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Energy System and Fuel Flow in a Rural Post-war Settlement in Rwanda

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Physics engineering

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Preface

Many top-down studies have been done to describe the national fuelwood energy systems in sub-Saharan African countries. Few of them tell anything about the actual course of fuel-related events in rural villages in their own context. Hopefully, this study will broaden the knowledge of local energy systems and may be useful in the understanding of huger energy and land use matters as well as being an interesting comparison to other case studies within the field. The target groups are researchers, development agencies, NGOs and other people of interest.

The essential data collection for this master thesis has been carried out during February–April 2007 as a minor field study (MFS) in the village Ngera in southern Rwanda. Ngera is a rural post-war settlement that is included in the environmental research exchange programme between the Swedish International Development Cooperation Agency research cooperation Sida-SAREC and the National University of Rwanda. This study is also financed with an MFS scholarship from Sida.

The thesis will finalise the authors' master degrees – Anna Bjereld, physics engineering student at Chalmers University of Technology, Gothenburg, and Johanna Thorén, biology student at Göteborg University, Gothenburg.

Acknowledgements

This study would not have been possible without several people's help. First of all we would like to direct special thanks to professor Hans Egnéus at the School of Global Studies, Göteborg University, who made the field trip to Rwanda possible, supported us and inspired us.

We also want to thank our eminent supervisors: Firstly, Ph.D. student Emmanuel Havugimana at the Department of Geography, National University of Rwanda, and at the School of Global Studies, Göteborg University, shared his knowledge with us and helped us to get in contact with the National University of Rwanda and the people in Ngera. Secondly, thanks to Professor Sverker Molander at the Department of Energy and Environment, Chalmers University of Technology, and associate professor Göran Wallin at the Department of Plant and Environmental Sciences, Göteborg University, who helped us to author this report and to look at our study from different perspectives.

Among all people in Rwanda, special thanks are directed to our open-hearted and talented interpreter Anselme Nirere, translation and interpretation student at the National University of Rwanda. Ph.D. student Donat Nsabimana at the Department of Biology, National University of Rwanda, and at the Department of Plant and Environmental Sciences, Göteborg University, helped us with soil sampling and soil analysis. Fidèle Hatungimana, in charge of social affairs by the Ngera Sectors office, helped us to understand the institutional network around Ngera and also shared his knowledge about fuel economic stoves. John R. Gakwavu, biology master student at the National University of Rwanda, helped us with plant identification and biomass inventory.

From the National University of Rwanda we received a warm welcome and access to personnel as well as laboratory resources, and for that we are very grateful.

Thanks also to Sida (Swedish International Development Cooperation Agency) that financed this study with MFS scholarships.

Last but not least we want to thank the villagers in Ngera, who gave us of their time to share their knowledge, experience and reflections with us.

Abstract

There is a need to understand what energy resources mean for the long term sustainable development in rural areas, to understand how to improve people's life quality and mitigate environmental impacts. This study aims at discussing the problems and the sustainability of the energy system in one rural settlement in the southern Rwanda, called Ngera. The settlement is one of the villages that were built after the genocide in 1994 to manage and resettle the returnees.

Through interviews, observations, participatory exercises and quantitative measurements, a description of the energy resources and energy system was achieved, and the processes biomass production, collection, combustion and energy services were understood and analysed.

Woody biomass is the main energy resource in Rwanda. For domestic use it serves as energy for food preparation, water heating, space heating, lighting and clothes washing. There is no electricity in the village and the inhabitants mostly collect and use trees and tree litter from nearby public forests and tree plots. The biomass of the woody plants in the forest where most of the villagers fetch fuel is 50-300 t/ha, depending on how dense the trees grow. The villagers spend in average one hour in the forest every day to collect and transport fuelwood to their homes. Through combustion of the fuelwood in a traditional Kinyarwanda three-stones stove or a fuel-economic stove called rondereza, the villagers get energy. After combusting the fuel the ash is put on arable plots to serve as fertilizer. Other energy carriers that the villagers use are non-woody biomass, fossil fuels like kerosene and diesel, as well as galvanic batteries and solar cells. They are used to get light or to use equipment such as radios and watches.

The Kinyarwanda stove is the most common in the village and has an efficiency of 16-21 %. Although the rondereza is well promoted by the government there are only two households in the settlement that have invested in it. There are some possible reasons for that; firstly, traditions keep people to what they are accustomed to, and secondly, there is a lack of both skills and monetary means. Thirdly, there are reasons such as lack of information, since the settlement is segregated from other villages, and participation in the training and education is scarce. Education is often dictated by men for men, and since men are not using the stove they are not keen on replacing stoves. Fourthly, Rwandan traditions say that one should not talk about family matters outside the family and therefore the knowledge is spread slowly.

The organic law, implemented in 2005, aims at protecting the environment. It forbids people to cut or harm trees. The law has led to an increase in labour input for the inhabitants to find fuel. Even though it is a good initiative in the long run, it affects and worsens especially the women's situation in Rwanda. They have to spend more time away from home, less time on their children, education and income work.

Contents

Definitions

biomass	living and recently living biological material, usually referred to fresh or dry mass
ecosystem	all living organisms and their habitat functioning together within an area
human capital	human labour, skills, gender roles, knowledge and other human attributes
natural capital	ecosystem, environment and all natural elements
physical capital	tools, equipment, infrastructure, buildings and other human-made capital
social capital	organisations, laws, policies, information flows and norms as well as formal and informal relation webs
energy system	the extraction of energy sources, transportation of energy carriers, conversion, distribution, and the final conversion that provides the desired energy service
livelihood strategies	strategies to improve life quality and protect from short-term and long-term changes in a livelihood situation
sustainable development	development that meets the needs of the present without compromising the ability of future generations to meet their own needs

1. Introduction

"If you cut a tree, you should grow two trees, Rwandans listen to the importance of a tree".
Rwandan song about tree cutting

1.1 Background

90 percent of Rwanda's population live in rural areas and are engaged in agriculture (Mitchell, 1997). In southern Rwanda about 50-70 percent of the families have farms smaller than 1 ha and in large areas 30-50 percent of the households' plots are less than 0.5 ha (Drechsel, 1998). The scarcity of land forces people to live and cultivate on steep slopes and acid soils where it is difficult to grow crops. In 1989, approximately 50 percent of Rwanda's cultivated land was on slopes of 10 degrees or steeper. Cultivation and deforestation on steep slopes makes the ground more exposed to running water and increases soil erosion (Gasana, 2002).

The high population growth increases the demand for land to agriculture, which has lead to destruction of the wetland and reduction of size of the national reserved areas. In addition to the massive deforestation, a loss of important genetic diversity within Rwanda's natural forests is occurring.

The total forest area in Rwanda is 307,000 ha, or approximately 12 percent of the total land area. Natural forests are estimated to have covered 36 percent of Rwanda, an area which has been reduced by 78 percent since 1990. Deforestation due to an increased demand of fuelwood, constructing material, over-grazing and cultivation of steep hills have all contributed to the highest deforestation rate in Central Africa (Mitchell, 1997). During the big resettlement program in the 1990s when hundreds of thousands new houses were built, trees were cut in order to get space and timber to construct the houses. One of the biggest issues for the villagers today is thus to get fuelwood for food preparation.

Reforestation programs have added eucalyptus trees to denuded hillsides and roadsides, though not on a scale sufficient to effectively counteract erosion. Reforestation programmes and tree cultivating started already in the 1930s and mainly eucalyptus and agroforestry species such as *Grevillea sp.*, *Cedrella sp.* and *Calliandra sp.* are planted (MINITERE, 2005).

1.1.1 Energy use in Rwanda

In Rwanda, biomass accounts for between 94 to 96 percent of total energy consumption, where fuelwood and plant wastes are the main fuels in households, industries and crafts (MINITERE, 2005, Wong, 2005). Although there are several field studies of local woodfuel systems in "developing" countries, little is known about the local fuel supply and fuel use in Rwanda. To get the ability to improve people's life quality and mitigate environmental impacts, there is a need to understand what energy resources mean for the long term sustainable development in rural areas. This case study will try to deepen the knowledge and understanding of the fuel use through describing the human, social, environmental and institutional issues through empirical investigations of the fuel use in a rural settlement and can be used as an opening for intellectual discourse.

A general energy system for the energy and material flows of any energy resource is described in *Figure 1*. The figure will act as an understanding for the fuelwood energy system in a rural settlement in Rwanda. In Rwanda 5,000 tonnes of fuelwood are consumed every day for domestic use. The supply is determined by the access to natural and plantation forests in the country as well as dung and crop residues from crop yields. The amount of dung and crop residues is though declining due to falling agricultural and livestock productivity (Wong, 2005).

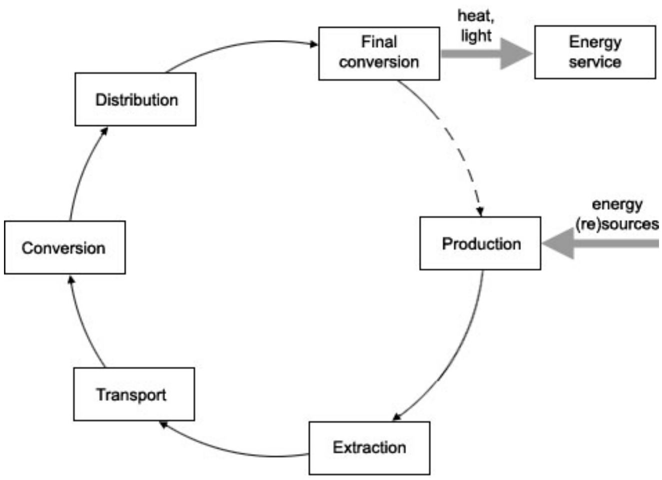

Figure 1. An arbitrary energy system can be understood as the material flow of an energy carrier (Rydén et al., 2003).

Another energy source in Rwanda is hydropower, which contributes to four percent of the total energy consumptions, and imported petrol products, which is used in 80 percent of the road transports (MINITERE, 2005).

1.2 Purpose and objectives

This case study aims at investigating and describing the energy system in one rural post-war settlement in Rwanda. Since biomass is the most commonly used energy carrier, the study will focus on processes in the woody biomass energy cycle, treated as a modified life cycle. The flow of energy, energy carriers and the management of the energy resources will be practically understood and theorised out of a bottom-up perspective. The study has an interdisciplinary approach, taking the technology as a starting point to describe the energy system, ending up in an understanding of its connections to and impacts on the social system.

The problems and the sustainability of the energy system will be discussed. The target is to analyse the ecosystem's potential to provide energy, and the consequences of the present energy system on the society and on the nature. The discussion will be based on the results of two objectives.

Objective 1. Describing the energy resources and energy system. This part aims at finding the major energy and related material flows in a rural post-war settlement. A simple fuelwood system looks like in *Figure 1* and the aim of this first objective is to concretise the system further.

Objective 2. Understanding and analysing the processes in the energy system. This is a sequel to the first objective, focusing on the human, physical, social and natural inputs to and outputs from different processes in the energy system (see *Figure 1*).

- *Production – biomass production*: Energy of sun radiation is bound in organic matter. The production and growth of biomass in the forests due to the ecosystem's conditions of growing as well as human's influences in outtake and input of biomass (needs, planning and conditions) which also is regulated by the legal actions and institutional aspects (law, policies and ownership). This process will be emphasised because the production of biomass is decisive for the supply of biomass.
- *Resource extraction – fuel collection*: After harvest, the biomass is no longer regarded as a part of the nature but rather as fuel. The process regards conditions and labour input to obtain fuelwood from forests. This process will be emphasised because the volume of biomass is decisive for the people's outtake of biomass and it is closely linked to biomass production.
- *Final conversion – combustion*: Energy bound in the fuel is transformed to heat and light. This part embodies stove use, efficiency of stoves and combustion and usage of fuel, and also how the energy carriers are used, quantitatively as well as qualitatively. This process will be emphasised because the procedure of combustion is relevant for how much energy the villagers obtain.
- *Consumption – energy services.* The heat and light from the combustion are used for different energy purposes – food preparation, lightening and other energy services. Also energy services that demand other fuels than biomass will be regarded. This process will be emphasised because energy services need the energy of combustion. The competition between different energy carriers and services determine the biomass demand.

1.2.1 Delimitations

The study will concentrate on the major energy and related material flows, which implies an inner limitation where some subsystems remain 'black boxes'. The outer limitation of the energy system is physically the borders of the settlement and its nearby surroundings, and institutionally the Rwandan policies and laws. It is the private households' fuel consumption that will be investigated, which means that common energy services, like the mill, common fires and beer production etc. not will be looked at.

The three processes transportation, conversion and distribution are not thoroughly investigated within this study. The transportation occurs in the absence of vehicles and equipment and the process of transportation does not have an impact on the physical flows of matter and energy in the energy system. Thus it is not complex enough to need a comprehensive analysis. Conversion is not relevant for a fuelwood energy system, since hardly any conversion occurs. Neither is distribution relevant within this study, except for some trade. Because of the geographical limitations for this study, it does not play an important role. The three processes are all looked at but do not play such an important role as the four chosen categories, which will be further discussed in chapter 3.2.

Biomass that is not used as fuel, that is, the biomass that is grown as crops and used as food or forage, will not be investigated. Neither will the possible transports of people with motor vehicles be studied.

2. The Rwandan context

Rwanda is a small landlocked country in East Africa with a surface of 26,340 km^2 and a population of 8.9 million, according to 2004 census (Sida, 2007). Rwanda is the 19th poorest country in the world according to the International Monetary Fund (2007) and also the most densely populated country in Africa (MINITERE, 2005). About 50 percent of the population is under 16 years of age. The population growth rate is of 2.2 percent and the life expectancy is 44.2 years (Sida, 2007).

Figure 2. Map of Rwanda (CIA, 2007).

2.1 History

Rwanda is, unlike many other countries in Africa, a nation with a common history and religion as well as language and culture. The three ethnic groups of Hutus, Tutsis and Twa migrated to Rwanda as farmers, pastoralis people and hunters and gathers, respectively. The Kingdom of Rwanda was formed in the 15th century by a Tutsi pastoral tribe. The Kingdom of Rwanda occupied approximately the territory controlled by the modern state of Rwanda (University of Pennsylvania, 2007).

In the end of the 19th century the first Europeans came to Rwanda. The Germans replaced the Kingdom of Rwanda and put it under the German rule as a part of German East Africa in 1885. After the defeat of the Germans in World War One it became a mandate territory of the League of Nations under the administration of Belgium. Belgium controlled the country until the independence in 1962 and was harsh in the ruling and more discriminating towards the people. In 1935 a national identification card on the basis of ethnicity was introduced and the people were registered as Tutsis or Hutus depending on how many cows they owned. The minority Tutsis was favoured in the Belgium ruled system and became the elite of the society. They were selected for education and administrative positions (Gendercide Watch, 2007).

The favouring of the Tutsis led to opposition and hatreds among the Hutus and conflicts between the groups (Ohlsson, 1999). In 1952 dissatisfied Hutus began the first massacres of the Tutsi population, because of the unfair mistreatment the Hutus had experienced. The killing was supported by the Belgian authorities, who had at that time switched alliance. Approximately 15,000 Tutsis were killed and more than 100,000 were driven into exile in neighbouring countries. In 1962 the Tutsi monarchy was abolished by the Hutu elite and the year after the country became independent.

The Tutsis who remained in the country were more or less neglected by the Hutus and under the regime of Juvénal Habyarimana, installed in 1973, even more Tutsis fled (Genercide Watch, 2007). Habyarimana turned the country into a one-party state, ethnically segregated where ninety percent of the educational and public positions were be held by Hutus (Ohlsson, 1999).

The Tutsi in exile later formed the Rwandan Patriotic Front, RPF, with its base in Uganda. In October 1990 they attacked Rwanda, which was the start of a civil war. RPF were claiming rights for the Tutsis to return to Rwanda and opposed against the undemocratic regime. The war lasted for two years and in 1992 peace negotiations between the Habyarimana's regime and the RPF in Arusha in Tanzania started. Habyarimana finally accepted an internationally-mediated peace agreement, which granted the RFP a share of political power and a military presence in the capital Kigali. Many members of Habyarimana's government and army did not agree with the negotiations and the situation in the country continued to be unstable.

The outbreak of the conflict came in April 1994 when the airplane with president Habyarimana was shot down. This was the beginning of the genocide where approximately 800,000 people, mainly Tutsis and moderate Hutus, were killed (Gendercide Watch, 2007). After three months of killing the RPF finally defeated the Hutu regime and ended the war and genocide in July 1994. Nearly two million Hutus then fled the country (CIA, 2007). These Hutus – the new case refugees – and the Tutsis – the old case refugees who fled the country in 1959 and during the regime of Habyarimana and descendants of them – returned in a period of four years, which resulted in a settlement crisis.

2.1.1 Settlement crisis

After the genocide, Rwanda faced a settlement crisis when over 2.5 million refugees returned from neighbouring countries in a period of four years (Hilhorst, 2000). Both new case and old case refugees were in need of shelter. There were survivors of the genocide who found their homes destroyed or feared to go back to their former homes and old case refugees who had no homes to return to or who no longer had right to claim their properties back.

Traditionally, people in Rwanda lived scattered, but after the genocide a villagisation policy was implemented, where one of the purposes was to settle all the returnees, but also to manage the land scarcity. Establishment of the settlements, so-called imidugudu (plural form of umudugudu), started up between 1994 and 1997. The government, with support of international organisations, helped the people to settle in villages with socioeconomic infrastructures such as schools, health centres, water and access to roads. The imidugudu were intended to help people to become self-sufficient, to enhance security of the people in rural areas and settle people of different ethnic origin and background together so as to enhance peace and reconciliation (RISD, 1999).

One of the intentions with the villagisation policy was to improve land use and distribution so that all people would have access to land and increase their production. Unfortunately it has not always turned out that way. People do not have land or the land is far away and their production rather decreases. (RISD, 1999)

Today, approximately 19.3 percent of the dwelling units are grouped in settlements around the country (Havugimana, 2007). The imidugudu have been little investigated and there is not much knowledge about how people get fuel and how the villagisation policy implementation has succeeded.

2.2 Climate and vegetation

Rwanda is often called the Land of a Thousand Hills and the country is dominated by mountain ranges and highland plateaus of the great watershed between the Nile and the Congo river basins. The vegetation in Rwanda ranges from equatorial forest in the north-west to tropical savannah in the east. There are wetland areas in the floodplains, national parks and forest reserves (Mitchell, 1997).

Due to the country's high altitude, the temperature and precipitation is more moderate than surrounding hot and humid regions. Almost all Rwanda is 1,000 meter above sea level; the central plateau is between 1,500 and 2,000 meter and in the north the highest peak is 4,507 meter. The temperature varies in different regions due to the variation in altitude. The areas east of Kigali have an average temperature of 17 degrees Celsius and an annual precipitation of approximately 1,500 mm. In south west of Rwanda the average temperature is 20 degrees Celsius and the annual precipitation is 1,200 mm (Nationalencyklopedin, 2007).

The climate is characterised by two rainy and two dry seasons. The long rain period lasts from mid-March to mid-May and the short rain period occurs during mid-October to mid-December. The growing seasons range over long periods and arable land is cultivated the whole year round. Despite relatively high rainfalls, Rwanda suffers from frequent droughts caused by erratic rainfall patterns.

2.3 Policies and laws

The Rwandan government has implemented policies and laws regarding deforestation and land scarcity problems but also regarding reconciliation and social structures within the country. These are presented in chronological order underneath and serve as an understanding to further readings.

Imidugudu (1994-)

Already before 1994 the need for housing was big, but the situation worsened during the genocide when houses and infrastructure were destroyed. In January 1997 the government implemented the ministerial directive, giving instructions on the procedures to be followed in both urban and rural housing construction. From then on, umudugudu construction was the only legal way to build on a plot (MINITRAPE, 1997). In four years, NGOs and agencies built 250 communities with 85,000 houses. Many more were constructed with local means only (Hilhorst, 2000). The Ministry of public works (MINITRAPE) had guidelines and procedures to be followed in the construction of imidugudu and so had the UN refugee agency (UNHCR), which provided most of the funding for the shelter construction programme. The construction of imidugudu started already in 1994 (see 2.1.1) after the end of the genocide, and the guidelines came in 1997. Hence they were hardly followed. The urgent need to provide shelter for all those who did not have a home contributed to sometimes a careless kind of building and little attention was therefore paid to provision of social infrastructure and access to farmland.

Inheritance Law (1999)
The 1999 Inheritance law gave all children recognised by civil law, male and female, the right to inherit property. Women got the right to inherit from fathers or husbands. This was a step in the direction to a non-discrimination policy, where women and men are equal. A family council is to determine the share of the inheritance to be inherited by the children and the share that shall be earmarked for the raising of minors. In the practice, however, women's rights to claim ownership are still weak. This is because people in rural areas often marry without signing proper marriage contracts, and thus the children are illegitimate in a juridical sense. The law cannot be applied retroactively, which implies that a great number of widowed or female orphaned genocide victims do not have the possibility to inherit their husbands' or fathers' land (Pottier, 2006, Scholz, 2005).

Gacaca court (2002)
In 2002 the Rwandan government launched the court system called gacaca. The gacaca court was implemented in order to try the more than 115,000 genocide suspects and to speed up the legal proceedings by using as many courts as possible and also for the reconciliation of Rwandans. From December 1996 to December 2000, the Rwandan courts managed to try about 6,000 suspects and at that rate it would take another 60 years to prosecute all the prisoners. There are 254,000 elected judges in 11,000 gacaca courts and the tribunals are legally established judicial bodies and can impose sentences as high as imprisonment (Inkiko-Gacaca, 2007).

National Forestry Policy (2004)
In 2004 a forestry policy was implemented to increase the total national forest area to 30% of the national land until 2020. Traditionally, gender roles forbid women to plant trees unless they are widowed or divorced, or if their husbands are absent or ill, even though there is no formal prohibition against women planting trees (den Biggelaar, 1996). The new policy, however, intends to provide women with enabling factors (i.e. education and training) and expects women to be dominant in the agroforestry activities. The policy involves afforestation programs, improved forest management, consumption reduction and capacity building. (MINITERE, 2004)

November 20 the Rwandans celebrate the National Tree Planting Day – a public holiday – when people are expected to go out planting trees. The National Tree Planting Day has the objective of increasing forestlands, mainly through planting trees on bare hillsides.

Land reform (2005)
Huge groups of returning refugees and landlessness after the genocide implied a need for a new land reform. The Rwandan government, promoted by the World Bank and FAO, finally decided on the 2005 Land law. The law promotes a liberalisation and privatisation of the land market, encouraging people to register their land estates that exceed a consolidating area of 1 ha. Since the average size of a Rwandan household's land properties is about 0.75 ha, most households are thereby banned from registration. In practice, it means that they are formally landless. (Pottier, 2006).

Organic law regulating tree devastation (2005)
In April 2005 the Organic law concerning protection, conservation and promotion of environment in Rwanda came into force. It says that it is forbidden to burn and cut trees or cause others to do so in protected forests and other protected areas. Anyone who does so is punished with imprisonment or fine. Furthermore it says that the National Fund for Environment will support anyone who aims at 'controlling soil erosion and drought' and 'afforestation and forestry, using renewable energy in a sustainable manner, using modern cooking stoves and any other means that can be used to protect forestry' (Official Gazette of the Republic of Rwanda, 2005). The modern cooking stoves, familiar as 'rondereza', reduce smoke emission, which protects stove users from inhaling cooking smoke (Karlsson, 2001).

3. Material and methods

The settlement chosen for this field study is called Ngera situated in southern Rwanda, see *Figure 2*. It was built in accordance with the imidugudu guidelines during the years of resettlement and is also one of the imidugudu that is investigated within the environmental research exchange programme between Sida-SAREC and the National University of Rwanda.

3.1 Description of the area and the village

Ngera is one of the imidugudu that was built after the genocide. It was established for returnees in 1997 by the Belgian project Cooperation Belgo-Rwandaise, Project de Relance Butare Sud-Est (Birgersson et al., 2006). People who live there are both new and old case refugees. The major part of the inhabitants is women and many of the villagers lived close to the settlement before they moved there. Some of the villagers became orphaned, widowed or refugees during the war or genocide.

The Ngera settlement is located on a hill ridge in a previous forest area about 20 km southwest of Huye. There are 41 houses in five rows covering an area of about three hectares, see *Figure 3*. When this study was carried out some of the houses were uninhabited and there are thus only 33 households in the umudugudu. The stove users in 29 of these households have shared their knowledge, experience and thoughts to enable this study.

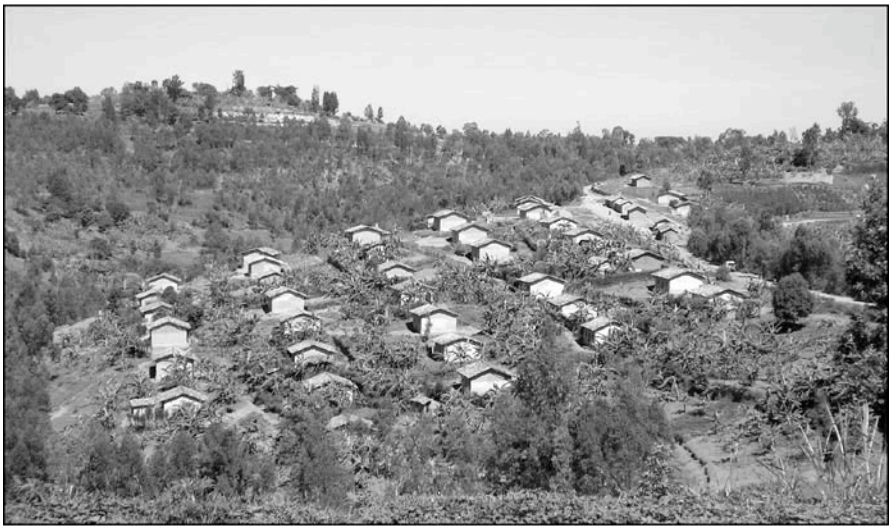

Figure 3. The Ngera umududgudu settlement. There are 41 houses in the village; all surrounded by a small garden where crops are grown or livestock is kept.

Close to the umudugudu there is a school and a health service centre. The main road to Huye is about 800 meters from the settlement. Three bars and a shop are placed in the centre of the village where the market is held in the evening. There is also a central diesel mill, where people can grind crops. The villagers get water from the water source close to the main road or the pond in the valley. While this study was carried out a coffee washing station close to the main road was under construction. Some people in the village and from nearby villages grow coffee plants. In the future coffee beans will be washed and treated in the station before exportation. Villagers who work in the washing station say that they get fuelwood, such as eucalyptus and coffee plants, from there.

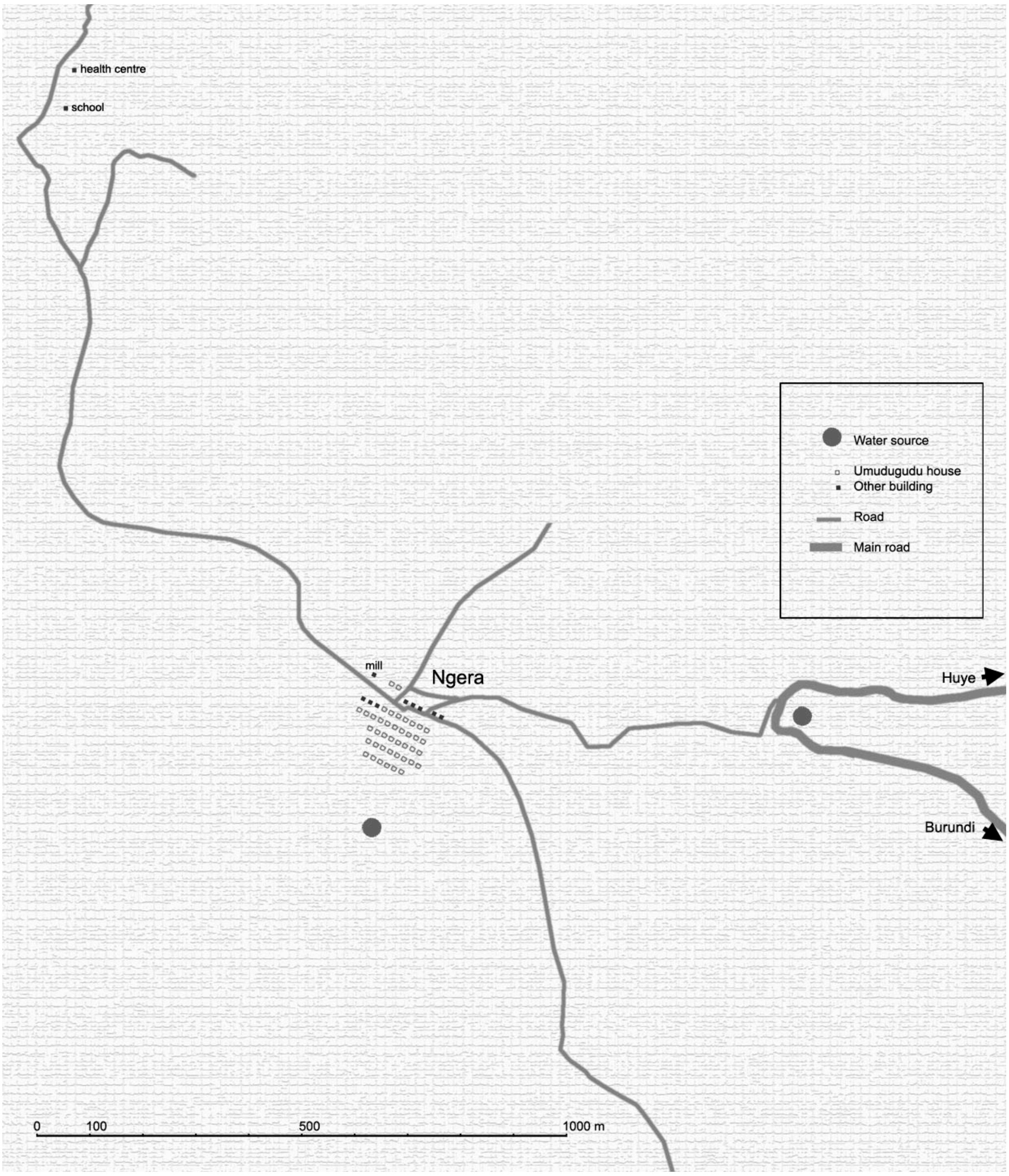

Figure 4. The Ngera umudugudu and its surroundings.

The size of an average family in Ngera is 3.8 members. The number of female heads of households in Ngera is higher (44.7 percent) than the average number in Rwanda (14.6 percent), because there are many widows and unmarried women (Birgersson et al., 2006). The interview respondents in this study have moved to the umudugudu between 1997 and 2006. Even though some respondents said that they moved in recently, the houses might have belonged to the same families longer than that. All interview respondents except one are women, and some women have moved into the houses of their husbands'.

Most houses have a separate kitchen where the stove is placed in a corner or against a wall. The kitchens have a window and sometimes a door to shut. No one has a chimney but only a window where the smoke can exit. The kitchen is often used as housing for goats and other livestock.

The Ngera umudugudu is situated in Ngera Sector. In this sector there are in total 21 imidugudu and each umudugudu has five representatives in the sector's office, who are elected for five years. They are elected to work in the sector council for security, social affairs and other relevant matters, and also to function as local leaders in the settlements. The elected are not paid and do not have any particular privileges. The duties are distributed among the five representatives as (1) coordinator for activities, (2) information, (3) security, (4) development, education, infrastructure etc. and (5) secretary work.

Beside this board, there is also a administration board with educated staff representing the government in the sector's office. At least 30 percent of these must be women. Both the elected and the administration board are excluded from the gacaca court, because they may otherwise affect the peoples' witnesses (Hatungimana, 2007).

3.2 Introduction to the energy system

There is no electricity in the umudugudu. The main source of energy used in Ngera is woody biomass, mainly forest litter collected from close forest areas. Some households also cut trees and use them as fuel.

The study will focus on different processes of the woody biomass energy system. Since the energy system is closely connected to the life cycle of biomass used as fuel, the first process starts in the forest where production of biomass takes place. The people in Ngera collect fuelwood there transport it to the village and their households. Occasionally the fuel is traded. Sometimes the fuelwood needs to dry before it is combusted in the stoves to obtain energy and to carry out different energy services. The stoves, or rather fireplaces, consist of three stones placed in a triangle around a central hearth. There are political incentives to promote a fuel-economic stove construction to reduce the amount of fuelwood. The ash is put on the food plots.

A general model of the woodfuel energy system that is to be investigated is summarised in *Figure 5*. The process of distribution has been removed from the model of Rydén et al. (2003) since there is no distribution in the energy system in Ngera.

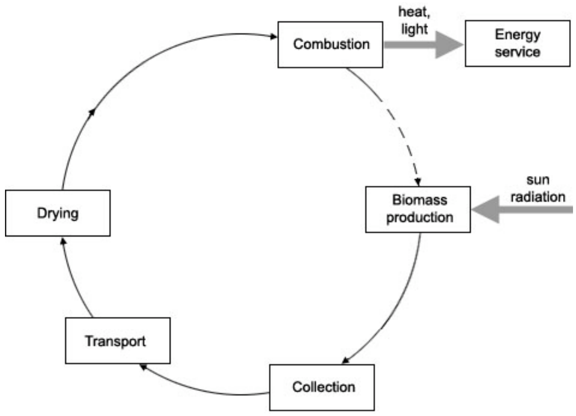

Figure 5. The figure shows the general energy system of fuelwood in Ngera. Compare the processes to Figure 1.

3.3 Method to fulfil the purpose and objectives

The investigation was carried out as an eight weeks' field study during February to April 2007. The Ngera umudugudu was visited about three days per week during this period to interview and collect data; more frequent visits were not possible due to transport arrangements and interpreter access. The days when not in field, interviews were transcribed and literature studies were done. Besides observations and literature reviews, the methods consist of interviews, quantitative measurements and participatory methods.

Participatory methods have increased in popularity among researchers and development workers in recent years. The methods can look different and reach from passive participation to self-mobilisation, but are all characterised by encouraging the inhabitants themselves under different forms to analyse their situation and discuss their resources and needs. Such an approach questions who defines the system; whose perspectives and whose worldviews that shall be dominating the investigation. For a further discussion, see for instance Mikkelsen (2005).

Since only Kinyarwanda is spoken in Ngera, the interviews and exercises were carried out together with an interpreter who translated between English and Kinyarwanda.

3.3.1 Energy resources and energy system

To get information about the energy resources and energy system, the following methods were used.

Questionnaire

In order to get an overview of the energy system, a questionnaire was done with 29 of the 33 households in the settlement. The criterion to take part in the interview was that the person uses the stove. The questionnaire consisted of 24 questions (Q1-Q24), that could mainly be answered with a quantity, with *yes* or *no* or with multiple reply alternatives. The questionnaire is attached in *Appendix I*. Information was obtained about stove use (how, when and for which purpose), fuelwood use (which fuel, how often, when and where collection is done), land ownership (land use and tree plantation), ash use, fuel trade, other energy carriers and knowledge about other energy carriers and stoves.

Semi-structured interview
A semi structured interview with Fidèle Hatungimana, in charge of Social Affairs at Ngera Sector office was done to get information about the imidugudu policy, the fuel economic stove and institutional organisation.

Side information
Whenever the questionnaire process brought information not relevant for the questionnaire itself but for the study as a whole, the interview left the formal structure and got semi structured. For instance, when the interview person mentioned charcoal production, or had a rare type of stove, some follow-up questions were asked, like *when*, *where*, *how*, *who* and *why*. Information was obtained about people's reflections, attitudes and knowledge.

GPS
A Garmin GPSmap 60CS navigation system was used to track the roads, facilities and main structure of the settlement. The GPS was also used to complement other methods used in this study. The coordinates collected with GPS equipment contain information about time, geographical position and altitude.

3.3.2 Biomass production

To get information about the biomass production, the following methods were used.

Inventory
To get information about the amount of available biomass, an inventory was made in the public forests and bushes where most people state that they collect fuelwood. Out of this information and biomass data tables, it is possible to estimate the biomass volume and the species composition of the forest. Information was obtained about the ecosystem, the age and state of the forest as well as biomass access.

Using a GPS system (see 3.3.1) three areas were mapped. The areas constitute the whole area where most people go to search for fuels. The three areas are all along the main road and have a size of 5,290 m^2, 9,740 m^2 and 1,110 m^2, respectively, see *Figure 6*.

Figure 6. The three black spots show the areas chosen for an inventory. The spots are enlarged in Figure 7.

Eight coordinates within the areas were randomly selected (see *Figure 7*), using the random function in Microsoft Excel 10.0.0. Using the GPS equipment, all these coordinates were then visited. At each coordinate, the circular area within the radius of three meters, defined with a string, was investigated together with a plant biology student at the National University of Rwanda. The investigation involved a general description of the spot, determining the species, counting the species and also taking measurements of the woody species (trees and big bushes). For a further discussion on forest estimations, see for instance West (2004).

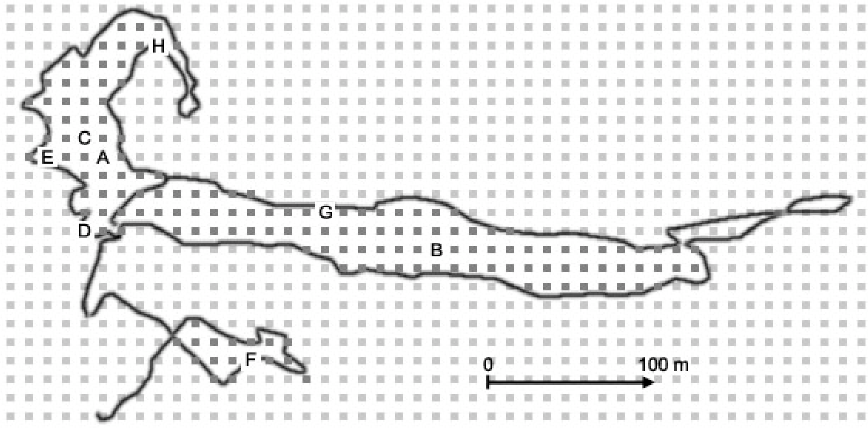

Figure 7. In order to investigate the public forests around Ngera where most people go to collect fuelwood, an inventory was made. Three forest areas were traced with GPS equipment and the coordinates for eight spots to investigate were selected randomly.

The measurements of trees and bushes were taken as the perimeter of the stem at breast height (130 centimetres above ground) and the height of the tree, estimating the relative height of the tree in comparison with a well-known object, in this case a human being (see *Figure 8*).

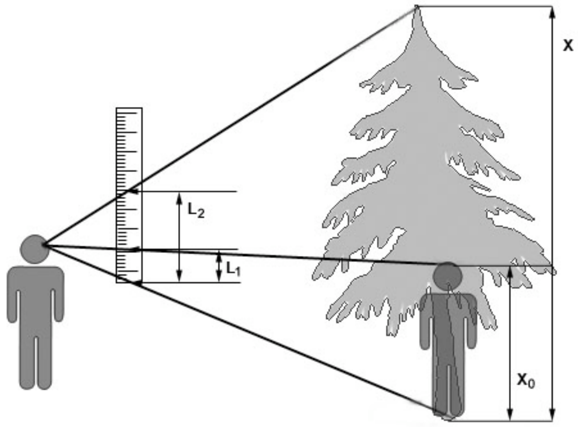

Figure 8. The concept of measuring tree height by comparing it to a relative height. The tree height X is equal to $X_0 \cdot (L_2/L_1)$. *(West, 2004)*

Often when biomass estimation is done, the trees that have a diameter less than 10 centimetres are subtracted. However, this is mainly done when the trees play a commercial role. This is not the situation in Ngera, where everyone collects and uses biomass for domestic purposes. In the forests where the collections take place the amount of biomass is small. It would be inappropriate to exclude the trees with a diameter less than 10 centimetres since all kinds of biomass play an important role for the villagers in Ngera.

Three different methods to calculate the biomass have been used. They are all based on regression equations and different assumptions. The reason for why such many methods have been applied is that variables, i.e. wood density and biomass volume, vary with climate, tree species and tree size. The forest area that has been investigated in this study is not exactly identical with any of the forest types for the available methods for biomass estimations. Thus three different methods have been used, that will result in a possible range of the amount of standing biomass.

The first method is to use allometric equations developed for different *Eucalyptus sp*. The relation S between the cross section area a at breast height of all trees in the forest area A is related to the aboveground biomass M_1 as

$$M_1 = 6.51S - 6.65 \text{ [t/ha]}$$

where $S = \Sigma a/A$ [m^2/ha].

(Burrows et al., 2000)

The second method is based on Montagu et al. (2002), but also includes the biomass in the roots, which can constitute more than 25 percent of the biomass in a hard wood tree. The online tool *Tree Carbon Calculator* has been used to calculate the biomass m, assuming that 50 percent of the tree biomass is carbon. The total biomass M_3 for the forest is then

$$M_3 = \Sigma m/\text{A} \text{ [t/ha]}.$$

(The Cooperative Research Centre for Greenhouse Accounting, 2006)

The third method suggests two different regression equations to calculate the tree biomass m from the diameter at breast height dbh in moist climatic zones:

$$m = 42.69 - 12.800dbh + 1.242dbh^2 \text{ [kg]};$$

$$m = e^{-2.134+2.530 \ln dbh} \text{ [kg]}$$

and thus the total biomass is

$$M_4, M_5 = \Sigma m/\text{A} \text{ [t/ha]}.$$

(Brown, 1997)

Soil samples

Soil samples were taken in order to investigate the ground's capability to ensure biomass growth. The soil quality where the fuelwood is collected within and nearby Ngera was measured. Two plots with different vegetation and topography were chosen and in each plot five holes were dug. Two samples were taken from each hole with two different depths, one in the top layer (0-10 cm) and the second at the bottom (10-20 cm).

In laboratory at the National University of Rwanda the pH values of these ten samples were measured. 10 grams of soil was mixed with 25 ml of distillate water and thereafter measured with the pH-meter Methrom ion analysis 826 pH mobile.

To analyse the nutrient content, soil from the soil samples was dried in 70° C during three days, until there was no significant mass difference from one day to another. The soil was then crushed and grinded. 40 gram of each sample was analysed in order to get information about the carbon-nitrogen ratio. Information was obtained about the pH value in the soil as well as the organic share in the soil, which in turn gave information about soil fertility and growing conditions.

Ash samples, own-produced

To learn about the mineral transport in the energy system, a fuelwood sample was combusted in an open fire and the ash was thereafter weighed. The ash was analysed in the same way as the soil samples regarding carbon-nitrogen ratio. Information was obtained about the purity of the ash.

Seasonal calendar and timeline

To get information about how the forest changes during the year and over time, a seasonal calendar and a timeline were used. Both methods are participatory exercises aiming at achieving a time perspective on a phenomenon. They are both described in detail in Mikkelsen (2005).

A seasonal calendar was drawn together with a group of women to enable a discussion on forest-related changes during the year. A circle was drawn on a paper to symbolise the year, marked with symbols that represent the different happenings of the year, like rain and harvest period. An arrow was drawn to point out the present season (see *Figure 9*). Quotes and information from the interview were noted.

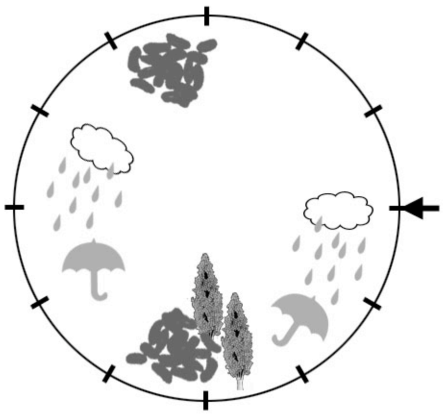

Figure 9. In order to study the variations in the energy system during a year, a seasonal calendar was constructed together with a group of women. Annual occurrences, like harvest and rain period, were marked. The arrow represents the present season.

Then a group discussion with stove users regarding how fuel outtake and other wood related issues vary during the year followed.

A timeline was drawn with the group to get information about the variation in forest condition during a period of several years. A line was drawn and important events in the past were pointed out; in this case the establishment of the settlement (1997), the law that prohibits tree cutting (2005), today (2007) and also the future (see *Figure 10*). Quotes and information from the interview were noted.

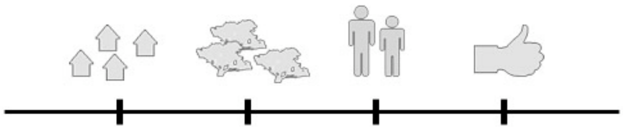

Figure 10. In order to study the variations in biomass during several years, a timeline was constructed together with a group of women. The establishment of the umudugudu (1997), the introduction of the organic law (2005), today (2007) and the future were drawn.

The group discussed how the forest and forest care changed over time and what expectations there are on the future. Information was obtained about time perspective on policies, reflections about the future and changes in plantation and tree cutting.

Other methods
To learn more about the biomass production process, direct observations and literature reviews as well as information from the GPS and questionnaire (Q3, Q14) have been used (see 3.3.1).

3.3.3 Collection

To get information about fuel collection, the following methods were used.

Fuel mapping
One way to get information about the biomass resources around the village is to make a collective map. A group of participants draw a map of the village where roads, houses, facilities, plots and forests are marked. Even though the map may not fit geographically, it will reveal the local people's view on their village and also open up for questions about land qualities, subjectivity and ownership. The method is further described in Mikkelsen (2005).

Due to time shortage, the mapping exercise for this study was carried out in a simplified way. A draft map with pre-drawn roads, houses and water sources was shown to different fuel collectors, who were asked to draw or mark out the forests where they usually go to collect fuel and why. The procedure was repeated with different fuel collectors until no more collection spots came up. Information was obtained about places where fuel is collected and reasons for collecting in different places.

Transect
A transect walk was made together with a group of villagers. In this study two young women and three children took part. Usually in a transect the participants walk from

point A to point B and stop at different spots during the way to discuss what they see, what it is used for, from where it comes, who uses it, and other common questions. The transect is thus a path where records of occurrences and phenomenon are noted. This method is described in Mikkelsen (2005).

In this study, however, the route for the transect was arbitrary chosen by the participants as they went to collect fuels. The questions focused on fuel, trees, fuel collection and fuel usage. The fuel piles were measured with scales. The transect walk was also tracked with a GPS (see 3.3.1). Information was obtained about where the collection takes place, how fuel is collected and what is collected.

Ranking matrix
To get knowledge about the reasons for why some kinds of fuel are collected and others not, a ranking matrix was carried out together with a group of fuel users.

A ranking matrix aims at comparing different qualities among objects. The ranking matrix is a good way to quantify abilities that at the first glance seem qualitative. It is also a good way to answer the 'why question' in the fuel system. Eleven cards with drawings of different kinds of fuels that are commonly used or had been mentioned during the study were made: bark, branches, charcoal, corn and sorghum wastes, cow dung, euphorbia, grass, leaves, roots, stems and sticks. There is a difference in size between branches and sticks, where the latter is smaller. The participants were asked to rank the different biomass items after their characteristics.

The participants discussed and compromised to decide which fuels that are easy to find, easy to collect and are expensive. The participants were also asked about other application areas for the different fuels. Information was obtained about the reasons for why the different fuelwoods are used or not, fuel access and qualities, advantages and disadvantages and non-fuel applications.

Other methods
When carrying out the timeline and seasonal calendar (see 3.3.2), matters about seasonal variations in fuel collection and changes in fuel collection over time were also discussed. Information from the questionnaire (Q10-Q16) and direct observations has also been used to help the understanding of the fuel collection (see 3.3.1).

3.3.4 Combustion

To get information about the combustion, the following methods were used.

Stove visits
When carrying out the questionnaire, kitchens were visited and notes were taken about the kitchens and stoves. Information was obtained about what the stoves look like and what the kitchens look like.

Stove experiment
To measure the efficiency of the stove, 1 litre of water was heated on a traditional Kinyarwanda stove from room temperature to boiling. Notes were taken about the fuel consumption. Besides information about stove efficiency, information was also obtained about how to use the stove.

Fuel pile weighing
Whenever a piece or pile of fuel material was found, the material was weighed on 50 kg scales and the owner was asked to estimate for how long the fuel would last, for how many persons and about its properties. This information was used to calculate the fresh mass fuel consumption per person or household and day.

Fuel sample, own-produced
As a complement to literature data about water and ash contents in fuel, an own fuel experiment was carried out. This information is necessary to analyse the results form the fuel pile weighing and the ash samples collected from households.

To find out the fresh and dry mass of fuelwood and leaves, a pile of fuel sticks (mostly *Eucalyptus sp.*) and a bag of leaves (mostly *Eucalyptus sp.*) were collected from the forest. The samples were dried in an oven with a temperature of 140° C during the night. Its mass was measured before and afterwards, and the difference represents the water contents. This information can be used to calculate the relation between the fresh and dry mass of fuel.

Then the biomass samples were combusted and weighed once again. In this way, the mass relation between fuel and ash amounts could be calculated.

Ash samples, collected from households
Another way to estimate fuel consumption is to use the relation between ash mass and fuel mass. Five households were asked to collect the ash from one day's stove use and save it in a pot. Notes were taken about how many times they had cooked and for how many persons. The five ash samples were then weighed. Information was obtained about ash generated per person or household and day. From this information together with the own-produced fuel sample (see previous section), fuel consumption per person or household and day was calculated.

Other methods
Combustion matters were discussed within the timeline and the seasonal calendar exercises (see 3.3.2). When carrying out the ranking matrix (see 3.3.3), questions were also asked about what fuels that are easy to lighten, burn long, are smoky, give most ashes and have the highest burning temperature. Direct observations and literature reviews as well as information from the questionnaire (Q4-Q5, Q9, Q17, Q20) and the semi-structured interview have been used as well (see 3.3.1).

3.3.5 Energy services

The methods mentioned in previous sections complemented with further questions about energy services also cover the process of desired energy services. Most information comes from the questionnaire (Q6-Q8, Q18-Q19, Q21) and direct observations (see 3.3.1), but also from the timeline, seasonal calendar (see 3.3.2) and the ranking matrix (see 3.3.3).

4. Results

The girl is three years old and crying her heart out every time we appear. She is not used to white people. Her tears are flowing and her jaws wide open, showing her rough rows of milk teeth. Even though Ngera is only 20 km away from Huye, this rural area has not much in common with the urbanised parts of Rwanda. During our visits, only once we speak to a person who knows some English. She studies in Kigali, the capital, but has come to the village during the holiday to see her mother. She and her brothers and sisters wanted their mother to move to the umudugudu when they had left home for school and work. The daughter tells us that they thought it would be good for her mother to live in a village with other people.

4.1 Energy resources and energy system

The main source of energy used in Ngera is woody biomass. Its life cycle is represented in *Figure 11*. Through combustion of the biomass, the villagers in Ngera get energy. Either by felling trees or collecting natural litter, people gets fuel from the forest. Stems are sometimes traded. To dry the fuelwood it is put around the stove. During the rainy season it takes more time to dry the fuelwood. Two household have constructed a shelf above the stove where they put the fresh fuel, which gets dry while using the stove underneath. Coveted fuels, i.e. stems, may first be used as building material. Sooner or later, however, the collected fuel is used in the private stoves. The bound energy is converted into heat and light when biomass is combusted. The obtained energy is used for cooking, water heating, lighting, space heating and drying of fresh fuel. In addition, batteries, LPG (Liquefied Petroleum Gas) and diesel can be used for light and entertainment, i.e. listen to the radio. Emissions are spread in the atmosphere and ashes are gathered and put on arable plots to serve as fertiliser and pH-raiser. Theoretically, both exhausts and ashes return to the ecosystem again sooner or later, although the ash is not necessarily put where it first came from.

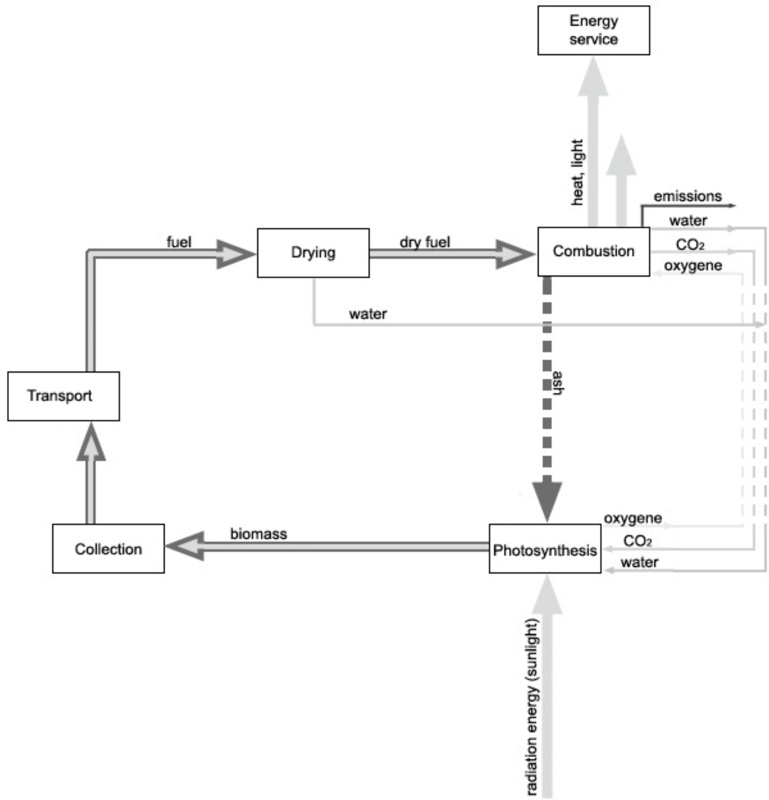

Figure 11. The energy flows and related material flows in the fuelwood system in Ngera. Energy from the sun radiation is bound in solid matter during the photosynthesis and then follows a biomass chain via collection, transport, drying and finally combustion. During the combustion, energy and material are again separated; energy in the available form of heat and light, and the biomass compounds as ash and emissions.

4.2 Processes in the energy system

The road up from the forest by the road to the houses is unbelievable steep and the fuel piles the women and children carry on their heads are heavy, ten kilos or more. But the hours in the forest are not only work, it can also be a time for a bit of chat with the other people around. "Collection, transport..." we try to keep in mind, but this walk to the forest is truly more than a study of the energy system.

The different processes occur at different geographical places around Ngera, carried out by different stakeholders. Besides the basic energy and material inputs, other inputs like gender roles and policy knowledge are decisive for the processes. The processes also affect the surroundings in different ways.

Figure 11 would be far too complex and confusing to hold all those inputs and outputs. Instead, the following chapters will focus on some of those processes and describe them more in detail. Deeper analyses are made around the biomass production (see 4.2.1), the collection of organic litter (see 4.2.2), the combustion (see 4.2.3), and the energy services (see 4.2.4).

4.2.1 Biomass production

"The forest brings the rain, so cutting down the trees means that it won't rain. The environment will get hurt and it will change."

Women's meeting, reasons to why the organic law was implemented

Where and what
The village is built on a hill ridge and almost all forests in the area grow on steep slopes. The forest areas that are considered as public by the villagers are by the tarmac main road and nearby the valley. Mainly bushes with a tree layer of mostly eucalyptus species grow there. The private tree plots are more scattered and sometimes closer to the settlement. On the private tree plots, eucalyptus and grevillea grow almost solely. According to the questionnaire, eucalyptus is planted for its material and fuel qualities and grevillea for its capacity to protect the soil from erosion. The plantation of trees occurred more often in the 1980s. Today only a few people in Ngera actually plant trees in order to supply themselves with fuel, but rather for above mentioned reasons such as protection and construction material.

According to the organic law, people in Rwanda are forbidden to cut down trees. During a group interview, the women said that the reason to the implementation of the law is to ensure a stable climate and a stable environment. However, one of the areas where most of the villagers mention that they collect fuel was recently cut down, probably for commercial or industrial purposes. The people still go there to collect what is left from the trees. The transect walk with a group of women and children showed that they arbitrary collect what is dry and gettable from the ground and not necessarily specific bush or tree species.

Species
The Ngera umudugudu and its surroundings is botanically characterised by coffee plants, banana plants and different *Eucalyptus sp.* as well as arable land with food crops. During the species identification done in the area shown in *Figure 6*, a species list with the different non-cultivated plants in the forest area around the main road was done. *Table 1* lists the wood species that are available in Ngera.

Table 1. Species list, accessible non-cultivated plants in Ngera and its surroundings.

	Scientific Name	Family
Tree layer	*Eucalyptus globules*	Myrtaceae
	Eucalyptus maideni	Myrtaceae
	Eucalyptus maculate	Myrtaceae
	Eucalyptus sp.	Myrtaceae
	Grevillea robusta	Proteaceae
	Albizia gummifera	Fabaceae
	Cupressus sp.	Cupressaceae

Bush and herb layer	*Euphorbia tirucalli*	Euphorbiaceae
	Caesalpinia decapetala	Caesalpiniaceae
	Tragia brevipes	Euphorbiaceae
	Pavetta ternifolia	Rubiaceae
	Clerodendrum rotundifolium	Verbenaceae
	Clerodendrum johnstonii	Verbenaceae
	Ficus urceolaris	Moraceae
	Maesa lanceolata	Myrsinaceae
	Lantana camara	Verbenaceae
	Rubus steudneri	Rosaceae
	Maytenus buchananii	Celastraceae
	Magnistipula butayei	Chrysobalanaceae
	Acanthus pubescens	Acanthaceae
	Allophylus sp.	Sapindaceae
	Rytigynia monantha	Rubiaceae
	Fragaria sp.	Rosaceae

How much – biomass estimation
The outcomes of the biomass estimation resulted in information about the biomass volume and area of the forest. Due to the topography, some parts of the forests were difficult to reach, and the borders that were defined for the forest estimation were therefore uncertain. Some randomised spots could be considered farmland rather than forest. On one spot of the forest, all trees had been cut recently and the plants left were different shrub and herb species, some still useful as fuelwood.

The GPS mapping shows that the three chosen areas along the main road have a total size of 16,140 m^2. The observations from the eight spots, each covering a horizontal area of approximately 28 m^2, are presented in *Appendix II*. The investigated area totals 226 m^2 which corresponds to 1.4 per cent of the total measured forest area. The forest is not very dense with trees. On the inventoried surface, 16 trees have been found. The tree density is 1400 trees per hectare; subtracting the parts of the forest with no trees at all (stating that these parts do not count as forest area but as deforested land or farmland). The total woody biomass volume is 200-300 t/ha in the forested areas and 50 t/ha in average. The age of the forest is, unlike for the trees grown on private land, rather spread – some of the trees are several decades whereas some are just a couple of years. Some eucalyptus trees have been cut several times and have regenerated from the main stem.

The total area that was selected for the inventory is A_1=226 m^2, but only a fourth of the spots were actually covered with trees – A_2=57 m^2. The results from the different methods to calculate the total biomass are listed in *Table 2*.

Table 2. The biomass was calculated in an inventoried area of 226 m² (A_1) with three different theories (see 3.3.2). Some randomised spots lacked trees; therefore biomass quantities have been calculated also only for the dense forest (A_2=57 m²) to get an estimation of the biomass in the Ngera surroundings.

Method	Biomass on area A_1 [t/ha]	Biomass on area A_2 [t/ha]	Comments
1	43	191	aboveground biomass
2	53	213	total biomass
3	83 62	333 249	aboveground biomass
Average:	60 (43-83)	250 (191-333)	

Conditions for growing – soil characteristics

Soil pH was measured and the value is between 3.9 and 6.6, usually around 4.2 to 4.5, which mean acidic soils. The measured pH values agree with and are comparable with last year's measurements (Birgersson et al., 2006).

Nutrients and minerals in the soil

The soil content of nitrogen and carbon was measured in a laboratory at Göteborg University. The correlation between carbon and nitrogen were good and indicates that that the nitrogen content is strongly dependent on the amount of organic matter in the soil, see Figure 12.

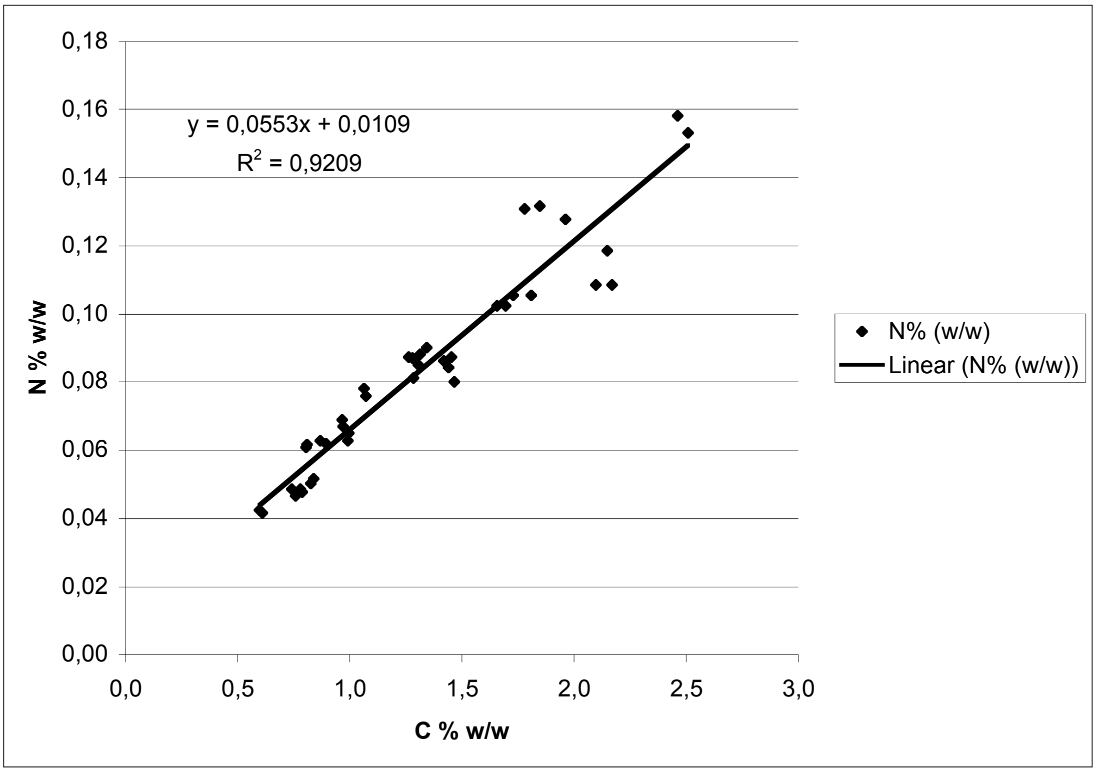

Figure 12. The relation between nitrogen versus carbon content in 10 soil samples from the forest by the main road in Ngera. The correlation is high, which is normal, and the small nitrogen share indicates that N is a limiting factor in the soil.

Future
During the timeline interview the women were asked what they think about the future and the forest's capacity to produce fuelwood. They presented one negative and one positive view: the negative view is that it will become more difficult to find and collect fuel and that the problem with soil erosion will worsen because of the lack of trees. The positive view is that it will become easier because the people plant trees and that there will be enough fuelwood for everyone. One woman said that as soon as you cut a tree you shall plant two new in order to ensure future needs.

Biomass production process analysis

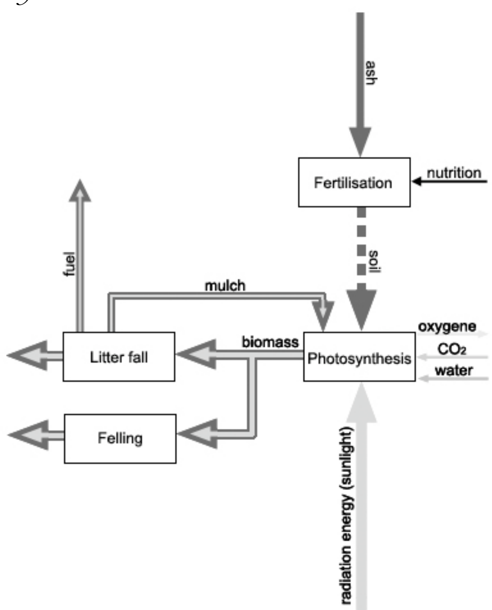

Figure 13. Inputs to and outputs from the biomass production process.

Eucalyptus is the dominant species in the umudugudu surroundings as in most parts of Rwanda. *E. globulus* and *E. maideni* are the most frequently found eucalyptus species in the area and both species have a solid timber characteristic, which is appreciated by the villagers in Ngera. *Grevillea robusta* is an exotic species, known as silky-oak. Both *G. robusta* and eucalyptus species grow in the forest as well as on the private plots. The villagers use mostly trees as fuel but in lack of trees smaller plants, such as shrubs, are used. *Euphorbia tirucalli* is a spurge plant commonly found in the area. In the umudugudu it is grown as fence around the houses and plots to separate the estates. It is also used as fuel but some women said it has the disadvantage that it takes one year for the euphorbia to become dry enough to be used as fuel. *Pavetta ternifolia* was the most common shrub species in the inventoried area. *Lantana camara*, another common plant, is exotic to Rwanda and is today spread throughout the country.

Biomass production is integrated in the ecosystem, which in turn is dependent on geographic position, altitude and climate. Nutrition and pH in the soil are crucial for the biomass production, and so is the plant composition.

In Ngera, as well as at many sites in Rwanda, the soils are characterised as acidic and high in exchangeable Al and deficient in N, P, K, Ca, Mg, total N and organic C. According to the minor field study in Ngera in 2006 (Birgesson et al., 2006), the soil is mainly oxisol.

Oxisols are characterized by very low native fertility, resulting form very low capacity to hold nutrient cations (such as Ca^{2+}, Mg^{2+} and K^{+}), low cation exchange capacity, CEC, and high phosphorus retention by oxide minerals (University of Idaho, 2007).

The analysis of carbon and nitrogen content also indicate that it is a relatively poor soil and most likely the nitrogen content is limiting for the biomass production. This limitation is likely to increase when the people are collecting organic material from the forest floor, the amount of nitrogen decreases. To summarize, the test results from the soil samples indicate limited growing conditions that may be worse in the future with the current management.

Humans have both direct and indirect impact on the biomass production. Direct, in that regard that they cut and plant trees. Indirect, in that regard that they treat private and public land in different ways; that policies and laws promote and prohibit different forest activities. As will be argued in the discussion in chapter 5, also knowledge, information and gender roles will play an important role.

4.2.2 Collection

We were accompanying some women when collecting fuel. When most of the big sticks from the ground were collected, the search for fuel slowed down.
"This one is dry", the oldest woman said and broke off a branch from a tree.
"But...", we said, "isn't it forbidden to do like that?".
"Not if they're dry", the woman replied.
"Then... what about this one?" we asked.
"That one is not dry!". She broke off another branch. "Oops, this one wasn't dry yet". The fresh branch dangled from the tree. "The next time I'll come here it will be dry!".

People collect fuelwood from public forests and private plots around the houses. All, except one household respondent, state that they own or rent land where they either can cultivate crops or trees. Five households state that they rent land, 18 households own land and five households both own and rent land. According to earlier research (Hauvigimana, 2006), however, only one household has a record on the estate. The land reform implemented in 2005 invalidated land claims (see 2.3). Ownership and rents are thus informal and due to tradition and scarce juridical knowledge. However, public and private areas will henceforth refer to the answers given in the questionnaire.

Where

Most of the inhabitants in Ngera collect fuelwood in public forest areas where the only cost is the own time and labour input. The forests are close to the settlement, not further away than one kilometre, and most of the villagers say that they go to a plot close to the main road (see *Figure 14*). Some villagers mentioned that they get sticks and branches from people who have cut down trees and used the stems as construction material e.g. for roads, houses or furniture.

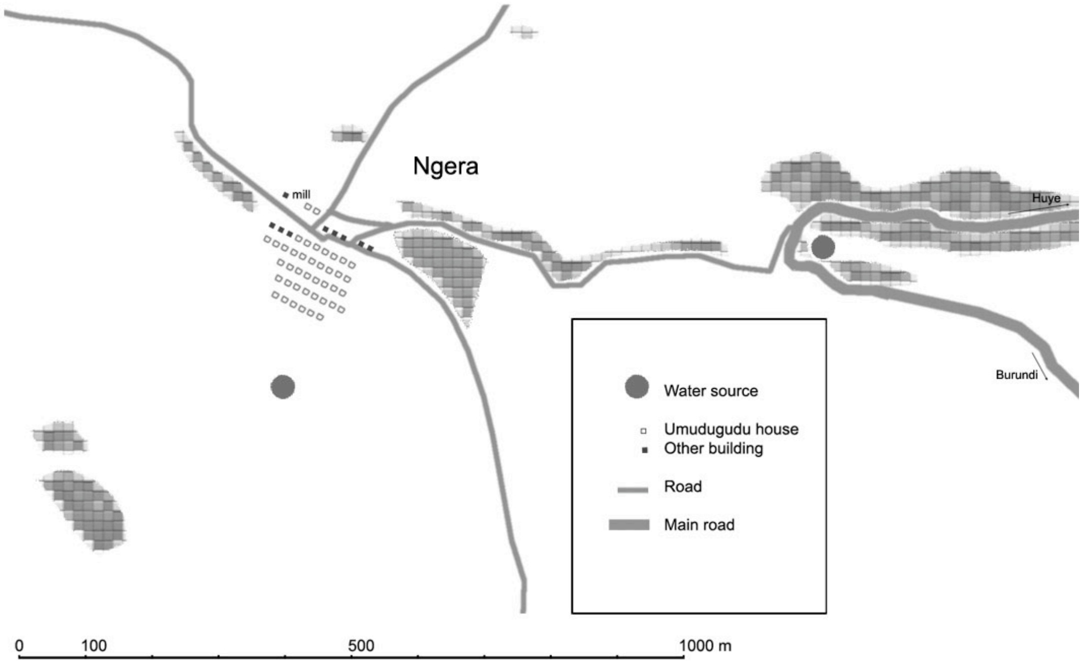

Figure 14. Fuel collectors were asked to mark on a map of Ngera where they go to collect fuel, which resulted in this fuel map. The shaded areas represent forests where fuel collection takes place. Most respondents mentioned the forests along the main road.

Who

Usually women collect the fuelwood. Children help when they are not in school. *Figure 15* shows how fuel providing is shared among women, children and others. The figure also includes other ways of obtaining fuels than stick collection (for instance tree cutting), why the result might be a bit misleading when it comes to collection.

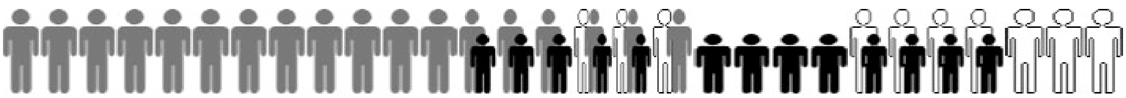

Figure 15. Representation of the households where the women (grey), the children (black), others (white) and combinations of the three do the fuel collection. Each household is represented by one character or group of characters. "Other" is in three cases the husband and otherwise a friend or someone hired. Out of the 29 households, in 12 cases the women alone gather fuel, in 3 cases together with children, in 1 case together with someone else and in 2 cases together with children and someone else. In 4 cases children alone gather fuel and in 4 cases children together with someone else. In 3 cases someone else collect alone.

When and how

A typical fuel collection includes searching for spots with organic litter and then picking sticks and other burnable material, like roots, bark, grass and leaves, from the ground. When the pile of sticks is big enough it is knit together with grass or banana leaves. If a woman has done the gathering of sticks and branches, the load has a fresh mass between 10 and 15 kg, and some less if there are children collecting. The women and the children carry the loads to the houses on their heads.

Most households send someone to fetch fuelwood every or every second day, or 4.4 days per week in average, and then spending almost two hours (115 minutes) collecting, according to the questionnaire. The time investment per day for getting fuels is thus estimated to a bit more than an hour (72 minutes). The time investment per household and day is though very spread, and differs between four minutes (the ones who almost only use own trees) and three hours. The time spent depends on what kind of fuel and what quality they can find. Several people say that this time may not be effective collection time because they might stop to talk to other people.

The time spent and the supply of fuelwood, do not differ a lot during the year, due to the stable climate in the country. During the big rains in March and April it might be difficult go out collecting and it also takes longer for the fuel to dry. Though, the collection time has increased since the village was built. The fuel collection was not as difficult when the villagers first moved to Ngera and they could use whatever fuels they felt like, but since the organic law came into force the situation has worsened. According to the timeline interview, the time spent on collection has increased from two hours a week to two hours per two days. In addition, the certainty of getting fuel is today smaller. Different villagers collect from the same spots, and sometimes there is nothing to find.

The women are the main collectors of the fuelwood. The men in the households are responsible for cutting down the trees. The tool used to cut down a tree is an axe or machete. There are not enough tools in some households. For instance, one household did not use the stumps in the garden due to lack of sharp axes.

Trade and ownership

Some villagers own tree plots where they used to live before they moved to Ngera. The owners sometimes go there to collect fuel, whereas others' plots are too far away to be worth the labour input. Instead they can sell the trees there and with the earned money buy fuelwood closer to home. There are four households in Ngera that state that they sell fuelwood and 10 households that they buy fuelwood, mostly stems and whole trees. The reason for buying fuel is usually disability or old age.

Before the umudugudu was built, most of the people owned tree plots with eucalyptus where they could collect fuel and the competition was smaller. During one of the group interviews, the women stated that a normal way of collecting fuel before they moved to Ngera was to cut down approximately five trees, leave them to dry and thereafter fetch them. Those people who did not have own tree plots collected branches.

Planning for fuel

Twelve households have planted trees where the main reason was to get fuelwood (other reasons are e.g. to get constructing material) whereas four households state that they have planted trees for other reasons than for fuelwood. However, there is confusion about if it is allowed to cut trees from the own land. 13 households have not planted trees at all and rely on the fuelwood available in public areas.

Collection process analysis

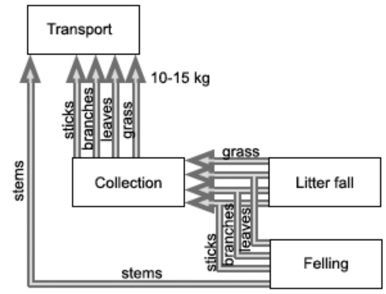

Figure 16. Energy and material flows into and out of the collection process. 10-15 kg is the average load a woman gets when collecting.

A typical fuel load after collection has a fresh mass of 10-15 kg. Doing this 4.4 times a week, the average collected fuel load per household is 6.3 to 9.4 kg per day, or 1.7 to 2.5 kg per person. The direct input is human labour. Gender roles and household composition is decisive for who collects. Ownership, policies and laws and the nearness to the road and the settlement, affect where the collection takes place and what the procedure looks like. How and what people collect come to knowledge about fuel demand and what is available.

This process might also have an impact on the human capital. It is possible that the collection plays a social role in the society, since women often go together and talk to each other. On the other hand, fuel collection is time consuming and has therefore a negative social impact on the individual as well. Spending hours in the forest might also threaten the health. ESMAP reports from back, neck and head injuries from heavy fuelwood loads, risks for miscarriage, assaults and accidents (2004). Other studies indicate risks for being raped and getting bitten by snakes.

4.2.3 Combustion

The women burst out in laughter when we ask them to show us their kitchens. Some refuse, some rush away to tidy up the mess before we are allowed to enter, and some just take us there, sceptical, shy or inquiring.

When the village was established, one requirement on the house construction was that there should be separate kitchens to protect people's health (Rwandan Initiative for Sustainable Development, 1999). This seems to be fulfilled - in the questionnaire survey, there are only three respondents that state that people sleep in the kitchen and 26 that they do not.

Figure 17. A traditional Kinyarwanda stove, which consists of three stones to the left. A fuel economic rondereza, which has circular walls to the right.

Who
The one who uses the stove is usually a woman in the household; often the same woman as the one who is responsible for the fuelwood collection. She can be the mother, the daughter-in-law or the maid. The only exception in the study among 29 households was the house where two orphan boys live alone.

The traditional Kinyarwanda stove
All but two of the 29 households have traditional stoves made of three stones, bricks or clay lumps placed in a triangle against a corner or wall (see *Figure 17* to the left). Sticks and other fuels are put in the middle. The ceramics pot or the more efficient aluminium saucepan is then balanced between the stones over the fire.

To start a fire, grass or leaves are put on fire with matches or sometimes with the fire from the neighbour's stove. Woody biomass like sticks, branches or big pieces of wood are used as main fuel. The log size depends on for how long the stove will be used. Cooking beans, which take several hours, demands logs or lots of sticks or branches, but for boiling water some thin sticks are enough. Since the sticks are usually too long for the stove, they will gradually be pushed into the stove centre manually while the stove is burning.

To estimate the efficiency of the traditional Kinyarwanda stove, a simple experiment was done. One litre of water was heated on the stove from room temperature (298 K) to boiling, as described in material and methods, section 3.3.4.

With data on general physical properties, the minimum amount of energy to boil 1 litre of water was calculated.

Water boiling point at 1800 m altitude (P = 0.81 atm): 95° C = 368 K Water density at 1800 m altitude: 997 kg/m^3 Heat capacity of water: 4.18 kJ/(kg·K)

(Nordling et al., 2006)

Thus, the minimum amount of energy needed to heat 1000 ml of water from 298 K to 368 K is

$E_{min} = m \cdot C_v \cdot \Delta T = 10^{-3}\ m^3 \cdot 997\ kg/m^3 \cdot 4.18\ kJ/(kg{\cdot}K) \cdot (368\ K - 298\ K) = 292\ kJ$

In the experiment, about 100 g of eucalyptus (3 sticks) was needed to get 1000 ml of water to start boiling. Due to lack of convenient weight measurement equipment, it was impossible to estimate the exact mass of the fuel used.

Energy contents in dry wood: 18.7 MJ/kg Energy contents in fresh wood (20 % water): 15.1 MJ/kg - 1.3 MJ/kg to vaporise the water = 13.8 MJ/kg

(World Bank, 1991)

It is appropriate to assume that the water contents in the fuel sticks are less than 20 percent, since 20 percent are the contents before drying due to the combustion of the own-collected fuel sample (see 3.3.4). 100 g eucalyptus sticks thus correspond to an energy amount between E = 1.4 MJ and 1.9 MJ. This means that the stove has an efficiency $\eta = E_{min} / E$ between 16 % and 21 %.

The fuel-economic rondereza stove
The two households that do not have the traditional stove have the semi-modern stove, familiar as the 'rondereza' (meaning to save or to economise), see *Figure 17* to the right. It is used in the same way as the traditional but demands less fuel. According to UNDP and GTZ (2005) it only requires about one third of the fuelwood required in a traditional cooking stove. UNDP estimation is more modest; 40 percent of the fuel demand of a traditional stove.

The rondereza is made from clay and other material and can be built in any household. The hearth is isolated with circular walls, only leaving one gap for fuel and oxygen supply. The stove top is open, and this is where the pot or saucepan is put.

The government of Rwanda encourages the people to use the fuel economic stove in order to protect the environment (see 2.3). In addition, ronderezas reduce smoke emission, which saves the women from inhaling cooking smoke. To encourage people to build ronderezas, the sector's office is working in two steps: First to inform and show the people the stove – one Rondereza is built outside the sector's office and most households (80 percent) in the nearby umudugudu have built one. The second step is in a practical to way help people in the implementation of the rondereza. People are gathered and learn techniques, and they are encouraged to help others to build ronderezas as well. The price for a rondereza stove is approximately 1,000 Rwandan franc – about 2 US dollars, but some people, e.g. elderly and disabled can get the stove from church for free.

Fidèle Hatungimana, in charge of Social Affairs at the Ngera Sector office, suggests two reasons for why the people in Ngera do not build ronderezas although the government and the local leaders have encouraged them to do so and even if it is more fuel economic: Either they do not have the skills or the money to build it, or they want to keep the traditional stoves because they are accustomed to them. During the meeting with the women's group, the participants gave roughly the same reasons for why they do not use them. Lack of skills and monetary means are the answers to why hardly anyone uses the rondoreza. They used to have traditional stoves and did so even before they moved to the settlement.

The two ronderezas that were found in the umudugudu were built by the husbands in the households. One woman, who uses the traditional stove, has a husband with plans of building a rondereza. The reasons among the respondents with traditional stoves for not building a rondereza are that they do not know how to build one or cannot afford it. Two respondents mentioned that the people in the umudugudu had been promised a 1,000 Rwandan francs subsidy and help to build it, but nothing has yet happened.

Stove knowledge
The sector's office and the government seem to be successful regarding their rondereza information, in this respect that almost all households spontaneously mentioned the rondereza when they were asked what other stoves they are acquainted with (see *Figure 18*). The charcoal stove, that is different from the traditional stove, is known by almost half of the households. It was earlier used by some of the households. The electric stove was mentioned by five respondents, and two respondents mentioned gas stove.

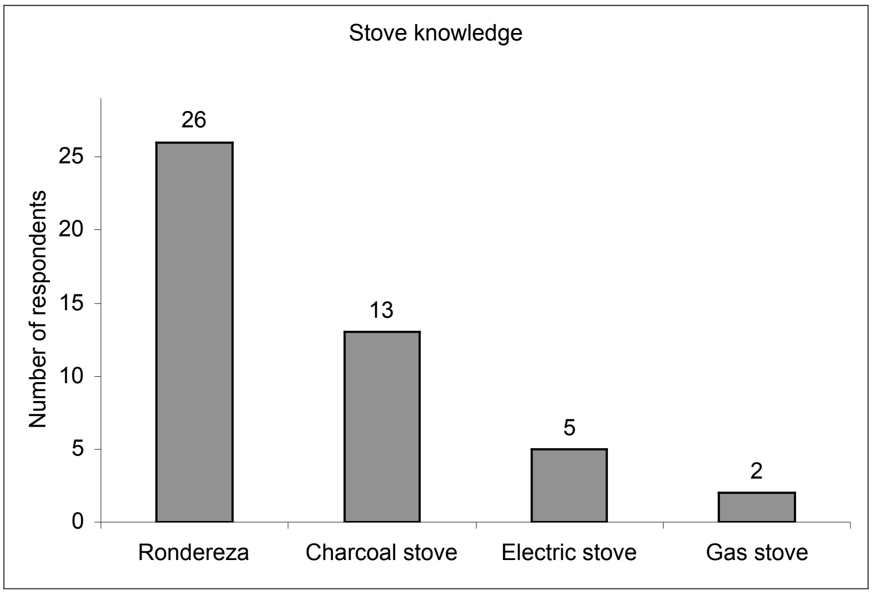

Figure 18. Number of households who have heard about different types of stoves. 26 respondents mention the rondereza, 13 mention the charcoal stove, 5 the electric stove and 2 the gas stove.

What fuelwood
All 29 households say that they use sticks and branches as fuelwood, 18 use stems, 17 use leaves and 16 use grasses. Ten respondents told that they use other fuels than the mentioned options. Other could be e.g. bark, banana leaves, stumps, whole natural trees, euphorbia and mixed bushes, and also straw and waste from sorghum, corn and beans like soya beans. The full outturn is to find in *Figure 19*.

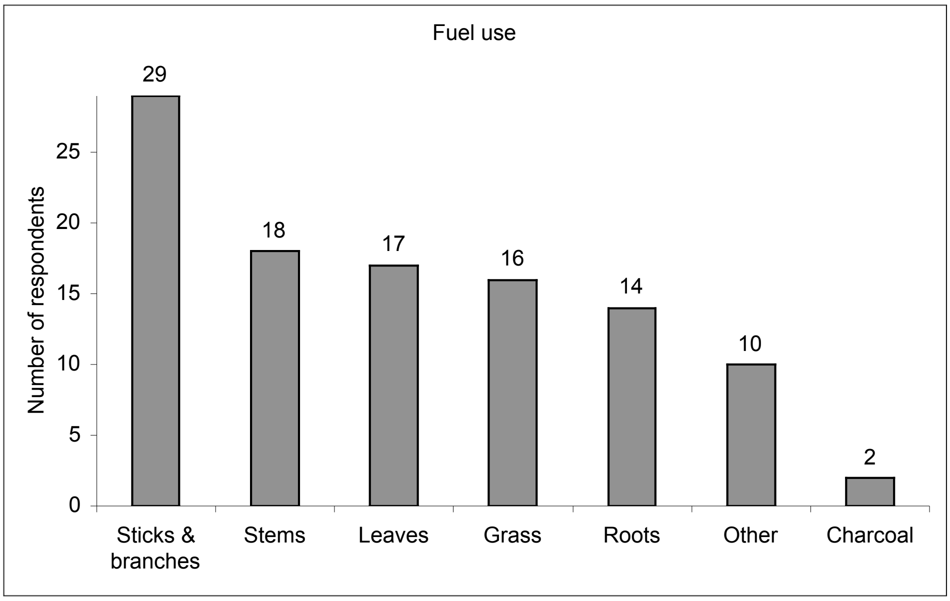

Figure 19. Number of the 29 households stating which specific fuels they use. Others can be bark, banana leaves or stumps.

In order to understand the reasons why different fuels are used, the questionnaire respondents as well as the women's groups were asked about fuel qualities and characteristics. Frequently mentioned opinions are that preferable fuel is the kind that is 'hard', e.g. the stem. Characteristic for the hard fuelwood is that it burns long and that it gives a small amount of ash – the fuel has a high density and there is almost a complete combustion. The hard fuelwood is not always available though. Always available fuel is leaves and grasses and almost always sticks. After the harvest, there is more crop waste available than otherwise, that can be used as fuel.

No one uses cow dung as fuel and the probable reason is that there are too few cows in the village and that the dung is used as manure instead. During the ranking exercise, the participants ranked cow dung as they know how it works and some people said they had used it earlier. *Table 3* shows the answers given when a group of women was asked to rank different fuels.

Charcoal is the most expensive fuel. It is more preferable than sticks and branches because it burns longer and does not need be under supervision to stay burning. No one in the village produces it any longer, and to buy it in the market is expensive. During the group interview some women said that charcoal was commonly used when Ngera was established. The villagers do not think that they will be able to use it in the future if the law does not change and the prohibition is cancelled.

When the villagers lack fuels it happens that they take parts of their furniture to burn. In this way, wood intentionally meant as building material gets recycled as fuel.

Table 3. Matrix ranking fuel qualities, done by a group of women.
Which fuel (is/has)...

easy to lighten	grass/leaves	*burns long*	stem	*easy to get*	leaves/grass	*easy to collect*	stem
	sticks		roots		sticks		sticks
	sorghum		charcoal		branches		branches
	cow dung		branches		stem		bark
	euphorbia		euphorbia		bark		euphorbia
	charcoal		bark		euphorbia		roots
	bark		sticks		sorghum		grass/leaves
	branches		cow dung		roots		cow dung
hard to lighten	root	*burns short*	sorghum	*hard to get*	cow dung	*hard to collect*	sorghum
	stem		grass/leaves		charcoal		charcoal

is cheap	grass/leaves	*is smoky*	cow dung	*much ash*	leaves/grass	*high temp.*	stem
	cow dung		grass/leaves		sorghum		branches
	sorghum		euphorbia		sticks		sticks
	sticks		sorghum		bark		bark
	bark		bark		stem		roots
	roots		roots		branches		euphorbia
	euphorbia		sticks		roots		charcoal
	branches		branches		charcoal		sorghum
is expen-sive	stem	*is not smoky*	stem	*little ash*	euphorbia	*low tem-perature*	grass/leaves
	charcoal		charcoal		cow dung		cow dung

According to the women's group, the villagers also got more ashes when they had better access to fuel. That means that the stoves were used more. For instance, they cooked beans more often a week than the possible times today.

Water and ash contents

As described in section 3.3.4, a typical fuel pile consisting of eucalyptus sticks and other burnable branches was dried. The 23 sticks weighed 679.2 g before and 552.7 g after drying. This means that an average stick has a water content of 18.6 %.

Eucalyptus leaves and other organic litter were also collected, which decreased in mass from 170.1 g to 147.1 g after drying. This corresponds to a water content of 13.5 %.

After burning the sticks, the ash had a mass of 20.5 g. The ash contents are thus 3.0 % of the fresh mass and 3.7 % of the dry mass.

The ash from the leaves and litter had a mass of 35.7 g. This means that the ash contents are 21.0 % of the fresh mass and 24.3 % of the dry mass.

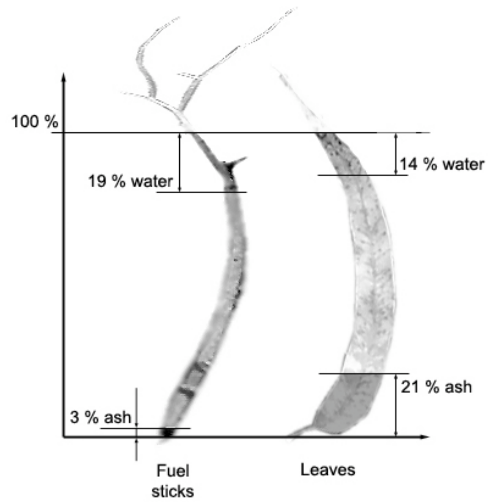

Figure 20. Ash remains and water contents in sticks and leaves according to a drying and combustion experiment.

Fuel consumption
Measurements of fuel piles resulted in knowledge about fuel consumption per person and day and per household and day (see *Table 4* and *Table 5*) (the water content is 0-20 %). The first estimation tells that the average daily fuel consumption is 2.0 kg per person and 7.7 kg per household (7.5 kg was the average for the measured households. Then a correction for the number of family members, which differed with a factor of 1.03 from the household in the questionnaire survey, has been multiplied).

The results corresponds to 1.8 ± 1.0 kg dry fuelwood with an energy value of 30 MJ and 37 MJ depending on water contents.

Table 4. Consumption of not yet dry fuel per day for individuals and households. The data is taken from scale measurements of ten fuel samples. Time refers to the time the fuel is assumed to last.

Fuel mass [kg]	Time [days]	Family members [ ]	Fuel/person/day [kg/day]	Fuel/day [kg/day]
13.5	2	4	1.7	6.75
4	0.5	6	1.3	8
7	4	3	0.6	1.75
15	3.5	2	2.1	4.29
15	1	4	3.8	15
3	1	2	1.5	3
2	1	2	1.0	2
7	1	4	1.8	7
15	1	4	3.8	15
12.5	1	6	2.1	12.5
		Average	2.0	7.5

Collection of five ash samples from the households resulted in a similar result about fuel consumption (see 3.3.4). The average dry fuel consumption is 2.0 ± 0.8 kg per person and day, and 7.8 kg per household and day (7.4 kg was the average for the measured households. Then a correction for the number of family members, which differed with a factor of 1.05 from the questionnaire survey, has been multiplied). 2.0 kg woodfuel corresponds to an energy value of 36 MJ.

Table 5. Fuel consumption per day for individuals and households. The data is taken from the five collected ash samples and calculated with information obtained from the fuel sample.

Ash mass [g]	Dining family members [ ]	Corresponding fuel/person/day [kg/day]	Corresponding fuel/day [kg/day]
225	4	1.9	7.5
109	2	1.8	3.6
165	4	1.4	5.5
124	3	1.4	4.1
493	5	3.3	16.3
	Average	2.0	7.4

Combustion process analysis

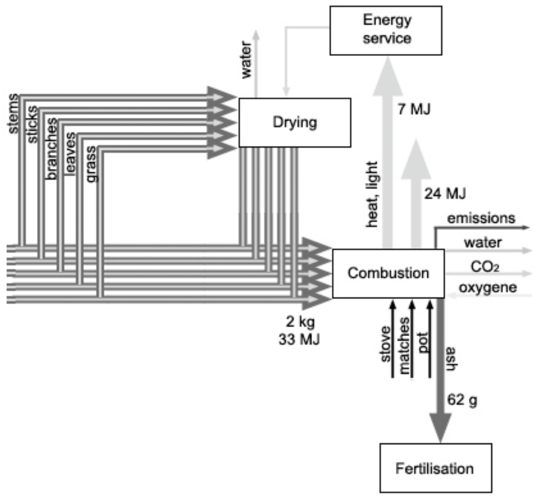

Figure 21. Inputs to and outputs from the combustion process. The energy and material quantities in the figure are calculated per person and day.

The two different series of fuel consumption estimations show similar values. Weighing of fuel piles tell that 2 kg not yet dry fuel (corresponding to 1.6 kg to 2.0 kg dry fuel) is the fuel consumption per individual and day, which corresponds to 30 MJ to 37 MJ. Collecting ash samples from the households show that the fuel consumption is about 1.9 kg dry fuel per person and day, or 36 MJ. The ash amount produced per person and day is about 60 g.

Since the traditional stove has an efficiency of 16 % to 21 %, the effective energy consumption is thus between 4.8 MJ and 7.8 MJ. The rest (25 MJ to 29 MJ) might be useful for lighting, space heating or could be regarded as waste energy.

The rondereza requires 40 to 70 percent less fuel than a traditional stove, which is in turn dependent on stove promotion and implementation, information and institutional organisation as well as economic conditions, knowledge and traditions (UNDP & GTZ, 2005, Hatungimana, 2007).

During drying and combustion processes, water evaporates. The combustion also demands oxygen and produces carbon dioxide and other emissions are produced. This is a threat to the stove users' health. Stove accidents, especially to children and elderly, are also a health risk (ESMAP, 2004).

Non-material inputs are human labour and skills, which are dependent on information flow, traditions and gender roles.

4.2.4 Energy services

Crunchy noises come from the radio when a cloud suddenly covers the sun. The woman is a gacaca court member and therefore she got the solar cell run radio for free, to keep informed with the national news. Unless it's not raining, the radio is turned on loudly the whole day, and our voices are drowned while we try to interview her.

The main stove application is cooking and water heating. When the stove users were asked for what purpose they use the stove, 29 and 28 households, respectively, answer that they use the stove for those purposes. Lighting, space heating and drying fuelwood are also common services (see *Figure 22*).

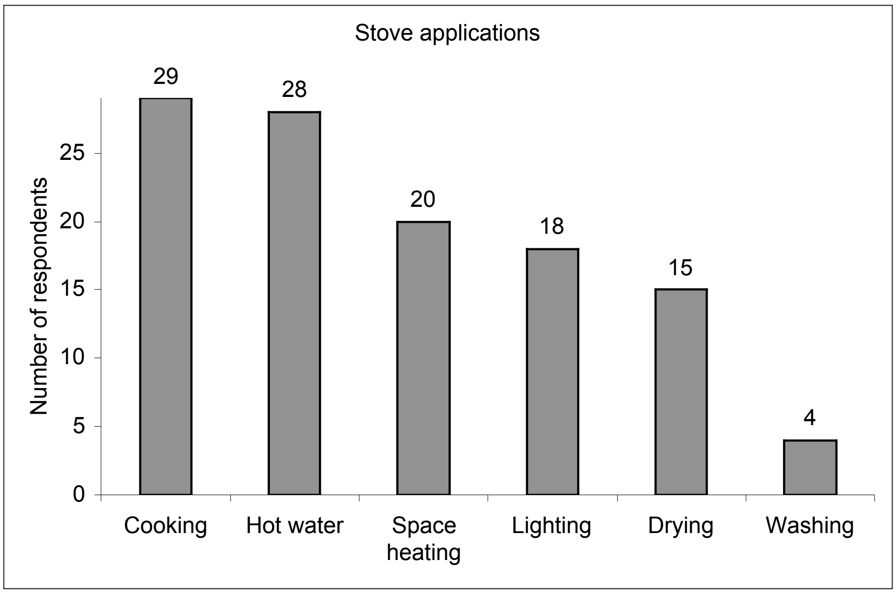

Figure 22. Number of the 29 households stating what purpose they use the stove.

Hot water is needed for food preparation, sorghum beer brewing and hygiene. Many use the stove for lighting the kitchen, or take sticks from the stove as fire torches to light up the house in the evening. Drying refers to dry the freshly cut fuelwood for some days before using it. Space heating means warming the house.

Some people state that they use the stove for clothes washing, while others says that it is impossible to use the stove for that purpose. To wash clothes, they rather go to the valley and use the cold water there.

Cooking
To get information about a normal day of stove usage the questionnaire respondents were asked how many times they used the stove the day before. The results show that the stove is usually used for cooking once or twice every day – one household did not cook on the stove yesterday, eleven households cooked once, 15 households cooked twice and two households cooked three times (see *Figure 23*).

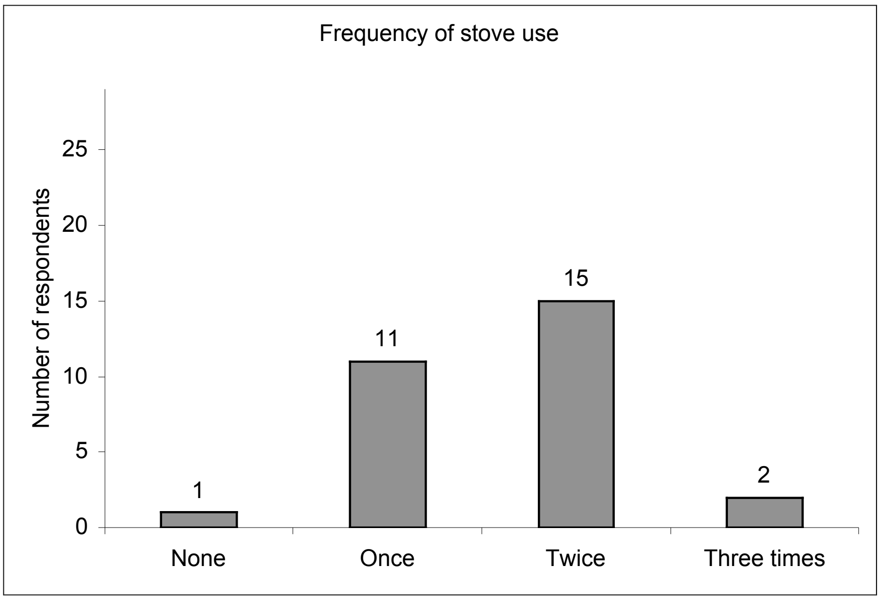

Figure 23. Number of the 29 households about how many times they used the stove for cooking yesterday.

Most people – all except five households – eat their main meal in the evening. According to the questionnaire, lunch and breakfast are rarer. This is because the women work during the day, or they are short of food. When discussing the timeline with the women's group, the women told that they do not have enough food these days. They have earlier experienced famine.

The breakfast often consists of porridge, where the stove is used for heating the water. The ones who have milk use the stove to heat it, and the breakfast can also include cassava bread, sauce and sweet potatoes.

About once a week the stove users in the households cook beans. According to the seasonal calendar, beans are boiled more often during the harvest period – two to three times a week. The beans are boiled for many hours and therefore a lot of fuel is required.

Boiling beans takes the whole afternoon and normally last for two or three days. Before the women moved to the settlement, they used to have beans three times a week. Sweet potatoes take about thirty to forty minutes to boil, depending on which pot that is used – the traditional of clay or the modern aluminium one. Using the latter means quicker cooking.

The people who drink beer brew banana beer in June or July and sorghum beer after the harvest in August or September, according to the seasonal calendar. Banana beer is brewed without boiling, which means that the stove is not used for this purpose. To prepare sorghum beer, sorghum flour is mixed with boiling water. This is either done in the households or at special occasions together in the village.

Lighting

Some of the households use other energy forms than biomass for lighting and five of the houses use the stove only. Among the rest, as appears in *Figure 24*, eight households sometimes use candles, 21 oil lamps, and eight use torches (which does not imply that they have constant access to candles, oil and batteries). Among the ones who use an oil lamp, eleven use kerosene, nine diesel, and six use LPG (liquefied petroleum gas) as fuel.

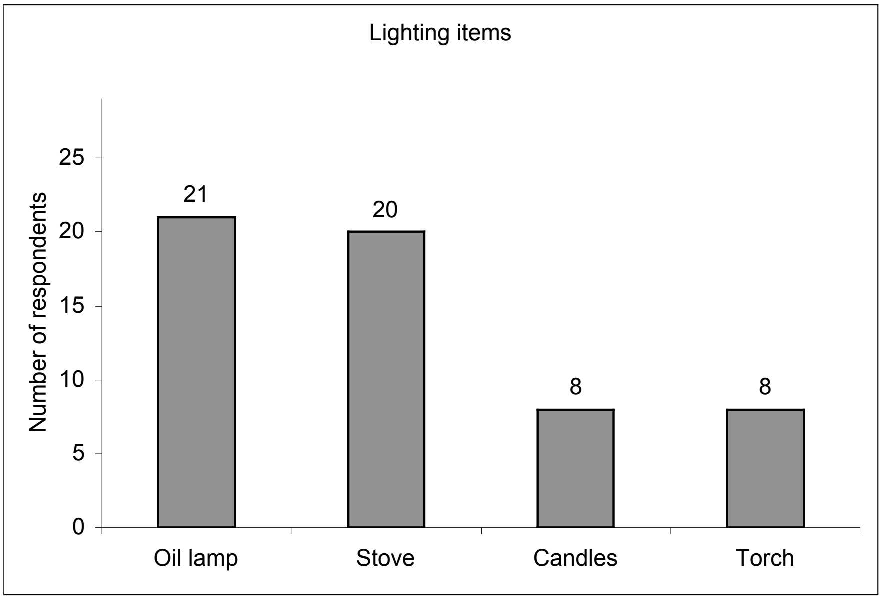

Figure 24. Number and share of the 29 households stating that they use specific lighting items.

Energy services from other energy carriers

Besides biomass, other energy carriers are used for e.g. clocks, watches, radio and lamps. As a part of the questionnaire, the respondents were asked what equipment they have that requires batteries. Twelve households stated that they have a radio, seven households that they have a watch and one household that they have a clock (see *Figure 25*). 14 households had no such equipment at all.

The batteries used are common galvanic battery cells, available in the local market. Two of the radios, however, are run by solar energy through a photovoltaic solar cell. The solar cell radios were distributed to gacaca court jury members to keep them up-to-date with news and the society.

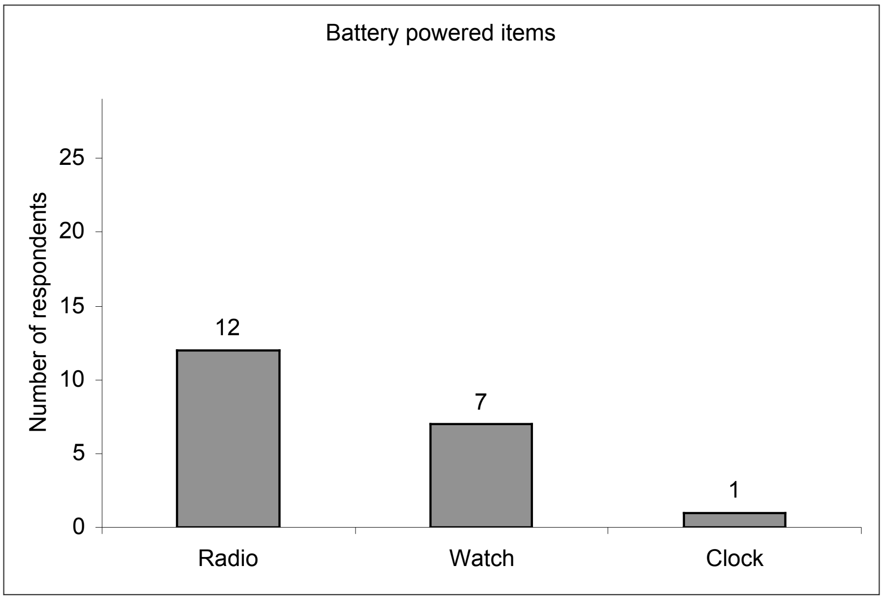

Figure 25. Number of the 29 households with access to equipment that requires batteries.

Energy services process analysis

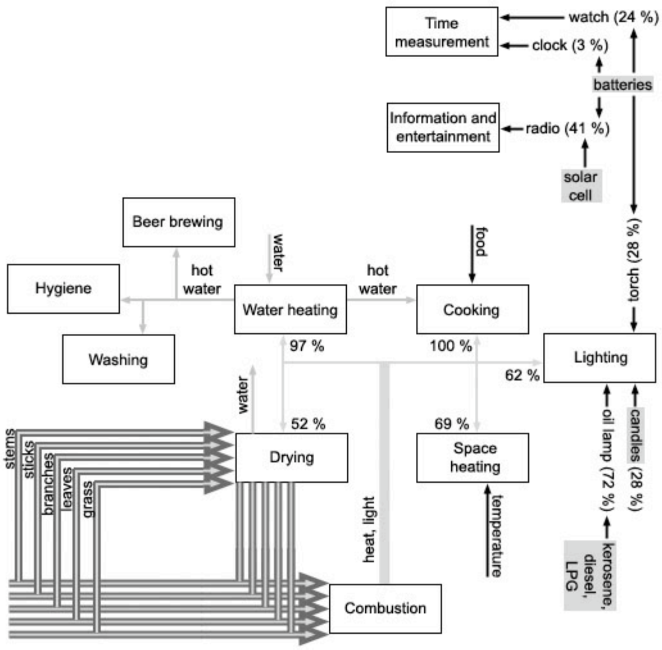

Figure 26. Inputs to and outputs from the different energy services' processes. The percentages represent shares of the 29 households in the questionnaire.

The heat and light obtained from the combustion in the stoves are used for different energy services. All of these services demand human labour that is related to gender roles and tradition. What energy services that are demanded differ between the households because of different needs, household composition and not at least economic conditions. Some women work in the coffee station all day and do not have time or need for cooking. During the rainy seasons more indoors space heating is demanded and also more drying of the fuels than in the dry seasons. Depending on harvest, crops and thus food access, the cooking habits differ.

When it comes to facilities like watches, radios and lighting items, most households can only afford one or none of them. And even if they actually own one, it is not sure that they have batteries or fuels to run them.

5. Discussion

This chapter aims on one hand at discussing the reliability of the results, on the other to discuss what the results mean and how they can be used for further reading and studies.

5.1 Validity of the results

A case study is a preferable method to understand and quantify a local energy system, and its advantages have been discussed in the methods chapter (see 3). It has, however, some shortages. A discussion on methods is therefore needed.

Sample selection

When taking samples for the qualitative as well as the quantitative research, it is difficult to find a random selection. For the questionnaire, all except four families – the ones who were often absent when the village was visited - were represented. That is, the households in the survey were chosen on a given criteria, i.e. to be present. This is an obvious bias. On the other hand, by covering as many as 86 percent of the households with the questionnaire, the bias is quite small. The fact that almost all villagers represented in the study are women might be a bias factor. The results should not be interpreted as covering the men's opinions and views.

To simply compose suitable women's groups where everyone can feel comfortable during the participatory exercises, they often consisted of family members and friends. This is also a bias factor, since interrelated people might share the same thoughts and interests.

Measurement of fuel piles and collection of ash samples from the households was not an arbitrary selection but hardly randomly selected. To that, the selections were rather small. Also here a small bias might be traceable.

The spot selection for the forest inventory is carried out randomly with the random function in Excel 10.0.0. The background data is gathered with GPS equipment, and the possible error margins arise from how the GPS trace mapping was carried out rather than the spot selection.

Time coverage

The field study is carried out during a limited period of time. The investigation of the energy system is thus only instantaneous. Trends and seasonal variations have not been observed. Because of the timeline and the seasonal calendar, it is possible to estimate the qualitative changes. The size of the energy and material flows are, however, only valid for the period when the village was visited.

Access to measurement equipment

Because the investigation was carried out as a field study, the access to measurement equipment was limited. Simple equipment gives rough data, but with inventive solutions, all sought-after information could be found at least and do not necessarily lead to less accurate results. The biggest problem came up when estimating fuelwood consumption. There is a certain insecurity regarding the water contents in the fuel that might constitute as much as twenty percent of the fuel mass. In field, there were no fixings to measure the water contents, which increased the error margins when estimating the fuelwood consumption.

The GPS error is relatively systematic and it should not affect the overall result. Errors foremost depend on imprecise GPS utilisation.

The interview situation
The interviews and participatory exercises were all carried out together with an interpreter, which increases the risk for misunderstandings between the interviewer and the respondent. Participatory methods have other sources of error as well, not at least expectations on the researchers among the local population and inversely that might contribute with a certain bias to the results.

Some parts of the study investigate illegal activities, e.g. tree cutting. Obviously, interview respondents might avoid exposing this behaviour. Information about illegal matters is therefore also considered by direct observing.

Error propagation in the system analysis
Some information that was obtained early during the study has been used as background data in calculations and concluding later in the study. GPS mapping is said to represent areas where people go to collect fuel. Experimental values on water and ash contents in fuel are used to calculate the fuel consumption. The daily energy consumption is calculated from experimental values on stove efficiency, calculated values on fuel consumption and questionnaire results on household size.

To reduce the suspicion that errors in the first assumptions propagate and distort the final results, the figures in this study need to be compared with figures in similar studies. Of course, the error margin cannot be eliminated, but at least the reliability of the values can increase.

Biomass estimation
Calculation of biomass is often based upon equations done for specific species. It is also done to calculate production of biomass for commercial purposes. This study includes all species within an area, and most of the plants are far too small to compare with the trees used in industrial areas. Therefore the margin of error is greater than if the forest would have contained large trees and not so much of brushwood.

According to this study, the water contents in fuel recently collected from the forest is 18.6 % for woody biomass and 13.5 % for organic litter. The result is in agreement with other studies; for instance with the World Bank stating 10 to 20 % (1991). Also the ash contents found in this study – 3.0 % for woody biomass and 21 % for organic litter – are also in agreement with the World Bank, even though the interval is broad – 1 % to 20 % (1991).

Assumptions about the water contents have been used to calculate energy consumption. On one hand, since the margins of error regarding water contents in this study are that big, the values for energy consumption have an amount of uncertainty. On the other hand, even though the values for ash contents in the wood are uncertain, the error is systematic since it is only used to recalculate fuel mass. Thus the fuel mass calculated from the ash samples is reliable.

The stove efficiency estimated in this study of 16 to 21 % is in accordance with ESMAP:s estimations of 12 to 18 % (2004).

The daily fuelwood consumption per capita has been estimated in three different ways. Firstly, the loads of branches, leaves and twigs that are collected in the forests and carried to the houses, distributed on all inhabitants in the village, are estimated daily to 1.7-2.5 kg (fresh), corresponding to 1.4-2.0 kg dry. Secondly, the fuel piles in the kitchen and around are estimated to be 2.0 kg per person and day (quite fresh) corresponding to 1.6-2.0 kg dry. Thirdly, after burning the dry fuel, the ash amount per person and day was 60 g, corresponding to 1.7 kg dry fuel per person and day. With a water share of 19 percent, these three results coincide pretty well with one another, and also with other studies. The two latter estimations hold together an expected value of 1.7 ± 0.8 kg per capita and day. The large error margin both reflects a big variance among the households and a margin of error caused by an uncertainty regarding water contents. A fuel study in a rural village in South Africa for instance estimates the fuel consumption to 1.9 kg per capita (Dovie et al., 2004).

To sum up, the short time in Ngera and the equipment used to carry out this study were limited. The complex system with legal aspects, traditions and cultural as well as natural conditions influence the results and cannot be understood separately. Traditions are difficult to see and understand for foreign researchers, but may have decisive impacts on local behaviour. On the other hand, researchers from another tradition might be able to discover relationships that are not obvious for the local researchers. However, the results are reasonable and the obtained quantitative data is in agreement with other fuel studies that have been published. To fully understand the situation for the people in rural areas this study is a relevant basic study.

5.2 The problems and the sustainability of the energy system

The Ngera umudugudu is acute affected by poverty. The achieved results indicate that the situation is difficult, which is reflected in the use of resources.

The study shows that any species, characteristics independent, are considered as fuel – an indication that the shortage of wood is acute (World Bank, 1991). During this field study it turned out that it is not the tree species that is interesting to the villagers in Ngera, but rather the different parts of the tree or bush. Times when the lack of efficient fuel is severe, the inhabitants use whatever they can find, sometimes even furniture.

Collecting organic litter that normally would be decomposed means that important fertilisers are taken away. Neither the ash is brought back to fertilise the forests and tree plots but rather the arable land. In the long run it will lead to depletion of the already nutrient-poor soils in the area of Ngera.

Besides poverty, one reason for the use and non-use of different fuels is the access to efficient tools. The cutting tools available in the village are machetes and axes, which go blunt quickly. Therefore, fuelwood that would be good for the people are left or taken by people who have better equipment.

Women are responsible for most of the domestic labour in the household, including fuel collection and food production. The duties, generally typical for women, are unpaid and often more invisible in the local society as well as within research areas than labour areas that generate in money. When access to fuelwood, arable land and livestock decrease, the women are more affected than men. According to the women in Ngera, food production has decreased and it has become more difficult to find fuel in recent years. Earlier studies indicate that when energy resources become scarcer the women have to work harder to obtain the same quantity of biomass. Furthermore, spending more time on fuel collection gives less time for education, employment and care of family members and more output and income out of the land, thereby contributing to the destruction of the ecological base (RWEDP, 2000, ESMAP, 2004).

When collecting organic litter, the collection comprises searching, picking and carrying. Women and children are involved in this duty. If a tree is to be cut, the collection comprises logging, transporting and cutting. These duties are traditionally carried out by men, but in Ngera, where women are the majority, it is also performed by women. There are several health risks connected to this duty such as backache due to carrying heavy loads of fuelwood for long distances, risks of miscarriage, usage of inefficient and harmful tools and risks of being raped or bitten by snakes (FAO, 2000).

After drying the fuelwood, it is combusted for its energy service purposes. These can be cooking, water heating, space heating, washing and lighting. It is performed in the kitchen by women, where the ventilation and lighting is poor. The women and also their young children are exposed to hazardous smoke and other emissions as well as low safety standards. According to FAO:s *Wood energy, Women and Health, A sub-regional training course in 1996* health-care services are often dedicated to men, and therefore the women are more vulnerable to emissions and safety risks.

Fuel collection is one of the most time-consuming duties in Ngera. Women and children spend almost two hours every second day to collect sticks and other burnable material from the forest. This is a new situation, according to the women during the timeline interview. Before moving to the settlement, they knew where to go to collect fuel. Now, the area is densely populated and the women are not sure to always find fuel when collecting. Much time is needed only to find a spot where the neighbours have not been recently. The implementation of the organic law in 2005 (MINITERE, 2005) made it even harder. It terminated the possibility to cut trees and branches for fuel. According to the government, the solution is to get the fuel saving stoves ronderezas which demands less fuelwood and less time of collecting. Although fuel shortage is a big issue for the villages in Ngera, no one in the focus group mentioned that they want more help and information about the rondereza. Almost all villagers know about the fuel-economic stove, but only one woman said that her family was considering an investment.

Out of this insight, it is appropriate to discuss two different sustainability matters:

(1) *Consumption reduction*. A discussion on what can be done to reduce the fuel consumption and how it works or why it has not been performed. What strategies do the households in Ngera utilise to compensate for fuel shortage?

(2) *Increase in biomass resources*. A discussion about the factors that contribute to strengthen the natural capital. What achievements have been reached regarding the national initiatives to protect the forests?

(1) *Consumption reduction*. Due to an increased population rate and a ban on tree cutting, the available biomass has diminished. It is clear that a decrease in access to biomass resources for the households is encountered with a set of livelihood strategies. The

Regional Wood Energy Development Programme in Asia (RWEDP, 2000) suggests seven household strategies to compensate for woody biomass shortage. Two of them, *Sacrificing other functions of the stove* and *Losing income-generating activities related to fuelwood*, are beyond the scope of this study and are therefore not discussed. The other strategies are:

Spending extra energy and time searching for fuelwood. The women state that they use more time today collecting fuel than some years ago. It is also possible that the labour input for other people has increased. Children help with the collection when they are not in school. The study does not tell if this is a new situation or if the children always have helped with the collection. Neither does it tell if the children have to sacrifice time from school.

Using alternative fuels for cooking. Logs from stems and charcoal made from trees were commonly used before. Some households even had charcoal stoves. Today, organic litter and sometimes household wastes from corn and soya beans have replaced much of the compact fuels.

Changing cooking practices. Two of the households have built the fuel-economic rondereza stove and one is planning for it.

Changing diets. The stove-users state that they cook beans – a fuel-consuming dish – only once a week in comparison to some years ago when they had beans three times a week. It is possible that also other cooking habits have changed, that have not been further investigated in this study.

Buying fuel. This is a strategy that does not seem to have been adapted in the umudugudu. The scarce monetary resources are given other priorities. The ones who buy fuelwood usually have other reasons for it, like disability, which stop them from collecting on their own.

Of the above strategies, the strategy that comprises changes in cooking practices seems to have a superior potential to reduce the fuel consumption. The advantages of fuel economic rondereza stoves are obvious. The input resources are rather small and the benefit is high. The cost is not very expensive and it is possible to build for free with natural materials that are found in the surrounding areas. It takes about one day to build it. The rondereza is institutionally well-promoted from governmental level down to the sector's office where a 'two-steps' programme has been developed to inform about the stove and organise the implementation. The questionnaire shows that almost everyone of the stove users knows about it.

The benefits from an implementation seem to be clear. The rondereza is very efficient, reducing the fuel needs with up to 70 percent (UNDP & GTZ, 2005). The consequences would be a reduction in biomass demand and released time resources for the women and children.

And yet, almost no households in Ngera have built it. The question arises why not more people are interested in building the rondereza stove. Fidèle Hatungimana, in charge of Social Affairs by the Ngera Sector office, suggests tradition, lack of money and lack of skills as reasons. This can be a good part of the truth. Habits are difficult to change and 1,000 Rwandan francs are more than most households can afford. Also the women in the group interview state that they do not know how to build it. Nevertheless, in the whole of east Africa, there is still no success story about implementation of fuel economic stoves (UNDP & GTZ, 2005).

Lessons learned from stove implementation projects in India (UNDP, 2004) give clues about the reasons for not implementing the semi-modern stove, in spite of the good incentives of the government. Mainly for the reason of scarce women representation in the process, the goals of the government did not meet the women's goals. Whereas the women especially were looking for a smoke reducing stove, the government introduced a fuel-saving one.

But there are probably other reasons as well. In the umudugudu where the sector's office is situated, most households have a rondereza. It might be that the people in this umudugudu are wealthier, more skilled and less conservative when it comes to cooking practices, but presumably there is another difference as well. One clue is the nearness to the organisational network and to institutional stakeholders. Representatives for the sector's office have let build a rondereza outdoors at the centre of the village, where everyone can see it and get to know about it. It is appropriate to believe that the information and the organisation promoting rondereza implementation might not reach distant areas like Ngera. Even though the women in Ngera have heard about the stove, the step to actually build one might be huge. The villagers in Ngera do not hold the responsibility alone for implementing the fuel-economic stoves. Since the information seem to spread slowly it is important that people from higher instances come to the secluded village to promote and help the villagers to build it and not to rely on their own will. Another aspect (which is further discussed below) is that it is important that women are taught to build and implement the stoves and not only the men. Two women mentioned that they had been promised the help and yet the assistance had not come. Therefore the benefits of the stove had not reached the village.

It is also possible that other hindrances prevent information circulation about the rondereza. Rwandan tradition says that one should not to talk about family matters outside the family (den Biggelaar, 1996). The kitchens can be regarded as a private matter – neighbours are not invited into the kitchens; many women were embarrassed when showing their stoves for this study. Therefore the knowledge about the rondereza and its possible advantages are slowly spread.

Another important reason can be gender roles and power relations within the households. A family must not be considered a democratic unit, but a group of individuals negotiating about rights and resources, having different power and bargaining positions (RWEDP, 2000). The few examples of rondereza implementation that were found in this study are not enough to prove this thesis, but they strengthen it. In both cases where the stove was implemented, and in the case where the household was planning for implementation, the husband was the one who had taken the decision and who would carry it through. In at least two of the cases, the wife was the one who came up with the idea. Since the woman is the one who benefits from implementation since she is the stove user, there might be a conflict of interests. The man will have to share his resources of labour with his wife, to increase her resources access of time and labour input. If there is also a monetary cost, the negotiation might be even harder.

(2) *Increase in biomass resources*. Except for changing and delimiting the outtake of biomass resources, one strategy to protect the forests must be to strengthen the natural capital. In Rwanda there are two national initiatives to meet this purpose. The first is the organic law, prohibiting people from cutting trees from public forests. The second is the tree plantation initiative, requiring people to plant trees on a reserved day each year. There is confusion among the people in Ngera about how to interpret the organic law. Some people say that it is allowed to cut old trees, some people say that it is not even allowed to cut trees from one's own land. Since no one legally owns land since the land reform (see 2.3), this last understanding is in some sense close to the truth. After all, some people in Ngera actually still cut trees from their plots.

Hindering the deforestation is a slow process and many years will pass before the achievements can be evaluated. Tree plantation is one of the most decisive measures to increase the biomass volume. This occupation is traditionally reserved for men.

In spite of the need for more biomass resources, there is almost no tree plantation in Ngera. 16 households state that they have planted trees but it was often long time ago. In this report, three proposals are suggested for why the planning for biomass supply is such absent.

Land scarcity. The access to land is limited and land is also needed for other purposes, not at least food production. Since the participants in the women's group state that lack of food is a bigger problem than lack of fuel, food production must be set first priority.

Gender roles. The second reason follows a line of arguments slightly similar to the reasons for why almost no one builds the rondereza stove. The women are the ones who gain from tree plantation since an increase in biomass resources contributes to decrease their labour input and release time resources. But tradition prohibits women from planting trees, and therefore they need the men's labour input. Negotiation within the households where access to resources is discussed from different position results in that no trees are planted. This conclusion is not that obvious, however. Men also profit from tree plantation as they get building material rather than fuelwood. Building material either gives possibilities to build new houses within the family or trade products which gains in monetary means.

Institution. The third reason discusses the national initiatives to prevent the forests. On one hand, people are encouraged to plant trees. On the other hand, people are by law not allowed to cut trees. Even though some people still use logs to heat their stoves, there is a widespread uneasiness in Ngera about cutting trees and almost everyone has changed the fuel consumption patterns since the organic law implementation. Because of the land reform where the state reclaimed all private owned land, it is difficult for the individuals to see the point in planting trees.

5.3 Final discussion

Using this field study as a starting point for discussion, there is a contradiction among the national initiatives to protect the forests, where women and poor are the big losers. Seen from a short-time perspective, the labour input for women and children in rural areas, for instance Ngera, has increased. Measures like rondereza implementation and tree plantation do not seem to be enough to compensate for the limited access to biomass, partly because social aspect such as gender roles and power relations between men and women have been ignored. It is even possible that the organic law and the related changes in fuel-consumption patterns led to a drift in gender roles. This study indicates that men had a bigger responsibility for fuel collection before the organic law was implemented, because tree cutting is regarded a more 'male' duty than stick collection. This means that the new fuel situation not only demands more from the women's time resources and labour input, but also strains them with a new area of responsibility and more psychical insecurity.

Furthermore, poor people will always be more affected by fuel scarcity than they who are better off. For instance, industry is given higher priority and will be supplied with fuel. A question that arose during the study is how the newly built coffee washing station will increase the pressure on the forests around Ngera. Will that lead to decreased access to fuelwood for the villagers nearby the washing station? Fuel scarcity also leads to decreased income due to the decreased time spent on household industries and the increased time spent on finding fuel. According to the WHO report *Fuel for Life* (2006) poor households tend to spend a larger percentage of their income on energy than well-off households. Poorer will become poorer.

What about the long-time profits from the national initiatives? When taking away the people's possibilities to harvest the trees they plant, their personal interests in contributing to the forest growth are at the same time removed. A situation might arise where the local population become alienated from the forest and the private tree plots and stop managing them. In the best case the forests recover and it will be possible to cut trees again in the future. In the worst case the forests might change into an even worse condition with illegal cutting and scarce afforestation, the women bounded over to spend hours searching for fuel.

Ecological aspects

The organic law (see 2.3) is good for the ecological conditions for growth. However, to forbid people cutting trees means that they collect the litter fall from the ground that would normally decompose and fertilise the forest. The soil will deplete as the nutrients go to other places and ecosystems. The cycle would be more ecologically sustainable if the ash was brought back to the system, but instead it is put on arable plots to fertilise food crops. If the Rwandan population keeps increasing at the predicted rate, the situation will probably worsen further. The access to fuel will decrease and the nutrients in the soil will deplete. On the other hand, the good intentions of hindering people to over-use the forest is good to ensure the access to trees for the future and it will also protect the soil from erosion and bind the water to the ground. In addition, trees help to recycle the soil nutrients, maintain and sometimes improve soil fertility. Conserving these ecosystems does not only ensure the services the ecosystem provides the people with; it also ensures the biodiversity. All organisms play important roles in the ecosystem to keep the cycle running. The organic law promotes the usage of the fuel-economic stoves, increases the energy efficiency and decreases the need of fuelwood and the emissions of green house gases.

6. Conclusions

6.1 Energy resources and energy system

The energy resources in Ngera mainly consist of woody biomass, mainly sticks and branches, from forests around the village. Also kerosene, diesel and LPG (liquefied petroleum gas) are being used in a small scale, as well as galvanic batteries and solar cells. The rough quantitative flows in the energy system are sketched in *Figure 27*.

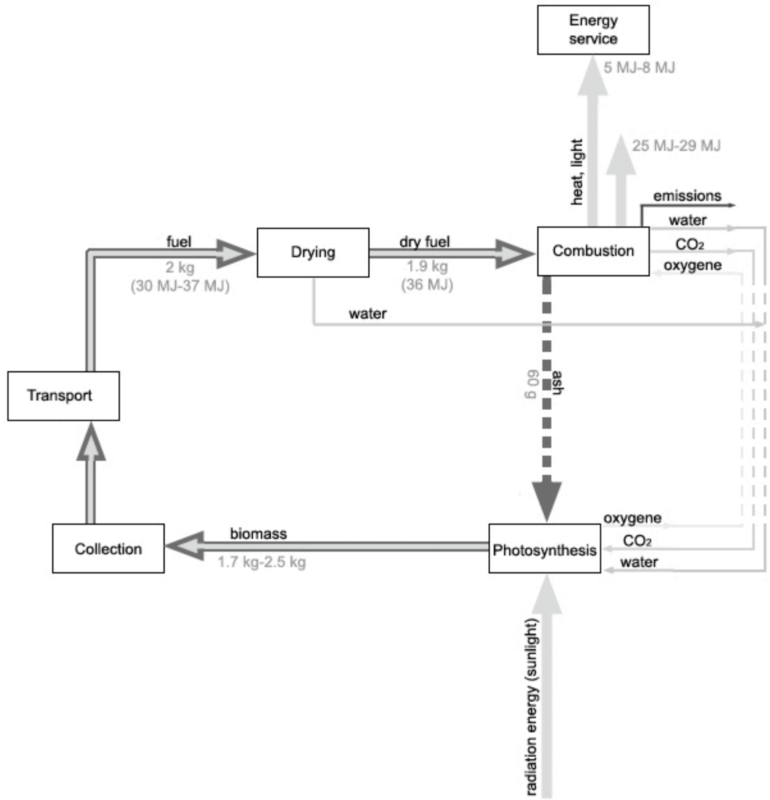

Figure 27. An approximate quantification of the energy flows and related material flows in Ngera. The values are calculated as an average per capita and day.

The kind of species that are used as fuelwood turned out not to be interesting for the fuel collectors. Rather it is the part of the tree that is interesting. This is an indication of big fuel scarcity. Charcoal is no longer used, since 2005 when the organic law was implemented. Neither is the hard stems used very often. Therefore, when the prohibition of cutting trees came into force the situation worsened.

6.2 Processes in the energy system

Biomass production. The forests consist mostly of eucalyptus species which also serve as main fuel. To protect the forests from deforestation, several political initiatives have been implemented, most noticeable a law that prohibits people from cutting trees, but also recommends the inhabitants to use fuel-economic stoves. This law, in combination with a big population on a small area, has made fuel collection a more time-consuming duty than it was before. This study suggests that the ban on cutting trees, in combination with landlessness and gender roles where women are not allowed to plant trees, may affect people's interests in planting trees and conserving the forests.

Collection. The fuelwood is mainly cut and collected in forest areas, either regarded private or public, around the umudugudu. Women and children are mainly responsible for fuel collection, mostly sticks from the ground, a procedure that takes a bit more than one hour every day. In average the collection for a household in Ngera is done two times a week and it takes approximately two hours each time. In addition the time spent depends on what kind and quality of fuel. Men sometimes help with tree cutting, however. The collection might be associated to some risks, but it is not clear that the time invested in fuel collection is only a negative burden. Fuel collection might function as a social arena for women where they meet and talk. This study suspects that a switch in responsibility for fuel procurement between men and women might have occurred since the prohibition of cutting trees; a switch that released men from tree cutting whereas women had to collect fuel.

Combustion. Most people in Ngera use a traditional Kinyarwanda stove with a low efficiency of less than 20 percent, even though a fuel economic stove is well promoted by the government. The simple reasons why more people do not get the fuel economic one are that they rather keep to traditional habits or that they lack skills or money to build it. Other reasons might be that the information about it is not spread because of distance to the village, absence of legal advisers and that women do not talk about private matters. It is also possible that a power inequality within the households between men and women stops the implementation. The ash residue of the fuel is put on arable land as fertilizers. Therefore it is not brought back to the forest ecosystem, which in turn leads to depletion of the soil.

Energy services. Women are responsible for the stove use, the food preparation and other fields of application related to the stove. The stove is used for cooking, water heating, drying fuelwood, space heating and lighting. Many households only have the stove for energy services. Some households also have other lighting items, radios and watches run by other energy carriers than biomass.

6.3 The problems and the sustainability of the energy system

If people could use whatever fuels they would like, charcoal is preferable. No one uses it any longer, and instead they take whatever they find in absence of descent fuel. The collection, usage and planning are due to institutional regulations. The organic law which forbids tree cutting has made the collection and use more difficult for the people in Ngera. The same law encourages people to implement the fuel economic stoves rondereza, but only two households have it. There might also be a lack of information distribution. The question is how information is spread and implemented in rural areas. There should be people in charge of this but apparently there is a deficiency in the system somewhere.

The services where energy is a necessary input work as a driving force in the energy system. The need of energy controls and runs all other processes. The organic law has led to more labour for the women in Ngera. The competition to get good fuelwood is harder than it was when they first moved to the settlement. Earlier many of the villagers used to own land where they cultivated trees and the reliance on finding fuel was greater. Since the biomass access works as the major brake in the energy system, this decrease in available fuelwood propagates in the whole system and affects the energy and material volumes as well as people's behaviour. The people are forced to use less good fuel, such as residues and litter. The material that normally functions as nutrient is thus not brought back to the ecosystems.

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Interview with Fidèle Hatungimana, Social Affairs at Ngera Sector, 2007-04-05

Appendix I: Questionnaire

1. How many persons live in this house?
2. When did you move here?
3. Do you own a land but your garden? Do you rent a land but your garden?
4. What kind of stove do you have? Can we see your stove?
5. Does anyone sleep where the stove is placed?
6. Do you use the stove for
    a) Cooking
    b) Hot water
    c) Washing
    d) Lighting
    e) Space heating
    f) Drying
    g) Other (What?)
7. Can you tell us how you used your stove yesterday? For instance, what did you cook?
8. Did you use it for something else than cooking? (What?)
9. What kind of fuel do you use?
    a) Charcoal
    b) Roots
    c) Stems
    d) Branches
    e) Leaves
    f) Grass
    g) Cow dung
    h) Other (What?)
10. Where do you collect the fuel you use?
11. Who cuts/collects the fuelwood?
12. Do you collect fuelwood every day or some days in a week? How much time do you spend each time?
13. Do you get fuel from your own land?
14. Do you have a tree plot? Does it serve you as fuel wood? Was it your main purpose when planting it? When exactly did you plant it?)
15. Do you sell fuel wood?
16. Do you buy fuel wood?
17. Does the ash serve for any purpose? Which one?
18. What do you use for lighting?
    a) Candle
    b) Oil lamp (What kind of oil?)
    c) Torch
    d) Stove
    e) Other (What?)
19. Do you have any equipment that requires batteries?
    a) Radio
    b) Music player
    c) Watch
    d) Clock
    e) Other (What?)
20. Have you heard about other types of stoves than the one you use?

21. Have you heard about other types of fuels than the ones you use, such as…?
    a) Charcoal
    b) Kerosene
    c) Electricity

Appendix II: Inventory results

The observations from the eight spots, each covering a horizontal area of approximately 28 m^2, are presented below.

A. S 2° 42' 844'' E 29° 42' 123"

Typical for the forest with a mixture of five trees and eight bushes: two *Verbenaceae sp.* (species unknown) and six *Pavetta trivifolia*.

Species	Perimeter	Estimated height (X_0, L_1, L_2)	Comments
Eucalyptus maideni	71.6 cm	14.2 m (1.6 m, 7, 62)	
	96.7 cm	14.9 m (1.6 m, 6, 56)	
	77, 72 cm	12.2 m (1.6 m, 8, 61)	double border tree
Albizia gumifera	8 cm	2.8 m (1.6 m, 11, 19)	
Unknown	7, 10 cm	ca 3 m	double tree

B. S 2° 42' 870'' E 29° 42' 220"

Grass meadow.

C. S 2° 42' 838'' E 29° 42' 118"

Very hilly area, no tree layer left, but litter from cut biomass on the ground.

D. S 2° 42' 865'' E 29° 42' 118"

No tree layer but some grass and four bushes: *Pavetta trivifolia*, *Ibiscus sp*, *Sida rhomboides*, *Cyperus latifolius*.

E. S 2° 42' 844'' E 29° 42' 107"

No tree layer. Grass, roots and some sticks.

F. S 2° 42' 903'' E 29° 42' 166"

Typical terrain with four trees and three bushes: *Pavetta trivifolia*, *Grevelia robusta*, *Euphorbia tirucali*.

Species	Perimeter	Estimated height (X_0, L_1, L_2)	Comments
Eucalyptus maideni	6, 10, 15, 9, 9 cm	5.7 m (1.7 m, 21, 70)	fivefold tree
Eucalyptus sp.	18.5, 11 cm	5.1 m (1.6 m, 27, 86)	double tree
Eucalyptus sp.	9, 11, 9 cm	4.6 m (1.6 m, 21, 61)	triple tree
Eucalyptus sp.	8 cm	3.1 m (1.6 m, 24, 46)	

G. S 2° 42' 860'' E 29° 42' 188"

Young terrain with three trees and five bushes: two *Pavetta trivifolia*, one *Eucalyptus maideni* (154 cm tall), one cut *Eucalyptus sp.* (42 cm tall), two unknown, one *Lantana camara*, on the border a triple *Eucalyptus sp.* of 88 cm, 97 cm and 76 cm, respectively.

H. S 2° 42’ 811’’ E 29° 42’ 139”

Very hilly area just by the forest border. Four small trees and some bushes: three *Pavetta trivifolia*, some unknown species, three *Albizia gumifera* of five meters each, one *Eucalyptus globulus* with 6 cm perimeter, five *Acanthus pubescens* and some *Fragaria sp.* and *Rubus steudneri*.

Energy System and Fuel Flow in a Rural Post-war Settlement in Rwanda

Anna Bjereld and Johanna Thorén

In the rural settlement Ngera in southern Rwanda, biomass is the main energy resource. The villagers collect sticks, leaves and branches from the surrounding forests and combust it in their tree-stones' stoves to get energy for cooking, light and space heating. The access to fuel is limited, resulting in that women and children spend hours every day searching for biomass.

Ngera is one of the settlements built after the genocide in 1994. The Rwandan government started up resettlement programmes to provide shelter for millions of refugees and others in need of housing. Today, almost twenty percent of the Rwandans live in those settlements, but little is known about their livelihood situation.

This report presents the outcomes of a case study of the fuelwood energy system in Ngera. It also discusses why such few people invest in tree planting and fuel economic stoves.