Availability of animal feed resources at farm and village scale in Umurera, Rwanda

MSc Thesis

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Abstract

Rwanda is the most densely populated country in Africa, resulting in intensification of farming systems and overexploitation of natural resources, the latter leading to food insecurity. In an attempt to solve the problem, the government initiated the 'One farm, one cow'-program. The main idea is to distribute cows to the poorest families, to provide them with milk and manure. Before animals are distributed farmers need to develop a stable and cultivate fodder. The objective of this research is to examine the viability of the program, leading to the following research hypothesis: 'Is it possible for each farmer in Umurera, Rwanda to produce sufficient fodder to keep cattle?'
On-farm measurements of both fodder production and livestock diet and outputs were performed. Based on these data, current and future possibilities for farmers in each of the three wealth categories to produce livestock fodder were assessed. The village Umurera is representative for the Central Plateau area in Rwanda.

The fieldwork-measurements revealed a large range in land-availability (0.10-2.86 ha). Most important fodder for cattle were: grasses (56%), parts of the banana plant (21%) and residues of several crops (15%). One quarter (25%) of the feed consisted of uncultivated grass. The farmer from WC-I (which is the lowest wealth-category occurring in the area) fed a lower percentage of grasses, but larger quantities of marshland-herbs and crop residues. The feed composition for cattle of WC-II and WC-III is almost equal. Some cattle in Umurera was underfed. The amount of fodder on offer for cattle ranged between 42 kg and 179 kg fresh weight per animal per day. The fodder-amounts on offer for local cattle of wealth-category II were substantially lower than amounts on offer for improved cattle, which is in agreement with literature. The same trend was not visible in the data from wealth-category III. The amount of refusals and the results of the chemical analysis of plant samples indicated a low quality of some fodder. On average farmers fed 3-4% *Cyperaceae* and 1-4% banana leaves. The milk yield in Umurera ranged between 1.33-4,58 l/d. The highest amount of milk was produced by an improved cow.

Calculations about the current possibilities for farmers to produce livestock fodder resulted in a negative conclusion for each of the three farmers from wealth-category I. The analysis also explored the effects of five scenarios in which the quantity of three cultivated fodder-plants was either increased, decreased or kept equal. The calculated annual fodder production (kg DM) per farmer indicates that in several scenarios two of the poorest farmers are likely able to keep local cattle. However, the GoR intends to distribute improved cattle, therefore the 'One farm, one cow'-program in its current set-up, is not viable. To be able to keep local cattle, the farmers need to make substantial investments, which might not be realistic in the first place. Furthermore, the annual production of fodder in Umurera is also likely to differ from the numbers used in calculations, which can directly affect the conclusion of this study. The viability of the program would increase in case the breed of distributed cattle would change from *B. taurus* to *B. indicus*.

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Abbreviations

Cat.	Category
DAP	Di-Ammonium Phosphate
DM	Dry Matter
DMY	Daily Milk Yield
Etc.	Etcetera
GDP	Gross Domestic Product
GoR	Government of Rwanda
Ha	Hectare
ISAR	Institute des Sciences Agronomiques du Rwanda
kg	Kilogram
l	Litre
m	Meter
ml	Millilitre
mm	Millimetre
MinAgri	Ministry of Agriculture
MSc	Master of Science
N	Nitrogen
NPK	Nitrogen, Phosphorus & Potassium
NUR	National University of Rwanda
PPA	Participatory Poverty Assessment
Prof.	Professor
spp.	Species
vs.	Versus
WC	wealth-wategory
yrs.	Years

1. Introduction

Rwanda is the most densely populated country in Africa (Bidogeza et al.. 2009); African tropical highlands often have high population densities because the soils are relatively fertile and the climate is favourable to intensive agriculture (Roose and Ndayizigiye 1997). The economy of Rwanda is primarily based on agriculture; the sector represents 45% of Rwanda's GDP and almost 90% of the active working population is employed in agriculture (Ansoms 2008a). As in most sub-Saharan countries, population growth results in intensification of crop-livestock systems, an increased pressure on arable land and a loss of communal grazing ground (Delve et al.. 2001). In 2000, the average land-surface available per Rwandan household was only 0.71 ha, which is even less compared to land availability during the eighties, when households possessed an average of 1.20 ha (Ansoms 2008b). Traditional livestock production systems disappeared and fodder bank practices have been introduced; zero-grazing livestock systems with cut and carry fodder supply. The increased land-use intensity caused soil degradation and soil erosion (Niang et al.. 1998, Roose and Ndayizigiye 1997). The continuing overexploitation of natural resources in Rwanda is an important cause of the most severe nutrient depletion rates in Africa (Drechsel and Reck 1998), leading to farmland ceasing to be productive and thus to food insecurity and malnutrition (Lewis & Nyamulinda 1996). As a result, the majority of Rwandan smallholder farmers face increasingly difficult living conditions (Ansoms 2009).

To improve the situation, the 'One farm, one cow'-program was initiated by the Rwandan government in 2006. The main goal is to fight poverty and improve livelihoods, through the provision of livestock (GoR 2006). The two major benefits of cattle are the production of milk and the provision of manure which can be used to increase crop production. The initiative is based on the idea that an individual who owns livestock, moves a step away from poverty and focuses specifically on households owning less than 0.75 ha of land. Before receiving cattle farmers need to prepare by developing appropriate housing (a 'zero-grazing unit') and by cultivating animal feed. Grass seed suitable for various ecological zones of the country will be distributed and disease control measures need to be in place before cattle is distributed. The increased milk production is an attempt to reduce the level of child malnutrition in the country (GoR 2006). Even though food production does not necessarily increase through use of livestock manure, due to increased nutrient losses, livestock is attractive for farmers due to their multiple functions (Giller et al.. 2011). The application of manure also plays an important role in maintaining soil fertility (Rufino et al.. 2007). Therefore, "It is hoped that by the end of the distribution period every Rwandese household has moved above the poverty line, is self-sufficient in food of animal origin and has manure to improve crop production" (GoR 2006).

The objective of this research is to examine the viability of the 'One farm, one cow'-program, as proposed by the Government of Rwanda (GoR). The research hypothesis of this research is: 'Is it possible for each farmer in Umurera to produce sufficient fodder to keep cattle?'
The hypothesis will be answered by analysing the production capacity of different farmers and by scaling these findings up to village scale. The amounts and composition of livestock feed, as well as the available land for each of the farmers are quantified to answer the research hypothesis.

2. Methodology

The fieldwork of this research was conducted in Umurera village (Kabusanza cell, Simbi sector, Huye district), which is representative for the Central Plateau-area in Rwanda. The fieldwork took place during twelve weeks from September 2010 until December 2010. The Central Plateau-area covers the central region of the country, which receives a mean annual precipitation of 1,150 mm (Hagedorn et al. 1997) and has an altitude-range of 1,500-2,100 m (Musabyimana 2008). Histosols and cambisols are dominant in the marshland, while ultisols, leptosols and cambisols are dominant uphill (Musabyimana 2008). Rainfall is bimodal throughout the country, with the long rain season from February till June and the short rain season from August until December (Hagedorn et al. 1997). The basal food crops for farmers in Kabusanza-cell are beans and sweet potatoes, other important food crops are maize, sorghum, banana and Irish potatoes. The main cash crops are coffee and vegetables (Musabyimana 2008).

Quantitative measurements on land-size (edge-length) were taken by myself, while the measurements on livestock feed were taken by eleven participating farmers. The farmers are divided in three categories: wealth-category I consists of the poorest farmers, while wealth-category III consists of relatively wealthy farmers (Bucagu *in prep*). For each category, four representative farmers were asked to participate in the research. Only three farmers were available in wealth-category III.

To realise on-farm measurements of livestock feed for 16 cattle and two goats, the farmers were provided with a mechanical hanging scale (0-100 kg) and one measurement-scheme per animal per week. The columns in the schemes summed up the main fodder species, as indicated by the farmer, and the rows covered the seven days of a week. The last column indicated ‘Others’, and was used to record uncommon types of livestock feed. All feed measurements were performed as fresh weights. The number of animals and species of which the feed quantities were measured depended on the situation of each farmer. Important factors were for example livestock species, number of livestock and willingness to participate. All farmers measured feed quantities for at least one ruminant and at least during the seven consecutive weeks.
The daily milk production (l/d) was measured by five farmers who owned a lactating cow during at least one week of the research-period. A cup (500 ml) was provided to measure the milk production per cow per day. Refusals of cattle were measured during the last five weeks of the research, but only by the farmers of wealth-category II. The weight of refusals were measured at the end of a day, using the mechanical hanging scale.

A measuring tape (0-50 m) was used to measure the edge-lengths of all fields. Fields were distinguished from each other using several features, such as a difference in altitude, the presence of drainage or irrigation-canals or cultivated ridges as well as a difference in crop under cultivation. The majority of the fields had a rectangular shape, meaning it was sufficient to measure the length of four edges. The surface of each field was calculated using the measurements of the edge-lengths. Measurements of the total edge-length were also necessary to estimate future possibilities for fodder production, in case a larger part of the edges is used to cultivate fodder.

Both quantitative and qualitative information has been collected through two rounds of interviews, both with the help of a translator (students from the National University of Rwanda). The interview during the first weeks was held to create an overview of the current situation for each farmer. General data were collected, such as number of household members, livestock and number of fields. The second interview was conducted during the twelfth week and focused on sources of several fodder plants, routes and rules for fodder collection, collection time, etc.

A large number of plant species being used as fodder were identified with the help of Prof. Esron Munyanziza. All species recorded on the measurement-schemes were later categorized in one of the following six groups.

1. Calliandra
2. Grass
    a. Pennisetum
    b. Other grass
3. Banana
    a. Pseudo-stems
    b. Leaves
4. Crop residues
    a. Sweet potato
    b. Bean
    c. Other crops
5. Herbs marshland
    a. Cyperaceae
    b. Commelina
6. Others

Group 4c contains residues of the following crops: sorghum, peas, rice, Irish potatoes and banana peelings.
Group 6 contains exceptions: leaves of ficus and avocado tree, *Amaranthus* and *Tithonia diversifolia*.

To analyse their chemical content, twelve samples of nine fodder species were collected, as well as 16 manure samples from all cattle included in this research. The samples were dried in an oven (at 70° Celsius) for 48 hours. Fresh and dry weights of the samples were measured using an electronic balance in the laboratory of the NUR.

3. Results

3.1 Categorization

Through the nationwide Participatory Poverty Assessment (PPA) exercise, the Government of Rwanda (GoR) distinguished a total of six wealth-categories, using property of land and livestock as main indicators of wealth (Ansoms 2008a). According to data on available land, household-size, number of livestock, etc., collected by Charles Bucagu (2007), representatives of three of those categories were found in Umurera (Bucagu *in prep*). The farmers participating in this research were therefore divided in one of three categories. In this study these were renamed into wealth-category I, II and III. The first interview was conducted to create an overview of the current situation for each of the farmers (Table 1).

Table 1 General information and categorization of the farmers

Farmer	Category	Hh-members	Livestock	Cattle	Goats	Pigs	Surface (ha)
A	1	4	1	0	1	0	0.11
B	1	4	2	0	2	0	0.10
C	1	4	3	1	2	0	0.13
D	2	5	3	1	1	1	0.51
E	2	5	7	3	3	1	0.39
F	2	6	7	3	4	0	0.44
G	2	7	5	2	2	1	0.48
H	2	5	6	3	3	0	0.48
I	3	5	10	3	6	1	1.37
J	3	7	8	3	4	1	0.90
K	3	7	4	3	1	0	2.86

The pattern in land availability per farmer is as expected, with one exception for farmer D. This farmer was classified as wealth-category I by mistake and will from now on be considered as a farmer from wealth-category II. All households of wealth-category I had only one adult in the family, explaining the low number of household members and probably also the level of poverty. The interview-questions concerning livestock included animals on loan, because farmers also feed animals of which they were not the owners. The bull of farmer C was not her property, therefore none of the farmers from wealth-category I owned cattle. This creates a clear distinction between wealth-category I and the other categories. The information collected in Umurera (Table 1) is in occurrence with the results of a survey conducted among 67 farmers in Kabusanza cell in 2007 (Musabyimana 2008).

3.2 Land data

3.2.1 Land availability

The surface of available land per farmer ranged between 0.10 and 2.86 ha (Figure 1). Largest differences were present between the first two wealth-categories and wealth-category III. An explanation could be privileges coming along with being the chief of a village (farmer I and K). The average surface of available land size is 0.71 ha, which is exactly the same as the number from the GoR in 2004 (Ansoms 2008b). The total land-surface is divided by field-location; either on the sloping hills around the houses or in the uninhabited marsh.

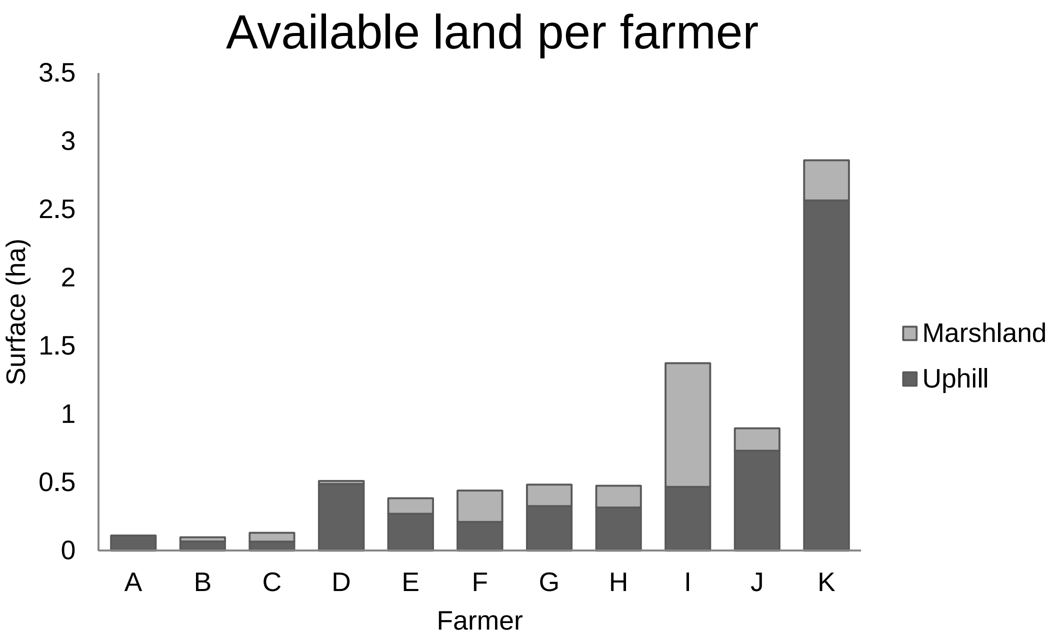

Figure 1 Total land-surface (ha) available per farmer, divided by field-location

This distinction was made, because a difference in soil fertility is expected between the two locations. Generally, people owned fields in the marshland within one of the cooperatives, while land located uphill was always for personal use. Farmers from wealth-category I and II only possessed marshland-fields owned within a cooperative, while the wealthiest farmers also possessed private fields in the marshland. According to one farmer (farmer J) all marshland is owned by the government, but managed by local cooperatives using a system of rent-prices depending on wealth-category.

3.2.2 Fertilizers

Mineral fertilizer

All farmers applied mineral fertilizers solely on fields located in the marshland and always in combination with organic fertilizer. Probably, the input of mineral fertilizer was concentrated on the marshland, because the soil is relatively fertile and moist. Higher yields can therefore be expected from field in the marshland compared to uphill-land. The interviews showed that farmers used NPK, DAP and urea. The amounts and ratios in which these mineral fertilizers were used were quite variable, but urea was always used in combination with NPK or DAP and never with both. The moment of application was the same for all farmers: at the beginning of each growing season, resulting in a frequency of twice per year. In general, farmers applied mineral fertilizer on all cultivated crops in the marshland. Several farmers quantified the amount of NPK or DAP, being applied directly in the seed hole (1-3 kg per acre). The majority of the farmers used urea, which was applied around the plant a few weeks after sowing (1-2 kg per acre).

Organic fertilizer

All farmers used manure or compost as organic fertilizer for their fields. Smallholder farmers in Rwanda consider farmyard manure as the most effective fertilizer (Hagedorn et al. 1997). The application was done at the beginning of each growing season and thus with a frequency of twice per year. Most farmers spread organic fertilizer equally over their fields, while a few farmers applied more on fields close to the homestead. The majority of the farmers used a compost-pit to mix and de-compose refusals, manure, garbage and crop residuals. Three farmers, two from wealth-category I, did not have a compost-pit, the reason is unknown. The third farmer planned to build a compost-pit soon. The farmers used a basket (15-20 kg if full) to carry compost from the homestead to fields. It was difficult to get comparable data on the quantities of fertilizer applied, because several management-systems were in use. Several farmers were unable to quantify the amount of organic manure. The quantifications of the other farmers vary from 5-6 baskets, up to 30 baskets per field.

3.2.3 Communal land

According to the interviewed farmers there is no communal land available in Umurera. The utilization of resources indeed appeared to be maximal; almost all the land in the area were cultivated and the few fields under fallow had owners. Among the farmers participating in the research were two chiefs of a ‘mudugudu’, a village, whom confirmed the information given by the other farmers. On the other hand, it is impossible to cultivate the sides of the creek. Therefore, the creek-sides did not have an owner and could thus be seen as communally-owned. Information about the sources of the two uncultivated fodder groups (group 2b and 5) can be found in the paragraph on fodder collection (§ 3.5).

3.3 Livestock feed

One farmer (farmer K) used a management system completely different from the general system of zero-grazing with cut and carry fodder supply. It was impossible to quantify the daily intake of his cattle within this research, because he owned a large pasture field where he let the cattle graze. The fodder measurements and the information on feed composition of his cattle are not representative and will therefore not be used.

3.3.1 Feed composition

Information about the feed composition for the two goats was excluded, because the focus of this research is on cattle. An overview of the actual livestock diet was created using the information from the measurement-schemes of all cattle (both young stock and mature animals). During the time of the research the most important fodder groups for cattle were: grasses (56%), different parts of the banana plant (21%) and residues of several crops (15%). The divide within the group of grasses is 31% of pennisetum (*P. purpureum*) and 25% of uncultivated grass. These data are comparable to observations in Kenya by Paterson et al. (1999). Cattle kept within a zero-grazing system was fed a diet of mainly pennisetum. Other fodder materials, such as crop residues, banana pseudo-stems, banana leaves and uncultivated grasses were fed depending on the season (Paterson et al. 1999). Recent findings by Ongadi et al. (2010) are similar; crossbred cattle was fed a diet of fresh pennisetum, supplemented with sweet potato vines and fodder trees and legumes (Ongadi et al. 2010).

Differences between wealth-categories

The feed composition was analysed separately for each of the wealth-categories (Figure 2). The results of wealth-category I need to be interpreted carefully, because they represent only one farmer. An important difference between the wealth-categories is the percentage of grasses fed to the cattle: this is about one-third lower for wealth-category I. The absence of grass is compensated for by feeding larger quantities of marshland-herbs and crop residues. The feed composition for cattle of wealth-category II and III is almost equal. There are slight changes in the exact percentages, but the three major fodder groups are similar; grasses (59%; 55%), banana plant (21%; 22%) and crop residues (14%; 14%).

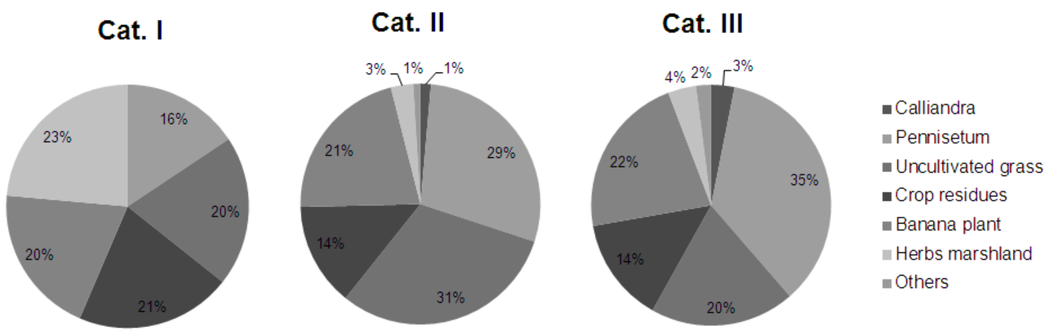

Figure 2 Overall feed composition of all cattle per wealth-category

As fodder, the most important part of the banana plant was the rhizome; only 3.1% and 2.5% of the total composition consists of banana leaves. The percentage of grass was divided in cultivated and uncultivated grasses: 54% vs. 46% respectively for wealth-category I, 47% vs. 53% for wealth-category II and 64% vs. 36% for wealth-category III. The highest percentage of pennisetum was fed by the wealthiest farmers, while the trend for the poorest farmers was to feed uncultivated fodder.

Interview vs. reality

Farmers were asked to rank their Top 3 of fodder species, according to use, for both the dry and wet season. The most important species was given three points, while the third species received one point. This information was translated into an ‘expected’ diet composition for each of the seasons, giving an idea about shifts in feed composition between the seasons. Grasses –cultivated and uncultivated combined- were the most important fodder species for both seasons. The biggest differences between seasons were the appearance of calliandra in the three highest scoring species for the wet season, and the importance of banana pseudo-stems during the dry season (receiving 25% of the points). The actual feed composition should be compared with information on the wet season, because the research-period mainly overlapped with the short wet season in Rwanda (Hagedorn et al. 1997). The biggest surprise was the small actual role of calliandra; from the interview it was expected to be an important fodder species, whereas in the on-farm measurements it was only a minor contributor to animal feed.

Perfect feed

The farmers also described the ideal feed for either cattle or goats. The most important species was pennisetum; all farmers included it in the diet. Eight farmers would feed uncultivated grass, even though time to collect was long. Four farmers would feed a diet of pure grass, two of them choose pure pennisetum while the other two would mix cultivated and uncultivated grasses. Main reasons to feed pennisetum were the sufficient availability and a preference of cattle. Five farmers mentioned calliandra, always offered together with other fodder plants. One farmer mentioned a ratio of 15 kg pennisetum mixed with 3-4 kg calliandra. The main reasons not to feed calliandra were the small size of the leaves and an aversion by livestock. Contradicting opinions existed about banana pseudo-stems as fodder; two farmers included them in the ideal diet, both because of the high water content, while one farmer emphasized banana pseudo-stems should never be fed to cattle.

3.3.2 Fresh fodder on offer

The average amount of daily fodder on offer for each week was calculated without using the measurements taken on Mondays. Often these were not representative; measurements from early in the morning were missing, because the new schemes were not yet available to the farmers. The measurements from the seven consecutive weeks were used to produce the trend lines of the average amounts of fresh fodder on offer per animal per day (Figure 3, Figure 4). This is the clearest manner to compare the data and the measurements of these weeks also have the highest quality with respect to data-collection.

The daily amount of fodder on offer for local cows of wealth-category II ranged between 42 kg (cow H) and 110 kg (cow G) (Figure 3), while for improved cattle the averages were 143 kg (cow F) and 179 kg (cow G) (Figure 4). These amounts from Umurera are comparable to data from on-farm experiments in Kenya by Paterson et al. (1999). They recorded a very consistent pennisetum intake of about 80 kg per animal per day, or the dry matter (DM) equivalent of this in terms of crop residues, weeds and parts of banana plants (Paterson et al. 1999). Cattle in their experiments were improved Friesian and Ayrshire cows. The average amount of fodder for cow H was surprisingly low, but still within the range of 35-65 kg found by Ongadi et al. (2010). This range is a result of surveys in Kenya among 236 improved cattle owning households. Fodder on offer depended on season and production system; more was offered during the wet season and in zero-grazing systems (Ongadi et al. 2010). The difference between feed demand and fodder on offer indicates malnourishment for some animals in Umurera. This conclusion is similar to that by Paterson et al. (1998), who suggested the presence of a large feed deficit after comparing the mean daily availability of pennisetum with estimations on daily requirements of cattle (Paterson et al. 1998).

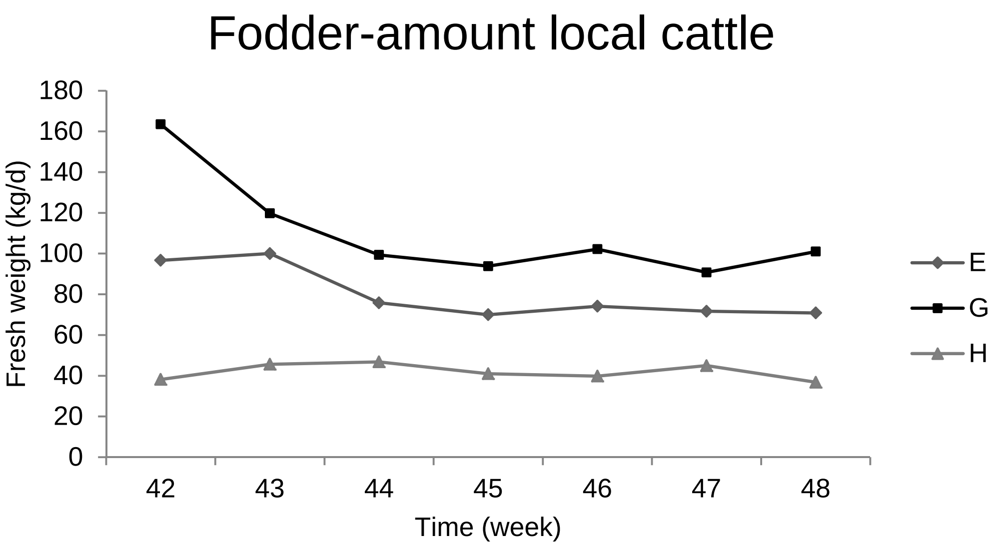

Figure 3 Average amount of fodder on offer per animal per day for local cattle of wealth-category II. Cow E, G and H are respectively 6,7 and >7 yrs. Cow H is lactating (1.85 l/d)

Feed demand depends largely on cattle breed and milk production. Most local tropical cattle belong to *Bos indicus* species (Hatungumukama et al. 2006). Their potential milk production is low, but these species are well-known for their low maintenance requirements. *Bos taurus* species are mainly found in temperate regions and have a high potential milk production and feed demand. Crossbreeding these species has widely been used to increase milk production in the tropics (Hatungumukama et al. 2006).

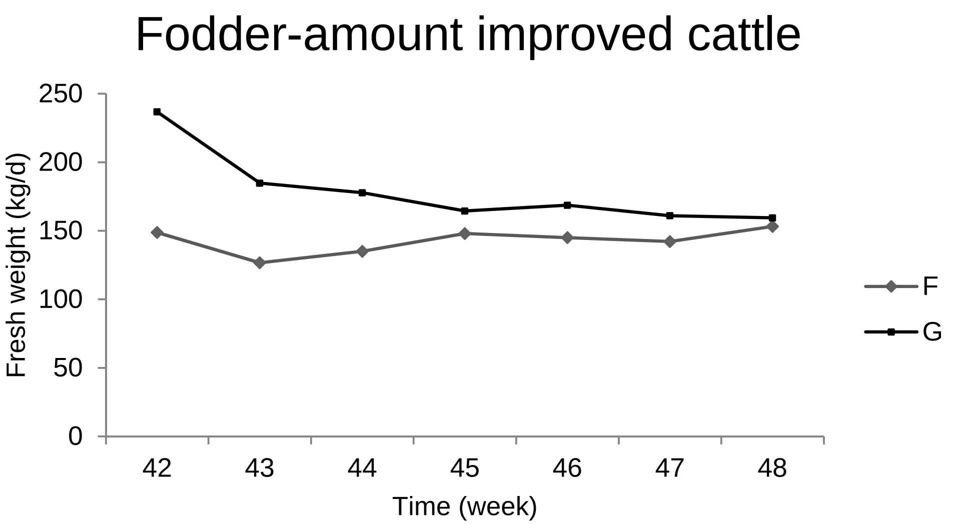

Figure 4 Average amount of fodder on offer per animal per day, for improved cattle of wealth-category II. Cow F and G are >3 and 2 yrs. Cow F is lactating (4.58 l/d)

The higher live weight of improved cattle automatically results in a higher feed demand. For example, a relatively small *B. taurus* breed like the Jersey can easily have double the live weight of a local cow (Felius 1985). The data about fodder on offer for wealth-category II (Figure 3, Figure 4) confirm breed as an explaining factor. Several farmers emphasized the large amount of fodder consumed by improved animals. However, the statement was not supported by the data of wealth-category III. An explanation might be the small number of cattle used within the research (one local and two improved, for wealth-category III), decreasing the reliability of the data. Another reason might be that information concerning the breed of cattle is not totally correct. Two farmers fed a relatively high amount during the first week. This could be the effect of rainfall, because it was the short rainperiod (Hagedorn et al. 1997). However, the same trend is not visible for the other farmers. Another explanation could be the time available for these farmers to collect fodder.

3.3.3 Fodder-quality

Twelve samples were taken from nine different fodder species; two samples were taken from three species. Included were both banana leaves and pseudo-stems, as well as samples from both field-locations of cultivated and uncultivated grass. The quality of fodder depends on its chemical composition and digestibility (Mwangi et al. 2004). Therefore, the samples were analysed for nitrogen, phosphorus and potassium content (Table 2). The dry matter (DM) content and the chemical composition of the pennisetum samples indicate the importance of separating marshland from uphill land. The sample from the marshland had a lower DM, but a higher N content. This can be explained by the relatively moist and fertile conditions of the marshland. Niang et al. (1998) recorded a DM content of pennisetum of 242 g/kg in southern Rwanda, with N of 11.5 g/kg, P of 1.8 g/kg and K of 1.3 g/kg (Niang et al. 1998). Rufino et al. (2008) used similar numbers for modelling livestock productivity with pennisetum as one of the feed on offer; a DM of 170 g/kg and N of 24 g/kg (Rufino et al. 2008). Juma et al. (2006) measured an average DM of 200 g/kg, with 12.2 g/kg N in a study conducted in Kenya (Juma et al. 2006). The DM digestibility of pennisetum is 0.546 g/kg (Rufino et al. 2008). It was impossible to find data on the DM digestibility of the other plant species.

Table 2 Location, dry matter content and chemical composition (g/kg) of twelve plant samples from Umurera

Name	Location	DM	N	P	K
Leucaena	Uphill	331.28	39.55	1.55	12.67
Sesbania	Uphill	239.49	38.20	2.32	15.70
Calliandra	Uphill	387.74	27.50	1.10	8.14
Pennisetum	Marshland	150.28	24.40	2.31	40.57
Cyperaceae	Marshland	216.47	21.80	1.60	31.42
Sw. potato plant	Marshland	122.90	19.10	2.32	21.35
Pennisetum	Uphill	214.51	18.20	1.84	27.24
Couch grass	Uphill	297.03	16.10	1.01	14.58
Banana leaves	Uphill	253.51	15.15	1.67	28.28
Couch grass	Marshland	308.50	13.35	3.54	29.73
Commelina	Marshland	241.61	12.70	1.83	26.53
Banana rhizome	Uphill	261.28	3.35	1.35	34.74

Drechsel and Reck (1998) studied smallholder farming systems in Butare, southern Rwanda. They measured a N concentration of calliandra ranging between 25-34 g/kg (Drechsel and Reck 1998), again confirming the results from Umurera.

Measurements by Niang et al. (1998) recorded a DM content of 378 and 381 g/kg and N of 35.7 and 37.4 g/kg (Niang et al. 1998). For sesbania, they found a DM content of 320 and 322 g/kg and N of 27.0 and 29.3 g/kg.

Literature covering the chemical composition of banana pseudo-stems or leaves is scarce. The latter were studied recently by Nyombi et al. (2010) during two crop cycles in Uganda, at two sites. An N content of 25.4 and 17.0 g/kg was recorded at the first site, these numbers were 25.0 and 16.5 g/kg for the other site (Nyombi et al. 2010). Unpublished data collected in Uganda show an average DM content of 340 g/kg for banana leaves and 119 g/kg for banana pseudo-stems (Van Asten 2011 pers. comm.).

The species containing the highest amount of nitrogen (Table 2) are the three leguminous shrubs (*Leucaena*, *Sesbania* and *Calliandra*). This is confirm the expectation, because legumes have the ability to fix atmospheric nitrogen (Mwangi et al. 2004). Fodder legumes also have a higher nutritive value than tropical grasses (Mwangi et al. 2004). Strikingly, the next three samples high in nitrogen all originate from the marshland, confirming its relatively high fertility. The sample of banana pseudo-stems contained a very low amount of nitrogen, while it is an important fodder species in Umurera. Therefore, at least part of the livestock feed had a low quality, which can result in decreased production of cattle (Paterson et al. 1999).

3.4 Livestock output

3.4.1 Milk

Milk production of crossbred cattle in the tropics depends on genetic and environmental factors. Factors influencing milk production are cattle breed, diseases, feeding, suckling and milking frequency (Hatungumukama et al. 2006). The highest daily milk yield (4.58 l/d) was recorded for cow F (Figure 5). The high production might be due to the presence of a suckling calf, because suckling is known to increase the milk ejection and milk production by (mixed) *Bos indicus* breeds (Hatungumukama et al. 2006). On the other hand, cow H was also suckled, but still produced a low amount of milk (1.85 l/d). Therefore, a more plausible explanation is cattle breed, because cow F is the only improved cow and Bee et al. (2006) concluded that milk production is affected by *Bos taurus* inheritance ($P < 0.05$) (Bee et al. 2006). The daily milk yield of cows F, H and K (4,58, 1,85 and 3,23 l/d respectively) is fairly equal over time, while the production of cow J (2.2 l/d) decreased substantially (Figure 5). The farmer stated that this cow was near the end of her lactation. A normal lactation-length for cattle in Umurera is 2-5 months.

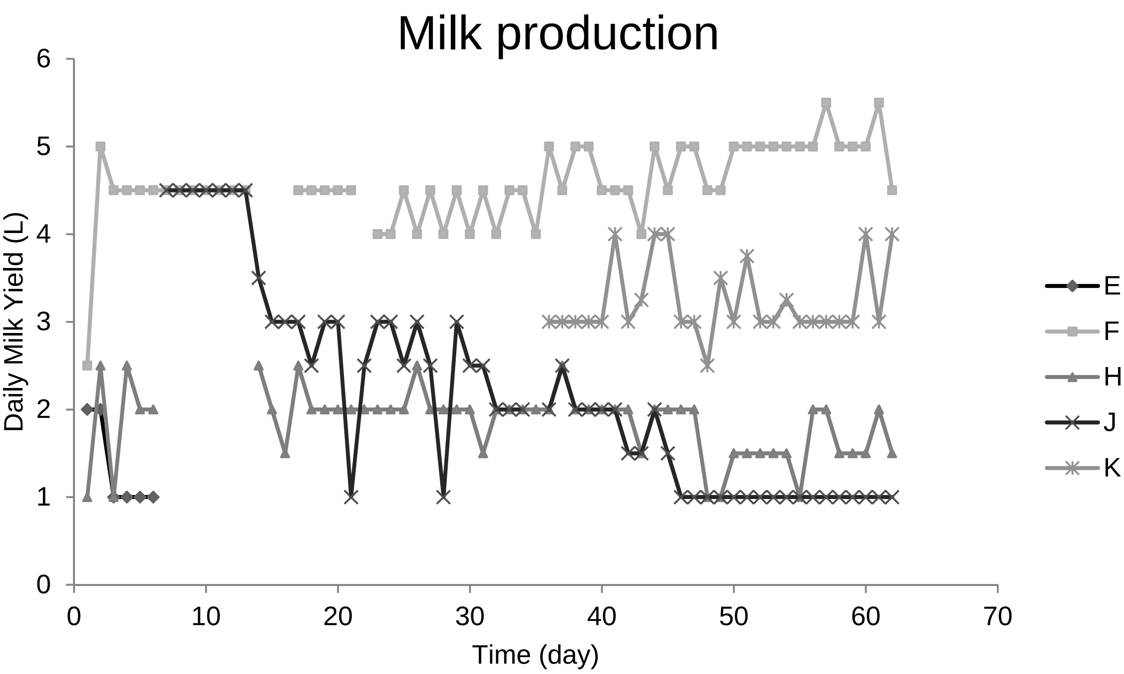

Figure 5 Milk production per day for cows of farmer E (6 yrs), F (> 3 yrs), H (> 7 yrs), J (8 yrs) and K (15 yrs). Cow F is partly improved, the other animals are local

Most research reporting on dairy production in Africa focuses on improved cattle, while there is little information on pure *B. indicus* breeds. The daily milk yield (DMY) of an improved cow in Umurera (4.58 l/d) is similar to yields found in literature. For example, a study on Jerseys in Kenya recorded an average DMY of 5.0 l/d (± 2.1) (Juma et al. 2006). Bee et al. (2006) measured a somewhat higher DMY of 6.7 l/d for crossbred cows (Friesian and Ayrshire) in Tanzania (Bee et al. 2006). A study by Paterson et al. (1999) recorded higher milk yields by improved cattle managed with a zero-grazing livestock system. They recorded a DMY of 10 l/d for crossbred cattle (Friesian and Ayrshire), fed mainly pennisetum and crop residues (Paterson et al. 1999). An important difference is the supplementation with 2 kg of concentrate, or its equivalent in the form of calliandra (6 kg fresh material), per animal per day (Paterson et al. 1999).

The average DMY of pure Sahiwal (*B. indicus* spp.) cows in Burundi was 6.69 l/d for milked and suckled cows, and 2.88 l/d for cows when only milked (Hatungumukama et al. 2009). There appears to be scope for improvement for DMY in the region when comparing these published yields with the DMY of cattle in Umurera. Inadequate nutrition is the main cause of low productivity by African cattle (Teferedegne 2000) and is generally seen as the most important limitation to milk production (Paterson et al. 1998). Therefore, improving feed quantity and quality should be the focus of attempts to reach the genetic potential of cattle in Umurera. Increasing fodder quality means increasing the protein content and/or digestibility of fodder. A high protein content is also essential in meeting the requirements of lactating cattle, as protein is secreted in the milk (Juma et al. 2006). A common way to increase the protein content of livestock diet is supplementation with commercial concentrates (Ongadi et al. 2010), but the majority of subsistence farmers is unable to invest in such additions (Mwangi et al. 2004). A more viable option for farmers in Umurera is supplementation with a protein-rich fodder such as for example *Calliandra calothyrsus* (see also § 5.1).

3.4.2 Refusals

The refusals of cattle were measured once a day by the farmers of wealth-category II. This was done at the end of the day during the final five weeks of the research-period. Only four farmers measured this type of output, because the willingness of farmers from the other categories to perform these measurements was not large enough. In case refusals were remaining at the end of a day, farmers put these inside the stable. Generally, the stable was emptied into a compost-pit once or twice a month. From here the organic fertilizer was returned to the land (§ 3.2.2).

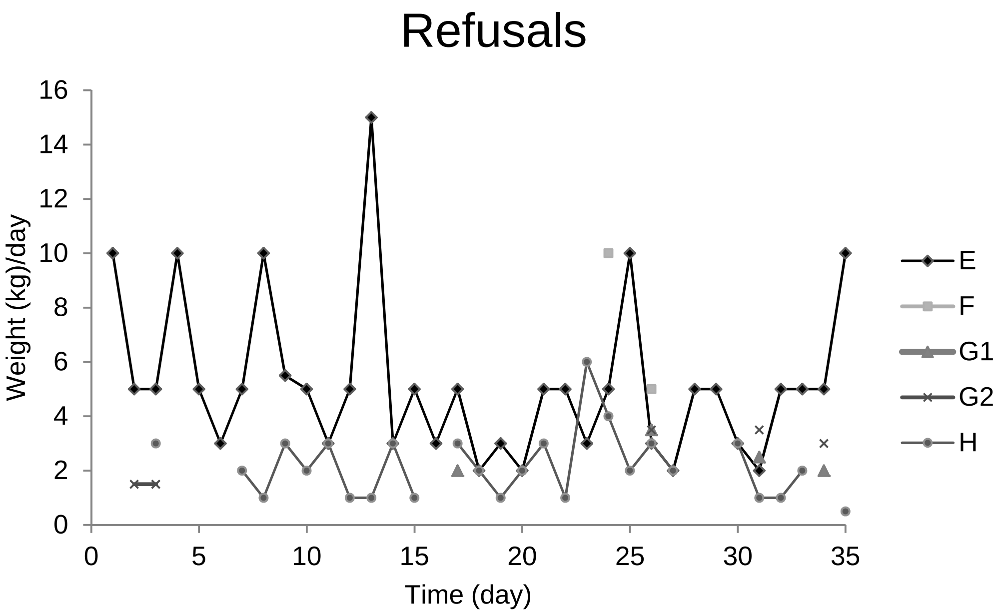

Figure 6 Total refusal weight (kg) per animal per day for cattle of wealth-category II

Surprisingly, refusals were recorded even for cow H (Figure 6), while the amount of fodder on offer for this animal was extremely low. Combining information about the diet composition of cattle (Figure 2) with the analyses of several plant samples (Table

2), the refusals become less surprising. At least part of feed offered to livestock is of low quality. For example, 3-4% of the diet consisted of *Cyperaceae*. At first, most farmers did not record this species, because the animals barely consumed these plants. The reason to offer it to livestock was to create more compost. A second example of fodder of poor quality is banana leaves. Farmer F and G fed 1% of banana leaves, while farmer E and H fed 2-4%. The amount of refusals left by cow F was so small that it was impossible to quantify with the scale available. The two single measurements for this animal can be explained by the feeding of avocado leaves; an avocado tree had been cut down. There is no such explanation for the peaks recorded for cow E (Figure 6); a regular diet was fed, containing uncultivated fodder, crop residues and pennisetum. An explanation might be sickness of the animal, but the frequency of the peaks indicate that low fodder quality is more likely to be the problem.

3.4.3 Manure

One of the two major benefits of cattle mentioned in the ‘One farm, one cow’-program, is the provision of manure for increased crop production (GoR 2006). However, due to increased nutrient losses in the use of manure compared to direct application of potential animal feed on arable land, food production does not necessarily increase through livestock manure (Giller et al. 2011). Generally, a part of the nitrogen taken up through feed is lost through urine, but improved storage and application of manure can increase the efficiency of its use (Rufino et al. 2006). On the other hand, manure plays an important role in smallholder farming systems, by providing organic fertilizer.

Table 3 Dry matter content and chemical composition (g/kg) of manure samples of cattle from Umurera

Animal characteristics	Farmer	DM	N	P	K
Bull, 14 months	C	357.85	17.20	2.10	12.73
Cow, 5 yrs	D	227.14	14.60	2.75	10.45
Cow, age unknown	E	180.72	10.50	2.96	12.38
Bull, 1 yr	E	246.71	13.90	2.37	4.36
Cow, lactating, > 3 yrs	F	217.92	16.95	2.11	7.82
Bull, 1 yr	F	219.43	14.70	2.20	9.08
Cow, 7 yrs	G	242.80	14.20	2.30	8.60
Cow, 2 yrs	G	350.28	13.80	2.28	5.72
Mature, lactating, 7-8 yrs	H	147.61	13.40	1.61	11.55
Calf, 9 months	H	188.21	13.10	2.78	7.82
Mature, 2 yrs	I	192.82	14.10	2.73	16.08
Heifer, 15 months	I	160.09	12.00	2.05	9.19
Cow, lactating, 8 yrs	J	149.19	15.80	1.95	8.56
Cow, 5 yrs	J	153.00	15.75	2.18	19.79
Cow, lactating, 15 yrs	K	158.83	15.60	2.83	11.64
Cow, 7-8 yrs	K	161.21	16.80	3.43	14.99

The farmers in Umurera were unable to quantify livestock output of manure, but a fresh manure sample from all sixteen cattle included in this research was collected. Drechsel and Reck (1998) analysed manure of cows in southern Rwanda and found an N-content of 16.3 g/kg (Drechsel and Reck 1998), which is similar to the results of the samples from Umurera (Table 3). To analyse nitrogen flows in African farming systems, Rufino (2008) used a DM content in ruminant manure of 350 g/kg, with a range of 200-500 g/kg, and a nitrogen concentration of 20 g/kg, with a range of 10-30 g/kg (Rufino 2008). Many samples from Umurera contain less DM (Table 3).

3.5 Collection of fodder

3.5.1 Routes and Rules

A distinction was necessary between cultivated fodder (such as *Pennisetum* and *Calliandra*) and uncultivated fodder (such as *Commelina* and *Cyperaceae*). None of the interviewed farmers used a specific collection route to harvest uncultivated fodder. Most farmers harvested these plants anywhere they were found; along the creek, growing between crops and along the numerous small paths between the marshland-fields, where the biggest proportion of the uncultivated fodder was collected. The big road uphill was not mentioned as fodder-source; one farmer stated it is cleaned too often to be of use. Cultivated fodder, on the other hand, was growing along edges of some uphill fields. Therefore, some farmers indicated to use a collection-route, for example first close to the house and later further away. The time passing before farmers returned to a spot for harvesting ranged between 2-4 weeks during the wet season, and between 4-16 weeks during the dry season. Wealthier farmers generally waited more weeks before returning to a spot, probably because their resources are more abundant.
The majority of the farmers indicated there were no rules for fodder collection. The collection of uncultivated herbs and grasses was generally allowed everywhere. People collected at and along paths, the creek and on arable fields, even when the field is not their property. Officially, permission was necessary when the owner of the land also owns livestock, but sometimes people collect without seeking permission. The harvest of cultivated species off land from somebody else is considered theft and punished as such.

3.5.2 Collection time

The total time needed to collect fodder per day differs strongly between the farmers. Cattle owning farmers spent between 45 and 420 minutes per day collecting fodder. The two goat keeping farmers collected fodder for 30 and 45 minutes per day during the wet season, but needed up to 120 minutes during the dry season. A relation was expected between fodder amount on offer and the time necessary for collection. Indeed, the only farmer who was able to collect fodder in less than one hour, is the farmer who fed the least average amount of fodder (42 kg/d). Another source of variation is the diet composition of fodder. The time necessary to collect a bag of uncultivated fodder is longer compared with the time needed to collect a bag of pennisetum.

3.5.3 Acquisition of fodder

None of the farmers sold fodder, while seven farmers purchased fodder during at least a part of the year, indicating a limited or insufficient availability of fodder in Umurera. It was not clear where the participating farmers purchased the fodder, but most likely this was outside the borders of the village. An explanation could be a relatively high livestock-density in Umurera, but this was not investigated. Among the farmers who bought fodder, we find all three farmers from wealth-category III as well as the only farmer from wealth-category I. Farmers bought only two plants; all farmers bought pennisetum and four farmers bought banana pseudo-stems.

3.5.4 Origin of ‘Other grass’

One quarter of the livestock diet consisted of uncultivated grass, which was also used by all farmers. To get an idea about the sources of this uncultivated fodder, farmers were asked to indicate the percentage that originated from their private property in case they would feed 10 kg of uncultivated fodder. Generally, most farmers estimated the amount to be less than 2.5 kg. One farmer from wealth-category I even collected all uncultivated fodder from public utilities and other people's property. Contradicting estimations were given by three farmers who estimated to harvest the majority of uncultivated fodder material on their private fields. Those estimations are conform the expectation, because among these farmers are the two village-chiefs, who both own more than 1 ha of land.

4. Analysis

The focus of this chapter is on farmers of wealth-category I, because these farmers are the target group of the ‘One farm, one cow’-program. To reach a conclusion concerning the situation of the poorest farmers, it is essential to study the data about mature cattle collected from the other wealth-categories.

4.1 Fodder on offer

These data quantify the actual amounts of fodder (expressed in dry matter (DM)) on offer per day for mature cattle in Umurera (Table 4). To calculate daily DM for each animal specifically, the results from the plant-sample analysis (Table 2) are combined with data about fodder amounts on offer per animal. The total of the three plant species is extrapolated to a daily overall total according to the diet composition of each animal, using the weighted average of the DM content. Averages are calculated for lactating, improved and local cows (Table 4). Lactating cows are E, F, H and J. Local cows are C, E, G2, H and J, the remaining animals are partly improved. The calculated total DM for improved cattle is higher compared to local cattle, which is conform the expectation. The annual DM on offer for lactating cattle is relatively low. The explanation might be the effect of the small number of cattle included in the research.

Table 4 Calculated dry matter on offer of three plant species for nine cows in Umurera

Animal	Pennisetum	Calliandra	Pseudo-stems	Leaves	Total (3 spp.)	Daily total	Year-round
D	5.72	3.18	9.23	5.89	24.01	36.3	13,262
E	2.98	0.27	2.64	0.45	6.35	15.6	5,709
F	9.75	-	7.23	0.35	17.34	26.3	9,616
G	8.63	0.76	11.72	0.56	21.67	36.4	13,308
G2	4.60	0.55	7.04	0.37	12.56	22.9	8,356
H	0.94	-	1.71	0.18	2.82	8.8	3,208
I	2.37	0.51	5.07	0.08	8.03	14.4	5,271
J	5.42	1.58	4.75	-	11.75	21.6	7,899
J2	5.39	1.52	4.35	-	11.26	20.6	7,542
Lactating	4.77	0.46	4.08	0.25	9.56	18.1	6,608
Improved	6.54	0.70	7.09	0.25	14.57	24.5	8,934
Local	3.93	1.12	5.07	1.38	11.50	21.0	7,687
Total	5.09	0.93	5.97	0.87	12.86	22.6	8,241

An important conclusion from the previous chapter is that fodder on offer cannot be equal to feed demand. Supporting this statement are measurements and observations from Umurera about refusals (§ 3.4.2). The refusals indicate a low quality of at least some of the fodder on offer, which is confirmed by information about feed composition and fodder-quality (Table 2). A low fodder quality is likely to result in a higher total DM needed to meet N requirements of cattle.
Numbers in literature about feed demand of improved tropical cattle confirm the conclusion. For example, the Kenyan Ministry of Agriculture (1992) estimated the requirement of dairy breeds at 14-17 kg DM per animal per day, resulting in 5,114-6,209 kg DM annually (Paterson et al. 1998). Measurements from surveys by

Paterson et al. (1998) revealed a mean daily availability of 8.8-9.6 kg DM, resulting in an annual total of 3,214-3,506 kg per animal (Paterson et al. 1998). One last example are results of feed-experiments with four crossbred lactating cows (Friesian x Zebu), executed by Khalili and Varvikko (1992). The daily feed uptake was recorded with an average of 12.2 kg DM per animal (Khalili and Varvikko 1992), leading to an annual uptake of 4,456 kg DM. These numbers from literature in general report a lower feed demand compared to the dry matter on offer in Umurera.

4.2 Fodder production

To calculate the expected fodder production at an annual basis, production numbers are necessary for the most important fodder species. All numbers are based on lactating cows, because the Government of Rwanda is working towards an ideal situation in which all households keep mature cattle, producing both milk and manure.

4.2.1 Pennisetum

Even though the yield potential of pennisetum is high in case fertilizer is applied, pennisetum yields of smallholders are often poor as most farmers do not apply mineral fertilizer to fodder crops (Mwangi et al. 2004). Indeed all farmers limited the use of mineral fertilizer to their marshland-fields, where almost no pennisetum was cultivated. Therefore, only production numbers without application of mineral fertilizer are used. For a simulation model the upper limit for pennisetum biomass production was set between 1.8 and 2.2 kg DM per m^2 per year (Tibayungwa et al. 2010). Data from experiments in the relatively fertile north of Rwanda by Niang et al. (1998) recorded an even higher yield of 3.35 kg DM per m^2 per year (Niang et al. 1998). A study in the highlands of Kenya by Mwangi et al. (2004) showed a yield of 1.50 kg DM per m^2 and 1.67 kg/m^2 per year (Mwangi et al. 2004). The average number of 2.13 kg per m^2 per year is used in the following calculations (§ 4.3 and § 4.4).

4.2.2 Calliandra

Results of experiments in Rwanda executed by Roose and Ndayizigiye (1997) measured a production of green calliandra cuttings of 6.99 kg per m per year (Roose and Ndayizigiye 1997). Research in Kenyan highlands by Paterson et al. (1999) showed that mature calliandra which was grown in hedgerows annually produced 2-5 kg DM per m per year (Paterson et al. 1999). A few years earlier Paterson et al. (1996) more specifically reported a yield of 3.8 kg DM per m per year, and a normal level of annual on-farm production ranging between 3-5 kg per m hedge per year (Paterson et al. 1996). The experiments conducted by Niang et al. (1998) measured a calliandra production of 3.0 kg DM per m per year for a single row of trees (Niang et al. 1998). The average number of 4.26 kg per m per year, is used in calculations below (§ 4.3 and § 4.4).

4.2.3 Banana pseudo-stems

It is difficult to find data on the production of banana pseudo-stems and banana leaves, because almost all research focuses on the production of banana fingers. Measurements on more than 250 banana plants in Uganda (2005-2007) show an average fresh weight of pseudo-stems of 32.42 kg per rhizome. The average total DM content of pseudo-stems was 3.84 kg (Van Asten 2011 pers. comm.) which automatically is the number used in the next calculations (§ 4.3 and § 4.4).

4.3 Current situation

Studying the resources currently used by farmers in Umurera to provide fodder for cattle, is as essential as quantifying fodder itself (§ 4.1). The focus is on available land and availability of several fodder plants, because these data are present for Umurera (Table 5). The first two columns contain measurements resulting from fieldwork, while the last three columns contain rough estimations. The number of calliandra trees and edge-length of pennisetum are estimated by the farmers themselves. The width of a pennisetum-ridge is assumed to be 1 m, therefore a cultivated ridge of 10 m translates into 10 m^2. The number of banana plants is calculated using both literature and empirical data.

Table 5 Currently available land, total edge-length and fodder resources per farmer

Farmer	Surface (ha)	Edge-length	Cultivated (%)	Pennisetum (m^2)	Calliandra (trees)	Banana (plants)
D	0.51	1175	33	391	60	153
E	0.39	1025	17	178	20	117
F	0.44	1209	40	480	180	132
G	0.48	1182	61	720	32	144
H	0.48	1126	28	320	-	144
I	1.37	2969	23	690	100	411
J	0.90	1544	63	972	150	270
A	0.11	268	57	153	34	33
B	0.10	317	16	52	18	30
C	0.13	491	13	66	5	39

African farmers often cultivate a small number of banana plants on fields close to the homestead (Hauser and Van Asten 2008). The number of such fields for farmers in Umurera is 10-15% of all fields, based on empirical data. Banana-plant densities show a large spatial variation, Hauser and Van Asten (2008) indicated a range of 1,000-5,000 plants per ha. The average of 3,000 plants per ha is multiplied with 10% of the total surface of each farmer, to estimate the number of banana plants. The percentage of edges currently cultivated with pennisetum is 43% for cattle keeping farmers, while this is 29% for farmers of wealth-category I (Table 5). This indicates there is scope to the increase fodder production.

Table 6 Current annual fodder production (kg DM) per farmer

Farmer	Pennisetum	Calliandra	Banana	Total (3 spp.)	Total
D	833	256	588	1676	2534
E	379	85	449	914	2249
F	1022	767	507	2296	3487
G	1534	136	553	2223	3894
H	682	-	553	1235	3841
I	1470	426	1,578	3474	6247
J	2070	639	1,037	3746	6881
A	326	145	127	597	1292
B	111	77	115	303	532
C	141	21	150	312	874

To calculate the current annual production (kg DM) per farmer (Table 6), the average production numbers (§ 4.2) are multiplied with the numbers about currently available fodder-resources per species per farmer. The number in the final column is calculated using the information of the specific diet composition (Table 6). Comparing the situation of cattle keeping farmers (D-J) with the situation of the other three farmers (A-C), the conclusion is that under current circumstances for farmer A, B and C it is impossible to keep cattle. The annual fodder production of these three farmers will not be sufficient to keep improved, nor local cattle. Using the rule of thumb that mature cattle daily needs 2.5% of its own live weight in fodder (DM), the annual demand of a local cow (200-250 kg) can be estimated at 1,826-2,283 kg DM. The conclusion is confirmed by the experience of farmer C. She was keeping an improved young bull (on loan), that died from malnutrition two weeks before the end of the research-period.

4.4 Future situation

In the near future (before 2017) the Government of Rwanda intends to change the lives of Rwandan families by distributing cattle to 368,400 households (MinAgri 2006). The previous paragraph (§ 4.3) revealed that under current circumstances the farmers of wealth-category I are not able to keep cattle. In this paragraph the expected annual fodder production (kg DM) per farmer is calculated for five future scenarios.

4.4.1 Specific cases

For each of the five scenarios, the quantity of three commonly cultivated fodder species is increased, decreased or kept equal. The total edge-length of all uphill fields is taken as potential area for cultivating pennisetum and calliandra. The edges of fields in the marshland are excluded from the calculations, because it is unlikely that farmers will cultivate fodder instead of crops on the most fertile fields. In all scenarios, the edge-length cultivated with fodder is increased to 100% of total measured edge-length. When both fodder species are increased, a ratio of 0.8:0.2 is used for pennisetum and calliandra respectively. It is not realistic to increase the production of calliandra maximally, because this plant should be offered in a mixture. When banana production is increased, the percentage of banana-fields is raised from 10 to 20%, still using a density of 3,000 plants per ha. Other numbers, on for example feed demand and annual production, are equal to the numbers used before (§ 4.1 and § 4.2).

Scenario I. Increase in pennisetum, calliandra and banana kept equal
Scenario II. Increase in pennisetum and calliandra, banana production kept equal
Scenario III. Increase in all three plant species
Scenario IV. Increase in pennisetum and banana, calliandra is kept equal
Scenario V. Increase in pennisetum and calliandra, banana production set at zero

In some scenarios the increase of cultivated edges is limited to one species, because in reality it might be impossible for farmers to realise the proposed change. For example, it is possible that one of the species is not sufficiently available at a nursery or that a farmer cannot afford a sufficient number of seedlings, to plant a few hundred meter of edges. In the last scenario, the banana production is set at zero to see if farmers can still maintain cattle in case banana pseudo-stems are excluded from the livestock diet. The scenarios with an increase in calliandra (scenario II, III and V) aim at increasing feed-quality and thus at increasing the milk production (§ 3.4.1).

Table 7 Total annual production (kg DM) of three fodder species per scenario per farmer

Farmer	I	II	III	IV	V
D	2937	3207	3795	3524	2620
E	1830	2070	2519	2279	1620
F	2454	1983	2490	2960	1476
G	2024	2223	2776	2577	1670
H	1850	2176	2729	2403	1623
I	3654	3643	5221	5232	2065
J	3577	3416	4452	4614	2379
A	777	760	887	904	633
B	592	616	731	707	501
C	662	764	914	812	614

The annual production of fodder (kg DM) from all fodder groups per farmer (Table 8) is extrapolated using the diet composition of each farmer specifically. These production numbers should be used with care, because it is unrealistic to assume simultaneous production growth from the other fodder groups, without new investments or input. The production of crop residues is expected to decrease in all the scenarios, because a smaller part of the land could be cultivated with crops.

Table 8 Total annual production (kg DM) of all fodder species per scenario per farmer

Farmer	I	II	III	IV	V
D	4441	4850	5739	5329	3962
E	4504	5096	6202	5610	3990
F	3726	3012	3782	4496	2242
G	3404	3738	4668	4334	2809
H	5755	6769	8489	7475	5049
I	6571	6551	9389	9409	3713
J	6583	6286	8195	8491	4378
A	1681	1643	1917	1955	1369
B	1041	1083	1285	1243	880
C	1856	2142	2562	2276	1722

For most farmers, the highest DM production (kg) can be expected from Scenario III, while for four farmers this would be Scenario IV. Scenario III is the one where cultivation of all three species is increased, while in Scenario IV the cultivation of calliandra is kept equal. Explaining this difference is the amount of fodder currently produced by farmer A, F, I and J, which partly is the result of a high number of calliandra trees. The other farmers currently possess a small number of calliandra trees and therefore the difference in total production is much larger. For all farmers, the least fodder production is expected for Scenario V, in which the production of banana plants is excluded. The big difference between Scenario V and the other four scenarios, points at the importance of banana pseudo-stems in keeping cattle in Rwanda. Farmer A and C are expected to be able to keep local cattle in some of the scenarios, but would be unable to do so in the last scenario.

The annual feed demand of a local cow weighing 200-250 kg is estimated roughly at 1,826-2,283 kg DM. According to this estimation and the calculated fodder production, farmer A and C are likely able to keep a local cow in two and four scenarios respectively. Farmer B, on the other hand, will even after the proposed changes be unable to keep local cattle. For all three farmers it will be impossible to keep (partly) improved cattle, because the annual production will not be sufficient to meet the higher feed requirements of improved cattle.

4.4.2 Village-scale

The total number of households in Umurera is 189 households. More than half of these households belong to the poorest wealth-category of farmers, who generally do not possess cattle (Musabyimana 2008). To cultivate sufficient fodder for at least 189 partly improved cattle in an area with the highest population density in whole of Africa (Bidogeza et al. 2009) is impossible. At this moment, the majority of the farmers do not possess cattle, which would mean an enormous increase in livestock-density in case all families in Umurera would receive cattle. Currently, the total amount of fodder consists for 25% of uncultivated grasses and weeds, which for a big part are harvested at public utilities; along the creek and paths, but also on arable land. The amount of uncultivated fodder available in Umurera will not increase, meaning that the pressure on fodder-resources will increase. Farmers can choose to focus on feeding purely cultivated fodder, but this will increase the pressure on arable land which is also needed for crop production.

It is impossible to find numbers on the resources needed to maintain cattle, which are comparable to the ones calculated in this section. Mwangi et al. (2003) estimated that Kenyan households keeping cattle had 0.2 ha planted with pennisetum (Mwangi et al. 2003). According to Paterson et al. (1998) calliandra-hedgerows with a total length of 250 m, equal to about 500 trees, are sufficient to produce fodder to supplement one dairy cow for a complete lactation (Paterson et al. 1998).

5. Discussion

5.1 Method used

The previous chapter showed that under current circumstances it is impossible for the three farmers of wealth-category I to keep cattle. After substantial changes with respect to the cultivation of fodder, farmer A and C are likely able to keep local cattle, while farmer B will still be unable.

The production number used in the calculations are uncertain. The averages of numbers from literature were used to calculate the annual fodder production after several changes (Table 7). These numbers have been estimated for several African countries, with different soil types. Another factor influencing plant production is precipitation, varying within the country and even recorded absent during a season. It is also assumed that farmers cultivate pennisetum on ridges of 1 m wide, while in reality this was not always the case. Next to this, farmers will likely cultivate fodder plants on the edges of uphill fields, which have a relatively low fertility. All these factors indicate that the actual production in Umurera is likely to be different than the calculated annual production of fodder, which can directly affect the main conclusion of this study.

Milk production of crossbred cattle depends on genetic and environmental factors. This creates opportunities for people in Umurera, who can attempt to increase the quantity and/or quality of livestock feed. The scenarios presented in the analyses (§ 4.4) assume farmers in Umurera to cultivate all the edges of their uphill-fields with fodder plants. To realise such a change, the farmers need a large number of seedlings, because the largest part of the edges is currently uncultivated. Farmers need time to plant and cultivate the seedlings, which also need time to mature. A realistic possibility for smallholders to increase feed-quality, is supplementation with a protein-rich fodder. Nutritional improvements are expected to increase milk production. The daily milk yield of most cattle in Umurera is low compared to local cows in Burundi (Hatungumukama et al. 2009), and therefore there seems to be scope for improvement. In Umurera, *Calliandra calothyrsus* is the most viable option, because the majority of the farmers already cultivate calliandra. Also, calliandra produced twice as much biomass in experiments in Rwanda compared with *Leucaena* (Roose and Ndayizigiye 1997) and *Sesbania sesban* is considered unsustainable because of a high mortality of seedlings (Niang et al. 1998). According to Paterson et al. (1998) a farmer needs 250 m of hedge to supplement one cow during one year (Paterson et al. 1998). For the poorest three farmers this would mean that they need to cultivate between 50 and 100% of their available field-edges with calliandra, resulting in high investments in terms of seedlings and time. Another possible downside of cultivating all the edges with fodder plants might be a decreased food production, due to competition between crops and fodder plants. This would result in serious problems for at least the poorest group of farmers. On the other hand, cultivating the edges of sloping arable fields is a way to control soil erosion (Roose and Ndayizigiye 1997), leading to less severe nutrient depletion.

The easiest way to solve the problem of farmers who have to support a family and feed cattle, would be to increase the arable land. Unfortunately, land-scarcity is one of the biggest problems in Rwanda and it is a problem not likely going to be solved in the near future. Furthermore, before receiving cattle, farmers need to establish a ‘zero-grazing unit’ (e.g. a stable) to keep cattle, again resulting in an investment in terms of time, space and materials (such as poles).

5.2 Research improvements

A major point of concern in this study is the reliability and accuracy of the information received from the farmers. A large part of this research is based on measurements taken by farmers in Umurera. This was the most effective way to collect the data on feed measurements, but many examples indicate the presence of misunderstandings between the researcher and the farmers. Most examples come from the measurement-schemes, but other examples originate from the interviews. One example is the fact that many farmers claim to possess improved animals, while information about lactation-length and average milk production indicates a high *B. indicus* inheritance. Often, livestock is bought at local markets, making it difficult for farmers to check information on breed, age etc.

The necessity of a translator between the researcher and the farmers made executing the fieldwork even more complicated. To ask the questions in the right manner and at the right time, is extremely important in the collection of quantitative data. As time progressed, both the researcher and each of the five translators showed large improvements in clarity, speed and detail. Therefore, to limit the number of translators to only one would be a valuable improvement, which might be reached in case of an increased salary.

The most important information-gap in this study is the lack of precise data on fodder resources. The surfaces currently under cultivation with pennisetum, the number of calliandra-trees and the densities of banana plants are all rough estimations. The research would improve greatly in case these numbers could be specified, because they are key for answering the research question. The sources of uncultivated fodder are also not clear enough, while this fodder group represents a large part of livestock feed. As a result of limited fodder availability many farmers purchase fodder, but again it is not clear where this is done, nor why nobody in Umurera sells fodder. The limited time available to conduct this research is the reason behind these numbers being estimations instead of measurements. Therefore, the research would improve in case a longer research period would be available. Expanding not only the number of research-months, but also increasing the number of farmers and therefore cattle included in the research, to for example ten per wealth-category would be even closer to perfect.

As indicated previously, the quality of the measurements taken by the farmers increased over time. One way to speed up this process would be to arrange a start-meeting, where all participating farmers can gather for explanation, practical instructions, plenary identification and naming of plants, general questions, etc. The benefits of such a meeting are expected to be enormous.

5.3 'One farm, one cow'-program

The Government of Rwanda hopes that all her civilians escaped poverty by the end of the distribution period. She would like to see all Rwandan families keep cattle, have manure to improve crop production and be self-sufficient in food of animal origin (GoR 2006). These are the main thoughts behind the 'One farm, one cow'-program, but it might be a mistake to assume a family will move from one wealth-category into the next, as a result of receiving cattle. The program might be trying to work the wrong way around, letting these families make the desired shift on paper, while in reality they are not able to feed cattle. Ideally, families would start to keep cattle as a result of increased resources, but when poor families receive cattle while not being able to feed them, nothing will change.

One quarter (26%) of the animals used within the 'One farm one cow'-program will be imported pure Jerseys, while the remaining cattle will be crossbred animals (GoR 2006). Generally, *B. taurus* breeds are not well adapted to tropical conditions, because of a low disease resistance and little tolerance to heat (Hatungumukama 2006). Also, even though a Jersey is a relatively small cow and generally has a lower production potential compared to larger *B. taurus* breeds, it still has a higher feed demand compared to *B. indicus* breeds. Therefore, it might be more viable to distribute local cattle to smallholders in Rwanda, because it will be easier to meet their lower maintenance requirements.

An alternative option would be the distribution of goats to smallholder farmers in Rwanda. Even though goats produce less manure and milk compared to cattle, it is realistic to produce sufficient milk for human consumption. Goats also still have multiple other functions, such as the provision of meat. An important benefit is the low feed requirement of a goat. The average amount of fodder on offer for the two goats included in this study was 9 kg and 14 kg per day.

6. Conclusion

The previous analyses lead to the conclusion that for each of the three farmers of wealth-category I, currently it is impossible to keep improved cattle, improved nor local. As a direct effect of the limited land-availability, these farmers currently cultivate too little fodder-resources to produce sufficiently fodder to keep cattle successfully.

Several changes in management have been proposed, of which the most important ones have a focus on an increased cultivation of fodder plants. Such changes were the basis of calculations for annual fodder production in several scenarios. In respectively two and four of the scenarios farmer A and C are likely able to keep local cattle, while farmer B will still be unable to do so.

However, the Government of Rwanda plans to distribute only improved cattle. Therefore, in the current set-up, the ‘One farm, one cow’-program does not seem to be viable. The farmers in Umurera will not be able to produce sufficient fodder to keep improved cattle. One quarter of the distributed cattle will be purebred Jerseys and, even though this improved breed is relatively small, a mature Jersey cow easily has double the live weight of an average local. Furthermore, the two farmers who might be able to keep local cattle, will only be able to do so after investing in substantial changes. It is also important to keep in mind the uncertainty of the numbers used to calculate the annual fodder-production. It is likely that the actual fodder production in Umurera is different from the fodder production numbers found in literature, which can directly affect the main conclusion of this study. The viability of the program would increase in case the breed of distributed cattle would change from *B. taurus* to *B. indicus*, but very poor farmers would still need to make large investments to be able to keep cattle. Therefore, to produce sufficient feed might still be problematic. Another solution would be the distribution of milking goats, because of their low feed requirements.

It is possible that some farmers in Umurera are able to realise the necessary investments, but not all the families in Umurera will be able to keep cattle. Currently all farmers feed uncultivated fodder, such as marshland herbs and uncultivated grasses, and for poorer farmers uncultivated fodder forms a larger proportion of the total diet. The competition for the available uncultivated fodder would therefore increase enormously, in case all 189 households in Umurera would keep partly improved cattle. Farmers could also feed purely cultivated fodder, but this would increase the pressure on arable land. A solution would be to increase the available land, but land-scarcity is one of the biggest problems in Rwanda and is unlikely to be solved ever.

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Appendix 1 Questionnaire

General questions

- What is the number of household members?
- How many fields do you own?
- Do you rent or loan any fields?
- Do you have access to communal lands?
- Do you co-own a part of the marshlands? If yes: surface, crop and number of co-owners?
- How many hectares is each of the fields?
- Do you harvest fodder plants (not crops) from the marshland?
- What is the distance from the homestead to each field (in meters)?

Fodder plants

- Which plant species do you currently use as fodder? In case the farmer uses calliandra: what is the source of the plants you own?
- Which crops do you -partly- use to feed your livestock?
- During the rest of the year, do you use other plants as fodder, different from the one's you currently use?
- For each of the plant/crop species mentioned before, do you have access to them year-round?
- What are the 3 main plant species you feed your livestock during the wet season?
- What are the 3 main plant species you feed your livestock during the dry season?
- How many hectares/nr of plants do you grow, per plant species?
- Where do you harvest the couch grass?
- Do you apply mineral fertilizer? If yes: how much, when and how?
- Do you apply organic fertilizer? If yes: how much, when and how?

Livestock

- What is the total number of livestock you own?
- What is the breed of the livestock you own?
- Does the livestock diet change over time/season?
- Are there any further additions to the livestock diet (water, salt, different plants)?
- How often do you feed the livestock, per day, and around what time?
- Can you give an estimation of the amount of feed the livestock eats per day (kg)?
- Do you ever let your animals graze outside?
- For what purpose do you use the refusals?
- What is the current moment in lactation (days since calving)?
- What is the normal length of lactation (in days per year)?
- What is the current milk production per day (L)?
- What is the average milk production per day (L)?
- For which purpose do you use the milk?
- Can you give an estimation of the amount of manure produced per day (L or kg)?
- How do you collect the manure?
- How often do you apply the manure to the fields?

- Do you apply the manure to all fields or only to selected fields?

Is it a problem to take some pictures (of the farm, the animals, the farmer)?

Round 2.

Final questions

- What is the total edge-length of pennisetum you grow?
- How many shrubs of calliandra do you own?
- Do you use specific routes to collect fodder?
- Are there any rules concerning the collection of fodder?
- How much time do you need to collect fodder/day?
- If you feed 10 kg of ‘Other grass’, how much comes from your own, private property?
- In your opinion, what is the ideal diet for your livestock?
- Where did you get the Calliandra-shrubs you own?
- What is the source of the Pennisetum-plants you own?
- Do you buy or sell any fodder?
- If yes, how much?
- Do you use a compost-pit?
- Specific questions for each of the farmers (see notebook)