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WOODY AND NON-WOODY BIOMASS UTILISATION FOR FUEL AND IMPLICATIONS ON PLANT NUTRIENTS AVAILABILITY IN THE MUKEHANTUTA WATERSHED IN ETHIOPIA

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ABSTRACT

Plant biomass is a major source of energy for households in eastern Africa. Unfortunately, the heavy reliance on this form of energy is a threat to forest ecosystems and a recipe for accelerated land resource degradation. Due to the increasing scarcity of traditional fuel wood resources, rural communities have shifted to utilisation of crop residues and cattle dung; which otherwise, are resources for soil fertility improvement. The objective of this study was to assess the supply and consumption patterns of fuel biomass and estimate the amount of nutrients that could be lost from burning non-woody biomass energy sources. A survey was conducted in the Mukehantuta watershed in Ethiopia, using a semi-structured questionnaire. An inventory of woody biomass was also carried out on the existing stock in the watershed. Annually, households in the watershed used 1999, 943, 11, 34 and 229 metric tonnes of wood, dung, charcoal, crop residue and tree residues, respectively. The existing wood biomass in the watershed was approximately 292 metric tonnes, implying that consumption exceeds potential supply. As a result of using dung and crop residue biomass for household energy, the watershed, respectively, loses 17.3, 4.3, 20.6, 15.6, 5.4, and 10.2 tonnes of N, P, K, Ca, Mg and Fe nutrients every year. The lost nutrients in terms of fertiliser equivalency are estimated at 37.5 tons of urea and 9.3 tons of Di-ammonium phosphate (DAP).

Key Words: Cattle dung, crop residue, soil fertility

RÉSUMÉ

La biomasse des cultures constitue une source importante d'énergie pour les ménages en Afrique de l'Est. Malheureusement, une grande dépendance sur cette forme d'énergie est une menace aux écosytèmes forestiers et facteur pour la dégradation accélérée des ressources de terre. Suite au manque accru des ressources traditionnelles en bois, les communautés rurales ont opté pour l'utilisation des résidues des cultures et la bouse, qui, sont autrement, des ressources pour l'amélioration de la fertilité du sol. L'objectif de cette étude était d'évaluer les tendances d'approvisionnement et consommation de l'énergie par la biomasse des cultures et estimer le la quantité d'élements minéraux pouvant être perdus à travers la biomasse brulée pour énergie. Une enquête était conduite dans le basin versant de Mukehantuta en Ethiopie, par utilisation d'un questionnaire semi-structuré. Un inventaire de biomass en bois était aussi fait sur les reserves existantes dans le basin versant. Annuellement, les ménages dans le basin versant ont utilisé 1999, 943, 11, 34 et 229 tonnes de bois, bouse, charbon, résidues des cultures, et résidues des bois, respectivement. La biomasse de bois existant dans le basin versant était approximativement 292 tonnes, indicant que la consummation excède l'approvisionnement potentiel. Comme résultats d'utilisation de la bouse et la biomasse des résidues de cultures comme source d'énergie dans les ménages, le basin versant perd des minéraux équivalent à 17.3, 4.3, 20.6, 15.6, 5.4, et 10.2 tonnes N, P, K, Ca, Mg et Fe chaque année. La perte d'élements minéraux en termes d'équivalent engrais est estimée à 37.5 tonnes d'urée et 9.3 tonnes de Di-ammonium phosphate (DAP).

Mots Clés: Bouse, residues des cultures, fertilité du sol

INTRODUCTION

Plant biomass fuel is a major source of energy supply in eastern Africa. In Ethiopia, it contributes over 95% of the country's total energy, of which woody biomass caters for 82% (EFAP, 1993). However, the heavy reliance on biomass energy has become a threat to forest ecosystems and a major cause of land resources degradation (Teketay, 2001). As fuel wood becomes scarce, rural households are left with no alternative source of energy, other than depending on locally available resources such as crop residues and cattle manure. About a decade ago, it was reported that crop residues and animal dung accounted for 8.4 and 9.4% of the fuel biomass sources in Ethiopia (EFAP, 1993).

The practice of using crop residues and cow dung for fuel has potential for consequently affecting soil nutrient stocks. The extent to which such widespread use of biomass as fuel energy sources has affected the level of nutrient stocks in the watersheds of Ethiopia remains uncertain.

The objective of this study was to assess the supply and consumption patterns of various sources of biomass energy and estimate the amount of nutrients that is lost from utilisation of non-woody biomass energy sources in Mukehantuta watershed in Ethiopia.

MATERIALS AND METHODS

Study site. This study was conducted in Mukehantuta watershed, which is administratively located in Were Jarso District, North Shewa zone of Oromiya National Regional State in Ethiopia. It lies at 9° 57' 33" - 10° 00' 07" N latitudes and 38° 16' 23" - 38° 19' 10" E longitudes. The altitude ranges from 2504 to 2573 m above sea level. The watershed comprises of about 1307 ha (HARC, 2010). The large portion of the watershed area is allocated for crop production (44%) followed by homestead (20%), woodlot (16) and pasture (14%). The forest resources in the area have declined over time. Currently, an increasing trend of trees especially eucalyptus species is observed (Selamu, 2013).

The survey. A household survey was conducted using a semi-structured questionnaire. Stratified and simple random sampling methods were used to select the respondents. The stratification of the households was made based on wealth status. The three wealth categories were rich, medium and poor. Farm size, livestock number and cash were used as wealth categorisation criteria (HARC, 2010). A total of 123 households, comprising of 18 rich, 45 medium and 60 poor households were selected in a proportional random sampling method per category from the nine villages taking male (101) and female(22) headed households.

Fuel biomass consumption was assessed after identifying the commonly used fuel types and their respective local units (e.g., firewood bundles, donkey-loads, dung basket and single dung-cakes). The biomass, in air dry basis, was measured using a weighing scale. The questionnaire also included household daily amount and type of fuel used for cooking a particular type of meal and the number of cooking days per week. The total annual biomass fuel consumption was calculated as:

Biomass consumption (meal^{-1}yr^{-1}) = Biomass (kg day^{-1}meal^{-1}) X Number of cooking (days yr^{-1}) .... (Equation 1)

The household energy utilisation was determined by multiplying biomass consumption by the respective specific energy contents of the different biomass resources in Mega joule given from secondary source.

The nutrient content of non-wood biomass fuel resources was estimated from secondary sources to estimate the annual nutrient losses by such burning. The amount of nutrient lost through utilisation of non-woody biomass as energy source was calculated as:

Nutrient lost (kg yr^{-1}) = non-wood biomass consumed (kg yr^{-1}) X nutrient concentration (g kg^{-1}) (%) .... (Equation 2)

An inventory of woody biomass from trees planted by the households was taken on 39 randomly selected households sub-sampled from 123 total sampled households to assess the existing wood biomass stock. The sampling procedure used to estimate the woody biomass resource was different for the different niches. For trees grown around homesteads, systematic sampling method was applied in which trees found at an interval of every five trees in a line were measured. The total number of trees grown in the homestead were counted per species. For the wood lot plantations, a squared sampling plot of 100 m^2 (10m *10m) was used. Total number of trees located in each sampling plot was counted and measurements were taken, whereas total count was applied and all the trees found in the farm land were measured for the case of scattered trees on farm lands.

Tree diameter at breast height (DBH) and height (H) of the sampled trees were measured using caliper and clinometers. The volume of the trees was estimated as:

Volume = $\pi/4$*DBH^2 * Height * form factor ……………….…............................….. (Equation 3)

The wood biomass stock of the households in dry weight bases was estimated by destructive sampling method. Trees representing diameter classes (0-5, 5-10, 10-15, 15-20, and 20-25 cm) from the different species were felled and their respective fresh biomass of the steam, branch and leaf was separately measured using a spring balance. The sub-samples of steam, branch and leaf were also taken and oven dried at 80 °C for 24 hours to determine the biomass on dry weight basis.

The annual crop residue biomass production of the watershed was estimated from the annual crop yield produced by the households. During the questionnaire interview, farmers were asked to give details on the land area cultivated and the respective yield obtained from the production in the study year. The annual crop residue biomass production was then calculated based on the dry matter conversion factor given by Kossila, 1984; FAO, 1987.

Crop residue (kg) = grain yield (kg) * conversion factor ……………………...………. (Equation 4)

Similarly, to estimate the annual dung biomass production, the data on livestock holding of the visited households in the watershed was collected by using the questionnaire. Then the annual animal dung production of the households was estimated based on approximate dung production of different animals per live weight given by ASAE (American Society of Agricultural Engineer (ASAE) as cited in Manure system Inc., 2012).

Manure production rate (kg day^{-1}) = total number of animal * production kg/day/animal ….. (Equation 5)

Household energy utilisation from the different biomass resources was statistically analysed (descriptive, correlation and analysis of variance) using the Statistical Package for Social Sciences (SPSS) version 17. A one-way ANOVA, using Scheffe Post-Hoc test, was conducted to compare the effect of wealth status on biomass fuel consumption. Tamhane's T2 Post-Hoc test was also used to compare the biomass fuel used for cooking different food and drinking stuff.

RESULTS AND DISCUSSION

Energy consumption patterns. The most important biomass fuel sources of the watershed were wood, cattle dung, tree residue (dead branches and litter fall) and crop residues. Wood biomass accounted for about 62.2 % of the biomass energy sources, followed by dung (29.3%), tree residues (7.1%), crop residue (1%) and charcoal (0.3%).

The estimated annual biomass fuel consumption in the watershed was 3216306.9 kg yr^{-1}, and average annual biomass fuel consumption per households was 7883 kg yr^{-1}. Similarly, the estimated total per *capita* consumption day^{-1} was 3.3 kg (Table 1). The per *capita* consumption of wood from our research was higher than the estimation (2.6 kg) provided by the Cooperation Agreement in the energy sector (CESEN, 1987), and the estimate (2 kg) used by joint UNDP and World Bank Energy demand assessment (World bank,1984). The possible reason for higher per *capita* consumption in the present study could be a shift from the fuel wood to non-woody biomass, such as crop residues and cattle dung. The calorific value for non-

TABLE 1. Fuel biomass consumption of the households in the watershed from different sources

Biomass energy sources	Total annual consumption (kg yr^{-1})	Mean annual consumption (kg yr^{-1} hh^{-1})	Consumption (kg capita^{-1}yr^{-1})	Consumption (kg capita^{-1} day^{-1})
Wood	1999161	4899.90	753.83	2.07
Dung	943129	2311.59	355.63	0.97
Charcoal	10594	25.96	3.99	0.01
Crop residue	34305	84.08	12.94	0.04
Tree residue	229118	561.56	86.39	0.24
Total	3216307	7883.09	1212.78	3.33

woody biomass is low (Rosillo-Calle *et al.*, 2007; Guta, 2012); hence, more biomass is burnt to acquire the desired amount of energy.

Wealth status had no significant effect on wood (f= 1.359, P=0.261), cattle dung (f=0.397, P=0.673), and tree residue (f=0.173, P=0.841) consumptions; though the annual income among the different wealth categories was significantly different (f= 5.53, P=0.005) (Table 2). The finding in our study showed that the consumption rate of biomass energy sources did not differ among farmers with varying resource endowments. Bewket (2003) reported similar research findings on a study of the relationship between some socio-economic factors and bio-fuel consumption of households' at Chemoga watershed, north western Ethiopia. On the contrary, Pandey (2002) stated that biomass fuel consumption rate is strongly influenced by income level. This indicate that under scarce condition and in the state of absence of alternative energy resource, the consumption rate of biomass energy resources does not differ between households of varying economic level. However, the crop residue biomass was only used by the poor households and charcoal was solely utilised by the rich households (Table 2). This implies that wealthier households prefer to use relatively clean and safer biomass fuel resource, while poor households rely more on unsafe biomass resources.

Similarly, the annual energy consumption of the households was compared between the rich medium and poor households. The analysis showed that there were no significant difference in energy consumption between the wealth categories (f = 1.633, P = 0.200) (Table 3). These results indicated that wealthier farmers are equally affected by scarcity of energy resources with poor households, though the rich households could relatively afford to invest for better access as there are no alternative sources of energy. Bewket (2003) reported similar findings from a study on the relationship between some socio-economic factors and bio-fuel consumption of households' at Chemoga watershed in northwestern Ethiopia. Data for the relationship between the fuel biomass consumption and household variables are presented in Table 4. There was a strong positive correlation between cattle dung utilisation and family size (r = 0.23), and the number of livestock owned by the household (r = 0.21). The association implies that households that keep more livestock utilise more dung-cake. This was because the dung is easily accessible than the fuel wood resource. That has a negative implication on the use of the dung resource for improving soil fertility. On the contrary, wood biomass utilisation had no correlation with family size; though there was a positive tendency. This is due to more utilisation of dung-cake as a result of increased family size. As family size increases, the likelihood of collecting dung from the grazing field also increased owing to increased labour availability and demand for fuel.

Wood biomass utilisation did not correlate with number of trees owned by the households. In this case, farmers preferred to maintain the available trees for construction purposes rather than for energy sources. They also retained the trees for utilisation during special occasions such as funerals and weddings.

TABLE 2. Mean biomass fuel consumption (kg yr^{-1}) by different wealth categories

Wealth categories	Number	Annual income (Birr*)	Biomass energy sources				
			Wood	Dung	Charcoal	Crop residue	Tree residue
Rich	18	12166^a±8108	6059^a±4693	2578^a±1975	177±522	-	530.3^a±541
Medium	45	10011^a±7463	4858^a±3705	2327^a±1419	-	-	534.1^a±583
Poor	60	6155^b±7968	4584^a±2462	2220^a±1403	-	172±709	591.5^a±529

Means within a column followed by the same letter(s) are not significantly different at 0.05 levels. * 21.58Birr H" 1EURO, July 2012

Cattle dung consumption for fuel significantly correlated with wood consumption (Table 4). This was partly due to the fact that farmers used cattle dung in combination with wood to avoid the smoke from burning dung. Use of crop residue showed a negative correlation with use of other sources of energy (Table 4), implying that the utilisation of crop residue was lower as far as the other energy sources were relatively accessible. Furthermore, crop residue consumption showed a negative correlation (r = -0.12) with land size. This was so because farmers allocated most of the land to production of crops such as teff and wheat, from which their residues could not be used for fuel purposes. Similarly, the number of trees did not show strong correlation with land size, simply because tree planting practices were mainly around the homesteads, as homesteads occupied less proportion of land size than the land allocated to crop production and pasture.

The household income had shown a strong correlation with utilisation of wood (r = 0.19), dung (r = 0.29) and charcoal (r = 0.48) biomass energy sources (Table 4). This showed that the higher the income of the household the more wood, dung and charcoal were used. The result implies that the households with higher income also utilise large amount of dung biomass for energy source that would otherwise, be used for soil nutrient amelioration. But the household income showed negative correlation with the utilisation of crop residues(r= -0.07) and tree residues(r = -0.06). This indicated that the rate of utilisation of the residues for energy source decreases as the income of the households increases. Hence the probability of residue retention on the farm field for nutrient recycling would relatively be higher for higher income households. The retention of residues on the agricultural soil could have a positive effect in enhancing and protecting the soil quality through reduction of erosive forces, maintenance of soil organic matter, addition of available nutrients, increasing of biological activity and improved soil structure and hence improve crop yield (Andrew, 2006; Blanco-Canqui and Lal, 2009).

Fuel consumption by food type. The amount of fuel biomass consumption differed with distinctive energy resource bases for different food and drinking stuff. There was a significant difference in fuel biomass consumption of wood (f = 28.5 P = 0.001), dung (f = 52 P=0.001), crop residue (f = 3.6, P = 0.001) and tree residue (f = 84.3, P=0.001) for the different food and drink types (Table 5). The majority of the households in the study watershed eat Enjera (national dish in Ethiopia). Enjera baking took the largest proportion of the biomass fuel consumption followed by Wat (stew), Coffee and Kolo (roasted cereals). Cooking Enjera also took significantly higher dung biomass than the rest of the meal types. On the other hand, there was no significant difference in wood consumption for preparation of Enjera, Coffee and Wat. This was because Enjera is prepared at an interval of two to three

TABLE 3. Mean energy consumption of households (MJ) by different wealth categories

Wealth categories of hh	N	Mean	Std. Deviation
Rich	18	142861.6[a]	91404.5
Medium	45	115692.1[a]	66062.8
Poor	60	113434.6[a]	46571.1

Means within a column followed by the same letter(s) are not significantly different at 0.05 levels

TABLE 4. Inter-correlation of annual fuel consumption (kg) and household variables

	1	2	3	4	5	6	7	8	9	10
Wood	1									
Dung	0.41	1								
Charcoal	0.11	0.07	1							
Crop residue	-0.03	-0.11	-0.02	1						
Trees residue	-0.27	-0.11	-0.11	-0.02	1					
Family size	0.07	0.23	0.07	-0.11	0.03	1				
Annual income	0.19	0.29	0.48	-0.07	-0.06	0.27	1			
Number of cattle	0.29	0.21	0.09	-0.10	-0.04	0.35	0.30	1		
Number of trees	0.02	0.02	-0.04	-0.08	0.02	0.08	0.04	0.17	1	
Land size (ha)	0.25	0.17	0.10	-0.12	-0.11	0.38	0.31	0.38	0.07	1

N = 123; and correlation greater than ±0.17 are statistically significant ($P < 0.05$)

TABLE 5. Biomass sources consumption (kg yr^{-1}) by different food and drinks

Food and drinks	Wood	Dung	Charcoal	Crop residue	Tree residue
Enjera	1023.4[a] ± 805.3	924.9[a] ± 931.4	-	64.5[a]±359.3	431.9a ± 421.4
Dabo	73.0[ci] ± 199.3	156.1[b] ± 210.4	-	0.2[b]±2.8	6.2b ± 43.0
Wat	886.7[abd] ± 774.7	251.0[b] ± 279.7	11.1[a]±123.4	-	5.6b ± 44.3
Kolo	557.8[ef] ± 556.3	170.3[b] ± 194.4	-	4.5[b]±49.4	58.0b ± 184.0
Nifro	409.3[f] ± 613.2	208.5[b] ± 280.2	-	6.7[b]±74.0	10.9b ± 71.9
Kita	318.0[fg] ± 479.7	139.4[b] ± 241.5	-	-	18.9b ± 94.3
Coffee	889.8[abh] ± 925.6	224.3[b] ± 449.0	14.8[a]±129.8	-	11.2b ± 61.7
Tela	529.0[defh] ± 1040.3	158.2[b] ± 309.7	-	1.5[b]±16.5	26.8b ± 147.5
Areke	121.6[cgi] ± 636.8	9.6[c] ± 72.9	-	-	-

Means within a column followed by the same letter(s) are not significantly different at 0.05 levels days and Wat and Coffee are prepared two to three times in a day. Farmers preferred preparing coffee and Wat using fuel wood more than dung-cake as they perceive the smoke from burning dung changes the test of coffee and Wat.

Fuel biomass sources and supply

Woody biomass resources. In the past, farmers used to collect wood for construction and fuel wood from the forest located far away from the watershed. Farmers started growing more trees around the homesteads because of forest degradation and less access to the forest resources. Hence, the fuel wood requirement of the households partially met from trees grown around the homesteads. Among the sampled households, 81 % used their own sources of trees from lopping, prunings, and tree residues and supplemented the requirement from other fuel sources. About 14 % of the household used to buy wood from the village standing trees whereas 3 % of the sample households collected wood from the bush lands found far away from the village. The rest, 2 %, of the sampled household used to access fuel wood through contractual arrangement. The contract is an agreement between two farmers in which one party serve in felling and splitting the wood (contributes labor), and the other party is the owner of the trees, and then finally shares the chopped fuel wood equally.

The most important trees grown in the watershed for fuel sources are *Eucalyptus globulus, Eucalyptus camaldulensis, Acacia decurrens, Acacia abyssinia, Faidherbia albida, Sesbania sesban, Rhus glutinosa and Acacia saligna.* Among these woody tree species, 62.5 % are exotic species. The wood biomass inventory data collected from the sub sampled farm households (39) showed that *Eucalyptus globulus* is the dominant tree species planted in the homestead (Table 6). From the sampled households, only 14 % used charcoal as fuel source out of which, 76.5 % bought charcoal from market, and 17.6 % collected charcoal left over from stove, after cooking with wood, and 5.8 % produced charcoal by themselves.

None wood biomass resources

Cattle dung. Cattle dung took the second largest share of the household energy source. The average number of cattle owned by the sampled households was 5.3 and 72.9 % of the dung used for fuel was collected from the livestock shed. The households prepared the dung-cake in an open field for sun drying. Each household, on average, produced 2293.6 kg of dung-cake year^{-1}. During rainy season (June - September), it was difficult to prepare the dung-cake. During this time, farmers dug a dome shaped pit with an average dimension of 1.7±0.65 m width and 1.8±0.78 m depth that could store 5.1 m^3 of dung from which, they could take the dung for preparation of the cake in off season. The dimension of the pit varied depending on the livestock size. The statistical analysis on the relationship between the number of livestock owned by the household and the size of the dung

TABLE 6. Tree biomass resource inventory of the studied household

Tree Species	Number of trees	Volume (m^3)	Biomass (kg)
Eucalyptus globulus	7542	572.1	266022.1
Eucalyptus camaldulensis	25	1.7	1248.7
Acacia decurrens	216	3.9	6908.0
Acacia abyssinica	83	1.2	2491.2
Sesbania sesban	20	0.2	300.0
Acacia saligna	67	2.3	423.4
Rhus glutinosa	72	1.9	1744.8
Faidherbia albida	20	0.1	280.7
Total	8045	590.4	279418.9

pit showed a positive correlation with r = 0.192, n = 123, P = 0.033. Some households also prepared the cake during the rainy season by plastering the fresh cow dung on the wall of their houses. Furthermore, women and children walk out to grazing field to collect both fresh and dry cattle droppings. The sampled households collected about 26.2 % of the consumed dung from grazing fields. Boys and girls who look after the cattle, collected fresh dung to prepare the cake on the grazing field and transport it back to their homes for cooking. Similarly, during the rainy season it was a common practice to dig small pits in the grazing fields for storing cattle dung. The annual dung biomass production by the households in the watershed is shown in Table 7.

Crop residue. Tef, wheat, chickpea, grass pea, faba bean, barley, niger seed (noug), oat, lentil, fenugreek and maize were main crops grown in the watershed (HARC, 2010). The crop residues, in the watershed were utilised for livestock feed, soil fertility improvement, sources of energy, roof cover and to generate income from sale. The portion of the harvested above ground biomass of crops that remains on the field are used for fuel source. The annual crop residue production by the watershed households is shown in Table 8. Among the crops grown in the watershed, maize stover and niger seed straws mainly used for energy source especially during the dry season. The study revealed that sampled households used to grow maize around their homesteads which made them utilise most of the stovers for energy source they were close to residences.

Supply and consumption pattern. The total biomass fuel consumption of the households was calculated by converting all the biomass resource bases to similar units based on their respective calorific values (Table 9). As indicated in (Table 6) the wood biomass inventory showed that the total wood biomass stock from the sub-sampled households (39) was 279418.9 kg that corresponds to 2923151 kg for the watershed. With the assumption that all the available wood biomass stock was to be utilised for fuel purpose and replacing the burned non wood biomasses with wood, the current supply and consumption patterns showed a deficit of -197837 kg of wood biomass (Table 9). Therefore, in order to fulfill the fuel wood demand of the households and to replace the dung and crop residue utilisation with fuel wood, every household is supposed to plant 700 trees year^{-1} for four consecutive years. In this respect, each household would have 2832 trees within four years in order to insure sustainable supply of fuel wood.

Perception of biomass energy. The major energy related problems facing the households were fuel

TABLE 7. Annual dung biomass production estimate for all households in the watershed

Type of livestock	Total number	*Fresh dung kg/ day/animal	*water %	dry mater kg/ day/animal	Total dry manure kg/yr/ws	Dry manure production kg/yr/hh
Oxen	879.0	13.5	87.3	1.7	545419.5	1336.8
Cow	524.1	10.4	87.3	1.3	248685.5	609.5
Heifer	291.9	7.2	87.3	0.9	95889.2	235.0
Bull	252.1	6.8	87.3	0.9	82814.9	203.1
Horse	29.9	7.2	79.5	1.5	16370.3	40.1
Donkey	401.4	5.2	79.5	1.1	161162.1	395.0
Sheep	1862.5	1.1	75.0	0.3	203943.8	499.9
Poultry	2315.3	0.1	74.8	0.02	16901.7	41.1
Total Source					1371186.7	3360

*Dung production per livestock and moisture content (Manure System Inc., 2012): American Society of Agricultural Engineers, data adapted from Committee S&E-412 report AW-D-1. Revised 6-14-73

TABLE 8. Annual crop residue biomass production estimate

Type of crop	Crop production (kg)			Residue production (kg)		
	Watershed	*District	**Conversion factor (CF)	Watershed	District	Average per hh
Teff	332470	12477973	1.5	498705	18716960	1222
Wheat	128620	2399023	1.5	192929	3598535	473
chickpea	96892	694474	1.2	116270	833369	285
Grass pea	136698	1151449	1.2	164036	1381739	402
Faba bean	6137	378804	1.2	7364	454565	18
Barley	17249		1.5	25873		63
Niger seed	5805	246591	4	23220	986364	57
Lentil	1526		1.2	1831		4
Maize	16353	2028386	2	32706	4056772	80
Aja/Oat	4544	152558	1.2	5454	183070	13
Total				1068388	30211372	2619

Sources: *District yield: CSA 2006 **CF: Conversion factors used for estimation of the amount of CRs from or fibrous by-products produced from different crops (Kossila, 1984; FAO, 1987)

TABLE 9. Supply and consumption pattern of biomass energy resources in the watershed

Biomass sources	Consumption kg $year^{-1}$	Efficiency MJ kg^{-1}	Conversion factor	Wood Equiv. (kg)
Wood	1999160	15.5	1	1999160
Dung	943130.1	13.8	0.89	839690.1
Charcoal	10594.73	29	1.87	19822.4
Crop residue	34305.17	15	0.97	33198.55
Tree Residue	229116.9	15.5	1.00	229116.9
Total annual consumption				3120988
Total existing biomass stock				2923151
Supply and consumption balance				-197837

Efficiency source: Guta, 2012

wood shortage, increased price of kerosene, limited supply of improved stoves and limited supplies of alternative energy sources such as Electricity and solar energy (Table 10). Respondents noted that use of non-woody biomass energy sources had increased gradually as a result of degradation of forest resources; inadequate access to improved technologies and limited income. The accessibility of the resource also determines the allocation of the biomass resource for the different household uses. About 42% of the households identified cattle dung as an easily accessible fuel source as compared to other biomass energy sources. Similarly, 36.6% perceived both cattle dung and wood as equally accessible; while 13.8% mentioned that wood is easily accessible and 5.7% indicated that wood, dung and tree residue are equally accessible. The ease accessibility of the dung resource is a fundamental reason for the allocation of dung biomass for energy purpose. This will reduce the practice of applying dung to the agricultural field. About 35% of the respondents had the view that dung must be used for fuel source, while 58.5% of the studied households believed that dung should be utilised for fertiliser purpose,. Those who preferred to use dung for fertility improvement reasoned out that dung has a potential to increase crop yield through improving soil fertility. However, the use of organic fertilisers was generally low due to their competing uses (Fig. 1). Up to 63% of the manure collected from the livestock shed was used as source of energy and 36% for soil fertility management. Even those who preferred to use dung for fuel purpose were coerced by absence of alternative energy sources coupled with increasing shortage of fuel wood to use the dung as a fuel source. Moreover, dung is an easily accessible fuel resource compared with other sources. Respondents (40%) also revealed that the available wood resources were reserved for household infrastructure construction and for special occasions like weddings and funerals.

The competing use of the biomass resources for energy purpose and other household uses is highly affecting the lives of the rural communities that influence the agricultural production and the environment. This calls for the formulation of a sound energy policy that should ensure the sustainable supply of household energy and utilisation without compromising the resource base. The energy policy shall facilitate the gradual transition from traditional fuel to modern energy sources by utilising the hydro, solar, wind and geothermal energy resource potential.

Non-wood biomass burning *versus* nutrient loss. Non-wood biomass burning by the households increased in the region. This led to nutrient losses (Table 11) through crop residue export from the mother fields. The uses of dung biomass for source of energy forced the farmers to abandon the practice of application of manure for soil nutrient amelioration. Sustainable soil productivity dictates that nutrient removal from the fields through harvesting should be reverse paralleled nutrient replenishment through

TABLE 10. Major energy related problems mentioned by the sampled households

Major problems	Male		Female		Total	
	n	%	n	%	N	%
Shortage of fuel wood	66	65	15	68	81	66
Increasing price of Kerosine	62	61	12	55	74	60
Low supply of improved stove	66	65	16	73	82	67
No other alternative source of energy	49	49	9	41	58	47

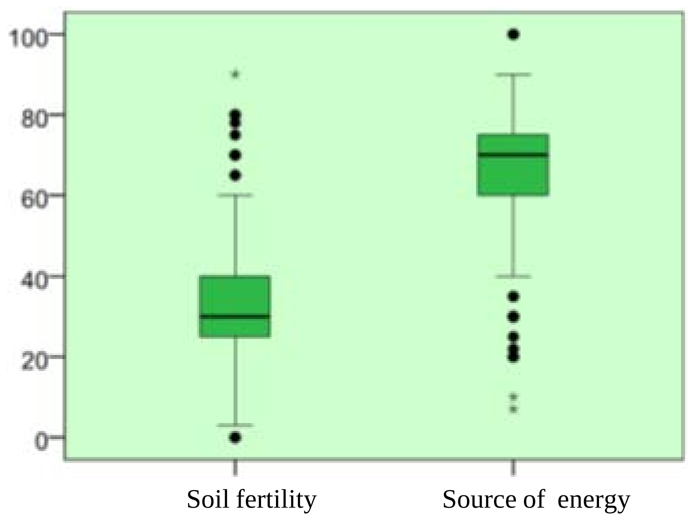

Figure 1. Competing use of cow dung for soil fertility management and energy source in Mukehantuta watershed Ethiopia.

TABLE 11. Estimated nutrient losses from burning dung and crop residue

Source	Nutrients (kg tonne^{-1} year $^{-1}$ on dry biomass bases)								
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Dung	18.3	4.5	21.3	16.4	5.6	10.78	0.78	0.02	0.09
Maize stover	-	1.18	12.4	2.29	1.73	0.28	0.06	0.01	0.02
Noug straw	6.6	3.6	28	-	-	-	-	-	-

Sources: Nutrient composition of maize stover (Kabaija and Little, 1988); Nutrient composition of dung (Lupwayi *et al.*, 2000); and nutrient composition of Noug straw (NewCROP, 2012)

externally sourced inputs such as manure or mineral fertilisers. However, high fertiliser prices and inadequate appreciation of the value of fertilisers prohibit active application of sufficient quantities of fertilisers. Thus, inadequate utilisation of nutrients is one of the challenging factors smallholder subsistence farmers face, culminating in persistent food insecurity and poverty in the region (Quinones *et al.*, 1998; Shapiro and Sanders, 1998).

As a result of using dung and crop residue for household energy, the watershed loses 17 tonnes of N, 4.3 tonnes of P, 20.6 tonnes of K, 15.6 tonnes of Ca, 5.4 tonnes of Mg, and 10.2 tonnes of Fe nutrients year-1. The burned dung and crop residue biomass could potentially supply N and P fertilisers equivalent to 37.5 tonnes of urea and 9.3 of DAP, respectively. These amounts of fertilisers could cater for 469.2 and 71.8 ha of land, respectively. Thus, scarcity of fuel wood resource has a large implication on agricultural productivity and food security.

CONCLUSION

The demand and supply patterns of biomass fuel in Mukehantuta watershed, Central highland Ethiopia reveal a negative biomass balance with a direct shift from use of the traditional wood biomass fuel to the non-wood dung and crop residue biomass. These have serious implications on heavy nutrient export through the residue and abandon the practice of application of manure for improving soil fertility that result in exacerbated food insecurity and poverty of communities in the region. Policy makers need to focus investment in strengthening institutional arrangement in the energy sector, development of alternative energy resources, build the capacity of rural communities and facilitate credit schemes to utilise biomass resource with the efficient technologies and increase prevalence of multipurpose trees in order to avert biomass resources degradation and subsequent escalation of food insecurity and poverty in the region.

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