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The urge for just transition: Evidence from understanding of wood fuel producers' livelihoods and vulnerability in the drylands of Ethiopia

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Wood fuel is not only the main source of energy for both rural and urban households but also a vital means of livelihood diversification for rural households to improve livelihood capital in developing countries like Ethiopia. However, the status of wood fuel producers' livelihood capital and their vulnerability is poorly understood in the drylands of Ethiopia. The main purpose of the research is to characterize the livelihoods of firewood and charcoal producers as well as identify sources of livelihoods' vulnerability in the dryland areas of the country. These urge to transit for sustainable energy use. The study used survey data collected from 857 sampled wood fuel producer households and Focus Group Discussions. The data were analyzed descriptively using livelihood measurement indicators and livelihood vulnerability indexes (exposure, sensitivity, and adaptive capacity indicators) in the context of farming, agro-pastoralist, and pastoralist communities. Results indicated that generally financial, human, and social capital of wood fuel producers were low whereas natural and physical capital were better. Results also indicated engagement in the production of wood fuel strengthened the producers' livelihood capital and delivered other benefits such as opportunities for livelihood diversification as well as reducing vulnerability and improved livelihoods. The pastoral and agro-pastoral communities' livelihood capital sources were more vulnerable than farming communities. The study has also identified that wood fuel production was one of the major coping strategies employed by the sampled households to mitigate the effects of different shocks. Finally, the study results implied that wood fuel production is the highest priority area of intervention to improve the livelihoods of communities in the dry lands. It is also worthwhile to establish sustainable approaches for wood fuel production keeping the dry land forest and environment safe. This

calls policy for a just transition toward an equitable wood fuel production system with the potential to deliver sustainable energy and rural development through the incorporation of wood fuel importance to rural livelihoods.

KEYWORDS

dryland forest, energy transition, livelihood capital, sustainability, vulnerability, woodfuel

Introduction

Worldwide, forests provide different tangible and intangible products and services to the livelihood of 800 million people (Heubach et al., 2011), and the contribution of forest resources to rural livelihoods has received high attention in the past decades (Angelsen et al., 2014). Forest income from timber and non-timber forest products (NTFPs) is a vital source of livelihood for many communities in Africa (Kiruki et al., 2020). Wood fuels (Charcoal and firewood) are one of the most important forest products and energy sources for most developing countries (Miranda et al., 2010). It can contribute 50–90% to household energy and up to 8% of all household income in developing countries (Singh et al., 2018).

Nowadays, wood fuel production in Africa has been steadily increasing over the years with a total production of 665 million m^3 of wood fuel in 2015 (UNEP, 2019). Among African countries, Ethiopia is the largest producer of wood fuel, producing 108 million m^3. The proportion of Ethiopia's wood fuel production and consumption pattern showed about 108,173,872 and 108,171,205 m^3, as well as import and export data, also estimated 3 and 2,670 m^3, respectively at the national level (UNEP, 2019). In Sub-Saharan Africa (SSA), including Ethiopia, wood fuel, especially charcoal, is a crucial domestic urban source of energy, and its production provides a means of income generation, livelihood support, and poverty alleviation to the rural communities (Openshaw, 2010; Jones et al., 2016; Smith et al., 2017). Thus, wood fuel production and trade are part of strategies that participants used to sustain their livelihoods depending on personal skills and characteristics, access and use of different tangible and intangible capital sources (physical, financial, social, natural, and human), and combined different activities (Schure et al., 2015). However, there is limited understanding of the motivation and livelihood of the people involved in wood fuel production (Schure et al., 2013).

Beyond forestry and energy issues of wood fuel, the livelihood characteristics of wood fuel producers and the role of wood fuel study including wood fuel's roles as a source of revenue for poor people are receiving more attention (Vedeld et al., 2007). Even though it is increasingly believed that wood fuel can provide important benefits to households in terms of income, its contribution to the livelihood of producer households has been underestimated. In this respect, there are only a few quantitative studies available. Although income from wood fuel production is a means to meet a wide range of essentials within rural livelihoods, the role of wood fuel production in the livelihoods of small-scale producers is not well-understood (Kiruki et al., 2020). Wood fuel policies in SSA, Ethiopia in particular, give less attention to livelihood improvement and vulnerability context of wood fuel producers (Zulu and Richardson, 2013). This shows that there is a major policy challenge to support wood fuel producer livelihoods without undermining ecological sustainability.

The knowledge of wood fuel contribution to a producer's livelihood is relevant, especially considering both the growing commercial wood fuel sector and the concentrated urban demand (Sola et al., 2019). Sustainable management options and policies related to climate change mitigation that affect the wood fuel sector should not be addressed without a detailed understanding of possible livelihood outcomes (Schure et al., 2014). Besides the economic contribution of wood fuel, there has been little attention to how involvement in the sector contributes to broader livelihood components. The contribution to livelihoods and economic activities encompasses more than just income, and there is a need to consider a broader range of factors, for instance social relations, human resources, and food security (Smith et al., 2017). However, many wood fuel-based livelihoods are thus not formal with uncertainty and risks from enforcement activities (Smith et al., 2015). Therefore, characterization of producer's livelihood and a better understanding of livelihood contribution is important to develop appropriate wood fuel policy and intervention mechanisms through just transition.

Ethiopia's dry forests host valuable flora and fauna species which are known for their rich composition of different Acacia species used as sources of wood fuel production (Abebaw et al., 2012). It covers about 55 million hectares of land and is one of the livelihood strategy components for farming, agro-pastoral and pastoral livelihood groups found in arid and semi-arid areas of the country (Lemenih et al., 2003; Lemenih and Bongers, 2011). Despite their contribution to local communities the dry forests are currently under severe threat of deprivation and have been declining over the past few years as a result of rapid settlement expansion and due to extreme use of the

forest resources for different purposes, especially wood fuel production. Wood fuel is a means of livelihood for most rural people and the increasing numbers of urban dwellers are also engaged in the charcoal and fuel wood trade in Ethiopia. However, there is limited empirical evidence that measures the broader livelihood capital of the producers as well as their motivation and vulnerability for the production of wood fuel.

It is believed that there is no single remaining dry forest that has not been used at least as a source of firewood or for charcoal production. For example, of all the harvested wood in the tropics, 80% is used for fuel purposes, and the proportion is higher (90%) in the African tropics, where dry forests are predominant (Murphy and Lugo, 1986). Many people in SSA including Ethiopia are dependent on dryland forest as a source of wood for fuel. For example, the share of total domestic energy in Ethiopia is as follows: fuel wood and tree residues (70%), or 85% of the total energy comes from biomass; the dryland forests contribute the highest share, more than 82% (Teketay, 2012). The remaining limited share comes from other sources although the country has huge untapped renewable energy sources. Moreover, factors like limited infrastructure, growing population, dependence on fossil fuel, high use of unsustainable biomass, and vulnerability to climate change reflects the current situation in Ethiopia and other SSA countries (Ayobami, 2021). These urge to transit for sustainable energy use. Because of that, just energy transition secures the future and livelihoods of households and communities as a whole in the transition to low carbon livelihood sources (Acey and Culhane, 2013). To date, the just transition sustainability studies mainly focused on energy transitions, while livelihood base transitions have recently gained increasing attention in sustainability transition studies (Tribaldos and Kortetmäki, 2022). However, for just transitions, there remains a lack of robust studies but an important avenue for research regarding livelihood and vulnerability.

Many of the previous studies conducted on wood fuel producers' livelihoods in Sub-Saharan African countries, Ethiopia in particular, mainly focused on financial aspects in terms of income contribution and biomass consumption for energy (Schure et al., 2014; Smith et al., 2015; Amanuel et al., 2019; Kiruki et al., 2020) and the negative effect of wood fuel production (Abeje et al., 2019; Alhassan et al., 2022). In Ethiopia, wood fuel production has limited success stories, because producers do not follow standardized methods and technologies as well as legal processes (Abeje et al., 2019). There is potential for wood fuel to be produced sustainably in the dryland forest, but this requires supportive policies. Previous studies identified that policy issues have contributed to the wood fuel sector remaining environmentally destructive and informal (Yalew, 2022). Limited understanding and punitive political attitudes toward the role of wood fuel production and marketing, complicated with difficulties in accessing secure resource tenure, market security, and start-up costs for wood fuel production, mainly charcoal, create challenges for poor communities to invest in the sector in Ethiopia. Many wood fuel-based livelihoods are thus informal and often ignored or penalized by governments (Smith et al., 2015). Benefits to wood fuel producers are poorly understood and more attention is given in favor of environmental influences against the sector. Therefore, it is better to understand the role of wood fuel production producers' livelihoods if wood fuel policies are to benefit the rural poor.

Even if wood fuels are among the most important forest products that provide livelihood capital to households, there is little quantitative evidence about the contribution of wood fuel in terms of improving livelihood capital sources and their vulnerability. Within this context, this study aims to investigate the urge for just transition evidence from the livelihoods of wood fuel producers and their vulnerabilities in dryland areas of Ethiopia through a sustainable livelihood framework approach. This study contributes knowledge that concerns forest management and policy discourse on energy transition related to climate change mitigation in dryland areas of the country as well as developmental and environmental issues through a sound policy.

Theoretical and analytical framework

The study used the concept of livelihoods and the Sustainable Livelihood Framework (SLF) as a conceptual framework to structure our analysis (DFID, 2001; Scoones et al., 2016), due to its holistic and multidimensional use to identify the potential variables that influence decisions by rural households to produce wood fuel. According to Chambers and Conway (1992), a livelihood becomes sustainable when it can manage through, and recover from, shocks, and maintain its capabilities and assets, and provide opportunities for the future generation in the short and long-term.

The SLF indicates livelihoods as comprising various combinations of subsistence and income-generating activities and strategies. These rely on financial, physical, human, natural, and social assets, which are organized within a perspective of vulnerability (seasonality, shocks, and trends). For example, transforming structures and processes are vital for shaping people's livelihood strategies. More specifically, these structures are local bodies like the forestry sector, forest policies, and local committees with forest protection, while key processes include government policies regarding wood fuel production and resource access. When the SLF is applied to wood fuel production, it follows an assessment of the socio-economic and underlying vulnerability contexts in which producers' livelihoods operate. The SLF incorporates livelihood assets, livelihood strategies, vulnerability, livelihood outcomes, and governance structures that influence power and access to wood

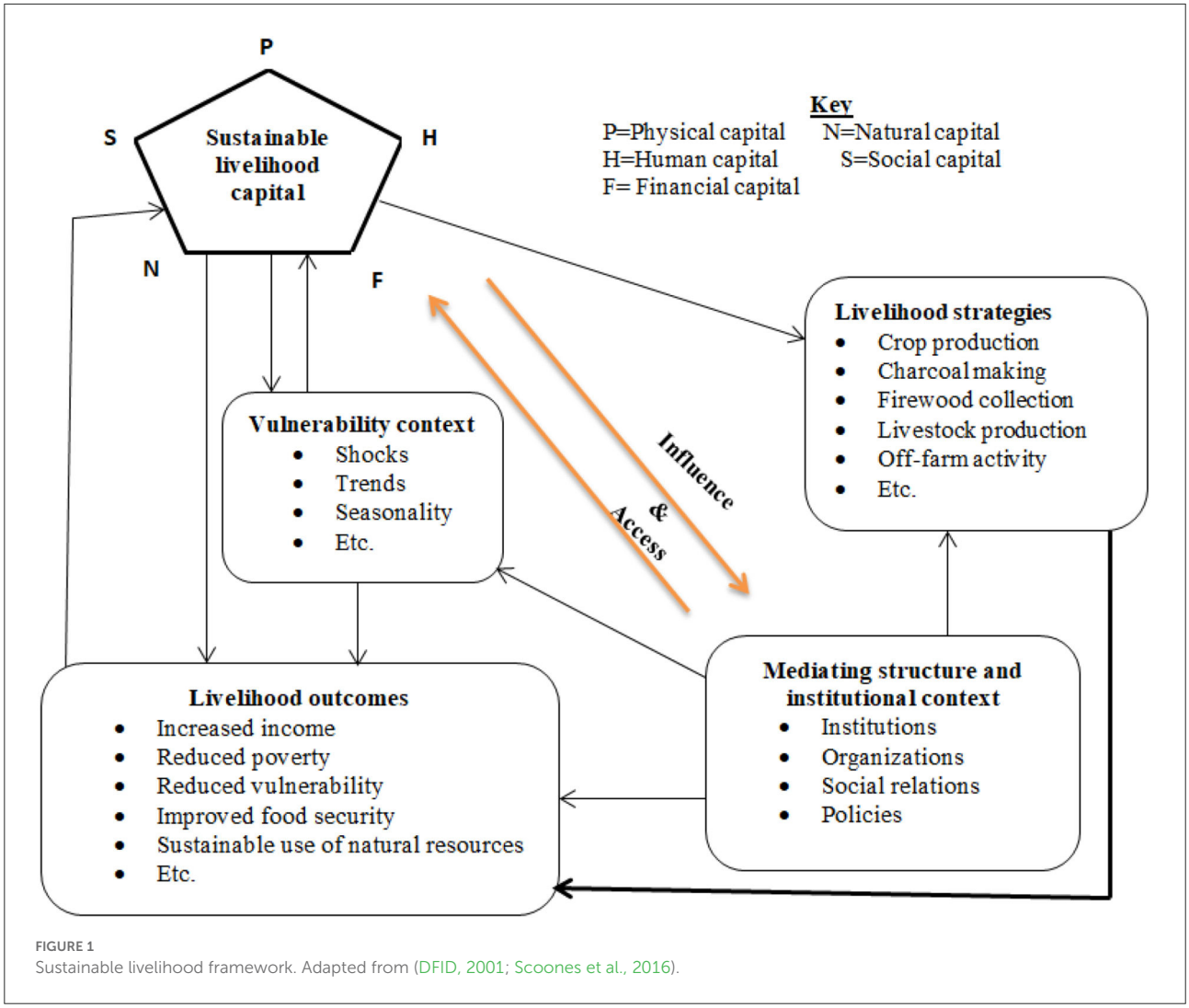

FIGURE 1
Sustainable livelihood framework. Adapted from (DFID, 2001; Scoones et al., 2016).

fuel resources and markets. Sustainability aspects related to how governance of the sector affects the environmental sustainability of the dry land forest resource management and extraction practices and thus the overall sustainability of producer-based livelihood outcomes.

Figure 1 describes that households under vulnerability contexts such as shocks struggle to depend on their capital to achieve positive livelihood outcomes through coping and diversification of livelihood strategies. Access to livelihood capital influences livelihood outcomes. For example, lack of this capital increases the vulnerability of households. Vulnerability contexts affect livelihoods and available assets. One of the coping mechanisms of vulnerability is diversifying livelihood strategies; however, diversification ability depends on livelihood capital access and the level of livelihood strategy choice. The success or failure of livelihood outcomes depends on capital endowment and institutions which allow the availability of livelihood strategy. Institutions, policies, and organizational processes are important to access or restrict opportunities to resources such as forest resources for wood fuel production for sustainable livelihoods. As the result, livelihood strategies vary in terms of environmental context, capital access, institutions, and structural processes. The ability of households to engage in different livelihood strategies is reliant on available capital access or control. Therefore, the option of livelihood strategy affects livelihood outcomes positively or negatively.

Generally, Figure 1 shows that a household's choice of livelihood strategy is affected by its access to five sources of capital, which are in turn mediated by institutions that add other mediating structures. Mediating structures and institutions always influence the capital and livelihood outcomes of households. In addition, exogenous factors like shocks, trends, seasonality, etc., influence livelihood strategies, assets, and livelihood outcomes. In the end, a livelihood strategy involved in a household also generates a livelihood outcome. The resulting livelihood outcome of a household can consequently influence

TABLE 1 List of sample surveyed districts taken from four research mandates of dryland areas.

No.	Name of districts	Research mandate center	Location
1	Kafta Humera	Mekelle	Northern Ethiopia
2	Jawi	Bahir Dar	Northwestern Ethiopia
3	Adami Tulu	Central Ethiopia	Central Ethiopia
4	Boset	Central Ethiopia	Central Ethiopia
5	Amibara	Central Ethiopia	Central Ethiopia
6	Awash Fentale	Central Ethiopia	Central Ethiopia
7	Ararso	Dire Dawa	Eastern Ethiopia
8	Kebribeyah	Dire Dawa	Eastern Ethiopia
9	Jeldesa	Dire Dawa	Eastern Ethiopia
10	Biyoawale	Dire Dawa	Eastern Ethiopia
11	Asseliso	Dire Dawa	Eastern Ethiopia
12	Abala Abaya	Hawassa	Southern Ethiopia

its capital through investment in education, financial savings as well as tree planting, and mediating structures and institutions.

Materials and methods

Study area description

The study was conducted in the dryland areas of Ethiopia. The data was collected from Mekelle, Dire Dawa, Bahir Dar, Hawassa, and the Central Ethiopia Environment and Forest Research Centers' mandate areas. More specifically, the Mekelle center represents dryland areas in the Northern part, Bahir Dar center represents dryland areas in the Northwestern part, Dire Dawa center represents dryland areas in the Eastern part, Hawassa center represents dryland areas in the Southern part and Central Ethiopia center represents the central parts of dryland areas in the country based on wood fuel production potential (Table 1). These listed places have the most typical wood fuel producers. In the listed study areas, three livelihood groups of the target population were considered (farming, agro-pastoral, and pastoral communities) based on their livelihood activity. The target population was wood fuel producers (firewood and charcoal producers) found in parts of the dry land woodland areas of the country. The study covered 12 districts and 4 kebeles per district.

Sampling techniques

This study focused only on wood fuel producers in the three livelihood groups that produce wood fuel in dryland areas of the country. The study employed a three-stage sampling procedure. In the first and second stages, the sampled districts and kebeles were selected from the total districts and kebeles through discussion with experts in zonal offices and local key informants. The wood fuel-producing kebeles were chosen based on interviews with experts and mapping of the geographical distribution of production kebeles. From this larger set, the four sampled kebeles per district were purposively selected. In the third stage of sampling after determining the number of livelihood groups available in each district and the following snowball sampling, a total of 857 households were selected and interviewed during the survey.

Data sources and data collection methods

The surveys were conducted with people who produce and sell wood fuel (charcoal or firewood) as one of their activities. To gain a comprehensive understanding of wood fuel producers' livelihoods, we used a mixed-methods approach, combining focus group-based rural appraisal tools and semi-structured interviews. A semi-structured interview was employed to gather quantitative data from wood fuel producer households. On the other hand, qualitative data were collected through focus group discussions (FGD). Researchers undertook one FGD per kebele with a combination of both men and women who were actively engaged in producing wood fuel (charcoal and firewood). Each focus group was comprised of 8–12 wood fuel producers in gender mixed groups. District and kebele experts and the research team selected the FGD participants; A core set of questions were addressed during the discussion. However, as is often the case with participatory research, we followed the interests and experiences of the participants of specific groups, which resulted in some data being collected only from certain groups. We have indicated where this occurred in the results section.

Methods of data analysis

Measurement of indicators of livelihood assets

The study followed the livelihood asset measurement design used by Chen et al. (2013). It is conducted through scaling and indexing approaches to determine the natural, physical, human, financial, and social capital to know their status. The Likert scale indicators were measured by rating scale methods using different weights. Accordingly, livelihood asset indices of (≤0.33), (0.34–0.66), and (0.67–1) were interpreted as poor, low, medium, and good or high, respectively. The questions that had three answer choices were measured as:

$$I = \ good\% * 1 + medium\% * 0.66 + poor\% * 0.33 \quad (1)$$

When the indicators have two answer questions (yes or no), they were interpreted as:

$$I = \ Yes\% * 1 + No\% * 0 \quad (2)$$

On the other hand, for the questions in the form of numbers, the "mean" value is the key point in the design of this type of method. Less than the mean value is classified as poor with the weight of 0.33; more than the mean but <1.5*mean is treated as average with the weight of 0.66, and more than 1.5*mean is classified as good with the weight of 1. After estimation of the weight of individual indicators, the value of each livelihood capital, and the end, the overall livelihood capital value has been computed. The integrated measurement was adopted following Chen et al.(2013) as follows:

$$C = \frac{\sum_{n=0}^{n} In}{Tn} \quad (3)$$

Where C is the criteria score for individual capital ($0 \leq C \leq 1$), n denotes the nth indicators of criteria ($n = 1, 2, 3 \ldots n$); I denotes the indicator, T denotes the total number of indicators; livelihood asset is the sum, i.e., (Natural capital + Human capital + Physical capital + Financial capital + Social capital)/5

Estimation of vulnerability index

Livelihood vulnerability index (LVI) was assumed as a function of adaptive capacity (AC), sensitivity, and exposure; that is V=f(I – AC), where I is the impact and AC is the adaptive capacity of the community. After exposure, sensitivity, and adaptive capacity were computed, the three contributing factors were integrated *via* the following equation:

$$Vk = \sum_{i=1}^{n} WkiXki - \left(\sum_{i=1}^{n} WkiYki + \sum_{i=1}^{n} WkiZki\right) \quad (4)$$

Where i = 1, 2, 3, … n households; k = 1, 2, and 3, representing community; Vk = vulnerability index for kth community; Wki = weight obtained from first scores of ith variables for kth community; Yki = sensitivity ith for kth community; and Zki = exposure ith for kth community. Thus, farming, agro-pastoral, and pastoral communities' vulnerability were scaled from −1 (least vulnerable) to 1 (most vulnerable).

Exposure indicators

Once values for each of the exposure components were calculated then averaged their value to obtain the exposure value. The exposure value is expressed as:

$$Ed = \frac{\sum_{i=1}^{n} WEiEi}{\sum_{i=1}^{n} WEi} \quad (5)$$

Where Ed is the exposure score, Ei is the exposure indicator, and W is the weight assigned to each indicator.

Sensitivity index

Sensitivity was affected by an internal or external disturbance (Gallopín, 2006). Livelihoods affected by different shocks were taken into consideration as sensitivity indicators for pastoralists, agro-pastoralists, and farming communities. The sensitivity score is expressed as:

$$Sd = \frac{\sum_{i=1}^{n} WMiMi}{\sum_{i=1}^{n} WMi} \quad (6)$$

Where Sd is the sensitivity score for a district, Wi weight of each shock indicator, and Mi is the value assigned to each indicator.

Adaptive capacity

The adaptive capacity of a household is considered to be a growing property of the five types of livelihood capital namely human, natural, social, financial, and physical capital (Dechassa et al., 2017).

Therefore, the adaptive index is expressed as:

$$ACd = \frac{WFCFC + WHCHC + WNCNC + WPCPC + WSCSC}{WFC + WHC + WNC + WPC + WSC} \quad (7)$$

where ACd is the adaptive capacity score, HC is the score of the human capital's indicators, NC is the score of the natural capital's indicators, SC is the score of the social capital's indicators, FC is the score of the financial capital's indicators, PC is the score of the physical capital's indicators, and W is the weight assigned to each indicator.

Results

Socio-economic characteristics of respondents

Table 2 shows descriptive statistics of dummy socio-economic variables. The dummy socio-economic characteristics of the interviewed household heads were evaluated based on their sex, educational status, household's labor access,

TABLE 2 Description of dummy socio-economic characteristics of respondents.

Variables	Category	Frequency	Percent
Sex of household head	Female	194	22.6
	Male	663	77.4
Educational status	Illiterate	688	80.4
	Literate	168	19.6
Household labor source	hired labor	285	33.3
	Own labor	572	66.7
Institutional membership	No	486	56.7
	Yes	371	43.3
Access to market information	No	532	62.1
	Yes	325	37.9
Access to extension service	No	734	85.6
	Yes	123	14.4
Trust between wood fuel producers and other actors	No	632	73.7
	Yes	225	26.3
Livelihood styles of sample households	Farming	322	37.6
	Agro-pastoral	315	36.8
	Pastoral	220	25.6

institutional membership, access to market information, access to extension services, trust between actors, and livelihood groups. We found that males constituted the majority (77.4%) of sample respondents and females constituted 22.6% (Table 2). This shows that male-headed households are more dominant than female-headed households in wood fuel production. Regarding education status, results showed that a majority (80.4%) of studied households were illiterate while 19.6% were literate (Table 2). The main labor source of the household was from own labor (66.7%) and the proportion of hired labor was 33.3%. On the other hand, 56.7% of sample interviewed household heads were not a member of any institutions, while the rest 43.3% were a member of different institutions.

The study also discovered that the majority (62.1%) of interviewed households have had no access to market information, while the remaining 37.9% of them have had access (Table 2). Similarly, the majority (85.6%) of interviewed households have had no extension access and the rest 14.4% of them have had extension access. In addition, the result revealed that 73.7% of interviewed households perceived that there was no trust between wood fuel producers and other actors such as government actors. The remaining small proportion (26.3%) of household heads perceived that there was trust between actors. As results showed that slightly high proportion of surveyed households (37.6%) were farming households followed by agropastoral households (36.8%) and pastoral households (25.6%).

On the other side, the description of continuous socioeconomic variables was evaluated based on age, family size, distance to forest, livestock holding, landholding, and annual cash income of interviewed household heads (Table 3). The average age of sample households was described as 40 years and the average family size was 5.8 persons per household. The mean livestock holding in Tropical Livestock Unit (TLU) of the surveyed household was 6 and the mean land holding was 3.5 ha. The results also showed that the mean annual cash income of surveyed households was 43,649.2 Ethiopian Birr. Regarding forest access, interviewed households perceived that on average they traveled 5.8 h in order to access forest resources for wood fuel production and other purposes. This shows that the availability of forest access is diminished from the residence of households in the surveyed areas.

Characterization of household livelihoods

As it was already explained in the methods of data analysis section, the wood-fuel producers' livelihood is characterized based on the assets position of the sampled households under each livelihood group. The results are also presented hereunder in that context.

Natural capital

In this study, access to land during the two rain seasons (short rain and long rain) and forest were used as an indicator to measure the natural assets (Table 4). Average short rain and

TABLE 3 Description of continuous socio-economic variables of respondents.

Variables	*N*	Mean	Std. deviation
Age of household head (years)	857	40.1	12.0
Family size	857	5.8	2.4
Livestock holding (TLU)	853	6.0	5.3
Total landholding (ha)	854	3.5	2.6
Total annual income (Ethiopian Birr)	857	43,649.2	27,296.3
Distance from residence to forest (hours)	857	5.8	3.1

long rain landholding size was 2.99 ha, 2.72 ha for farming households, 1.26 and 1.12 ha for agro-pastoralists as well as 0.89 and 1.79 ha for pastoralists households, respectively. Access to forests also takes about 5.44, 3.07, and 7.59 h for farming, agro-pastoralists, and pastoralists, respectively. The overall natural asset value index was found to be 0.65, 0.42, and 0.27 for farming, agro-pastoralists, and pastoralists, respectively. Focus group discussants also perceived that dryland forests in the farming, agro-pastoral, and pastoral areas were degraded due to the complete removal of trees (especially Acacia species). Unsustainable wood fuel production practices (not replanting cut trees) were unanimously identified as a major factor for natural assets degradation across all livelihood groups. FGD participants also pointed out that dryland forest loss due to wood fuel production was strongly connected to a change in rainfall patterns and increased frequency and intensity of run-off from the forest reserves.

The FGD groups perceived increased scarcity in NTFPs, which include firewood, charcoal, wild fruit, grasses, medicinal plants, and construction materials such as farm tools and poles. Before they engaged in charcoal and firewood production practices, participants reported that all NTFPs used to be available near to residential areas and easily accessible. Greater difficulty in accessing these products demanded more time and labor, for example, to collect firewood. This had necessitated shifting activities that demanded more physical labor from women and children to men in the three livelihood groups. This has further intensified firewood and charcoal production from distant forests and later it has severely affected the resources base for NTFPs and forced producers to downsize the level of wood-fuel production.

Financial capital

This study used income from different sources as indicators of financial assets. These include income from agricultural and non-agricultural products as well as income from, firewood, charcoal, off-farm, and livestock cash income (Table 4). The overall financial assets index of wood fuel producers was 0.39, 0.24, and 0.15 for farming, agro-pastoral, and pastoral households, respectively.

In the dryland areas, income from wood fuel production improved producers' financial status thereby increasing their ability to invest in other income generation activities and spend on household consumption. FGD participants confirmed that farming household groups cover their purchase expenses for farm inputs such as fertilizer, farm tools, and seed and settle their debt with charcoal income. Likewise, firewood and charcoal producing agro-pastoral and pastoral households pay for farm labor and other necessities from the sales of firewood and charcoal. In the farming livelihood groups, available wood fuel resources were limited, and hence income from wood fuel was not sustainable enough to hire farm labor.

According to FGD participants, charcoal and firewood-based financial assets were vulnerable to fines and confiscations from the regulating authorities. The impacts of fines and confiscations on each individual varied relying on the severity level of the enforcement activity. As a result of enforcement activities, households lose their income and they become vulnerable to food insecurity, debt, financial insecurity, stress, and reduced access to goods and services.

Human capital

Knowledge and skills due to training, labor availability, education, and health status were used as indicators measuring the human capital position of sampled producers (Table 4). The result revealed that the overall human assets value was higher in farming households (0.39), followed by agro-pastoral households (0.23) and pastoral households (0.22) for wood fuel producers.

The FGD participants expressed the producers' feelings of exhaustion after work, which affected their ability to pursue alternative livelihood strategies and social relations. Producing wood fuel was also linked with the risk of respiratory illnesses from exposure to kiln smoke and dust. The linkage between wood fuel production and access to education may be positive and negative. The FGD participants stated that the attraction of substantial incomes from wood fuel production causes children to drop out of school when they produce wood fuel or to help their parents to produce and sell wood fuel. On the other

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TABLE 4 The status of livelihood capital across livelihood groups.

Capital sources and their indicators	Farming	Agro-pastoral	Pastoral	Total
	Mean (score)	Mean (score)	Mean (score)	Mean (score)
Natural capital				
Short rain landholding	2.99 (0.89)	1.26 (0.32)	0.89 (0.22)	1.77 (0.21)
Long rain landholding	2.72 (0.61)	1.12 (0.42)	1.72 (0.12)	1.72 (0.20)
Distance to forest access	5.44 (0.45)	3.07 (0.52)	7.59 (0.46)	5.12 (0.59)
Total asset index value	**0.65**	**0.42**	**0.27**	**0.33**
Financial capital				
Cash from agriculture	5,966.66 (0.62)	2,898.14 (0.21)	1,709.05 (0.01)	3,745.99 (0.28)
Non-agricultural cash income	154.27 (0.35)	298.12 (0.15)	856.08 (0.14)	387.3 (0.21)
Firewood cash income	4,422.47 (0.41)	1,893.97 (0.43)	510.48 (0.26)	2,488.85 (0.36)
Charcoal Cash income	6,328.21 (0.23)	10,796.83 (0.33)	11,146.27 (0.22)	9,207.54 (0.26)
Market information	51.6%(0.43)	41%(0.01)	13.7%(0.02)	37.9%(0.15)
Livestock cash income	3,622.48 (0.26)	4,154.31 (0.32)	4,354.34 (0.23)	4,005.84 (0.27)
Total asset value index	**0.39**	**0.24**	**0.15**	**0.26**
Human capital				
Education Status	45.5 (0.46)	5.7 (0.06)	1.8 (0.02)	19.6 (0.11)
Hired labor to firewood collection	18 (0.18)	55.2 (0.55)	24.1 (0.24)	33.3 (0.33)
Own Labor to firewood collection	82 (0.82)	44.8 (0.45)	75.9 (0.76)	66.7 (0.67)
Own labor to Charcoal production	75.2 (0.75)	56.6 (0.57)	58.6 (0.59)	65.3 (0.65)
Hired labor to Charcoal production	24.8 (0.25)	43.4 (0.43)	41.4 (0.41)	34.7 (0.35)
Training on crop production	38.2 (0.38)	0 (0.00)	0 (0.00)	14.4 (0.14)
Training on Sanitation	34 (0.34)	5.4 (0.05)	4.5 (0.05)	15.9 (0.16)
Training on family health and planning	39.1 (0.39)	8.6 (0.09)	4.5 (0.05)	19 (0.19)
Training on Rangeland management	5.3 (0.05)	7.9 (0.08)	1.8 (0.02)	5.4 (0.05)
Training on livestock production and marketing	24.2 (0.24)	6.3 (0.06)	4.5 (0.05)	12.6 (0.13)
Total index value	**0.39**	**0.23**	**0.22**	**0.29**
Physical capital				
Production asset	4,483.21 (0.07)	1,121.71 (0.04)	711.23 (0.02)	1,279.35 (0.06)
Household furniture	58,557.83 (0.93)	30,391.46 (0.96)	11,297.36 (0.36)	36,046.49 (0.94)
Livestock	4.3 (0.35)	5.9 (0.47)	6 (0.54)	5.3 (0.65)
Total index value	**0.45**	**0.49**	**0.92**	**0.55**
Social capital				
Membership in formal or informal institutions (%)	68.8 (0.72)	45.7 (0.57)	15.9 (0.54)	45.6 (0.22)
Trust between producers and traders (%)	27 (0.28)	34.3 (0.43)	13.6 (0.46)	26.3 (0.37)
Assistance from relatives in the village (mean)	12.74 (0.46)	0.00	0.00	1.23 (0.18)
Assistance from non-relatives in the village (mean)	7.22 (0.26)	0.00	0.00	2.68 (0.39)
Assistance from relatives outside the village (mean)	4.77 (0.17)	0.00	0.00	1.79 (0.26)
Assistance from non-relatives outside the village (mean)	3.01 (0.11)	0.00	0.00	1.10 (0.16)
Total asset value index	**0.33**	**0.17**	**0.18**	**0.26**

side, wood fuel income could pay for school fees, uniforms, stationery, and vocational skills training.

Physical capital

In reference to physical assets, privately owned assets that included a household's productive assets (farm tools, axes, carts, etc.), household furniture (radio, mobile phone, chair, table, bed, mats, improved cook stoves), and livestock ownership were examined (Table 4). The result showed that the overall physical asset index value of (0.92), (0.49), and (0.45) were scored for pastoral, agro-pastoral, and farming groups of wood-fuel producer households, respectively. This indicated that the asset value of pastoral households was slightly greater than agro-pastoral and farming households. Increasing income generated from producing wood fuel improved producers' ability to purchase household furniture and productive assets.

Social capital

Participation in wood fuel production strengthens social assets, through improved ability to support others. Social capital in our study is measured in terms of membership in different groups or associations, ability to obtain assistance from friends or relatives as well as trust with each other and institutional organizations (Table 4). Overall, the social asset values of wood fuel producers were 0.33, 0.18, and 0.17 for farming, pastoral, and agro-pastoral communities, respectively. All focus groups described those wood fuel producers lending tools and exchange of labor among themselves. They expressed their ability to financially support family members with wood fuel income (such as paying school fees). On the other hand, non-producing community members also benefited from the wood fuel trade within the village, thus supporting the local businesses.

Within the three livelihood groups, following the start of wood fuel production in the dryland areas, FGD members have seen a lower level of burglary. Participants also clarified that past frequencies of burglary within the village were connected to poverty and food insecurity, as individuals would take crops or assets to sell for cash to purchase food. The growth of wood fuel production within the village, accompanied by expanded livelihoods among community individuals has led to an apparent decline in the burglaries. Participants had seen expanded levels of trust between community individuals as a result. Nevertheless, participants expected that when the tree assets declined to a point when wood fuel production was not sustainable, poverty levels and the rate of burglary might increase once more.

The wrongdoing and casualness of the wood fuel production weakened producers' social assets through an expanded risk of struggle with specialists including the Ranger service office, Improvement Operators, and neighborhood community specialists such as Natural Resource Management Committees (NRMC), and village leaders. FGD participants moreover reported clashes with other community individuals who, as non-producers, would undermine producers by reporting them to the authorities.

Overall livelihood capital sources livelihood pentagon

A pentagon diagram was designed to put in the overall capital index values of the five livelihood capital sources (Figure 2). Accordingly, the aggregated values of livelihood capital were 0.44, 0.31, and 0.35 for farming, agro-pastoral, and pastoral households. As shown in Figure 2, the pentagon is skewed and does not form a perfect pentagon. The capital with the highest capacity is the physical capital or asset, followed by financial capital, natural capital, human capital, and social capital. This structure is not sustainable because it does not represent a perfect or balanced pentagon that would best describe a sustainable livelihood status. For example, the livelihoods approach is people-centered; it looks to gain an accurate and realistic understanding of people's strengths in terms of capital. The pentagon gives information about people's capital position visually and the inter-relationships among various capital sources in life. The high capacity of physical assets implies that it can generate multiple benefits for households. Households with access to land (natural capital) are also well-endowed with financial capital, as they can use the land not only for direct productive activities but also to rent out or share crops for additional income to the households. In the same way, livestock may also build social capital such as prestige and connectedness to the community for owners while similarly being productive physical capital.

Vulnerability contexts and coping strategies among the livelihood groups

Vulnerability contexts among the livelihood groups

The vulnerability indices (LVI) being relative values are compared across the three livelihood styles. Regarding the overall LVI, pastoralists were found to be the most vulnerable (0.523) followed by agro-pastoralists (0.492); while farming communities (0.406) were relatively better off (Table 5). Moreover, the overall adaptive capacities of each livelihood group were estimated. Accordingly, the farming communities (0.589) were found to be better in adaptive capacity followed by agro-pastoralists (0.473), and the least in adaptive capacity was recorded for pastoralists (0.419).

The different shocks were mentioned by the household which led them to produce wood fuel to mitigate those shocks (Figure 3). The household survey indicated that out of the total

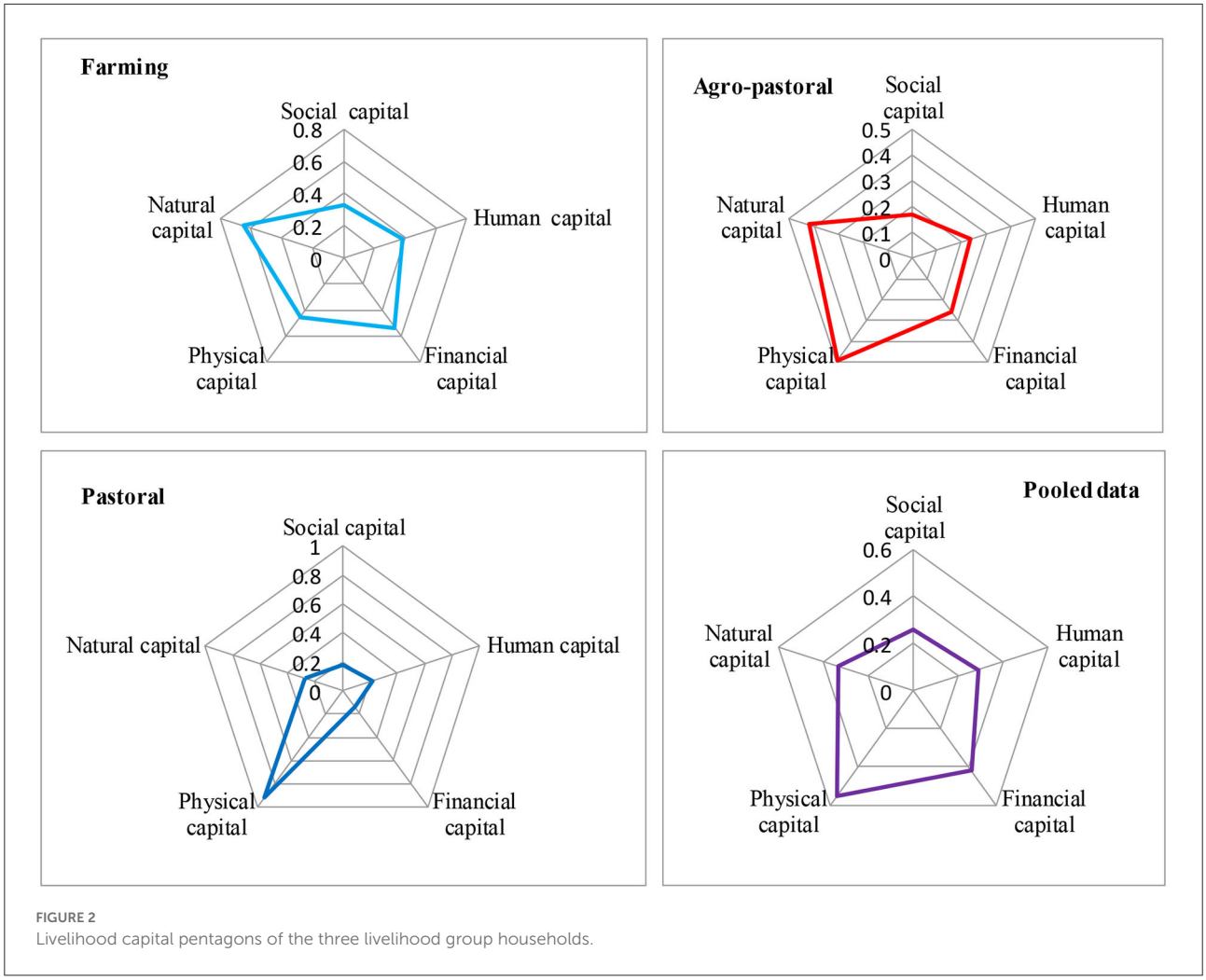

FIGURE 2
Livelihood capital pentagons of the three livelihood group households.

TABLE 5 The index score for vulnerability and its main components.

Indices	Livelihood styles or groups		
	Farming	Agro-pastoral	Pastoral
Exposure	0.421	0.488	0.534
Sensitivity	0.414	0.465	0.557
Adaptive capacity	0.589	0.473	0.419
Vulnerability	0.406	0.492	0.523

wood fuel producers about 24.9% of them use wood fuel income to mitigate drought shock, followed by seasonal importance during the time of agricultural output price reduction (17.4%), crop disease (11.6%) and family sickness (10.7%). The rest of the respondents reported that producing more wood fuel helped then to mitigate the effects of livestock disease (7.3%), increasing agricultural input price (7.1%), flood (6.9%), household business failure (5.4%), employment loss (5%), and conflict (3.7%) shock, respectively. The focus group discussants also pointed out that there are periods when households had insufficient income from other sources in a year. Often this situation is observed in June, July, and August when households had sold most of the previous year's food crops and new crops are not ready for harvest.

Households were asked if they had experienced any form of shock in the past 10 years. The most frequently reported severe shocks were drought, food price increments, and crop and livestock disease by 42, 12, 11, and 10% of sample households (Figure 4), respectively.

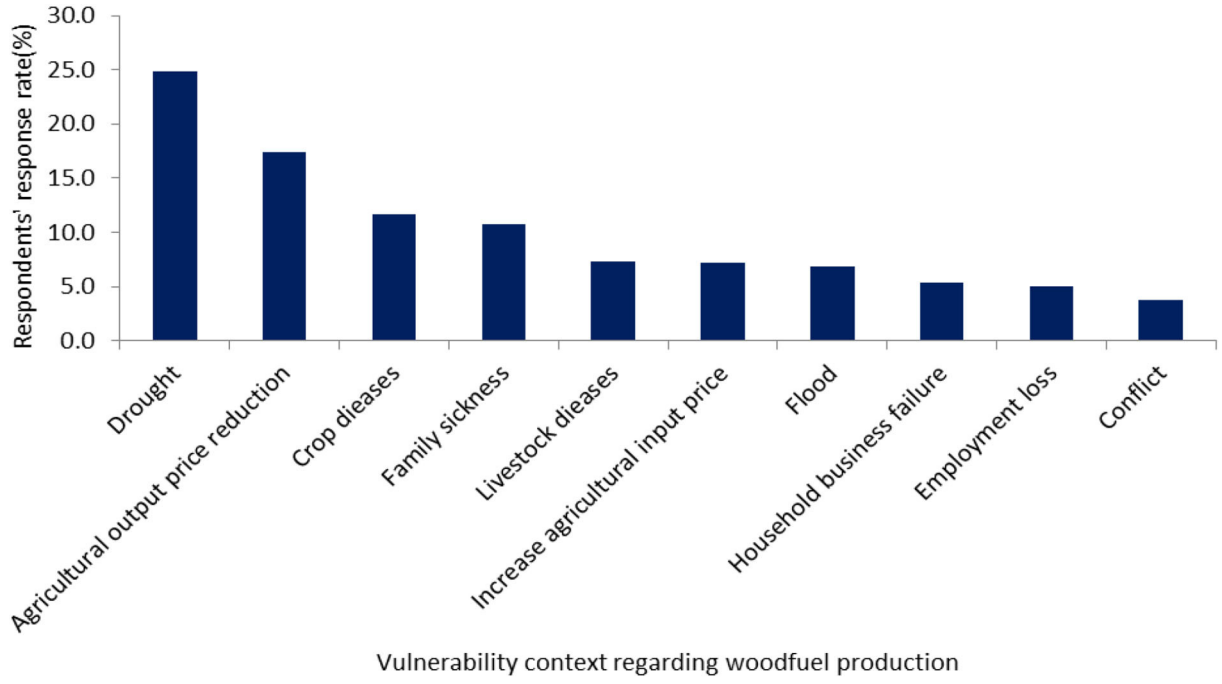

FIGURE 3
Vulnerability context.

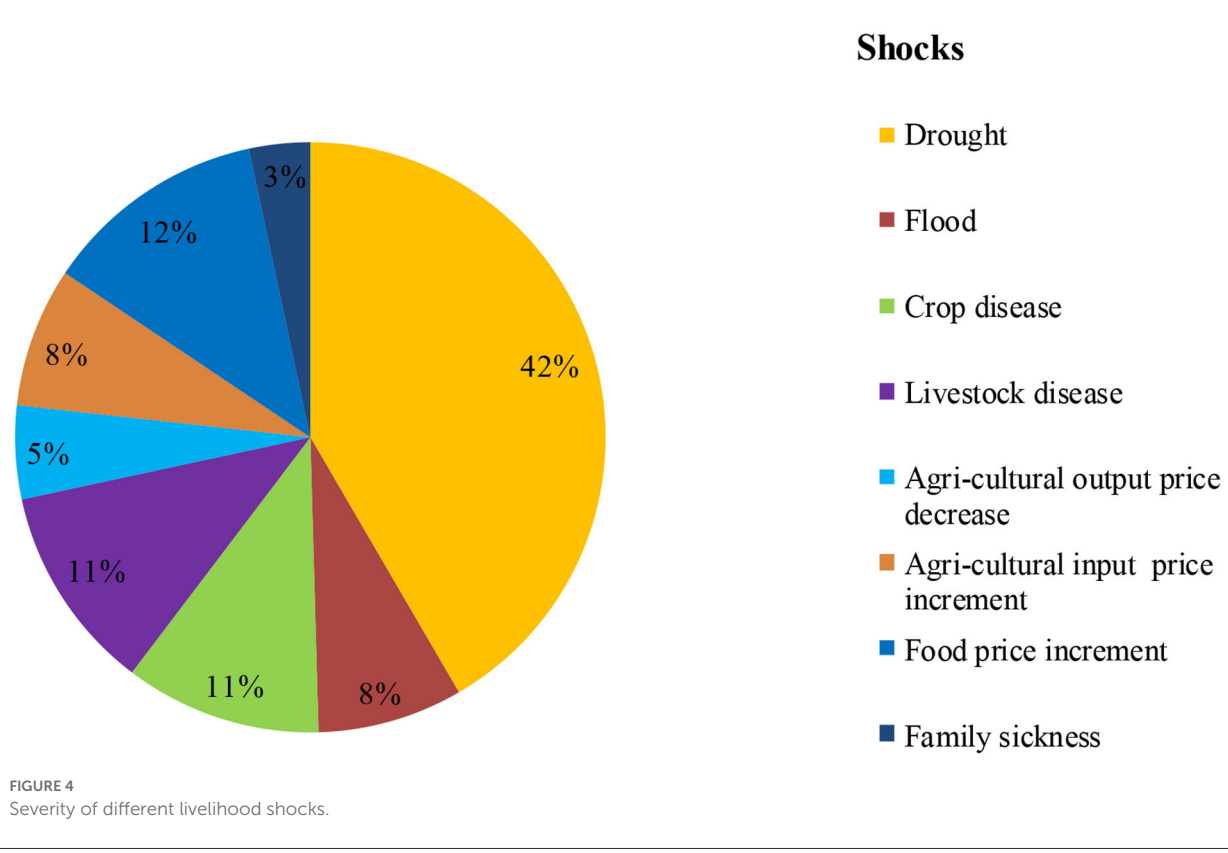

FIGURE 4
Severity of different livelihood shocks.

Livelihood outcomes and trends

Engaging in wood fuel production not only builds on financial capital but also improves other livelihood capital. Focus group discussants revealed that income generated from wood fuel sales was used to purchase physical capital (such as furniture, farm tools, etc.), settle social needs (contribute to different social networks, development activities, dowries, etc.), improve human capital (such as pay school fee, health, etc.) and access to natural capital (access to land). The study result showed that the majority (50.9%) of wood fuel producers use their income to meet family requirements, followed by social obligation (21.4%), settling a debt (17.1%), and tax expenses (10.6%) (Figure 5).

This indicated that access to forest resources showed a decreasing trend for those who are found in dryland areas of the country. This results in negative livelihood outcomes of natural assets created by increasing scarcity and distance to the remaining forest resources (Figure 6). The relationship between decreasing forest resources, declining availability of alternative forest-based income, and increasing time commitments to travel to remaining resources restricted the ability of an individual to further diversify their livelihood strategies, and instead stimulated specialization in, and dependence on, wood fuel production as a livelihood strategy.

The FGD participants in the different wood fuel producers' livelihood groups in the targeted study areas also revealed that communities use wood fuel for their consumption and commercial purpose due to a lack of other alternatives. Therefore, the declining trend of forests in the study area is one of the causes of livelihood vulnerability and vulnerability to natural resource degradation. As shown in Figure 6, sampled households and focus group discussants agreed that the status of the forest is declining at times. They stated that 15 years ago wood fuel was available around their residential areas. Now, they have to travel a long distance to access it. The findings suggest that unsustainable wood fuel production results in negative livelihood outcomes on natural capital (access to forest resources). This implies that consideration of wood fuel sustainability is important to prevent the negative effect of livelihood resources.

Coping strategies among the livelihood styles

The results showed that wood fuel producer households in the study area engaged in different strategies to address vulnerability regarding livelihood. Accordingly, the selection and practice of coping strategies depend mainly on the livelihood groups' (farming, agropastoral, and pastoral) households and the level of difficulties encountered in the wood fuel producer's household. The findings revealed that food price increment shock was mitigated by the household mainly through livestock selling (26.1%), firewood collection (16.3%), reduced meals (10.8%), borrowing (9.4%), selling other assets (7.9%), and charcoal making (6.9%), while about 17.2% of them did nothing. Shocks from agricultural input price increment was mitigated through livestock selling (18.8%), firewood sale (17.6%), charcoal making (10.6%), borrowing (10.2%), out-migration (9%), and selling other assets (7.8%), while 14.3% did nothing, respectively.

Discussion

Our findings reveal the present livelihood capital and vulnerability of wood fuel producers among farming, agro-pastoralists, and pastoralists living in dryland environments of Ethiopia. The status of access to livelihood capital was found to be differential in characteristics among the three livelihood groups. In this study, household access to the five considered livelihood capital resources along with their subcomponents is presented in Table 3 based on the field data findings. The result showed that livelihood capital owned by households are different in terms of vulnerability. Physical capital is varied by the studied households. Each of the considered physical capital components such as household furniture, productive assets, and livestock holdings showed the highest overall capital value index in pastoral households (0.92) followed by agro-pastoral households (0.49) and farming households (0.45). Recent findings showed that the performance of physical capital along with human capital is efficiently endorsed by newly incorporated livelihood capital sources which are known as psychological capital with implications for household vulnerability and livelihood security (Li et al., 2020; Tora et al., 2022). Households that have several physical capital sources such as farm equipment, infrastructure, etc. have some means to adapt to different vulnerabilities (Faso, 2016). For example, coupling energy access with productive use of energy on business and livelihood improvement activities are recognized mechanisms to accelerate just sustainable energy transition (Gebreslassie et al., 2022).

Human capital was measured in terms of knowledge and skills due to training, labor availability, education, and health status to quantify the human capital position of sampled producers (Table 4). The finding revealed that the human capital index ranged from 0.22 for pastoral households to 0.39 for farming households. The human capital value index showed below the medium value index of livelihood capital (0.60) in the three livelihood groups of wood fuel producer households. Previous findings indicate that human capital is the most significant livelihood resource for countryside communities (Xu et al., 2019) in the dryland areas (Tora et al., 2022). Financial capital is measured in terms of cash income from different sources including wood fuel. The overall financial capital index value of the three livelihood groups showed that there are significant differences. The finding revealed that the capital index value was estimated as 0.39 for farming households, followed by agropastoral households (0.24), and

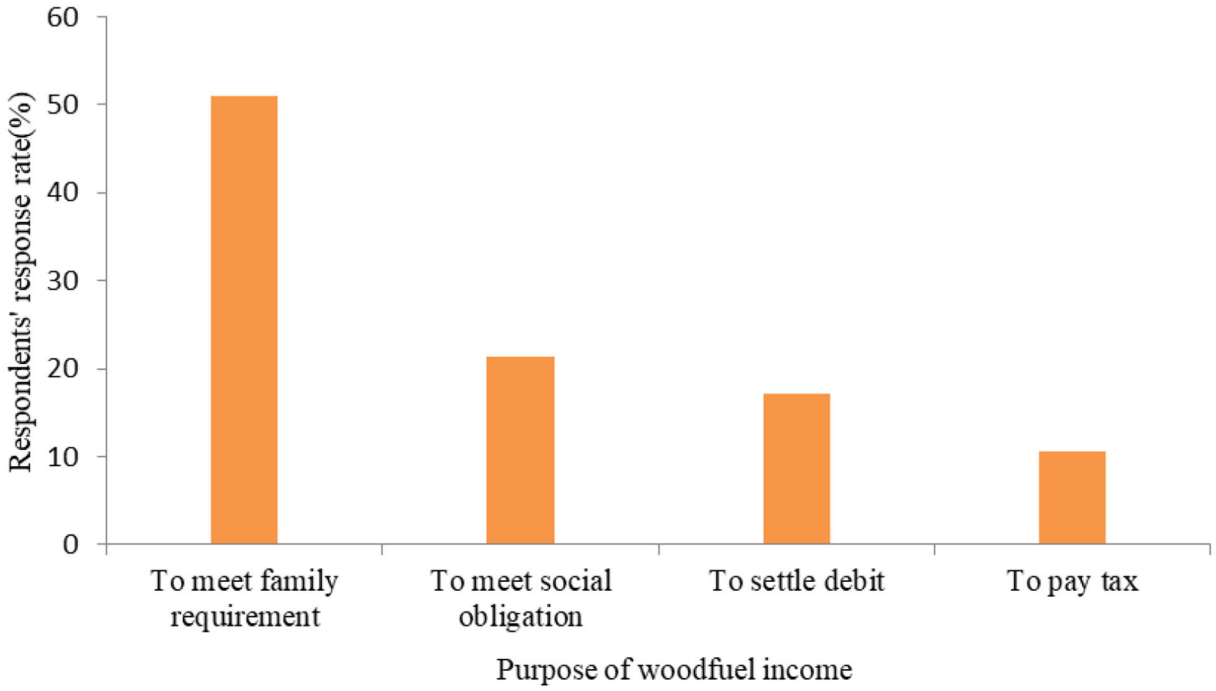

FIGURE 5
Purposes of wood fuel income for households.

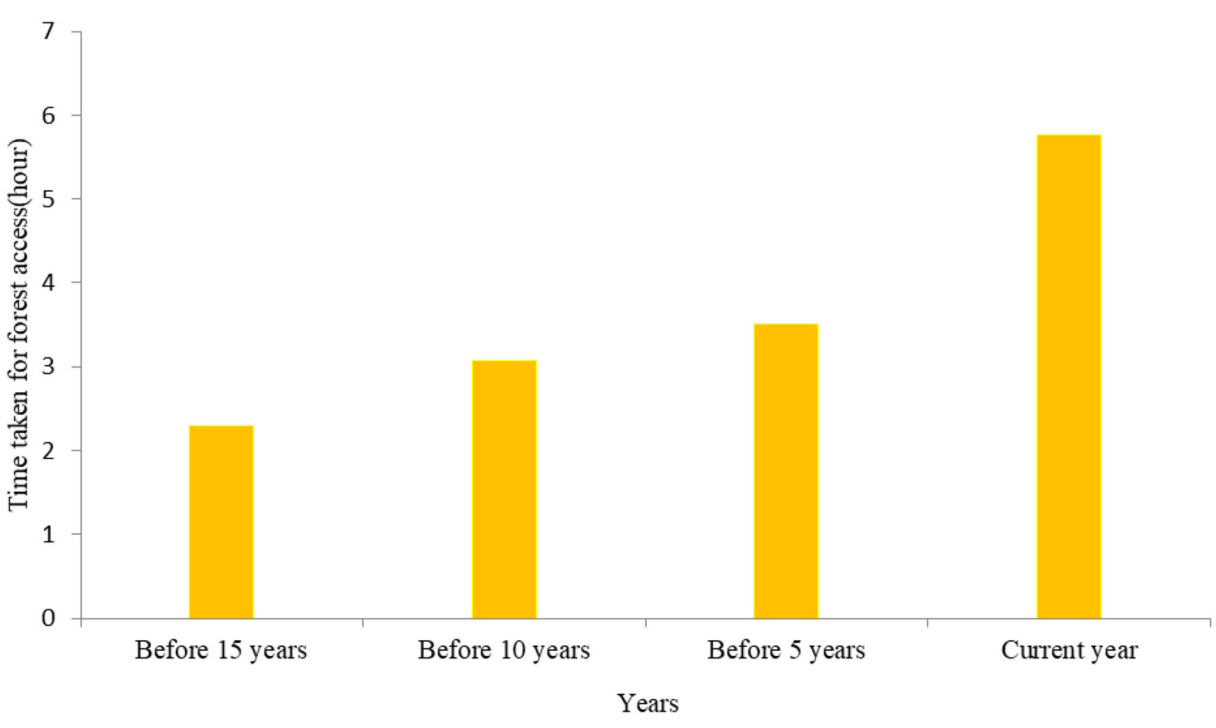

FIGURE 6
Trend of forest access to wood fuel producers.

pastoral households (0.15). Financial capital is a deficient resource in the study households, especially pastoral households as described by different scholars (such as Elizondo et al., 2017; Tora et al., 2022).

An inventory of natural capital revealed the households' access to landholding among the three livelihood style households in the dryland areas. The survey findings demonstrated that the natural capital did not support their subsistence, which was akin to the lowermost proportion of households in rural China (Xu et al., 2019). The most significant components of natural capital considered in this study were short-rain landholding, long-rain landholding, and distance from forest access in the surveyed households, as well as trees, rangeland, and water access, all of which were considered in KIIs and FGD. The overall financial capital index of wood fuel producers was 0.39, 0.24, and 0.15 for farming, agro-pastoral, and pastoral households, respectively. This differential access status has implications for communities' likelihood of exposures to livelihood vulnerabilities and capability to build secure livelihoods in line with Tora et al. (2022). Among financial livelihood capital sub-components, wood fuel (firewood and charcoal) are the main sources of cash income, especially for agro-pastoral and pastoral households (Table 4). However, the existing policies and strategies of Ethiopia ignore the economic potential of wood fuel (Sola et al., 2019). On the other hand, national energy policy has focused on the development and promotion of renewable energies in both urban and rural areas, with less investment and support for wood fuel production; ignoring livelihood improvements, there is a general strategy that eliminates wood fuel (Yalew, 2022). Hence, these factors come from a lack of policy for supporting sustainable wood fuel production that contributes to the degradation of dryland forest and other agricultural lands endangering the livelihoods and food security of many households dependent on it (Amanuel et al., 2019). To combat this, Ethiopia needs energy transitions that accommodate policy changes related to the livelihoods of communities who depend on wood fuel. For example, Ethiopia has planned for a total of 1,710,988 households (1,406,201 urban and 304,787 rural households) to substitute ethanol for firewood and charcoal between the years 2015 and 2030 (Yalew, 2022). This will reduce deforestation and greenhouse gas emissions by 441,000 ha and 65 Mt CO_2e, respectively.

Social capital was also quantified by different sub-indicators such as support, trust, and membership in different institutions. Overall, the social asset values of wood fuel producers were 0.33, 0.18, and 0.17 for farming, pastoral, and agro-pastoral communities, respectively. Similar to other livelihood capital sources, social indicators are found at low levels of access. However, a socially chained community has a better capacity to withstand shocks. This give credence to the effects of social capital on the livelihood of the community where indelicacy of social capital drives human vulnerability (Tagalo, 2020; Tora et al., 2022).

In livelihood and development studies, the capital pentagon has been an open discourse by various practitioners and organizations. The finding of our study from five livelihood capital sources shows that the structure of the pentagon is not sustainable because it does not represent a perfect or balanced pentagon that best describes a sustainable livelihood status. For example, the livelihood approach is people-centered; it pursues an accurate and realistic understanding of people's strengths in terms of capital. This is because the lack of livelihood capital access is believed to better describe rural livelihood insecurity. This investigation has a message to contribute toward managing rural vulnerability through livelihood capital diversity and improvement. The pentagon gives information about people's capital position visually and the inter-relationships among various capital sources in life. Furthermore, the pentagon answers the literature-based gaps of livelihood and vulnerability assessment regarding who is vulnerable and how households lacking capital access are vulnerable (Moret, 2017; Mengistu, 2022). The high capacity of physical assets implies that it can generate multiple benefits for households. Households with access to land (natural capital) are also well-endowed with financial capital, as they can use the land not only for direct productive activities but also to rent out or share crops for additional income to the household. In the same way, livestock may also build social capital such as prestige and connectedness to the community for owners while also being productive physical capital. The finding concurs with Robaa and Tolossa (2016) who demonstrated that vulnerability of rural households to food insecurity was indicated by inadequate access to basic capital such as landholding, the capacity of production, and the inability of the nature-oriented resources to support rural livelihoods (Mthethwa and Wale, 2020).

The pentagon indicates in Figure 2 that is in line with each livelihood capital source and revealed that households' access status to respective capital as the construction of the pentagon is based on the aggregate ownership status of overall households' capital. The overall status of the five livelihood capital sources owned by farming, agro-pastoral, and pastoral households is comparatively presented in descending order as PC > FC > NC > HC > SC. In general, the overall capital indexes of all were below the moderate capital status (0.60) as indicated by Chen et al. (2013). Therefore, regarding the status of the overall capital access among farming, agro-pastoral, and pastoral wood fuel producer households, there is a deficiency of livelihood capital. The deficiency of access has an implication on the households' vulnerability that is crucially detected by capital. The literature stated that deficiency of livelihood resources and insecurity of livelihood trigger people's escalating susceptibility to climate, among other drivers (Awal, 2015; Tora et al., 2022), while poor people's resilience is boosted by the pivotal role of owned capital (Ha-Mim et al., 2020). Other recent studies also consistently stated that a great number of livelihood resources and strategies empower herding

households to have a higher level of sustainable living standards in dryland areas (Kiruki et al., 2020). Conversely, the household livelihood capacity becomes limited regarding livelihood capital improvement and the strategies pursued (Zhao et al., 2019). Furthermore, our findings agreed that households possessing the required capital have a greater likelihood of creating positive, sustaining alternatives in drought-prone areas (Ibrahim et al., 2018; Amanuel et al., 2019; Tora et al., 2022).

The vulnerability context refers to exposures to unfavorable developments like rainfall failure, and livestock loss that would cause considerable harm to livelihood, as well as the lack of means to cope with the loss without losing the household's livelihood base (Brobbey, 2019). This definition is directly linked to this study. This finding is supported by Asfaw et al. (2021), who reported that low adaptive capacity in the lowland area contributed to smallholder farmers being more vulnerable. There are periods when households had insufficient income from other sources in a year. Often this situation is observed in June, July, and August when households have sold most of the previous year's food crops and new crops are not ready for harvest. Households were asked if they had experienced any form of shock in the past 10 years. The most frequently reported severe shocks were drought, food price increments, and crop and livestock disease.

Livelihood outcomes indicated that households who engaged in wood fuel production not only build on financial capital but also improve other livelihood capital sources such as physical capital (farm tools), human capital (school fees, health, etc.), natural capital (access to land) and social capital (settle social needs, social networks) stated by FGD participants. The findings of the study imply that access to forest resources for wood fuel production showed a decreasing trend (Figure 6). The implications of these results are negative livelihood outcomes of natural assets created by increasing scarcity and distance to the remaining forest resources (Figure 6). This finding agreed with previous findings (for example, Smith et al., 2017) that demonstrated that negative livelihood outcomes were related to the diminishing of natural assets such as forest, time conflicts created by increasing scarcity and distance to the remaining forest resources, and vulnerability to punitive enforcement activities. The relationship between decreasing forest resources, declining availability of alternative forest-based income, and increasing time commitments to travel to remaining resources restricted the ability of an individual to further diversify their livelihood strategies, and instead stimulated specialization in, and dependence on wood fuel production as a livelihood strategy. The findings of this study agreed with Amanuel et al. (2019) who demonstrated that the status of dryland forests has been shrinking at a significant rate over the past 30 years. This is due to the lack of forest and energy policy recognition for sustainable wood fuel production despite the potential livelihood benefits in the country. The finding implies that the country urgently needs to transit toward integration of sustainable energy and livelihood options.

Over-dependency of people on natural resources for subsistence needs coupled with high rates of deforestation for commercial interests renders most of the forest communities' people vulnerable to natural and financial shocks (FAO, 2015; Alhassan et al., 2022). Wood fuel producers mentioned different shocks and their coping mechanisms (Figure 7). In general, our result showed that selling livestock, firewood, other assets, and charcoal as well as replanting were the most common coping strategies for different shocks by households, while some of the households did not practice any coping mechanisms (Figure 7). These results are supported by the findings of other studies (Jones et al., 2016; Amanuel et al., 2019) that found that households produce wood fuel, especially charcoal in bulk to respond to coping livelihood vulnerabilities, or they turn to charcoal production as a long-term response to scarcity. Similarly, wood fuel is considered a coping strategy for shocks that influence the household's income stream and reduce its asset base (Schure, 2014; Mensah et al., 2022). However, the current wood fuel production is unsustainable due to a lack of policy support in Ethiopia as well as many SSA countries (Mensah et al., 2022). From this finding, there is an implication to urgently transition toward sustainable initiatives. For example, facilitating the transition of urban households from wood fuel energy sources to other renewable energy and transit wood fuel producers toward more non-forest-based livelihood options is a pivotal approach based on the context of the area and living system of local communities. Other previous studies demonstrated that households' commonly performed coping strategies to manage vulnerability are selling assets, reduced consumption, and livelihood diversification, and the strategies differ among household groups (Amanuel et al., 2019; Mengistu, 2022). Communities are also different in their vulnerability and proficiency to manage risks based on their capabilities and existing environmental situations (Sime, 2019; Mengistu, 2022). Gebreslassie et al. (2022) recognized that energy transition requires inclusive energy policies and infrastructure support for the livelihood of the local communities to ensure sustainability. Overall, there is an opportunity to elaborate on the conditions under which wood fuel producers, consumers, and other stakeholders shift toward sustainable wood fuel production. This issue urgently needs targeted policy options and actions just to transition to sustainable wood fuel production in the country.

Conclusions and policy implications

The objective of the study was to characterize and understand livelihood capital sources as well as analyze the vulnerability of farming, agro-pastoral and pastoral communities. Sustainable livelihood among wood fuel producers will help to reduce poverty and over-dependency on

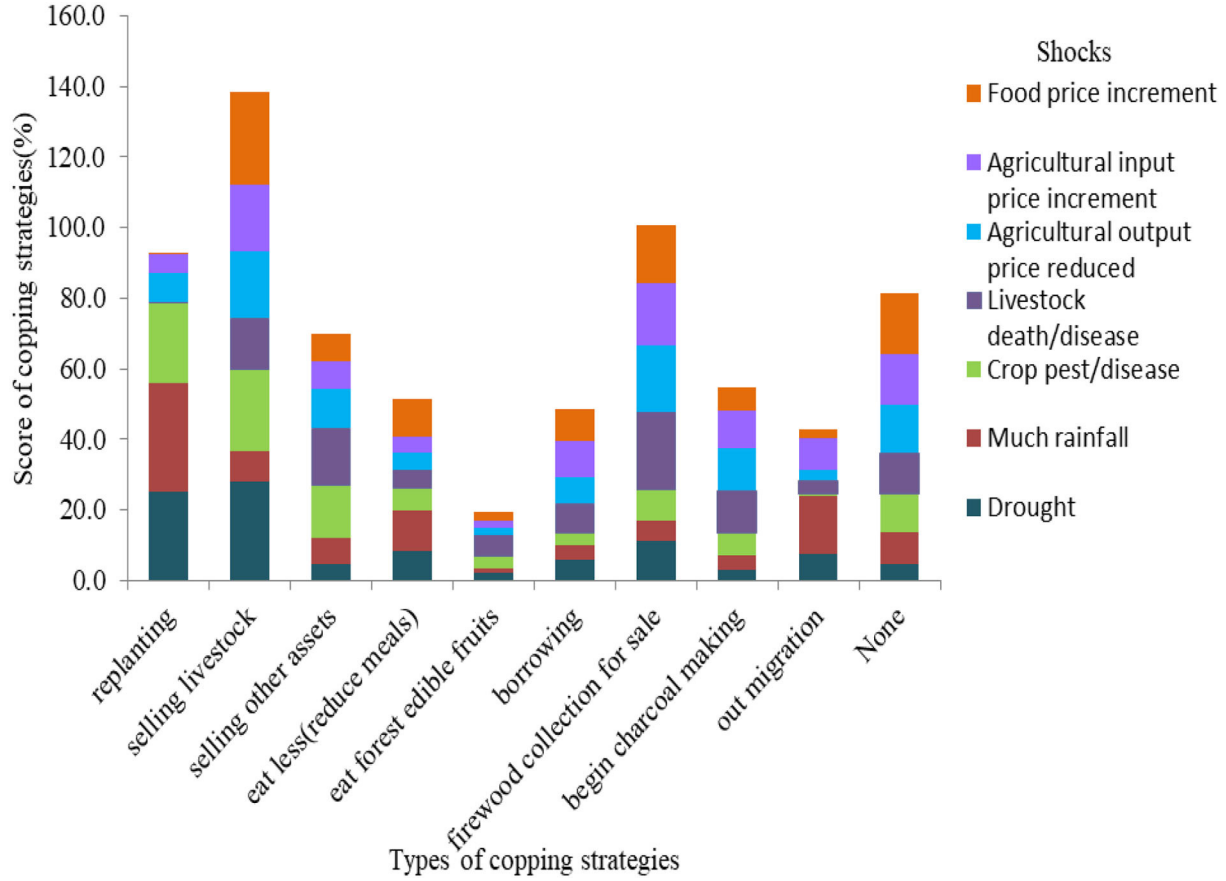

FIGURE 7
Coping strategies by households that faced economic shocks.

forest resources. However, the result indicated that the index of the capacity of five principal livelihood capital sources is unbalanced, and social, human, and financial capital sources are less acquired ones. This is confirmed in the analysis of the livelihood capital sources, which determine adaptive capacity indicating that communities in dryland areas did not fare well in all the five capital sources. The vulnerability index also revealed that pastoralists and agro-pastoralists are more vulnerable than farming communities. The findings also showed that access to forest resources shows a decreasing trend in dryland areas of the country. Selling livestock and firewood, replanting, borrowing, and charcoal production were the main coping mechanisms. Therefore, creating opportunities for different livelihood options is important to improve the livelihood asset and reduce the excessive dependency of the people on forests and other natural resources. Consideration of improved production technologies and active management of the dryland forest with community participation is also important. As shown in our result and different previous research, wood fuel demand in urban areas of Ethiopia is increasing which urges high wood fuel production in rural areas, especially dryland areas; and there is an indication that the forest cover is diminishing. However, the existing established policy of the country affects wood fuel producers by banning the activity without provisioning livelihood options to producers of dependent communities. Therefore, there is a need to link policy frameworks and interventions for just energy transition for urban households and diversify livelihood options of wood fuel producers as well as launch sustainable wood fuel production mechanisms and interventions. This will help reduce over-dependency on dryland forest by wood fuel producers as well as reduce urban household dependency on wood fuel energy in order to ensure wood fuel production is socially, economically, and environmentally sustainable.

The available literature on the subject and our findings revealed that wood fuel contributes mainly to the livelihoods of rural people and high energy to satisfy the demand in urban areas. Thus, there is a need to introduce improved and affordable stoves and solar power in rural and urban areas to reduce the burden on the dryland forests. Moreover, the establishment of

woodlots and plantations for wood fuel production should be considered as an alternative; however, this is challenged by the complex tree tenure, access, and benefit-sharing mechanisms that may discourage producers to engage in such activities.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Ethiopian Environment and Forest Research Institute. The participants provided their written informed consent to participate in this study.

Author contributions

GG: overall management and planning, proposal development, material preparation, coordination, data collection, data editing, data analysis, and manuscript preparation. AS: conceptualization, proposal development, material preparation, data collection, editing, and reviewing the manuscript. TA: proposal development, data collection, and data entry. GS: data collection, data entry, and coordination. MA: data collection and data entry. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abebaw, D., Kassa, H., Kassie, G. T., Lemenih, M., Campbell, B., and Teka, W. (2012). Dry forest-based livelihoods in resettlement areas of Northwestern Ethiopia. *For. Policy Econ.* 20, 72–77. doi: 10.1016/j.forpol.2012.02.002

Abeje, T. M., Tsunekawa, A., Adgo, E., Haregeweyn, N., Nigussie, Z., Ayalew, Z., et al. (2019). Exploring drivers of livelihood diversification and its effect on adoption of sustainable land management practices in the upper blue nile ethiopia. *Sustainability.* 11, 2991. doi: 10.3390/su11102991

Acey, C. S. E., and Culhane, T. H. (2013). Green jobs, livelihoods and the post-carbon economy in African cities. *Local Environ.* 18, 1046–1065. doi: 10.1080/13549839.2012.752801

Alhassan, J., Ofosu, A., Iddrisu, S., and Kofi Garsonu, E. (2022). Wood fuel producers' insight on the environmental effects of their activities in Ghana. *J. Sustain. Forest.* 2022, 1–17. doi: 10.1080/10549811.2022.2053162

Amanuel, W., Tesfaye, M., Worku, A., Seyoum, G., and Mekonnen, Z. (2019). The role of dry land forests for climate change adaptation: the case of Liben Woreda, Southern Oromia, Ethiopia. *J. Ecol. Environ.* 43, 1–13. doi: 10.1186/s41610-019-0109-4

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., et al. (2014). Environmental income and rural livelihoods: a global-comparative analysis. *World Dev.* 64, S12–S28. doi: 10.1016/j.worlddev.2014.03.006

Asfaw, A., Bantider, A., Simane, B., and Hassen, A. (2021). Heliyon Smallholder farmers' livelihood vulnerability to climate change-induced hazards : an agroecology-based comparative analysis in Northcentral Ethiopia (Woleka Sub-basin). *Heliyon* 7, e06761. doi: 10.1016/j.heliyon.2021.e06761

Awal, M. A. (2015). Vulnerable population to climate change in Bangladesh: livelihood constraints and adaptation strategies. *Am. J. Soc. Sci.* 3, 87–95. Available online at: http://www.openscienceonline.com/journal/ajss

Ayobami, A. B. (2021). Performance of wood bottom ash in cement-based applications and comparison with other selected ashes: overview. *Resour. Conserv. Recycl.* 166, 105351. doi: 10.1016/j.resconrec.2020.105351

Brobbey, L. K. (2019). *The Livelihood and Political Economy of Charcoal Production and Trade in Ghana* (Doctoral thesis). Kwame Nkrumah University of Science and Technology, Kumasi.

Chambers, R., and Conway, G. (1992). *Sustainable Rural Livelihoods: Practical Concepts for the 21st Century*. London: Institute of Development Studies.

Chen, H., Zhu, T., Krott, M., Calvo, J. F., Ganesh, S. P., and Makoto, I. (2013). Land use policy measurement and evaluation of livelihood assets in sustainable forest commons governance. *Land Use Policy* 30, 908–914. doi: 10.1016/j.landusepol.2012.06.009

Dechassa, C., Simane, B., and Alamirew, B. (2017). "Farmers' livelihoods vulnerability to climate variability and change in Didesa Basin southern part of Abay Basin, Ethiopia," in *Climate Change Adaptation in Africa* (Cham: Springer), 267–284.

DFID (2001). *Sustainable Livelihoods Guidance Sheets Sl Approaches in Practice Drought and Water Security*. London.

Elizondo, D., Mordt, M., Munoz-Blanco, J., Paz, C., Gonzalez, C., and Iftikhar, U. (2017). *Guid-ance Notes: Application of the Sustainable Livelihoods Framework in Development Projects.* Panama City: UNDP.

FAO (2015). *Global Forest Resources Assessment 2015 Desk Reference*. Rome.

Faso, B. (2016). *Analyses of Determinants of Pastoralist and Agro-Pastoralist Households' Adaptation to Climate Change in the Sudano-Sahelian Zone*.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environ. Change* 16, 293–303. doi: 10.1016/j.gloenvcha.2006.02.004

Gebreslassie, M. G., Cuvilas, C., Zalengera, C., To, L. S., Baptista, I., Robin, E., et al. (2022). Delivering an off-grid transition to sustainable energy in Ethiopia and Mozambique. *Energy Sustain. Soc.* 12, 1–18. doi: 10.1186/s13705-022-00348-2

Ha-Mim, N. M., Hossain, M. Z., Rahaman, K. R., and Mallick, B. (2020). Exploring vulnerability–resilience–livelihood nexus in the face of climate change: a multi-criteria analysis for mongla, Bangladesh. *Sustainability* 12, 7054. doi: 10.3390/su12177054

Heubach, K., Wittig, R., Nuppenau, E. A., and Hahn, K. (2011). The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural west African communities : a case study from northern Benin. *Ecol. Econ.* 70, 1991–2001. doi: 10.1016/j.ecolecon.2011.05.015

Ibrahim, A. Z., Hassan, K. H., and Kamaruddin, R. (2018). The level of livelihood assets ownership among vulnerability group in East Coast of Malaysia. *Eur. J. Sustain. Dev.* 7, 157–157. doi: 10.14207/ejsd.2018.v7n3p157

Jones, D., Ryan, C. M., and Fisher, J. (2016). Charcoal as a diversification strategy : the flexible role of charcoal production in the livelihoods of smallholders in central Mozambique. *Energy Sustain. Dev.* 32, 14–21. doi: 10.1016/j.esd.2016.02.009

Kiruki, H. M., van der Zanden, E. H., Kariuki, P., and Verburg, P. H. (2020). The contribution of charcoal production to rural livelihoods in a semi-arid area in Kenya. *Environ. Dev. Sustain.* 22, 6931–6960. doi: 10.1007/s10668-019-00521-2

Lemenih, M., Abebe, T., and Olsson, M. (2003). Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, south-east Ethiopia. *J. Arid Environ.* 55, 465–482. doi: 10.1016/S0140-1963(03)00053-3

Lemenih, M., and Bongers, F. (2011). *Dry Forests of Ethiopia and Their Silviculture*. Silviculture in the Tropics. 8, 261–272. doi: 10.1007/978-3-642-19986-8_17

Li, W., Shuai, C., Shuai, Y., Cheng, X., Liu, Y., and Huang, F. (2020). How livelihood assets contribute to sustainable development of smallholder farmers. *J. Int. Dev.* 32, 408–429. doi: 10.1002/jid.3461

Mengistu, N. A. (2022). Rural livelihood vulnerabilities, contributing factors and coping strategies in Takusa Woreda, North Western Ethiopia. *Cogent. Soc. Sci.* 8, 2095746. doi: 10.1080/23311886.2022.2095746

Mensah, K. E., Damnyag, L., and Kwabena, N. S. (2022). Analysis of charcoal production with recent developments in Sub-Sahara Africa: a review. *Afr. Geogr. Rev.* 41, 35–55. doi: 10.1080/19376812.2020.1846133

Miranda, R. C., Sepp, S., Ceccon, E., Mann, S., and Singh, B. (2010). *Sustainable Production of Commercial Woodfuel: Lessons and Guidance From two Strategies. The Energy Sector Management Assistance Program*. Washington, DC: World Bank.

Moret, W. (2017). *Aspires Vulnerability Assessment Handbook for Economic Strengthening Projects*. *FHI360*. Washington, DC: USAID.

Mthethwa, S., and Wale, E. (2020). Household vulnerability to food insecurity in rural south Africa: evidence from a nationally representative survey data. *Int. J. Environ. Res. Public Health* 18, 1917. doi: 10.3390/ijerph18041917

Murphy, P. G., and Lugo, A. E. (1986). Ecology of tropical dry forest. *Annu. Rev. Ecol. Syst.* 67–88. doi: 10.1146/annurev.es.17.110186.000435

Openshaw, K. (2010). Biomass energy : employment generation and its contribution to poverty alleviation. *Biomass Bioenergy* 34, 365–378. doi: 10.1016/j.biombioe.2009.11.008

Robaa, B., and Tolossa, D. (2016). Rural livelihood diversification and its effects on household food security: a case study at Damota Gale Woreda, Wolayta, Southern Ethiopia. *East Afr. Soc. Sci. Res. Rev.* 32, 93–118. doi: 10.1353/eas.2016.0001

Schure, J. (2014). *Woodfuel for Urban Markets in the Congo Basin A Livelihood Perspective* (Doctoral thesis). Wageningen University, Wageningen.

Schure, J., Ingram, V., Arts, B., Levang, P., and Mvula-Mampasi, E. (2015). Institutions and access to woodfuel commerce in the Democratic Republic of Congo. *For. Policy Econ.* 50, 53–61. doi: 10.1016/j.forpol.2014.06.010

Schure, J., Ingram, V., Sakho-Jimbira, M. S., Levang, P., and Wiersum, K. F. (2013). Formalisation of charcoal value chains and livelihood outcomes in Central- and West Africa. *Energy Sustain. Dev.* 17, 95–105. doi: 10.1016/j.esd.2012.07.002

Schure, J., Levang, P., and Wiersum, K. F. (2014). Producing woodfuel for urban centers in the Democratic Republic of Congo: a path out of poverty for rural households?. *World Dev.* 64, S80–S90. doi: 10.1016/j.worlddev.2014.03.013

Scoones, I., Action, P., and Rugby, P. (2016). *Book Review Sustainable Livelihoods and Rural Development Development : Book Review*. Brighton: Annual Review of Environment and Resources.

Sime, G. (2019). Rural livelihood vulnerabilities, coping strategies and outcomes: a case study in central rift valley of Ethiopia. *Afr. J. Food Agric. Nutr. Dev.* 19, 14602–14621. doi: 10.18697/ajfand.86.16815

Singh, D., Aung, T., and Zerrif, H. (2018). Energy for sustainable development resource collection polygons : a spatial analysis of woodfuel collection patterns *?*. 45, 150–158. doi: 10.1016/j.esd.2018.06.003

Smith, H. E., Eigenbrod, F., Kafumbata, D., Hudson, M. D., and Schreckenberg, K. (2015). Criminals by necessity : the risky life of charcoal transporters in Malawi. *For. Trees Livelihoods.* 24, 8028. doi: 10.1080/14728028.2015.1062808

Smith, H. E., Hudson, M. D., and Schreckenberg, K. (2017). Livelihood diversification : the role of charcoal production in southern Malawi. *Energy Sustain. Dev.* 36, 22–36. doi: 10.1016/j.esd.2016.10.001

Sola, P., Schure, J., Eba'a Atyi, R., Gumbo, D., Okeyo, I., and Awono, A. (2019). Woodfuel policies and practices in selected countries in Sub-Saharan Africa—A critical review. *Bois et Forêts des Tropiques* 340, 5–19. doi: 10.19182/bft2019.340.a31690

Tagalo, R. D. (2020). How does government discourse make people vulnerable?. *Disast. Prev. Manag.* 29, 697–710. doi: 10.1108/DPM-07-2020-0225

Teketay, D. (2012). *Rehabilitation of Degraded Forest and Woodland Ecosystems in Ethiopia for Sustenance of Livelihoods and Ecosystem Services. Forests Under Pressure: Local Responses to Global Issues* (Vienna: IUFRO), 299.

Tora, T. T., Degaga, D. T., and Utallo, A. U. (2022). Impacts of livelihood assets on livelihood security in drought-prone Gamo lowlands of southwest Ethiopia. *Geogr. Sustain.* 3, 58–67. doi: 10.1016/j.geosus.2022.02.002

Tribaldos, T., and Kortetmäki, T. (2022). Just transition principles and criteria for food systems and beyond. *Environ. Innovat. Soc. Transit.* 43, 244–256. doi: 10.1016/j.eist.2022.04.005

UNEP (2019). *Review of Woodfuel Biomass Production and Utilization in Africa A Desk Study*. Nairobi.

Vedeld, P., Angelsen, A., Bojö, J., Sjaastad, E., and Berg, G. K. (2007). Forest environmental incomes and the rural poor. *For. Policy Econ.* 9, 869–879. doi: 10.1016/j.forpol.2006.05.008

Xu, D., Deng, X., Guo, S., and Liu, S. (2019). Sensitivity of livelihood strategy to livelihood capital: an empirical investigation using nationally representative survey data from rural China. *Soc. Indic. Res.* 144, 113–131. doi: 10.1007/s11205-018-2037-6

Yalew, A. W. (2022). The Ethiopian energy sector and its implications for the SDGs and modeling. *Renew. Sustain. Energy Transit.* 2, 100018. doi: 10.1016/j.rset.2022.100018

Zhao, Y., Fan, J., Liang, B., and Zhang, L. (2019). Evaluation of sustainable livelihoods in the context of disaster vulnerability: A case study of Shenzha County in Tibet, China. *Sustainability*. 11, 2874. doi: 10.3390/su11102874

Zulu, L. C., and Richardson, R. B. (2013). Energy for sustainable development charcoal, livelihoods, and poverty reduction : evidence from sub-Saharan Africa. *Energy Sustain. Dev.* 17, 127–137. doi: 10.1016/j.esd.2012.07.007