Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Use of Life Cycle Assessment (LCA) to facilitate continuous improvement of on-farm environmental performance: a sheep dairy case study

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Business Studies

In

Management

At Massey University, Manawatū,

New Zealand

Raynisha Mohan

2018

Abstract

Farm management practices have in recent times seen a shift towards a greater focus on sustainable agriculture, concerning environmental impacts and food safety. In New Zealand, the sheep dairy industry has seen rapid growth in the past decade as an alternative dairy source. The importance of sustainability in this industry has been recognised with New Zealand government programmes such as the Primary Growth Partnership, designed to boost the exports of the emerging industry, with a focus on sustainable production. Utilising a Life Cycle Assessment (LCA) based environmental certification scheme as a tool to support continuous improvement of on-farm environmental management can potentially support the emerging sheep dairy industry to define and communicate the sustainability of their farming practices.

This research aims to inform the practice of environmental labelling with application to sheep dairy products and offer a way of validating the sustainability statements made by New Zealand sheep dairy producers in their marketing approaches. The two key objectives of the study were (1) to determine the environmental hotspots of New Zealand sheep dairy farming and what mitigation strategies can be developed, and (2) Develop key performance indicators (KPIs) for an LCA-based farm certification system focussed on sheep dairy in New Zealand. To address objective 1, an LCA study was conducted on a New Zealand sheep dairy case-study farm. Sensitivity analysis around the type of imported grain feed and pesticide used were also conducted. To address objective 2, a review was conducting on four existing environmental certification schemes. Following this, a prototype list of KPIs based on the LCA findings was then designed.

The LCA study utilised a cradle-to-farmgate boundary and included the following activities: livestock emissions; the production and use of fertiliser, herbicides, and pesticides; production of imported supplementary feed; production and use of fuels and electricity; and lastly emissions from milking shed and effluent. The results showed that both the off-farm and on-farm stages contributed to environmental impacts and the production and use of fertilisers, application of pesticides, and enteric fermentation of livestock were found to be the biggest hotspot areas. A prototype environmental certification scheme comprising a Tier 1 KPI framework was then formulated, combining both the LCA results and previously consolidated indicators. Each KPI was categorised under the following themes: land management, nutrient, pesticide, water management, and lastly, energy and carbon management.

This is dedicated to my parents, Mohan and Shanti.

Acknowledgements

I would like to thank my fantastic supervisors from Massey University - Associate Professor Craig Prichard from the School of Management, Professor Sarah McLaren from the School of Agriculture and Environment and NZLCM, and Dr. Eli Gray-Stuart from the School of Engineering and Advanced Technology.

Craig, thanks for introducing me to the world of sheep dairying and the Ewe Can Dairy crew. I appreciate you always having the door to your office open for me to pop by if I ever got stuck with writing or just to chat about sheep milk smoothie bowls and silicon udders for marketing events.

Sarah, thank you for teaching me all about Life Cycle Assessments and Carbon Footprinting. You've helped spark a passion in that field and I truly appreciate all the time and the countless Zoom meetings spent helping me review my GaBi models.

Eli, thanks for always being very supportive and helping me get my head around greenhouse gas calculations.

Thank you to the farm director and sheep dairy manager of the case-study farm for their time and assistance with the project, as well as providing me access to their sheep dairy unit.

I would like to thank Jay Howes from the Fertiliser and Lime Research Centre, for giving me my first crash course on nutrient budgeting and for helping me navigate Overseer. I would also like to express my gratitude to Bob Longhurst from AgResearch for his time and assistance with understanding sheep dairy farming systems.

Special thanks to my friends, postgrad office mates and staff in the School of Management for all the support throughout the completion of my masters.

Finally, I would like to thank my family. This could not have been possible without your support and I am extremely grateful for all the encouragement that you have given me.

June 2018

Ray Mohan

Table of Contents

Abstract i

Acknowledgements iii

Chapter 1: Introduction 1

1.1 Aim 2

1.2 Method and Approach 2

Chapter 2: The Drivers of the Emerging New Zealand Sheep Dairy Industry 5

2.1 Consumer Demands 5

2.2 New Zealand Government Initiatives 6

2.3 Effluent Management Research 7

2.3.1. Effluent Management Guidelines 7

2.4. Summary 8

Chapter 3: LCA and the Sheep Dairy Industry - Literature Review 9

3.1 Introduction to LCA 9

3.2 Stages of LCA 10

3.3 Goal and Scope definition 11

3.4 Life Cycle Inventory 12

3.5 Life Cycle Impact Assessment 13

3.6 Interpretation 13

3.7 Limitations of LCA 13

3.8 Past and Present Literature 14

3.9 Sheep Dairy System 15

3.10 Sheep Dairy Case-studies 15

3.11 Sheep Meat Case-studies 17

3.12 Discussion 18

3.12.1 System Boundaries 18

3.12.2 Functional Unit 18

3.12.3 Allocation 19

3.12.4 Environmental Hotspots Identified 19

3.12.5 LCA and Carbon Footprint Studies in New Zealand 20
3.13 Conclusion - Issues Identified 24
Chapter 4: Environmental Certification & Eco-labelling Systems 25
4.1 New Zealand Environmental Schemes 25
4.2 Characteristics of Certification Systems 27
4.2.1 Agricultural-Focussed Schemes 27
4.3 Categorising Environmental Indicators 31
4.4 Determining the Legitimacy of Certification Systems 32
4.5. Summary 33
Chapter 5: The LCA Case Study 34
5.1 Goal and Scope 36
5.2 Inventory Analysis 38
5.3 Life Cycle Inventory Analysis (LCI) 40
5.4 Life Cycle Impact Assessment (LCIA) 47
5.5 Normalisation 58
5.6 Sensitivity Analysis 59
5.6.1 Maize grain supplement feed 59
5.6.2 Impact of simazine use versus atrazine use 61
5.7 Interpretation 64
5.7.1 Freshwater Ecotoxicity 64
5.7.2 Marine Ecotoxicity 65
5.7.3 Marine Eutrophication 65
5.7.4 Terrestrial Acidification 65
5.7.5 Terrestrial Ecotoxicity 65
5.7.6 Freshwater Eutrophication 65
5.8 Key Findings 65
5.8.1 Fertiliser Use 66
5.8.2 Herbicide Use 66
5.8.3 Pesticide Use 66

5.8.4 On-farm Fuel Use 66
5.8.5 Milking Parlour 67
5.8.6 Sheep Emissions 67
5.8.7 Barley Feed 67
5.8.8 Consideration of Limitations 68
Chapter 6: Development of Prototype Farm Environmental Certification Scheme 70
6.1 Consolidated indicators for prototype scheme 70
6.2 LCA Results and Indicator Development 77
Chapter 7: Discussion and Conclusions 79
7.1 Environmental Hotspots – On-farm versus Off-farm 79
7.2 Prototype KPIs for environmental LCA Farm Certification 81
7.2.1. Framework design 84
7.3 Sample Eco-labelling 85
7.4 Conclusion – Areas for Further Research 86
Appendix A 87
Appendix B Sensitivity Analysis - Impact of on-farm rearing of replacements on carbon footprint ..92
Appendix C – Sample marketing for prototype certification system 95
References 100

List of Figures

Figure 1 - Stages in a LCA study (Reproduced from Circular Ecology (2017)) *10*
Figure 2 - Overview of a dairy sheep farming operation (Reproduced from Vagnoni et al., 2015) *15*
Figure 3 - System Boundary of Dairy Sheep Rearing LCA *38*
Figure 4 - Climate Change results for case study farm *48*
Figure 5 - Proportion of nitrous oxide to methane emitted by sheep *48*
Figure 6 - Fossil Depletion results for case study farm *49*
Figure 7 - Freshwater Ecotoxicity results for case study farm *50*
Figure 8 - Freshwater Eutrophication results for case study farm *50*
Figure 9 - Human Toxicity results for case study farm *51*
Figure 10 - Marine Ecotoxicity results for case study farm *52*
Figure 11 - Marine Eutrophication results for case study farm *52*
Figure 12 - Metal Depletion results for case study farm *53*
Figure 13 - Particulate Matter Formation results for case study farm *54*
Figure 14 - Proportion of emissions to air from fertiliser use *54*
Figure 15 - Photochemical Oxidant Formation results for case study farm *55*
Figure 16 - Proportion of overall emissions for photochemical oxidant formation *55*
Figure 17 - Terrestrial Acidification results for case study farm *56*
Figure 18 - Proportion of contribution to terrestrial acidification impact category *56*
Figure 19 - Terrestrial Ecotoxicity results for case study farm *57*
Figure 20 - Proportion of total emissions for terrestrial ecotoxicity *57*
Figure 21 - Normalised results for impact categories *58*
Figure 22 - Impact category results for maize vs. barley feed production *60*
Figure 23 - Impact category results for on-farm pesticide use scenarios *62*
Figure 24 - Normalised results for total LCA – Simazine scenario *63*
Figure 25 - Normalised results of impact category for LCA stages (produced using GaBi software) *64*
Figure 26 - Prototype eco-labelling *85*

List of Tables

Table 1 - Sheep dairy carbon footprint studies 17
Table 2 - Summary of NZ LCA and carbon footprint studies discussed 23
Table 3 - Sheep dairy farm input and production data 35
Table 4 - Materials and activities dataset 39
Table 5 - Transport of fertiliser from manufacture to farm 40
Table 6 - Herbicide used on case-study farm 42
Table 7 - Transport of herbicide from manufacture to farm 42
Table 8 - Pesticides used on case study farm 43
Table 9 - Transport of pesticide from manufacture to farm 43
Table 10 - Barley grain production inputs (retrieved from Chobtang, 2016) 44
Table 11 - Pesticide input for hectare of barley crop 45
Table 12 - Nutritional value of barley versus maize (Retrieved from Mills, 1982) 59
Table 13 - Input requirements for maize grain production (retrieved from Chobtang, 2016) 59
Table 14 - Percentage difference in normalised total results for supplement feed scenarios 61
Table 15 - Percentage difference in normalised total results for on-farm pesticide use scenarios 63
Table 16 - Primary review of indicators from certification schemes 71
Table 17 - Land Management Indicators 73
Table 18 - Nutrient Management Indicators 74
Table 19 - Pest Management Indicators 75
Table 20 - Energy and Carbon Management Indicators 75
Table 21 - Water Management Indicators 76
Table 22 - Link between LCA result and indicator themes 78
Table 23 - Tier 1 Prototype KPIs 83