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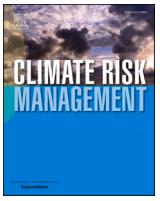

The importance of different land tenure systems for farmers' response to climate change: A systematic review

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ABSTRACT

Climate change increasingly affects agricultural systems, making it necessary for farmers to adapt to changing climatic conditions. An important element shaping farmers' adaptation decisions and their vulnerability is their respective land tenure system. Especially land tenure security can strongly influence farmers' incentives for adapting to climate change. We review the literature to understand to what extent tenure security and other land tenure characteristics affect farmers' ability to withstand climate change and how climate change is operationalised. 106 mostly peer-reviewed studies are examined using thematic network analysis and a network of interactions between land tenure and climate change in farming contexts is devised. The results show that three main interactions link land tenure systems and climate change with regard to agricultural livelihoods: (i) land tenure characteristics influence farmers' adaptation uptake, type and intensity, (ii) certain tenure settings contribute to vulnerability of different socio-demographic groups in agricultural systems, e.g. women, migrants and indigenous communities, and (iii) the perception of tenure security itself is affected by climate change. Yet, the concept of tenure security is poorly defined in most studies, at times resulting in misleading conclusions and leaving important research gaps with regard to optimal land tenure incentives for farmers' adaptation response. Climate change is often simplistically integrated into the assessments, without validation and analysis of longer term trends. None of the studies reviewed provides a comprehensive and systematic treatment of the multiple dimensions linking climate change and land tenure. Further exploration and empirical validation of the connection between land tenure and climate change in agricultural systems is thus warranted. This should include a more critical engagement with the exigencies of climate change response for agricultural systems, such as the need for flexible approaches to deal with climatic uncertainty. The results of this review are relevant for informing adaptation policy, where sustainable land governance has an integral role to play. Designing smart land tenure interventions based on improved understanding of (local) interactions between land tenure and climate can support farmers in effectively addressing the adverse effects of climate change.

1. Introduction

Globally, almost one billion people are thought to live under insecure tenure arrangements, with wide-ranging consequences for

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their livelihoods (Prindex, 2020). Estimates for tenure insecurity prevalence differ widely, a survey carried out in 140 countries between 2016 and 2020 found perceived tenure insecurity shares of between 2% (Turkmenistan) and 48% (Philippines) of the population (ibid.). Those households do not have the security of fully controlling the land they use and depend on, worrying that they may lose their claim. Tenure security is often defined as "the certainty that a person's rights to land will be recognised by others and protected in cases of specific challenges" (FAO, 2002, 3.31).

Lack of secure tenure particularly affects (smallholder) farmers, which crucially depend on their land and the right to use it. Land is valuable to farmers not only in an economic sense. It also shapes social relations, people's identity and is often deeply intertwined with cultural practices (Alexander, 2007; Bonnemaison, 1984). In the context of increasing natural resource scarcity and less available land per capita due to population growth, uncertainty with regard to tenure has been associated with a number of negative behavioural patterns, which may undermine farmers' development efforts and resilience to shocks: tenure insecurity can demotivate long term investment into livelihoods and adoption of improved farming practices, it might constrain farmers' ability to use their land as collateral for credit, it could trap populations affected by disasters and impede them from migrating into safe areas, where they fear to lose the claim to their land and it can fuel conflict over land and the resources tied to it (Lambrecht and Asare, 2016; Mitchell and McEvoy, 2019).

Governments with the support of international experts and donor organisations have attempted to resolve such problems for decades. However, land reform efforts have often proven ineffective, slow and at times even harmful, particularly in sub-Saharan Africa (Platteau, 2000). This warrants continued interest in land tenure research, with climate change now emerging as an additional stressor for land tenure systems, further complicating already complex policy debates (Boone, 2014). Climate risk in the form of rising temperatures, changing precipitation patterns and intensifying extreme events poses new challenges especially for farmers, who rely on weather and climatic conditions to sustain their livelihoods (Hertel and Rosch, 2010). Oftentimes, this not only means more adverse weather conditions, but also increased uncertainty. Where farmers were once able to predict weather and take informed farming decisions, their traditional knowledge accumulated over generations starts to fail them in the face of mounting climate uncertainty (Chengula and Nyambo, 2016; Ebhuoma and Simatele, 2019).

The recent IPCC special report on land highlights the importance of the climate change-land nexus, including the link to land tenure (IPCC, 2019). It reports how insecure land tenure can hinder adaptation and how limited recognition of customary land rights can increase vulnerability, with medium confidence. The authors call for more research into optimal tenure modalities and the policy interventions needed to achieve those (Mirzabaev et al., 2019), with tenure regulations and reforms themselves discussed and promoted as a form of adaptation (IPCC, 2019). As climate change accelerates and countries recognise the need to respond to climate impacts, better understanding adaptation incentive structures and determinants of agricultural resilience gains more relevance. Adaptation can be defined as "[T]he process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities (…)" (IPCC, 2014, p.5). In this context, the study of land tenure systems including tenure insecurity and its implications for smallholder farmers' livelihoods deserves further attention and a new focus: While so far studies on land tenure in rural areas have concentrated on agricultural intensification and development, the performance of different land tenure systems in the face of climate change has been neglected.

In this review we seek to address this gap, analysing the existing literature with regard to the insights it provides concerning the link between land tenure and climate change in agricultural systems. In particular, the following two questions are considered:

(1) What does the literature say about how land tenure systems shape farmers' ability to withstand climate change?

(2) How is climate change operationalised in land tenure studies?

While many studies aim to identify effects of tenure insecurity, in this review we also consider evidence and conceptual arguments that concern land tenure systems and their components as a whole. This stems from the understanding that tenure insecurity is a complex construct which as a highly individual and distinct perception is challenging to measure. For policy-relevance, it is thus also important to consider drivers and determinants of tenure insecurity, when studying incentive structures around land tenure. Section 2 provides a brief overview of the debate on tenure security and agricultural development, followed by an outline of the review methodology in Section 3. In Section 4 the results for both research questions are presented. Section 5 then critically evaluates the present state of research, discussing in particular the operationalisation of tenure security and climate change as abstract concepts and the need for flexible land governance in the face of climate change, as well as remaining research gaps. The final section concludes.

2. Context: land tenure security and agricultural development

The importance of tenure security for incentivizing agricultural investment by farmers has already been discussed at length and is commonly advocated for by experts (Feder and Feeny, 1991; Hayes et al., 1997; Holden and Ghebru, 2016). Reviews of the empirical literature have shown that land tenure security or tenure-strengthening interventions have positive effects on agricultural investments (Higgins et al., 2018), human well-being and environmental outcomes (Tseng et al., 2021) and agricultural productivity (Lawry et al., 2017), although some findings across the mentioned reviews are contradictory. Recent studies have found no effects of land certification on agricultural investment (Huntington and Shenoy, 2021), or smaller effects than expected (Ho, 2021). The main theoretical explanations for a potential positive effect of secure tenure on agricultural investment are: i) freedom from expropriation, ii) use of land as collateral and iii) possibility for gains from trade (Besley, 1995). Such arguments are based on new institutional economics more widely, with its main components property rights theory (Demsetz, 2000) and theories of transaction costs (Barrows and Roth, 1990). They postulate that property rights determine incentives to efficiently use assets and maximise output, and with increasing pressure on land, clearly defined property rights can lower transaction costs of land governance and use. Land rights in itself can be understood as property rights to land, thus forming a specific subset of property rights (FAO, 2002).

Yet, what actually constitutes secure property rights or land tenure security has been the subject of fierce debate. The FAO definition based on the recognition and protection of peoples' land rights is difficult to measure and operationalise. Despite the diversity and inherent complexity of land tenure systems shaping tenure security, the state of tenure security has historically been equated with private property, as presumably most secure form of control over land which minimises transaction costs. This follows from major contributions within new institutional economics (Coase, 1937; North, 1990) and the property rights school (Demsetz, 1967) and for land has been termed the evolutionary theory of land rights (ETLR), as it includes the belief that under population growth and increasing resource scarcity, individualisation of landholding will occur on its own (Platteau, 1996). This long dominant theory was called increasingly into question from the early 1980s onwards (Fenske, 2011; Platteau, 1996; Simbizi et al., 2014). Numerous empirical studies have since argued and found evidence against the ETLR, showing that presumably insecure tenure holdings can be judged secure by their tenants and vice versa (Michler and Shively, 2015; Sjaastad and Bromley, 2000). Since then, many different definitions for tenure security have been proposed, which comprise varying layers of complexity and cut across academic disciplines. Fig. 1 is an attempt to categorise some of the most important developments in this field. Given the large amount of studies on this topic, the illustration does not aim for completeness.

It shows that first definitions of secure tenure centred on economic understandings, which were quickly joined by legal approaches to tenure security. Over time and with mounting empirical evidence contradicting economic theory on tenure security, more complex psychological and systemic definitions entered the academic debate. Nowadays, many different definitions are used and empirical work often approximates tenure security with single indicators, frequently without discussing their theoretical value (Arnot et al., 2011).

One influential theoretical contribution argues that titling of land is key to allow for reaping benefits from formerly informal land holdings (De Soto, 2000). This builds on the ETLR, but believes that policy interventions are needed to bring about (individual) formalisation of land tenure. In practice, such recommendations have led to large-scale land titling programmes especially in African countries, with limited success and insufficient consideration of the complexities of customary, often communal and multi-layered land tenure (Sjaastad and Cousins, 2009). Given the complex and highly diversified nature of land tenure systems, such land reforms have been criticised (e.g. Peters, 2009; Simbizi et al., 2014; Boone, 2019). Numerous studies, some of them concisely synthesized in Peters (2009), have shown that conventional, private titling often does not lead to the desired outcomes, but can instead intensify conflict over land and open up land markets for investors, thus increasing tenure insecurity. While private land titles likely enhance the tenure security of individuals, they exclude farmers with secondary rights to land, formerly recognised under customary arrangements (Lund, 2000). Private property rights to land have shown to often be at odds with local land tenure norms, so much that farmers may disregard official land tenure reforms and continue relying on their customary tenure practices (Ensminger, 1997).

In response to such criticism, more recent titling programmes have shifted to recognising customary tenure structures and entrusting local authorities with enforcing land laws (for instance in Tanzania). Increasingly, communal and customary tenure systems themselves are recognized as potentially secure systems (Fenske, 2011; Tzeutschler, 1999). Nobel prize laureate Elinor Ostrom in a myriad of case studies and detailed field research from across the world showed that groups can efficiently manage resources and devise their own complex rules and enforcement systems, which may under certain circumstances produce outcomes that are superior to private or state ownership (Ostrom, 1990). Her work mostly centred on common pool resources such as irrigation schemes, pastures and fishing grounds, but is equally important for land tenure of arable land.

Tenure security, however, is not solely defined by legal recognition or the type of ownership, but a complex construct and embedded in wider social and institutional dynamics (Chimhowu, 2019; Simbizi et al., 2014). Perceived tenure security is increasingly considered as more important for behavioural incentives and tenure mechanisms than legal recognition (Bruce and Migot-Adholla,

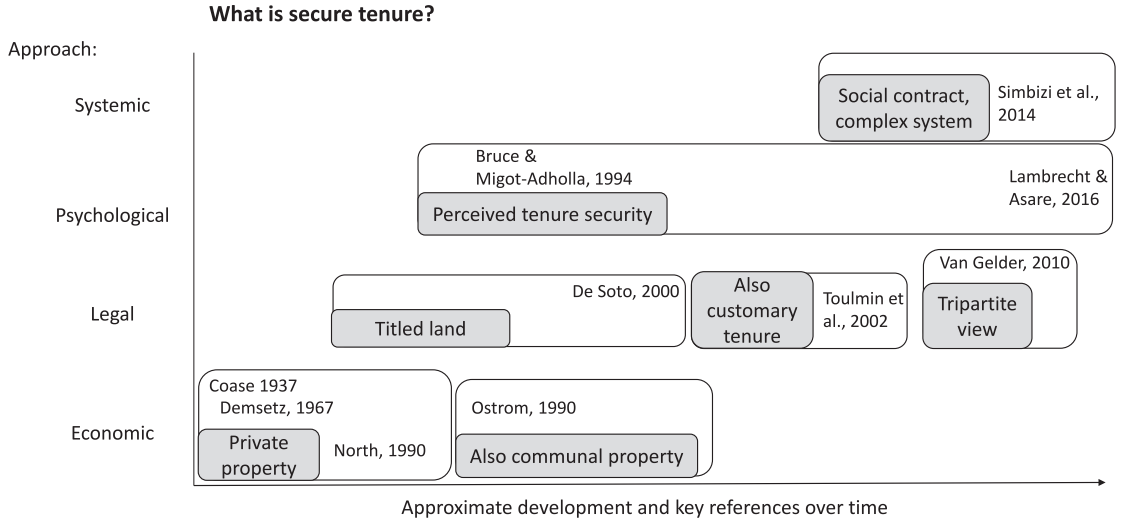

Fig. 1. Conceptual graph showing the development of secure tenure, including some seminal references of different definitions or extensions.

1994; Lambrecht and Asare, 2016). Van Gelder (2010) usefully distinguishes between three forms of tenure security: legal tenure security, de facto tenure security and perceived tenure security. Simbizi devised a comprehensive conceptual framework for understanding and measuring tenure security, including indicators measuring the interactions between different land tenure system elements (Simbizi, 2016; Simbizi et al., 2014). Standard economic theory appears to place too much value on the design of the land tenure system as potential source of tenure insecurity, whereas empirical evidence rather points to other factors, such as conflicts within the family or with outsiders over land. Generally, the focus on tenure security may also be misplaced and can only capture part of the relations and incentives around land tenure (Fenske, 2011).

In real-life settings, different understandings of tenure security and formal land claims have contributed to increasing dispossessions of smallholder farmers and indigenous groups through elite land capture, land concentration and large-scale land acquisitions (LSLAs), particularly in the global South and especially since the sudden interest in farmland after 2008 (De Schutter, 2011). Land held under communal and often customary tenure arrangements is disproportionally affected by LSLAs, with detrimental effects on smallholders' livelihoods (Dell'Angelo et al., 2017, 2021).

Climate change is important to consider in this context, because it can have important implications for both tenure security and agricultural production. Agricultural livelihoods especially in lower- and middle-income countries are highly dependent on weather and climate, while land tenure arrangements are shaped in part by climatic suitability (Kalkuhl et al., 2020; Kugbega and Aboagye, 2021). So far only little abstraction from the limited empirical literature on this nexus has occurred. Borras, Franco and Nam (2020) identify three main interconnections between climate change and land in the context of LSLAs, however, they do not consider the role of land rights in such processes. The IPCC in its 2019 special report on "Climate Change and Land" has mentioned *land tenure security* as desired outcome for climate change mitigation and adaptation (IPCC, 2019), but falls short of a more comprehensive discussion on what securing tenure means, especially for marginalised groups in the context of land inequality (Franco and Borras, 2021).

3. Methods: review and analysis process

Despite the vast amount of literature studying the linkages between tenure security and agricultural development, much less research integrates climate change into the equation. This study attempts to fill this gap, for which we follow a systematic review process using comprehensive keywords for the literature search, with the final sample for analysis determined in an iterative process of screening and evaluating relevant literature based on transparent inclusion criteria (Berrang-Ford et al., 2015; Koutsos et al., 2019). To identify the existing literature on land tenure, climate change and agriculture, the database Scopus was searched using the following search term:

TITLE-ABS-KEY (("land tenure" OR "land rights" OR "tenure security" OR "secure tenure" OR ("property rights" AND "land")) AND ("climate change" OR "climate risk" OR "adaptation" OR "vulnerability" OR "coping" OR "adaptive capacity" OR "drought" OR "flood" OR "hazard" OR "disaster"))

In order to capture all relevant literature on the topic, the search terms were formulated rather openly. A range of possible keywords linked to climate change and weather extreme events were used, since literature may also refer to sudden-onset climatic events instead of gradual climate change. The search string contains no explicit reference to agriculture or rural livelihoods, as this might have falsely led to the exclusion of relevant documents.

The Scopus search returned 1117 documents. Google Scholar was also searched and results were triangulated with the Scopus results, however snowball-sampling proved more efficient to detect documents of interest that were missed by the initial Scopus search.

In a second step, all Scopus search results were screened for relevance to the topic, namely a link to agriculture and rural livelihoods. 305 documents were examined in greater detail to determine if they should be included in the final sample. The inclusion and exclusion criteria are listed in Table 1.

Most documents that passed the final selection stage were peer-reviewed articles or book chapters, but a few selected reports were included, which were deemed to be of great relevance to the topic. The focus on crop agriculture led to the exclusion of articles on pastoralist livelihoods, unless interaction with crop agriculture systems or mixed farming systems was discussed. While issues of land

Table 1
Inclusion and exclusion criteria for documents in the final review analysis.

Criteria type	Inclusion criteria	Exclusion criteria
Publication characteristics	• Written in English • Appeared before and including December 2021 • Peer-reviewed articles, book chapters and selected grey literature	• Written in languages other than English • Appeared after December 2021
Focus on agriculture	• Focus on crop agriculture • Clear link with rural areas and land	• Focus on urban areas • No focus on crop agriculture
Integration of climate change	• Integration of effects of climate change and/or weather extremes in the analysis	• Insufficient engagement with climate change or weather extremes • Focus on climate policy only
Focus on land tenure characteristics	• Integration of land tenure characteristics	• Mere mention of land tenure systems

tenure security for pastoralists under a changing climate are critical for their resilience, they pose different questions from those for agriculturalists and where thus excluded. Importantly, a distinction was drawn between land tenure and land use and mere effects on land use change were not considered. A final limitation was to exclude literature focusing on the impacts of climate policies on land tenure (e.g. REDD+, but also zoning). Although most studies retained concern low income countries, the geographical scope of the review was not limited.

The overall search revealed that the link between land tenure, tenure insecurity and climate change is a relatively recent field of study with few publications before the year 2008 and a rise in publications afterwards. This is in stark contrast to the comprehensive body of literature discussing land tenure, food security and agricultural development (see Fig. 2).

The above exclusion filters left 106 studies for detailed review, which included seven studies that were subsequently added after reading the 99 documents retained from the Scopus query. We then followed a thematic network analysis approach (slightly modified version of Attride-Stirling, 2001) using the qualitative analysis software MAXQDA, to extract insights on how land tenure characteristics influence farmers' ability to adapt and how climate change is integrated into such studies. MAXQDA is a software programme facilitating qualitative data analysis and the use of mixed methods. In MAXQDA, textual data can be organised, coded and analysed. Thematic network analysis is a method that allows to identify common patterns in textual data and to aggregate them to higher order thematic networks. As such the method lends itself well to systematically exploring a body of literature, with few preconceptions regarding the content.

After reading the first few papers, a coding framework was devised which was used for coding all 106 documents. Besides extracting descriptive information regarding the methodology and scope of the documents, the empirical evidence and hypotheses found regarding interactions between land tenure and climate change in agricultural contexts were used to fill a thematic network of (presumably causal) interactions. The network was subsequently interpreted according to information regarding the concrete linkages found or assumed, the direction of effects identified, if available the strength of effects and possible contradictions between studies. Particular emphasis was placed on how climate change and land tenure were integrated in the research, including which variables were used, if any.

4. Results

Out of the documents finally included in this review, the majority focused on climate change and only included land tenure as a side aspect (N = 59), with some focusing on land tenure and treating climate on the side (N = 10). Although only 37 documents directly discussed the link between land tenure and climate change or extreme events in agricultural systems (in the following referred to as "core sample"), the remaining 69 documents were also reviewed, in order to capture all relevant information. The core sample is largely case study-based or contains conceptual articles, with few detailed empirical studies. It also suffers from methodological shortcomings and no study provides a comprehensive and systematic overview on the different interactions between land tenure and climate change.

Fig. 3 shows the locations of case studies within the review sample by continent (N = 38). As can be seen, the large majority of case studies concentrates on lower income countries, with only few studies focusing on the United States and Australia. 47 % of the case studies (48 out of 103) are located in sub-Saharan Africa, pointing to the special relevance of the topic for this region, whereas no studies were found for Europe and North Africa.

4.1. What does the literature say about how land tenure systems shape farmers' ability to withstand climate change?

Three main linkages or interactions between land tenure and climate change in agricultural systems could be identified and

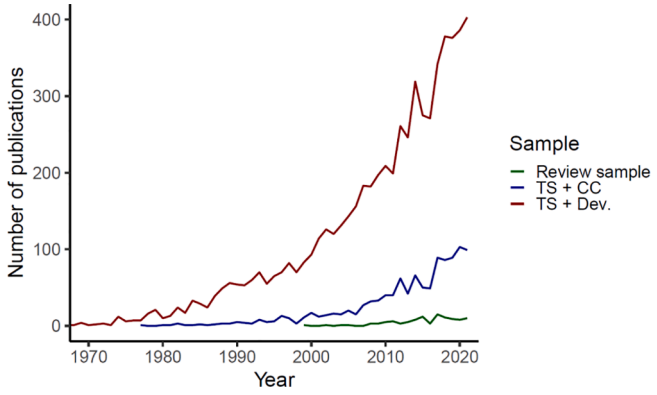

Fig. 2. The development of publications over time for a) land tenure and agriculture/development/investment (red line, total N = 6157), b) land tenure, climate change and agriculture (blue line, total N = 1117), c) land tenure and explicit climate change integration (green line, total N = 106). The full search strings for a) and b) can be found in Annex A, Annex B contains the full list of studies included in c). Few studies appeared before 1970 (not shown here).

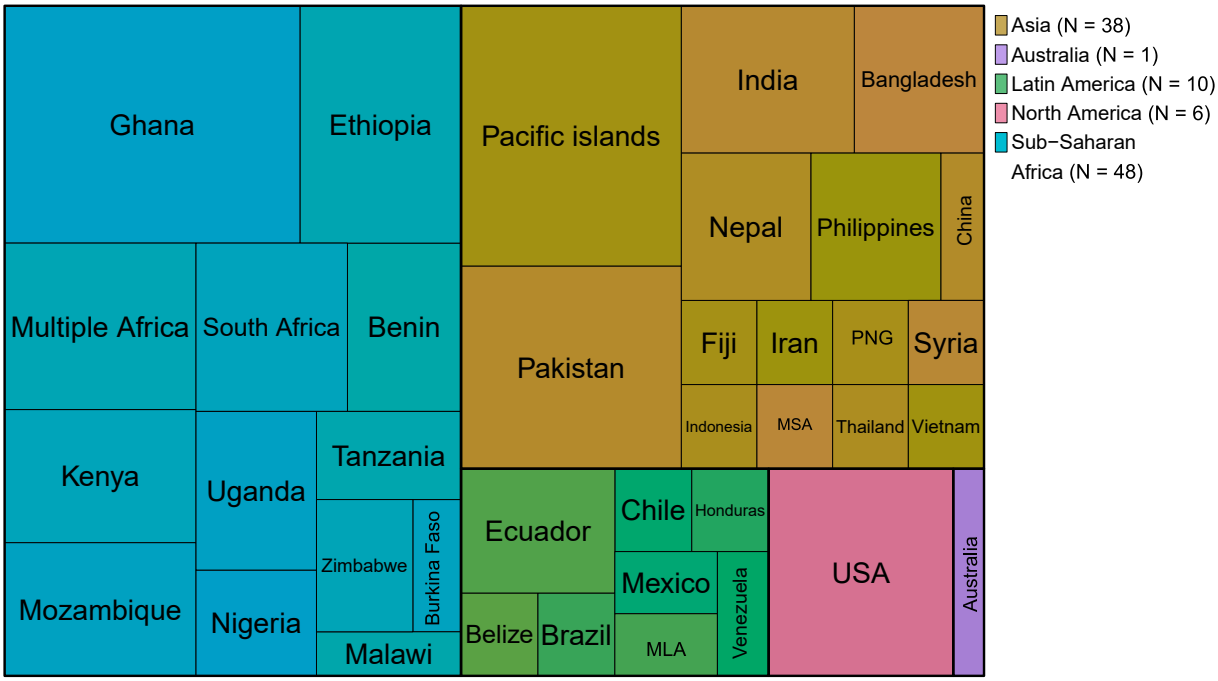

Fig. 3. Case study areas included in the review documents, with the size of each square corresponding to the number of publications per country or region. Abbreviations used: PNG: Papua New Guinea; MLA: Multiple Latin America; MSA: Multiple Southeast Asia.

grouped into a thematic network, which influence in how far farmers within those tenure arrangements are able to address climatic pressures (Fig. 4). First, a bulk of research considers in how far land tenure characteristics affect farmers' decisions to adapt to climate change, or to cope with it. A second strand of the literature seeks to understand the importance of land tenure dynamics for vulnerability/resilience of farmers and demographic sub-groups to climate change. Finally, a third link regards the reverse impact climate change might have on land tenure systems, particularly with regard to perceived tenure security. A fair share of publications address more than one of those linkages, particularly the conceptual-, case study- and grey literature. This also illustrates that the three interactions are not independent from each other and the division is not always clear cut.

The methodologies employed within the review sample are distinctly spread across the three main interactions identified. While most studies can be qualified as belonging to the social sciences, namely economics, political science, human geography and

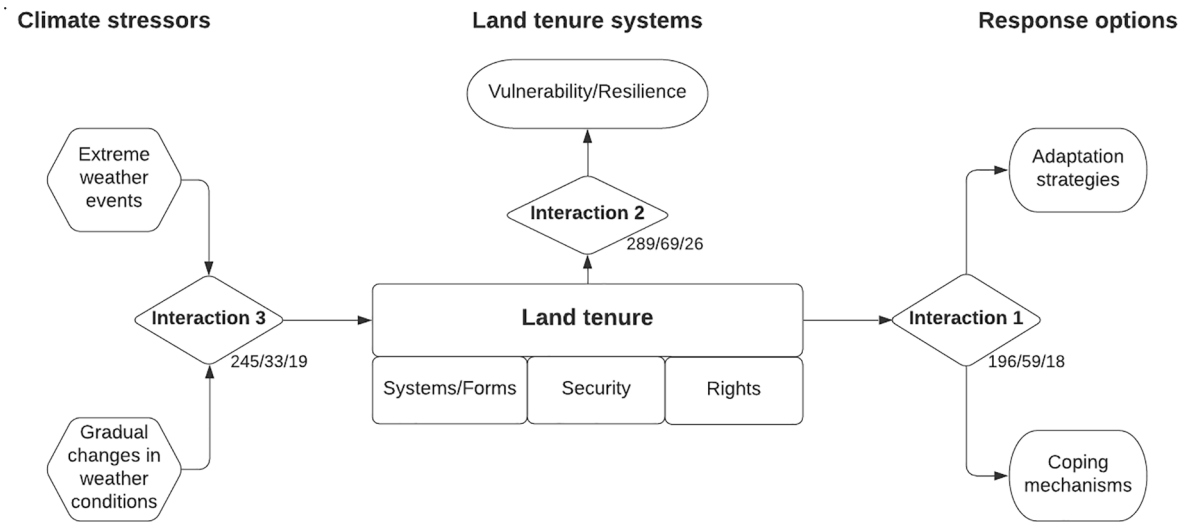

Fig. 4. Overview thematic network of climate change and land tenure interactions in agricultural systems. The numbers below the interactions indicate the amount of codes assigned, the number of documents containing information on the interaction and the number of documents that are part of the core sample, respectively. Arrows indicate potential effects of system components.

anthropology, the sample also contains a few natural science papers (e.g. Graw et al., 2017; Sharma and Sharma, 2011) and legal science articles (e.g. Barrière, 2017; Richardson, 2017). Of particular interest for this review are the empirical studies using statistical or qualitative research methods. Data used for the studies vary according to discipline, the qualitative studies mostly rely on small N interview and focus group data, whereas the econometric literature uses cross-sectional household survey data often from one specific location in a country, with sample sizes rarely exceeding 500 observations. Some of the studies integrate observed climate data from weather stations, commonly for mean temperature and precipitation.

Fig. 5 gives on overview on which methods were used for studying which interaction between land tenure and climate change.

It becomes apparent that the first interaction has received most attention in the econometric and statistical literature with 30 studies, whereas more qualitative evidence exists for the second interaction. The effect of climate change on land tenure dynamics has received least empirical attention (N = 10), but has also been discussed in conceptual and review studies. A look at the core sample of most relevant papers according to their focus shows, that most have discussed the vulnerability aspect of land tenure characteristics (N = 22), whereas a considerable amount of studies looking at the first interaction with adaptation uptake do not fall into the core sample. Considering the different geographies, the first interaction on adaptation and coping is the most studied interaction for the African case studies, whereas in Latin America and Asia the second interaction on vulnerability and resilience has received more attention.

4.1.1. Uptake of adaptation strategies and coping mechanisms under different land tenure regimes

Interaction 1 describing the influence of tenure security and other tenure indicators on adaptation and coping decisions of farmers is best quantified in the literature (see Fig. 6 for this part of the network). This mirrors the many studies focusing on the investment effects of secure tenure. In the adaptation studies integrating climate change, land tenure is rarely the focus. Many papers investigate barriers or drivers of adaptation generally and then find that land tenure systems are an important factor with statistically significant influence (Alam, 2015; Roco et al., 2014). At the same time, adaptation can also influence land tenure, for instance where improvements into land strengthen land rights, which is however much less studied (Garibay et al., 2010). Finally, tenure policies themselves can be regarded as adaptation, where they improve farmers' resilience to climate change (McEvoy and Mitchell, 2019; Mensah, 2015).

Integration of land tenure characteristics in literature quantifying this interaction is often simplified, more than half of the quantitative studies only distinguish between whether a farmer owns land or not, with most of them equating ownership with tenure security (Fig. 7). Noteworthy for their integration of tenure variables into econometric models are the studies of Alemayehu and Bewket (2017), Akugre et al. (2021) and Jha et al. (2021), who use perceived tenure security, and the study of Yegbemey et al. (2013), who use both variables regarding the mode of acquisition of land and different land rights that are held. However, Alemayehu and Bewket's study does not disclose how they define and measure perceived tenure security.

As regards the adaptation effects, most studies either assess uptake of adaptation generally using a binary variable (yes/no) (N = 13), or the uptake of several strategies, using multinomial or multivariate models (N = 10). A few analyses also focus on coping strategies following climatic shocks (Batool et al., 2018; Hisali et al., 2011). All quantitative studies focus on one country and often one region, which is reasonable given the diversity of land tenure systems even within countries, but still an important caveat.

For the uptake of adaptation generally or different adaptation strategies more specifically, results vary according to the study location and type of tenure variable used. Land ownership was found to positively influence uptake of adaptation by some (Diendéré, 2019; Fosu-Mensah et al., 2012; Roco et al., 2014), while other studies found mixed effects depending on the adaptation strategy (Lokonon and Mbaye, 2018; Ullah et al., 2019) and again others report negative effects of land ownership on uptake of adaptation (Alam, 2015; Ali and Erenstein, 2017).

With regard to the effect of formal or informal land tenure on adaptation, evidence is equally inconclusive. In a study from Uganda,

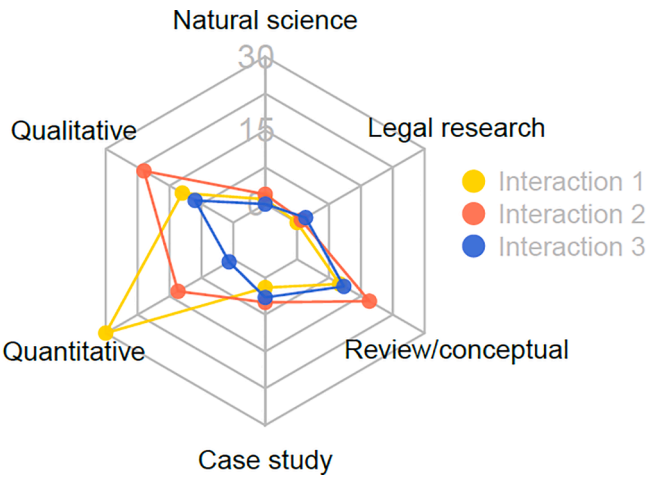

Fig. 5. Type of evidence for the three main interactions between land tenure and climate change identified from the review sample (in N documents). The total number of methods used adds up to more than 106, since some documents employed more than one method.

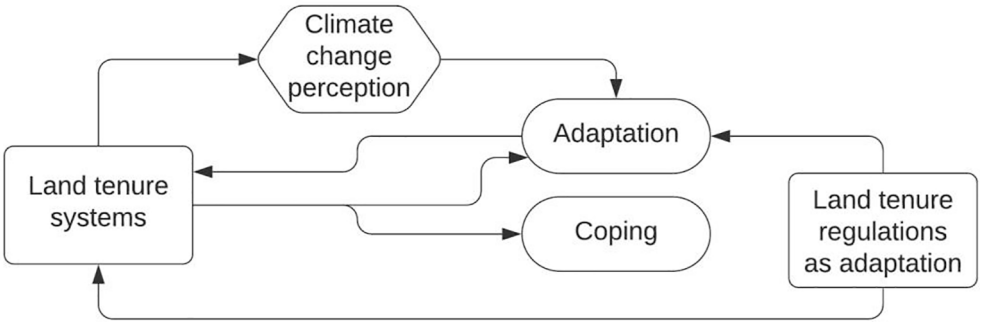

Fig. 6. Network of interaction 1 regarding potential land tenure influences on adaptation and coping strategies.

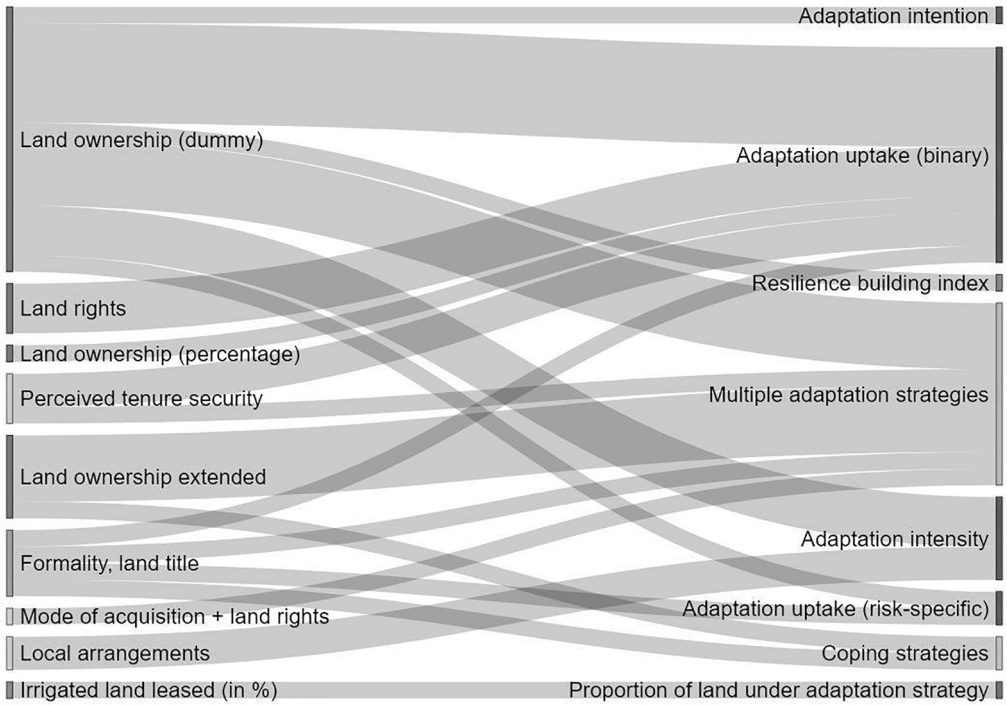

Fig. 7. Sankey diagram showing key variables used in the quantitative literature on interaction 1: Independent variables approximating tenure security on the left and adaptation outcome variables on the right. The width of the bars illustrates the amount of studies using a specific link.

Hisali et al., 2011 distinguish farmers' responses to different shocks and find that formal types of land tenure enable farmers to cope with droughts, livestock epidemics and floods more efficiently than customary tenure arrangements would, via the use of technology and reducing consumption. For some adaptation strategies, formal land titles are required, in particular for the uptake of insurance (Otsuki and Jasaw, 2017). Yet in Nepal, while a higher share of unregistered land was found to deter investment into larger water tanks, for other adaptation strategies no significant difference with largely titled land was found (Piya et al., 2013). A qualitative case study from Northern Ghana states that collective organisation, often associated with customary tenure, would benefit farmers, by enabling them to share costs and benefits of larger adaptation infrastructure, such as irrigation schemes (Otsuki and Jasaw, 2017). Some studies also consider the intensity of adaptation, using the number of adaptation strategies adopted by farmers as dependent variable, mostly finding positive effects of land ownership on adaptation intensity (Diendéré, 2019; Roco et al., 2014; Teklewold et al., 2019).

In contrast with the literature on land tenure and agricultural development, when integrating climate change into the analysis, studies often focus not only on agricultural intensification such as increased input use, but also on biodiversity conservation and land restoration efforts. A prime example is the implementation of agroforestry systems. Planting of trees leads to a number of interesting questions with regard to land tenure: on the one hand, farmers with insecure tenure are often reluctant to plant trees, because they do not know if they can reap benefits from planting them in the future (Antwi-Agyei et al., 2015). On the other hand, planting trees can actually establish rights over land and thus increase tenure security (Besley, 1995). This has led to the practice in some farming areas of

not allowing renters of land to plant trees on it (Panichvejsunti et al., 2018). In communal areas, the planting of trees can be seen as an unfair practice, when land claims are created in this way and land is thus taken away from the community pool (Kongsager, 2017).

Agroforestry practices are a good example of a peculiarity specific to the interlinkage between land tenure and adaptation uptake: the time dimension of adaptation responses is important when considering which land tenure characteristics (especially tenure security) enable which forms of responses. A number of studies discuss this issue, noting that adaptation strategies with longer return-to-investment periods, such as agroforestry, soil conservation techniques and larger infrastructure construction, require more secure tenure arrangements (Mutabazi et al., 2015; Piya et al., 2013; Teklewold et al., 2019). Otherwise farmers would fear not to be able to benefit from the investment taken, in case they lose their land before benefits incur. This in turn means that investments with a shorter time horizon may not be so sensitive to secure tenure arrangements.

4.1.2. Land tenure systems and farmers' vulnerability

The impact of land tenure characteristics on farmers' vulnerability has received more attention in a qualitative manner and from case studies, as opposed to the first interaction. Also in this strand of literature, tenure security in quantitative studies is most often operationalised via land ownership (Abid et al., 2019; Fernandez et al., 2015a; Rondhi et al., 2019). Few studies consider land titles (Panichvejsunti et al., 2018), distinguish between common and privately governed land (Toni and Holanda, 2008) or use an index of land tenure measures representing different aspects of tenure security (Ajefu and Abiona, 2020). Quantification is largely limited to descriptive computation of vulnerability indices, where the underlying mechanisms are assumed to hold and land tenure is included in the form of land ownership (Enete et al., 2016; Fernandez et al., 2015b; Olivares et al., 2017).

Fig. 8 shows the thematic network for interaction 2, the components of which are further discussed below. Land tenure systems especially influence farmers' vulnerability in a concrete disaster context, as many studies noted (Garibay et al., 2010). Vulnerability (or reversely resilience) is affected via various channels: Most often discussed in the literature were climate change perception of farmers, opening up of land markets, access to credit, general income level or asset ownership and conflicts arising due to tenure questions. A frequent theme were demographic groups that are particularly vulnerable to climate change due to their land tenure settings. Further, Antwi-Agyei and Stringer (2021) document that complex land tenure settings can complicate effectiveness of extension advice.

Few quantitative studies investigate causal relationships between land tenure characteristics and vulnerability proxies or channels affecting vulnerability. In econometric analyses, notably the perception of climate change has been studied. The evidence is inconclusive, with one study finding that land ownership leads to a more accurate perception of climate change (Abid et al., 2019), a second study reaching the opposite conclusion of less accurate perception (Rondhi et al., 2019) and a third study finding no significant effect (Lokonon and Mbaye, 2018). The intuition here is that long-term knowledge (often, but not always associated with land ownership) can enable farmers to better know about past changes in the climate and allow them to put recent changes into perspective. Qualitative and case study evidence also links land tenure systems with farmers' income and asset base, highlighting the importance for vulnerability/resilience in the face of climate change (Chagutah, 2013; Eriksen and Silva, 2009; Garibay et al., 2010).

On a general level, farmers without titles to their land are often said to be particularly vulnerable, especially in the context of natural disasters and relocation. Without having evidence of their land rights they then face potential loss of their land (Charoenkalunyuta et al., 2011; Mitchell, 2014). If the fear of losing land gets too large, people may even prefer to stay in a hazardous situation rather than migrating, which could trap them in highly vulnerable environments or induce them to quickly return to their land after a disaster (Garibay et al., 2010). However, it is not necessarily land titles formally registered with state authorities that are needed. Case study evidence also shows that communal recognition of land rights can act as a strong safety net in the face of disasters, where afterwards villagers jointly reclaim their land and acknowledge pre-existing land rights (Garibay et al., 2010). The term "living cadastres" has even been coined for older-aged community members who thanks to their long memory and often respected position within the community can testify in case land tenure disputes arise (Garibay et al., 2010). Yet, with more severe disasters and long-term displacement such social recognition of land claims may reach its limits.

Not owning land or having an official title can also be an obstacle for obtaining credit due to lack of collateral, which farmers need to invest more into their land (Bizikova et al., 2015; Ullah et al., 2019). However, what constitutes sufficiently secure collateral for

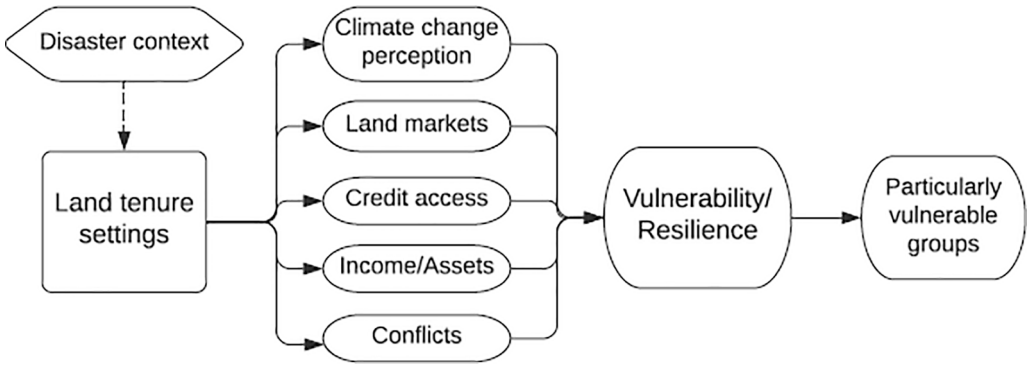

Fig. 8. Network of interaction 2 regarding potential land tenure influences on vulnerability/resilience to climate change. The dotted arrow represents a potential further compounding factor, influencing the rest of the chain.

obtaining credit varies considerably across countries. While pledges from local leaders can at times be sufficient for obtaining credit (Garibay et al., 2010), in other instances (in Zimbabwe) not even 99-year government leases are sufficient (Mutandwa et al., 2019).

Some further avenues by which different land tenure arrangements can affect farmers' vulnerability to climate change concern conflicts over land, which can arise due to unclear claims or competing user interests (Mapfumo et al., 2013), unsustainable use of land and clearing of forests by farmers with insecure land tenure, but also the opening up of land markets when transforming formerly communally managed land into individualised private property (Ianni, 2014). Such modern land reforms do not always positively affect farmers, but have also been found to attract large-scale land investments and force farmers to sell their small parcels, leaving them arguably in a more vulnerable position than before (Kongsager, 2017). With regard to customary and communal tenure systems, some studies also mentioned the importance of social cohesion and communal safety nets provided by such systems in the face of climatic shocks (Albert et al., 2018; Otsuki and Jasaw, 2017).

The theme most discussed in the literature, but rarely quantified, is which demographic groups are most vulnerable to climate change due to their land tenure situation. Most frequently mentioned are women (Casolo, 2009; Friedman et al., 2019; Mcleod et al., 2018; Nyahunda et al., 2021; Otsuki and Jasaw, 2017; Quan and Dyer, 2008; Reale and Handmer, 2011; Robledo et al., 2012), pastoralists (Descheemaeker et al., 2016; Quan and Dyer, 2008; Reale and Handmer, 2011; Smucker and Wisner, 2008), indigenous peoples (Hansungule and Jegede, 2014; Quan and Dyer, 2008) and migrants (Antwi-Agyei et al., 2015; Etongo et al., 2015; Otsuki and Jasaw, 2017). Gendered constraints to adopting climate adaptation practices are quantified in a study for Ethiopia (Tsige et al., 2020), which finds that women living in male-headed households have much lower access to land than men or women in female-headed households. Distribution of land depends on decisions taken by men, especially widows are left in a vulnerable position, who often depend on the remaining family's goodwill to let her keep some land after the deceased husband. Challenges for migrants arise with regard to permanent access to land. Often they are dependent on the receiving communities' benevolence to allocate land for their use, which can be revoked at any time and thus bars long-term investment into land, such as planting trees (Antwi-Agyei et al., 2015; Etongo et al., 2015). This enumeration shows that insecure land tenure arrangements frequently coincide with existing vulnerabilities.

4.1.3. Climate change impacts on land tenure systems and perceived tenure security

The third interaction from climate change on land tenure has received least explicit attention in the literature so far, especially in peer-reviewed studies, as also noted by other scholars (Holden and Ghebru, 2016). Climate change and land tenure variables are mostly mentioned as concurrent drivers of low agricultural intensification or food insecurity. Some grey literature reports and particularly studies focusing on climatic extremes and disaster risk reduction have however discussed this interaction, without statistically studying it (Garibay et al., 2010; Quan and Dyer, 2008). Only one peer-reviewed study econometrically analyses a part of this interaction: Using a large cross-sectional dataset for nine African countries, Kalkuhl et al. (2020) find that sharecropping is endogenous to climatic conditions, notably low mean precipitation levels, but do not find a link with climate risk, represented by precipitation variability.

Despite this dearth of empirical evidence, some studies mention the linkage or present anecdotal evidence. Fig. 9 shows the thematic network for interaction 3 and reveals that impacts of gradual climate change or from extreme events on land tenure are mostly indirect, thus involving mediating steps in between land tenure indicators and climate impacts. Two main channels exist: the first represents cultural or psychological impacts on tenure due to climate change. This can take the form of traditional tenure systems being lost due to climatic changes as a cultural effect (Garibay et al., 2010; Rahimzadeh, 2020). It can also mean climatic events that affect farmers' perceived tenure security, due to (repeated) incidents that spur worry about land (Garibay et al., 2010; Reale and Handmer, 2011).

The second channel of physical impacts translates into second order effects, which can then influence tenure security. Land use generally is threatened by physical impacts on land and its loss, for instance due to sea level rise or land degradation, which can have effects on tenure security (Bastakoti et al., 2017; Chagutah, 2013; Garibay et al., 2010; Hansungule and Jegede, 2014). This links to the legal debate on compensation for territory lost due to climate change (Dietrich and Wündisch, 2015).

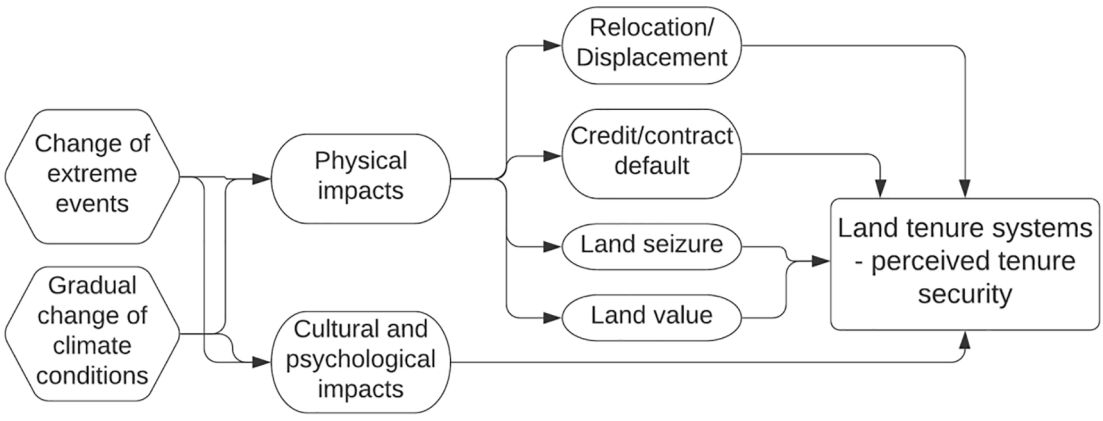

Fig. 9. Network of interaction 3 regarding potential climate change influences on land tenure systems, particularly tenure security.

But physical consequences of climate change can also challenge farmers' tenure security by destroying the basis of their livelihoods, rendering them vulnerable to claims that may cost them their land. This can happen for instance when crop production is lower or altogether lost due to unfavourable weather conditions: farmers who owe rent or sharecropping shares to the land owner, or credit instalments to banks, fear for their land, when they cannot meet their obligations (Mapfumo et al., 2013; Reale and Handmer, 2011). Kugbega and Aboagye (2021) in a study of Central Ghana found that farmers' tenure security is lowest in the dry season, when seasonal resource scarcity induces herders to venture into farm land, further aggravated by climate change.

Especially weather extreme events can lead to severe challenges to tenure security of farmers, as they often displace farming communities temporarily, require resettlement (Constable, 2017; Albert et al., 2018; Ha'apio et al., 2018) or can result in distress asset sales (Holden and Ghebru, 2016). Returning to one's land can then be rendered difficult, where land rights are not adequately documented or land records are lost or destroyed (Garibay et al., 2010; Mitchell, 2014). In addition, extreme events, temporary vacation of the land and often lack of documentation have created situations prone to external pressure on land. It has been cautioned and cases have been reported where following weather extreme events, farmers were forced to sell their land or external actors seized it (Davis et al., 2015; Garibay et al., 2010; Quan and Dyer, 2008), sometimes even governments (Reale and Handmer, 2011). Disputes over land between local groups, for instance between farmers and herders, can be further compounded in such exceptional situations, adding to the overall fragility of land tenure (Edwards, 1999; Garibay et al., 2010).

4.2. How is climate change operationalised in land tenure studies?

Climate change is prominently mentioned in all studies included in the review sample, but not all integrate it explicitly into their analysis. Of particular interest are the empirical studies, notably the quantitative literature. Qualitative studies mostly incorporate climate change into their analysis by synthesizing evidence from climate impact assessments, while then asking farmers about their climate change perceptions during interviews and focus group discussions (Mapfumo et al., 2013; Mcleod et al., 2018).

The quantitative studies (N = 41) mostly use variables linked to the perception of climate change (N = 14), focus on extreme events (N = 8) or integrate information on temperature and/or precipitation (N = 10). Some studies only qualitatively discuss climate change in the case study region and/or summarise evidence (N = 6), mention climate impacts and challenges conceptually (N = 3) or use a combination of the three. Two studies do not mention climate change at all, but only a particular extreme weather event.

The studies who do not integrate any climatic variables into their regression, thus do not attempt to distinguish between adaptation and agricultural practices that could be pursued also in the absence of climate change (Rahut and Ali, 2017; Tsige et al., 2020), although some in separate analyses ask farmers about their perceptions of climate change (Diendéré, 2019; Yila and Resurreccion, 2013). None of the studies validate climate perceptions with observed climate data, but a few studies link observed or reanalysed climate data with household survey or census data for their analyses (Bastakoti et al., 2017; Fernandez et al., 2015a; Kalkuhl et al., 2020; Akugre et al., 2021).

Within the studies that explicitly integrate climate change into their quantification, the large majority uses different measures of climate change adaptation as outcome variable and some additionally include climatic variables such as mean temperature and precipitation in their regressions, but do not let them interact with the land tenure variables. The only link between climate change and land tenure in those studies is via the adaptation variables, where either researchers or farmers define them to be adaptation strategies, as opposed to mere good agricultural practices (Alemayehu and Bewket, 2017; Bryan et al., 2009; Gbetibouo et al., 2010). Some adaptation studies control for the perception of climate change, thus ensuring that at least from an internal perspective, farmers intend to address perceived changes in the climate system. This is either done using two stage hurdle models, where the first stage includes whether or not farmers perceive climate change, whereas the second stage focuses on adaptation uptake (Mutandwa et al., 2019). Another approach is to already filter responses at the data collection stage: in a study conducted in Chile, Roco et al. (2014) only consider replies that confirm adaptation measures by farmers to be taken in reaction to perceived climate change. Notably, more recent studies that appeared after 2020 include more explicit interactions of climate and land tenure (e.g. Ajefu and Abiona, 2020; Bezabih et al., 2021). Interacting tenure variables with weather variables is one approach to determine mediation effects of land tenure characteristics on e.g. agricultural outcomes under extreme weather (Ajefu and Abiona, 2020; Thennakoon et al, 2020). However, this is only a valid approach when potential endogeneity of the land tenure variable is taken into account.

When analysing the effect of land tenure settings on perception of climate change itself, the link between the two concepts is more explicit (Abid et al., 2019; Lokonon and Mbaye, 2018; Rondhi et al., 2019). Kalkuhl et al. (2020)'s study stands out, since they use both mean temperature and precipitation, but also coefficients of variation of the two in their regression model on the uptake of sharecropping arrangements, engaging in detail with the concept of climate risk.

Not always are slow onset changes or climatic variability referred to, some studies link their analyses to specific hazards such as drought, heavy precipitation events and floods and discuss the potential link with climate change as an amplifying factor (Enete et al., 2016; Jabbar et al., 2020; Panichvejsunti et al., 2018). None of those studies makes reference to longer term climate signals or links to attribution studies. Yet, extreme events allow for a more targeted inclusion in regression models, with farmers asked questions specifically about their response to concrete events, establishing a direct link (Hisali et al., 2011; Schuck et al., 2005).

5. Discussion

From the reviewed literature it appears that perceived tenure security and other properties of land tenure systems are of high relevance for strengthening farmers' resilience to climate change. Yet, important parts of the network remain insufficiently understood, as evidence on the strength, robustness and sometimes even direction of dynamics is lacking. Many claims remain to be

empirically investigated and where possible quantified. This is especially the case for the third interaction of climate change impacts on land tenure systems, which has received least attention so far and is not commonly considered in policy discussions. Psychological impacts of climate change on perceived tenure security are not well understood, even though the importance of perceived tenure security for technology uptake has long been known.

Besides the general gap in empirical research on the topic, we identified three key shortcomings of the reviewed literature: 1) a myopic treatment of land tenure (security), 2) superficial operationalisation of climate change, and 3) lack of critical engagement with climate change exigencies in farming environments. Addressing those gaps and reaching a sound understanding of how land tenure systems shape farmers' resilience is important in order to design appropriate policy interventions, which improve incentives around land for adaptation and climate resilience.

5.1. Simplified definitions and understanding of tenure security

Most of the studies reviewed have shown a one-dimensional treatment of land tenure indicators, equating single variables (often private ownership) with tenure security, without engaging with this highly complex concept. Although not all studies using land ownership as explanatory variable explicitly call this tenure security (e.g. Rahut and Ali, (2017) do not), the focus on land ownership as a farmer characteristic appears misplaced. Private does not necessarily mean secure and "[…]Property is not a thing, but a social contract" (Lund, 2000, p.18). Studies considering land tenure as a relevant factor for farmers' resilience to climate change thus do not build on the rich debate and more complex understanding of tenure security from the literature on land tenure and agricultural development, which represents a major shortcoming. Understanding adaptation incentive structures is such an important undertaking, that it requires full attention to relevant farm characteristics such as tenure security. Studies should integrate a more diverse understanding of tenure security and land tenure systems, as well as critically engage with the new perspective climate change as a stressor brings to land tenure and agricultural systems.

For illuminating the three identified interactions empirically, ideally the perceived tenure security of farmers is directly measured and integrated, as this is likely to be the ultimate driver or constraint in farmers' behaviour under climate change with regard to land tenure. Yet, for informing policy and keeping in mind that such measurements can also be flawed, the drivers and components of tenure security should be studied to enable recommendations for farmers' adaptation and ability to withstand climate shocks. Comprehensive analyses comparing how different land tenure characteristics affect farmers' ability to adapt, shape their vulnerability and how they themselves are affected by climate change can lead to more practical recommendations for policy, since they can more easily be influenced than subjective tenure security. In fact, the use of the term "tenure security" may be misplaced and misappropriated: While there is a common understanding that tenure security is a desirable property, the question of what actually determines tenure security still requires more research. Often, under the disguise of tenure security, specific governance regimes and property regulations have been imposed, which may not be best suited for a given farming context. With the advent of climate change it seems more important than ever to re-evaluate the notion of tenure security and discuss its specific determinants.

Further, in econometric studies more attention should be paid to endogeneity concerns. The literature on land tenure and agricultural development has long been plagued by severe challenges with reverse causality, which make it difficult to find convincing identification strategies for causal inference. In our review, we encountered only few reflections on this problem (contrary to the literature on land tenure and agricultural development), a more rigorous treatment and search for novel approaches appears warranted.

5.2. Lack of proper climate change integration

Although the studies reviewed make extensive reference to climate change, adequate operationalisation of climate change is often lacking. Better integration of climatic variables is needed in order to identify interactions between land tenure systems and the complexity and non-linearity of climate change. This requires identifying the relevant climatic indicators changing within a study region and comparing across climatic indicators. Studies reviewed mostly refer to mean temperature and precipitation, if at all, only few studies use a more diverse set of weather variables. Future studies should include more complex weather variables, such as percentiles and coefficients of variation, to capture nonlinear effects. This is especially important where tenure security, vulnerability and the need for adaptation is affected via channels such as crop growth, with plants responding to climatic conditions in a nuanced way. Here the study of land tenure under climate change could be informed by advances in fields such as statistical crop modelling, where a range of weather variables including interaction terms are used to capture complex relationships.

Studying the impacts of weather extreme events makes the link between land tenure security or settings and this particular event more tangible and presumably easier to recall for farmers, yet the weather extreme itself or the probability of its occurrence would need to be linked to climate change. This was not done in the studies reviewed, but could be done in future research, at least where attribution studies for the extreme event in question already exist. Including interaction terms of land tenure variables and the extreme event, as done in Thennakoon et al. (2020) and Ajefu and Abiona (2020) also improves upon the validity of findings regarding land tenure and climate interactions.

Specific to the adaptation interaction, a common problem concerns the distinction between agricultural practices that can be considered as adjustments to climatic changes, i.e. adaptation, and those that might also be pursued by farmers in the absence of climate change for intensification purposes or in response to other stressors (Sherman et al., 2016). This challenge is also evident in the review sample and mostly has not been sufficiently addressed, making claims relating to climate change difficult. Even where studies control for farmers' perception of climate change first (Abid et al., 2019; Lokonon and Mbaye, 2018), it is not clear whether such

perceptions alone can establish a sufficient link with a complex phenomenon such as climate change and if a research design placing agricultural practices in the context of climate change does not influence the replies farmers give. Making this distinction between adaptation and development is not trivial, since land tenure incentives may function differently under climate risk.

One step towards higher validity in adaptation and land tenure research could be to match farmers' climate change perceptions with observed climate data, as has already been done in other analyses of socio-economic implications of climate change (Brüssow et al., 2019; De Longueville et al., 2020). In addition, farmers could be asked to report perceived climatic changes with regard to different time steps, including knowledge passed on by family members. Given the highly local nature of household survey data, joining such observations with larger climate datasets can be challenging, different datasets should thus be compared and ideally datasets with high spatial resolution be chosen.

5.3. Lack of critical engagement with exigencies of climate uncertainty

Besides better empirical integration and identification of land tenure and climate change interactions, more theoretical contributions are also needed. It appears that the abundant theoretical frameworks on land tenure and agricultural development have been adopted into the new context of climate change (adaptation), without re-evaluating their aptitude.

Most studies do not consider the exigencies that climate change poses for agricultural livelihoods. Climate change puts new pressure on agricultural systems, it does not only require constant adaptation to gradual changes and overall increase in agricultural output (as in the past), but also effective ways of dealing with residual risk that is too high to adapt to. Risk-sharing, reacting to increasingly unpredictable and extreme climate hazards and coping with growing pressure on natural resources, for instance via livelihood diversification, sets new requirements for efficient and equitable resource governance and tenure systems, in order to avoid negative response patterns, such as distress asset sales. It is no longer only stability and increase in production that is needed, but also the ability to deal with the unexpected: Climate change may increase the trade-off between stability and flexibility. Well-designed land tenure systems can reduce this pressure by enabling farmers to best respond to climate change. Consequently, relevant questions to ask before planning adaptation policy would be: What do land tenure systems need to fulfil in order to protect agricultural livelihoods? How can they best enable adaptation and support a resilient development?

The needs for agricultural adaptation to climate change are not static, but dynamically evolve with a changing climate. This requires a degree of flexibility in the response strategies, which should be valued as a property of adaptation planning and adaptation recommendations (Dilling et al., 2019; Arial et al., 2011). While stability in the form of secure tenure has been the centre of attention and flexible tenure has been recommended for pastoralists, much less thought has been given to flexible arrangements that enable farmers to respond to gradual and sudden-onset climate changes. This could for instance mean cultivating several crops in different locations as a natural insurance against climate risk (Ensminger, 1997), although it remains to be established how effective this is, and being able to more easily gain access to land in areas less at risk of climate change, particularly with regard to extreme events.

To answer such questions, the value of customary, communal tenure systems in the face of climate change and the social cohesion such traditional systems often entail deserve further study. Moves towards private property, titling and individualisation of tenure often destroy such social safety nets, which may however be needed in dealing with the worsening effects of climate change. In fact, research on the development of internal institutions (i.e. institutions not enforced by the state) and key features such as trust have shown that they may have developed in alignment with exigencies from climate and geography. Buggle and Durante (2021) show that areas in Europe with higher weather variability in the past until today exhibit higher levels of trust. Similarly, Platteau (2000) reasons that internal institutions in African countries with their often strong focus on egalitarianism have developed as a result of the dependence on weather and the need for joint insurance against weather variability, which is echoed for the Swiss Alps in Ostrom (2003). Most recently, the IPCC report on land recognised the need for strengthening collective action and for preserving local and traditional knowledge of communities, next to enhancing their tenure security (Mirzabaev et al., 2019). To achieve both of those goals, smart and careful land interventions are needed.

The literature on land tenure and agricultural development has long acknowledged the problematic effects that can arise from liberalising and privatising once cohesive communal and customary land tenure systems (Toulmin et al., 2002). Traditional tenure systems may for instance be better at preserving and encouraging the use of local knowledge by farmers and can be more flexible than individual tenure, as they allow for redistribution more easily (IIED, 1999). That being said, customary tenure systems are not necessarily collective in the sense that all members of a community enjoy equal access and rights to land. In fact, they can be organised quite hierarchically and often provide little access to land for women (Lund, 2000). Communal tenure is also not free from market-like behaviour and should not be idealised as a panacea against neo-liberal reforms, as Chimhowu elaborates (Chimhowu, 2019; Chimhowu and Woodhouse, 2006).

Yet, a proper debate on the merits and drawbacks of either privately governed land, land managed by the state, by groups themselves or by local authorities would be useful with the aim of identifying the most suitable governance mode to support farming communities in addressing climate change. This would allow to identify whether and under what circumstances private or communal systems of land governance are better able to incentivise climate change adaptation and other resilience-strengthening behaviour. Here the ideas and findings of Elinor Ostrom's work on the commons can offer valuable guidance (Ostrom, 1990; Ostrom, 2003). We thus argue to not only consider the security of tenure as important driver of adaptation and resilience, but also the form of tenure as a factor in its own right. Given the complexity of tenure and its incentive structures, no easy solutions exist. Mixed tenure systems combining forms of private control, while retaining space for communal projects such as irrigation schemes and a sort of communal responsibility towards each other may prove most effective in dealing with climate risk (see also Ostrom, 2003).

Some important factors which were omitted from this review and discussion, but likely shape the interactions between land tenure

and climate change and thus need consideration are the political stability of countries, LSLAs and population growth. Another limitation of our review is the fact that we only included documents written in English language. Since many of the case study countries are non-English-speaking countries, this likely leads to omission of relevant research published in other languages. The complexity of both land tenure and climate impacts as well as responses require further research, to disentangle and systematically compare distinct land tenure settings under climate change. The high variance in land tenure arrangements and local specifications make it difficult to draw general conclusions from land tenure studies. It is thus important to increase the evidence base, building on the existing advances in the field of land tenure and agricultural development, while testing novel methodologies to overcome common challenges in the study of land tenure and climate. Such research is also needed to inform global land use research and thus macro-level projections on climate change impacts, where the role of institutions and governance so far has received limited attention (Wang et al., 2016).

6. Conclusion

The aim of this review was to identify and understand how land tenure systems influence farmers' ability to withstand climate change and how climate change is operationalised in such studies. Three main interactions between land tenure and climate change in farming contexts were found: first, land tenure characteristics affect the uptake intensity and type of adaptation or coping strategies undertaken by farmers. Second, land tenure systems also influence farmers' vulnerability to climate change, in particular the vulnerability of different demographic groups within farming communities, such as women, migrants and indigenous peoples. Third, land tenure systems themselves are impacted by climate change, in particular the perceived tenure security of farmers, mostly via indirect channels. Despite a rich set of interactions and linkages found, most parts of this thematic network are yet to be explored and validated empirically. This is especially due to simplistic definitions of tenure security, lack of research on other tenure characteristics and limited integration of and engagement with climate change in the studies reviewed. Appropriate theory linking previous land tenure frameworks to the emerging threat posed by climate change risk and uncertainty is scarce.

Both adaptation and land policy can highly benefit from a more in-depth engagement with the complexity and local distinction of land tenure in the context of climate change. In fact, neglecting the importance of local land governance structures and incentives around land can severely hamper effectiveness of climate change adaptation policies and projects. For successful adaptation investments, it is thus of great importance to move beyond a narrow focus on land tenure (security) and integrate more nuanced perspectives into the climate adaptation research and policy agenda. Reversely, ongoing land reform processes should consider and address emerging risks from climate change, which require more flexible solutions than past land reforms have offered. Depending on context, optimal tenure settings should be identified which enable farmers to best respond to climate change. This requires enhanced attention to the value and functioning of customary and collective land tenure systems, but also to avenues that recognise and strengthen land rights of vulnerable groups.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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