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Fuelwood scarcity and its adaptation measures: an assessment of coping strategies applied by small-scale farmers in Dodoma region, Tanzania

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Abstract

In Tanzania, the majority of the rural population still relies on fuelwood as their major source of cooking energy. The adaptation measures of small-scale farmers in response to increasing fuelwood scarcity play a key role in altering the course of nutrition insecurity, environmental degradation, and economic instability. This study delivers a classification of coping strategies that does not exist in the literature. Furthermore, it analyses the adaptation measures applied by small-scale farmers in the semi-arid region of Dodoma district in response to fuelwood scarcity. A comparison between two case study sites provides information on the choice of adaptation measures by households. Overall, 28 coping strategies from 24 studies are identified, then differentiated into preventive and acute measures that are arranged into eight clusters. The classification is then used as a codebook to identify applied coping strategies at two case study sites. In total, 23 adaptation measures, including two strategies not cited in the literature, were identified through 39 household interviews. This suggests that the majority of coping strategies applied are independently from regional and social conditions. The majority of the strategies applied at the case study sites and described in the literature are acute measures that do not tackle the underlying problem triggering forest degradation. It is observed that the adaptation measures across the case study sites are widely congruent, thus showing that acute strategies are not replaced by preventive strategies but rather co-exist.

Introduction

Globally, around 2.7 billion people rely on solid biomass as primary cooking fuel (IEA 2016). In order to supply this demand, nearly half of globally harvested wood is used for energy production (Bruinsma 2003). In sum, traditional bioenergy represents approximately 15% of total global energy use (Creutzig *et al* 2015) and is responsible for 1.9%–2.3% of global CO_2 emissions annually (Bailis *et al* 2015). It is predicted that, through the next decade, the number of people dependent on it will remain unchanged at approximately 2.3 billion people (IEA 2017), with the population of Sub-Saharan Africa (SSA) remaining reliant on woodfuels also for the coming decades (Iiyama *et al* 2014). Around 78% of the population in SSA still relies on solid biomass—especially fuelwood[4] and charcoal—for cooking (IEA 2017). Nearly three-quarters of those dependent on fuelwood for cooking live in rural areas (IEA 2014), while those in urban areas are more likely to use charcoal (Arnold and Persson 2003).

With a population of more than 50 million, only 2% of the Tanzanian population has access to clean cooking energy, while in rural areas, fuelwood dependency is 89% (NBS 2014, GTF 2017). At the same time, mainland Tanzania is affected by deforestation, losing approximately

[4] Wood in the rough (such as chips, sawdust and pellets) used for energy generation. It can also be termed as firewood (FAO 2008).

370 000 ha per year (FAO 2015), with a forest cover of roughly 48 million ha (NAFORMA 2015). The country is among the top ten countries reporting the greatest annual loss of forest area between 2010 and 2015 (FAO 2015). Fuelwood utilization covering domestic fuelwood demand for cooking could be a major driver of forest degradation, depending on the geographic context (Bailis *et al* 2015, Creutzig *et al* 2015, Masera *et al* 2015, IEA 2017). In this paper, we understand fuelwood scarcity as something that can be observed when behavioral changes, such as coping strategies, become necessary.

In particular, due to continued fuelwood scarcity, rural households are developing strategies to cope with the added stress, such as increasing labor for fuelwood collection, collecting fuelwood from non-forest areas, or using crop residues (Brouwer *et al* 1997, Jagger and Shively 2014). In this context, women in SSA generally carry the majority of this burden, as they are traditionally responsible for collecting fuelwood and for developing strategies to respond to its increasing scarcity (Köhlin *et al* 2011). There are a wide variety of coping strategies applied on the ground. In this research paper, coping strategies are defined as adaptation measures applied by rural households due to a fuelwood shortage occurring. Studies show that these coping strategies negatively affect the nutritional and environmental situations of the people (Heltberg *et al* 2000), such as omitting or substituting dishes with high nutritious value (e.g. dry beans) (Makungwa *et al* 2013). According to Heltberg *et al* (2000), fuelwood collection and forest degradation are closely related. An increase in fuelwood collection can lead to the degradation of forests and forested areas while, in turn, this degradation can lead to physical fuelwood scarcity. Brouwer *et al* (1997, p 256) attributes a 'chronic character' to this self-reinforcing process, which worsens over time, while Matsika *et al* (2013) refers to the energy poverty cycle that links high usage of fuelwood to localized environmental degradation. Although coping strategies seek to alter or manage the cause of the problem, often it is beyond the reach of households to address the root of the problem (Brouwer *et al* 1989, p 352). From a more theoretical viewpoint, Foeken and Hoorweg (1988) suggest differentiating coping strategies between preventive responses and those reflecting an acute scarcity. For example: planting trees or using alternative cooking technologies with higher efficiency can be understood as preventive responses because they hold the capacity to alter the cause of the problem. The latter includes different technologies, such as using improved cooking stoves (ICS). As an alternative to the traditional fuelwood based three-stone-fire stoves (TSF), ICS reduces fuelwood consumption through its higher thermal efficiency rates (Zein-Elabdin 1997, Ochieng *et al* 2013). However, acute strategies are more common: these are short-term adjustments that do not affect the underlying cause of the problem. Specifically in the context of fuelwood scarcity and food security, several authors highlight that energy-demanding dishes with high nutritional value, such as dry beans, are omitted or substituted (FAO 1990, Brouwer *et al* 1996b, Makungwa *et al* 2013). To mitigate fuelwood scarcity, Akther *et al* (2010) identifies several substitutes for fuelwood, including leaves, twigs, cow dung, and crop residues.

As coping strategies play an intermediary role between scarcity, societal impact, and environmental conservation, they must be considered as a leverage point that can alter the course of nutrition insecurity, environmental degradation, and economic instability. However, there is neither a review of coping strategies from different thematic areas nor a suitable classification scheme available. Particularly important are coping strategies with regard to fuelwood scarcity in regions that are classified as semi-arid. In Tanzania, these areas are in the center of the country, with Dodoma region being one of them. This region is also characterized by unimodal precipitation (WFP 2013). Although fuelwood scarcity in Dodoma can be observed, the role and the potential of coping strategies are not yet evaluated. Scientific data for the interplay between preventive and acute strategies is missing.

In order to close these research gaps and to provide more detailed insights into general strategies from the literature and strategies applied on the ground, this research paper provides: (1) a literature review of coping strategies and their classification; (2) an assessment of coping strategies at two case study sites (CSS); and (3) a quantitative comparison of the coping strategies applied by households at the two CSS.

Methods

Review of coping strategies from literature

In a first step, we identify coping strategies that households in rural areas apply to cope with fuelwood scarcity in the literature. The review articles by Brouwer *et al* (1989) and Sola *et al* (2016) on energy access, food security, and nutritional impacts provide the baseline for this review. Additional literature is identified using the bibliographic databases Web of Science, ScienceDirect and Google Scholar. In addition, relevant reports were searched for on websites of the FAO, the WFP, and the World Bank. The following broad search terms and their synonyms were used: (i) fuelwood and nutrition security; (ii) fuelwood and food security; (iii) fuelwood and alternative energy; and (iv) fuelwood and environment. Original and review articles were both included in the review process.

In total, we found 46 articles that were preselected based on their title and abstract. Subsequently, the articles were screened on the eligibility criteria, 'coping strategies due to fuelwood scarcity'. Out of this, 24 articles were identified as eligible for a full review process (table 1).

In a second step, we classify the identified coping strategies from the literature. In particular, we differentiate

Table 1. 24 articles identified for the full review process on coping strategies applied due to fuelwood scarcity.

Author (Date)	Topic
Howes (1985)	Rural energy
Shanahan (1986)	Woodfuel and rural households
Cecelski (1987)	Energy and women
Brouwer *et al* (1989)	Fuelwood shortage and nutritional impacts in developing countries
Dewees (1989)	Woodfuel crisis
FAO (1990)	Fuelwood scarcity and its impacts
Bradley and Kenya Woodfuel Development Programme (1991)	Woodfuel, women and woodlots
Brouwer *et al* (1996b)	Fuelwood and food security
Brouwer *et al* (1996a)	Wood quality and food security
Brouwer *et al* (1997)	Fuelwood availability and its impacts
Madubansi and Shackleton (2006)	Energy profiles and consumption
van't Veld *et al* (2006)	Firewood crisis in India
Akther *et al* (2010)	Fuelwood scarcity and adaptation measures
World Bank (2010)	Household cookstoves
Bandyopadhyay *et al* (2011)	Forest, biomass use and poverty
Köhlin *et al* (2011)	Energy, gender and development
Cardoso *et al* (2012)	Use of fuelwood in a semi-arid region
Damte *et al* (2012)	Fuelwood scarcity and adaptation measures
WFP (2012)	Firewood and alternative energy
FAO (2013)	Firewood and alternative energy
Makungwa *et al* (2013)	Fuelwood and food security
Guta (2014)	Fuelwood scarcity and socio-economic factors
Boafo *et al* (2016)	Ecosystem service-sharing
Baudron *et al* (2017)	Forests and dietary diversity

between preventive and acute measures (Foeken and Hoorweg 1988). The former potentially reduces deforestation, while acute measures are used ad hoc in order to cope with immediate fuelwood scarcity.

Study area

The study was conducted at the two case study sites—Idifu and Mzula—both located in the Chamwino district of Dodoma region, Tanzania (figure 1). Dodoma region is semi-arid, consisting mainly of savannas and grasslands (Mutabazi 2016) and is part of the unimodal zone with one long rainy season that lasts from December to April (WFP 2013). There is a growing perception by the farmers of a decrease in rainfall that is leading to drought. At the same time, farms steadily move into new areas, accelerating the clearing of forest land (Goulden *et al* 2009), leading to dilapidated forest and woodland areas (Mutabazi 2016). Idifu has approximately 1200 households (Hafner 2016), while Mzula has around 750 households (Mutabazi 2016). Most of the households are subsistence farmers. Fuelwood is the main energy source for cooking and boiling water in both villages. At the case study sites, two different cooking technologies are used. In Idifu, ICS have been introduced and adopted by several households, replacing TSF. Mzula households rely solely on TSF.

Assessment of coping strategies in the Dodoma region

Within our assessment, 39 household interviews were conducted in the two villages of Mzula ($n = 20$) and Idifu ($n = 19$). The interviews included a mix of unstructured and semi-structured questions in order to identify a full range of coping strategies. In the first part, households were asked about their livelihood, routines, responsibilities, and changes in their daily routine. In the structured part, direct questions about fuelwood availability and applied coping strategies were asked.

In Idifu, we only interviewed households using ICS, while in Mzula only households using TSF were sampled in order to assess differences in the choice of coping strategies. In Idifu, households were purposive sampled; in Mzula households were randomly sampled. In both villages, we only interviewed women, because women are mainly responsible for fuelwood collection and food preparation (Lim *et al* 2012, Kahimba *et al* 2015). The interview questions were professionally translated from English to Kiswahili.

The interviews were transcribed and analyzed using structured qualitative content analysis, based on the procedure described by (Mayring 2016, p 115). Three measures were taken to indicate and rank the coping strategies that households apply in Mzula and Idifu villages. First, the classification of the coping strategies from the literature was used as the codebook. In the second step, the codebook was used to systemize the applied coping strategies and to identify additional strategies that are not yet cited within the existing literature. Multiple coping strategy responses per household were possible. In a third step, the extracted strategies underwent a quantified ranking. The ranking is based on how often the strategies are mentioned by the households.

In order to identify differences in the choices of coping strategies by the households if preventive measures are applied, a quantitative comparison of the identified

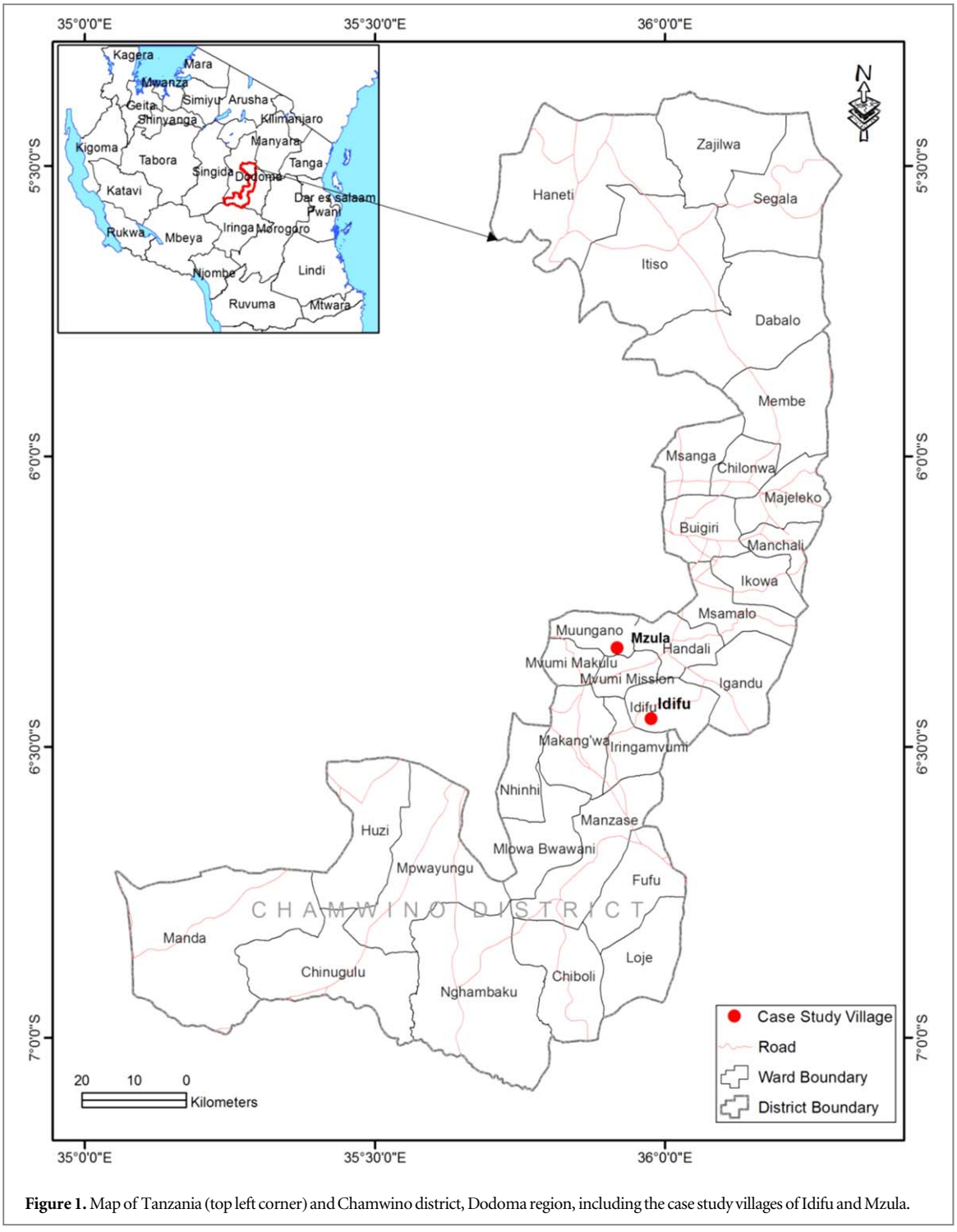

Figure 1. Map of Tanzania (top left corner) and Chamwino district, Dodoma region, including the case study villages of Idifu and Mzula.

strategies between the CSS was completed. Therefore, both the strategies and the number of applied strategies are compared.

Results

Classification of coping strategies based on existing literature

In total, the 24 studies identify 28 coping strategies that address the problem of fuelwood scarcity. Three preventive strategies in two clusters and 25 acute strategies in six clusters are identified (table 2).

Household responses to fuelwood scarcity and comparison between the CSS

The analysis of data collected in Mzula and Idifu show that a total of 23 strategies are applied in the villages, 21 of which are already identified in the codebook. We find two strategies used to cope with existing fuelwood scarcity that are not cited in literature:

- *Use of improved collection means*
  Farmers use transportation means, such as wheelbarrows, oxcarts, or bicycles, to carry the collected wood. This facilitates the transportation of larger amounts of wood.

Table 2. Classification of coping strategies from existing literature including the respective sources.

	Clusters	Coping strategies	Authors
Preventive strategies	Increased fuelwood provision	On-farm tree planting	Dewees (1989), Köhlin *et al* (2011)
		Improved forest management	Köhlin *et al* (2011)
	Decreased fuelwood demand	Use of improved cooking technologies	World Bank (2010)
Acute strategies	Alternative fuelwood consumption	Use of private trees instead of trees from communal land	van't Veld *et al* (2006)
		Cut down a tree as a fuelwood source	Shanahan (1986)
		Shift to lesser quality of fuelwood	Brouwer *et al* (1989, 1997)
		Use of trees that produce food and fodder (fruit, spice or foliage trees)	Shanahan (1986)
		Decrease of stock building in fuelwood	Bradley and Kenya Woodfuel Development Programme (1991)
	Increased use of substitutes for fuelwood	Use of crop residues instead of fuelwood (rice husks and straw, maize cobs, etc)	Brouwer *et al* (1996a), Akther *et al* (2010)
		Use of animal dung instead of fuelwood	Akther *et al* (2010), Köhlin *et al* (2011), Cardoso *et al* (2012), Damte *et al* (2012), Baudron *et al* (2017)
		Use of twigs and leaves instead of fuelwood	Howes (1985), Brouwer *et al* (1989, 1997), Akther *et al* (2010)
	Increased input of time and effort	Increase in walking distance to collect fuelwood	Howes (1985), Brouwer *et al* (1989), FAO (1990), Köhlin *et al* (2011), Cardoso *et al* (2012), WFP (2012), Guta (2014)
		Increase in frequency of fuelwood collection	Brouwer *et al* (1989, 1997), FAO (1990), Guta (2014)
		Increase in time spent to collect fuelwood	Howes (1985), Brouwer *et al* (1989), FAO (1990), Bandyopadhyay *et al* (2011), Köhlin *et al* (2011), Guta (2014)
		Change in weight of bundle collected	Cecelski (1987)
	Market-based measures	Sell or barter food to procure fuelwood	Brouwer *et al* (1996b, 1997), WFP (2012), FAO (2013)
		Purchase fuelwood	Brouwer *et al* (1997), Madubansi and Shackleton (2006)
		Decrease in sales and exchange of fuelwood	Brouwer *et al* (1997)
	Utilization of human resources and social relationships	Change in who collects (children, older people, men)	Howes (1985), FAO (1990), Köhlin *et al* (2011)
		Borrowing fuelwood from friends	Brouwer *et al* (1996a), Boafo *et al* (2016)
		Sex in exchange for fuelwood	FAO (2013)
	Decreased food and health	Switch to food of lower nutritional value	Brouwer *et al* (1989, 1996b), WFP (2012), FAO (2013)
		Undercook food to save fuelwood	FAO (1990, 2013), WFP (2012)
		Eat fewer meals	FAO (1990, 2013) Brouwer *et al* (1996a), WFP (2012)
		Replacement of long-time cooking dishes with high nutritional value (esp. beans)	FAO (1990), Brouwer *et al* (1996b), Makungwa *et al* (2013)
		Omit snacks (maize kernels or scones)	Brouwer *et al* (1996a)
		Reduced food for vulnerable people (infants, toddlers and sick people)	FAO (1990)
		Boiling water insufficiently or not at all to save fuelwood	Brouwer *et al* (1989), WFP (2012)

- *Gathering remains of charcoal production*
  Farmers report that they produce charcoal as a business in order to earn money. In most cases, charcoal production takes place outside of the villages, near the mountains due to the proximity of the forest. Two women mentioned that they sometimes go to the charcoal production sites of other people to collect the remains of the charcoal.

The acute strategies applied to cope with fuelwood scarcity show the direct negative impact on livelihoods in the villages. Fuelwood scarcity reduces the number of daily meals cooked (Mzula 55%; Idifu 37%). Cutting off branches of intact trees or shrubs instead of collecting dry fuelwood (Mzula 75%) demonstrates that the scarcity situation leads to further destruction of forests. The increase of workload to collect fuelwood due to extended walking distances (Mzula 70%; Idifu 79%), leads to a lack of time for domestic work, including agricultural activities. In addition, the quality of fuelwood is reduced as villagers cite collecting twigs instead of proper fuelwood (Mzula 60%; Idifu 47%).

Our analysis shows that two strategies are used by more than 50% of the households in both villages: *Increase in walking distances to collect fuelwood* and *to ask a neighbor for fuelwood*. The identified coping strategies of both CSS and their respective quantified rankings are presented in table 3.

Regarding the two villages, 17 different strategies (including one preventive strategy) are identified for Mzula and 16 different strategies (including two preventive strategies) for Idifu (table 3). The preventive strategies applied are:

- *use of ICS; and*
- *on-farm tree planting.*

Comparing the coping strategies between the two CSS, it can be noted that many of the applied strategies and the number of used strategies are congruent. Despite the fact that preventive measures are applied in Idifu, ten out of the 23 strategies are identical in both CSS. On average 4.7 strategies are applied per household in Mzula ($N = 20$) and 4.1 strategies (excluding ICS) in Idifu ($N = 19$). Our findings show that acute strategies to cope with fuelwood scarcity are not simply replaced by preventive strategies, but preventive strategies are an additional strategy used by households to manage the scarcity situation.

Discussion

Methodological approach

The applied research design for data collection is based on two different sampling methods in order to identify differences in coping strategies if preventive measures, in this case ICS, are applied. Only female farmers are interviewed, including female household heads and wives of male household heads. We select female interviewees as several studies indicate that women in SSA, including, specifically, the Dodoma region, are mainly responsible for fuelwood collection and the preparation of food. Hence, women are responsible for developing strategies to respond to fuelwood scarcity (Brouwer *et al* 1989, Köhlin *et al* 2011, Lim *et al* 2012, Kahimba *et al* 2015).

Qualitative social research offers several approaches to analyze the content of interviews (Barton and Lazarsfeld 1979, Mayring 2016). Thereby, the development of classification schemes based on the literature, own data, and the revision of previously developed categories is a common process for empirical-qualitative research (Barton and Lazarsfeld 1979). Additionally, Mayring (2016, p 115) describes structured qualitative content analysis, which seeks to identify specific aspects in interview material based on classification criteria that were developed beforehand. Both analytical approaches provide the stringent methodological framework applied in this study.

Classification of coping strategies

The systematic literature review of 24 articles and the identification of 28 coping strategies provide a comprehensive overview of adaptation measures to fuelwood scarcity. Nevertheless, a full systematic review would enhance our understanding of how farmers make their choices. Overall, we differentiate between preventive and acute measures in order to outline the different characteristics of applied strategies. Measures are grouped into two and six clusters, respectively, offering a holistic classification of coping strategies across the thematic areas. However, other authors use different clusters. Köhlin *et al* (2011), Damte *et al* (2012), and Schuenemann *et al* (2018) mainly differentiate between supply side and demand side strategies, while Egeru *et al* (2014) distinguishes between short-term and long-term coping mechanisms. Brouwer *et al* (1997) divides coping strategies into fuel collection, type of fuel used, and fuel use. In contrast, our approach offers practitioners direct strategic pathways to select appropriate strategies, depending on the cluster from which a strategy is needed.

Applied coping strategies at the CSS

Context-dependency of coping strategies

Literature reveals a wide variety of coping strategies when fuelwood is scarce. The fact that more than 90% of the identified strategies at the CSS are similar to those mentioned in the literature underlines the context-independence of coping strategies. This means they are applied autonomously from regional and social conditions. However, exceptions must be carefully considered. For example, the *use of animal*

Table 3. Coping strategies derived from the household interviews of both CSS including a quantified ranking. The ranking is based on how frequently they were mentioned by the households. Multiple responses are possible.

	Clusters	Coping strategies	Coping strategies applied in Mzula ($N = 20$)	Coping strategies applied in Idifu ($N = 19$)
Preventive strategies	Increased fuelwood provision	On-farm tree planting	15 %	58 %
	Decreased fuelwood demand	Use of improved cooking stoves (prerequisite)	0 %	100 %
Acute strategies	Alternative fuelwood consumption	Cut wet fuelwood instead of collecting dry fuelwood	75 %	0 %
		Cut down a tree as a fuelwood source	5%	5%
		Use of private trees instead of trees from communal land	5%	5%
		Use of wet fuelwood instead of dry fuelwood	0%	3%
		Use of fuelwood with less quality	0%	5%
	Increased use of substitutes for fuelwood	Use of twigs instead of fuelwood	60%	47%
		Use of crop residues instead of fuelwood (esp. maize residues)	15%	21%
		Use of cow dung instead of fuelwood	0%	11%
	Increased input of time and effort	Increase in walking distance to collect fuelwood	70%	79%
		Increase in frequency of fuelwood collection	25%	32%
		Increase in time spent to collect fuelwood	10%	0%
		Change in weight of bundle collected	5%	0%
	Market-based measures	Use of improved collection means (wheelbarrow, oxcart, bicycle)[1]	0%	37%
		Purchase fuelwood	5%	11%
		Purchase charcoal	5%	0%
		Hire someone to collect fuelwood	5%	0%
	Utilization of human resources and social relationships	Ask a neighbor for fuelwood	85%	53%
		Involve children in fuelwood collection	10%	0%
		Gathering remains of charcoal production[1]	10%	0%
		Ask relatives for fuelwood	0%	5%
	Decreased food and health	Eat fewer meals	55%	37%

[1] Newly identified coping strategies.

dung as a source of fuel for cooking is described and evaluated by several authors (Akther *et al* 2010, Köhlin *et al* 2011, Damte *et al* 2012). Its use has strong cultural and taste connotations (Köhlin *et al* 2011), but can only be applied if livestock farming is practiced. The two newly identified strategies, *use of improved collection means* and *gathering remains of charcoal production*, can also be considered as context-dependent strategies, since they are not yet mentioned in the literature.

Identification process of applied coping strategies

In total, 23 coping strategies are identified at the CSS. One major difficulty in identifying coping strategies is the fact that farmers themselves do not necessarily define their adaptation measures as coping strategies. Therefore, the methodology of structured interviews and questionnaires are not suitable for directly identifying coping strategies from different thematic areas. For example, the strategy *increase in walking distances to collect fuelwood,* described by several authors (Howes 1985, Brouwer *et al* 1989, Köhlin *et al* 2011, WFP 2012) and applied by more than 70% of the farmers at the CSS, is a strategy that is not considered as an adaptation measure by farmers but rather as a necessity due to the situation. This corresponds with the findings of Schindler *et al* (2016, p 42) that farmers consider indirect linkages taking their complex livelihoods into account while scientists rather focus on direct casual impact chains. On the other hand, not every adaptation measure described in the scientific literature can be identified as such on the ground. Damte *et al* (2012) proves that Ethiopian households use dung and crop residues as a source of energy for cooking, however these are not considered as substitutes for fuelwood. Hence, an open and participatory process is needed to identify and understand the adaptation measures applied by the farmers when fuelwood is scarce.

Using coping strategies from the scientific literature as a codebook to identify similar strategies on the ground in a specific social and cultural context is an approach that must be implemented carefully. Some authors use generic terms to describe strategies, whilst others describe specific and context-dependent strategies. In their articles, Brouwer *et al* (1989, 1997) describe the generic strategy *shift to lesser quality of fuelwood*. Typically, twigs, leaves, crop residues, and animal dung are considered to be inferior energy forms. Our study identifies that the strategy *to cut and use wet fuelwood instead of dry fuelwood* can also be considered as using inferior energy forms. However, to cut branches off intact trees or shrubs as well as the use of wet fuelwood as a change in fuelwood supply is not mentioned in the reviewed literature. One reason could be that in many cultures the cutting and drying of wet fuelwood is a common process. However, households at the CSS define collecting fuelwood as a process of collecting dry wood from the ground or cutting off dead branches without any drying procedure. Cutting and drying wet fuelwood instead of collecting dry fuelwood was described as a very recent development due to the degradation of the forests. Hence, it is important to assess and clearly define coping strategies within their contextual dependencies.

Preventive versus acute strategies

The findings of this research show the multidimensional impact of fuelwood availability on rural livelihoods. The scarcity of fuelwood negatively affects food and nutrition security, soil fertility, and labor availability (Sola *et al* 2016). Only 9% of the identified coping strategies at the CSS can be considered as preventive. The same holds true for the literature review with preventive measures making up around 10% of the options. Our findings show that the statement by Brouwer *et al* (1989, p 352), 'in most cases, because of lack of access to resources such as land, labor and cash, it is beyond the reach of households to alter the cause of the problem,' is still valid. Identified coping strategies due to a fuelwood shortage are mainly short to mid-term adjustments that do not offer a sustainable solution for a positive feedback loop of fuelwood collection, degradation of forests and forested areas, and physical fuelwood scarcity. Although strategies such as *improved collection means* (e.g. *wheelbarrows*) (Idifu 37%) might have a short-term impact on reduced workload and time to collect fuelwood, these do not solve the situation of an imminent fuelwood scarcity. We base our results solely on the perception of local farmers due to the fact, that no historical data for the region is available.

Comparison of coping strategies between the CSS

Our assessment shows that preventive and acute measures to cope with fuelwood scarcity are applied at the CSS. In both villages, households use an average of about four strategies to cope with fuelwood scarcity (excluding ICS). Although ICS were introduced in Idifu village in 2015, the average number of coping strategies was only slightly lower than in Mzula, where TSF are used. This indicates that the number of applied adaptation measures was not at all, or only insignificantly, reduced due to ICS usage in Idifu. Hafner *et al* (2018) show that the fuelwood savings of ICS in Idifu is between 15.6% and 37.1% compared to TSF. Hence, we would expect that the overall number of coping strategies in Idifu to be lower than in Mzula due to the reduced demand for fuelwood in Idifu. The findings suggest that the reduction of fuelwood demand for cooking purposes does not automatically lead to a reduction in the number of applied coping strategies.

Around 43% of the applied coping strategies between the two CSS are congruent, even if preventive measures are applied in Idifu. This shows that small-scale famers do not cope with fuelwood scarcity by simply replacing acute strategies with preventive strategies. Preventive strategies are applied as an additional strategy by

households in order to manage and adapt to the scarcity situation. Preventive strategies, such as planting on-farm trees or using ICS, might have a greater potential to reduce fuelwood scarcity than acute measures. The usage of ICS and local tree plantations might improve the fuelwood situation in deforested areas of Mzula and Idifu in the mid- to long-term. However, measures such as tree plantations need several years before fuelwood is produced; thus deforestation is not reduced in the short term (Egeru *et al* 2014). Uckert *et al* (2017) indicate that limited financial capacities and a lack of awareness are bottlenecks for adopting energy-efficient fuelwood consumption solutions. Our findings, regarding the comparison of coping strategies between the CSS, suggest that if the aim is to reduce forest degradation, then decreasing fuelwood demand alone may not be effective. This corresponds with the findings of Damte *et al* (2012) that supply side strategies alone may not be effective at addressing the problem of forest degradation. Further research analyzing the interplay of preventive and acute measures is needed in order to understand the choice behavior of households with regards to coping strategies.

Identifying and disseminating additional local strategies to cope with fuelwood scarcity is not enough to solve the problems of degraded and deforested areas in Tanzania. Likewise, leap-frogging from fuelwood based forms of cooking toward non-fuelwood based energy forms cannot be expected in the near future (Grimsby *et al* 2016). In this context, Maes and Verbist (2012) suggest focusing on enhancing the efficiency of traditional energy systems instead.

Conclusion

The adaptation measures of small-scale farmers to fuelwood scarcity play a key role in altering the course of nutrition insecurity, environmental degradation, and economic instability. In this study, a classification of coping strategies in line with existing literature was completed. A total of 28 coping strategies from 24 studies are identified, differentiated into preventive and acute measures, and then grouped into eight clusters. This classification scheme is then used as a codebook to identify applied coping strategies in Mzula and Idifu villages, Dodoma region, Tanzania. During this process, we identify 23 strategies, including two measures not cited in the literature. This suggests that the majority of coping strategies have a context-independent character. Both the majority of the applied strategies in the CSS as well as those described in the literature are acute measures that do not tackle the underlying problem of deforestation and forest degradation. We observed that the type, as well as the number, of coping strategies between the CSS are widely congruent, suggesting that acute measures are not replaced with preventive strategies, but rather these co-exist. Therefore, decreasing fuelwood demand alone may not effectively address the problem of forest degradation.

In order to enhance the understanding of the choice behavior of households with regards to coping strategies, not only does further research need to analyze the interplay between preventive and acute measures, but it must provide a full systematic literature review for different thematic and regional areas.

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