Climate Change and Household Welfare in Rural Tanzania

Der Wirtschaftswissenschaftlichen Fakultät

der Gottfried Wilhelm Leibniz Universität Hannover

zur Erlangung des akademischen Grades

Doktorin der Wirtschaftswissenschaften

Doctor rerum politicarum

Genehmigte Dissertation

von

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Geboren am 18.07.1984 in Neubrandenburg

2020

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Tag der Promotion	13. März 2019

Acknowledgements

First, I would like to thank my main supervisor Professor Dr. Ulrike Grote for her invaluable advice and guidance through this undertaking. I also thank Professor Dr. Hermann Waibel for useful comments during research seminars and for taking over the role of the second referee. I extend sincere thanks to Professor Dr. Anja Faße for her support at all stages of this thesis.

In addition, I am grateful to have been part of the Trans-SEC project, which aims at "Innovating pro-poor Strategies to safeguard Food Security using Technology and Knowledge Transfer". The project is funded by the German Federal Ministry of Education and Research (BMBF) and the German Federal Ministry for Economic Cooperation and Development (BMZ) and enabled data collection for my research. I acknowledge the support by the Tanzanian farmers and the interviewer team, which built the base for successful data collection.

I would like to thank all my colleagues at the Institute for Environmental Economics and World Trade and at the Institute of Development and Agricultural Economics for their tireless comments when discussing ongoing research. For the successful implementation of field work and fruitful discussions, I extend my special thanks to my colleague and friend Dr. Luitfred Kissoly.

Zusammenfassung

Der Produktionswert des landwirtschaftlichen Sektors ist in den letzten 30 Jahren in vielen afrikanischen Volkswirtschaften konstant angestiegen, trotzdem herrscht Ernährungsunsicherheit weiterhin vor. Dies ist insbesondere für Tansania der Fall, wo das Bevölkerungswachstum stärker war als heimische Produktionszuwächse, die vor allem durch die Ausweitung von Land zu landwirtschaftlichen Zwecken erreicht wurden. Bevölkerungsdruck und eine Übernutzung von natürlichen Ressourcen führte zu weitverbreiteter Bodenverschlechterung.

Unter den Bedingungen des Klimawandels haben es Bauern noch schwerer ihren Ertrag zu steigern bzw. stabil zu halten um ihre Familie das ganze Jahr ernähren zu können. Klimavariabilität und eine Häufung von extremen und wiederkehrenden klimabedingten Schocks wie Dürren und Fluten treten bereits heute in Tansania auf. Einige Bauern passen ihre landwirtschaftlichen Praktiken bereits den veränderten Umständen mithilfe von traditionellen Anpassungsmaßnahmen an. Politische Entscheidungsträger suchen simultan nach nachhaltigen Formen der Intensivierung landwirtschaftlicher Produktion um Ernährungssicherung zu gewährleisten und gleichzeitig die Übernutzung natürlicher Ressourcen zu begrenzen.

Die vorliegende Arbeit zielt darauf ab zum Verständnis von Anpassungsverhalten beizutragen und die Wirkung verschiedener Anpassungsentscheidungen auf die Wohlfahrt von Kleinbauern in Tansania, insbesondere auf deren Ernährungssicherung, zu evaluieren. Im Einzelnen sind die Ziele, (a) die Identifikation der Determinanten der von den Farmhaushalten gewählten Strategien als Reaktion auf den wahrgenommenen Klimawandel und deren Implikationen auf die einzelnen Dimensionen der Ernährungssicherung; (b) die Ausarbeitung der Verbindung zwischen der Wahrnehmung der tansanischen Kleinbauern von klimatischen Veränderungen und ihrem Verhalten; und (c) Erkenntnisse zu gewinnen ob nachhaltige Intensivierung für die ländlichen Kleinbauern in Tansania armutsmindernd ist. Die Arbeit besteht aus vier Kapiteln und basiert hauptsächlich aus Befragungsdaten von 900 kleinbäuerlichen Haushalten in Tansania, die 2014 und 2016 als Panel erhoben wurden.

Kapitel eins stellt eine Einführung in die Arbeit dar durch die Vermittlung von allgemeinen Hintergrundinformationen und dem Hervorheben der Forschungsziele. Ein Überblick über die Hauptergebnisse und angewandte Methoden und Theorien wird ebenfalls präsentiert.

In Kapitel zwei werden mithilfe der Befragungsdaten aus 2014 die durch die Kleinbauern am häufigsten gewählten Strategien der Klimaanpassung untersucht. Die Studie wendet einen logistischen Regressionsansatz an um die determinierenden Faktoren für die einzelnen Anpassungsstrategien zu identifizieren. Der Effekt dieser selbst gewählten Strategien wird dann auf die vier Dimensionen der Ernährungssicherung hin ausgewertet unter Verwendung von Methoden des Propensity-Score-Matchings. Ergebnisse deuten darauf hin, dass die Verwender der Strategien durchschnittlich eine bessere

Ernährungssicherung aufweisen als die Nichtverwender. Insbesondere zeichnen sie sich durch einen diversifizierteren Nahrungskonsum, eine höhere Proteinaufnahme und besseren ökonomischen Zugang zu Nahrung aus. Eine über das Jahr gesehen stabilere Nahrungsversorgung des Haushalts kann anscheinend durch die Strategie eines veränderten Getreideportfolios erreicht werden.

Kapitel drei baut auf dem vorherigen Kapitel auf und entwickelt die Verbindung zwischen der Wahrnehmung der Bauern von klimatischen Veränderungen und ihren damit verbundenen Anpassungsentscheidungen weiter. Fast alle Bauern der Stichprobe nehmen klimatische Veränderungen wahr und berichten von diesen in irgendeiner Form betroffen zu sein. Nichtsdestotrotz ändern einige von ihnen nichts an ihren landwirtschaftlichen Praktiken. Innerhalb der Gruppe, die sich anpasst, wählen nur 10% investitionsintensive und eher langfristig orientierte Strategien, wie zum Beispiel die Investition in ein Bewässerungssystem oder Terrassenanbau. Die Wahrnehmung der Bauern wird grundsätzlich durch Beobachtungen von historischen meteorologischen Daten bekräftigt. Den Annahmen von Grothmann und Patt (2005) folgend, wurde der Entscheidungsprozess der Bauern in Bezug auf den wahrgenommenen Klimawandel mithilfe des logistischen Regressionsansatzes untersucht. Die Ergebnisse deuten darauf hin, dass der Entscheidungsprozess demnach durch eine begrenzte adaptive Kapazität und auch durch die Anpassungsabsicht beeinflusst wird. Diese wird durch die von den Bauern kürzlich gemachte Erfahrung von klimabedingten Schocks und dem damit verbundenen monetären Verlust dargestellt, aber auch durch seine persönlichen Eigenschaften wie Extraversion und Pflichtbewusstsein.

In Kapitel vier wird untersucht ob Maßnahmen der nachhaltigen landwirtschaftlichen Intensivierung armutsmindernd und demnach dem ökonomischen Interesse der Bauern entsprechen, die ihre Familien mithilfe ihrer landwirtschaftlichen Aktivitäten versorgen müssen. Die Anwendung einer bodenschonenden Landwirtschaft wurde auf verschiedenen Ertragsniveaus mithilfe einer Quantil-Regression untersucht. Das Mulchen wird hierbei besonders häufig angewandt, gefolgt vom Fruchtwechsel, dem Brachen, der Mischkultur und dem Bäume pflanzen. Die Ergebnisse deuten darauf hin, dass marginalisierte Bauern den größten Effekt auf ihr landwirtschaftliches Einkommen durch die verstärkte Anwendung von Mulchen haben. Mit steigendem Ertragsniveau bleibt der positive Effekt durch das Mulchen bestehen, aber er schwächt sich etwas ab.

Schlüsselwörter: Kleinbauern, Ernährungssicherung, Tansania, Klimawandel, Anpassung.

Abstract

The production value of the agricultural sector has constantly increased in many African economies over the last thirty years, but food insecurity is still prevailing. This is especially the case for Tanzania, where population growth was stronger than domestic production increases, which were mainly achieved by the expansion into new land for agricultural purpose. Population pressure and an overuse of natural resources as inputs led to widespread soil degradation. Under the changing climatic conditions, farmers are even more challenged to stabilize or even increase their yields in order to provide for their family in any season of the year. Climate variability and an accumulation of extreme and recurring climate-related shocks such as droughts and floods are prevailing in Tanzania. Some farmers already adjust their agricultural practices to these challenges with the application of mainly traditional adaptation measures. Policymakers are simultaneously looking for sustainable forms of intensifying agricultural production to ensure food security while limiting the overuse of natural resources.

The overall objective of this thesis is to contribute to the understanding of the adaptation behavior and to evaluate the impact of different adaptation decisions on the welfare of smallholder farmers in Tanzania, especially on food security. The specific objectives are to (a) identify the determinants of adopting strategies in response to perceived climatic changes by farm households and their implications for different food security dimensions in Tanzania; (b) find evidence on whether sustainable intensification is pro-poor for small-scale farmers in rural Tanzania; and c) elaborate on the link between smallholders´ perception of climatic changes and their behavior in Tanzania. The thesis consists of four chapters and is mainly based on cross-sectional survey data from 900 small-scale farm households in Tanzania collected in 2014 and partly on the follow-up survey conducted in 2016.

An introduction to the thesis is provided in chapter 1 through general background information and by highlighting the research objectives. An overview of the main findings and methodologies used is also presented.

Chapter two analyses the farmers´ most frequent choices of climate-smart adaptation strategies building on baseline survey data. The study employs a logistic regression approach to identify determining factors of the different adaptation strategies. The impact of these self-chosen strategies on the four dimensions of food security is then evaluated using propensity score methods. Results indicate that adopters of climate-smart strategies are on average more food-secure. Specifically, they showed a more diverse pattern of food consumption, greater protein intake and better economic access to food. A more stable food provisioning for the household throughout the year appears to be realized through the adoption of a changing crop portfolio.

Chapter three builds up on the previous chapter and further elaborates on the link between farmers´ perception of climatic changes and their related adaptation decision. Almost all farmers in the sample

perceive climatic changes and report to be somehow affected by these, but still some do not change their agricultural activities at all. Within the group of those who adapt, only 10% chose investment-intensive and rather long-term adaptation strategies such as investing into irrigation or building terraces. Farmers´ perceptions are generally supported by observations from historic meteorological data. Based on the framework of Grothmann and Patt (2005), the farmers´ decision-making process on private adaptation to perceived climatic changes was analyzed using a logistic regression approach. Results reveal that a limited adaptive capacity plays a role in the adaptation decision, but also the intention to adapt. This is represented by the farmers´ more recent experience with climate-related shocks and their related monetary loss, but also by personality traits such as extraversion and conscientiousness.

Chapter four evaluates whether the use of sustainable intensification practices is pro-poor and thus in the economic interest of the farmers, who have to sustain their families based on their agricultural activities. The use of Conservation Agriculture (CA) was analyzed at differing levels of agricultural output based on a quantile regression approach. Mulching is most frequently applied, followed by crop rotation, fallowing, intercropping and tree planting. Results indicate that marginalized farmers have the strongest crop income effect from an increased use of mulching. With increasing levels of agricultural output, the use of mulching remains beneficial for farmers, but the effect appears less pronounced.

Keywords: smallholders, food security, Tanzania, climatic changes, adaptation.

Table of Content

List of Abbreviations

AE	Adult Equivalent
ATE	Average Treatment Effect
ATT	Average Treatment Effect of the Treated
BMBF	German Federal Ministry of Education and Research
BMZ	German Federal Ministry for Economic Cooperation and Development
CA	Conservation Agriculture
CSA	Climate-Smart Agriculture
CSI	Coping Strategy Index
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
FE	Fixed Effect
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GoT	Government of Tanzania
HH	Household
i.e.	Id est
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPIP	International Personality Item Pool
MAHFP	Months of Adequate Household Food Provisioning
MNL	Multinomial Logistic Regression
NBS	National Bureau of Statistics
NDC	Nationally Determined Contribution
NNM	Nearest Neighbour Matching
N	Number of observations
OLS	Ordinary Least Squares
PPP	Purchasing Power Parity
RCP	Representative Concentration Pathway
SAM	Social Accounting Matrix
SE	Standard Error
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
TMA	Tanzanian Meteorological Agency
UNFCCC	United Nations Framework Convention on Climate Change
URT	United Republic of Tanzania
VHO	Village Head Office
WFP	World Food Program

Chapter 1: Introduction

1.1 Background of the study and research motivation

The production value of the agricultural sector has constantly increased in many African economies over the last thirty years (NEPAD 2013). However, poverty rates and food insecurity levels have not equally decreased and partly stagnate on a relatively high level (NEPAD 2013; Pretty et al. 2011). One reason for this is that population growth was faster than productivity increases (NEPAD 2013). The population in Tanzania increased from 21 million in 1984 to 53 million in 2015 according to the Word Development Indicators (World Bank 2018). With a predicted annual growth rate of 2.6% per year, the population in 2035 is estimated to reach at 100 million inhabitants. Agriculture represents about 30% of the Tanzanian Gross Domestic Product (GDP) and it employs about 75% of the population and is thus the fundament of many families in Tanzania. Annual GDP growth since 1990 ranged between 5-7% (World Bank 2018). With a declining Global Hunger Index (GHI) score[1] from 42 to 29 between 1990 and 2017, the score remained on a serious level of hunger (IFPRI et al. 2017). Therefore, although the agricultural output value has constantly risen, it is not enough on a per capita perspective and Tanzania became a net importer for cereals (NEPAD 2013). Increasing agricultural production was mainly achieved by the expansion into new land for agricultural purpose (Pretty et al. 2011). In 2015, about 45% of land area was used for agriculture, which represents an increase of more than 6% since 2000 (World Bank 2017). The take-up of sustainable land use management practices is generally low and therefore soil erosion is widespread (Nkonya et al. 2015; Kassie et al. 2013; Shetto et al. 2007). Common practices of burning crop residues after harvest or selling them to pastoralists or allowing pastoralists to let their livestock graze on their plot after harvest increase soil erosion, as these practices leave the soil bare and vulnerable towards erosion by wind or water (Owenya et al. 2011). Not replenishing lost nutrients in combination with low use of fertilizer cannot build a basis for a stable outcome in agricultural production but results in nutrient mining, soil erosion and soil degradation (Nkonya et al. 2015; Owenya et al. 2011). These negative effects on the environment are not reflected in market prices and therefore represent negative externalities (Baumol and Oates 1988). Another reason for increased soil erosion is related to Tanzania's Ujamaa "villagization" campaign of 1973-1976, which successfully aimed at the relocation of about five million rural peasants into concentrated settlements. Their former homesteads were widely dispersed, but facilitated long and regular fallow periods to replenish nutrients taken up by crops. With

[1] with a score of 0 indicating ‚no hunger' and 100 ‚worst hunger'

more concentrated settlements, an increasing population and less available new land, the traditional practice of leaving land fallow becomes less feasible (Kassie et al. 2013; Shetto et al. 2007).

In addition, changing climatic conditions make it even more challenging for small-scale farmers to provide for their family based on traditional agricultural practices. Climate variability and an accumulation of extreme and recurring climate-related shocks such as droughts and floods are already prevailing in Tanzania (URT 2007). Climate change and food security are strongly interlinked (Tibesigwa et al. 2015; Lema et al. 2014). Farmers are highly vulnerable to yield variations coming from climate-related shocks as production is mainly rain-fed and small-scale (URT 2007). Yields from commonly grown but water-demanding crops such as maize become more unreliable with the changing climatic conditions, which lead to less predictable income and prices and more vulnerable households (FAO 2008b).

The Sustainable Development Goal (SDG) 2 aims not simply at ending hunger, but at achieving food security and improved nutrition while promoting sustainable agriculture (UN 2018). Food security is achieved when all its four dimensions are considered, namely access to food, availability of food, utilization of food and stability of food provisioning over time. These dimensions are based on the concept by FAO (1996): food security exists "when all people at all times have access to safe, nutritious and sufficient food to maintain a healthy and active life". The SDG Report shows that past advances in reducing world hunger were recently vanishing mainly due to factors related to climatic changes such as conflict, drought and disasters (UN 2018). The Tanzanian government reacted already with a climate action plan, submitted to the UN Framework Convention on Climate Change (UNFCCC) in Paris in 2015 (UNFCCC 2015), thus setting own priorities towards adaptation and mitigation of climate change. The farmers are thus encouraged to use 'climate-smart' agriculture and generally more soil conserving practices such as Conservation Agriculture (CA). Business as usual would mean further land degradation and the crowding-out of remaining natural habitats. Therefore, a sustainable form of agricultural intensification without the overuse of natural resources could be the pathway now and in the future to improve the country´s food security status (Pretty et al. 2011).

The decision to adapt is however not only influenced by the farmer's awareness of climate change, as awareness is not necessarily founded only on experience, but can also ground on mass media (radio, newspaper) or on public extension officials informing about the potential threat of climatic changes (Elum et al. 2017). The decision process is also based on 1) a risk appraisal, i.e. the farmers' judgement of how strongly or often the farm is or will be affected, and 2) an adaptation appraisal, where the farmer takes the given adaptive capacity into account (Grothmann and Patt 2005).

Based on this background, one motivation of the thesis is to understand the role of traditional agricultural practices in rural Tanzania and whether they enable the families to be food secure in the entire four dimensions, whereas many studies rather look at either the availability or access dimension (Branca et al. 2011; Di Falco et al. 2011). The suitability of so-called Sustainable Agricultural Practices (SAPs) for smallholder farmers remains a discussion point of ongoing research. Conservation agriculture as an example for SAPs has proved to be a successful approach especially in Latin America. However, a yield increase or a more stable yield from applying it is not always quantifiable in the context of Sub-Saharan Africa (SSA) as various studies showed, for example in Lesotho, Kenya, Tanzania and Zimbabwe (Thierfelder et al. 2017; Marongwe et al. 2011). The focus of the thesis is therefore on the welfare effect of measures taken up by farmers against low soil fertility, but especially against perceived climatic changes over time.

Another motivation is to find out more about the adaptation decision process. Empirical findings on adaptation so far mainly conclude that farmers are more likely to adapt to change depending on their adaptive capacity in terms of education, access to extension and access to credit (Nkonya et al. 2015; Kassie et al. 2015; Below et al. 2012; Di Falco et al. 2011). Grothmann and Patt (2005) already put forward the neglect of motivation in the decision-making process and propose a more cognitive perspective that builds on interdisciplinary research. Therefore, the thesis takes into account the farmers´ personality in the decision process as well as their personal experiences in the recent past besides their long-term observation and thus perception of climatic changes. Building on comprehensive household surveys conducted in the semi-arid Dodoma and semi-humid Morogoro region of Tanzania in 2014 and 2016 respectively, the thesis intents to explain why some farmers do not adjust their agricultural activities despite having the knowledge and the adaptive capacity to do so and puts forward more insights into the farmers´ attitude for change.

1.2 Research objectives

The overall objective of this thesis is to contribute to the understanding of the adaptation decision process itself and evaluate the impact of different adaptation decisions on the welfare of smallholder farmers in Tanzania.

The specific objectives are as follows:

a. To identify the determinants of adopting different climate-smart strategies by farm households and their implications for food security across the different dimensions in Tanzania,

b. To elaborate on the link between smallholders´ perception of climatic changes and adaptation in Tanzania,
c. To find evidence on whether sustainable intensification is pro-poor for small-scale farmers in rural Tanzania.

1.3 Methodologies

The thesis applies a set of theoretical and empirical methodologies that are shortly introduced in this section.

In the first essay, a logistic regression approach is applied to identify determining factors of the farmers´ most frequent choices of adaptation strategies in response to perceived climatic changes. To account for the coexistence of all outcome possibilities, a multinomial logistic regression approach is additionally applied, with one outcome as the baseline being compared with the others (Cameron and Trivedi 2009). The impact of these self-chosen strategies on the four dimensions of food security is then evaluated using propensity score methods. Rosenbaum bounds are additionally computed to control for hidden bias, possibly caused by unobserved heterogeneity (Becker and Caliendo 2007). The dimensions of food security can be named and described as i) food availability, including production, distribution and the exchange of food; ii) food access that relates to affordability, allocation and personal preferences; iii) utilization of food, including issues referring to nutritional quality and quantity, social value and food safety; and iv) stability of food provisioning over time (FAO 2008a). The benefit of the numerous questions in the questionnaire's module on food security is the generation of various food security indicators covering the four dimensions of food security. Since each of the indicators has its limitations in fully covering one dimension and can overlap, two metrics per dimension were included in the analysis for more robust results, where possible (Coates 2013; Maxwell et al. 2014). The essay in chapter 2 can therefore explore the effects of adaptation to climate change on aspects of food security other than the dimensions of availability or access. The "stability" pillar is especially neglected in empirical research, yet this can be hypothesized to be an important factor for increasing food security in the context of small-scale farmers. It captures their suffering from climate variability and is related to the other dimensions of food security (FAO 2008a).

The second essay (chapter 3) aims to contribute to the missing link between perception and adaptation to climate change. The analysis therefore builds on the framework for adaptation towards climatic changes introduced by Grothmann and Patt (2005), in which they describe the decision-making process of why some people show adaptive behavior while others do not, despite the same perceived climatic changes. It is based on the 'protection motivation theory' developed by Rogers and Prentice-

Dunn (1983; 1997) which was found to be applicable in different research areas related to human reaction to threats (Grothmann and Patt 2005). Following this framework, the logistic regression approach includes variables related to the adaptive capacity of the farmer, but also variables related to the farmers´ experience and personality. The farmers` reported perceptions on climatic changes were validated using observations from close meteorological stations in each of the study regions. Aggregated indicators were calculated and analyzed based on daily observations of precipitation and temperatures from 1970 to 2010 using R.

The essay in chapter four focuses on CA, as it is often described as a key toolbox in the transition of farming systems to higher levels of productivity without overusing natural resources (Kassam et al. 2009; Silici 2010). It is an approach within the concept of sustainable intensification, which aims at producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services (Pretty et al. 2011). CA is based on three pillars that include (a) a minimum to zero soil disturbance, (b) a permanent soil cover via crop residue retention, cover crops or agroforestry tree species, and (c) crop diversification through crop rotations and/or intercropping (Mutua et al. 2014; Kassam et al. 2009). In order to evaluate the effect of sustainable measures at different levels of agricultural output and control for socio-economic and farm characteristics, a quantile regression is employed. The use of other CA measures is also included in the set of covariates to control for the substitutive or complementary use of CA measures, as most farmers only apply one or two CA measures, if any. Following Machado, Parente and Silva (2015) quantile regression was performed using Qreg2. This is a Stata module based on robust and clustered standard errors when heteroscedasticity is present.

1.4 Structure of the dissertation and main findings

This thesis is structured into four different chapters. Chapter one provides a general introduction to the thesis including some background information, stating research problems, highlighting the research objectives and providing structural arrangement of the thesis. Chapter two to four are specific articles on Tanzania. A summary of the articles included in this thesis is presented in Table 1.1 and each chapter is briefly elaborated below.

Chapter two analyses the farmers´ most frequent choices of adaptation strategies in response to perceived climatic changes building on baseline survey data. This chapter aims to answer the following research questions: a) which strategies in response to climatic changes do small-scale farmers adopt in Tanzania?, b) what are the determinants for their take-up?, and c) what is the impact of adopted climate-smart strategies on food security? Farmers most often chose strategies related to adjustments in

their crop portfolio, i.e. increasing their portfolio of crops grown or substituting some crop or variety with a more drought-tolerant or earlier maturing crop or variety of the same crop. Only few farmers chose to plant trees on their plots in response to perceived climatic changes. Results indicate that adopters of climate-smart strategies are on average more food-secure. Specifically, they showed a more diverse pattern of food consumption, greater protein intake and better economic access to food. A more stable food provisioning for the household throughout the year appears to be realized through the adoption of a changing crop portfolio towards more drought-resistant or earlier maturing cultivars of the same crop or to change the crop entirely, i.e. from highly preferred but water-demanding maize towards traditional crops such as sorghum or millet.

Chapter three builds on the previous chapter and further elaborates on the link between farmers´ perception of climatic changes and their related adaptation decision. 97% of the sampled farmers perceive climatic changes in the past 20 years and report to be somehow affected by these, especially through lower yields and more frequent crop failures. 46% of them relate this to a lower average annual rainfall volume and 38% to more extreme temperatures on average. Farmers´ perceptions are generally supported by observations from historic meteorological data over a time span of 1970-2010. However, observations did not confirm a change in rainfall volume, but a change in the distribution of rainfall. Specifically, the number of days with precipitation per year decreased over time, but the rainfall intensity on the rainy days simultaneously increased. Despite their perception of climate-related changes, still about one fifth of them do not adapt their agricultural activities at all. Within the group of adapters, only 10% chose investment-intensive and rather long-term adaptation strategies such as investing into an irrigation system or planting trees. The majority reported to adapt using rather short-term strategies, which can be switched from season to season, but do not need long-term investment. These strategies include adjustments of the crop portfolio such as diversification or the shift towards a drought resistant or earlier-maturing crop or cultivar of the same crop. Rather evasive strategies towards perceived changes include going to the forest more often, eating less or replanting. Based on the framework of Grothmann and Patt (2005), the farmers´ adaptation behavior in response to perceived climatic changes was analyzed using a logistic regression approach. Results reveal that farmers only intend to adapt, if he or she recently experienced some monetary loss because of a climate-related shock. Given a high intention, the farmer still depends on access to financial means and networks to realize the adaptation strategy, especially for the investment-intensive long-term strategy. A more conscientious person appears to be less likely to choose the latter, as they feel more bound to traditional strategies and are likely to follow rather the majority (McCrae and Costa 1987; Roberts et al. 2009).

Chapter four evaluates whether the use of sustainable intensification practices is in the economic interest of the farmers, who must sustain their families based on their agricultural activities. The chapter intends to contribute to the debate on whether CA as an environmentally friendly agricultural practice can have a positive crop income effect for small-scale farmers in SSA, as the suitability of CA systems for smallholder farmers remains a discussion point of ongoing research. Despite its success stories in other regional contexts such as Latin America, a yield gain or a more stable yield from applying conservation agriculture is not always quantifiable in various studies in SSA countries, for example in Lesotho, Kenya, Tanzania and Zimbabwe (Thierfelder et al. 2017; Marongwe et al. 2011). Other studies show that in practicing CA, the farmer can achieve a higher and more stable yield and income from their farm compared to conventional agriculture in the long run (Kassam et al. 2009; Owenya et al. 2011). Despite the potential economic benefit and efforts to promote CA practices, the pick-up rate remains low especially in Tanzania, where soil fertility depletion and erosion remains a big problem (Kassie et al. 2013; Shetto and Owneya 2007). In the context of small-scale farm households in rural Tanzania, the analysis focuses on measures of CA at different levels of intensification. The farmers' most frequently used CA measures are identified first including their extent of use on their farms, combinations of measures and their distribution in the two agro-climatically varying regions and on differing levels of intensification. In a next step, factors associated with the adoption of these environmentally friendly measures are presented. Finally, it is analyzed what are the effects on agricultural income of using these measures for low versus higher intensified farm households in the sample. Mulching, i.e., leaving crop residues on the field after harvest, is the most frequently applied measure, with a larger share of farmers in Kilosa than in Dodoma. Other frequently applied practices are crop rotation, fallowing, intercropping and tree planting. Most farmers do not apply more than one CA practice on their farm, so the frequencies of combinations are rather low. The use of CA was analyzed at differing levels of agricultural output based on a quantile regression approach. Results indicate that marginalized farmers have the strongest crop income effect from an increased use of mulching. With increasing levels of agricultural output, the use of mulching remains beneficial for farmers, but the effect becomes less pronounced. Therefore, only mulching appears to be a pro-poor practice, whereas the use of other the other practices seem to not make a difference in the farmers´ crop income.

Table 1.1 Overview of articles included in the dissertation

	Title of the article	Authors	Published in/ submitted to/ Presented at
1	Implications of climate-smart strategy adoption by farm households for food security in Tanzania (2017)	Kathleen Brüssow, Anja Faße, Ulrike Grote	Published in *Food Security* (2017) 9 (6): 1203-1218; earlier version presented at Tropentag 2015 Berlin & at Jahrestagung der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaus e.V. (Gewisola) in Weihenstephan 2017
2	Smallholders' Perception of and Adaptation to Climate Change – Evidence from Tanzania (2018)	Kathleen Brüssow, Christoph Gornott, Anja Faße, Ulrike Grote	Published in *Climatic Changes* (2019) 157(3) 545-563; earlier version presented at 7th Annual Alliance Graduate Summer School "Research Methods in Sustainable Development" in Paris, France (June 2018); Presented at Tropentag 2018 in Ghent, Belgium
3	Is Sustainable Intensification pro-poor? Evidence from small-scale farmers in rural Tanzania (2017)	Kathleen Brüssow, Anja Faße, Ulrike Grote	Published in *Resources* (2017), 6(3), 47; earlier version presented at TransSEC Annual Meeting 2016 in Morogoro, Tanzania

Note: All chapters are mainly developed, analyzed and written by the first author with contributions of Anja Faße, Christoph Gornott and Ulrike Grote. Authors´ contributions to the chapters in detail are as follows: Kathleen Brüssow was responsible for supervision of the data collection activities (second wave), data cleaning (baseline and the second wave), which were the basis for the chapters to follow. For chapters two and three, Kathleen Brüssow generated the idea, performed statistical analyses and wrote the papers. For chapter four, Kathleen Brüssow and Christoph Gornott generated the initial idea. Kathleen Brüssow further developed the idea, performed the analysis and wrote the paper. Christoph Gornott provided the aggregated indicators on climatic changes from historical climate data. Anja Faße contributed on shaping the ideas, provided feedback and revised the drafts of the papers. Ulrike Grote provided suggestions on various aspects during writing and commented and edited the final versions of the papers.

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Chapter 2: Implications of climate-smart strategy adoption by farm households for food security in Tanzania

This chapter is published:

Brüssow, K., Faße, A., Grote, U. (2017). Implications of climate-smart strategy adoption by farm households for food security in Tanzania. *Food Security* (2017) 9: 1203-1218. DOI: 10.1007/s12571-017-0694-y.

It is available electronically at: http://link.springer.com/article/10.1007/s12571-017-0694-y.

Chapter 3: The Link between Smallholders' Perception of Climatic Changes and Adaptation in Tanzania

This chapter is published:

Brüssow, K., Gornott, C., Faße, A., Grote, U. (2019). The link between smallholders' perception of climatic changes and adaptation in Tanzania. *Climatic Change* (2019) 157(3): 545-563. DOI: 10.1007/s10584-019-02581-9.

It is available electronically at: http://link.springer.com/article/10.1007/s10584-019-02581-9.

Chapter 4: Is Sustainable Intensification Pro-Poor? Evidence from Small-Scale Farmers in Rural Tanzania

This chapter is published:

Brüssow, K., Faße, A., Grote, U. (2017). Is Sustainable Intensification Pro-Poor? Evidence from Small-Scale Farmers in Rural Tanzania. *Resources* (2017) 6(3) 47: 1-16. DOI: 10.3390/resources6030047.

It is available electronically at: https://doi.org/10.3390/resources6030047.