A comparison of the use of bean stakes in northern Rwanda

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Abstract

The title of the N2Africa project is 'Putting nitrogen fixation to work for smallholder farmers in Africa'. The internship took place in northern Rwanda and focuses on climbing bean (type of common bean *Phaseolus vulgaris*). The length and density of bean stakes are important factors in the production of climbing bean, which is the reason to focus on their use. The aim of this work is to increase the knowledge on the use of bean stakes in northern Rwanda. The objective was addressed through interviews with twenty farmers from four wealth categories and five sites, as well as through the collection of quantitative data in several bean fields of the interviewed farmers.

The average stake length was around 2m and generally increased with each wealth category. Stake length was consequently higher in Muko, which might be related to the fact that most farmers in Muko used tripods as staking method. The stake length was surprisingly equal for the different fields of the same farmer (with one exception). All farmers used both pennisetum and wood as staking material and the highest contribution always came from either of them. Focusing on the separate contributions of the different types, the majority of stakes were wood (29 times wood vs. 11 times pennisetum). Also stake density increased substantially with each wealth category, while the distance between stakes decreased. Stake density ranged between 1.95-3.72 stakes m^{-2}. In general, the differences between fields of the same farmer are small.

For the cultivation of climbing beans two systems were in use; the traditional system with random seed distribution and the modern system, in which seeds are sown in lines. The main difference in the use of bean stakes found between the sites is the staking method; mainly tripods at Muko and individual stakes at the other sites. Generally, tripods were used on the hillsides, because the soil is less deep, while lines of individual stakes were more frequently used in the valleys. Most farmers added stakes directly on the day of sowing, but this could also happen four weeks later, depending mostly on the availability of stakes. A large variety of plant species was used as staking material to support climbing beans. The most important stake types were *Pennisetum* and wood, most frequently *Eucalyptus*. The preferred stake species of a farmer seemed to depend on which factor he/she focused; pennisetum when a farmer focused on availability and price and wooden when the focus was on strength or a long life length. The majority of the farmers purchased at least part of their staking material. The total annual investment ranged between 1,000 and 100,000 Rwf (equal to 1.67-167 USD). The price for wooden stakes (10-60 Rwf) was always higher than the price paid for pennisetum stakes (5-30 Rwf). The life length of a pennisetum stake in northern Rwanda is 2-4 seasons, while for a wooden stake this is 4-6 seasons. All farmers stored stakes in bundles, close to the house or at least within the compound and if possible sheltered from rain. The most important reasons to replace stakes were insect damage and weather conditions. Therefore, the most desired improvements were fertilizer, a higher quantity of high-quality stakes and insecticides. According to the farmers the three most important constraints to bean production are poor soils, availability and quality of bean stakes and unfavorable weather conditions. Fifty percent of the farmers thought it would be possible to produce their own stakes, without purchasing any. The other farmers saw land scarcity as an insurmountable problem. Most of those farmers first needed to invest in changes. Farmers were asked to describe a perfect bean field. The result is a field with tripods of wooden stakes with a length of at least 3m and a distance of 30-60 cm between stakes and the number of plants being 3-6 per stake.

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1. Introduction

The title of the N2Africa project is ‘Putting nitrogen fixation to work for smallholder farmers in Africa’. The project is linking atmospheric nitrogen to the protein and nitrogen needs of African smallholder farmers. To improve the welfare of farm households, the project aims to increase the production of four grain legumes (bean, soybean, cowpea and groundnut). More specifically, the goal is to increase biological nitrogen fixation (BNF) by 46 kg/ha and to increase the average legume yield by 945 kg/ha (N2Africa, no date, online). This internship took place in and around Musanze, northern Rwanda; one of the eight countries currently involved in the N2Africa project. Climbing bean is a type of common bean (*Phaseolus vulgaris*) and is one of the most important crops in Rwandese farming systems, especially in the higher altitude areas. The country has the highest per capita consumption of beans in the world. It is well known that both length and density of bean stakes are important factors in the production of climbing bean (Reckling et al. 2011), which is the reason to focus on their use.

The aim of the work executed as part of this internship is to increase the knowledge on the use of bean stakes in northern Rwanda. N2Africa partners in Rwanda are CIAT-TSBF, Development Rural Durable (DRD), Development Rural du Nord (DERN) and the Rwanda Agricultural Board (RAB), formerly known as the National Agricultural Research Institute (ISAR). There are two ways in which the objective was addressed. First of all, in cooperation with one of the partners, farmers were interviewed in order to get an insight into farmer’s visions and opinions on the cultivation of climbing bean and common practices with respect to bean stakes. Quantitative data on the use of bean stakes were collected on several bean fields of those interviewed farmers: stake type, length of stakes, stake density, distance between stakes, etc. The ultimate goal of N2Africa is to improve the welfare of farm households and it is my wish that my work, the data collected in this report, will provide part of the knowledge necessary to reach this goal.

2. Methodology

Two types of activities were undertaken to collect information on the use of bean stakes in northern Rwanda. The first step was conducting interviews with twenty farmers who were growing climbing beans, living across five sites in northern Rwanda. The interviews were conducted with the help of a translator employed by ‘Development Rural Durable’ (DRD), an agricultural non-governmental organization (NGO), or with a student hired on a daily basis. Through the nationwide Participatory Poverty Assessment (PPA) exercise the government of Rwanda distinguished six successive wealth categories using property of land and livestock as main indicators of wealth (Ansoms 2008). The interviews at each site were conducted with people from four different wealth categories; umutindi, umukene, wifashije and umukungu. The first being the poorest farmers and umukungu being relatively wealthy. Three of the sites (Kinoni, Cyabingo and Nemba) are N2Africa-sites, while the remaining two (Rugarama and Muko) are not. Relatively many farmers were interviewed in Muko, which is a result of close collaboration with an agricultural PhD-student who had two of her research sites in the area. Only one farmer was interviewed in Nemba, because of the large distance between Musanze and this site. The statements made in the next section (3. Results) were always made taking these absolute differences into account. The interviews resulted in qualitative information on cropping systems, staking methods and different stake species, as well as information on the main constraints and improvements for bean production. Also quantitative information was collected through the interviews; the price of stakes, the life span of several stake types, replacement, etc. (Appendix 1).

After the interviews, field visits were made to a maximum of three bean fields per farmer, for a total of eighteen farmers. One farmer had already harvested his beans, while it was impossible to reach another farmer. In the field, quantitative data on for example field size, stake length, stake density, distances between stakes, and sources of stakes were collected (Appendix 2). The slope of a field was estimated and the size was measured by taking steps along at least two of the edges, or along more in case this was necessary. Per field, at least three stakes were measured to produce a number for the average, highest and lowest stake length, using a 5m measuring-tape. In case stakes were bent, the actual length of stakes was measured. After walking through the whole field, to get an overall idea of the situation, the percentages of each of these three stake length classes were estimated, as well as those of each stake type. According to their origin, the stakes were classified into several types. ‘Wood’ was all staking material originating from trees (*Eucalyptus*, *Grevillea*, *Alnus*, etc.) and shrubs (*Vernonia* and *Calliandra*). The distance between loose stakes, or between the closest stakes of two tripods, was measured at least five times to record the range. The same method was used for the distance between the stakes of tripods. When stakes were tied together they were classified as tripods, also when two or four stakes were tied together.

3. Results

This section is divided in two parts, according to the method of information collection. The first subsection summarizes the data collected measuring the bean fields of the interviewed farmers, while the second subsection contains qualitative information, which was collected through the interviews. Table 1 gives an overview of the distribution of the farmers who participated in this research. The wealth categories are successive, with umutindi being the poorest farmers and umukungu being relatively wealthy farmers.

Table 1 Distribution of farmers per wealth category across the sites

Site	Umutindi: 1	Umukene: 2	Wifashije: 3	Umukungu: 4	Total
Rugarama	0	2	1	0	**3**
Muko	1	3	3	1	**8**
Cyabingo	0	3	1	0	**4**
Kinoni	1	2	1	0	**4**
Nemba	0	0	1	0	**1**
Total	**2**	**10**	**7**	**1**	**20**

3.1 Measurements

3.1.1 Stake length

The length of stakes (in centimeter) was measured in several fields of each farmer for at least three average, three tallest and three of the shortest stakes in a specific field. Also, the relative contribution of each of these stake length classes were estimated and recorded as a percentage of the total stakes (%Average, %Highest and %Low). A summary of the data on the length of stakes is shown in Tables 2 and 3, the complete set of data can be found in Appendix 3. It is important to keep in mind there is only one farmer from umukungu (WC 4) (Table 1). In agreement with the expectation, the average stake length generally increases with each wealth category. The only exception is the average stake length for wealth category II. Overall, there was not much variation in the relative contribution of stakes with an average length, while differences were found between the contributions of tallest and shortest stakes.

Table 2 Stake length (cm) and percentage per wealth category

Category	Average	Highest	Lowest	%A	%H	%L
WC 1	210	252	130	65	23	12
WC 2	197	269	134	70	12	18
WC 3	215	294	138	68	21	11
WC 4	290	326	153	78	13	8

Table 3 Stake length (cm) and relative contribution per site

Site	Average	Highest	Lowest	%A	%H	%L
Rugarama	201	275	128	65	16	19
Muko	238	305	144	68	21	11
Cyabingo	194	258	137	74	14	12
Kinoni	184	262	128	71	11	18

Focusing on the differences between sites, the stake length is consequently higher in Muko and lowest in Kinoni and Cyabingo. This fact might be related to the fact that in Muko most farmers use tripods as staking method. Again, there is not much variation in the relative contributions of stake with an average length, while differences were found between the contributions of tallest and shortest stakes. The actual stake lengths were surprisingly equal for the different fields of the same farmer (with one exception).

3.1.2 Stake types

Information on the use of stake types for each field was collected. The types in use in each field, as well as the estimation of their relative contribution (%) to the total amount of stakes is described (Table 4). W = wood, P = *Pennisetum*, Ric = *Ricinus communis*, R = reed, M = maize residues and B = bamboo. Clearly, the most important staking material across all sites is pennisetum and wood; all farmers used both and the highest contribution always came from either of them. Focusing on the separate contributions of the different types, the majority of stakes was made of wood (29 times wood vs. 11 times pennisetum). Several farmers owned a field with only wooden stakes and one farmer had one field with only pennisetum stakes. The only other significantly contribution came in the form of reed was found in Muko, which very likely is the result of the difference between hydrological conditions between the valley and the hills. The wooden stakes in the first field of Farmer 1 consisted of almost only calliandra, but this was an exception. For all farmers in Kinoni, wood is consequently most important, suggesting a high availability. The differences between the different fields of one farmer are large, without a clear distinction between the wealth categories.

Table 4 Stake types and their relative contribution (%), per field per farmer

Code	WC	Site	Stake types	W	P	Ric.	R	M	B
1	2	Rugarama	W, P	94	6	-	-	-	-
			W, P	97	3	-	-	-	-
			W, P, M	48	41	-	-	11	-
2	2	Rugarama	W, P	10	90	-	-	-	-
			W, P, M, Riz	85	10	3	-	2	-
3	3	Rugarama	W, P	60	40	-	-	-	-
4	1	Muko	W, P, R	20	75	-	5	-	-
			W, P, R	20	50	-	30	-	-
5	2	Muko	W, P, M	90	8	-	-	2	-
6	3	Muko	W, P	1	99	-	-	-	-
			W, P, R	50	40	-	10	-	-
			W, P, R, B	20	70	-	9	-	1
7	2	Muko	W, P	40	60	-	-	-	-
			W, P	90	10	-	-	-	-
			W, P	50	50	-	-	-	-
8	3	Muko	W, P, R	30	60	-	10	-	-
			W, P, R	60	10	-	30	-	-
			W, P, R	65	25	-	10	-	-
9	4	Muko	P	-	100	-	-	-	-
			W, P	30	70	-	-	-	-
			W, P	70	30	-	-	-	-
10	3	Muko	W, P, R	45	50	-	5	-	-
			W, P	30	70	-	-	-	-

			W, P	10	90	-	-	-	-
13	3	Cyabingo	W, P	75	25	-	-	-	-
			W, P	95	5	-	-	-	-
			W, P	80	20	-	-	-	-
14	2	Cyabingo	W, P, R	94	5	-	1	-	-
			W, P	95	5	-	-	-	-
15	2	Cyabingo	W, P	20	80	-	-	-	-
16	2	Cyabingo	W, P	98	2	-	-	-	-
			W	100	-	-	-	-	-
			W, P	98	2	-	-	-	-
17	1	Kinoni	W, P	60	40	-	-	-	-
18	2	Kinoni	W, P	95	5	-	-	-	-
			W	100	-	-	-	-	-
19	3	Kinoni	W, P	80	20	-	-	-	-
			W, P	90	10	-	-	-	-
			W, P	75	25	-	-	-	-
20	2	Kinoni	W, P	96	4	-	-	-	-
			W, P	98	2	-	-	-	-
			W	100	-	-	-	-	-

3.1.3 Stake density and distance between stakes

Table 5 summarizes the stake density and distances between stakes per wealth category, while Table 6 summarizes the same information per site. The complete data can be found in Appendix 4. Stake densities are given in number of stakes per square meter, while distances between stakes are in centimeter. The two trends in Table 6 are according to the expectation. The stake density increases substantially with each wealth category, while the distance between stakes decreases. Distances between the stakes of a tripod are relatively large and, with a range of 75-85 cm, close to equal. This is sensible, because the length of stakes used for tripods normally is relatively long (Appendix 3) and the distance between stakes needs to be large in order for a tripod to be effective.

Table 5 Stake density (number m^{-2}) and distance between stakes (cm) divided by wealth category

Category	Density	Distance	Within tripod
WC 1	1.95	78	85
WC 2	2.27	68	80
WC 3	2.66	50	75
WC 4	3.72	38	80

No tripods were found in Cyabingo and the data for Rugarama and Kinoni are both based on only one field. The trend found in Table 6 is comparable to Table 3; the highest density was found in Muko, while the two lowest were close together and found in Cyabingo and Kinoni. In general, the differences between fields of the same farmer are small. The largest differences were found in the fields of an umukene farmer. The lowest densities (< 2 stakes m^{-2}) all represent fields of farmers from the two poorest wealth categories; umutindi and umukene (Appendix 4).

Table 6 Stake density (number m^{-2}) and distance between stakes (cm) divided by site

Site	Density	Distance	Within tripod
Rugarama	2.56	57	85
Muko	2.72	49	76
Cyabingo	2.15	56	-
Kinoni	2.12	78	90

3.2 Interviews

3.2.1 Cropping systems

Two major cropping systems were in use in northern Rwanda to cultivate climbing beans. The first is the traditional system with random seed distribution, contrary to the modern system, in which seeds are sown in lines. The most important reasons to sow beans in lines were an increased yield, easier weeding, a reduction in the necessary number of seeds, as well as a reduction in the number of stakes. The increased production is supposed to be due to the fact that beans cultivated in lines have more light to conduct photosynthesis. Clearly, the modern system was promoted by the government of Rwanda through the work of district officials and trainings given by agricultural technicians (also Catholic Relief Services). Several farmers said that they cultivated using the traditional system, because they were not trained otherwise.

3.2.2 Staking methods

Another important difference was found in staking method; either as individual stakes or tied together in tripods (also possible with four or two stakes). The most important benefits of tripods were the fact that they work as windbreaks (especially when the soil is not deep) and that they combine the strength of weaker stakes, which is particularly important for pennisetum. Tripods were also claimed to improve bean yield, probably because tripods in general were higher compared to loose stakes. Downsides of the use of tripods were the facts that plants are restricted and that the sun cannot reach all the bean plants. Especially at the point where the stakes of a tripod connect, the plant density per stake was extremely high sometimes. Most often used for tripods was pennisetum, because these stakes are often taller than wooden stakes.
Individual stakes were preferred in case the soil was deep or when the biomass of the bean plants was low, because than a shorter stake length was sufficient. Eucalyptus was mentioned as preferred species to use as individual stake, because they are strong and can therefore be put into the ground deeply. Generally, tripods were used on the hillsides, because the soil is not deep, while lines of individual stakes were used mostly in the valleys. Contradictory information was received on the quantity of stakes necessary for these two staking methods. A few farmers named a lower quantity for tripods, while one farmer told us she only created tripods in case she had enough stakes. Currently, the RAB runs a trial in Rwerere to test and further develop another staking-method, using wires or grass connected to a construction of wooden poles. Since the trial was set up in May 2011, there are no results available yet.

3.2.3 Management of bean fields

When the total number of fields of a farmer was known, it was possible to calculate a ratio by dividing the number of bean fields by the total number of fields (Table 7). The 14 ratio's have a range between 0.2 and 1. Both farmers who cultivated all their land with climbing beans were living in Kinoni. In most cases, stakes were added to bean fields directly, on the day of sowing, but the addition of stakes could also happen till up to 4 weeks later. The timing of stake addition depended mostly on the availability of stakes. Most of the farmers who immediately added stakes to their bean fields live in Muko, which might be indicating that bean stakes are relatively easy available. The number of bean plants per stake was estimated by the farmers and ranged between 3-10 plants/stake. The suggested number of bean plants per stake is 4 (pers. comm. Ndekezi 2011). Muko record a relatively high number of plants per stake, possibly due to the fact that many farmers there used tripods. All farmers rotated climbing beans with another crop, almost always maize, in one case potatoes. Only some of them rotated the location of their bean fields.

Table 7 Brief overview of the twenty interviewed farmers

Code	Name	Site	Category	Nr. of fields	Bean fields
1	Munyakabaya Joseph	Rugarama	Umukene	8	3
2	Ndengeye Felicien	Rugarama	Umukene	-	2
3	Bizimana Innocent	Rugarama	Wifashije	-	1
4	Mpazayabo Vestine	Muko I	Umutindi	-	2
5	Karasira Theodore	Muko I	Umukene	2	1
6	Maniragabi Esperance	Muko I	Wifashije	-	3
7	Barayakuriza Donathen	Muko II	Umukene	-	4
8	Nyirabanzi Emmaculae	Muko II	Wifashije	-	5
9	Birekeraho Carithou	Muko II	Umukungu	14	3
10	Bayaruge	Muko II	Wifashije	11	6
11	Kadari Sylvestre	Muko II	Umukene	3	2
12	Muitire Valeus	Nemba	Wifashije	7	4
13	Nkinzehiki Leonard	Cyabingo	Wifashije	10	4
14	Hakorimana Kidala	Cyabingo	Umukene	4	2
15	Hategekimana	Cyabingo	Umukene	5	1
16	Rubabaza Andre	Cyabingo	Umukene	4	2
17	Kamugasa Benedicte	Kinoni	Umutindi	2	1
18	Hakizimana Jean de Dieu	Kinoni	Umukene	2	2
19	Niragire Charles*	Kinoni	Wifashije	8	3
20	Mukeshimana Parusi	Kinoni	Umukene	2	2

* sells stakes

3.2.4 Stake types

A large variety of plant species was used as staking material to support climbing beans. The two most important stake types were *Pennisetum* and wood (Table 4). Wooden stakes included stakes from *Eucalyptus*, *Grevillea*, *Vernonia*, *Alnus* and *Calliandra*. Overall, *Eucalyptus* was the most frequently used wooden staking material. Encountered only rarely were *Ricinus*, reed, residues of maize plants and bamboo. Reed was only found in Muko, probably because of its hydrological conditions. It was also the only site where *Grevillea* was not used as stakes. *Calliandra* was encountered in the field a few times, but only mentioned as staking-material by one farmer. *Vernonia* was only used by farmers in Kinoni and Rugarama.

The preferred stake species of a farmer seemed to depend on which factor he/she focused. Pennisetum was mentioned when a farmer focused on availability and price, while wooden stakes were always mentioned when the focus was on strength or a long life length. Most farmers (10) named *Pennisetum* as preferred staking material. A very important benefit of pennisetum was that most of the stakes after purchasing could be broken into two, or even three, pieces. Transport was also easy, there are more stakes in a bundle (cheap), the stakes are easily available and the plant also re-grows quickly. Side benefits of cultivating *Pennisetum* are erosion control and the production of fodder. Wood was always preferred because of its long durance and strength. Two farmers, both from Kinoni named *Vernonia* as their preferred stake species.

3.2.5 Purchasing stakes

Among the twenty interviewed farmers were four who never purchased stakes. One of these farmers limited the number of fields cultivated with beans by the amount of cultivated stakes, while another farmer let the stake density depend on the availability of stakes. The two other farmers cultivated a sufficient number of stakes, one even enough to sell a part of them (Farmer 19, Table 7). The remaining farmers purchased stakes once (11 farmers) or twice (4 farmers) per year. The percentage of stakes that was purchased ranged between 20-100%. The three farmers who purchased 100% of the stakes were from the two poorest wealth categories. No clear differences were found between the sites. The biggest range was found in Muko, which probably is a result of the high number of farmers interviewed at this site.
The two most important stake types were pennisetum and wooden stakes (see previous paragraph). The price of *Pennisetum* ranged between 5-30 Rwf, while wooden stakes were bought for prices ranging between 10-60 Rwf (100 Rwf equals 16 cents, USD). It was impossible to specify the prices for wooden stakes per species. The price per stake was always higher for wood compared to prices paid for pennisetum. Wooden stakes were always more expensive; about one and a half to four times the prices of pennisetum stakes. This ratio was calculated while taking into account that pennisetum stakes were often long enough to be divided in two, or even three, pieces. Prices of only two other stake species were mentioned; reed and *Vernonia*. The price of the latter was in between the prices of pennisetum and wood, while reed was the cheapest option possible. Prices for wooden stakes are highest in Muko and Kinoni, while the price for pennisetum stakes were highest in Nemba and Muko. One farmer in Muko complained about an increased price, stakes used to be 10-15 Rwf, but now costed up to 30 Rwf. The total annual investment in bean stakes per farmer ranged between 1,000 and 100,000 Rwf (equal to 1.67-167 USD), clearly showing the large differences between farmers. The above range leaves out the farmers who never purchased stakes.

3.2.6 Storage and life length of stakes

The life length of a pennisetum stake in northern Rwanda generally is about 2-4 seasons, which equals 1-2 year. The average life length of a wooden stake is 4-6 seasons, equaling 2-3 years. *Vernonia* usually lasts 2 years (4 seasons) and reed only 1 year (2 seasons). There are no significant differences between the life length of stakes between the different the sites.
All farmers stored stakes in bundles, close to the house or at least within the compound and if possible sheltered from rain. Only one farmer stored his stakes inside the house, mainly against thievery. Five farmers stored at least part of the stakes under some trees near the house, but most farmers stored the bundles against the house, underneath the edge of the roof. Bundles were stored standing, placed upside down. Most farmers said that the rain could still affect the stakes during storage, especially in combination with wind.

3.2.7 Replacement of stakes

All farmers claimed that stakes being ‘old’ was the most important reason to replace them. After asking for more specific reasons, 95% of the farmers named insect damage as one of the most important. The insects live belowground, come with rain and destroy the lower part of the stakes, making it likely they are termites, but this suggestion is not confirmed. The effect of the insects was the same for both wood and pennisetum. The other reasons were all related to the weather: too much rain and strong wind, breaking the stakes or making them rot. Some farmers claimed that the effect of rain was worst while stakes are in the fields, but the majority said the biggest effect was during storage of the stakes. One farmer replaced short stakes by longer ones, in case he had the opportunity. All old stakes were used in the kitchen, as firewood.

3.2.8 Constraints to bean production

One of the interview questions was an open question asking farmers their view on the main constraints to bean production, which resulted in a wide variety of answers. The constraint most often mentioned (17 times) was poor soil fertility and/or a lack of fertilizer, whether this was mineral or organic. Since nearly all farmers considered soil fertility as a problem, there were no differences between the sites. The next most important factor was bean stakes, mentioned by 16 of the farmers. Several specific reasons were given: their length (7 times), their strength (5 times), the density (6 times) and stakes being too old (1 time). Those reasons were all spread across sites. The third most important constraints were all related to the weather: too much or too little rain, too much sun and strong winds. Too much rain was most often mentioned (13 out of 14 farmers), while strong winds were mentioned two times and insufficient rain was named only once (in Kinoni). All farmers in Kinoni and Cyabingo named a surplus of rain as a constraint, contrary to Muko where only half of the interviewed farmers complained about this constraint. Strong sun was named five times, twice in Kinoni, twice in Cyabingo, once in Rugarama, which are all hilly places. Insect damage, often lice, was mentioned six times, relatively often in Muko. Among the varies ‘other’ reasons were land scarcity, soil erosion, a lack of labor, flower-eating birds, a high plant density, a badly prepared soil and a lack of training in agricultural practices. Soil erosion was mentioned twice, the other reasons were given only once.

3.2.9 Means to improve bean production

As poor soil fertility was one of the most important constraints, it is not surprising that fertilizer was most frequently suggested (15 times mineral, 1 time organic) as a valuable improvement. In some cases this improvement was mentioned indirectly, when farmers wanted money in order to buy mineral fertilizer. Also not very surprisingly, changes with respect to bean stakes were also often suggested. Longer (>2m) and stronger stakes were each named six times, spread across the sites. A higher stake density was desired by six farmers, of which four of them were from Muko. Five farmers, spread across sites, suggested the application of insecticides as a way to improve production. The other suggestions were only made once or twice: erosion control measures (create terraces, plant pennisetum and/or create gutters), training by a technician, seed selection, to plant trees around the fields and one farmer suggested to have a different climate.

3.2.10 Possibilities to increase stake production

All farmers were asked if in their opinion it could be possible to cultivate all the necessary stakes on their land, without having to purchase any, for example after planting more pennisetum or tree seedlings. Ten of the interviewed farmers thought that this is, or could be, possible. Three of them already produced a sufficient number of stakes, while the other seven would first need to invest in changes. Two out of those three farmers worked the other way around, by letting the number of bean-fields or the stake density depend on the production and 'survival' of staking material. The other ten farmers thought that it would be impossible to cultivate a sufficient number of stakes. The main reason was a limited land availability: other reasons were related to a lack of input in the form of seedlings, or money to buy seedlings. Two farmers were planning to increase the number of cultivated stakes in the near future.

3.2.11 Potential cultivation area

For various reasons it was impossible to measure the space available for each farmer, where he or she could possibly cultivate staking material. Such space is named 'potential cultivation area'. An important reason is the fact that land of smallholder farmers is divided into small, scattered plots, which made it too time-consuming to visit and measure each of them. Most farmers seemed to have at least some potential cultivation area, but the edges were in some cases too steep to be of use. The edges of land on hillsides had often already been planted with pennisetum, most frequently on the lower sides, but in other cases on all the edges. Some hills in Rwanda are so steep that this type of erosion control is essential. A number of farmers had already taken all opportunities to cultivate staking material; they grew pennisetum on the edges of their fields, with several trees at the corners. The land in the valleys seemed to be even more sufficiently occupied compared to land on the hillsides and therefore holds less potential cultivation area. In most cases, the valleys seem unsuitable to grow trees, but very suitable to grow pennisetum.

3.2.12 The perfect bean field

Farmers were asked to describe how a perfect bean field looked like in their eyes. As far as possible, the 'average', general idea of such a field for smallholder farmers in northern Rwanda can be summarized as done below. Most farmers preferred stakes of at least 3 m, but a decent number of farmers called for a length of 4-5 m. Eucalyptus was most often the preferred stake type.

Stake length: 3 m.
Stake type: Wood
Staking distance: 30-60 cm.
Number of plants/stake: 3-6
Staking method: Tripods

4. Discussion

Over time, small changes were made to improve the methodology used in this study. For example, some of the questions were altered and a few new questions were added to the questionnaire after the first set of interviews. It was clear that also the translator, the way questions were asked and explained, improved as time went on. Furthermore, it needed some practice to reach a workable method to take the quantitative measurements. Taking area measurements on steep hillsides, of often non-rectangular fields, turned out to be difficult, which is the reason that data on field sizes taken in the valley have a higher accuracy than those on the hillsides.
To gather qualitative information on some issues, some interview questions needed to be open. A risk of open questions is the difficulty to get a clear and definite answer. Some farmers for example needed help to come up with an answer, increasing the chance that the answers were biased by the translator. Also, the information derived from the interviews does not always agree with what I observed in the field. For example, the information on the current cropping system of seven farmers differed from my observations in the field. This could be because in some cases it was impossible to visit all farmers' fields, but it could also be an interview bias.
A last methodological problem is related to time. The moment in the growing season when the fields were visited defined the amount of work and precision of the measurements. Measurements were more time-consuming and difficult at the height of the growing season, compared with earlier in the season. Of course, after the growing season, it is impossible to take any field measurements, which happened in one case.

One of the most remarkable results is that the majority of the tripods were found in the valleys of Muko, while almost none were found at other sites. This result is the exact opposite of the statement of several farmers, that tripods are preferred at hillsides and loose stakes in the valley. Either the statement or the measurements were not representative.
Another surprising fact is that only one of the interviewed farmers sold stakes. Even while actively searching for farmers who sold stakes, it was impossible to find more. Maybe few farmers sell very many stakes, or there is seasonal variation in the cultivated bean surface, which would result in farmers using stakes the one season and selling them the next. Still, both explanations make it highly unlikely to encounter only one stake-selling farmer.
The question about a perfect bean field managed without any financial limitation, was very difficult to explain to farmers, which has likely biased the results. For farmers who are among the poorest people on earth, it is close to impossible to imagine having no financial limitations.
The difficulty with interpreting results of work conducted on smallholder farms in Africa, is the large heterogeneity. For example, it is hard to classify which cropping system a farmer uses, when differences are found between fields on the same farm and even within fields. The plan was to compare the practices from farmers' fields with those at the ISAR-station in Musanze, but after visiting several stations it became clear that also for the national research institute (currently RAB) it is difficult to cultivate climbing bean under consistent practices, which was the reason not to take measurements.

5. Conclusion

The main difference in the use of bean stakes found between the sites is the staking method; mainly tripods at Muko and individual stakes at the other sites. As bean cultivation using the traditional system is discouraged, most farmers used the modern system, in which seeds are sown in lines. The average stake length is around 2m and increases substantially with each wealth category. Tallest stakes were found in the valleys of Muko, which is likely to be related to use of tripods at this site. All farmers used both pennisetum and wooden stakes, the latter originated most often from eucalyptus. Stake density ranged from a bit less than two stakes/m^2, to almost four and was also related to wealth category. The distance between stakes decreased with an increase in wealth category. The stake densities and distances between stakes were quite equal for the different fields of the same farmer, while differences were found between the relative contributions of stake types, for example pennisetum and wood.
In general, richer farmers have more consistency in their management practices than farmers who are more restricted by poverty. The lack of differences that were found between the sites, in the use of bean stakes, is partly the effect of the large heterogeneity encountered in smallholder farming systems in Africa.

Pennisetum usually lasts 2-4 seasons, while wooden stakes last 4-6 seasons. Main reasons for replacement were insect damage and weather conditions. Stakes were stored close to the household, in bundles, upside down and as much as possible sheltered against the rain. The price for wooden stakes (10-60 Rwf) was always higher than the price paid for pennisetum stakes (5-30 Rwf). The majority of the farmers invest once per year in purchasing bean stakes. Investments in stakes per farmer equaled 1,000-100,000 Rwf. Therefore, farmers could save money if they were able to produce their own stakes. Another possible improvement would be increasing the length of time stakes can be used, through improved storage.
The most important constraints to bean production were poor soil fertility, availability and quality of bean stakes and weather conditions. Therefore, the most desired improvements were fertilizer, a higher quantity of high-quality stakes and insecticides. Half of the farmers thought it was possible to produce 100% of the necessary stakes on their land, but seven of them would first need to invest in substantial changes. According to the interviewed farmers a perfect bean-field can be described as follows.

Stake length: 3 m.
Stake type: Wood
Staking distance: 30-60 cm.
Number of plants/stake: 3-6
Staking method: Tripods

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Appendix 1: Interview questions for farmers

What is your name?
Which wealth category are you in? (umutindi, umukene, umekene wifashije or umukungu)
How many fields do you own in total?
At this moment, how many fields do you cultivate with climbing beans?
Which cropping system do you currently use for climbing beans?
In the past, did you ever use a different system?
Why do you use this system?
Without a government, would you practice intercropping or mono-cropping for climbing beans?

How many plants do you grow on 1 stake?
Which species do you currently use as stakes?
Example: eucalyptus, alnus, pennisetum, rizinus, calliandra, maracamia, grevillea, vernonia, etc.
Which of those species do you grown on your own land?
Which species do you prefer to use as stakes, and why?

Do you purchase stakes? If yes, how often?
What percentage of all the stakes that you currently own, did you purchase?
Where do you buy stakes? (Inside or outside the village, at the market)
From whom do you buy stakes?
What is the price of stakes?
Pennisetum:
Wood:
Ricinus:
Vernonia:
Reed:
Others:

How many seasons does a stake generally last?
Can you give a range? (Min. and max. number of seasons?)
What are the main reasons for the replacement of stakes?
How do you store the stakes when you do not use them?
In your opinion, would it be possible to cultivate 100% of the stakes on your own land?
Do you think that bean stakes are a constraint in bean production? Why?
If you would have no financial limitation, how would you say that a perfectly staked bean field look like?
What are other constraints in bean production?
Which improvements/solutions do you think are possible, with respect to staking?

When do you normally add stakes to a bean field? (Nr of weeks)
Do you rotate the bean fields?
What is the total annual investment with respect to bean stakes?

Appendix 2: Measurement form

Date:	
Place:	
Name:	
Wealth category:	
Total nr. of fields:	
Nr. of bean fields:	
Field size:	
Slope:	
Cropping system:	
Stake species:	
% per species:	
Stake distance:	
Stake density:	
Average height (+ %)	
Lowest (+ %)	
Highest (+ %)	
Field size:	
Slope:	
Cropping system:	
Stake species:	
% per species:	
Stake distance:	
Stake density:	
Average height (+ %)	
Lowest (+ %)	
Highest (+ %)	
Field size:	
Slope:	
Cropping system:	
Stake species:	
% per species:	
Stake distance:	
Stake density:	
Average height (+ %)	
Lowest (+ %)	
Highest (+ %)	
Comments:	

Appendix 3: Stake length (cm) per field per farmer

Code	WC	Site	Average	Highest	Lowest	% A	% H	% L
1	2	Rugarama	189	270	126	90	5	5
			186	250	112	60	15	25
			174	235	102	50	25	25
2	2	Rugarama	179	249	118	60	10	30
			204	262	133	60	20	20
3	3	Rugarama	274	384	174	70	20	10
4	1	Muko	236	248	131	60	30	10
			221	287	137	60	30	10
5	2	Muko	202	256	163	70	5	25
6	3	Muko	193	279	126	60	10	30
			199	272	121	60	15	25
			216	300	137	70	25	5
7	2	Muko	201	266	125	50	30	20
			235	321	176	70	20	10
			256	388	152	85	10	5
8	3	Muko	235	367	143	60	35	5
			244	334	132	55	40	5
			238	350	134	60	35	5
9	4	Muko	308	349	175	80	15	5
			294	327	162	70	20	10
			267	303	122	85	5	10
10	3	Muko	241	287	155	70	15	15
			237	266	142	80	15	5
			262	294	161	80	15	5
13	3	Cyabingo	204	271	138	75	12.5	12.5
			191	252	133	65	30	5
			195	263	142	70	15	15
14	2	Cyabingo	196	233	119	70	10	20
			187	245	111	80	5	15
15	2	Cyabingo	166	224	128	70	15	15
16	2	Cyabingo	210	281	161	80	10	10
			195	276	152	65	25	10
			199	276	149	90	5	5
17	1	Kinoni	174	221	121	75	10	15
18	2	Kinoni	225	310	129	65	5	30
			214	271	128	55	5	40
19	3	Kinoni	162	332	115	70	20	10
			173	217	135	70	15	15
			176	235	126	75	20	5
20	2	Kinoni	193	269	170	80	15	5
			170	281	120	70	3	27
			167	219	112	80	5	15

Appendix 4: Stake density and distance between stakes

Code	WC	Site	Density	Distance (cm)	Within tripod
1	2	Rugarama	2.96	60-90	-
			2.11	40-60	-
			2.25	40-70	-
2	2	Rugarama	2.20	50-75	-
			2.95	50-70	-
3	3	Rugarama	2.92	30-50	70-100
4	1	Muko	2.18	40-90	70-100
			2.00	30-120	70-100
5	2	Muko	1.58	45-55	60-90
6	3	Muko	3.72	25-45	60-75
			3.81	30-45	60-85
			3.41	30-45	60-80
7	2	Muko	2.37	30-70	30-110
			2.15	60-90	-
			1.98	70-100	60-110
8	3	Muko	2.67	35-50	60-80
			2.39	35-50	60-90
			2.55	35-55	60-90
9	4	Muko	3.58	30-40	70-90
			3.86	30-50	70-90
			3.71	30-50	70-90
10	3	Muko	2.09	35-60	60-90
			2.43	30-60	60-100
			2.54	30-50	60-90
13	3	Cyabingo	2.21	40-60	-
			2.14	50-70	-
			2.32	40-70	-
14	2	Cyabingo	2.74	35-70	-
			2.81	40-50	-
15	2	Cyabingo	1.83	50-90	-
16	2	Cyabingo	2.33	60-90	-
			2.59	60-90	-
			2.48	60-80	-
17	1	Kinoni	1.67	80-110	-
18	2	Kinoni	1.82	80-100	80-100
			1.93	90-110	-
19	3	Kinoni	2.38	50-70	-
			2.44	60-90	-
			2.57	50-90	-
20	2	Kinoni	2.49	40-90	-
			2.28	30-110	-
			1.53	50-100	-