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***Improving Small-Scale Agriculture and Countering
Deforestation:
The Case of Biochar and Biochar Producing Stoves in Embu
County, Kenya***

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The MFS Scholarship Programme gives Swedish university students the opportunity to carry out fieldwork in low- and middle income countries, or more specifically in the countries included on the *DAC List of ODA Recipients*, in relation to their Bachelor's or Master's thesis.

Sida's main purpose with the Scholarships is to stimulate the students' interest in, as well as increasing their knowledge and understanding of development issues. The Minor Field Studies provide the students with practical experience of fieldwork in developing settings. A further aim of Sida is to strengthen the cooperation between Swedish university departments and institutes and organisations in these countries.

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Abstract

This research examines the introduction and diffusion of biochar as a soil amendment and biochar producing stoves in Embu County, Kenya, together with its related socio-economic potentials and challenges. The area has seen rapid rates of deforestation together with declining soil fertility during the last couple of decades. Biochar as a soil amendment and biochar producing stoves offers a viable solution to these problems, at the same time as it may improve the productivity in the small-scale agriculture, the main income-generating activity in the area. In order to do so, it is of utmost importance that these innovations are well adapted to local socio-economic, geographical and cultural pre-conditions. Through a case study in Embu County, I have investigated the perceptions and pre-conditions of small-scale farmers in relation to local socio-economic geographical or cultural challenges and the related potential solutions. The findings suggest that these new innovations have a high potential in the area and that they could play a vital part of a sustainable agricultural intensification process.

Key Words: Biochar; soil amendment; biochar producing stoves; Integrated Soil Fertility Management (ISFM); new agricultural innovations; deforestation

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2. Introduction

Kenya has, together with neighbouring countries in the East African region seen a rapid economic development during the last decade. However, almost 50% of the population remain below the poverty line and are considered food insecure. A majority of the Kenyan population is residing in rural areas and is to a large extent depending on small-scale or subsistence agriculture in order to meet daily basic needs (KNBS, 2013). Especially vulnerable are women residing in rural areas since they are, even more so than men, relying on subsistence farming and lack equal access to social and economic assets (IFAD, 2014). Furthermore, rapid and sustained population growth since Kenya gained its independence from the United Kingdom in 1963 has resulted in a high pressure on agricultural land in areas with high productive capacity of the soil. Although further extension of farmland could somewhat improve the situation it cannot be the only strategy in order to increase food production, simply because there is not sufficient amounts of land left to extend into (NEMA, 2013). Improved agricultural practices and new agricultural innovations, with potential benefits for small-scale farmers in multiple ways are thus of great importance in order to alleviate poverty and achieve food security among the rural population in Kenya.

Among the main challenges for small-scale farming in Kenya today we find an array of interrelated processes such as land degradation, soil erosion, diminishing sources for fuel-energy, climate change, and lack of access to water (IFAD, 2014). Kenya has in recent decades experienced rates of population growth at above 3 per cent per annum (KNBS, 2011a), something that has further increased the pressure on arable land and exacerbated the above-mentioned processes. It is within this context that application of charred organic matters, or biochar, has emerged as a possible solution for the small-scale agricultural sector in Kenya and in other similar contexts. Putting it simply, the production of biochar implies the charring of different organic matters, with a resulting end product, biochar, that can be used as a soil amendment. The emphasis on local production of biochar is made possible through the invention and possible introduction of small-scale biochar producing stoves, allowing local farmers to produce their own organic soil amendments while simultaneously generating heat for e.g. cooking food on an energy efficient stove. In addition to the opportunity to produce their own organic soil amendments the introduction of biochar producing stoves has a potential to greatly reduce levels of hazardous smoke in the process of cooking. At present, a majority of rural Kenyan households use a traditional three stone stove with an open fire for cooking or heating. This method exposes the household members responsible for cooking, mainly women, to high levels of harmful smoke, with related health problems. The technical features of the biochar producing stove greatly reduces the amount of smoke produced and could lead to significant health improvements among women in rural household.

Furthermore, global climate change may pose a serious threat to the agricultural sector in Kenya. Current predictions suggest that countries such as Kenya, situated on the equator, may to a large extent be affected by climatic changes, such as a change of precipitation patterns and temperatures. Current scenarios, coupled with the economic reality in Kenya and many other developing countries, suggest that the small-scale agricultural sector

will be among the sectors facing the most severe consequences (NEMA, 2013). Among the findings that are discussed in this thesis are serious concerns among small-scale farmers interviewed in Embu County, Kenya, regarding changing and increasingly erratic weather patterns in the region. The perception among a vast majority of farmers interviewed is that there is a strong correlation, and importantly, causality between on the one hand historical and current rapid rates of deforestation, and on the other hand a changing climate. Biochar and biochar-producing stoves have a number of different potentials in relation to these interlinked problems, some of which are described and discussed in this thesis, namely:

- The potential use of feedstock other than wood when cooking with a biochar producing stove, instead of the commonly used firewood or charcoal jiko, may to a large extent reduce the use of firewood on a household level. If wood were to remain the preferred type of fuel, the increased energy efficiency of the biochar producing stoves would regardless result in reduced usage of wood for cooking or heating.
- The application of biochar to poor or eroded agricultural lands has a potential to restore the quality of the soil and increase agricultural productivity per unit of land. If carried out in a responsible manner this may significantly reduce the need of further deforestation in order to extend agricultural lands.
- The application of biochar to soil may greatly reduce the need for inorganic fertilisers. The available scientific research suggests that biochar may enhance the efficiency of organic and inorganic fertilisers applied to agricultural lands in the tropics. This could further increase the production capacity of these lands, and thus reduce the demand for an extension of agricultural lands in areas with a high population pressure, at the same time as it could reduce expenses related to the purchase of inorganic fertilisers.

It has been proven that turning biomass into biochar may prevent the emissions of large amounts of carbon dioxide and other greenhouse gases to the atmosphere. Biochar production could thus play an important role in mitigating the emissions of greenhouse gases and alleviate climate change (Scholz et al., 2014). This development and debate is of great interest, especially to countries and sectors more vulnerable to climatic change, and this is important to keep in mind. However, despite the fascinating nature of the topic, it lies outside the scope of this thesis to discuss this potential to any further length. Instead the focus is placed on the role of, and challenges related to, new agricultural technologies and practices in improving small-scale agricultural production and combating deforestation in rural areas of the Global South. This is done through a single case study in which the implementation of biochar and biochar producing stoves is studied in Embu County, Kenya. The collection of data took place during nine weeks of field studies in the selected area.

It is furthermore important to note that there are a number of actors currently working with the development of biochar production systems. Although this thesis, and the research project that I have collaborated with, focus on local small-scale production where the benefits are mainly to be experienced by the individuals and societies directly involved, there are other actors investigating the potential to turn production and sale of biochar into a profitable business on a large scale. A number of critics (e.g. Monbiot, 2009) of the development of biochar projects have raised concern about the potential negative effects

related to these large-scale projects, including the conversion of vast amounts of fertile lands to plantations for the feedstock used in biochar production, something that could further reduce the availability of farmland for small-scale farmers. With this in mind, I advise the reader to pay attention to the difference between the small-scale project discussed here and larger scale projects with a more profit-oriented focus.

2.1. Outline of the Thesis

The following sections will provide an extended description of the features and potential of biochar and biochar producing stoves, followed by an introduction to the area of study. Thereafter follows a discussion on a number of key concepts on a general level, such as the role of, and challenges related to, the diffusion of new agricultural innovations in largely traditional societies in the Global South; the relation between small-scale agriculture and deforestation; and the concept of Integrated Soil Fertility Management (ISFM). Furthermore, I discuss the methods employed for the collection and analysis of relevant data, both in the field and at home, together with a number of challenges that I have encountered in the data collection process in Kenya. Thereafter follows a section presenting the data collected in the field, through secondary sources and through a thorough literature review. Subsequently, I discuss the collected and analysed data in relation to the broader conceptual framework. The final section concludes

3. Background

3.1. The Origin of Biochar and Its Relevance for a Discussion on the Diffusion of Technologies

A theoretical area of interest, and the focus of this thesis, is the academic discussion of how technology and knowledge are transferred between the Global North and South, and the potential socio-economic effects this may have for small-scale farmers and their geographical surroundings in the Global South. To exemplify this transfer of new agricultural technologies and practices, I have chosen to study the development and diffusion of biochar and biochar producing stoves in the context of Embu County, Kenya. Putting it simply, the production of biochar involves the charring of various organic matters, such as wood or farm wastes, in a zero- or low oxygen environment. The end product of the charring process, biochar, is subsequently added to agricultural soil and acts as a soil amendment (Lehmann & Joseph, 2009; Rodriguez Tejerina, 2010). The increasing academic and policy-making interests emerging around biochar as a soil amendment are not only due to the possibility to produce soil amendments in a sustainable manner through locally available organic sources. This interest also derives from the notion that biochar is not only more stable than any other soil amendment; it also increases nutrient availability in soil more than other soil amendment, organic or inorganic (Lehmann & Joseph, 2009). Biochar thus offer a “*unique opportunity to*

improve soil fertility and nutrient-use efficiency using locally available and renewable materials in a sustainable way” (Lehmann & Joseph, 2009:6).¹

There is evidence that farmers in the Amazonian basin in Latin America used a soil amendment similar to what is today known as biochar, and thus created the renowned *Terra Pretas* to improve their agricultural production, as far back as 6000 years ago (Barrow, 2012). The existence of these ‘dark earths’ with high levels of soil fertility is often used to support modern research on biochar as a soil amendment (Leach et al., 2010). Nonetheless, while much of the inspiration for continuous research is derived from the excitement surrounding the physical soil features and agricultural potential of the *Terra Pretas*, what we see today is the development of a completely new technology. Furthermore, the development of biochar producing stoves, with the multiple purposes of producing biochar for agricultural purposes, providing an energy-efficient method of cooking and heating, and addressing the problem of environmentally damaging and unhealthy traditional modes of cooking and heating, is an effect of recent technological breakthroughs and has no precedent.

There is proof that charcoal has been produced locally throughout societies in the Global South for millennia (Lehmann & Joseph, 2009). Furthermore, the method of slash-and-burn agriculture is widely spread in sub-Saharan Africa and bears similarities with the application of biochar to soil (Barrow, 2012). The final aim of slash-and-burn practices is to enrich soil with stable carbon from burned biomasses through the ashes left in the fields. However, there is evidence pointing towards a rather minor contribution of carbon to soil through slash-and-burn agriculture. Glaser et al. (2002) claims that the slash-and-burn method only contributes around 3 per cent of original biomass carbon to soil, whereas up to 50 per cent of biomass carbon could be stored through the production of biochar. The carbon stored in biochar is furthermore more stable compared to carbon stored in ashes contributed through slash-and-burn, offering potential soil benefits for centuries or even millennia (Nguyen et al., 2009). The on-going development of modern biochar and biochar producing stoves thus offers a potential to address multiple problems faced by e.g. small-scale farmers in the Global South, a potential largely different to that derived from previous uses of charcoal and wood burning stoves.

Many farmers engaged in small-scale agriculture in the Global South cannot afford to purchase sufficient amounts of organic or inorganic fertilisers. Given that organic matters already exist on a vast majority of farms, the production and application of biochar as a soil amendment offers a more economically viable solution to these farmers (Barrow, 2012). Although the recent increase in academic and policy-making interest largely springs from the potential of biochar as a soil amendment, there are a number of further potential benefits that can be realised through the production and use of biochar in the small-scale agricultural sector in the Global South. The low- or zero oxygen in which biomass is turned into biochar offers a clean and efficient source of energy (Lehmann & Joseph, 2009; Rodriguez Tejerina, 2010). Many countries in the Global South are heavily relying on biomass, mainly wood, in order to

¹ For an extended technical description of the physical structure and agricultural potential of biochar, see e.g. Lehmann, J. & Joseph, S., 2009, ‘Biochar for Environmental Management: Science and Technology’, Earthscan, London, United Kingdom

meet their energy needs. As will be discussed later, tropical forests are already under great pressure and any path that could reduce the need for firewood, and thus ease the problem of deforestation, is of great interest.

The type of biochar producing stove that is referred to throughout this thesis is a type of small-scale gasifier that converts biomass into biochar while simultaneously producing gases that can be burnt and produce energy for cooking or heating (Helander & Larsson, 2014).

Keeping the above discussion in mind, the development of biochar as a soil amendment and biochar producing stoves can be placed in a number of different categories of innovations, as defined by Sunding & Zilberman (1999). These categories include: ‘*Yield-Increasing Innovations*’; ‘*Cost-Reducing Innovations*’; and ‘*Innovations that Protect Health and the Environment*’ (ibid.). When adopting these categories it further becomes evident that these innovations offer multiple potential benefits to small-scale farmers, given that diffusion and adoption is successful.

Photo 1: Biochar Producing Stove, Embu County, Kenya



(Photo: Anders Magnusson, Embu County, Kenya, 2015-01-23)

3.2. The Case of Embu County, Kenya

The collection of qualitative data providing material for this research was situated in Embu County in central Kenya (Map 1), situated on an altitude of 1350 metres above sea level

(Embu County News, 2013). The collection of material for this research was conducted in the Manyatta Division, one of the five sub-counties of Embu, which is situated in the upper area of the county and extends into the Mount Kenya National Park and Mount Kenya Forest Reserve. The total population of Embu County were estimated at 516.212 persons in 2009, of these the Manyatta Division accounted for 154.632, making it the most densely populated constituency of the county with 575 persons per km² (KNBS, 2011b). Manyatta Division, as well as other parts of Embu County is dominated by small-scale agriculture, with an average farm size of 0.8 hectare. Due to population growth, currently at 1.4 per cent annually, and limited access to agricultural land, the average farm size has seen a constant decline during the last three decades (ECG, 2013; NEMA, 2013). Population growth, decreasing farm sizes, declining land fertility, low levels of education and limited knowledge of sustainable agricultural methods are identified as the key factors resulting in high levels of poverty and increasing socio-economic vulnerability, especially among the rural population. Currently, somewhere in between 35-45 per cent of the population in Embu County are defined as living in poverty, with the rural poverty line being set at KSh 1562 per month (approximately 135 SEK) (KNBS, 2013; NEMA 2009).

Due to the rural nature of the study area, combined with the high incidence of poverty, above 85 per cent of the energy consumed is derived from woody biomass, mainly in the form of firewood or charcoal (ECG, 2013). The majority of food preparation and water heating in Kenya employs wood or charcoal as the source of energy, and takes place over an open three stone stove (Whitman et al., 2011). The World Health Organization (WHO, 2014) claims that the traditional means of cooking among rural poor is one of the most serious health hazards on a global scale and that women are likely to suffer the most due to the division of household tasks. Furthermore, local estimations taking both population growth and increasing demands for energy into account, predict the total amount of woody biomass consumed for the purpose of energy generation to double by 2020 (NEMA, 2009). Local development plans have identified the large dependency on firewood for energy consumption as the single most important factor contributing to the high rates of deforestation in the region, with severe soil erosion and flooding as some of the consequences (ECG, 2013; NEMA, 2009).

As has been previously discussed, the aim of this thesis is to discuss the role of new agricultural innovations in societies relying on traditional methods of farming in rural areas. A certain emphasis will be placed on the role that these new innovations may play in countering the process of deforestation in the area. The area of study chosen is of certain interest to this research due to a combination of factors. The villages where the field study has been conducted are bordering the Mount Kenya National Park, parts of which are densely forested. Prior to the formation of the protected area, logging was intense and inhabitants could rely on the forests to meet their demands for wood, both for fuel and timber. This situation has drastically changed after large areas of natural forests were protected and the local population are now increasingly relying on trees being replanted on farms in order to secure their energy needs (ECG, 2013). This has created a situation in which the replanting of forests is competing with agricultural production for access to land. This is in an area that is already experiencing a heavy and increasing population pressure. It is these competing uses of potentially productive farmlands in the area, both land already cleared and land still covered

by forests, that provide an interesting local context for the general discussion on the role and potential of new agricultural innovations in the Global South.

Map 1: Location of Embu County



(ECG (Embu County Government), 2013, 'County Integrated Development Plan 2013 – 2017')

3.3. Biochar in the Context of Embu County

The reason for situating this research in Embu County was an initial contact with my academic supervisor *Yahia Mahmoud*, who is involved in the research program '*Bio-char and smallholder farmers in Kenya - improved use efficiency of farm-level organic resources in relation to energy, crops and soil*'. This research program (hereafter IITA-SLU-LU research program) was initiated by the International Institute of Tropical Agriculture (IITA), the Swedish University of Agricultural Sciences (SLU), Lund University (LU), and the World Agroforestry Center (ICRAF), and is currently conducted in three different parts of Kenya, one of them Embu County. The on-going IITA-SLU-LU research program has three main

pillars. The first one is of a techno-engineering character where the focus is put on the stoves that will produce biochar at the scale of the farm. The second is about studying the application and evaluation of the effects of that biochar on the soil. The third pillar is the study of the socio-economic impacts of the application of this new technology. Although not officially part of the research program, one aim of this thesis is to contribute towards the aforementioned third category.

Photo 2: Biochar Field Trials, Embu County, Kenya



(Upper half: biochar applied to soil; lower half: no biochar applied to soil. Photo: Anders Magnusson, Embu County, Kenya, 2015-01-23)

The combination of the geographical and socio-economic factors of Embu County described above and the current work of the IITA-SLU-LU research program in the area constitute an attractive environment for a study on the role of new agricultural innovations when it comes to countering deforestation and improving small-scale agriculture in the Global South. It has been proven that biochar as a soil amendment has a large potential when it comes to increasing the productive capacity of soil in the tropics and semi-tropics, many of which have experienced large soil degradation and erosion (Benhin, 2006; Scholz et al., 2014). Furthermore, the type of biochar producing stove currently being tested in the area is a sort of gasifier stove that allows organic materials to go through pyrolysis and produce gases and heat that can be used for cooking or heating. The burning process also produces charcoal, or biochar, that can be saved for the later agricultural use described above. This stove will result in a cleaner and more energy efficient process of cooking or heating, with a potential to save

on both fuel and time. Innovations that have the potential to increase the productive capacity of agricultural soil, and simultaneously provide clean and efficient energy while reducing the reliance on firewood as an energy source is clearly of interest when it comes to the discussion of intensifying small-scale agriculture and countering deforestation in rural Kenya.

Previous research in Embu County has shown the agricultural and environmental potential of biochar and its application to soil in the area (e.g. Åslund, 2012). Similar results have shown that biochar producing stoves, using organic matter as fuel, may greatly reduce the cost of fuel for e.g. cooking, reduce the time needed for collecting firewood, and reduce health hazards related to cooking over open fires (e.g. Bhattacharya & Abdul Salam, 2002; Helander & Larsson, 2014). These initial findings further support the idea that biochar as a soil amendment and biochar producing stoves may play a key role in improving soil, reducing deforestation and improving livelihoods for the rural poor in Embu County.

3.4. Delimitations

Biochar has received an increasing amount of attention within the academic community during the last decade, and the debate about its potentials has been fierce. Some of the opinions in this debate have been summarized and discussed by Leach et al. (2010), mainly of interest when it comes to the potential role of biochar to sequester carbon dioxide and provide a large-scale solution to global climate change. A large number of research projects with the aim to further understand the environmental potential of large-scale biochar projects are currently underway and I find it unwise to propose any definite opinion within these matters before further results has been made available. With this in mind, and given other limiting factors such as time and resources available for this field study and thesis writing, I do not intend to discuss at any further length the possible potential of large scale biochar projects when it comes to sequestering carbon dioxide and mitigating climate change on a global scale. I find the debate about the potential of biochar to mitigate climate change on a global scale very interesting; however, it lies outside the scope of this thesis. In addition, a number of research projects are currently underway with the aim of establishing e.g. the optimal application rates of biochar, the optimal feedstock for different types of crops, and the different outcomes when various types of biochar are applied to different types of soil. The outcome of these research projects are of great importance to the future development of biochar as a soil amendment, however, I do not intend to discuss or contribute to these largely natural scientific discussions and projects in this thesis.

Instead I have focused on a relatively small geographical area with a majority of the population heavily relying on environmental factors, such as soil quality and weather patterns, for their daily subsistence and income generation. These topics are largely related to the issue of climate change; however, I choose to focus on the perceptions of rural farmers when it comes to the socio-economic aspects of the diffusion of these new innovations. Instead of addressing the larger natural scientific debate on e.g. emissions, sequestration of greenhouse gases, or physical soil characteristics, I have adopted a human geographical standpoint and mainly discuss the relation between human activities and their environmental surroundings.

4. Aim and Research Questions

The aim of this thesis is to contribute to a further understanding of the socio-economic impacts and challenges related to the introduction and diffusion of biochar as a soil amendment and biochar producing stoves in Embu County. It has been made clear that these innovations have a large potential to improve soil quality, alleviate the problems of soil erosion, and improve energy-efficiency, while simultaneously reducing hazardous pollution, during the process of cooking or heating. In order to utilize the full agricultural, economic and environmental potential of biochar and biochar-producing stoves in Embu County, it is of crucial importance to be aware of the local socio-economic challenges and impacts related to the implementation of these new agricultural practices and technologies. Socio-economic research related to the introduction of biochar as a soil amendment and biochar producing stoves has so far been limited, and it is my intention to contribute toward filling this knowledge deficit. I do not believe that any larger generalisations can be drawn from this research alone, but the ambition is to contribute towards a better understanding of the socio-economic impacts and challenges related to the implementation and diffusion of new agricultural innovations and practices.

New or improved agricultural practices and technologies, such as biochar and biochar producing stoves, may play an important role in rural and agricultural development, but, as is argued by Bonnen, it is important to keep in mind that “*increases in productivity arise not from technological change alone*” (1987). New technologies require new ways of dealing with the material life, and these should be in line with the socio-economic, geographical and cultural conditions of the given context. My research is in line with Bonnen’s argument that it is crucial to understand socio-economic, geographical and cultural preconditions in any given society in order to reap the full benefits of technological improvements. Among the aims of this thesis is to put the possible introduction of biochar and biochar producing stoves in Embu County, Kenya, into a broader framework of introducing new agricultural technologies and practices into largely different cultural settings in the Global South, compared to the intellectual origin or place of development in the Global North. My aim is to discuss if there are certain socio-economic or cultural preconditions that need to be met prior to any such introduction, and I do this through analysing the situation and perceptions of farmers within the chosen context. Furthermore, and in line with the above discussion, if biochar as a soil amendment and biochar producing stoves are to have any impact on the rates of deforestation in Embu County, it is crucial that the diffusion of these new technologies and practices is successful.

Thus, this thesis has a number of building blocks and fundamental aims, including: a general discussion based on a thorough literature review on the potential of new agricultural innovations, such as biochar and biochar producing stoves, when it comes to improvements in soil quality and agricultural productivity; a general discussion on the possible relation between intensification in small-scale agriculture and rates of deforestation; as well as a more case-specific discussion on the diffusion of new agricultural innovations and practices, and perceptions and pre-conditions among small-scale farmers in Embu County.

With this in mind, this research falls under the category of applied research, whereby the aim is to produce and publicise knowledge on which subsequent decisions can be made (Mikkelsen, 2005). In order to do this I have settled on a number of research questions, namely:

- What role could biochar as a soil amendment and biochar producing stoves play when it comes to improving small-scale agriculture and reducing rates of deforestation in Embu County, Kenya?
- Which problems, e.g. environmental or socio-economic, are perceived to be of importance in the eyes of small-scale farmers in Embu County, Kenya?
- Are there any certain socio-economic, geographical or cultural challenges or aspects that need to be taken into account prior to or during the introduction and diffusion of biochar as a soil amendment or biochar producing stoves in the area?

As we have seen, the introduction of biochar and biochar producing stoves denotes a large potential to alleviate several problems often faced by small-scale farmers in the Global South. By using the context of small-scale farmers in areas predominantly relying on agriculture in Embu County, Kenya, I intend to discuss this potential on a local level. However, in order to do so, we need to understand a number of key factors at play, both during the process of diffusion and during the subsequent local use of these new innovations. The existing academic discussion around the diffusion of new agricultural innovations is of interest in this context. Furthermore, it is well known that small-scale farmers in the Global South are facing problems of decreasing soil fertility and erosion. In addition to this, rapid rates of deforestation have been observed in many parts of the Global South. The relation between agricultural intensification, declining soil fertility and deforestation is widely debated, both within academia and the broader context of development practice. Many concepts and practices emerging from this debate are of relevance to, and could affect the environment and livelihood of residents in rural areas of the Global South. The introduction and use of biochar and biochar producing stoves is related and could provide a solution to the above-mentioned problems. In order to provide a comprehensive debate about the potential role of these innovations in the context of Embu County, it is of vital importance that we gain a thorough understanding of these debates and concepts. The aim of the next section is to furnish such an understanding.

5. Conceptual Framework

Ever since Thomas Malthus published '*An Essay on the Principle of Population*' in 1798, the academic debate around the relation between food production and population growth has been vibrant. The main argument proposed by Malthus was that global food production could not keep up with unchecked population growth. Malthus assumed that global human population would double over a time span of 25 years and then continue to grow exponentially. At this

pace of population growth, Malthus argued the agricultural production would not be able to keep up, resulting in a food deficit on a global scale (Elwell, 2003). Although Malthus' predictions were later refuted, mainly due to the birth of industrial agriculture, his contribution provided a crucial point of departure for one of the most fundamental academic debates in the history of the social sciences. One of the key opponents to the Malthusian theory was Ester Boserup who showed that a common reaction to population growth and shortages of land is the adoption of intensification techniques in the agricultural sector, thus making possible increased output per unit of farmland (Boserup, 1965). This intensification includes a combination of changes, such as intensified use of labour, increased frequency in cultivation, improved land management and the adoption of improved technologies. It is with this in mind that I discuss the diffusion and adoption of new agricultural innovations, the relation between small-scale agriculture and deforestation, and the concept of Integrated Soil Fertility Management (ISFM).

5.1. The Diffusion and Adoption of New Agricultural Innovations

Technological changes and new agricultural innovations have largely reshaped global agriculture during the past 100 years (Sunding & Zilberman, 1999). However, according to Shaw, "*a convincing body of evidence*" (1987:1) shows that the historical transfer of technologies and innovations from the Global North to the Global South has failed to create the sought after impacts among populations in many countries in the Global South. At least not if these desired consequences was to increase employment and income, as well as cater for basic needs or build up a technological capacity in the countries involved (ibid.). Shaw further argues that the poor outcome of previous technology transfers was largely due to the historical neglect of local socio-economic and environmental conditions, management practices and poor extension services (ibid.). However, Shaw continues by both arguing for and noting a contemporary shift in the attitudes towards, and methods used, for the diffusion of new agricultural innovations, largely driven by academic research. Now, almost three decades later, it is obvious that this trend of recognising local pre-conditions and practices during both the process of innovation and diffusion has gained further strength.

With increasing global population pressure, decreasing soil fertility and increasing amounts of farmland being degraded there is a need for further intensification of the agricultural sector if agricultural output is to keep up with food demand in the coming decades. Tilman et al. takes a number of environmental aspects into account and argues both that this agricultural intensification needs to be sustainable and that it is best achieved through transfers and diffusion of innovative agricultural innovations to farmers in 'under yielding' nations in the Global South (2011). The authors argue that agricultural intensification through the introduction of new innovations and improved soil management should be the preferred path for global agricultural development, if the aim is to increase total output while simultaneously protecting ecosystems and biodiversity, and avoid major increases in greenhouse gas emissions (ibid.).

As noted by Klerkx et al., agricultural innovation is "*not just about adopting new technologies*" (2012:458). The successful introduction of new types of technologies and practices requires a comprehensive recognition of, for example, existing local market

structures, farming systems, the infrastructure for diffusion, the local policy environment and of crucial importance, the perceptions and attitudes among the potential individual adopters. An interesting discussion on the topic of the diffusion of new agricultural innovations, more specifically wood burning stoves, is provided by Agarwal (1983) who claims that in order for a new technology to diffuse and be adopted successfully in rural areas of the Global South, it is of utmost importance to involve the potential adopters in the innovation process. The involvement of the end-users in the innovation process should both guarantee that the innovation suits specific local needs, and safeguards the transfer and survival of local indigenous skills and knowledge. Agarwal further discusses the unsuitability of using a ‘*top-down approach*’ in the implementation process of new agricultural innovations and suggests “*that a close interaction between designers, users, local artisans and extension agents is likely to be a crucial element in the successful diffusion of wood-stoves*” (Agarwal, 1983:367).

Another factor that is likely to influence the process of adoption and diffusion of a new innovation is the potential adopters previous experience with similar innovations. As is argued by Abadi Ghadim & Pannell (1999), improved technical and management skills, through previously dealing with similar innovations, are likely to positively affect adoption rates. This is in line with the above discussion on potential adopters’ involvement in the innovation process, and further strengthens the argument that it is of importance to take local skills and knowledge into account while developing new innovations if diffusion is to be successful in any specific socio-economic, cultural or geographical setting.

5.2. The Relation between Small-Scale Agriculture and Deforestation

The last half-century has seen a rate of tropical forest clearance never before experienced. This clearing is mainly driven by human activities. The trend has been especially sharp in Africa where the estimated average annual loss of tropical forests has been at 0.8 per cent of the total forest covered area on the continent (FAO, 2001). This is of certain interest to this thesis due to the fact that the clearing of land for agricultural purposes has been estimated to account for approximately 90 per cent of all deforestation experienced in the tropics since the 1960’s (Chichilnisky, 1994; Geist & Lambin, 2002). Although the clearing of forests have allowed for an extended availability of agricultural lands for both small- and large scale agriculture, there are a number of inherent dangers with clearing of natural forests, especially in areas that are already facing problems with soil erosion, depleted soil and diminishing biodiversity. Tree cover; together with tree and crop residues, provides a number of beneficial qualities to soil, such as the transfer of nutrients through mulching and the protection against water and wind erosion. If trees are not being replanted, these benefits are lost once forests are cleared for agricultural extension, something that threatens soil quality on a global scale (Pimentel et al., 1981; 1986). Benhin argues that:

“Managing forests on a sustainable basis implies the use of all the components of the forests in a way and at a rate that does not lead to a long-term decline in their ability to perform all their functions, thereby maintaining the forests’ potential to meet the needs and aspirations of the present and future generations.” (Benhin, 2006:9)

As is further argued by e.g. The Brundtland Report (WCED, 1987) and Agenda 21 (UNCED, 1993), persistent rural poverty is one of the significant factors behind the expansion of agricultural lands, and thus also tropical deforestation, especially in sub-Saharan Africa. The clearing of tropical forests often provides short-term economic benefits for rural farmers, both in terms of the direct generation of income derived from sales of products, an increase in land available for agriculture and through what is called slash-and-burn agriculture, where forests or crop residues are cleared, left to dry and then set on fire in order to create an ash-fertilized field (López, 1995; Benhin, 2006). This method of improving soil fertility through the transfer of ashes to soil is common throughout countries in sub-Saharan Africa, partly due to the high cost of imported fertilisers. However, a number of empirical studies (e.g. Allen, 1983; Benhin, 2006) situated in the tropics claim that these short-term improvements in soil fertility (i.e. agricultural production) tend not to be sustainable in the long run, and that soil fertility and agricultural productivity are set to decline in the long term after tropical forests are cleared. Tropical soils are generally speaking more prone to soil erosion compared to soil from the temperate zones. This is because the natural vegetation is far more important than the actual soil when it comes to storing nutrients and maintaining adequate soil fertility in most of the tropical regions (Ruthenberg, 1980). The protection offered by forests and other natural vegetation is therefore a key aspect in regard to maintaining soil productivity in the long run (Benhin, 2006). Again, this is of fundamental importance in areas dominated by resource-poor small-scale farmers who might not be able to restore soil fertility through the application of chemical fertilisers due to a lack of economic resources. If this artificial way of restoring soil fertility is not an economically viable option, and likely even if it is, the best way to restore depleted soil is through the protection, or re-establishment, of forests or other native ecosystems (Tilman, 1999).

Another route towards increasing productivity in the small-scale agricultural sector is through the intensified use of already cleared land. This process of intensification normally occurs either when availability of a key factor, such as land or labour, falls, or when demand for agricultural output increases (Carswell, 1997). Increased agricultural productivity through intensification may be achieved for example through improved agronomic practices, increased or improved inputs, the introduction of improved seeds and crop varieties, or other technological innovations (Tilman, 1999). Furthermore, high population pressure may act as a further stimulus in this intensification process. The availability of labour provides an opportunity to adopt labour-intensive practices in the agricultural sector, and thereby potentially raise the productivity of both labour and land (Tomich et al., 2001).

An intensified use of cleared land may initially reduce the need to expand agricultural practices into currently forested areas. If local food demand can be met through improved output of already converted farmland, the need for further conversion should diminish. However, a number of academic studies as well as basic economic theory suggest that it might not be that simple, especially in an increasingly globalised world where the sale of agricultural products is no longer limited to the local market. If improved agricultural practices through intensification lead to increases in farm generated income, such as through the sales of cash crops for a global market, the agricultural value of surrounding areas not previously converted into farming is likely to increase. To put it simply, intensification and

technological improvements make agricultural activities more profitable thus providing an incentive for farmers to further expand their production (Angelsen & Kaimowitz, 2001, (a) (b); Geist & Lambin, 2002; Barbier & Burgess, 1997).

A large number of academic studies have been conducted in order to investigate if agricultural intensification increases or reduce rates of deforestation; however, no encompassing conclusion has been arrived at. The impact on forests seems to be highly dependent on the local context; however, researchers such as Benhin argue that the broader institutional framework seems to be of importance in any context (2006). Benhin further states: “*It should be possible for policymakers to identify technology strategies that may bring about a win-win situation or as close as possible to that target*” (2006:16), thus identifying the important role of policymakers when it comes to the protection of tropical forests and their vital environmental functions.

5.3. Integrated Soil Fertility Management (ISFM)

The need for humans to use land for food production is among the most basic of relationships between humanity and its geographical surroundings. Ever since the agricultural revolution, humans have largely reshaped their geographical surroundings, and since the beginning of the industrial agriculture, this is happening at an unprecedented pace. There are few other activities that have reshaped the surface of the planet as much as agriculture, a development that is likely to continue in the future. This makes the future of global agricultural development and production of fundamental interest from a geographical standpoint. It is with this in mind that I intend to bring a discussion on agricultural development and the potential of ISFM into this thesis. ISFM has been defined as the “*development of adoptable and sustainable soil management practices that integrate the biological, chemical, physical, social, cultural and economic processes that regulate soil fertility*” (CIAT et al., 2001). It thus provides an interdisciplinary approach to confronting the increasing problems of access to fertile and productive agricultural lands for small-scale farmers.

Pressure on land in rural areas of the Global South is increasing with rapid rates of population growth, soil erosion, declining soil fertility and an increased number of local, national and international actors competing over the most fertile agricultural lands. In the case of Kenya, the population relying on agriculture for their income has tripled in the last three decades, whereas the area of land under cultivation has only increased by 50 per cent. This has led to a development where land per capita has decreased from 0.42 hectares per capita in 1960, to 0.15 hectares per capita in 2005 (FAO, 2008). In addition to this, the world has seen a major shift of production methods within the increasingly globalised agricultural sector, where small-scale agricultural production for the local markets has been replaced by large-scale industrial farms, dominated by monoculture and producing for the global market. Despite this, Ashley & Maxwell (2002) maintain that the “*...case for agriculture-led poverty reduction rests heavily on the productive efficiency of small farms and on their contribution to local economies*”. A similar argument is posed by Vanlauwe who states that one of the keys to breaking the “*vicious circle underlying rural poverty*” (Vanlauwe et al., 2010) in sub-Saharan Africa is focusing attention on increased farm productivity in a sustainable manner.

The most commonly used methods for increasing agricultural production since the dawn of industrial agriculture has employed an increased use of inorganic fertilisers. Although this has in many cases increased food production, a number of scholars argue that a continued increase in the application of chemicals will not provide a comprehensive and sustainable solution for the future of global agriculture. Although the application of chemicals may mask the effects of soil degradation in the short term, it does not provide a long-term solution (Rickson et al., 2015). Instead, in a reality where approximately 12 million hectares of agricultural lands are lost annually due to soil degradation, there is a need to adopt a comprehensive strategy that enables soil conservation and increased productivity of available agricultural lands (ibid.). The concept of Integrated Soil Fertility Management (ISFM) aims at maximizing use efficiency of soil nutrients and improving farm productivity in tropical areas. Fertilisers and organic inputs, such as manure or compost, are vital parts of ISFM (Vanlauwe et al. 2010), however, the focus is not strictly on improving soil fertility in the short term. Environmental sustainability is a vital part of the concept and thus, it offers a long-term solution to the problems discussed above. Furthermore, the available research claims that the application of biochar to soil will improve soil properties and make soil more responsive to the application of other fertilisers and organic inputs. Thus biochar as a soil amendment could act as one of many building blocks in the broader framework of ISFM and further contribute to agricultural improvements in a more sustainable manner (Lehmann & Joseph, 2009; Röing de Nowina et al., 2011).

ISFM, and other methods of improving agricultural productivity without endangering already fragile ecosystems in areas such as sub-Saharan Africa, have gathered attention under the last two decades. This is due to an increasing amount of reports declaring declining soil fertility and rapid soil nutrient depletion, combined with rapid population growth, the root causes of declining food production per capita in many countries in sub-Saharan Africa (Drechsel et al., 2001). The combination of growing population pressure, and declining soil fertility leads to a number of consequences, including the expansion of agriculture into marginal lands (ibid.), often with both limited productive potential and important ecosystem functions, something that has been discussed earlier in this thesis in relation to small-scale agriculture and rates of deforestation.

6. Methodology

6.1. Overview

In order to understand the potential benefits, implications, and challenges of any implementation of new innovations within the agricultural sector in the Global South, it is of utmost importance to understand the local context. Farmers in the Global South, especially in sub-Saharan Africa, too often in the past have been seen as a homogenous group and regional or local differences have not been taken into account within the broader work of development agencies. During the last decades we have seen somewhat of a shift towards an increased recognition of specific local preconditions in planning and conducting development

interventions. This push has been driven by academia and it is my intention to further recognise this importance.

In order to fully understand the complex reality and challenges of daily life as a small-scale farmer in rural areas of Embu County, the field study included a large focus on qualitative data collection, mainly done through semi-structured interviews. The aim of the semi-structured interviews was to gather a more in-depth view of the farmers, the potential adopters, perceptions about the new agricultural innovations discussed in this thesis. As Alan Bryman states, *“Its proponents essentially claim that it is only through qualitative research that the world can be studied through the eyes of the people who are studied”* (2012:617). I argue, in line with what is discussed by Bryman in relation to qualitative data collection, that one must attempt to understand the study participants. Especially so when a further aim of the research is to possibly implement a change in the future. As is discussed in the conceptual section on the diffusion of new agricultural innovations, the reality, both physical and social, of the adopters of a new technology is likely to be fundamentally different from the reality of those developing and assisting in implementing that same technology. In addition, throughout the entire research process, and especially while in the field, I have tried to recognize the problems related to the differences between myself, a relatively affluent university student from Europe, and those who have participated in the study, resource-constrained small-scale farmers in rural Kenya. Given that the time spent in the field was limited it was hard to build a relationship of trust with the respondents, however, I did my best to adapt to the local culture and reality and made clear that I was there to learn from the people I met and engaged with. This is in line with what is discussed by writer Sultana who states that it is of utmost importance to *“avoid exploitative research or perpetuation of relations of domination and control”* (2007:375).

Furthermore, a number of academics and institutions writing about the emerging potential of biochar and biochar producing stoves have stressed the need for further qualitative studies to be conducted (e.g. Barrow, 2012; Scholz et al., 2014), something that acted as a large motivation for me while planning this research. An increasing number of quantitative research projects are being conducted in relation to the potential of biochar, mainly within the natural sciences. However, the need for further qualitative studies is supported by an aspiration not only to measure for example the impacts on soil, but also to understand how this new innovation will be implemented and what consequences it may have on rural farming societies and their geographical surroundings. This is in line with arguments circulating in the broader academic discussion of quantitative versus qualitative methods of data collection, where quantitative methods aspire to measure a given situation and qualitative methods attempt to further understand it (Mikkelsen, 2005).

Within Kenya alone, there are 42 different ethnic groups, each with their own traditions, cultures, and languages. Although this may not necessarily constitute an obstacle when planning and conducting development work, it is of great necessity to keep in mind. A nation-wide development program or diffusion of a new agricultural innovation may be perceived very differently within different ethnic groups and in different geographical contexts. This field study has been conducted in the Manyatta Division in Embu County, and keeping the aforementioned heterogeneity of the Kenyan society in mind it is important to note that no general conclusions can be drawn and applied on a larger scale. A similar

geographical setting may have an entirely different cultural, social or economic composition, and vice versa. The limited time available for this field study did not permit a second case study to be conducted and subsequently compared to the findings from the Manyatta Division. However, in order to avoid an overly homogeneous dataset, respondents have been sampled from a number of different villages within the chosen setting. The collected and analysed data cannot be generalised to any larger geographical area, however, I argue that by conducting data collection in more than one village, the data may be of somewhat greater relevance on a larger scale. As noted, no scientific conclusions can be drawn if the data were to be generalised and account for a larger geographical area, however, it does give some further indications as to what the situation might be like in similar geographical, social, cultural, or economic settings.

With this in mind I have chosen to conduct a single case study in a number of selected villages within one specific locality, namely the Manyatta Division in Embu County. The villages in which the interviews have been conducted are *Kibugu*, *Ndunduri*, *Kithiria*, *Gatwe*, *Gichingia*, *Gicherori*, *Kithiga*, *Kyuru*, *Ithithe* and *Ngerwe*. A total of ten villages, all located in the Manyatta Division and in relative proximity to each other, but with distinct differences in terms of geographical setting, level of socio-economic and physical development and modes of access, something that affects potential trading of goods produced. I believe that the relative heterogeneity of the villages visited will somewhat circumvent a situation where one specific geographical, social or economic factor affect the entire material. At the same time, a majority of the population in all of the villages visited are relying on small-scale agriculture for their income and food security, something that is of importance to the study, given the that focus of the research is to provide potential solution faced by small-scale farmers in rural areas of the Global South.

In order to provide a holistic dataset, taking into account a number of different perspectives, both specific to the local context and relevant on a more general scale, I choose to adopt a mixed methods approach during the process of data collection and analysis. A majority of the time in the field was spent on collecting qualitative data through semi-structured interviews. Simultaneously, and in order to verify or reject the findings of these interviews, I engaged in participatory observations in the villages where interviews were conducted. Furthermore, and more thoroughly described below, I had the opportunity to participate in and observe a workshop conducted by staff from the IITA-SLU-LU research program in Kibugu, the central town in the area. Prior to my arrival in Kenya I engaged in a thorough literature review centred around the available academic articles on the development and potential of biochar and biochar producing stoves in both the Global North and South. This literature review has been further extended and intensified following my departure from Kenya. In addition to the literature review conducted in Sweden a number of secondary data sources were collected from various actors in Embu County. These consist mainly of official documents and development plans from ministries and other public offices in Embu Town, as well as various notes from farmers interviewed. Additionally, and again in order to verify or reject the findings from the previously mentioned sources of data, I choose to use quantitative data previously collected in Embu County by staff from the IITA-SLU-LU research program. This quantitative dataset revolves around the current situation and habits of farmers in the area and focuses on a wide array of issues beyond general population statistics, such as modes

of cooking and heating; fuel type and demands; use of organic/inorganic fertiliser; attitudes towards the introduction of new technologies in the agricultural sector etc. The dataset was collected and summarised in order to provide a baseline survey that could be used for later research in the area, and I have chosen to use this available data in order to provide a more holistic set of data for analysis.

6.2. Literature Review

Prior to, during, and after the field study in Embu County a thorough literature review was conducted. Initially, the aim of the literature review was to get familiar with the geographical and academic area of study. Initial academic readings on the development of biochar and biochar producing stoves further increased my interest in the subject. These readings, combined with an early analysis of qualitative materials collected in Embu County, led me to focus further on readings and collection of material on the issues of new agricultural innovations, intensification of small-scale agriculture, and deforestation in the Global South. A number of relevant books and articles have been sourced through extensive searches in for example the Lund University database 'LUBsearch' and Google Scholar, and through advice from my academic supervisor at Lund University, Yahia Mahmoud.

6.3. Characteristics of Previously Collected Quantitative Dataset

During 2013 and 2014, a baseline survey was conducted in the three geographical areas of study that are part of the IITA-SLU-LU research program. Prior to entering the field, I intended to collect a similar set of quantitative data in order to compare with the findings of the qualitative data collected. However, time and resource constraints made this data collection impossible and I have chosen to rely on the quantitative data previously collected within the research program. A number of variables relevant to this research have been singled out from the original set of data and subsequently analysed using the quantitative data analysing software SPSS in order to provide descriptive statistics relevant to this thesis.

A total of 57 households were surveyed in Embu County. Of these 79 % of households were male headed and the remaining 21 % were female headed. When looking at the educational level of household heads, 5 % out of the 57 household heads had no formal education, 47 % had completed primary school, 32 % had completed secondary school, and the remaining 16 % had proceeded to college. The age of the heads of household ranged from between 31-86 with 57 % between 31-60 years of age and the remaining 43 % between 61-86 years. Furthermore, 42 % of the households had access to farms of 1 acre (0.4 hectare) or less, a further 35 % held farms ranging in between 1.25-3 acres (0.5-1.2 hectares), and the remaining 23 % had farm sizes of between 3.25-7 acres (1.3-2.8 hectares).

6.4. Sampling of Case and Qualitative Interview Respondents

In order to locate the specific case that has been studied I used what Bryman summarizes as a *critical case sampling* (Bryman, 2012:419). Early in the research planning process I decided to conduct a case study in Embu County, Kenya. The reason for this decision being an interest in the on-going IITA-SLU-LU research program, '*Bio-char and smallholder farmers in Kenya*', described above. Although information about the progress of the research program

was rather limited prior to entering the field, I held a belief that working in Embu County, and within the context of the IITA-SLU-LU research program, would provide me with the interesting framework for a case study on the socio-economic conditions, impacts and challenges related to the implementation of biochar and biochar-producing stoves in the area. The case was intentionally selected because it contains a number of aspects relevant to the general discussion on changing agricultural methods and technologies. Embu County, and Kenya, have a high incidence of small-scale-, and subsistence farmers relying on local agriculture. Kenya is located in a region that may be to a large extent affected by climate change and has seen rapid rates of deforestation in certain areas, such as Embu County. The country's population and culture are highly diverse. Furthermore, the general lack of pre-existing research on the socio-economic impacts and aspects in relation to the introduction of biochar and biochar-producing stoves made it preferable to carry out a qualitative case study where flexibility and a cumulative understanding were of importance (Desai & Potter 2006).

While planning this minor field study, I had a number of objectives and research questions in mind. In the initial stages of the project, I decided to adopt an iterative approach to the research. I decided to remain open to alterations directed by the process of data collection and analysis and let these alterations guide the forthcoming steps of the research. This is in line with Mikkelsen's statement that "*field studies are a continuous learning process*" (2005:155). Access to information was limited prior to entering the field, and the environment in which the research has been conducted is ever changing, thus it has been important for me to think iteratively and remain open to modifications in the research aims, methods of data collection and analysis (2005:150).

The final sampling of specific locations and interviewees took place after my arrival in Kenya, in collaboration with staff involved in the IITA-SLU-LU research program. The sampling depended to a large degree on the current development of the program in different villages. Given the lack of up-to-date information about the development of the research program prior to my arrival I choose to adopt a combination of *opportunistic* and *snowball sampling* when it came to selecting villages and respondents (Bryman, 2012:424). My initial intention was to visit and carry out interviews and observations in villages where the project had already been implemented, together with villages where it was about to be. In addition, I intended to visit villages not involved in the research program in order to make comparisons regarding the attitudes towards challenges and the impacts of the program. However, initial findings whilst in the field suggested that the research program was not rolled out to the degree that I had expected, something that required a change of these plans. Instead of adopting these criteria for the sampling of villages and respondents I relied on a method of random sampling where villages and respondents did not have to meet any specific pre-conditions other than being located within the geographical area of study.

6.5. Collection of Qualitative Data

In collaboration with my local gatekeeper and translator, Francis Njiru, who previously assisted researchers working together with the IITA-SLU-LU research program in the area, I conducted a total of 40 semi-structured qualitative interviews in the 10 villages mentioned above. Out of the 40 interviews, 23 respondents were male and the remaining 17 were female.

The average age of respondents was 55.5 years, with the youngest being 20 years old and the oldest at 81 years old. Two of the respondents had never attended any formal education while another 3 held a college or university degree. On average participants had attended 7 years of formal education. Farm size among the participants of the study ranged between 0.25-12 acres (0.1-4.9 hectares) with an average of 2.25 acres (0.9 hectares). The length of interviews ranged between 16-48 minutes with an average length of 31 minutes and 15 seconds.

A number of these interviews were planned ahead, and the respondents had had previous experience of participating in studies related to the IITA-SLU-LU research program. However, a number of interviews, especially those during the last weeks of my time in the field, were scheduled the day before or even on the same day with respondents who had had no previous experience of the research program, and importantly no personal relation to the gatekeeper and translator. Francis Njiru holds a university degree and is a well-respected person in the area of study, something that could possibly result in a bias when it comes to the sample of respondents. With this in mind we decided to try to conduct interviews with a number of villagers with whom he had very limited previous contact or personal relation. This was in order to compare the responses of the various groups of respondents and thus avoid a bias in the sample of interviewees.

Prior to entering the field, an interview guideline (Appendix A) was prepared in collaboration with staff at the IITA-SLU-LU research program with previous experience from the area of study. This guideline acted as an initial set of questions in order to get started with the interviewing process as soon as possible after entering the field. However, after the first 6 interviews conducted, I decided to slightly modify this guideline in order to better suit my personal interviewing preferences, and in order to provide for further in-depth discussions on a number of specific topics. Given the semi-structured character of the interviews, I allowed the respondents to partially guide the direction of the interview in order to fully understand their individual priorities, challenges and socio-economic pre-conditions. Prior to entering the field I had a number of ideas regarding the possible responses of the interviewees, some of which have been verified and some of which have been either modified or completely rejected. Given that I am an outsider and the time in the field was limited to 9 weeks I do not believe that I could have collected data fully reflecting an '*insiders view*', however measures have been taken to avoid the most obvious potential biases. These measures include the close collaboration with my local gatekeeper and translator, the opportunity for respondents to guide the interview, and my openness to answer any questions the respondents had to me.

Although the interview guidelines were rather loose and every individual respondent had opportunities to guide the development of the interviews and the topics discussed, a number of general themes emerged during the data collection. These include: the problems and possible solutions related to deforestation and a changing climate in the area; the modes of preparing food and possible alterations; the inputs and outputs of the local farms and related challenges and opportunities; and the implementation of new technology, practices and knowledge in order to improve the general situation on the farm. The findings will be further presented and discussed below.

6.6. Analysis of Qualitative Data

All qualitative interviews conducted in Embu County were recorded, except for one where the respondent did not feel comfortable with the use of a digital recorder, and I subsequently transcribed the interviews myself. A majority of the interviews were transcribed while I was still in the field, something that allowed me to re-familiarise myself with the material gathered, and simultaneously analyse it while immersed in the atmosphere. This allowed me to initiate a process of analytic induction at an early stage, and further allowed me to modify the focus of the interviews conducted during the final weeks of the field study. An iterative process has directed the data collection and analysis where previously collected data has evolved into guiding ideas, focusing the outcome of the later data collection. Furthermore, this iterative process has continued after leaving the field, where a majority of more structured analysis of the qualitative data has taken place. This is in line with a discussion provided by Flowerdew and Martin who argue that: “...analysis should not be an *afterthought*” (2005:219).

After transcribing the interviews I engaged in a process of open coding in order to begin the process of structuring and analysing the collected material. After analysing the results of the open coding, the next step involved a further structuring of the materials through a process of axial coding. Here, a number of key concepts were adopted, based on previous knowledge, readings and the aim of my thesis, in order to categorise the data and allow for a connection between the knowledge developed through the literature review, the previously collected quantitative data, and the material gathered during the qualitative interviews. These key concepts are closely related to the conceptual framework discussed above and include: deforestation and use of and relation to the forest; perceptions on the changing climate; the diffusion of previous innovations and perceptions on new technologies and changing farm practices; perceptions on modes of cooking; availability of farm land; and perceptions of soil fertility.

7. Findings

7.1. Findings of Previously Collected Quantitative Dataset

Through analysing the baseline survey (previously conducted within the IITA-SLU-LU research program) a number of interesting findings have emerged. These findings and their relevance are presented below and will be more thoroughly discussed in the following sections.

Out of the 57 households surveyed, 55 stated that they apply both organic (mainly manure produced at the household) and inorganic fertilisers to their soil. In addition, 72 % of the households declared that they apply ashes from cooking to their soil in order to improve soil quality. Furthermore all of the households stated that they would be willing to use, produce and experiment with alternative fertilisers, and that they believe they could improve their agricultural yields. When asked how yields could be improved, 79 % of the households gave either more or better fertilisers as the main factor. A further 14 % stated that access to more knowledge would be the most important factor to improve yields, other

explanations were access to more labour or access to more capital. This interest in experimenting with new methods and innovations in relation to improvements in soil management is of utmost importance when it comes to the introduction of biochar as a soil amendment. If the local farmers do not show any interest in experimenting with different methods, diffusion could be complicated, and even unwarranted.

All households surveyed declared that they used firewood as a source of energy, and 74 % of those stated that they have their own woodlot. A number of households have stated that they sometimes purchase firewood, however a majority of these spend less than KSh (Kenyan shilling) 1000 per month (approximately 86 SEK). Moreover, 72 % of the households derive some of their energy from the burning of charcoal, making it the second most important source of energy in the area. Most of the households have more than one type of stove, however, the most commonly used is the traditional three stones stove with firewood as feedstock. 60 % of the households stated that this is the type of stove they use primarily. This is followed by: different types of improved jikos (19 %), charcoal jiko (9 %), gas cooker (7 %), and kerosene stove or electric oven or kettle (5 %). All of the households declared that they would be interested in using, producing, or experimenting with alternative types of energies. The main reasons for this interest are: in order to save time (40 %), in order to reduce smoke (23 %), in order to reduce costs (19 %) and in order to save firewood and preserve the environment (12 %). Similar to the above-presented findings on alternative fertilisers, the entire sample of households surveyed showed an interest in experimenting with alternative energies. Again, this initial interest is of great importance for any diffusion of new innovations to be successful.

7.2. Findings of Qualitative Data Collected Through Interviews and Observations

When discussing the constraints faced by farmers in the area of study there are a number of topics that have been recurring throughout the qualitative data collection. Many of the respondents have raised concerns about the limited access to land in the area. Due to a change in inheritance laws, where the land is divided equally among all the children and not only among boys, access to land is becoming more and more scarce. This situation is further aggravated due to the increasing population pressure in the area. Concerns about the diminishing availability of productive agricultural lands have been recurrent throughout the entire process of qualitative data collection. Some of the older respondents in the sample have described a drastically changing situation in regard to the relation between farmers and their geographical surroundings. On a number of occasions, older respondents provided anecdotes from their childhood, where farmland was largely available to anyone, the soil was left in fallow at regular intervals and crops were rotated on a regular basis. These older respondents described a clear picture of diminishing fertility and availability of soil and have connected this development to the increasing population pressure in the area. For example, one respondent stated:

“You see, in those days there was no competition for land, but this time there is a big competition for land. Those days, we were using this land for food; this land was enough for us then. We could produce more maize then, the land was more fertile, but

this time around we have to use manure, and some fertilisers. How we used the land back then, it was very beautiful. It's been a lot of degradation... ..because of the population, and the overutilization of the land. We could afford to do crop rotation in those days, but this time around it's not possible.”

(Interview 10)

“Protect the forest, we have to protect the forest. We got some information that we should not destroy trees, and that we should plant some trees in our shamba. But you see now, if you plant so many of them you might not be able to grow some of the crops, because they take so much space.”

(Interview 10)

A majority of respondents have described a situation in which they can no longer afford to set aside areas with agricultural potential for the planting of trees. A vast majority of respondents have mentioned the importance of re-planting trees in the area, but the lack of access to land makes them unable to do so. For example:

“The farms are becoming smaller and smaller so there's no space for trees. It's different because in the past they didn't have the right to inherit, but now they all get their share. So there might be no space to plant more trees.”

(Interview 25)

According to almost all the respondents, the clearing of forests and lack of re-planting of trees is a major problem in the area of study. The majority of respondents acknowledge that they are currently overusing the forests and that this situation is a major problem, a problem that they believe is likely to be intensified in the future. The notion that trees are important for preserving soil fertility and vital ecosystems is not common, however, it is clear that a popularly held view is that there is a clear link between the clearing of trees and an increasingly changing climate. For example:

“You see, weather is natural, it's not man-created. But when man interferes with the weather, it is not good. You see, we cut trees, we do other things like burning charcoal, and the weather is changing.”

(Interview 12)

“It is, the weather and the rain and the trees, they work together. When there are no trees there's no rain.

- *Are people planting more trees now?*

They are planting, but not everywhere. The farms are so small so there's no space for the trees, unless you have a woodlot.”

(Interview 40)

All but two of the respondents have specifically stated that they have experienced negative changes in the climate during the last decades. They further hold the belief that these changes

will continue in the future, unless drastic changes are implemented soon. The most common changes experienced include diminishing and highly erratic rainfalls and a rise in average temperatures. 38 out of the 40 respondents claim that the rain patterns have changed during the last decades, from a situation where the long rains “*used to start exactly on the 15th of March*” (Interview 13), to a current reality where not even the experts can predict the arrival of the rainy season. In an area where irrigation schemes are not particularly widespread this increasing unpredictability of the rains create substantial problems for small-scale farmers. In relation to the perceptions about the changing climate and of large interest to this research is the commonly held opinion among a majority of the respondents that the clearance, and lack of re-planting of trees is the core underlying reason to why the climate is changing.

All respondents have stated that they apply organic manure to soil in order to improve their yields. Furthermore, a majority of respondents have stated that they in addition apply inorganic fertilisers to their soil. Of these respondents, the vast majority holds the position that inorganic fertilisers account for a large expense on a yearly basis, and a number of respondents express the view that they would like to reduce their use of inorganic fertilisers. In a majority of cases, this is due to a combination of lack of access to capital and the large expense that purchase of inorganic fertilisers stands for. However, a number of respondents have also declared a concern about the effects of the quality of their soil and the marketability of their goods when chemicals are used on a regular basis.

“It’s barely enough, I would need much more fertiliser than I’m using now. It’s never enough, because of the price, it’s too expensive, and we can’t afford it.”
(Interview 8)

“There are benefits [with organic farming]. I don’t spend as much money on fertilisers and people like my crops more. They come and buy because they know there are no chemicals in them.”
(Interview 22)

Another related limitation discussed by a large number of respondents is the general lack of capital available for, for example, improvements in their farming practices, the opportunity to pay for sufficient education for their children, or for necessary knowledge inputs in the farming. Together with the lack of access to adequate amounts of land the lack of capital and know-how stands out as the main socio-economic constraints as perceived by the respondents. Most of the respondents are largely positive towards changing their methods of farming or adopting new innovations, however they are restricted by the lack of human and physical capital necessary to obtain new knowledge or technologies.

Similar to the aforementioned findings describing lack of capital and knowledge as limiting factors when it comes to access to and quality of farmland and problems of deforestation rates in the area of study, a majority of the respondents have claimed that the same causes are the underlying limiting factors when it comes to the diffusion and adoption of improved cook stoves. Around half of the respondents stated that they are in possession of some kind of improved cook stove, and the attitudes towards these have been largely positive. Among the ones who have not adopted any kind of improved cook stove, the main reason for

this was a lack of sufficient amounts of cash for the purchase. When further discussing this absence of improved cook stoves and the use of the traditional three stones stove it became evident that although the role of tradition is important at some occasions, all of the participants would prefer to upgrade their modes of cooking. The main reasons behind this aspiration being the opportunity to save on firewood or charcoal and thus reduce expenses related to cooking; reduce the time allocated for cooking or heating; a general wish to follow trends in technological improvements; and a desire to reduce the amounts of hazardous smoke in the household.

“I hear that it [improved cooking stove] saves a lot of firewood. The reason I don’t have it is because of money.”

(Interview 22)

“That one [improved cooking stove], it simplifies the cooking, it improves our environment. If I can get it I would like to have one.”

(Interview 24)

“I would rather try it [improved cooking stove]. The tradition wouldn’t be a hindrance for trying something new. I’m willing to try something new.”

(Interview 25)

“We have to go with the change of the environment. If there are other technologies you change with it, in case our pocket can allow it.”

(Interview 28)

A number of different types of improved cook stoves have previously been introduced in the area, however, many of the participants in this study have expressed various complaints regarding these cook stoves. These complaints include longer time allocated for cooking due to the stoves being slower than the traditional three stones stove and an increased work burden in the process of preparing the stove, due to specific size requirements of the feedstock. These complaints aside, a vast majority of participants have expressed a wish to participate in trials involving new innovations and practices as well as a largely positive attitude towards the purchase of new innovations, such as improved cook stoves, given that they can afford it. Two of the respondents stated that they were not interested in participating in trainings, or change modes of cooking, giving the reason that they were too old to change.

A small number of respondents, exclusively the ones who either held large amounts of land or had current or previous employment outside the agricultural sector, stated that they were using electricity, biogas or kerosene as the main source of energy for cooking or heating. These respondents were generally positive about the change of cooking methods and highlighted reduced amounts of time allocated to the collection of feedstock and process of cooking together with drastically reduced levels of smoke in the household as important improvements.

With three weeks left of the field study, staff from the IITA-SLU-LU research program conducted a participatory workshop with the aim of distributing 20 biochar

producing cook stoves (hereafter ‘Jiko2015’) to households in the area. Farmers were trained in how to use these improved cook stoves, the areas of improvement compared to a number of previously distributed improved cook stoves and the traditionally used three stones stove with an open fire, and the potential agricultural and environmental benefits of adding biochar to their soil. In the weeks after the workshop I conducted a total of nine interviews with household members who participated in the training and subsequently received and started using a ‘Jiko2015’. The findings of these interviews suggested that farmers were both pleased and enthusiastic about the new method of cooking food. All respondents expressed positive feelings regarding the efficiency of both time and feedstock compared to previous modes of cooking and heating. An additional benefit mentioned by all of the respondents was the reduced amount of smoke produced by the ‘Jiko2015’, again compared to the previous modes of cooking and heating.

“I think this one [‘Jiko2015’] will be saving on wood, and it seems to be faster, so I’m intending to use it as from today, now that I’m back.”
(Interview 34)

“With the three stones a lot of heat is lost. Actually what we need is heat, not smoke.”
(Interview 34)

“It [‘Jiko2015’] saves a lot of firewood, as compared with the three stones, and I also think it’s faster; it’s cooking ugali [common Kenyan dish] very fast. It’s a big improvement.”
(Interview 39)

Photo 3: Farmers participating in workshop, Embu County, Kenya



(Photo: Anders Magnusson, Embu County, Kenya, 2015-02-26)

However, a number of concerns were also raised, mainly related to the specific demands placed on the feedstock. Namely the need for wood or other feedstock to be completely dry in order to reduce the levels of smoke, and the need for wood to be chopped into smaller sizes,

compared to when using the traditional three stone stove with an open fire. This could theoretically increase the workload in relation to preparing feedstock for cooking or heating. However, the farmers expressed positive feelings about the ease with which the 'Jiko2015' was used, more specifically the fact that they did not need to attend to the stove after the fire had been prepared and lit. When specifically asked to compare the additional time needed to prepare the feedstock with the time saved during the cooking process all of the farmers stated that the initial time-investment was well worth it when subsequent savings were accounted for.

8. Discussion

8.1. Overview

According to the analysed results of the qualitative and quantitative materials collected, the adoption and diffusion potential of biochar as a soil amendment and biochar producing stoves is high. The majority of respondents were already experimenting with various types of organic wastes, such as coffee husk and the cover of macadamia nuts, as soil amendments, and the interest in trying new types of organic soil amendments was profound. Furthermore, a majority of the respondents stated that they experience various problems related to the current modes of cooking and that they were interested in experimenting with new types of stoves introduced by outside actors. The willingness and interest to try new innovations and practices is of fundamental importance for the discussion provided next.

8.2. Biochar as a Soil Amendment

The empirical evidence from Embu County supports the view that the application of biochar as a soil amendment has a great potential in the area and that local farmers are ready to adopt these new practices. All of the respondents declared an interest in experimenting with new types of fertilisers, and a vast majority held the belief that an increased use of inorganic fertilisers is the key to improving their yields. As has been previously discussed, biochar as a soil amendment has a potential to directly improve soil fertility and to improve the impact on soil of supplementary inorganic fertilisers. Given that the biochar can be produced at almost no cost at the household level it may act as a cost-efficient substitute to expensive inorganic fertilisers. However, a number of essential criteria need to be fulfilled in order for any larger scale of diffusion to be successful, these criteria are discussed below.

As has been the case with the biochar producing stoves introduced through the IITA-SLU-LU research program, where currently 20 local households participate in initial trials, it is of importance to make sure that a small number of farmers are getting on board in an early stage of the diffusion process. Furthermore, it is of immense importance that substantial trainings are conducted with these farmers prior to any extended introduction of the methods. Two of the key constraints identified by farmers in relation to their possibility to improve their agricultural production were the lack of access to knowledge and the lack of access to capital. These aforementioned initial trainings could provide sufficient know-how

on how to use biochar as a soil amendment and thus address the problem of the lack of access to knowledge in this specific case. Furthermore, an initial set of satisfied adopters are likely to provide a foundation on which further diffusion can build (Agarwal, 1983). In addition, the fact that biochar can be produced locally with biomass already available to farmers at low or no cost other than the time necessary for the collection of these materials, makes it a highly suitable innovation for resource-constrained small-scale farmers in the area.

I argue, supported by empirical material collected independently in Embu County and previous academic studies, that if the aforementioned criteria are met the diffusion of biochar as a soil amendment has a large potential to succeed. Given the presented claims about the potential of biochar to improve soil productivity this could prove to be a viable and affordable solution to combat the declining soil fertility for farmers in the area. With this in mind, application of biochar to soil may act as part of the solution when it comes to increasing productivity and thus reduce the need to increase the cultivated area. Diminishing access to land and a need to avoid further deforestation makes it hard to further extend the cultivated area and in order to increase the production intensification is needed. Although biochar in itself seems to be able to provide a number of various benefits for the small-scale farmers in the area, I argue that it would be wise to think of it mainly as a part of a potential solution. A number of various inputs, such as organic and inorganic fertilisers, are already widely used in the region, and biochar has a potential to further add to already available methods, as part of an ISFM framework, in order to provide a broader and more holistic framework for the future.

This is especially so among the farmers producing macadamia nuts for markets outside of their own village. A number of private actors, such as the Kenyan company 'Jungle Nuts', have recently entered the region and started purchasing organically produced macadamia nuts bound for export. The prices paid by 'Jungle Nuts' are both constant, with a minimum of KSh 120 (approximately 10.5 SEK) per kilogram and high compared to the KSh 35-60 per kilogram paid by the conventional buyers. However, the farmers that have turned to organic production have experienced a decline in yields without the application of inorganic fertilisers and pesticides. Any organic soil amendment that could play a role in improving the yields would be of great benefit to these farmers and could act as an important tool for combating poverty in the area.

However, when looking at the potential for biochar as a soil amendment to reduce the rates of deforestation in the area it becomes more problematic. If the productive capacity of soil can be increased through these new innovations there is a risk that this may even further increase the hunt for new agricultural lands. If the income per unit of soil increases due to a rather cheap and locally available soil amendment there is a risk that local farmers will seek to further expand the area of land under cultivation, and thus increase the pressure on the remaining forests. Although the results of the qualitative interviews clearly stated that the local population places high values on the remaining forests in the area the fact remains that the areas of the Global South with high levels of poverty tend to also have high rates of deforestation. Thus, if biochar, as part of ISFM, is to play any larger role when it comes to reducing rates of deforestation in Embu County it is of immense importance that the Kenyan Government and other local institutions put in place coherent and protective environmental policies. Although an intensified use of land already cleared *may* improve the

situation when it comes to reducing the pressure on forested areas previous research shows that this cannot be taken for granted.

8.3. Biochar Producing Stoves

As has been made evident from the quantitative data collection all of the respondents are interested in experimenting with alternative sources of energy. This initial interest is of fundamental importance when it comes to the diffusion of biochar producing stoves. Furthermore, findings from the qualitative interviews have made it clear that the respondents are concerned both about the unsustainable use of firewood, one of the driving forces of deforestation in the area, and the expenses related to the purchase of feedstock for current modes of cooking and heating. Any innovation that could reduce the dependency of firewood and simultaneously reduce the expenses related to the purchase of feedstock is thus likely to be received with an initial positive attitude.

As mentioned earlier on, a number of improved cooking stoves have previously been introduced in the area, partly through development aid projects, and partly through the local markets. A majority of these have been introduced with the aim of reducing the need for firewood used for cooking and heating. These stoves have been rather widely distributed throughout the area of study; however, many of the respondents have expressed a concern with the use of these stoves. In many cases, the ambition to save on firewood in the process of cooking have resulted in a less efficient cooking stove, with the outcome that preparation of food or heating of water takes longer time. Given that time is highly valued among the respondents, this outcome is negatively perceived and the improved stoves are not used as much as intended. Taking into account the discussion provided by Adesina & Baidu-Forson (1995), the subjective preferences expressed by the adopters is of crucial importance in order for the adoption to be successful. Although the introduction of the previous improved stoves may not have been a large success the fact that potential adopters are somewhat familiar with similar innovations could increase the possibility for the successful introduction and diffusion of the 'Jiko2015'. This is due to the fact that previous experience with similar innovations is likely to improve technical and management skills (Abadi Ghadim & Pannell, 1999).

According to the findings of the qualitative interviews it seems like the developers of previous cooking stoves introduced in the area have not fully taken local perceptions and needs into account during the process of development. Although the problem of the specific size requirements of feedstock and the necessity for feedstock to be completely dry remains with the 'Jiko2015', the respondents perceive these problems to be minor in relation to other benefits experienced with the 'Jiko2015'. Especially the ease with which the stove is used after it has been prepared and lit, and the time- and energy efficiency has been raised as highly positive features. If the initial 20 persons taking part in the trial of these improved stoves are satisfied, this may largely simplify and make more efficient a later, and more extended, diffusion process. As has been discussed previously in this paper, successful adoption among an initial set of farmers may play an important role in relation to further diffusion of new technologies in the agricultural sector (Agarwal, 1983). The findings discussed by Adesina & Baidu-Forson suggest that an initial set of satisfied adopters may share the technology with other farmers in the area, and thus "*setting into motion an*

endogenous process of technology diffusion” (1995:7). Furthermore, a number of respondents have stated that they are positive towards both receiving and sharing information and advice with others in their nearby surroundings, something that further supports the importance of the above argument.

In addition, the adoption of improved biochar-producing stoves may have large consequences on a household level through e.g. providing clean and efficient energy for cooking and heating and through reducing the dependency of costly and/or time-consuming purchase and/or collection of firewood or charcoal. The two major reasons behind the wish to experiment with different types of energy discussed above were defined as ‘*in order to save time*’ and ‘*in order to reduce smoke*’. The introduction of energy- and time efficient biochar producing stoves has a large potential when it comes to addressing these problems. As was mentioned in the beginning of the thesis, in a vast majority of households women are the ones responsible for collecting firewood and preparing food in the area, and women are thus also the ones being affected by the above-mentioned problems to a larger degree. The introduction of biochar producing stoves could thus not only lead to general improvements in relation to the process of cooking in the area of study. It also has the potential to specifically target some of the gender-related imbalances experienced and provide substantial improvements for women in the area of study. The issue of gender-related problems has not been at the core of this research, however, the potential to specifically target problems mainly experienced by women constitutes a great additional benefit when discussing the diffusion of these innovations. The reduction of exposure to hazardous smoke, combined with a decrease in time allocated for basic household tasks are two key components when it comes to improving the livelihoods of women in the area. Furthermore, improved health and increased availability of time may result in subsequent positive development benefits, such as longevity and opportunities for income-generating activities when time allocated for basic household tasks is reduced.

The introduction of energy-efficient biochar producing stoves has a large potential when it comes to reducing rates of deforestation in the area. As has been discussed, participants in the study are increasingly aware of changes in their local environment and there is a widespread belief that the clearing of trees is connected to the changing weather patterns. These issues are perceived to be of great importance and any measure taken that could reduce the amount of firewood consumed by a household is of interest. It has been somewhat hard to define the core underlying factors of the wish to reduce household use of firewood. I find it likely that a desire to reduce expenses related to purchase of firewood or charcoal acts as the principal motivation, however, the widespread notion that it is important to preserve the local environment and reduce rates of deforestation is likely to act as a further incentive. During the initial trials participants expressed largely positive feelings about the newly introduced ‘Jiko2015’, and given that it continues to be viewed in a positive light this innovation has a potential to provide users with a triple-win. The energy-efficient stove is likely to reduce the amount of firewood used, resulting in less trees being cleared and less time and resources being allocated to the collection and purchase of firewood. Furthermore, the reduced levels of smoke produced by the ‘Jiko2015’ holds a vast potential to reduce levels of hazardous pollution on the household level, thus further improving the health and livelihood of those using these stoves.

9. Conclusion

This thesis began with the notion that there is a need to sustainably increase agricultural output in order to meet future food demand, while simultaneously preserving fragile ecosystems and the tropical forests. A fundamental part of this increase in agricultural output could be achieved through the intensification of small-scale agriculture in the Global South. In order for this intensification process to be successful, it is of immense importance that it is well adapted to and preferably partly developed by the preferences and pre-conditions of the local populations that are targeted. By using the case of the introduction of biochar as a soil amendment and biochar producing stoves in Embu County, Kenya, I have discussed the introduction of new agricultural innovations and their potentials to improve soil fertility, restore degraded agricultural lands and reduce rates of deforestation. Through the collection and analysis of empirical material collected in Embu County this thesis has shown that there is a large potential for the introduction and diffusion of these innovations in the area. The participants of the study have expressed a clear desire to experiment with both alternative fertilisers and alternative types of energy for cooking or heating. This desire is a vital first step in the introduction of any new innovation.

Furthermore, the participants have expressed their concern about the on-going processes of land degradation, deforestation and increasing expenses related to the purchase of both inorganic fertilisers and energy. With this in mind, the introduction of biochar as a soil amendment and biochar producing stoves could target some of the main problems faced by the population in the area. This further adds to the notion that the introduction and diffusion of these new innovations could be successful. As lack of pre-existing knowledge and access to capital are perceived as major constraints to development by the participants in the study I argue, with support from the previously discussed literature that it is vital to properly educate a number of potential adopters prior to any larger scale introduction of these innovations in the area. As has been discussed, a number of early adopters may prove crucial for the forthcoming steps of the diffusion process.

In addition, and has been manifested throughout this research, it is vital for the successful development and diffusion of new agricultural innovations to take the local socio-economic, geographical and cultural pre-conditions into account. When acknowledging the characteristics and perceptions of the participants in this study it is clear that there is both a need and wish for improvements in the immediate surrounding environment and the small-scale agricultural sector. The productivity of the small-scale agriculture is relying on a well-functioning physical environment. It is with this in mind that I argue that any potential improvements of this environment through the introduction of biochar as a soil amendment and biochar producing stoves is likely to have large long-term positive developmental impacts on the livelihoods of those relying on small-scale agriculture. Given that the small-scale agricultural sector is the main income-generating sector in the area I have emphasized the importance of addressing these issues in an inclusive and sustainable manner in order for the potential benefits to reach as many households as possible.

As has been highlighted throughout this thesis, no general conclusions can be drawn from these findings and applied to other socio-economic, geographical or cultural context. However, given the heterogeneity of respondents when it comes to factors such as age, farm size and years of education, the emerging picture, where a vast majority of respondents have expressed an interest in experimenting with alternative types of fertilisers and energies should be of interest to other researchers investigating the various potentials of biochar as a soil amendment and biochar producing stoves.

As has been discussed previously in this thesis, a number of research projects are currently underway with the aim of investigating the various potential benefits of biochar production. In this thesis, I have chosen to discuss the introduction and diffusion of biochar as a soil amendment and biochar producing stoves on a household level and I would like to further highlight the importance of the scale of this production. Many of the actors conducting research on the potential of biochar do this with the aim of implementing large-scale profit-oriented biochar projects. I would once again like to underline the necessity of separating the different scales of biochar production systems when discussing the potential benefits for the people being involved in and affected by these projects. Among the findings presented here are potential benefits for small-scale farmers, such as improved soil fertility, decreased reliance on expensive fertilisers and reduced expenses and health hazards related to cooking and heating. These benefits cannot be applied to large-scale projects with an aim of producing profitable biochar for markets. In addition, the potential benefits when it comes to reducing rates of deforestation in the area are not applicable when discussing these large-scale projects. In fact, a reverse development is possible. These large-scale projects might occupy large amounts of fertile land for the production of feedstock employed in the production of biochar and thus pushing small-scale farmers into frontier or forested areas.

9.1. Suggestion for Further Research

There might be a potential for a middle ground between these small- and large-scale projects. An idea that emerged during discussion with local farmers, and would be of interest to try out in the context of Embu County is cooperation with local coffee cooperatives when it comes to the production of biochar as a soil amendment. Given that the production process is managed and carefully controlled by the local population the local coffee cooperatives could provide a viable route toward efficient production of high quality biochar. A vast majority of coffee producers in the region sell their produce through local coffee cooperatives. The coffee berries are picked from the bushes and sold as they are, including husk. This husk could be used as feedstock in the production of biochar, something that could be administered on a larger and more efficient scale at the coffee processing plants instead of at the household level. Some scepticism has been raised about the capacity of small-scale farmers to efficiently produce biochar of consistent quality (The African Biodiversity Network, 2009). Parts of this production could instead be shifted towards the coffee cooperatives or other similar actors, and the biochar subsequently distributed to farmers based on their initial contribution of coffee husk. This thought is further elaborated by e.g. Barrow (2012), who argues that this would increase both the efficiency and quality of biochar production. If this method were applied to any large extent small-scale farmers would lose some of the benefits related to the

generation of energy if biochar is produced at the household level. However, if the method were applied only to a small share of available biomass, such as the case of coffee husk in Embu County, only a minor share of this energy would be produced outside of the household.

I argue that it would be of interest to further investigate the potential of producing biochar at the local coffee cooperatives in the area, simultaneous with further research into the potential of production at a household level. If it turns out that biochar produced at the household level does not hold adequate quality production could be shifted towards the coffee cooperatives. Local households would lose out on the opportunity to generate cheap and clean energy at the household level, however they would still gain access to a cheap and sustainable soil amendments.

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Appendix A

Interview Guidelines

Interview number:

Date:

Village:

Introductory Questions

What is your name?

Male

Female

How old are you?

Have you attended school?

If yes, for how many years?

Do you have any children?

If yes, how many?

If yes, do they live on the farm?

How long have you lived on this land?

How big is your farm?

What are you producing on the farm?

Do you mainly produce crops for your own consumption or cash crops?

Cash crops:

Own consumption:

Do you have any animals?

How many, and what kind?

Availability of Feedstock, and Alternative Use

Maize stovers/cobs?

Alternate use?

Banana leaves?

Alternate use?

Dried manure?

Alternate use?

Coffee husk/pulp?

Alternate use?

Wood?

Alternate use?

Tree pruning?

Alternate use?

Tea plants?

Alternate use?

Others?

Alternate use?

1. Use of Land, and Possible Changes?

1.1 - Have you used your land in a similar way during the last decade, or have you changed anything?

- *If any changes, what kind of changes are they?*

- *What do you think of the changes/lack of changes?*

1.2 – Do you use any fertilisers?

What kind? Organic/inorganic?

1.3 – Do you know of any projects/changes that have been implemented by external actors in your area?

- *If so, what do you think of this?*

- *If not, would you like it to happen?*

1.4 - Do you believe that you could improve your agricultural production, through changed agricultural practices?

- *If so, how would you like to change your agricultural production?*

- *And what is it that has stopped you so far?*

2. Local Environment

2.1 - Have you observed any changes in the local environment during the last decade?

- *If so, what kind of changes? Have these changes affected you?*

2.2 - Have you/the community tried to adapt to these changes?

- *If so, how have you tried to adapt?*

2.3 - Do you think that the future will bring further changes?

- *If so, what kind of changes?*

- *If so, how would you/the community react to these changes?*

3. Cooking

3.1 – Who is responsible for cooking in the household?

3.2 – What type of stove do you use?

3.3 - What fuel is used for cooking?

- *How much is used on a weekly basis?*

3.4 - Do you collect or purchase this fuel?

- *How much time or money is spent on a weekly basis?*

3.5 - Do you have any experience with modern, improved, cook stoves?

- *If yes, for how long?*

- *If not, what's the reason(s) behind it?*

3.6 - Would you consider changing your daily patterns when it comes to cooking and stoves?

- *Why? Why not?*

3.7 - Do you feel that a modern, improved cook stove would be an important change in your life?

- *Why? Why not?*

3.8 - Do you have any health problems?

- *If any, do you consider these to be related to cooking indoors/outdoors?*