Malawi Journal of Sci. & Techn. **Vol. 7**, 59–66 (2004) Printed July 10, 2005

Users' Perceptions Of Crop Residues As a Fuel For Rural Households: A Case Study Of Zomba District, Malawi

Justice S. P Mlatho,[1⋆] Elizabeth. M. T. Henry,[2] Sian. A. Jones,[1] Sarah. A. White[3]
[1] *Physics Department, Chancellor College, Box 280, Zomba, Malawi*
[2] *Chemistry Department, Chancellor College, Box 280, Zomba, Malawi*
[3] *Mathematical Sciences Department, Chancellor College, Box 280, Zomba, Malawi*

July 10, 2005

ABSTRACT
Numerous regional studies have demonstrated that the major problem facing wood reliant communities such as rural households in Malawi is the need for alternative energy sources as wood becomes increasingly scarce. Increase in the use of crop residues as fuel by these rural households would reduce their dependence on fuel wood. In this study randomly selected household heads in six villages in rural areas of Zomba district were interviewed to identify potential crop residues for use in direct combustion during cooking and heating and the problems associated with using these crop residues. Pigeon peas stems, rice husks, sorghum stalks, maize stalks, cassava stems and maize cobs were identified as the major potential fuel sources. The use of crop residues varied with location but an average of 86% of the households used crop residues for part of their energy needs. The main problems associated with the use of crop residues were smoke, fly-ash and high burning rate. A major cause of the problems was the widespread use of the three stone stove that was inappropriate for burning most crop residues.The results of the study show that crop residues have great potential for use as a fuel-wood substitute for household energy needs and should be considered as a viable alternative source of energy when energy policies are being formulated. Energy policy should also promote efforts to address the problems by development of more appropriate stoves capable of burning crop residues.

Key words: Household fuels, direct combustion, public perception, fuel-switching, food-switching, health impacts.

1 INTRODUCTION

In Malawi, 93% of the energy is provided by fuelwood, 3.5% by petroleum, 2.3% by electricity, 1% by coal and 0.2% by other biomass (Malawi Government, 2000a). The transport sector uses most of the petroleum products with households using relatively small quantities of paraffin. Coal is used mainly by industries to generate heat. Electricity consumption is dominated by industries and households in urban areas, where only 15% of the total population resides. Of the total urban population, approximately 20% have access to electricity whereas in rural areas, access drops to 1% (Chiwaya, 1999). Wood fuel, therefore, remains the major source of energy for rural and urban households in Malawi and rural demand for fuel wood for cooking and heating was estimated at two thirds of Malawi's total wood consumption (Malawi Government, 2002).

The demand for fuel wood in Malawi is growing faster than the sustainable supply and it is estimated that only 55% of the total wood consumption is supplied from sustainable yield (Malawi Government, 2002). In Malawi, fuel wood demand has contributed greatly to deforestation, estimated at 2.8% per year, and fuel wood energy demands are a significant pressure indicator for the forest resource. There is global awareness that rural communities of poor underdeveloped countries such Malawi must undergo a process of environmen-

⋆ Corresponding author: smlatho@chanco.unima.mw

tally sound energy transition from unsustainable energy sources, to structured and diversified energy sources and that this transition requires production of low cost user friendly alternative new and renewable sources of energy (Food and Agricultural Organisation, 1995; Malawi Government 2002). The potential of agricultural residues as an alternative energy source is well recognised in other wood deficient countries (Massaquoi, 1992; Wilhelm et al., 2004). The term agricultural residue refers to the full spectrum of organic material produced as a by-product in agricultural operations. There are two categories of agricultural residues: crop residues and animal residues. Crop residues include woody residues (e.g. corn cobs), crop straws (e.g. rice straws), green crops (e.g. tops of root crops) and crop processing residues (e.g. rice husks). Woody residues, crop straws and green crops residues are usually generated on-farm, whereas crop-processing residues are sometimes generated off-farm. Most developing countries have agriculture-based economies with agriculture contributing over 60% of the gross domestic product (GDP) in some cases and wastes associated with agricultural activities can represent a very significant product within the energy sector if properly utilised.

There are several countries in Africa (including Ethiopia, Swaziland and Ghana) that use large quantities of crop residues as an energy source) and studies indicate that economic, environmental and health impacts are among the factors that affect the willingness of households in a country or district to use crop residues as an alternative energy source (Benin et al, 2003; Massaquoi, 1992), For example, when the logistical cost of crop residue collection from the farm exceeds the economic value of the crop residues as a fuel the residues are usually abandoned on the field and therefore play no role in the energy supply. Crop residue collection also raises several questions including which family member collects the residues, by what means and who makes the decisions on fuel collection. Knowledge of household composition especially [1][Author ID2: at Thu Jun 23 19:17:00 2005]gender and age is therefore necessary for understanding crop residue use patterns and their potential as household fuel. There is inadequate information on the contribution of crop residues to the energy supply of rural households in Malawi. The lack of knowledge about the use of residues as an energy source may be due to the scattered nature of the residue generation, its seasonality and differences in local situations (Koopmans & Koppejan, 1997). This study was conducted to identify potential crop residues that could be used in direct combustion during cooking and heating and the problems associated with using these crop residues in rural Malawi.

2 METHODOLOGY

2.1 Study Area

Malawi is located south of the equator between latitude 9.75 degrees and 17.1 degrees south and between longitudes 30 degrees and 36 degrees east. It is bordered to the north and northeast by the Republic of Tanzania, to the west by the Republic of Zambia and to the southwest and east by the Republic of Mozambique. Malawi is divided into three regions namely southern, central and northern regions.

The study area is the rural area of Zomba district in the southern region. A detailed map of this area is shown in Figure 1. The total land area of Zomba district is 94,276 km2 and the population is 480,746. Only 7% of the total land area is forested, mainly by pine plantation (Malawi Government, 2000c). Most of the rural population of Zomba district depends on agriculture for their livelihood with a small number depending of fishing. The study was carried out in 2000.

2.2 Household Survey

A structured questionnaire was used to interview rural householders in Zomba District on the use of crop residues in direct combustion. The opinions of the rural households were used in identifying the factors that affect the use of crop residues and in identifying the problems faced by the rural households when using the crop residues as a source of energy in direct combustion during cooking. The sampling method used was a three-stage cluster sampling method as described by Miller (1991). This method was chosen to minimise the cost of the final interviews. The first stage involved selecting two from the six traditional authorities of the rural areas of Zomba District. The second stage involved selecting three villages using a simple random method in each traditional authority selected in stage one. At the third stage, 33 households in each village were selected using a systematic sampling method. Statistical analyses were carried out using Statistical Package for Social Scientists (SPSS) for Windows. Chi-squared statistic tests (Pearson and Likelihood-ratio statistic tests) of independence between village and use of crop residues were carried out to check if the variation of crop residue use with village was significant at the 5% significance level. To test the null hypothesis (that there was independence between use of

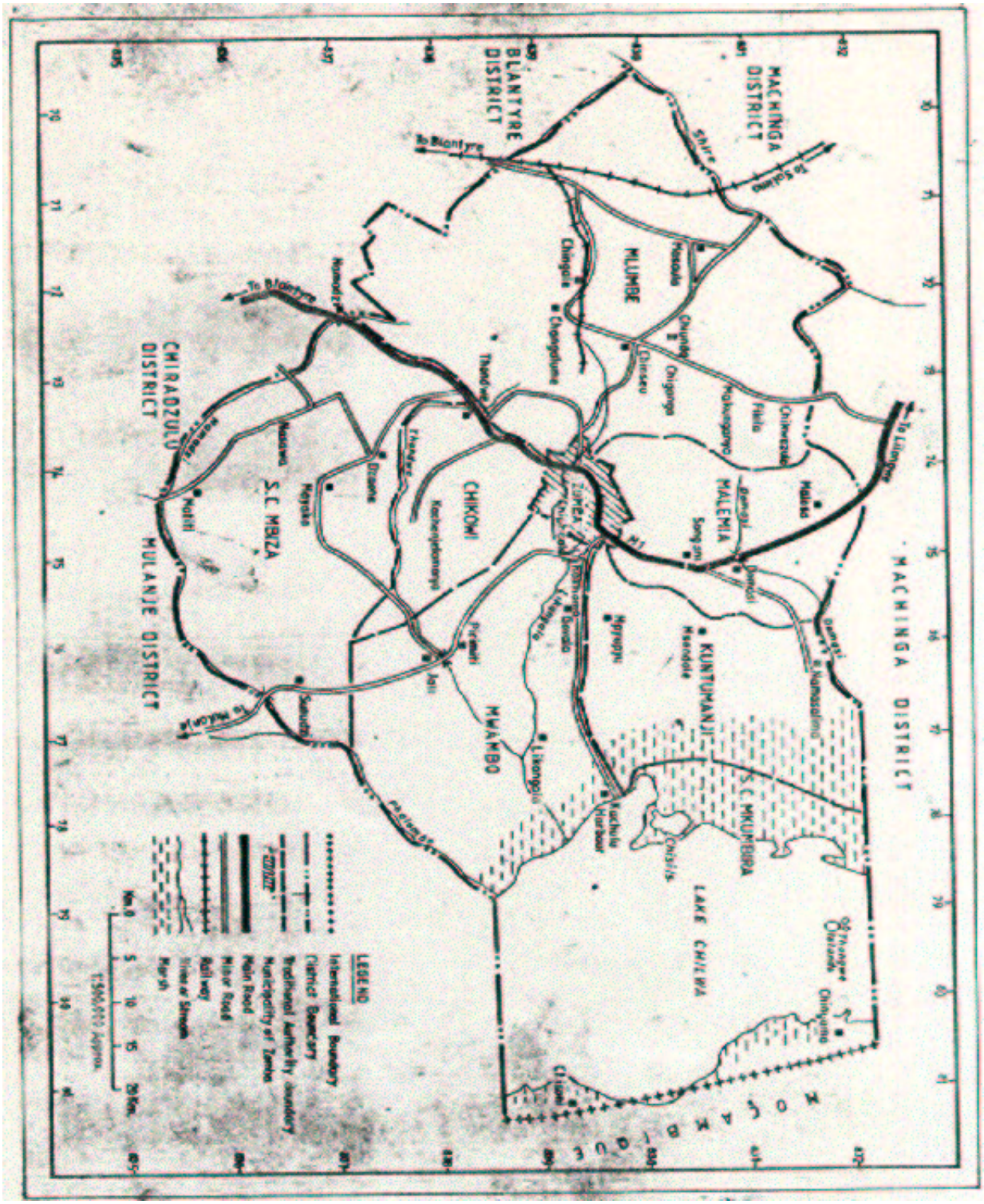

Figure 1: Study Area

crop residue and village) against the alternative hypothesis (that there was association between use of crop residues and village), the data was weighted by its frequency.

3 RESULTS AND DISCUSSION

3.1 Potential Crop Residues

From the survey carried out in the six selected villages, the crop residues identified for use in direct combustion were pigeon pea stems, cassava stems, maize stalks, maize cobs and rice husks. Only 3% of the households used rice husks as a fuel despite its availability in the households, and most households expressed ignorance on the use of rice husks as a fuel. However, 98.5% of the households used open fire stoves which are not appropriate for rice husks unless the husks are made into briquettes.

3.2 Crop Residues Use in Households

Table 1 shows crop residue use in the six villages. 171 of the 198 households interviewed used crop residues as a source of energy for part of their energy requirements although the extent to which each crop residue was used depended mainly on its availability. The p-values of both Pearson Chi-squared test and Likelihood-ratio test were below 0.001, indicating that there was evidence at the 5% significance level that there was some association between village and use of crop residues. The dependence of crop residue use on village could be due to the greater availability of firewood in some villages. The villages with the highest number of households not using crop residues were Kabota (33.3%) and Chikwenga (30.3%). During the survey in Kabota it was observed that most households used firewood from the forest of a nearby commercial estate forest, which is a distance of less than 2 km from Kabota. These households used crop residues only when access to the firewood became difficult. For the case of Chikwenga, it was noted that, unlike the other villages, there were some areas of bush nearby where households could collect firewood. It was also observed that use of crop residues by certain areas or villages reduced could be explained by low availability due to poor crop production. For example, in Chikwenga the household heads complained that they did not grow pigeon peas because the dust from a local cement company's factory hinders the growth of the crop. 98% of the households were solely reliant on firewood and/or crop residues as a source of energy. Only 1% of the households used charcoal and paraffin for cooking due to the high cost of these commercial energy sources.

3.3 Problems Associated with the Use of Crop Residues as a Fuel

Table 2 summarises the problems faced by the rural households when using crop residues as a source of energy for direct combustion. The major problems reported were ash entering uncovered pots during cooking, too much smoke produced, little to no production of char and high burning rate. 88% of respondents reported problems in using crop residues as fuel. These problems have a direct implication on food switching and fuel switching patterns, the health of the cook and the labour allocation of the households (Kgathi & Mlotshwa, 1997).

Food switching and fuel switching: The implication of the high burning rate and the production of little to no char during the combustion of the crop residues is that meals that require prolonged periods of cooking, for example beans or pigeon peas which are the important sources of protein for the households, cannot be easily cooked using crop residues because of the time and labour involved. Thus, increased use of crop residues for cooking might lead to a decreased intake of high protein vegetable foods such as pigeon peas and beans and hence have a negative influence on the dietary habits of the households as they switch from more energy-intensive to less energy-intensive foods. Beans are the recommended source of protein for Malawian families (Chilingo-Mpoma et al., 1990). Protein energy undernutrition is prevalent among the Malawian population and reduction in protein intake is known to result in reduction of physical and mental work output in adults and to contribute to high levels of sickness, mortality and impaired cognitive development among children (Malawi Government, 2000b). Therefore food-switching strategies resulting from fuel switching may have a serious negative impact on family health and national productivity.

Health impacts: Smoke can have serious health effects on the most exposed family members. Wood-fuel and crop residues smoke contains a number of potentially dangerous substances including carcinogens such as polycyclic aromatic hydrocarbons (PAHs) and benzo(a)pyrene (BaP). Studies in Zimbabwe have shown that the smoke levels from wood combustion typically exceed the recommended limit by 13 - 50 times (SADC, 1996). Acute respiratory infections (ARI) have been causally linked with exposure to pollutants from domestic biomass fuels in developing countries Ezzati & Kammen (2001); World Bank (2000); WHO (2001). Earlier studies reported that women and children are in particularly exposed to high levels of smoke in kitchens thereby having a

Table 1: Households and the fuels used for cooking and heating

Village	Total number of households for each village	Firewood	Firewood & crop residues	Firewood, crop residues and charcoal	Firewood, crop residues, charcoal and paraffin
Mpindimule	33	0	33	0	0
Chikwenga	33	10	22	0	1
Chimimba	33	2	29	1	1
Kabota	33	11	21	1	0
Chilunga	33	2	31	0	0
Chilumpha	33	2	31	0	0
Total	198	27	167	2	2
Percentage	100%	14%	84%	1%	1%

Table 2: The specific problems facing the rural households in using crop residues as a source of energy in direct combustion

Problem	Mphindimule	Chikwenga	Chimimba	Kabota	Chilunga	Chilumpha	Total of households for each reason	%-age for each reason
No problem	0	10	3	9	1	1	24	12
High burning rate	12	16	10	18	23	22	101	51
Ash goes into the food during cooking if pot is not covered	29	23	19	22	32	32	157	79
Does not produce char	23	16	14	19	31	27	130	66
Use large quantity of the crop residues to cook one main meal	1	0	9	7	0	0	17	9
Too much smoke	10	2	13	2	2	0	29	15

high risk of respiratory diseases and eye problems SADC (1996), World Bank (2000). Children in Gambia carried on their mothers' back while the mothers cooked over smoky cookstoves were six times more likely to develop ARI than unexposed children (World Bank, 2000).ARI is the number one cause of infant and child mortality in developing countries and among children less than five years old, 27% of deaths are associated with ARI (Bendahmane, 1997).

Labour allocation and gender implication of crop residues: Table 3 gives information on the members of the households who do the fuel collection and cooking in the 198 households interviewed. Wives were the main fuel collectors in the study area, followed by children. These findings support the predictions of household economics, which teaches that household chores like fuel wood collection are expected to be undertaken by members of the household with a low opportunity cost of labour such as women and children (Kgathi & Mlotshwa, 1997). It is noteworthy that when husbands were involved in fuel (especially firewood) collection, most of them (78%) bought the fuel from traders. There were more men involved in fuel collection in Chilunga than the other villages because there are few sources of firewood in that area and many of the households buy firewood from traders.

Wives are also cooks in most households with an average percentage of 87%, seconded by children with 31% and lastly husbands with 4%. Thus, in the households of Zomba Rural, women do much more of the cooking than men, which means

Table 3: Labour allocation for fuel collection and cooking in households

		Fuel collection			Cooking duty		
Favourite fuel	Village	Wife	Children	Husband	Wife	Children	Husband
Firewood	Mpindimule	29	6	5	30	15	0
	Chikwenga	26	5	3	28	9	0
	Chimimba	19	1	4	20	2	0
	Kabota	29	3	3	30	10	1
	Chilunga	29	14	13	29	18	1
	Chilumpha	26	9	3	27	7	1
Crop residues	Mpindimule	1	0	0	1	0	0
	Chikwenga	2	1	0	2	0	1
	Chimimba	4	3	0	3	0	3
	Kabota	0	0	0	0	0	0
	Chilunga	1	0	1	1	0	0
	Chilumpha	2	0	0	2	0	0
Percentages		85%	21%	16%	87%	31%	4%

that health effects associated with the use of crop residues will have more impact on women than other members of the households.

3.4 Factors Affecting Use Of Crop Residues As Source Of Fuel In Zomba District

3.4.1 Availability of firewood

As discussed above, the extent to which the crop residues were being used at the time of the survey depended on the availability of firewood in each village. Where firewood is readily available people are less willing to use crop residues as in the case with Kabota and Chikwenga.

3.4.2 The combustion products

The effect of the crop residue combustion products on the health of the cook and the household members is the other important factor to be considered. This is why tobacco stem, which produces a choking smoke, is not utilised as fuel. 87% of the households (Table 4) complained of smoke produced during combustion of both firewood and crop residues as being a problem. This might be due to the three stone stoves used for cooking by over 98% of the households and the poor ventilation of the kitchens. The problem of fly-ash going into the food during can have a serious negative effect on the quality and acceptability of the food.

3.4.3 The quantity and seasonal availability of the crop residues

The quantity of the crop residues produced each year also affected the degree to which residues were being used. The availability of the residues was seasonal and at times there were no crop residues available for use as a fuel. It was found that most of the households used crop residues for a period of up to two months after harvest. Very few households used the crop residues for three or more months because of the quantities available. However the period of use of the crop residues could be increased if the households were using a more fuel-efficient stove than the three stone stove which has efficiency in the range 15% and 20% (Kammen, 1995).

Table 4: The number of households that complained of smoke being a problem (33 households interviewed for each village).

Village	Smoke a problem	Not a problem
Mpindimule	29	4
Chikwenga	31	2
Chimimba	31	2
Kabota	22	11
Chilunga	30	3
Chilumpha	30	3
Total	173	25
Percentage	87%	13%

3.4.4 Competing usage

Crop residues have other various usages apart from being used as a source of fuel. Table 5 shows the other uses indicated by the households interviewed. A high percentage of the households (89%) used maize stalks as compost in the garden thereby decreasing its utilization in fuel. 45% of the households used cassava stems for planting purposes, whereas sorghum stalks were mainly used as a building material. None of the households inter-

Table 5: Other uses of crop residues (percentages)

Crop residue	No other use	Compost in garden	Planting	Feeds for animal	Building material	Burn to clear the garden
Maize stalk	9	89	0	0	2	0
Cassava stems	55	0	45	0	0	0
Sorghum stalks	58	2	1	0	30	9
Pigeon pea stems	95	0	0	0	0	5
Maize cobs	100	0	0	0	0	0
Rice husks	100	0	0	0	0	0

viewed reported an alternative usage of maize cobs and rice husks. Thus, maize cobs, rice husks and pigeon peas stems have a high potential for use as a source of fuel in direct combustion since they have very limited alternative uses.

3.5 The Most Popular Crop Residues In Zomba District

Pigeon pea stems, sorghum stalks and cassava stems were reported as the most popular crop residues that households were willing to use. Table 6 shows the frequency with which households chose each crop residue as the most appropriate one for use. The reasons for the households choosing these residues as being the best for direct combustion were as follows:

3.5.1 Good char production

One of the reasons for households choosing these crop residues was that they produce more char than the other crop residues. Most of these crop residues produce some char and that means the households can use them to cook meals, which require prolonged periods of cooking. About 61% of households used sorghum stalks, pigeon peas stems and cassava stems because of the char.

3.5.2 Less ash production

The households also chose the most popular crop residue on the basis of the ash produced during combustion. A high percentage of households selected their favoured residue because it produced less ash during combustion. One of the factors that affect the production of ash during the cooking of a particular meal is the amount of residues used, which in turn relates to the calorific values and burning rates of the different crop residues.

4 CONCLUSION AND RECOMMENDATIONS

Several problems have been identified with the use of crop residues as a fuel in direct combustion and some of them are smoke, quantity and seasonal availability. It has been found that a large percentage of the households in rural areas of Zomba District are using the crop residues as a fuel despite the problems associated with their use. These results suggest that crop residues, which are produced in large quantities in Zomba District, and Malawi as a whole, could provide a large amount of energy for rural households. It is therefore recommended that crop residues should be promoted as a source of energy whenever energy policies are being formulated. There is also a need to develop a crop residue stove that will reduce most of the problems associated with the use of crop residues as fuel in households. Introduction of a fuel saving stove for use with crop residues would reduce the amount of crop residues consumed per meal cooked and, thus, reduce the labour and health hazards for women and children who do most of the fuel collection and cooking

ACKNOWLEDGEMENTS

The authors would like to thank Chancellor College Research and Publications Committee for their funding of this project. Our gratitude is also extended to the Faculty of Science at Chancellor College for financial, administrative and technical support to Justice Mlatho during his MSc. in Environmental Sciences studies.

References

Bendahmane, D.B. (1997). *Environmental Health Report No. 38: Air Pollution and Child Health - Priorities for action.* U.S. Agency for International Development, U.S.A.

Chiligo-Mpoma, M., Butao-Ayoade, R., Chikagwa, I. & Cusack G. (1990). *Nutrition facts for Malawian families.* Department of Economic Planning and Development, Malawi.

Chiwaya, A. (1999). Introduction to the Malawian Power Sector. *M. R. Bhagavan (ed.) Reforming the Power sector in Africa.* pp 19–28. Zed books Ltd, London & New Jersey.

Environmental Affairs Department (EAD) (2000). *State of Environment Report for Malawi 2000.* Ministry of Natural resources and Environmental Affairs, Malawi.

Ezzati, M. & Kammen, D.M. (2001). Quantifying the effects of exposure to indoor Air Pollution from Biomass Combustion on Acute Respiratory infections in Developing countries. *Environmental Health Perspectives (5) 109.* 481-488.

Kammen, D. (1995). Cookstoves for the Developing world. *Scientific American 273.* 72–75.

Kgathi, D.L. & Mlotshwa, C.V. (1997). Fuelwood Procurement, Consumption and Substitution in Selected Areas of Botswana. *D. L. Kgathi, D. O. Hall, A. Hategeka, & M. B. M. Sekhwela (eds.) Biomass Energy Policy in Africa: Selected Case Studies.* pp 10–57. Zed Books Ltd, London & New Jersey.

Koopmans, A. & Koppejan, J (1997). Agricultutral and Forest Residues generation, Utilisation and Availability, paper presented at the *"Regional Consultation on Modern Application of Biomass Energy"* in Kuala Lumpur, Malaysia, 6–10 January 1997.

Massaquoi, J.G.M. (1992). Agricultural Residues as Energy Sources. *M.R. Bhagavan & S. Karekezi (eds.) Energy for Rural development.* pp 76–85. Zed books Ltd, London & New Jersey.

Miller, D.C. (1991). *Handbook of Research and Social Measurement.* SAGE publishing Inc. USA.

Ministry of Agriculture and Irrigation Development (2000). *National Plan of action for Nutrition.* Ministry of Agriculture and Irrigation Development, Malawi.

Ministry of Energy and Mining (1997). *National sustainable and Renewable Energy Programme.* Ministry of Energy and Mining, Malawi.

National Research Council of Malawi Agricultural Science Committee (1999). *Malawi Agricultural and Natural Resource Research Master plan.* Ministry of Agriculture and Irrigation Development, Malawi.

SADC (1996) *SADC Regional Workshop on Biomass Energy Technology:* 30 Sept. — 18 Oct. 1996. SADC, Malawi.

World Bank (2000). *Energy and Health for the poor: Indoor Air Pollution.* Issue No. 1 September 2000. [online]. Available: `http://wbIn10108.Worldbank.org/sar/sa.nsf`. [2001, August 15].

World Health Organisation (WHO) (2001). *An Anthology on Women, Health and Environment: Domestic Fuel Shortage and Indoor Air Pollution* [Online]. Available: `http://ww.who.int/m/topics/women-environment` [2001, August 15]