Potential multi-dimensional impacts and trade-offs of improved livestock feeding options in Babati, Tanzania

Internship Report
MSc Internship Farming System Ecology

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Preface

First and foremost I would like to express my appreciation to my supervisors; Assistant professor Dr. ir. Jeroen Groot of Farming System Ecology, Wageningen University and Birthe Paul PhD fellow researcher at CIAT-Kenya and Wageningen University. Jeroen, thank you so much for facilitating the possibility of having this internship with CIAT and your support to complete this internship. Birthe, thank you for guiding me through all the work and advice during the whole internship period. I would also like to give special thanks to Stephanie a post-doctoral researcher and Carl a graduate assistant at Farming System Ecology group (FSE), Wageningen University and Celine a consultant at CIAT-Kenya thank you so much for all professional supports and cooperation to make all this possible. Thank you all.
Executive summary

This is an academic report that was written in fulfilment of the academic requirements pertaining to guidelines for an internship in the Farming Systems Ecology at Wageningen University and Research Center, The Netherlands. This internship was carried out in the Farming Systems Ecology Group using an Africa RISING (AR) dataset for Babati, Tanzania. It was a four-month full-time internship (November 2014 to March 2015).

The aim of the internship was to generate a feed based farm typology and to model selected farms to evaluate the potential impacts of improved livestock feeding scenarios on whole farm performance.

Tasks performed during the internship include:

- Farm typology generation using multivariate analysis of the rapid characterization survey AR Babati dataset.
- Selection of farms representing the identified feed based farm types from nine detailed characterised farms and the entire AR dataset.
- Configure the current situation of three farms and implement improved livestock feeding scenarios.
- Model-based evaluation and impact analysis of improved livestock feeding scenarios.

A large variation among the smallholder farmers in farm size, livestock feeding and management and feed resource availability was observed in Babati, Tanzania. The farms were grouped into six feed based farm types: (Type 1) Small farm with small livestock herd, (Type 2) Small farm with medium livestock herd and high inputs, (Type 3) Intermediate farm with large livestock herd, (Type 4) Small farm specialized in small ruminants, (Type 5) Intermediate farm specialized in dairy, and (Type 6) Large farm with large livestock herd. The cluster analysis was made on the basis of household resource endowment and livestock feeding management: (i) household wealth indicators and feed resource availability (livestock size, farmland area, and crop residue (cereal, legume and other residue) allocation); (ii) poultry ownership and livestock grazing time (number of poultry and time the animal spent on grazing); (iii) improved cattle and poultry ownership (number of improved cattle and poultry), (iv) small ruminant ownership and supplementation (number of small ruminant and amount of purchased concentrate supplement), and (v) labour hours and supplementation (labour hour spent on the animal and the amount of purchased concentrate supplement).

The bio-economic model FarmDESIGN was used to analyse the current farm configurations and two improved livestock feeding scenarios for the three selected farms representing the common farm types: Type 1, 3 and 4 constituting 38, 41 and 9% of total farms, respectively. Improved forage (Napier Grass and Desmodium) and purchased concentrate supplement based improved livestock feeding scenarios were implemented for each farm. In the model based entry point identification and evaluation we have only tried to give insight on the potential impacts of the new feed components included into the farming system with regards to: soil organic matter balance, soil nitrogen availability, and feed value and greenhouse gas emission. The evaluation showed potential improvement: increased organic matter balance, amount of nitrogen available to the crop and animals and decreased N in soil losses (in the second scenario). However, minor increase in greenhouse gas emission intensity per litter of milk has been observed, which is due to the low milk yield considered in all the scenarios with the improved feed value, that the same level of milk production is considered in all the scenarios and the base line. Thus with improved milk yield greenhouse gas emission intensity per litter of milk...
will potentially decrease. From this analysis, further detailed analysis and multi-objective optimization modelling would be suggested considering crop and livestock exploration.
1. Introduction

Crop-livestock mixed farming systems are the mainstay of smallholder agriculture in Tanzania. Babati in Tanzania represents agro-ecologies and crop-livestock systems that represent diverse environments in the region. Smallholders are diverse in their farm resource endowment and allocation; crop and livestock management; farmers’ production objectives, long-term aspirations and risk attitudes (Tittonell et al. 2007). Farm typologies aim at meaningful groupings of farms into subsets, homogenous according to specific criteria (Anderson et al., 2007) which can be used for technology targeting. Creating feed based typologies attempts for a meaningful compromise between analysing every single farm and assuming broad categories such as smallholders in general. The feed based farm typology is aimed to consider smallholders diversity in livestock feeding strategies which could be a base in developing feeding scenarios.

Farm typologies can be structural (related to household wealth categories) and functional typologies that attempt to simplify household strategies based on livelihoods, resources, and production objectives. Different approaches can be used to construct farm typologies, such as qualitative, participatory, expert based and quantitative typologies (Alvarez et al., 2014). However, the quantitative approach is used in this study. The quantitative approach is complemented with the expert knowledge-based approach contributing to the scientific standards (accuracy, reproducibility) and considering interests and perceptions of the stakeholders. Quantitative typologies are constructed based on surveys and multivariate statistics and cluster analysis, whereas the expert knowledge typologies are defined by stakeholders (Giller et al., 2011).

In Babati livestock is kept on farmlands and is fed different crop residues from cereals, (maize, rice and sorghum), legumes (bean, pigeon pea and lablab) and sunflower. Off-farm grazing and cut and carry system were also practiced by some farmers in the area. There are variability’s in availability and allocation of feed resource and livestock feeding management practice among smallholder farmers in the Babati district. Consequently, this study aims to understand the feed based farm diversity and implement and evaluate the impacts of improved livestock feeding options.

1. Objective

The study was designed with two main objectives; 1) to generate a feed-based farm typology for Babati that will assist in a) selection of representative farms for ex-ante impact assessment of technologies; b) targeting of livestock feeding interventions to appropriate farming systems; c) determining the scaling out potential for dissemination of technologies at larger scales; 2) to analyse the impact of improved livestock feeding at whole farm level to assist the implementation of improved livestock feeding scenarios.

2. Research questions and hypotheses

1. Is there feed based diversity among smallholder farming systems in Babati, Tanzania?
   - The relative use of different feed resources determines the type of feeding system in place;
2. Do the farm types correspond to the particular intensification level? Which factors describe each type and intensification level regarding inputs and resource allocation?
   - Each farm type corresponds to a certain technology package in terms of livestock husbandry;

3. What are the impacts of improved livestock feeding scenarios at the whole farm level?
   - The different improved livestock feeding scenarios has impacted the whole farm differently;

4. Materials and methods
   4.1. Conceptual framework

The potential multi-dimensional impacts analysis of improved livestock feeding scenario analysis worked in the following framework (Figure 4.1.1), the activity started with a functional typology construction from the dataset gathered through rapid characterization exercise. This was followed by a more detailed farming system description, allowing complete farming system diagnosis of selected farms. The information will be then synthesized and analysed towards the implementation and trade off-analysis of improved feeding scenarios.

![Figure 4.1.1: Component of farming systems analysis and improved feeding system based entry point identification.](Adapted from Timler et al., (2014).)

4.1.1. Sampling and data collection

Babati district in Tanzania was selected as site representing diverse agro-ecologies and crop-livestock systems. During April 2013, eight local enumerators and staff of Farming System Ecology Group, Wageningen University were involved in completing the survey of 160 households in the Babati and Kongwa & Kiteto districts in Tanzania, of which 96 households of the Babati district were surveyed. The rapid characterisation survey was focused in assessing farm resource, management strategies, farm productivity and household economy. The data was collected through rapid characterization survey as first phase of farming systems analysis within the Africa RISING (AR) program. The rapid characterization survey was focused on the characterization of farming systems and identification of...
initial entry points for sustainable intensification in Tanzania, which was conducted from April to December 2013 (Timler et al., 2014).

The Babati district dataset from the AR project were used to understand the feed based characteristic of smallholders in Babati district. From the dataset presented in Microsoft Excel spreadsheets data on household socioeconomic conditions, livestock size and feeding management and labour data was extracted to understand the feed based diversity among smallholders. Farm household resource endowment indicators (farm size, family size, presence or absence of livestock) were used to categorise farms into different wealth categories, and then farms were chosen from Babati district for further detailed characterization to be used in FarmDESIGN model (Timler et al., 2014).

4.1.2. Description of variables

Quantitative variables on structural characteristics of farms (household size, farm land area, livestock size), livestock management indicators (number of improved cattle, number of small ruminants, number of poultry, labour hours spent on the animal), grazing system (time the animal spent on grazing, feeding on crop residue (amount of cereal, legume and other crops (sunflower) residue allocated as feed)), supplementation (amount of purchased concentrate supplement) were used to run the PCA (Table 4.3.1). More data from the dataset were checked to include as a variable; however, due to lack of the information other data’s were not included in the analysis.

Table 4.1.2.1: Variables for feed based farm diversity analysis from AR project Babati dataset

<table>
<thead>
<tr>
<th>Code</th>
<th>Variable</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>hhsize</td>
<td>Household size</td>
<td>no.</td>
</tr>
<tr>
<td>area</td>
<td>Farm land area</td>
<td>tlu</td>
</tr>
<tr>
<td>tlu</td>
<td>Livestock size</td>
<td>ha</td>
</tr>
<tr>
<td>cttlimprd</td>
<td>Number of improved cattle</td>
<td>no.</td>
</tr>
<tr>
<td>smrumt</td>
<td>Number of small ruminant</td>
<td>no.</td>
</tr>
<tr>
<td>poultry</td>
<td>Number of poultry</td>
<td>no.</td>
</tr>
<tr>
<td>crrresidue</td>
<td>Amount of cereal residue allocated as feed</td>
<td>kg year⁻¹</td>
</tr>
<tr>
<td>lgmresidue</td>
<td>Amount of legume residue allocated as feed</td>
<td>kg year⁻¹</td>
</tr>
<tr>
<td>othresidue</td>
<td>Amount of other residue allocated as feed</td>
<td>kg year⁻¹</td>
</tr>
<tr>
<td>lbhranml</td>
<td>Labour hour spent on animal</td>
<td>hour day⁻¹</td>
</tr>
<tr>
<td>timegrz</td>
<td>Time the animal spent grazing on the field</td>
<td>hour day⁻¹</td>
</tr>
<tr>
<td>puchfeed</td>
<td>Amount of purchased concentrate supplements</td>
<td>kg</td>
</tr>
<tr>
<td>cttlocal</td>
<td>Number of local cattle</td>
<td>no.</td>
</tr>
</tbody>
</table>

Matrix of X-Y plots was used to check correlations between the variables and select non-correlated variables. Accordingly, number of local cattle owned by the farmers was excluded from the analysis, which showed strong correlation ($r^2=0.93$) with tropical livestock unit (Figure 4.3.1). These show that increase in number of local cattle result increase in tropical livestock unit as well, which is non-discriminating (Pengelly et al., 2001). These are attributed to the dependence of the farmers on local cattle.
4.1.2: Relation between number of local cattle and total livestock size (TLU) in the Babati district.

4.2. Data normalisation

From the entire Babati dataset of 96 farms, five farms (Long 12, Shaurimoyo 1, 3, 4 and 15) were taken out due to absence of livestock, whereas two farms (Shaurimoyo 2 and 7) were omitted during PCA due to missing labour hour per animal data (NA). Moreover eight farms (Long 2 and 12, Shaurimoyo 5, Hallu 7, 11, 12, 13 and 14) were deleted during data normalisation when checking for distribution of farms using histogram and box plots. These farms show non-normal distribution in either of the following variables: number of improved cattle, amount of cereal, legume and other crop residue and amount of purchased concentrate supplements.

4.3. Statistical analysis

Multivariate and cluster analysis were used to identify explanatory variables (discriminating variables) and to group farms in homogeneous types. Multivariate statistics, principal component analysis was used to reduce the number of variables and preserve the maximum of the total variability of the sample. R statistical software package was used to perform the multivariate and cluster analysis.

4.4. FarmDESIGN

Useful tools describing and explaining the outcomes of the current configuration of selected farms as well as for exploring alternative farm configuration was used.

FarmDESIGN is a bio-economic, static modelling tool, assessing structural as well as functional farm characteristics. New version of the model which will also quantify greenhouse gas emission was used. Information on climate, soil, labour balance, crops, livestock, inputs, exports, and greenhouse gas component indicators and assets will be entered into the model. Synergy between farm components (crop, soil, livestock, manure, household, forages) can be captured through this model, identifying ranges of possible variables for the single factors, setting constraints as well as desired outcomes, the interplay of farm components can be illustrated and manipulated, in order to explore and evaluate

\[ y = 1.6908x - 0.894 \]

\[ R^2 = 0.929 \]
options for the (re-) design of the whole farming system (Groot et al., 2012).
https://sites.google.com/site/farmdesignmodel/home

4.5. Selection of farms for FarmDESIGN

Initially we wanted to select representative farms for each type of the detailed characterization dataset. However we could not find representative farms for the six types among the nine farms of the detailed characterization whose farm selection was solely based on resource endowment representing three different farm typologies. Unfortunately not all six farm-types were represented in the original set of detailed characterised farms. From the nine detailed characterised farms; one farm (Seloto 2) belonged to farm type 1, four farms (Matufa 11, Hallu 5, Seloto 16 and Shaurimoyo 12) belonged to farm type 3 and two farm (Sabilo 13 and 14) belonged to farm type 4. However, none of the detailed characterised farms represented farm type 2, 5 and 6, while two farms (Long 2 and Shaurimoyo 5) did not belong to any type since they were identified as outlier farm during clustering. Thus, we decided to select representative farms from the entire dataset used to build farm typologies. To select representative farms from the dataset a PAM (Partitioning Around Medoids) R package was used to select the most representative farms from each typology. PAM is a robust method that operates on the dissimilarity matrix of the entire dataset by minimizing the sum of dissimilarities. A medoid (centre of the cluster) will enable us to select the representative farm, whose average dissimilarity to all the farms in the cluster is minimal (Kaufman and Rousseeuw, 1990).

Accordingly, Hallu 4, Seleto 8, Hallu 16, Matufa 13, Sabilo 6 and Hallu 8 were selected representing farm type 1-6 respectively. These farms which are selected from the entire dataset would be used for further detailed characterisation and in FarmDESIGN. The descriptive statistics table with their divergence value from the typology means are presented in Appendix 2.

From the detailed characterised farms: Seloto 2, Hallu 5 and Sabilo 13 were selected representing farm type 1, 3 and 4, respectively. The selection of these farms was made by comparing the divergence value computed for each farm from the respective typology means. Selecting representative farms from the group may have also some subjectivity; however it is always common when the typology is built based on other criteria. The divergence value indicates in green shows relatively smaller deviation from the typology means, while values indicate in orange and dark red shows intermediate and the largest deviation respectively. Therefore, three farms (Seloto 2, Hallu 5 and Sabilo 13) were selected representing farm type 1, 3 and 4 respectively for FarmDESIGN.

The descriptive statistics table with their divergence value of all variables from their respective typology means for detailed characterisation dataset for the nine detailed characterised farms were computed and presented in Appendix 3.
5. Result and Discussion

5.1. Farm typologies

Principal component analysis (PCA) was conducted on selected variables for 80 farmers. Five principal components (PC) with eigenvalue above one were included for the cluster analysis, based on the Kaiser criterion, as suggested in the typology construction general guideline for the Humid tropics project (Alvarez et al., 2014). The five PCs explained 71.7% of the total variation and characterized as follows.

(i) Household wealth indicator and feed resource availability (livestock size, farmland area, and crop residue (cereal, legume and other residue) allocation explained 30.1% of the total variation).

(ii) Poultry ownership and grazing time (number of poultry and time the animal spent on grazing explained 12.3% of the variation).

(iii) Improved cattle and poultry ownership (number of improved cattle and poultry, 10.8%).

(iv) Small ruminant ownership and supplementation (number of small ruminant and amount of purchased concentrate supplement - 9.5%).

(v) Labour hour and supplementation (labour hour spent on the animal and the amount of purchased concentrate supplement - 9.1%).

Table 5.1: Correlation matrix between the principal components (PC) and the variables from Babati dataset

<table>
<thead>
<tr>
<th>Variables</th>
<th>PC1</th>
<th>PC2</th>
<th>PC3</th>
<th>PC4</th>
<th>PC5</th>
</tr>
</thead>
<tbody>
<tr>
<td>hhsize</td>
<td>-0.58</td>
<td>-0.48</td>
<td>0.20</td>
<td>-0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>area</td>
<td>-0.89</td>
<td>0.16</td>
<td>-0.10</td>
<td>-0.22</td>
<td>-0.17</td>
</tr>
<tr>
<td>tlu</td>
<td>-0.74</td>
<td>-0.09</td>
<td>0.16</td>
<td>0.32</td>
<td>0.29</td>
</tr>
<tr>
<td>cttlimprd</td>
<td>-0.18</td>
<td>-0.40</td>
<td>-0.62</td>
<td>-0.13</td>
<td>-0.13</td>
</tr>
<tr>
<td>smrumnt</td>
<td>-0.47</td>
<td>-0.14</td>
<td>0.02</td>
<td>0.68</td>
<td>0.31</td>
</tr>
<tr>
<td>poultry</td>
<td>-0.01</td>
<td>-0.61</td>
<td>-0.58</td>
<td>0.07</td>
<td>0.12</td>
</tr>
<tr>
<td>lbhranml</td>
<td>-0.01</td>
<td>-0.34</td>
<td>0.36</td>
<td>0.19</td>
<td>-0.66</td>
</tr>
<tr>
<td>timegrz</td>
<td>-0.24</td>
<td>-0.49</td>
<td>0.57</td>
<td>-0.22</td>
<td>0.05</td>
</tr>
<tr>
<td>crlresidue</td>
<td>-0.77</td>
<td>-0.01</td>
<td>-0.12</td>
<td>-0.23</td>
<td>-0.24</td>
</tr>
<tr>
<td>lgmresidue</td>
<td>-0.80</td>
<td>0.19</td>
<td>-0.05</td>
<td>-0.22</td>
<td>-0.11</td>
</tr>
<tr>
<td>othresidue</td>
<td>-0.60</td>
<td>0.46</td>
<td>-0.04</td>
<td>-0.02</td>
<td>0.22</td>
</tr>
<tr>
<td>puchfeed</td>
<td>0.16</td>
<td>-0.25</td>
<td>0.17</td>
<td>-0.57</td>
<td>0.53</td>
</tr>
</tbody>
</table>

The hierarchical cluster was applied to the five principal components listed in (Table 5.1); the cluster identified six groups of farms (Figure 5.1).
Figure 5.1: Result of the Principal Component Analysis and the Hierarchical Cluster
The largest household and livestock size (TLU), farm land area (ha) and amount of crop residue allocated as the feed was on average found on farms of larger size (Type 6). The amount of crop residue allocated as feed increased with increasing farmland area, whereas the livestock size (TLU) increased except for farm in small farmland area (1.6±0.2) and more livestock size (10.1±1.4) (Type 4) (appendix 1). Labour hour spent on animal management (hr per day) and the grazing time spent by the animal decreased with increasing farmland area, livestock and household size (Figure 5.3). The largest number of small ruminants and poultry with the largest amount of legume residue were on average found on farms of the relatively larger size (Type 5 and 4) (Figure 5.3d). The amount of purchased concentrate supplements decrease with increasing farmland area (Figure 5.2).

Figure 5.2: Average farmland area, TLU, household size, number of small ruminant, poultry and improved cattle, amount of purchased concentrate supplement and different crop residues by farm types. The bar represents mean ± standard error of mean.
5.2. Description of farm types

The six identified feed based typology of the smallholders in Babati (Appendix 1):

1. **Type 1 – Small farm with small livestock herd**: small family size, land constrained, smaller livestock size, less improved cattle - small ruminant-poultry, semi-zero grazing, low supplementation and relatively less labour hour on animal, represented 37.3% of farms in the dataset.

2. **Type 2 – Small farm with medium livestock herd and high inputs**: land constrained, extended grazing, high supplementation, no improved cattle, small ruminant-poultry, 3.75% of the farms;

3. **Type 3 – Intermediate farm with large livestock herd**: more labour hour on animal, smaller livestock size, less improved cattle-small ruminant-poultry, very low supplements, land constrained, and 41.25%.

4. **Type 4 – Small farm specialized in small ruminants**: more small ruminants, larger livestock size, land constrained, low input, average labour hour on animal, 8.75%.

5. **Type 5 – Intermediate farm specialized in dairy**: more improved cattle and poultry, large family size, semi-zero grazing, supplementation, higher labour hour, 3.75%.

6. **Type 6 – Large farm with large livestock herd**: more family and livestock size, larger farmland area, semi-zero grazing, residue based grazing, low supplementation, improved cattle-small ruminant -fewer poultry, 5%.
5.3. Configuration of selected farms

5.3.1. Current farm situation

The model-based analysis of the configuration of the current farm situation and evaluation of entry points for improving animal nutrition has been performed for three farms selected to represent the most common three farms among the six feed based farm typologies from the detailed characterized farms in Babati, Tanzania. The farms were chosen from the feed based typology based on information from the rapid characterization, but configured on the model using raw data from the detailed characterization. For each type the farms were chosen based on the feed resource (different crop residues allocation, purchased feed supplement), grazing time, and farm area and livestock size. These farms were chosen to represent the most common farm types: 1, 3 and 4.

The configuration of the current farms as shown in Table 5.2.2 enables us to evaluate the impact of the improved livestock feeding scenarios and compare with the original farm situation.

‘Sabilo 13’ represents Type 4 farms, is an intermediate farm with a relatively larger farm area (2.4 ha) and relatively large livestock size (9.5 TLU), and the greatest diversity in animals. The farm makes the most operating profit 5273035 Tsh and adds the most organic matter (4086 kg/ha/year) to the farms, which is attributed to import of substantial amounts of manure (840 kg DM/year) into the farm, while the farm shows -2051 kg/ha organic matter balance.

‘Hallu 5’ represents Type 3, is an intermediate farm with large farm area (4 ha) and relatively large livestock size (7.7 TLU). They add the smallest organic matter 1580 kg/ha/year and shows the highest deficiency of organic matter balance -3845 kg/ha/year, which is attributed to the low livestock density (1.9 TLU/ha) to produce sufficient amount of manure to fertilize the farm from own manure. The farm makes the most operating profit (almost 5043164 TSH).

‘Seloto 2’ represents Type 1, is a small farm with the smallest farm area (0.8 ha) and livestock size (4.4 TLU) with the largest number of poultry. The farm makes the smallest operating profit (3855839 TSH) compared to the other two farms, which might have resulted from the small farm size. The farm adds the most 3863 kg/ha/yr organic matter showing the lowest deficient in organic matter balance -828 kg/ha/year, which is due to high livestock density per ha (5.4 TLU) than the other farms.

In the current farm configuration and each scenario we assume import of substantial amounts of grazing grass and concentrate supplements to balance dry matter intake, energy and protein requirement of the animals (Table 5.2.2).

Table 5.2.1: Current situation and exploration options for the three farms

<table>
<thead>
<tr>
<th>Farm</th>
<th>Hallu 5 (Type 3)</th>
<th>Sabilo 13 (Type 4)</th>
<th>Seloto 2 (Type 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm area (ha)</td>
<td>4</td>
<td>2.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Crops currently grown</td>
<td>Maize, Pigeon pea and Sunflower</td>
<td>Maize, Bean, Sunflower, Pigeon pea and Chickpea</td>
<td>Maize, Bean and Pigeon peas</td>
</tr>
</tbody>
</table>
Animals currently owned
- 9 local cow
- 2 local bull
- 3 local calve
- 6 local goats
- 7 chicken

2 local bull
3 local calve
10 sheep
3 donkey
12 chicken

6 local goats
7 chicken
12 local cow
6 local bulls
3 Local cows
4 Local bulls
24 local goats
4 Local goats
10 sheep
45 Local Chickens
3 donkey

Feed imports
- 13500kg DM grazing grass and 1500kg DM Sunflower seed cake
- 26800kg DM grazing grass & 2900kg DM Sunflower seed cake
- 8300kg DM grazing grass and 87kg DM maize bran

Operating Profit (TSH/year)
- 5043164
- 5273035
- 3855839

Organic matter added (kg/ha/yr)
- 1580
- 4,086
- 3863

Organic Matter Balance (kg/ha/year)
- -3845
- -2051
- -828

Labour balance (hours/year)
- 0
- 0
- 0

GHG CO₂ eq (Mg/ha/year)
- 4
- 13
- 12

Exploration
- Scenario_1 = 3
- Scenario_2 = 4
- Scenario_1 = 3
- Scenario_2 = 4
- Scenario_1 = 3
- Scenario_2 = 4

Crop Exploration
- Grow the same crops
- Forage crops (Desmodium & Napier grass) included
- Grow the same crops
- Forage crops (Desmodium & Napier grass) included
- Grow the same crops
- Forage crops (Desmodium & Napier grass) included

Feed imports
- Grazing grass
- Sunflower cake
- Maize bran
- Scenario_1
- 12995
- 2420
- Scenario_2
- 6000
- 8300

- Scenario_1
- 26920
- 3250
- Scenario_2
- 22500
- 2580

- Scenario_1
- 8300
- 230
- Scenario_2
- 8500
- 1420

- Scenario_1
- 87
- Scenario_2
- 390

Forage area (ha) in Scenario 2
- 0.4
- 0.4
- 0.2

5.4. Improved livestock feeding based explorations

Dual-purpose legume crops such as lablab, cowpea, and chickpea have been identified as a food crop, that the proportion used in feeding livestock is very negligible from this study. Supplementary feeds like maize bran, sunflower seed cake and maclik were used by some farms, where only about 33% of the total farm use maize bran, sunflower seed cake and maclik. On average 132 kg of purchased concentrate supplements (maize bran, sunflower seed cake and maclik) is used per farm per annum.

Integration of improved forages crops of the whole farm in the rotation or intercropping was expected to contribute to improve animal performance, soil conservation, profit maximization, risk minimization, pest control (push-pull) and whole farm performance, thus potentially addressing a
number of constraints and critical points facing farmers (Timler et al., 2014). Introduction of high yielding fodder for cutting like Napier grass and Desmodium were considered as promising innovations.

**Napier grass** (*Pennisetum purpureum*)

Napier grass is a perennial tropical grass native to the African grasslands (Farrell, et al., 2002). It has low water and nutrient requirements, and therefore can make use of uncultivated lands (Strezov, et al., 2008). With the decreasing farm land size emphasis on high yielding fodder for cutting like Napier grass is of great importance due to its wide ecological range, high biomass production, ease of propagation and management and potentials to grow in mixture with legumes like Desmodium species and others [http://www.fao.org/ag/agp/agpc/doc/newpub/napier/napier_kenya.htm](http://www.fao.org/ag/agp/agpc/doc/newpub/napier/napier_kenya.htm). In addition, in the recent years, it has been incorporated into a pest management strategy (push-pull) and contributes to soil management (soil fertility and erosion control in arid land) [http://dbpedia.org/page/Pennisetum_purpureum](http://dbpedia.org/page/Pennisetum_purpureum). The plant has high biomass production, at about 40 tons/ha/year (Strezov, et al., 2008), yielding an average of 10 tons /ha/year without or under low input in Africa and can be harvested 4-6 times per year (Farrell, et al., 2002).

**Silver leaf Desmodium** (*Desmodium uncinatum*)

Silver leaf Desmodium is a N-fixing legume that improves the soil N status and can provide nitrogen to neighboring crops. Average biomass yield of Desmodium uncinatum of 7 tons/ha/ year DM with increases of 90 and 150 kg/ha in soil nitrogen when sown in mixed Desmodium/grass stands and in pure stand, respectively [http://www.tropicalforages.info/key/Forages/Media/Html/Desmodium_unicinatum.htm](http://www.tropicalforages.info/key/Forages/Media/Html/Desmodium_unicinatum.htm)

The potential impacts of improved livestock feeding scenarios for the three farms (Hallu 5, Seloto 2 and Sabilo 13) are presented in Table 5.2.3. Considering the potentials of improved forage crops and purchased concentrate supplements to improve livestock and whole farm performance and greenhouse gas mitigation through implementations of improved livestock feeding scenarios, new feed components (improved forage crops and purchased concentrate supplement), were included in the model. The model based entry point evaluation shows the potential of improved livestock feeding at whole farm level.

Decision variables: crop areas, forage crop area, grazing grass import and purchased concentrate supplements were allocated upper and lower limits specific to each farm. Constraints were set on the feeding of the animals such that the model did not under or over feed the animals, and on the areas of the fields, such that it is not possible for the model to allocate more land than that which is available. The scenarios all used two objectives, namely to maximize organic matter balance per ha and to minimize the greenhouse gas emission.

The entry point evaluation result of all the scenarios has been presented in Table 5.2.3. Comparing all the scenarios for each farm type, almost all solutions generated were an improvement from the current farm situation, except the farm operating profit, which shows loss by 1.5 to 4.2% in the scenario purchased concentrate fed to the animals, which is attributed to feeding cost, whereas relatively higher decrease by 8.7 to 19.6% has been observed in the scenario improved forage and
purchased concentrate fed to the animals. This is attributed to the allocation of some portion of crop land into a forage area 10, 17 and 25% for Hallu 5, Sabilo 13 and Seloto 2, respectively, which subsequently resulted decrease in gross margin from crops. The decrease in farm profitability also explained by not increased milk production as result of improved feed value while the feed cost increased in all the scenarios. The result shows potential improvement in soil organic matter balance in all the scenarios by 0 to 0.9% and 0.2 to 1.7% in the scenario of purchased concentrate fed to the animals and improved forage and purchased concentrate fed to the animals, respectively. This is attributed to increase in the amount of organic matter added to the soil by 0.4 to 1.3% and 2.4 to 6.1% in the scenario, purchased concentrate fed to the animals and improved forage and purchased concentrate fed to the animals, respectively. The observed improvement in organic matter balance in all the scenarios shows the potential impacts of improved forage and purchased concentrate supplements, which will improve nutrient available to the animals and the soil as well.

Examining the nitrogen balance, in the scenario, purchased concentrate supplement fed to the animals, the amount of nitrogen fixed and crop nitrogen uptake did not show improvement except for farm Seloto 2 that shows decreased amount of crop nitrogen uptake by 5.8%. However, in the scenario, improved forage and purchased concentrate fed to the animals the amount of nitrogen fixed by the crop increased by 20.0, 76.5 and 172.7% for farm Hallu 5, Sabilo 13 and Seloto 2, respectively, and improved the amount of crop nitrogen uptake by 35.3, 23.1 and 40.7% for farm Hallu 5, Sabilo 13 and Seloto 2, respectively (Table 5.2.3). This is due to potential impacts of improved forage Desmodium and Napier grass and imported concentrate supplement fed to the animals. The amount of nitrogen in the imported crop product increased by 15.8, 3.7 and 11.0% for farm Hallu 5, Sabilo 13 and Seloto 2, respectively. This is attributed to the import of substantial amounts of purchased concentrate in the scenario, purchased concentrate supplement fed to the animals. Whereas the amount of nitrogen in the imported crop product decreased by 24.6, 14.9 and 29.1% for farm Hallu 5, Sabilo 13 and Seloto 2, respectively, which is attributed to the potential decrease in crop product import in this scenario as a feed for the animals. The amount of nitrogen supplied to animals increased by 12.5, 3.6 and 8.6% and 26.6, 11.9 and 20.7% in the scenario purchased concentrate fed to animals and improved forage and purchased concentrate fed to the animals, respectively. The improved availability of nitrogen to the animals, similarly resulted improvement in the amount of nitrogen in manure to soil in all the scenarios, in the scenario purchased concentrate fed to animals by 4 to 12.2% and 11.7 to 24.5% in the scenario improved forage and purchased concentrate fed to the animals. The high import of concentrate supplement and increased availability of nitrogen from improved forage crops resulted increase in nitrogen volatilization in all the scenarios from 8 to 28.6% and 24 to 60% in the scenario purchased concentrate fed to animals and improved forage and purchased concentrate fed to the animals, respectively. However, the amount of nitrogen in soil losses decreased by 5.1 to 100% in scenario improved forage and purchased concentrate fed to the animals, which is attributed to the potential impact of improved forage to decrease the negative environmental impact at the whole farm level while improving soil nutrient availability. Whereas the nitrogen in soil losses increased by 6.4 to 116.7% in the scenario purchased concentrate supplement fed to the animals, which is attributed to the import of more concentrate supplement.

From this analysis the overall nitrogen use efficiency in all the scenarios have been decreased by 4.1 to 14.9% except for farm Hallu 5 which increased by 0.9% in the scenario, improved forage and purchased concentrate fed to the animals. This is attributed to the limited improvement in the crop
and animal output; that the same level of crop and animal productivity have been considered, where the nitrogen input has been improved in each scenario.

Greenhouse gas emission intensity as expressed by CO2-eq (Mg/litter of milk) shows minor increase by 0 to 2% in the scenario, purchased concentrate fed to the animals and 1.6 to 6.3% in the scenario, improved forage and purchased concentrate fed to the animals. The observed increase in greenhouse gas emission intensity in all the scenarios might have resulted from not increased milk productivity, that the same level of milk yield 0.84 kg/day/cow have been considered in all the scenarios. However, with better feed it is expected that milk production will also improve, which is not considered in this analysis. Thus with improved milk yield greenhouse gas emission intensity per litter of milk will potentially decrease.
Table 5.2.2: Percentage increases and decreases for selected indicators in the FarmDESIGN model using improved livestock feeding scenarios (multipurpose forage crops and purchased concentrate supplements) for the farm ‘Hallu 5’, ‘Sabilo 13’, and ‘Seloto 2’ Babati, Tanzania. (%)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hallu 5</th>
<th></th>
<th>Sabilo 13</th>
<th></th>
<th>Seloto 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current Situation</td>
<td>Purchased concentrate fed to animals</td>
<td>Improved forage and purchased concentrate fed to animals</td>
<td>Current Situation</td>
<td>Purchased concentrate fed to animals</td>
<td>Improved forage and purchased concentrate fed to animals</td>
</tr>
<tr>
<td>Fixation (kg/ha/yr)</td>
<td>30</td>
<td>0.0</td>
<td>20.0</td>
<td>17</td>
<td>0.0</td>
<td>76.5</td>
</tr>
<tr>
<td>Crop N uptake (kg/ha/yr)</td>
<td>51</td>
<td>0.0</td>
<td>35.3</td>
<td>91</td>
<td>0.0</td>
<td>23.1</td>
</tr>
<tr>
<td>N in import crop product (kg/ha/yr)</td>
<td>57</td>
<td>15.8</td>
<td>-24.6</td>
<td>197</td>
<td>3.7</td>
<td>-14.9</td>
</tr>
<tr>
<td>N import manure (kg/ha/yr)</td>
<td>None</td>
<td>0.0</td>
<td>0</td>
<td>9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>OM added (kg/ha/yr)</td>
<td>1,580</td>
<td>0.4</td>
<td>6.1</td>
<td>4103</td>
<td>1.3</td>
<td>3.7</td>
</tr>
<tr>
<td>N in manure to soil (kg/ha/yr)</td>
<td>49</td>
<td>12.2</td>
<td>24.5</td>
<td>158</td>
<td>4.0</td>
<td>11.9</td>
</tr>
<tr>
<td>N supplied to animal (kg/ha/yr)</td>
<td>64</td>
<td>12.5</td>
<td>26.6</td>
<td>205</td>
<td>3.6</td>
<td>11.7</td>
</tr>
<tr>
<td>N in crop product export (kg/ha/yr)</td>
<td>36</td>
<td>0.0</td>
<td>-8.3</td>
<td>59</td>
<td>0.0</td>
<td>-22.0</td>
</tr>
<tr>
<td>N in animal product export (kg/ha/yr)</td>
<td>None</td>
<td>0.0</td>
<td>0</td>
<td>10</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>N volatilization (kg/ha/yr)</td>
<td>7</td>
<td>28.6</td>
<td>57.1</td>
<td>28</td>
<td>8.0</td>
<td>24.0</td>
</tr>
<tr>
<td>N in soil losses (kg/ha/yr)</td>
<td>6</td>
<td>116.7</td>
<td>-100.0</td>
<td>84</td>
<td>6.4</td>
<td>-5.1</td>
</tr>
<tr>
<td>Overall N use efficiency (%)</td>
<td>54.7</td>
<td>-8.6</td>
<td>0.9</td>
<td>39.8</td>
<td>-4.1</td>
<td>-9.4</td>
</tr>
<tr>
<td>GHG (CO2-equ (Mg)/ha/yr)</td>
<td>4</td>
<td>25.0</td>
<td>25.0</td>
<td>13</td>
<td>0.0</td>
<td>7.7</td>
</tr>
<tr>
<td>GHG emission intensity (CO2-equ (Mg)/litter of milk)</td>
<td>4.9</td>
<td>2.0</td>
<td>6.1</td>
<td>6.3</td>
<td>0.0</td>
<td>1.6</td>
</tr>
<tr>
<td>OM balance (kg/ha/yr)</td>
<td>-3845</td>
<td>0.0</td>
<td>-0.2</td>
<td>-2049</td>
<td>-0.2</td>
<td>-0.9</td>
</tr>
<tr>
<td>Farm operating profit (Tsh)</td>
<td>5043164</td>
<td>-4.2</td>
<td>-19.6</td>
<td>5273035</td>
<td>-1.5</td>
<td>-8.7</td>
</tr>
</tbody>
</table>
6. Conclusions

Large variation among the smallholder farmers with regards to farm size, livestock feeding and management and feed resource availability were observed. The model-based improved livestock feeding entry point evaluation showed that the improved livestock feeding options generated new insights into the possible improvement that farmers would take towards improved livestock and whole farm performance. The entry points identified in this analysis showed potential improvement at whole farm level with regards to soil organic matter balance, soil nitrogen availability, feed value and reducing the negative environmental impacts. However, multi-objective optimization modelling will be required, using the entry points presented, as there is a need to work further on crop and livestock productivity through the use of improved varieties of crop and graded animal types. These will help to increase farm operating profit from increased crop and livestock productivity. Moreover, with improved milk yield greenhouse gas emission intensity per litter of milk will potentially decrease. The potential entry points generated by FarmDESIGN should give insight to implement the improved livestock feeding scenarios towards sustainable intensification of crop-livestock systems, where further detailed analysis will be required. Objectives and willingness of the farmers needs to be considered to adopt the improved livestock feeding options. Involvement of local farmers is very important in the process of developing and adapting feed intensification options as this will have financial and land use implication for smallholder farmers.
Reference


http://dbpedia.org/page/Pennisetum_purpureum
http://www.tropicalforages.info/key/Forages/Media/Html/Desmodium_uncinatum.htm


### Appendix 1: Characteristics of feed based farm types in the Babati district identified by cluster analysis (Mean and Standard Error of Mean)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
<th>Type 5</th>
<th>Type 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms</td>
<td>30</td>
<td>3</td>
<td>33</td>
<td>7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Number of household size</td>
<td>5.9±0.4</td>
<td>7.3±0.9</td>
<td>7.3±0.3</td>
<td>9.1±0.5</td>
<td>10.0±0.0</td>
<td>10.3±2.5</td>
</tr>
<tr>
<td>Farm land area (ha)</td>
<td>1.0±0.1</td>
<td>1.0±0.0</td>
<td>2.1±0.2</td>
<td>1.6±0.2</td>
<td>2.7±0.7</td>
<td>7.8±1.2</td>
</tr>
<tr>
<td>Livestock size (tlu)</td>
<td>2.7±0.4</td>
<td>5.0±2.5</td>
<td>4.4±0.50</td>
<td>10.1±1.4</td>
<td>5.7±1.5</td>
<td>13.8±2.4</td>
</tr>
<tr>
<td>Number of improved cattle</td>
<td>0.2±0.1</td>
<td>0.0±0.0</td>
<td>0.2±0.1</td>
<td>0.0±0.0</td>
<td>2.7±0.3</td>
<td>0.5±0.5</td>
</tr>
<tr>
<td>Number of small ruminant</td>
<td>4.8±0.8</td>
<td>7.3±5.5</td>
<td>6.2±1.0</td>
<td>26.6±5.0</td>
<td>12.3±5.0</td>
<td>20.3±4.5</td>
</tr>
<tr>
<td>Number of poultry</td>
<td>10.9±2.0</td>
<td>7.7±2.3</td>
<td>7.2±1.2</td>
<td>13.4±3.2</td>
<td>36.7±8.8</td>
<td>5.0±2.9</td>
</tr>
<tr>
<td>Amount of cereal residue allocated as feed (kg)</td>
<td>1270±174.6</td>
<td>1042.4±346.0</td>
<td>2605.9±273.9</td>
<td>2085.9±392.5</td>
<td>3284.6±895.2</td>
<td>9748.0±4101.8</td>
</tr>
<tr>
<td>Amount of legume residue allocated as feed (kg)</td>
<td>134.1±24.5</td>
<td>141.6±92.5</td>
<td>581.2±79.9</td>
<td>401.7±169.3</td>
<td>736.7±357.8</td>
<td>1793.7±176.2</td>
</tr>
<tr>
<td>Amount of other residue allocated as feed (kg)</td>
<td>4.8±4.8</td>
<td>0.0±0.0</td>
<td>21.4±12.2</td>
<td>0.0±0.0</td>
<td>0.0±0.0</td>
<td>473.5±163.1</td>
</tr>
<tr>
<td>Labour hour spent on animal (hour day⁻¹)</td>
<td>7.4±0.4</td>
<td>9.0±0.6</td>
<td>10.1±0.3</td>
<td>9.7±0.8</td>
<td>9.0±0.0</td>
<td>6.8±3.0</td>
</tr>
<tr>
<td>Time the animal spent grazing on the field (hour day⁻¹)</td>
<td>6.2±0.6</td>
<td>10.3±1.9</td>
<td>8.6±0.3</td>
<td>8.3±0.4</td>
<td>9.0±0.0</td>
<td>7.5±0.5</td>
</tr>
<tr>
<td>Amount of purchased feed-concentrate supplement (kg)</td>
<td>43.2±10.1</td>
<td>584.7±82.7</td>
<td>12.3±4.7</td>
<td>7.1±7.1</td>
<td>86.0±76.2</td>
<td>25.0±25.0</td>
</tr>
</tbody>
</table>

Tropical Livestock Units (TLU) is livestock numbers converted to a standard unit. One TLU is equivalent to one cattle with a body weight of 250 kg. Conversion factors are: cattle = 0.5, sheep = 0.1, goats = 0.1, chicken = 0.01 (FAO TLU sub-Saharan Africa, Harvest Choice, 2011).
## Appendix 2: Descriptive statistic of the selected representative farms for all typology variables from the respective typology means.

<table>
<thead>
<tr>
<th>Type</th>
<th>Farm</th>
<th>Value</th>
<th>Hhsize</th>
<th>Area (ha)</th>
<th>TLU</th>
<th>Cattle improved</th>
<th>Small ruminant</th>
<th>Poultry</th>
<th>Labour hour/animal</th>
<th>Time grazing (hr-1 day)</th>
<th>Cereal residue (kg)</th>
<th>Legume residue (kg)</th>
<th>Other residue (kg)</th>
<th>Purchased supplement (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Hallu 4</td>
<td>Mean</td>
<td>5.87</td>
<td>1.03</td>
<td>2.67</td>
<td>0.23</td>
<td>4.83</td>
<td>10.93</td>
<td>7.4</td>
<td>6.17</td>
<td>1269.13</td>
<td>134.13</td>
<td>4.79</td>
<td>43.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value of the farm</td>
<td>7</td>
<td>1.42</td>
<td>5.56</td>
<td>0</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>1351.55</td>
<td>333.71</td>
<td>143.73</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divergence</td>
<td>1.13</td>
<td>0.39</td>
<td>2.89</td>
<td>-0.23</td>
<td>5.17</td>
<td>-4.93</td>
<td>-1.4</td>
<td>0.83</td>
<td>82.42</td>
<td>199.58</td>
<td>138.94</td>
<td>-43.2</td>
</tr>
<tr>
<td>Type 2</td>
<td>Seloto 8</td>
<td>Mean</td>
<td>7.33</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>7.33</td>
<td>7.67</td>
<td>9</td>
<td>10.33</td>
<td>1042.43</td>
<td>141.55</td>
<td>0</td>
<td>58.676</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value of the farm</td>
<td>6</td>
<td>1.11</td>
<td>1.53</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>1517.04</td>
<td>324.44</td>
<td>0</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divergence</td>
<td>-1.33</td>
<td>0.11</td>
<td>-3.47</td>
<td>0</td>
<td>-7.33</td>
<td>-4.67</td>
<td>0</td>
<td>-1.33</td>
<td>474.61</td>
<td>182.89</td>
<td>0</td>
<td>691.324</td>
</tr>
<tr>
<td>Type 3</td>
<td>Hallu 16</td>
<td>Mean</td>
<td>7.3</td>
<td>2.12</td>
<td>4.42</td>
<td>0.21</td>
<td>6.24</td>
<td>7.15</td>
<td>10.09</td>
<td>8.58</td>
<td>2605.86</td>
<td>581.17</td>
<td>21.35</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value of the farm</td>
<td>5</td>
<td>2.02</td>
<td>4.53</td>
<td>0</td>
<td>15</td>
<td>3</td>
<td>12</td>
<td>8</td>
<td>2758.26</td>
<td>953.46</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divergence</td>
<td>-2.3</td>
<td>-0.1</td>
<td>0.11</td>
<td>-0.21</td>
<td>8.76</td>
<td>-4.15</td>
<td>1.91</td>
<td>-0.58</td>
<td>152.4</td>
<td>372.29</td>
<td>-21.35</td>
<td>-12.3</td>
</tr>
<tr>
<td>Type 4</td>
<td>Matufa 13</td>
<td>Mean</td>
<td>9.14</td>
<td>1.57</td>
<td>10.14</td>
<td>0</td>
<td>26.57</td>
<td>13.43</td>
<td>9.71</td>
<td>8.29</td>
<td>2085.93</td>
<td>401.76</td>
<td>0</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value of the farm</td>
<td>7</td>
<td>1.21</td>
<td>13.04</td>
<td>0</td>
<td>15</td>
<td>4</td>
<td>12</td>
<td>7</td>
<td>1654.95</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divergence</td>
<td>-2.14</td>
<td>-0.36</td>
<td>2.9</td>
<td>0</td>
<td>-11.57</td>
<td>-9.43</td>
<td>2.29</td>
<td>-1.29</td>
<td>-430.98</td>
<td>-401.76</td>
<td>0</td>
<td>-7.14</td>
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Appendix 3: Descriptive statistic of the detailed characterised farms for all typology variables from the respective typology means.

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<th>TLU</th>
<th>Cattle improved</th>
<th>Small ruminant</th>
<th>Poultry</th>
<th>Labour hour/animal hr-1 day</th>
<th>Time at grazing (hr-1 day)</th>
<th>Cereal residue (kg)</th>
<th>Legume residue (kg)</th>
<th>Other residue (kg)</th>
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* Show those detailed characterised farms, which are identified as an outlier during the cluster analysis and now did not belong to any type.