

Tables and figures	5
List of acronyms	6
Glossary.....	7
Summary	10
Zusammenfassung	15
1 General introduction	21
1.1 Societal and scientific relevance of the topic	21
1.2 Research needs	25
1.3 Subject and aim of the work.....	26
2 Method	28
3 State of knowledge – science, applications, and practical adoption	31
3.1 Challenges of farm management and decision support of farms – application potentials of digital systems	31
3.1.1 Technical support for farm management	31
3.1.2 Decision support systems (DSS) for management.....	33
3.1.3 DSS in agriculture	35
3.1.4 Evaluation of available DSS	41
3.1.5 Data networking in agriculture.....	42
3.1.6 Conclusion and evaluation	43
3.2 Challenges in nutrient management.....	45
3.2.1 Complex nutrient and data flows.....	45
3.2.2 Nutrient budgeting	47
3.2.3 Technical and technological developments	50
3.2.4 Necessity for system optimization	51

3.2.5 Conclusion and evaluation	52
3.3 Digital solutions for nutrient management	53
3.3.1 Digital systems for nutrient management.....	53
3.3.2 Interconnection of the systems and data	55
3.3.3 DSS for nutrient management.....	56
3.3.4 Data sovereignty and data security	58
3.3.5 Conclusion and evaluation	60
4 Publications	64
4.1 Conceptual Design of a Comprehensive Farm Nitrogen Management System	64
4.2 A Digital Advisor Twin for Crop Nitrogen Management	66
5 General discussion	68
5.1 Data networking to empower management decisions	68
5.1.1 Data networking on the farm	68
5.1.2 Widening the system boundaries of future nutrient management	70
5.2 Definition and introduction of a Regional Nutrient Management System (RNMS)	72
5.2.1 System context and concept introduction	72
5.2.2 Technical requirements for a RNMS	76
5.2.3 Architecture of a RNMS	79
5.2.4 Cross-system nutrient management through a data space for agriculture	80
5.2.5 Data interlinking in agricultural value chains	85
5.2.6 Data interlinking in regional nutrient cycles and at the landscape level.....	88
5.3 Data-based decision support for nutrient management.....	95
5.3.1 Requirements for a DSS	95
5.3.2 Example of a DSS in organic farming	99
5.4 DSS and the practiced implementation of the decision – the human factor	102

6 Conclusion and outlook 106

7 References 109

8 Appendix..... 130

 A. Acknowledgement 131

 B. Academic Curriculum Vitae 132

 C. Publication Reprints 134

 Conceptual Design of a Comprehensive Farm Nitrogen Management System 135

 A Digital Advisor Twin for Crop Nitrogen Management 160