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Review

Household Fuelwood Consumption and Its Implication for Carbon Dioxide Emission

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Abstract: This review paper aims to gather informative data on the impact of climate extremes on the physical environment, public health, and the livelihoods of people in Ethiopia. The primary sources of data for this review were peer-reviewed journal articles obtained from electronic databases such as PubMed, Central, Scopus, and Web of Science. Globally, the vast majority of households in developing countries depend on wood energy for their daily energy needs. Such consumption trends are expected to remain a common feature of traditional wood energy production and consumption, at least in the short- to medium-terms. This situation increases the demand for firewood and charcoal from the forest. The process of harvesting standing trees for charcoal and fire wood leads to forest degradation. Although woody biomass has the function of energy consumption, and as a source of income for rural villagers and urban poor dwellers practicing agriculture, wood energy generally has low priority in national policies of developing countries. However, unsustainable management and negative environmental consequences in humid and dry forests is derived from the use of fuel wood energy. Still now there is an unsystematic assessment of the economic contribution and environmental consequences of wood energy use, so its significance and consequences have been minimized. This deforestation and forest degradation contributes 1–2.4 Gt CO_2e of greenhouse gases, which is 2–7% of global anthropogenic emissions, with global greenhouse gas emissions mostly CO_2.

Keywords: fuelwood; carbon; emission

1. Introduction

1.1. Background

Energy is one of the necessities to sustain human life, but in rural areas, most people do not have enough access to efficient and affordable energy resources [1]. Worldwide, about 2.5 billion people use firewood and charcoal as their main source of energy for cooking and heating their homes [1]. Fuelwood accounts for 60–95%, 25–60%, and <5% of the total energy used in developing countries, middle-income countries and developed countries respectively [2]. Also, other traditional biomass (agricultural wastes and animal dung) are the major source of energy in developing countries [2,3].

Due to its far low-cost accessibility compared to most alternative available forms of fuels, energy consumption in any developing country is characterized by a complete dependence on wood fuels for household cooking, lighting and heating [4–6]. An estimated 1–2.4 Gt CO_2e of greenhouse gases are emitted annually in the production and use of fuelwood and charcoal, which is 2–7% of global anthropogenic emissions. These emissions

are due largely to unsustainable forest management and inefficient charcoal manufacture and wood fuel combustion [7].

In fact, over 80% of the energy supply in African countries comes from wood [8]. Nevertheless, fire wood and charcoal are still the main sources of energy from wood [8]. Fuelwood is the predominant form of wood energy in rural areas of several developing countries, while charcoal remains a significant energy source for many urban households in Africa, Asia and Latin America. Nearly 60% of urban dwellers also use woody biomass as an energy source for cooking [9].

Achieving global access to clean energy is necessary, but there is a significant factor, especially in developing countries where there is inadequate access to modern energy sources, known as energy poverty [10,11]. Household patterns of energy consumption normally represent status and welfare as well as the stage of economic development. Generally, as the national economy develops, more energy is consumed [7]. In developing countries like Ethiopia, households preferentially invest their limited financial resources into fuel wood rather than electricity in order to meet their domestic energy needs [12,13]. Heavy reliance on biomass fuels extracted is one of the main causes of deforestation and environmental degradation besides permanent and land conversion agriculture, settlement, and infrastructural development [14]. Fuel wood extraction for energy requires global concerns over both environmental consequences and the adverse health consequences of indoor air pollution generated by burning wood, animal dung and agricultural residues [15,16].

Rural people's livelihood depends fully or partially on products derived from local forests [17]. Among all forest resources, fuel wood contributes more income to rural livelihoods. For wood forest products, reference [17] estimated that 52% and 46% of rural forest income emanates from the sales of fuel wood and timber respectively. This means that forests play an indispensable role in sustaining rural household income and livelihoods. About 95% of households use fuel wood from natural forests, which were estimated to be 30,000 tons, and 2.08 t CO_2e is emitted per household per year in Adaba Dodola, Ethiopia households [18]. This implies that the use of fuel wood energy sources contributes to forest degradation and carbon dioxide emission.

Understanding the economic impact of fuel wood in rural households is of paramount importance in the bid to mitigate forest degradation and fight against poverty [8]. Although the release of GHGs due to the burning of fuel wood looks sensitive, the continuous atmospheric accumulation of GHGs may pose serious problems of climate change in the future. So this paper will assess the impact of fuel wood use on environmental degradation as well as its implication for carbon emission.

1.2. Methodology

This review paper aims to gather informative data on household fuelwood consumption and its implication for carbon dioxide emission in Ethiopia. The data was collected through an extensive and intensive review of relevant literature published from 2000 to January 2024. The primary sources of data for this review were peer-reviewed journal articles obtained from electronic databases such as PubMed, Central, Scopus, and Web of Science. Additionally, other sources like Google, Google Scholar, institutional repositories, annual reports, conferences, gray literature, and books were utilized to access data.

1.3. Conceptual Framework

Rural households in Ethiopia depend on biomass or traditional fuels for cooking to meet their energy needs. Firewood, charcoal, and animal dung are among the traditional fuels used by the rural households in the district. Other fuels used together with these are electricity for households which are connected to the district town or center. But the access to electricity, biogas, and improved cook stoves in the rural kebele of the district does not exist and only some people, like teachers, agricultural experts, and health experts, are subject to use kerosene. Different fuel mixtures are used in the same areas of households [19].

Rural communities have several options for obtaining firewood and charcoal. This fuelwood may be produced by the household, and collected from natural forests, woodlots, and on-farm tree resources. In the district, only urban communities purchase these fuelwoods from the market. The choice of energy sources (fuel types) and the level of fuel production from different sources are specific to households. It is therefore influenced by household demographics, geophysical, socio-economic attributes, policy and institution, as well as different fuel sources (Figure 1).

The household determinants used in this review were founded on previous studies on household fuelwood energy use and alternatives. Households with lower incomes, nearer distance from the forest and the market are more reliant on fuelwoods in the forest. The family size is also directly related to energy requests through available labor for collection to fulfill the actual demand for consumption and income generation. So this increase in the amount of fuelwood extraction from the forest also increases the amount of CO_2 emitted through the combustion of forest biomass. Estimating the amount of CO_2 emission from the combustion of forest biomass helps to make policies and necessary disciplines for the future that will restrict fuelwood extraction from the forest.

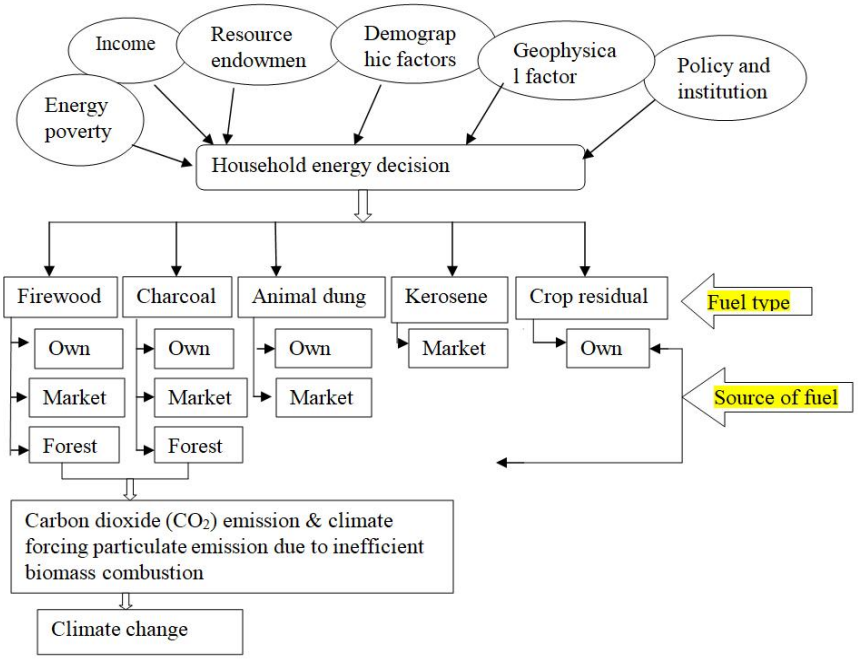

Figure 1. Conceptual framework.

2. Fuelwood Consumption for Carbon Dioxide Emission Scenario

2.1. Concepts and Definitions

According to UBET (Unified Energy Terminology), fuelwood include all types of bio-fuels derived directly and indirectly from forests and other tree production systems [20]. It consists of woody biomass, i.e. stems, branches, twigs, etc., and sawdust and other residues from logging and wood processing activities, as well as firewood, black liquor and charcoal from these sources [2].

Fuel wood is commonly used among rural residents to release energy by burning different parts of wood such as logs and twigs. It is a preexisted and oldest source of energy, which has remained the dominant and significant source of fuel for over half of the world's population [20]. The term fuelwood comprises charcoal and firewood used to provide energy for cooking and heating [21]. In most of the African countries, charcoal is produced in rural areas and sold to urban residents this was shown in Figure 2 below which is captured in Ethiopia. Firewood is the main source of energy in rural areas [22].

In Ethiopia, households depend on wood fuels (firewood and charcoal) for virtually all of their domestic energy needs. Rural households consume firewood directly, while urban households consume charcoal, produced by partial burning (pyrolysis) of wood. Charcoal produced in rural areas is sold to merchants or charcoal traders who then sell it to the users households [18,23].

Figure 2. On site photo in Burning of fuel wood in Ethiopia, i.e. fire wood and charcoal.

2.2. Overview of Global Fuel Wood Energy Use

Historically, wood has been the major source of energy or important biofuel [24,25]. Fuelwood is used both for households and commercial enterprises in rural areas. It is also the major source of energy for cooking and heating for low-income households. It is the main substitute or supplementary fuel for domestic cooking and heating for the middle-income savers [4]. This indicates wood has been used for cooking and heating since the discovery of fire [25]. Today, about half the world's annual harvest of round wood, or about 1.8 billion cubic meters per year, is used for energy. Developing countries account for almost 90% of the world's wood fuel production from which 70% of energy is based on burning biomass as their primary source of energy. Globally, 68% of biomass energy is wood fuel [26].

Different factors like cultural barriers, widespread poverty and daunting geographic conditions make other sources of energy unpopular or unavailable and the widespread use of wood fuel in a long history [7]. 1.8 billion People will still be dependent on fuel wood in sub-Saharan African countries in 2040. Because of this indicator, it is important that governments should put in place sustainable fuel production systems and sustainable lifecycle systems for their use [9].

The production of charcoal and firewood in Africa has been steadily increasing over the years, and a total of 665.6 million m^3 of fuelwood was produced in 2015 [27]. Ethiopia, the Democratic Republic of Congo (DRC) and Nigeria were the largest producer of fuelwood, with the amount of 108 million m^3, 82.5 million m^3 and 65 million m^3 of wood fuel in 2015 [27]. Other countries in the top-ten producers of wood fuel in Africa include Ghana, Uganda, Kenya, Tanzania, Egypt and Mozambique [7].

In the evaluation of the environmental impact of firewood collection, forest degradation rather than deforestation is emphasized because the former is deeply linked to the behavior of the local population, including firewood collection, overgrazing and fires, whereas the latter is mostly due to forest exploitation and commercial logging [28]. Figure 3 below shows that 68% of global primary energy supply of resources in 2015 is comprised by fuelwood [29].

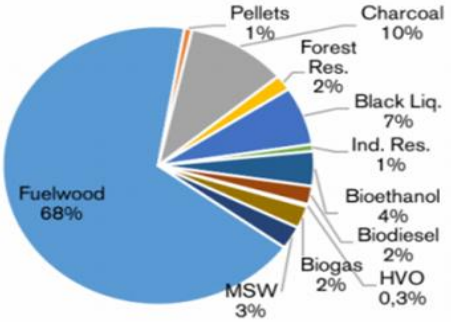

Figure 3. Global primary energy supply of biomass resources in 2015 [29].

2.3. Sources of Fuel Wood

The primary sources of wood fuels are both forest and non-forest land. Forest and other wooded land include natural forests (including degraded forests), government and private tree plantations, community forests, wood and timber plantations, village or private woodlots, scattered trees in farm boundaries, scrub lands, canal and river banks and roadsides, private trees in homesteads home and garden woodlots [2,4,30]. Non-forest land includes agricultural land, agro-forestry systems, wasteland, line trees, home gardens, etc. [7,31].

Reference [22] noted that because of the increasing fuelwood demand in peri-urban and urban areas, forests in rural areas have been overexploited. According to reference [32], if fuelwood dependency on forests is not restricted, 90% of rural areas in sub-Saharan Africa will fall into extreme poverty by 2030. This implies that because of the belief that most fuelwood originates from forests, extreme poverty will be concentrated in marginal rural communities adjacent to forests [33]. From the Figure 4 below women were collected fuel wood from the forest for consumption and sale in Ethiopia.

Figure 4. On-site photos of collection of fuelwood from forests in Ethiopia.

2.4. Wood Fuel and Rural Livelihood Strategies

The term "livelihoods" refers to the living system of peoples including their capabilities, assets and strategies. It should be sustainable when it can cope with and recover from stress and shock. It is also the improvement of capabilities and assets both now and in the future without undermining the natural resource base [34]. Forest is one of the natural assets from which fuel wood extraction is established by people to livelihood systems for cooking and heating [35]. The contribution of forests to the rural livelihoods at the household level and at national economy as a whole is significant but is largely unrecorded and consequently unrecognized. Fuel wood business supports the livelihood of the rural people in the villages and is an alternative [2]. Due to these reasons, rural area households have never completely restricted the selling and use of forest wood as a source of energy [3,36].

Apart from energy sources, wood fuel is also a good source of income and employment for the people living in rural areas. Charcoal production from the forest plays a very significant role in the livelihoods of the people in the study villages [37]. The income obtained from selling charcoal has changed the livelihood of people living in rural areas. With charcoal and fire wood businesses, the rural society can raise money which can be used to build a brick house, buy food, clothes and furniture, pay for school fees of their children and treatment of the family [2]. Generally, making and selling charcoal improve the livelihoods of villagers because it provides income and fuel wood for families [2].

According to the World Bank 2002 cited in reference [2] one-quarter of the poor depend directly or indirectly on forests for their livelihoods. For poor people, forests are a major source of forest products and income (ibid). Charcoal is rarely produced in rural communities and is mainly sold to urban areas [34]. It is more popular in urban areas because it is smokeless, easy to store and has a higher calorific value (30 MJ/kg) compared to firewood (15 MJ/kg) [38]. The use of traditional fuels in many cities in developing countries, nonetheless, remains high, especially in the dwelling of low-income groups because of the increased cost of modern fuels [39].

Fuel wood provides a multidimensional benefit to rural communities. These include the production and sale of charcoal and fire wood which provide employment opportunities directly related to fuel wood [7]. For instance, 2.5 million people in marketing and transportation and about 700,000 charcoal producers are also practicing, along with their families in Kenya [40].

Reduction in rangeland carrying capacity, and increase in biodiversity depletion, soil erosion, land degradation and gully formation are the results of tree removal and charcoal burning [7]. These actions, in turn, reduce grazing areas, thus jeopardizing the livelihoods of many pastoralists and creating rangeland resource conflicts [7].

2.5. Household Wood Fuel Energy Sources of Ethiopia

In Ethiopia, households are very dependent on traditional biomass fuels such as wood, charcoal and dried dung for their primary energy consumption households [18]. According to references [23] and [41], traditional biomass accounts for roughly 90% of total primary energy use in Ethiopia. About 99% and 84% of rural households and urban, respectively, depend on biomass as their major cooking fuel [42]. This indicates that both urban and rural households have upgraded their biomass use, from low-quality residues and dung to wood and charcoal [39].

The country's biomass fuel, such as charcoal, branches, wings and leaves, was about 105,172,465 tons per year; and from 2000 to 2013 the charcoal consumption of the country increased from 48,581 to 4,132,873 tons per year [23]. This indicates that fuel wood, such as charcoal and firewood, plays a vital role in household energy use in Ethiopia, accounting for about 88–91% as a source of energy households [18]. Reference [28] studied that based on the response of sampled households in the Ginchi district, 40.71% and 27.43% of fuel wood were extracted from the communal forest and state forest, respectively. Electric cities share a small but growing source of energy in urban and peri-urban areas of Ethiopia [26].

The high demand for wood fuel has driven the unsustainable exploitation of tree resources with soil, igniting the kilns and allowing carbonization under limited air supply. The source of labor for charcoal production activities was mainly household labor. Some big charcoal traders employed people in rural areas to make charcoal for them. Income was another contribution of wood fuel. People made money by selling charcoal and firewood, creating employment opportunities in the process of manufacturing charcoal households [18]. This was enhanced by a large number of people demanding firewood and charcoal in rural and urban areas, respectively households [18]. So the main reasons for people engaging in charcoal making were basically economic as most charcoal was made for sale.

This happens when there is a lack of affordable conventional fuels due to increasing economic hardships in the country. However, the major reasons why people use wood fuel as an alternative source for heat energy generation are energy poverty, low income, poverty, and the lack of adequate national grids [4]. The need to reduce dependence on fossil fuels and their adverse contribution to global warming pushes the world community to shift towards biomass energy which is supposed to be relatively clean [26]. Ethiopia is considered

the number one country in the world facing energy poverty [43]. This indicates that in Ethiopia it is important to build potential energy sources in order to reduce poverty level by providing adequate energy to society [22].

Generally, fuel wood consumption is a major cause of forest degradation and environmental pollution in Ethiopia due to the following reasons:

- Cutting of trees for fuel: wood without replacement has become a serious problem contributing to land cover change in the study area and causing soil erosion and land degradation[23,36].
- Most of the energy consumption is from fuel wood causing significant deforestation.
- Inefficient cooking stoves have caused the wastage of a lot of energy and exacerbated deforestation in the study area; [15,35].
- And high consumption rate of fuel wood due to the absence of affordable alternative energy sources for people in the study area [23].

In Ethiopia, collecting fuelwood is actually hard and time-consuming work, which is a difficult burden for women [13]. As pressures on the local resource base develop, the distances traveled, collection times, and other demands for women also increase. In addition, women's health may be impaired by fuelwood use because it emits more smoke and dirt than modern fuels [15,37,44]. Fuelwood covers 69% of biomass fuels which means it shares a large cover of biomass fuels due to its easily accessibility and availability in Ethiopia (Figure 5).

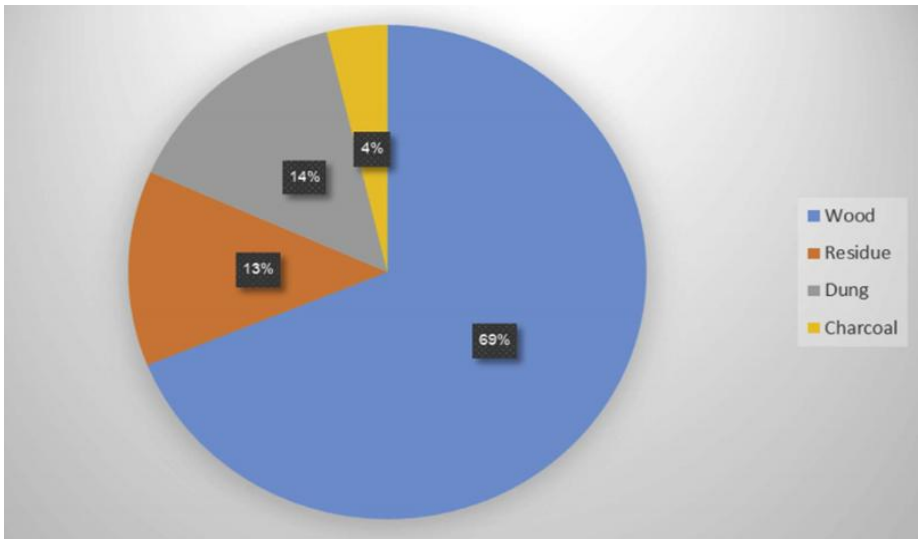

Figure 5. The share of different biomass fuel in Ethiopia, 2013. Source: reference [26].

2.6. Pattern of Household's Fuel Wood Consumption

The patterns of household energy consumption or the differences in levels of household energy consumption are determined by patterns of household size and income, types of energy application, efficiencies of wood energy devices and households' accessibility to fuels [39]. Household patterns of energy consumption normally represent the status and welfare as well as the stage of economic development [44,45]. The household energy consumption pattern is expected to increase in the future in line with economic growth and a rise in per capita income [46]. It is also projected that increases in household energy consumption result from changes in lifestyles [47].

Household income influences energy consumption patterns in many ways. Firstly, a rise in income raises energy consumption due to an increase in dishes prepared. For example, supplementary items like vegetables, milk, meat and other food items are added to the food grains and more energy is required to cook the additional food. Secondly, with increasing incomes, the constraints of fuel prices on households will decrease [1]. This resulted in wood removals from forests for energy account for about half of the wood removed from forests [47].

The survey revealed that people with low incomes spent much time harvesting fuel wood in order to meet their domestic energy needs [1]. The "energy ladder" conceptualizes household fuel choices as ascension along a hierarchical order that corresponds to increases in income from "inferior" traditional biomass energy resources to transitional fuels, and eventually "superior" modern commercial fuels. The energy ladder approach perceives

a continuous monotonic fuel substitution process as income increases [13]. An increase in income could even lead to growth in the traditional fuel demand [48]. The assumption of the energy ladder, that income dictates the switch from one fuel to another, such that households abandon one completely when ascending the ladder, is not necessarily accurate, as the multiple fuel use approach suggests.

Equally, an increase in population size and larger households may have other competing demands for limited household resources [49]. So larger households may use cheap and unsafe household fuels as a cost-saving measure. The use of such cheap and unsafe household fuel sources may have negative effects on the health of household members and increase household risk and vulnerability to poverty. On the other hand, a large household size may indicate the availability of household labor for fuel wood collection.

The agro-ecological situation, as well as socio-cultural factors, also influences the total energy consumption of the sector, determining why it differs from place to place [50]. Fuel accessibility includes the location of households—whether urban or rural; prices of fuels and, particularly for wood fuels and agricultural residues, as well as the time taken to collect these fuels. It is the combination of all these factors that determines the amount of wood energy consumed in the household sector [46].

2.7. Fuel Wood and Income

Apart from energy sources, fuelwoods from forests provide alternative income generation and employment opportunities for rural communities [34,44]. Charcoal production extracted from forests and the sale of firewood play a significant role in the livelihoods of rural people [37]. Wood removals from forests for energy account for about half of the wood removed from forests [3]. The income obtained from fuelwood businesses supports the livelihoods of rural people and is an alternative [2]. Due to these reasons rural households never completely restricted the sale and use of forest wood as a source of energy [47].

Even though forest contributes fuelwood to total household energy use, most countries have no clear and reliable assessments of the amount of fuelwood collected from forest, and have not adequately assessed the contribution of fuelwood to the household economy [35]. The contribution of forests related to fuelwood to the livelihoods and households' economy is significant, but is largely unrecorded and consequently unrecognized [2].

Income measures are increasingly used as an indicator of the well-being of forest villagers, their use of forest products, and even the value of forest. The methods for estimating income are often underreported. However, little analysis is available for the methods required to measure income [51]. Significantly, wood fuel also has the greatest share in the forest income related todomestic energy sources [17]. From this, only firewood contributes to the forest income with a share of 47–52% [17,24]. Also, charcoal production appeared to be important, accounting for 48.7% to 53.9% of the household economy in Pongwe-Msungura and Saleni villages in Tanzania [2].

In rural areas of Ethiopia, most households depend on wood fuel extracted from natural forests for consumption, sales, and use as additional income-generating activities for households [18]. Firewood income constitutes the largest proportion (79%) of the forest income in Jelo forest in Ethiopia [52]. Widespread poverty, combined with the lack of or very limited alternative livelihood opportunities and the general underdevelopment situation, is a key underlying cause of forest loss in the landscape [4,16,34]. Low economic growth and commercial development have contributed to a high dependence on forests, which were used mainly for the subsistence of energy (e.g., fuel wood) [14].

Women and children can collect the fuelwood needed by the households. Even if wood fuel collecting trips were long or becoming longer, it would probably not be a matter of concern, particularly to men. A more desirable development is to provide opportunities for both men and women to raise their incomes. This would allow them to send their children to school and buy the fuel they need. But apparently, this scenario is not considered realistic in many countries [44,46].

2.8. Environmental Implication of Fuel Wood Consumption

Fuel wood uses have both negative and positive implications on the environment. The negative impact of fuelwood on the environment is when the local community extracts various forest resources like fire wood, charcoal, fodder, timber, medicine, honey, fruit and others, these activities would harm the ecosystem of the forest [17]. Due to unsustainable mining from environmentally sensitive areas, fuel wood use has negative

environmental impacts, such as degradation of watersheds and catchment areas, loss of biodiversity and habitats, etc. [22,46]. Despite the importance of firewood and charcoal, their use led to environmental degradation, which was a critical problem in most countries including Tanzania [2].

When identifying the drivers of deforestation and forest degradation, different researchers often turn a blameful eye toward wood fuel harvesting and charcoal production [37]. Deforestation is the "long-term or permanent loss of forest cover and implies transformation into another land use", whereas forest degradation is the "long-term reduction of the overall potential supply of benefits from the forest, which includes carbon, wood, biodiversity and other goods and services". In short, deforestation can be considered as the permanent reduction in the quantity of forested land, whereas forest degradation can be considered as the quality decline in forests or wood resources [22,53].

When fuelwood becomes scarce, the resort to lower substitutes usually used as animal fodder (e.g., crop residues) or soil fertilizer (e.g., animal dung), and additional indirect financial costs related to the increase in fuelwood prices or a substitution towards more expensive sources of energy, all contribute to decreasing the well-being of local people [14,53]. According to reference [25] about 18% of global carbon emissions are related to deforestation and land use change. There is an estimation of 32,313 tons of CO_2e emitted annually from fuel wood consumption households [18]. The estimated emission corresponds to about 8733 tons of carbon with the assumption of a carbon density of 95 tons ha^{-1} for dry Afromontane forests like that of the Adaba area households [18]. The annual CO_2 emission from the use of firewood corresponds to the removal/deforestation of about 92 ha of forest households [18].

The contribution of households' energy consumption in the West Bank to global CO_2 emission is about 0.016%, while the contribution of total energy consumption by all sectors is about 0.041% [54]. This result shows that wood is the most polluted energy source in terms of CO_2 and NO_x emissions. The total amounts of CO_2, NO_x, and SO_2 by households in the West Bank are 4.7 million tons per year, 3.02 thousand tons per year, and 2.23 thousand tons per year respectively [54].

In rural areas of Ethiopia, fuelwood collection from open-access natural forests is a common activity for domestic energy consumption and income generation for households [18,23]. Consequently, heavy dependence on fuelwood is one of the leading causes for deforestation and CO_2 emissions [15,16]. Generally, the annual fuelwood consumption was calculated by multiplying the weight of fuelwood in one week by the number of weeks within one year which equals 52 [55].

Besides the hardship associated with gathering and cooking, indoor air pollution associated with fuel wood use is worse in poor countries where households' houses are not equipped with separate living and cooking places [23,28]. It causes health-related problems, particularly for women lactating children and the elderly [56]. Furthermore, smoke from the use of fuel wood and dung for cooking contributes to acute respiratory infections. However, if the supply source is properly managed, fuelwood can contribute positively to the local and global environment. Fuel wood is neutral CO_2, provided that the rate of harvest equals the rate of re-growth. Therefore, extended use of wood energy is gaining widespread support as live trees and vegetation serve as sinks and reservoirs of carbon.

Mostly, annual carbon emissions were calculated based on the Clean Development Mechanism and the United Nations Framework Convention on Climate Change [57]. Equation (1) is an estimation of carbon dioxide, including default net calorific values, emission factors, and carbon storage in forests:

$$E = FC \times f_{NRB} \times NCV \times EF \quad (1)$$

where E is emission in tons of carbon dioxide equivalent (tCO_2e); FC is the quantity of fuelwood consumed in tons or kilo grams; and f_{NRB} is the fraction of non-renewable woody biomass.

3. Conclusions

In rural areas of developing countries, the lack of access to clean energy sources such as electricity makes the rural household highly dependent on fuelwood energy [16]. Low economic growth and commercial development have contributed to a high dependence on forests, which were used mainly for the subsistence of energy e.g., fuel wood [14]. Most households depend on wood fuel extracted from natural forests for consumption, sales, and use as additional income-generating activities for households [18]. This has a great

effect on the economic, social as well as environmental sustainability of the forest sector in the country [49]. It also resulted in ecological imbalance and increased use of agricultural residues and animal dung, and deprives the land of essential nutrients that are necessary for soil fertility.

An estimated 1–2.4 Gt CO_2e of greenhouse gases are emitted annually in the production and use of fuelwood and charcoal, which account for 2–7% of global anthropogenic emissions. These emissions are mainly due to unsustainable forest management, inefficient charcoal manufacture, and wood fuel combustion [7].The need to reduce dependence on fossil fuels and their adverse contribution to global warming pushes the world community to shift towards biomass energy which is supposed to be relatively clean [26]. Demand for clean energy consistently increases in line with rising household incomes in these economies. There is an opportunity to greatly expand the use of clean and renewable energy technologies, which will have a positive climate impact. If sustainably produced and utilized, wood is a carbon-neutral source of energy. In such cases, forest productivity, biodiversity, and climate change are also major concerns for the implementation of sustainable wood energy systems [2].

4. Recommendations

Countries will make a clear assessment of the amount of fuelwood that can be collected from ongoing forest operations [8,58]. The economic and environmental roles of fuelwoods extracted from forest and non-forest areas should be recognized and fuelwoods should be treated as an important sub-sector that needs to be developed. Fuelwood energy development should be integrated into rural energy supply strategies and implemented as a common task for all relevant sectors.

Fuelwood should be seen as a significant product in its own right rather than just as a byproduct from agricultural land. Integrated fuelwood production on agricultural land should be promoted. Current reforestation and afforestation efforts should be continued in natural forest management. The selection of fast-growing tree species for fuelwood energy crops, identification of appropriate provenance to match specific conditions, and improvement of the survival and growth rates of trees at degraded sites and waste lands, should be supported by further research and diagnosis.

The effective use of by-products and residues from the wood industry, partly by converting them into modern wood energy, should be encouraged to reduce wood waste and supply additional fuels. More key data on wood energy supply should be collected to support wood energy policies. Wood energy subjects should be integrated into the training curricula of relevant sector education and training programs. The priority within wood energy conservation programs should be the supply of convenient, healthy, and attractive household stoves at affordable prices to reach the maximum number of fuelwood energy users. The cost-effectiveness of wood energy development projects in terms of global CO_2 savings should be communicated to interested donor agencies.

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Informed Consent Statement

Not applicable.

Data Availability Statement

The data used to support the findings of this study was found in related published articles that listed in the corresponding author.

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Conflicts of Interest

The authors declare no conflict of interest.

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