90	77	4.53	0.33	24.90
	Std dev	19.4	9.37	1.24	10.70	35	2.13	0.16	11.70

The values of depreciation, greenleaf intake, electricity, carbon dioxide, process waste, and water waste are in millions. Firewood is in thousands of metric tons *(Source: Author's own calculation).*

.

The mean environmental efficiency for the small-scale tea processors was 49%, indicating that the factories could reduce 51% of environment-detrimental inputs (electricity and firewood) without compromising output. The efficiency levels varied across the 54 factories. Two of the 54 factories were found to be efficient. Further discussion with key informants revealed that these two factories use dry firewood, have a good steam trap system, unlike the rest, and have excellent machinery maintenance practices. Firewood with less moisture content will burn faster and consume less energy. The least efficient factory had a score of about 8%. This inefficiency is perhaps due to the use of poor-quality firewood, a poor steam system, and underutilization of machine capacity, hence the greater consumption of energy.

The study noted that ten factories had an efficiency score of 0–25%, while 38 factories had an efficiency score of 26–75%. Only six factories had an efficiency score of above 75% (Figure 2.1). This further affirms the view that the small-scale tea factories are environmentally inefficient.

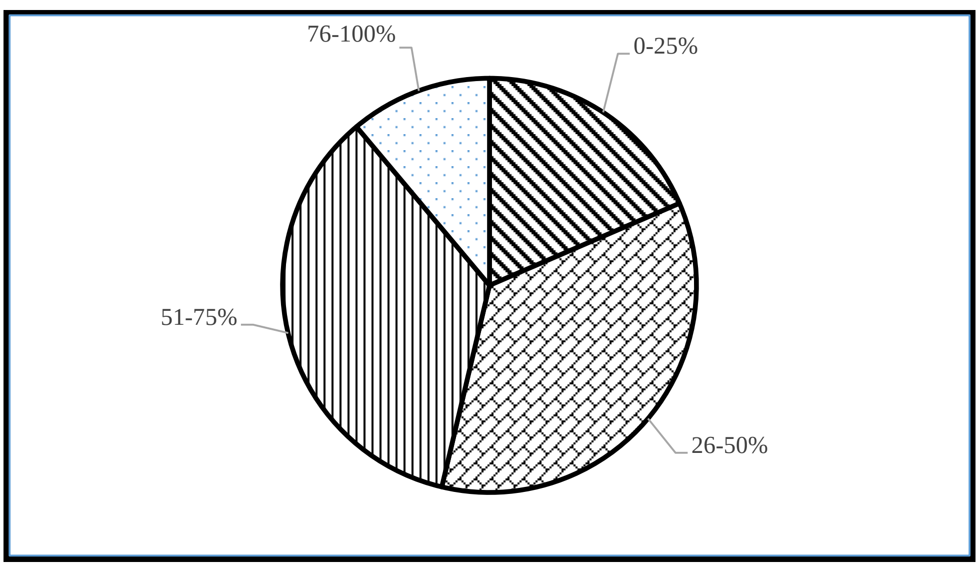


Figure 2.1: Percentage distribution of efficiency levels for the 54 small-scale tea factories in Kenya for the period 2012–2016 *(Source: Author's own calculation)*

The mean environmental efficiency for the small-scale tea processors decreased from 49% in 2012 to 29.4% in 2013. After that, it took an upward trajectory, rising from 29.4% in

2014 to 36.8% in 2016 (Figure 2.2). A few key informants indicated that the upward trajectory for the period under consideration was a result of the introduction of an energy manager from 2013, periodic energy audits, staff training, and sensitisation regarding energy-saving measures. Moreover, the tea factories also incorporated the use of renewable energy (for example solar power). In addition, the tea factories have undergone a Rainforest Alliance certification process. This is a buyer-driven certification. This certification process promotes environmentally, socially and economically sustainable methods of tea production. The processed tea can, therefore, fetch a premium price at the tea auction in Mombasa, Kenya. Studies have shown that customers prefer environmentally sound products and are willing to pay more for them (Dunk, 2002).

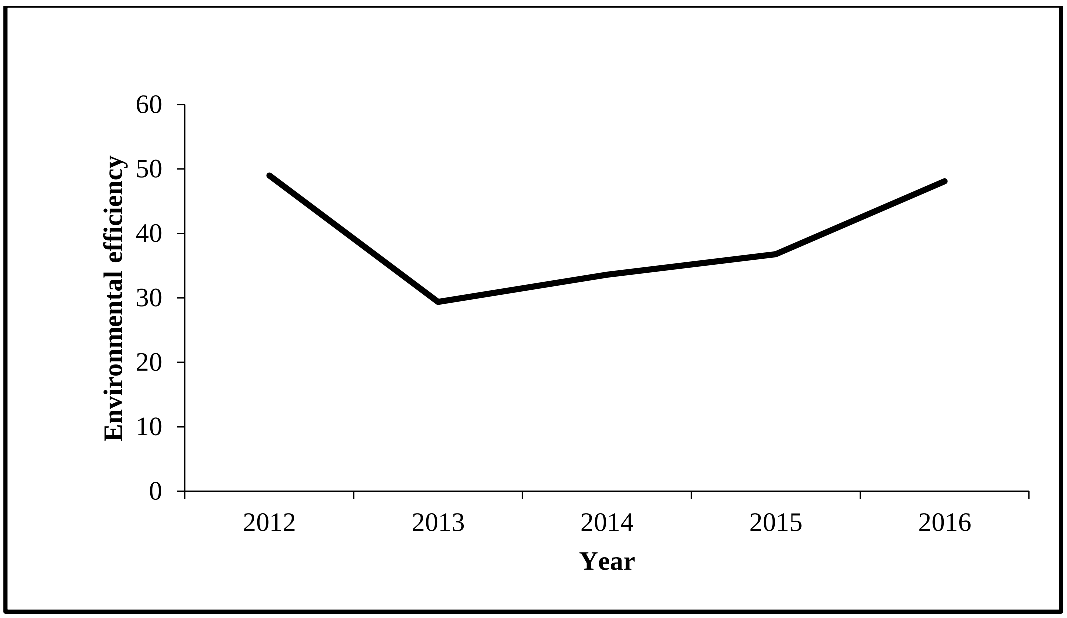


Figure 2.2: Environmental efficiency trend for the 54 small-scale tea factories in Kenya for the period 2012–2016 (*Source: Author's own calculation)*

The environmental efficiency varied by Regions (Figure 2.3). Region 1 had an efficiency score of 59%, Region 2 scored 49%, Region 3 scored 48%, Region 4 scored 44%, Region 5 scored 58%, Region 6 scored 21%, and Region 7 scored 64%. The best-performing Region was Region 7. The worst was Region 6. Interviews with regional leaders and operation directors indicated that Region 6 performed poorly because of poor quality raw material and low uptake of new technologies. Poor quality raw material leads to greater consumption of energy since it contains much fibre. Further, interviews revealed that

Region 7 performed well partly because it has only three factories, and mostly because it uses dry firewood obtained from tropical forests (Kakamega and Mt. Elgon); hence, lower consumption of energy. Environmental efficiency levels varied significantly in Regions 1, 2, 3, 4 and 5. However, there were no significant variations in environmental efficiency levels in Regions 6 and 7.

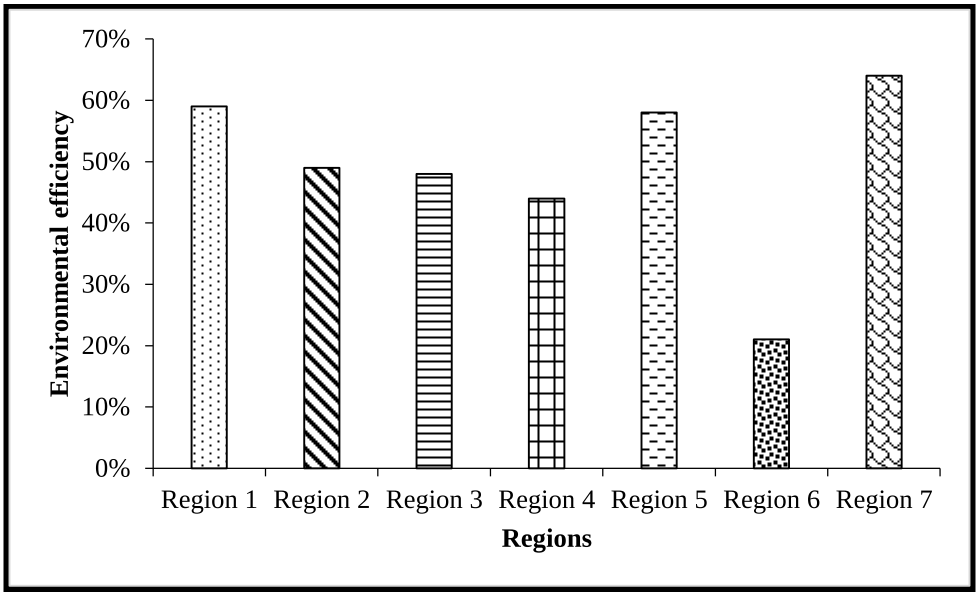


Figure 2.3: Average environmental efficiency of small-scale tea processors per Region for period 2012–2016 (*Source: Author's own calculation)*

Statistical tests confirmed that the Regions were indeed different in terms of environmental efficiency (Table 2.2). Region 1 and Region 2 had a statistically significant difference in the mean environmental efficiency levels. Region 2 and Region 3 had a statistically significant difference in the mean environmental efficiency levels. Regions 2 and 4 had a statistically significant difference in the mean environmental efficiency levels from Region 5. Regions 6 and 7 had no statistically significant difference in their environmental efficiency levels with the other Regions. Interviews with a few key informants revealed that Regional differences may be attributed to factory age, factory size, machinery maintenance practice, quality of the raw material, and the willingness of Regional leaders to adopt new technologies. The above classification can provide a reference for Regional policy.

Table 2.2: Kruskal Wallis test for Environmental Efficiency of small-scale tea factories per Region

Region	Counties	Obs	Rank Sum
1	Kiambu	55	6882
2	Murang'a, Nyeri	45	7541
3	Kirinyaga, Embu	40	5132
4	Meru, Tharaka Nithi	35	5277
5	Bomet, Kericho	45	4962
6	Kisii, Nyamira	35	4712
7	Kakamega Trans Nzoia	15	2079

Source: Author's own calculation

The environmental efficiency score varies significantly by Regions (Table 2.2). The chi-squared was 14.970, with p (0. 0205; $p<0.05$). The chi-squared with ties was 14.971, with p (0. 0205; $p<0.05$). This was significant at 5% level. The null hypothesis was thus rejected. Environmental efficiency levels vary significantly in Regions1, 2, 3, 4 and Region5. However, there is no significant difference in environmental efficiency levels in Regions6 and 7. Following the significant results of a Kruskal Wallis test, a Dunn test (post hoc test) was performed (Table 2.3).

Table 2.3: Dunn test for Pairwise comparison of Environmental Efficiency of small-scale tea processors in Kenya per Region for the period 2012–2016

Regions	1	2	3	4	5	6
2	-2.705					
	(0.0034)*					
3	-0.196	2.315				
	(0.4225)	(0.0103)*				
4	-1.519	0.955	-1.243			
	(0.0644)	(0.1698)	(0.1069)			
5	0.947	3.481	1.063	2.302		
	(0.1719)	(0.0002)*	(0.1439)	(0.0107)*		
6	-0.563	1.872	-0.350	0.865	-1.384	
	(0.2868)	(0.0306)	(0.3631)	(0.1936)	(0.0831)	
7	-0.592	1.245	-0.436	0.505	-1.217	-0.165
	(0.2768)	(0.1066)	(0.3315)	(0.3067)	(0.1118)	(0.4345)

The values in parenthesis are the standard error of means. *denotes Significance level at 10% based on t-statistics *(Source: Author's own calculation).*

Table 2.4: Summary statistics showing the determinants of environmental efficiency for small-scale tea processors in Kenya (2012–2016)

Variable	Mean	Std. Dev	Min	Max
*EE	0.3937	0.217	0.044	1
Profit	0.015	0.0273	-0.017	0.279
Factory age	35.389	10.654	15	53
Finance cost	17.364	0.948	14.307	20.052
Supply	0.648	0.478	0	1
Size	19.940	0.828	13.204	22.405

Source: Author's own calculation

*EE is the Environmental Efficiency

Overall, the profit range of the small-scale tea processors in Kenya ranged from -1.7% to 2.7% (Table 2.4). The average profitability was 1.4%. The mean factory age was 35 years, with the oldest being 53 years and the youngest 15 years. Profit and finance costs had a negative effect on environmental efficiency (Table 2.5). This indicates that higher profits lead to a decline in environmental efficiency. Firms that are purely concerned with pursuing profit figures do not take a balanced approach to improving energy efficiency (Zhang et al., 2016). Holding other factors constant, a 1% increase in profits leads to a decrease in environmental efficiency by1.1598. The results corroborate the findings of (Long, Zhao, & Cheng, 2015; Zhang et al., 2016) who reported similar evidence.

Similarly, the cost of finance had a negative effect on environmental efficiency. High finance costs inhibit the processors in adopting improved technologies. On the condition of other factors remaining unchanged, a 1% increase in finance cost leads to a decrease in environmental efficiency by 0.0598646. Supply and factory age and size showed a positive relationship with environmental efficiency. These factors, however, were not significant.

Table 2.5: Tobit regression of determinants of Environmental Efficiency for small-scale tea processors in Kenya (2012–2016)

Variable	Coefficient	Std Error
Supply	0.0073	0.0285
Factory age	0.0008	0.0012
Profits	-1.1598**	0.4683
Finance cost	-0.0598***	0.0146
Size	0.0038	0.0156
_cons	1.3397***	0.3818

Source: Author's own calculation

*significant at 10; ** significant at 5% and *** significant at 1%.

Overall, the profit of the small-scale tea processors in Kenya ranged from 0.9% to 1.6% (Table 2.6). The average profitability was 1.4%. The disparity in profitability was low, with an index of only 2.7%. The results from DEA showed an average efficiency score of 49%. The average environmental efficiency exhibited an increasing trend from 2014 to 2016.This shows that tea processors are gradually paying attention to environmental sustainability. A few key informants revealed that tea firms had undergone structural changes such as periodic energy audits, hence the gradual improvement in environmental sustainability. On average, tea factories have been in existence for about 35 years.

Table 2.6: Descriptive statistics of variables for small-scale tea processors in Kenya for period 2012–2016

Variable		Overall	2012	2013	2014	2015	2016
Return on Asset	Mean	0.015	0.0167	0.014	0.0097	0.019	0.013
	Std.	0.027	0.038	0.033	0.009	0.0292	0.016
Growth	Mean	2.711	20.032	-22.823	-5.376	49.745	-28.025
	Std.	33.319	9.972	10.596	22.225	11.367	23.382
Leverage	Mean	0.786	0.757	0.772	0.756	0.929	0.717
	Std.	0.495	0.201	0.184	0.196	0.790	0.690
Capital Intensity	Mean	0.025	0.023	0.019	0.028	0.031	0.021
	Std.	0.009	0.008	0.006	0.009	0.011	0.007
EE	Mean	0.3937	0.230	0.166	0.186	0.200	0.229
	Std.	0.217	0.081	0.044	0.064	0.096	0.12
Factory age	Mean	35.4	35.389	35.389	35.389	35.389	35.389
	Std.	10.7	10.734	10.734	10.734	10.734	10.734
Size of firm	Mean	138.385	147.353	148.315	139.074	127.148	130.037
	Std	58.939	9.039	68.344	56.085	51.193	57.669

Source: Author's own calculation

EE is the Environmental Efficiency; * is significant at 10%; ** is significant at 5%, and *** is significant at 1%; Std is the standard deviation.

The correlation coefficients of all variables used in the regression analysis are presented in Table 2.7. The correlations preliminarily show that there is a negative correlation between EE and financial performance (-0.15, $p<0.05$). The correlation coefficients of all the constructs were below the recommended cut-off value of 0.9 (Table 2.8), indicating lack of multicollinearity (Hair, Anderson, Tatham, & Black, 1998). Potential multicollinearity was examined by computing the variance inflation factor (VIF). None of the VIF values exceeded the critical value of 10, which further demonstrated the absence of multicollinearity (Hair et al., 1998).

Table 2.7: Pairwise correlation of variables for small-scale tea processors in Kenya for the period 2012–2016

	ROA	EE	growth	leverage	Capital intensity	Size	Factory age
ROA	1						
EE	-0.154	1					
	(0.0114)**						
growth	0.122	0.057	1				
	(0.0449)**	(0.3508)					
leverage	-0.0334	-0.0001	0.125	1			
	(0.5849)	(0.9981)	(0.0397)				
Capital intensity	0.19	-0.1896	0.341	0.1689	1		
	(0.0017***)	(0.0017)***	(0)***	(0.0054)***			
Size	-0.0462	-0.0003	-0.1257	-0.0847	-0.1969	1	
	(0.45)	(0.9959)	(0.039)	(0.165)	(0.0011)		
Factory age	-0.1523	0.031	-0.0432	-0.079	-0.1357	0.1836	1
	(0.0122)**	(0.6115)	(0.4799)	(0.1959)	(0.0258)**	(0.0025)	

Source: Author's own calculation

EE is the Environmental Efficiency; ROA is the Return on Assets;* is significant at 10%; ** is significant at 5%, and *** is significant at 1%; the values in parenthesis are the standard deviations.

Table 2.8: VIF variables for small-scale tea processors in Kenya for the period 2012–2016

Variable	Variance inflation factor(VIF)	Tolerance (1/VIF)
Capital intensity	1.26	0.7964
growth	1.16	0.8613
Size	1.08	0.9298
Environmental Efficiency	1.06	0.9458
Factory age	1.05	0.9532
leverage	1.04	0.9610
Mean VIF	*1.11*	

Source: Author's own calculation

Overall, the most profitable firms were not environmentally efficient (Table 2.9). Furthermore, 81.3% of factories that had good environmental performance (0.8-1.0) also had comparatively low profitability, ranging from -0.25% to 1.23%. This further implies that in the short run, firms that try to be ecologically sustainable might not perform well financially.

Table 2.9: Mean Environmental Efficiency and profitability of the small-scale tea processors in Kenya for the period 2012–2016

Profitability (ROA)	Environmental Efficiency levels				
	0-0.2	**0.2-0.4**	**0.4-0.6**	**0.6-0.8**	**0.8-1**
-1.74--0.25	4.4	0.0	0.0	0.0	0.0
-0.25-1.23	60.0	63.2	72.1	87.1	81.3
1.23-2.72	15.6	23.1	23.0	3.2	18.8
2.72-4.21	13.3	3.4	1.6	6.5	0.0
4.21-0	6.7	10.3	3.3	3.2	0.0
Grand Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

Source: Author's own calculation

First, the appropriateness of the model was checked by performing a Breusch and Pagan Lagrangian multiplier (LM) test. The test rejected the Pooled OLS in favour of a random effects model. Additionally, a Hausman test rejected the fixed effects model in favour of the random effects model. Variation across entities was thus random and uncorrelated with the independent variables included in the model. This affirmed there were no significant differences across the factories. RE allows the generalising of inferences beyond the sample used in the model. Panel unit roots, co-integration and cross-section dependence, were not concerns for the present study due to the small time frame (5 years) of panel data (Baltagi, 2005).

The empirical results of the regression analysis for the effect of environmental efficiency on profitability are presented in Table 2.10**.** The null hypothesis was accepted; environmental efficiency had a negative effect on financial performance. The results showed that environmental efficiency had a negative effect on profitability ($\beta = -0.007$, $p < .5$). These results support the argument that companies engaged in environmental sustainability may not perform well financially since environmental sustainability is a cost that eats into the profits. Similar to the evidence documented by Bouslah et al., (2009), environmentally responsible business decisions limit the strategic alternatives for firms, forcing firms to forego revenue-boosting alternatives. The present study confirms previous literature findings by Jaggi and Freedman (1992) about a negative effect of environmental performance on profitability. Contributions in the field of value-destruction theory and the trade-off theory suggest a negative relationship when resources are channelled towards less-profitable sustainable activities (Alshehhi et al., 2018). Similarly, a negative effect of the environmental dimension of CSP on FP, using the Granger causality approach, has been previously reported (Francoeur et al., 2009).

The Wald test results are chi-square (12) = 29.34 p = 0.003, showing a linear relationship. Consequently, a 1% change in EE reduces profitability by 0.7%. Intuitively, initial efforts to improve EE may yield negative financial returns. The negative effect suggests that investment in the natural environment comes as a cost to firms and hinders it in profit maximisation (Friedman, 1970). These factors increase financial burdens and operating risk. As noted by Salama (2005), a considerable amount of time must elapse before environmental sustainability yields positive financial returns.

Further, the finding supports the natural resource-based view that environmental capabilities need to develop over time to become valuable (Hartmann & Vachon, 2018). The efficiency-enhancing technologies adopted by the small-scale tea industries in Kenya, such as steam boilers, CFUs, and super-efficient motors and fans, are capital intensive, which eats into the profits. Fortunately, investment in long-term, capital-intensive projects is likely to reduce actual GHG emissions (Haque & Ntim, 2018).

Similarly, cleaner production activities of the high-cost scheme were reported to have a greater contribution to non-financial performance, as compared with financial performance. Therefore, cleaner production initiatives of the low-cost scheme have a greater contribution to financial performance, as compared with non-financial performance (Zeng et al. 2010). Furthermore, the position of neoclassical economists holds that socially responsible behaviour will net a few economic benefits, while its numerous costs will reduce profits and shareholder wealth (Francoeur et al., 2009). Further, Jaggi and Freedman (1992) provide evidence that good pollution performance is negatively associated with economic performance over a short period. Accounting measures such as Return on Assets are often used to evaluate initiatives that affect the firm in the short term. In sum, the finding of this study supports the debate that the implementation of better environmental management practices limit the abilities of firms to pursue revenue-enhancing projects (Lizal & Earnhart, 2010).

Table 2.10: Random Effect Model results for small-scale tea processors in Kenya for the period 2012–2016

Variables	**Random Effects**
Environmental Efficiency	-0.0070 (0.0031) **
Growth	0.00011 (0.000) ***
Size	-0.0024 (0.007)
Factory age	-0.0091 (0.0055) *
Capital intensity	-0.0018 (0.0039)
leverage	-0.0075 (0.004) *
Region 2	-0.0037 (0.0059)
Region 3	-0.0082 (0.006)
Region 4	0.0003 (0.0061)
Region 5	0.0011 (0.0059)
Region 6	-0.0074 (0.0073)
Region 7	0.0166 (0.0084) **
sigma_u	0.0072
sigma_e	0.0224
rho	0.0936

Source: Author’s own calculation

* is significant at 10%; ** is significant at 5% and *** is significant at 1%; values in parentheses are standard errors

Conversely, Kamande and Lokina (2013) observed that improving eco-efficiency had no significant impact on the profit of the studied manufacturing firms in Kenya. Similarly, in South Africa, no relationship between environmental management practices and financial performance was observed (Nyirenda, Ngwakwe, & Ambe, 2013). The decision to undertake EE-enhancing practices increases the financial outlay of the tea factories. However, environmental efficiency improves resource efficiency; hence, reduced costs and increased competitiveness in the long term (Daddi, Iraldo, Testa, & Giacomo, 2018). Similarly, environmental management also offers added capacity for reducing wastes, effluents, and emissions in the production process (Hartmann & Vachon, 2018). Furthermore, waste minimisation helps to reduce lead times and increase product quality (Perey, Benn, & Edwards, 2018).

2.6 Summary, Conclusion and Policy Implications

2.6.1 Introduction

The objective of this chapter was to determine the effect of environmental efficiency on the profitability of the small-scale tea processors in Kenya. This study was motivated by the fact that production costs have been persistently on the rise, despite the measures taken to contain them. Understanding the levels of inefficiency/efficiency can help to address the continued increase in production costs and to provide opportunities for technological innovation. Summary and conclusion of the findings are observed and implication for policy inferred.

2.6.2 Summary

This study adopted the non-parametric DEA approach method to estimate the environmental efficiencies of the small-scale tea processors in Kenya. A census was conducted. Data covering five years (2012, 2013, 2014, 2015 and 2016) for the54 factories under the management of KTDA was collected. Tobit regression was later used to determine the source of efficiency differentials among the processors. The findings indicated that the small-scale tea processors in Kenya were inefficient for the period 2012–2016. It would be expected that their investment in EE technologies would result in improved EE levels. However, the environmental efficiency index was only 49%. Fortunately, the processors' environmental efficiency showed an upward trajectory during the 2012–2016 period. Environmental efficiency levels varied across the Regions. Limited key informants' interviews attribute these variations to factory age, factory size, machine maintenance practices, quality of the raw materials, and the willingness of Regional leaders to adopt new technologies. Further, the findings also revealed that the pursuit of excessive profitability, without simultaneously taking a balanced approach to improving energy efficiency, would cause a decline in environmental efficiency. When the processors pursue profit figures, environmental efficiency is neglected since it is considered an additional cost, which might erode firms' competitiveness (Huang et al., 2014).Similarly, high finance costs discourage the processors from adopting improved environmental technologies; hence, a decline in environmental efficiency. The supply of raw materials, factory age, and factory size had a positive relationship with environmental efficiency. Results showed a negative effect of EE on FP. Further, the results revealed that a 1% change in EE reduces profitability by 0.7%. The findings provide answers for the persistent rise in production costs for the tea industries. The findings are consistent with the trade-off hypothesis, suggesting that environmental sustainability comes with financial outlays; hence, firms experience lower profits and reduced shareholder wealth. This finding also supports the natural resource-based view that environmental capabilities need to develop over time to be appreciated.

2.6.3 Conclusion

In conclusion, the present study demonstrated that small-scale tea processors are environmentally inefficient. The processors can reduce 51% of their input resources without compromising on their output. The study findings also revealed a significant negative effect of environmental efficiency on financial performance. A key contribution to the methodology made by this study has been the measurement of environmental constructs using input and output indicators of production by utilising the DEA methodology. Furthermore, the determinants of firm-level EE have also been determined.

2.6.4 Policy implications

The key findings have important implications for the government, tea factories' management, and tea farmers. For the government, the growing demand for energy consumption could be controlled by appropriate policies that would enhance the adoption of renewable energy (solar power, and gasifiers among others), hence the reduction of GHG emissions. This could be achieved through tax reliefs and tax holidays for the development of environmental efficient technologies. Stringent environmental regulation should also be put in place to reduce pollution, for example, statutory energy audits. Factories would improve production technology owing to stringent environmental regulation. For tea factories' management, it is essential to enact Regional policies due to the significant differences in Regional environmental performances. Moreover, Regional leaders should be sensitised on the importance of new technologies.

Interventions that could promote awareness, where knowledge of good environmental practice is sensitised to all factory staff through regular staff training, could also be important. Furthermore, integrating awareness programmes through farmer field schools, where farmers are informed about good quality leaf picking (two leaves and a bud) for preventing energy losses at factory level, could be considered. Other strategies that could promote energy efficiency at factory level include replacing inefficient motor and fans with high-efficiency motors, lagging the steam systems, the proper lubrication of parts, sharpening of the parts, implementation of good maintenance practices, and optimum machinery utilisation. The strategies mentioned above could seal potential loopholes for energy losses and process waste. Periodic internal energy audits could also provide potential areas for improvement. Moreover, factories need to create and strengthen their energy committees to ensure the implementation of the energy audit reports. Considering the specific objective of the study, that is, the relationship between environmental sustainability and corporate financial performance, this study has several managerial and policy implications to suggest. A clear message is highlighted for top-level managers: environmental performance is negatively related to corporate financial performance in the short run. Managers should, therefore, engage in activities of a low-cost nature during this period to compensate for the financial outlays.

This study further demonstrated that corporate environmental initiatives lead to poor financial performance in the short term. Therefore, it is recommended that regulators and policymakers should endorse appropriate environmental legislation to enhance firms' uptake of environmental initiatives. The proposed regulation should compensate for short-term financial outlay. Strategies that could promote compensation for the short-term negative impact on financial performance include reductions of costs related to regulations and inspections. Government subsidies, for example, tax waivers on environmental technologies, could also be adopted. Moreover, the government could introduce a tax holiday for the factories when the technologies adopted exceed a certain monetary threshold.

CHAPTER THREE

TECHNICAL EFFICIENCY AND PROFITABILITY OF THE SMALL-SCALE TEA PROCESSORS IN KENYA

3.1 Introduction

This chapter responds to the second objective of the thesis. It synthesises the literature on Technical Efficiency and the determinants of TE and discusses the theoretical and analytical models used before analysing the effect of Technical Efficiency on profitability. Further, the chapter discusses the results and provides policy implications.

3.2 Theoretical Framework

Aigner et al. (1977) and Meeusen and Van den Broeck (1977),who simultaneously proposed the Stochastic Frontier Model, drew their works upon the Farrell (1957) seminar paper on efficiency measurement. Productive efficiency is thus defined as the ability of a firm to produce a given level of output at the lowest cost. Three broad quantitative approaches have been developed for measuring productive efficiency, as described below.

Frontier efficiency has been used extensively in measuring the level of inefficiency/efficiency. Frontier functions can be classified into parametric and nonparametric linear programming approaches. The non-parametric approach is composed of the data envelopment analysis (DEA) and the free disposal hull (FDH). The parametric approach is composed of the stochastic frontier approach (SFA), the thick frontier approach (TFA) and the distribution-free approach (DFA). These methods differ mainly in the assumptions made about the functional form, whether or not random errors have been accounted for, and the probability distribution assumed for the inefficiency. However, there is no consensus among researchers as to the best method for measuring efficiency (Kibaara, 2005). Two methods have partial strength and weakness. The econometric method is stochastic and parametric. It distinguishes the effects of noise with the effects of inefficiency and confounds the effect of misspecification of functional form with inefficiency. It generates good results for models with a single output and multiple inputs.

The SFA approach inquires that a functional form is specified for the frontier production function while the DEA approach uses linear programming to construct a piece-wise frontier that envelops the observations of all firms. An advantage of the DEA method is that multiple inputs and outputs can be considered simultaneously, and inputs and outputs can be quantified using different units of measurement. However, a strong point of SFA in comparison with DEA is that it considers measurement errors and other noise in the data. This point is essential for studies of firm-level data in a developing economy like Kenya, as data generally include measurement errors. The SFA specifies the relationship between output and input levels and decomposes the error term into two components: a random error and an inefficiency component. The random error is assumed to follow a symmetric distribution with zero mean and constant variance, while the inefficiency term is assumed to follow an asymmetric distribution and may be expressed as a half-normal, truncated normal, exponential or two-parameter gamma distribution (Ogundari, 2008). However, the major drawback of SFA is that it requires the specification of a functional form, which causes both specification and estimation problems(Chen, Wu, Song, & Zhu, 2017).

The concept of efficiency involves a comparison between the optimal values and expected values of output and input of a production line. The comparison can take the form of the ratio of minimum potential to observed input required to produce a given output, or the comparison can take the form of the ratio of observed to maximum potential output obtainable from given set of inputs. In these two comparisons, the optimum is defined in terms of production possibilities and technical efficiency. Technical efficiency reflects the ability of the firm to maximise outputs, given the inputs, (output-oriented) or to minimise inputs used in the production of a given output (input-oriented). Technical efficiency reflects the production of given outputs at minimum cost, or the utilisation of given inputs to maximise revenues or the allocation of inputs and outputs to maximise profits (Ndicu, 2015). This theory guides the current study by underscoring the importance of input-oriented technical efficiency measurement in cost control, which takes place when the business employs all its resources efficiently, producing the most output from the least input.

3.2.1 Empirical literature

Efficiency estimates and trends for 41 firms in the agro-processing industry in Kenya were analysed for the period 2011–2013 by Ndicu (2015). The findings showed that the agro-processing industry had an overall efficiency score of 44%. The efficiency score was distributed as to 53%, 60% and 57% for the food, beverage, and non-food sub-sectors, respectively. This study concluded that an average 56% technical potentiality was not achieved by the agro-processing industry in the periods 2011, 2012 and 2013. The study tested a translog production function as the best functional form to fit the data, using SFA. Further, the study did not analyse the sources of technical inefficiencies in the manufacturing sector. The present study estimated the technical efficiency in a one-step approach that incorporated the inefficiency component, using the Cobb Douglas function.

Ngui-Muchai and Muniu (2012), empirically investigated the technical efficiency of firms in the Kenyan manufacturing food, metal and textile sub-sectors, using data covering two periods: 1992/1993 – 1994/1995, and 2000/2001 – 2002/2003. The stochastic frontier approach was used in the analysis. The results showed that the technical efficiency scores varied among the sampled firms in each period. The average technical efficiencies were recorded at 52%, 58%, and 60%for the food, metal, and textile sub-sectors, respectively. This implies that nearly 48%, 42% and 40% of technical potentialities were not achieved in the 1992/1993 – 1994/1995 period. The present study measured the output variable as the total output cost of production, whereas the Ngui-Muchai and Muniu (2012) study calculated the output variable as the difference between gross output and raw materials and indirect inputs.

Lundvall and Battese (2000) estimated a translog production function for the Kenyan manufacturing sector using unbalanced panel data for the period 1993 –1995. The output variable used in the empirical analysis was the value added of all output produced by the firm each year. The input variables consisted of capital, which was defined as the replacement cost of existing machinery and other equipment employed in the production process, multiplied by the degree of capacity utilization. Wages included the total wage bill, including all allowances for the firm in one year. This study reported an average technical efficiencies of 77%, 80%, 76%, and 68% for the food, metal, textile and wood sub-sectors, respectively.

A DEA model was used to determine the efficiency of manufacturing companies in Kenya from 2009 to 2011 by Haron and Chellakumar, (2012). They chose 30 companies and evaluated net sales, earnings after tax, raw material, staff expenses, plant, and machinery. Their study showed that a company with high DEA efficiency also has good performance. Further, the small-sized manufacturing companies were the best-performing companies in terms of relative efficiency (83%). Following distantly were the large-size manufacturing companies (69%), and finally, medium-sized manufacturing companies at68 percent.

In Tunisia, 27 hotels were examined using the DEA approach to measure efficiency and the ROA indicator for profitability performance (Aissa & Goaied, 2016). Regression results showed the significant influence of a hotel's efficiency on its profitability performance. Shieh (2012) employed DEA to estimate the cost efficiency of Taiwan hotels, and evaluated three financial ratios for profitability performance: the ratio of net operating profit before taxes, the ratio of earnings before taxes, and return on assets before taxes. In contrast to the study above, Shieh indicated that cost efficiency does not significantly influence profitability performance.

The technical and environmental efficiency of Kenya's manufacturing sector was estimated using a stochastic frontier approach by Kamande, (2014). It was evident that manufacturing firms in Kenya were generally technically inefficient. The environmental efficiency measure was negative, implying that firms were also environmentally inefficient. Results further showed that technical inefficiency and environmental efficiency were inversely related, implying that technical efficiency and environmental efficiency move together. The findings suggest that there is a gain in efficiency for firms when environmental concerns are incorporated into business objectives.

The technical efficiency of the 16 manufacturing companies listed on the Nairobi Securities Exchange was measured using DEA (Haron & Chellakumar, 2014). The DEA model was applied, using both the Constant Returns to Scale (CCR) and Variable Returns to Scale (BCC) models. The results revealed that the source of inefficiency was attributable to its scale and technical efficiency following the slacks results.

3.2.2 Overview of literature

The novelty of this study is threefold. First, unlike previous studies that measured the performance of tea firms in Kenya using profitability and financial ratios (Ng'ang'a, 2011; Kaimba & Nkari, 2014), this study measured firm performance by technical efficiency. Besides, previous studies on technical efficiency in Kenya have focused on the agricultural and manufacturing sectors. The literature on technical efficiency of the small-scale tea processors in Kenya, using a parametric approach, is not documented. Furthermore, this study used panel data models and accordingly was able to account for potential heterogeneity across firms. Thirdly, the study employed Region-specific frontiers for comparison rather than as pooled. This is in tandem with Lundvall and Battese (2000) who found sector-based equations to be more appropriate than pooled equations. The primary motivation for measuring the technical efficiency is to understand the differences in the levels of efficiency, as well as differences in the context within which production takes place (Trujillo & Iglesias, 2013). It is based on the preceding that this study sought to determine the technical efficiency, and its determinants, of the small-scale tea industry in Kenya.

3.3 Methodology

This section discusses the design and empirical methodologies used to determine the effect of technical efficiency on the profitability of the small-scale tea processors in Kenya.

3.3.1 Research Design

The present study used a two-stage SFA to determine the TE for the empirical analysis of all the 54 small-scale tea-processing firms in Kenya for the period 2012–2016. This was a non-experimental study and relied on quantitative analysis. The data source was derived from the individual tea firms under the management of the Kenya Tea Development Agency (KTDA). The first step estimated technical efficiency, using a one-step approach. For the second stage, a Stochastic Meta-Frontier (SMF) model, as proposed by Huang et al. (2014) that uses SFA to estimate meta-frontier parameters, was used. Thirdly, the relationship between TE and profitability was determined using the Spearman correlation coefficient.

The parameters of the stochastic frontier and inefficiency model were simultaneously estimated in a one-stage maximum likelihood estimation (MLE). The two-stage approach has been criticized because of its inconsistency in the assumption of independence of the inefficiency effects. This is because the specification of the second stage regression, in which the technical efficiency scores are hypothesized to be related to the explanatory variables, disagrees with the hypothesis that the inefficient component is independently and identically distributed (Wongnaa & Awunyo-vitor, 2017).

3.3.2 Estimation of Technical Efficiency

The study adopted SFA to measure the TE of the small-scale tea processors, prompted by the fact that the production function of the processors may be uniform. The technically efficient processors lie on the frontier, while the relatively less efficient ones lie below the frontier. The input-oriented efficiency score indicates how much the inputs can be reduced for a given level of output. An output-oriented efficiency score shows by how much the output can be increased for a given level of inputs. This study adopted the input-oriented measure of TE because the tea processors have control of their inputs, but not of the output.

3.3.3 Technical Efficiency Model

A maximum likelihood estimation (MLE) one-stage approach procedure was adopted for this study. The one-stage approach is more useful since it avoids statistical problems that are encountered during estimation with the two-stage method (Wongnaa & Awunyo-vitor, 2017). Technical efficiency estimates were derived by estimating a stochastic production frontier from each ecological Region by using Equation 3.1. For example, given the j^{th} Region, the stochastic frontier of the i^{th} firm can be modelled as in Equation 3.1.

$$Y_{ji} = f^{i}(X_{ji})e^{V_{ji}-U_{ji}}, \text{ Where } U_{ji} \sim N[\delta_j Z_{ji}, \sigma^2] \qquad 3.1$$

where j=1,2…J; i=1,2…N and where Y_{ji} and X_{ji} respectively denote the output and input vector of the i^{th}factory in the j^{th} Region. Following standard stochastic frontier modelling, $V_{ji}$is a normally distributed random variable with zero mean and variance σ^2 and which represents statistical noise. The non-negative random errors U_{ji} represent technical inefficiency and δj (j=1, 2,) is the Region-specific parameters to be estimated. U_{ji}, follows a half-normal distribution and is assumed to be independent ofV_{ji}. Z_{ji} is the exogenous vector of variables determining inefficiency specific to each farming household within each region. A factory's technical efficiency is then defined by Equation 3.2.

$$TE_i^j \frac{Y_{ji}}{f^i(X_{ji})e^{V_{ji}}} = e^{-U_{ji}} \qquad 3.2$$

The ratio of the j^{th}Region's production frontier to the metafrontier is defined as the Technology Gap Ratio (TGR) represented by Equation 3.3.

$$TGR_i^j = \frac{f^j\,(X_{ji})}{f^M(X_{ji})} = e^{-U_{ji}^M} \leq 1 \qquad 3.3$$

At a given input level X_{ji} – a firm's observed output Y_{ji} with respect to metafrontier $f^M(X_{ji})$- has three components: the TGR, the factory's technical efficiency, and the random noise component (i.e. Equation 3.4).

$$\frac{Y_{ji}}{f^M(X_{ji})} = TGR_i^j \times TE_i^j \times e^{V_{ji}} \qquad 3.4$$

As the random noise component is obtained from the stochastic frontier estimation, the decomposition in can be expressed by Equation 3.

$$MTE_i^j = \frac{Y_{ji}}{f^M(X_{ji})e^{V_{ji}}} = TGR_i^j \times TE_i^j \qquad 3.5$$

Since the SFA estimates of the Region-specific frontiers are $f^j\big(X_{ji}\big)$for all j=1, 2,.J Regions, the estimation error of the Region-specific frontier is shown in Equation 3.6.

$$\text{In}\hat{f}^j(X_{ji} - \text{In}f^j\big(X_{ji}\big) = e_{ji} - \hat{e}_{\text{ji}} \qquad 3.6$$

Defining the estimated error as$V_{ji}^M = e_{ji} - \hat{e}_{ji}$, the relation to the metafrontier can be written as (Equation 3.7).

$$\text{In}\hat{f}^j\big(X_{ji}\big) = \text{In}f^M\big(X_{ji}\big) - U_{ji}^M + V_{ji}^M, \forall\, i, j = 1, 2, \ldots, J \qquad 3.7$$

Thus, the metafrontier estimation approach proposed by Huang et al. (2014) can be summarised in the estimation of the two following regressions (Equation 3.8-3.9)

$$\text{In}Y_{ji} = \text{In}f^{j}(X_{ji}) + V_{ji} - U_{ji}, i = 1, 2, \dots, N_j \qquad 3.8$$

$$\text{In}\hat{f}^{j}(X_{ji}) = \text{In}f^{M}(X_{ji}) + V_{ji}^{M} - U_{ji}^{M} \qquad 3.9$$

where $\text{In}\hat{f}^{j}(X_{ji})$is the estimates of the Region-specific frontier. This should be estimated j times, one for each Region. The estimates from all jRegions are then pooled to estimate the metafrontier (Eq. (10)). To ensure that the metafrontier is larger than or equal to the Region-specific frontiers$\left(\text{In}f^{j}(X_{ji}) \leq \text{In}f^{M}(X_{ji})\right)$, the estimated TGR must always be less than or equal to unity (Equation 3.10).

$$T\hat{G}R_i^j = \hat{E}(e^{-U_{ji}^{M}} | \hat{e}_{ji}^{M}) \leq 1 \qquad 3.10$$

where $\hat{e}_{ji}^{M} = \text{In}\hat{f}^{j}(X_{ji}). \text{In}\hat{f}^{M}(X_{ji})$ are the estimated composite residuals of Equation3.10. The corresponding estimated Meta technical efficiency (MTE) is equal to the product of the estimated TGR and the estimated individual firm's technical efficiency (Equation 3.11).

$$M\hat{T}E_i^j = T\hat{G}R_i^j X\hat{T}E_i^j \qquad 3.11$$

Identifying the magnitude of persistent inefficiency is essential, especially in short panels, because it reflects the effects of inputs like management, as well as other unobserved inputs that vary across firms but not over time. Previous models on SFA did not consider persistent technical inefficiency (Kumbhakar, Wang, & Horncastle, 2015). The error term is decomposed into technical inefficiency and statistical noise. The technical inefficiency component is further decomposed into two – a persistent component and a residual component. Such a decomposition is desirable from a policy point of view because the persistent component is unlikely to change over time without any change in government policy or management, whereas the residual component changes both across firms and over time (Kumbhakar et al., 2015). Unfortunately, if the persistent inefficiency component is significant for a firm, then it is expected to operate with a relatively high level of inefficiency over time unless some changes in policy and/or management take place. Thus, a high value is of more concern from a long-term point of view because of its persistent nature (Kumbhakar et al., 2015). The models are specified in Equations 3.12 to 3.14.

$$y_{it} = \beta_o + X_{it}^t\beta + \epsilon_{it} \qquad 3.12$$

$$\epsilon_{it} = V_{it} - U_{it}, \qquad 3.13$$

$$U_{it} = U_i + \tau_{it} \qquad 3.14$$

The error term ϵ_{it} is decomposed to $V_{it} - U_{it}$, as where U_{it},is technical inefficiency and V_{it} is statistical noise. The technical inefficiency part is further decomposed to $U_i + \tau_{it}$, where U_i is the persistent component (for example, time-invariant management effect) and τ_{it} is the residual (time-varying) component of technical inefficiency, both of which are non-negative. It is worth mentioning that the former is only firm-specific, while the latter is both firm- and time-specific.

3.4 Data sources, analysis and Descriptive Statistics

The data source was derived from each tea-processing firm under the management of the Kenya Tea Development Agency (KTDA) for the period 2012–2016. The factories were broadly grouped into two Regional clusters, East of Rift Valley and West of Rift Valley. East of Rift Valley spans seven counties, namely Kiambu, Murang'a, Nyeri, Kirinyaga, Embu, Meru, and Tharaka Nithi Counties. West of Rift Valley covers eight counties, namely Bomet, Kericho, Nandi, Uasin Gishu, Kisii Nyamira, Kakamega and Trans Nzoia Counties. The output, input and inefficiency variables are summarized in Table 3.1. The study used one output variable and four input variables. Output (y) represents the total output costs incurred by the firms. The output is valued in Kenya shillings (Ksh). The Cobb Douglas function in the empirical model was specified with the following four input variables: Natural log of the total cost of labour in tea production (Kshs); Natural log of the total cost of capital (Kshs); Natural log of the total cost of energy (Kshs); and Natural log of leaf collection cost (Kshs).

Table 3.1: Descriptive statistics for small-scale tea processors in Kenya for the period 2012–2016

Variables	East of Rift Valley (N=175)		West of Rift Valley (N=95)		Mean Difference
	Mean	Std Dev	Mean	Std Dev	
Output cost	19.533	0.271	19.971	0.666	0.438***
Leaf costs	20.583	0.313	20.731	0.733	0.148**
Energy	18.100	0.285	18.512	0.718	0.411***
Capital	17.038	0.434	17.389	0.498	0.35***
Labour	17.803	0.269	18.211	0.639	0.407***
Size	19.919	0.723	19.977	0.997	0.057
Factory age	35.142	10.469	35.842	11.028	0.69
Finance cost	17.099	0.803	17.851	1.005	0.751***
No. of employees	116.74	23.753	178.242	80.122	61***
Distance to market	14.046	0.559	14.389	0.486	0.343***
Leverage	0.767	0.483	0.8223	0.516	0.073
Mgt compensation	16.124	0.472	16.299	0.590	0.175***
Total Ha(Land)	69674	0	158505	0	100629.4

Source: Author's own calculation

Firms in the West of Rift Valley Region have, on average, the highest level of cultivated land, distance from firm to market, management compensation, finance cost, energy cost, labour expense and capital use (Table 3.1). However, it is also worth noting that there is a significant difference in the above-mentioned variables within all the Regions. Presence of technical inefficiencies and regions production frontier were tested (Equations 3.15 to 3.16), using the generalized likelihood ratio statistic (Table 3.2).

1. $H_o: \gamma = 0$ 3.15

2. $H_o: f\left(X_{ij}, \beta_j^{Pool}\right) = f\left(X_{ij}, \beta_j^{E}\right) = f(X_{ij}, \beta_j^{W})$ 3.16

Table 3.2: Results of tests of hypotheses for small-scale tea processors in Kenya

Null hypothesis	Location	Chi-square	Critical Value	Decision
There is no technical inefficiency				
	*East R/V	41.36	5.412	Reject H_0
	**West R/V	41.33	5.412	Reject H_0
There is no difference between the regional frontiers				
Pooled estimation		387	142	Reject H_0

Source: Author's own calculation
*East R/V is East of the rift valley regions, **West R/V is West of the rift valley regions

The first hypothesis tested for the presence of technical inefficiencies in small-scale tea processors. The hypothesis assumed that technical inefficiency effects are not present in small-scale tea processors. The Kodde and Palm table showed the critical value. Its LR statistic of 41.32 exceeds the 1% critical value of 5.412 (at one degree of freedom). Hence, the outright rejection of the null hypothesis of no technical inefficiency is indicated. The use of stochastic frontier analysis is also justified, as opposed to Ordinary Least Square (OLS) analysis. The test confirms that technical inefficiency is present in the tea processing firms. Traditional stochastic frontier models assume that firms share similar production possibilities and differ only in their levels of inefficiency (Njuki & Bravo-Ureta, 2018). To examine whether the two Regions, East and West of Rift Valley, share similar production possibilities, a likelihood-ratio (LR) test was calculated. The hypothesis implies that the production technology assumed in the two regions and the pooled sample are similar and that the stochastic frontiers are the same for all three groups.

The null hypothesis of the test is that the stochastic production frontier models for the two Regions are the same for all firms. To test the hypothesis, the stochastic frontiers for each Region were first estimated. After that, the stochastic frontier including firms from all the Regions was estimated. Following Battese et al. (2004), the likelihood ratio statistic is defined by $\lambda = -2 [\ln L(H0) - \ln L(H1)]$, where ln L (H0) is the value of the log-likelihood function for the stochastic frontier, estimated by pooling the data for all Regions. Ln L (H1) is the sum of the values of the log likelihood functions of the three Regional production frontiers. The statistical value of the likelihood-ratio test was 387, which is significant as it is higher than the critical value of the Chi-squared distribution with degrees of freedom given by the difference between the number of parameters estimated under H1 and H0, that is, 272–130=142. This hypothesis was rejected, implying that the production environments and technologies are heterogeneous, justifying the specification of different production frontiers for the two Regions. This, therefore, called for meta-frontier analysis. This indicates that the environment variables had a significant effect on the parameters for each Region across the period of analysis.

3.5 Regression results and discussion

In all three frontiers, the estimated mean output elasticities of all the inputs have positive signs, with all of them being significant, thus indicating a positive and significant relationship between inputs and the output (Table 3.3).

Surprisingly, for the environmental variables, size, age, distance to market, and leverage were not significant in any of the Regions. The literature on the effect of size on the efficiency of a firm is mixed. Large firms tend to be more efficient than small firms are because they have market power and enjoy the benefits of scale economies (Lundvall & Battese, 2000). It is also possible that, for some firms, an increase in size may lead to temporary coordination problems within the firm, resulting in lower efficiency (Faruq & Yi, 2010). In particular, finance cost had a negative effect on the efficiency of small-scale tea processors in all Regions. High finance costs discourage technical innovation and increase monetary constraints on production. Facilitating timely monetary liquidity, as needed for production, reduces inefficiency (Sardaro, Pieragostini, Rubino, & Petazzi, 2017).

In the Region West of Rift Valley, management compensation was found to have an adverse effect on efficiency. In the Region East of Rift Valley, management compensation was found to have a positive effect on efficiency. Furthermore, the number of employees was found to have a positive effect on efficiency.

Table 3.3: MLE Regional stochastic frontiers estimates for East and West of Rift Valley, small-scale tea processors in Kenya, 2012–2016

	East of Rift Valley		West of Rift Valley		Pooled	
	Coefficient	**Std.**	**Coefficient**	**Std.**	**Coefficient**	**Std.**
Production frontier						
Labour	0.414***	0.020	0.430***	0.027	0.431***	0.015755
Energy	0.408***	0.021	0.438***	0.031	0.423***	0.014913
Capital	0.103***	0.015	0.096***	0.018	0.097***	0.009997
Material	0.145***	0.016	0.111***	0.023	0.122***	0.010857
Environmental Variables						
Experience	0.009	0.018	0.021	0.020	0.004	0.011
Size	-0.3501	0.474346	0.077814	0.202143	0.011	0.190
No. Employees	-0.05754***	0.013587	-0.03552***	0.00728	-0.036**	0.006
Finance cost	3.877802***	0.78439	1.769759***	0.376991	2.342***	0.327
Management benefits	-1.46351***	0.451514	0.292658	0.36099	-0.674***	0.206
Distance to market	-0.13345	0.330403	-0.15056	0.552021	-0.323	0.273
Leverage	-0.45478	0.598387	-0.27305	0.325947	-0.279	0.262
Constant	-34.6796***	12.59143	-35.5831***	10.11708	-28.610***	6.281
V sigma	-6.80375	0.175195	-7.05854	0.413062	-6.873	0.159
Log(likelihood)	308.58		146		443	

Source: Author's own calculation

Note: The asterisks indicate levels of significance. *** Significant at 1%. ** Significant at 5%. * Significant at 10%

The mean TE estimates vary between the Regional frontiers (Table 3.4). Specifically, the mean TE was 82% for the Region East of Rift Valley and 79% for the Region West of Rift Valley. The overall TE was 76% for the pooled sample. With technical efficiency scores being estimated as input-oriented measures, the results imply that the input costs of the tea processors in the East and West of Rift Valley Regions could be reduced by 18% and 21%, respectively, without decreasing the output. This is plausible only if the producers can use the resources available to them more efficiently. Furthermore, 24% technical potentiality exists for the pooled sample. Persistent inefficiency for the East and West Regions of the Rift Valley was 15% and 16%, respectively. As noted by Kumbhakar et al., (2015), persistent inefficiency is caused by factors beyond the control of firms. These factors are summed up into regulatory and management challenges. This, therefore, calls for immediate policy interventions at both regional and national level.

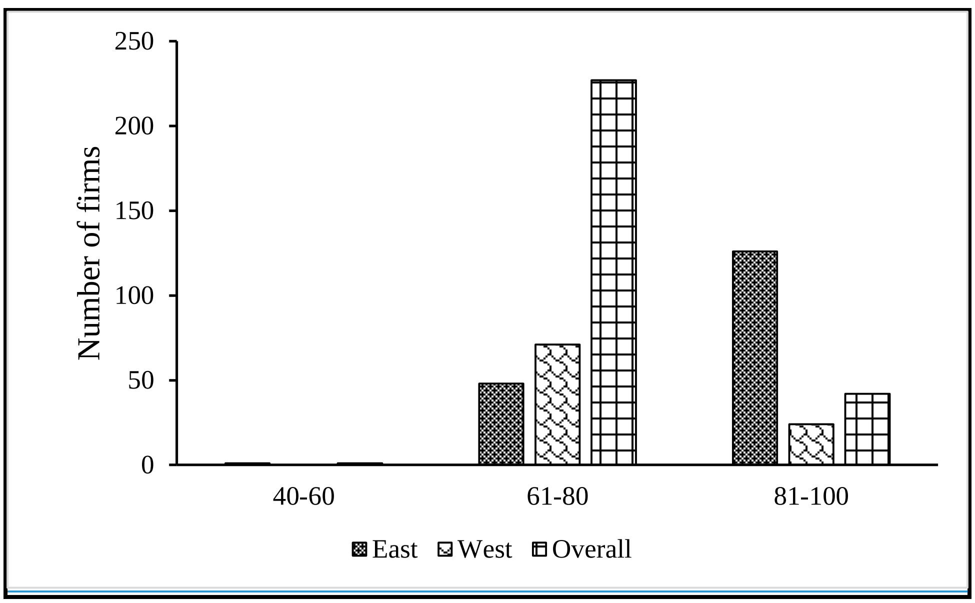
Table 3.4: Technical efficiency derived from the Region-specific frontiers for the small-scale tea processors in Kenya, 2012–2016

	East of Rift Valley			West of Rift Valley			Pooled		
	Residual	**Persistent**	**Overall**	**Residual**	**Persistent**	**Overall**	**Residual**	**Persistent**	**Overall**
Mean	0.963	0.850	0.821	0.948	0.844	0.786	0.952	0.804	0.764
Std Dev	0.047	0.040	0.042	0.048	0.055	0.035	0.048	0.050	0.041
Min	0.607	0.773	0.491	0.619	0.747	0.689	0.630	0.726	0.477
Max	0.991	1	0.993	0.999	1	0.862	0.999	1	0.906

Source: Author's own calculation

For the Region East of Rift Valley, most of the tea firms (65%) had their technical efficiencies in the 81–100% range. However, 25% had their technical efficiencies in the 61–80% range, indicating that at least 20% of their potential output is lost to inefficiency. For the Region West of Rift Valley, 75% of the tea firms had their technical efficiencies in the range of 61–80% (Figure 3.1). This implies that at least 20% of the potential output of firms in this Region is lost to factors that the tea firms cannot control.

Furthermore, the distribution of technical efficiencies for the pooled sample revealed that 84% of the tea firms had their technical efficiencies in the 61–80% range, while only 16% obtained the highest technical efficiencies in the range of 80–100%. The implication is that small-scale tea firms have at least 20% of their potential outputs lost to inefficiency.



Source: Author's own calculation

Figure 3.1: Frequency distribution of technical efficiency of the small-scale tea processors in Kenya, 2012–2016

The production input elasticities for the various agro-ecological Regions are significant (Table 3.5). For instance, the results showed that a 1% rise in the levels of labour, energy, capital and material costs in the East Region has the effect of increasing output costs by 43%, 47%, 6.4%, and 10.4%, respectively.

Table 3.5: Input elasticities of the small-scale tea processors in Kenya, 2012–2016

Variable	Elasticity		
	East of Rift Valley	West of Rift Valley	Pooled sample
Labour	0.43306	0.409631	0.446272
Energy	0.471283	0.44617	0.444967
Capital	0.064514	0.142121	0.103164
Leaf cost	0.10399	0.082076	0.083195

Source: Author's own calculation

All the input coefficients are significant and have the expected positive signs (Table 3.6). This signifies the role that the input variable plays in affecting TGR in tea production. Regarding environmental variables, the higher the finance cost is, the further apart the production frontier is from the metafrontier. This is an indication of the importance of financial access for reducing the technology gap faced by some tea firms and Regions.

Table 3.6: Estimated parameters for the metafrontier of the small-scale tea processors in Kenya, 2012–2016

Variables	Coefficient	Standard errors
Labour	0.4205297***	0.0096135
Energy	0.5028959***	0.0096938
Capital	0.0622338***	0.0046796
Leaf cost	0.0495603***	0.0066809
_cons	0.8930605***	0.0812615
Second step environmental variables		
Finance cost	0.4354155**	0.1725658
Transport cost	0.3106676	0.1959522
Management agent fees	0.1897783	0.2798058
Constant	-12.77646***	5.152583
Sigma2	-5.085686***	0.0244114
Gamma	1.987961***	0.1064378
log likelihood	587.61	

Source: Author's own calculation

*** Significant at 1%. ** Significant at 5%. * Significant at 10%

The results show that the average TE, MTE, and TGR are 76%, 74% and 97%, respectively (Table 3.7). TGR is the distance from the respective Region-specific frontiers to the metafrontier. MTE measures the distance from the i^{th} factory to the metafrontier. TE represents the Region-specific production frontiers. The significance of measuring MTE is that it allows us to make efficiency comparisons of firm units across ecological Regions (O'Donnell et al., 2008). The TE measures indicate that firm units could achieve technical efficiency if they were to operate at the most optimal levels within the Region. The results of MTE and TGR indicate that there is scope for improving the performance of the small-scale tea industry.

As indicated above, the high cost of finance reduces the TE. This could be addressed by expanding towards owners' equity and exploring possibilities for gaining access to cheaper sources of funds, as well as negotiating for better terms of borrowing with the financiers. In general, East of Rift Valley is more technically efficient in operation with respect to the overall small-scale tea industry (80.7%), followed by West of Rift Valley (77.3%). This implies that the overall efficiency of firms in East of Rift Valley is superior to that in West of Rift Valley. Limited Key Informants interviews further indicated that firm/regional differences could be attributed to the quality of raw material, applicable governance mechanism, technical capabilities of staff, soil quality, cultural issues, cash flow and capacity utilisation of firms. Poor quality leaf leads to greater energy consumption, resulting in high energy costs that subsequently increase inefficiency. Poor governance mechanisms such as bureaucracy lead to inefficiency. Factories that suffer from cash shortages do not operate optimally, which increases inefficiency. In general, the technical efficiency values, computed relative to the meta-frontier function across the Regions, are substantially lower than their mean TEs.

Table 3.7: Summary statistics of Regional efficiency measures for the small-scale tea processors, 2012–2016

	Obs	Mean	SD	Min	Max
East of Rift Valley					
TGR	175	0.983996	0.016395	0.893018	0.998365
TE	175	0.820732	0.041666	0.491103	0.992768
MTE	175	0.807559	0.042677	0.490201	0.989024
West of Rift Valley					
TGR	95	0.984799	0.020878	0.892041	0.998414
TE	95	0.785596	0.035248	0.688844	0.862169
MTE	95	0.773896	0.042704	0.658831	0.859266
Overall					
TGR	270	0.970356	0.022458	0.871254	0.996757
TE	270	0.763604	0.040897	0.477134	0.906497
MTE	270	0.740676	0.038062	0.468875	0.893848

Source: Author's own calculation
Obs is observation.

To determine the relationship between technical efficiency and profitability, the following hypothesis was proposed: TE has a positive relationship on profitability. A Pearson correlation coefficient was used to test this relationship. The results revealed no significant relationship between TE and profitability (Table 3.8). The null hypothesis was rejected, and hence efficiency does not result in profitability. This implies that performance among the firms is derived from their different capabilities, and not merely from their use of resources (Keramidou, Mimis, & Fotinopoulou, 2013).

Table 3.8: The Pearson Correlation Coefficient between Profitability and Technical Efficiency for small-scale tea processors, 2012–2016

	Efficiency	Profitability
Efficiency	1	
Profitability	-0.2015	1

Source: Author's own calculation

Similar evidence was documented by Keramidou, Mimis, and Fotinopoulou (2013), who reported no correlation between profitability and efficiency. This implies that firms that have the capability of producing their products with the best practices are not always capable of generating the maximum profits. Similarly, (Palečková, 2015), using Granger causality and correlation coefficient, did not confirm any relationship between profitability and efficiency. This contrasts with the findings of Kosmidou et al. (2008) who found a negative correlation of efficiency on profitability.

3.6 Summary, Conclusion and Policy Implications

3.6.1 Introduction

This section provides a summary of the technical efficiency analysis and the factors that influence its variation among the small-scale tea processors in Kenya. It also provides policy implications arising from the findings and identifies areas for further research.

3.6.2 Summary

Growth in the manufacturing sector has declined, or at best stagnated, since 2012. This is mostly attributable to the poor performance of the agro-processing industry. Increased production costs do little to alleviate poverty and improve GDP growth. Furthermore, the productivity of the small-scale tea processors has largely stagnated, even where improved technologies have been adopted. Consequently, this study sought to determine the technical efficiency of the small-scale tea processors using an SFA approach for panel data. The MTE estimates for the Regional frontiers were also determined.

On average, the technical efficiency level derived from the Regional frontier was 76%, and that from the metafrontier was 74%, while the technological gap ratio was 97%. East of the Rift Valley Region is, on average, more technically efficient than West of the Rift Valley Region is. The results showed that the tea factories could use resources more efficiently by reducing 24% of the current application level, without compromising the output. This finding also highlights the need to explore the possibilities of gaining access to cheaper sources of finance to reduce the high cost of finance.

3.6.3 Conclusion

The study showed that the small-scale tea processors in Kenya were technically inefficient for the period 2012–2016. The inefficiencies were observed to have emanated from the small-scale tea processors exhibiting decreasing returns to scale. This results in higher average costs per unit. Optimal scales would, therefore, be achieved if these processors could employ fewer production inputs.

The results showed that the tea factories could use resources more efficiently by reducing 24% of the current application level, without compromising the output. This is significant, not only for GDP growth but also for poverty alleviation. Thus, improving firm efficiency should be accorded priority in pursuit of securing the sustainability of the industry. Moreover, the findings revealed the presence of persistent technical inefficiency in all Regions. The implication is that a greater percentage of total inefficiency among these processors is caused by factors beyond their control. These factors are management and regulatory challenges. Regarding management, aspects entailing appropriate governance of these processors should be explored. On the regulation aspect, the tea processors are subjected to around 42 types of taxes, including high agency fees. This results in the processors encountering working capital problems, leading to reductions in efficiency. These factors require immediate and radical policy reforms to save the ailing industry. These factors arise due to policy and management challenges.

In summary, this study established that firm unit in the two agro-ecological Regions of Kenya’s small-scale tea industry do not share the same production frontier. This can be attributed to the quality of raw material, governance mechanism, technical capabilities of staff, soil quality, cultural issues, cash flow and capacity utilisation of the firms.

The results revealed that technical efficiency did not correlate with firm profitability. Using Pearson correlation coefficients, the findings of this study show that, in the case of the small-scale tea processors in Kenya, profitability ratios do not correspond with firm efficiency. Profitability ratios are not a good proxy for efficiency, and should not be used as the only firm criterion of performance.

3.6.4 Policy Implications

The management of the small-scale tea processors in Kenya should expand towards owners' equity and explore the possibilities of accessing cheaper sources of funds, as well as negotiating for better terms of borrowing with the financiers to address their high finance costs. A possible approach could be the factories working jointly to negotiate for cheaper finances with the lending institutions. Regional leaders in the West of the Rift Valley should be sensitised on the uptake of improved technologies to facilitate a catch up with their counterparts on the East of Rift Valley.

CHAPTER FOUR

INTEGRATED EMERGY AND ECONOMIC EVALUATION OF THE TEA PROCESSORS IN KENYA.

4.1 Introduction

This chapter responds to the third objective of the thesis. It synthesises the literature on integrated Emergy and economic evaluation and discusses the methodology used before computing Emergy indices. Further, the chapter discusses the results and provides policy implications.

4.2 Literature review

High energy costs, persistent rises in production costs, and increasing demands from stakeholders for environmental sustainability have all cast doubt on the sustainability of the tea industry in Kenya. Past research has focused on establishing the brand, marketing methods, tea culture, tea quality, soil fertility, GHG emissions, tea cultivation and energy conservation (Azapagic et al., 2015; Cheserek, Elbehri, & Bore, 2015; Langat et al., 2015; Azapagic, 2013; Ng'ang'a, 2011). Nevertheless, the relative sustainability of the small-scale tea processors remains unclear. This stems from the limitations of these disciplines and the analysis methods used for the quantitative studies. Research that has explored the comprehensive ecological and economic characteristics of tea production remains scanty. Therefore, a thorough assessment of the sustainability of the tea industry production systems requires a consideration of the economy, ecology and environment in equivalent terms.

Without such research, it is difficult to meet the current demand to develop sustainable production alternatives that could transform the tea industry; therefore, such research is needed. A widely applicable quantitative evaluation framework needs to be used to solve this economic, energy and environmental trilemma, as well as to support comprehensive management policies that would protect lands and reduce atmospheric pollution (Lu, Lin, Campbell, Sagisaka, & Ren, 2012). Neoclassical economic assessment methods have been applied to evaluate ecosystem services and the environmental impacts of agricultural and production systems. However, most economic studies have failed to consider ecology, and most ecological studies have ignored the economy. Moreover, contingency valuation approaches, although integrative, are based on the subjective opinion of people, and hence cannot objectively evaluate the contributions from both the economy and environment on an equal basis (Cheng et al., 2017). The Emergy evaluation approach has addressed this gap. Through Emergy evaluation, the stability and resilience of the system are understood, and growth actualised (Peter & Swilling, 2014).

Odum and co-workers developed Energy Systems Theory (EST) and Emergy evaluation methods during the 1980s (Odum, 1996). Emergy is defined as the available energy of one kind that is used up in the transformations that directly and indirectly make up a product or service (Odum, 1996). Emergy was offered as a common denominator for quantifying both economic and environmental contributions to a system in equivalent units, solar emjoules (sej). All kinds of energy, material and information (money) could be converted to Emergy by multiplying by the appropriate Unit Emergy Values (UEVs), which are defined as the Emergy required to produce a unit of goods (sej/g), services (sej/J), information (sej/bit), or the buying power of money (sej/$). Emergy evaluation can assess different qualities and types of energies, materials, and information according to a common unit, the solar equivalent joule (sej). Emergy evaluation has been used to link the environment and economy because it can objectively account for the contributions to a system/process from both the environment and the economy on an equal basis, that is, in terms of Emergy.

Emergy evaluation thus determines the value of any resource based on what is necessary for it to be produced (Pulselli, Patrizi, & Focardi, 2011). As opposed to other methods that rely solely on inputs of monetary flows, it is a bio-physical approach that estimates the contribution of nature in economic activities (Tilley &Brown, 2006). In its perspective, a sustainable system relies more on local and renewable resources.

Despite growing recognition that natural resources sustain the economy, they are largely neglected in economic decision-making. Natural resource overexploitation and ecosystem degradation often depend on the fact that monetary values are the only parameters driving human actions. The neoclassical economic approach has restrictive assumptions of a profit maximisation paradigm and fiscal targets. However, this is increasingly becoming incongruent in the face of the almost perfectly inelastic global supply of the natural inputs. Emergy evaluation and corresponding indices and ratios are used to assess the long-term sustainability and efficiency of systems. Based on thermodynamics, it quantifies the nonmonetized and monetised resources, services and commodities necessary for production in the common units of the solar energy it took to make them (Saladini et al., 2016).

Agriculture is a direct beneficiary of natural resources. Hence the continuous and efficient functioning of the natural resources system is indispensable. Achieving a farmer's financial wellbeing and motivation to continue farming (a short-term objective), and fulfilling ecosystem requirements to retain its sustainable and efficient functioning (a long-term objective) are equally essential to accomplish (Jaklič, Juvančič, & Debeljak, 2013). Contributions to agricultural production include natural and economic inputs. However, the difficulty in assigning a value to natural contributions leads to a gap in the assessment of the value of natural resources and that of economic resources (Zeng et al., 2013). The relative sustainability of the small-scale tea processors in Kenya remains unclear. The quantitative evaluation and comparison of these systems, which simultaneously considers both ecological and economic factors, constitutes an essential first step in documenting their relative sustainability. It is from the preceding view that the present study sought to determine an integrated Emergy and economic evaluation for the tea industry in Kenya. Policy insights are revealed, with consideration of both environmental and ecological perspectives.

The decoupling theory proposes that sustainability should be positioned around stratagems and actions to decouple economic and population growth from resource exploitation and environmental impacts (Peter & Swilling, 2014). According to the International Resource Panel, 'decoupling' applies the concept of sustainable development in two dimensions; resource and impact decoupling. Resource decoupling means reducing the rate of use of resources per unit of economic activity. Impact decoupling means maintaining economic output while lessening the adverse environmental impact of any economic activities that are undertaken (UNEP, 2002).

The theory relies on explicitly empirical foundations to implement and actualise economic and ecological efficiencies. The theory involves making use of methodological tools such as life-cycle analysis, Emergy evaluation, and material flow analysis to understand the stability and resilience of the system and how growth may be actualised (Peter & Swilling, 2014). This theory guides the current study as the basis for Emergy analysis.

4.2.1 Empirical literature

Many analytical tools are available for assessing environmental impacts and the sustainability of ecological, economic systems, such as Life Cycle Assessment (LCA), Material Flow Analysis, exergy analysis, and Emergy evaluation (Lu, Yuan, Campbell, Qin, & Cui, 2014). Emergy evaluation is appealing and has been applied widely in the evaluation of production systems (Zeng, Lu, Campbell, & Ren, 2013; Ting & Ping-an, 2016; Feng et al., 2015; Singh et al., 2016; Lu et al., 2012). This is attributable to its ability to compare different qualities and types of energy, materials, and information through using a common unit, the solar equivalent joule. Emergy, therefore, can account for the contributions of the environment to the economy and quantify economic activities on an equal basis. In Kenya, Emergy analysis has been conducted on soil erosion (Cohen, Brown, & Shepherd, 2006) and biofuel and biomaterial production (Saladini et al., 2016). An integrated Emergy and economic evaluation of the tea production chain in Anxi has been conducted in China (Zeng et al., 2013). The goal of this present study was to provide scientific evidence for the development of more sustainable modes and strategies for the sustainable development of the tea production system in Kenya. To achieve this goal, this study employed an integrated evaluation method that combines Emergy evaluation and economic analysis.

4.3 Methodology

An Emergy assessment starts with the delimitation of the system under analysis (Figure 4.1). The system′s diagram includes the most important flows of materials, energy, and money. Once the system under analysis is delimited, a table is drawn up with the raw data collected and processed to calculate the Emergy flows, which are computed by multiplying the first ones by the appropriate Emergy unit values. All inputs were converted into Emergy units, based on the12.0 E + 24 sej y-1planetary baseline (Brown, Campbell, De Vilbiss, & Ulgiati, 2016), with all cited Unit Emergy Values (UEVs) converted to this baseline, if they were not originally published relative to it. Values are reported in scientific format (for example, 2.5E03 is the same as 2500). Emergy calculation is performed based on the transformities as previously described (Odum et al., 2000; Cohen, Brown, & Shepherd, 2006; Saladini et al., 2016).

Ninety percent of the Emergy input required for labour was assumed to be FN, which left 10% to be classified as FR (Zeng et al., 2013b). The Emergy/money ratio of Kenya in 2012 was extrapolated to be 3.45E+03 sej/$, based on the Emergy/money ratio in 2001 (1.17E+13sej/$) published by Cohen, Brown,& Shepherd, (2006). This was done by applying the relative GDP deflator for Kenya from 2001 to 2012 (2.195) and after that converting to the 12.0 E + 24 sej y-1planetary baseline from the15.83 E + 24 sej y-1planetary baseline. The Emergy of purchased resources was deduced from their cost, multiplied by the Emergy/money ratio, considering the near linear correlation between the Emergy/money ratio and real GDP that was found for the U.S. by Campbell and Lu (2009). All monetary values were converted to US$ in 2012 from Kenya shillings, based on the annual exchange rates in that year. To avoid the problem of double counting, only the Emergy of tea leaves was considered as the only local renewable resource for the processing sub-system.

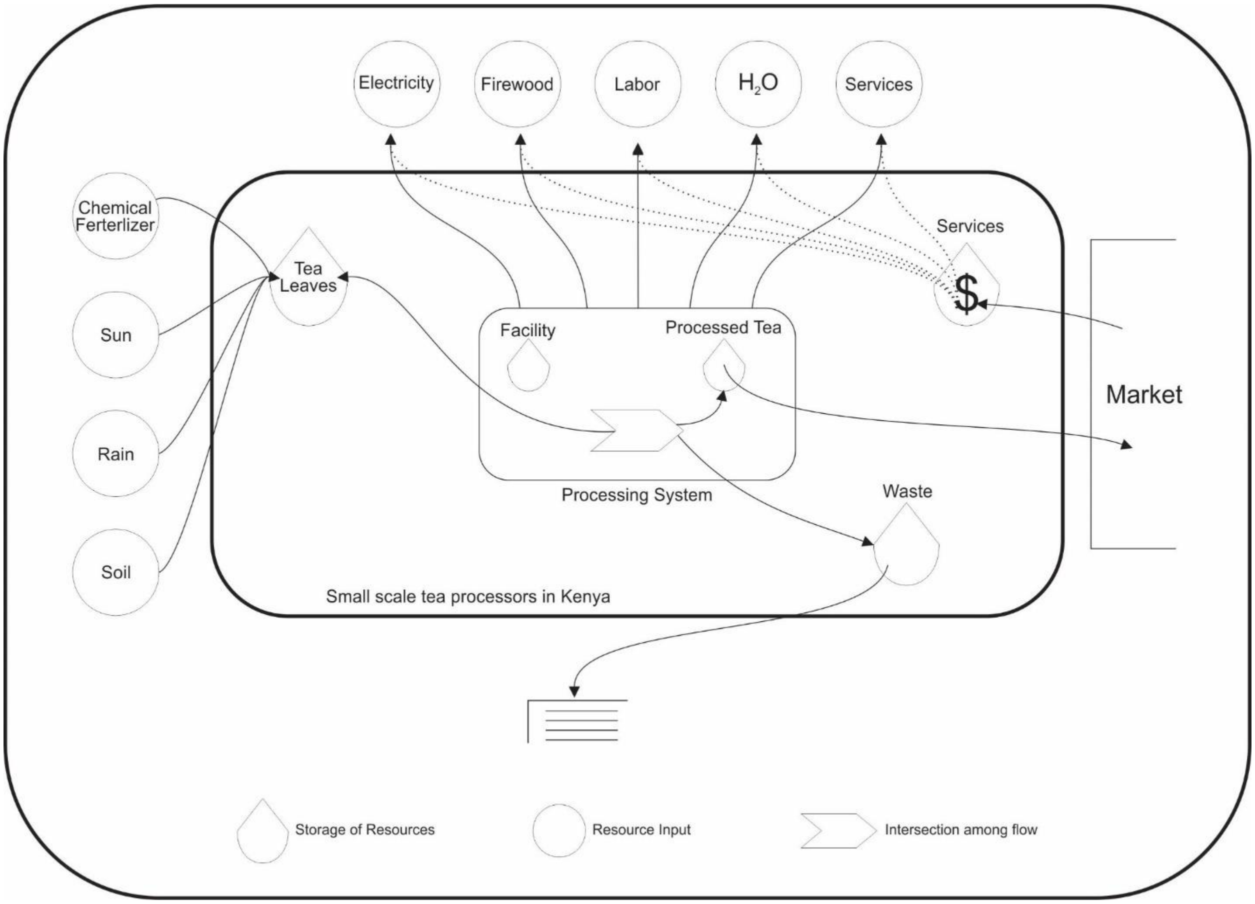
In the economic analysis, the economic output/input ratio and the economic benefits per unit (EBU) were calculated. The economic output/input ratio is a measure of the economic cost efficiency, while EBU, defined as the economic output minus input, is an indicator of the net economic benefits of the system.

Widely used Emergy indices were calculated (Table 4.1), being Empower Density (EPD), Emergy Self-Sufficiency Ratio (ESR), Environmental Loading Ratio (ELR), Emergy Yield Ratio (EYR), Emergy Exchange Ratio (EER), Emergy Sustainability Index (ESI), Emergy Index for Sustainable Development (EISD), and Unit Emergy Value (UEV).

The Emergy Yield Ratio (EYR) is the total Emergy used, divided by total Emergy invested. The EYR is a measure of how much an investment pushes a process to exploit local resources and enhances its contribution to the economy. In other words, EYR reflects the ability of a certain system to provide energy to the economy by magnifying its investment. The higher the EYR value, the lower the system′s dependence on economic investment. The Emergy Yield Ratio (EYR) is widely used to reflect the ability of purchased resources to capture local free environmental resources (Odum, 1996). The Emergy Sustainability Index (ESI) is the ratio of the EYR to the ELR. It measures the contribution of a resource or process to the economy per unit of environmental loading. The Emergy Exchange Ratio (EER) measures the price of products derived from the system and whether each gained extra benefit over costs from selling the products on the market.

To quantify the Emergy of a system or a product, all the inputs must be quantified and expressed in a common unit, called a solar Emergy joule (sej). To do this, suitable conversion factors, called UEVs (expressed in sej/J, sej/g or other units), are used. UEVs represent the Emergy per unit product, which are used to convert different flows of energy and matter into equivalent solar energy. Thus, all inputs (from nature and the economy) used in a production system are put together on a common basis: solar energy. Therefore, it is possible to interpret quantitative results from the calculated Emergy indices that relate the Emergy flows of the system being evaluated with those of the environment and larger economy within which it is embedded (Garcia, Kimpara, Valenti, & Ambrosio, 2014).

The Emergy diagram shows the biophysical value of all the input flows necessary to a process, namely: renewable (R) and non-renewable (N) resources and materials (M) and services (S) from the economy (F) (Figure 4.1). The total Emergy (U) used up to produce a product, a service or an asset is useful to place the own system and its outputs in an energy hierarchy (Buller, Silva, Ortega, & Bergier, 2016). Local renewable resources such as sun, rain, and wind enter the system from the left (Figure 4.1). Non-renewable resources that are created within the system boundaries represent local resources, such as soil organic matter (SOM). Imports to the system are shown on the top and right of Figure4.1. Imports include the Emergy of fuels and minerals (F), goods (G), and the total imported service Emergy (P2I), which is the product of the dollars of imports (I) and the average Emergy to money ratio (P2) of the world. The Emergy of import services accounts for the money spent to purchase and import goods to the system. The flow of money is shown with a dashed-line and ($) in the system diagram. The exports to the markets on the lower right have pathways for fuels, goods, and services like those discussed for imports. Emergy is not only a measure of what went into a product, but it is a measure of the useful contributions that can be expected from that product as a system self-organises for maximum production (Tiezzi, Bastianoni, & Marchettini, 1996).



Source: Adapted from Odum (1996)

Figure 4.1: Emergy diagram for the small-scale tea processors in Kenya

4.4 Study Area and Data

The study area comprises fourteen counties in Kenya, namely Bomet, Embu, Kakamega, Kericho, Kiambu, Kirinyaga, Kisii, Meru, Murang'a, Nandi, Tharaka-Nithi, Nyamira, Nyeri, Trans-Nzoia and Vihiga (Figure 4.2). The total area under tea bushes for the small-scale industry is 123,839 hectares. The optimum tea-producing zone is within an altitude between 1500 and 2700 metres above sea level. The tea farming is mainly rain-fed, and most of the tea-growing areas go through a regular 3-month drought between December and March. Tea production is influenced by extreme weather events, particularly drought, frost, and hailstorms. The crop requires a well-distributed annual rainfall above 1200mm, a temperature range of 18–30 °C, and well-drained soils. A daytime maximum temperature more than 30 °C and night minimum temperature below about 14 °C leads to a reduction in the rate of growth. Radiation plays a vital role during photosynthesis, which is directly related to tea leaf assimilation and dry matter production (Cheserek et al., 2015).

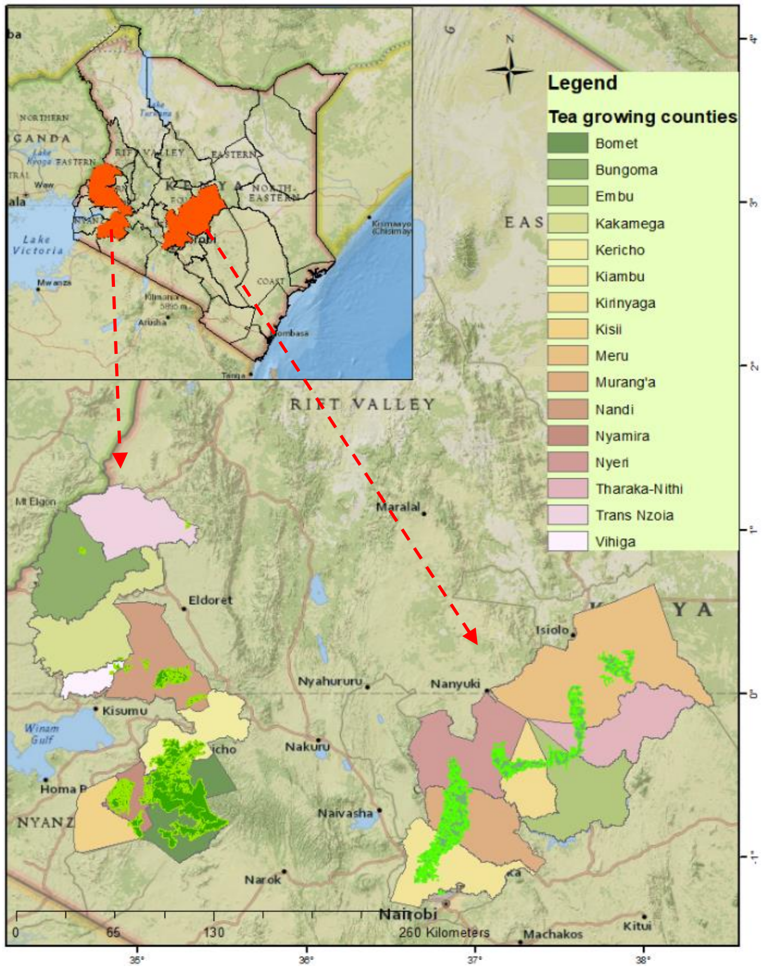


Figure 4.2: A map showing the tea growing counties (small scale tea) in Kenya (*Source: Author 2019).*

ArcGIS took the meteorological data, comprising solar radiation, rainfall and wind speed, while the economic data were collected from the 54 small-scale tea factories in Kenya. All annual Emergy inputs to and outputs from the processing sub-system were evaluated based on the annual flows per ha. All Emergy inputs were aggregated into local renewable resources (R), local non-renewable resources (N), purchased renewable resources (FR), and purchased non-renewable resources (FN) for the calculation of a suite of Emergy indices (Table 4.1)

Table 4.1: Emergy Indices and ratios used for evaluating small-scale tea processors in Kenya, 2012–2016

Index	Unit	Description	Reference
Empower Density (EPD)	U/area	An indicator of the total energy use per unit area in a region or nation	Odum (1996) and Brown and Ulgiati (2004)
Environmental Loading Ratio (ERL)	(N+F)/R,F/R (this study)	A measure of the potential pressure on the local environment, or the ecosystem stress due to production activity	Odum (1996)
Emergy Yield Ratio (EYR)	Y/F	An indicator of the production efficiency of a system or process to exploit local resources	Odum (1996) and Brown and Ulgiati (2004)
Emergy Exchange Ratio of Yield (EER_Y)	Ym/Y	A measure of the Emergy benefits gained from the sale of a product	Odum (1996) and Lu et al. (2009)
Emergy Exchange Ratio of Input (EER_I)	F/Fm	A measure of the Emergy benefits gained from the purchase of inputs	Lu et al. (2009)
Emergy Sustainability Index (ESI)	EYR/ELR	An indicator of system sustainability, i.e., the yield of the system per unit environmental stress	Brown and Ulgiati (1997) and Lu et al. (2009)
Emergy Index for Sustainable Development (EISD)	EYR×EER/ELR	An indicator of the sustainability of the system, considering the effects of market exchange on the Emergy yield	Lu et al. (2003b); Lu et al. (2009)

4.4 Results and Discussion

Results of emergy and economic analysis of the small scale tea processors are presented.

4.4.1 Emergy input structure

Detailed Emergy analysis tables are presented in the appendices (Appendix 1 to14). Among the seven regions, the Em-power density was highest for Region 1 (8.21E+10sej/ha/yr). Following closely was Region 7 (1.79E+09sej/ha/yr), Region 6 (6.89E+08sej/ha/yr), Region 2 (4.27E+08sej/ha/yr), Region 3 (3.98E+08 sej/ha/yr), Region 4 (1.72E+08 sej/ha/yr), and Region 5 (1.24E+08 sej/ha/yr) (Table 4.2). This indicated that the degree of economic development was higher for Regions 1. In general, the total Emergy of the purchased non-renewable resources (93.4%) was much higher than the purchased renewable resources (6.3%) and the renewable resource of 0.3% (Figure 4.3). the detailed structure of the emergy inputs for the seven agroecological regions are presented in Figure 4.4. Similar evidence was documented by (Zeng et al., 2013) who reported that the Emergy of the purchased non-renewable resources was much higher than the purchased renewable resources for the Anxi tea production chains in China. In this study, the purchased non-renewable resource was highest for Region 1.

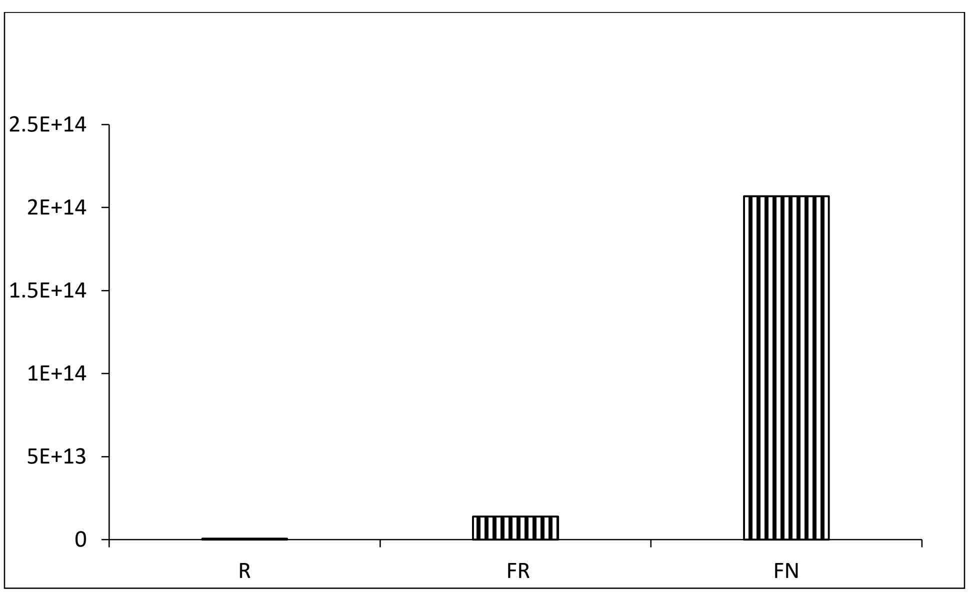


Figure 4.3: Aggregate structure of the Emergy inputs for the small-scale tea processors in Kenya, 2012–2016 (/ha/yr). (Source: Author's calculation)

The Emergy Self-Sufficiency Ratio (ESR) was highest for Region 4 (0.35), followed by Region 3 (0.18), Region 7 (0.17) and Region 2 (0.15). This compares poorly with Region 1(0.00), region 6(0.05) and region 5(0.05). This indicated that the utilization of local resources was greater for Regions 4, 3, 7and 2than for Regions 1, 6and 5 (Table 4.2).

The Emergy Exchange Ratio (EER) was highest for Region 1 (9.67), followed by Regions 4(1.84) and 7(1.10), respectively (Table 4.2). Farmers benefited from trading their tea on the market. The farmers of the Regions as mentioned earlier, for example, Region 1 received more than nine times the economic rewards for their inputs due to the high price of their tea on the market. In contrast, farmers from the other regions achieved an ecological, economic loss from the sale of their tea on the market. The Emergy Yield Ratio (EYR) was highest for Region 4 (1.54), followed by Region 3 (1.22), Region 7 (1.20) and Region 2 (1.17), in that order (Table 4.2). This indicates that the highest Emergy output per unit economic Emergy input was obtained with the Region 4.

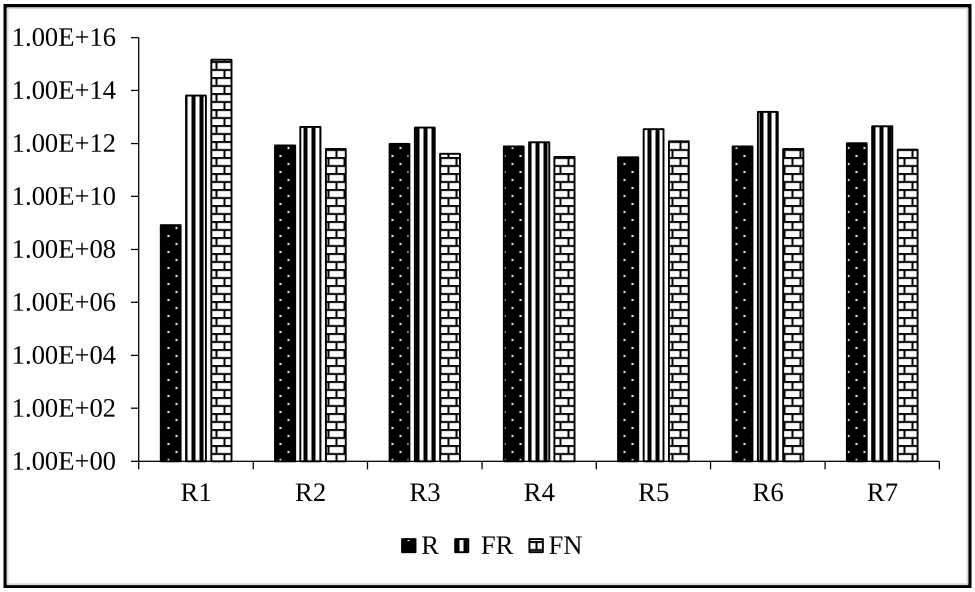
The Environmental Loading Ratio (ELR) was highest for Region 1(22.47) (Table 4.2). This indicated that Region 1had the highest dependence on non-renewable resources, the lowest utilization rate of renewable environmental resources, and the most significant pressure on the environment. The Emergy Sustainability Index (ESI) was highest for Region 7 (11.15), followed by Region 2 (9.50) and Region 4 (9.48) (Table 4.2). Region 1had the lowest ESI because it had the highest ELR, that is, its ELR was 204 times greater than that of Region 7. As a result, the ESI of Region 7 was 279 times that of Region 1. The Emergy Index for Sustainable Development (EISD) in Region 4 had the highest EISD (17.48), followed by Region 7 (Table 4.2).

Table 4.2: Emergy Indices and ratios for the small-scale tea processors in Kenya, 2012–2016 (/ha/yr).

Indices	***R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
Em-power density	8.21E+10	4.27E+08	3.98E+08	1.72E+08	1.24E+08	6.89E+08	1.79E+09
Emergy self sufficiency	0.00	0.15	0.18	0.35	0.06	0.05	0.17
Emergy investment ratio	23.47	5.85	4.54	1.85	15.36	21.17	5.01
Environmental loading ratio	22.47	0.12	0.89	0.16	0.32	0.04	0.11
Emergy yield ratio	1.00	1.17	1.22	1.54	1.07	1.05	1.20
Emergy exchange ratio	9.67	0.70	0.84	1.84	0.75	0.18	1.10
Emergy sustainability index	0.04	9.50	1.38	9.48	3.32	27.29	11.15
Emergy index for sustainable development	0.43	6.65	1.16	17.48	2.50	4.97	12.16

Source: Author's own calculation

*R1…7 are the Regions under study.



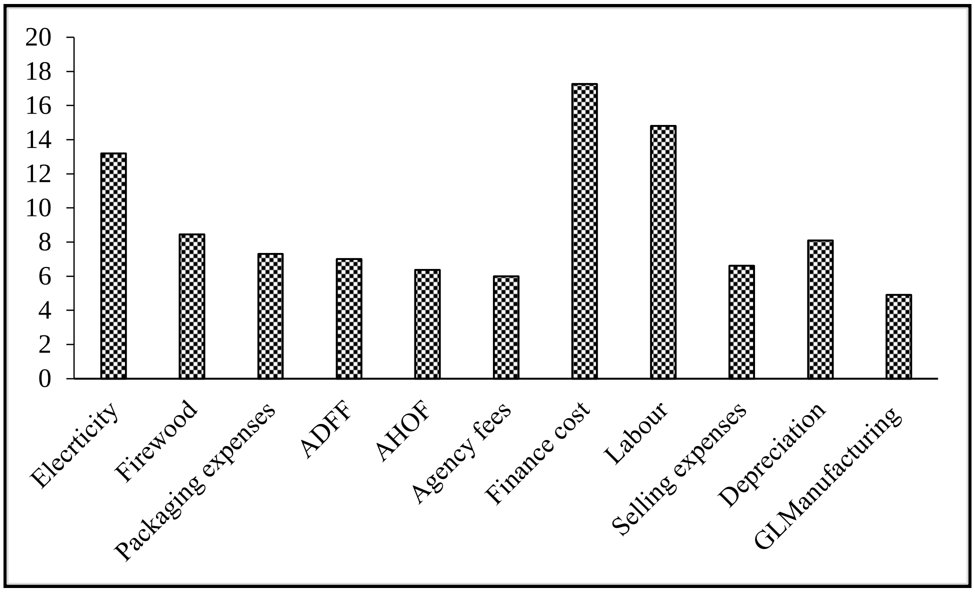
Source: Author's own calculation

Figure 4.4: Detailed structure of the Emergy inputs for the small-scale tea processors in Kenya, 2012–2016 (/ha/yr).

Where R is local Renewable resources, FR is purchased renewable resources; FN is the purchased nonrenewable resources.

4.4.2 Economic Viability

The input structure showed that the three most substantial economic costs for the small-scale tea processors in Kenya are finance costs (17%), labour (15%) and electricity (13%) (Figure 4.5). Fortunately, the economic balance of the whole processing sub-system was positive, indicating that the small-scale tea processors are profitable (Table 4.4). However, the processing system was cost inefficient recording an index of 2.5. The market value was based on the 2012 average annual prices to cater for inflation.



Source: Author's own calculation

Figure 4.5: Aggregates structure of the economic inputs for the small-scale tea processors in Kenya, 2012–2016 (unit/ha/yr)

Economic analysis focuses on the monetary flows and stocks of the system, while Emergy evaluation brings the environmental contributions, such as solar radiation, water, and green leaf, into the picture, which are inputs that are considered free in economic analysis. Market price reflects the value of a product or service, which is determined by the interplay between buyers and sellers. The results of this study showed that the small-scale tea processors in Kenya relied on purchased non-renewable resources and that the key to making tea production more sustainable is to find ways to decrease the economic cost of capital, electricity, and labour. The high dependence on economic resources is represented in the Emergy Yield Ratio (EYR), which indicates the amount of energy derived from nature that the process returns to the economic sector. An EYR close to one, as found in the present study, demonstrates that the system consumes as much Emergy as it makes available to the economy. A higher ratio denotes a greater capacity to incorporate contributions from nature and lower dependence on economic resources. In the present study, the EYR was 1.179 (Table 4.2), implying that the system delivers the same amount of Emergy that contributed to its processes. In other words, the system is inefficient in local resources exploitation, being able only to transform resources that were previously produced in other processes. Systems like this one are not likely to create new opportunities that contribute to regional development. Another indicator that corroborates this statement is the high Emergy Investment Ratio (EIR) of 11.036, which indicates a high demand for economic resources. A combined interpretation of EYR and EIR shows that small-scale tea processors could contribute to local development, based on a lower use of external and non-renewable resources. The Environmental Loading Ratio (ELR) of the small-scale tea processors was evaluated to determine the impact of the production system on the ecosystem. Values close to zero mean the environmental impact and ecological stress are minimal. A higher ELR denotes a more significant impact being made by an economic system on the natural environment. An ELR of 3.44, as found in the present study, indicates high environmental impact due to the high non-renewable Emergy fluxes.

The ESI considers both ecological and economic compatibility. The larger the ESI is, the higher the sustainability of a system concerned is. It indicates whether a process provides a suitable contribution to the user, with low environmental pressure. A system with a high ESI value usually has higher sustainability. The ESI reveals two aspects of sustainability; economic development and ecological sustainability. A system is sustainable when its EYR is high, and its ELR is low. It is generally considered that at $ESI < 1$, the system is driven by high consumption; at $1 < ESI < 10$, the system is vibrant and exhibits the potential for sustainable development; and at $ESI > 10$, the system is economically underdeveloped (Feng et al., 2015). The ESI of the present study was 8.88, indicating the potential for sustainable development by these processors. The Emergy Exchange Ratio is an indicator of the fairness of market exchange. The higher the value ratio an input has, the higher the benefit is that it brings to the system that purchased it. The EER of the present study was 2.154, indicating fair trading.

Table 4.3: Economic inputs to and outputs from for the small-scale tea processors in Kenya 2012-2016 (Ksh/ha/yr)

Input (I)	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**Total**
Electricity	2.84E+04	2.55E+04	2.56E+04	2.67E+04	2.20E+04	1.99E+04	1.70E+08	1.70E+08
Firewood	3.44E+04	2.22E+04	1.95E+04	5.03E+03	3.09E+04	9.36E+04	1.09E+08	1.09E+08
Packaging expenses	2.54E+04	1.60E+04	5.38E+03	8.68E+03	1.71E+05	1.27E+04	9.41E+07	9.44E+07
ADFF	2.14E+04	5.11E+03	8.10E+03	5.25E+04	9.89E+03	8.70E+04	9.04E+07	9.05E+07
AHOF	5.80E+03	6.20E+03	4.07E+04	1.19E+04	1.21E+04	9.72E+03	8.21E+07	8.22E+07
Agency fees	1.35E+04	6.57E+04	2.01E+04	5.41E+03	1.46E+05	8.01E+04	7.70E+07	7.74E+07
Finance cost	1.34E+05	1.94E+04	1.72E+04	1.25E+04	2.18E+04	2.54E+04	2.23E+08	2.23E+08
Labour	3.37E+04	4.19E+04	1.16E+04	1.16E+05	3.99E+04	2.13E+05	1.91E+08	1.91E+08
Selling expenses	2.49E+04	1.84E+04	1.02E+04	3.10E+04	1.55E+05	1.16E+04	8.53E+07	8.55E+07
Depreciation	2.76E+04	5.25E+03	5.65E+04	5.69E+03	8.94E+03	8.96E+04	1.04E+08	1.05E+08
GL Manufacturing	1.37E+04	4.84E+03	8.57E+03	8.65E+03	1.43E+04	7.81E+03	6.33E+07	6.33E+07
Total input	3.63E+05	2.31E+05	2.23E+05	2.84E+05	6.32E+05	6.50E+05	1.29E+09	1.29E+09
Output(O)								
Tea	8.28E+05	7.31E+05	8.63E+05	7.77E+05	7.17E+05	5.90E+05	4.37E+09	4.37E+09
Indices								
O/I	2.28	3.17	3.86	2.74	1.13	0.91	3.50	17.59
EBU	464893.3	500209.9	639600.3	492887.7	84773.45	-60129.8	3.08E+09	3082528012

Source: Author's own calculation

O/I is the ratio of output to input; EBU is the economic benefit unit (Output minus Input)

4.5 Summary, Conclusion and Policy Implications

4.5.1 Introduction

This section provides a summary of the study findings. It also concludes and makes policy inferences.

4.5.2 Summary

The objective of this chapter was to determine the environmental/ecological sustainability of the small-scale tea processors in Kenya. This study adopted the Emergy methodology to estimate the environmental efficiencies of the small-scale tea processors in Kenya. A census was conducted. Data covering five years (2012, 2013, 2014, 2015 and 2016) for the 54 factories under the management of KTDA was collected. The findings indicated that the small-scale tea processors in Kenya were ecologically/economically unsustainable.

4.5.3 Conclusion

The present study demonstrated that small-scale tea processors are environmentally/economically unsustainable. The processors relied heavily on purchased non-renewable resources. Further, the processors were cost inefficient recording an index of only 2.5. Fortunately, the study findings also revealed a mean positive economic output input benefit, indicating that the processors are profitable. A vital contribution to the methodology made by this study has been the measurement of environmental/economic constructs using Emergy methodology that measures contributions from both the environment and economy in a common metric of solar joules. It is worth noting that the small-scale tea processing sub-system is vibrant and exhibits the potential for sustainable development, as can be observed from the ESI.

4.5.4 Policy Implication

The processors relied heavily on purchased non-renewable resources hence rendering the processing subsystem economically and ecologically unsustainable. The processors should consider the use of renewable resources, for example, solar power and gasifiers. This will in turn reduce electricity bill in the long run. In addition, high labour costs can be contained by automation of factory processes, for instance, the use of conveyor belts and robotics for routine services. Due to the high cost of finance, the management agency may consider issuing a green instrument that could substantially reduce the cost of capital, while simultaneously reducing environmental impacts. A green instrument refers to any financial instrument or investment, for example, equity, debt, and grant, issued under contract to a firm in exchange for the delivery of positive environmental externalities. Economic instruments such as taxes, user-charges, deposit-refund systems, and emissions trading are among the most robust tools available for integrating environmental concerns directly in the operation of a market economy. Green instruments are more directly linked to a company's general management than to its cash management, and therefore constitute an excellent vehicle for measuring the environmental performance of an investment project (the financing of a wind farm, setting up least-cost renewable energy sites, green infrastructure, among others).

CHAPTER FIVE

SYNTHESIS, CONCLUSION AND RECOMMENDATIONS

The small-scale tea sub-sector is an important economic activity in Kenya. Hence it is vital to ensure that the sector remains sustainable. High production costs constitute the major challenge affecting the sustainability of the small-scale tea processors in Kenya. Manufacturing entities are under pressure to ensure the efficient use of resources. While acknowledging the sustainability initiatives pursued by the small-scale tea processors in Kenya, the output of such measures has not been measured. With such a backdrop, this study sought to determine the sustainability of the small-scale tea processors in Kenya. The primary motivation of the study stems from the fact that although the subject of sustainability is essential, only a limited number of studies have focused on the environmental efficiency, technical efficiency, and Emergy evaluation of small-scale tea processors in Kenya. Understanding the levels of inefficiency/efficiency can help to address the persistent rise in production costs.

In sum, the study established that the small-scale tea processors were not sustainable for the period under consideration. Moreover, new knowledge of aspects responsible for the persistent rise in factory production costs was also revealed. The study was conceptualized into four intricate, yet interrelated chapters. The first chapter dealt with a general introduction to the study. The second and third chapters dealt with the determination of the effects of environmental efficiency and technical efficiency on the profitability of the small-scale tea processors in Kenya. Finally, the fourth chapter dealt with the computation of Emergy indices to assess the ecological/environmental sustainability of the small-scale tea processors in Kenya by integrating aspects from the economy and environment into a common metric of solar joules.

5.1 Synthesis

Small-scale tea processors in Kenya have been implementing environmental efficiency-enhancing techniques in their production. Before this study, the results of their initiatives had not been tested. Consequently, this study sought to measure the environmental efficiency of these processors and to investigate the drivers of such efficiency in the sub-sector. The study adopted a two-step approach. In the first step, the Inverse Data Envelopment Analysis approach for panel data was used to generate the environmental efficiency scores. In the second step, Tobit regression was used to analyse the predictors of environmental efficiency. The results showed that the tea processors were environmentally inefficient, recording a mean efficiency index of only 49%. Factories have the ability, therefore, to reduce 51% of environmentally detrimental inputs without compromising output. The findings also reveal that the pursuit for excessive profitability, without simultaneously taking a balanced approach to improving energy efficiency, would cause a decline in environmental efficiency. Similarly, high finance costs discourage the processors from adopting improved environmental technologies, resulting in a decline in environmental efficiency. Further, this study sought to determine the effect of environmental efficiency on the financial performance of small-scale tea processors in Kenya. A Random Effects model was used. The results showed a negative effect of environmental efficiency on profitability. For theory, a vital contribution to the methodology made by this study is the measurement of environmental constructs using input and output indicators of production by the DEA methodology.

For the second objective, this study sought to determine and compare the technical efficiency (TE), Technology Gap Ratios (TGRs) and Meta-Frontier Technical Efficiency (MTEs) of tea production between the regions East and West of the Rift Valley. The empirical analysis was carried out by employing the stochastic meta-frontier approach. The approach allows the comparison of technical efficiency across regions. Furthermore, a regression that separates the effects of persistent inefficiency from time-varying inefficiency was adopted to inform policy reforms in the tea sub-sector in Kenya. On average, the technical efficiency level derived from the regional frontier was 76%, while that from the meta-frontier was 74%. The technological gap ratio was 97%. In general, the region East of Rift Valley was more technically efficient in operation for the overall small-scale tea industry (80.7%), followed by the region West of Rift Valley (77.3%). This implies that the overall efficiency of firms in the region East of Rift Valley is superior to that of the region West of Rift Valley. Thus, tea factories could use resources more efficiently by reducing 24% of the current application level, without compromising the output. Moreover, it was observed that the processors had a persistent inefficiency component of about 20%. This implies that factors beyond their control partly caused the inefficiency of these processors. This implies, therefore, that structural and managerial aspects were involved in the greater inefficiency of the small-scale tea processors. No significant relationship between technical efficiency and profitability was observed. A key contribution to the methodology made by this study has been the use of a model that distinguishes persistent, technical and residual inefficiencies. Further, this study demonstrated that the processors in East of Rift Valley and West of Rift Valley do not share the same production frontier. Surprisingly, the study demonstrated that profitability and technical efficiency do not correspond, and therefore the use of profitability as the only performance criterion of a firm could be misleading and give biased results.

For the third objective, this study sought to determine the ecological/economic sustainability of the small-scale tea processors. Emergy analysis is a promising tool for the evaluation of the environmental-economic performance of the production system. Consequently, Emergy analysis and corresponding indices and ratios were used to assess the long-term ecological/economic sustainability and efficiency of the tea processing sub-system. Based on thermodynamics, it quantifies the nonmonetized and monetised resources, services and commodities necessary for production in the common units of the solar energy it took to make them. This is predicated on the fact that natural resources sustain the economy, and are largely neglected in economic decision-making. The relative sustainability of the small-scale tea processors remains unclear. Quantitative evaluation and comparison of these systems that simultaneously considers both ecological and economic factors is an essential first step in documenting their relative sustainability. The results revealed that the tea processors were not ecologically/economically sustainable. The processing sub-system relied heavily on purchased non-renewable resources. The total Emergy for the purchased non-renewable resources was 93.4%, purchased renewable resources were 6.3%, and renewable resource was 0.3%. The results further showed that the small-scale tea processing sub-systems were profitable, with an average positive economic benefit. Further, the processing system was cost inefficient recording an economic output/input ratio of 2.513. A key contribution to the methodology made by this study has been the use of Emergy analysis to fill the gap in ecological-economic valuation caused by the difficulty in assigning a value to the environmental contributions to the economy.

5.2 Conclusion

In conclusion, the study demonstrated that:

a) The effect of environmental efficiency on profitability revealed that combating negative environmental impacts is costly, and substantially eats into the profits of the firms. Similarly, high finance costs discourage processors from adopting improved environmental technologies.

b) The small-scale tea processors were technically inefficient for the period under consideration. Further, no relationship between technical efficiency and profitability was observed.

c) The small-scale tea processing system relied heavily on purchased non-renewable resources, thus rendering the processing sub-system ecologically and economically unsustainable. More so, the processing system is cost inefficient, but profitable.

5.3 Recommendation

Based on the findings of this study, the following recommendations are made:

a) For practice, the tea processors might consider sourcing alternative finances or negotiate for better terms of borrowing.

b) Processors should consider issuing a green instrument that simultaneously reduces the cost of finance and negative environmental impact.

c) The processors might consider shifting production time to off-peak hours to contain the energy costs.

d) The processing system might consider use of renewable resources to make the processing system ecologically and economically sustainable.

e) For policy, the results revealed a persistent inefficiency that was caused by factors beyond the producers'control. This calls for managerial and regulatory interventions. Such interventions include reducing bureaucracy and increasing accountability and responsibility by workers to ensure proper work ethic, and should also ensure proper governance mechanisms are put in place.

f) Environmental conserving technologies are expensive and it is important that the government considers subsidizing them in the short run because they generate positive externalities.

In sum, the objectives of the study were met and the information generated will add to the increasing resource knowledge of sustainability. For context, the study noted that the small-scale tea processors are vibrant and exhibit the potential for sustainable development. The study was limited to the small-scale tea processors in Kenya. Hence, generalizability should only relate to this sub-sector. Due to the significant contribution of the manufacturing and agricultural sector in accelerating GDP growth and achievement of Vision 2030, the sustainability of small-scale tea processors should be fast-tracked. It was not possible to determine the many reasons for the inefficiency of these processors that is caused by factors beyond their control, and accordingly future research could examine these reasons for inefficiency and so fill in the gap resulting from this limitation.

REFERENCES

Aigner, D. J., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and determination of stochastic frontier function models. *Journal of Econometrics*, 6, 21-37.

Aissa, S. B., & Goaied, M. (2016). Determinants of Tunisian hotel profitability: The role of managerial efficiency. *Tourism Management*, 52, 478–487. DOI: 10.1016/j.tourman.2015.07.015

Almeida, C. M. V. B., Madureira, M. A., Bonilla, S. H., & Giannetti, B. F. (2012). Assessing the replacement of lead in solders: effects on resource use and human health. *Journal of Cleaner Production*, 1–8. http://doi.org/10.1016/j.jclepro.2012.08.002

Alshehhi, A., Nobanee, H., & Khare, N. (2018). The Impact of Sustainability Practices on Corporate Financial Performance: Literature Trends and Future Research Potential. *Sustainability* (Switzerland), *10*(494), 1–25. http://doi.org/10.3390/su10020494

Azapagic, A., Bore, J., Cheserek, B., Kamunya, S., & Elbehri, A. (2015). Global Warming potential of production and consumption of Kenya tea. *Journal of Cleaner Production*, *112*(5), 4031–4040.

Baltagi, B. (2005). *Econometric Analysis of Panel Data* (3rd ed.). John Wiley& Sons.

Bouslah, K., M'Zali, B., Turcotte, M.-F., & Kooli, M. (2009). *The Impact of Forest Certification on Firm Financial Performance in Canada and the U. S.*

Brown, M. T., Campbell, D. E., De Vilbiss, C., & Ulgiati, S. (2016). The geobiosphere emergy baseline: A synthesis. *Ecological Modelling*, 339, 92–95. http://doi.org/10.1016/j.ecolmodel.2016.03.018

Brown, M.T., & Ulgiati, S. (2004). Emergy analysis and environmental accounting. Encyclop. Energy 2, 329–354.

Buccina, S., Chene, D., & Gramlich, J. (2013). Accounting for the environmental impacts of Texaco's operations in Ecuador: Chevron's contingent environmental liability disclosures. *Accounting Forum*, *37*(2), 110–123. http://doi.org/10.1016/j.accfor.2013.04.003

Buller, L. S., Silva, G., Ortega, E., & Bergier, I. (2016). Soil Loss as a Negative Externality in the Emergy Accounting: Case Study of an Agricultural Commodities Municipality in the Brazilian Savannah. *Journal of Environmental Accounting and Management*, *4*(2), 129–147. http://doi.org/10.5890/JEAM.2016.06.004

Busch, T., & Hoffmann, V. H. (2011). How hot is your bottom line? Linking carbon and financial performance. *Business & Society*, 50, 233-265.

Campbell, D.E., & Lu, H.F. (2009). The emergy to money ratio of the United States from 1900 to 2007. In: Brown, M.T. (Ed.), Emergy Synthesis 5: Theory and Application of the Emergy Methodology. *The Center for Environmental Policy*, Gainesville, pp. 413e448

Cesar, J., Guimar, F. De, & Nodari, C. H. (2015). Cleaner production, environmental sustainability and organizational performance: an empirical study in the Brazilian Metal-Mechanic industry. *Journal of Cleaner Production*, 96, 118–125. http://doi.org/10.1016/j.jclepro.2014.06.027

Chang, Y. T. (2013) Environmental efficiency of ports: A Data Envelopment Analysis approach, *Maritime Policy & Management*, 40:5, 467-478, DOI: 10.1080/03088839.2013.797119

Chang, Y. T., Zhang, N., Danao, D., & Zhang, N. (2013). Environmental efficiency analysis of transportation system in China: A non-radial DEA approach. *Energy Policy*, *58*(2013), 277–283. http://doi.org/10.1016/j.enpol.2013.03.011

Charnes A., Cooper W.W. & Rhodes E. (1978), Measuring the efficiency of decision-making units. *European Journal of Operational Research,* 2, 429 -444.

Chen, J., Song, M., & Xu, L. (2015). Evaluation of environmental efficiency in China using data envelopment analysis. *Ecological Indicators*, 52, 577–583. http://doi.org/10.1016/j.ecolind.2014.05.008

Chen, J., Wu, Y., Song, M., & Zhu, Z. (2017). Stochastic frontier analysis of productive efficiency in China’s Forestry Industry. *Journal of Forest Economics*, 28, 87–95. http://doi.org/10.1016/j.jfe.2017.05.005

Cheng, F., Lu, H., Ren, H., Zhou, L., Zhang, L., Li, J. Zhao, D. (2017). Integrated emergy and economic evaluation of three typical rocky desertification control modes in karst areas of Guizhou Province, China. *Journal of Cleaner Production*, 161, 1104–1128. http://doi.org/10.1016/j.jclepro.2017.05.065

Cheserek, B. C., Elbehri, A., & Bore, J. (2015). Analysis of Links between Climate Variables and Tea Production in the Recent Past in Kenya. *Donnish Journal of Research in Environmental Studies*, *2*(2), 5–17.

Chofreh, G. A., Goni, A. F., Shaharoun, A., Ismail, S., & Klemes, J. (2014). Sustainable enterprise resource planning: imperatives and research directions. *Journal of Cleaner Production*, 71, 139–147. http://doi.org/10.1016/j.jclepro.2014.01.010

Cohen, M. J., Brown, M. T., & Shepherd, K. D. (2006). Estimating the environmental costs of soil erosion at multiple scales in Kenya using emergy synthesis. *Agriculture, Ecosystems and Environment*, *114*(2–4), 249–269. http://doi.org/10.1016/j.agee.2005.10.021

Cooper W.W., Seiford L.M. & Tone K. (2000). *Data Envelopment Analysis, a Comprehensive Test with Models, Applications, References and DEA-Solver Software*. Kluwer Academic Publishers, Boston.

Cooper, W.W. (1999). Operational research/Management science – Where it's been – where it should be going. *Journal of the Operational Research Society*, 50: 3–11.

CPDA. (2008). *Report on small-scale tea sector in Kenya*. Christian Partners Development Agency.

Creswell, J. W. (2013). *Research Design_ Qualitative, Quantitative, and Mixed Methods Approaches*.SAGE Publications, Inc (2013). http://doi.org/10.1007/s13398-014-0173-7.2

Daddi, T., Iraldo, F., Testa, F., & Giacomo, M. R. De. (2018). The influence of managerial satisfaction on corporate environmental performance and reputation. *Business Strategy and the Environment*, 1–10. http://doi.org/10.1002/bse.2177

Davé, A., Oates, M., Turner, C., & Ball, P. (2015). Factory eco-efficiency modelling. *International Journal of Energy Sector Management*, *9*(4), 547–564. http://doi.org/10.1108/IJESM-05-2013-0004

Delmas, M. A., Nairn-birch, N., & Lim, J. (2015). Dynamics of Environmental and Financial Performance: The Case of Greenhouse Gas Emissions. *Organization and Environment*, 28 (4), 374-393

Dunk, A. S. (2002). Product quality, environmental accounting and quality performance. *Accounting, Auditing & Accountability Journal*, *15*(5), 719–732. http://doi.org/10.1108/09513570210448975

Dutta, A. K., & Nath, A. (2015). Productivity Analysis of Black Tea Production in Tea Industry. *International Journal of Research in Mechanical Engineering and Technology*, *5*(1), 5.

Elsayed, K., & Paton, D. (2005). The impact of environmental performance on firm performance: Static and dynamic panel data evidence. *Structural Change and Economic Dynamics*, 16, 395-412.

Everett, T., Ishawaran, L., Ansaloni, G. P., & Rubin, A. (2010). Economic growth and the environment. The quarterly journal of …. Retrieved from http://qje.oxfordjournals.org/content/110/2/353.short

Eweje, G. (2011). A Shift in Corporate Practice? Facilitating Sustainability Strategy in Companies, *Corporate Social Responsibility and Environmental Management*. 18, 125–136

FAOSTAT (2015). *FAO statistical pocket book*. World food and agriculture

Farell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society Series A (General)*, 120, 253-290.

Faruq, H. A., & Yi, D. (2010). *The Determinants of Technical Efficiency of Manufacturing Firms in Ghana*. Working paper 62, Faculty Scholarship, Xavier University, Cincinnati. http://www.exhibit.xavier.edu/economics_faculty/62.

Feng, J., Wang, J., Zhang, X., Zhao, F., Kanianska, R., & Tian, D. (2015). Design and Implementation of Emergy-Based Sustainability Decision Assessment System for Protected Grape Cultivation. *Sustainability*, 7, 14002–14025. http://doi.org/10.3390/su71014002

Francoeur, C., Makni, R., & Bellavance, F. (2009). Causality between Corporate Social Performance and Financial Performance: Evidence from Canadian Firms. *Journal of Business Ethics*, (89), 409–422. http://doi.org/10.1007/s10551-008-0007-7

Friedman, M., (1970). "The Social Responsibility of Business Is to Increase Its Profits." The New York Times Magazine, pp.173-178.

Garcia, F., Kimpara, J. M., Valenti, W. C., & Ambrosio, L. A. (2014). Emergy assessment of tilapia cage farming in a hydroelectric reservoir. *Ecological Engineering*, 68, 72–79. http://doi.org/10.1016/j.ecoleng.2014.03.076

Gatimbu, K. K., & Wabwire, J. M. (2016). Effect of Corporate Environmental Disclosure on Financial Performance of Firms Listed at Nairobi Securities. *International Journal of Sustainability Management and Information Technologies*, *2*(1), 1–6. http://doi.org/10.11648/j.ijsmit.20160201.11

Government of Kenya (2013). *Kenya Vision 2030 progress report*, accessed from http: //www.vision2030.go.ke/cms/vds/Vision_2030-_ score_booklet.pdf on 25th July 2013.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (1998). *Multivariate data analysis*. Upper Saddle River, NJ: Prentice Hall.

Haque, F., & Ntim, C. G. (2018). Environmental Policy, Sustainable Development, Governance Mechanisms and Environmental Performance. *Business Strategy and the Environment*, 27, 415–435. http://doi.org/10.1002/bse.2007

Haron, M., & Chellakumar, J. A. (2012). Efficiency Performance of Manufacturing Companies in Kenya: Evaluation and Policies. *Int. J. Manag. Bus. Res.*, *2*(3), 233-242.

Haron, M., & Chellakumar, J. A. A. (2014). Understanding the Efficiency of Listed Manufacturing Companies in East Africa Using a Non Parametric Approach: A Case Study of Kenya. *Global Illuminators*, 1, 127–136.

Hart, S. L., & Dowell, G. (2011). A Natural-Resource-Based View of the Firm: Fifteen Years After. *Journal of Management*, *37*(5), 1464–1479. http://doi.org/10.1177/0149206310390219

Hartmann, J., & Vachon, S. (2018). Linking Environmental Management to Environmental Performance: The Interactive Role of Industry Context. *Business Strategy and the Environment*, 27, 359–374. http://doi.org/10.1002/bse.2003

Hong, N. B., & Yabe, M. (2015). Technical Efficiency Analysis of Tea Production in the Northern Mountainous Region of Vietnam. *Global Journal of Science Frontier Research*, *15*(1), 13.

Huang, Y., Wong, Y., & Yang, M. (2014). Proactive environmental management and performance. *Management Research Review*, *37*(3), 210–240. http://doi.org/10.1108/MRR-09-2012-0196

Jaggi, B. & Freedman, M. (1992). An examination of the impact of pollution performance on economic and market performance: pulp and paper firms, *Journal of Finance & Accounting*, Vol. 19 No. 5, pp. 697-714.

Jaklič, T., Juvančič, L., & Debeljak, M. (2013). Incorporation of Emergy Analysis into Decision-Making at the Farm Level: A Conceptual Model and its Implications for Agri-Environmental Policy Design.

Kagira, E. K., Kimani, S. W., & Githii, K. S. (2012). Sustainable Methods of Addressing Challenges Facing Small Holder Tea Sector in Kenya: A Supply Chain Management Approach. *Journal of Management and Sustainability*, *2*(2), 75. http://doi.org/10.5539/jms.v2n2p75

Kaimba, G. K., & Nkari, I. M. (2014). Impact of cost reduction strategies on performance of tea factories in Embu County, Kenya. *European Journal of Business and Social Sciences*, *3*(9), 26–48.

Kamande, M. (2014). *Technical and Environmental Efficiency of Kenya's Manufacturing Sector: A Stochastic Frontier Analysis*. The thirteen annual conference on Global Economic Analysis, United Nations Conference Centre, Bangkok, Thailand 2010 (p. 33).

Kamande, M. W., & Lokina, R. B. (2013). Clean Production and Profitability. The *Journal of Environment & Development*, *22*(2), 169–185. http://doi.org/10.1177/1070496512471948

Karagiorgos, T. (2010). Corporate Social Responsibility and Financial Performance: An Empirical Analysis on Greek Companies. *European Research Studies*, *XIII* (4), 85-108

KEPSA. (2014). *Kenya Tea Development Agency*. Nairobi.

Keramidou, I., Mimis, A., Fotinopoulou, A. & Tassis, C. D. (2013). Exploring the relationship between efficiency and profitability. *Benchmarking: An International Journal*, 20(5), 647–660. DOI: https://doi.org/10.1108/bij-12-2011-0090

Kibaara, B. (2005). *Technical Efficiency in Kenya's Maize Production: An Application of the Stochastic Frontier Approach*. Unpublished thesis, Colorado State University, Colorado, USA.

Kimathi, C. K., & Muriuki, F. M. (2013). *A Showcase of Smallholder Agriculture in the EAC: The Case of the Smallholder Tea Sector in Kenya*.

King, A., & Lenox, M. (2002). Exploring the locus of profitable pollution reduction. *Management Science*, 48, 289-299.

KNBS. (2015). *Economic Survey*. Government of Kenya, Nairobi.

KNBS. (2017). *Economic Survey*. Government of Kenya, Nairobi.

Kodde, D.A., & Palm F.C. (1986). Wald criteria for jointly testing equality and inequality restrictions. *Econometrica*, *54*(5), 1243–48.

Kosmidou, K., Tanna, S., & Pasiouras, F. (2008). Determinants of profitability of domestic UK commercial banks: panel evidence from the period 1995-2002. Economics finance and accounting applied research working paper series no. RP08- 4. Coventry: Coventry University.

Kumar M. S., & Madheswaran, S. (2010). Environmental efficiency of the Indian cement industry: An interstate analysis. *Energy Policy* (Vol. 38).

Kumbhakar, S. C., Wang, H., & Horncastle, A. (2015). *A Practitioner's Guide to Stochastic Frontier Analysis Using Stata*. Cambridge University Press, New York, NY.

Kupiec, P., & Lee, Y. (2012). What Factors Explain Differences in Return on Assets Among Community Banks? *Journal of Money Credit and Banking*, 17, 69–83.

Langat, N., Thoruwa, T., Wanyoko, J., Kiplagat, J., Plourde, B., & Abraham, J. (2015). Models and experiments for energy consumption and quality of green tea drying. *Energy Science & Engineering*, *3*(1), 43–50. http://doi.org/10.1002/ese3.49

Lizal, L., & Earnhart, D. (2010). *The Effect of Corporate Environmental Performance on Financial Outcomes – Profits, Revenues, and Costs: Evidence from the Czech Transition Economy*.

Long, X., Zhao, X., & Cheng, F. (2015). The comparison analysis of total factor productivity and eco-efficiency in China's cement manufactures. *Energy Policy*, 81, 61–66. http://doi.org/10.1016/j.enpol.2015.02.012

Low, S. M., & Umesh, V. M. (2014). Management accountants' perception of their role in accounting for sustainable development. *Pacific Accounting Review*, 26(1/2), 112–133. http://doi.org/10.1108/PAR-06-2013-0052

Lu, H. F., Kang, W. L., Campbell, D. E., Ren, H., Tan, Y. W., Feng, R. X., … Chen, F. P. (2009). Emergy and economic evaluations of four fruit production systems on reclaimed wetlands surrounding the Pearl River Estuary, China. *Ecological Engineering*, *35*(12), 1743–1757. http://doi.org/10.1016/j.ecoleng.2009.08.001

Lu, H., Lin, B. Le, Campbell, D. E., Sagisaka, M., & Ren, H. (2012). Biofuel vs. biodiversity? Integrated emergy and economic cost-benefit evaluation of rice-ethanol production in Japan. *Energy Policy*, *46*(1), 442–450. http://doi.org/10.1016/j.energy.2012.08.005

Lu, H., Yuan, Y., Campbell, D. E., Qin, P., & Cui, L. (2014). Integrated water quality, emergy and economic evaluation of three bioremediation treatment systems for eutrophic water. *Ecological Engineering*, 69, 244–254. http://doi.org/10.1016/j.ecoleng.2014.04.024

Lundvall, K. & Battese, G.E. (2000). Firm size, age and efficiency: evidence from Kenyan manufacturing firms. *Journal of Development Studies*, *36*(3), 146–63.

Martínez-Ferrero, J., García-Sánchez, I., & Ruiz-Barbadillo, E. (2018). The quality of sustainability assurance reports: The expertise and experience of assurance providers as determinants. *Business Strategy and the Environment*, 1–16. http://doi.org/10.1002/bse.2061

Meeusen, W. & Vanden Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production Functions with composed error. *International Economic Review*, 18, 435- 444.

Mir, M. Z., & Rahaman, A. S. (2011). In pursuit of environmental excellence. *Accounting, Auditing & Accountability Journal, 24*(7), 848–878. http://doi.org/10.1108/09513571111161620

Moutinho, V., Madaleno, M., & Robaina, M. (2017). The economic and environmental efficiency assessment in EU cross-country: Evidence from DEA and quantile regression approach. *Ecological Indicators*, 78, 85–97. http://doi.org/10.1016/j.ecolind.2017.02.042

Ndicu, S. (2015). *Efficiency Analysis of the Agro-Processing Industry in Kenya*. Unpublished Masters' thesis, Kenyatta University, Nairobi.

Ng'ang'a, S. I. (2011). The PESTLE dynamics in tea trade: Effects on return to the farmer and sustainability of the smallholder tea enterprise", *in the First International Conference Proceedings of on Tea Science and Development,Karatina University, Nyeri 2015* (pp. 162–181).

Ngui-Muchai, D.M. & Muniu, J.M. (2012). Firm Efficiency Differences and Distribution in the Kenyan Manufacturing Sector. *African Development Review*, *24*(1) 52–66.

Ngwakwe, C. C. (2012). Rethinking the accounting stance on sustainable development. *Sustainable Development*, *20*(1), 28–41. http://doi.org/10.1002/sd.462

Nissi, E., & Rapposelli, A. (2005). *Assessing Ecological Efficiency via Data Envelopment Analysis*.

Njuki, E., & Bravo-ureta, B. E. (2018). Irrigation water use and technical efficiencies: Accounting for technological and environmental heterogeneity in U.S. agriculture using random parameters. *Water Resources and Economics*, 1–12. http://doi.org/10.1016/j.wre.2018.02.004

Nyirenda, G., Ngwakwe, C. C., & Ambe, C. M. (2013). Performance in a South African Mining Firm. *Managing Global Transitions*, *11*(3), 243–260.

O'Donnell, Christopher J., Prasada Rao, D.S., & Battese, George E. (2008). Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empir. Econ. 34*(2), 231–255.

Obeng, P. A., & Agyenim, J. B. (2015). *Institutional Matrix for Sustainable Waste Management*. University of Cape Coast, Ghana.

Odum, H.T. (1996). *Environmental Accounting Emergy and Environmental Decision Making*. John Wiley & Sons, New York.

Odum, H.T., Brown, M.T., & Brandt-Williams, S. (2000). *Handbook of Emergy Evaluation: A Compendium of Data for Emergy Computation Issued in a Series of Folios. Folio #1*. Introduction and Global Budget. University of Florida, Gainesville, 17 pp

Ogundari, K. (2008), 'Resource-Productivity, Allocative Efficiency and Determinants of Technical Efficiency of Rainfed Rice Farmers: A Guide for Food Security Policy in Nigeria', *Agricultural Economics*, Vol. 54, No. 5, pp. 224–33.

Ortega, E. (2005). Brazilian Soybean Production: Emergy Analysis with an Expanded Scope. *Bulletin of Science, Technology & Society*, *25*(4), 323–334. http://doi.org/10.1177/0270467605278367

Owuor, P. O. (2011). *Tea in Kenya: Production and country profile*. Two and a Bud, 58, 10–18.

Owuor, P. O., Kavoi, M. M., Wachira, F. N., & Ogola, S. O. (2007). Sustainability of Smallholder Tea Growing in Kenya. *International Journal of Tea Science*, *6*(1), 1–23

Palečková, I. (2015). *Relationship between Profitability and Efficiency in the Czech Banking Sector*. In: Palečková, I. and Szarowská, I. (eds.), Proceeding of the 15th International Conference on Finance and Banking. Karviná: Silesian University, 286–291.

Perey, R., Benn, S., & Edwards, M. (2018). The place of waste: Changing business value for the circular economy. *Business Strategy and the Environment*, 27, 631–642. http://doi.org/10.1002/bse.2068

Peter, C., & Swilling, M. (2014). Linking complexity and sustainability theories: Implications for modeling sustainability transitions. *Sustainability* (Switzerland), 6(3), 1594–1622. http://doi.org/10.3390/su6031594

Pintea, M., Stanca, L., Achim, S., & Pop, I. (2014). Is There a Connection Among Environmental and Financial Performance of a Company in Developing Countries? Evidence from Romania. *Procedia Economics and Finance*, *15*(14), 822–829. http://doi.org/10.1016/S2212-5671(14)00527-9

Porter, M. E., & Van Der Linde, C. (1995). Green and competitive: ending the stalemate. *Harvard Business Review*, *28*(6), 128–129. http://doi.org/10.1016/0024-6301 (95)99997-E.

Pulselli, F. M., Patrizi, N., & Focardi, S. (2011). Calculation of the unit emergy value of water in an Italian watershed. *Ecological Modelling*, *222*(16), 2929–2938. http://doi.org/10.1016/j.ecolmodel.2011.04.021

Republic of Kenya. (2010). *Agricultural Sector Development Strategy*.

Saladini, F., Vuai, S. A., Langat, B. K., Gustavsson, M., Bayitse, R., Gidamis, A. B., … Bastianoni, S. (2016). Sustainability assessment of selected biowastes as feedstocks for biofuel and biomaterial production by emergy evaluation in five African countries. *Biomass and Bioenergy*, 85, 100–108. http://doi.org/10.1016/j.biombioe.2015.11.016

Sardaro, R., Pieragostini, E., Rubino, G., & Petazzi, F. (2017). Impact of Mycobacterium avium subspecies paratuberculosis on profit efficiency in semi-extensive dairy sheep and goat farms of Apulia, southern Italy. *Preventive Veterinary Medicine*, 136, 56–64. http://doi.org/10.1016/j.prevetmed.2016.11.013

Saunders, M., Lewis, P., & Thornhill, A. (2013). *Research methods for business students* (9th Edition). New York: Cengage Learning.

Schaltegger, S., & Synnestvedt, T. (2002). *The link between "green" and economic success : environmental management as the crucial trigger between environmental and economic performance*, 339–346. http://doi.org/10.1006/jema

Schrettle, S., Hinz, A., Scherrer, M., & Friedli, T. (2014). Turning sustainability into action: Explaining firms' sustainability efforts and their impact on firm performance. *Intern. Journal of Production Economics*, 147, 73–84.

Shieh, Hwai-Shuh. (2012). Does Cost Efficiency Lead to Better Financial Performance? A Study on Taiwan International Tourist Hotels. *Journal of Hospitality Financial Management*: Vol. 20: Iss. 1, Article 5

Siddique, S. P., & Sciulli, N. (2018). Sustainable development of small companies : Investors' perspectives. *Business Strategy and the Environment*, 1–14. http://doi.org/10.1002/bse.2073

Singh, R. J., Ghosh, B. N., Sharma, N. K., Patra, S., Dadhwal, K. S., & Mishra, P. K. (2016). Energy budgeting and emergy synthesis of rainfed maize-wheat rotation system with different soil amendment applications. *Ecological Indicators*, 61, 753–765. http://doi.org/10.1016/j.ecolind.2015.10.026

Taulo, J. L., & Sebitosi, A. B. (2016). Material and energy flow analysis of the Malawian tea industry. *Renewable and Sustainable Energy Reviews*, 56, 1337–1350. http://doi.org/10.1016/j.rser.2015.11.072

Tea Board of Kenya. (2010). *Opening Emerging Markets for Kenyan Tea*, Nairobi.

Tea Board of Kenya. (2011). *Opening Emerging Markets for Kenyan Tea*, Nairobi.

Testa, F., Rizzi, F., Daddi, T., Gusmerotti, N. M., Frey, M., & Iraldo, F. (2014). EMAS and ISO 14001: the differences in effectively improving environmental performance. *Journal of Cleaner Production*, 68, 165–173. http://doi.org/10.1016/j.jclepro.2013.12.061

Tian, D., Zhao, F., Mu, W., Kanianska, R., & Feng, J. (2016). Environmental efficiency of Chinese open-field grape production: An evaluation using data envelopment analysis and spatial autocorrelation. *Sustainability* (Switzerland), *8*(12), 13. http://doi.org/10.3390/su8121246

Tiezzi, E., Bastianoni, S., & Marchettini, N. (1996). Environmental cost and steady state: The problem of adiabaticity in the emergy value. *Ecological Modelling*, 90(1), 33–37. http://doi.org/10.1016/0304-3800(95)00141-7

Ting, Y. I., & Ping-an, X. (2016). Emergy analysis of paddy farming in Hunan Province, China: *A new perspective on sustainable development of agriculture*, *15*(0). http://doi.org/10.1016/S2095-3119(16)61375-8

Trujillo, J. C., & Iglesias, W. J. (2013). Measurement of the technical efficiency of small pineapple farmers in Santander, Colombia: a stochastic frontier approach. *Revista de Economia e Sociologia Rural*, 51(1), s049–s062. http://doi.org/10.1590/S0103-20032013000600003

Wal Sanne van der (2008). *Sustainability issues in the Tea Sector-A Comparative analysis of six leading production countries*; SOMO Publication, Amsterdam, The Netherlands, 1-110.

Wang, K., & Wei, Y.M. (2014) China's Regional industrial energy efficiency and carbon emissions abatement costs. *Applied Energy*, 130, 617–631.

WBCSD. (2010). Vision 2050: *The new agenda for business*. World Business Council for Sustainable Development http://doi.org/10.1111/j.1530-9290.2009.00117.x

WCED. (1987). *Our Common Future*. World Commission on Environment and Development.

Wongnaa, C. A., & Awunyo-vitor, D. (2017). Scale efficiency of maize farmers in four agro ecological zones of Ghana: A parametric approach. *Journal of the Saudi Society of Agricultural Sciences*, http://doi.org/10.1016/j.jssas.2017.08.003

Worrell, E., Allwood, J., & Gutowski, T. (2016). The Role of Material Efficiency in Environmental Stewardship. *Annual Review of Environment and Resources*, *41*(1), 575–598. http://doi.org/10.1146/annurev-environ-110615-085737

Zeng, S.X., Meng, X.H., Yin, H.T., Tamb, C.M., Sun, L. (2010). Impact of cleaner production on business performance. *Journal of Cleaner Production*, 18, 975-983.

Zeng, X., Lu, H., Campbell, D. E., & Ren, H. (2013). Integrated emergy and economic evaluation of tea production chains. *Ecosystem Engineering*, 60, 354–362.

Zhang, F., Fang, H., Wu, J., & Ward, D. (2016). Environmental efficiency analysis of listed cement enterprises in China. *Sustainability* (Switzerland), *8*(5), 1–19. http://doi.org/10.3390/su8050453

APPENDICES

Appendix 1: Region one emergy analysis table for small-scale tea processors in Kenya, 2012–2016

Item	Raw data (unit/ha/yr)					Unit	UEV	Solar emergy					
	1	2	3	4	5		(sej/unit)	1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	0.13	0.13	0.13	0.13	0.13	Tj	1.00E+00	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.35E-01	1.35E-01
Wind (TJ/ha/yr)	47.70	47.70	47.70	47.70	47.70	Tj	1.85E+00	8.84E+01	8.84E+01	8.84E+01	8.84E+01	8.84E+01	8.84E+01
Rain (GJ/ha/yr)	0.38	0.38	0.38	0.38	0.38	Gg	1.10E+02	4.13E+01	4.13E+01	4.13E+01	4.13E+01	4.13E+01	4.13E+01
Geothermal (GJ/ha/yr)	19.15	19.15	19.15	19.15	19.15	Gj	7.78E+00	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02
tea	9267.94	11336.73	11727.03	10457.45	12642.36	g	7.49E+04	6.94E+08	8.49E+08	8.78E+08	7.83E+08	9.47E+08	8.30E+08
subtotal R= tea								6.94E+08	8.49E+08	8.78E+08	7.83E+08	9.47E+08	8.30E+08
Purchased renewable FR													
labor (10%)	33.64	40.38	41.81	36.34	43.67	$	1.52E+12	5.10E+13	6.12E+13	6.34E+13	5.51E+13	6.62E+13	5.94E+13
Water	14154.99	17417.27	17698.62	16050.28	18873.74	g	3.03E+05	4.29E+12	5.28E+12	5.37E+12	4.87E+12	5.72E+12	5.11E+12
subtotal								5.53E+13	6.65E+13	6.87E+13	5.99E+13	7.19E+13	6.45E+13
Purchased non-renewable FN													
labor (90%)	302.73	363.39	376.32	327.03	393.00	$	1.52E+12	4.59E+14	5.51E+14	5.70E+14	4.96E+14	5.96E+14	5.34E+14
Electricity	6765.40	7538.18	7370.43	6793.35	7753.50	j	2.10E+05	1.42E+09	1.58E+09	1.55E+09	1.43E+09	1.63E+09	1.52E+09
Depreciation	290.69	314.47	330.70	338.11	329.67	$	1.52E+12	4.41E+14	4.77E+14	5.01E+14	5.12E+14	5.00E+14	4.86E+14
Building maintenance	60.17	68.26	71.94	67.61	74.58	$	1.52E+12	9.12E+13	1.03E+14	1.09E+14	1.02E+14	1.13E+14	1.04E+14
Insurance	16.13	19.84	21.58	20.61	21.41	$	1.52E+12	2.44E+13	3.01E+13	3.27E+13	3.12E+13	3.24E+13	3.02E+13
Agency fees	127.66	135.36	120.36	125.83	190.29	$	1.52E+12	1.93E+14	2.05E+14	1.82E+14	1.91E+14	2.88E+14	2.12E+14
Transport costs	50.07	51.39	51.78	62.35	40.23	$	1.52E+12	7.59E+13	7.79E+13	7.85E+13	9.45E+13	6.10E+13	7.75E+13
Steam(wood fuel)	178455.62	219584.07	223131.11	202350.10	237946.14	j	2.34E+04	4.18E+09	5.14E+09	5.23E+09	4.74E+09	5.57E+09	4.97E+09
subtotal								1.28E+15	1.44E+15	1.47E+15	1.43E+15	1.59E+15	1.44E+15
Purchased resources F= FR+FN								1.34E+15	1.51E+15	1.54E+15	1.49E+15	1.66E+15	1.51E+15
TOTAL INPUT U=I+F								1.34E+15	1.51E+15	1.54E+15	1.49E+15	1.66E+15	1.51E+15
OUTPUT YM	8.10E+03	9.99E+03	1.01E+04	9.17E+03	1.08E+04	$	1.52E+12	1.23E+16	1.51E+16	1.53E+16	1.39E+16	1.63E+16	1.46E+16
yield made tea	2.14E+06	2.64E+06	2.68E+06	2.43E+06	2.86E+06	g							
Indices													
Em-power density								7.29E+10	8.22E+10	8.4E+10	8.093E+10	9.05E+10	8.21E+10
emergy self sufficiency								5.18E-07	5.622E-07	5.69E-07	5.268E-07	5.7E-07	5.49E-07
emergy investment ratio								24.24	22.72	22.45	24.81	23.11	23.47
environmental loading ratio								23.24	21.72	21.45	23.81	22.11	22.47
emergy yield ratio								1.00	1.00	1.00	1.00	1.00	1.00
emergy exchange ratio								9.16	10.03	9.91	9.35	9.83	9.67
emergy sustainability index								0.04	0.05	0.05	0.04	0.05	0.04
emergy index for sustainable development								0.39	0.46	0.46	0.39	0.44	0.43

Appendix 2: Region two emergy analysis table for small-scale tea processors in Kenya 2012-2016

Item	Raw data (unit/ha/yr) 1	2	3	4	5	Unit	UEV (sej/unit)	Solar emergy 1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	1.47E-01	1.47E-01	1.47E-01	1.47E-01	1.47E-01	Tj	1.00E+00	1.47E-01	1.47E-01	1.47E-01	1.47E-01	1.47E-01	1.47E-01
Wind (TJ/ha/yr)	4.59E+01	4.59E+01	4.59E+01	4.59E+01	4.59E+01	Tj	1.85E+00	8.51E+01	8.51E+01	8.51E+01	8.51E+01	8.51E+01	8.51E+01
Rain (GJ/ha/yr)	1.68E+05	1.68E+05	1.68E+05	1.68E+05	1.68E+05	Gg	1.10E+02	1.85E+07	1.85E+07	1.85E+07	1.85E+07	1.85E+07	1.85E+07
Geothermal (GJ/ha/yr)	2.11E+01	2.11E+01	2.11E+01	2.11E+01	2.11E+01	Gj	7.78E+00	1.64E+02	1.64E+02	1.64E+02	1.64E+02	1.64E+02	1.64E+02
tea	9.14E+06	1.14E+07	1.20E+07	1.06E+07	1.22E+07	g	7.49E+04	6.85E+11	8.57E+11	8.99E+11	7.97E+11	9.17E+11	8.31E+11
subtotal R= tea								6.85E+11	8.57E+11	8.99E+11	7.97E+11	9.17E+11	8.31E+11
Purchased renewable FR													
labor (10%)	9.70E-03	1.19E-02	1.26E-02	1.36E-02	1.50E-02	$	1.52E+12	1.47E+10	1.80E+10	1.91E+10	2.07E+10	2.27E+10	1.91E+10
Water	1.17E+07	1.43E+07	1.48E+07	1.34E+07	1.52E+07	g	3.03E+05	3.55E+12	4.33E+12	4.47E+12	4.07E+12	4.61E+12	4.21E+12
subtotal								3.56E+12	4.35E+12	4.49E+12	4.09E+12	4.63E+12	4.23E+12
Purchased non-renewable FN													
labor (90%)	8.73E-02	1.07E-01	1.14E-01	1.23E-01	1.35E-01	$	1.52E+12	1.32E+11	1.62E+11	1.72E+11	1.86E+11	2.05E+11	1.71E+11
Electricity	1.50E+03	1.70E+03	1.78E+03	1.50E+03	1.77E+03	j	2.10E+05	3.14E+08	3.57E+08	3.74E+08	3.15E+08	3.72E+08	3.46E+08
Depreciation	4.87E-02	5.17E-02	5.77E-02	6.16E-02	6.17E-02	$	1.52E+12	7.39E+10	7.83E+10	8.74E+10	9.33E+10	9.35E+10	8.53E+10
Building maintenance	4.11E-03	4.51E-03	4.64E-03	4.78E-03	4.73E-03	$	1.52E+12	6.23E+09	6.83E+09	7.03E+09	7.24E+09	7.17E+09	6.90E+09
Insurance	5.26E-03	6.89E-03	7.76E-03	7.54E-03	8.07E-03	$	1.52E+12	7.98E+09	1.04E+10	1.18E+10	1.14E+10	1.22E+10	1.08E+10
Agency fees	1.94E-01	2.31E-01	1.91E-01	2.20E-01	2.88E-01	$	1.52E+12	2.94E+11	3.50E+11	2.90E+11	3.34E+11	4.37E+11	3.41E+11
Transport costs	3.59E-03	1.32E-02	1.06E-02	2.73E-03	2.37E-03	$	1.52E+12	5.44E+09	1.99E+10	1.60E+10	4.14E+09	3.59E+09	9.82E+09
Steam(wood fuel)	5.65E+04	6.89E+04	7.12E+04	6.48E+04	7.34E+04	j	2.34E+04	1.32E+09	1.62E+09	1.67E+09	1.52E+09	1.72E+09	1.57E+09
subtotal								5.22E+11	6.30E+11	5.87E+11	6.38E+11	7.60E+11	6.27E+11
purchased resources F= FR+FN								4.09E+12	4.98E+12	5.08E+12	4.73E+12	5.39E+12	4.85E+12
TOTAL INPUT U=I+F								4.77E+12	5.83E+12	5.98E+12	5.52E+12	6.31E+12	5.68E+12
OUTPUT	2.21E+00	2.70E+00	2.79E+00	2.54E+00	2.87E+00	$	1.52E+12	3.36E+12	4.09E+12	4.23E+12	3.85E+12	4.36E+12	3.98E+12
yield													
mdtea	2.14E+06	2.62E+06	2.70E+06	2.46E+06	2.78E+06	g							
Em-power density								3.58E+08	4.38E+08	4.49E+08	4.15E+08	4.74E+08	426544391
emergy self sufficiency								0.14	0.15	0.15	0.14	0.15	0.15
emergy investment ratio								5.97	5.81	5.65	5.93	5.88	5.85
environmental loading ratio								0.12	0.12	0.11	0.13	0.14	0.12
emergy yield ratio								1.17	1.17	1.18	1.17	1.17	1.17
emergy exchange ratio								0.70	0.70	0.71	0.70	0.69	0.70
emergy sustainability index								9.50	9.69	10.81	8.95	8.54	9.50
emergy index for sustainable development								6.68	6.80	7.65	6.23	5.90	6.65

Appendix 3: Region three emergy analysis table for small-scale tea processors in Kenya 2012-2016

Item	Raw data (unit/ha/yr) 1	2	3	4	5	Unit	UEV (sej/unit)	Solar emergy 1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01	Tj	1.00E+00	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01
Wind (TJ/ha/yr)	4.44E+01	4.44E+01	4.44E+01	4.44E+01	4.44E+01	Tj	1.85E+00	8.22E+01	8.22E+01	8.22E+01	8.22E+01	8.22E+01	8.22E+01
Rain (GJ/ha/yr)	3.34E-01	3.34E-01	3.34E-01	3.34E-01	3.34E-01	Gg	1.10E+02	3.68E+01	3.68E+01	3.68E+01	3.68E+01	3.68E+01	3.68E+01
Geothermal (GJ/ha/yr)	2.12E+01	2.12E+01	2.12E+01	2.12E+01	2.12E+01	Gj	7.78E+00	1.65E+02	1.65E+02	1.65E+02	1.65E+02	1.65E+02	1.65E+02
tea	1.07E+07	1.28E+07	1.37E+07	1.25E+07	1.42E+07	g	7.49E+04	8.02E+11	9.60E+11	1.03E+12	9.38E+11	1.07E+12	9.59E+11
subtotal R= tea								8.02E+11	9.60E+11	1.03E+12	9.38E+11	1.07E+12	9.59E+11
Purchased renewable FR													
labor (10%)	1.20E-02	1.27E-02	1.29E-02	1.39E-02	1.60E-02	$	1.52E+12	1.83E+10	1.92E+10	1.95E+10	2.10E+10	2.42E+10	2.04E+10
Water	1.09E+07	1.32E+07	1.37E+07	1.26E+07	1.42E+07	KG	3.03E+05	3.31E+12	4.00E+12	4.15E+12	3.82E+12	4.31E+12	3.92E+12
subtotal								3.33E+12	4.02E+12	4.17E+12	3.84E+12	4.34E+12	3.94E+12
Purchased non-renewable FN													
labor (90%)	1.08E-01	1.14E-01	1.16E-01	1.25E-01	1.44E-01	$	1.52E+12	1.64E+11	1.73E+11	1.75E+11	1.89E+11	2.18E+11	1.84E+11
Electricity	1.24E+03	1.45E+03	1.46E+03	1.29E+03	1.31E+03	j	2.10E+05	2.61E+08	3.04E+08	3.06E+08	2.71E+08	2.76E+08	2.84E+08
Depreciation	1.64E-02	1.62E-02	1.75E-02	1.45E-02	1.80E-02	$	1.52E+12	2.48E+10	2.45E+10	2.65E+10	2.20E+10	2.72E+10	2.50E+10
Building maintenance	1.18E-02	1.74E-02	1.01E-02	1.07E-02	1.15E-02	$	1.52E+12	1.78E+10	2.64E+10	1.53E+10	1.62E+10	1.74E+10	1.86E+10
Insurance	3.68E-02	4.33E-02	4.78E-02	4.87E-02	5.13E-02	$	1.52E+12	5.57E+10	6.57E+10	7.25E+10	7.39E+10	7.77E+10	6.91E+10
Agency fees	5.87E-02	6.90E-02	5.98E-02	6.69E-02	8.95E-02	$	1.52E+12	8.89E+10	1.05E+11	9.06E+10	1.01E+11	1.36E+11	1.04E+11
Transport costs	2.92E-03	3.05E-03	2.04E-03	1.81E-03	1.61E-03	$	1.52E+12	4.43E+09	4.63E+09	3.10E+09	2.75E+09	2.44E+09	3.47E+09
Steam(wood fuel)	1.68E+04	2.04E+04	2.11E+04	1.94E+04	2.19E+04	j	2.34E+04	3.94E+08	4.77E+08	4.95E+08	4.56E+08	5.14E+08	4.67E+08
subtotal								3.57E+11	4.00E+11	3.84E+11	4.06E+11	4.80E+11	4.05E+11
purchased resources F= FR+FN								3.68E+12	4.42E+12	4.56E+12	4.25E+12	4.82E+12	4.35E+12
TOTAL INPUT U=I+F								4.49E+12	5.38E+12	5.58E+12	5.19E+12	5.88E+12	5.30E+12
OUTPUT	2.49E+00	3.02E+00	3.13E+00	2.88E+00	3.25E+00	$	1.52E+12	3.78E+12	4.57E+12	4.74E+12	4.37E+12	4.92E+12	4.48E+12
yield													
mdtea	2.48E+09	3.00E+09	3.11E+09	2.86E+09	3.23E+09	gms							
Em-power density								3.37E+08	4.04E+08	4.19E+08	3.89E+08	4.42E+08	3.98E+08
emergy self sufficiency								0.18	0.18	0.18	0.18	0.18	0.18
emergy investment ratio								4.60	4.61	4.44	4.53	4.52	4.54
environmental loading ratio								0.89	0.89	0.88	0.89	0.89	0.89
emergy yield ratio								1.22	1.22	1.23	1.22	1.22	1.22
emergy exchange ratio								0.84	0.85	0.85	0.84	0.84	0.84
emergy sustainability index								1.36	1.37	1.40	1.37	1.37	1.38
emergy index for sustainable development								1.15	1.16	1.19	1.16	1.15	1.16

Appendix 4: Region four emergy analysis table for small-scale tea processors in Kenya 2012-2016

Item	Raw data (unit/ha/yr) 1	2	3	4	5	Unit	UEV (sej/unit)	Solar emergy 1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	1.33E-01	1.33E-01	1.33E-01	1.33E-01	1.33E-01	Tj	1.00E+00	1.33E-01	1.33E-01	1.33E-01	1.33E-01	1.33E-01	1.33E-01
Wind (TJ/ha/yr)	4.73E+01	4.73E+01	4.73E+01	4.73E+01	4.73E+01	Tj	1.85E+00	8.76E+01	8.76E+01	8.76E+01	8.76E+01	8.76E+01	8.76E+01
Rain (GJ/ha/yr)	3.92E-01	3.92E-01	3.92E-01	3.92E-01	3.92E-01	Gg	1.10E+02	4.31E+01	4.31E+01	4.31E+01	4.31E+01	4.31E+01	4.31E+01
Geothermal (GJ/ha/yr)	1.78E+01	1.78E+01	1.78E+01	1.78E+01	1.78E+01	Gj	7.78E+00	1.38E+02	1.38E+02	1.38E+02	1.38E+02	1.38E+02	1.38E+02
tea	8.65E+06	1.05E+07	1.05E+07	9.89E+06	1.17E+07	g	74895.768	6.48E+11	7.87E+11	7.86E+11	7.41E+11	8.74E+11	7.67E+11
subtotal R= tea								6.48E+11	7.87E+11	7.86E+11	7.41E+11	8.74E+11	7.67E+11
Purchased renewable FR													
labor (10%)	9.01E-03	1.09E-02	1.11E-02	1.01E-02	1.20E-02	$	1.515E+12	1.37E+10	1.64E+10	1.68E+10	1.53E+10	1.82E+10	1.61E+10
Water	3.14E+06	3.75E+06	3.69E+06	3.51E+06	4.02E+06	KG	303221.73	9.52E+11	1.14E+12	1.12E+12	1.06E+12	1.22E+12	1.10E+12
subtotal								9.66E+11	1.15E+12	1.13E+12	1.08E+12	1.24E+12	1.11E+12
Purchased non-renewable FN													
labor (90%)	8.11E-02	9.77E-02	9.95E-02	9.07E-02	1.08E-01	$	1.515E+12	1.23E+11	1.48E+11	1.51E+11	1.37E+11	1.64E+11	1.45E+11
Electricity	4.31E+02	4.79E+02	4.38E+02	4.20E+02	4.50E+02	j	2.100E+05	9.05E+07	1.01E+08	9.20E+07	8.81E+07	9.45E+07	9.32E+07
Depreciation	3.08E-02	2.80E-02	2.97E-02	2.99E-02	2.96E-02	$	1.515E+12	4.67E+10	4.24E+10	4.50E+10	4.53E+10	4.48E+10	4.49E+10
Building maintenance	3.53E-02	4.29E-02	4.26E-02	4.55E-02	4.99E-02	$	1.515E+12	5.35E+10	6.50E+10	6.45E+10	6.89E+10	7.57E+10	6.55E+10
Insurance	8.41E-03	1.11E-02	1.18E-02	1.24E-02	1.32E-02	$	1.515E+12	1.27E+10	1.68E+10	1.79E+10	1.87E+10	1.99E+10	1.72E+10
Agency fees	1.53E-02	1.70E-02	1.44E-02	1.69E-02	2.23E-02	$	1.515E+12	2.32E+10	2.58E+10	2.18E+10	2.57E+10	3.38E+10	2.60E+10
Transport costs	1.90E-03	1.81E-03	1.45E-03	1.46E-03	9.98E-04	$	1.515E+12	2.87E+09	2.75E+09	2.20E+09	2.21E+09	1.51E+09	2.31E+09
Steam(wood fuel)	1.78E+05	2.12E+05	2.08E+05	1.98E+05	2.27E+05	j	2.342E+04	4.16E+09	4.97E+09	4.88E+09	4.64E+09	5.32E+09	4.80E+09
subtotal								2.66E+11	3.06E+11	3.07E+11	3.03E+11	3.45E+11	3.05E+11
purchased resources F= FR+FN								1.23E+12	1.46E+12	1.44E+12	1.38E+12	1.58E+12	1.42E+12
TOTAL INPUT U=I+F								1.88E+12	2.25E+12	2.23E+12	2.12E+12	2.46E+12	2.19E+12
OUTPUT	2.29E+00	2.76E+00	2.70E+00	2.57E+00	2.97E+00	$	1.515E+12	3.48E+12	4.18E+12	4.09E+12	3.89E+12	4.51E+12	4.03E+12
yield													
mdtea	2.05E+09	2.45E+09	2.41E+09	2.29E+09	2.63E+09	gms							
Em-power density								1.48E+08	1.77E+08	1.75E+08	1.67E+08	1.93E+08	1.72E+08
emergy self sufficiency								0.34	0.35	0.35	0.35	0.36	0.35
emergy investment ratio								1.90	1.86	1.83	1.86	1.81	1.85
environmental loading ratio								0.16	0.16	0.16	0.17	0.16	0.16
emergy yield ratio								1.53	1.54	1.55	1.54	1.55	1.54
emergy exchange ratio								1.85	1.86	1.84	1.83	1.83	1.84
emergy sustainability index								9.25	9.77	9.66	9.22	9.50	9.48
emergy index for sustainable development								17.11	18.17	17.75	16.92	17.43	17.48

Appendix 5: Region five, emergy analysis table for small-scale tea processors in Kenya 2012-2016 (/ha/yr).

Item	Raw data (unit/ha/yr) 1	2	3	4	5	Unit	UEV (sej/unit)	Solar emergy 1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	0.118	0.118	0.118	0.118	0.118	Tj	1.00E+00	1.18E-01	1.18E-01	1.18E-01	1.18E-01	1.18E-01	1.18E-01
Wind (TJ/ha/yr)	48.386	48.386	48.386	48.386	48.386	Tj	1.85E+00	8.97E+01	8.97E+01	8.97E+01	8.97E+01	8.97E+01	8.97E+01
Rain (GJ/ha/yr)	0.282	0.282	0.282	0.282	0.282	Gg	1.10E+02	3.10E+01	3.10E+01	3.10E+01	3.10E+01	3.10E+01	3.10E+01
Geothermal (GJ/ha/yr)	30.290	30.290	30.290	30.290	30.290	Gj	7.78E+00	2.36E+02	2.36E+02	2.36E+02	2.36E+02	2.36E+02	2.36E+02
tea	3.43E+06	4.34E+06	4.12E+06	3.72E+06	4.55E+06	g	7.49E+04	2.57E+11	3.25E+11	3.09E+11	2.79E+11	3.41E+11	3.02E+11
subtotal R= tea								2.57E+11	3.25E+11	3.09E+11	2.79E+11	3.41E+11	3.02E+11
Purchased renewable FR													
labor (10%)	7.80E-03	9.19E-03	1.18E-02	6.12E-03	7.37E-03	$	1.52E+12	1.18E+10	1.39E+10	1.78E+10	9.28E+09	1.12E+10	1.28E+10
Water	9.25E+06	1.14E+07	1.12E+07	1.13E+07	1.32E+07	KG	3.03E+05	2.80E+12	3.47E+12	3.40E+12	3.43E+12	4.01E+12	3.42E+12
subtotal								2.82E+12	3.48E+12	3.41E+12	3.44E+12	4.02E+12	3.43E+12
Purchased non-renewable FN													
labor (90%)	7.02E-02	8.27E-02	1.06E-01	5.51E-02	6.63E-02	$	1.52E+12	1.06E+11	1.25E+11	1.60E+11	8.35E+10	1.01E+11	1.15E+11
Electricity	1.30E+03	1.48E+03	1.30E+03	1.30E+03	1.47E+03	j	2.10E+05	2.72E+08	3.12E+08	2.74E+08	2.74E+08	3.08E+08	2.88E+08
Depreciation	3.19E-01	3.32E-01	3.68E-01	3.52E-01	4.21E-01	$	1.52E+12	4.83E+11	5.02E+11	5.57E+11	5.34E+11	6.38E+11	5.43E+11
Building maintenance	5.26E-03	6.31E-03	7.10E-03	7.37E-03	8.63E-03	$	1.52E+12	7.97E+09	9.57E+09	1.08E+10	1.12E+10	1.31E+10	1.05E+10
Insurance	7.00E-03	9.06E-03	1.03E-02	1.00E-02	1.10E-02	$	1.52E+12	1.06E+10	1.37E+10	1.55E+10	1.52E+10	1.66E+10	1.43E+10
Agency fees	3.09E-01	3.55E-01	2.50E-01	3.32E-01	4.45E-01	$	1.52E+12	4.68E+11	5.38E+11	3.79E+11	5.03E+11	6.74E+11	5.12E+11
Transport costs	1.66E-03	1.68E-03	1.33E-03	1.43E-03	1.42E-03	$	1.52E+12	2.51E+09	2.54E+09	2.01E+09	2.17E+09	2.15E+09	2.28E+09
Steam(wood fuel)	4.47E+04	5.52E+04	5.41E+04	5.46E+04	6.38E+04	j	2.34E+04	1.05E+09	1.29E+09	1.27E+09	1.28E+09	1.49E+09	1.28E+09
subtotal								1.08E+12	1.19E+12	1.13E+12	1.15E+12	1.45E+12	1.20E+12
purchased resources F= FR+FN								3.90E+12	4.68E+12	4.54E+12	4.59E+12	5.47E+12	4.63E+12
TOTAL INPUT U=I+F								4.15E+12	5.00E+12	4.85E+12	4.87E+12	5.81E+12	4.94E+12
OUTPUT	2.02E+00	2.47E+00	2.42E+00	2.47E+00	2.89E+00	$	1.52E+12	3.05E+12	3.74E+12	3.67E+12	3.74E+12	4.38E+12	3.72E+12
yield													
mdtea	1.19E+09	1.48E+09	1.45E+09	1.46E+09	1.71E+09	gms							
Em-power density								1.04E+08	1.26E+08	1.22E+08	1.22E+08	1.46E+08	1.24E+08
emergy self sufficiency								0.06	0.06	0.06	0.06	0.06	0.06
emergy investment ratio								15.16	14.38	14.71	16.46	16.05	15.36
environmental loading ratio								0.35	0.31	0.30	0.31	0.33	0.32
emergy yield ratio								1.07	1.07	1.07	1.06	1.06	1.07
emergy exchange ratio								0.74	0.75	0.76	0.77	0.75	0.75
emergy sustainability index								3.03	3.41	3.53	3.43	3.20	3.32
emergy index for sustainable development								2.23	2.55	2.68	2.64	2.41	2.50

Appendix 6: Region six, emergy analysis table for small-scale tea processors in Kenya 2012-2016 (/ha/yr).

Item	Raw data (unit/ha/yr) 1	2	3	4	5	Unit	UEV (sej/unit)	Solar emergy 1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	0.14	0.14	0.14	0.14	0.14	Tj	1.00	0.14	0.14	0.14	0.14	0.14	0.14
Wind (TJ/ha/yr)	50.81	50.81	50.81	50.81	50.81	Tj	1.85	94.15	94.15	94.15	94.15	94.15	94.15
Rain (GJ/ha/yr)	0.28	0.28	0.28	0.28	0.28	Gg	109.92	31.31	31.31	31.31	31.31	31.31	31.31
Geothermal (GJ/ha/yr)	28.95	28.95	28.95	28.95	28.95	Gj	7.78	225.09	225.09	225.09	225.09	225.09	225.09
tea	8.32E+06	1.04E+07	1.02E+07	1.02E+07	1.21E+07	g	7.49E+04	6.23E+11	7.80E+11	7.62E+11	7.64E+11	9.04E+11	7.67E+11
subtotal R= tea								6.23E+11	7.80E+11	7.62E+11	7.64E+11	9.04E+11	7.67E+11
Purchased renewable FR													
labor (10%)	9.16E-03	1.39E-18	1.21E-18	7.73E-19	1.17E-18	$	1.52E+12	1.39E+10	2.11E-06	1.84E-06	1.17E-06	1.77E-06	2.78E+09
Water	4.43E+07	5.45E+07	5.22E+07	4.72E+07	5.81E+07	KG	3.03E+05	1.34E+13	1.65E+13	1.58E+13	1.43E+13	1.76E+13	1.55E+13
subtotal								1.35E+13	1.65E+13	1.58E+13	1.43E+13	1.76E+13	1.55E+13
Purchased non-renewable FN													
labor (90%)	8.24E-02	1.02E-01	1.11E-01	7.68E-02	8.03E-02	$	1.52E+12	1.25E+11	1.55E+11	1.68E+11	1.16E+11	1.22E+11	1.37E+11
Electricity	5.59E+03	6.52E+03	6.00E+03	5.34E+03	6.52E+03	j	2.10E+05	1.17E+09	1.37E+09	1.26E+09	1.12E+09	1.37E+09	1.26E+09
Depreciation	3.87E-02	4.15E-02	4.36E-02	4.29E-02	4.51E-02	$	1.52E+12	5.86E+10	6.30E+10	6.61E+10	6.49E+10	6.84E+10	6.42E+10
Building maintenance	4.89E-02	5.75E-02	6.40E-02	5.86E-02	6.39E-02	$	1.52E+12	7.42E+10	8.71E+10	9.71E+10	8.88E+10	9.68E+10	8.88E+10
Insurance	6.76E-03	1.63E-02	9.38E-03	2.07E-02	9.28E-03	$	1.52E+12	1.02E+10	2.47E+10	1.42E+10	3.14E+10	1.41E+10	1.89E+10
Agency fees	2.00E-01	1.99E-01	1.79E-01	1.84E-01	2.62E-01	$	1.52E+12	3.03E+11	3.02E+11	2.71E+11	2.78E+11	3.97E+11	3.10E+11
Transport costs	2.02E-03	2.12E-03	2.18E-03	1.94E-03	1.96E-03	$	1.52E+12	3.06E+09	3.22E+09	3.31E+09	2.95E+09	2.97E+09	3.10E+09
Steam(wood fuel)	2.96E+04	3.63E+04	3.48E+04	3.15E+04	3.87E+04	j	2.34E+04	6.93E+08	8.51E+08	8.15E+08	7.38E+08	9.08E+08	8.01E+08
subtotal								5.76E+11	6.38E+11	6.22E+11	5.85E+11	7.03E+11	6.25E+11
purchased resources F= FR+FN								1.40E+13	1.71E+13	1.64E+13	1.49E+13	1.83E+13	1.62E+13
TOTAL INPUT U=I+F								1.47E+13	1.79E+13	1.72E+13	1.57E+13	1.92E+13	1.69E+13
OUTPUT	4.34E+04	5.23E+04	5.05E+04	4.61E+04	5.60E+04	$	1.52E+12	6.58E+16	7.93E+16	7.66E+16	6.99E+16	8.49E+16	7.53E+16
yield													
mdtea	3.14E+07	3.86E+07	3.70E+07	3.35E+07	4.12E+07	KG							
Indices													
Em-power density								5.96E+08	7.29E+08	6.99E+08	6.37E+08	7.82E+08	6.89E+08
emergy self sufficiency								0.04	0.04	0.04	0.05	0.05	0.05
emergy investment ratio								22.52	21.99	21.57	19.49	20.25	21.17
environmental loading ratio								0.04	0.04	0.04	0.04	0.04	0.04
emergy yield ratio								1.04	1.05	1.05	1.05	1.05	1.05
emergy exchange ratio								4489.46	4420.89	4451.71	4461.69	4419.20	4446.19
emergy sustainability index								25.52	28.35	27.86	27.10	27.63	27.29
emergy index for sustainable development								114575.20	125322.22	124029.00	120931.23	122088.40	121189.51

Appendix 7: Region seven, emergy analysis table for small-scale tea processors in Kenya 2012-2016 (/ha/yr).

Item	Raw data (unit/ha/yr) 1	2	3	4	5	Unit	UEV (sej/unit)	Solar emergy 1	2	3	4	5	Average
Renewable R													
Radiation (TJ/ha/yr)	7.25	7.25	7.25	7.25	7.25	Tj	1.00E+00	7.25E+00	7.25E+00	7.25E+00	7.25E+00	7.25E+00	7.25E+00
Wind (TJ/ha/yr)	47.65	47.65	47.65	47.65	47.65	Tj	1.43E+00	8.83E+01	8.83E+01	8.83E+01	8.83E+01	8.83E+01	8.83E+01
Rain (GJ/ha/yr)	0.26	0.26	0.26	0.26	0.26	Gg	8.48E+01	2.87E+01	2.87E+01	2.87E+01	2.87E+01	2.87E+01	2.87E+01
Geothermal (GJ/ha/yr)	32.30	32.30	32.30	32.30	32.30	Gj	6.00E+00	2.51E+02	2.51E+02	2.51E+02	2.51E+02	2.51E+02	2.51E+02
tea leaves	1.17E+07	1.49E+07	1.39E+07	1.19E+07	1.52E+07	g	7.49E+04	8.75E+11	1.12E+12	1.04E+12	8.92E+11	1.14E+12	1.01E+12
subtotal R= tea								8.75E+11	1.12E+12	1.04E+12	8.92E+11	1.14E+12	1.01E+12
Purchased renewable FR													
labor (10%)	0.02	0.02	0.02	0.01	0.02	$	1.52E+12	2.82E+10	3.26E+10	3.53E+10	2.19E+10	2.76E+10	2.91E+10
Water	1.29E+07	1.60E+07	1.51E+07	1.29E+07	1.63E+07	KG	3.03E+05	3.91E+12	4.84E+12	4.59E+12	3.92E+12	4.93E+12	4.44E+12
subtotal								3.93E+12	4.87E+12	4.62E+12	3.94E+12	4.96E+12	4.47E+12
Purchased non-renewable FN													
labor (90%)	1.68E-01	1.94E-01	2.10E-01	1.30E-01	1.64E-01	$	1.52E+12	2.54E+11	2.93E+11	3.18E+11	1.97E+11	2.48E+11	2.62E+11
Electricity	1.87E+03	2.27E+03	2.13E+03	1.76E+03	2.12E+03	j	2.10E+05	3.93E+08	4.76E+08	4.47E+08	3.70E+08	4.45E+08	4.26E+08
Depreciation	1.00E-01	9.70E-02	1.10E-01	1.13E-01	1.06E-01	$	1.52E+12	1.52E+11	1.47E+11	1.66E+11	1.71E+11	1.60E+11	1.59E+11
Building maintenance	9.58E-03	8.34E-03	7.20E-03	1.34E-02	1.47E-02	$	1.52E+12	1.45E+10	1.26E+10	1.09E+10	2.03E+10	2.23E+10	1.61E+10
Insurance	1.42E-02	1.93E-02	2.26E-02	2.18E-02	2.27E-02	$	1.52E+12	2.16E+10	2.92E+10	3.43E+10	3.31E+10	3.45E+10	3.05E+10
Agency fees	5.92E-02	6.98E-02	5.08E-02	1.08E-01	7.50E-02	$	1.52E+12	8.96E+10	1.06E+11	7.70E+10	1.64E+11	1.14E+11	1.10E+11
Transport costs	7.80E-03	6.56E-03	6.06E-03	4.85E-03	3.88E-03	$	1.52E+12	1.18E+10	9.94E+09	9.19E+09	7.35E+09	5.88E+09	8.84E+09
Steam(wood fuel)	6.22E+04	7.71E+04	7.30E+04	6.25E+04	7.85E+04	j	2.34E+04	1.46E+09	1.81E+09	1.71E+09	1.46E+09	1.84E+09	1.66E+09
subtotal								5.46E+11	6.00E+11	6.18E+11	5.95E+11	5.87E+11	5.89E+11
purchased resources F= FR+FN								4.48E+12	5.47E+12	5.24E+12	4.54E+12	5.55E+12	5.05E+12
TOTAL INPUT U=I+F								5.35E+12	6.59E+12	6.28E+12	5.43E+12	6.68E+12	6.07E+12
OUTPUT	3.87E+00	4.91E+00	4.58E+00	3.76E+00	4.87E+00		1.52E+12	5.87E+12	7.44E+12	6.94E+12	5.70E+12	7.39E+12	6.67E+12
yield													
mdtea	2.69E+06	3.33E+06	3.16E+06	2.70E+06	3.39E+06								
Indices													
Em-power density								1.58E+09	1.94E+09	1.85E+09	1.60E+09	1.97E+09	1.79E+09
emergy self sufficiency								0.16	0.17	0.17	0.16	0.17	0.17
emergy investment ratio								5.12	4.90	5.04	5.09	4.88	5.01
environmental loading ratio								0.11	0.10	0.11	0.12	0.10	0.11
emergy yield ratio								1.20	1.20	1.20	1.20	1.20	1.20
emergy exchange ratio								1.10	1.13	1.11	1.05	1.11	1.10
emergy sustainability index								10.54	12.01	10.98	9.73	12.51	11.15
emergy index for sustainable development								11.55	13.56	12.14	10.21	13.84	12.16

Appendix 8: Region one economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 1 money						
	2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
INPUT (I)							
Electricity	2.92E+04	2.99E+04	3.13E+04	2.46E+04	2.71E+04	2.84E+04	7.83
Firewood	2.72E+04	3.73E+04	3.83E+04	3.08E+04	3.84E+04	3.44E+04	9.48
Packaging expenses	2.32E+04	2.84E+04	2.70E+04	2.24E+04	2.62E+04	2.54E+04	7.01
ADFF	2.14E+04	2.12E+04	2.20E+04	1.94E+04	2.31E+04	2.14E+04	5.90
AHOF	5.11E+03	6.03E+03	6.34E+03	5.99E+03	5.54E+03	5.80E+03	1.60
Agency fees	1.23E+04	1.50E+04	1.16E+04	1.21E+04	1.64E+04	1.35E+04	3.72
Finance cost	1.48E+05	1.63E+05	1.69E+05	1.54E+05	3.60E+04	1.34E+05	36.95
Labour	2.89E+04	3.47E+04	3.60E+04	3.12E+04	3.76E+04	3.37E+04	9.28
Selling expenses	1.93E+04	2.05E+04	2.94E+04	2.59E+04	2.93E+04	2.49E+04	6.85
Depreciation	2.50E+04	2.70E+04	2.84E+04	2.91E+04	2.84E+04	2.76E+04	7.60
GLManufacturing	1.32E+04	1.56E+04	1.32E+04	1.16E+04	1.50E+04	1.37E+04	3.78
Total input	3.53E+05	3.99E+05	4.12E+05	3.67E+05	2.83E+05	3.63E+05	100
OUTPUT (O)							
TEA	6.97E+05	8.59E+05	8.67E+05	7.89E+05	9.27E+05	8.28E+05	
INDICES							
O/I	1.97	2.15	2.10	2.15	3.28	2.28	
EBU, O-I	3.43E+05	4.60E+05	4.55E+05	4.21E+05	6.44E+05	4.65E+05	

Appendix 9: Region two economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 2 money						
	2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
INPUT (I)							
Electricity	2.50E+04	2.47E+04	2.80E+04	2.36E+04	2.61E+04	2.55E+04	11.05
Firewood	1.77E+04	2.31E+04	2.31E+04	2.25E+04	2.46E+04	2.22E+04	9.63
Packaging expenses	1.41E+04	1.62E+04	1.67E+04	1.52E+04	1.80E+04	1.60E+04	6.96
ADFF	4.76E+03	4.81E+03	5.03E+03	5.23E+03	5.74E+03	5.11E+03	2.22
AHOF	5.07E+03	5.87E+03	6.46E+03	6.93E+03	6.68E+03	6.20E+03	2.69
Agency fees	5.64E+04	6.76E+04	5.60E+04	6.44E+04	8.43E+04	6.57E+04	28.50
Finance cost	1.68E+04	1.89E+04	2.21E+04	3.09E+04	8.45E+03	1.94E+04	8.43
Labour	3.23E+04	3.95E+04	4.21E+04	4.54E+04	5.00E+04	4.19E+04	18.15
Selling expenses	1.32E+04	1.59E+04	1.93E+04	2.18E+04	2.19E+04	1.84E+04	7.99
Depreciation	4.55E+03	4.82E+03	5.39E+03	5.75E+03	5.76E+03	5.25E+03	2.28
GLManufacturing	4.54E+03	4.73E+03	5.05E+03	4.58E+03	5.28E+03	4.84E+03	2.10
Total input	1.95E+05	2.26E+05	2.29E+05	2.46E+05	2.57E+05	2.31E+05	100
OUTPUT (O)							
TEA	6.17E+05	7.53E+05	7.77E+05	7.07E+05	8.01E+05	7.31E+05	
INDICES							
O/I	3.17	3.33	3.39	2.87	3.12	3.17	
EBU, O-I	4.22E+05	5.26E+05	5.48E+05	4.60E+05	5.44E+05	5.00E+05	

Appendix 10: Region three economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 3 money						
	2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
INPUT							
Electricity	2.52E+04	2.52E+04	2.70E+04	2.53E+04	2.55E+04	2.56E+04	11.47
Firewood	1.37E+04	1.88E+04	2.07E+04	2.10E+04	2.31E+04	1.95E+04	8.71
Packaging expenses	4.79E+03	5.56E+03	5.35E+03	5.20E+03	6.00E+03	5.38E+03	2.41
ADFF	6.70E+03	7.53E+03	7.80E+03	8.55E+03	9.90E+03	8.10E+03	3.62
AHOF	3.34E+04	3.76E+04	3.98E+04	4.66E+04	4.61E+04	4.07E+04	18.23
Agency fees	1.71E+04	2.01E+04	1.75E+04	1.95E+04	2.62E+04	2.01E+04	8.98
Finance cost	1.93E+04	1.83E+04	2.07E+04	2.33E+04	4.63E+03	1.72E+04	7.72
Labour	1.03E+04	1.09E+04	1.10E+04	1.19E+04	1.37E+04	1.16E+04	5.19
Selling expenses	7.04E+03	8.28E+03	1.09E+04	1.24E+04	1.23E+04	1.02E+04	4.57
Depreciation	5.60E+04	5.53E+04	5.98E+04	4.96E+04	6.15E+04	5.65E+04	25.27
GLManufacturing	7.50E+03	8.68E+03	8.48E+03	8.10E+03	1.01E+04	8.57E+03	3.84
Total input	2.01E+05	2.16E+05	2.29E+05	2.32E+05	2.39E+05	2.23E+05	100
OUTPUT (O)							
TEA	7.29E+05	8.81E+05	9.14E+05	8.42E+05	9.49E+05	8.63E+05	
INDICES							
O/I	3.62	4.07	3.99	3.63	3.97	3.86	
EBU, O-I	5.28E+05	6.65E+05	6.85E+05	6.10E+05	7.10E+05	6.40E+05	

Appendix 11: Region four economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 4 money						
	2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
INPUT (I)							
Electricity	2.90E+04	2.84E+04	2.99E+04	2.35E+04	2.27E+04	2.67E+04	9.40
Firewood	3.94E+03	5.19E+03	5.35E+03	4.82E+03	5.84E+03	5.03E+03	1.77
Packaging expenses	8.08E+03	9.58E+03	9.13E+03	7.72E+03	8.87E+03	8.68E+03	3.06
ADFF	5.46E+04	5.52E+04	5.23E+04	4.77E+04	5.30E+04	5.25E+04	18.50
AHOF	1.06E+04	1.20E+04	1.31E+04	1.24E+04	1.16E+04	1.19E+04	4.21
Agency fees	5.07E+03	5.69E+03	4.83E+03	4.95E+03	6.52E+03	5.41E+03	1.91
Finance cost	1.58E+04	1.54E+04	1.62E+04	1.25E+04	2.87E+03	1.25E+04	4.42
Labour	9.85E+04	1.19E+05	1.21E+05	1.10E+05	1.31E+05	1.16E+05	40.79
Selling expenses	2.63E+04	3.17E+04	3.23E+04	2.95E+04	3.51E+04	3.10E+04	10.91
Depreciation	4.54E+03	4.77E+03	5.98E+03	6.33E+03	6.82E+03	5.69E+03	2.00
GLManufacturing	9.01E+03	8.18E+03	8.68E+03	8.74E+03	8.64E+03	8.65E+03	3.05
Total input	2.65E+05	2.95E+05	2.98E+05	2.68E+05	2.93E+05	2.84E+05	100
OUTPUT (O)							
TEA	6.70E+05	8.06E+05	7.89E+05	7.51E+05	8.68E+05	7.77E+05	
INDICES							
O/I	2.53	2.73	2.64	2.80	2.96	2.74	
EBU, O-I	4.05E+05	5.11E+05	4.91E+05	4.82E+05	5.75E+05	4.93E+05	

Appendix 12: Region five economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 5 money 2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
INPUT (I)							
Electricity	2.58E+04	2.45E+04	2.91E+04	1.49E+04	1.58E+04	2.20E+04	3.48
Firewood	2.92E+04	3.87E+04	4.19E+04	2.05E+04	2.42E+04	3.09E+04	4.89
Packaging expenses	1.72E+05	2.10E+05	2.23E+05	1.16E+05	1.31E+05	1.71E+05	26.99
ADFF	9.68E+03	1.12E+04	1.27E+04	7.24E+03	8.62E+03	9.89E+03	1.56
AHOF	1.16E+04	1.28E+04	1.59E+04	9.95E+03	1.03E+04	1.21E+04	1.92
Agency fees	1.62E+05	1.86E+05	1.55E+05	9.69E+04	1.30E+05	1.46E+05	23.11
Finance cost	2.79E+04	2.50E+04	3.22E+04	1.82E+04	5.69E+03	2.18E+04	3.45
Labour	3.69E+04	4.34E+04	5.56E+04	2.89E+04	3.48E+04	3.99E+04	6.32
Selling expenses	1.35E+05	1.72E+05	2.03E+05	1.12E+05	1.55E+05	1.55E+05	24.60
Depreciation	7.96E+03	8.27E+03	9.17E+03	8.79E+03	1.05E+04	8.94E+03	1.42
GLManufacturing	1.49E+04	1.85E+04	1.95E+04	9.58E+03	9.30E+03	1.43E+04	2.27
Total input	6.33E+05	7.50E+05	7.96E+05	4.43E+05	5.36E+05	6.32E+05	100
OUTPUT (O)							
TEA	5.89E+05	7.20E+05	7.08E+05	7.22E+05	8.44E+05	7.17E+05	
INDICES							
O/I	0.93	0.96	0.89	1.63	1.57	1.13	
EBU, O-I	-4.44E+04	-2.99E+04	-8.80E+04	2.78E+05	3.08E+05	8.48E+04	

Appendix 13: Region six economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 6 money						
	2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
Electricity	2.16E+04	2.25E+04	2.34E+04	1.48E+04	1.71E+04	1.99E+04	3.06
Firewood	8.08E+04	1.12E+05	1.15E+05	7.22E+04	8.82E+04	9.36E+04	14.39
Packaging expenses	1.30E+04	1.57E+04	1.46E+04	9.11E+03	1.13E+04	1.27E+04	1.96
ADFF	8.54E+04	9.30E+04	9.92E+04	7.16E+04	8.56E+04	8.70E+04	13.37
AHOF	8.91E+03	1.10E+04	1.09E+04	9.49E+03	8.24E+03	9.72E+03	1.49
Agency fees	8.82E+04	9.98E+04	7.44E+04	5.65E+04	8.18E+04	8.01E+04	12.32
Finance cost	2.88E+04	3.33E+04	3.22E+04	2.34E+04	9.36E+03	2.54E+04	3.91
Labour	1.94E+05	2.41E+05	2.61E+05	1.80E+05	1.89E+05	2.13E+05	32.75
Selling expenses	1.00E+04	1.24E+04	1.28E+04	9.99E+03	1.26E+04	1.16E+04	1.78
Depreciation	8.18E+04	8.79E+04	9.23E+04	9.06E+04	9.54E+04	8.96E+04	13.77
GL Manufacturing	9.05E+03	9.25E+03	8.99E+03	5.79E+03	5.96E+03	7.81E+03	1.20
Total input	6.21E+05	7.38E+05	7.45E+05	5.44E+05	6.04E+05	6.50E+05	100
OUTPUT (O)							
TEA	5.16E+05	6.21E+05	6.00E+05	5.48E+05	6.66E+05	5.90E+05	
INDICES							
O/I	0.83	0.84	0.81	1.01	1.10	0.91	
EBU, O-I	-1.05E+05	-1.16E+05	-1.44E+05	3.94E+03	6.14E+04	-6.01E+04	

Appendix 14: Region Seven economic inputs and outputs (ha/yr)

Item	Economical raw amounts for region 7 money						
	2012	2013	2014	2015	2016	AVERAGE	Percentage (%)
INPUT (I)							
Electricity	5.78E+04	6.11E+04	5.83E+04	3.51E+04	3.83E+04	5.01E+04	13.21
Firewood	2.90E+04	4.01E+04	4.03E+04	2.23E+04	2.85E+04	3.21E+04	8.45
Packaging expenses	2.83E+04	3.64E+04	3.24E+04	1.88E+04	2.28E+04	2.77E+04	7.30
ADFF	3.13E+04	2.96E+04	2.80E+04	1.99E+04	2.43E+04	2.66E+04	7.01
AHOF	2.28E+04	2.66E+04	2.92E+04	2.09E+04	2.13E+04	2.42E+04	6.37
Agency fees	2.65E+04	3.02E+04	1.90E+04	1.58E+04	2.19E+04	2.27E+04	5.98
Finance cost	8.61E+04	9.09E+04	8.24E+04	5.46E+04	1.37E+04	6.56E+04	17.27
Labour	5.44E+04	6.29E+04	6.81E+04	4.23E+04	5.32E+04	5.62E+04	14.80
Selling expenses	2.08E+04	2.77E+04	3.07E+04	1.90E+04	2.73E+04	2.51E+04	6.61
Depreciation	2.93E+04	2.84E+04	3.21E+04	3.29E+04	3.09E+04	3.07E+04	8.10
GL Manufacturing	2.13E+04	2.21E+04	2.12E+04	1.31E+04	1.54E+04	1.86E+04	4.91
Total input	4.08E+05	4.56E+05	4.42E+05	2.95E+05	2.98E+05	3.80E+05	100
OUTPUT (O)							
TEA	1.13E+06	1.44E+06	1.34E+06	1.10E+06	1.42E+06	1.29E+06	
INDICES							
O/I	2.78	3.147895	3.031446	3.73218	4.78567	3.38918	
EBU, O-I	7.25E+05	9.79E+05	8.97E+05	8.05E+05	1.13E+06	9.07E+05	

Appendix 15: Research Permit

THIS IS TO CERTIFY THAT:
MS. KARAMBU KIENDE GATIMBU
of EMBU UNIVERSITY,772-60202
MERU,has been permitted to conduct
research in *Bomet , Embu , Kakamega , Kericho , Kiambu , Kirinyaga , Kisii , Meru , Muranga , Nandi , Nyamira , Nyeri , Tharaka-Nithi , Transnzoia , Uasin-Gishu Counties*

on the topic: *SUSTAINABILITY OF THE SMALLHOLDER TEA ENTERPRISES IN KENYA*

for the period ending:
21st December,2017

Permit No : NACOSTI/P/16/5498/15156
Date Of Issue : 21st December,2016
Fee Recieved :Ksh 2000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.
2. Government Officer will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one (1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEACH CLEARANCE PERMIT

Serial No.A 12429

CONDITIONS: see back page