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# Adapting to Fuelwood Scarcity: The Farmers' Perspective

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About 3 billion people worldwide depend on fuelwood to meet their domestic energy needs. Almost 90% of the population in Sub-Saharan Africa use fuelwood-based forms of energy. However, its use is often unsustainable and is one driver of environmental degradation. In Tanzania, the majority of rural residents depend on fuelwood as their major source of cooking energy. The adaptation measures applied by small-scale farmers in response to fuelwood scarcity are typically unsustainable with regard to socio-economic, environmental, and food security dimensions. This study applies a methodological framework that assesses the personally experienced impact of coping strategies by local stakeholders on sustainability criteria. This framework comprises (1) the selection of appropriate adaptation measures; (2) the identification of local sustainability criteria; and (3) the participatory impact and frequency assessments at two case study sites in the semi-arid region of Dodoma in central Tanzania. Overall, eight coping strategies from 23 measures applied in the region were selected and four sustainability criteria defined by local key informants were identified. The participatory impact and frequency assessment show that the strategies of "on-farm tree planting" and "use of improved cooking stoves" are rated as positive across all four sustainability criteria and are regularly applied by the farmers. Two of the eight strategies are clearly negative: "eat fewer meals" and "increase in walking distance to collect fuelwood." These measures are regularly and widely used by farmers, thus amplifying the negative rating. Overall, the experiences of farmers suggest that applied coping strategies have the greatest negative effect on the environmental condition and, on average, a rather positive effect on economic conditions. The results offer an approach for developing a reliable monitoring of how adaptation measures are applied in response to fuelwood scarcity and to achieve distinct values for benchmarking.

**Keywords: participatory impact assessment, firewood scarcity, energy access, sustainability, coping strategies, Dodoma, Tanzania, food security**

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## INTRODUCTION

Globally, nearly three billion people rely on solid biomass as their primary cooking fuel (Jagger and Shively, 2014; IEA, 2016). To supply this demand, over half of globally harvested wood is used for energy production (Bailis et al., 2015). Access to cooking energy is especially important to the population in Sub-Saharan Africa, which is highly dependent on fuelwood[1] and will remain so

[1] Wood in the rough (such as chips, sawdust and pellets) used for energy generation (FAO, 2008).

for the coming decades (Iiyama et al., 2014). Using fuelwood for domestic demand is thought to drive environmental degradation, although the specific impact depends strongly on the geographic context (Bailis et al., 2015; Creutzig et al., 2015; Masera et al., 2015; IEA, 2017).

With fuelwood scarcity increasing, rural households in Sub-Saharan Africa are developing strategies to cope with the additional stress, such as increasing labor to collect fuelwood, collecting fuelwood from non-forest areas, using crop residues, and improving means of collection (e.g., bicycles, wheelbarrow or oxcarts) (Guta, 2014; Jagger and Shively, 2014; Scheid et al., 2018). Studies show that coping strategies negatively affect the food security of the population concerned, such as omitting or substituting dishes with extended cooking times, even though these typically carry high nutritional value (e.g., dry beans) (Brouwer et al., 1996; Kees and Feldmann, 2011; Makungwa et al., 2013; Sola et al., 2016). Women in Sub-Saharan Africa generally carry the majority of the burden as they are traditionally responsible for collecting fuelwood, cooking, and developing strategies to mitigate the increasing fuelwood scarcity (Heltberg, 2004). There are a wide variety of coping strategies applied on the ground, which can be differentiated into supply side and demand side strategies (Köhlin et al., 2011; Damte et al., 2012; Schuenemann et al., 2018). Most of these strategies are an acute response (Scheid et al., 2018), with the goal to alter or manage the cause of the problem. However, often it is beyond the reach of the household to address the root of the problem (Brouwer et al., 1989).

As coping strategies are located at the interface between fuelwood scarcity and its impact on socio-economic, environmental and food security factors, these must be considered as leverage points requiring detailed assessment. Although energy access is an integral part of sustainable development, the seventh United Nations Sustainable Development Goal[2], there is no impact assessment regarding the sustainability of coping strategies in response to fuelwood scarcity with respect to socio-economic, environmental, and food security factors of the affected population. Sustainability impact assessments not only help identify the positive and negative impacts, but also supports directing decision making toward sustainability (Bond and Morrison-Saunders, 2011). Of special interest in this context are coping strategies with regard to fuelwood scarcity in semi-arid regions, as these areas are generally characterized by low density of trees and forests as well as long respective regrowth rates. In Tanzania, these areas are located in the center of the country, with the Dodoma region being one of them. Here, fuelwood scarcity can be observed, with farmers applying a wide variety of adaptation measures (Scheid et al., 2018). In rural Tanzania, fuelwood dependency is high. Approximately 90% of the rural population uses fuelwood to meet their domestic energy demand (NBS, 2014). Mainland Tanzania is also affected by deforestation, losing approximately 370,000 ha annually (FAO, 2015), with a forest cover of roughly 48 million ha (NAFORMA, 2015). Therefore, depending on fuelwood for cooking remains a major issue in rural Tanzania (IEA, 2014). However, little is known about the perceived sustainability of the strategies applied by smallholder farmers. In order to design sustainable fuelwood strategies, the local residents—as the central actors—need to be involved (Soussan et al., 1991). This can only be realized if the methodological approach applied involves the community and their holistic perspective on local livelihoods when assessing the sustainability impact of coping strategies (Millstone et al., 2010). The latter is essential for developing appropriate interventions to the adaptation measures that will enhance sustainable access to cooking energy.

The aim of this study is to assess the positive and the negative impacts of coping strategies on sustainability criteria as well as the frequency of use of the selected adaptation measures. Using two case study sites (CSS) in Dodoma region, this paper applies three steps to close the identified research gaps and to assess the impact of coping strategies on the affected population. First, we select local coping strategies in response to fuelwood scarcity. In a second step local sustainability criteria are identified while in a third step, participatory impact assessment is carried out. The results of this study offer an insight into the impact of coping strategies on their sustainability from the farmers' perspective. The methodological approach develops a reliable monitoring on adaptation measures applied in response to fuelwood scarcity.

# METHODS

## Study Area

Our case study sites are Idifu and Mzula, two villages located in the Chamwino district of Dodoma region, Tanzania (**Figure 1**). The region, classified as semi-arid and consisting mainly of savannas and grasslands (Mutabazi, 2016), is part of the unimodal zone with one long rainy season that lasts from December to April (WFP, 2013). The food and livelihood security of the local population is utterly dependent on these rains (USAID, 2008). However, a decrease in annual rain fall and in the number of wet spells can be determined (Mkonda and He, 2017). This leads to droughts and associated yield losses, such that farms must steadily expand or move to new areas in order to feed the family; both accelerate the clearing of forest land (Goulden et al., 2009). Degraded forest and woodland areas are the consequence (Mutabazi, 2016). This can also be observed in the data provided by World Resources Institute (2019) which is presented in form of a map in **Figure 1**. Despite some progress, the lack of regular intake of foods and the prevalence of undernourishment are two major problems in the region (Leyna et al., 2010; FAO, 2017). As a result, the food security situation in the case study villages is alarming with stunting a common phenomenon, especially for children under the age of 5 (MoHCDGEC et al., 2016). Most households comprise subsistence farmers, who use fuelwood as their main energy source for cooking and boiling water in both villages. Idifu consists of approximately 1,200 households (Hafner, 2016) and Mzula has around 750 households (Mutabazi, 2016). Two different cooking technologies are used at the case study sites. In Mzula households rely on three stone fire stoves, while Idifu saw the introduction of improved cooking stoves (ICS), subsequently, adopted by several households, thus replacing three stone fire stoves.

[2]https://sustainabledevelopment.un.org/sdg7 (accessed 03.12.2018).

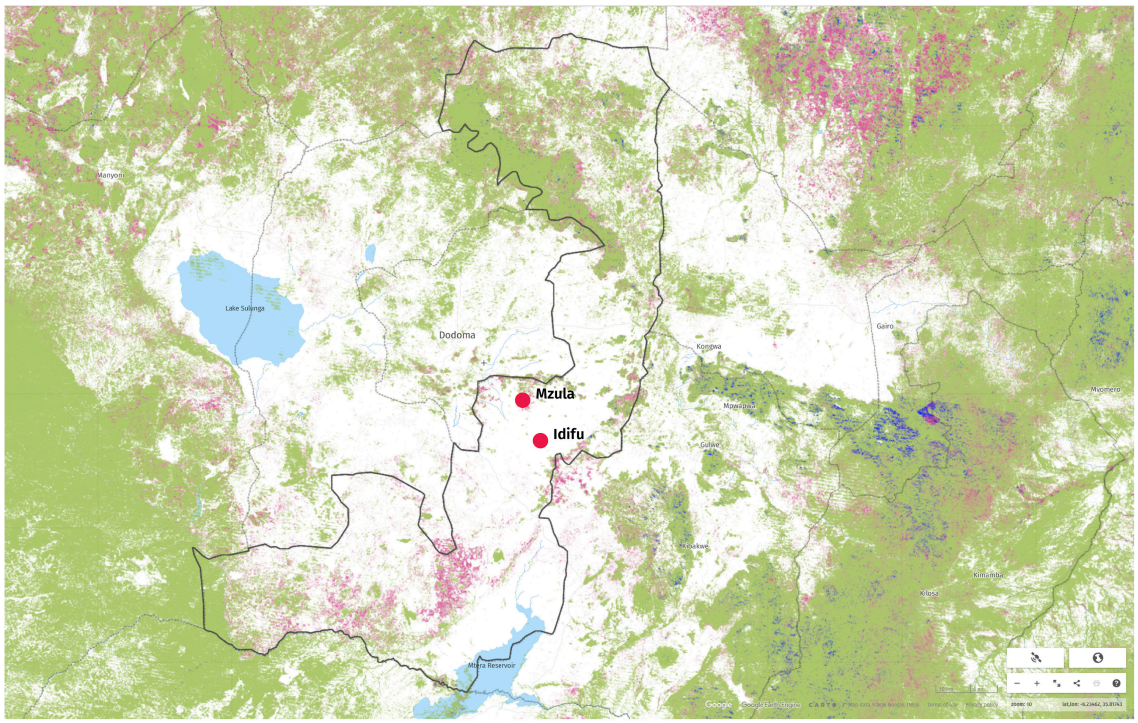


**FIGURE 1 |** Map of Chamwino district displaying the tree cover (green), tree cover loss (red) and tree cover gain (blue) with canopy density of 10%, including the case study villages Mzula and Idifu (World Resources Institute, 2019).

## Framework for Participatory Impact Assessment (FoPIA)

The methodological approach used for the impact assessment is based on the Framework for Participatory Impact Assessment (FoPIA). FoPIA is a policy impact assessment tool for sustainable development that is regularly adapted to be applicable in specific local contexts including case study regions in countries of the Global South (König et al., 2010, 2012, 2013; Morris et al., 2011; Purushothaman et al., 2013). Schindler et al., (2016a; 2017) refine the approach to be applicable at the community level when assessing agricultural strategies. For our research, this specific FoPIA approach is applied with the objective of assessing the sustainability of coping strategies in response to fuelwood scarcity. An essential part of the FoPIA process is the participatory adaptation of evaluation criteria. Via the application of this impact assessment methodology, the farmer's perspectives with respect to the positive and negative effects of adaptation measures and its trade-offs are identified. The applied FoPIA approach, based on Schindler et al. (2016a), comprises three main parts: (1) selection of local coping strategies due to fuelwood scarcity; (2) identification of local sustainability criteria; and (3) the participatory impact assessment of coping strategies on sustainability criteria as well as the frequency assessment of the selected adaptation measures (**Figure 2**). The following methodological steps are applied as part of the impact assessment.

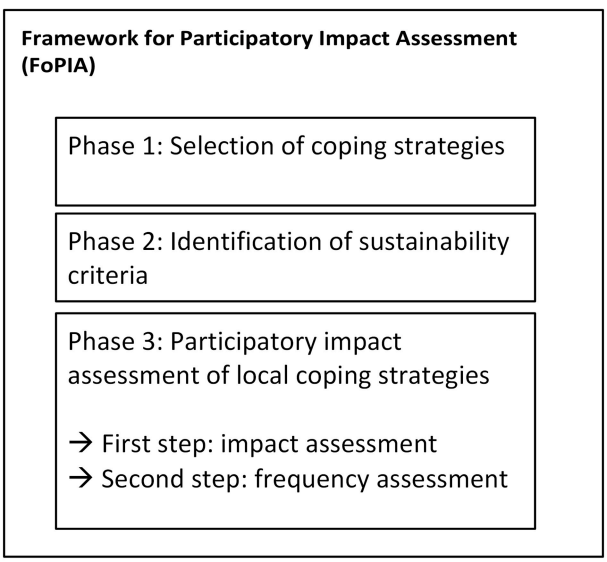


**FIGURE 2 |** Process of the applied methodological framework.

## Phase 1: Selection of Coping Strategies

This study builds upon the work of Scheid et al. (2018), which identifies coping strategies in response to fuelwood scarcity. This was done by conducting household interviews ($n = 39$)

**TABLE 1 |** Coping strategies derived from the household interviews of both case study villages including a quantified ranking.

| | Cluster | 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 | 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) | 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 | 10% | 0% |
| | | Ask relatives for fuelwood | 0% | 5% |
| | Decreased food and health | Eat fewer meals | 55% | 37% |

*The ranking is based on how frequently they were mentioned by the households. Multiple responses are possible (Scheid et al., 2018).*

in the case study villages, Mzula and Idifu (Scheid et al., 2018). Only women were interviewed, because they are principally responsible for fuelwood collection and food preparation (Lim et al., 2012; Kahimba et al., 2015). A total of 23 adaptation measures were identified, differentiated into preventive and acute measures, then grouped into eight clusters, "offering a direct strategic pathway to select appropriate strategies" (Scheid et al., 2018, p 6) (see **Table 1**). Research by König et al. (2010, 2013) and Schindler et al. (2016a) shows that stakeholders have difficulties distinguishing between indicators. In this study, two steps are used to select eight out of the 23 identified strategies. First, for a comprehensive assessment of coping strategies, measures from each cluster need to be assessed. Hence, the most frequently mentioned strategy from each of the eight clusters was pre-selected and assigned to the respective CSS with the most mentions. Secondly, thereafter five key informant interviews were conducted with experts (officials from the local and regional levels) and one scientist with extensive knowledge on the FoPIA process. The objective was to screen the 23 adaptation measures regarding their positive learning effects for the farmers and to align them with the eight pre-selected strategies. As a result, seven of the eight pre-selected strategies were identified as suitable and one strategy was exchanged. The key informants remarked that the strategy "use of crop residues instead of fuelwood", which did not belong to the pre-selected strategies, can be characterized as a critical measure with potentially negative effects on soil fertility and associated agricultural productivity (see also Amacher et al., 1993; Dendukuri and Mittal, 1993; Mahiri, 2003; Köhlin et al., 2011). Despite its limited application by the farmers, it offers learning effects for all involved stakeholders and was recommended to be included in the impact assessment. Therefore, the strategy "use twigs instead of fuelwood" was exchanged for the strategy "use of crop residues instead of fuelwood" from the same cluster. The selected coping strategies for each CSS are shown in **Table 2**.

## Phase 2: Identification of Sustainability Criteria

As adaptation measures in response to fuelwood scarcity are not inherently sustainable (Akther et al., 2010; Matsika et al., 2013), it is necessary to assess their long-term effects on sustainability. The three criteria of social, environmental, and economic conditions must be considered to achieve sustainable energy access (Guta, 2014; Mainali et al., 2014) and, therefore, are identified as part of the sustainability criteria for this research. In order to

**TABLE 2 |** Eight coping strategies selected for the impact assessment and their clusters assigned to the respective case study villages.

| Case study village | Clusters | Selected coping strategies |
|---|---|---|
| Mzula | Utilization of human resources & social relationships | Ask a neighbor for fuelwood |
| | Increased use of substitutes for fuelwood | Use of crop residues instead of fuelwood (esp. maize residues) |
| | Alternative fuelwood consumption | Cut wet fuelwood instead of collecting dry fuelwood |
| | Decreased food and health | Eat fewer meals |
| Idifu | Increased input of time & effort | Increase in walking distance to collect fuelwood |
| | Market-based measures | Use of improved collection means (wheelbarrow, oxcart, bicycle) |
| | Increased fuelwood provision | On-farm tree planting |
| | Decreased fuelwood demand | Use of improved cooking stoves |

include the intrinsic aspect of food security, it was identified as an additional sustainability criterion to broaden the range of sustainability criteria and provide food security with a rank appropriate to its importance. In a final step, four key informant interviews with experts from the region were conducted. The objective was to define the four identified sustainability criteria in a way that the farmers would understand. The issue of long working hours and time poverty due to the lack of access to basic infrastructure is, especially for women, a major component of the daily routine and social life in this region (Heltberg, 2004; Wodon and Blackden, 2006; Köhlin et al., 2011). Therefore, the criterion social condition is defined based on working hours and workload. The definition of the environmental condition rests upon reducing the amount of forest degradation, which is a tangible factor for farmers. The economic condition considers the income of the farmers, due to its present role in their daily life. A tangible and countable factor for food security is the number of meals consumed per day, which is considered as the definition for the food security condition. The four sustainability criteria and their definitions are in **Table 3**.

**TABLE 3 |** The four sustainability criteria, their definitions, and the respective questions of the positive rating rounds.

| Criterion | Definition | Question for the positive rating round |
|---|---|---|
| Social condition | Reduced working hours and workload | How intense do you experience the positive effect of the coping strategy **x** on the criterion social condition on a scale from 1 (low effect) to 3 (strong effect)? If you estimate that there is no positive impact, please indicate the stone[a]. |
| Environmental condition | Reduced forest degradation of adjacent forested areas | How intense do you experience the positive effect of the coping strategy **x** on the criterion environmental condition on a scale from 1 (low effect) to 3 (strong effect)? If you estimate that there is no positive impact, please indicate the stone. |
| Economic condition | Improved income of the farmers | How intense do you experience the positive effect of the coping strategy **x** on the criterion economic condition on a scale from 1 (low effect) to 3 (strong effect)? If you estimate that there is no positive impact, please indicate the stone. |
| Food security condition | Sufficient amount of food consumed per day (=3 meals) | How intense do you experience the positive effect of the coping strategy **x** on the criterion food security condition on a scale from 1 (low effect) to 3 (strong effect)? If you estimate that there is no positive impact, please indicate the stone. |

[a] *Respondents privately indicated their response to a research assistant using beans and a stone as indicators. This is discussed in detail in "Phase 3" of this paper.*

## Phase 3: Participatory Impact Assessment of Local Coping Strategies

### Phase 3: Step 1: Impact Assessment

After elaborating the coping strategies in response to fuelwood scarcity as well as the relevant sustainability criteria, the impact assessment was conducted. The objective during this process is for farmers to rank their assumed impacts of the coping strategies on each of the sustainability criteria. For the impact assessment, we organized two workshops in each CSS. According to Scheid et al. (2018), there are a variety of adaptation measures applied in the region. One preventive strategy is the use of ICS, which offers reduced fuelwood consumption through its higher thermal efficiency rates (Zein-Elabdin, 1997; Ochieng et al., 2013). ICS are considered to be an alternative to traditional fuelwood-based three stone fire stoves (for respective efficiencies cf. Hoffmann et al., 2015). In order to include the preventive strategy of ICS, we only invited households using ICS in Idifu. In Mzula, ICS are non-existent; hence, only households with three stone fire stoves participated. Therefore, in Idifu, households were purposive sampled; in Mzula households were randomly sampled. We only invited female farmers because women are mainly responsible for fuelwood collection and food preparation (Lim et al., 2012; Kahimba et al., 2015). A minimum of 6 to a maximum of 8 farmers participated in each workshop. In total, 28 participants attended the workshops. One workshop group assessed two coping strategies. Each workshop was conducted by a facilitator, a researcher, and a research assistant. The discussion was led by an experienced facilitator while the documentation of the results was carried out by a research assistant. The researcher was responsible for observing the workshop process, assisting in structuring the discussion, and reporting of the farmer's votes to maintain the quality of assessments and results. We conducted a positive impact rating followed by a negative impact

rating because, during pretesting of the method in Tanzania, Schindler et al. (2016a) find that performing the positive and negative rating of impacts at the same time is difficult for the farmers. Workshops were structured in the following way: (a) introduction and definition of the selected coping strategy; (b) introduction and definition of the four sustainability criteria; (c) positive scoring round; (d) negative scoring round; and (e) discussion and documentation of impact arguments. In steps (a) and (b), the selected coping strategy as well as the four sustainability criteria were introduced and defined using pictures and a flipchart for an interactive presentation. In step (c) and (d), the participants were asked to think about the positive and negative impacts that the coping strategy may have according to each criterion and to rate the impact. The rating itself was done using a four-point scale with 0 (no effect), 1 (low effect), 2 (medium effect), and 3 (strong effect). Although the discussions were carried out as a group, the ratings were carried out privately, with each farmer receiving three beans and one stone that were used to indicate her rating to the research assistant. The beans indicated the impact of the rating, while the stone indicated no impact. Farmers hid the selected amount of beans (or stone) in their hand while the research assistant noted each rating on their respective rating sheet. For example, for the impact of the coping strategy "ask a neighbor for fuelwood" on the criterion "food security condition," the question was stated as follows: "How intense do you experience the effect of the coping strategy "ask a neighbor for fuelwood" on the criterion food security condition on a scale from +1 to +3? If you estimate that there is no positive impact, please indicate the stone." Subsequently, all positive impact ratings were carried out in the same manner. After the positive rating round was finished, the moderator repeated the process of the negative scoring rating round (scale from −1 to −3). A stone indicated no negative impact. Once all ratings were finalized, the results of both scoring rounds were presented to the group. In an open discussion, participants were asked to comment on their own scoring results. The moderator went criterion by criterion to ask the reasons behind the positive and negative ratings by the participants. The arguments given by the stakeholders were directly translated from Swahili into English and documented by the research assistant. The arguments were analyzed using qualitative content analysis. In order to understand and link the ratings and the arguments of the participants, each participant was assigned a number. The main arguments of the farmers are presented in the result section.

### Phase 3: Step 2: Frequency Assessment

After the impact assessment, farmers were asked to indicate how often the assessed coping strategy is applied. Due to seasonal differences in the application of the selected coping strategies, answers regarding the frequency of application need to be differentiated into seasonal strategies and non-seasonal strategies. Strategies directly connected with the collection of fuelwood or substitutes are considered as seasonal strategies, especially since fuelwood is rarely collected during the rainy season. The following strategies are mainly applied during the dry season, which lasts from May to November:

- Use of crop residues instead of fuelwood;
- Cut wet fuelwood instead of collecting dry fuelwood;
- Increase in walking distance to collect fuelwood; and
- Use of improved collection means

Adaptation measures applied throughout the year are considered to be non-seasonal strategies:

- Ask a neighbor for fuelwood;
- Eat fewer meals;
- On-farm tree planting; and
- Use of improved cooking stoves

The rating was completed using the Likert-Scale method. The corresponding ratings are 1 = never, 2 = rarely (less than once a month), 3 = sometimes (1–3 times a month), 4 = often (4–6 times a month), and 5 = very often (almost every day). As before, ratings were made privately. Each farmer received five beans that were subsequently used to show the researcher their score, which was then noted on the respective rating sheet.

The National Institute for Medical Research Tanzania and the Ministry of Health, Community Development Gender, Elderly & Children Tanzania granted an ethical clearance for conducting this study. Interviewing participants is integral part of the ethical clearance. All participants were informed that the interview material is used for scientific purposes and their oral and informed consent was given.

# RESULTS

## Impact Assessment of Coping Strategies in Mzula

### Assessment Result for the Coping Strategy "Ask a Neighbor for Fuelwood"

Overall, the strategy is rated positively on all four dimensions in the following range: *food security condition* (+2.88), *environmental condition* (+2.75), *economic condition* (+2.63), and *social condition* (+2.5). The positive ratings are related to the additional fuelwood farmers receive from their neighbors, the additional time that can be used for other household chores, and the reduced amount of fuelwood that needs to be collected from the forest. Almost no negative rating is made for the respective criteria. The frequency assessment shows that this strategy is rarely applied by the farmers (1.75).

### Assessment Result for the Coping Strategy "Use of Crop Residues Instead of Fuelwood"

The highest rating is for the *social and economic condition* (+2.86), followed by the *food security condition* (+2.29) and *environmental condition* (+2.14). The arguments for the positive ratings are additional cooking fuel and, therefore, sufficient amounts of cooked food, saving time because it takes less time to collect residues than fuelwood, conservation of trees, and selling the additional fuelwood. Negative impacts are assessed for the *food security condition* (−1.0), *environmental condition* (−0.71), and *social condition* (−0.43). The negative ratings are related to the increased workload needed to bring the crop residues from the fields back home and the lack of residues during the rainy season. The frequency assessment indicates that the strategy is rarely used by the farmers (1.86).

### Assessment Result for the Coping Strategy "Cut Wet Fuelwood Instead of Collecting Dry Fuelwood"

The highest positive rating is on the *food security condition* (+2.67), followed by *social condition* (+2.5) and *economic condition* (+2.33). The positive ratings are mainly based on the fact that wet fuelwood is abundant and can easily be stored and dried. According to the farmers, this is more efficient and needs less work than collecting dry fuelwood. Some farmers produce local beer made out of millet flour, which is traditionally cooked with wet wood. An equal negative rating for *environmental* and *food security condition* (−2.50) is found, followed by *social condition* (−2.0) and *economic condition* (−1.5). The farmers perceive that cutting wet fuelwood from trees results in droughts due to reduced forest cover. In addition, wet fuelwood is heavier and more difficult to carry, leading to headaches and back pain, which negatively affects social conditions. According to the frequency assessment, the strategy ranges between sometimes and often (3.5) used.

### Assessment Result for the Coping Strategy "Eat Fewer Meals"

No positive rating is made for the respective criteria. The highest negative rating concerns the *economic condition* (−2.83), followed by *social condition* (−2.5) and *food security condition* (−2.17). The main arguments for the negative ratings involve that food is needed as a source of energy in order to perform their daily activities related to work and household chores. Eating fewer meals or skipping meals is a necessity that is sometimes used as a coping strategy (2.83).

The entire rating results for Mzula are in **Tables 4**, **5**.

## Impact Assessment of Coping Strategies in Idifu

### Assessment Result for the Coping Strategy "Increase in Walking Distance to Collect Fuelwood"

The highest positive rating is on *economic condition* (+1.5) followed by the *food security condition* (+0.25). The positive ratings mainly came from the few farmers who sell fuelwood on the market. Their argument is that the scarcity of fuelwood opens business opportunities for them. The highest negative rating is on *social condition* (−2.75), followed by *food security condition* (−2.25), *environmental condition* (−1.88), and *economic condition* (−1.63). Stated reasons are that the increase in walking distance result in a reduced number of meals, other household chores not be completed (fetching water, milling, cleaning), and other business opportunities need to be canceled [brewing local beer, selling mandazi (local cakes)]. Furthermore, it leads to an increase in environmental degradation—adjacent forests are already cleared, moving on to other forested areas. According to the farmers this adaptation measure is used often to very often (4.5).

### Assessment Result for the Coping Strategy "Use of Improved Collection Means"

The highest positive rating is on *social condition* (+2.5), followed by the *food security condition* (+2.0) and *economic condition* (+1.0). The positive assessments are based on the reduced amount of work, additional time that can be used for other household chores (cooking), and business opportunities from selling the surplus fuelwood. By far, the highest negative rating is on the *environmental condition* (−2.75), followed by the *food security condition* and *economic condition* (−1.38). The argument on the *environmental condition* is that wheelbarrows and oxcarts lead to soil erosion on the edges of the forest while the increased amounts of collected fuelwood lead to a further forest degradation. Arguments for the negative ratings in *economic* and *food security condition* include that improved collection means require money for hiring e.g., the driver and a guard for the protection of the collected fuelwood in the forest. These additional expenses are missing for buying food items. The frequency assessment shows a high usage of improved collection means (4.75).

### Assessment Result for the Coping Strategy "On-Farm Tree Planting"

The highest positive rating is on *environmental condition* (+2.83), followed by *food security condition* (+2.5), *economic condition* (+2.17), and *social condition* (+1.83). The arguments given consider the service provision of trees (shade, clean air, food (fruits, herbs), fuelwood, and protection for their fields). Planting and cultivating the trees needs some additional work but this is not seen as a major burden. Negative ratings are only made for *social condition* (−1.17) and *economic condition* (−0.67). The respective arguments are that cultivating the trees during the dry season is difficult because farmers are usually not on their fields. Furthermore, tree seedlings are bought from tree nurseries, which requires additional income for the farmers. The frequency assessment indicates that on-farm tree planting is done once in a while by the farmers (3.33).

### Assessment Result for the Coping Strategy "Use of Improved Cooking Stoves"

The highest positive rating is on *food security* and *social condition* (3.0), followed by *environmental condition* and *economic condition* (2.83). The arguments are that ICS need less fuelwood, thus reducing the cooking time and producing less smoke than three stone fire stoves. Business opportunities that ICS offer are also mentioned. Some participants use the ICS as a business to cook for others or they receive income by teaching other households how to construct an ICS. Regarding the negative assessment, all four criteria are rated with "no impact." The frequency assessment shows that ICS are frequently used among the participants (4.83).

All rating results for Idifu are found in **Tables 6**, **7**.

# DISCUSSION

## Key Findings of the Impact Assessment

The results of the participatory impact assessment offer (a) insights into the perceived positive and negative effects of coping strategies in response to fuelwood scarcity; and (b) a weighting factor through the frequency of usage from a farmer's perspective. This assessment shows that farmers have a clear perception on how adaptation measures affect their daily life across social,

**TABLE 4 |** Results of the impact assessment of Mzula with the positive (+) and negative (–) ratings.

| | Mzula | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Ask a neighbor for fuelwood** | | | | **Use of crop residues instead of fuelwood** | | | | **Cut wet fuelwood instead of collecting dry fuelwood** | | | | **Eat fewer meals** | | | |
| | ***n* = 8** | | | | ***n* = 7** | | | | ***n* = 6** | | | | ***n* = 6** | | | |
| **Criteria** | **(+)** | ***SD*** | **(–)** | ***SD*** | **(+)** | ***SD*** | **(–)** | ***SD*** | **(+)** | ***SD*** | **(–)** | ***SD*** | **(+)** | **SD** | **(–)** | ***SD*** |
| Social condition | 2.50 | 0.53 | 0.00 | 0.00 | 2.86 | 0.38 | 0.43 | 1.13 | 2.50 | 0.84 | 2.00 | 0.89 | 0.00 | 0.00 | 2.50 | 0.55 |
| Environmental condition | 2.75 | 0.71 | 0.00 | 0.00 | 2.14 | 1.21 | 0.71 | 0.95 | 0.33 | 0.82 | 2.50 | 0.55 | 0.00 | 0.00 | 0.00 | 0.00 |
| Economic condition | 2.63 | 0.74 | 0.00 | 0.00 | 2.86 | 0.38 | 0.00 | 0.00 | 2.33 | 1.21 | 1.50 | 0.84 | 0.00 | 0.00 | 2.83 | 0.41 |
| Food security condition | 2.88 | 0.35 | 0.13 | 0.35 | 2.29 | 0.95 | 1.00 | 1.41 | 2.67 | 0.82 | 2.50 | 0.55 | 0.00 | 0.00 | 2.17 | 0.98 |

*Corresponding values: 0 = no effect, 1 = low effect, 2 = medium effect, 3 = strong effect.*

**TABLE 5 |** Results of the frequency assessment of Mzula.

| Mzula | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ask a neighbor for fuelwood** | | **Use of crop residues instead of fuelwood** | | **Cut wet fuelwood instead of collecting dry fuelwood** | | **Eat fewer meals** | |
| Freq. | SD | Freq. | SD | Freq. | SD | Freq. | SD |
| 1.75 | 0.71 | 1.86 | 1.07 | 3.5 | 1.05 | 1.83 | 0.98 |

*Corresponding values: 1=never, 2=rarely, 3=sometimes, 4=often, 5=very often Freq. = Frequency.*

environmental, economic, and food security dimensions. This corresponds with Schindler et al. (2016b, p 42), who find that farmers consider indirect linkages taking their complex livelihoods into account. The two popular coping strategies that are rated positively are *on-farm tree planting* and *use of improved cooking stoves*. These strategies offer the potential to be strengthened and fostered by policy makers and international organizations. The adaptation measures *use of crop residues instead of fuelwood* and *ask a neighbor for fuelwood* are rated positively by the farmers across all four criteria, but however with a low frequency of usage. According to Scheid et al. (2018), the latter strategy enjoys a wide dissemination among the farmers in the region and, thus, can be characterized as a commonly known strategy that is only rarely used. The seasonal strategy *use of crop residues instead of fuelwood* is only used by a few farmers (Scheid et al., 2018). The low frequency of usage as well as the low dissemination among the farmers supports the findings of other authors suggesting that crop residues are only partially used as a substitute for fuelwood (Cooke et al., 2008; Köhlin et al., 2011; Guta, 2014). If they are used, the so called fuel-food trade-off (Heltberg et al., 2000), explaining that crop residues can be used as mulch associated with higher agricultural output or as cooking energy, could be part of the consideration of affected farmers.

The two negative rated strategies are *eat fewer meals* and *increase in walking distance to collect fuelwood,* both widely cited in the literature as adaptation measures with a high negative impact on the affected people (Brouwer et al., 1996; Cardoso et al., 2012; FAO, 2013; Guta, 2014). The former strategy is regularly practiced among half of the affected people at the CSS (Scheid et al., 2018), which supports the interlinkage between fuelwood scarcity and food security (Sola et al., 2016). The already alarming situation of degraded local forest resources is amplified by the negative result of the strategy *increase in walking distance to collect fuelwood* and its high frequency of usage. The findings of Scheid et al. (2018) that the same strategy is widely used by farmers in the region, especially during the dry season, aggravates the negative rating result. Hence, raising awareness of alternative, already practiced, coping strategies might be a way to reduce the use of adaptation measures that negatively impact livelihoods. Both negative rated strategies, coupled with their frequency of use, can be considered as indicators of the extent of fuelwood scarcity, while the literature suggests various different indicators appropriate for assessing fuelwood scarcity (Dewees, 1989; Brouwer et al., 1997; van't Veld et al., 2006; Bandyopadhyay et al., 2011; Damte et al., 2012). The regular practice of adaptation measures indicates a scarcity situation. As a short-term measure, strengthening small-scale farmers in semi-arid regions requires a minimal stock of solid fuels and, in the long-term, the sustainable use of available fuelwood resources, as already called for by Heltberg et al. (2000). With respect to the semi-arid region of Dodoma, it is clear that three out of the four objectives of Sustainable Development Goal 7 are not achieved: access to energy is not reliable, sustainable, or modern.

Regarding the adaptation measure *on-farm tree planting*, some of the farmers started planting trees during the data collection in 2017/18. Hence, their assessment involves future expectations. Trees planted in this region are usually used for fuelwood, medicine, shade, timber, agroforestry or food and fodder.

Due to the research design, in Idifu village only ICS users participated in the workshops. The cooking stove design used,

**TABLE 6 |** Results of the impact assessment of Idifu with the positive (+) and negative (–) ratings.

| | Idifu | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Increase in walking distance to collect fuelwood $n = 8$ | | | | Use of improved collection means $n = 8$ | | | | On-farm tree planting $n = 6$ | | | | Use of improved cooking stoves $n = 6$ | | | |
| **Criteria** | **(+)** | ***SD*** | **(–)** | ***SD*** | **(+)** | ***SD*** | **(–)** | ***SD*** | **(+)** | ***SD*** | **(–)** | ***SD*** | **(+)** | ***SD*** | **(–)** | **SD** |
| Social condition | 0.00 | 0.00 | 2.75 | 0.71 | 2.50 | 0.53 | 0.00 | 0.00 | 1.83 | 0.98 | 1.17 | 0.41 | 3.00 | 0.00 | 0.00 | 0.00 |
| Environmental condition | 0.00 | 0.00 | 1.88 | 1.55 | 0.00 | 0.00 | 2.75 | 0.71 | 2.83 | 0.41 | 0.00 | 0.00 | 2.83 | 0.41 | 0.00 | 0.00 |
| Economic condition | 1.50 | 1.31 | 1.63 | 1.30 | 1.00 | 0.53 | 1.38 | 1.19 | 2.17 | 0.75 | 0.67 | 1.03 | 2.83 | 0.41 | 0.00 | 0.00 |
| Food security condition | 0.25 | 0.71 | 2.25 | 0.89 | 2.00 | 1.07 | 1.38 | 1.41 | 2.50 | 0.55 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 |

*Corresponding values: 0 = no effect, 1 = low effect, 2 = medium effect, 3=strong effect.*

**TABLE 7 |** Results from the frequency assessment of Idifu.

| Idifu | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Increase in walking distance to collect fuelwood** | | **Use of improved collection means** | | **On-farm tree planting** | | **Use of improved cooking stoves** | |
| Freq. | *SD* | Freq. | *SD* | Freq. | *SD* | Freq. | *SD* |
| 4.5 | 0.76 | 4.75 | 0.46 | 3.33 | 1.51 | 4.83 | 0.41 |

*Corresponding values: 1=never, 2=rarely, 3=sometimes, 4=often, 5=very often Freq. = Frequency.*

is described by Hafner et al. (2018). The ICS is a mud-based stove using locally available input materials for construction. Due to its design, wood can be supplied only via a wood entry slot with a diameter of approximately 12.9 cm to 14.2 cm, thus requiring fuelwood to be resized prior to burning. For some of these farmers, stove stacking was identified as they use ICS and traditional three stone fire stoves depending on the cooking purpose. The positive impact rating, as well as the high user frequency, show a positive assessment of ICS, which is controversially discussed in the literature. Many researchers refer to the benefits connected to ICS regarding reduced fuelwood and time consumption during cooking (Uckert et al., 2017; Hafner et al., 2018), while other scholars warn that ICS might reduce diet variety (Mwampamba et al., 2013). Masera et al. (2000) indicate that ICS are inflexible because pot sizes cannot be adjusted, consequently limiting the amount and types of food cooked. An extensive assessment of the effect ICSs have on the social, economic, environmental, and food security situations of the people is needed for a final evaluation.

## Fuelwood Scarcity and Potential Trade-Offs

The results offer a clear and transparent identification of trade-offs between the selected coping strategies and the four sustainability criteria based on the ratings of the farmers. In general, the impact assessment results are more positive than negative. Nevertheless, farmers are blunt about adaptation measures with negative effects. Respondents suggest that coping strategies have the highest negative effect on environmental conditions. However, the aspect of fuelwood scarcity and its impact on environmental degradation is controversially discussed in the literature (Cooke et al., 2008). The three strategies with the highest negative impact on the environmental conditions, as perceived by the smallholders, are *cut wet fuelwood instead of collecting dry fuelwood, use of improved collection means,* and *increase in walking distance to collect fuelwood*. While the latter strategy is a mere reaction to the prevalence of fuelwood scarcity, the first two strategies have the potential to accelerate forest degradation through an increased rate of extraction, as shown by Masera et al. (2015). This research shows that small-scale farmers in semi-arid regions are well aware of the negative impact of fuelwood scarcity on their livelihood as well as the necessary coping strategies. This adds a new perspective to the statement of Brouwer et al. (1989, p 352) that "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," something farmers are well aware of.

The two strategies with both positive and negative ratings, thus resulting in a neutral assessment by the farmers, exemplify the trade-offs farmers deal with. The strategy to *cut wet fuelwood instead of collecting dry fuelwood* was rated positive and negative for all four sustainability criteria. The trade-off can be located between the *economic condition* and *environmental condition*. During discussions, stakeholders pointed out that cutting wet fuelwood saves time and, therefore, provides time for other (business) activities. At the same time, it leads to the destruction of the remaining forest areas. A similar argument is observed for the adaptation measure *use of improved collection means*, which

received equally positive and negative ratings. In this case, the additional fuelwood positively affects cooking behavior and the social condition of the farmers, but with clear negative hazards for the environment. One farmer argues "I can sell some of the firewood collected with the wheelbarrow and buy food items like tomatoes and oil, [. . . ]" and continues, "people are destroying the environment because they are clearing the mountains and also the wheel of the wheelbarrow and the steps of the cow cause soil erosion." Despite the neutral rating, both seasonal adaptation measures enjoy a high frequency of usage and are applied by several farmers at the CSSs (Scheid et al., 2018). This indicates that the rather short-termed positive aspects on social, economic, and food security conditions outweigh the rather long-term negative aspects on the environment. This opens the trade-off discussion between the necessity of short-term actions and sustainable long-term adaptation measures (Tittonell et al., 2007). These examples highlight the missing maneuverability of small-scale farmers when it comes to the applying adaptation measures and is far more complex than the fuel-food trade-off discussed by several authors (Heltberg et al., 2000; Guta, 2014). In most cases, farmers have to deal with multiple trade-offs between short- and long-term objectives with both biophysical and socio-economic dimensions (Tittonell et al., 2007). Trade-offs cannot be avoided (Morris et al., 2011), however Tittonell et al. (2007) argue that understanding these trade-offs is essential for addressing farm-scale questions such as the efficient use of available resources.

## Participatory Impact Assessment

Beyond discussing our quantitative results, we also discuss our methodological approach to ease the further application and adaptation of the underlying framework.

Stakeholder involvement is crucial for identifying region-specific and implicit information (König et al., 2012). Farmers have valuable knowledge about the characteristics and dynamics of their own ecological and socio-economic environment (Millstone et al., 2010, p 78). During the impact assessment, challenges were observed and while taking them into account could improve the outcome of the assessment. The farmers complained that the assessments took too long. One reason for the lengthy assessment was the separation of positive and negative rating rounds. Nevertheless, this approach was necessary to ensure a clear separation of positive and negative impacts and to reduce the complexity of the rating process (Schindler et al., 2016a). This response also underlines that the reduction of the coping strategies from 23 to 8 was a necessary step in order to reduce the complexity and the amount of time needed for the participatory approach. Conducting more workshops could potentially provide added value to the research findings.

For this study, only female farmers were interviewed, including female household heads and wives of male household heads. We selected female interviewees as several studies indicate that women in Sub-Saharan Africa, including the Dodoma Region (Kahimba et al., 2015), are principally responsible for fuelwood collection and food preparation (Brouwer et al., 1989; Köhlin et al., 2011; Lim et al., 2012). Other studies covering the same region note that women only talk freely if men are not present. Therefore, the quality of the results is improved if female participants are assessed separately from male participants (Jakobsen, 2012; Schindler et al., 2016a, 2017). However, research on adaptation measures in response to fuelwood scarcity including male participants would add a further valuable perspective, as a broader picture would be developed.

The private evaluation proved to be a valuable way for participants to express their secret individual opinion. Inconsistencies between the ratings and the arguments given by the farmers were observed. In a few cases, farmers gave a positive or a negative rating but did not support their rating with any arguments. Although retroactive adjustments by the researchers could have been made, inconsistencies are understood as an essential part of participatory impact assessments and were not removed or modified.

The results reflect the experienced impact of farmers and must be assessed carefully as they reflect individual opinion. To exemplify: farmers mentioned that the strategy *ask a neighbor for fuelwood* reduces the amount of fuelwood collected from the forest, because they do not have to enter the forest to collect fuelwood themselves. Although this might be true from an individual perspective, from a scientific point of view, taking wood from neighbors does not lead to a reduction because the total amount of fuelwood collected does not change, rather it shifts to others. Schindler et al. (2016b) describes this as a gap between scientists' theory and farmers' practice. Researchers try to identify cause and effect relationships while farmers apply trial and error strategies (Hoffmann et al., 2007). Therefore, bi-lateral impact assessments of local stakeholders and scientists are important for adding the tacit knowledge of farmers into formal research processes (Hoffmann et al., 2007; Schindler et al., 2016b).

During, and particularly at the end, of the dry season, which lasts from May till November, small-scale farmers are busy collecting and storing fuelwood in order to be prepared for the rainy season. Hence, some of the coping strategies in response to fuelwood scarcity are highly seasonal, which must be reflected in the impact and frequency of usage. Adaptation measures that are regularly applied only during the dry season might have a more severe impact through its regularity than strategies where the impact is spread throughout the year. The standardization of frequency assessments of adaptation measure in response to fuelwood scarcity can help to develop a more thorough picture of how farmers cope.

Since 1995, six core areas of impact assessment have been developed. This study avails itself of criteria from the approach of sustainability assessment that considers environmental, social, and economic implications (Bond et al., 2012). In order to assess the long-term effects of adaptation measures in response to fuelwood scarcity, this study identifies four sustainability criteria, including the aspect of food security, as the latter is essential for the local population (Leyna et al., 2010; MoHCDGEC et al., 2016; FAO, 2017). However, other authors set different priorities. Garnett et al. (2013) and McKenzie and Williams (2015) prioritizes the importance of environmental sustainability, while Schindler et al. (2016a, 2017) address the

three traditional sustainability dimensions—social, economic and environment—as well as food security. However, they address them on different hierarchical levels.

## CONCLUSION

Coping strategies in response to fuelwood scarcity play an intermediary role between the scarcity of fuelwood and its impact on socio-economic, environmental, and food security factors. We apply a methodological framework that includes the participatory identification of coping strategies and sustainability criteria, as well as impact and frequency assessment components, to assess the experienced effects of coping strategy application by local stakeholders. The strategies of *on-farm tree planting* and *use of improved cooking stoves* are identified as the most popular among farmers and are also rated positively throughout the applied sustainability criteria. Therefore, further political and financial support by donors and the Tanzanian government on various levels could help the local population in their struggle to guarantee an adequate and sustainable fuelwood supply in the mid- to long-term. This is essential, as in rural areas of Sub-Saharan Africa, a further development of cooking processes with regard to modern energy is especially unlikely to be achieved in the coming decades. The strategies with a clear negative rating are *eat fewer meals* and *increase in walking distance to collect fuelwood*. Both measures are regularly and widely practiced by farmers, thus aggravating the negative rating result. The common practice of skipping meals due to fuelwood scarcity is especially alarming and shows how closely fuelwood scarcity is linked to food insecurity. Our results offer a clear and transparent insight into the impact of coping strategies on their sustainability from the farmers' perspective. This study is important for the future monitoring of the application of adaptation measures in response to fuelwood scarcity and to achieve distinct values for benchmarking. Policy implications of the findings include e.g., that it is critical that a careful on the ground analysis of existing and positively perceived coping measures is carried out before implementing external strategies. Further scientific evaluation of coping strategies in response to fuelwood scarcity is necessary to support the impact ratings provided by the farmers.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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