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Enhanced food security via adoption of Improved Cooking Stoves and local wood plantations in Tanzania

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Firewood supply is a severe challenge in degraded and deforested areas of Tanzania which negatively affects the livelihoods of rural dwellers. The majority of rural households cook with energy-inefficient traditional three-stone-fire-stoves. Especially women and children who are mainly responsible for firewood collection spend substantial time to collect firewood which increasingly compromises their available time for agricultural activities. Our analysis showed that Improved Cooking Stoves as well as enhanced planting of on-farm trees realize time savings and can improve agricultural land use management schemes in semi-arid areas of Tanzania.

Improved Cooking Stoves were implemented in a participative way within the case study villages. The quantitative and qualitative field-based stove performance test Controlled Cooking Test demonstrated that the implemented Improved Cooking Stoves reduce the demand of firewood by almost 30 % and decreased cooking time by around 20 % compared to the traditional three-stone-fire-stoves. Farmer's local knowledge - here on loam construction - supported the sustained adoption and dissemination process of locally manufactured two-pot Improved Cooking Stoves which provided additional available time for agricultural activities.

In addition, on-farm wood plantations (either as bordering or intercropped plantations) close to homesteads reduce the number of walks to collect firewood and therefore save time. Nevertheless, tree husbandry faces several challenges caused by environmental as well as anthropogenic factors. Capacity building and creation of local know-how on constructing and using Improved Cooking Stoves as well as tree husbandry are central for the realization of socio-economic benefits. It is important to monitor the implementation of Improved Cooking Stoves and the adoption process of planted trees regarding slow-down of dissemination rates or incomplete usage practices. The identification of bottlenecks for sustained adoption is central for endurance and enhanced dissemination of the two innovation strategies which provide substantial "free" time for agricultural activities.

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Introduction

The importance of forests and woodlands for human life is manifold. Forests are crucial as a source of livelihoods, providing direct benefits like firewood, charcoal, timber, fodder, human food, and medical services, among others (Chhatre and Agrawal 2008). On a global scale, around 2.7 billion people, of which approximately 90% live in developing countries (Urmee and Gyamfi 2014), still depend on traditional biomass energy, such as firewood, charcoal, crop residues, and dung, for both cooking and heating and will do so in the future (Raman *et al* 2013). The demand for wood as cooking fuel is one of several factors contributing to deforestation in Tanzania (Angelsen and Kaimowitz 1999). It is estimated that over 97% of annual wood production in Tanzania is used as fuel wood, meeting about 91% of the country's primary energy demand (Kaale 2012).

Because of its multiple socio-economic benefits, Improved Cooking Stove (ICS)[1] have the potential to substitute for traditional three-stone-fire (TSF) stoves in rural Tanzania, thus reducing cooking-related firewood consumption (Zein-Elabdin 1997). With its higher thermal efficiency, the introduction of ICS can reduce the absolute amount of biomass needed for cooking compared to TSF stoves (Ochieng *et al* 2013).

ICS may save time directly via time savings during cooking and indirectly by reduced overall firewood demand compared to TSF which reduces the need for firewood collection. For example, in 2000, people in the arid region of Singida traveled more than 10 km to collect wood (IEA 2006), respectively 10 hours go and return (Johnson 1999). This benefits the most vulnerable members in local communities; in rural Tanzania mostly women and children are responsible for firewood collection. The saved time induced by ICS results in additional "free time" which can be used to intensify agricultural activities and contribute to food security especially for subsistence farmers.

In addition, the time savings induced by ICS can be further supported by on-farm wood production by substituting firewood collection from remote forests. Therefore, combined ICS and on-farm firewood production bear large potential to enhance firewood and food security. We did further research to show the impact of ICS and on-farm wood plantation on time and firewood consumption as well as on domestic firewood production. We defined the following research questions:

- Do ICS with a two-pot design have different firewood and time consumption patterns than TSF?
- What are the effects of tree plantations on the production system: direct (change of crop and fodder yields) and indirect (time savings)?

Methods

We conducted a Controlled Cooking Test (CCT) January 2016 in Idifu village in the semi-arid Dodoma region. The CCT is an efficacy test that is designed to assess actual impacts on household fuel consumption using locally available fuels, pots, and local cooks (Kshirsagar and Kalamkar, 2014; Bailis 2004). During the two CCT test a total of 40 households were assessed. Each selected household conducted two cooking tasks per day, resulting in 80 test samples. The first cooking task consisted of the "fast" cooking meal "rice and vegetables" and the second cooking task of the "slow" cooking meal "beans and rice."

In addition, we used the tool of destructive measurement of biomass sampling in order to assess biomass yields of tree plantations (*Gliricidia Sepium*). We used a trial plot plantation in Laikala in the semi-arid region of Dodoma. The shrub species Gliricidia Sepium was intercropped with maize

[1] The term Improved Cooking Stove does not pre-suppose any technical improvements. The term only indicates a different cooking technology. Improvements depend not only on the technology but also on other factors like the operators or the fuel used.

with a 3m by 3m cropping grid. In total an area of 2000 m² was assessed. The grow period of the shrubs was 24 months.

Results and Discussion

Following the CCT test in January 2016, the firewood and time consumption per meal and cooking device was analyzed in order to identify the total firewood and time consumption patterns (Tab 1). The table displays the performance of the households when the meal "rice and vegetables" and the meal " beans and vegetables" were cooked. We found a significant reduction in both firewood and time for cooking task "rice and vegetables" - between the traditional TSF stove technology and the ICS model. The realized time savings for cooking task "rice and beans" were significantly different between ICS and TSF. With ICS the average firewood consumption for cooking purposes per year and household amounts up to 1140 kg (air-dried).

Tab 1: Firewood and time savings (Three-Stone-Fire stoves vs Improved Cooking Stoves)

	Type of Stove		
	Three-stone-fire stove (N =19)	Improved Cooking Stove (N =19)	
Meal	Firewood consumption (g)	Firewood consumption (g)	Total firewood savings (g)
Rice and vegetables	2187 (SD 879)	1375 (SD 792)	812 * (37.1 %)
Beans and rice	4241 (SD 1540)	3576 (SD 696)	665 (15.6 %)
Meal	Cooking time (min)	Cooking time (min)	Total time savings (min)
Rice and vegetables	82.4 (SD 28.3)	60.3 (SD 13.6)	22.1 * (26.8 %)
Beans and rice	179.7 (SD 43.3)	138.8 (SD 23.1)	40.9 * (22.8 %)

* Differences are significant at a level of significance of 0.05 %

In Tab 2 the total space demand of Gliricidia Sepium plants per farmer is displayed based on different cropping patterns in order to cover the domestic firewood demand for cooking. An average woody biomass production potential of 0.647 kg (air-dried) per Gliricidia Sepium plant per year was measured. This equals an annual production of around 1150 kg which is equivalent to the annual firewood consumption for cooking with ICS. In order to cover the firewood demand for cooking by domestic on-farm tree plantations approx. 1800 trees of G. Sepium with a 2-year growth period are needed (2300 kg, air-dried).

Tab 2: Space demand of Gliricidia Sepium per household to cover the firewood demand for cooking purposes by own plantations

Cropping pattern	3m by 3m	1m by 1m	0.5m by 0.5m
Space demand	16344 m² (4 acre)	1816 m² (0.45 acre)	454 m² (0.11 acre)

Cooking with ICS instead of TSF stoves realized an annual time saving of approx. 143 hours due to faster cooking. Considering the current situation that most households cook with TSF, the annual

time spent to collect firewood is 450 hours. Due to on-farm wood plantations, the time expenditure to collect firewood from public sites does not occur.
A combined application of cooking with ICS and on-farm wood plantations may create around 593 hours of "free" time.

Conclusions and Outlook

Our normative approach displayed the firewood and time saving potentials induced by ICS and on-farm tree plantations. However, farmers face limitations which do not allow to produce the amounts of trees needed to reach firewood autarky. Limiting factors are moral hazard, space limitations (negative impact on food security), limited access to tree/ shrub seeds or financial limitations. Therefore, the findings of this research display an optimal production program of crops and trees. Nevertheless, the individual production regime may vary and is subject to the needs and individual preferences of the farmer.
In a next step, we will analyse different copping systems (monocropping vs. intercropping with trees). We use a randomized complete block design with three replications and five treatment plots in order to show whether biomass yields differ between monocropping and intercropping systems. By providing evidence-based results on the positive effects of tree plantations on agricultural land use management practices as well as on food security in semi-arid areas of Tanzania, rural dwellers shall be further incentivized to engage in tree planting activities.

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