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Environmental and socio-economic Impact of improved Stoves - The Case of the Tsotso Stove in Northern Namibia

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Abstract

Stoves with improved efficiency have been introduced in developing countries since 1970. While the focus initially lay on fuel savings and the main concern was deforestation, it is nowadays recognised that a stove programme can and should include a variety of benefits for the stove users, producers, and the environment. In the light of this change, this thesis serves to analyse the environmental and socio-economic impacts of the Tsotso Stove in Northern Namibia. A system dynamics approach was further used to gain a holistic view of the connections between the stoves, households and the environment. To create a valid, representative conceptual model, a pre-survey was conducted. Based on this model, 32 households were interviewed. From these interviews, five parameters were derived: effect on deforestation, time savings, effect on health, effect on budget and cooking satisfaction. The results show that the way the stove is used and thus also its impact varies significantly between households. While on average the stove is used 1.6 times per day, the minimum was only about 0.15 times and the maximum 5 times per day. Concerning the environmental performance, the calculations suggest that the wood savings that can be achieved are significant. Nevertheless, improved stoves should be embedded in a wider strategy in the fight against deforestation. From a system dynamics perspective, the stove is important, for it gives the households another option besides a switch to dung as fuel when firewood becomes scarce. Concerning the socio-economic impact, the households that use the stove continuously throughout the year profit the most from it. The biggest benefits are time-savings, which, on average, account to 15 minutes per day. For households that buy fuelwood, money savings can be as high as 100 US$ per month, while the average is around 9 US$. The effect on health is difficult to evaluate, but this study suggests a positive impact, mainly due to an increase in safety. Finally, the survey results indicate that the Tsotso Stove has better handling properties than the traditional stove. As a main result, this thesis shows that the Tsotso Stove has a positive environmental impact, whose significance is limited due to the low dissemination level, and a beneficial socio-economic impact, that varies greatly between household.

Acknowledgements

During the field work phase of this thesis, I worked with the Desert Research Foundation of Namibia (DRFN), in particular with the staff of Namibia's programme to combat desertification (NAPCOD). The thesis is based on surveys that were conducted during my stay in Onkani, where I was supported by Ottilie Amaambo, NAPCOD‘s local facilitator, and Esther Iiyambo, a local stove producer. The surveys were prepared and evaluated at the DRFN office in Windhoek, where I was supported by my local supervisors Hopolang Phororo and Patrik Klintenberg. The writing of the thesis took place in Lund, Sweden with the help of my Lund University supervisor Bodil Elmqvist.

First of all I especially want to thank all the people named above, secondly the DRFN and NAPCOD for hosting my research and last but not least my fellow students in Sweden and Germany for advise and support.

Contents

Chapter 1

Introduction

About 2 billion people in the world rely on non-modern fuels to fulfil their cooking needs (UNDP, UNDESA, WEC, [46]2000). These people make use of biomass such as wood, crop residues and dung. In Namibia, 80% of the rural population rely on fuelwood (Wamukonya, [51]1997), p.3), and a switch to processed fuels like kerosene or even electricity is in general difficult for rural households, since people are poor and the dissemination of modern fuels is difficult (Worldbank, [53]1996). It has been found that the stove determines to a great deal the socio-economic and environmental impact of biomass use. These impacts are either internal or external to the households using the stove (Barnes et al., [4]1993, p.120). Within the households, the stove determines e.g. how much time is needed for cooking, how much wood is being used and the level of emissions that the household members are exposed to. External impacts are the stove's effect on deforestation and greenhouse gas emissions.

Realising the great potential benefits of improved stoves, several stove programmes have been conducted in the past, initially focusing on energy-efficiency, while nowadays the focus has shifted towards development concerns (Joseph et al., [21]1990, p.4; Nyström, [35]1994, p.26).

1.1 Thesis Aim

Compared to the huge number of different stove programmes that have been launched throughout the developing World, monitoring and evaluation efforts have been insufficient (Gill, [17]1987, p.140; Wallmo, Jacobson, [50]1998, p.100). Although there are efforts to achieve uniformity in the way stove programmes are monitored (see, for example S. Joseph, [22]1990), there is a definite need for detailed analysis to understand the relationships between stoves and their users (Nyström, [35]1994, p.33) which ultimately determines the stove's impact on the environment.

> Taking the example of the Oshana and Omusati region in northern Namibia, the aim of this thesis is therefore to evaluate the socio-economic and environmental impact of the Tsotso Stove.

In order to do this, five thesis questions were established:

- What is the stove's impact on deforestation?
- Does the stove help families to save time and if yes, how much?
- What is the stove's impact on the household members' health?
- What is the stove's impact on the households' bugdet?
- What is the stove's impact on cooking satisfaction?

What distinguishes this thesis from a stove programme evaluation is that it further tries to increase the understanding of the system comprised of stoves, households and the environment by applying a system dynamics approach.

1.2 Limitations

The limitations of this study can already be drawn from its title. From a spatial point of view, this thesis is limited to northern Namibia, although some conclusions might also apply for other semi-arid areas in southern Africa. Northern Namibia, and in particular the Omusati and Oshana region were chosen since this is the area where the Tsotso Stove, the main improved stove in Namibia, was introduced by the thesis partner, the Desert Research Foundation of Namibia. It is further restricted in a sense that it only evaluates the socio-economic and environmental impact of the Tsotso stove that is reflected in the 5 questions already shown in section 1.1. This was not planned from the beginning, but was the outcome of the pre-survey that was used to create the conceptual model. If respondents had reported on cultural or political impacts of the stove, they would have been included. Please note that the focus lies on an evaluation of the impact of the stove, not on an evaluation of the stove itself.

A last limitation is that the impacts are assessed with the help of a conceptual model, which disregards time as a factor. The reasons for and outcomes of this are discussed in section 3.3.3.

1.3 The Structure of this Thesis

The thesis is structured as follows: After this introduction, a background chapter will follow that serves to make the reader familiar with Namibia, the study area, the Tsotso stove, and the Onkani Stove programme.

In the methodology chapter I will first present the approach of this thesis, system dynamics. After a section that describes the position of the thesis in the wider context of stove programmes, I will then introduce causal loop diagrams. It follows a description of how this tool was used to create a conceptual model, whose nature and limitations are then discussed. Afterwards my surveys will be described and criticised.

The results chapter is divided into seven parts. After presenting the results of the pre-survey, I will go over to explain how the frequency of stove use was determined. The next five sections will deal with the parameters that were chosen to represent the impact of the stove. First the effect on deforestation will be discussed (this effect will be further discussed in two sections of the discussion). After that the results for the four socio-economic parameters will be presented.

The discussion chapter starts with two sections concerning the environmental impact of the stove. While the first serves to explore how significant the wood savings that can be achieved are, the second tries to explain the role of the Tsotso Stove from a system dynamics perspective. The next section will sum up and discuss the results concerning the socio-economic impact of the stove. Finally, an outlook shall serve to discuss the role of the stove in the future, its dissemination potential and what the results from wider dissemination might be.

The conclusion chapter sums up the main findings and gives recommendations regarding future research as well as the future of the stove program.

Chapter 2

Background

2.1 A brief History of Stove Programmes

The first improved stove programmes that focused on energy-efficiency started in the 1970s when the oil crisis increased prices of modern fuels and forced households in developing countries to continue relying on biomass. The higher oil prices, in combination with increasing deforestation and several publications predicting a “fuelwood crisis”, led governments, NGOs and donors to concentrate on improved stoves. The movement was strengthened by early studies that suggested that simple design changes can increase the efficiency of stoves three to six fold. Trusting that the efficiency gain alone would be enough to guarantee a quick adoption and wide dissemination of stoves, a wave of stove programmes started around 1980. (Barnes et al., [5]1994, p.4)

These programmes, focussing only on dissemination, did neither take into account local customs and the economic background of the target areas, nor did they consider prices or availability of biomass fuel. Furthermore, the 75% stove savings that could be achieved in laboratory tests, could not be reproduced in the field. This resulted in a failure of many early stove programmes. (Worldbank, [53]1996)

These early failures, in turn, helped stove programme designers to find out what determines the success of a stove programme. These lessons learned can be divided with the help of three questions:

- In which situation are stove programmes successful?
- Which shape should stove programmes assume?
- Which benefits does the improved stove need to produce?

Regarding the first question, it is generally accepted that stove programmes are more successful in areas where fuelwood is already scarce, and people therefore either spend a lot of money buying wood or spend a lot of time collecting it (Barnes et al., [4]1993, p.125). Concerning the second question, experience has shown that programmes using a top-down approach and relying heavily on donor funding to subsidise the stoves performed much worse than programmes that were participatory from the beginning and in which funding was used to establish a self-sustaining stove industry (Barnes et al., [5]1994, p.19; Department for International Development, [12]2000, p.6). The last question concerns the stove itself and the benefits it can provide for its user. Stove programmes have shown that superior efficiency is not sufficient to guarantee a widespread dissemination of stoves. Rather, the stove has to be competitive with the traditional stove in a multitude of factors, such as ease of use, safety, time-saving and attractiveness so that the user clearly perceives the benefits it creates (Hulscher, Luo, Koopmans, [20]1999, p.3).

As a reaction to these lessons learned, a new phase of stove programmes started, which is coined the “Phoenix phase” by Smith (as cited in Joseph, Prasad, van der Zaan, [21]1990, p.4). This phase is characterised by a focus on development-concerns such as indoor air quality or the potential income generating effects of stove programmes (Joseph et al., [21]1990, p.4; Nyström, [35]1994, p.26). This more holistic understanding of the role of improved stoves is also underlying this thesis.

2.2 Namibia

2.2.1 Natural conditions

Namibia's climate is characterised by arid to semi-arid conditions, with rainfall varying between 90 and 600 mm per year, and an extremely high rate of evapo-transpiration (Langanke, [25]2001, p.7; Matthew, [28]2001, p.1). The rainfalls are highly variable, both spatially and temporally; they rise along a gradient from south west to north east, increasing from 100 mm in the Namib desert to 500-700 mm in the north east. The rainfalls occur highly seasonal, with 90% of the rain falling between October and April in most of Namibia (MAWR, [32]1999, p.22).

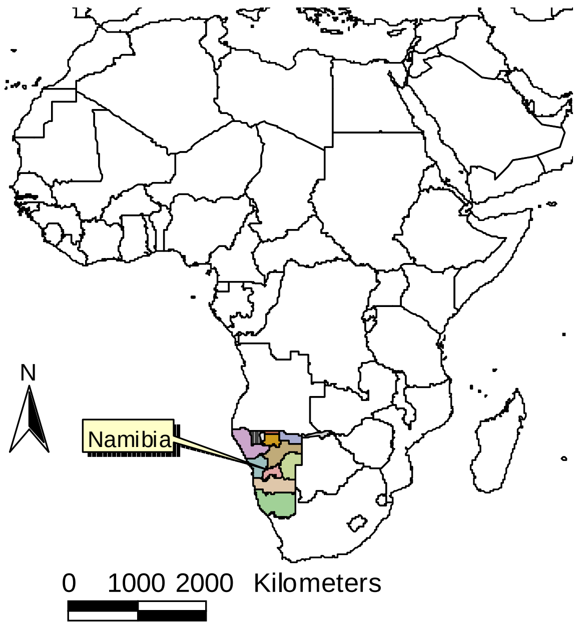

Figure 2.1: Africa and Namibia (source: Digital Chart of the World).

The arid climate, together with the acid, crystalline rocks that make up the largest share of the bed-rock in Namibia result in sandy, infertile soils with a low content of organic matter (Langanke, [25]2001,p.10). The main groups of soils that can be found throughout Namibia are unconsolidated sands (arenosols), and weakly developed soils like lithosols, xerosols, regolsols and vermosols (FAO, [13]1973). Only 3% of Namibia's soils have a clay contents greater than 5% and provide some water holding capacity. In general, soils are deficient in macro- and micronutrients (Langanke, [25]2001, p.10).

The growth and distribution of the vegetation is determined by soil and climatic conditions. The vegetation distribution is correlated to the precipitation gradient, the variability of rainfall, the soil conditions and the landforms. It is further influenced by anthropogenic activity, which started centuries ago (Langanke, [25]2001,p.14). Giess ([16] 1971) distinguishes between three main vegetation zones, desert (16%), Savannah (64%) and dry woodlands (20%). He further differentiates 14 Vegetation types (see figure 2.2). Due to the climatic conditions and the low quality soils, the growth of woody biomass is fairly low (Matthew, [28]2001, p.1).

2.2.2 Land use

According to Langanke ([25]2001, p.15), the "agricultural sector of Namibia is divided into a commercial farming sub-sector, where farmers operate on freehold title deed land, and a communal farming sub-sector where farmers operate on land under a communal tenure system". The latter is mainly situated in the northern and central parts of Namibia (Langanke, [25]2001, p.15). Though supporting 95% of the nations farming population (Kruger, [24]1997, p.45), the communal areas fill only 48% of the total agricultural land. The result is a very uneven land distribution, with the communal farm sizes being around 2 hectares, while the commercial farms have an average landholding of 8620 hectares (NRC et al.,[34]2000). According to the Namibia Red Cross et al. ([34]2000, p.34), six different land use schemes can be distinguished:

- Irrigated cropping along the rivers
- Dryland cropping and livestock production on communal areas in the north
- Large stock production on commercial farms in central and eastern areas
- Small stock production in the south and along the Namib desert
- Wildlife for game ranches, tourism and meat production in parks, on private farms and in communal areas in the north east and north west

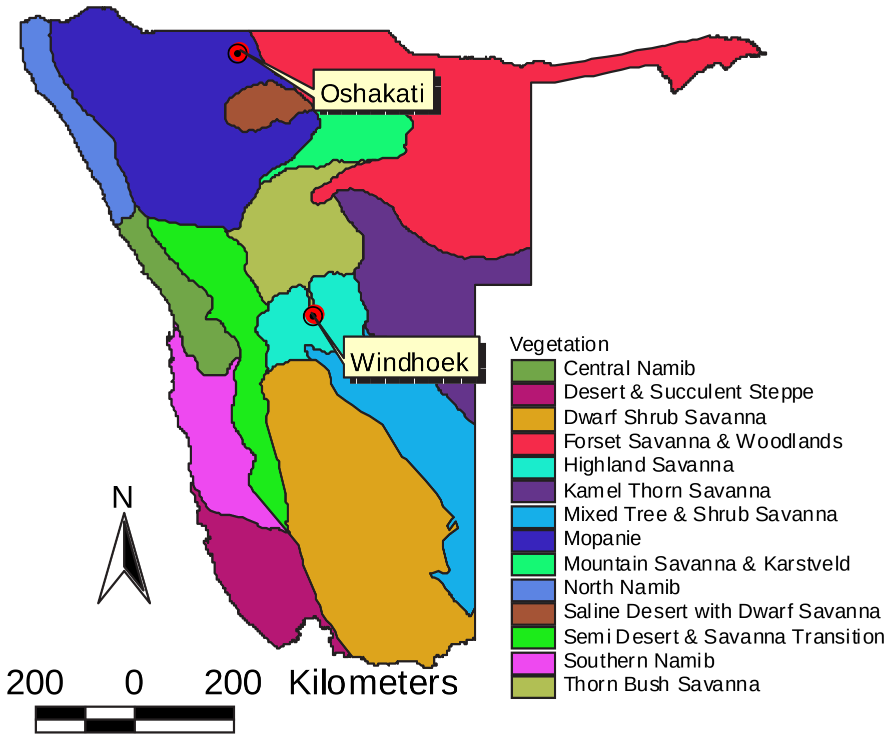

Figure 2.2: Vegetation of Namibia (source: Giess, [16], 1971).

- Diamond mining in the south-western area

Although agriculture contributes only 9% to the Gross Domestic Product, it is the income provider for most Namibians, especially in the north, where the communal agriculture acts a safety net for the poor rural population (Langanke, [25]2001, p.16).

2.2.3 Demography

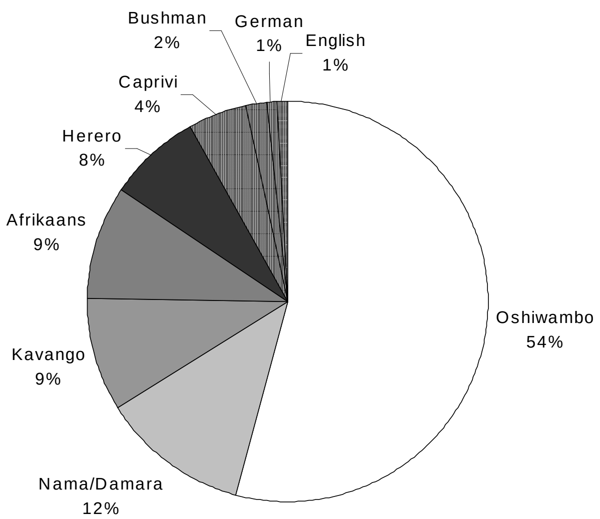

Figure 2.3: Ethnical composition of Namibia's population according to the Central Statistics Office ([9]1994).

Namibia is one of the most scarcely populated countries, with an average population density of 2.2 people per km^2. According to the 2001 census, almost 780,000 of the 1.8 million Namibians live in one of the four O-regions: Omusati, Oshana, Ohanguena and Oshikoto. In this area, formerly called Owamboland, the population density is about seven times higher than the average. (Central Bureau of Statistics, [8]2001) Almost 60% of the 295,000 households in Namibia are still situated in rural areas (United Nations Human Settlements Programme, [47]2000). With at least 10 different ethnic groups, Namibia consists of a multitude of African and European cultures. Figure 2.3 shows the different ethnicities and their share of the population. (CSO, [9]1994)

Population growth in Namibia has been on average 2.6% from 1991 to 2001 (CBS, [8]2001, p.13), which corresponds to a doubling of the population every 27 years.

2.2.4 Rural Poverty

According to Cecelski et al. ([6]2001, p.6), Namibia's income distribution "is one of the most unequal in the world, inherited from the colonial period, despite rich mineral, livestock and fisheries resources". Poverty prevails especially in the rural households, of which 60% live in poverty and are subjected to food and livelihood insecurity (Ministry of Mines and Energy, [33]1997). The reasons for rural household food insecurity are low levels of food production, a limited number of productive assets, the lack of income generating opportunities and inadequate purchasing power (Schneider, [39]1999, p.39)).

Furthermore, rural areas often lack important social services like health care and education as well as safe water and adequate sanitation. Since rural households rely on agriculture, they are also especially vulnerable towards droughts and environmental degradation. (Schneider, [39]1999, p.39))

2.2.5 Fuelwood Situation

Of the rural households, the majority of 90% use biomass energy to fulfil their energy needs. Most of the biomass is used for cooking. Fuelwood, the main fuel source, is getting increasingly scarce, especially in the highly populated area of the north. Surveys in this area indicate that households, on average, are collecting wood nine times per month and have to walk almost 15 km per trip. (Cecelski, et al., [6]2001, p.6)

Biomass will continue to be a highly important fuel source, since, for geographical and economic reasons, only 16% of the population are provided with electrical power (Stewart Scott Namibia, [43]2002, p.2).

The low growth of woody biomass, the increasing population and the absence of alternative fuel sources result in increasing pressure on biomass resources.

2.3 Study Area

As can be seen on figure 2.4, the study area is part of the Oshana and Omusati-region, two of the 4 O-regions (see section 2.2.3), the constituency is called Uuvuudhyia. Figure 2.5 shows the study area in detail.

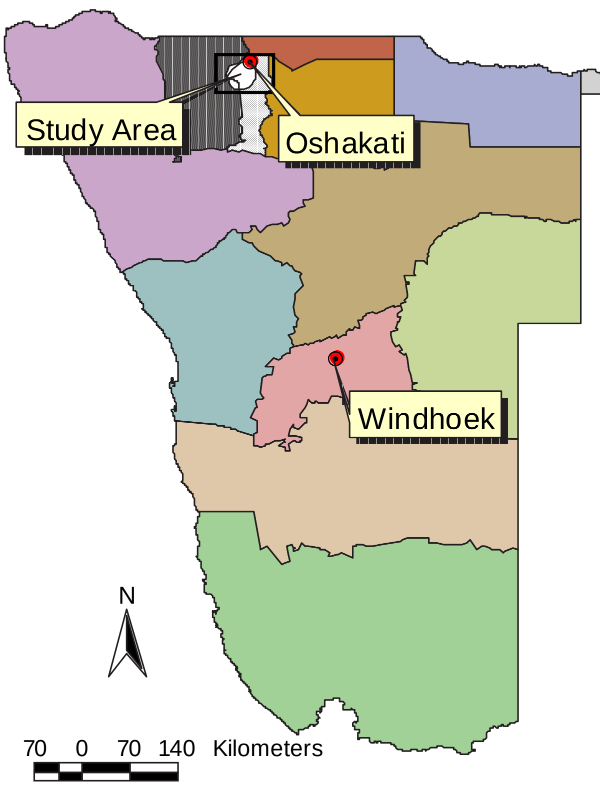

Figure 2.4: Map showing northern Namibia and the position of the study area (source: DRFN).

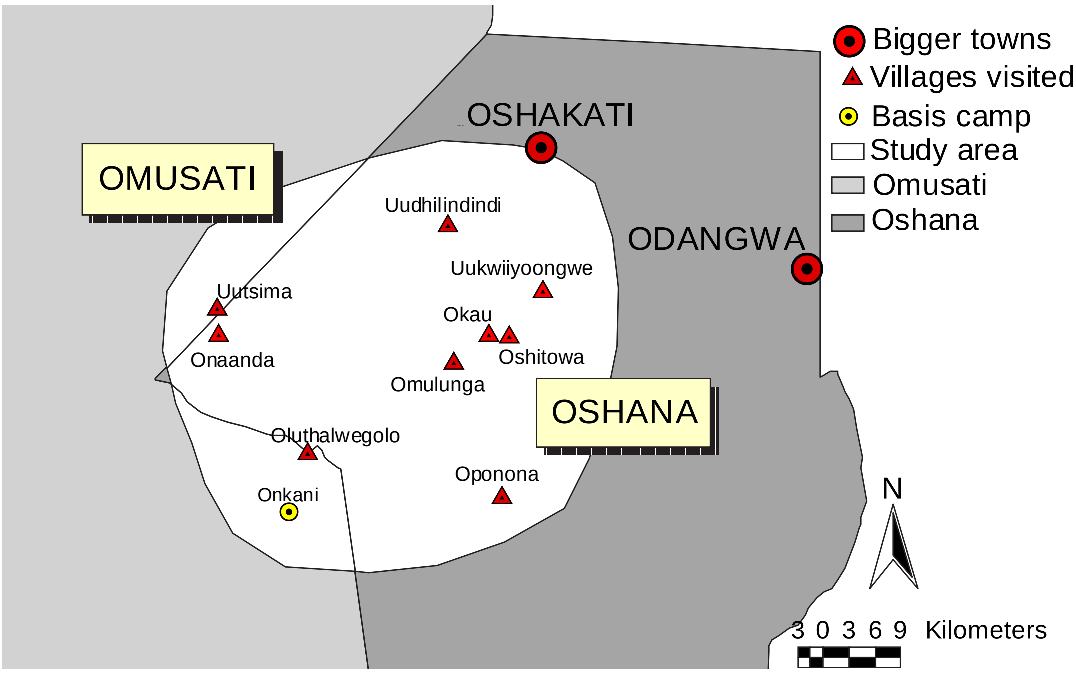

Figure 2.5: Map showing the study area including villages visited (source: DRFN).

2.3.1 Natural Conditions

The average annual rainfall in the study area is 400 mm and is highly variable (Langanke, [25]2001, p.36). The variability increases with decreasing rainfall from south-west to north-east (Schneider, [39]1999, p.42). Almost all of the rain (96%) falls between November and April, with a maximum in January, February and March, when two thirds of the yearly rainfall precipitates (Langanke, [25]2001, p.36). The mean annual temperature in Oshana and Omusati is 23°C (Wamukonya, [51] 1997, p.5).

The study area's soils have a poor nutrient status and show a high concentration of sodium and salt. The texture is dominated by sand, which is either loamy or clayey. The main soil types in the Uvuudhyia constituency are arenosols and cambisols, which, according to the LERIS landscape ecological risk classification (Trippner, [45]1998, p.15), show "moderate to high" soil risks. Since the relief is rather flat, the main cause of erosion is wind. According to the Northern Namibia Environmental Project (NNEP) (Verlinden & Dayot,[49]1999, p.47), the soil is able to provide good yields for the first three years of cultivation only, afterwards manure is needed. (Langanke, [25]2001, p.35)

Both regions, Oshana and Omusati, are characterised by an extremely flat topography (Selanniemi et al., [41]2000, p.6; Selanniemi et al., [40]2000, p.6). They are part of the Cunene river basin, which is part of the Kalahari basin (Langanke, [25]2001, p.30). Perennial rivers are missing, but numerous watercourses, called Oshanas, form a wide delta (Marsh & Seely, [31]1992; Selanniemi et al., [41]2000, p.6). The most important Oshana is the Cuvelai River, which has its source in Angola and drains towards the Etosha pan (Marsh & Seely, [31]1992).

The vegetation in the Omusati and Oshana region can generally be classified as Mopane Savanne. The dominant tree species is *Colosphermum mopane* (Wamukonya, [51] 1997, p. 5). The Oshana region has a very poor diversity of woody species, comprising only 11 tree and 20 shrub layer species. The woody resource is scarce with 80% of the area showing no or little woody vegetation. (Selanniemi et al., [41]2000, p.3)

The Omusati region has slightly higher (though still low) woody species diversity with 29 tree and 40 shrub species. The woody resources are also scarce, with dense shrub lands and areas without vegetation dominating the area. (Selanniemi et al., [40]2000, p.3).

2.3.2 Human Activity

The subsistence strategy of the majority of households in the 4 O-regions is centred on livestock farming, with support by migratory seasonal grazing and rain fed agriculture. In addition to this, management of trees for fodder, edible fruits, firewood and construction is an important activity. Nowadays, however, off-farm incomes become more and more important. (Langanke, [25]2001, p.39)

The main cereal crop of the 4 O-regions is pearl millet (or mahangu in Oshiwambo), which allows annual yields of 100-400 kg/ha. These yields could be increased with the use of synthetic fertilisers, but the latter are expensive and, the risk of droughts always present, virtually no one falls back on using fertilisers. All in all, the land use system is that of low-input agriculture. (Langanke, [25]2001, p.32)

Since all surface water is ephemeral, people and agriculture rely on pipelines and groundwater wells to fulfil their water needs (Schneider, [39]1999, p.43).

Land use problems are numerous, with natural and socio-cultural causes. The main environmental constraints were summarised by Verlinden and Dayot ([49]1999, p.61):

- A low number of perennial surface water resources,
- insecure and low rainfall,
- a high potential evaporation rate,
- the majority of arable areas consisting of sandy soils that lack water retaining capacity and some nutrients,
- a high salinity of the soils in areas that are seasonally flooded,
- limited resources of groundwater.

Similarly, they summarised the man-made problems of the region:

- High population pressure, resulting in deforestation and, locally, in the depletion of grazing land near water points,
- declining soil fertility due to land shortages and low input agriculture,
- infrastructure developments that change and disturb surface flows,
- human and animal waste contaminating surface water,
- solid waste accumulating uncontrolled near and within settlements,
- the disappearance of wildlife,
- the occurrence of uncontrolled fires in livestock areas.

What should be added to this list are the breakdown of traditional land management practices and the problem of controlling access to land. According to Langanke "the role of traditional authorities in allocating land and regulating access to resources is breaking down, as those authorities are increasingly being corrupted or ignored" (Langanke, [25]2001, p.41). The results are the fencing off of large areas of communal land by private investors and a concentration of cattle and land in the hands of a few farmers, leaving the poor farmers marginalised. To combat this process, an Agricultural Land Reform Bill is supported by many Namibians. (Langanke, [25]2001, p.41)

The described problems led the LERIS-project (Trippner, [45]1998, p.37) to conclude that "the recent utilisation of natural resources must be considered to have reached its upper limit. This means the Uuvudhiya Constituency is close to over-exploitation..." and "If the recent climatic trend of under average rainfalls in the Uuvudhiya Constituency continues and the utilisation pressure by cattle is increasing and focusing around some few water places, a serious decline in regeneration capacity with a long-term loss of range land has to be expected".

2.3.3 Demography

Compared to the rest of Namibia, the population density in the study area is high, with 25 (Oshana) and 14 (Omusati) persons per km^2 (Selanniemi et al., [41]2000, p.4; Selanniemi et al., [40]2000, p.4). The generally high population density in northern Namibia is a result of the apartheid regime, that forcibly concentrated population in the north (Cecelski, et al., [6]2001, p.6), and the relative high availability of water and arable land compared to rest of Namibia (Langanke, [25]2001, p.42). In both regions the majority of the population is rural, and more than 50% are working in the agricultural sector (Wamukonya,[51] 1997, p.5), mainly as subsistence farmers (Matthew, [28]2001, p.1). The average annual income is approximately 8500 N$(Omusati, 1540 US$) and 10,500 N$(Oshana, 1900 US$) (Wamukonya, [52] 1998 cited in Matthew, [28]2001, p.4).

2.3.4 Politics

North-central Namibia was subjected to armed conflict the last 20 years, hence its modern development did not start until independence was acknowledged in 1990 (Langanke, [25]2001, p.30). The area used to be divided in kingdoms, which were separated from each other by woodlands (Schneider, [39]1999, p.43). Settlement patterns have been affected by the artificial division of Namibia and Angola, by continued warfare and by the migration of men and cattle from Angola to Namibia (Malan, [10]1995, p.18). Nowadays, a local government is in place as well as a system of traditional leadership. Both of which making decisions about development issues. (Langanke, [25]2001, p.33).

2.3.5 Fuel-wood Situation

As already described, woody vegetation is scarce in the study area, the reasons being over-cutting and poor soil conditions (Selanniemi et al. [41]2000, p.3). Cutting takes place for a number of reasons, according to Langanke, the building of a homestead, for example, affords 1000 trees, with another 4000-6000 trees needed for fencing. Last but not least, 93% of the rural households in Namibia rely on fuelwood to fulfil their energy needs (CBS, [7]1999, p.18), the consumption estimated to range from 0.2-1 ton per person and year (NRC et al., [34]2000, p.28). According to a study conducted by Stewart Scott Namibia, “Wooded areas have been overexploited in and around the densely populated areas of Northern Namibia and the larger urban centres”, thus “Namibia must now deal with major environmental and socio-economic problems related to deforestation and desertification” (Stewart Scott Namibia, [43]2002, p.2).

2.4 The Stoves

2.4.1 The Traditional Stove

The traditional stove basically consists of three stones or bricks that are positioned around a fire in a triangular formation. The pot is placed on the stones, while fuelwood can be added from between the stones.

In contrast to the Tsotso Stove, the traditional stove can be built by everyone and does not require any special material (Karekezi, Ranja, [23] 1997, p.59).

The stove can be considered highly versatile and functional. It is highly versatile, for it burns all kinds of biomass, can be adjusted to fit pots of any size and it can easily be controlled by adjusting the fuelwood supply (Gill, [17]1987, p.138). It is highly functional, for it performs a number of tasks besides the cooking of food. Its heat can be used for space heating, its fire for lighting and the smoke to keep away insects and to preserve the thatch, food and timber (Gill, [17]1987, p.138; Karekezi, Ranja, [23] 1997, p.59). Finally, the stove can be important as a gathering place or carry symbolic value (Gill, [17]1987, p.139).

The view that traditional stoves have a very low efficiency has changed over the last years, for nowadays its multi-functionality and the flaws of early tests are acknowledged. For many years however, low efficiency values were accepted as common knowledge without testing this assumption. Gill ([17]1987, p.138) states that most low figures given in the literature are anecdotal, while tests resulted in a wide range of efficiency values. He concludes that traditional stoves "can have significantly higher efficiencies than has generally been assumed" (Gill, [17]1987, p.138).

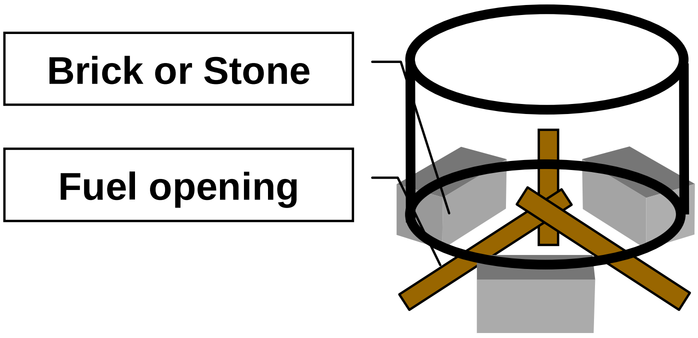

Figure 2.6: Schematic drawing of the traditional three-stone stove.

Nevertheless, the traditional stove has a number of drawbacks. First of all, although acknowledging that the efficiency of the traditional stove is not as low as has been assumed, it is still not as high as that of some improved stoves. The results are a high consumption of wood and long cooking times. Secondly, the stove emits significant amounts of smoke, which can pose a health threat to the persons staying close to it (George, [15]2002, p.29). Finally, the openness of the stove can result in accidents, leading to injuries or damages to the dwelling (George, [15]2002, p.29).

2.4.2 The Tsotso Stove

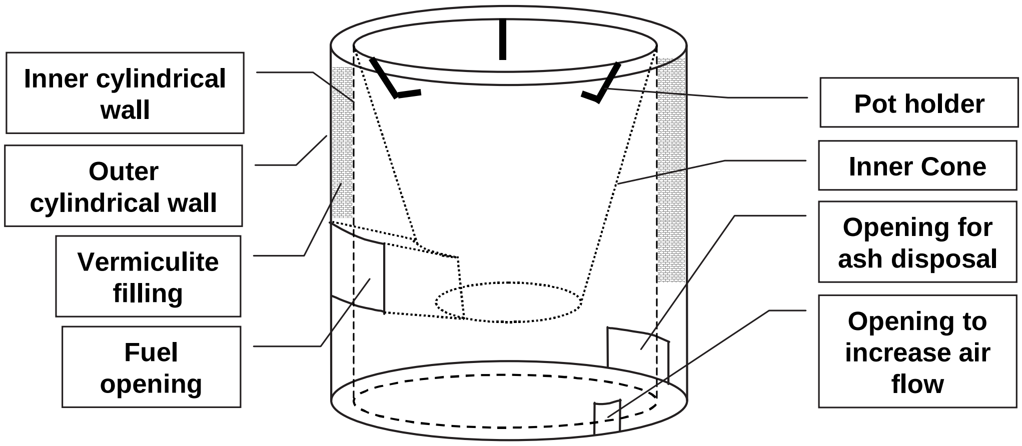

Figure 2.7: Schematic drawing of the Tsotso Stove.

The origins of the Tsotso Stove lie in Zimbabwe, where it was developed by the Development Technology Centre (Karekezi, Ranja, [23] 1997, p.61-62; R3E [38]2002, p.5). For the Namibian Tsotso Stove project the design of the stove was changed by the Namibian Ministry for Mines and Energy (Schneider, [39]1999, p.49). The Tsotso is a single pot metal stove (Lasten, [26]2001, p.9). It consists of metal sheets that form a cylinder in which a perforated metal cone is hung in. The cylinder is made of 0.5 mm thick sheets of galvanised metal and is filled with a vermiculite/cement mixture, which serves to reduce heat loss. Three openings are in the cylinder, one to fill the cone with wood, one to clean out the ash and one to increase the air flow. The cone used to be made of thinner metal sheets, but this was changed when it was observed that the thin metal sheets broke down quite fast. Two handles are attached to increase the portability of the stove. The weight of the stove is around 10 kg for the medium sized stove. On top three pot holders are assembled. The stove is sold in three sizes, although by now the smallest size was abandoned due to a lack of demand.

The manufacture of the stove is held as easy as possible to facilitate the learning process for local artisans. It can be build through a simple cut-fold-fasten procedure and only very few tools and materials are required. No electricity is required to manufacture the stove. In an assessment of the Tsotso Stove programme, the Energy and Energy Efficiency Bureau of Namibia (R3E) concludes that "the thought that went into the design of the Tsotso is commendable and is "appropriate technology" at its best". (R3E, [38]2002, p.5).

Nevertheless, a follow up report revealed several flaws of the stoves examined, which resulted from non-uniform production within and between production centres. These are:

- A poor finish (poorly folded seams, ugly surface painting)
- A non-uniform isolation layer
- Varying dimensions of the stoves (including grate diameter, weight of stoves, height of combustion chamber)
- The use of sheet metal that is too thin, resulting in a reduction of lifetime (Lasten, [26]2001, p.12)

Figure 2.8: The Tsotso Stove

Positive characteristics of the stove are its efficiency, its ability to burn a wide range of fuels and the provision of a safe cooking environment. The efficiency is higher than that of the traditional stove for three reasons; the Tsotso Stove acts as a windshield, its walls are insulated and the shape of it results in a focusing of the heat on the pot. (Stewart Scott Namibia, [43]2002, p.8).

In an attempt to compare different biomass stoves, Ballard-Tremeer and Jawurek ([3]1996, p.427) conducted a computer-controlled version of the standard water boiling test with several stoves. One of the stoves tested, called the one pot metal stove, has a similar architecture to the Tsotso Stove. Although it is not exactly the same stove (the stove tested has, for example, no lateral opening for fuel), the results of the tests give an idea of the results the Tsotso Stove would achieve. In the following, the results of the one pot metal stove will be used to validate the survey findings.

The results are shown in table 2.1. The parameter *efficiency* describes how much energy of the fuelwood is transferred to energy that is used to heat up the water. The parameter *time to reach boil* gives an idea of how fast the stove is. The parameter *CO to* CO_2 is a measure for how imperfect the combustion is; the less oxygen available, the more toxic CO is generated. The parameter *total* SO_2 says how much SO_2, a harmful gas, is emitted. Finally, the parameter *TSP* stands for Total Suspended Particles, which is a measure of the level of particulate matter emitted.

This emission data and its effects will be discussed together with other impacts on health in section 4.5.

Table 2.1: Emission data of open fire and 1-pot metal stove, taken from Ballard-Tremeer et al. ([3] 1996, p.427)

Stove type (no. of tests) / parameter	Open fire (6)	1-pot metal stove (6)
Efficiency [%] (st.dev.)	14 (2.1)	20 (3.1)
Time to reach boil [min.](st.dev)	22 (3)	16 (2)
CO to CO_2 *mol. ratio* [%]	1.3	5.25
Total SO_2 per test [g]	0.058	0.694
Total TSP per test [g]	0.891	0.976

2.5 The Onkani Tsotso Stove Programme

The Onkani Tsotso Stove project was initiated by the Desert Research Foundation of Namibia (DRFN) and Namibia's Programme to Combat Desertification (NAPCOD) which is implemented by the DRFN and

Namibia's Economic Policy and Research Unit (NEPRU) (Hamayulu, [19]2000, p.4). NAPCOD is part of Namibia's Biomass Energy Management Programme (NBEMP), which is co-ordinated by the Ministry of Mines and Energy (MME). NBEMP, in turn, networks with the South African Development Community-wide Programme for Biomass Energy Conservation (ProBEC). (Matthew, [28]2001, p.1)

The goal of NBEMP is to "to put in place a National Biomass Energy Management Strategy that will contribute to the sustainable utilisation and supply of traditional biomass energy for private households and small-scale industries in Namibia" (Matthew, [28]2001, p.2) while NAPCOD strives to "to combat desertification by promoting the sustainable use of natural resources for the benefit of all Namibians both present and future" (Hamayulu, [19]2000, p.4). The focus of both institution is thus on the sustainable use of natural resources, in this case woody biomass. In this light, the Onkani Tsotso Stove project aims at reducing the unsustainably high consumption of firewood.

The Onkani Tsotso Stove project was started in August 2000 as part of the first phase of Namibia's Biomass Energy Saving Project (NamBESP), which represents the implementation level of ProBEC. The goal of the first phase was to establish six stove production sites within the 4 O-regions. In Onkani, this was conducted by the DRFN and NAPCOD, who informed community members about the way in which fuel-efficient stoves can help to combat desertification and trained two school leavers in manufacturing the Tsotso and the Mbwangu stove. The school leavers in turn taught other community members. The Stove manufacturers were provided with a building for manufacturing, tools to produce the stove, and stove templates.

The costs to produce a stove commercially were approximated by Lasten ([26]2001, p.16/17), and are shown in table 2.2. Right now the stoves are sold for 110N$ (16 US$) and are being subsidised with 32 N$ (4.64 US$) by NamBESP (Lasten, [26]2001, p.17).

Table 2.2: Costs involved in the production of the Tsotso Stove, taken from Lasten ([26]2001, p.16/17)

	Costs in N$ per stove	Costs in %
Material costs	64.5	45.4
Direct labour Cost	50	35.2
Direct transport Cost	12.5	8.8
Indirect cost (Rent of building)	15	10.6
Total Production Cost	142	100

Regarding the evaluation of phase one of the NamBESP project, Lasten ([26]2001) gives a list of successes, constraints and recommendations. The successes include the manufacturing and distribution of improved stoves, the creation of employment and the increase of awareness for the topic of biomass conservation and improved stoves. According to Lasten ([26]2001, p.20), the number of stoves disseminated up to 2001 were more than 350. Compared to the number of households of the whole area the NamBESP programme covers, this number is low, and the "potential for demand remains largely untapped" ([26]2001, p.20). Constraints that hinder a wider dissemination of stoves are a lack of transport possibilities, lack of skills such as business management, marketing and stove design. Recommendations made to enable the stove production to shift to a fully commercial level are to disregard the creation of further production sites, to minimise the production costs and to establish retail agents to alleviate the restrictions created by a lack of transportation. (Lasten, [26]2001, p.17-19)

The R3E and the DRFN ([38] 2002) also point to the lack of marketing, which they see as the most important constraint. They argue that one root of this problem is that the stoves status in society is that of a "poor man's solution" which results in a discouragement of manufacturers. This low perception of the stove has not been observed during this study; neither was it expressed by interviewees during the pre-survey, when people were asked what the drawbacks of the stove are, nor by the stove producer at the Onkani production centre. Furthermore, the fact that the price of the stove is considerable (while the majority do not pay for fuelwood), makes it seem contradictory that the stove is associated to be a "poor man's solution".

Chapter 3

Methodology

3.1 System Dynamics

The approach chosen for this thesis is system dynamics. According to Sterman ([42]2000, p.4), “system dynamics is a method to enhance learning in complex systems”. The underlying concept – system – is well explained by Checkland ([11]1981, p.3), who states that it “embodies the idea of a set of elements connected together, which form a whole, this showing properties which are properties of the whole, rather than properties of its component parts”. In the case of this thesis, this means that the system made up of stoves, households and the environment shows properties that are the result of the system and cannot be understood when looking at isolated parts of it. The field of system dynamics used for this thesis was developed by Jay Forrester and his colleagues at the Institute for Technology in Massachusetts in the 1960s (Ford, [14]1999, p.5). Checkland and others differentiate between a “hard” and a “soft” thinking approach in system dynamics. The “hard” approach is characterised by a clear task that the model is supposed to solve. The “soft” approach, in comparison, can yield completely unexpected answers at later stages. Checkland uses the example of an analysis of a weapons system to clarify the difference; while a “hard” approach will yield an analysis of how good the weapon system is, a “soft approach” could also produce strategies like disarmament as a result. (Checkland, [11]1981, p. 190)

For this thesis the hard approach was chosen, since the clear aim is to assess the impact of the Tsotso Stove. A soft approach that would have allowed to consider, for example, alternative measures to reduce deforestation, was regarded to be too broad for a thesis of this size. Within this thesis the system dynamics approach serves to elucidate how the stove’s (primary) characteristics result – through several impact channels – in benefits/drawbacks for the household using it and the environment.

Since it is assumed that the part of reality that is of interest can be described by a model which is based on rules, the approach used in this thesis is rooted in the epistemological stance of positivism. The way knowledge is acquired is both through deduction and induction; the pre-survey is inductive, for the evidence is gathered in order to create a hypothesis, while the main survey is deductive, since the evidence gathered is used to support and quantify the created hypothesis.

3.2 Positioning the Thesis in the wider Context of the Stove Programme

Figure 3.1 shows two cycles, the learning and action cycle for the stove programme and the modelling cycle that was used in this thesis (Please note that the modelling cycle also represents another learning and action cycle). As can be seen, the modelling cycle serves to gain insight in one of the steps of the learning and action cycle, the effect of the decision (introducing improved stoves) on the real world (indicated by the blue field). Both cycles are taken from Sterman ([42]2000, p.88), and both of them have been adapted – the modelling cycle also in a structural sense – to match the approach of this thesis. After articulating the problem and establishing the dynamic hypothesis, a first formulation in the form of a Causal Loop Diagram (CLD) was created. To test this formulation, the pre-survey was conducted and the evaluation of it resulted in a revised formulation. This second formulation was then used to design the main survey, in which the focus was not to test the formulation in a qualitative way, but in a quantitative manner. In other words,

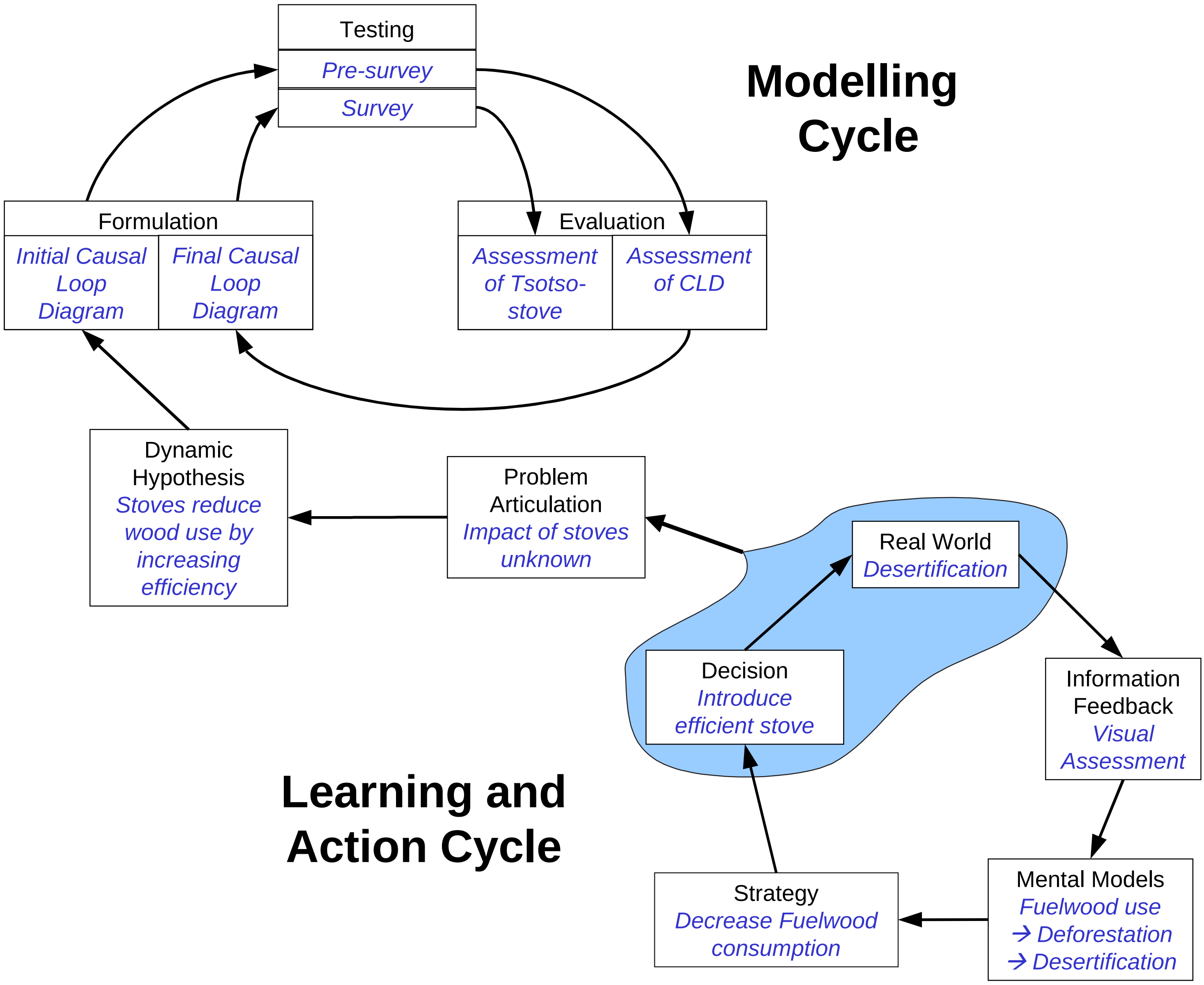

Figure 3.1: Diagram showing the cycle of learning and action and the modelling cycle that is used to gain insight in one of its steps (Adapted from Sterman [42]2000, p.88).

the pre-survey served to establish the important links in the CLD while the main survey's purpose was to quantify the links.

3.3 The Conceptual Model

3.3.1 Introducing Causal Loop Diagrams

The tools used in this thesis are Causal Loop Diagrams (CLDs) and interviews. According to Sterman ([42]2000, p.102), CLDs are "maps, showing the causal link among variables with arrows from a cause to an effect". CLDs thus consist of variables and arrows. Variables can be a condition, a situation, an action or a decision which is influenced by other variables and influences other variables (Maani & Cavanna, [27]2000, p.25). Variables that are not influenced by other variables are called exogenous variables, since they are outside of the system and are not influenced by it. Variables that are influenced by the system are accordingly called endogenous variables. Within the conceptual model, the key exogenous variables are the stove's primary characteristics, while the key endogenous variables represent the secondary characteristics. (Sterman, [42]2000, p.97)

Arrows between variables indicate a causal association. If the correlation between the variables is positive, than this is indicated by a small "+" next to the arrow. If it is negative, a "-" is used. (Maani & Cavanna, [27]2000, p.25-27)

Figure 3.2 shows a part of the CLD that serves as theoretical framework, it can be read like this: An increase in efficiency results in a decrease in wood consumption, a decrease in wood consumption, in turn, results in an increase of time savings e.g. through less collecting. Both correlations are negative, meaning that an increase in one parameter results in a decrease in the other.

3.3.2 The Creation of the Conceptual Model

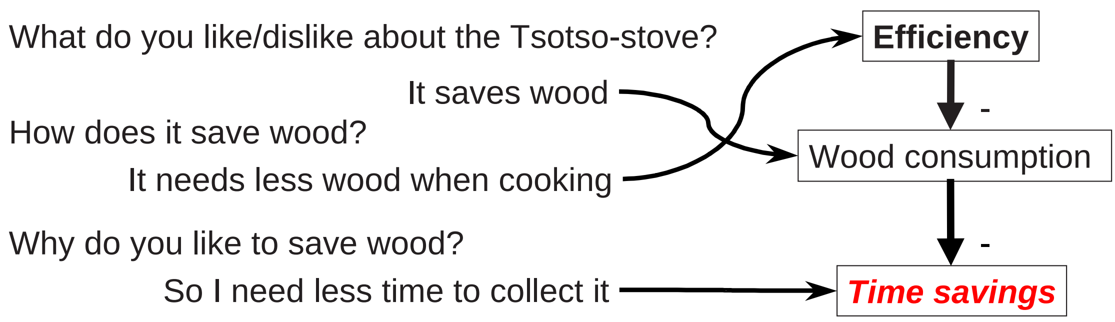

Figure 3.2: Diagram showing how the responses to the questions of the pre-survey were used to construct the conceptual model

Figure 3.2 shows how the pre-survey was used to arrive at the conceptual model (a CLD). The idea was to include the opinions of the rural population, without performing true, and most probably very time consuming group modelling that strives for full participation. Instead it was chosen to conduct a survey that would result in a CLD that basically consists of the responses given by the interviewees with only few of my thoughts added.

According to the typology introduced by Pretty ([37]1995, p.1252), the described participation procedure is best referred to as participation by consultation. This means that "people participate by being consulted or by answering questions...and professionals are under no obligations to take on board people's views". While the first part fits, the second part of the definition does not apply to this thesis, since there is an obligation to take on board people's views in order to construct a representative model.

3.3.3 The Nature of the Conceptual Model

What is noteworthy about the conceptual model used is that it is static, i.e. it does not include time as a factor of change. The benefits of dynamic models are that possible feedback loops can be detected and considered. In this sense, they give a better picture of reality. The benefits of the static model used here is that quantification is still within the scope of a master thesis. It was this possibility to quantify the stove's impact, together with a belief that a dynamic analysis will not yield findings that make the static approach invalid that made me choose a static model.

The assumption made, is that in the current situation, the impacts of the stove will not change over time. One justification for this assumption is that, at the current level of dissemination, the introduction of the stove cannot be expected to cause any changes in the socio-economic or environmental world that would change the system behaviour. In a way, this approach is comparable to the linear approximation of a non-linear curve, a reasonable procedure as long as the time steps chosen and the deviations of the gradient are small enough. In the long run, however, two trends can be expected to influence the impact of the Tsotso Stove, these are the growing population and the ongoing deforestation and desertification. The results of this is most probably a strengthening of some of the positive impacts of the stove (as long as the natural resource base is not completely destroyed) for wood will become scarcer, leading to longer collecting times and higher prices. However, as already mentioned above, I do not believe that the general structure of the model will be made invalid by these two trends.

When predictions about future situations with a wider dissemination of the stove are made, the assumption that feedback loops do not exist does not hold anymore, for the system will surely feedback on itself. An example of this could be that the use of the Tsotso Stove can result in a re-growth of woody biomass, which would make it easier to collect wood and thus would decrease the positive impacts of the stove. Therefore, predictions including a wider dissemination of the stove were only conducted for the environmental impact (which is assumed to behave more docile) and these were confronted with a (dynamic) causal loop diagram.

3.3.4 Critique of the Conceptual Model

The critique of the system dynamics approach centres around the conceptual model, in particular, its ability to represent the part of reality that is important to solve the question it has been created for. This ability cannot be taken for granted for a number of reasons:

Imperfect pictures of reality In general, models are made up by people who never have a perfect picture of reality. Therefore, in the case of this study, the model was created using the knowledge of the local population and my own. While this adds to the credibility of the model, it is certainly not a guarantee for full representativeness. After all, the structure of the model reflects the correspondents' and my own picture of reality, and since these pictures are imperfect, the model created from them will also be imperfect.

The need to simplify Using the approach that I used, it was important to arrive at a model that would be complex enough to solve the question, but easy enough to be testable. In the search for a testable model, certain connections were already (consciously and subconsciously) disregarded by me. In case one of these connections was important after all, there was no way through which it could have emerged in later phases of the study.

Household diversity It is assumed that the model created is applicable for all households possessing the stove. In order to guarantee that, it would have been necessary to perform group modelling with all of these households, an impossible task. Considering only the views of some of the households, however, reduces the credibility of the model, for it cannot be assured that the sample chosen fully represents the population as a whole. The high diversity between households aggravates this problem.

Disregard of time This point has already been described in section 3.3.3.

Albeit all the points of critique above reduce the quality of this thesis, they are only consequences of the limited resources available to conduct this study.

3.4 The Surveys

3.4.1 Description of the Surveys

For the pre-survey, semi-structured open-ended interviews were conducted in order to create a CLD that shows all relevant connections between stove, household and environment and which can then be used to compile a questionnaire to quantify the connections. Semi-structured interviews were chosen so that answers of the respondents could be scrutinized. The sample size for the pre-survey is 16, comprising 3 men and 13 women. 13 of the respondents owned a Tsotso Stove, 3 had only heard of it. The latter were interviewed to get an idea of which drawbacks make people decide not to purchase the stove. The reason for focusing on women was that in the majority of households, women are responsible for cooking. The average age of the respondents was 40 years.

For the main survey, structured interviews were conducted that covered both open and closed questions (see Appendix). The goal of this survey was to quantify the connections established through the pre-survey. The limited flexibility of the questions of the main survey is believed to be compensated by the semi-structured approach used for the pre-survey. Structured interviews are characterised by an exact determination of wording and sequence of questions, they were chosen to achieve comparability between interviews.

The sample size for the main survey is 32, comprising 5 men and 27 women. When men were interviewed, it was made sure beforehand that they actually use the stove on a regular basis. The average age of the respondents was 38 years. Considering the number of stoves sold and assuming that no two stoves went to the same household, the sample frame is 360. The sample thus makes up approximately 9% of all households possessing a Tsotso Stove. The respondents were chosen by Esther Iiyambo, who heads the Onkani Tsotso Stove Programme, for she, as the stove seller, knows which households possess the stove (please note that in this survey only households possessing the stove were interviewed). In the process of choosing interviewees, it was tried to include 2 to 5 interviewees per village, so that a certain spatial representativeness is given. From a mathematical point of view the sample is not representative, for it was not chosen randomly. The approach of choosing respondents is represented best by the snowball sampling method, for which a contact person (in this case Esther Iiyambo) provides the contact with the widely distributed and elusive population of potential interviewees (Bailey, [2]1987, p.88). One result of this sampling method, is that the homogeneity of the sample is not known, which makes the use of averages in general questionable, this should be considered whenever average figures are given.

Most interviews (42 out of 48) were conducted with the help of a translator, since the majority of the respondents did not speak English. The main translator was Esther Iiyambo.

3.4.2 Critique of the Surveys

First of all, it should be said that relying completely on survey results is probably not the best way to gather the information searched for in this thesis. Especially parameters like cooking time and wood consumption could have been determined more precise (but also more time-consuming) through observation of different households. Due to inexperience and time constraints this was not done.

Regarding the survey, though I tried to stick to the common rules of conducting surveys, both surveys have a number of flaws that should be discussed here.

First of all, several problems arose from the combination of a white, male person conducting the interview and a black, local person who translates questions about a product that she herself sold to the respondents. Table 3.1 shows the problems and how it was attempted to solve them.

Table 3.1: Problems arising from the characteristics of interviewer and translator and how it was attempted to solve them.

Problem	Measures to solve them
In the cases when a translator was needed, I had to completely rely on the translator and could not check if answers or questions were translated correctly	In some occasions a third person who speaks both languages was present. Attention was paid to the matching of question and answers.
I was, quite obviously, not able to blend in. Thus some respondents seemed nervous when conducting the interviews, while others might have answered what they thought they should, for they felt grateful that a white person travelled all the way to visit their home.	Nervous respondents were assured that there is no reason to be afraid. The use of a translator helped to create a casual, friendly atmosphere.
The fact that the translator was the producer and seller of the product she was asking questions about might have prevented the respondents from speaking out against it.	The respondents were asked to speak openly and not to hold back points of criticism.

Concerning the pre-survey, a point of critic is that it mainly consisted of “why”-questions. The result is that many respondents were put in a defensive position (Mikkelsen, [29]1995, p.109), and questions like "why do you want to save time" were regarded as stupid.

Regarding the main survey, the main issue is how reliable the answers given are. Some questions might not have been answered correctly, since the respondents did not have access to the information. According to Bailey ([2]1987, p.116) the reasons for that can be that the respondent forgot the answer, does not want to give it because it involves emotional stress or because an "answer or method of answering is expected which the person is not familiar with". It is my belief that the latter case fits to the questions involving statements about time, for most of the population do not use a watch. The first case might apply to questions that asked the respondent to recall his actions or occurrences in the last month or years. A method to cross-check the most important questions would have been to observe the cooking behaviour of households. This was not done, due to resource and time constraints.

Another point of critic regards the closed questions of the main survey that used an attitude scale. Here the way the questions are posed is decisive. In this regard, most of the statements are posed in a way that discriminates against the traditional stove, e.g. in case the respondent articulates his agreement, she/he gives a statement in favour of the Tsotso Stove. Therefore the closed questions were not used in the same extent as the open questions.

Finally the representativeness of the sample has to be discussed. As has already been stated, the sample was not chosen randomly and thus is not representative from a mathematical point of view. In addition to this, four other reasons make the representativeness of the sample questionable:

- The poorest parts of the population cannot afford the stove, thus they are excluded from the survey.
- To be able to conduct as many interviews as possible, schools with a high number of employees that purchased the stove were visited. Thus teachers are over-represented in the sample.
- 32 (9%) out of the 360 households that purchased the stove were interviewed. While this number might be sufficient to make statements for all the households that possess the stove, it cannot be used to make assumptions about the whole of the households (0.4 % of 7700) of the study area.
- For most of the calculations not all interviews could be used, thus many calculations rely on less than 32 interviews and their results should therefore not be seen as representative for the wider population.

Concluding it can be said that, strictly speaking, the sample should not be used to make predictions. However, since no better sample is available, the results that were found using this sample give the best idea so far of what the present and potential impacts of the Tsotso Stove are.

Chapter 4

Results

In this chapter, the findings of the pre- and main survey are described. These results represent by no means raw data, for in order to create them, the interview responses have been subjected to calculation and compilation.

The first section presents the findings of the pre-survey, which take the form of a CLD, the conceptual model of this thesis. The second section deals with the question "how much is the stove being used" since this is an important finding and is used to determine the results of the next five sections that address the five secondary characteristics, effect on deforestation, ability to save time, effect on health, effect on budget and cooking satisfaction.

4.1 Pre-Survey Results

The rationale of the pre-survey, was to arrive at a conceptual model that is not solely based on my (limited) thoughts and knowledge but also a product of the respondents' knowledge. Therefore 16 persons were interviewed, with some of them possessing the stove and some having heard of it. Table 4.1 shows some answers that were given, complemented with my thoughts.

Table 4.1: Answers of the pre-survey that were used to create the conceptual model (My added thoughts in black italic)

Benefit (+) or Drawback (-)	What do you like/dislike about the Tsotso Stove?	How/why does this characteristic occur?	And why do you like/dislike that?	And why do you like/dislike that?	Resulting path in CLD
+	It cooks faster	fire goes directly to the pot	saves time	More time to: Cook tea in the morning, pounding grain, collecting water, visiting friends	Efficiency →cooking time per meal →*Time Savings*
+	It uses less wood	*efficiency*	saves time when collecting wood, saves money, protects the forest	time for kitchen duties, laundry, visiting friends	Efficiency →fuel consumption per meal →*Time Savings, Deforestation*
+	You can take it to the field	portable	saves time that was used to go home to cook	time for other work	Weight →ability to cook in the field →*Time Savings*

Benefit (+) or Drawback (-)	What do you like/dislike about the Tsotso Stove?	How/why does this characteristic occur?	And why do you like/dislike that?	And why do you like/dislike that?	Resulting path in CLD
+	Good for rainy season	*isolation of fire*	one can cook when it rains	the joy of eating good food	Insulation, Weight →number of meals per day →*Health*
+	It is safer	no fire caused by wind, cold on the outside			Insulation →cold surface, protection from wind →*Health, Budget*
+	Ash collecting and disposing is easy	*ergonomics*	*practical handling*		Ergonomics →*Cooking Satisfaction*
+	Parts do not move when stirring	*ergonomics*	*practical handling*		Ergonomics →handling properties →*Cooking Satisfaction*
+	It looks better	*appearance*	*cautious handling*		Appearance→durability →*Budget*
+	Effective when it is windy	*isolation*			Insulation →number of meals per day →*Health*
-	It does not heat	*efficiency, isolation*	one needs to use old stove when feeling cold		Insulation →cold surface, need to heat with trad. stove →*Deforestation*
-	It breaks down too fast	*durability*			Endurance →durability →*Budget*

A drawback of the stove that was also mentioned by interviewees was its price, it is not shown in table 4.1, for it is outside the scope of the conceptual model (see figure 4.3).

The way in which the answers were used to arrive at a conceptual model has already been explained in section 3.3.2. Figure 4.1 shows the final result of the pre-survey, the conceptual model. According to the model, a stove's performance and success (level of use) are determined by its primary characteristics, these are:

Efficiency: The amount of resources needed to perform a certain task (e.g. boiling one litre of water). The resources are fuel and time.

Insulation: The way the flame and its heat is isolated and protected from the outside of the stove.

Ergonomics: How difficult it is for the user to perform certain tasks.

Appearance: How the stove looks and how the user perceives it.

Endurance: How much the stove can be used before it breaks down or has to be repaired.

Weight: How heavy the stove is.

Since the user's behaviour and perception play an important role, it is not only the physical properties that determine the performance of a stove but also how good it matches needs and possibilities of the user. The primary characteristics are thus the result of the stove's physical properties and its user's behaviour and

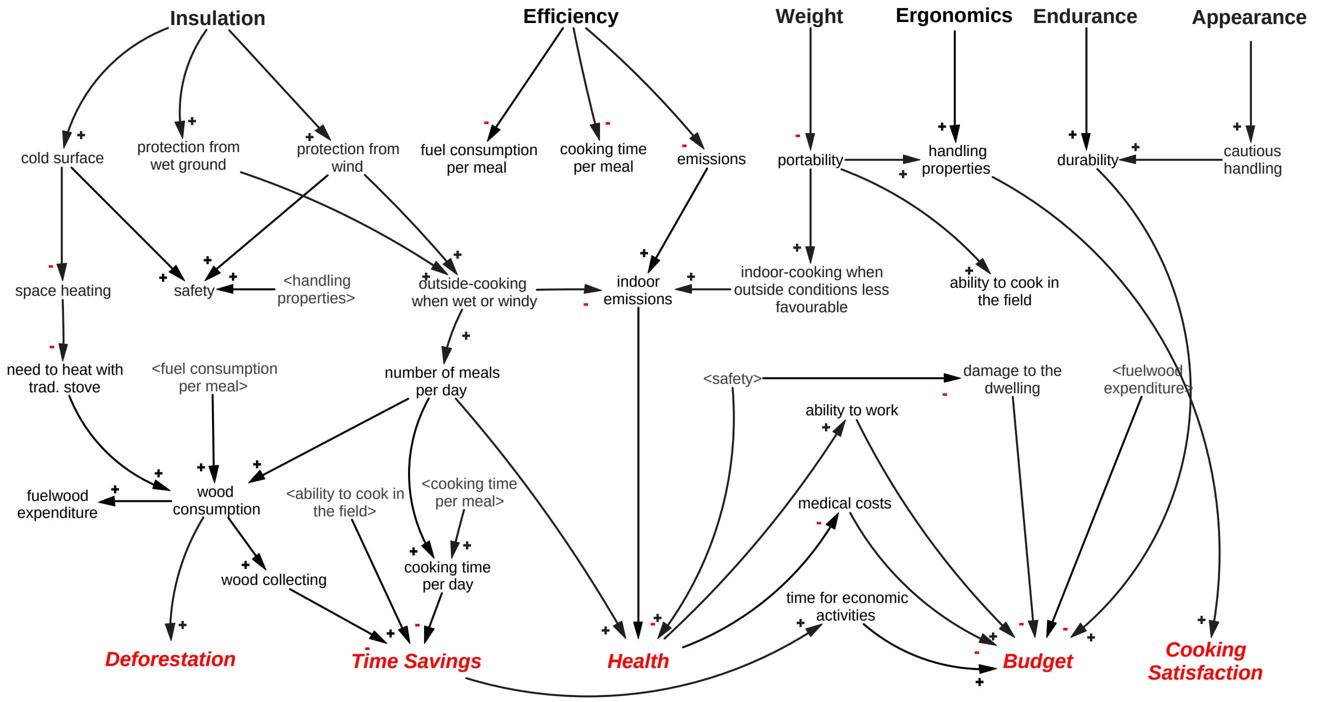

Figure 4.1: The theoretical model.

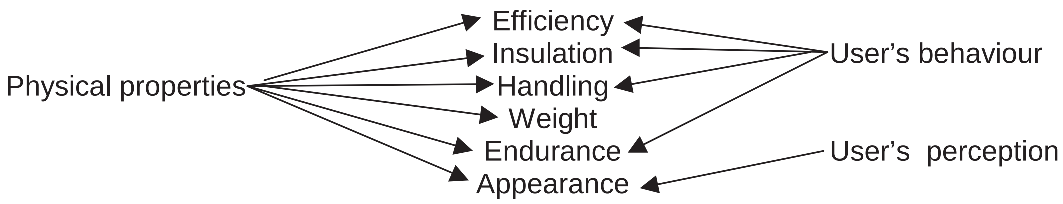

Figure 4.2: Primary characteristics of a stove and what determines them.

perception (see figure 4.2). The stove's primary characteristics are the key exogenous variables, for they are not influenced by the model. As such, they result in a number of secondary characteristics, i.e. how much time the user needs to cook, how much money is needed to maintain the stove, how comfortable and safe it is to cook, etc. The conceptual model serves to describe how exactly the primary characteristics (in bold black) determine the secondary characteristics (in bold red italic). It is obvious, that the different parameters, such as the stove ergonomics, might also have an impact on the users cooking behaviour. However, the assumption made here is that the user, in case the new stove forces her/him to change its behaviour significantly, does not accept the stove. Thus it is assumed that the stove does not change the user's behaviour significantly, although it does change the outcomes of it. The secondary characteristics, that will be used to evaluate the performance of the stove, are:

- Effect on deforestation
- Time-saving ability
- Effect on health
- Effect on budget
- Cooking satisfaction

They represent the endogenous key variables, for they are determined by the model itself. They influence two important variables:

- Together with the stove's price and availability (this includes marketing), they determine the dissemination level of the stove.
- Together with the stove's price, they determine the frequency of use of the stove (see figure 4.3).

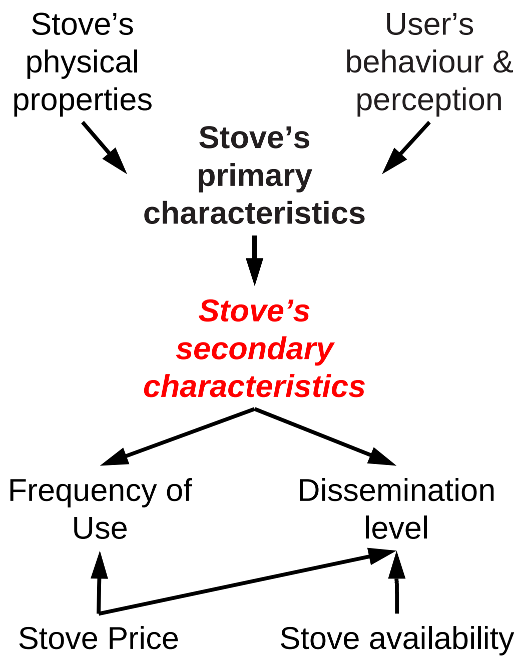

Figure 4.3: Flow chart explaining how stove performance and success are determined.

An evaluation of the dissemination level is not part of the thesis question, since this has been assessed by previous reports (see Stewart Scott Namibian, [43]2002, R3E & DRFN, [38]2002 or Lasten, [26]2001) and is influenced by several factors (e.g. marketing, transportation) that are outside the central question of this study. However, it will be discussed in the discussion chapter when a step back is taken to present an outlook. The frequency of stove use will be discussed in the next section since it influences the socio-economic and environmental impact of the stove.

4.2 Frequency of Stove Use

4.2.1 Calculation

Figure 4.4 shows which factors were considered when calculating the usage of the Tsotso Stove. This diagram is not part of the conceptual model (figure 4.1) for it describes which variables determine the use of the Tsotso Stove, while the conceptual model describes how primary characteristics of the stove result in secondary characteristics.

Rather complicated calculations including numerous assumptions were necessary to determine the frequency of stove use, since most respondents found it difficult to give a number for how often they use the stove per year or on average per day. The fact that calculations were used shall not indicate that these numbers are more precise than direct answers, on the contrary, they are probably much worse, but nevertheless had to be determined.

First of all, it has to be taken into account when the stove is being used, in the rainy season, when it is windy, or all year long. The next step is to consider the number of meals per day that are cooked with the Tsotso Stove in the month it is being used. Finally, the month and the times per day that the traditional stove is used for heating have to be considered, since this reduces the use of the Tsotso Stove. Several assumptions had to be made in the course of the calculations, these are:

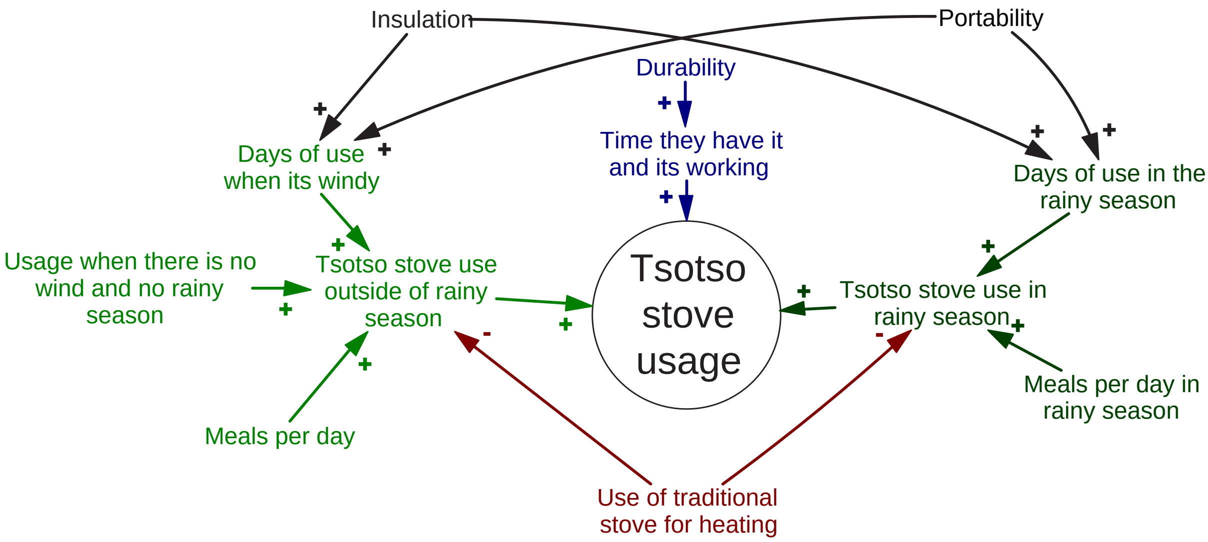

Figure 4.4: CLD explaining how the stove use was calculated.

- People are in a hurry 4 times/week (some respondents stated that they use the stove when they are in a hurry)
- People cook meat 1 time/week (some respondents stated that they use the stove when preparing meat)
- If no further information is available, the times they use the old stove for heating are subtracted, since it is assumed that they use the traditional stove also for cooking under these circumstances
- People stay at cattle posts 5 days a week (in some cases the stove is placed at the cattle post)
- If no further information is available, the time when it is windy is assumed to be 2 month
- If no further information is available, the time of winter is assumed to be June -August
- If no further information is available, the time of the rainy season lasts 4 month
- Firewood is scarce 1 month/year (some respondents stated that they use the stove when firewood is scarce)

4.2.2 Stove Distribution

The Tsotso Stove has so far been introduced in about 360 households. This data was taken from sales records of the Onkani Stove Project that is the only producer and seller of the stoves in the study area. It is noteworthy that, with one exception (an interviewee cooking at his cattle post) all households own the traditional stove besides the Tsotso Stove. Gas-stoves could be found in 6 households and paraffin-stoves, still a very rare cooking tool, could only be found in 2 places.

4.2.3 Frequency and Reasons for Use

The frequency of how often the Tsotso Stove is used by the household varies between 0.14 and 5 times per day. The average is 1.6 times per day. Figure 4.5 shows the frequency distribution of different usage-intervals. Households have different patterns of usage, some only use the stove during specific seasons, some just use it for specific meals. Figure 4.6 shows how often the Tsotso Stove is used and gives an idea of its share of total stove use. Actual calculations resulted in a usage of approximately 66%, meaning that, when cooking, two out of three times the Tsotso Stove is being used. Table 4.7 and 4.8 show answers given to the questions, “When do you use the Tsotso Stove?” and “Why do you sometimes use the old stove?”. The answers give the impression that some of the households interviewed use the stove in a risk-minimising

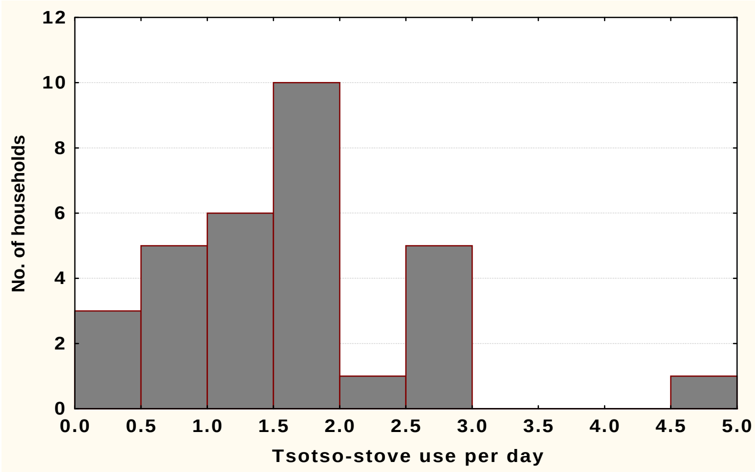

Figure 4.5: Histogram showing the distribution of uses per day.

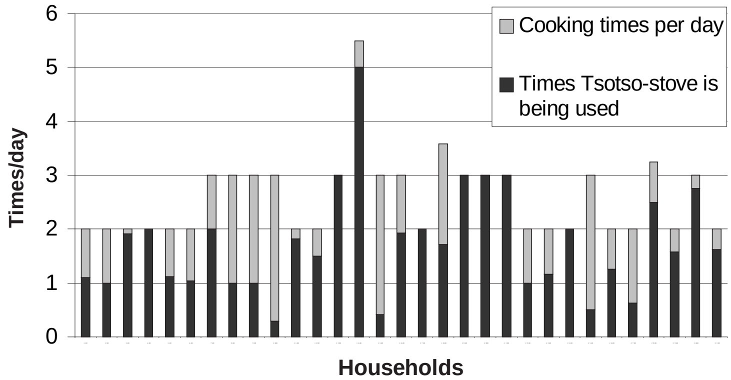

Figure 4.6: Diagram showing how often the different households cook and how often they use the Tsotso Stove for cooking.

way, i.e. they try to save it for times or occasions, in which cooking with the traditional stove is difficult or impossible or would take too long. Besides this, the other major reasons for not using it include its limited size ("making homebrew","using big pot") and the fact that households can usually only afford one Tsotso Stove ("when using two stoves"). It is noteworthy that cultural considerations seem to play a minor rule, for only two respondents stated that they use the traditional stove for cultural reasons. However, cultural considerations might subconsciously determine the frequency of the traditional stove use.

4.3 Effect on Deforestation

Since the Tsotso Stove project was initiated to help control desertification through a reduction of deforestation, this section will focus on the Tsotso Stove's ability to reduce wood consumption. Its ability to reduce the emissions of CO_2 and other green house gases can easily be estimated as soon as the amount of wood it saves is determined. The prioritisation of deforestation was chosen since I deem this problem to be more acute in the study area than, for example, greenhouse gas emissions.

4.3.1 Wood Savings

Four factors determine how much wood the stove is able to save in comparison to the traditional stove (see figure 4.9). First of all, the number of households that possess the stove has to be determined, and furthermore, which of these households use wood as a burning material. Secondly, the share of Tsotso Stove-use has to be derived from the interviews (see section 4.2). Thirdly the average number of cooking times per day has to be taken into account. Finally, the actual savings that can be achieved per meal that is being cooked have to be estimated.

Figure 4.7: Answers to the question "When do you use the Tsotso Stove?"

Answer	No. of answers
Always	13
In the rainy season	11
When its windy	6
When in a hurry	3
When wood is scarce	3
When preparing meat	3
When using both stoves	3
At the cattle post	2
When using small pots	1
In the morning	1
For fatcook and fish	1

Figure 4.8: Answers to the question "Why do you sometimes use the traditional stove?"

Answer	No. of answers
To save the Tsotso Stove	8
When using two stoves	7
When using a big pot	6
When making Homebrew	5
When the weather is good	5
When the Tsotso Stove broke down	2
When at home	2
Because it's our culture	2
When there is enough firewood	2
When wanting to heat and cook	1
Because it's easy to use	1
When using dung	1

The number of households that possess the stove, taken from the sales information given by the Onkani Tsotso Stove production office accounts to 360. This number is only a rough estimate, since the stove can also be bought in the next bigger city, Oshakati (2 of the 32 respondents stated that) and the number of stoves already broken down is not known. The number of households that use only wood for cooking purposes was only 10 out of 29 (the 3 households that were interviewed in Oshakati were excluded from the calculations since they do not represent the general rural conditions in the study area). Estimating that the 4 households that use both dung and wood use both fuel sources alike, it is assumed that approximately 41% of the households use wood, the rest uses only agricultural residues (see figure 4.10). The high number of households that use dung as a cooking fuel, especially compared to statistics about the whole of Namibia stating that only 8% of the population use dung as fuel (Wamukonya,[51] 1997, p.8), already indicates how scarce wood is in this specific area.

It has to be said, that the exclusion of all household that use dung in this calculation, shall not indicate that saving dung is not an environmental benefit. In contrast, dung that is not used as cooking fuel is an important fertiliser of the soil, which improves the agricultural productivity of the area. This study, however, solely focuses on the direct effects of the Tsotso Stove on the woody biomass.

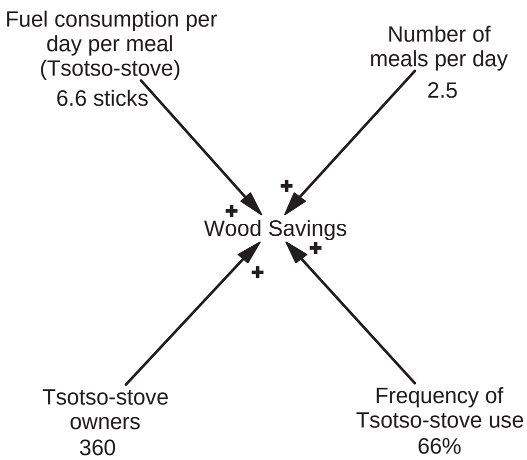

Figure 4.9: CLD showing how wood savings are calculated.

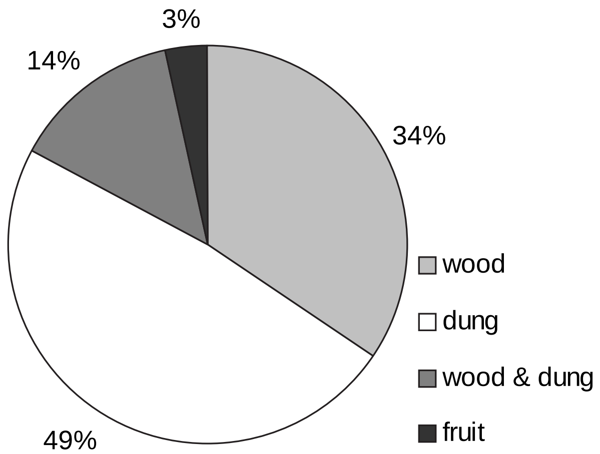

Figure 4.10: Different fuel types and their shares.

Assuming that the calculated 41% are a representative sample, the total number of households using the Tsotso Stove and wood as cooking fuel can be estimated to be $0.41 * 360 \approx 150$.

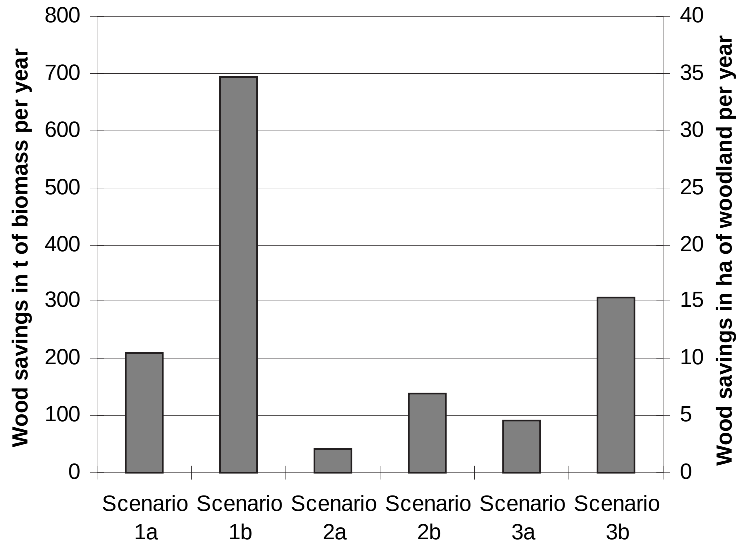

Figure 4.11: Wood savings for the different scenarios in tonnes of biomass and ha of woodland. A hectare of woodland is assumed to carry 20 tonnes of wood (Stewart Scott Namibia, [43]2002, App. p. 9).

Figure 4.6 shows how often, in average, the households cook per day, and how often they use the Tsotso Stove in this cause. Excluding all households that do not use wood as cooking fuel, the mean cooking times per day is roughly 2.6, and about 63% of the time the Tsotso Stove is being used.

The wood savings that can be achieved per dish with the Tsotso Stove, compared to the traditional stove are difficult to determine. In the survey, the interviewees were asked how many pieces of wood they need to cook Mahangu-pap, the traditional staple food, with both the Tsotso- and the traditional stove. The reported savings are about 60%, which is much more than the 30% savings that have been determined by Ballard-Tremeer and Jawurek in a computer-controlled version of the standard Water Boiling Test ([3]1996, p. 427). Thus two questions have to be asked:

- Are the households able to save more wood than the test data suggests by using the Tsotso Stove in a very efficient way?
- If they are not, did they underestimate their wood use with the Tsotso Stove or did they overestimate the wood consumption of the traditional stove?

From these questions three scenarios can be created:

1. The respondents gave accurate numbers. In this scenario the wood savings are the most.
2. The respondents overestimated the wood consumption of the traditional stove. For this scenario the wood use of the traditional stove is not allowed to be more than 42% higher than the wood use of the Tsotso Stove. This scenario is the most modest when it comes to the wood savings achieved by using the Tsotso Stove and the overall wood consumption.
3. The respondents underestimated the wood consumption of the Tsotso Stove. For this scenario the wood consumption of the Tsotso Stove is not allowed to be less than 70% of the wood use of the traditional stove. In this scenario, the overall wood use is high, and the savings achieved by using the Tsotso Stove lie between Scenario 1 and 2.

Finally, the savings in pieces of wood have to be converted to savings in kg of wood. Since it is not clear what size the respondent had in mind when responding to the questions, a minimum and maximum estimate will be used to arrive at a rough estimate of how many kg of wood are currently saved by using the Tsotso Stove. The minimum accounts to 0.2 kg (a), the maximum to 1 kg (b). Figure 4.11 shows the results of the different scenarios.

A discussion of the significance of the woods savings will be presented in section 5.1 together with a positioning of the Tsotso Stove from a system dynamics perspective.

4.4 Time Savings

There are basically three ways, in which the Tsotso Stove can help households to save time (see figure 4.12).

1. The stove saves time because it cooks faster than the traditional stove.
2. The stove saves time because its use results in a reduced amount of wood that needs to be collected.
3. A number of households use the stove in the field. Before they had the stove, these families used to go home to cook, the time for going home and back to the field is thus saved.

In some cases the Tsotso Stove led to an increase in the overall times per day that a meal is cooked. In these cases, this additional use costs time and thus has to be subtracted from the time savings. It should be said, however, that the provision of an additional meal per day should not be considered a negative effect of the stove, since it contributes to the health of the members of the household.

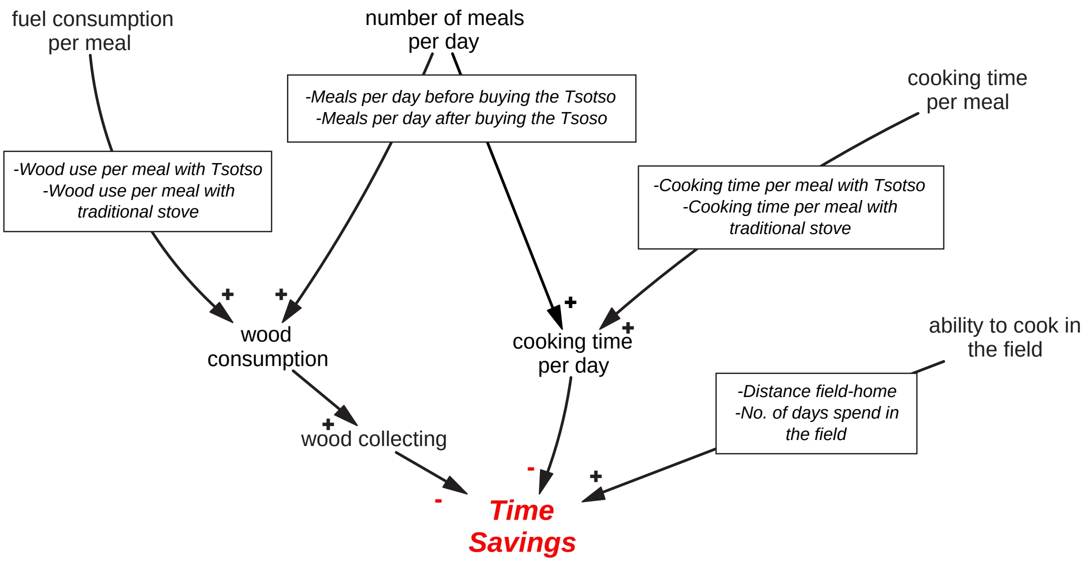

Figure 4.12: Causal Loop Diagram showing the different ways in which the introduction of the Tsotso Stove can result in time savings. The questions that were used to quantify the connection are shownin boxes.

4.4.1 Calculations

To estimate how much time the stove saves through an increase in cooking speed, the respondents were asked how long they need to cook Mahangu-pap (the local staple food) and how long it takes to boil water with both, the traditional and the Tsotso Stove. As in the case of wood consumption, the answers given by the interviewees indicate much greater efficiency than the test data suggests. On average, the respondents stated that the Tsotso Stove takes only 57% of the time the traditional stove takes, which corresponds to time savings of 43%, while the tests conducted by Ballard-Tremeer and Jawurek resulted in time savings of only 27% ([3]1996, p. 427). Once again it is unclear if the respondents answered correctly or if they rather gave rough estimates. In opposition to the case of wood consumption, however, it is my belief that the respondents answers regarding time saving should be looked at more critically, for two reasons:

- Most of the interviewees did not have a watch, neither with them, nor could one be found at the dwelling.
- Unreasonable high relative gains (differences between traditional and Tsotso Stove) were stated by some respondents.

In order not to overestimate the actual time savings, the answers given for the Tsotso Stove were assumed to be true, and the answers for the traditional fire were corrected in case they resulted in time savings bigger than 27%. It was further assumed that the households cook Mahangu-pap (which most of them cook 1-2 times per day) as often as they boil water. The amount of time saved per dish was then multiplied with the frequency of the Tsotso Stove use per day, and time that is being lost in the cases where the households cook more often since purchasing the Tsotso Stove was subtracted.

To calculate how much time is being saved through a decrease in wood-collection, the data collected for the previous section regarding wood consumption was combined with answers given by the respondents regarding their time spent collecting wood. It was assumed that the relation between wood consumption and wood-collecting time is linear, which might not necessarily be true, since not only the actual collecting takes time, but also the walking to the place of collection.

Finally, the easiest time-saving method to determine was the time saved by staying in the field to cook, instead of walking home. Nine households stated that they do use the stove in the field and they were asked how long it takes to walk to the field and back. Then it was assumed that they spend on average 4 days a week in the field (in reality the work in the field is unevenly distributed between the dry winter and the rainy summer). Figure 4.13 shows how much time the families save through the different ways. There are only

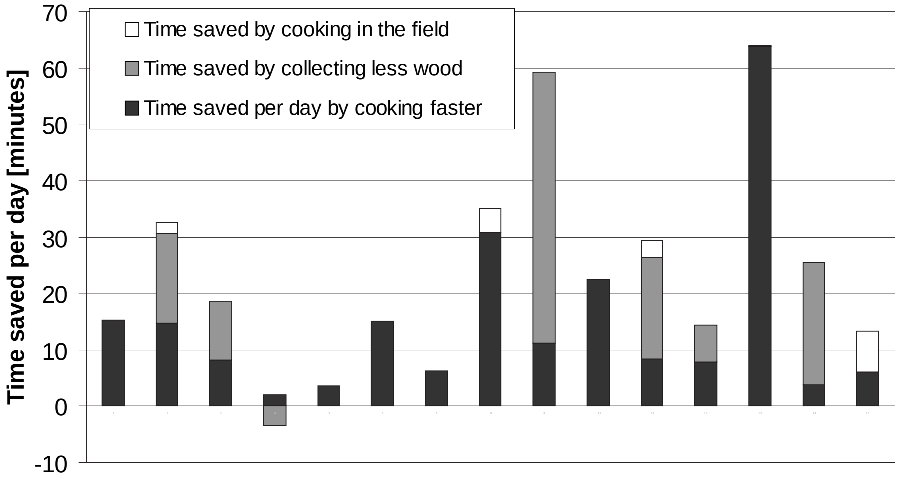

Figure 4.13: Diagram showing the savings in time through different ways for 15 households.

15 columns, since the information given by the respondents were only in these cases sufficient to perform the calculations. These 15 households save about 15 minutes on average per day by using the Tsotso Stove. The time savings are, however, very unevenly distributed, which is shown by the high standard deviation of 16.5 minutes. The figure clearly shows that faster cooking and less wood collecting are the main paths through which time is being saved. The negative figure is the result of an increase in cooking times per day that took place in one household once the Tsotso Stove was being introduced.

In general, these calculations should not be looked at as precise results, since the responses by the interviewees inherit a great amount of uncertainty, and the results are made even more insecure by the assumptions underlying the calculations. Therefore, the numbers shown are not more than a first rough estimate.

4.5 Effect on Health

Figure 4.14 shows how, in theory, the Tsotso Stove can influence the health status of the user. The ways in which it can influence the health of the household members are:

1. Through a change in number of meals per day.

2. Through a change in safety that leads to fewer accidents.

3. Through a change of exposure to indoor emissions.

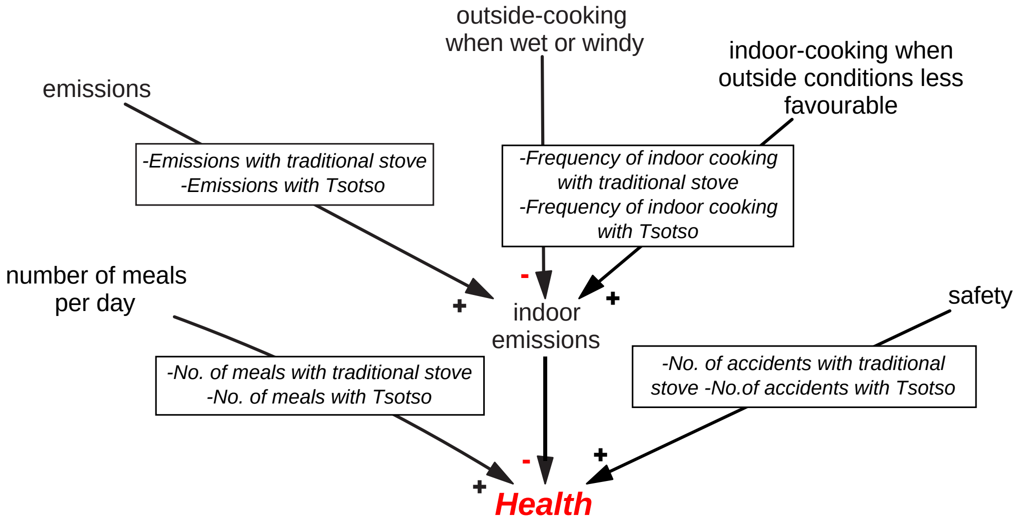

Figure 4.14: Causal Loop Diagram explaining in which ways the Tsotso Stove can influence health

4.5.1 Increasing Health through an Increase in Meals per Day

The assumption underlying this subsection is that an increase in meals per day corresponds with an increase in the uptake of nutrition, and that this leads to improved health. In only 4 of the 32 cases the respondent stated that she/he cooks more since possessing the Tsotso Stove. In these cases the introduction of the stove lead to an increase in the frequency of cooking in the rainy season, which can be difficult when using the traditional stove. The additional cooking times per day, averaged over a year, of the 4 respondents are 0.04, 0.33, 0.58 and 1. The low number of cases indicates that the stoves impact on the user's health via an increase in meals per day is of minor importance.

4.5.2 Influencing Health by changing the Exposure to Indoor Emissions

The amount of exposure to indoor emissions, that can have detrimental effects on the respiratory system of the user, is a product of the frequency of indoor-cooking and the amount of emissions produced per cooking event. It should be stated that the problem of indoor emissions is not as significant in Namibia as it is in other developing countries, for cooking takes place outdoors most of the time and even when cooking inside, the room is usually a lofty hut, and not a fully closed room.

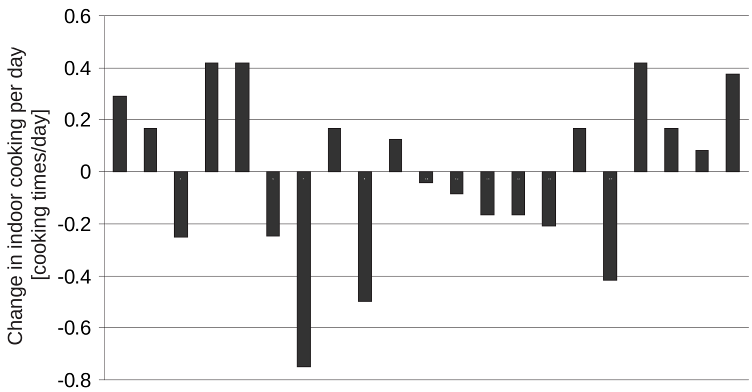

Figure 4.15: Change in the frequency of indoor-cooking of the different interviewees.

In 21 of the 32 cases, the interviewees agreed that the introduction of the Tsotso Stove has led to a change in the frequency of them cooking inside. In some cases, it led to an increase, this was often the case when the household used to cook outside with their traditional stoves. In some cases, however the insulation and the portability of the stove led to a decline in indoor cooking events. In these cases, the users often used to cook inside in the rainy season with the traditional stove, because the ground was too wet outside or the threat of the next rainfall event was too big.

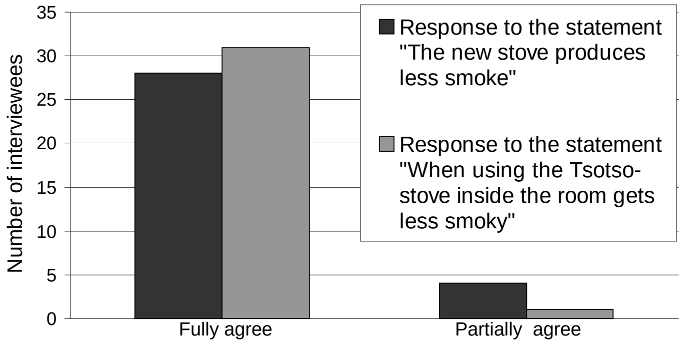

Figure 4.16: Answers regarding the perceived indoor emissions of the Tsotso Stove.

An average close to zero indicates that the stove has not led to a significant increase or reduction of indoor cooking-events. Figure 4.15 shows the changes in the frequency of indoor cooking for the 21 households.

The increased wood-efficiency of the stove indicates that the Tsotso Stove produces fewer emissions than the traditional stove. This assumption has been examined through 2 statements that the interviewees expressed their opinions on. They could respond with "fully agree", "partially agree", "partially disagree" and "strongly disagree". The statements were "The new stove produces less smoke than the traditional stove" and "When using the Tsotso Stove the room gets less smoky". Figure 4.16 shows the results for the two questions. As can be seen, the respondents, without exception, had the impression that the stove has fewer emissions than the traditional stove.

While the survey could only determine the Tsotso Stove's impact on the quantity of smoke emitted, the stove tests conducted by Ballard-Tremeer et al. (see section 2.4.2) tried to determine the quality of the emissions. This data suggests that the emissions of the Tsotso Stove are more dangerous than the ones of the traditional stove. According to the tests, the Tsotso Stove (in this case called 1-pot metal stove) has a higher ratio of CO-Emissions in relation to the CO_2-emissions and also higher emissions of SO_2 and total suspended particles (TSP). The data is shown in table 2.1. According to the Department for International Development, "indoor air pollution is mainly due to high levels of particulate matter (respirable suspended particles) and gaseous material" like carbon monoxide ([12]2000, p.19). Considering the results of the survey and the stove testing data, the effect of the introduction of the Tsotso Stove on its user's exposure to dangerous emissions is difficult to evaluate. Prioritising the stove testing data, it has to be said that when cooking with the Tsotso Stove, more dangerous emissions are released. Taking into account the frequency of use of the Tsotso Stove, the carbon-monoxide emitted from households using it is approximately twice as much as that from households using only the traditional open fire.

4.5.3 Increasing Health through a Raise in Safety

According to the interviewees, cooking accidents are not a common phenomenon, neither with the old, nor with the new stove. 26 of the respondents said they never had an accident with any of the two stoves. Others mentioned that they had 1 accident once with the old stove, or that they heard that accidents happened with the old stove in other households. One Interviewee stated that she has 1 accident per month with both stoves, one replied that they sometimes have accidents with the old stove, and one interviewee answered that the amount of accidents dropped from 4.5 to 2.5 per month. Nevertheless, the interviewees seemed to be convinced, that the Tsotso Stove is safer than the traditional stove, for all interviewees fully agreed to the 3 statements:

- The Tsotso Stove is safer to move.
- The Tsotso Stove is safer because its surface is not hot.
- The Tsotso Stove is safer because the fire is protected from the wind.

On first sight, the result seems contradictory. It seems that the interviewees clearly feel that the stove is safer, but this increased safety cannot be translated into cooking accidents, since these are in general, very rare. The definition of an accident, however, is vague and it could be that the respondents only considered major accidents, and not smaller ones like minor burns. Furthermore, it might be, that the level of safety stayed the same, but that less caution is needed to achieve it with the Tsotso Stove. Thus, in this case, the unanimous responses to the three statements should be considered proof enough that the stove is safer.

4.5.4 Conclusion-The Tsotso Stove's Influence on Household Health

While an increase in the number of meals does not seem to be an important way through which the Tsotso Stove influences its user's health, an increase in safety and a change in the quantity and composition of indoor emissions does. The direction of the influence is clear for the first of the latter two; the stove is safer than the traditional stove and thus decreases the number of injuries that take place in the kitchen. The way in which the stove changes the quantity and composition of emissions is more difficult to evaluate, for it seems that, when cooking with the Tsotso Stove, households are exposed to more harmful indoor emission but less smoke. Considering the loftiness of the buildings used for cooking and the fact that outdoor cooking is preferred most of the time, it can be concluded, that, because it is safer, the Tsotso Stove probably results in an improvement of the household's members' health.

4.6 Effect on Budget

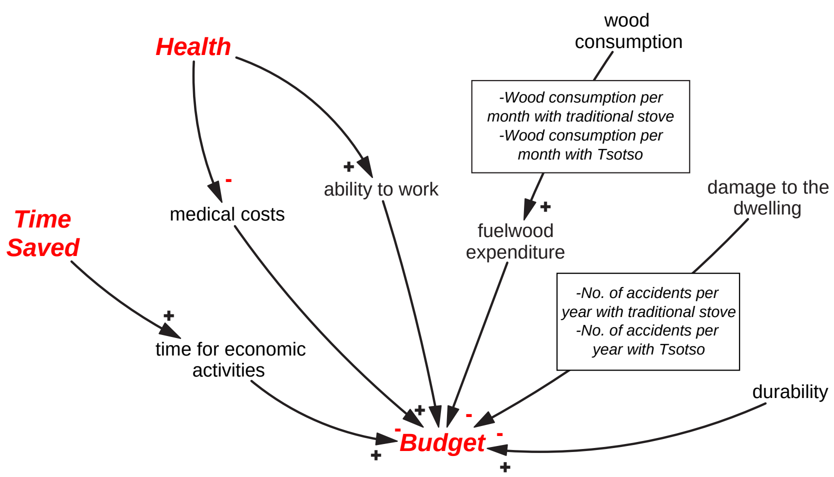

Figure 4.17: Causal Loop Diagram explaining in which ways the Tsotso Stove can increase the family budget.

Since the traditional stove is for free, the Tsotso Stove initially creates cost for the household that purchases it. Its use however, can help the households regain the money they spend. The time it takes for the household to regain this money is called the "payback time". Besides calculating the "payback time" of the Tsotso, the ways through which the stove can increase the family budget by reducing costs and by increasing income was examined (see 4.17). Unfortunately, not all of these ways could be quantified.

4.6.1 Saving Money through increased Safety

An increase in safety, which can be expected due to the design of the Tsotso Stove, should lead to a decrease in accidents in which parts of the dwelling catch fire (please note that the focus here lies on accidents that lead to the destruction of belongings, not to injuries of household members). To check this assertion, the interviewees were asked to report on accidents in which they lost parts of their belongings before and after they bought the Tsotso Stove. In 6 of the 32 cases, the interviewees agreed that they did have accidents in which parts of or items in the house caught fire when they used the traditional stove. The frequency of these events varied between the interviewees; 1 respondent could not give a number, 1 said that accidents were common, 1 said they once have had an accident in their home, 1 replied that it happens once every 5 years, another one said it happens once every year and 1 interviewee said that it happens 6-10 times per year. None of the interviewees ever experienced any accidents with the Tsotso Stove. The answers indicate that the introduction of the Tsotso Stove has led to a decline in cooking accidents that damaged the user's belongings. However, the high number of interviewees who stated that they never had any accidents suggests that the destruction of belongings through fires is not a decisive burden on family budgets. Altogether, although the Tsotso Stove is probably safer than the traditional stove, no significant increase in income can be expected to derive from this.

4.6.2 Saving Money through a Reduction of Wood Consumption

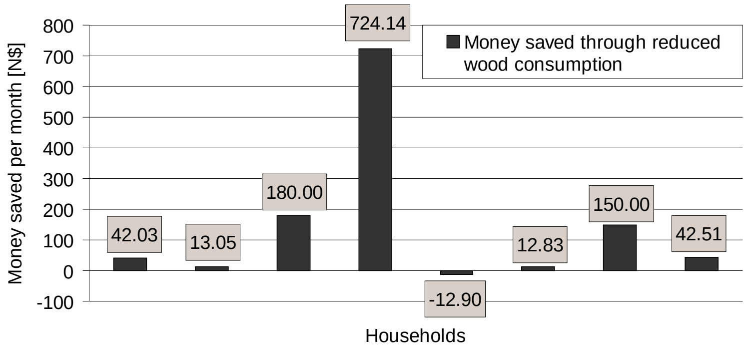

Figure 4.18: Money saved per day through a reduced wood consumption by 8 households.

9 of the 32 interviewees stated that they usually buy fuelwood to cover their fuel needs. All others collect either wood or animal dung. For 8 of the 9 persons, the savings through a reduction in wood consumption could be calculated. It was not possible to calculate the 9th interviewee's savings since no information on the wood consumption was given. One interviewee represents a special case, for this person was using the stove 5 to 8 times per day for preparing food that she sold at the street. While this person saves more than 700 N$ (102 US$) per month, the remaining households save 60 N$ (8.9 US$) on average per month, resulting in a payback time of about two month. In one case, additional cooking procedures after purchasing the stove actually led to additional costs of 13 N$ (2 US$) per months. Figure 4.18 shows the savings of the 8 different interviewees, it reveals big differences in savings between different households.

4.6.3 Raising Income and Reducing Cost through improved Health

The health of the members of the household can be influenced by the Tsotso Stove in a number of ways, already described in section 4.5. An increase in health should result in lower medical expenses, and in an increase in income due to a better maintained workforce. Since section 4.5 suggests a positive effect of the stove on the household members' health, the two proposed ways to improve the household's budget probably exist. A quantification of these two ways, however, is difficult and was not included in this study.

4.6.4 Raising Income through an Increase of Time available for economic Activity

According to the pre-survey, the time saved through the use of the Tsotso Stove is being used for various activities, such as kitchen duties, collecting water, visiting friends and working. If an increase in time can really be transformed into a raise in income, depends on the specific situation of the person that profits from the time savings. The assertion could, for example, hold for women who, besides cooking, work in shops (which is quite common), or for women who sell goods that they produce with the help of the stove, for example fatcook (a local pastry). If the person profiting from the time savings does not perform an income-generating activity, however, it is questionable if time can easily be transformed into income. One reason for this is the high rate of unemployment of about 40% (Schneider, [39]1999, p.42) and the lack of income-generating activities in this rural area. This fact is also reflected in the preference of money saving over time saving, expressed by 6 interviewees during another survey in the area (Cecelski et al., [6] 2001, p.77). A quantified testing of the hypothesis underlying this paragraph was beyond the scope of this study.

4.6.5 Reducing Expenditure through high Durability

Although included in the conceptual model and target of a number of survey questions, the effects of the primary characteristics Endurance and Appearance could not be evalued. While the survey results suggest that the stove is considered to look better than the traditional stove, and most respondents stated that this results in cautious handling, the actual durability of the stove could not be determined. The reason for this is that the answers depended on the date the stove was produced, since in the beginning the stoves were produced with a thinner inner wall, which made them less durable. Apart from that, the programme is also still too young to determine an average lifetime. The problem of determining the lifetime is further aggravated by the fact that many households still use the stove, as long as it has not broken down completely.

Thus a third kind of stove, the half-broken Tsotso Stove does exist. In this respect, the conceptual model fails to represent reality.

4.6.6 Conclusion-Income generating Ability of the Tsotso Stove

The impact of the introduction of the Tsotso Stove on the users' budget remains difficult to estimate. The most direct effect and the only quantified way in which the stove saves money is through a reduction in wood consumption. The savings of 60 N$ per day (720N$/year) in average are significant in an area in which the yearly income lies around 9000 N$ (see 2.3). However, these savings only materialise for the minority of the population that buys wood. Furthermore, 3 of the 8 respondents that bought firewood were not living in the rural area, but in Oshakati. Therefore, altogether, the reduction in wood consumption cannot be expected to have a direct effect on the user's budget for the majority of the rural population.

None of the other ways, in which the Tsotso Stove can improve its user's budget could be quantified. It can be expected that the increase in available time has significant effects on the budgets of the users that pursue an income generating activity. For all others, the assumption that an increase in available time can be translated into an increase in income remains questionable. The savings that result from an improved health status of the users is probably the most difficult to estimate, and it is my opinion that it will be almost impossible to quantify the effect. Data about the medical expenditures, and information about the type and frequency of illnesses prior and after the purchase of the Tsotso Stove, however, could give an idea of the cost savings and income increases that result from an improvement of the stove user's health. Finally, the savings that result from a decrease in accidents in which parts of the dwelling catch fire, are found to be negligible, since these accidents seem to be a rather rare phenomenon, regardless of which stove is being used. Apart from the initial costs, the Tsotso Stove most probably has a positive effect on its user's budget. The size of this effect depends on a number of factors, which vary strongly between the different households.

4.7 Cooking Satisfaction

Five statements were formulated that were supposed to compare the Tsotso Stove's handling properties with the ones of the traditional stove. The result should tell if cooking with the Tsotso Stove increases the joy or satisfaction of cooking, the statements were:

1. Handling the pot is easier with the Tsotso Stove.
2. Handling the fire is easier with the Tsotso Stove.
3. Handling the ash is easier with the Tsotso Stove.
4. Handling the firewood is easier with the Tsotso Stove.
5. Cooking with the Tsotso Stove is more fun because its so easy to handle.

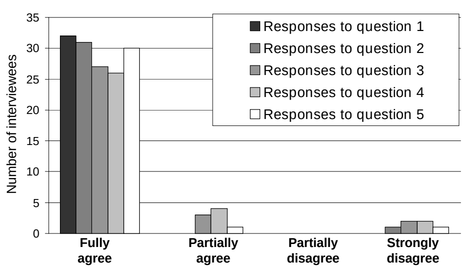

Figure 4.19: Responses to 5 statements regarding the handling properties of the stove.

The responses to the questions are shown in figure 4.19. The diagram shows that the majority of the interviewed Tsotso Stove users fully agree to statement 1-5. Thus it seems that the handling and ergonomics of the Tsotso Stove are superior to that of the traditional stove. Furthermore, the superior handling seems to translate into an increase in cooking satisfaction.

Chapter 5

Discussion

5.1 Environmental Impact

5.1.1 Significance of Wood Savings achievable with the Tsotso Stove

This section shall serve to put the wood savings that can be achieved through the adoption of the Tsotso Stove in a wider context, so that its usefulness as a tool to fight deforestation can be evaluated. Therefore it is necessary to:

1. Make an estimation of the total amount that can be harvested sustainably (meaning that the annual harvest does not exceed the annual growth)
2. Calculate the total fuel wood consumption for different dissemination levels of the Tsotso Stove and different frequencies of its use.

Table 5.1 shows the different values used for calculating the annual increase in woody biomass, and their source. To facilitate the finding of data, it is assumed that the woody biomass solely consists of mopane (*Colophospermum mopane*) the main tree species of the area.

Table 5.1: Data needed to calculate the annual woody biomass growth.

	Estimate	Source
Area of the study region that is part of the Omusati/Oshana region	25,700/17,300 ha	Extracted from map of Namibia (source: DRFN)
Average volume of *woody biomass* per ha in the Omusati and Oshana region	3.2/0.9 m^3ha^{-1}	Selanniemi et al., [41]2000, p.19; Selanniemi et al., [40]2000, p.17
Wood density of Mopane (the main tree species in the area)	1150 kgm^{-3}	Peeler Fife Company, [36] 2003
Growth rate of the woody biomass	1.5 $\%a^{-1}$	Calculated using data from Millington, Critchley, Douglas & Ryan ([30]1994, p.171) for growing stock and sustainable yield

Since many of the parameters are difficult to determine (e.g. the volume of woody biomass), the data is not without errors. The *growth rate* was calculated with the help of a Worldbank paper, in which remote sensing data was checked against secondary data to arrive at different land cover classes (Millington et al., [30]1994, p.171). The one that was found to represent the vegetation in the study area was the "open woodland" class. Unfortunately, though describing a number of error sources, no approximation of the total error is given in this publication. This publication can also be used to cross-check the data given by two reports conducted by the Namibia-Finland Forestry Programme concerning the average volume of *woody biomass* in the Oshana and Omusati region (Selanniemi et al., [41]2000; Selanniemi et al., [40]2000). According to the reports, the average volume is 3.2 and 0.9 m^3ha^{-1}, while the country average, according to the Worldbank paper, it is around 10 m^3ha^{-1} (Millington et al., [30]1994, p.171). The much lower numbers of the two reports make sense, considering the depletion of woody resources in the area and the widespread conversion of forests into agricultural land. In the reports, the sampling error given was around 20% for the Omusati region and 40% for the Oshana region. In both reports it is stated, however, that the main sources of error are probably the volume functions that were used. The parameters *area* and *wood density* are rather easy to measure and their insecurities are negligible in comparison.

With the help of this data, an estimate of the annual growth of woody biomass in the area can be made, by using the following simple calculation:

$$Regrowth[kga^{-1}] =$$

$$Area[ha] * Woody\_biomass[m^3ha^{-1}] * Wood\_Density[kgm^{-3}] * Growth\_rate[a^{-1}]$$

The result is an annual growth of about 5000 tons of biomass.

Table 5.2 shows the estimates used for calculating the total amount of wood fuel needed by the population of the study area.

Table 5.2: Data needed to calculate the annual woody biomass consumption.

	Data	Estimate	Source/Calculation
a	Population of study area	$50,000$	Estimated with the help of population density data of the Omusati and Oshana region (Selanniemi, et al. 2000, p.4; Selanniemi, et al. [40]2000, p.4) multiplied with the parts of the study area, that belong to these areas
b	Percentage of households using wood as cooking fuel	41%	Taken from the survey
c	Persons per household	6.5	Mean of the households interviewed in the survey
d	Total number of households using wood as fuel	3154	$a/c * b$
e	Average fuel wood consumption per day and person	$1kg$	Government of Namibia, Ministry of Environment and Tourism, Directorate of Forestry ([18]1996).
f	Average fuel wood consumption per day per household	$6.5kg$	$c * d$
g	Fraction of Tsotso Stove use of total stove use	0.35%	Calculated from Survey results. Please note that this number is lower than the number given above, for, even if in 63% of all cooking events the Tsotso Stove is used, 2 times a day it is assumed that two stoves are needed.
h	Fraction of traditional stove use	0.65%	$1 - g$

	Data	Estimate	Source/Calculation
i	Share of fuel needed with Tsotso Stove compared to traditional stove for one cooking event	0.35/0.7	Data from scenario 1 and 2 section 4.3.1
j	Average fuel wood consumption per day per household with Tsotso Stove use in current way	5.4/6.4kg	$g * f * i + h * f$
k	Average fuel wood consumption per day per household with only Tsotso Stove use	2.3/5kg	$f * i$

The accuracy of the calculations depends, of course, on the exactness of the data, therefore the parameters where a relatively large error can be expected are discussed. First of all, it should be stated that the correctness of the data that was taken from the survey (b, c, g, h, u, i) depends on the representativeness of the sample, which cannot be taken as granted (see subsection 3.4.2). The number of persons per household can be verified with national data, according to the United Nations Human Settlements Programme ([47]2000) the average household size in Namibia is around 6, and therewith only slightly lower than the one found in survey. The average fuel wood consumption per day and person (e) had to be taken from secondary sources, since the survey results are considered too uncertain, mostly because the households' wood consumption was determined by asking how many sticks were used, and not how many kilograms of wood. Wamukonya ([51]1997, p.14), gives a much lower number for the Oshana-region of 0.42 kg per day and person, since the sample size of Namibia's Strategic Forestry Plan (Government of Namibia, [18]1996) is much bigger though (973 to 100), their number was preferred. For the share of fuel needed with the Tsotso Stove compared to the traditional stove for one cooking event (i), it was decided to use the highest and lowest wood savings that were determined in section 4.3.1. This was done, since it is not clear which data represents the true efficiency gains that can be achieved.

With the help of the data, three scenarios were calculated:

Current situation: Of the 3154 households using wood, only 150 (4.7%) possess the Tsotso Stove. They use it 63% of all the times they cook. Two times per day they cook with two stoves at the same time.

Full dissemination: All households using wood possess one Tsotso Stove. The frequency of use is the same as in the previous scenario (63%).

Only Tsotso Stove used: Every household using wood possesses one or more Tsotso Stoves, and does not use another stove beside it.

As can be seen in figure 5.1, the current consumption of wood exceeds the sustainable harvest by far. Furthermore, even with 100% dissemination, the Tsotso Stove alone is not able to reduce the wood use sufficiently, if the percentage of the use of the Tsotso Stove stays at the current level. Only if all households would possess the Tsotso Stove and would decide to cook with nothing else, could the wood consumption be reduced to a sustainable level, assuming that the efficiency is as high as reported by the interviewees. The conclusions that can be drawn from these rather hypothetical and static calculations, are

- that simple calculations that basically consist of a multiplication of stove efficiency gains with the number of stoves disseminated do not give a valid picture of the savings achieved.
- that the Tsotso Stove can be a helpful tool in the battle against deforestation, but that it alone is probably not sufficient to solve the problem.
- that the impact of an increase in stove dissemination and usage depends on the actual efficiency of the Tsotso Stove in comparison to the traditional stove.

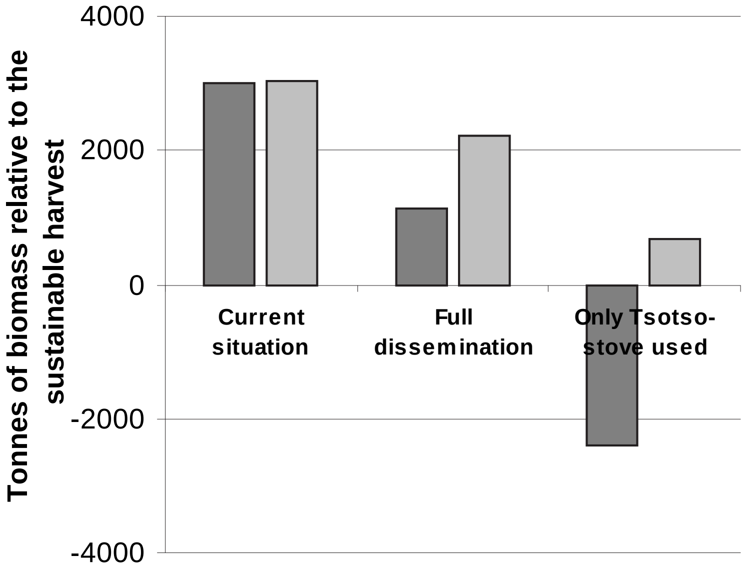

Figure 5.1: Wood consumption relative to the sustainable harvest. For the dark grey columns i (relative share of fuelwood needed with the Tsotso Stove) is 0.35, for the light grey columns 0.7.

It has to be said here, that the calculations above give only a very crude picture of reality. Apart from the already described insecurities in the data, a number of factors not included in the calculation limit its usefulness:

- The total wood consumption of households is much higher than the fuelwood consumption, for wood is been used extensively for fencing and as fuel for fires that are being lit for social reasons.
- It is assumed in this calculation that the population stays stable, while the actual growth rate between 1991 and 2001 has been 2.6% (CBS, [8]2001).
- Finally, the ratio of households using dung is assumed to be stable, which is probably not true for a situation were wood is becoming more and more scarce.

An analysis from a more dynamic and systemic point of view follows in the next section.

5.1.2 The Role of the Tsotso Stove from a system dynamics Perspective

Figure 5.2 is a causal loop diagram showing two balancing loops that limit the consumption of fuelwood. Note that this diagram differs from figure 4.1, for it aims at understanding the relationship between woody resources and wood users, and not the relationships between primary and secondary characteristics of the stove. As such, it is more abstract and serves to analyse changes over time, which have so far been neglected.

The figure shows several circles, in which either a “B” or a “R” is written. The circles indicate that a causal loop exists. A causal loop comes into existence when one variable influences itself through a loop. An example taken from the figure would be: The more wood resources, the more wood growth, the more growth, the more wood resource. This loop is reinforcing, for an initial increase (decrease) in one variable results in further increase (decrease), this is indicated with an “R”. “B” in contrast, stands for loops that balance themselves out, meaning that an increase in one variable will lead to a decrease in this variable until equilibrium is reached. An increase in traditional stove wood users, for example, will result in decreasing wood resources, which will make people use dung instead of wood, which reduces the number of traditional stove wood users.

According to the figure, what the introduction of the Tsotso Stove does – from a system dynamics point of view – is to add a negative feedback loop to the wood production -wood consumption system. The feedback loop is indicated with a 1 in figure 5.2 and goes like this: In the cause of the overexploitation of the woody biomass, fuelwood users will find themselves having ever greater difficulties in finding enough

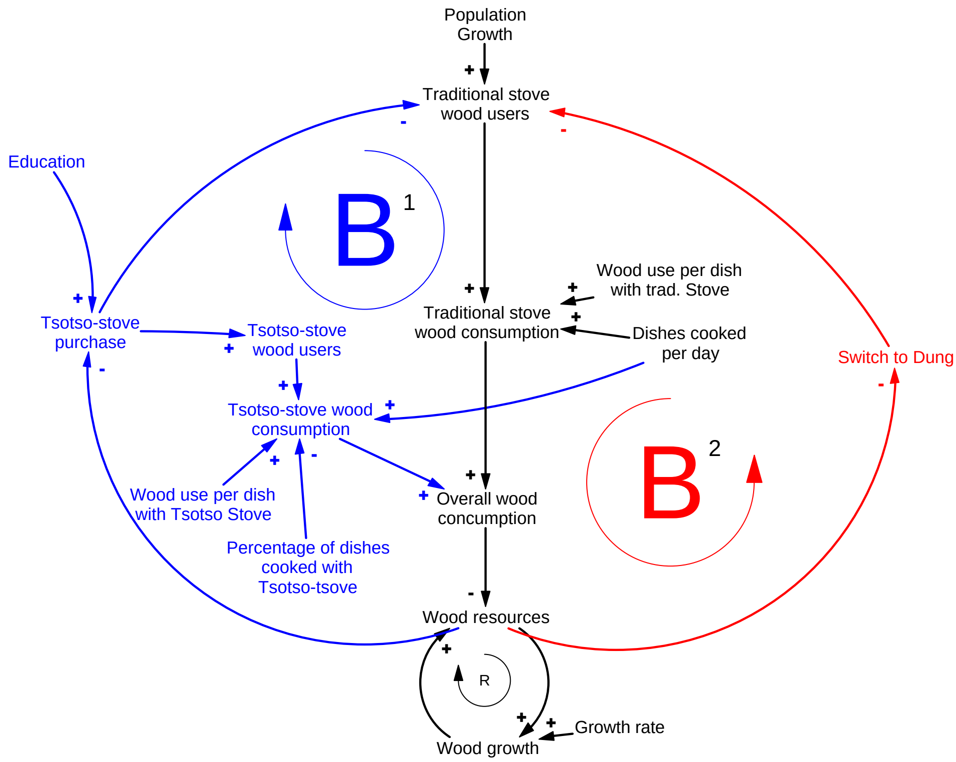

Figure 5.2: Causal Loop Diagram showing the role of the Tsotso Stove from a system dynamics perspective.

wood. As a result, they will consider buying a more efficient stove, so they need less wood. Without the Tsotso Stove being available as an alternative cooking device, the only possibility for the families who face wood-shortages is to switch to dung as their cooking fuel (feedback loop 2).

What is decisive when evaluating the effect of the Tsotso Stove on the woody biomass is the strength of the added feedback loop and the state of the woody biomass at which the loop comes into play. To assess these questions it is useful to take a look at the other negative feedback loop that is created by a change to dung as cooking fuel. The change to dung has not helped to save forests, since it usually does not occur before all the wood that is within reasonable reach of the households has been exploited. Therefore it can be expected that, assuming that a switch to the Tsotso Stove is only triggered by wood scarcity, it will not occur early enough to save the forests in the study area. Furthermore, in opposition to changing to dung as a fuel, changing the stove costs money, which decreases the potential impact of the feedback that the Tsotso Stove creates, because many people just cannot afford the stove.

One way to strengthen the discussed feedback loop would be to change the people's reasons for buying the stove. If the stove would be bought out of the knowledge that it can save money, time and the people's environment, than households might buy it earlier, and not as a last resort when wood is becoming unavailable. This change in behaviour could be brought about through education.

Another way could be to subsidise the stoves even more, so that a greater share of the population can afford to buy it. Subsidies, however, are generally considered to have potential detrimental effects to stove programmes, for they can "sour" stove projects (Barnes, et al.,[5] 1994, p.25), meaning that they can create contempt towards the stove.

A factor that threatens the success of every action that serves to save the natural resources is population growth. Even if the whole of the population switches to wood and great per household savings can be achieved, the system cannot be stable in the long run if the population continues to rise. Therefore, to achieve a sustainable level of natural resource consumption, technical innovations like the Tsotso Stove have to go hand in hand with socio-cultural changes that reduce the birth rate.

5.2 Socio-economic Impact

What becomes apparent when looking at section 4.2 is that the Tsotso Stove is used in a number of ways. Some families use it in a risk-minimising way, meaning that they save it for the occasions in which it is difficult or impossible to cook with the old stove. For these families, the stove helps to provide a warm meal in all weather. Other households, in contrast, use the stove all the time. In this case the stove helps the people to save time and/or money and also facilitates the cooking process. What is most probable is that for both kinds of users the stove presents an improvement of their living situation.

Figure 5.3 shows how the four socio-economic parameters are influenced. This figure is a simplified version of figure 4.1 (the conceptual model). It further includes the survey results since the different connections are marked as being significant, not significant or not determined.

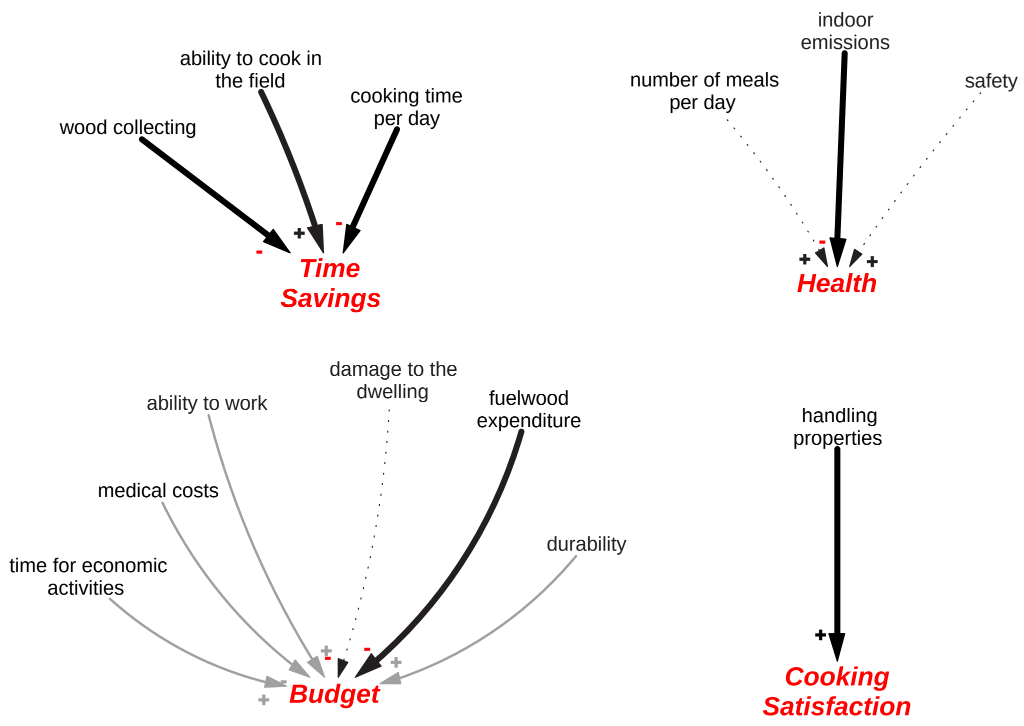

Figure 5.3: Diagram showing the 4 parameters and how they are influenced. Bold arrows stand for significant connections, dashed for insignificant connections and grey lines indicate that the connection was not examined.

From the different ways in which the Tsotso Stove improves living conditions, the time-saving ability is probably most important. One reason for this is that the persons who benefit from it are almost always women, who then have more time for other household duties or for taking care of their children. In some cases it can also lead to an increase in income, when the woman follows an income-generating activity, either producing handcraft at home or selling goods at a local shop.

Another positive impact is that on health. While the effect created by a change in the quantity and composition of emissions is difficult to assess, the assumption that the stove increases the safety of the kitchen environment seems to be correct. This increase in safety should result in a reduction of accidents and thus have a positive effect on the household's health.

The impact of the introduction of the Tsotso Stove on the households' income varies for a number of reasons. First of all a direct effect that is caused by a reduced need to buy fuelwood does only exist for the families that actually buy fuelwood and do not collect it. Secondly an indirect effect, caused by additional free time that is used for an economic activity, depends heavily on the stove user's ability to use extra time for an economic activity. While the indirect effect is difficult to quantify, the direct effect was calculated and the savings were shown to be significant.

The survey clearly indicates that the ergonomics of the Tsotso Stove are superior to the traditional stove.

This result, however, looses weight when the fact that all statements in the questionnaire were formulated in a positive way is being considered. Nevertheless, it can be said that the general attitude towards the stove's handling properties is very positive and that they are in no way an obstacle for further dissemination of the stove.

All in all it can be said that the socio-economic impact of the Tsotso Stove on households is beneficial, which should facilitate wider dissemination of the stove. In other words, from a socio-economic stance, there are no major obstacles that prevent further dissemination, with the exception of the stove's price.

5.3 Outlook

This section shall serve to discuss the future impact of improved biomass stoves in general, and of the Tsotso Stove in particular. In order to do this, three questions have to be answered:

1. Is there a role for the Tsotso Stove in the future?
2. Will wider dissemination take place?
3. What will be the potential results from wider dissemination?

5.3.1 Is there a role for the Tsotso Stove in the future?

Regarding the first question, it should first be discussed if there is a role for biomass stoves in the future of Namibia. In general, there is the hope that people in the developing world will follow in the footsteps of the developed world by climbing up the "energy ladder". In this respect, it could be predicted that, in the future, biomass might not play a significant role as an energy source. According to the Worldbank, however, a switch to processed fuels like kerosene or even electricity is in general difficult for rural households, since people are poor and the dissemination of modern fuels is difficult (Worldbank, [53]1996). This is especially true for Namibia with its widely dispersed population and a poor rural infrastructure.

Secondly, it should be discussed what other biomass stoves are currently being promoted, and if they might displace the Tsotso Stove. For all I know, the Tsotso Stove programme is by far the biggest initiative undertaken to disseminate improved stoves in Namibia. During my stay I had the opportunity to conduct a survey that searched to explore the acceptance of three stoves, that were given to three "Women for Action"-centres by the R3E. Besides the Tsotso Stove, there was a solar stove and a stove that is currently being promoted by Terrasol, called the Vesto Stove. The Vesto Stove is a semi-gassifying stove, it can burn all biomass energy sources and is said to be extremely efficient. It is currently being mass-produced in Swaziland and costs 450 N$. Although the survey consists of only three interviews, it reveals some strength and weaknesses of the stoves. The solar stove was considered by far the worst alternative, mostly because it takes a long time to heat. The Tsotso and the Vesto Stove were both well accepted, mostly because they cook fast and consume less wood. Taking into account the high price of the latter (450 N$), however, it will be difficult to achieve widespread dissemination, considering that the much lower price of the Tsotso Stove (110 N$) already poses a major obstacle to its dissemination.

Concluding, it can be said that biomass as an energy source and thus improved biomass stoves will continue to be of major interest in Namibia. Furthermore, the Tsotso Stove will probably continue to be the most important improved biomass stove in Namibia.

5.3.2 Will wider dissemination take place?

A number of reports tried to answer this question (see Stewart Scott Namibian, [43]2002, R3E & DRFN, [38]2002 or Lasten, [26]2001). These reports mainly focused on supply-sided constraints. Commonly named reasons for the low dissemination level are the lack of transportation possibilities and the lack of marketing skills of the stove producers. Experiencing the situation in Onkani, it is my impression that lack of transportation is the biggest problem (personal communication: Esther Iiyambo). It presents an obstacle for buying the raw material, distributing the stoves and marketing them.

Demand-sided constraints have not been investigated so far and should be the subject of further research. Nevertheless, some points can be made with the help of the surveys conducted for this study. In the pre-survey, when the respondents were asked what they thought was a drawback of the stove, it was often expressed that the stove is expensive by interviewees possessing the stove, and respondents that did not own the stove often gave the price as the only reason for not having it.

Summarising it can be said that, to achieve widespread dissemination, demand- and supply-sided constraints have to be addressed. The easiest way to ease supply-sided constraints would be to provide transportation for the stove-programmes. The problem of this is that it will result in increased costs. To provide each programme with a car, for example, would create immense costs, for cars in general are costly to maintain since almost no tarred roads are available. Thus alternative means of providing transport should be explored (for example donkey carts or the sharing of a car). Once transport is provided, it should be used to market and transport the stove to reach the households that can afford to buy the stove but do not, because they never heard of it or do not realise the benefits it yields. The demand-sided constraints are already addressed by the subsidisation of the stove (app. 30%). However, the costs of the stove are still too high for the poorer part of the population. For this share of the population, other means of payment should be explored, which is in general difficult due to the lack of work available in the area. The ending of the subsidies will probably result in an increase in the share of the population who cannot afford the stove and is thus not recommendable.

In the present situation, wider dissemination cannot be expected unless the obstacles described will be overcome or the external conditions change considerably. Such a change could be brought forth by further exploitation of woody biomass. Should wood become even scarcer, the purchase of wood could become an important expenditure for the majority of the households (already donkey carts that come from other areas sell wood to the local population). In such a situation, the wood-saving ability of the Tsotso Stove might be valued more important, this in turn, resulting in wider dissemination of the stove. However, there are other ways in which the population can react on wood scarcity (switch to dung, for example) and more importantly, the described future scenario is not desirable. Therefore it should not be relied on this "automatic" way of dissemination, but rather efforts should be undertaken too lift the dissemination of the stove to significant levels.

5.3.3 What will be the potential results from wider dissemination?

This question was tried to be answered by this thesis by taking a look on the current impact of the stove and extrapolating the results. Figure 5.4 shows the conceptual model without all connections that are considered insignificant after conducting the study.

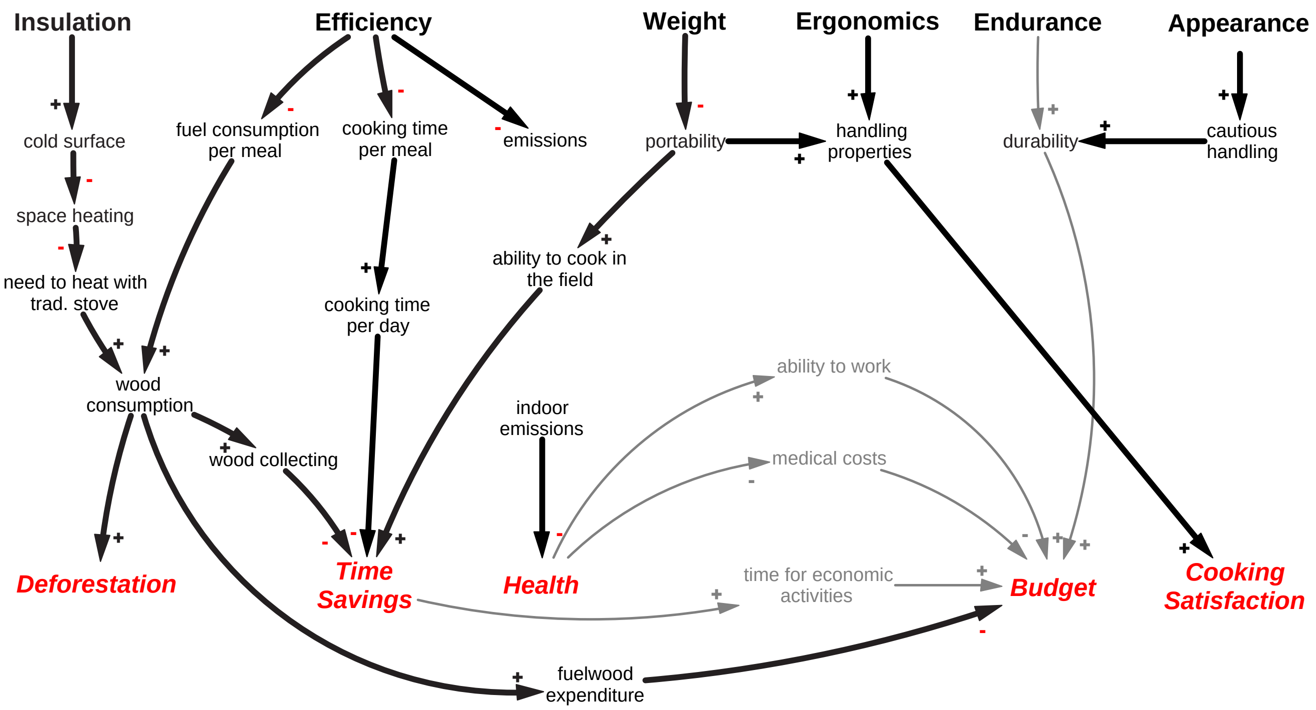

Figure 5.4: The conceptual model without connections that were found to be less important, bold arrows stand for significant connections, grey ones for connections that could not be determined.

The impact on deforestation was subject of section 5.1. Wider dissemination of the Tsotso Stove will most probably alleviate the pressure put on woody biomass and hopefully be a step towards the sustainable use of wood resources. This, in turn, should help in the fight against desertification, and thus help to maintain the productivity of the land.

The impact on households is described in section 5.2. Wide dissemination will help most households to save time and improve health. Additionally, some households will be able to save money. Finally the stove will increase the joy of cooking. The outcomes of all this are difficult to foresee. It can only be hoped that the additional free time will be used purposefully and will help to improve the living standard of the population. This could, for example, happen if the time is used to educate children or to visit friends and family members. The improvement of health is a benefit in itself but will hopefully also help to decrease medical costs and maintain the people's workforce. The saving of money should allow people to improve their living condition by purchasing goods that they enjoy or help them in their everyday life. Finally, the increase in cooking satisfaction will hopefully make cooking more enjoyable.

Chapter 6

Conclusions

The conclusions that can be drawn from this study are:

- The Tsotso Stove has the potential to help in the fight against deforestation, but in order to have a significant impact, wider dissemination must take place. Furthermore, it should be stated that the Tsotso Stove alone is no panacea in the fight against deforestation, but should be part of a bigger strategy, that includes socio-cultural changes, such as a reduction of the birth rate.
- The socio-economic impact of the stove is beneficial. First of all, the stove helps households to save time (15 minutes on average per day). Secondly, households purchasing wood save money (60 N$ ≈ 9 US$ on average per month). Thirdly, a switch from the traditional to the Tsotso Stove probably improves the household members' health by increasing the safety of the kitchen environment. Finally, the Tsotso Stove has superior ergonomics compared to the traditional stove, which should increase the joy and satisfaction of cooking. It should be added that the use of the stove and thus its benefits vary widely among the households.
- Regarding research recommendations, it should be said that observation or stove testing in the field would have added credibility to this study. This can be a field of future research, but, considering the costs of it and the low level of dissemination of the stove, resources might be used more effectively.
- Regarding recommendations for the future, it is my opinion that the Tsotso Stove programme should be continued and wider dissemination of the Tsotso Stove should be pursued. For this to happen, cost-efficient ways to address the lack of transportation of the stove producers have to be found, and measures to reach the poorer parts of the population that so far cannot afford the stove, should be explored.

Bibliography

[1] Ayoub, Josef & Brunet Eric. (1996). Performance of large portable metal Woodstoves for Community Kitchens. *Renewable Energy, 7*, 71- 80.

[2] Bailey, Kenneth D. (1987). *Methods of Social Research*. New York: The Free Press.

[3] Ballard-Tremeer, G. & Jawurek, H. H . (1996). Comparison of Five Rural, Wood-Burning Cooking Devices: Efficiencies and Emissions. *Biomass and Bioenergy, 11*, 410-430.

[4] Barnes, Douglas F., Openshaw, Keith, Smith, Kirk R. & van der Plas, Robert. (1993). The Design and Diffusion of improved stoves. *The World Bank Research Observer, 8*, 119-141.

[5] Barnes, Douglas F., Openshaw, Keith, Smith, Kirk R. & van der Plas, Robert. (1994). *What Makes People Cook with Improved Biomass Stoves? - World Bank Technical Paper 242*. Washington, DC: Worldbank.

[6] Cecelski, Elizabeth, Makhabane, Tieho Tienho, Ndevashiya, Walde Natangwe & Hasheela, Tuvoye Hendrina. (2001). *Gender and Biomass Conservation in Namibia: A case study with special reference to GTZ/ProBEC Interventions*. Windhoek, GTZ.

[7] Central Bureau of Statistics. (1999). *Statistical abstract 1999, No.6*. Windhoek: Office of the President, National Planning Commission, Central Bureau of Statistics.

[8] Central Bureau of Statistics. (2001). *Namibia Population and Housing Census*. [Online]. Available: http://www.npc.gov.na/census/index.htm [2003, October 15].

[9] Central Statistics Office, National Planning Commission. (1994). *1991 Population and Housing Census. Basic Analysis with Highlights*. Windhoek: Central Statistics Office.

[10] Malan, J. S. 1995. *Peoples of Namibia*. South Africa, Pretoria: Rhino Publishers.

[11] Checkland, Peter B. .(1981). *Systems Thinking, Systems Practice*. Chichester: Wiley.

[12] Department of International Development. (2000). *Poverty reduction aspects of successful improved household stove programmes*. [Online]. Available: http://www.esd.co.uk/downloads/ses_poverty_reduction_stoves_R7368.pdf [2003, October 8].

[13] Food and Agricultural Organisation of the United Nations. (1973). *Soil map of the world*. Paris: UNESCO.

[14] Ford, Andrew (1999). *Modelling the environment*. Washington: Island Press.

[15] George, Emma. (2002). *Woodstoves for Uganda: Testing stoves and finding better designs*. Ministry of Energy and Mineral Development.

[16] Giess, W. (1971). *A preliminary vegetation map of South West Africa*. Dinteria 4:5-114.

[17] Gill, Jass (1987). Improved stoves in developing countries - A critique. *Energy Policy, 15*, 135-144.

[18] Government of Namibia. 1996. *Namibia Forestry Strategic Plan 1996*. Namibia: Ministry of Environment and Tourism, Directorate of Forestry.

[19] Hamayulu, Reinhold L. (2000). *A Socio-economic Baseline-Study of Onkani Village*. Windhoek: Polytechnic of Namibia.

[20] Hulscher, Wim, Luo, Zheng & Koopmans, Auke. (1999). Stoves on the Carbon Market. In *Meeting of the Household Energy Development Organization Network (HEDON)*, December 1999, The Netherlands. Enschede.

[21] Joseph, Stephen, Prasad, K. Krishna, van der Zaan, Hanske B. (1990). *Bringing Stoves to the People - An Assessment of Impact*. Nairobi, Kenya: Foundation of Woodstove Dissemination.

[22] Joseph, Stephen (1990). *Guidelines for Planning, Monitoring and Evaluating Cookstove Programmes*. Rome: FAO.

[23] Karekezi, Stephen & Ranja, Timothy (1997). *Renewable Energy Technologies in Africa*. London: Zed Books Ltd.

[24] Kruger, A.S. (1997). *Pastoral and agro-pastoral resources. Comprehensive assessment of environmental problems and opportunities for USAID intervention in Namibia*. Windhoek: Namibia Resource consultants.

[25] Langanke, Tobias. (2001).*Indicators for national level monitoring of Desertification. Towards linking local level and national level monitoring. An example from north-central Namibia*. Germany; Mainz. Johannes Gutenberg-University Mainz.

[26] Lasten, Mika. (2001) *Report on the Technical Consultation in Northern Namibia on the Project for Biomass Energy Saving, Namibian Biomass Energy Savings Project (NamBESP)*. Windhoek: Desert Research Foundation of Namibia.

[27] Maani, Kambiz E. & Cavanna, Robert Y. (2000). *Systems Thinking and Modelling: Understanding Change and Complexity*. Auckland: Prentice Hall

[28] Matthew, Catherine. (2001). *Namibia's Biomass Energy Management Programme - Results of a Baseline Survey in Northern Namibia - Working Document*. Windhoek: DRFN.

[29] Mikkelsen, Birtha. (1995). *Methods for Development Work and Research: A Guide for Practitioners*. Delhi: Sage Publications.

[30] Millington, A.C., Critchley R.W. , Douglas T.D. & Ryan, P. (1994). *Estimating Woody Biomass in Sub-Saharan Africa*. Washington, DC: Worldbank.

[31] Marsh, A. & Seely, M.K. (1992). *Oshanas. Sustaining people, environment and development in Central Owambo,Namibia*. Windhoek: Desert Research Foundation & Swedish International Development Cooperation Agency.

[32] Ministry of Agriculture, Water and Rural Development. (1999). *Rainfall Distribution in Namibia: Data analysis and mapping of spatial, temporal, and southern oscillation Index aspects. Phase one Report*. Windhoek: Ministry of Agriculture, Water and Rural Development.

[33] Ministry of Mines and Energy (*unpublished draft* 1997). *Namibian National Energy Policy Project*.

[34] Namibia Red Cross, Namibia's Economic Policy and Research Unit & the Secretariat of the Pacific Commission. (2000). *State of Environment Report on Agriculture and Land Resources. Final Report*. Windhoek: Directorate of Environmental Affairs, Ministry of Environment and Tourism.

[35] Nyström, Maria (1994). *Focus - Kitchen design - A study of housing in Hanoi*. Lund: Lund University.

[36] Peeler Fife Company. (2003). *Mopane (Colophospermum mopane)*. [Online]. Available: http://peelerfifes.com/woods/mopane/index.shtml [2003, September 6].

[37] Pretty, Jules N. (1995). Participatory Learning for Sustainable Agriculture. *World Development, 23*, 1247-1263.

[38] Renewable Energy Efficiency Bureau of Namibia & Desert Research Foundation of Namibia. (2002). *Namibian Biomass Energy Study Evaluation September 2002*. Windhoek: Renewable Energy Efficiency Bureau of Namibia.

[39] Schneider, Stephanie. (1999). *Dissemination of improved Cookstoves - Towards a Workable Strategy for the Omusati Region in Northern Namibia*. Sweden: Kungl. Tekniska Högskolan. (Cecelski et al., [6] 2001)

[40] Selanniemi, Thomas, Chakanga, Moses & Angombe, Simon. (2000). *Inventory Report on the Woody Resources in the Omusati Region*. Windhoek: Directorate of Forestry of the Ministry of Environment and Tourism.

[41] Selanniemi, Thomas, Chakanga, Moses & Angombe, Simon. (2000). *Inventory Report on the Woody Resources in the Oshana Region*. Windhoek: Directorate of Forestry of the Ministry of Environment and Tourism.

[42] Sterman, John D. (2000). *Business Dynamics - Systems Thinking and Modeling for a Complex World*. Boston: McGrawHill.

[43] Stewart Scott Namibia. (2002). *Biomass Energy Study - Final Report*. Windhoek: Stewart Scott Namibia.

[44] Stockholm Environmental Institute. *Charcoal Potential in Southern Africa - Zambia*. [Online]. Available: http://www.sei.se/chaposa/pres_zambia.html [2003, August 19].

[45] Trippner, C. (1998). *Landscape-Ecological Risk Information System Pilot Area North, Uuvudhiya Constituency*. Unpublished.

[46] United Nations Development Programme, United Nations Department of Economics and Social Affairs, World Energy Council. (2000). *World Energy Assessment - Energy and the Challenge of Sustainability*. New York: United Nations.

[47] United Nations Human Settlements Programme. *Global Urban Observatory*. [Online]. Available: http://www.unhabitat.org/habrdd/conditions/safrica/namibia.htm [2003, October 15].

[48] United States Central Intelligence Agency. (2003). *The World Fact Book - Namibia*. [Online]. Available: http://www.cia.gov/cia/publications/factbook/geos/wa.html [2003, September 6]

[49] Verlinden, A. & Dayot, B. (1999). Working with local knowledge systems in a GIS for natural resource assessment, plannin and management in North Central Namibia. in *Regional Workshop on spatial approaches for land use and local governance*, November 1999, South Africa, Pretoria.

[50] Wallmo, Kristy, Jacobson, Susan K. (1998). A social and environmental evaluation of fuel-efficient cook-stoves and conservation in Uganda. *Environmental Conservation, 25*, 99-108.

[51] Wamukonya, Lucy (1997). *Study on Energy Consumption Patterns of Rural and Peri - urban Households in Namibia*. Windhoek: Ministry of Mines and Energy.

[52] Wamukonya, Lucy. (1998). *Energy Consumption in Rural Namibia*. Windhoek: Ministry of Mines and Energy.

[53] World Bank (1996). *Rural Energy and Development*. Washington DC: The Worldbank.

[54] Zein-Elabdin, O. (1997). Improved stoves in Sub-Saharan Africa: the case of the Sudan. *Energy Economics, 19*, 465-475.

Chapter 7

Appendix

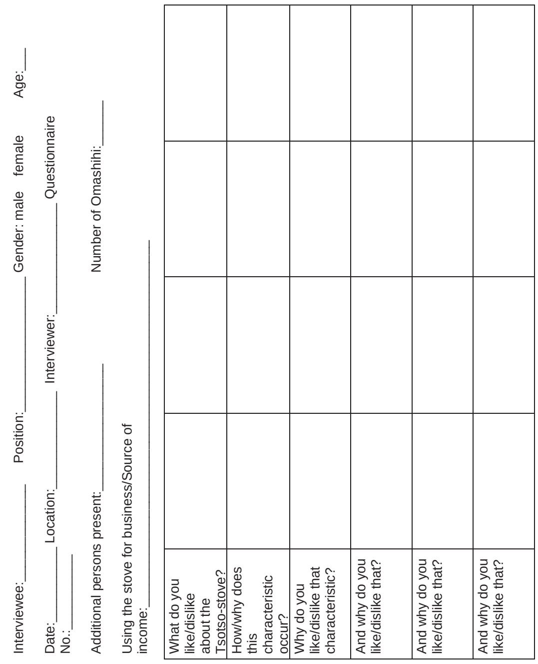

Figure 7.1: Questionnaire of the Pre-Survey

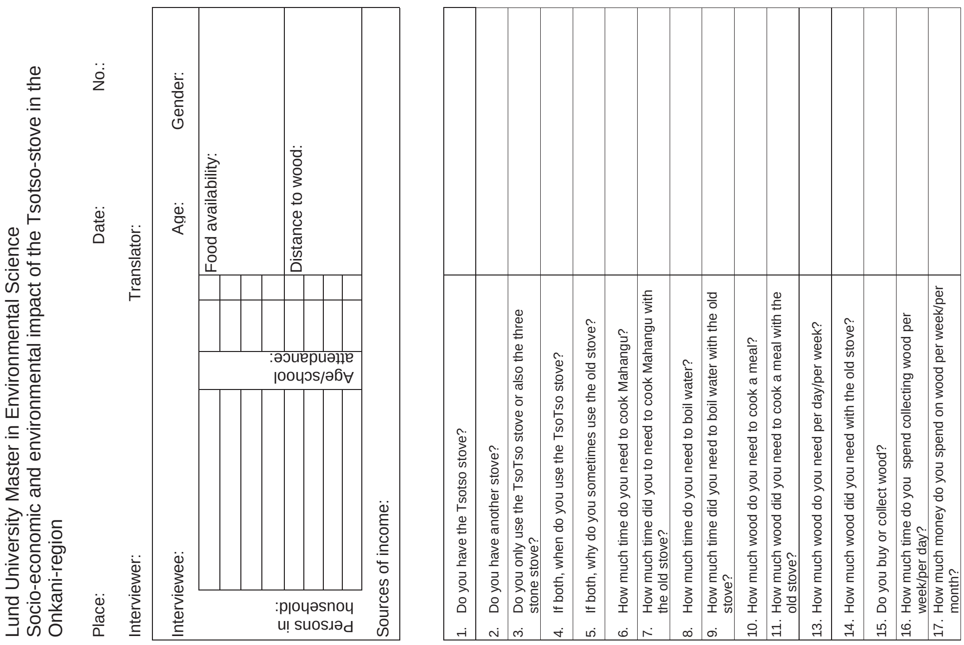

Figure 7.2: Questionnaire of the Survey page one

1. Do you use the stove to cook in the field?	
2. Did you used to go home for lunch when you were in the field before you had the Tsotso stove?	
3. If yes, can you estimate how much time you save now that you cook in the field?	
4. How much time does it usually take to walk from the field to your home?	
5. How often do you cook per day?	
6. How often did you cook per day with the old stove?	
7. Do you cook in the rainy season?	
8. Could you cook with the old stove in the rainy season? If yes, inside or outside?	
9. Do you cook inside or outside in the rainy season with the new stove?	
10. How often do you cook per day in the rainy season?	
11. How often did you cook per day in the rainy season with the old stove?	
12. How long is the rainy season?	
13. Do you cook when it is windy?	
14. Do you cook inside or outside when it is windy?	
15. Could you cook with the old stove when it was windy?	
16. Did you cook inside or outside with the old stove when it was windy?	
17. Which month is it windy?	
18. Do you cook inside when it is too sunny?	
19. How many month is it really sunny?	
20. Did you cook inside when it is too sunny with the old stove?	
21. Do you cook outside whenever it does not rain?	
22. How often do you cook inside per week?	
23. How often did you cook inside per week with the old stove?	
24. How many cooking accidents do you have per month?	
25. How many cooking accidents did you have per month with the old stove?	
26. Did sections of or items in your house ever catch fire when you used the old stove?	
27. If yes, how many times per year?	

Figure 7.3: Questionnaire of the Survey page two

1. Do you use the old stove for heating?				
2. How often do you use the old stove for heating?				
3. How long have you had the stove?				
4. Does it still cook as well as it did in the beginning?				
5. Has it broken down?				
6. How long did the stove last?				
7. Do you use the Tsotso stove for something else than cooking?				
8. If yes, what for?				
9. Did you use the old stove for the same purpose?				
	I strongly disagree	I partially disagree	I partially agree	I fully agree
10. Handling the pot is easier with the Tsotso stove.				
11. Handling the fire is easier with the Tsotso stove.				
12. Handling the ash is easier with the Tsotso stove.				
13. Handling the firewood is easier with the Tsotso-stove.				
14. The Tsotso stove is easier to move.				
15. Cooking with the Tsotso-stove is more fun because its so easy to handle.				
16. The Tsotso stove looks nicer than the old stove.				
17. Because the Tsotso stove looks nice, I am careful when handling it.				
18. The new stove does not heat the room/house when its cold				
19. The Tsotso stove is safer because its surface is not hot.				
20. The Tsotso stove is safer because the fire is protected from the wind.				
21. The new stove has fewer emissions.				
22. When using the stove inside the room gets less smoky.				
23. I cook more since I use the new stove				
24. I cook more often inside since I use the new stove				
What I like the best about the Tsotso-stove				

Figure 7.4: Questionnaire of the Survey page three