Quantifying Greenhouse Gas Emissions from Woodfuel used in Households

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Abstract. The combustion of woodfuel for residential use is often not considered to be a source of greenhouse gas (GHG) emissions in households since emissions from woodfuel combustion can be offset by the CO2 absorbed by the growth of the forest as a carbon sink (IPCC, 2006). However, this only applies to wood that is harvested in a renewable way, i.e., at a rate not exceeding the regrowth rate of the forest from which it is harvested (Drigo et al., 2002). This paper estimates the share of GHG emissions attributable to non-renewable woodfuel harvesting for use in residential food activities, by country and with global coverage. It adds to a growing research base estimating GHG emissions from across the entire agri-food value chain, from the manufacture of farm inputs, through food supply chains, and finally to waste disposal (Tubiello et al., 2021). Country-level information is generated from United Nations Statistics Division (UNSD) and International Energy Agency (IEA) data on woodfuel use in households. We find that, in 2019, annual emissions from non-renewable woodfuel use in household food consumption were about 745 million tonnes (Mt CO2eq yr^{-1}), with uncertainty ranging from −63 % to + 64 %Overall, global trends were a result of counterbalancing effects: the emission increases were largely fuelled from countries in Sub-Saharan Africa, Southern Asia, and Latin America while significant decreases were seen in countries in Eastern Asia and South-eastern Asia. The Food and Agriculture Organisation of the United Nations (FAO) has developed and regularly maintains a database covering GHG emissions from the various components of the agri-food sector, including pre- and post-production activities, by country and world regions. The dataset is developed according to International Panel on Climate Change guidelines (IPCC, 2006), which avoids overlaps between Agriculture, Forestry and Other Land Use (AFOLU) and energy components. It relies mainly on UNSD Energy Statistics data, which are used as activity data for the calculation of the GHG emissions (Tubiello et al., 2022). The information used in this work is available as open data with DOI https://doi.org/10.5281/zenodo.7310932 (Flammini et al., 2022a).

Keywords: Agri-food systems, GHG emissions, sustainable woodfuel, household, food consumption

1. Introduction

In 2019, about 27% of the global population relied on traditional biomass (wood, crop residues, animal dung, etc) to meet household energy needs (IEA, 2020). The dependence on woodfuel is greatest in developing countries where it provides about one-third of total energy and is commonly used for cooking and residential heating (FAO, 2010). Approximately 70% of households in Sub-Saharan Africa depend on wood-based biomass as their primary cooking fuel. That figure is roughly 44% in South-East Asia (World Bank, 2011).

Woodfuel for domestic purposes is obtained from many supply sources, not only from forestlands. These sources include trees outside forests (such as scrubs, bush fallow, dead wood, dry branches, twigs), trees planted with agricultural crops (agroforestry or forest plantations), residues of wood harvesting, by-products of land cover change, and salvage harvesting (FAO, 2010). Several studies have examined the impact of woodfuel use in households on deforestation and human health. For the former, extensive research was conducted as a response to the 1970s and 1980s "fuelwood crisis", where conclusions were made that harvesting of fuelwood for energy is not the primary source of forest depletion (Arnold et al., 2006; Dewees, 1989; World Bank, 2011).

In terms of impact on human health, around 3.2 million premature deaths are caused due to the inhalation of polluted air in households, sourced mainly from the traditional use of biomass for heating and cooking. The pollution comes in the form of small particles that are absorbed into the lungs and enter the bloodstream. Air is considered polluted when the mean concentration of particulate matter (PM_{10} and $PM_{2.5}$) and other combustion-derived indoor pollutants such as Carbon Monoxide are beyond WHO air quality guideline values (WHO, 2014). Another study pointed at an estimation of 3 million deaths per year from indoor air pollution by open fires and smoky stoves (IEA, 2021; WHO, 2021). However, very few studies have examined the climate impact of woodfuel consumption for residential use, except in the context of carbon offsets for carbon financing (e.g., using improved cookstoves). For example, one report estimated that the global potential for GHG emission reductions for improved cookstoves (ICS) is estimated at 1 Gt CO_2 per year (Lee et al., 2013).

This paper strives to quantify the GHG emissions, by country, attributable to household food systems consumption of woodfuel, including cooking, kitchen appliances and food refrigeration. Previous reports have set the CO_2 emissions associated with woodfuel consumed in households to 0 which is in line with International Panel on Climate Change (IPCC) guidelines (IPCC, 2006). Such emissions are in fact covered by the 'forestry' and 'land use' components of the AFOLU sector, while the limited emissions of CH_4 and N_2O from woodfuel burning are reported under the Energy sector. This is based on two assumptions: i. combustion of biomass is considered renewable and has no net CO_2 emissions impact (the CO_2 absorbed by the tree during its growth is equivalent to the amount released during burning or decomposition process); ii. all CO_2 that is sequestered over the years by trees is released during burning. Therefore, the wood removed by land-cover change (net forest conversion), or forestland degradation will eventuate, at some point, into a release of CO_2. Following the IPCC approach, it is not possible to single out the amount of CO_2 associated with woodfuel burning at the household used for cooking.

In a renewable biomass harvesting scenario, the expectation is that the wood removed will fully regrow. New trees take up the carbon that is produced by the combustion the carbon balance in the atmosphere remains neutral. On the other hand, woody biomass is non-renewable if its extraction results in a long-term loss in carbon stocks, i.e., if the extraction rate does not allow the biomass to regrow (Drigo et al., 2014). At the same time, to estimate the real emissions associated with woodfuel, it is not possible to simply apply an emissions factor to the amount of woodfuel burned, since some part of wood harvested as woodfuel can be considered sustainable. This is determined if the rate of extraction is at or below the annual increment.

In FAOSTAT, emissions associated with the 'unsustainable' share of woodfuel burned are already covered under emissions on 'forestland' (forest degradation) and 'net forest conversion' (deforestation) therefore, adding emissions from woodfuel for cooking to total agri-food emissions would result in a double-counting.

In this publication, we define wood harvested beyond the sustainable harvest level (i.e. the wood extraction flow that allows wood to regrow) as non-renewable biomass (NRB). Obtaining accurate information about NRB fractions has historically been a challenging exercise (Lee et al., 2013). A milestone approach on the assessment of the fractional NRB was through the use of a spatial model called Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) which was first applied in Mexico by FAO in 2002 (Drigo et al., 2002). The WISDOM model has over the years been subsequently applied to other countries and world regions. Bailis et al. (2015) presents non-renewable biomass fraction (NRBf) by applying an evolution of the WISDOM model to a number of countries across Asia, Africa and Latin America.

This paper presents a methodology to apply the NRBf to woodfuel consumption used for food in the household, based on data from the UNSD Energy Statistics database. Our methodology does not distinguish between woodfuel emissions associated with the deforestation component and the degradation component. However, previous research estimated that emissions from forest degradation were one-fourth of those from deforestation in 2001–2010, and increased to one-third in more recent years (2011–2015) (Federici et al., 2015).

The results are presented consistently to FAOSTAT countries and regions, in an effort to further expand FAOSTAT work on disseminating data on GHG emissions from agri-food systems at the country-level. Accounting for GHG emissions across all agri-food systems activities will help researchers, policymakers, and businesses uncover novel climate mitigation opportunities through food system interventions.

2. Materials and methods

2.1 Gap filling

The UNSD fuelwood data used herein are gap filled to improve the quality of the available timeseries and to estimate data for missing countries. Notably, the original UNSD energy dataset had missing data for China for the entire time series, and this gap was filled by complementing it with IEA Energy data for primary solid biofuels (defined as any plant matter used directly as fuel or converted into other forms before combustion). The NRBf data was available for most countries in regions such as Africa, Asia, and Latin America. For countries with no data available on their NRBf values, sub-regional and regional NRBf averages were used and applied accordingly.

2.2 Emissions estimates

For FAO, biofuel is defined as "any fuel produced directly or indirectly from biomass", while woodfuel is described as all types of biofuels derived directly or indirectly from woody biomass (grown on either forest or non-forest land) (FAO, 2004). GHG emissions are calculated according to the IPCC guidelines, at Tier 1 (IPCC, 2006), by applying the following formula:

$$E_{i,g} = A_{iy} * f_w * NRBf_i * EF_g \qquad (1)$$

where

E = GHG emissions by gas (g) in select country or region I, for select inventory year, y, kilotonnes of CO_2 equivalent (kt CO2e yr^{-1})

A = volume of woodfuel consumed in the household (activity data) for select country or territory i, for select inventory year y, reported in cubic metres (m^3)

f_w = share of woodfuel used for cooking for select country y,

NRBf = non-renewable biomass fraction for select country y, based on FAO WISDOM,

EF = emission factor of woodfuel, by gas, based on IPCC (2006) default values,

The volume of woodfuel consumed in the household is extracted from UNSD Energy Statistics database (Flow 1231): Consumption by households and converted to energy by applying a representative calorific value of 11.2. The calorific value is calculated by multiplying the average heating value of air-dried wood fuel and completely dry wood and its average density. This heating value is estimated from the heating value of woods typically used as woodfuel, as reported in the IEA Energy Statistics Manual (IEA, 2004). The average density of the woodfuel is estimated by taking the density of woods typically available in tropical countries (FAO, 2007). This assumes that most of unsustainable wood harvesting for food preparation takes place in pan-tropical countries. Based on FAO categorization, the regions that have one or more country designated as pan-tropical are Sub-Saharan Africa, South Asia, Eastern Asia, Latin America, South-Eastern Asia, North Africa and Melanesia The share of woodfuel used for cooking is set to unity for all tropical countries concerned (i.e., in tropical countries all woodfuel used in the household is for cooking), while countries with little-to-no tropical coverage would have its share set as 0.847. The rest is used for heating (Daioglou et al., 2012; Morgan, 2011).

The NRBf fraction is obtained from the ‘expected’ NRBf, where suboptimal harvesting of woodfuel is assumed. The NRBf referenced is taken from the average of the low plantation productivity variant and the high plantation productivity variant of $NRB_{B1} + NRB_{B2}$. The latter is generated with the assumption that woodfuel users can meet their woodfuel demand from both land cover change by-products and from other sources (Bailis et al., 2015). For each country, a single NRBf is assumed for all years reported.

The calculation was run using R software for all countries and world regions, mapping UNSD to FAOSTAT countries for the application of subregional and regional statistics.

2.3 Data uncertainty and limitations

There are limitations and uncertainties associated with the estimates presented herein. First, we note that, although we assume that all fuelwood in tropical households (and the vast majority in the non-tropical countries of the regions concerned) is used for food preparation, the input data refer to fuelwood energy use in households without further breakdown. Second, the underlying data on energy use have gaps, especially in China and Africa. For countries with no data, these were imputed from the IEA Energy Database instead. Thirdly, for the underlying NRB fractions, out of 90 countries and territories, 6 were imputed based on regional averages. The uncertainty in the original woodfuel consumption data is much smaller for some countries than for others, depending on whether the activity data are collected using specific surveys where a sense of the uncertainty can be measured, or whether national statistical offices use proxies and/or assumptions. In our case, using the level of uncertainty for "biomass in small sources" and "less-developed statistical systems" (such as energy statistics), an uncertainty of ±60 % can be assumed for activity data (IPCC, 2006, volume 2, chap. 2, Table 2.15). Fourthly, the NRB fractions also possess uncertainty in regard to their temporal bias due to a similar number used for all years attached. Uncertainty in activity data was then combined with uncertainty in fuel emission factors (−15 % to 18 %), computed by taking the IPCC lower and upper values of emissions factors of wood/wood waste. Uncertainty on the conversion factor is calculated as ±12%. Lastly, the uncertainty for the NRBf values was computed to be ±1.3%. The resulting overall uncertainty from the energy statistics and emission factors was obtained by applying the IPCC (IPCC, 2006) default error propagation method, resulting in the range of −63 % to +64 %.

An additional limitation of this methodology is that, although unsustainable woodfuel extraction could be associated with both deforestation and forest degradation, our methodology does not single out the emissions that are attributable to each of them.

Finally, this analysis relies on static information about the NRB fraction of countries, whereas this fraction can change over time. An assessment of country NRB fractions should be undertaken on a regular basis, in order to have more precise and realistic figures of woodfuel use emissions.

3 **Results**

The results show that, globally, for the year 2019, the GHG emissions associated with the unsustainable (or non-renewable) fraction of woodfuel used in households were 741,652 kt for CO_2 emissions, 1,987 kt for CH_4 and 26.5 kt for N_2O. Therefore, the CO_2eq emissions were above 0.7 Gt in 2019, 6% greater than in 1990 (Figure 1). These emissions can be compared with the total 4.84 Gt CO_2 yr^{-1} from deforestation (4.04 Gt CO_2) and forest degradation (0.80 Gt CO_2) estimated at global level by Federici et al. (2015) over 1991-2015. This amount of emissions associated with unsustainable woodfuel use in the household should be added to the 1.3 Gt CO_2eq yr^{-1} associated with household food consumption (excluding bioenergy) in the year 2019 reported in FAOSTAT (Tubiello et al., 2022). Therefore 2 billion tonnes are a more precise figure of the emissions associated with human activity at this important step of the agri-food chain.

The top 10 countries (out of 90 countries covered by the dataset) are responsible for 69% of global GHG emissions attributable to woodfuel use for household food systems in 2019. No country from Latin America and the Caribbean were among the top 10 GHG emitters. However, in terms of GHG emission per person (based on population data from FAOSTAT), higher values can be seen in African countries: out of the 10 top emitters, five are from Sub-Saharan Africa, three are from Southern Asia, one from Eastern Asia and one from South-eastern Asia.

Nigeria and India were the largest emitters in 2019 in absolute terms. It is to note that China saw the biggest reductions in CO_2 emissions over the time frame of 1990 to 2019, and China was the highest emitter from 1990 to 2006 (Figure 2).

Sub-Saharan Africa, South Asia and Eastern Asia were the largest emitters among subregions, although with different trends over 2005-2019. Eastern Asia decreased over the whole period, from 138 Mt CO_2eq yr^{-1} in 1990 to 135 Mt CO_2eq yr−1 in 2000 and further decreased to 51 Mt CO_2eq yr^{-1} in 2019, while emissions in Sub-Saharan

Africa nearly doubled from 202 in 1990 to 379 Mt CO_2eq yr^{-1} in 2019. Southern Asia was a significant emission source in 2019 but has increased only slightly (around 3% over a 19-year period) since 1990, from 197 to 203 Mt CO_2eq yr^{-1} in 2019. Emissions increased only by 1% in Latin America and South-eastern Asia decreased by more than 60% over the same period (Figure 3).

We also compared estimates of emissions from woodfuel use in household food consumption with the estimates from net forestland conversion in FAOSTAT. As discussed in the Materials and methods section, FAO estimates of emissions from net forestland conversion are proxies for deforestation emissions data. It is also important to note that there are various sources of woodfuel use in households as described in the Introduction section, and net forestland conversion is just one of them. On a global scale, woodfuel household food CO_2 emissions were between 15% to 23% of the global net forest conversion CO_2 emissions (Figure 4).

4 Discussion

36.3% of overall household food emissions can be attributed to unsustainable harvest of woodfuel used in the household for cooking (0.7 Gt CO_2eq in 2019). For comparison, the GHG emissions of the whole agri-food sector amount to 16 Gt CO_2eq yr^{-1} and 6 Gt CO_2eq yr^{-1} alone from post-agricultural production activities (including food processing, transport, retail and household consumption). Household woodfuel emissions correspond to 4.7% and 12.5% respectively.

Although these GHG emissions are covered in the AFOLU section, according to the IPCC guidelines, as part of the 'deforestation' activity, these emissions are strictly related to the cooking, which happens towards the end of the agri-food chain. This paper presents an estimation of the emissions from 'unsustainable' woodfuel use for cooking in the households. It is important to understand the magnitude of these emissions versus total deforestation emissions and total household emissions because any mitigation action of these emissions cannot be enacted without addressing cooking systems. In other words, to reduce this important share of agri-food system emissions, any mitigation action should focus on, or at least consider, providing alternative and/or more efficient cookstoves to the users of unsustainable woodfuel for cooking. An intervention aimed only at halting deforestation or reducing household emissions will be partial or ineffective.

The high proportion of non-renewable woodfuel consumption in regions such as Sub-saharan Africa is reflective of the population where low-income households have a higher dependency on biomass for their energy needs (Dutschke et al., 2006) and energy use is less varied than their middle- and upper- income counter parts (the only two primary services are cooking and lighting) (Sovacool, 2011). The massive reduction in non-renewable woodfuel emissions from China over the period can be attributed to the exponential income of rural farmers with strong rural energy policies which supported the development of other energy sources (most notably, electricity) (Yao et al., 2012).

The updated assessment of total agri-food system emissions as supplemented by the data in this work still reaffirms previous findings and works by the IPCC (2019), Crippa et al. (2021) and Tubiello et al. (2022). However, the most significant difference with previous work was observed in relation to household consumption emissions. Our updated value estimates of global food-related household consumption emissions, 1.9 Gt CO_2eq., were bigger than our previous estimates of 1.2 Gt CO_2eq (Tubiello et al., 2022), fuelled mostly by woodfuel combustion in household food systems. FAOSTAT estimates in this work are more than 4 times those of EDGAR-FOOD (Crippa et al., 2021) (with reference to 2015, the last year for which EDGAR data were available) and they represent a significant share of total agri-food system emissions (Figure 5).

A notable trend with the incorporation of non-renewable woodfuel emissions into the overall household food system emissions is the amplification of country-level emissions in countries/territories with high dependence on woodfuel as their source of energy (Schilmann et al., 2021; World Bank, 2011).

Our refined assessments of emissions contributions highlight the importance of non-renewable woodfuel into the overall food systems emissions. Referring to our previous work (used for FAOSTAT), the total food system emissions were 16.5 Gt CO_2eq in 2019. Within the overall composition of the total food system emissions, the pre- and post-production sector emissions is 5.8 Gt CO_2eq (38%). Out of the overall pre- and post-production sector, the non-renewable woodfuel combustion constitutes 0.75 Gt CO_2eq of the total (Tubiello et al., 2022). Regarding the three major components of the food system (on-farm production, land use change and pre- and post- agricultural production activities, as defined in Tubiello et al. 2021), our analysis highlights that in 2019, household food systems took the biggest share (31%) while non-renewable woodfuel combustion was 36% of household food systems (Figure 5).

5 Data availability

The GHG emission data presented herein cover the period 1990–2019 at the country level. They are available as open data, with DOI https://doi.org/10.5281/zenodo.7310932 (Flammini et al., 2022a).

6 Conclusions

This paper provides updated details of the FAOSTAT database on GHG emissions along the entire agri-food systems chain (Tubiello et al., 2022), with a focus on improving the estimates of the household consumption emissions.

The data are provided in open-access mode to users worldwide and are available by country over the period 1990-2019, with plans for annual updates. The major trends in non-renewable woodfuel consumption within household food-systems that were identified in this work can help locate emissions hotspots in agri-food systems and inform the adoption/effectiveness of policies on cooking fuel switches on the country, regional and global level. This work also emphasizes the increasingly important role that pre- and post-production processes along supply chains play in the overall GHG footprint of agri-food systems, in a regional and global level.

This paper also helps to expand the impacts of woodfuel use beyond just health measures but to also highlight the climate impact attached to using non-renewable woodfuel as a source of cooking fuel. Finally, the methodological work underlying these efforts complements and extends recent pioneering efforts by FAO and other groups in characterizing technical coefficients to enable quantifying the weight of agri-food systems within countries' emissions profiles.

7 Competing interests

At least one of the (co-)authors is a member of the editorial board of *Earth System Science Data*. The peer-review process was guided by an independent editor, and the authors also have no other competing interests to declare.

8 Disclaimer

The views expressed in this paper are the authors' only and do not necessarily reflect those of FAO or UNIDO.

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TABLES

Table 1. Typical heating values of woods used as fuelwood

Wood Type	**Heating value**
Air-dried wood (10% to 20% moisture content)	16 MJ/kg
Completely dry wood (oven-dried)	18 MJ/kg
Average	17 MJ/kg

Source: IEA Biofuel Energy Statistics (Page 174 of the IEA Energy Statistics Manual) (IEA, 2004)

Table 2. Typical densities of woods used as fuelwood

Wood Type	Density
Air-dried wood	725 kg/m^3
Oven-dried wood	593 kg/m^3
Average	659 kg/m^3

Source: Wood-energy supply/demand scenarios in the context of poverty mapping (Table A2.4) (FAO, 2007)

Table 3. List of tropical countries

Algeria	Benin	Lao People's Democratic Republic	Guinea-Bissau
Angola	Dominica	Liberia	Timor-Leste
Antigua and Barbuda	Dominican Republic	Libya	Rwanda
Argentina	Ecuador	Madagascar	Saint Helena
Bolivia (Plurinational State of)	El Salvador	Malawi	Saint Kitts and Nevis
Botswana	Equatorial Guinea	Malaysia	Anguilla
Brazil	Ethiopia	Maldives	Saint Lucia
Belize	Eritrea	Mali	Saint Vincent and the Grenadines
Solomon Islands	Falkland Islands (Malvinas)	Mauritania	Sao Tome and Principe

British Virgin Islands	Fiji	Mauritius	Senegal
Brunei Darussalam	French Guiana	Mexico	Seychelles
Myanmar	Djibouti	Mozambique	Sierra Leone
Burundi	Gabon	Namibia	Viet Nam
Cambodia	Gambia	Nepal	Somalia
Cameroon	Ghana	Curacao	South Africa
Cabo Verde	Grenada	Aruba	Zimbabwe
Central African Republic	Guadeloupe	Saint Maarten (Dutch part)	South Sudan
Sri Lanka	Guatemala	Bonaire, Sint Eustatius and Saba	Sudan
Chad	Guinea	New Caledonia	Suriname
Chile	Guyana	Vanuatu	Togo
Colombia	Haiti	Nicaragua	Trinidad and Tobago
Comoros	Honduras	Niger	Turks and Caicos Islands
Mayotte	India	Nigeria	Uganda
Congo	Indonesia	Panama	Egypt
Democratic Republic of the Congo	Cote d'Ivoire	Papua New Guinea	United Republic of Tanzania
Costa Rica	Jamaica	Paraguay	Venezuela (Bolivarian Republic of)
Cuba	Kenya	Peru	Guinea-Bissau

Source: Journal of Tropical Psychology, Volume 1 (Morgan, 2011)

Table 4. Non-renewable fractions (NRBf) based on country and region

Country/region	**NRB fraction**	**Country/region**	**NRB fraction**
Angola	0.350	Malawi	0.371
Argentina	0.283	Malaysia	0.465
Bangladesh	0.510	Mali	0.291
Belize	0.993	Mauritania	0.348
Benin	0.217	Mexico	0.268

Bhutan	0.559	Mozambique	0.397
Bolivia (Plurinational State of)	0.325	Myanmar	0.085
Botswana	0.895	Namibia	0.476
Brazil	0.238	Nepal	0.524
Brunei Darussalam	0.872	Nicaragua	0.579
Burkina Faso	0.476	Niger	0.235
Burundi	0.570	Nigeria	0.511
Cambodia	0.384	Pakistan	0.836
Cameroon	0.758	Panama	0.496
Central African Republic	0.264	Papua New Guinea	0.403
Chad	0.237	Paraguay	0.384
Chile	0.138	Peru	0.309
China	0.16	Philippines	0.214
Colombia	0.344	Rwanda	0.585
Congo	0.099	Senegal	0.361
Costa Rica	0.18	Sierra Leone	0.219
Côte d'Ivoire	0.163	Singapore	0.755
Democratic Republic of the Congo	0.24	Solomon Islands	1
Dominican Republic	0.33	Somalia	0.524
Ecuador	0.99	South Africa	0.238
El Salvador	0.372	Sri Lanka	0.244
Equatorial Guinea	0.94	Sudan	0.411
Eritrea	0.679	Suriname	0.181
Ethiopia	0.613	Thailand	0.03
French Guiana	0.165	Timor-Leste	1
Gambia	0.412	Togo	0.44
Ghana	0.286	Trinidad and Tobago	0.554
Guatemala	0.334	Uganda	0.613

Guinea	0.297	United Republic of Tanzania	0.235
Guinea-Bissau	0.279	Venezuela (Bolivarian Republic of)	0.527
Guyana	0.039	Viet Nam	0.115
Haiti	0.666	Zambia	0.340
Honduras	0.637	Zimbabwe	0.377
India	0.231	Eastern Asia	0.16
Indonesia	0.434	Latin America and the Caribbean	0.396
Jamaica	0.185	Melanesia	0.702
Kenya	0.635	Northern Africa	0.369
Lao People's Democratic Republic	0.273	South-eastern Asia	0.421
Lesotho	0.525	Southern Asia	0.484
Liberia	0.283	Sub-Saharan Africa	0.415
Libya	0.327		

Source: Authors' own elaboration.

FIGURE LEGENDS

Figure 1. Global GHG emissions from non-renewable woodfuel use in households for cooking from 1990 to 2019 (Mt), including uncertainty ranges. Source: Authors, based on data from IEA and UNSD (2022)

Figure 2. GHG emissions trends from the top 10 emitters of 2019 from 1990 to 2019 (Mt CO2eq). Source: Authors.

Figure 3. Share of global GHG emissions from household woodfuel use in food sector stratified according to sub-region. Source: Authors.

Figure 4. Trends in CO_2 emissions from net forestland conversion and woodfuel use in household food consumption from 1990 to 2019. Source: FAOSTAT, 2022

Figure 5. Proportion of emissions for non-renewable woodfuel use in household food systems in comparison to i) the overall food system (Pie Chart 1), ii) pre- and post-production (Pie Chart 2) and iii) household food systems (Pie Chart 3), for the year 2019. Source: FAOSTAT, 2022

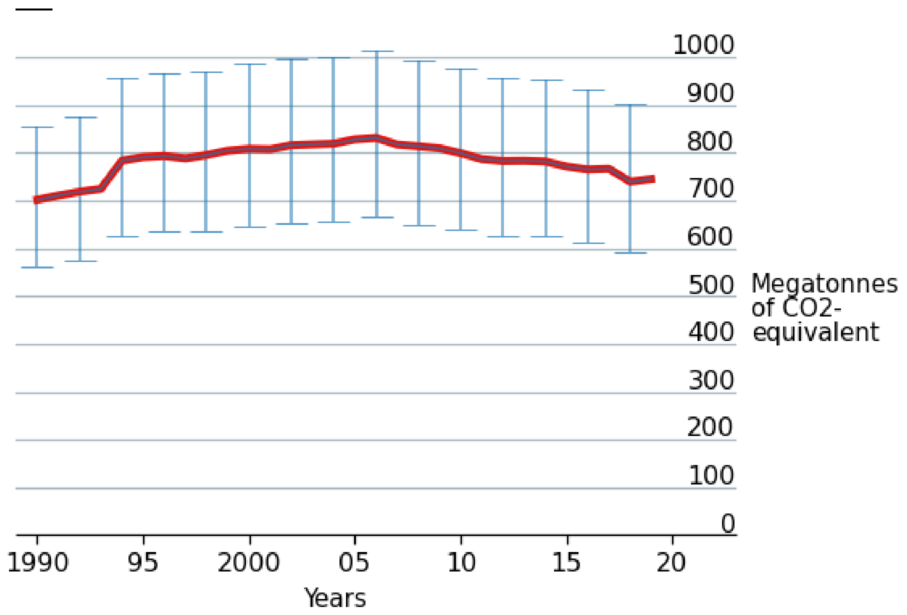


Figure 1. Global GHG emissions from non-renewable woodfuel use in households for cooking from 1990 to 2019 (Mt), including uncertainty ranges. Source: Authors, based on data from IEA and UNSD (2022)

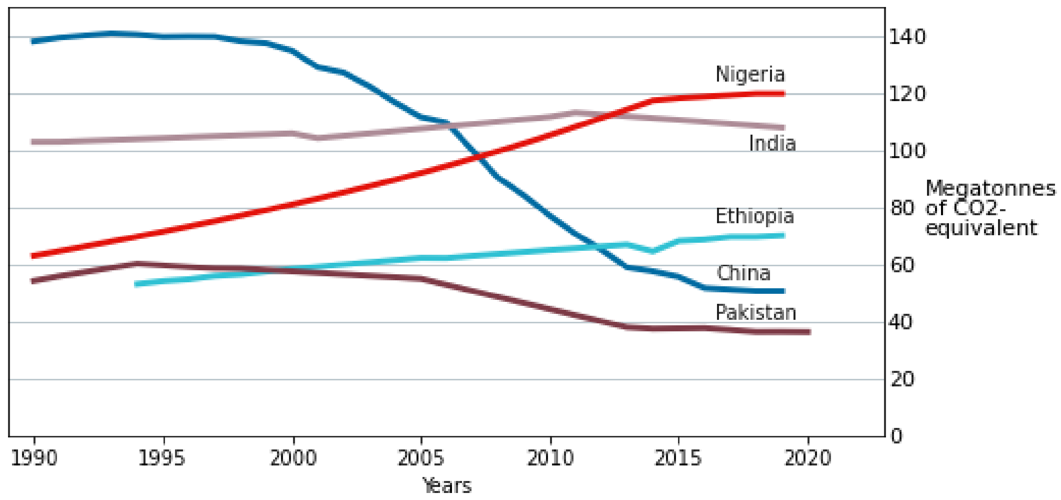


Figure 2. GHG emissions trends from the top 5 emitters of 2019 from 1990 to 2019 (Mt CO2eq). Source: Authors.

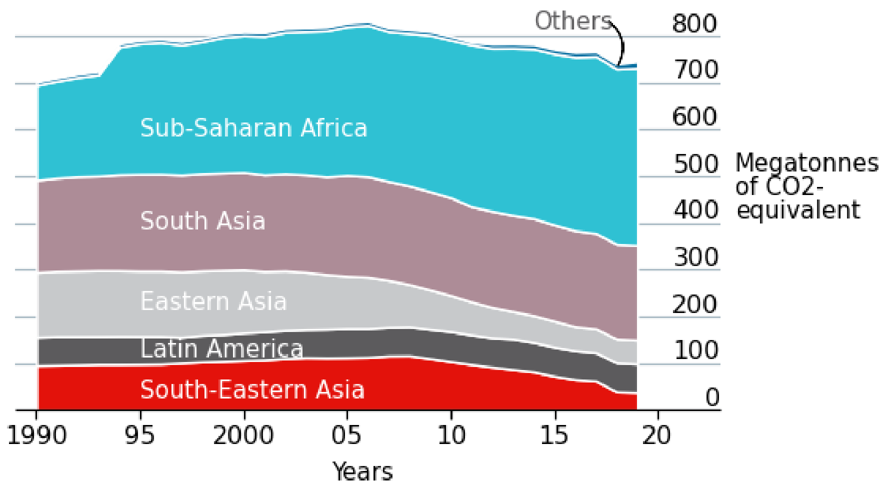


Figure 3. Share of global GHG emissions from household woodfuel use in food sector stratified according to sub-region. Source: Authors.

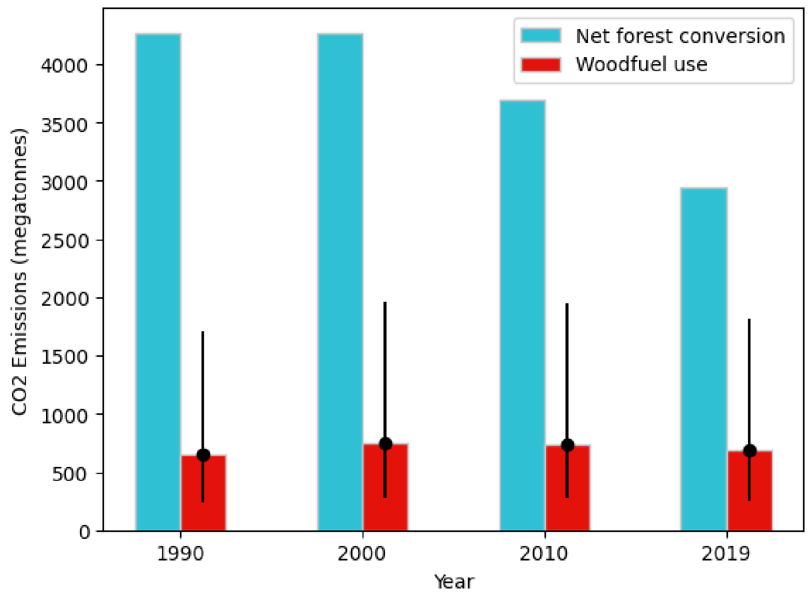
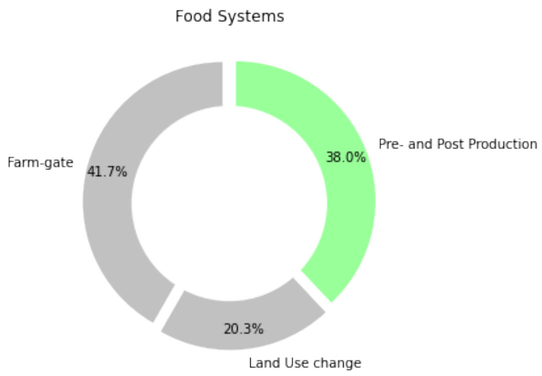
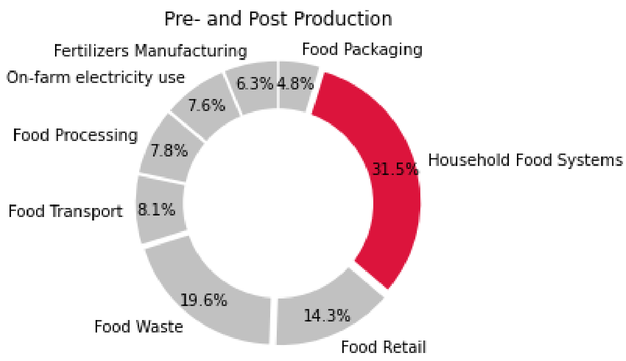


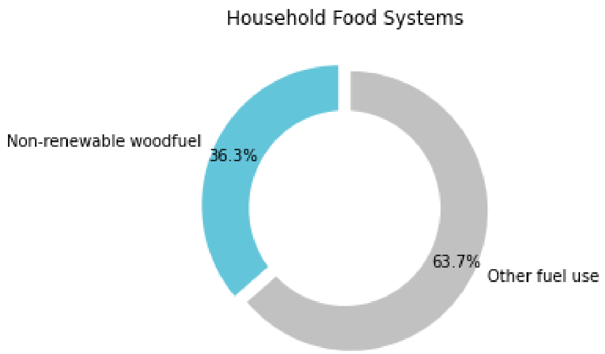
Figure 4. Trends in CO2 emissions from net forestland conversion and woodfuel use in household food consumption from 1990 to 2019. Source: FAOSTAT, 2022



Pie Chart 1



Pie Chart 2



Pie Chart 3

Figure 5. Proportion of emissions for non-renewable woodfuel use in household food systems in comparison to the overall food system (Pie Chart 1), pre- and post-production (Pie Chart 2) and household food systems (Pie Chart 3) for the year 2019. Source: FAOSTAT, 2022