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Agricultural Practices in Relation to Soil Properties and Water Supply in a Miombo Forest Village

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Abstract

A field study on soils and agricultural practices was carried out in the miombo forest village Ihombwe, Mikumi division, Kilosa district, Tanzania. A soil type distribution map was made, and soil properties were analysed and related to use of crops, crop rotation and farmers ideas of valuable soils. In addition a crop calendar was produced to survey the use of the agricultural land throughout the year. The main issues were to examine whether soil type or proximity to water was more important when choosing a site to cultivate and whether there was a correlation between the soil type of a field and what was grown there. The fieldwork consisted of interviews with village farmers, a visual mapping of the soils in the village, soil sampling for analysis, and measurements of infiltration capacity.

Soil sample analyses indicate that most soils in the village are typical miombo soils, comparable with previous studies of similar environments. At least 50 different crops are grown in the village. Most respondents use shifting cultivation in one way or another and crop rotation is often used to maximize the land use over the year. Proximity to water appears to be a more important factor than soil type in selection of agricultural land, but if possible people seem to choose the black alluvial soil, close to the stream, for cultivation. The choice of crop does not seem to be related to soil type, but rather to access of water. Some crops can be grown in a dryer environment, and are therefore grown on the slopes, while other crops have a higher demand of water and need to be grown close to the stream.

Key words: Miombo, shifting cultivation, soil classification, water supply, crop rotation, crop calendar, sustainability, Tanzania

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Contents

1 Introduction

Most of the African continent south of Sahara is covered by grass- and woodlands. Miombo woodlands that, despite their relative anonymity, are among the most extensive vegetation types on the continent, are characterised by tree species from the legume family, in particular species of *Brachystegia*, *Julbernardia*, and *Isoberlinia.* The area covered by miombo woodland reaches from the centre of Tanzania to the north parts of South Africa. Today some 50 million people live in miombo woodlands (in Zambia, Malawi, Zimbabwe, Congo-Kinshasa, Mozambique, Angola and Tanzania), and an additional 15 million urban dwellers depend on products from the miombo woodlands for their basic needs. (Campbell et al., 1996)

The areas covered by miombo woodland are characterized by a climate with a dry season, with no rain for months, and a rainy season, with an annual precipitation of 650-1400 mm or less. Hence, the ecosystem is completely dependent on the water falling during the rains ('long rains' in March-May, and 'short rains' in December-January in Tanzania). The soils are generally leached and poor in nutrients. Thousands of endemic species are found in the forest, and several of the major rivers in southern Africa have their origin here (Rodgers et al., 1996). The edible vegetables, mushrooms, tubers, and fruits, that the forest supplies, serve as an important buffer against starvation for the rural population, especially between the growing seasons or when the harvest is poor.

This ecosystem is today threatened by a massive devastation and fragmentation. Charcoal and firewood are sold to larger towns and cities, valuable timber species are cut and sold, and an increasing population pressure causes expansion of farmland at the cost of the forest/woodland.

When trying to find a way for the population of the miombo area to use their natural resources in a sustainable way, it is important to fully understand the complexity of the problem. The aim of this study is to map the distribution of different soil types in a miombo forest landscape, analyse soil properties and relate this to use of crops, crop rotation and farmers' ideas of valuable soils. In addition a crop calendar was produced to survey the use of the agricultural land throughout the year. Using this approach we have examined whether soil type or proximity to water is more important when choosing a site to cultivate and whether there is a correlation between the soil type of a field and what is grown there. In total this study will increase the knowledge of driving forces of the expansion of anthropogenic landscape in a miombo woodland.

This study is connected to the previous, and presently ongoing work of a group of researchers from Uppsala University and the Swedish University of Agriculture. The objective of their work is to find solutions for a more sustainable use of the miombo woodlands. In order to be able to do so, an extensive understanding of the nature and ecosystem of the miombo, as well as of the life situation for the people living in the area is required. Therefore, scientists in plant and animal ecology, anthropology, and earth sciences cooperate to form as complete a picture as possible of these miombo related issues.

The field study was conducted during October and November 2001.

2 Material and method

2.1 Study area

The study was carried out in Tanzania, in the village Ihombwe, north of Mikumi in Kilosa District, Morogoro region (latitude 7° 15'S – 7° 20' S, longitude 36° 45' – 36° 55'), (Figure 1). The village is a fairly rectangular area, mostly covered by Miombo woodland, and is managed by the village government.

A valley runs through the village. At the bottom of the valley there is a stream that has a water flow throughout the year. There are also some tributary creeks, most of which are dry during a large part of the year. Most of the nearly 1000 people in the village live near the main stream, and make a living by subsidence farming (Figure 2).

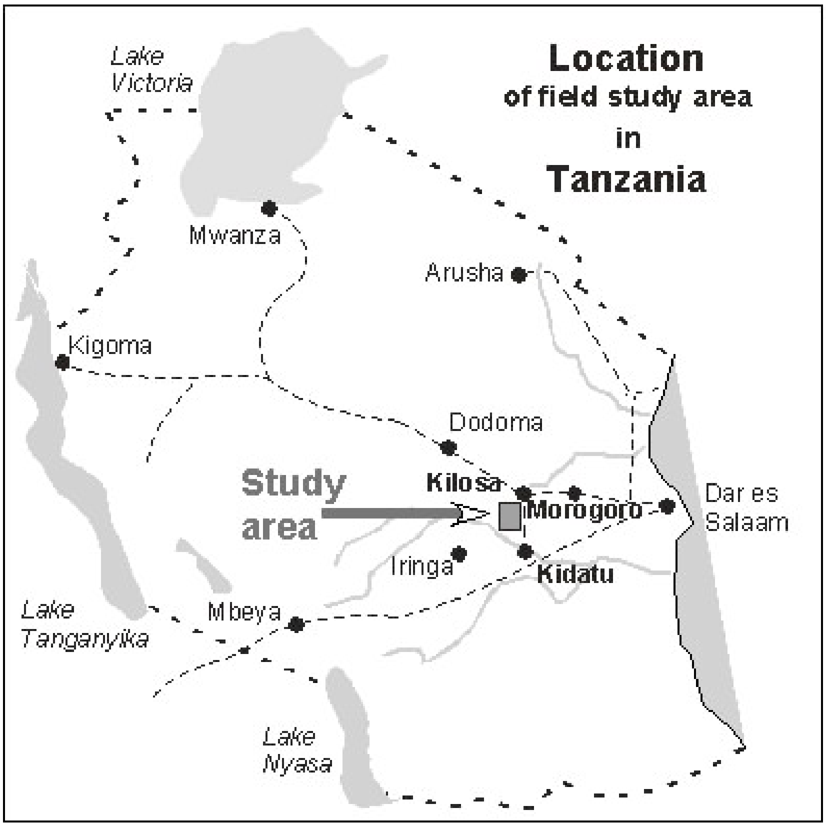


Figure 1: Location of the study area in Tanzania. *The area around Ihombwe village is marked.*

2.2 Interviews

The interviews, which were made in Swahili using Tanzanian interpreters, were conducted in all parts of the village in order to obtain information from respondents cultivating different soils. The interview households were distributed over the village and determined by whether anyone was at home when we passed. The aim was to interview both men and women of different age groups. The distribution of age and sex of the respondents was affected by the households chosen and who was at home, since the interviews were conducted without previous notice. There were two different interpreters during different interviews, one male and one female. With the female interpreter the interviews were made with approximately equal amounts of men and women, whereas fewer women were interviewed using the male interpreter. The number of interviews conducted was approximately 40. However, not all respondents answered all the questions, mainly due to the time aspect – to avoid bothering the respondents too much in their daily work we did not want for the interviews to last more than approximately half an hour. The exact numbers of male and female respondents is difficult to account for, since some interviews were performed with groups consisting of both men and women, but approximately 60 percent of the respondents were men.

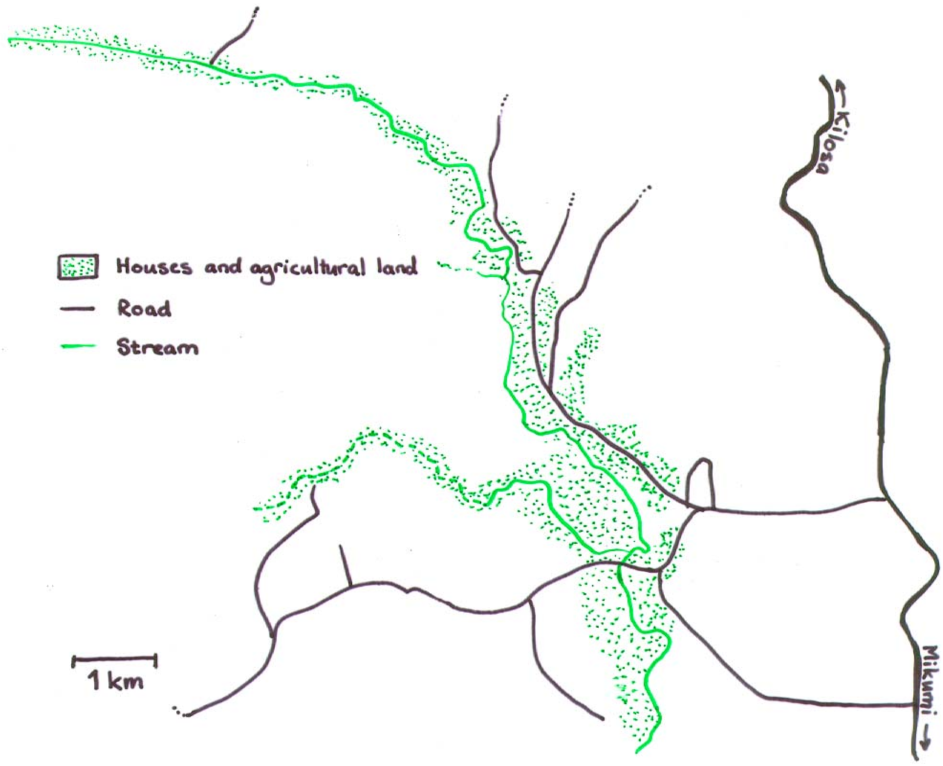


Figure 2: Schematic map of the inhabited area of Ihombwe village.

The interviews, which consisted of questions about the soils in the area and the agricultural practice, were done both sitting down and walking around the fields, which enabled own observations. The questions asked can be seen in Appendix 1.

2.3 Mapping

When drawing conclusions concerning what soils the farmers prefer, it helps to have a picture of the distribution of the soils in the landscape. Therefore a simple map of the distribution of different soil types in the village, based on the local classification system, was produced. The classification was obtained from the interviews with the farmers. The mapping was limited to cover areas that are presently used for agriculture and some adjacent areas.

The classification system of soils done by the farmers is coarse and based on experience of farming the soils in the village. Since most of the local soil names are related to colour and structure, the mapping was done visually. In some cases where there was doubt of how to classify a soil a sample of that soil was taken for comparison with other soil samples.

2.4 Soil samples

To be able to describe the soils scientifically, samples were gathered from the different kinds of soils as recognised in the interviews with the farmers. The colours of the samples were determined using a Munsell colour chart (1967). In addition samples were sent to Mlingano Soil Service Institute in Tanga, Tanzania for analysis regarding texture, pH, organic carbon content, nitrogen content, available phosphorus, CEC, exchangeable bases, and base saturation.

Particle size distribution
The particle size distribution was determined by dividing the grains of the soil into four different fractions; <2 μm (clay), 2-20 μm (fine silt), 20-50 μm (coarse silt), and 50-2000 μm (sand). The content of each fraction in the soil sample is displayed in weight percentage.

pH
pH was measured both in soil/water and in soil/0.01 M KCl solutions.

Organic carbon content
The amount of organic material in a soil is often expressed as the amount of organic carbon. Organic carbon in soils mainly serves as an energy source for soil- and microorganisms that decompose organic material (Bridges, 1978). This is important in farming, as other elements that can limit the growth of the crops are released.

Total nitrogen content
Being a very important fertilising element, without which a plant cannot grow, it is interesting to know the nitrogen content in a soil. Besides being built into organic matter, nitrogen occurs as nitrate, nitrite, and ammonium ions as well as in gas form. It constantly changes between these forms, why one usually measures the total nitrogen content instead of the occurrence of each fraction (FitzPatrick, 1986).

C/N ratio
The carbon/nitrogen ratio describes the soil's carbon content in relation to the nitrogen content. The ratio is mainly used as an indicator of the rate of decomposition of organic material. The optimal condition is a C/N ratio of approximately 25. If the ratio is higher than 30 there is a nitrogen deficiency. The microorganisms need nitrogen to grow, and if the ratio is lower than 20 there is an energy (carbon) deficiency. In most soils the C/N ratio is approximately 10 (Havlin et al., 1999).

Available phosphorus
Next to nitrogen, phosphorus is the second of the two most important nutrients for plants. A large part of the P is often bound rather firmly in the soil and is therefore inaccessible to the plants. When evaluating the soil from an agricultural point of view and in a shorter time perspective the important thing is therefore the available fraction of phosphorus. (FitzPatrick, 1986) There are two common methods for evaluating the amount of phosphorus in a sample; Bray's method, which is used for soils with pH lower than 7.4, and Olsen's method, which is used for soils with pH higher than 7.4 (Havlin et al., 1999).

Cation Exchange Capacity

One important chemical quality of a soil is that the particle surfaces have unbalanced charges. In a neutral soil the surfaces generally have a negative net charge, which enables it to bind positively charged ions, cations. The bounds are usually quite weak why one cation can easily be exchanged by another. These exchangeable cations are made out of base cations like Ca^{2+}, Mg^{2+}, K^+ and Na^+, and acidic cations, Al^{3+} and H^+. If pH changes quickly the exchangeable cations can buffer, and the environmental effect will be smaller. The amount of exchangeable cations, or the cation exchange capacity – CEC, can therefore be used as a measure of how resistant a soil is to rapid changes in acidity (FitzPatrick, 1986).

Exchangeable bases and base saturation

The exchangeable base parameter is simply the amount of each base cation in the soil sample, whereas the base saturation describes how large part of the CEC is made out of base cations (Havlin et al., 1999).

All the samples were gathered from the top layer of the soil (0-10 cm). We did not sample complete soil profiles due to time constraints.

2.5 Infiltration capacity

The infiltration capacity is a measure of how fast water moves vertically in a soil where the pores are filled with water. It is based on Darcy's law

$$q = K_{sat} \frac{dH}{dz}$$

where q is the flow of water [m^3/m^2s], K_{sat} is the conductivity [m/s], and dH/dz shows the change of head per metre [m/m]. The flow is calculated as

$$q = \frac{Q}{A}$$

where Q is the discharge [m^3/s] and A is the total area [m^2]. Darcy's law gives a good approximation of how fast the soil absorbs water and how good it holds it.

The conductance, K_{sat}, tells us something about the structure of the soil and it can vary greatly. K_{sat} can be approximately 1 m/h in gravel or coarse sand while it might be 0.1 mm/h in clay. Macropores, which can be caused by e.g. biological activity or drought affect K_{sat} and can change it several orders of magnitude. In a saturated soil most of the water travels in the largest pores, and this is why the macropores can make such a big difference.

To measure the infiltration capacity a PVC pipe with a diameter of 10.2 cm (4 inches) were used. They had been cut off at a length of approximately 14 cm and one end was sharpened to make it possible to drive it into the ground. During measurement a few centimetres of the cylinder is in the ground. Water is poured both into and around the cylinder, and after waiting a while for the soil to get wet, the infiltration capacity can be measured as how fast the water level inside the cylinder falls. Pouring water around the cylinder decreases horizontal water flow due to pressure differences between the wet soil under the pipe and the dry soil around it. Even so, the infiltration capacity is overestimated using this method.

3 Results

3.1 Interviews, soil

3.1.1 Soil classification

During the almost 40 interviews that were carried out in the village, approximately 20 names or descriptions of the cultivated soils in the village were mentioned. Most of the names were simple in the sense that they described a property of the soil that could easily be seen when looking at them, e.g. ‘black soil’, ‘red soil’ or simply ‘soil’. The other names described properties that affect cultivation, like ‘clay’, ‘sand’, and ‘hard’. Another soil name that was mentioned was ‘tiftif’ - a black soil that the farmers described as soft and easy to cultivate. From the look of it ‘tiftif’ would probably be characterised as loam.

It was quite clear after some interviews that people had different names for the same soil. Two neighbours could have a similar looking soil that one of them called ‘black’ and the other called ‘soil’, so later we have used a coarser classification of the soils in the cultivated area. Further, it can be mentioned that in many places, especially in the valleys, the soils had an inhomogeneous sand content. Some farmers mentioned this and described their soils as ‘a mix of red soil and sand’ or ‘sandy black soil’, whereas others named their soils ‘red’ or ‘black’ despite similar properties.

3.1.2 Signs for good land

33 out of 38 respondents have answered the question about which signs in nature they look for when searching good farmland. Dense forest (33%), mitalula trees (*Acacia polyacantha*) (18%) and tall grasses (55%), especially a species of grass locally called ‘sanze’, were the most frequent answers (see Appendix 2 for a list of all species mentioned). Some people simply ‘look at the soil’, where black soil (12%) with rotten grasses and leaves (9%) are preferred. It was also mentioned as positive with a soft and fertile soil without stones and large cracks. Proximity to water (15%) and ‘valley’ was considered important by some people whereas others simply prepared a spot to see if the yield would be satisfying (12%). One respondent told us that she grew the fast growing amaranth to test the soils’ capacity before settling on that piece of land.

3.1.3 People’s opinion of the cultivated land

Most of the farmers claimed to be happy with the soils they cultivated though some were not completely contempt since the soil was ‘not as good as it used to be’, that ‘its fertility had decreased due to cultivation’. Of the remaining, less pleased, respondents a large majority were cultivating sand or sandy soils. Some respondents were asked for examples of bad soils, and regardless of what soils they were cultivating, most of them answered ‘sand’ or ‘stony’.

Sand was not always mentioned in negative terms, though. Some of the interviewed farmers were happy to cultivate a mix of sand and clay, since the sand content made the soil easy to prepare. A couple of the respondents said that all soils are good but for different crops.

3.2 Interviews, agriculture

The agriculture in the village Ihombwe was mostly subsistent, family agriculture. For most people the agriculture is the only source for income and food. Some of our respondents were asked to approximate the size of their land. The answers varied from 4 to 20 acres. In addition to the subsistent farmers there were also landowners who did not live in the village. They lived for example in the nearby town Mikumi and hired day labour or lived in Ihombwe part of the year.

Some of them were said to own large pieces of land and were able to work the land by tractor. The rest of the agriculture in Ihombwe was little or not mechanised at all. Most of the tilling, sowing, and harvesting was done by hand and using hoes.

There was no tradition of holding livestock in the village why no manure was deposited on the fields. Nor did anybody mention any use of artificial fertilisers.

The extension officer connected to the village (‘Mama Chamba’, Mrs P. Nkane) lived in Mikumi and we performed a short interview with her. She was connected to the Ministry of Agriculture and the research centres and her aim was to teach the village farmers the use of new technology in agriculture, primarily regarding crop protection, e.g. pesticides, and methods to avoid weeds. Since the village consisted of eight sub-villages, she was planning to have one contact farmer in each sub-village and to have demo plots at every contact farmer to show the new technologies. There was still, in her opinion, a lot of potential agricultural land, and her aim was that the small farms should expand as long as there is more land. She had only been working in the village for one year and she was the first extension officer there. During that first year she had met scepticism among the farmers. Since the farmers were so widely spread it was also difficult to spread the information and to do follow-ups.

3.2.1 Shifting cultivation and fallow

All of the respondents were asked if they used shifting cultivation or fallow and it was obvious that these methods were used in the village more or less by everybody, but with some variations. One method was to move to another piece of land, for example in another sub-village, and grow that land while the old land was in fallow. When it had recovered its fertility they shifted again. This method seemed to be quite common. Those who had enough land around their house were able to leave parts of their fields in fallow without having to move.

Small yields and bad crops were mentioned as being indicators of when to shift agricultural land. The time from clearing of new land to declined harvests and fallow was said to be 5-10 years. The time a ‘tired’ soil needs to recover was mentioned to be 3-5 years, sometimes only 1 or 2. The vegetation on the land shows when it is fertile again. The density and length of the vegetation as well as certain kinds of grasses were indicators of good farmland. Some of the farmers described that the soil will get fertile again as grasses rot and decompose.

Three respondents out of 26 said that they did not use shifting cultivation because the land was still strong and fertile. Five farmers would have liked to do it but they did not own enough land or they were too old to move. One man said that he only harvested once a year and therefore his land did not get ‘tired’. Another farmer had noticed a yield decline, but he intended to dig deeper and rotate the crops to retain the yields.

With the agricultural practice used in the village, there is a rotation of crops in many fields during each year.

3.2.2 Crops

Lots of different crops were grown in the village (see Appendix 3). One of the staple foods was maize, which all respondents grew. Beans were also grown by most people, as was cassava, banana and papaya but the last three were in general not considered to be a crop in the same way as maize and beans. Sesame was very common and so was pigeon pea. Quite a large part of the farmers grew rice, sorghum or peanuts. Rice is a crop that has high demands of water supply and could therefore only be grown in the wet areas close to the stream. Mango trees and sugarcanes were also frequently grown close to the water.

Additionally, almost everybody grew some vegetables. This was predominantly done close to the stream because of their high demand of water. The most common vegetables grown included: amaranth, tomato, pumpkin, and cabbage varieties called ‘kabechi’, ‘figili’, and ‘sukumawiki’. Other crops that were grown to some extent were onion, millet (bulrush and finger), eggplant, African eggplant and cowpea.

Some respondents were asked what they considered to be a good and a bad yield respectively. The answers varied a lot. For maize a good yield was 6-50 bags per acre and a bad yield 5 bags per acre. For rice a good yield was 20-50 bags per acre and a bad yield 15-20 bags. For beans a good yield was 5-8 bags. The great span can be caused by different reasons: the bags might not be the same size, people may not know the size of one acre and the yield can vary from one place to another. Some respondents were not used to measure the yield in bags per acre. Instead they notice in the barn if the yield is good or bad.

Approximately half of the respondents claimed to sell some of their yield, i.e. if they have enough. Sesame and maize seemed to be the main cash crops, but also pigeon peas, peanuts and beans were sold to some extent. Sorghum, sunflower, cowpea and rice were also mentioned as crops that could be sold. Some respondents sold to customers that came to their house to buy, some sold in Mikumi (transportation mostly by bike) or in the village. Some people claimed that it was hard to find a market for their crops, for example the sub-village Ibegezi was mentioned as a bad place for market contacts.

3.2.3 Crop rotation and location of crops

The agricultural land in the village is situated at different distances from the stream. This affects the water supply and hence the period of the year when the land can be cultivated.

Some land close to the stream was wet enough to be cultivated throughout the year. Crops grown there include: maize, taro, sugarcane, bananas, cabbage, chinese cabbage, tomato, onion, pumpkin and beans. This land might be flooded during part of the rainy season, and rice seems to be the crop grown under such circumstances, if anything is grown at all. Many of the respondents were complaining that maize doesn’t grow well when it is too wet.

A lot of agricultural land in the village is located in the valley, but not right next to the stream. This implies that most of this land can only be grown during the rainy season. This land is suitable for most kinds of crops. The respondents described how they prepare the land in October and November and when the rain comes in November and December they start to sow for example maize, sesame, sorghum, rice and pigeon pea. Some crops were more often grown during the big rains, for example beans, sweet potatoes and vegetables that can be sown in the maize field after the maize harvest approximately in April. It seemed to be less common to grow another crop after sorghum and sesame. Those crops were sometimes sown later, for example in January.

Some farmers cultivated the slopes that were generally drier than the other land. Sesame, sorghum, finger millet and peanuts were crops mentioned to be grown on this type of land. Sorghum and cassava were said to be drought resistant by one of the farmers. The crops were sown in January or February and only one harvest was taken per year, except for one farmer who grew peanuts from November to March and March to June.

Some crops were grown all year around and were harvested now and then when they were ready, for example sugarcane, banana, fruits like papaya, mango, lemon, and guava, and the tubers taro, tannia, and cassava. Pigeon peas were harvested after 8-10 months, which is a relatively long time. Taro is grown close to the stream. It is ready to harvest when the leaves turn yellow.

Four respondents were asked about how often they weed rice and maize. The flooded rice was weeded 1-2 times. The maize was weeded 2-3 times. The rainy season was considered to be a period of hard labour.

Table 1 shows where different crops are grown in relation to the soil type and the location of the field. The location of a field is either low or high, where low means at the bottom of the valley, close to the stream, and high is on the slope, further away from the water. The 'Number of respondents'-column shows how many of the respondents grow the crop. For each location the different soil types occurring on this type of land is represented as a separate column. The most common soil type is black and the mixture of red and black. Only a few farmers had the other kinds of soils shown in the table. The farmers are limited to the piece of land they own and they can not always choose the most optimal combination of crop and soil type, but Table 1 indicates which crops can be grown on each soil. The crops are divided into the groups: cereals, tubers, fruits, vegetables and others.

3.2.4 Agricultural calendar

To get an idea of when the farmland is cultivated three agricultural calendars were made (Figure 3). They show during which periods the most common crops in the village are grown and since that differs a bit due to the availability of water the farmland was divided into 'land moist all year around' (very close to the stream), 'low land' (in the valleys) and 'high land'.

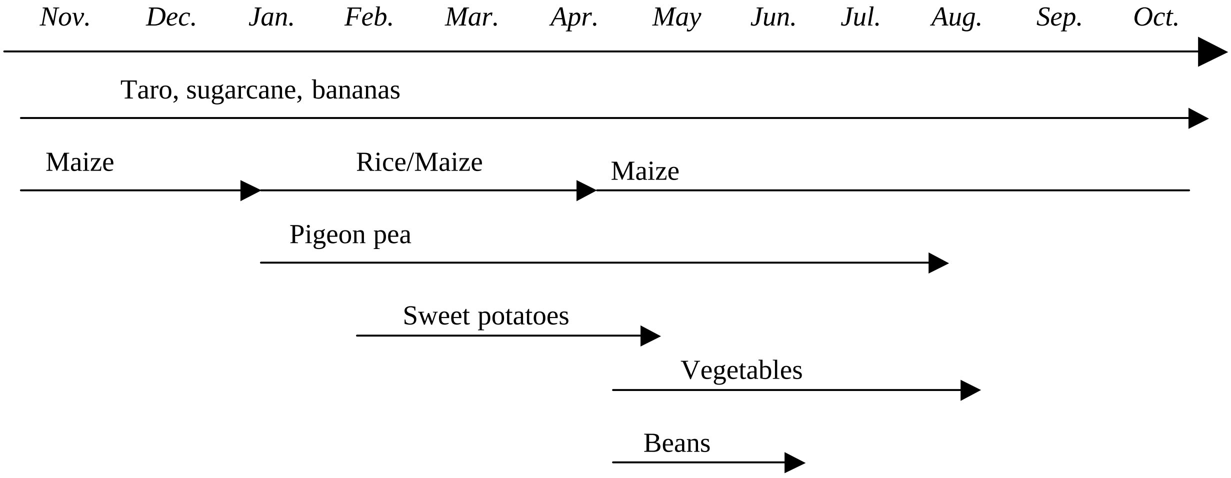
Most of the sowing is made when the short rains come which can vary from November to January. In these crop calendars the rains are considered to start in November. The calendars are based on data from interviews with farmers in the village. There were variations in the gathered information. For example the time period between sowing and harvesting differed, but in the calendars an average is used.

On the farmland in the valleys ('land moist all year around' and 'low land') it is possible to take two (or sometimes three) yields per year. The farmland on the 'high land' is more limited because of the lack of soil moisture in the dry season so that land is often sown when the rain comes and one yield is collected. Some crops are grown all year around, and the species' water demand affects their placement.

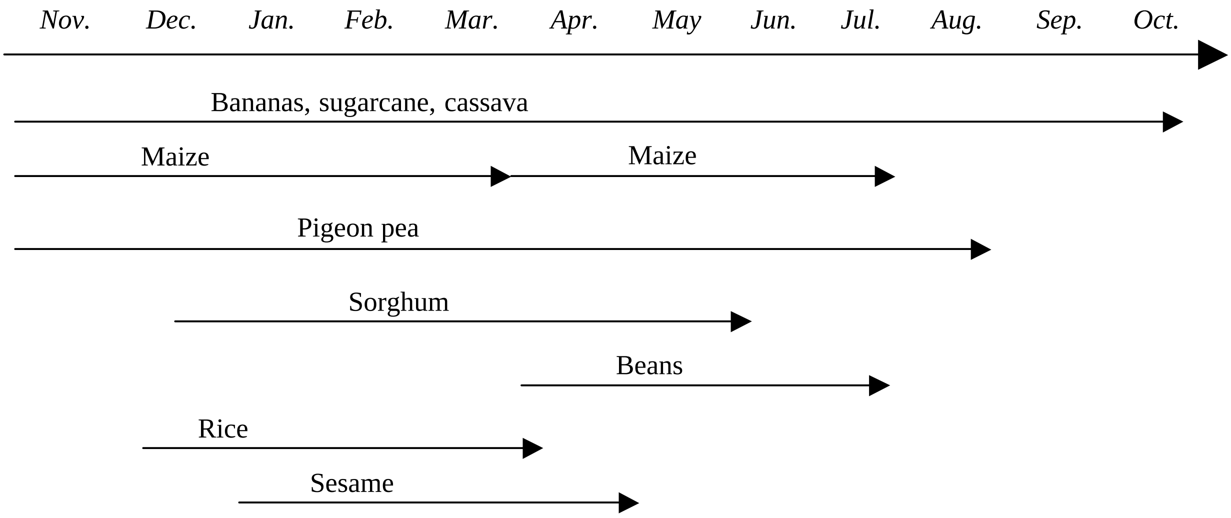
Table 1: Distribution of crops based on field location and soil type. *The location of a field is either low or high, where low means at the bottom of the valley, close to the stream, and high is on the slope, further away from the water. The 'Number of respondents'-column shows how many of the respondents grow the crop. For each location the different soil types occurring on this type of land is represented as a separate column. The crops are divided into the groups: cereals, tubers, fruits, vegetables and others.*

Field location	*Low*	*Low*	*Low*	*High*	*High*	*High*	*High*	*High*	*High*	***Number of respondents***
Soil type	Black	Red	Red + Black	Black	Red	Red + Black	Black + Sand	Sand	Black + Ash	
Rice	86%	7%	7%							14
Maize	51%			26%	11%	9%				35
Sorghum				44%	28%	11%	6%	6%	6%	18
Vegetables	78%		17%	6%						18
Beans	54%	4%		19%	4%	12%	4%	4%		26
Cow pea	25%			50%	25%					4
Pumpkin	25%		25%	25%	25%					4
Bambara beans					67%				33%	3
Taro	67%	33%								3
Sweet potatoes	18%	9%	9%	18%	27%	9%	9%			11
Cassava				43%	33%	10%	5%	5%	5%	21
Banana	45%	9%	18%	9%	9%	9%				11
Papaya				56%	11%	22%			11%	9
Mango				25%	50%				25%	4
Pineapple					33%	67%				3
Sunflower				50%	50%					2
Groundnut				33%	33%	17%			17%	6
Sesame	14%			48%	10%	10%	10%	5%	5%	21
Pigeon pea	14%			57%	14%	7%			7%	14
Sugarcane	75%		25%							8

Agricultural calendar – on land moist all year around



Agricultural calendar – on low land



Agricultural calendar – on high land

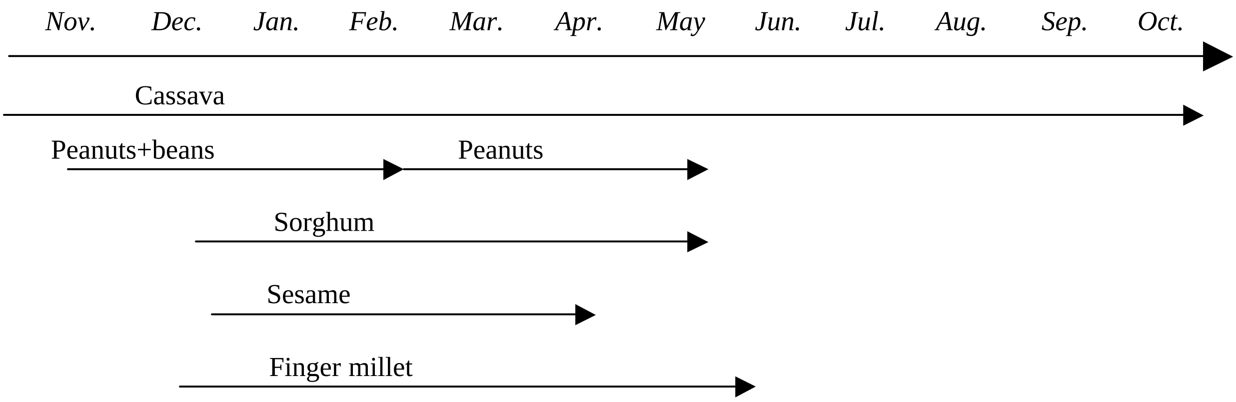


Figure 3: Agricultural calendars for Ihombwe *showing when different crops are grown throughout the year for different locations. The rains are assumed to start in November.*

3.2.5 Intercropping

Intercropping was used by some farmers in the village to save space and time. For example, maize could be sown together with beans, tomato, pigeon pea (when it is cut) and amaranth. Maize could also be grown with peanuts or rice, but then the rice or peanuts would be sown when the maize is 2-3 months old. Other mixes were African eggplant and okra, one row bulrush millet and one row finger millet, and pumpkin in combination with cowpea and sweet potato. Farmers that chose not to use intercropping did so because they did not think it was good (without further explanation). Intercropping might take place to some extent anyway, e.g. when maize is grown between the banana plants, maize between the cassava rows or a mix of vegetables and taro close to the stream.

3.2.6 Problems identified by the farmers

Some of the respondents were asked about what they considered to be the greatest problems with cultivation. Most people mentioned wild animals coming out of the forest and raiding the crops, for example maize and cassava. Wild pigs, warthogs and bush buck occur mostly at night while baboons, monkeys and birds come during the day. To prevent this problem people guarded their maize fields and hunted the animals during the most sensitive period, i.e. as it ripens. Cassava, which grows and ripens continuously, is vulnerable a long time and was therefore grown close to the house for protection. A couple of farmers also mentioned that rodents eat seeds when sown.

Most of the farmers seemed to consider the wild animals to be the main problem, but some also said that they have problems with insects, for example grasshoppers on small millet plants, lice on beans and borers on cereals during the storage. Chemical treatment was not common in the village but the farmers living in Mikumi were able to use it and at least one family in the village owned a mechanical spray machine. This family was hired to spray the fields that belonged to landowners from Mikumi.

Water was another problem. Either it was too dry or it is too wet so that the land is flooded and the soil can be swept away or sand can be left on the clay.

3.2.7 Production and availability of seed

Most of the farmers in Ihombwe seemed to grow and save their own seed for the next growing season to a large extent. In the village you could, at least during October, see old pigeon pea, okra and cabbage varieties carrying seeds. Some seeds were bought in Mikumi, for example peanuts and Chinese cabbage. Seed of sweet potatoes were saved in the ground. Cassava was vegetatively reproduced by cutting the stem and planting the pieces directly in the soil. Neighbours also bought seeds from each other.

3.3 Mapping

After finishing the interviews we combined the information regarding soil names with observations made when visiting the farmers and settled for a rather coarse classification system. The soils were grouped mainly by colour but also by their appearance in terms of e.g. structure and vegetation. The main classes were

Red soil — Hardly surprising this soil is easily recognised by its colour, which ranges from reddish brown/dark reddish brown (2.5 YR 4/8-3/6) to bright reddish brown (5 YR 5/8) and brown (7.5 YR 4/4-4/6) when dry. When wet the soil has different shades of dark reddish brown, e.g. 2.5 YR 3/4 and 5 YR 3/4. The shade of red differs depending on where the soil is situated, and at some locations it is mixed with the black soil.

Black soil — This soil is also known locally as ‘soil’, or ‘clay’. It occurs mainly in the valleys and has a variable structure, mainly due to various amount of sand being mixed in. The colour varies more on dry soils than on wet. The dry soil ranges from brownish black (10 YR 2/2) to dull yellowish brown (10 YR 5/4), whereas the wet is dark brown (10 YR 3/3) to black (10 YR 1.7/1).

Pale soil — This soil is found on the hills, where there is no agricultural activity. This is probably the reason why it was not mentioned during the interviews. Despite the fact that the colour resembles some of the black samples, we considered it to be so different from the other soils that it was relevant to make it a separate class. The colour is dull yellowish brown, e.g. 10 YR 5/4, when it is dry, and brownish black, e.g. 10 YR 3/1, when moist.

Grey soil — In a few spots this grey soil was found. Like the pale soil it is mainly found in the forest but the colour is quite different, 10 YR 4/2 dry, and 10 YR 2/1 wet.

Sand — Sand occurs mainly in the valleys, where there is or has been water, close to the stream or creeks that can be dry during part of the year. The patches of sand can be very local, but the phenomenon can be seen throughout the entire village.

The result of the mapping (Appendix 4) shows some patterns concerning the distribution of the soils in the landscape. Almost all the soil close to the stream is black and more or less mixed with sand. Black soil also occurs in areas a little further away from the stream, but then only in low land, which could potentially be covered by water during the rainy season. The sand, as well as the black soil, has probably been brought there by the massive amounts of water that flush down the slopes after heavy rains. This theory is supported by observations of the soil on some of the hills, where only coarse fractions like gravel and small stones are left on the surface, as if the finer fractions had been washed away. The change and moving of the soil is a constantly ongoing process that sometimes changes the flow of the stream and the tributary creek. This leads to a net transport of sand and finer fractions downstream.

On the hills the soil is generally quite dry and seems unfertile. In some spots the top centimetres consist of sand and coarser fractions, probably due to erosion caused by the rains. To the west of the stream most of the hills are covered by the bright or the grey soil, whereas the area between the stream and the Kilosa-Mikumi road, south of the road to the village has the red soil. Along the small road through the village the soil alters between black and a mix of red and black, where the ridges tend to have a more reddish shade. In Appendix 4 only the observed spots have been included, which explains the incomplete colouring. It is still reasonable to assume that the areas in the south, surrounded by red or pale soil, is covered by the same kind of soil as their respective surroundings.

3.4 Soil samples

Eight soil samples were taken, most of them from the soil that was referred to as ‘udongo’ or black soil, though we thought they were dissimilar. One sample was taken from a red soil and one from what had been described as a mix of black and red soil. In addition one soil sample was gathered from a soil that was lighter than the ones found in the agricultural area, a type that only occurred in the forest.

L1	Red soil, near house. Cultivated, used to be pigeon pea at the spot. There are some cracks and macropores due to drought and biological activity.
L2	Black soil overlaying red. On slope, by the road to the village. Not cultivated, grass. Some macropores.
L3	Red/Black soil. Cultivated before, but the field was probably left in fallow last season. Some cracks and macropores here and there.
L4	Pale soil in forest with sandy patches on the surface.
L5	Black soil in forest. The land has probably been cultivated earlier but has been in fallow for a few years (maybe 5). Under a big tree there are big cracks. Away from the tree there are no cracks at all.
L6	Black soil by the creek. Cultivated field with remains of pigeon pea. Not prepared for the next season. Easy to dig with few cracks.
L7	Black soil on slope. Sandier greyish soil with no cracks or macropores but with some holes made by rodents. Cultivated.
L8	Black soil by the creek, right next to field that has been prepared for the rains. Wet soil that holds water well. Cultivated.

The figures below the thick line in the middle of table 1 are values from a number of studies, compiled by Frost (1996). The means, standard deviations, and ranges describe the data of 34 to 84 different soil samples, the exact number varying between the different parameters, from soils in miombo woodlands. Frost points out, however, that these data do not show the variation of soil properties within a landscape, e.g. in catenas and on slopes where differences within a short distance are to be expected. As this is the case where this study was conducted, the figures should be used primarily as a guideline for comparison

Table 2: Physical and chemical properties of soil samples L1-L8. *The "typical values" are from Frost (1996).*

Sample No.	Depth (cm)	Particle size distribution (weight %)				pH		Organic matter		
		50-2000 μm	20-50 μm	2-20 μm	<2 μm	H_2O	KCl	C (%)	N (%)	C/N
L1	0-10	16	26	14	44	7.3	6.5	1.88	0.12	16
L2	0-10	48	8	14	30	7.0	5.3	2.24	0.15	15
L3	0-10	30	12	18	40	6.9	5.7	2.66	0.18	15
L4	0-10	74	6	6	14	7.0	5.5	1.10	0.10	11
L5	0-10	42	8	14	36	7.1	6.2	5.03	0.28	18
L6	0-10	50	10	14	26	7.2	6.2	3.63	0.19	19
L7	0-10	76	10	2	12	7.1	6.1	1.38	0.10	14
L8	0-10	22	14	28	36	6.8	5.2	4.30	0.29	15
Typical values for miombo										
Mean	0-20					5.60	5.00	1.40	0.10	
Standard deviation						0.7	0.5	0.9	0.10	
Range						4.2-6.9	3.9-6.1	0.3-3.8	0.02-0.62	

Sample No.	Available P (ppm)		Exchangeable cations (meq/100g)				CEC	B.S.
	Bray	Olsen	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	meq/100g	%
L1		1.39	29.1	0.9	0.95	0.15	30.19	100
L2	15.46		11.1	2.0	0.77	0.09	13.82	100
L3	28.51		19.5	4.7	1.21	0.13	26.06	98
L4	10.41		3.5	0.7	0.22	0.09	4.47	100
L5		18.61	32.5	8.3	0.70	0.16	41.25	100
L6		28.10	17.5	3.9	2.10	0.12	23.16	100
L7		27.76	5.5	1.3	0.57	0.04	7.32	100
L8	7.57		15.2	5.7	0.33	0.31	22.91	94
Typical values for miombo								
Mean	13.40		2.72	1.46	0.32	0.06	7.56	57.60
Standard deviation	13.3		3.00	1.85	0.36	0.10	5.31	32.8
Range	0.0-54.0		0.00-15.00	0.00-8.40	0.00-2.34	0.01-0.48	1.80-25.10	3.0-100.0

The pH values from measurements in water and potassium chloride differ a lot. The difference ranges from 0.8 to 1.7 pH units for the different samples, which is more than can be considered reasonable.

As for carbon and nitrogen, the values seem to be reasonable. All the nitrogen data are within the range of previous studies, and six out of eight are within average ± standard deviation (not L5 and L8). For carbon six out of eight samples are within the previous range (not L5 and L8), and four are also within average ± standard deviation (L1, L2, L4 and L7).

All soil samples agree with the previous data range for phosphorus, only L3, L6 and L7 are higher than average + standard deviation, and they are all quite close to the limit. It can also be noted that L1 has a particularly low P content. This could possibly be due to iron or calcium in the soil, as they can react with phosphorus and form secondary minerals. These reactions, however, are pH-dependent, and it is therefore hard to know whether this is the case here, as the pH values are less reliable.

Almost all the soils are rich in calcium; in fact this is the only cation analysed where concentrations exceed the previous range. L2, L4 and L7 are within the range but only the last two are within average ± standard deviation. The parental rocks vary greatly in this area, due to tectonic activity, which could explain the variation of calcium content. Sodium, on the other hand, is ‘normal’ where only L8 has a concentration higher than average ± standard deviation.

As a result of the high calcium content the CEC is generally high. L4 and L7, which had “normal” calcium content, consequently had normal CEC, whereas the calcium rich L1, L3 and L5 exceeded the previous range for CEC in miombo soils. All the analysed soils have high base saturation, indicating good buffering properties and that no common cation has been forgotten.

***Table 3: Infiltration capacity**, K, measured at the soil sampling spots L1-L8 and two additional locations, one on a black sandy soil by one of the tributary creeks (farmland) and one on a red soil (woodland/forest).*

Soil sampling spot		**K (10^{-5}m/s)**		
L1	28	9	10	
L2	28	6	17	
L3	71	7	5	
L4	17	20	9	10
L5	42	12	1	3
L6	4	13	2	
L7	20	17		
L8	36	63		
Black sandy soil by tributary creek	30	28		
Red soil in the forest	17	2		

Table 3 shows the results of the infiltration measurements for the spots where the soil samples (L1-L8) were taken. The infiltration capacity was also measured at two additional measurement locations, one on black sandy soil by one of the tributary creeks (farmland), and one on a red soil in the forest (woodland). The experiment was repeated two to four times in each spot. The right column is the quotient of the highest and the lowest K values for each soil sampling spot. For some of the measuring locations the quotient is close to 1, and hence the variation between the measurements is small. Some of the variation at the other measuring locations can be explained by local variation of macropores and cracks.

One source of uncertainty is the drought that made the clay soils very hard, which in turn made it difficult to force the PVC pipes into the ground. The soil adjacent to the pipe may then have been affected and some of the water moved horizontally under the PVC pipe. Since the calculations of the K values are based on the assumption of vertical flow only this makes the measurements less reliable. This is probably part of the reason why e.g. L3 and L5 has a quotient larger than 10.

4 Discussion

The interviews show a large range of answers to some of the questions. Two neighbours can have different opinions on soil quality and naming even though they have adjacent fields with similar characteristics. The main reason for this could be migration to the village, bringing people with different experiences and different frames of reference together. Coming from a dry and fast eroding environment this village might seem very fertile, while the native Ihombwe farmer might have seen a decline in fertility during the past years. Bringing people of different background together could cause a conflict between the traditional agricultural practice of Ihombwe and cultivation practices of other regions. The answers regarding signs of good land were quite homogeneous but there were some differences which may be explained by the varying experiences of people from different regions.

As mentioned in the results some farmers claimed not to use intercropping because it was no good. They did not give any further explanations but one possible reason could be that some extension officer at some point has advocated monocultures. It is not certain that these people fully understood why or actually agreed with this opinion, but it is possible that they gave the answers they thought we expected or wanted, which makes the interview results less reliable. This behaviour is not likely to occur in questions about e.g. what each farmer grows, since that subject is less charged in terms of what is ‘expected’ or what is the ‘correct answer’. Another thing that can affect the answers is if the respondent thinks that the complete answer would be too long or too complicated for us to understand.

For the soil samples there is a considerable difference between pH values measured in water and potassium chloride. A difference of 0.8-1.7 pH units is unreasonably large, which implies that there might be something wrong with some of the pH data. This in turn makes the interpretation of the chemical properties of the soils and their effect on cultivation difficult, especially as pH affects many of the other analysed parameters.

The results of the lab analysis indicate that the difference between the analysed soils is limited; most values seem to be normal compared to previous studies of miombo soils. It is therefore hard to draw conclusions about which of the soils is more suitable for agriculture, and there does not seem to be a significant difference in nutrient content that would make people choose e.g. the black soil rather than the red. One exception could be that e.g. L4 consists primarily of coarse material, which could make it less suitable for cultivation, and that L1 has very low available phosphorus content that could have a negative effect on the yield.

The spot where L4 was collected is located in the forest, quite far from any agricultural areas, which corresponds well to the reasoning above. L1 is a red soil that was gathered from a field with pidgeon pea, near a house on the top of a ridge, quite far from the stream. The family living there claimed that the soil was good for various crops, most of the which were drought resistant crops grown in dry places in the rest of the village. Despite this it is difficult to draw conclusions about whether the low phosphorus content affect the crop production since only a limited area around the house was cultivated.

Despite the fact that most of the interviewed farmers claimed to be contempt with their soil, regardless of soil type, there was a tendency for people to choose to cultivate the black soil when possible. It can be noted that the farmland is distributed by the village government, which may limit the possibility to choose a site to cultivate. The fact that people tend to cultivate black soil does not mean that soil type is more important than proximity to water when choosing land for agriculture.

The black soil is an alluvial deposit and occurs primarily at the bottom of the valley, i.e. by the main stream, where people live and cultivate (cf. Figure 2 and Appendix 4). It is reasonable to assume that access to water is one of the most important limiting factors for agriculture in this area. This becomes even more obvious when studying the agricultural calendar, which suggests that the land of many farmers can be cultivated only during the rainy season. The farmers who cultivate land by the stream have a possibility to grow crops throughout the year. Hence, proximity to water seems to be the more important factor when choosing agricultural land, but people tend to prefer the black soil to the red when they have a possibility to choose.

The choice of crop does not seem to be related to soil type, but rather to access of water. Some crops can grow in a dryer environment, and are therefore cultivated on the slopes, while other crops have a higher demand of water and need to be grown close to the stream. In the cases where a crop is primarily grown on a certain soil, e.g. rice on black soil, this is probably because of its demand of water, and the stream is almost exclusively bordered by the black alluvial soil.

The population in the village seemed to increase, especially in some parts of the village, where many of the respondents had moved in during the last two years. Despite this the village was still pretty sparsely populated, and large areas of agricultural land were not intensively cultivated. The agricultural system of shifting cultivation, fallow, and no fertilisers requires extensive areas, and if the village population would increase too much, it would be hard to continue using the traditional methods in a sustainable way. There is a risk that the fields would then not be left in fallow long enough to regain its fertility (cf. Lawton, 1982).

All results in this study indicate that people live on and cultivate land fairly close to water. The proximity enables people to meet their daily needs of water, as well as to lengthen the growing season in a climate where water is the main limiting factor for agriculture. If people will continue to live in the valleys, which seems plausible, the larger part of the forest in this area is not likely to end up as agricultural land. There are probably other factors that will have a larger effect on the future of the miombo in Ihombwe village.

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Appendix 1 - Interview questions

- What is your name? Which tribe? How many children?
- How long have you lived here?
- Can you describe where your land is?
- How long have you cultivated your land?
- Do you think it is a good land for agriculture?
- Was the land cultivated before you came here?
- Did you clear it?
- Did you now that it was a good land before you cleared it?
- How can you tell it is a good land before you clear it?
- Do you have possibilities to shift into another land and leave the fields in fallow?
- What indicates that it is time for fallow?
- How long time does the land need to recover?
- How do you know that it has recovered?
- What is a good yield? What is a bad yield?
- Do you sell your harvest?
- Do you have the same type of soil in all your land? What type is it? What do you call your soil?
- Which type of soil is the best for agriculture? Which types of soils are not suitable for agriculture?
- Do you have different crops on different types of soil/locations on your land? Why?
- What are you planning to do in the field from now to the next dry period?
- When do you sow and harvest the different crops?
- How many times do you have to harvest?
- What do you consider as the biggest problems with your agriculture?
- When is the work load the most during the year?

Appendix 2 – List of indicators for good and bad agricultural land

List of species that were mentioned as indicators of good and bad agricultural land. Translation to Latin by (Ruffo, 2001).

Species that indicate good land:

	Local name	Latin name
Grasses	Bagalala	
	Bogamboga	
	Ferigugu	
	Koroga	
	Ngugu	
	Sanze	
Trees	Mkuyu	Ficus sycomorus
	Myombo	Brachystegia boehmii
	Mtalula	Acacia polyacantha
	Msada	Vangueria infausta
	Msungwi	Vitex mombassae
	Msang’we*	Annona senegalensis
	Mgude	Sterculia quinqueloba
	Mkoga	
	Mng’ongo	Sclerocarya birrea
	Mnuduru	
	Mwiza	Bridelia micrantha

Species that indicate bad land:

	Local name	Latin name
Grasses	Kimundi	
	Nalu	
	Nyaganga	
	Nyovyi	
Trees	Muhani	
	Mgung’u	
	Msoro	Pseudolachnostylis maprouneifolia

* Translation from (Chilimo, 2001)

Appendix 3 - Crops grown in Ihombwe village

Crops grown in Ihombwe village, given in Swahili, English and Latin. Some of the local tree species were identified using (Maundu et al. 1999), some of the crops were translated to Latin with the use of (Tropcrop).

Swahili	English	Latin
Bamia	okra	*Abelmoschus esculentus*
kitunguu	onion	*Allium cepa*
mchicha	amaranth	*Amaranthus spp.*
korosho	cashew nut	*Anacardium occidentale*
nanasi	pineapple	*Ananas comosa*
mtopetope, tomokwe	cherimoya	*Annona cherimola*
msitafeli		*Annona muricata*
karanga	ground nut, peanut	*Arachis hypogaea*
sukumawiki		*Brassica oleracea var.*
kabechi	cabbage	*Brassica oleracea capitata*
chinese	chinese cabbage	*Brassica pekinensis*
figili		*Brassica …*
mbaazi	pidgeon pea	*Cajanus cajan*
pilipili (holo, mbuzi, ukwale)	pepper (paprika)	*Capsicum …*
papai	papaya	*Carica papaya*
mnazi	coconut	*Cocos nucifera*
magimbi	taro	*Colocasia esculenta*
matango	cucumber	*Cucumis sativus*
boga	pumpkin	*Cucurbita …*
mboga ya maboga	d.o. leaves	*Cucurbita …*
karoti	carrot	*Daucus carota*
ulezi	finger millet	*Eleusine coracana*
soya maharagwe	soya bean	*Glycine max*
alizeta	sunflower	*Helianthus annus*
viazi vitamu	sweet potato	*Ipomoea batatas*
matembele	d.o. leaves	*Ipomoea batatas*
fiwi	hyacinth bean	*Lablab purpureus*
nyanya	tomato	*Lycopersicon esculentum*
embe	mango	*Mangifera indica*
mhogo	cassava	*Manihot esculenta*
ndizi	banana	*Musa spp.*
tumbako	tobacco	*Nicotiana*
mpunga	rice	*Oryza sativa*
uwele	bulrush millet	*Pennisetum glaucum*
maharagwe	kidney bean	*Phaseolus …*
pera	guava	*Psidium guajava*
nyonyo	ricin	*Ricinus communis*
muwa	sugercane	*Sacharum officinarum*
ufuta	sesame	*Sesamum orientale*
ngongwe,nyanya chungu	african egg plant	*Solanum macrocarpon*
bilinganya	egg plant	*Solanum melangena*
mnavu	black nightshade	*Solanum nigrum*
viazi ulaya	potato	*Solanum toberosum*
mtama	sorghum	*Sorghum bicolor*
ukwaju	tamarind	*Tamarindus indica*
mahole	tannia	*Tannia xanthosoma*
kweme		*Telfairia pedata*
mbia		*Tylosema fassoglense*
choroko	green gram	*Vigna radiata*
njugu, njugu mawe	bambara bean	*Vigna subterranea*
kunde, kalwagila	cow pea	*Vigna unguiculata*
mahindi	maize, corn	*Zea mays*
mlenda		

Appendix 4 – Soil map, Ihombwe village