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SUMMARY

This particular report is from Work Package 6 that is comprised of stakeholders from universities, institutes, and farmer's organizations. It is the first deliverable report, which according to the project set-up it is known as Deliverable 6.1.1 (D 6.1.1). The report covers issues of three sub-work packages (Bio-energy production, improved processing, and additional biomass utilization) in combination as they are very much interlinked. Additionally, the report covers some technical implementation aspects of Work Package 7.

The project was designed to be implemented in *Idifu* and *Ilolo* villages in Chamwino district (Dodoma region) with *Ndebwe* as a control village. In Kilosa district (Morogoro region) the project sites are *Ilakala* and *Changarawe* villages and control village is *Nyali*. In Chamwino district the important crops grown are sorghum, millets, sunflower, and peanuts whereas in Kilosa district the crops of major concern are maize and sesame.

The philosophy behind this project was to work on proven technological systems which were termed as Up-grading Strategies (UPS) with vertical or horizontal interventions. It was therefore inevitable to establish a reasonable and prioritized number of UPS for implementation in the two case study villages in each of the two districts. This was done parallel with setting baseline information on the ground to enable full implementation of the project. This involved screening the prevailing post-harvest processes, screening the prevailing use of crops and livestock waste products in provision of energy, study the sources of biomass and their utilization for bioenergy and establish demand for additional biomass for bioenergy, and obtain some preliminary test results for further guidance.

In order to obtain the requisite information and baseline data a number of methodologies were used. They include baseline household survey, field visits by WP 6 teams, literature search, consultation with equipment dealers, laboratory tests of some aspects for some of the UPS, and Focus Group Discussions (FGD). Based on the field visits of the case study sites in the two districts needs for improved postharvest systems, use of crop biomass for energy provision, and use of additional biomass for bioenergy and other uses were quickly highlighted in line with improving the Food Value Chain (FVC).

Based on the clustering of upgrading strategies as provided by the baseline report from Deliverable 3.1.1 (Identifying, defining and typologizing FVC and upgrading strategies) and

the findings of two field trips in 2013 a systematic conceptual approach on UPS-forming was delivered to the project consortium. The approach addressed multiple constraints and issues within the case-study sites and suggested a framework for upgrading strategies interconnecting multiple upgrades (Appendix 1). The offered upgrades were linked within a process chain but also have the potential of significantly improving post-harvest processes and bioenergy production when implemented as stand alone. By the nature of a demand driven, people centered approach and the project goal of UPS-selection at village level and based on the UPS identification framework, a number of the suggested upgrades were prioritized in focus group discussions held by WP 3 and distributed back to the consortium. These were later named as UPS 2 (Byproducts for bioenergy), UPS 3 (Improved processing), UPS 4 (Improved wood supply), and UPS 5 (Improved Cooking Stove). It must be noted here that two of the proposed UPS, which were sunflower oil processing and storage have been shifted to work package 7 and will only be supported by task 6.1 team where the main issues of concern are engineering based.

During and after setting of the UPS design and testing of a pyrolysis technology abbreviated as *Top Lid Upright Draft* (TLUD) bioreactor was held at the University of Hoheinhem (UHOH) and the designs have been transferred to Sokoine University of Agriculture for fabrication and field testing using maize cobs. Airtight storage experiments for sunflower seeds was also held at UHOH but the experiments are still going on. Preliminary extraction of data from the baseline survey done by WP 3 has given some insight on the amount of crops that can be available for analysis on investment in improved processing technologies. Maize production in the entire villages of Ilakala and Changarawe is estimated at 673 and 780 metric tons, respectively. From the estimate of maize production and research results from the literature the corresponding amount of maize cobs that can be available for running the TLUD bioreactors has also been estimated at 155 and 179 metric tons in Ilakala and Changarawe villages, respectively. At Ilolo village the estimated production of sorghum, bulrush millet, and sunflower is 2317, 1327, and 674 metric tons, respectively while production of the same crops in Idifu stands at 310, 260, and 109 metric tons. Therefore, in terms of agricultural production Ilolo appears to have higher production potential.

From FGD it has been revealed that in all the four CSS natural forests were the main sources of firewood whereby 90% is collected and only 10% is derived from logging. Firewood is also sourced from communal areas while own plots and other places are of minor importance. However, there is a wide variation between the regions with regard to the time spent for collecting firewood as in Chamwino it takes 100-200 minutes, which is almost two-three times higher than that of Kilosa estimated at 45-75 minutes. Preliminary results from the household baseline survey gives a range of 63 – 90 kg of average firewood consumption per household per week, indicating high variances among households and CSSs. This is slightly higher than the generally accepted values of 2.5-3 t/year per HH in Sub Saharan Africa mentioned in Adkins (2010).

As a parallel effort to improve utilization of fuelwood for cooking, use of improved cooking stoves were emphasized. This will be done through training and knowledge workshops so as to strengthen and activate their own ability. This will also involve participatory learning and doing as much as possible. Measures and indicators for impact assessment will also be developed.

Keywords: Food Value Chain, Upgrading Strategies, TLUD, fuelwood, improved cooking stove, maize, sorghum, millet, sunflower

1. Introduction, Background and Aims

1.1 Introduction

The Trans-SEC project, with the title *Innovating Pro-poor Strategies to Safeguard Food Security using Technology and Knowledge Transfer* is implemented in Kilosa and Chamwino Districts in Morogoro and Dodoma regions, respectively. Formulation of the project went through various stages in German and Tanzania in dialogues and meetings that involved multi-stakeholders at governmental and institutional levels. The project is based on Food Value Chains (FVC) and the related supports in the two selected districts. It is run by a consortiium of researchers, policy makers, and other implementation actors in Germany and Tanzania. By considering all the chain segments and actors in crops and livestock production the post-harvest chain that includes processing for food and bioenergy production, waste products handling and utilization, and use of additional biomass was considered as a key component, and named as Work Package 6 (WP6) of the consortia (Trans-SEC, 2013).

1.2 Background

The post-harvest value chain in Tanzania, particularly in the earmarked districts is weak as it does not offer the expected returns to the farmers. This is despite the increased demand for food and need to have diversified food products to cope with the ever increasing population, especially in urban areas. Coupled with poor market linkages the sub-sector is multifaceted with a lot of technical problems including untimely harvesting, poor and rudimantary processing methods, inadequate and often innapropriate storage methods, and poor knowledge among the farmers and entrepreneurs. As a result there have been losses of up to 30-50% of food grains and more than 50% of pershables in physical terms (HLPE, 2014; Obayelu, 2014, and Keret, et.al., 2013;) and unquantified losses in monetary terms. These have denied the farmers of the needy income and made them food and nutrition insecure, resulting in a poverty vicious cycle. In this sub-sector part of the commodities produced are sold in the informal trade business and part is consumed in the producing households after a certain degree of processing or in the fresh mode depending on the type of the crop commodity.

Increased agricultural production is expected to produce a lot of farm wastes which in most cases are left on farm after harvesting. Improving the post-harvest subsector through processing results in waste products or by-products. The chief waste products in primary processing includes maize cobs after shelling; threshed heads of sunflower, millet, sesame and rice after threshing; and groundnut shells after decortication. Other products are obtained in the secondary processing phase, for example, cake after seed oil extraction and bran after dehulling of cereals. After harvesting, stover and other materials remain in the field for direct nutrient recycling but often the roaming livestock feeds on them to create another cycle of nutrients. Whereas in some areas these wastes are potentially used in other life supporting activities, in other areas they are not viewed as potential resources. Efficient utilization of crop and livestock waste products may help to increase returns to farmers and hence contribute to improved livelihood.

FVC requires extensive use of energy throughout. In the post-harvest segment energy is required in processing, heating, and food preparation. Depending on the nature of the activity use of fossil fuels, wood, agricultural biomass, and solar is variably practiced. Solar energy is used for direct sun drying, fossil fules are used to run some processing machines and automobiles, and wood is potentially used in household cooking. Use of agricultural biomass is not common and the quantities available may be a limitation. The continued use of wood is threatening the environment if measures to plant more trees and devise efficient use methods are in place. This may be complemented by better use of agricultural wastes where the economies of scale prove to be worth.

In addition to use of wood to meet the household cooking energy there is also increased use in construction of living houses. Simple storage houses, platforms for maize shelling, and simple storage structures also make use of wood. As the demand for wood increases with the increasing population and the dwidling forest reserves there is a clear need to have additional biomass supply. This can be realized through setting up of fast growing and conveneient wood resources that can cope with demand. However, the agricultural land is also shrinking in size hence establishment of wood lots in the agricultural land must be fairly compettitive compared with crops production.

Nonetheless, previous research and dissemination efforts in Kilosa and Chamwino have not addressed hollistically the FVC aspects to bring about significant changes in the livelihood of the farmers and the related stakeholders. Moreover, a few efforts to address crops and livestock production have to some extent delienated post-harvest issues, which constitute one of the very important segments of FVC.

Therefore, it is from this background that Trans-SEC has endeavored to work on post-harvest processes and bioenergy production, waste product utilization, and additional biomass utilization. However, it is a pre-requisite to set a benchline of issues before proceeding with full implementation of the project.

1.3 Aims

The major aim of this report is to draw a baseline for the analysis and enhancement of post-harvest processes, biomass and waste product utilization within the FVC that are important in bringing changes that are anticipated by the stakeholders, especially farmers. Being the first deliverable of WP 6, the report draws observations, lessons, and mutual agreements obtained as a result of performing the following:

a) Screening the prevailing post-harvest processes, notably primary processing (maize shelling, sorghum/millet threshing, groundnut decortication, drying), secondary processing (oil extraction and dehulling of cerals), storage, packaging and transportation focusing on product quality, losses, labor, technology availability and cost, energy requirements, and agro-environmental impacts.

b) Screening the prevailing energy provision systems for cooking, lighting and transport in terms of quantitative and temporal availability, costs and environmental impact.

c) Screening the prevailing use of crops and livestock waste products in provision of energy and improving soil nutrients and enriching the dietary uptake of livestock and improve livestock keeping practices. Additionally, screening for the possibility of using human waste in energy production and enrichment of soils was considered.

d) Study the sources of biomass and their utilization for bioenergy and establish demand for additional biomass for bioenergy and feed. In addition, select the appropriate tree species and types for dissemination and efficient use of these resources in providing household cooking energy.

e) Obtain some preliminary test results for further guidance.

2. Methodology

The study was done following four main approaches, which were: household baseline survey and team visits; literature search and information exchange; consultation with equipment manufacturers and service providers; Upgrading Strategies (UPS) formulation, selection, and implementation plans; setting a platform for UPS testing and evaluation; and Focus Group Discussions (FGD).

2.1 Household baseline survey and team visits

Household baseline survey was done at the main Trans-SEC project level by using a structured questionnaire which included questions that were specifically designed for WP6. This was done in Changarawe and Ilakala villages in Kilosa District with Nyali as a control village and Idifu and Ilolo villages in Chamwino District with Dembwe as a control village, involving 150 households per village who were randomly sampled with the assitance of village authorities. The important and relevant questions asked were broadly on:

- Important crops and area planted, with details on total production, harvesting period, trend on average yield, and postharvest losses and their causes.
- Consumption, citing consumed and sold quantities
- Storage, citing on quantities stored for home consumption and for marketing, start and duration of storage before marketing, storage technology, and storage losses and their contributing factors.
- Byproducts at harvest: type of byproducts, their quantities, and their main use.
- Processing, citing on whether processing is done at home or at a business enterprise, and whether at the business level the farmers take the byproducts freely or at a cost (value mentioned).
- Dissemination of storage and processing UPS, indicating whether there are problems faced and if solutions are known, and reasons for no solution in some cases. Interest to invest in storage and processing in the next five years was sought and where interest was lacking to find out why.
- Energy source: type of energy source utilized; time for firewood collection, headloads collected per day, and whether they stockpile firewood.

- Agroforestry, citing on various questions on trees including species, number, age, and type of cultivation; share of trees planted, purpose for use of trees, and means and place of acquiring seedlings; and whether there are preferred trees but inaccessible.

The data was coded using SPSS software and translated. The information obtained from the household baseline survey was complemented with report from familiarization visits by the WP 6 consortium and the various visits by the PhD students. In these visits researchers made physical observations and interrogated farmers who were involved in the main baseline and those who were not involved to give some more in-depth information.

2.2 Literature search and information exchange

Literature with respect to agricultural and livestock production, bioenergy harnessing and utilization, waste product utilization and biomass production and utilization was consulted. This was complemented by information exchange between the work package researchers and researchers from other partner institutions, notably ARIs, who have some experience of working in the project villages before. Valid and valuable information was taken.

2.3 Consultation with equipment manufacturers and service providers.

A potential local field equipment manufacturer namely *Intermech Engineering Ltd* was contacted to present the type and modes of processing technologies that are manufactured at the company and the selling price. Preference of local manufacturers to suppliers of foreign made equipment was aimed at reducing the cost of purchasing the equipment, availability of after sales services in the nearby and financial empowerment.

2.4 Upgrading Strategies (UPS) Formulation, Selection, and Implementation Plans

2.4.1 Formulation of UPS

Based on the concept of the Trans-SEC project and from experience of the stakeholders a number of interventions, which are referred to as Upgrading Strategies (UPS) were typologized within the identified Food Value Chains. These were byproducts for bioenergy production; improved processing: maize shelling, millet/ sorghum threshing, and optimization of sunflower oil extraction and cleaning; optimization of cereal storage systems; Biogas technology; collection of manure; aadditional biomass utilization; and Improved cooking stoves. A systematic approach in a conceptual framework showing interlinkages of some of the proposed issues is appended (Appendix 1). Optimized storage system and optimized sunflower oil processing also appeared in WP7; hence they were dropped and remained with six potential UPS. However, storage systems and oil extraction were designed to be considered in collaboration with WP 7 as the main implementer upon being selected by the farmers in the respective CSS. The six UPS were conceptualized giving the key constraints that will be addressed, brief description, indication of proven success in Tanzania, types of food crops applicable, brief technical specifications, possible limitations, and linkages to other FVCs. Based on these factors discussion with farmers and other stakeholders before selection of the preferred ones by the farmers for implementation was held. Description of the proposed UPS prior to selection was as follows:

(a) Utilization of crop byproducts (on-farm and processing) for bioenergy production.

FVC components; key constraints addressed: Inadequate utilization of crop waste products, erratic supply of energy, lack of awareness on better processing methods, low value accorded to some waste and byproducts, and haphzard disposal.

Brief description: On-farm crop residues are not efficiently used, and are left to decompose for additional soil biomass and some are utilized by livestock *in situ*. Few crops are primarily processed at both household and peri-urban centers whose by-products could be utilized in various ways, including energy production. The same applies to secondary processing, where the by-products obtained have some limited use. Promoted use of these products will add value the FVC, reduce use of fuelwood, and serve the environment from being polluted by such wastes. Residues from processing, especially threshing and shelling, are usually high in highly lignified structural components and therefore most suitable for thermo-chemical conversion. A pyrolysis treatment of these (already dry) residues will provide thermal energy for drying, roasting or cooking applications as well as biochar, which can be used as soil amendment or energy carrier.

Proved success in Tanzania: Limited (only maize shelled cobs are somehow used for heating and ironing in almost all maize growing areas).

Type of food crops applicable: Maize, millet, sorghum, sesame, groundnuts, sunflower.

Technical specifications: A top-lid-up-draft (TLUD) barrel-reactor can be built from scrap material and is capable of operational temperatures between 400 and 900 °C. Construction of mobile multi-purpose devices for drying, cooking, roasting and char production is possible.

Possible limitations: Low energy values from waste/ by-products, lack of economic quantities, cost of conversion methods, cost of suitable energy appliances, e.g., cook stoves. It also requires knowledge on good operation to avoid dangers from fire and harmful flue gases.

Linkage to other FVC components*:* Marketing, natural resources, production of crops, processing. Bio-char as soil amendment will increase water and nutrient holding capacity and therefore contribute to natural resources. As energy carrier, a tradable commodity is available.

(b) Improved processing of crops (shelling, threshing and cleaning)

FVC components; key constraints addressed: Poor knowledge, erratic supply of energy and lack of awareness on better processing methods.

Brief description: Primary processing is still performed directly on the field or with technically insufficient constructions. Threshing and shelling are performed in a labour-intensive way, the products are of minor quality and polluted with dust, animal litter and insects. Proper technology is available and has been focused by numerous projects, implementation and awareness of added value is lacking. Both, manufacturers and supplies are available somewhat close to the CSS and would be willing to demonstrate operation and maintenance of their machinery to the stakeholders. Business models should be developed to facilitate stakeholders to purchase the machinery.

Proved success in Tanzania: Machinery is built in Tanzania (the engine is imported). This is the most successful processing industry in Tanzania.

Type of food crops applicable: Maize, millet, sorghum, groundnut, sunflower.

Technical specifications: Both, mobile and stationary solutions with multiple drives (from hand cranks over animal traction up to electrical motors) are available. Technical issues will not need to be focused within this improvement but rather the ability for implementation and development of a business model will be focused. Where possible the stakeholders will be trained on how to operate the machinery in multiple workshops. The machines are manufactured and available in Morogoro (Tanzania) and the manufacturer offers training at a modest cost.

Possible limitations: Might be too expensive and education is necessary for operation. Comparative advantages might only be present if there is shortage of labour or the harvested area is huge. Development of a business-model is necessary.

Linkages to other FVC components: Residues can be processed to thermal energy and char, therefore a link to natural resources and markets can be established.

(c) Collection and utilization of manure for crops and vegetable production

FVC component(s); key constraints addressed: Poor collection of manure, inappropriate storage of manure, inadequate transport means for manure.

Brief description: Livestock (cattle, goats and sheep) are normally raised under extensive system of production. However, at night they are usually kept in night shelters/kraals. When the kraal is full of manure the animals are shifted to a new one. Instead of moving to a new kraal manure could be collected, stored in a side shelter and applied to nearby farms and vegetable plots to increase soil fertility. The same system applies to keeping of pigs and poultry, but will require an improved housing structure for collection of manure. Good collection and storage of manure will reduce nutrient wastage. Application of organic manure will increase crop/vegetable yield and improve soil structure.

Proved success in Tanzania: Limited

Type of food crops /livestock applicable: Maize, millet, sorghum, sesame, groundnuts, sunflower, cattle and pig manure.

Technical specifics, dimensions: Where it is desirable to collect manure a properly designed house is required. For pigs and goats a raised platform with slatted floor is the most ideal. For intensive and extensive production where kraals are used, manure should be collected regularly and moved to adjacent storage shelter to allow for decomposition and upon drying the product becomes less bulky for transportation to distant farms. In both cases properly designed storage structures are needed to reduce wastage and loss of critical nutrients through leaching or evaporation. The cost of a simple kraal (cattle/goats/sheep) with a solid foundation, a storage shelter, and an ox-cart may not exceed Euro 1800. For pigs/poultry the structure may cost around Euro 800.

Possible limitations: Inadequate stocks, distance to farms.

Linkage to other FVC components: Food crop production, natural resources, marketing, environment.

(d) Production and use of biogas

FVC component (s); key constraints addressed: inadequate use of animal and human waste for energy production, high cost of alternative energy sources.

Brief description: In places with fast depletion of affordable sources of cooking energy, alternative sources of energy must be sourced. This can come from electricity, petroleum and natural gas, but under most village conditions it may not be feasible. Other alternatives include renewable energy sources such as solar, wind and biogas, but cost of the harnessing methods may pose limitations. However, production of biogas may have more advantages as the bio-slurry produced is a very healthy organic fertilizer. Moreover, the practice may change the way people keep their animals positively.

Proved successes in Tanzania: Kilimanjaro, Njombe, and Arusha regions. MIGESADO PROJECT in Dodoma.

Type of waste: Cattle and pig manure

Technical specifics, dimensions: Several types of bio-digesters have been introduced in some parts of Tanzania with variable success in the generation, use, and maintenance. The bio-digesters are the floating drum, the fixed dome, and the tubular plastic types. The most preferred bio-digester is the fixed dome type currently being disseminated by CAMARTEC (Arusha – Tanzania). Experience shows that for a sizeable household the digester volume should not be less than 6 cubic metres, requiring about 40-60 litres of water per day for the wet-state bio-digester and less for the solid-state type. For management purposes and sustained biogas production using cow manure the floor of the kraal must be solid in order to prevent sand/soil from entering the digester. Such a system can also be integrated with manure collection. A complete 6 m^3 system with appliances including setting of manure collection floor and diversion of spent bio-slurry to a collector may cost about Euro 800.

Possible limitations: Competition with other energy sources, maintenance cost, cost of appliances, cultural taboo.

Linkage to other FVC components: Natural resources through reduction of deforestation, food production by use of bio-slurry.

(e) On-farm wood supply (through education and training).

FVC component(s); key constraint addressed: Acute shortage of cooking energy; use of crop residues and manure for cooking instead of replenishing soil nutrients, high harvesting pressure on native woodlands for wood extraction to supply fuelwood, poles, timber and other wood products, and malnutrition related to eating half-cooked food.

Brief description: Tree planting in various niches in farmlands and at homestead provides alternative source of wood biomass for supply of cooking energy (firewood and charcoal), wood products (e.g., poles & timber), fodder and other environmental benefits (e.g.

prevention of soil erosion). This can be achieved by planting trees in farm boundaries, woodlots or retention of naturally regenerating tree species on-farm. Capacity building on tree nursery and environmental education to farmers (individuals and farmer groups), religious and academic institutions (especially primary schools) will be necessary for the success of this UPS.

Proved success in Tanzania: Boundary tree planting work and the woodlot technology (planted and natural woodlands called Ngitilis) has shown great success at Ihumwa village, Dodoma (Kimaro *et al*. 2014), Mkundi in Morogoro (Kimaro *et al*. 2007), and in Shinyanga and Tabora regions (Ramadhani *et al*. 2002, Nyadzi *et al*., 2003) under the ICRAF and SUA research programmes.

Type of food crops applicable: Boundary tree technology can go with any crop depending on farmer's choice and the appropriate tree spacing and species types. Woodlots can go with any crops if sequential cropping arrangement is done but often this approach targeted marginal sites where crops are not the main part of the production system.

Technical specifics, dimensions: Suitable tree species can be selected in collaboration with farmers depending on agro ecologies, spacing vary with species and site conditions but initial spacing of 2 x 2m can be adopted and trees thinned latter. For woodlots, 3 x 3m or 3 x 4m is suitable dimensions. Depending on species, planting crops at least 3 m away from the farm boundary may help mitigate competition.

Possible limitations: (i) Low capacity and motivation to plant trees by farmers due to low awareness, labour intensive nature of the task, the length of time needed to realize benefits (could even exceed span of education period of a pupil), and misconception against impacts of tree on farms etc. (ii) Reduced crop yield due to failure to control competition.

Linkage to other FVC components: Food Production, Animal husbandry, Natural resources (concepts of agro forestry or agro-silvo-pastoralism), crop residues.

(f) Improved cooking stoves

FVC component(s); key constraint addressed: Forest degradation and deforestation to supply wood fuel, high reliance on wood fuel (fuel wood & charcoal) as the main source of energy.

Brief description: Improved methods for utilization of fuel-wood include improved stoves to be manufactured within the village. Used materials (clay, iron and bricks) as well as design and functionality will be developed and closely adapted to demand and existing technologies. Different types will be explored in field trips. The objective is to save up to 40% of firewood but also to raise awareness of indoor air pollution. Recovery of ash as fertilizer is also crucial. Measurements of emissions (human health and environmental pollution indicators) for Life Cycle Assessment (LCA) and determination of proper chimney design are being done in Germany (UHOH).

Proved success in Tanzania: Sucesses have been shown by TaTEDO, which is a center for sustainable renewable energy technology; modern energy supply in Mbezi luis (Dar es Salaam); and selected villages across the Eastern Arc Mountains of Tanzania. In comparison to an open fire, modern cooking devices reduce emissions up to 70 percent, reduce poverty for users and producers, save time and/or money, and contribute to income generation for stove producers, builders and vendors.

Types of crops applicable: All

Technical specifics, dimensions: Small scale cooking stoves with one, two or three holes can be used at the household level and large scale cooking stoves can be used for commercial and large scale use (e.g., Preparation of local brews). Production can be from mud, mud bricks and combination of mud bricks and cement. Material and sophistication depends on size, intended use and costs. Potential of construction of multi fuel stove for utilization of residues exist.

Possible limitations: Costs of the improved stoves, inadequate diffusion of knowledge on construction of improved cooking stoves, inclusion in existing buildings with exhaust system, suitability to both wood and additional biomass.

2.4.2 Prioritization and selection of UPS

Based on crops and livestock production situation, and the enviromment in the Case Study Sites/villages, not all the UPS were suitable for the entire 4 CSSs. Therefore, the following proposal (Table 1) was presented to farmers and other stakeholders for discussion and final selection.

Table 1. Proposed UPS in the respective CSS

Sn	Upgrading Strategy (UPS)	Villages/sites in Kilosa district	Villages/sites in Chamwino district
1.	Utilization of crop byproducts (on-farm and processing) for bioenergy production	Ilakala Changarawe	Ilolo Idifu
2.	Improved processing of crops (shelling, threshing and cleaning)	Ilakala Changarawe	Ilolo Idifu
3.	Collection and utilization of manure for crop and vegetable production	-	Idifu
4.	Production and use of biogas	Ilakala	Idifu
5.	On-farm wood supply (through education and training)	-	Ilolo
6.	Improved cooking stoves	Ilakala Changarawe	Ilolo Idifu

The proposed UPS in the respective villages were together discussed by stakeholders including farmers in the target households. The farmers were guided to make their own decision in a prioritized manner for their implementation in collaboration with respective research Task groups. The selected UPS will finally be tested in the target CSS. However, some preliminary laboratory and field implementation could be conducted prior to full implementation to provide more guidance.

2.4.3 Implementation Plans

Implementation plans were deduced from information gathered in the baseline work and the UPS which were finally selected by the farmers. It considered the working with a few selected farmers groups in the respective CSS and foreseen cost of implementation in line with the project budget. It is expected that farmers will be the main contributor for implementation of the target UPS.

2.5 Preliminary testing and evaluation of UPS

2.5.1 Byproducts for bioenergy

Agricultural residues in form of solid biomass are becoming more attractive due to its availability and suitability as biofuel in rural areas of Africa (Ait-Oubahou, 2013; Quaak, 1999), hence there is need to convert them to mitigate the energy crisis in Tanzania, especially in rural areas. Gasification and pyrolysis are attractive thermochemical processes which are suitable to be implemented in rural areas (Amalendu, 2003; Bridgwater, 2006; Jahirul *et al*. 2012). The process is shown in Fig. 1.

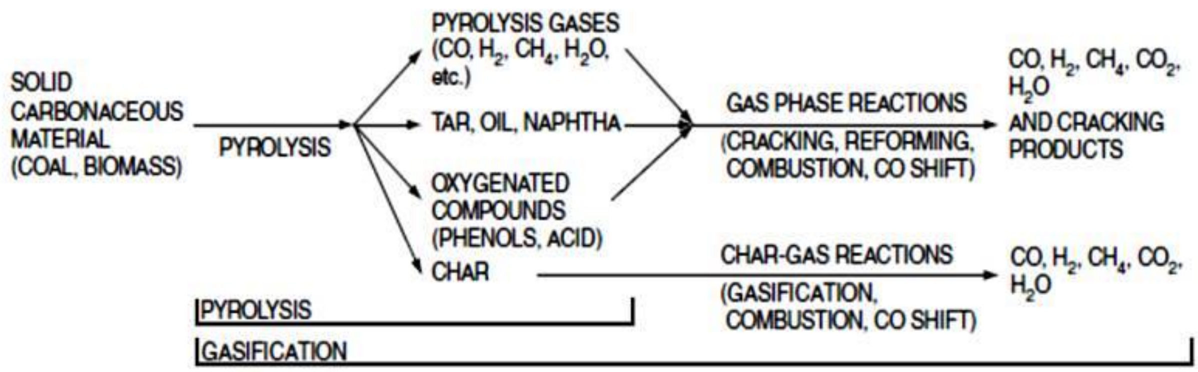


Figure 1. Fundamental process of pyrolysis and gasification (edited from Higman and van der Burgt, 2008)

Cheap, multi-function and applicable reactor is necessary to provide energy for cooking and at the same time produce good quality biochar. Various improved kilns and microgasifiers have been developed for decades for implementation in developing countries. Among the gasifiers, the top-lit updraft reactor was selected due to its high flexibility for up or down-scaling, easy construction and handling. The reactor has the work principle of *barrel-in-barrel* method. The construction and field test was carried out in Ethiopia by Claus (2011) and showed a promising results. The reactor was further developed by Gersdorf (2012). The inside part and operation zone are shown in Fig. 2.

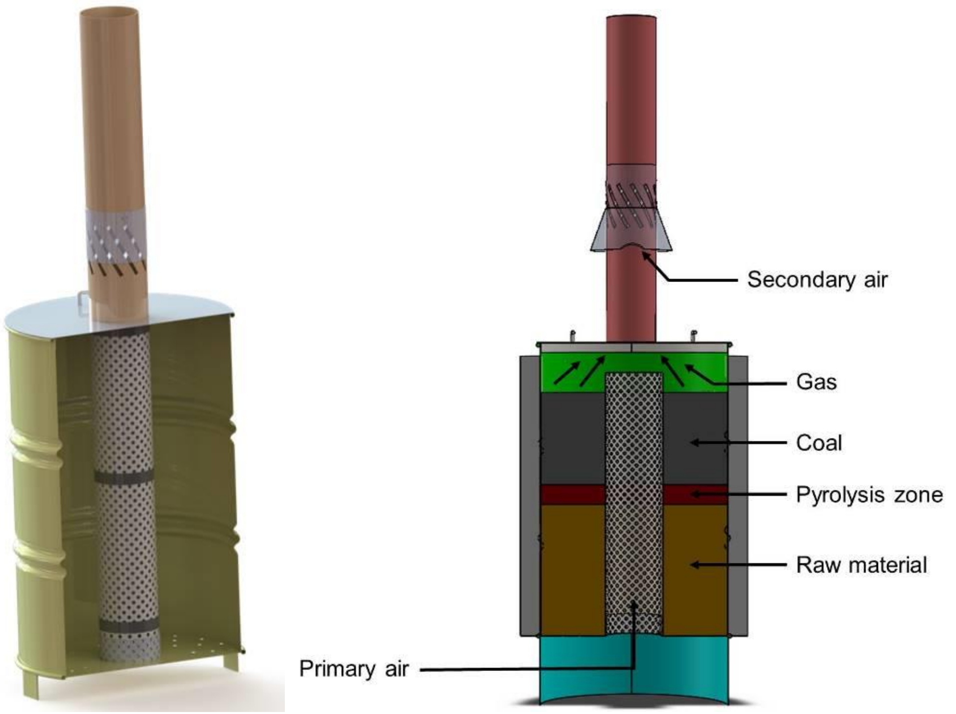


Figure 2. Inside visualization (left) and the work principle of modified TLUD reactor (right)

The reactor consists of oil barrel, perforated cylinder, and chimney attached to the lid. The air flows on natural draft from the bottom to the chimney. Optimum operation of the reactor is expected to give good quality of char and sufficient energy for cooking.

The objectives of preliminary implementation of this UPS were to identify and utilize wastes and additional biomass for energy provision as well as establish a pilot-demonstration plant for bioenergy, by adopting the following methodological approach.

2.5.1.1.1 Preliminary testing at University of Hohenheim

First of all the pyrolyzer was designed using Solidworks 2014 (Dassault Systèmes, Velizy Villacoublay, France) CAD software. The construction was carried out in Germany at the metal workshop of Hohenheim University. Glass wool was used as the insulation material.

The preliminary observation was carried out using an international standard 200-litre drum. It has a weight of 18 kg when empty and a capacity of up to 200 kg of solid biomass. Testing of the TLUD reactor was carried out at the University of Hohenheim using wood chips, due to their availability. Spiritus was sprayed on the surface of the material for the ignition.

2.5.1.2 Setting a platform for testing at the respective CSS

Work between MVIWATA and SUA focused on group formation and field survey in Ilakala village for potential agricultural wastes, which can be accommodated as a raw material for bioenergy production. Maize cobs will be used as a raw material and will be derived from the farmers own harvest after shelling. Simultaneously, a market survey was conducted by SUA for available spent barrels in Morogoro market. From those barrels, new design of TLUD reactor in accordance to the size of each barrel was made. Feasibility study in Ilakala village will be conducted at a later stage.

2.5.1.3 Construction and optimization of pilot TLUD reactor

In Germany, another reactor using better insulation system was constructed. The inlet opening of primary air was modified to be adjustable (See Fig. 3). Vermiculite insulation type isolit V400 (K. Hoffmann GmbH; Plettenberg, Germany) was utilized with 80 mm thickness on the outside wall of the barrel.

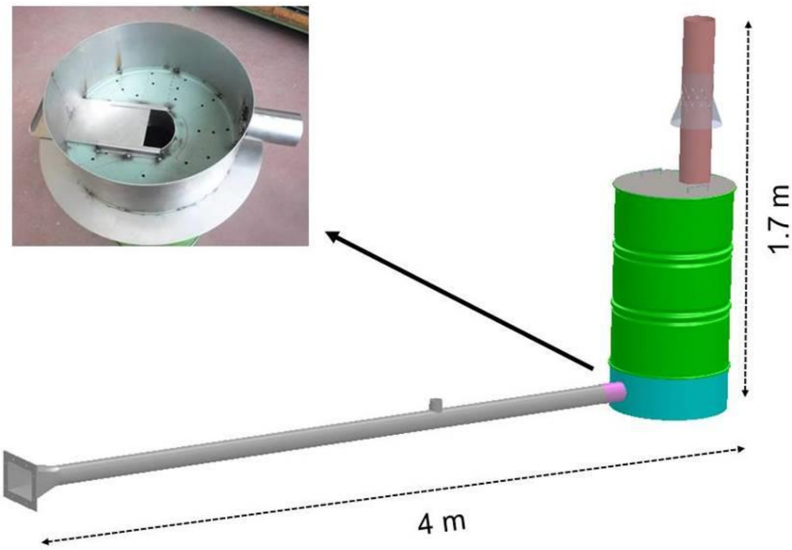


Figure 3. Modified TLUD reactor with adjustable inlet opening of primary air on the bottom

A 4-m pipe was built and installed on the reactor for the purpose of air flow measurement only. The pipe enables attachment of flow sensor equipment in laminar condition.

The chimney of this reactor was shifted to the side, in order to allow space for cooking on the surface of the lid by using the heat released from thermochemical process in the reactor, as shown in Fig 4.

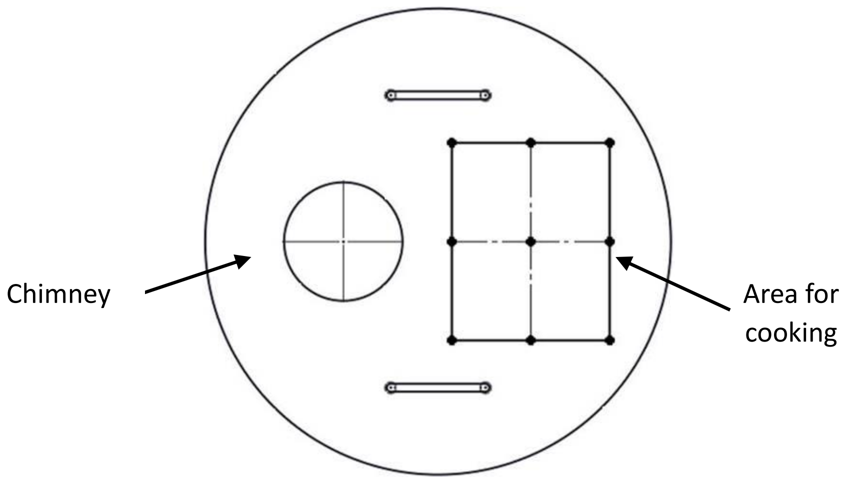


Figure 4. Shifted chimney, and space to locate stove for cooking

The weight of the reactor is approximately 300 kg, due to the weight of insulation material (see Fig. 5). Therefore, the investigation of the optimum design of mobile unit for the reactor was also included, with the purpose of enabling the mobility of the reactor and collecting the char easily.

Figure 5. The distance between outer wall of drum and inner wall of ring in mm (left), and insulated TLUD reactor (right)

The optimization strategy was applied by operating the reactor at different air flow rates which are referred to as air openings and amount of material filled into the drum (30%, 60%, and 90%). The measurement comprises temperature and air flow as exemplified in Fig. 6. Furthermore temperatures at 9-point matrix on the area for cooking were also added.

The whole reactor including the mobile unit is settled on a digital balance PFWA-KB30 (I.H.G Industriewaagen, Renchen, Germany), that has capacity up to 3000 kg to monitor any weight changes of solid material inside during the experiments.

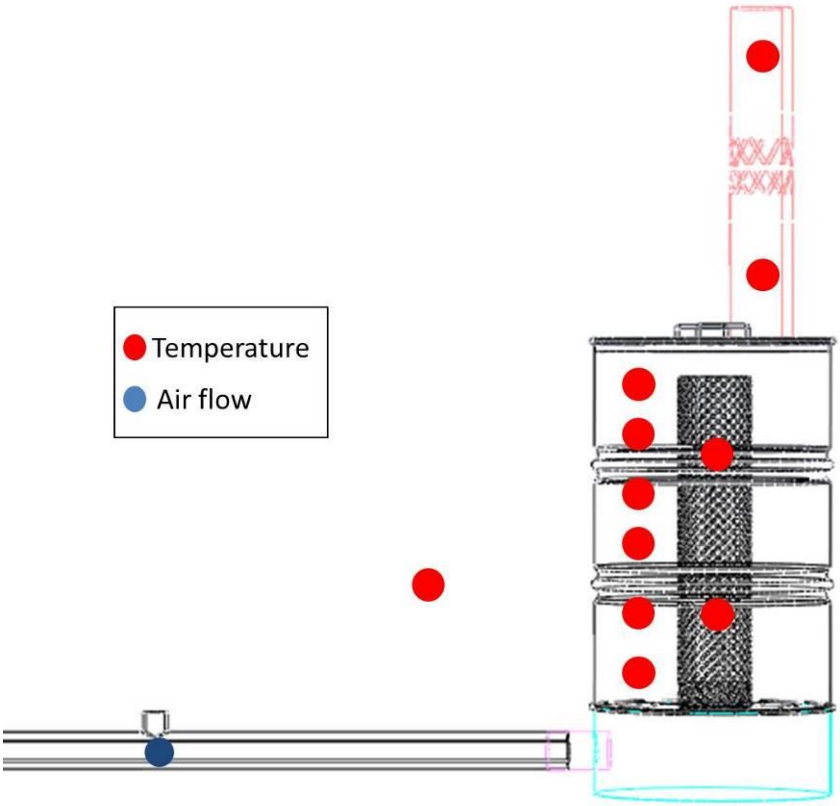


Figure 6. Air flow and temperature measurement of TLUD reactor

Laboratory analysis of ash content and calorific value of raw material, and char produced from each process is carried out according to DIN CEN/TS 15403 using muffle furnace, and DIN 51900-3 using bomb calorimeter. Evaluation of the performance is implemented (Antal Jr *et al*., 2000; Claus, 2011). The effective yield of char, η (%), is estimated in Eq. 1.

$$\eta = \frac{m_{char} \cdot (100 - \%ash_{char})}{m_{raw\ material} \cdot (100 - \%ash_{raw\ material})} \quad (1)$$

Where m_{char} is the mass of char produced (kg) and $m_{raw\ material}$ the mass of raw material inserted into the drum (kg) on dry matter basis.

The redesigned reactor will be manufactured at the Engineering Workshop at SUA, and the prototype will be tested at SUA and Ilakala village at a site that will be chosen by the farmers.

2.5.2 Improved processing

Improved processing is comprised of three UPS: maize shelling, sorghum/millet threshing, and sunflower oil processing. Whereas maize shelling and sorghum/millet threshing are solely implemented by WP6 sunflower oil processing is a joint activity with WP7 as the leader.

2.5.2.1 Sunflower oil processing

(a) Work at UHOH

Currently, experiments for the optimization of sunflower oil extraction via a mechanic screw press are conducted at the University of Hohenheim. It involves use of the oil press CA59G (IBG MonfortsOeketech GmbH, Mönchengladbach, Germany) to press sunflower seeds. The speed of the motor, ω_m and the screw press speed, ω_s were measured using digital tachometer DT-2234 (Fa. ZEITECH, Berlin, Germany). The correlation between ω_m and ω_s was fitted into linear equation, as shown in Eq. 2 (R^2 = 0.989).

$$\omega_s = 0.096 \cdot \omega_m - 1.426 \qquad (2)$$

In order to optimize the mechanical extraction in terms of oil recovery, process factors such as press cylinder, nozzle, and rotational speed of the screw were taken into account. Press cylinder with 1-mm holes diameter was used in this study.

The experimental design consists of experiments at different speed and nozzle diameter (see Table 2).

Table 2. Level of process factors

Level	**Screw speed, ω_s(rpm)**	**Nozzle diameter, $Ø_N$ (mm)**
Low	18	4
Middle	28	5
High	40	6

Measurement of the temperature of press cylinder (T_1), press head (T_2), crude oil (T_3) and press cake (T_4) was conducted using thermocouple type K (Greisinger electronic, Regenstauf, Germany) as shown in Fig. 7. A data logger switch unit 34970A (Agilent technologies, Böblingen, Germany) was carried out to record the data in 12-seconds interval.

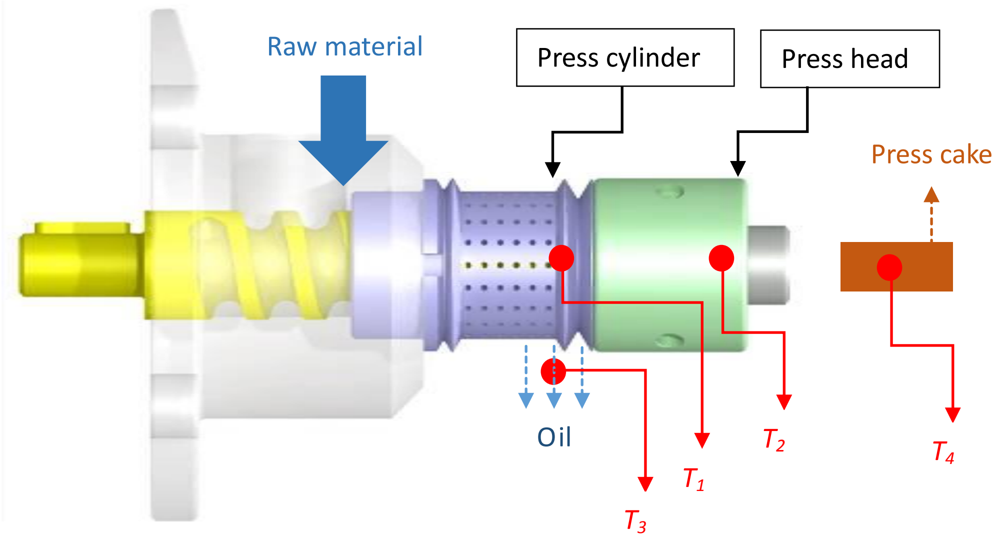


Figure 7. Temperature measurement of press cylinder (T_1), press head (T_2), crude oil (T_3) and press cake (T_4) of oil press CA59G

An i200 AC current clamp (Fluke, Glottertal, Germany) was used to measure power used by the motor. Power *P* (watt) of the pressing machine was calculated using Eq. 3.

$$P = \frac{3 \cdot 400 \cdot I \cdot 0.85}{1.73} \qquad (3)$$

Where *I* is measured current in Ampere and measured from the electricity outlet of the motor.

Oil recovery efficiency of the extraction process was calculated based on oil content of the raw material, and pressed cake as described by Beerens (2007). The oil content was extracted using automatic extraction system SOXTHERM 2000 (C. Gerhardt GmbH & Co. KG, Königswinter, Germany).

After experiment, the weight of press cake, m_p and crude oil, m_c (kg) was also measured to estimate mass balance of the whole process. Throughput, *S* (kg/h) was estimated using Eq. 4.

$$S = \frac{m_s}{t} \qquad (4)$$

Where m_s was total mass of sunflower seeds (kg), and *t* time of the extraction (h).

Crude oil from the extraction was stored for seven days in a two-liters plastic container to let the sedimentation process take into effect (Karaj and Müller, 2014). The volume of clear oil was further estimated.

(b) Sunflower oil processing in Tanzania

The Ram Press, which is a horizontal manually operated screw expeller, was discouraged from use as it was very laborious and unfriendly to women operators. Currently, the mechanical screw expeller operated by a diesel engine or electric motor has been identified for adoption. Such units may include a mechanical filter press depending on the level of investment. However, the processing technology capable of producing oil of the quality equivalent of single refinery as applied in other parts of Tanzania (Fig. 8) will be adopted in the CSS while at the same time look at the possibilities of improving the individual processes.

Investment in improved processing will be done after conducting a detailed feasibility study, development of a business plan, and acquisition of funds by the farmers to acquire the extraction unit and its accessories. Figure 9 shows the extraction mill without a filter press.

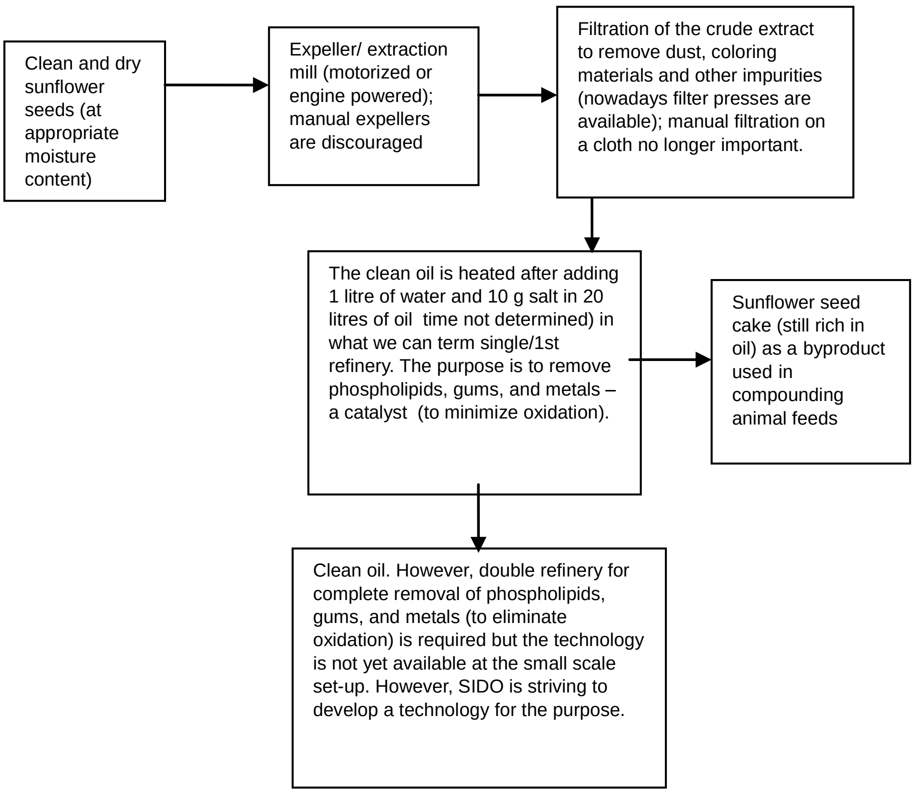


Fig. 8. A simple sunflower oil processing flowchart at a small scale level (in both rural and urban setups) in Tanzania.

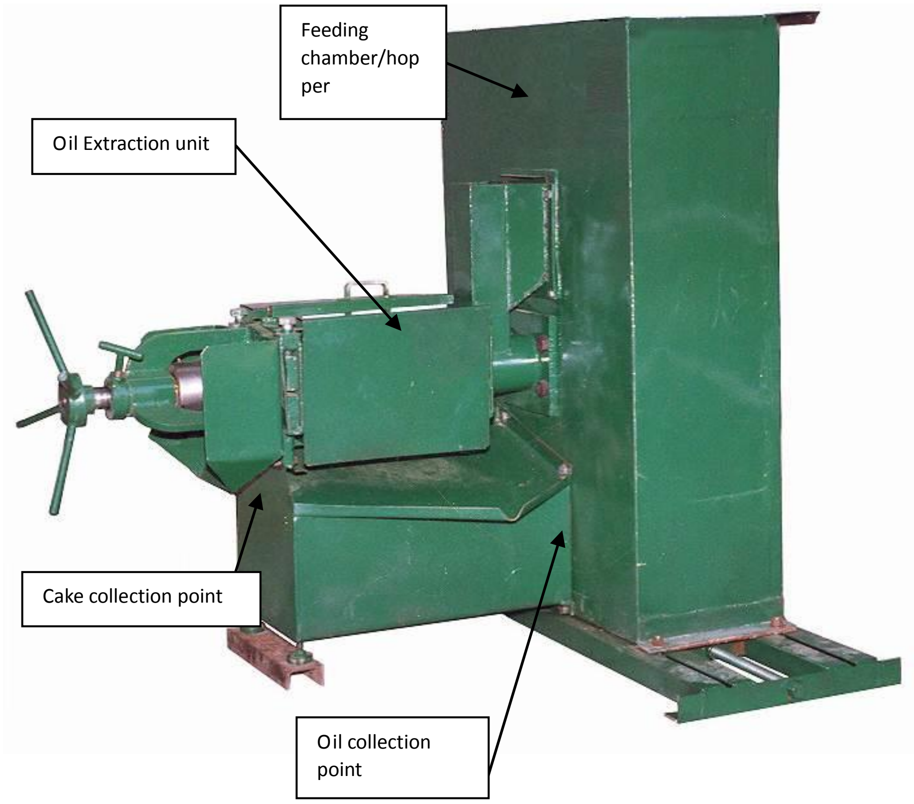


Fig.9 Photographs of sunflower oil extraction mill

2.5.2.2 Maize shelling

Since there is no maize sheller available at Ilakala and Changarawe villages, implementation will start by group formation by MVIWATA followed by feasibility study. The results of the feasibility study will be used to develop a business plan that will be used to solicit funds for investment. For simplicity shelling machines made locally will be given more emphasis (Fig 10).

Fig.10 Photograph of a motorized shelling machine made locally

2.5.2.3 Sorghum/millet threshing

The same methodology as for the maize sheller will be applied but this will be for Idifu and Ilolo villages.

Fig.11. Photographs of an engine-powered sorghum/millet threshing machine made locally

2.5.2.4 Improved grain storage systems

After appropriate processing, optimal storage will retain the products quality and quantity for a maximum of time. This will facilitate price driven sales which can increase income. Also, product quality is increased and contamination reduced, which will benefit the well-being and food security of farmers / consumers. Experiments conducted at the University of Hohenheim are investigating the long-term hermetic storage of high oleic sunflower seeds.

Three metal barrels with a volume of 0.3 m^3 each were equipped with sensors for measuring CO_2, relative humidity, pressure and temperature in the head gas space above the stored kernels. The CO_2sensors (CO_2Engine BLG) were manufactured by SenseAir (Sweden) and measure up to 300,000 ppm of CO_2 with a repeatability of ±0.1 %vol. CO_2 ±2 % of measured value and an accuracy of ±0.2 %vol. CO_2±3 % of measured value. The measuring principle is non-dispersive infrared waveguide technology. The sensor circuit boards are also equipped with a combined moisture and temperature sensor (SHT15) manufactured by Sensiron (Switzerland). The moisture sensor follows a capacitive measurement principle in a range from 0 – 100 % RH with inaccuracy of ±2 % RH. The temperature sensors measure from -40 – 60°C with an accuracy of 0.4°C at 25°C. The pressure sensor (BMP085), manufactured by Bosch (Germany), are absolute pressure sensors sealed at 300hPa and measure from 300 – 1100hPa pressure with an accuracy of ±1hPa. Currently, measurements of all values are either taken every five minutes or on demand, the data is stored locally and cloud-based, in raw and graph form. The sensor boxes, which are mounted inside the storage barrels, are equipped with a battery and a memory card to facilitate measurements even with a loss of grid power or internet connection. The tightness of the barrels was tested for pressure above ambient conditions by pouring in liquid nitrogen and for pressure below ambient conditions by pouring in boiling water. The barrels were filled with 5 kg of freshly harvested and dried sunflower seeds (PR65H22) on October, 9th 2014 at a moisture content of 12.35±0.07 %.

The measured CO_2 value is corrected to the actual pressure by equation 1 as stated in the sensors datasheet, the pressure is corrected to a temperature of 20°C by equation 2.

$$\frac{CO_2}{4.026 * 10^{-3} * P + 5.780 * 10^{-5} * P^2}$$

(5)

CO_2 Measured value in ppm

P Pressure in kPa

$$\frac{P}{t + 273.15} * 293.15 \quad (6)$$

P	Pressure in hPa
t	Temperature in °C

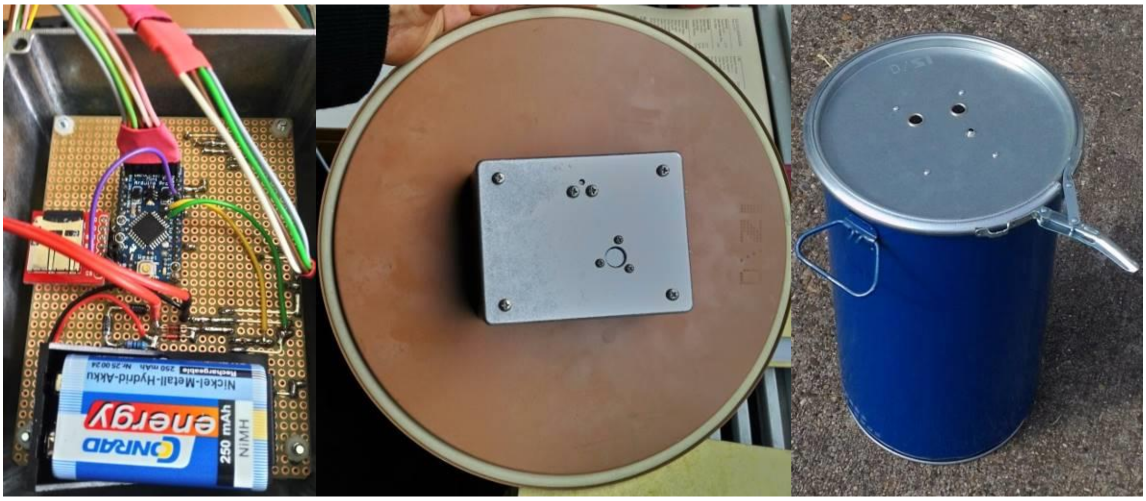


Figure 12: Inside view of sensor box, barrel lid and storage barrel

2.5.3 Improved tree planting

Two FGD and key informant interviews were conducted in September 2014 by ZALF, together with Trans-SEC Partners of ARI and SUA, aimed at gathering background information on the current in-depth situation on firewood supply for later UPS implementation and also assist the interpretation of the baseline survey data. Participants included the village head, executive officer, farmers, member of Mazengo group (bee-keeper), subvillage heads and representatives from environmental village committee. Gender balance between women, men, elders and youth was observed. This was followed by UPS group formation by MWIVATA. The next step will be to assist the UPS group manage their issues. In order to facilitate the group consolidation some issues were raised with regard to rights and duties of the UPS group and were discussed. They include:

- Organisational structure (managing board, chairman, treasurer, general meetings, etc.), Aim of the group
    - Incorporation of group aims into articles of association: Income, afforestation, erosion control, water retention, etc.

- Information on different shareholder models (community based ownership, contracts for single households, utilization of added value, etc.)
- Fees/contribution (financial or labour).
- Occurring responsibilities (voluntary tasks should be distributed on the shoulder of all members)
- Who are beneficiaries in case of group income? Important role of group chairman and treasurer (trust and reliability over life span of trees).
- Are they facing imbalances?
- Agreement on a kind-of compensation to ensure sufficient performance of the most basic and important tasks (e.g. maintenance of nursery)?

In the end the group members will be individually enabled to agree on following questions:

1. Will I own the trees at the time of harvest? (Are there other models of participation?)
2. Will I be able to sell my forest products? (What is the group task in strengthening market power/capacity/competence?)
3. Will I have access to information on how to grow and maintain the trees? (Agreement on supervision plan: necessary periodical or running backing through experts, degree on involvement into monitoring and evaluation)
4. Will I have a good association to represent me? (How to empower the group to make sure points one to three are in place and will stay in place in the future?)

After the UPS Group had successfully planted trees in the village, a program for monitoring and evaluation has to be developed for assessment of tree growth performance and other factors.

Reporting for tree growth performance:

- Shoot diameter, length, weight after harvest (pruning).
- Tree spacing, density of stands, survival
- Root collar diameter (RCD),
- Diameter at breast height (DBH) and height assessments.

To achieve an understanding of impacts on yield and growth rates additional parameters have to be observed and reported, i.e., site conditions, tree species, field preparation, maintenance (watering, pruning, weeding, fertilizing, pest control, etc.). In addition, our research will contribute to close agroforestry knowledge gaps by analyzing the optimum spacing and interactions of boundary trees with nutrient management options to enhance crop yield. In order to fill knowledge gaps few trees may also be destructively sampled for dry weight determination for contributing to developing biomass equation to estimate biomass yield.

Training on tree and forest management will broaden knowledge on wood lots, shadow trees as single trees on plots, boundary tree planting as technologies for on-farm wood production to address land degradation problems in dry lands, time for cuttings (shoots to be newly planted), pruning branches and tree harvest.

Initially, it was proposed to deal with “Sustainable charcoal production” but due to several restrictions (e.g. management efforts, expenditures and unclear legal status) including environmental concerns it will not be implemented. Although in FGD of every village in CSS charcoal making was mentioned to be a main source of tree and forest losses and forest degradation the improved charcoal making was difficult to address within the project boundaries. However, this issue is of high importance, thus a Master thesis could provide evidence for feasibility. As good practices are already established in the district of Kilosa, Morogoro some issues of improved kiln technology and natural resource management will be captured via bioenergy training units during stove building workshops and through farmers’ site visits at sustainable charcoal plots.

2.5.4 Improved cooking stoves

An initial FGD was conducted in Sept. 2014 to identify and incorporate existing knowledge about improved stoves in the CSS villages (and sub villages). This was based on the following questions: Who has some experiences? Who owns or uses improved stoves? What are reasons and experiences for adoption?

A second FGD included a requirement analysis for achieving background information which contributes to successful implementation of the UPS - “improved cook stoves”. The important issues were as follows:

- General housing and kitchen situation
  - Indoor/outdoor (talk about occasions, preferences, income groups, etc)
  - Single houses or rooms available for cooking, practice of natural ventilation of fresh air
- Needs to adapt stove design to single user (to be announced as work in progress)
  - Cooking habits, kind of food, knowledge about quality aspects, cultural diversity, meals from other countries/regions
  - Baking opportunities needed
  - Extending storage life of food by drying/heating
  - All day, celebrations, special occasions (brewing, hot tubes, washing, etc.)

It was agreed that UPS group members shall monitor the implementation performance. Training therefore will include reporting methods. Trained trainers from the UPS group shall construct, report the time of ICS construction, and repeatedly accompany households (HH) after ICS installation. Other issues discussed included type of trainers and members involved, HH type of stove and kitchen, date of installation, ICS stove usage and experiences compared to "3-stone-fires", meal types, nutrition status, and firewood savings (see monitoring sheet in Annex).

3. Results

The results of this report are subdivided into three main areas: selected UPS and implementation plan, baseline information, and preliminary UPS results.

3.1 Selected UPS and implementation plans

3.1.1 Selected of UPS

Out of the six UPS that were submitted to the farmers, only four were chosen as suitable strategies. Byproducts for bioenergy production was chosen in Ilakala while improved processing was chosen in all the four CSSs. Wood supply was chosen only in Ilolo CSS and Improved cooking stove was an UPS that was chosen by all the four CSSs, focusing on training in Ilakala and Ilolo and actual implementation in Changarawe and Idifu. The following table provides a brief summary.

Table 3. Selected UPS by the participating households

UPS	Ilakala	Changarawe	Ilolo	Idifu
1. Utilization of crop byproducts (on-farm and processing) for bioenergy production	X			
2. Improved processing of crops – processing machine (shelling, threshing and cleaning)	X	X	X	X
3. Biogas production and use				
4. Collection and utilization of manure for crop and vegetable production				
5. On-farm wood supply (through education and training)			X	
6. Improved cooking stoves	Training	X	Training	X

Reasons for the choice of by-products for bioenergy in Ilakala was prompted by the relatively higher production of maize which yields biomass of relatively larger quantities of biomass compared with all the other cereals. Byproducts from sesame, which is grown in Ilakala, and by-products from millet/sorghum, which is grown in Ilolo and idifu, have low mass density and may not produce as much energy as maize cobs. However, energy values from these biomass materials need to be established. Farmers in Ilakala are also confident of producing enough maize and there is also a possibility of expanding production. Due to inadequacy of inorganic fertilizers the biochar that can be produced from biomass conversion processes might have also attracted the farmers.

Improved processing was an UPS acceptable to all the four CSSs as an indication that farmers face a lot of challenges during primary processing. It is apparent that every household is involved in processing, whereby all the gender transect within the family except very young children is involved. The traditional technology whereby the harvested crop is beat on the ground or on a platform is laborious and drudgerious. If not handled properly some spillage losses and incomplete threshing may reduce the yield realized by the farmers. These reasons might have triggered need for improved processing but the main limitation is affordability of the available technologies due to the poor financial capability of the farmers in these areas. However, organizing the farmers in small business groups might offer a feasible solution.

Collection of manure and biogas production, both of which depend on livestock production were not selected as priority UPSs despite the benefits that can be realized. This was probably attributed to the nature of livestock (cattle) keeping practice, whereby the animals are grazed during day time and returned to the kraals during the night, leading to small amount of manure that can be collected. Lack of sufficient grazing land and absence of zero grazing culture might also have discouraged farmers in Idifu despite facing shortage of wood resources and low fertility in their farms. It was expected that since farmers in Ilakala selected the use of byproducts for bioenergy would also have chosen production of biogas but that was not the case. The only reason could be that livestock keepers in this village are imigrats who have ventured into farming very recently and have no influence on decision making on matters where majority are purely crop farmers. However, due to the forecasted potential of biogas production and utilization, this UPS will be considered as an add-on whereby a PhD student will be involved, and probably would integrate it with other potential energy sources.

On-farm wood supply that was chosen for Ilolo is a result of relative scarcity of cooking energy compared with Idifu. However, being in a semi-arid area, both villages will need to improve the availability of wood or alternative energy resources instead of depending on the fast depleting forest resource.

Although the task teams did not consider improved cooking stove to be a priority in all the four CSS, it was proved by the farmers in all the villages to be among the priority UPS. This indicates that either the available cooking stoves/ methods are inefficient or farmers would like to use technologies that make use of small amounts of biomass. Farmers in Ilakala and Ilolo villages where previous dissemination efforts did not yield fruitfull results would need further training on making of better stoves or better utilization of what is already available. Fresh dissemination is required in Changarawe and Idifu where no previous dissemination effort is known to have taken place.

Byproducts for bioenergy production, improved processing, improved wood supply and improved cooking stoves were finally in the whole trans-SEC project referred to as UPS 2, UPS 3, UPS 4, and UPS 5, respectively. Refer Table 4.

Table 4. The selected UPS per village

UPS	Ilakala	Changarawe	Ilolo	Idifu
1. Rainwater harvesting &Fertiliser micro-dosing &Optimised weeding	✓ (tiedridges)	✓ (tiedridges)	✓ (infiltrationpits)	✓ (infiltrationpits)
2. Byproducts for bioenergy	✓			
3. Improved processing	✓(maize sheller)	✓(maize sheller)	✓ (millet threshing)	✓(millet threshing)
4. Improved wood supply			✓	
5. Improved cooking stoves	✓ (training)	✓	✓ (training)	✓
6. New product development			✓(sunflower oil pressing)	✓(sunflower oil pressing)
7. Optimized market oriented storage	✓	✓ (training)	✓ (training)	✓ (training)
8. Poultry-crop integration		✓		
9. Market access system (m-IMAS)	✓	✓		
10. HH nutrition education &Kitchen garden training	✓	✓	✓	✓
UPS groups (total)	**7**	**7**	**7**	**6**

The four UPS mentioned above (2, 3, 4 and 5) are directly under WP 6 where the implementing task teams are multidisciplinary in nature. However, due to technical synergies within the Trans-SEC project WP 6 will also be part of implementation of UPS 6 (storage technology) and UPS 7 (sunflower oil processing technology) under WP 7.1.

3.1.2 UPS Future Implementation plans

Through technical meetings and dilagues the detailed implementation plan for each UPS is summarized as provided in Tables 5-11.

3.1.2.1 UPS no. 2: Byproduct for Bioenergy

Implementers: Simon Munder, Sebastian Romulli, Valerian Silayo, Yusto Yustas, Jeremia Makindara, and Claude Maeda

Case Study Site/Village: Ilakala

Table 5. Future implementation plan for UPS 2

s/n	Activity	Institution	Duration (months)											
			12(2014)	1-3	4-6	7-9	10-12(2015)	1-3	4-6	7-9	10-12(2016)	1-3	4-6
1	Redesign and rebuilding of the reactor using size of materials available in Tanzania	UHOH	x										
2	Field measurements at Hoheinhem?	UHOH		x									
3	Manufacturing of the redesigned reactor in Tanzania	SUA		x									
4	1st round of field and laboratory measurements of feeding materials and testing of the reactor in Tanzania	SUA		x									
5	Feasibility study (availability and collection of byproducts, competition with others, performance, marketability of device and biochar products)	SUA		x									
6	Implementation (participatory training, generation of dissemination materials)	SUA and UHOH			x	x	x						
7	Monitoring	SUA			x	x	x	x	x	x	x	x	
8	Ex-post assessment	SUA				x							
9	Analysis and report writing	SUA		x	x	x	x	x	x	x	x	x	x

3.1.2.2 *UPS no. 3: Improved Processing*

(a) Maize sheller

Implementing scientists: ValerianSilayo, Yusto Yustas, Jeremia Makindara, Claude maeda, and Nixon Elly.

Case Study Site/ Village: Changarawe & Ilakala

Table 6. Future implementation plan for UPS 3(a)

s/n	Activity	Institution	Duration (months)										
			12(2014)	1-3	4-6	7-9	10-12(2015)	1-3	4-6	7-9	10-12(2016)	1-3	4-6
1	Planning, collection of baseline data and generation of a business plan	SUA	x	x									
2	Selling the business plan for successful financing	SUA, MVIWATA		x									
3	Implementation (Purchase the machine, installation and training at the CSSs) or move to alternative enterprise in case of non-funding, e.g., poultry.	SUA, Supplier		x	x								
4	Monitoring	SUA		x	x	x	x	x	x	x	x	x	
5	2nd wave of survey/ ex-post assessment	SUA				x							
6	Analysis and report writing	SUA		x	x	x	x	x	x	x	x	x	x

(b) Millet/sorghum threshing/cleaning machine

Implementers: Valerian *Silayo, Yusto Yustas, Jeremia Makindara, Claude Maeda, and Nixon Elly*

Case Study Site/Villages: Ilolo & Idifu

Table 7. Future implementation plan for UPS 3(b)

s/n	Activity	Institution	Duration (months)										
			12(2014)	1-3	4-6	7-9	10-12(2015)	1-3	4-6	7-9	10-12(2016)	1-3	4-6
1.	Planning, collection of baseline data and generation of a business plan	SUA	x	x									
2	Selling the business plan for successful financing	SUA, MVIWATA		x									
3	Implementation (Purchase the machine, installation and training at the CSSs) or move to alternative enterprise in case of non-funding, e.g., poultry.	SUA		x	x								
4	Monitoring	SUA		x	x	x	x	x	x	x	x	x	
5.	2nd wave survey/ ex-post assessment	SUA				x							
6	Analysis and report writing	SUA		x	x	x	x	x	x	x	x	x	x

3.1.2.3 UPS no. 4: Improved Wood supply

Implementers: Götz Uckert, Mathew Mpanda, Anthony Kimaro

Case Study Site/Village: Ilolo

Table 8. Future implementation plan for UPS 4

s/n	activity	Institution	Duration (months)										
			12(2014)	1-3	4-6	7-9	10-12(2015)	1-3	4-6	7-9	10-12(2016)	1-3	4-6
1.	Validation of baseline survey and situation analysis	ZALF, ICRAF	x										
2.	Find and engage an MSc student	ICRAF	x	x									
3.	Identify tree species experts for the nucleus group	ICRAF									x		
4.	Implementation (training and capacity building on nursery setting and tree planting)	ICRAF, ZALF		x									
5.	Monitoring	ICRAF		x	x	x		x	x	x	x	x	
6.	2nd wave survey/ ex-post assessment	ICRAF, ZALF					x						
7.	Analysis and report writing	ICRAF, ZALF		x	x	x	x	x	x	x	x	x	x

3.1.2.4 UPS no. 5: Improved stoves

Implementers: Götz Uckert, Mathew Mpanda, Anthony Kimaro

Case Study Site/Village: Changarawe & Idifu (Ilakala & Ilolo reduced M&E)

Table 9. Future implementation plan for UPS 5

s/n	Activity/Milestone	Institution/Role	Schedule /Duration (months)										
			12(2014)	1-3	4-6	7-9	10-12(2015)	1-3	4-6	7-9	10-12(2016)	1-3	4-6
1.	Validation of baseline survey and situation analysis	ICRAF, ZALF	x										
2.	Find and engage an MSc student	ICRAF		x									
3.	Identify expert for the nucleus group						x						
4.	Implementation through training and capacity building			x									
5.	Monitoring			x	x	x	x	x	x	x	x	x	
6.	ICS-TSF contest					x	x	x	x	x	x	x	
7.	Ex-post assessment					x							
8.	Analysis and report writing			x	x	x	x	x	x	x	x	x	x

In UPS 2-5, implementation will be through groups of farmers selected from the 150 households that were involved in the baseline household survey. It is anticipated that groups of 20-40 farmers will be involved.

3.1.2.5 Linkages with WP 7.1

Implementation plans for WP 7.1 in two UPS, which are *New Product Development – Sunflower oil processing* (UPS 6) and *Profitable and Market Oriented Storage* (UPS 7) are as provided in tabular form below.

(a) UPS no. 6: New product development (sunflower oil processing)

Implementers: Valerian Silayo, Simon Munder, Sebastian Romulli,.......

Case Study Sites/Villages: Idifu and Ilolo

Table 10. Future implemntation plan for UPS 6

s/n	Activity	Institution	Duration (months)										
			12(2014)	1-3	4-6	7-9	10-12(2015)	1-3	4-6	7-9	10-12(2016)	1-3	4-6
1.	Planning	SUA	x	x									
2	Mini-survey (baseline)	SUA, MVIWATA		x									
3	Implementation (Purchase the machine, installation and training at the CSSs) or move to alternative enterprise in case of non-funding, e.g., poultry.	SUA			x	x							
4	Monitoring	SUA			x	x	x	x	x	x	x	x	
5.	2nd wave survey/ ex-post assessment	SUA					x						
6	Analysis and report writing	SUA					x	x	x	x	x	x	x

(b) UPS no. 7: Profitable and Marketable Oriented Storage

Implementers: Valerian Silayo, Simon Munder, ...

Case Study Site/Village: Ilakala

Table 11. Future implemntation plan for UPS 7

	Activity/Milestones	**Institution**	**Duration (months)**										
			12 (2014)	1-3	4-6	7-9	10-12 (2015)	1-3	4-6	7-9	10-12 (2016)	1-3	4-6
1	Planning		x	x									

2	Min/participatory-survey (baseline)			x									
3	Implementation (including training)				x	x	x	x	x	x	x	x	x
4	Monitoring				x	x	x	x	x	x	x	x	x
5	Min-survey (post)											x	
6	Reporting											x	x

3.2 Baseline and general survey results

3.2.1 Byproducts for bioenergy production

Agricultural waste product can be categorized into materials for disposal or materials with usefull value to the human livelihood, which are referred to as byproducts. Waste can be generated from crops and livestock production at various stages of the value chain. Though not directly linked to agriculture, human faeces are also an important waste, which can be used depending on social-cultural practices.

Waste from crops can be categorized into on-farm and processing wastes. From the Trans-SEC project set-up, the target crops are maize and sesame in Kilosa district (Morogoro region) and sorghum, bulrush millet and sunflower in Chamwino district (Dodoma region). Byproducts from maize include maize stover in the filed, maize cobs after shelling, and chaff after manual winnowing of the shelled grain bulk to obtain clean grain. The chief uses of maize stover is self-recycling in the field as soil biomass and grazing by livestock. According to Maithel (2009) the amount of maize cobs can be estimated from production figures (Appendix I), using the following equation:

$$RP = GR \times RPR \qquad (7)$$

where:

RP = Residues production (tonnes/year)

GR = Grain production (tonnes/year)

RPR = Residue-product ratio

From the baseline household survey data, information on maize production was obtained from 142 households in each of Ilakala and Changarawe villages, whereby mean production per household was about 874 kg and 1,134 kg, respectively. The National Census data of

2012 (NBS, 2012) estimates the number of households in Ilakala and Changarawe at 770 and 688, respectively. From the RPR of 0.18-0.27 based on dry weight residues provided in Kishore (2008) the mean RPR of 0.23 can be used to estimate production of cobs. Therefore, production of maize cobs per household can be estimated at 201 and 261 kg for Ilakala and Changarawe, respectively. Therefore, assuming that every household in the study areas is involved in maize production the estimated production of maize cobs in Ilakala and Changarawe villages was about 154,785 kg and 179,444 kg, respectively. This data could be used as a basis for investment on use of maize cobs either at the household level or groups of farmers.

As the produced cobs may be used to produce household energy the equivalent amount of fuelwood and other energy sources that can be served needs to be established. However, maize cobs are rarely used as they burn very fast and produce unsuitable soot that makes them unsuitable for use unless conversion methods to suitable forms or improved use methods are devised. Technology for pyrolizing maize cobs for direct heating and production of biochar has been devised at UHOH and will be ready for testing after downsizing to suit available manufacturing materials in Tanzania. Sucessful testing and dissemination will lead to reduced consumption of wood from natural forests but will depend on how long the maize cobs will last upon using the disseminated pyrolysis technology. Note that there is no known use of maize chaff as a source of energy.

With regard to sesame, the straws are just left to decompose or burnt at the threshing sites. The ash obtained from burning could be used to improve soils but this practice is rare and yet to be experimented. Burning contributes to environmental pollution but no study has been done to compare the effect of burning and direct disposal of this crop's residues.

Similar with maize, sorghum, bulrush millet and sunflower stover are left to decompose on-farm or grazed by livestock. The threshed heads of sorghum, bulrush millet and sunflower and the chaff obtained from winnowing have been used for soil improvement by burrying them in the dug out trenches (Ilolo Village), some of them are just burnt or disposed-off by dumping. The solids which result from local brewing that make use of sorghum is used to feed livestock as it contains essential ingredients. Processing of sunflower into oil which is rarely practiced in the CSS results in energy-rich cake, which is an essential ingredient in compounding livestock feeds.

Waste from livestock includes excreta from cattle, goats, poutry, and pigs, which can be used to generate biogas or used as organic fertilizers but the amounts produced are difficult to quantify, especially for cattle which are normally grazed. From the literature, biogas production is mostly suited to cattle dung (Bond & Templeton, 2011; Silayo, 1992) but there are no operational biogas plants among the existing plants that were visited in all the CSS in Kilosa and Chamwino districts. Collection of livestock manure for improving soil fertility is not common. However, a few livestock keepers available in these villages are not grouped into crop farmers and are not well integrated due to conflicts especially in Kilosa district. It also follows that a very few of them are included within the group of farmers selected for the project in some CSSs.

Human faeces could be collected and used for bio-energy production but the idea faces four constraints: (i) Movement of human beings is not static, hence difficult to quantify the amount of faeces produced (ii) Production of faeces is seasonal-dependent as during food surplus periods people tend to eat more and vice versa (iii) It may be socially unacceptable to handle and use human faeces for any productive work (Mjema, 2014; Buxton,2010) (iv) The human waste sanitary system does not exist, hence most of the faeces is collected at individual household level or community level pits, from which it can be culturally difficult to draw and feed a biogas plant. From these facts investing in human faeces conversion system requires in-depth scientific research and long-term cultivated interest.

In all the CSS, household energy is mainly derived from solid fuels including wood from natural forests and rarely on wood lots. Crop residues are rarely used to provide household energy. In Idifu and Ilolo CSS in Chamwino district, solid fuels from natural forests are available at very long distances and are depleting very fast. This threatens the environment unless suitable mitigation measures are taken. Crop byproducts could be used to provide household energy but the practice is rare and mostly such byproducts are left to decompose in the field or fed to livestock during grazing. Note that although maize is not a priority crop in Chamwino district, maize cobs are traded as an important livestock feed within the villages.

3.2.2 Improved processing and storage

3.2.2.1 Kilosa district

The crops of choice for intervention in Kilosa district are maize and sesame. From the household baseline survey, yearly production of maize in the entire villages of Ilakala and Changarawe villages is estimated at 673 and 780 metric tones, respectively. The harvested maize is transported to the household premises for safety while waiting for processing and completion of drying. Processing of this crop into grains is done manually mainly by shelling the dry cobs on a slated raised platform and the grains are collected on the ground. The shelling is done by use of a relatively heavy stick by the family members but the performance rate, suitable moisture content, grain quality, and losses accrued from this process are not yet established. Shelling is mainly performed at the household level by all gender. However, labour profile distribution in the study areas is not yet documented.

Secondary processing of maize is only through milling into whole maize flour for household consumption by using diesel powered milling machines. This is the mostly available processing technology allover Tanzania and mostly owned by village level entrepreneurs. However, the number of milling machines at Ilakala and Changarawe has yet to be established. In other areas dehulling preceeds milling into flour, a process that removes the germ and the hull, both of which are essential in maintaining nutrional status of maize floor for human consumption. Therefore, the process is not favored by nutritionalists and is not available in the Case Study Sites. A 20-25HP grain milling machine (complete with motor or engine) costs about USD 1400. Where dehulling is practiced, for example in urban areas, the bran obtained is an essential ingredient in compounding energy-rich animal feeds. In Uganda, the normal price of maize bran is U Sh 100 per kg at the level of poultry and livestock keepers and manufacturers of feed meals (Ahmed, 2012). However, in Tanzania there is no reliable data on the price of maize bran available.

Sesame is harvested by cutting the straws, which are tied into bundlles and made to stand at an angle against a standing tree or any other method of leaning them at an angle. After a few days the seeds will appear relatively dry and stripped off from the bundles by manual beating. The seeds are stored in bags ready for selling to other entrepreneurs. There is no processing of sesame seeds into oil known to exist in this district.

Storage, which is part and parcel of processing, is faced with several challenges, including low efficacy of pesticides, high resistance of some of the storage pests like *Prostephanus tranchantus*, unsuitable storage systems, and lack of incentives for improved investment in storage. As communal or cooperative storage may require very high investment in additional to management problems accruing from the past history of cooperative societies management individual household level storage may suffice. The amount of maize that may require storage at the household level as generated from the household baseline survey is estimated at 874 and 1,134 kg in Ilakala and Changarawe, respectively. However, suitable and optimized storage systems must be given attention for both food and seed grains.

3.2.2.2 Chamwino district

In Chamwino district the study was done in Idifu and Ilolo villages where the crops of choice are sorghum and bulrush millet and sunflower. Based on the NBS (2013) the number of households is 1169 and 1251 for Idifu and Ilolo, respectively. From the household survey data the corresponding production capacity of threshed sorghum is estimated at 310 and 2317 metric tonnes at Idifu and Ilolo, respectively. With regard to bulrush millet, production is estimated at 260 and 1,327 metric tonnes for idifu and Ilolo, repectively. These crops are used for household consumption and also traded for food uses or alcohol production for sorghum in particular. After harvesting, the millet and sorghum heads are threshed manually but the work rates, moisture content, losses, and grain quality are not yet established. Use of sorghum for producing alcohol results in a pulp that is used to feed livestock. However, the quantities involved and the nutritional qualities have not been established. Moreover, this business is done by very few individuals.

With regard to sunflower, production is estimated at 109 and 674 metric tonnes in Idifu and Ilolo villages, which may correspond to single refined oil of about 28,000 kg and 175,000 kg, respectively assuming that all the oil (26% oil) is extracted. However, this extraction rate is seldomly achieved as most of the oil remains in the cake that comprises the seed hull. Prior to oil extraction, sunflower seeds are removed from their heads by simple beating on the ground but the effect of this method on quantity and quality of the seeds obtained is not yet established. The currently practiced technology of sunflower extraction uses a diesel-powered mill, followed by cloth filtration or mechanical filter press, and a little bit of heating with salt and water as admixtures. A few sunflower oil processing machines exist in the nearby areas though their exact number is not yet established but farmers would wish to process their own seeds in order to realize higher income from their produce. However, the oil processing technology available in these areas does not result in good oil recovery since a good amount of oil remains in the cake. Near complete recovery can be attained by using solvent extraction on the cake but the technology is sophisticated and expensive to be acquired and operated at a rural set up. Furthermore, the technology of removing the hull before extraction which greatly increases oil recovery does not exist at the small-scale processing level.

3.2.3 Improved wood supply/tree planting

In this section, the background situation based on several FGD was established in the four Trans-SEC case study villages in September 2014 is presented. On the one hand this information was an indicator that prompted the selection of this UPS by the villagers and on the other hand it may enable the in-depth interpretation of quantitative and qualitative analyses of the baseline survey data. The focus was to understand the following four issues: (i) Origin of cooking energy especially firewood sources (own plots, communal forests, markets, etc.), (ii) Extent of firewood (and charcoal) consumption, (iii) Impact of distance to firewood collection sites on social and economic situation, and (iv) Storage strategies and conditioning of firewood.

Analyses will contribute to develop scenarios which cope with firewood scarcity leading in turn to jeopardizing the cooking energy supply.

3.2.3.1 Overall population of trees in the CSS

The following tables (Tables 12 & 13) of preliminary results outline the current situation of trees on own plots as mentioned by households in the baseline survey. These will act as a benchmark for additional survey and analyses to assess the possible contribution of on-farm trees to sustainable energy consumption of households derived from UPS-Implementation.

Table 12: On-farm trees owned by households (Preliminary results from household baseline survey)

Village	1 Changarawe	2 Ilakala	3 Nyali	4 Ilolo	5 Ndebwe	6 Idifu
N=	50	78	86	56	73	68
(missing)	29	30	37	31	22	18
mean	14	21	10	57	17	26
SD	9	9	6	13	11	18
Min	1	1	1	1	1	2
Max	140	200	103	809	143	192

The low average rate of tree planting activities in all villages mirror low awareness and interests in the issue of tree planting. However, villagers in FGD showed increased consciousness towards tree planting due to scarcity of firewood.

Table 13: On-farm trees planted last year by households (Preliminary results from household baseline survey)

Village	1 Changarawe	2 Ilakala	3 Nyali	4 Ilolo	5 Ndebwe	6 Idifu
N=	50	77	85	51	65	61
(missing)	29	31	38	36	30	25
mean	2	2	1	5	1	1
SD	0	0	0	0	0	0
Min	0	0	0	0	0	0
Max	70	70	46	80	10	20

3.2.3.2 Brief background on forest issues in both Idifu and Ilolo

In the mid 1990s, the area around Idifu and Ilolo villages was covered by forest. This area was protected by the HADO (Hifadhi ya ardhi Dodoma-a land conservation initiative) programme, which was originally put into practice in 1986 and funded by Germany through GTZ. Via this initiative villagers from the surrounding settlements were prohibited from keeping livestock/ cattle and intruding the forest for agricultural activities. In the late 1990s and early 2000s however, HADO initiative started to become increasingly weak – anecdotal evidence refers to political manipulation (some political leaders sought vote on expenses of degrading natural resource, forest so to say by allowing overgrazing and unsustainable agricultural activities in forest area).

(a) Forest and firewood situation in Ilolo

The village of Ilolo is located in Chamwino district, close to the township of Mvumi mission. It is now surrounded by deforested hills. The degradation of forest is occurring very fast. Within a few years (5-7) vast areas of forest have been cleared.

Through FGD it was revealed that there is no protected communal forest and there is no data available specifically on the acreage of remaining other forests for firewood collection. However, forests on communal land, which are open for legal firewood gathering, were identified. These places are hilly areas encircling the village (see following Resource Map of

Ilolo). It was stressed that those hilly places are also used by residents of other villages. It was also reported that, Ilolo village population is, due to proximity, using the hilly places for firewood collection more often than other villages.

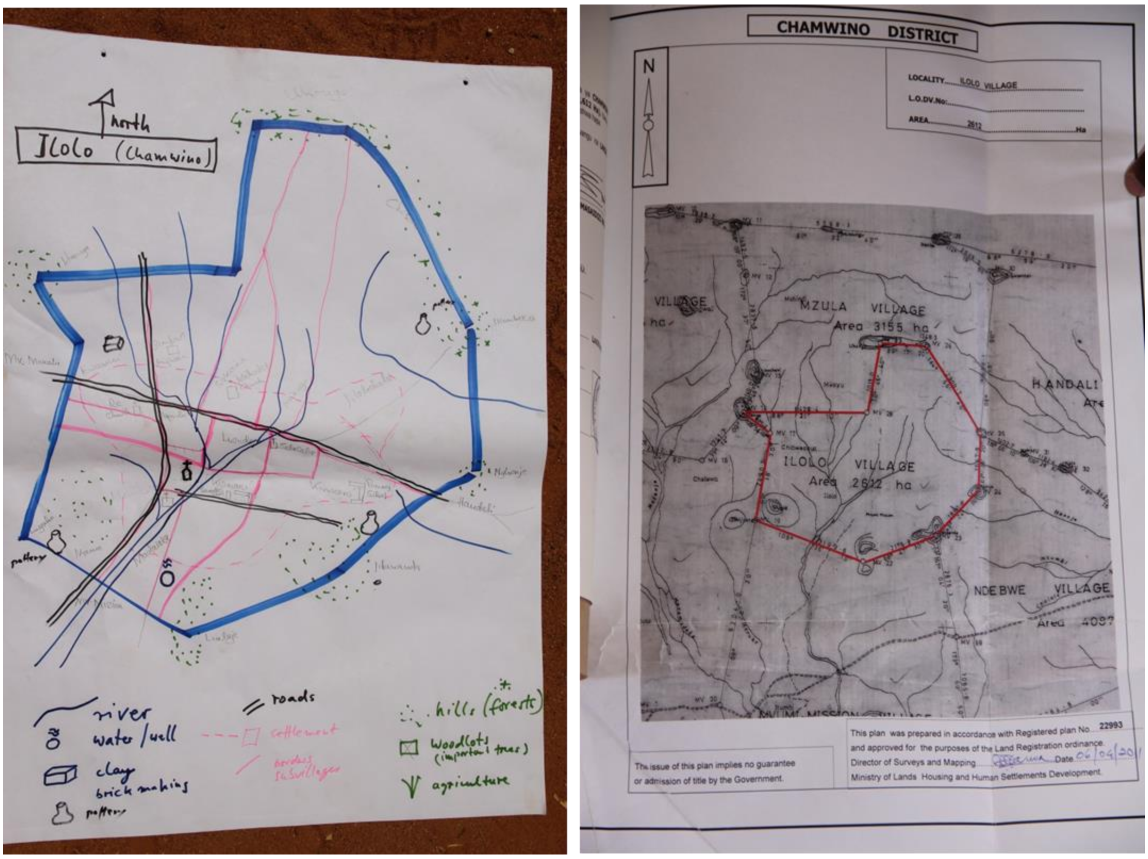


Figure 13: Resource map of Ilolo, places for main ICS materials (bricks, clay and water)

The map was drawn to outline (a) sub villages, (b) location of forests, (c) soil types,(d) hill tops, (e) wells, (f) schools, (g) sub villages (12), (h) pottery, (i) soil-clay, and (j) brick making. However, it was tedious work to locate the boundaries of sub villages.

According to the baseline survey of the households 10% need less time, 17% the same time and 72% need more time to fetch firewood compared to five years ago. These results were confirmed by the participants of the FGI. The households presently using less or same wood collection time were assumed to lack awareness on firewood importance (not collecting themselves or rich households using charcoal) or a likely proximity to the last existing source of firewood in the village, which is the mango trees.

When interrogated on how long firewood resources will last if no intervention will take place, the villagers answered that apparently the firewood is almost finished, especially the one on hilly side sections (Mihongo and Misami), which were usually used for firewood collection. FGD participants assumed that firewood crisis is on the way to escalate.

Deforestation in Ilolo was attributed to some villagers conducting agriculture activities (growing crops) in those former forests which led to tree felling (case of weakened HADO as already explained). In an attempt to mitigate the situation a specific regulation was set by the district council and implemented by wards and the villagers who were tasked to discipline the defaulters through fee/charges. There is also an environmental committee at work but participants of the FGD were of the opinion that tree felling will noticeably decrease and lead to possible reforestation in the area only if education on importance of tree planting/agroforestry is provided for all the people and everybody is involved on protecting the planted trees (especially due to ownership). Strategies of the village to cope with the high demand of firewood (e.g., willingness to participate in agroforestry in Ilolo; tree planting activities) were discussed in controversy to the usual practices. Currently, in Ilolo village there are no improved (bred) tree species for planting. The only thing that was done was to assist the re-growth of traditional trees (maotea ya asili) by protecting them by using thorns. Interestingly, it was argued that villagers who do not participate in planting and protecting trees benefit more.

The Mazengo-Group

The group has 16 active members, 3 dormant member, and sex ratio of 11 men to 8 women. Membership per sub village was distributed as follows: 0 in Malicela, 0 in Kivukoni, 1 in Kisimani, 1 in Lusinde, 2 in Mapinduzi, 2 in Sabasaba, 0 in Mazengo, 0 in Nyerere, 1 in Sokoine, 2 in Jamhuri, 0 in Madaraka, and 10 in Bwawani subvillages, consisting of some bee-keepers. It was decided (after initial push by mission of the catholic church) to establish a tree nursery for growing trees at a hill top within the village for tree planting and put in place bee boxes. The proposed types of tree species and their intended use were: (a) Mitimaji (shade, bee boxes, firewood), (b) Uzazi wa mpango (shade, bee boxes), and (c) an unknown species (flower for bees, firewood, bee boxes). The nursery is a joint venture together with Ilolo secondary school. The later is providing watering service and the area for the tree nursery. The main challenge was water supply management, leading to poor survival rates of the trees at the nursery. Currently, the water supply of the whole village costs 400,000 TSh per month and water is purchased at 50 TSh per bucket.

Trans-SEC contribution on Tree Nursery establishment

On 23rd – 25th October 2014 ICRAF conducted training on tree nursery establishment and management at Ilolo, Chamwino District, in Dodoma. The objective of this training was to increase capacity on establishing and managing tree nurseries. The training was conducted at Ilolo village for three days including important techniques such as: (a) key site preparation activities, (b) practical training on substrate mixing processes, and (c) filling process of substrate into the poly bags. Additionally, some group members were trained and practically engaged in arranging filled poly bags into beds while other group members were trained on handling and direct sowing of seeds in the poly bags. Species selected for raising a nursery at Ilolo are found in Table 14.

Table 14: Important species raised in the Ilolo nursery

Species name	Uses
Tectonagrandis	Timber, poles, fuelwood
Khayaanthotheca	Timber, poles, building material
Gliricidiasepium	Soil fertility, fodder
Afzeliaguanzensis	Timber, poles, building material
Terminalia mentaly	Shade, ornamental
Acacia nilotica	Fuelwood, soil fertility, fodder
Caesalpiniapulcherrima	Live fence
Albizialebbeck	Poles, fuelwood
Entandrophragmabusse	Timber

During the three days of training only less than eight members of the Mazengo were found to be very firm in constant practice. Therefore, a follow up has to allow combination of both groups, the Mazengo and the UPS-Group of “Improved wood supply” of Trans-SEC. This was aimed at additionally encouraging tree planting in Ilolo.

(b) Forest and firewood situation in Idifu

For accessing additional information on top of the baseline survey the Trans SEC project conducted two FGD on bioenergy-wood supply and ICS. Currently, there is no protected forest owned by the Idifu village. Forest degradation and deforestation is occurring very fast. Specific data on the forest acreage is not available. Everybody is allowed to fetch firewood and cut trees in communal forests or other communal areas (hilly areas which are located at the south side along the village border or even beyond). Apparently this source of firewood has dwindled due to unsustainable consumption. The current forest is commonly used by all villages surrounding the mountains for firewood collection. If no intervention occurs, firewood will not be available any more within a period of 1-5 years, according to the villagers. The main reasons for depletion of forest resource were agriculture (growing crops) and grazing activities. Additionally, houses at the foothills are increasingly affected by erosion.

When requested to provide their views on how deforestation could be decreased the FGD participants proposed the following measures, although they look controversial to what is generally practiced:

(i) Reduction of the current carrying capacity of cattle. Consensus among farmers with regard to the number of cattle to keep could not be achieved due to different involvement in livestock keeping (numbers varied between 5 and 20). This social/environmental conflict seems to be increasing as some farmers even left the meeting.

(ii) Tree planting to stop erosion.

(iii) Research to come up with new ways to stop degradation, but not by enforcing HADO again. It was argued that HADO deprived them from an important income source (selling livestock) and from an energy source for transport and cultivation (cow carts, oxen plough). Some farmers stated that pastoralism was their main economic activity.

The village has set up strategies to lessen the high demand of firewood from the forest. One of them was to strengthen the environmental committee, which is already existing but not active due to lack of funds or income. Another possibility that was pointed out was for everybody to be actively participating in tree planting, reforestation and increases of trees in the area. The baseline survey results indicate that of all HH 6% needed less time, 15% the same time, but 78% needed more time to fetch firewood compared to the situation within the last five years. The villagers participating in the FGI confirmed these results. For those who said that time increase is not an issue, they argued that some of them might have misunderstood the question. It was furthermore stated that decreases in firewood collection time are non-realistic and speculation were that the question was either misunderstood or that the interviewees were not involved in firewood collection. Lastly, it was argued that others might be those who are buying firewood from other villagers. To illustrate this argument the participants of the FGD outlined in length that previously 4 hours were spent daily for firewood collection. Currently, however, 5 hours are spent in two days for firewood gathering as now, the women have to go to the forest on the first day, cut a tree and collect firewood on the following day. In summary, the overexploitation of forest resources for firewood collection has resulted in even more devastating tree cutting practices. As outlined the time to reach forests for villagers of Idifu is long. Additional information on distances to the forest and time for firewood collection is exemplary shown in the resource map below.

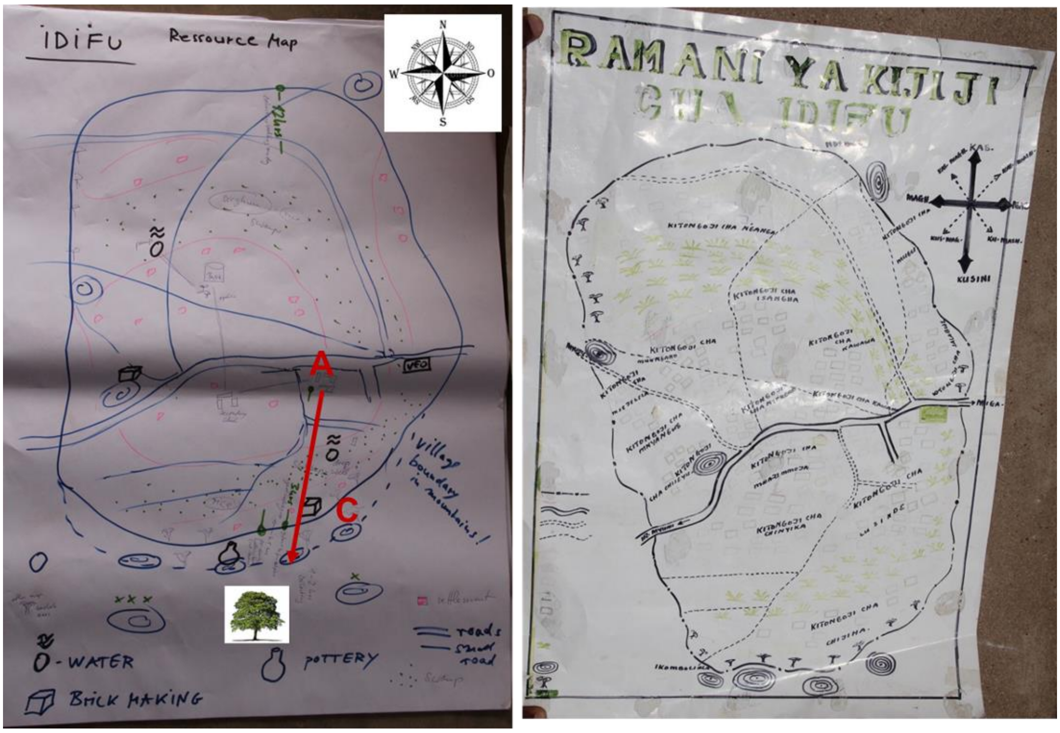


Figure 14: Resource map of Idifu, places for main ICS materials (bricks, clay and water). Example: 3hrs walk from primary school A to forest in first southern mountain range, 2 hrs of collecting, packed with head-load the trip back is 4-5hrs (including resting).

The previously existing forests used for firewood collection in the mountains bordering the village in the South are now completely depleted. Villagers have to go to the next mountain range, which is shared by three other villages too.

It is difficult to estimate the area required for tree planting to allow sustainable consumption of firewood on the one hand and to meet the total wood demand on the other. The main reason is that the village and forest areas are not surveyed in detail. Currently however, agroforestry is not practiced in the village. Education is nevertheless provided for all villagers on the importance of tree planting/agro-forestry expecting that villagers will plant and protect trees. Among the villagers, thosee who are not interested in tree planting are more than those who are interested.

There is no nursery in the village, but the farmers are interested in establishing a sustainable group for tree planting. As a precondition villagers agreed on the need for implemented and enforced by-laws, which have to ensure tree planting and protection of trees. A stepwise introduction of tree planting as well as close connection to the tree planting group in Ilolo is highly recommended. Due to water shortages in Idifu the nursery of Ilolo has to be carefully extended.

(c) *Firewood collection situation in Ilakala*

One of the outcomes of the baseline survey was that firewood collection time has increased compared to the situation five years ago (about 7% HH needed less time, 28% the same time, but 62% needed more time to fetch firewood). Based on these results discussion with the 10 participants of the FGD consisting of leaders of the village (1) and sub villages (4), a village extension officer (VEO) (1) and members from the environmental committee (4) was held to analyse the situation on forest resources and firewood.

Ilakala village has a forest reserve of about 1000 ha where bee keeping is also practiced. There are still forests to collect firewood in the village (communal lands) but time for collecting firewood has increased. In FGD, women outlined that four hours for firewood collection for households located in the centre of Ilakala (Shuleni) has to be separated into time to reach the forest (1 ½ hr), the collection time of about 1 hour (because they have to look for remaining pieces) and 1 ½ hours to return; time for the whole trip exceeds six hours when the woman has to carry a baby. According to this situation they stockpile firewood for occasions like sickness or heavy rains.

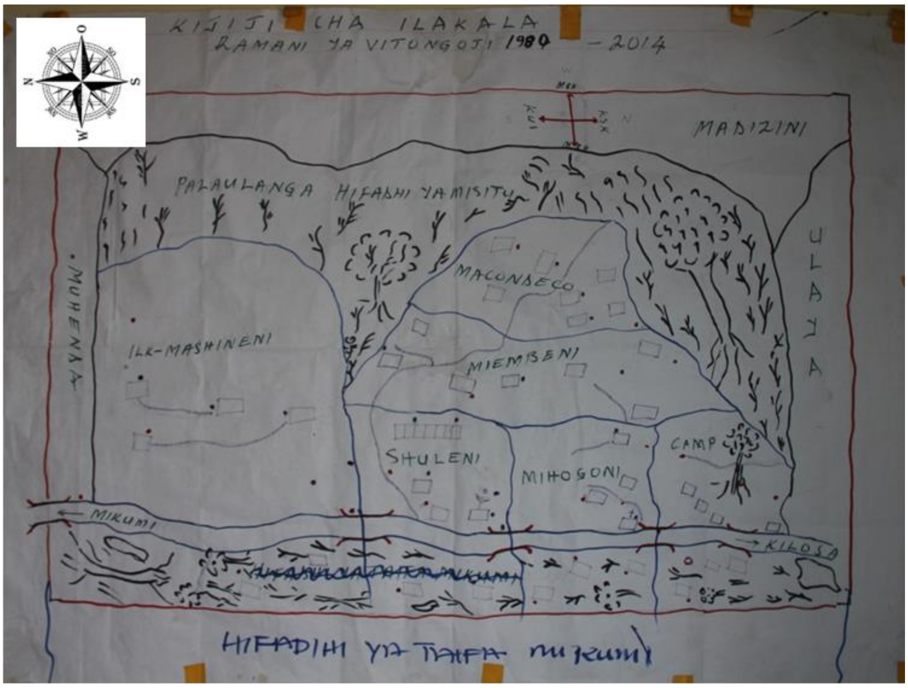


Figure 15: Resource map of Ilakala, places for main ICS materials (bricks, clay and water). Example a) 2hrs trip from household A (sub village of Mihogoni, close to the road) as well to forest in eastern part of sub village. Example b) 2hrs trip from household B (sub village of Shuleni) and household C (sub village of Miembeni) to village forest in the north-east.

The FGD group mentioned the relevance of brick burning for the need of firewood as many villagers build up modern houses. The alternative usage of rice husks (residues from paddy growers) to burn bricks was discussed. In addition, this situation was discussed in comparison with Changarawe village where it was established that 75% of the people live in houses with grass thatched roofs, implying that their use is more on poles and sticks for roofs and poles for the walls.

A coincidence whereby FGD and group formation took place on the same day at the same time (morning hours) led to an exceptional outcome. This was contribution of the FGD to the process of the UPS Group formation through awareness rising and training in basic knowledge on ICS (improved cooked stoves).Together with the selected 20 UPS group members discussion on needs for further improvements on already established ICS at a few households at Ilakala was held.

(d) Firewood collection situation in Changarawe

In the FGD participants stated a decrease of firewood in the village forest. Before a few years there have been plenty of wood. The time to reach forests for villagers of Changarawe is comparatively longer because of: (i) not living within the former village boundaries and (ii) shorter distance to next urban settlement of Kilosa. Only womenn go to fetch firewood, which takes approximately 5 hours. Based on baseline survey it was further learnt that firewood collectionn time has increased compared to the situation 5 years ago as 13% of HH needed less time, 14% needed the same time, but 58% needed more time to fetch firewood.

The participants ranked the importance of factors leading to the decrease of availability of firewood as follows: (i) charcoal making, (ii) opening of new farms, and (iii) timber sowing. Although the size of the forest is unknown they are very conscious about the impact of charcoal making. In the FGD it was categorically stated that if no intervention will take place, in 2020 the forest will be completely depleted. There will be no trees anymore, whether small or large ones. In turn they projected that the forest could be sustained until 2020 only if charcoal making business will cease. Charcoal trading is done by business men and before felling trees for charcoal valuable trees of the forest stand are sold to timber traders. Villagers will come and start farming after clearance of the land has been done purposely or after timber and charcoal production have taken place. If the soil is of good condition for farming even more people may come from outside the village. A recent initiative (4 years ago) on tree planting offered training in growing teak but failed due to lack of tree seedlings and low awareness. Additionally, it was noticed that villagers cooperate with outsiders for destructing the forest.

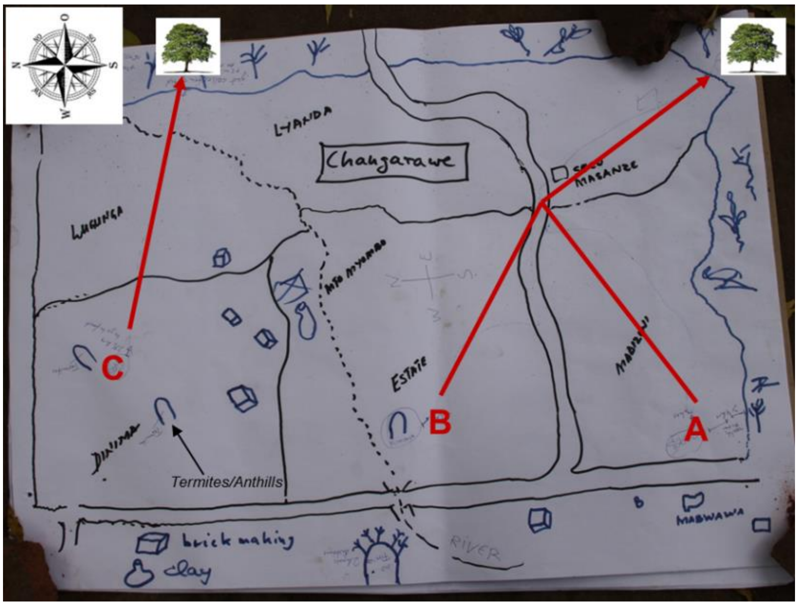


Figure 16: Resource map of Changarawe, places for main ICS materials (bricks, clay and water). Example a) 3hrs trip from household A (subvillage of Madizini, close to the road) as well as from household B (subvillage of Estate near termite-anthill) to forest in south-eastern mountains. Example b) 4hrs trip from household A (subvillage of Madizini, close to the road) with bus (2000 TSh fee) to forest in southern mountains. Example c) 2 ½ hrs trip from household C (subvillage of Dinima, far from road) to village forest in the east and additional collecting time of 45 -60 min.

There are plenty of possible sources for brick making in the villages. Especially close to the river there are easy to be exploited sites of good soil conditions. In Changarawe there is no pottery by now.

3.2.4 Wood-based biomass utilization (cooking stoves, etc)

In all the four CSS, a quick situation analysis reveals that crop-based biomass is rarely used as sources of heating and cooking. Most of them are left in the field for self-degradation or grazing by animals. This necessitates fetching of wood from around or long distances depending on availability as revealed in the Focus Group Discussion (FGD). Participants of the FGD and the upcoming members of the UPS Group of “Improved Cook Stoves” proposed the name of the group “KIKUNDI CHA MAJIKO BANIFU”. All the participants were involved in the household baseline survey and were ready to organise the group and be trained for their own benefit or become trainers for the rest of the group members and beyond.

3.2.4.1 Best tree species for cooking

Firewood collection in Idifu is selective as there are some of the tree species which are more suited to cooking and others to brewing (traditionally they use green/wet biomass hence tree felling is necessary). The best tree species for cooking include: *muhogolo, mzasa*, and *mkungugu* (local names). Others which are rarely collected due to scarcity are *mkambala, mfuku, mtema, mvugala, nguweli, mtundula, mkakatika, mpelemehe, msungina*, and *mkologogwe*. Usually these are cut at the base near the ground level, with minimal sprouting expected.

3.2.4.2 Issues from FGD with stake in improved cooking stoves

The main type of cooking stove (CS) used was the "three stone stove". However, there exists one type of "improved cooking stove", which is designed by moulded clay replacing the stones. Concerning the cooking energy situation and location it was stated that most of the CS were kept indoor whether in the main house or in a small room outside the main house. The amount of energy required depends on the type of food to be cooked.

List of dishes and time spent to cook

Cooking *Mlenda* relish takes about 30min; *Uwele* (pearl millet) after *mlenda* 30 min; *mtama mweupe* (sorghum) 30 min; *safe-majani ya kunde* (cowpeas leaves) relish 60-90 min; blanching of vegetables 60 min; rice (which is cooked only in some occasions) 60 mins; maize flour (porridge)10-20 min. The quantity of firewood used is proportional to the time spent for cooking.

Most villagers are using clay pots while some use aluminium pots as cooking utensils; size of the pot reflects the number of consumers (e.g., 10 people need as mass of the flour 5 kg per pot). Cooking during ceremonial events, usually between June and July every year, is on a mixture of maize and beans, traditionally known as "*makande*". The meal is prepared during the night and cooked for four hours. The trench (a ditch or long hole) dug on the ground with approximately 20 ^{x} 0.3 ^{x} 0.2 m and the firewood are filled along both sides of the trench. The cooking process may consume 2-3 oxen carts (20 bundles of firewood/oxen cart while 30 kg of firewood/bundle) of firewood.

Issues raised from brewing

About 50 % of villagers are brewing from maize bran and fermented sorghum. One batch of brewing is producing 8 buckets/tins (20 litres each) of the local type of beer (commone), and each tin is sold at 7000 TSh. The process goes through different stages and takes about 12 hrs in total to complete. The first step consumes a lot of firewood (2 bundles) in a short time while the second step consumes only one bundle for keeping heat of the brew for about 6 hours.

Issues raised from salt making

Salt making is done throughout the year. In April-May, 18 kg of salt is sold at 10,000 TSh , while in other months of the year it is sold at only 4,000-6,000 TSh. Additionally, there is a barter system used, whereby 1 kg of salt is exchanged for 2 kgs of sorghum equivalent, which is equivalent to 150 TSh. In salt making, 3-5 oxen carts of firewood are needed per batch. However, the amount of salt per batch has not been quantified. Note that all types of firewood (wet and dry /fibrous and dense) are used for salt making.

Issues raised from brick makers

Brick making business is done between May and November (dry season) while from November onwards agricultural activities take over. Producing one brick can consume up to4 kgs of firewood but this needs to be verified further. Types of bricks made are: mud bricks, fired mud bricks, and sand bricks (cement/sand) but only the fired mud bricks require use of fuelwood. Usually clay sand ratio for mud bricks is 2:1 except where naturally occurring clay soil is molded into bricks and used as is after drying or traditionally fired. They charge 100 TSh per mud brick and 200 TSh per fired brick. Water and clay resources are available throughout the year. Approximately 400 bricks were needed to build one room of a house. Therefore transport is an issue, because of the need to use an oxen cart which can carry 100 bricks and cost 5,000 TSh per trip. They are interested in ICS making.

Issues raised from pottery / pot makers

In pottery business a lot of firewood is needed as four head-loads are burnt within an hour to create the necessary heat for about 420 pots (*size not provided*). This activity is done between June and November. Pottery soil(clay soil) is scarce compared to that for brick making. Therefore, clay soil is collected from hill areas, sieved, pounded, and soaked for 2 days, and then moulded. Pots were dried before firing. Pottery practitioners are also interested in ICS making.

Other issues

Tools required for collection and preparation of firewood are machete, axe and *mundu* (version of machete). Reduction of length and size of firewood is done for cooking (small sized firewood) but for salting and brewing this is rarely done (big sized firewood).

The role of cooking fire for lighting is not an issue as they use kerosene lamps, solar lamps or even very durable dry cell battery torches.

Though not often considered in research, starting a fire in a three stone stove has its own importance. Current practices for lighting-up fires of three stone stoves are (in order of relevance):

(i) Use of plastic bags and match boxes,
(ii) Use of dry grass and match boxes
(iii) Use of already lightened firewood from neighboring household (also very common)
(iv) During rainy season, dry stover from maize and sorghum or any other crop residue kept during dry season are used to light the TSS with match boxes.

The most active time for collection of firewood is between June and November. During the rainy season the number of villagers going to the forest is reduced drastically due to slippery that causes unsafe conditions in the forest. Usually stockpiling is done during the dry season. Since brewing activities require wet/green biomass (burning more slowly and with less heat) firewood is collected throughout the year.

3.3 Prelimary test results

3.3.1 Byproducts for bioenergy production

3.3.1.1 Preliminary test of TLUD reactor

From the preliminary test, it can be seen that both combustible gas and high amount of char can be produced from the reactor. The duration of the operation was 4 hours, and the flame that resulted from combustion in the *after-burner* (Fig. 17) lasted around 2 hours. However, there was formation of tar at the bottom part of the lid. This is a confirmation that the drum cannot be filled entirely with biomass, otherwise there will not be enough space for the gas to escape and may cause blockage of the chimney simultaneously.

Figure 17. Preliminary test (left), produced char (right), and remaining tar attached on the lid of TLUD reactor at University of Hohenheim

Some bricks were placed in front of the secondary air inlet on the *after-burner* to break the wind because the fluctuation of wind speed has been affecting the equilibrium of combustion process in terms of the proportion between syngas and excess air. This phenomenon exemplified that a wind breaker should be installed along with the shutter of the inlet of secondary air.

Sieving of the wood chips as pretreatment was considered as an important step before filling the drum. This is because small particles could slip into primary air channel and block the air access into the reactor. Furthermore, the blockage would become worse as the particles are converted into black sticky tar. However, with use of dry maize cobs, this phenomenon will probably not occur.

3.3.1.2 Feasibility study of the reactor and available agricultural waste

According to the group formation done by MVIWATA, it was demonstrated that the reactor has good prospects to be implemented in the villages. One of the most interesting scenarios for the villagers is the use of combustible gas coming out from the chimney. The gas is considered as potential fuel for cooking.

As one of the most cultivated crops in Morogoro, the remaining cobs from maize production have been selected by the farmers to be the agricultural waste potential for application of the reactor. This is because it will serve as a potential means of disposal and at the same time obtain energy for cooking. This will in turn serve as a means of reducing degradation of woodlands and also relieve women from walking long distances in search of fuelwood. Maize cobs will also become a traded commodity and therefore increase returns from maize cultivation.

In order to determine feasibility of the reactor further tests should be conducted to establish the amount of maize cobs required to run one reactor for the whole year and implication on availability of the cobs and sustainability of the technology. The estimated 201 and 261 kg of maize cobs per household in Ilakala and Changarawe respectively may be sufficient to run the pyrolyzer only for a few days or months depending on family size. This may necessitate buying maize cobs from farmers who will not be accessible to pyrolyzers.

3.3.1.3 Redesign of the pyrolyzer barrel

In order to be able to use locally available materials and reduce manufacturing costs, a survey was made on the size of barrels available in Morogoro, Tanzania. Table 15 gives the available drums found in the Morogoro market, and all of them are made from metal (mild steel).

Table 15. Available barrels in Morogoro, Tanzania

No	Height (cm)	Outside diameter (cm)	Wall thickness (cm)	Price per unit (TSH)
1	89 ± 1	59 ± 1	1.2	60,000.00
2	90 ± 1	38 ± 1	1.2	20,000.00
3	67 ± 1	44 ± 1	1.2	20,000.00

The technical drawings for each barrel were made at the University of Hohenheim and delivered in October, 17th 2014 to SUA for consideration on construction and field test. Barrel 3 was considered and the drawing was modified at SUA (Figs. 15&16) to accommodate a cooking pot on the top surface while allowing enough space between the chimney and the pot. Material for the chimney will be acquired from local hardware shops and the drum will be insulated with clay soil embedded between the drum and thin mild steel outer.

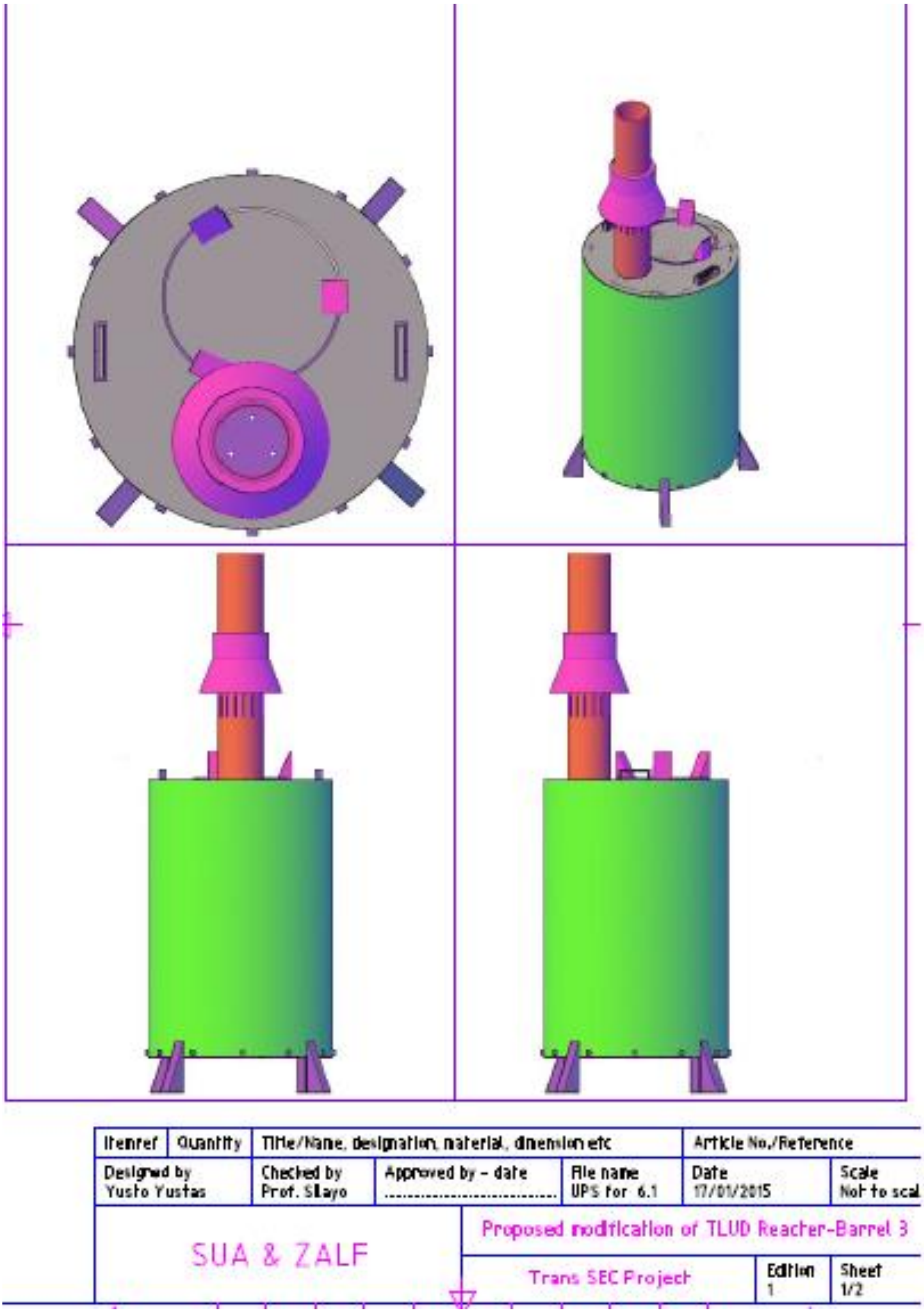


Fig. 18. Assembly drawing of the modified TLUD bioreactor

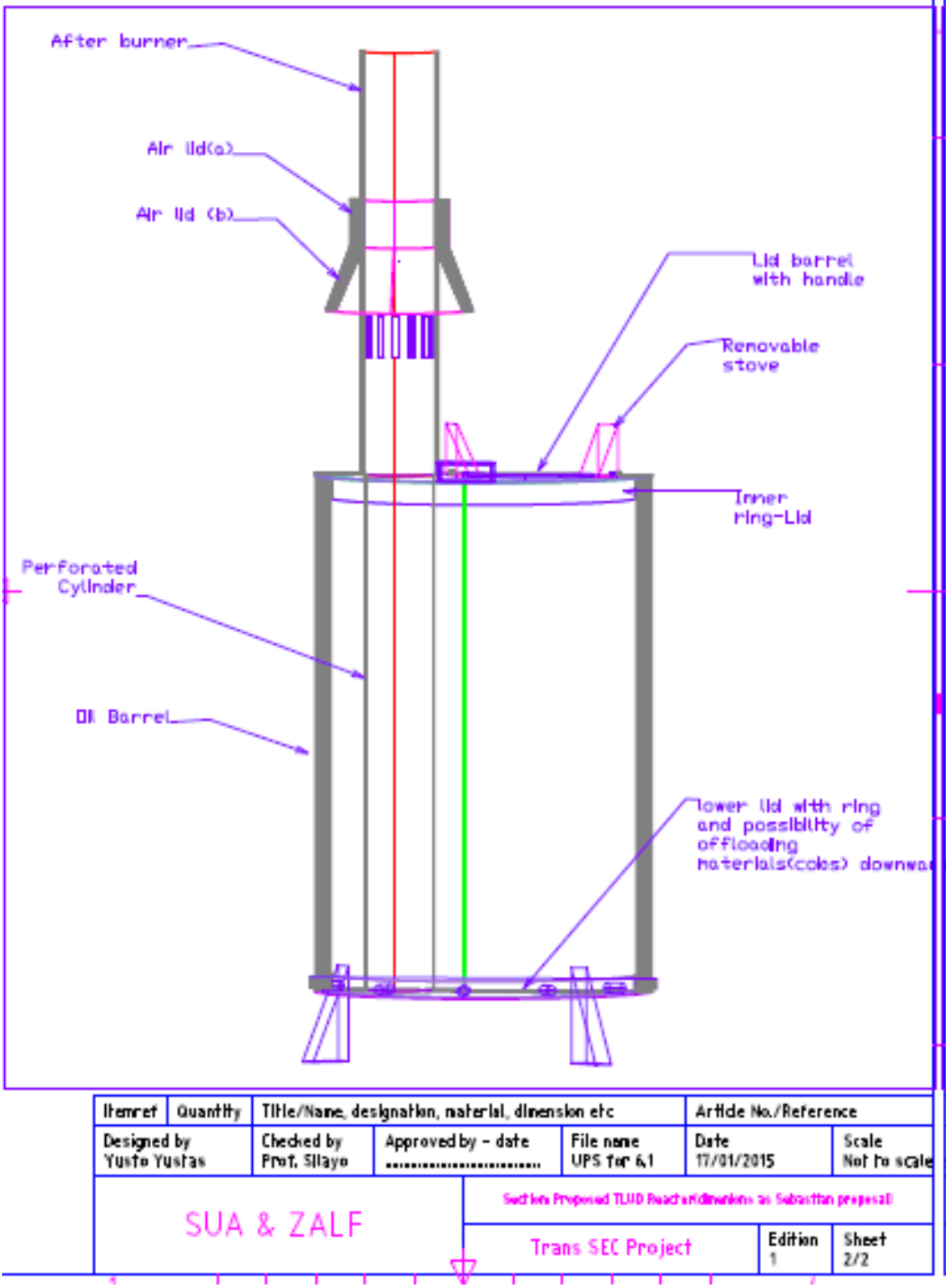


Fig. 19. Inner view of the modified TLUD

3.3.1.4 Ongoing activities

In this study, at UHOH two solid fuels were selected as the object for the TLUD; corn/maize cob and wood chips. The cobs were acquired from Südgetreide GmbH, located in Weisweil and wood chips from Matthias Mörk GmbH, located in Renningen, Germany. The characteristics are shown in Table 16.

Table 16. Physical properties of raw material

Raw material	Water content (%-m/m)	Bulk density (kg/m^3)
Corn cobs	11	140
Wood chips	12	200

Also, Kishore (2008) has given some properties of maize/corn cobs including proximate analysis, which are fixed carbon (16.8%), volatile matter (82.1%), ash (1.1%) and Higher Heating Value of 18.8 MJ/kg.

As for the mobile unit, a metal frame with four wheels on the bottom was installed. The frame was also equipped with char collection system, which consists of two pedestal bearings which are connected to two rods welded on the outer wall of the reactor, as demonstrated in Fig. 20. The data logger is a custom unit, which was built and fabricated at University of Hohenheim.

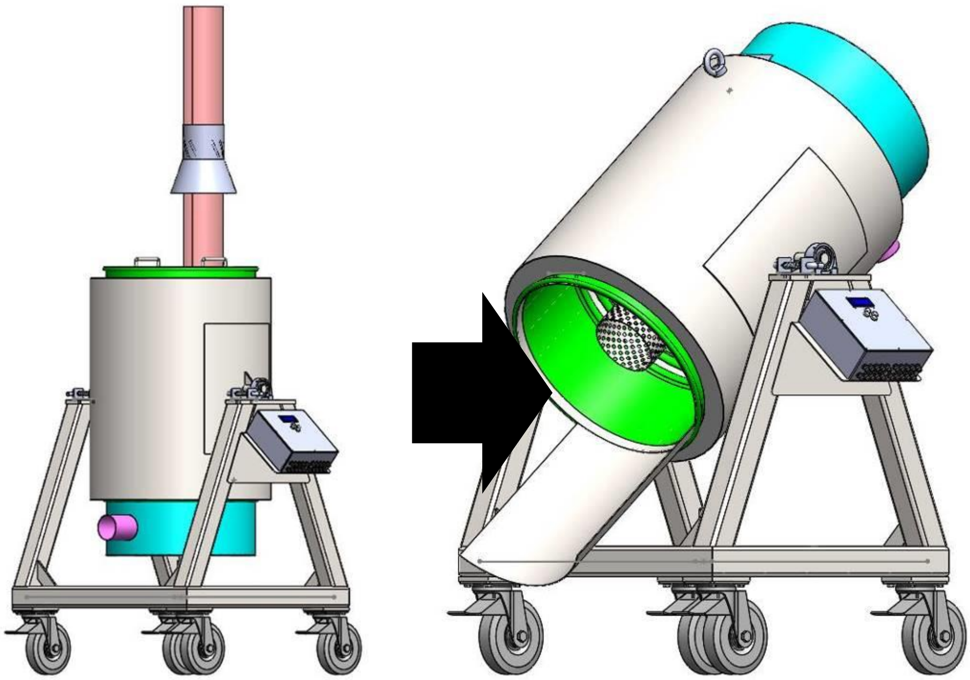


Figure 20. Mobile unit (left) and char collection system (right) of modified TLUD reactor

The experiments to optimize the reactor are still ongoing at the moment. The expected results would be a good fitting of mathematical model, whereas the optimum condition in terms of amount of biomass and flow rate of primary air can be recommended for each raw material. On the other hand, the amount of energy converted into heat for cooking will be estimated to evaluate the feasibility and safety. Results will be presented in the next delivery report.

3.3.2 Improved processing (maize shelling, millet/sorghum threshing, sunflower oil extraction, and storage)

Four farmers groups, one in each of the four CSS have been formed by MVIWATA. Feasibility study and busness plans will be developed from January 2015 onwards for maize shelling and millet/sorghum threshing. Results for sunflower oil production will be provided after successful acquisation, installation and operation of the oil expeller to produce crude oil.

With regard to storage, work done at UHOH has provided some useful results. The three storage repetitions reached a maximum CO_2 concentration of 195,914 ppm, 187,948 ppm and 182,440 ppm, respectively. The points of maximum CO_2 concentration did not match the points of minimum pressure which were 922.9 hPa, 926.1 hPa and 932.5 hPa resulting in a pressure difference to ambient pressure at sealing of 44.7 hPa, 43.5 hPa and 37.1 hPa respectively. Nevertheless, the points of minimum pressure represent a major shift in the increase rate of CO_2, the shifting point after which the curves flatten and the correlation decreases.

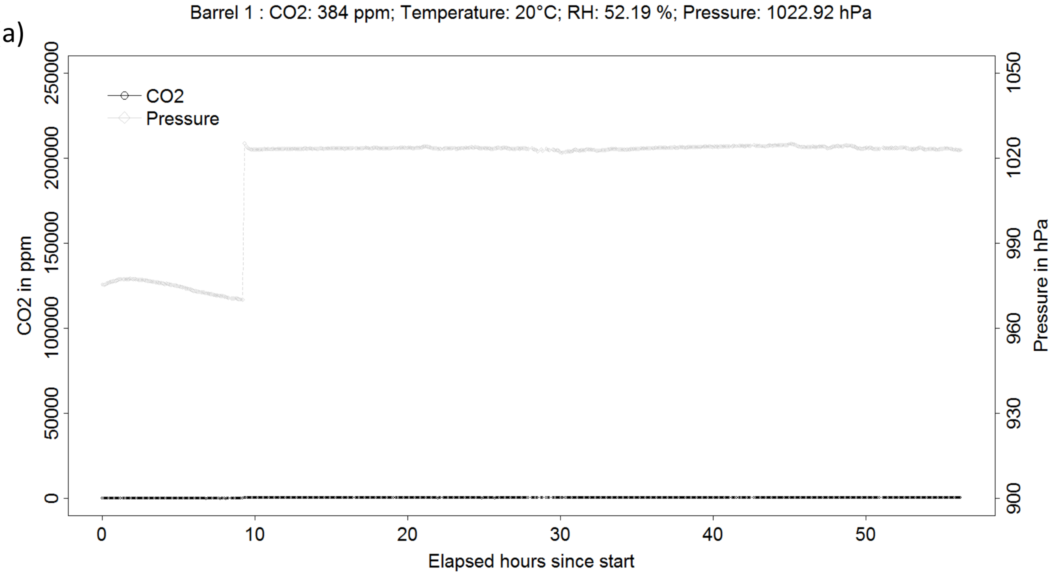
The three repetitions required different amounts of time in order to reach the shifting point. While repetition I reached the point after 379.1 hours, repetition II required 528.5 hours and repetition III required 930.8 hours. All repetitions showed a very strong negative correlation (Pearson's) between CO_2 and pressure development before reaching the shifting point. After reaching the shifting point, the correlation becomes moderate and positive, indicating either a loss of gas from the headspace to the ambience or an over proportional formation of gases other than stoichiometric CO_2 from respiratory processes. Table 13 provides an overview of key factors denounced by the current experiment.

Table 16: Overview of preliminary core-parameter of airtight storage experiments. R_a refers to Pearson's coefficient of correlation between CO_2 and pressure before reaching the shifting point while R_b shows the overall coefficient of correlation.

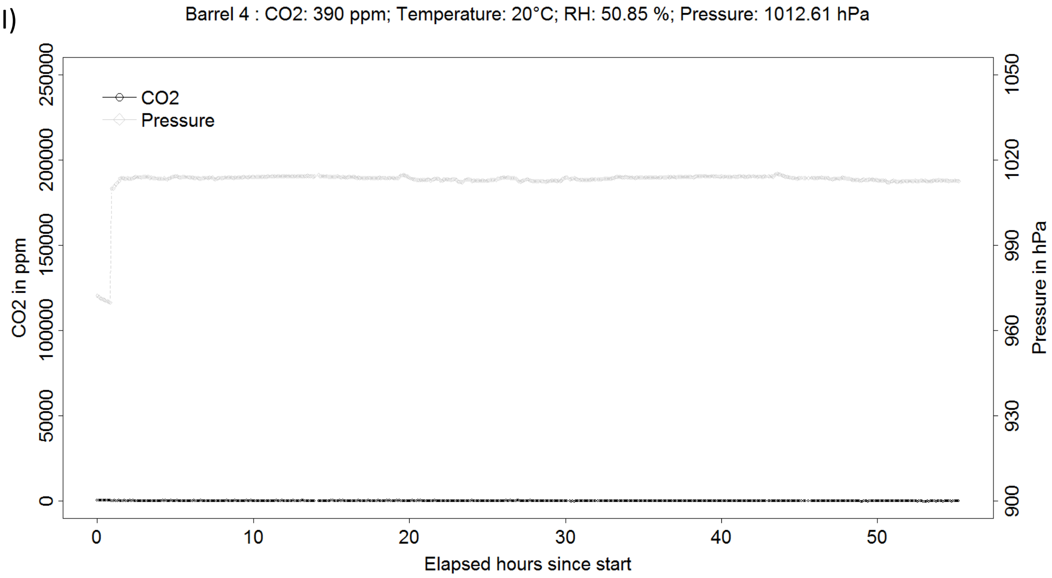
	$CO_{2\text{-}max}$ [ppm]	**$Pressure_{min}$ [hPa]**	**ΔP_{max} [hPa]**	**Shifting point [h]**	**R_a**	**R^2_a**	**R_b**	**R^2_b**
Rep I	195,914	922.9	44.7	379.6	-0.997	0.995	-0.839	0.704
Rep II	187,948	926.1	43.5	528.5	-0.996	0.993	-0.926	0.856
Rep III	182,440	932.5	37.1	930.8	-0.988	0.977	-0736	0.543

(1) Tightness tests

(a)



(II)



(III)

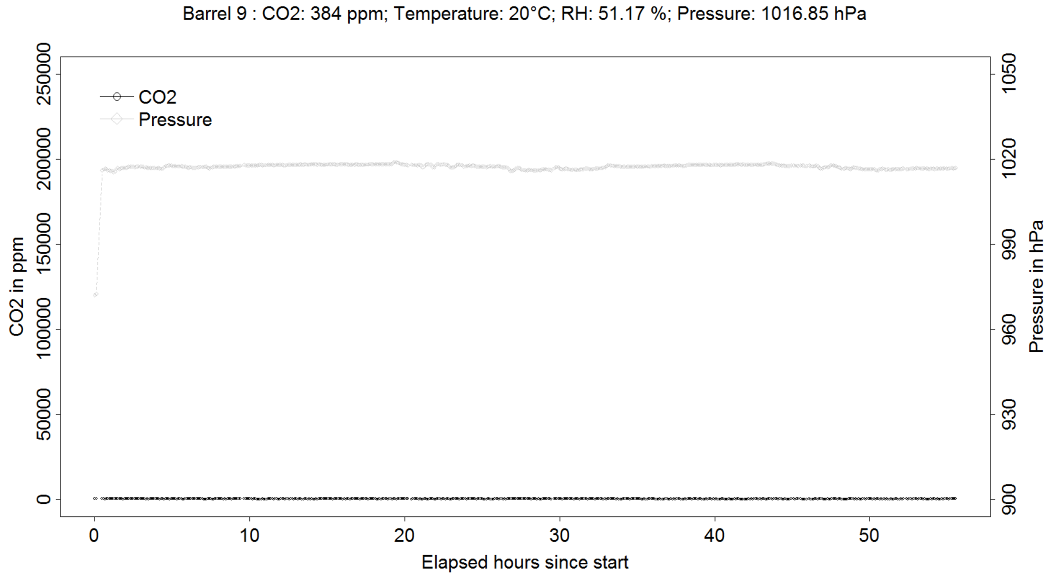
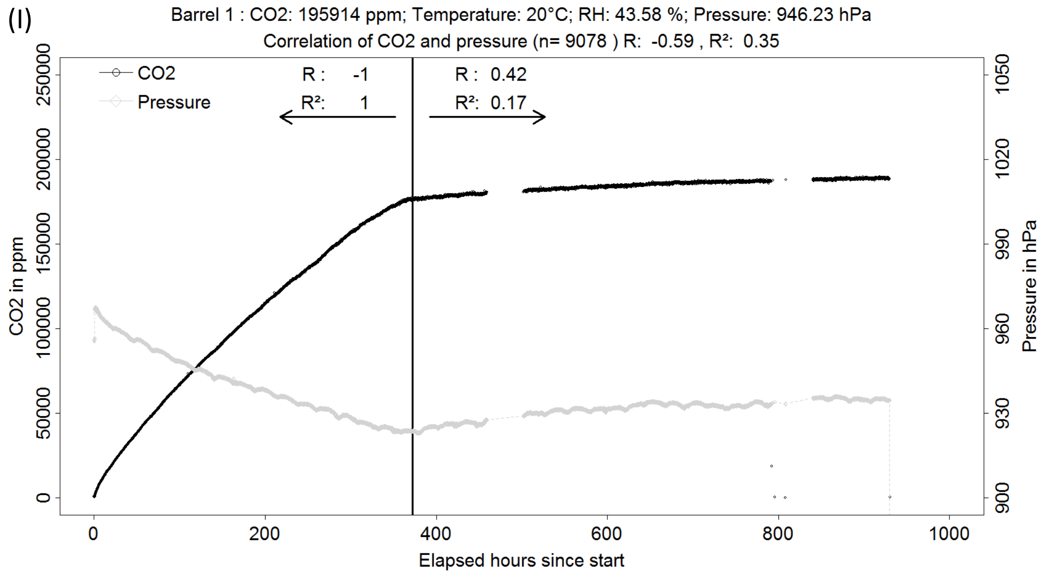


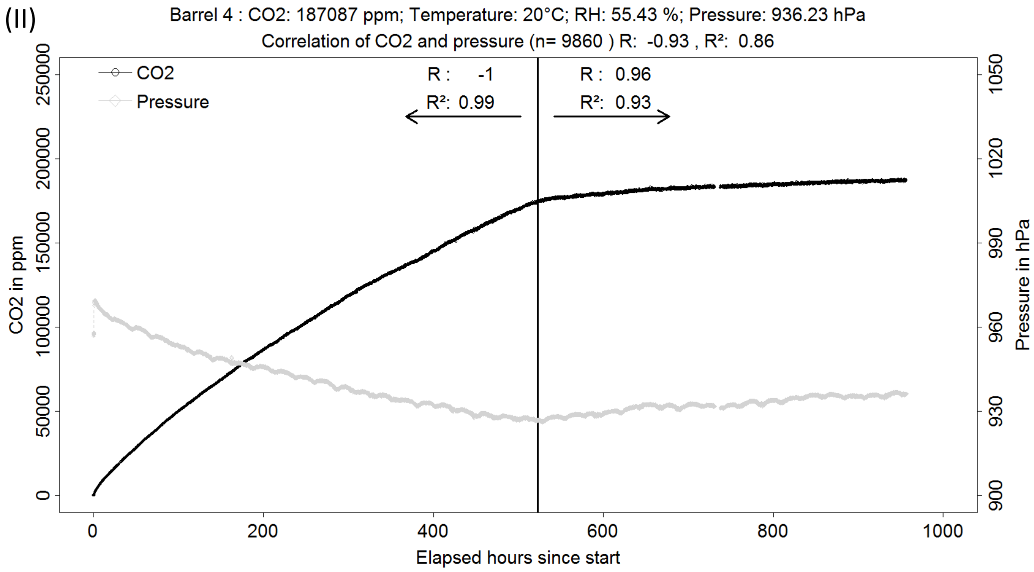
Figure 21: Repetition (I), (II) and (III) of overpressure tightness tests. After pouring in liquid nitrogen, the pressure increased to around 1020 hPa and was retained for at least 2 days.

(2) Storage tests

(I)



(II)



(III)

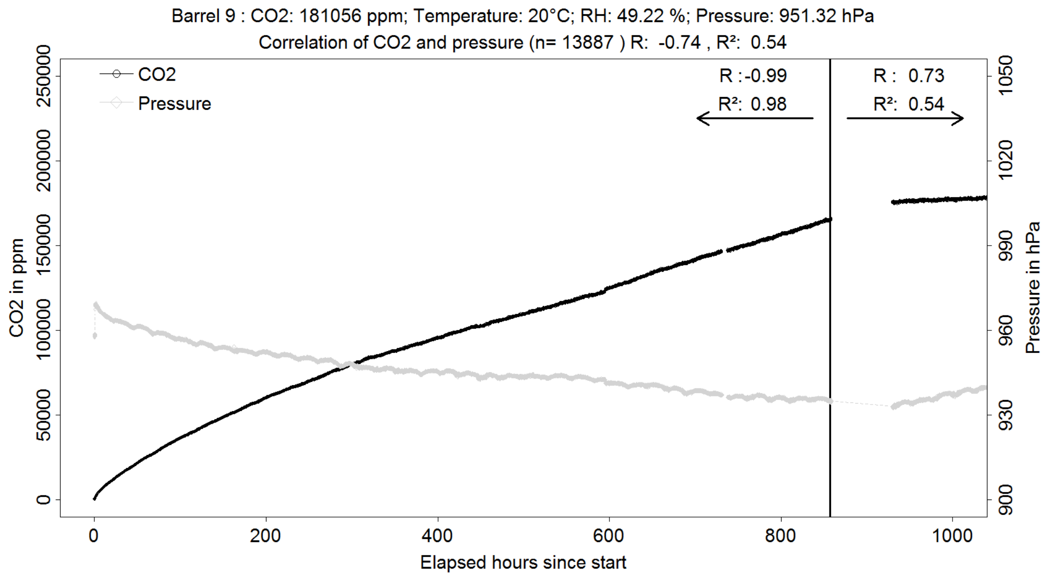


Figure 22: Repetition (I), (II) and (III) of airtight storage experiments. The graphs show the head gas CO2 concentration, pressure and correlation between the two magnitudes before the shifting point, after the shifting point and for the overall experiment.

(3) Sensor verification

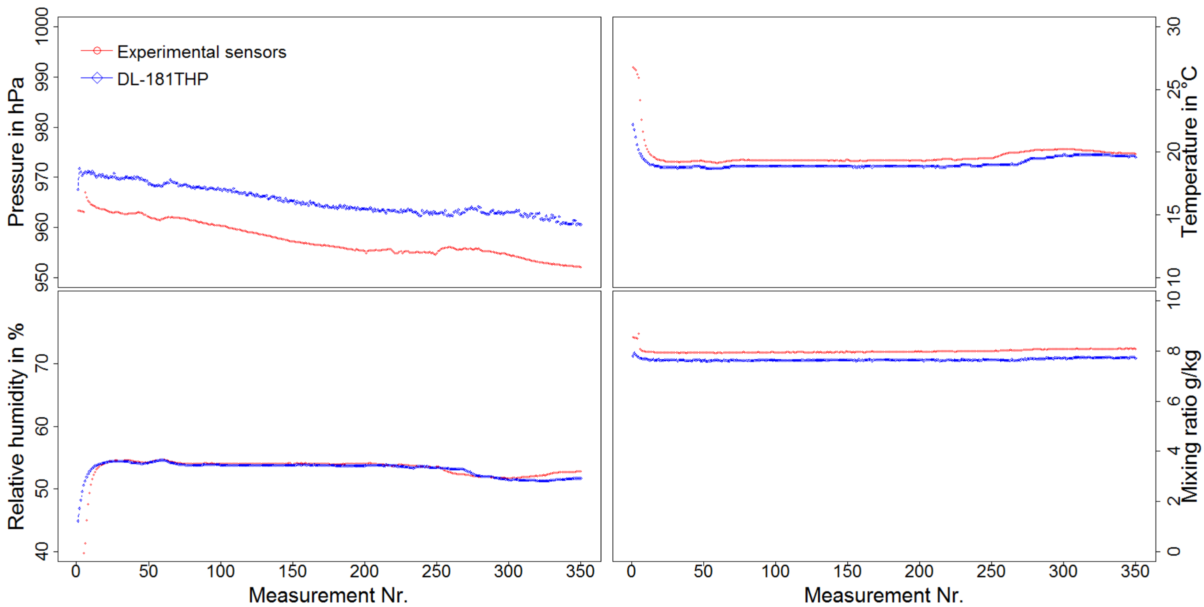


Figure 23: Comparison of sensors used in the experiment and commercially available sensor stick Voltcraft DL-181THP. The measurements are consistently congruent or parallel. Only in the pressure measurement, the DL-181THP shows a higher noise, which is owed to a less precise built in sensor. The pressure also shows a systemic difference of 10 hPa with the experimental sensors being closer at the pressure stated by local weather stations.

More results will be provided after further research and training on best storage practices which will be conducted in the field in future.

3.4 Choice of Equipment and Technology

3.4.1 Byproducts for bioenergy production

The mobile top-lid-up-draft (TLUD) barrel-reactor that was designed at UHOH will be built from scrap metals of the sizes available in Tanzania. This reactor has already been redesigned and will be built at the Department of Agricultural Engineering and Land Planning workshop at Sokoine University of Agriculture.

3.4.2 Improved processing

3.4.2.1 Maize shelling

Some farmers, in form of groups would wish to ownmachines for shelling as a business or for shelling of their own product. The prices of these machines, which are locally manufactured at Morogoro Tanzania, are as shown in Table 17.

Table 17. Price of different maize shelling technologies

Type	**Model**	**Power requirement**	**Total price (USD)**
Manual/table maize sheller	-	-	100
Manual pedestal maize sheller	1000 kg/day	-	700
Motor powered maize sheller	100 kg/h	1 HP	1150
Engine powered maize sheller	1500 kg/h	13 HP	3250

A quick observation in the past revealed inadequacy and inefficiency of manual/table and manual pedestal types. Since there is no electricity in these villages at the moment use of motor powered shellers is out of context. Therefore, use of diesel engine-powered maize sheller is recommended but only after positive feasibility study results. However, the owners of the technology at the village must be trained on best practices of operating and managing the machine.

3.4.2.2 Millet/sorghum threshing

There are two mechanical threshing machines that provide threshing service around Idifu and Ilolo villages but they are not sufficient and winnowing is done separately. Therefore, there is need to have more machines for use by the farmers in these areas, preferably a mechanical sorghum/millet threshers in combination with a winower. The manufacturing price of threshing machines at Morogoro is shown in Table 18.

Table 18. Price of different millet/sorghum threshing technologies

Type	**Model**	**Power requirement**	**Total price (USD)**
Engine powered sorghum thresher	750 kg/h	6.6 HP	2500
Engine powered sorghum thresher	1200 kg/h	8 HP	3250

A 6.5HP engine powered cleaner/winnower with a capacity of 2000 kg/h can be availed at a price of USD 2500. Buying the thresher and the cleaner separately will probably be an expensive option. Therefore, there will be a need to explore the possibility of making an integrated thresher and clener/winnower at a moderate cost from Intermech Engineering Ltd., in Morogoro.

3.4.2.3 Sunflower oil extraction

Mechanized sunflower oil expellers are used in various places ranging from motor driven to diesel powerd units, which are also suitable for otrher types of seeds, notably groundnuts, sesame, neem, and pumpkin seeds. A diesel-powered milling unit manufactured at Intermech Engineering Ltd in Morogoro Tanzania will cost about 5.3 million Tanzanian shillings. The price of the filter press is about 3.1 million Tanzanian shillings. Thus the overall cost of an extraction system including some small appliances that are capable of producing single refined oil may be estimated at 9 million Tanzanian shillings approximately. A much more improved technology capable of producing double refined oil is being worked out by the Small Industrial Development Organization (SIDO) in Dar es Salaam, Tanzania. However, this may not be suitable for village scale processing.

3.4.3 Optimized storage

In all the CSSs there is no technology that is worth the name of an optimized storage system. Storage in traditional cribs was only suitable before the outbreak of the Larger Grain Borer. The common storage of cereals in polypropylene bags is for short-term storage as huge losses due to the Larger Grain Borer may occur even after applying storage pesticides. This calls for use of improved storage systems. The IRRI bag that was recently communicated between the task teams is worth investigating.

3.4.4 Improved wood supply

Training and establishment of tree nurseries based on work by previous reserachers in the area will be adaped from January 2015 onwards.

3.4.5 Improved cooking stove

Production of cooking stoves and improvement on the previously established stoves will be done from January 2015 onwards.

4. Conclusions, Recommendations and Messages

4.1 Conclusions

Baseline work that involved household survey at the apex project level, literature search, consultation with equipment suppliers, and Task team's field visists at different times was successfully conducted. In participatory discussion with stakeholders four Upgrading Strategies (UPS), which *are By-products for Bioenergy, Improved Processing, Improved Wood Supply, and Improved Cooking Stoves* were selected for implementation. In addition to these UPS, it was mutually agreed that two other UPS, *namely Profitable and Market Oriented Storage* and *New Product Development (Sunflower Oil Processing)* will be implemented jointly with the WP 7.1 Task team. The UPS in improved processing was chosen in all the four CSS while by-products for bioenergy and improved wood supply were chosen only in Ilakala and Ilolo villages, respectively. The UPS on improved cooking stove was chosen in all the four CSS but implementation in Ilakala and Ilolo will be on training only. Groups of between 20-40 households for testing the UPS have been formed and full implementation is scheduled to start from January 2015. Baseline production and availability of raw materials data for testing the UPS was successfully generated. This data has enabled estimation of production of maize, sesame, bulrush millet, sorghum, and sunflower to be used as a guide on investment in improved processing technologies. As one of the activities of this work package development of TLUD reactor has shown a good suitability for rural application. The reactor will utilize maize cobs, a potential waste for bioenergy production. Preliminary test results at UHOH have given an insight and guidelines for development and testing of the maize cobs pyrolyzer in Tanzania. With the use of information from the literature the amount of maize cobs destined for bioenergy production was estimated and its potential will be established after testing of the requisite technology and possession of feasibility report. However, awareness of safety and proper use of the reactor needs to be imparted to the operators along with further integration of the reactor into the community. An optimized condition during operation of the reactor is expected to provide good quality of char, and sufficient energy for cooking. Equipment and machines for improved processing will be required at some stage and will all be manufactured in Morogoro, Tanzania after positive feasibility study reports and acquisition of funds by the formed farmers groups. Inadequate wood supply and inefficient harnessing of cooking energy from biomass are real problems facing farmers. These problems can be solved through training and implementation of tree planting and use of efficient and improved cooking stoves.

4.2 Recommendations

Implementation of the UPS should focus on training and establishment of business models to secure funds from creditors that will assist them to establish business enterprises. Sucessful manufacturing and testing of the bio-reactor at SUA should be extended to Ilakala and find out the possibility for manufacturing in workshops in the nearby town of Kilosa. Due to high temperature condition and emission, the reactor is not recommended to be used inside a house. Moreover, the operation should also be done under supervision of trained operators or the operators themselves. Investigation on the emission of gas coming out from the chimney to study the toxicity and ecological side of the reactor should be conducted. Farmers groups should solicit their own funds after successful investigation on costs and benefits of the interventions. In case of failure to acquire credits the groups will be required to establish alternative simple and affordable enterprises that are capable of generating sufficient income to invest in other enterprises. Training and improvement on sunflower oil processing to produce single refined oil is essential but efforts should be tried to link the village small scale processors with the large scale ones. Possibilities of adopting the sunflower oil processing machines to sesame oil processing in Ilakala village should be sought out. Due to the possibility of future increase in livestock production, generation of biogas from cattle manure should be studied using scholarly activity (PhD studies).

4.3 Messages

(i) Farmers know their problems than anybody else hence they only need to be guided to prioritize them and give appropriate solutions. However, this requires participation of farmers' apex organizations such as MVIWATA.

(ii) The surveyed villages are constrained by poor processing of crops and inefficient cooking appliances hence short and long-term interventions are required.

(iii) Combustible gas produced from TLUD reactor is a very attractive choice for villagers. However, a safe and suitable method to integrate the gas into cooking is still under investigation.

(iv) Gas collection system of the reactor is limited at the moment by high amount of tar which can be distortion to the system. A proper gas cleaning system is necessary to be further investigated.

(v) Successfull dissemination of improved and new technologies requires knowledge of the past history with regard to a particular technology in the specific area or other areas with similar characteristics.

(vi) Investment by farmers is hampered by unavailability and high cost of proven technologies. However, the long thought expectations that donor funded projects can bail them out will perpetuate their poverty unless they are trained on means of solociting for sustainable funding mechanism and establish viable alternative businesses.

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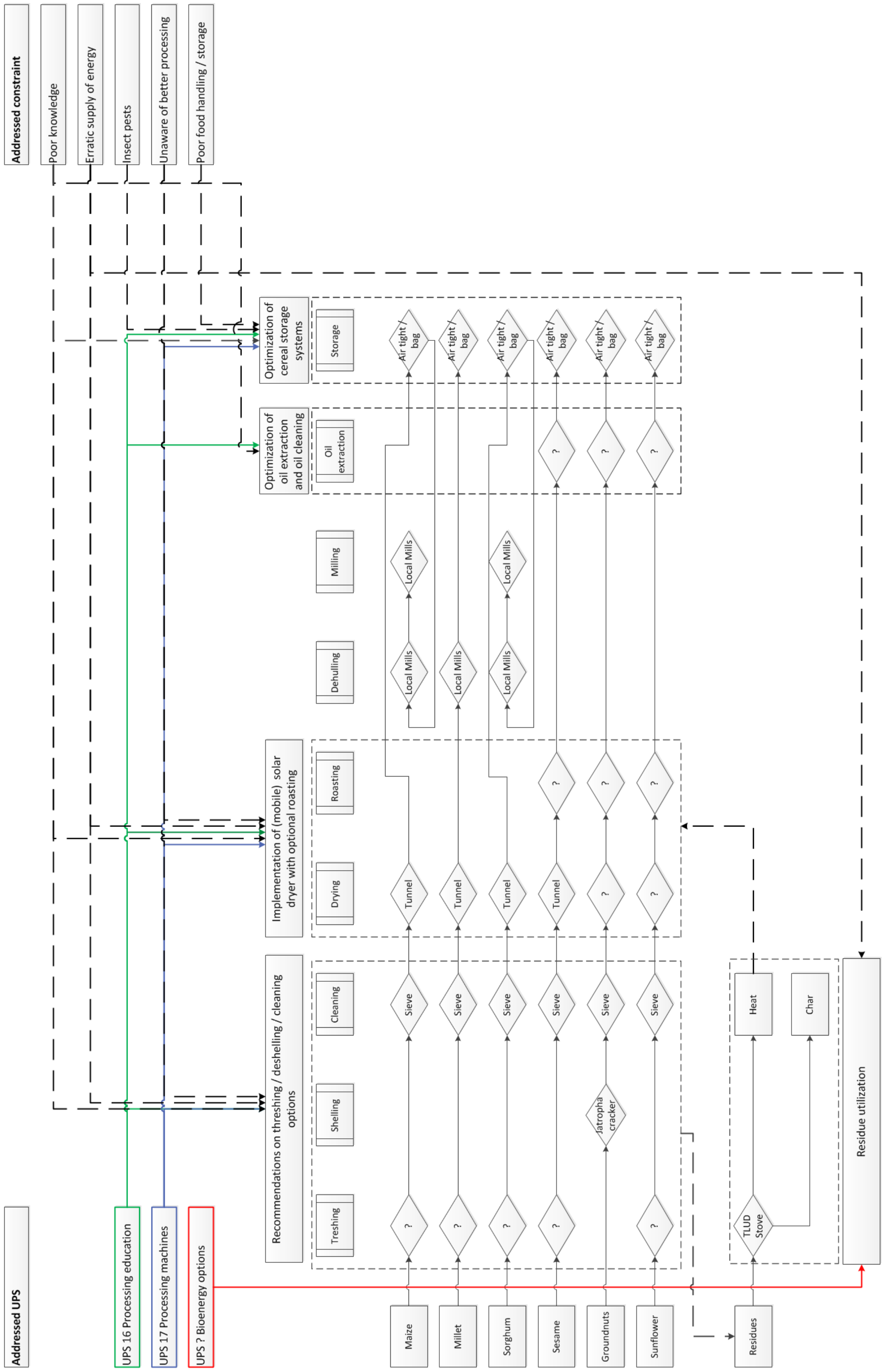
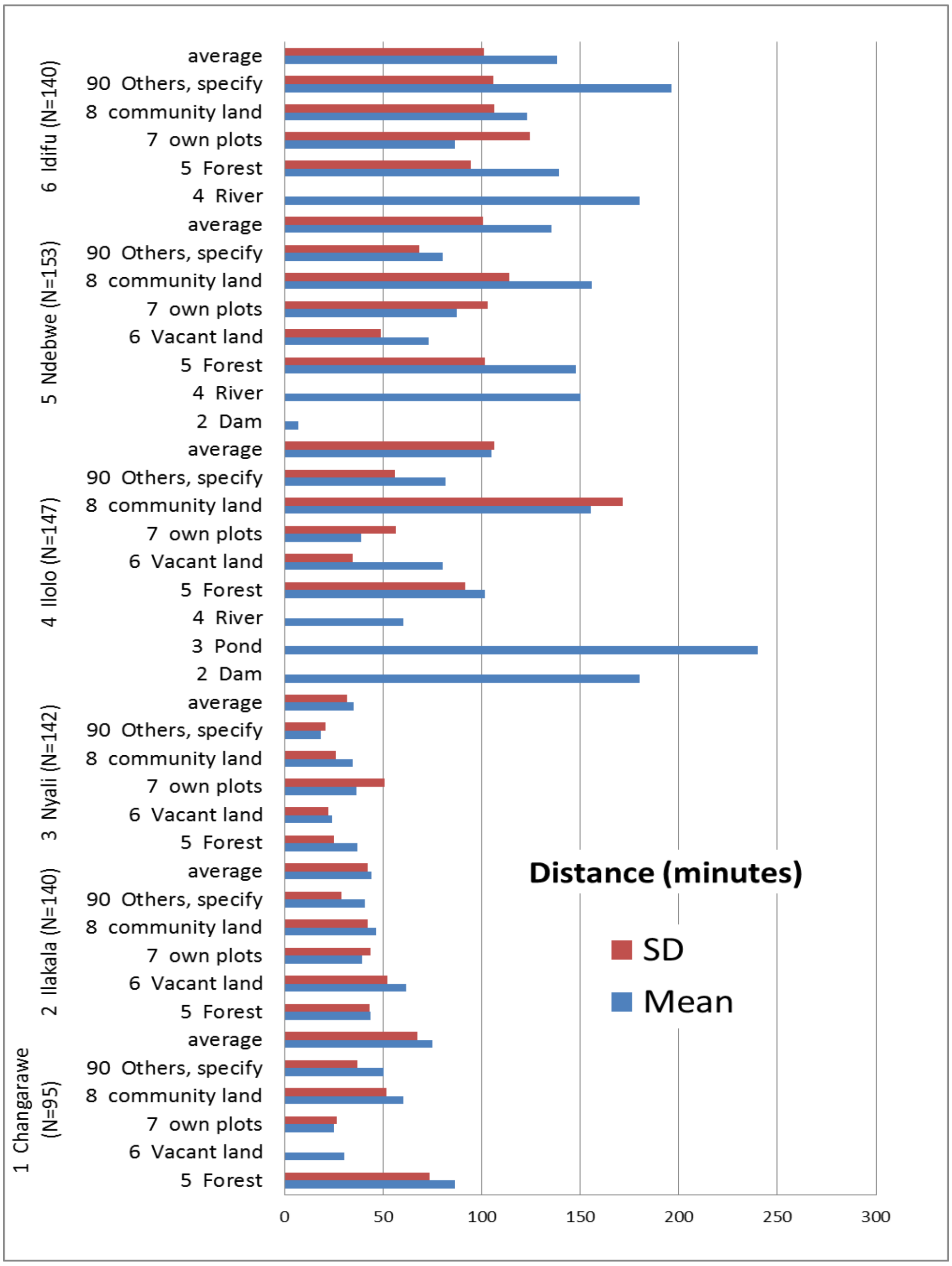
Appendices

Appendix 1. Conceptual Framework for some Upgrading Strategies



Appendix 2: Time in minutes to reach places for firewood collection for the 4 CSS and 2 control sites.


6 Idifu (N=140)
average
90 Others, specify
8 community land
7 own plots
5 Forest
4 River
5 Ndebwe (N=153)
average
90 Others, specify
8 community land
7 own plots
6 Vacant land
5 Forest
4 River
2 Dam
4 Ilolo (N=147)
average
90 Others, specify
8 community land
7 own plots
6 Vacant land
5 Forest
4 River
3 Pond
2 Dam
3 Nyali (N=142)
average
90 Others, specify
8 community land
7 own plots
6 Vacant land
5 Forest
2 Ilakala (N=140)
average
90 Others, specify
8 community land
7 own plots
6 Vacant land
5 Forest
1 Changarawe (N=95)
average
90 Others, specify
8 community land
7 own plots
6 Vacant land
5 Forest
0
50
100
150
200
250
300
Distance (minutes)
SD
Mean