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ESTIMATION OF HOUSEHOLD ENERGY CONSUMPTION INTENSITIES AROUND AND WITHIN MIOMBO WOODLANDS IN MOROGORO AND SONGEA DISTRICTS, TANZANIA

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ABSTRACT

The aim of the study was to estimate households' fuel consumption intensities. Stratified random sampling design was used to select a total of 568 respondent households. Data was collected using pre-tested and pilot-tested questionnaires, direct measurements, direct observations, interviews and focus group discussions. A statistical package for social sciences (SPSS) and Microsoft excel computer programmes were used to analyse data. Results showed that 79.8% - 83.2% of households use firewood as energy source at a rate of 6.734 – 6.746 kg household^{-1} day^{-1}, and they use *charcoal* as energy source at a rate of 3.336 – 3.344 kg household^{-1} day^{-1}. It is concluded that the household wood fuel consumption is of a sizeable intensity and has the highest contributory effect on total household energy consumption. There was a notable difference in the inter-strata wood fuel consumption. It is recommended that strata (location)-specific strategies would be appropriate in addressing wood fuels issues in the study area: "one-size-fits-all" approach in addressing wood fuel issues in the study area, whenever feasible, should be discouraged.

KEY WORDS: Household, energy, consumption, intensities

INTRODUCTION

Background information

Understanding human decision making about resource use and in-depth understanding of the impacts of drivers such as demographic, governance and economic factors, and climate variation and land-use policy on resource use are central to sustainable natural resource management (Holmes 2005, Odada *et al.* 2009). Factors which affect patterns and levels of household energy consumption include age of the household head (Erlandsen and Nymoen 2008, Lenzen 2006), income, fuel price, price of related appliances, opportunity cost for firewood collection (UNDP/World Bank 2003, Adelekan and Jerome 2006, Lenzen 2006), level of urbanisation, availability of fuel and related appliances, cultural preferences (Adelekan and Jerome 2006), household size (Hartmann and Sherbinin 2001, Lenzen 2006), house type, tenure type, employment status, geographical location, number of children, and car ownership (Lenzen 2006). Fuchs and Lorek (2000) classified the determinants of direct energy consumption by households into six categories: *economic factors* (disposable income, consumer prices, spending pattern, availability of credit), *socio-demographic* factors (household size and structure, age, behavioural factors, lifestyle, attitudes), *living situation* (per-capita floor space, dwelling type, house age, standard of insulation), *technology* (energy efficiency of household appliance), *supplier* (efficiency, energy content of energy carrier) and *climatic factors*.

Piet and Boonekamp (2007) posited that, choices made by households are not only affected by income and energy prices, but also by others factors such as composition of households, owned versus rented dwellings, and energy use standards for new dwellings or appliances. Jiang (2007) asserted that the main drivers of energy use and carbon emissions are demography (population size; composition – age and gender; distribution – spatial, rural/urban), economic growth, technology, policy and lifestyle. Abrahamse (2007) categorised salient determinants of energy consumption into two groups: *societal factors* (technological developments, economical growth, demographic factors, institutional factors and cultural factors) and *individual-level factors* (awareness, beliefs, values, attitudes and knowledge). The household sector consumes the greatest proportion of total energy across the globe. It accounts for 25-30% of total energy in developed countries, 30-95% of total energy in developing countries, and 50-95% of total energy in Sub-Saharan Africa (Byer 1987, Dzioubinski and Chipman 1999, Leach and Gowman 1987). In Tanzania, the household sector accounts for 80-91% of total energy consumption in the country (URT 2003, Sawe 2005, Kaale 2005, Iddi and Hakan 1997, Simon and Kaale 2005). Statistics further reveal that in sub-Saharan Africa (SSA) household cooking alone takes up to 60-80 per-cent of the total national energy use (Andrea and Goldemberg 1996). In SADC region, households consume 97 per-cent of wood energy for cooking, heating and cottage industries (SADC Energy Sector 1993) in Monela and Kihiyo (1999).

Miombo woodlands as source of woodfuel

The Miombo woodlands which constitute more than 90% of total forest area in Tanzania are chief sources of firewood (fuel wood) and charcoal. The hardwoods from natural forests produce a heavier and more concentrated fuel than most fast growing softwood species (Gauslaa 1998, Malimbwi *et al.* 2001, Zahabu 2001, Lusambo 2002). An extensive body of literature (Mansilla *et al.* 1991, Lusambo 2002, Kofman 2012, Demirbas 2001, 2003) underlines that people prefer using natural forests (hardwood) to plantation forests (which are mainly softwood), as wood fuel for several reasons. Lusambo (2002) found that some people prefer natural forests because they collect it free of charge, while others assert that, unlike softwood, hardwood is denser and thus burns for a longer period. Demirbas (2003) puts forward that the salient factors that affect the suitability of wood for fuel include moisture content (the higher the moisture content, the lower the energy value), extractives (the more the extractives, the higher the energy value) and ash content (the energy value increases inversely with ash content). The author (ibid) underlines that in light of the above-mentioned factors, hardwood is preferred as source of fuel to softwood. Nonetheless, he cautions that if one singles out extractive content, then softwood performs better than hardwood. Demirbas (2001) explains that the net energy available from biomass when it is converted ranges from about 8 MJ kg^{-1} for green wood, to 20 MJ kg^{-1} for air dried, implicitly supporting the concept that energy value of wood increases as moisture content decreases.

According to Kofman (2012), firewood from hardwood has a higher heating value per m^3 due to higher density. He further points out that the amount of dry matter per m^3 varies with plant species and ranges between 340-590 kg dry matter/m^3 solid (for hardwood species) and 350-480 kg dry matter/m^3 solid (for softwood species). The findings further revealed that hardwoods generally have natural moisture content of between 40 and 50%, while softwoods have moisture content of between 50 and 60%. The author comments that on a dry-weight-for-weight basis, both hardwood and softwood are good fuel sources. It is arguably asserted that hardwoods are preferred as sources of fuel, because they have high net energy value attributable to lower moisture content and higher density. The net energy value for hardwood ranges from 10.8 to 12.7 MJ kg^{-1}

while that of soft wood is from 5.7 to 10.4 MJ kg^{-1}. During their study, Mansilla *et al.* (1991) found that if assessed on a volume basis (which is the mostly used criterion by households Lusambo 2002), hardwood is a better source of fuel wood than softwood.

Problem statement and justification of the study

In Tanzania, no detailed study has been conducted to establish intensities of household energy consumption. This is underpinned by a number of studies: Sawe (2005) asserted that there is inadequate data on Tanzanian rural energy consumption; It is also reported that little is known about economics of household energy consumption in developing countries (EASE 2001, Christoph and Adrian 2000); and OECD (2002) reported that in most of the developing countries the drivers behind household energy consumption patterns are poorly understood. Understanding household energy consumption intensities is paramount in assessing energy efficiency development (Christoph and Adrian 2000, Hi-chun and Heo 2000, Alan 2004, Ramirez *et al.* 2006). The perceived government apathy in addressing household energy issues may be attributed to quality and amount of available data on household energy consumption, because poor quality and unavailability of baseline data on energy consumption seriously impedes energy planning and policy-related work (Thomas 2005, URT 2001, 2003) and environmental protection (Fox 1984). UN (2007) insisted that in order to accomplish the MDGs, reliable and timely relevant information is pre-requisite. The objectives of this study were therefore to: estimate the intensities of household energy consumption and analyse the variation of households' woodfuel consumption along the rural-periurban-urban continuum in miombo woodlands of eastern and southern Tanzania, using Morogoro and Songea regions as study areas. In the context of this study, the term *intensities of household energy consumption* denote "amount of energy consumed in homes to meet the needs of the household members for cooking, lighting, heating, power and processing agricultural crops".

It is envisaged that the findings of this study will contribute to efforts towards development of efficient and modern energy services and consequently curb environmental problems and foster improved livelihoods of the poor households. Policy and decision makers will make use of the findings from this study to devise short-term, medium-term and long-term strategies for sustainable natural resource management. The public will also be made more aware of the situation on the ground and thus facilitate positive changes in their energy-related behaviour and way of thinking and attitudes; and for prudent environmental management.

Conceptual Framework

Figure 1 presents a conceptual framework showing the salient factors affecting household energy consumption with consequent environmental impacts. According to Linda (1999), the conceptual framework acts as a basis for discussing the relationships between different groups, individuals or issues and can always be progressively revisited as further information becomes available. The understanding of household energy consumption in developing countries is mainly built on the concept of fuel substitution, commonly known as the energy ladder hypothesis (Leach 1992, Hosier and Kipondya 1993, Chaudhuri and Pfaff 2003, David 1998, Hosier and Dowd 1987, Campbell *et al.* 2003, Alam *et al.* 1998). The hypothesis postulates that as household socio-economic status rises, the household in question abandons lower-level energy source(s) and switches to modern ones. Another hypothesis that tries to describe the household energy consumption is the "inverted-U hypothesis" (Foster *et al.* 2000). This hypothesis postulates that household energy consumption varies proportionally with per capita income up to a certain level after which it starts decreasing, thereby making an inverted-U shape graph. Energy consumption is also explained by a popularly used poverty–environment hypothesis which claims that poor people rely heavily on biomass fuels and thus causing forest degradation and deforestation; and that addressing poverty issues is the key for sustainable forest resources management (Baland *et al.* 2007).

When modelling household energy consumption, distinction should be made between direct energy use and indirect energy use. Direct energy use refers to the

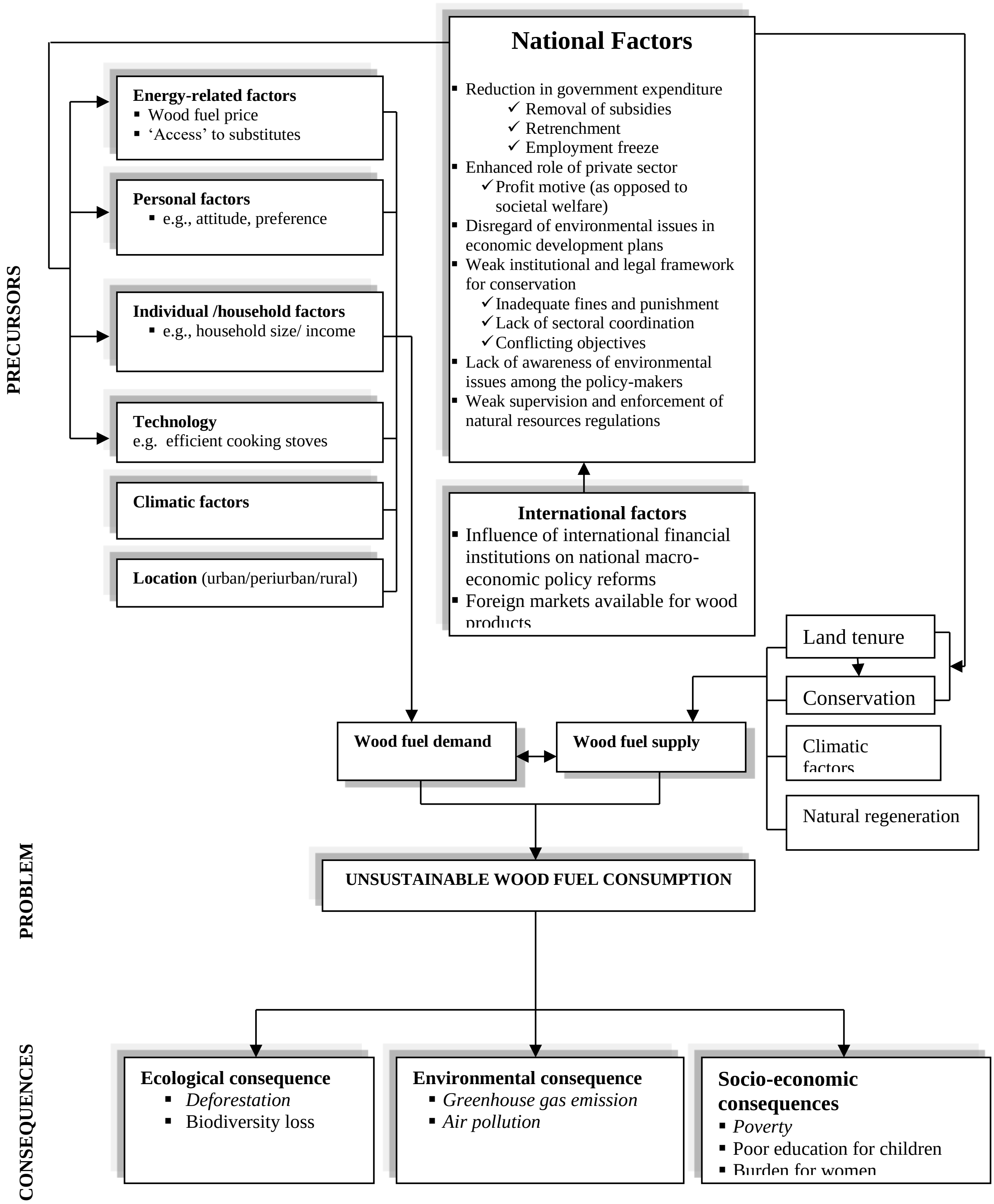

Figure 1: Conceptual framework for wood fuel consumption in Tanzania
Source: Adapted from Kulindwa *et al.* (2000, p.332); Arntzen and Kgathi (n.d,); Kalipeni (1994, p. 21)

consumption of energy carriers purchased by the household itself (fuels and equipment) in order to cater for energy services. Indirect energy use refers to the energy used during various stages of production (and distribution) of commodities, also referred to as `embodied energy' or 'grey energy' (Christoph and Adrian 1998, Hi-chun and Heo2000). The present study strives to address households' direct energy use. Various studies have pointed out factors affecting household energy consumption (Leach and Gowman 1987, Kaale2005, TaTEDO 2005, CIFOR 1997, Christoph and Adrian 1998, Hi-chun and Heo 2000): current disposable income, household size, household type, fuel accessibility, fuel affordability, fuel reliability, fuel flexibility, low-pollution, climatic conditions, effective household size, dwelling type and ownership, household power relation; tradition and customs, stock of liquid assets (wealth); future income expectation, urban-rural location differences, and level of consumer indebtedness. The specific objectives of the study were to: analyse household fuel consumption intensities; determine total household energy consumption; analyse contribution of each fuel to total household energy; and analyse household *woodfuel* consumption intensities.

METHODOLOGY

Study sites

This study involved households around and within the eastern and southern miombo woodlands in Tanzania: *Morogoro* and *Songea* districts in *Morogoro* and *Ruvuma* regions respectively. Selection of Morogoro and Ruvuma as study regions was guided by Carissa *et al.* (2005) who carried out a deskwork study (based on an extensive literature review) to identify the regions within the country where critical ecosystem services for human well-being are stressed, signalling the need for immediate attention. The ecosystems functions covered were biodiversity, energy resources, water, and food and fibre production. Carissa *et al.* (2005) argued that Morogoro is a priority region for ecosystems-related researches, because it is stressed in all the four ecosystem services. The authors (ibid) also established that Ruvuma Region has serious data gaps in all the above-mentioned ecosystem services. The present study therefore, based on the above-mentioned information, considered these two regions as research-priority areas.

Research design and Sampling procedure

The design of the present study was a *descriptive* and *cross-sectional survey*. It is a descriptive study because it sets out to rigorously describe household energy consumption intensities It is a one-time cross-sectional study; it cannot therefore gauge the temporal variations or trends in the data collected.

The sample design for the present study entailed nine steps: defining target population, defining sample frame, determining primary sampling units, defining secondary sampling units, defining reporting domain, defining explicit strata, defining measure of size, defining ultimate sampling units, and allocation of sample. The overall objective was to have a study sample which is *sufficient* and *representative* of the target population. The target populations for this study were communities in Morogoro and Songea districts. The sampling frame was in three types depending on the sampling phase. During sampling of villages in rural areas and wards in peri-urban and urban areas, the sampling frame was the list of villages and list of wards in the municipalities respectively. During sampling of hamlets in rural areas and streets in peri-urban and urban areas, the sampling frame was the list of all hamlets in the selected villages and list of all streets in the selected wards respectively. When sampling households for the study, the sampling frames that were used are the updated lists of households registers in the sampled hamlets and streets. All chairpersons and executive officers in the selected study sites were asked to update lists of households in their respective areas by excluding households which no longer existed and/or adding those ones which were missing in their lists. *Stratified random sampling* design was used in the present study. Stratification was carried to sub-divide the study sites in the study districts into *rural*, *peri-urban* and *urban* areas.

In designing a household survey, stratification of the population to be surveyed prior to sample selection is a commonly used technique. It serves to classify the population into subpopulations – strata – on the basis of auxiliary information that is known about the full population. Sample elements are then selected, independently, from each stratum in a manner consistent with the measurement objectives of the survey (Turner 2003). Thus, one reason for stratification is to reduce the chance of being unlucky and having a disproportionately large (or small) number of the sample units selected from a sub-population that is considered significant for the analysis. Stratification is done to ensure proper representation of important sub-population groups without biasing the selection operation. It is important to note, however, that proper representation does not imply proportionate sampling. In many applications one or more of the strata may also be estimation domains (discussed above), in which case it might be necessary to select equal-sized samples in the affected strata, thus producing a disproportionate sample by stratum. Hence, both proportionate and disproportionate allocation of the sample units among the strata are legitimate design features of a stratified sample, and the choice depends on the measurement objectives of the survey (Turner 2003). For household surveys that are large-scale and multipurpose in content a particularly useful method is so-called implicit stratification. Its essential criterion is geographic, which generally suffices to spread the sample properly among the important sub-groups of the population, such as urban-rural, administrative regions, ethnic subpopulations, socio-economic groups, etc (Turner 2003).

According to Ross (2005), the technique of stratification is often employed in the preparation of sample designs because it generally provides increased accuracy in sample estimates without leading to substantial increases in costs. Stratification does not imply any departure from probability sampling – it simply requires that the population be divided into subpopulations called strata and that probability sampling be conducted independently within each stratum. The sample estimates of population parameters are then obtained by combining information from each stratum. In some studies, stratification is used for reasons other than obtaining gains in sampling accuracy. For example, strata may be formed in order to employ different sample designs within strata, or because the subpopulations defined by the strata are designated as separate 'domains of study'. Variables used to stratify populations in education generally describe demographic aspects concerning schools (for example, location, size, and program) and students (for example, age, sex, grade level, and socio-economic status). Stratified sampling may result in either *proportionate* or *disproportionate* sample designs. In a proportionate stratified sample design the number of observations in the total sample is allocated among the strata of the population in proportion to the relative number of elements in each stratum of the population.

In social, business, economic and political studies stratified random sampling technique is more widely used than simple random sampling technique. The reason is that stratified sampling increases precision, ensures adequate representation and creates administrative convenience (Zewotir n.d). Since the stratified sample is selected randomly, albeit in different fashion from simple random sample, the methods of population characteristics estimation are also different (Chaudhuri 1992, Tryfos 1996). In most practical cases, however, the data collected with stratified sampling technique is analysed as if the data were from simple random sampling design. The primary reason is that the methods of analysis in simple random sampling are popular and simple. The second reason is that statistical analysis are readily available and easily invoked in many commercial statistical package; and most statistical packages provide testes of hypothesis and estimations about various parameters with the assumption of simple random sampling technique. In other words, the analysis will be done as if the sample comes from simple random sample where samples came from simple stratified random sampling technique (Chaudhuri 1992, Tryfos 1996). In stratified sampling the population is partitioned into groups, called strata, and sampling is performed separately within each stratum (Ahmed n.d). When sample is selected by simple random sampling technique independently within each stratum, the design is called stratified random sampling. *Rural areas* in the context of the present study refer to communities *bordering* the *forests*. *Urban areas* refer to the community residing *fairly* in the *centre* of *municipality*. *Peri-urban* areas refer to the areas geographically located within the municipality, but lying on its periphery.

Rural area sample selection

The first step was to get the list of all forests in each district, from respective *District Forest Catchment Offices*. The forests were then stratified into miombo woodlands and non-miombo forests. Where applicable, miombo woodlands were further grouped (stratified) into protective and productive miombo woodlands. One forest (miombo woodland) was randomly selected from each miombo woodlands stratum**.** Villages bordering the selected forests were *operationally* designated as *rural areas*. Out of villages bordering a selected forest, one village was *randomly* selected. *Hamlet(s)* were then randomly selected from each selected village. The respondent households were randomly selected from each stratum using a *random number table*. Random selection of *woodlands* (forests), *villages*, and *hamlets* was made possible through the use of the *playing cards* method: the names of *forests*; *villages* or *hamlets* were written on the lower parts of the cards, the cards were then thoroughly mixed together, and the desired sample size randomly selected from the pool of the cards.

Urban area sample selection

The municipalities in each district were *operationally* designated as *urban areas*. The list of all wards in the municipality (urban area) was sought. The wards which are within the municipality, but are located on the periphery (i.e. bordering the municipality) were excluded from the list. One *ward* was then randomly selected from the remaining list. Subsequently, one *street* (equivalent to *hamlet* in rural areas) was randomly selected from the list of the ward's streets. Households in the selected *street* were, as in the case of rural areas, stratified into wealth categories: *low*, *medium*, and *high*. Respondent households were then randomly selected from each stratum. A r*andom number table* was used to select respondent households. Random selection of *wards* and *streets* was made possible through the use of the *playing card* method.

Peri-urban area sample selection

All the wards within the municipalities which are located on the *periphery* of the municipalities were designated as *peri-urban* areas. Selection of peri-urban ward was purposeful. The selected *peri-urban ward* had to be in closest proximity with the selected *forest* (in relation to other peri-urban wards). The study "street(s)" within the selected peri-urban ward was randomly selected using a *playing card* technique. The households within the *selected street* were accordingly stratified into low-wealth category, medium-wealth category, and high-wealth category; and subsequent respondent households were randomly selected from each stratum.

Development of research instruments

The main research instruments used in the present study are *questionnaires* (for household surveys) and *checklists* (for Focus Group Discussion and interview of key informants). Figure 3 presents five sequential steps involved in questionnaire development: background, conceptualization, format and data analysis, establishing validity, and establishing reliability. Questionnaire construction began by first defining the *domain of information* in order to obtain the required information. This was achieved through an extensive and rigorous search of pertinent literature. Efforts were made as much as possible, to make the questionnaire: *brief* (keeping questions short, and asking one question at a time); *objective* (paying attention to neutrality of the words); *simple* (using language which is simple in words and phrase); *specific* (asking precise questions); and *informative* (covering all necessary information needed). All three types of question formats were used: *multiple choice* (closed ended) questions, *numeric open-ended* questions, and *text open-ended* questions. Attention was also given to issues such as *opening* questions, question *flow*, and location of *sensitive* questions.

Sample size determination

The sample size for the present study was computed using equations 1 and 2 as recommended by Bartlett *et al.* (2001):

$$n = \left(\frac{n_0}{1+\frac{n_0}{N}}\right) \qquad (1)$$

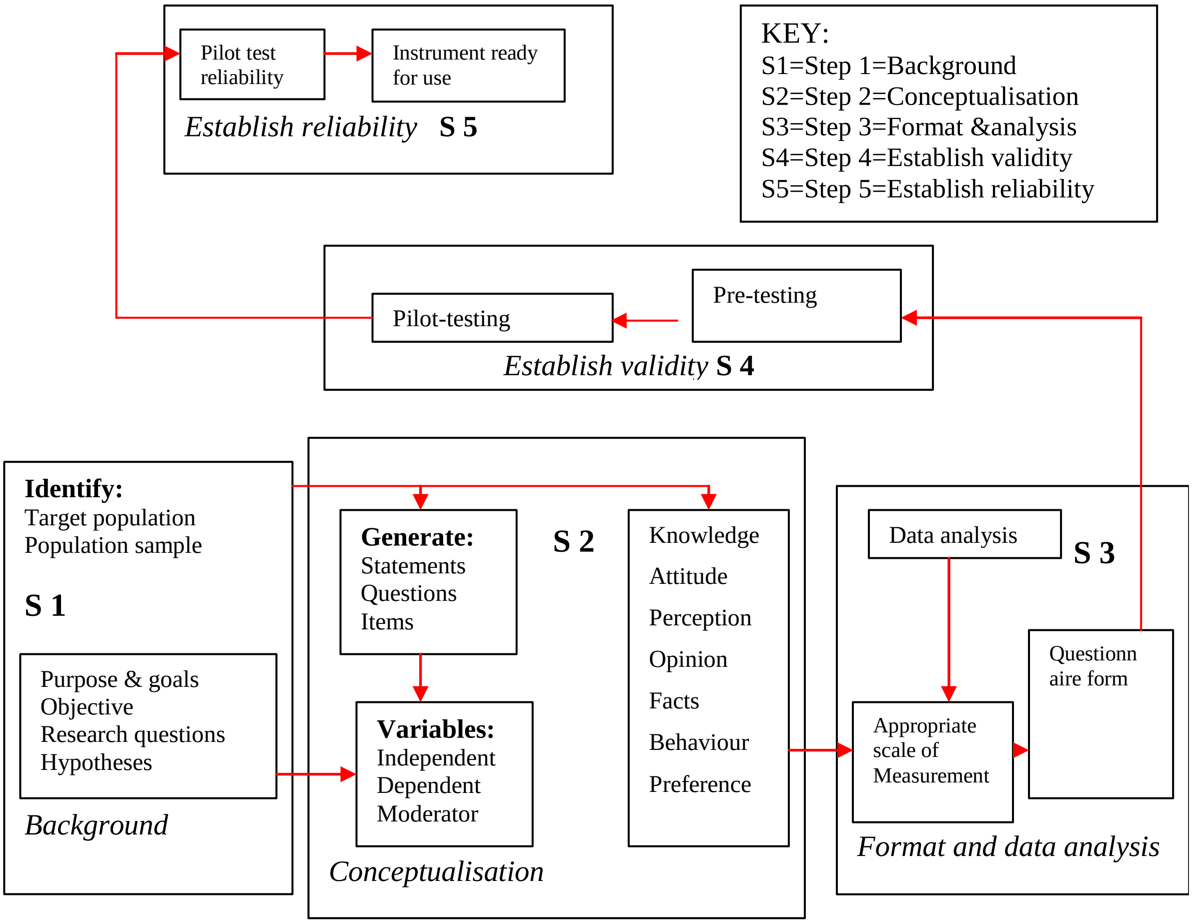

Figure 3: Sequential steps in questionnaire development. *Source:* Adapted from Radhakrishna (2007).

The computation of sample size for *categorical* data, according to Bartlett *et al.*, (2001), follows the same way as in *continuous* data, except in the computation of n_0, which is:

$$n_0 = \left(\frac{t^2 \times pq}{d^2}\right) \qquad (2)$$

Where: *p* is the proportion of respondent that will give you information of interest (the proportion *confirming*), *q* viz (1-*p*) is the proportion not giving you information of interest (proportion *defective)*, and *p* q* is the estimate of variance (*which is maximum when p = 0.50 and q=0.50)*. The maximum population variance of 0.25 will give the maximum sample size. Consequently, the equation used to determine stratum sample size (n_h) from a stratum population (N_h) is:

$$n_h = \left(\frac{384}{1+\frac{384}{N_h}}\right) \qquad (3)$$

This equation was consequently used to independently determine sample size in each stratum. The researcher's task to determine the total population in the respective stratum (N_h) also called stratum sampling frame, and then apply the equation 3 to compute the required stratum sample size (n_h). This allocation of sample to strata can reasonably be termed proportionate allocation because the sample size in the stratum increases with an increase in stratum population, and the resulting sampling fractions are approximately the same (Table 1).

Table 1: Sampling of respondents in respective strata

Stratum (h)	N_h	n_h	W_h
Morogoro rural	189	167	0.88
Morogoro peri-urban	137	115	0.84
Morogoro urban	104	82	0.79
Sub-total$_1$ (Morogoro)	**430**	**364**	
Songea rural	104	91	0.88
Songea peri-urban	74	62	0.84
Songea urban	59	51	0.86
Sub-total$_2$ (Songea)	**237**	**204**	
TOTAL (Pooled)	**667**	**568**	

The notations used are defined as follows: the subscript *h* denotes the coressponding quantities in stratum *h*. N_h is a total number of units in stratum *h* (h = 1, ..., L); L is the total number of strata. The notation n_h represents the number of units observed in stratum *h*. The notation W_h means is a sampling fraction in stratum h (i.e. n_h / N_h).

Data collection and Analysis

Data collection

Data was collected using a number of techniques: direct measurements of household fuels, household questionnaire survey, focus group discussion, key informant interview, and researcher's direct observation. Questionnaires were both pre-tested and pilot-tested before actual data collection. The traditional paper and pencil *interviewer-administered* mode of questionnaire administration was used in the present study. The choice of this mode of questionnaire administration (as opposed to *self-administered* mode) was based on two primary factors: (a) *interviewer-administered* questionnaire administration mode is the most feasible and practical in Tanzania (b) In the present study, the questionnaire survey was to be conducted *concurrently with actual measurements* of fuels consumption. The interviewer had to introduce himself and explicitly explain the objectives of the survey, and how beneficial would the findings be. The respondent was also informed that he/she was at liberty to either participate in the survey or not. The point was made clear to the respondents, that the information which they provided will be used exclusively for the survey purpose and that all the respondents will remain anonymous. To demonstrate and stress the issue of respondent anonymity: (1) respondents were not asked to *provide their names* during the interview, and (2) the sampling frames (containing the up-dated list of households arranged in alphabetical order) were always kept by the hamlet/street leaders, such that the research team had no access whatsoever, to the names of the respondents.

The direct measurements were conducted to quantify the fuels consumed by the households. The fuels involved in direct measurement were firewood, charcoal, kerosene, crop residue and grid electricity. The initial plan (before the pilot study) was to measure daily fuels consumption for the sampled households (respondents) for 7 consecutive days and then compute the average daily consumptions. After the pilot study, it was evident that adopting this measurement approach would mean an extended data collection period (at least 11 months). In order to cope with the scheduled data collection duration of 6 months (according to the Commonwealth Scholarship Guidelines), measurements were taken only for a single day. The procedure was that the sampled households were visited one morning before commencing their cooking activities. Measurements were taken for the available fuels and recorded in the measurement sheet. The same households were re-visited the following day (at the same time) and measurement of the remaining fuels were then taken and recorded. The difference in measurements, i.e., Measurement (1st day) minus the Measurement (2nd day) was taken as the household daily fuel consumption intensity. The instruments used for fuel measurement (except for electricity which involved reading of the meters) are spring balance (for measuring firewood, charcoal, and crop residue) and beakers (for measurement of kerosene).

Data analysis

In order to undertake the various analyses, it was inevitable to make some assumptions. *The first assumption* (which sounds implausible) was that households have constant intensities of fuel consumption throughout the year. The nature of the present study (cross-sectional) prompted this assumption. It sounds implausible because the literature points out that fuel consumption intensity varies with seasonality, and sometimes varies between weekends and weekdays within the same week. It was not possible to capture such dynamics. *The second assumption* was that households did not deliberately adjust their fuel consumptions to impress the researcher since they knew that the researcher was going to measure their fuels consumption. The possibility of adjusting consumption is highly attached to wood fuels in order to show that they don't exert pressure on forest resources. *The third assumption* was that all information provided by households during questionnaire administration was authentic and that respondents spoke out their minds to the best of their knowledge. The present study made use of various conversion factors during data analysis. *First*, to compute *wood fuel* (m^3 of round wood) consumption it was necessary to convert weight of firewood consumed (kg) and that of charcoal (kg) to their round wood equivalent volumes (m^3 of round wood). Table 2 shows how these conversions were carried out. *Second*, appropriate conversion factors (Table 3) were used to convert *fuels' physical units* into their equivalent *energy values* (*oil equivalent*). This then made it possible to compute household total energy consumptions.

Within-strata data analysis

In each stratum, standard methods which are used for simple random sampling (SRS) were applied. Data analysis was carried out using *SPSS* and *Excel* statistical computer programmes. Prior to detailed analysis, data were arranged in such a way as to facilitate analyses. Descriptive statistical analysis was conducted. The general purpose of descriptive statistical method is to summarise, organise and simplify a set of scores (Gravetter and Wallnau 2004, 2007). In the present study, the *central tendency* (average or representative score) for numeric data (*interval or ratio*) was determined by *mean*. The central tendency determination for *discrete variables* was a *mode*. The measure of *variability* within the numeric (*interval or ratio*) data was *standard deviation*.

Table 2: Conversion factors for firewood and charcoal into wood volume

Fuel	*Unit*	*Conversion into wood volume*	*Source*
Firewood	kg	$1m^3$ of wood = 725kg of firewood	▪ Kaale (2005) ▪ Amous (1999)
Charcoal	kg	$1m^3$ of wood = 165kg of charcoal	▪ Amous (1999)

Table 3: Conversion of fuels' physical units into their equivalent energy units (oil equivalent)

Fuel type	*Physical unit*	*Energy unit*(kgoe)*	*Source*
Firewood	kg	1kg = 0.32 kgoe	Mutinga (2001)
Charcoal	kg	1kg = 0.74 kgoe	Janssen *et al*, (2004)
Kerosene	litre	1litre = 0.84 kgoe	Janssen *et al*, (2004)
Electricity	kWh	1kWh = 0.086 kgoe	Janssen *et al*, (2004)
Crop residues	kg	1kg = 0.45 kgoe	Janssen *et al*, (2004)
Petrol	litre	1litre = 0.755 kgoe	Mutinga (2001)
Diesel	litre	1litre = 0.88 kgoe	Mutinga (2001)
Natural gas	m^3	$1m^3$ = 0.83 kgoe	Mutinga (2001)

*the energy unit can be converted to other units as follows:

- 1 kgoe = 0.001tonnes of oil equivalent (toe)
- 1 toe = 41.868 gigajoules (GJ)
  = 396.83 therm
  = 10,000,000 kilocalories (kcal)
  = (396.83) × 10^5 British thermal units (Btus)
  = 7.33Barrels of oil equivalent (boe)
  = 1.43 tonnes of coal equivalent (tce)

The *categorical* variables were summarised using *bar charts* and *pie charts*; whereas *numerical variables* were summarised using *histograms*. The central limit theorem and the standard errors of the mean and of the proportion are based on the premise that the samples selected are chosen with replacement. However, in virtually all survey research, sampling is conducted without replacement from populations that are of a finite size N. In these cases, particularly when the sample size n is not small in comparison with the population size N (i.e., more than 5% of the population is sampled) so that n/N is greater than 0.05, a finite population correction factor (fpc) is used to define both the standard error of the mean and the standard error of the proportion. The finite population correction factor is expressed as (Starsinic 2011):

$$FPCF = \sqrt{\frac{N-n}{N-1}} \quad (4)$$

When developing confidence interval estimates for population parameters, the finite population correction factor is used when samples are selected without replacement from a finite population. If more than 5% of the population is sampled, the finite population correction factor significantly reduces the width of the confidence interval. If less than 5% of the population is sampled, the finite population correction factor has little or no practical effect on the confidence interval width. Equation 5 defines the confidence interval estimate for the mean. In sampling without replacement from a finite population, the confidence interval estimate of the proportion is defined in equation 6.

$$95\%\ C.I\ of\ the\ mean = \bar{X} \pm t_{\propto/2}\frac{s}{\sqrt{n}} \times \sqrt{\frac{N-n}{N-1}} \quad (5)$$

$$95\%\ C.I\ of\ proportion$$
$$= p\ \pm Z\sqrt{\frac{P(1-P)}{P}} \times \sqrt{\frac{N-n}{N-1}} \qquad (6)$$

As an inferential statistic for wood fuel consumption in the study area, the 95% confidence interval was computed using sample statistics (percentage of households using firewood, charcoal). The standard formula for computing a 95% confidence interval for population proportion is well explained (e.g., Gravetter and Wallnau 2004, 2007; Marketvision Research 2008, Morrisette and Khorram1998, Koether 2008). It is recommended, however, that for a finite population (small population) the finite population correction factor (FPCF) should be incorporated in the standard formula in order to reduce standard error (e.g., Ali 2005, Heinze *et al.* 2006, Max 2008, Abrache n.d.). The population is said to be finite if sample size (n) is greater than 5% of population (N). The computations of confidence intervals in the present study incorporated the finite population correction factor.

All strata (population) data analysis

A proper analysis of survey data requires that sampling design be taken into account, when conclusions are wanted about finite population. However, many computer programs for standard statistical analysis implicitly assume simple random sampling (Zewotir n.d). In this study, methodology appropriate to stratified random sampling design was used to compute the population parameters mainly: population mean, population standard error, confidence interval, population proportions, and variance of proportions. Equations for computing population parameters in stratified random sampling design are summarised in Table 4.

Table 4: Equations for computing population parameters in stratified random sampling design

Population Parameter	Computational equation
Population mean	$\bar{y}_{st} = \frac{\sum N_h \bar{y}_h}{N}$
Population standard error	$S_{\bar{y}st} = \sqrt{\frac{1}{N^2}\sum_{h=1}^{L}\frac{{N_h}^2 S^2{}_h}{n_h}\left(\frac{N_h - n_h}{N_h}\right)}$
Confidence interval	$C.I = \bar{y}_{st} \pm tS_{\bar{y}st}$
Population proportions	$p_{st} = \frac{1}{N}\sum N_h\, p_h$
Variance of population proportions	$Variance = \frac{1}{N^2}\sum {N_h}^2\left(1 - \frac{n_h}{N_h}\right)(p)_h(1 - p_h)/(n_{h-1})$
Where: L = The number of strata N_h = The size of stratum h (h = 1, …, L) N = Total population (N = $\sum_{h=1}^{L} N_h$) $\bar{y}_h$ = Mean of stratum h (h= 1, …, L) n_h = Number of units observed in stratum h $S^2{}_h$ = Variance of stratum h (h=1, …, L)	

Source: Ross (2005), Turner (2003), Ahmed (2009), Lohr (1999)

In stratified sampling, stratum variables are mutually exclusive (non-over lapping), e.g., urban/rural areas, economic categories, geographic regions, race, sex, etc. The population (elements) should be homogenous within-stratum, and the population (elements) should be heterogeneous between the strata (Ahmed 2009). According to the author (ibid), strata totals are additive but not the strata means. Further, variance estimated under stratified sampling is always lower than the variance estimated under simple random sampling. Stratified random sampling can be used for a variety of reasons. First, stratification is a common way of improving the precision of estimators (i.e., to reduce the variance), in particular when estimating characteristics of the entire population. Some variables, e.g., company revenue, can have such a large population variance that very large samples are needed to make reliable inferences. If it is possible to form groups within which the target variable varies little, stratified sampling can lead to more precise outcomes than simple random sampling (with equal sample size). Precision improves because the variance within the strata is less than the variance for the population as a whole. Second, the interest is often not only in the population as a whole, but also in specific subpopulations or in making comparisons between subpopulations. In simple random sampling, it is a matter of chance how many elements end up in the strata. Small sub-populations in particular will then be poorly represented in the sample. Stratification is a way of ensuring that all subpopulations of interest are sufficiently represented in the sample to allow reliable statements to be made. Third, it is possible in stratification to use different data collection techniques for different strata. For instance, it may be desirable in a business survey to approach small companies by means of a brief paper questionnaire and to have large companies take part in an extensive telephone or personal interview. The selection and estimating methods may also differ for each stratum. Fourth, for administrative reasons, sampling frames are often already divided into 'natural' parts, which may even be kept at geographically different locations. In this case separate sampling may be more economical (Banning *et al.* 2012, Annon 1991, Teddie and Yu 2009). In the context of this study, various working definitions were formulated as follows:

Household head refers to a person responsible for day-to-day provisions for all household members. Household members mean people living and eating together for at least one month before this study was carried out. Household income is the total income from all household members with exception of maids and servants of that respective household.

Analysis of variation in woodfuel consumption along rural-periurban-urban continuum

A priori hypothesis was formulated and tested. This hypothesis was concerned with the variation of households' fuel consumption along rural–periurban–urban continuum. A one-way between groups analysis of variance (ANOVA) was carried out to analyse if there is statistical difference in biomass consumption (intensities) among rural, peri-urban, and urban areas for Morogoro District, Songea District and pooled sample. The test hypotheses were as follows:

$$H_0: \mu_{rural} = \mu_{peri-urban} = \mu_{urban} \qquad (7)$$

$$H_1: \quad \text{At least two } \mu s \text{ are different} \qquad (8)$$

RESULTS

Respondents' characteristics

The socio-economic characteristics for 568 respondents who took part in the present study are summarised and presented in **Table 5**. The findings reveal that both *household heads* and those who are *not* household heads participated in answering survey questionnaires. It is also evident from the findings **(Table 5)** that the study sample comprised of both *male-headed* households and *female-headed* households, *albeit* the former constitutes the majority. Female-headed households can further be categorised into two groups: those who are married and those who are not. The study attained a *fairly good gender balance*: the number of *male respondents* was comparable to that of *female respondents*. Household income distribution for the respondents (as recorded in the field) is presented in **Table 6.**

Table 5: Socio-economic characteristics of respondents (sample statistics)

Characteristic	**N**	**%**
Respondents		
Household head	307	54
Not household head	261	46
Gender of the household head		
Male-headed household	468	82.4
Female-headed household	100	17.6
Marital status of respondent		
Married	433	76.2
Never married	34	6
Widowed	67	11.8
Divorced	18	3.2
Separated	16	2.8
Marital status of female-headed household		
Married	36	36
Not married	64	64
Dwelling categories (status)		
Concrete/burnt bricks/iron roof	318	56
Concrete/burnt bricks/grass roof	60	10.6
Unburnt bricks/iron roof	18	3.2
Unburnt bricks/grass	9	1.6
Mud-house/iron roof	36	6.3
Mud-house/grass roof	69	12.1
Other types	58	10.2
Educational level of household head		
Illiterate	99	17.4
Primary education	382	67.3
Secondary education	63	11.1
Adult education	3	0.5
College education	9	1.6
University education	6	1.1
Others	6	1.1
Main occupation of household head		
Employee	44	7.7
Formerly employed	24	4.2
Causal labourer	7	1.2
Artisan	9	1.6
Herder/cultivator	231	40.7
Trade/shop	24	4.2
Petty business	96	16.9
Firewood/charcoal vending	3	0.5
Housework	57	10
Others	73	12.8
Ownership of dwelling		
Rented	84	14.8
Owned	484	85.2

Table 6: Distribution of household monthly income (exchange rate 2007: 1US$=1,255Tshs)

Income *month*$^{-1}$ (Tshs)	N	%
< 10,000	80	14.2
10,000 – 20,000	86	15.1
21,000 – 30,000	55	9.7
31,000 – 40,000	50	8.8
41,000 – 50,000	55	9.7
51,000 – 60,000	44	7.7
61,000 – 70,000	19	3.3
≥ 71,000	179	31.5
Total	**568**	**100**

Household fuel consumption intensities in the study sites

The *average quantities* of households' fuels consumption in the study area are summarised and presented in **Tables 7.** Note that the computations of wood fuel equivalence **(Table 8**) were effected through the use of standard and commonly used conversion factors

Using the appropriate conversion factors, the household total energy consumption was computed. It was of interest to determine the percentage contribution of wood fuel to total household energy. **Table 9** and **Table 10** present respectively, the total household energy and percent contribution of each fuel to total energy consumption.

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Table 7: Household cooking and lighting fuels in the study area (mean ± s.e)

Location	Daily fuels consumption per household				
	Firewood (kg)	Charcoal (kg)	Crop residues (kg)	Kerosene (l)	Electricity (kWh)
Morogoro:					
Rural	9.90 ± 0.38	2.80 ± 0.26	12.00 ± 1.22	0.20 ± 0.01	21.30 ± 4.48
Peri-urban	5.52 ± 0.42	3.12 ± 0.30	13.50 ± 1.50	0.21 ± 0.01	19.10 ± 1.75
Urban	3.50 ± 0.30	2.90 ± 0.17	-	0.22 ± 0.01	20.20 ± 1.10
Overall	**6.95 ± 0.007**	**2.92 ± 0.005**	**9.57 ± 0.022**	**0.21 ± 0.0002**	**20.33 ± 0.057**
Songea:					
Rural	9.80 ± 0.43	4.80 ± 0.92	13.40 ± 1.74	0.23 ± 0.02	-
Peri-urban	10.22 ± 0.55	3.73 ± 0.67	13.30 ± 1.76	0.20 ± 0.02	28.00 ± 0.00
Urban	7.20 ± 2.00	4.62 ± 0.30	-	0.28 ± 0.02	22.00 ± 1.48
Overall	**9.28 ± 0.028**	**4.42 ± 0.018**	**10.03 ± 0.039**	**0.23 ± 0.001**	**714.22 ± 0.018**
Pooled sample:					
Rural	7.60 ± 0.32	3.20 ± 0.30	13.00 ± 1.24	0.20 ± 0.01	21.30 ± 4.48
Peri-urban	7.50 ± 0.40	3.30 ± 0.27	13.40 ± 1.55	0.21 ± 0.01	19.80 ± 1.76
Urban	4.20 ± 0.54	3.64 ± 0.18	-	0.24 ± 0.01	21.00 ± 0.90
Overall	**6.74 ± 0.006**	**3.34± 0.004**	**9.95 ± 0.018**	**0.21 ± 0.0002**	**20.75 ± 0.046**

Table 8: Wood fuel consumption in the study area (mean ± s.e)

Stratum	Morogoro District			Songea District			Pooled sample		
	% in use	(m^3/hh/yr)	(m^3/capita/yr)	% in use	(m^3/hh/yr)	(m^3/capita/yr)	% in use	(m^3/hh/yr)	(m^3/capita/yr)
Rural	93.2	4.1 ± 0.2	0.82 ± 0.04	98.9	6.3 ± 0.4	1.26 ± 0.08	88.8	5.0 ± 0.2	1.00 ± 0.04
P/urban	87.8	5.0 ± 0.4	1.25 ± 0.10	95.2	6.9 ± 0.5	1.38 ±0.10	90.4	5.7 ± 0.3	1.14 ± 0.06
Urban	96.3	5.9 ± 0.4	0.98 ± 0.07	100	9.9 ± 0.7	1.65 ± 0.12	97.7	7.5 ± 0.4	1.25 ± 0.07
Overall	**92.23**	**4.82± 0.007**	**0.99 ± 0.002**	**98.02**	**7.38±0.014**	**1.39± 0.003**	**91.48**	**5.83± 0.005**	**1.11 ± 0.001**

Table 9: Total household energy consumption in the study area (mean ± s.e)

District	Stratum	Per household (toe/hh/year)	Per-capita (toe/capita/year)
Morogoro	Rural	0.801 ± 0.04	0.16 ± 0.01
	Peri-urban	0.96 ± 0.09	0.24 ± 0.02
	Urban	1.16 ± 0.08	0.19 ± 0.01
	Overall	0.94 ± 0.002	0.19 ± 0.0003
Songea	Rural	1.482 ± 0.08	0.30 ± 0.02
	Peri-urban	1.744 ± 0.10	0.35 ± 0.02
	Urban	1.92 ± 0.09	0.32 ± 0.02
	Overall	1.67 ± 0.002	0.32 ± 0.001
Pooled	Rural	1.052 ± 0.04	0.21 ± 0.01
	Peri-urban	1.242 ± 0.07	0.25 ± 0.01
	Urban	1.480 ± 0.07	0.25 ± 0.01
	Overall	1.22 ± 0.001	0.23 ± 0.0002

Table 10: Percentage contribution of each fuel to total household energy (for cooking, lighting and running machines)

Fuel/total energy	Rural	Peri-urban	Urban	Overall
Total Energy (toe/hh/year)	1.052 ± 0.04 (mean ± s.e)	1.242 ± 0.07 (mean ± s.e)	1.48 ± 0.07 (mean ± s.e)	1.22 ± 0.001 (mean ± s.e)
		Percent contribution:		
Firewood	70.20	52.28	8.50	49.45
Charcoal	13.80	21.66	55.80	26.55
Kerosene	5.50	5.02	3.20	4.78
Electricity	0.70	3.57	26.6	7.93
Crop Residue	9.60	12.45	0.00	8.16
Petrol	0.20	1.80	2.70	1.32
Diesel	0.00	2.96	3.20	1.73
Solar	0.00	0.18	0.00	0.05
Gas	0.00	0.08	0.00	0.03
Total	**100.00**	**100.00**	**100.00**	**100.00**

From the above findings it can be deduced that the intensity of firewood consumption increases from *urban area* to *rural area* and the one for charcoal shows the reverse patterns: decreases from urban areas to rural areas, while total wood fuel wood fuel consumption (firewood and/or charcoal) increases from *rural areas* to *urban areas*.

Confidence interval for wood fuel consumption intensities

As an *inferential statistic* for wood fuel consumption in the study area, the 95% confidence interval was computed using sample statistics (quantities of firewood and charcoal), and are presented in **Table 11.**

Table 11: Confidence interval for wood fuel consumption intensities

	N	***n***	$\left(\frac{n}{N}\right)$	*FPCF*	**Sample statistic** Average consumption (kg/hh/day) (*SD* is shown in brackets)		**Inferential statistic (95%C.I.)** Average consumption (kg/hh/day)	
					Firewood	Charcoal	Firewood	Charcoal
1. Morogoro District								
1.1 Rural	189	167	0.88	0.342	9.90 (SE = 4.0)	2.80 (SE = 1.4)	9.69–10.11	2.73–2.87
1.2 Peri-urban	137	115	0.84	0.402	5.52 (SE = 3.5)	3.12 (SE = 1.9)	5.26–5.78	2.98–3.26
1.3 Urban	104	82	0.79	0.462	3.50 (SE = 1.6)	2.90 (SE = 1.4)	3.34–3.66	2.76–3.04
1.4 Overall	**430**	**364**	**0.85**	**0.392**	**6.95 (SE = 0.007)**	**2.92 (SE = 0.005)**	**6.943–6.957**	**2.915–2.925**
2. Songea District								
2.1 Rural	104	91	0.87	0.355	9.80 (SE = 4.0)	4.80 (SE = 2.5)	9.51–10.09	4.62–4.98
2.2 Peri-urban	74	62	0.84	0.405	10.22 (SE = 4.1)	3.73 (SE = 2.2)	9.81–10.63	3.51–3.95
2.3 Urban	59	51	0.86	0.371	7.20 (SE = 5.3)	4.62 (SE = 2.0)	6.66–7.74	4.42–4.82
2.4 Overall	**237**	**204**	**0.86**	**0.374**	**9.28 (SE = 0.028)**	**4.42 (SE = 0.018)**	**9.252–9.308**	**4.402–4.438**
3. Pooled sample								
3.1 Rural	293	258	0.88	0.346	7.60 (SE = 4.4)	3.20 (SE = 1.9)	7.41–7.79	3.12–3.28
3.2 Peri-urban	211	177	0.84	0.402	7.50 (SE = 4.4)	3.30 (SE = 2.0)	7.24–7.76	3.18–3.42
3.3 Urban	163	133	0.82	0.430	4.20 (SE = 3.1)	3.64 (SE = 1.8)	3.97–4.43	3.51–3.77
3.4 Overall	667	568	0.85	0.386	6.74(SE =0.006)	3.34 (SE = 0.004)	6.734–6.746	3.336–3.344

Inter-strata variation of wood fuel consumption intensities

The ANOVA findings indicated that overall, there is a *small* (η = 0.05) statistically significant difference in household firewood consumption across rural, peri-urban and urban areas [$F_{(2, 357)}$ = 8.915, $p < 0.001$]. *Rural* household firewood consumption (M = 7.60kg/day, s.e = 0.32) was found to be statistically significantly different from that in *urban* areas (M = 4.20kg/day, s.e = 0.54) ($p < 0.001$). Similarly, *peri-urban* household firewood consumption (M = 7.50kg/day, s.e = 0.40) was statistically significantly different from that in *urban* areas ($p < .001$). There was a *medium* (η = 0.06) statistically significant difference in household w*ood fuel* consumption across the strata i.e., rural, peri-urban and urban [$F_{(2, 516)}$ = 17.238, $p < 0.001$]. There was a statistically significant difference in household wood fuel consumption between *rural* (M = 5.0 m^3/year, s.e = 0.20) and *urban* (M = 7.5 m^3/year, s.e = 0.40) ($p < 0.001$); and between *peri-urban* (M = 5.7 m^3/year, s.e = 0.30) and urban ($p < 0.001$).

When analysis was segregated by study districts, in *Morogoro district*, there was a *small* (η = 0.04) statistically significant difference in firewood consumption across the strata [$F_{(2, 207)}$ = 4.762, $p < 0.05$]. Rural firewood consumption (M = 9.90 kg/day, s.e = 0.38) was statistically different from that of urban area (M = 3.5 kg/day, s.e = 0.30) ($p < 0.01$). There was also a statistically significant difference between the household firewood consumption in *peri-urban* (M = 5.52 kg/day, s.e = 0.42) and urban areas ($p < 0.01$). There was a *small* (η = 0.04) statistically significant difference in household w*ood fuel* consumption across the strata i.e., rural, peri-urban and urban [$F_{(2, 316)}$ = 6.999, $p < 0.01$]. There was a statistical significant difference in household wood fuel consumption between *rural* (M = 4.1 m^3/year, s.e = 0.20) and urban (M = 5.9 m^3/year, s.e = 0.40) ($p < 0.01$). In *Songea District*, there was a *medium* (η = 0.12) statistically significant difference in household w*ood fuel* consumption across the strata i.e., rural, peri-urban and urban [$F_{(2, 197)}$ = 13.617, $p < 0.001$]. There was a statistical significant difference in household wood fuel consumption between *rural* (M = 6.3 m^3/year, s.e = 0.40) and *urban* (M = 9.9 m^3/year, s.e = 0.70) ($p < 0.001$); and between *peri-urban* (M = 6.9 m^3/year, s.e = 0.50) and *urban* areas ($p < 0.001$).

DISCUSSION

Reporting with *95% confidence*, overall, households in the study area use *firewood* as energy source at a rate of 6.734 – 6.746 kg household^{-1} day^{-1}, while they use c*harcoal* as energy source at a rate of 3.336 – 3.344 kg household^{-1} day^{-1}. On average, woodfuel consumption is estimated at 5.83 m^3/household/year (equivalent to 1.11 m^3/capita/year). Results revealed further that on average, household total energy consumption (M ± s.e) is 1.22 ± 0.001 *toe household^{-1} year^{-1}* (equivalent to 0.23 ± 0.0002 *toe capita^{-1} year^{-1}*), while household wood fuel consumption (M ± s.e) is 5.83±0.005 *m^3 household^{-1} year^{-1}* (equivalent to 1.11 ± 0.001 *m^3 capita^{-1} year^{-1}*). Wood fuel contributes a significant share to total household energy: firewood and charcoal account, respectively, for 49.45% and 26.55 % of total household energy consumption. The findings of this study are corroborated by a number of other studies. According to Hosier (1985), the average per-capita woodfuel consumption is estimated at an average of between 1.5 m^3 and 5 m^3 of wood per year. On the other hand, Mangi (2011) estimated the fuel wood and charcoal consumption to be 0.67 m^3 and 0.14 m^3 respectively. The study conducted by Rehut *et al.* (2016) established that wood fuel accounts for 35% to 46% of the total household energy. FAO (2010) posited that woodfuel contributes sizeably to total energy: Africa (32%), America (17.6%), Asia (41.7%), Europe (8.1%), and Oceania (0.6%). Furthermore, Preston (2012) estimated the per-capita fuel wood consumption to be 0.51 m^3/capita/year.

Other authors who have reported the intensity of wood fuel consumption in Tanzania are as follows: Mnzava (1985), reported that Tanzania is the second largest fuelwood consumer in Africa (after Nigeria), with a per capita consumption of approximately 2.5 m³/year. Mnzava (1991) reported that the average wood fuel use per capita is about 1.5 m3 person -1year-1 (equivalent to 1 tonne of wood). However, Ishengoma and Ngaga (2001), suggest that the average consumption of wood fuel per capita per year in five urban areas of Tanzania was 1.03 m3, with regional variations: Dar es Salaam 0.6m^3; Mbeya 0.99m^3; Dodoma 0.9 m^3; Arusha 1.86m^3 and Mwanza 0.81m^3. Kaale (2005) reported that in 1967 Tanzania had a population of 12.3 million people with annual national wood fuel consumption of 24.6 million m^3 and per capita consumption of 2.0m^3 $year^{-1}$. In 2002, population was 34.6 million with an annual national wood fuel consumption of 44.8 million m^3 and 2003 per capita wood fuel consumption of 1.0-1.5 m^3 $capita^{-1}year^{-1}$.

It is evident from the findings that households' woodfuel consumption is of sizeable amount and therefore concerted effort is needed by all pertinent stakeholders reduce the negative ramifications to forest resources attributable to woodfuel consumption and thus improve forest sustainability. The Ministry of Natural Resources and Tourisms needs to promote, disseminate and scale-up the uptake of improved *firewood* and *charcoal* stoves; promote and disseminate the improved charcoal making technology and promote tree planting (using *well-researched* suitable species for wood fuel). Further, the Ministry of energy should intervene by increasing households' accessibility to electricity and subsidizing its costs. Furthermore, the Ministry of energy should strive to avail alternative fuels for household cooking and heating purposes e.g. *briquettes* (saw-dust/charcoal), LPG and natural gas.

The findings have revealed a statistically significant difference between strata (rural, peri-urban, and urban areas) in the consumption of wood fuel. This suggests that it is more plausible to address strata-based wood fuel consumption issues separately: a one-size-fits-all approach in addressing wood fuel related problems is likely to be futile. Location specific strategies should be devised to address the current wood fuel consumption problems.

CONCLUSIONS AND RECOMMENDATIONS

It is evident that the household wood fuel consumption is of a sizeable intensity and has the highest contributory effect on total household energy consumption. There was a notable difference in the inter-strata wood fuel consumption. It is recommended that strata (location)-specific strategies would be appropriate in addressing wood fuels issues in the study area: "one-size-fits-all" approach in addressing wood fuel issues in the study area, whenever feasible, should be discouraged. It is further recommended that in order to reduce woodfuel consumption intensities the use of improved firewood and charcoal stoves should more promoted among the households in the study area.

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REFERENCES

Abrache, J., n.d., Sampling distribution and confidence interval estimation. Advanced Quantitative Methods. School of Business Administration, AL Akhawayn University.

Abrahamse, W. 2007. Energy Conservation through behavioural change: Examining the effectiveness of a tailor-made approach. PhD thesis, Wageningen University, the Netherlands.

Adelekan, I.O. & Jerome, A.T. 2006. Dynamics of household energy consumption in Traditional African City, Ibadan-Nigeria. *Environmentalist* 26: 99-110.

Ahmed, S. 2009. Methods in survey sampling. Stratified sampling. pp53.

Alam, M., Sathaye, J. & Barnes, D. 1998. Urban household energy use in India: Efficiency and policy implications. *Energy Policy* 26(11): 885-891.

Alan, P. 2004. Energy Efficiency-its potential: Some perspectives and experiences. Background paper for International Energy Agency Energy Efficiency Workshop. Paris.

Ali, Z. 2005. Health professionals in tobacco control: evidence from global health professional survey (GHPS) of dental students in Bangladesh. A report prepared for World Health Organization (WHO), South-East Asia Regional Office (SEARO), New Delhi, India.

Andrea, B. & Goldemberg, J. 1996. Desertification, Energy consumption and Liquified Petroleum gas use, with an emphasis on Africa. Energy for Sustainable Development. Vol.2. No.5.

Arntzen, J.W., & Kgathi, D.L., n.d. Some determinants of the consumption of firewood energy in developing countries: The case of Rural Botswana. Unpublished.

Baland, J., Bardhan, P., Das, S., Mookherjee, D. & Sarkar, R., 2007. Environmental impact of poverty: Evidence from firewood collection in rural Nepal. (Online) at http://people.bu.edu/dilipm/wkpap/nepal300607.pdf . Accessed on 03.06.2007.

Banning, R., Camstra, A. & Knottnerus, P. 2012. Sampling designs and estimation methods. pp 87.

Bartlett, J.E., Kotrlik, J.W. & Higgins, C.C. 2001. Oroganizational Research: Determining Appropriate Sample Size in Survey Research. *Information Technology, Learning, and Performance Journal*, 19 (1): 43-50.

Byer, T. 1987. Review of Household Energy Issues in Africa. Washington, DC: World Bank. Unpublished. 86 pp.

Campbell, B.M., Vermeulen, S.J., Mangono, J.J & Mabugu, R. 2003. The energy transition in action: Urban domestic fuel choices in a changing Zimbabwe. *Energy Policy* 31(6): 553-562.

Carissa, W., Marlene, R., & Duraiappah, A.K. 2005. Connecting poverty and ecosystem services. A series of seven country scoping studies. Focus on Tanzania. United Nations Environment Programme (UNEP) and International Institute for Sustainable Development (IISD). pp 33.

Chaudhuri, A. 1992. Survey Sampling: Theory and Methods. New York: Marcel

Chaudhuri, S. and Pfaff, A.S.P. 2003. Fuel choice and indoor air quality: A household-level perspective on economic growth and the environment. (Online) at http://www.duke.edu/~asp9/fuel-choice-submission.pdf Accessed on 23.05.2009.

Christoph, W. & Adrian, P. 2000. Modelling lifestyle effects on energy demand and related emissions. *Energy Policy*, 28:549-566.

David, M. 1998. Rural household energy consumption: The effects of access to electricity-evidence from South Africa. *Energy Policy* 26(3): 207-217.

Demirbas, A. 2001. Biomass resource facilities and biomass conversion processing for fuel and chemicals. *Energy Conversion and Management*, 42:1357-1374.

Demirbas, A. 2003. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. *Energy Conversion and Management*, 44 (13): 2093-2109.

Dzioubinski, O. & Chipman, R. 1999. Trends in consumption and production: Household energy consumption. Economics and Social Affairs, United Nations. Unpublished.

Enabling Access to Sustainable Energy (EASE) Study. 2001: Country Inception Phase Report: Tanzania. Unpublished. PP.56.

Erlandsen, S. & Nymoen, R. 2008. Consumption and population age structure. *Journal of Population Economics* 21:505-520.

FAO. 1987. Simple technologies for charcoal making. FAO forestry paper No. 41. Forest Industries Division, Forestry Department.

FAO. 2010. Criteria and indicators for sustainable woodfuel. FAO Forestry Paper 160. pp 92.

Foster, V., Tre, J.P. & Wodon, Q. 2000. Energy Consumption and Income: An inverted-U consumption at the household level. The Word Bank Poverty Group.

Fox, J. 1984. Firewood consumption in Nepali village. *Environmental Management*, 8 (3): 243-250.

Fuchs, D.A. & Lorek, S. 2000. An inquiry into the impact of globalization on the potential for "sustainable consumption" in households. Report presented at the workshop on sustainable household consumption: Impacts, Goals and Indicator for energy-use, transport and food. 17-19 November 2000, Norway.

Gauslaa, Y. 1998. Management and regeneration of tropical woodlands with special references to Tanzanian conditions. A literature review. *Lidia*

, 2: 37-112.

Gravetter, F.J. & Wallnau, L.B. 2004. *Statistics for the behavioural Sciences*. Sixth edition. Thomson Learning Academic Resource Centre, pp 746.

Gravetter, F.J. & Wallnau, L.B. 2007. *Statistics for the behavioural Sciences*. Seventh edition. Thomson Learning Academic Resource Centre, pp 760.

Hartmann, B. & Sherbinin, A. 2001. Exploring the links between global environmental change, human security and population: A meeting in the AVISO Policy Briefing series. Unpublished.

Heinze, D.T., Feller, P., McCorkle, B.A. & Morsch, M. 2006 Computer-assisted auditing for high volume medical coding. Perspectives in Health Information Management, CAC Proceedings.

Hi-chun, P. & Heo, E. 2000. The direct and indirect household energy requirements in the Republic of Korea from 1980-2000. An input-output analysis. pp. 17.

Holmes, C.M. 2005. Cultural variations, decision making and local institutions: An examination of fuel use in Western Tanzania. *Society and Natural Resources*, 18:61-73.

Hosier, R.H, & Kipondya, W. 1993. Urban household Energy in Tanzania. Price, Substitutes and poverty. Storkhom Environment Institute (SEI). PP.20.

Hosier, R.H. & Dowd, J. 1987. Household fuel choice in Zimbabwe: An empirical test of energy ladder hypothesis. *Resources and Energy* 9: 347-361.

Iddi, S. & Hakan, S. 1997. Managing Natural Forest at the Village level: - Reaching the ultimately development goal. XI World Forest Congress. Antalya, Turkey, 13 to 22 October 1997. Volume 5, Topic 26.

Ishengoma, R.C. & Ngaga, Y.M. 2001. Wood fuel consumption in urban areas of Tanzania. Consultancy Final Report. MNRT and ORGUT, Dar-es-Salaam, Tanzania.

Jiang, L. 2007. Population/household dynamics, energy consumption and Carbon emission in the US, China and India. Third Annual Symposium of

Population, Work and Family policy Research Collaboration. Social and Economic well-being of Canada's population in 2017. Ottawa Congress Centre, December 12-14, 2007.

Kaale, B.K. 2005. Baseline Study on Biomass Energy Conservation in Tanzania. SADC Programme for Biomass Energy Conservation (ProBEC). Report. pp.55.

Kalipeni, E. 1994. Population growth and environmental degradation in Malawi. In: E. Kalipeni (ed.), Population growth and environmental degradation in Southern Africa (pp 17-38). Lynne Rienner Publishers, Boulder London.

Koether, R.T. 2008. *Confidence intervals for proportions*. Hampden-Sydney College.

Kofman, P. 2012. Development of International solid biofuel standards. Forestry and Wood.

Kulindwa, K.A., Sosovele, H. & Mgaya, Y.D. 2000. Tanzania: Rufiji, Ruvu, and Wami Mangroves. In Wood, A., Stedman-Edwards, P., and Mang, J. (eds.). *Root Causes of Biodiversity loss.* pp 309-336. Earthscan Publication Ltd.

Leach, G. 1992. The Energy Transition. *Energy Policy:* 116-123.

Leach, G. 7 Gowen, M. 1987. Household Energy Hand book. Washington, D.C, World Bank Technical Report No. 67.

Lenzen, M. 2006. Environmental implication of an aging society: Integrated Sustainability Analysis. The University of Sydney, Australia. Unpublished.

Linda, M. 1999. Questioning Virtuous Spirals: Microfinance and Women Empowerment in Africa. Journal of International Development. Volume 11, Issue No. 7, pp 957-984.

Lohr, S. L. 1999. Sampling: Design and Analysis. Pacific Grove: Duxbury Press.

Lusambo, L.P. 2002. Socio-economic Analysis of Landuse Factors causing Deforestation of Miombo woodlands. Case study of Kilosa District-Tanzania. M.Sc. Dissertation.

Malimbwi, R.E., Misana, S., Monela, G.C., Jambiaya, G. & Nduwamungu, J. 2001. Charcoal Potential in Southern Africa (CHAPOSA). Final Report, pp 67.

Mansilla, H., Garcia, R., Tapia, J., Duran, H. & Urzua, S. 1991. Chemical characterization of Chilean hardwoods. *Wood Science and Technology*, 25:145-149.

Market Vision Research. 2008. Sampling error and survey reliability. Online at www.mv-research.com . Accessed on 30/12/2008.

Max, S. 2008. Finite population correction factor. http://www.stanelymax.net/course_material/course_material.htm. Accessed on 29/12/2008.

Mnzava E.M. 1985. Tanzanian Tree-Planting: A voice from the villagers. In: Wazeka, R. (ed.). Unasylva-No.150–Forestry and the crisis in Africa. http://www.fao.org/docrep/r5265e/r5265e00.htm . Accessed on 04/03/2009.

Monela, G.C. & Kihiyo, V.B.M.S. 1999. Wood energy in Sub-Saharan Africa. Pp.153-160.

Morisette, J.T. & Khorram, S. 1998. Exact Binomial Confidence Interval for Proportion. Remote Sensing Brief. *Photogrammetric Engineering and Remote Sensing*, 64(4): 281-283.

Odada, E.O., Ochola, W.O. & Olago, D.O. 2009. Understanding future ecosystem changes in Lake Victoria basin using participatory local scenarios. *African Journal of Ecology*, 47(Supp.1): 147-153.

Organisation for Economic Cooperation and Development (OECD). 2002. Towards Sustainable Household Consumption? Trend and Policies in OECD countries. Online at http://www.ine.gob.max/dgipea/download/towards_sust.pdf. Visited on 19/10/2006.

Piet, G.M., and Boonekamp, A. 2007. Price Elasticities, Policy measures and Actual developments in Household Energy Consumption-A bottom-up analysis for the Netherlands.

Preston, K.M. 2012. Fuelwood collection and consumption. A case study of Lupeta, Tanzania. MSc. Dissertation.

Rahut, D.B., Behera, B. & Ali, A. 2016. Household energy choice and consumption intensity: Empirical evidence from Bhutan. *Renewable Energy Reviews*. 53:993-1009.

Ramirez, C.A., Blok, K. & Neelis, M. 2006. Adding apples and oranges: The monitoring of energy efficiency in the Dutch food industry. *Energy Policy*, 34: 1720-1735.

Ross, K.N. 2005. Sample design for educational survey research. pp89.

Sawe, E.N. 2005. Rural energy and stoves development in Tanzania. Experiences, Barriers and Strategies. Unpublished.

Starsinic, M. 2011. Incorporating a Finite Population Correction Factor in American Community Survey Variance Estimate. Research Survey Methods. pp11.

Teddie, C. and Yu, F. 2009. Mixed methods sampling: A typology with examples. Journal of Mixed Methods Research. 1:77. Doi:10.1177/2345678906292430.

Thomas, A. 2005. Development of a least cost energy supply model for the SADC region. A dissertation submitted in the fulfilment of the requirements for the degree of Masters of Science in Engineering. University of Cape town, South Africa.

Tryofos, P. 1996. Sampling Methods for Applied Research: Text and cases.

Turner, A.G. 2003 Sampling strategies. pp 45.

UNDP/World Bank. 2003. Household fuel use and fuel switching in Guatemala. Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP). Report.

United Nations. 2007. Population below poverty line, rural, percentage-United Republic of Tanzania. United Nations Statistics Division. Unpublished.

United Republic of Tanzania (URT). 2001. National Forest Programme in Tanzania (2001-2010). Ministry of Natural Resources and Tourism. pp 110.

United Republic of Tanzania (URT). 2003. The National Energy Policy. Ministry of Energy and Minerals.

Wilson, I. 2002. Some practical sampling procedures for development research. Statistical services centre, University of Reading, UK. A paper presented at a conference on “Combining Qualitative and Quantitative Methods in Development Research, held at Centre for Development Studies, Swansea University on 1-2 July 2002. York: John Wiley.

Zahabu, E. 2001. Impact of charcoal extraction to Miombo woodlands. The case of Kitulanghalo Area, Tanzania. A dissertation submitted in partial fulfilment for the Degree of Master of Science in Forestry of the Sokoine University of Agriculture.

Zewotir, T. n.d. The Effect of Stratified Sampling with proportional Allocation on Inference about Population Mean. pp 14.