

1	Introduction.....	1
1.1	Challenges in Life Cycle Assessments for Agricultural Systems.....	2
1.2	Research Questions and Research Targets of This Work.....	6
2	Results.....	11
2.1	Application of the Cereal Unit in A New Allocation Procedure.....	14
2.1.1	Introduction.....	16
2.1.1.1	Need for an Allocation Procedure in Attributional LCA Modeling for Agricultural Products.....	17
2.1.1.2	Different Allocation Methods as Source of Uncertainty ....	18
2.1.1.3	Unintended Ignoring or Double Counting of Environmental Burden due to Different Allocation Methods.....	19
2.1.1.4	The Cereal Unit as Basis for an Allocation Approach.....	22
2.1.2	Material and Methods — the Cereal Unit.....	23
2.1.3	The Cereal Unit Allocation Procedure.....	23
2.1.3.1	Calculation Procedure.....	23
2.1.3.2	Comparison of Different Allocation Approaches.....	26
2.1.4	Discussion.....	28
2.1.4.1	Cereal Unit Allocation versus Other Allocation Alternatives.....	28
2.1.4.2	Vegetable and Animal in the Same System.....	29
2.1.4.3	Agricultural Co-Products in Supply-Chains.....	31
2.1.4.4	Error and Uncertainty Analysis.....	32
2.1.4.5	The Cereal Unit — Representative of Most Agricultural Products and Co-Products.....	33
2.1.4.6	Cereal Unit in Other Countries.....	34
2.1.5	Conclusions.....	35
2.2	Supplementary Data – Application of the Cereal Unit.....	37
2.2.1	Cereal Unit Conversion Factors for Several Agricultural Products.....	38
2.2.2	Material and Methods – The Cereal Unit.....	50
2.2.2.1	Calculation of the Cereal Unit.....	51
2.3	Modeling Crop Rotation in Agricultural LCAs.....	60
2.3.1	Introduction and Problem Description.....	62
2.3.1.1	Historical Outline of Crop Rotation.....	64
2.3.1.2	Features of Crop Rotations.....	65
2.3.1.3	Positive Crop-Rotation Effects: the Example of Crop Residues.....	66
2.3.1.4	Existing Approaches and Limitations for Inclusion of Crop-Rotation Effects in LCA.....	68
2.3.1.5	The Need to Include Crop-Rotation Effects in LCA: the Example of Crop Residues.....	72
2.3.2	Material and Methods.....	73
2.3.2.1	Mathematical Description of Crop Rotations.....	73
2.3.2.2	By-Product Allocation Approaches and Product-System Expansion.....	78
2.3.3	Methodological Proposal.....	79
2.3.4	Discussion.....	85
2.3.5	Conclusions.....	90
2.4	Crop Rotations and Crop Residues are Relevant for Carbon Footprints.....	92

2.4.1	Introduction.....	94
2.4.2	Methods .....	96
2.4.2.1	Reference Studies.....	99
2.4.2.2	Integrating Crop Rotation Effects and Crop Residues in PCF Results.....	100
2.4.3	Results and Discussion .....	102
2.4.3.1	Impacts of Considering Crop Rotations .....	104
2.4.3.2	Impacts of Considering Crop Residues .....	106
2.4.3.3	Life Cycle Inventory Methods for Assessing Sustainable Agricultural Practices .....	109
2.4.4	Conclusion .....	112
2.5	Supplementary Material – Crop Rotations and Crop Residues.....	114
3	Discussion.....	121
4	Conclusions.....	137
5	Prospects.....	143
6	International Initiatives on Global Challenges for Agriculture.....	147
6.1	Global Challenges and International Agreements.....	147
6.2	Importance of Land Use Activities for Anthropogenic Climate Change.....	149
6.3	International Initiatives on Land Use.....	151
6.3.1	Reducing emissions from deforestation and forest degradation (UN-REDD / REDD+) .....	151
6.3.2	The New Vision for Agriculture by World Economics Forum	152
6.4	FAO Activities Related to Agriculture and Climate.....	152
6.4.1	FAO-Framework: Climate-Smart Agriculture (CSA) .....	153
6.4.2	FAO Framework: FAO-Adapt – Guidance for Climate Change Adaption.....	155
6.4.3	FAO Framework: Save and Grow – Sustainable Crop Production Intensification.....	155
6.4.4	FAO Framework: Global Plan of Action for Genetic Resources (GPA).....	156
6.4.5	FAO Framework: Sustainable Land Management .....	157
6.4.6	FAO Programme: Reducing Enteric Methane for Improving Food Security and Livelihoods .....	158
6.4.7	FAO Programme: Mitigation of Climate Change in Agriculture (MICCA).....	158
6.4.8	FAO Programme: Economics and Policy Innovations for Climate-Smart Agriculture (EPIC).....	159
6.4.9	FAO Programme: Integrating Agriculture in National Adaption Plans (NAPs).....	160
6.4.10	FAO Programme: Livestock Environmental Assessment and Performance (LEAP) Partnership.....	160
6.4.11	FAO-Project: Sustainability Assessment of Food and Agriculture Systems (SAFA) .....	161
6.5	Milestones in the Evolution of the Term ‘Sustainability’ .....	161
6.6	Measuring Sustainability – Life Cycle (Sustainability) Assessment .....	164
	References.....	167
	Annex — Online Tables .....	193