Supplementary Material

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# Interview Question Guide

## Interview Questions in Kiswahili

## Maswali ya Mahojiano

* Umri:
* Jinsia:
* Ngazi ya elimu:
* Mapato (kama unataka kusema):
* Idadi ya watu ndani ya nyumba:
* Idadi ya watu wanaoshiriki katika kilimo:
* Ukubwa wa shamba:
* Ukubwa wa njama:
* Umiliki wa shamba: Kodi (Mwenyeji) ya Mwenyewe

**Mazoea ya Kilimo**

* Ulianza lini kilimo? Ulikua kwenye shamba?
* Una shamba kila mwaka karibu au kila sasa? Tafadhali eleza.
* Niambie kuhusu shughuli zako za kila siku za kilimo. Je, una utaratibu wa kila siku?
* Je, unatumia zana yoyote kusaidia kwa shughuli za kilimo?
* Kuna mazoea ya kilimo ambayo unayotumia?
* Kuna mazoea yoyote ambayo yamepitishwa familia yako au yanayotumika ndani ya nchi?
* Unakua mazao gani? Wanabadilika kulingana na msimu? Una sababu maalum za kuchagua mazao haya?
* Ni mabadiliko gani kubwa uliokutana wakati wa miaka yako ya kilimo?
* Je! Unaongea na wakulima wengine?
* Wakati gani unaweka mbegu kwenye ardhi? Unajuaje ni wakati mzuri?
* Unafanya nini na mavuno?
* Je, mavuno yamekuwa kama nini kwa misimu iliyopita?

**Udongo**

* Ni viashiria gani unatumia kupima afya ya udongo na uwezekano? Unawezaje kupima uzazi wa udongo?
* Unajisikia je kuhusu udongo katika mashamba yako? Ungependa kuiboresha?
* Je, unatumia pembejeo ya udongo mara kwa mara kwenye udongo? Unatumia nini?
* Umejaribu marekebisho tofauti ya udongo?
* Je! Mashamba yako yanaathirika sana katika miaka kavu?
* Una bajeti ya miradi ya kuboresha ardhi?
* Je! Unafikiria ni njia bora zaidi ya kuboresha afya ya udongo na mavuno ya mazao?
* Ni mazao gani inakupa faida zaidi?
* unahusika je na magugu na wadudu?

**Binafsi / Baadaye**

* Unapenda nini zaidi kuhusu kilimo?
* Nini ngumu zaidi kuhusu kilimo kwa ajili yenu?
* Je! Ni kilimo tu chanzo chako cha mapato?
* Unao malengo au mipango kwa shamba lako?

**Mbolea kutoka kwa taka ya chakula (Mboji?)**

* Ungehisi je kuhusu kutumia mbolea kutoka kwa taka ya chakula?

## English Translation for Interview Questions

## Interview Questions

**Respondent**

* Age:
* Sex:
* Education Level:
* Income (if you would like to disclose):
* Number of Household Members:
* Number of Members who participate in agriculture:
* Farm Ownership: Rent or Own?
* Farm size:
* Plot sizes:

**Agriculture Practices**

* When did you start farming? Did you grow up on a farm?
* Do you farm all year around or at certain periods? Please explain.
* Tell me about your daily activities of farming? Do you have a daily routine?
* Do you use any tools to help with the farming activities?
* Are there any particular agricultural practices that you use?
* Are there any practices that have been passed down your family or are locally used?
* What kind of crops do you grow? Do they change based on season? Did you have any special reasons for choosing these crops?
* What was the biggest change you encountered during your years farming?
* Do you communicate with other farmers?
* When do you start seeding? How do you know when to start?
* What do you do with the harvest produced?
* What has the harvest been like in the past few seasons?

**Soil**

* What key indicators do you use to gauge soil health and viability?
* How do you gauge soil fertility?
* How do you feel about the soil in your fields? Would you like to improve it?
* Do you regularly apply inputs on the soil? Do you use fertilizers, manure, or compost?
* Have you experimented with different soil amendments?
* Are your fields greatly affected in dry years?
* Do you have a budget for land improvement projects?
* What do you think is the most effective way to improve soil health and crop yields?
* What has been your most consistent crop in terms of making a good profit?
* How do you deal with weeds and pests?

**Personal/Future**

* What is the most satisfying part of farming for you?
* What is the hardest part of farming for you?
* Is farming your only source of income? What goals or plans do you have for your farm?

**Compost**

* How would you feel about using compost from urban food waste?

# Soil Analysis Methods

## Compost Analyses at University of Waterloo

For OC and TN analyses, carbonates were first removed from the compost samples through acid washing (1). Samples of 2.0 g were treated with 50.0 ml of 0.5 M HCl mixed on a reciprocating shaker (Heidolpj Unimax 1010 DT, Schwabach, Germany) at 240 rpm three times over 24 hours. After settling, the acid solution was removed with a pipette and the sample was washed with 50 ml distilled deionized water once and shaken at 240 rpm every four days to remove the acid from the compost samples. The samples were then oven-dried at 45°C for 2 days after which they were ground in ball mill (Retsch® ZM1, Haan, Germany) to 250 µg and analysed in an Elemental Analyzer (Costech 4010, Cernusco, Italy) for OC (%) and TN (%).

The extractable P content was determined using the Olsen P ascorbic acid method (2), analyzed on a Shimadzu 1800 UV-Vis Spectrophotometer (Shimadzu Corp., Kyoto, Japan) at 880 nm wavelength.

For ammonium (NH4+) and nitrate (NO3-) analyses, 5 g of compost samples were extracted with 25 ml 2.0 M KCl using a reciprocating shaker (Heidolpj Unimax 1010 DT, Schwabach, Germany) at 180 rpm for 15 minutes. The extract was filtered through Whatman 42 filter paper. For NH4+ analysis, 0.2 ml filtrate was reacted to 0.5 ml of Reagent A and Reagent B. Reagent A is comprised of 0.05 g sodium nitroprusside (also called sodium nitroferricyanide), 13 g sodium salicylate, 10 g sodium citrate, and 10 g sodium tartrate dissolved in 100 ml of water and then diluted in a 1:1 ratio with deionized distilled water. Reagent B is comprised of 6 g sodium hydroxide in 100 ml water, and 2 ml bleach (5% sodium hypochlorite). Absorbance was read 1 hour after colour development using a Shimadzu 1800 UV-Vis Spectrophotometer (Shimadzu Corp., Kyoto, Japan) at a wavelength of 650 nm. For NO3- analysis, 0.1 ml filtrate was reacted to 1.0 ml vanadium chloride reagent and absorbance was read 8 hours later when the colour had developed using a Shimadzu 1800 UV-Vis Spectrophotometer (Shimadzu Corp., Kyoto, Japan) at 540 nm wavelength.

## Soil Analyses at Agriculture Research Institute - Ukiriguru

A mechanical analysis was used to determine soil texture along with the USDA soil texture classification (3). Soil pH was measured at 1:2.5 soil to water ratio, and at 1:2.5 soil to 0.01 M KCl solution. According to (4), soil pH measured in water is representative of soil pH in the field whereas soil pH measured in a salt solution like CaCl2 or KCl are less dependent on recent fertilizer history. After pH measurement in water, the supernatant liquid from settled samples was used to measure EC (3). The CEC was analysed using the pH 7 ammonium acetate method (3,4).

The SOC in the soil samples was determined using a dichromate redox method where consumption of oxidant was measured calorimetrically without external heating (also known as the Walkley and Black method) (3,4). The TN was determined using a Kjeldahl oxidation (3). The available P content was determined using the Olsen (5) bicarbonate extractant method followed by the Murphy (6) procedure for calorimetric determination (3,4).

Bulk density core sampling was conducted by a soil technician from ARI-Ukiriguru at only one point in time, halfway between T1 soil sampling and T2 soil sampling. The bulk density analysis was subsequently conducted at ARI-Ukiriguru. A 5 cm diameter thin-sheet metal tube of known weight and volume was used to collect soil samples for bulk density. The soil was dried at 105°C for two days and weighed. The bulk density was determined by subtracting the weight after drying from the known weight of the tube and then divided by the known volume of the tube.

## Soil Analyses at University of Waterloo

For WHC, 30 g of soil samples were wetted using free-flowing water in pre-weighed containers with perforations on the bottom to allow for the water to drain. At field capacity (i.e., when excess water had drained), the container plus wet soil were weighed. The WHC (%) was determined by first subtracting the weight of the container from the final weight to obtain soil wet weight, then the dry soil weight was subtracted from wet soil weight, divided by the dry soil weight, and multiplied by 100. For NH4+ and NO3- analyses of soil samples, the same methods were used as described under Compost Analyses at University of Waterloo.

Soil microbial biomass analyses for carbon (SMB-C) content provide a measure of the quantity of living microbial biomass present in the soil (7). For the analyses, the soils were first incubated for ten days with deionized distilled water at 50% WHC to revive microbial activity within the soils. The laboratory processes of extraction and fumigation were performed as per the method described by (7). Incubated soil samples were divided into 30 g for fumigation with ethanol-free CHCl and 30 g remained unfumigated. Both fumigated and unfumigated samples were extracted with 0.05 M K2SO4 solution. The extracted samples were filtered, freeze-dried for 72 hours, and then analysed for SMB-C using an elemental analyser.

# Procedure for Exporting Soil Samples from Tanzania

Due to regulations passed in 2017, all export of soil and rock samples from Tanzania now require testing by the Ministry of Energy and Minerals and an export permit to carry soils out of the country.

Exporting soil and rock samples from Tanzania is an involved and arduous process. However, the documentation and resources explaining the intricacies and steps of the process are limited. The aim of this supplementary document is to first present soil analysis resources available within Tanzania for both farmers and researchers, and, more importantly, to delineate the application process for exporting soils outside of Tanzania.

## Methods

After conducting a field trial in Mwanza, Tanzania to investigate the effect of soil amendments on soil parameters under short duration cultivation, the soil samples required analysis for bulk density, soil pH, soil texture, available phosphorus (P), total nitrogen (N), organic carbon (C), electric conductivity (EC), cation exchange capacity (CEC), nitrate (NO3-), ammonium (NH4+), water holding capacity, and soil microbial biomass.

Most of the analyses were conducted at the Agriculture Research Institute (ARI) – Ukiriguru, which is located within the vicinity of Mwanza city. However, the institute did not have the capacity to conduct nitrate, ammonium, water holding capacity, and soil microbial biomass analyses.

Sokoine University of Agriculture (SUA) in Morogoro was consulted regarding analyses that the ARI – Ukiriguru was unable to perform. While the list of analyses available at SUA was extensive, there was one critical analysis (soil microbial biomass) that they were unable to perform. Therefore, the decision was made to export the remaining soil samples for further analysis at the University of Waterloo in Canada. The steps for the application process for the soil export permit were recorded through the process. Information presented in this document was primarily collected through direct observation and first-hand account of the processes.

## Soil Analyses within Tanzania

Soil samples taken in the vicinity of, and surrounding, Mwanza City area can be analyzed at the Agriculture Research Institute - Ukiriguru (ARI - Ukiriguru). These samples can be analyzed upon request of researchers or farmers that want to have a better understanding of the characteristics of their soils. The institute requests 1 kg of soil per sample and recommends two depths: 0 – 30 cm, and 30 – 50 cm for sample analyses. The costs for analyses at ARI - Ukiriguru are relatively affordable, providing an array of analyses for 25,000/- Tsh (Tanzanian shillings) in total per sample. This translates to USD $11 per sample\*. The cost covers sample preparation, soil texture, pH, EC, CEC, available P, total N, organic C, and exchangeable bases. These analyses are accompanied with a comprehensible explanation of the results for each farmer or researcher that requests an analysis. The institute also offers bulk density sampling and analysis for which they provide a field technician to take samples. However, the technician must be paid expenses for the day, which was 50,000/- Tsh in 2018 at the time the researcher requested bulk density sampling. The institution was unable to perform analyses of water holding capacity, soil microbial biomass, nitrate, and ammonia. The remaining samples were air-dried and sieved to less than 2 mm for transport. However, due to the lack of an export permit, the soils were transported within the country to Sokoine University of Agriculture.

Sokoine University of Agriculture (SUA) is better known for its soil laboratory facilities. The university is in Morogoro, Tanzania which falls between the capital city of Dodoma and the largest city and international port of entry, Dar es Salaam. The list of analyses provided by SUA is more extensive and includes analyses of plant matter as well. Soil analyses that are additional to the ones provided by ARI - Ukiriguru include extractable minerals, lime requirement, suspended solids, nitrate and ammonia, soil moisture/water holding capacity, and ashing. A comparison of the costs of select analyses at ARI-Ukiriguru and at SUA are shown in Supplementary Table 1. However, the university did not at the time have the capacity to perform soil microbial biomass analyses, which was a critical parameter for analysis. Therefore, the soils were transported to Dodoma, Tanzania’s capital city, to begin the soil export permit application.

**Table 1:** Cost comparison of select soil analyses at Agriculture Research Institute (ARI)-Ukiriguru and Sokoine University of Agriculture (SUA) in Tanzanian Shillings (Tsh) and equivalent US Dollars (eUSD).

|  |  |  |
| --- | --- | --- |
|  | Cost per sample (Tsh) | Cost per sample (eUSD\*) |
| Analysis | ARI - Ukiriguru | SUA | ARI - Ukiriguru | SUA |
| Particle Size Analysis (Soil Texture) | 4,000 | 3,750 | 1.78 | 1.67 |
| Available P | 2,500 | 5,250 | 1.11 | 2.33 |
| Total N | 3,500 | 9,000 | 1.56 | 4.00 |
| Organic C | 2,500 | 7,500 | 1.11 | 3.33 |
| CEC | 5,000 | 9,000 | 2.22 | 4.00 |
| Bulk Density | 1,000 | 2,550 | 0.44 | 1.13 |
| Soil Moisture | n/a | 3,000 | n/a | 1.33 |
| N-NO3 | n/a | 9,000 | n/a | 4.00 |
| N-NH4 | n/a | 9,000 | n/a | 4.00 |
| Soil Microbial Biomass | n/a | n/a | n/a | n/a |

\*conversion rate: 2,250 Tsh = 1 eUSD (2018)

## Exporting Soils from Tanzania

Though there are regional offices for the Ministry of Energy and Minerals in cities around Tanzania, and letters of transporting soil samples within the country can be obtained from these offices, the process to export soil samples from Tanzania can only be completed in Dodoma, the capital city. Soil samples can be transported within the country through ground transportation, by car or bus, without any need for documentation. However, transporting soil samples by air even within the country requires justification and support from the local Ministry of Energy and Minerals office.

In Dodoma the process is started by the person requesting the permit (hereafter referred to as the applicant) at the Regional Office in Kizota. In Kiswahili this office is called *Ofisi ya Afisa Madini Mkazi* (hereafter referred to as the Kizota Office). Other locations that are part of the process include the Geological Survey Tanzania Lab in Dodoma town, the banks (all of which are located within a few meters of each other on Nyerere St.), District Head Office (in Kiswahili: *Ofisi ya Mkuu wa Wilaya*, hereafter referred to as District Office), Tanzania Revenue Agency (TRA), and University of Dodoma (UDOM).

There are various choices of local transportation within Dodoma city for travel to and from Kizota, the cheapest of which are motorbikes (called *boda boda*) where the passenger rides behind the driver and there is not much room for baggage. The next option is a rickshaw (called a *bajaj*), which is a less expensive mode of transport than the last option of a taxi. The recommended mode of travel is by *bajaj*, which offers a relatively low-cost mode of transportation with room for accompanying baggage, such as the packages of soil samples.

Following are the steps for the export permit application process:

1) The first step is the Kizota office where the process is started. At the Kizota office a sample of the soil samples is taken and sealed for soil testing at the GST Lab, primarily to check for rare minerals. Use local transportation to get to the Kizota Office. The road leading to the office is off the main highway onto dirt roads. At the office, the officers require a letter of introduction and justification from the organization for which the soil or rock samples are being exported. They also require a little portion of two or more of the soil samples, which they put into a container that has to be bought by the person requesting the analysis.

The number of containers that are submitted for soil testing depends on the number of locations from which the soils were taken or the number of different types of soils that are within the sample set. For one type of soil taken from one location, they only require one container to be filled with about 50g of soil in total from two or more soil samples. Though only 50g in total is required for soil testing, they may end up taking more as a scale may not be available to measure the amount taken. Before the soil is put in the container, two holes are made in the container and two on the lid, so that after the soil is placed in the container, it can be sealed with wire and metal tags, each with a ministry commission tag number. These numbers are written in a book and the applicant signs for these tags.

2) Using local transportation, the container of soil samples must be taken to the GST Lab in Dodoma town. Upon receiving the container, the sample reception at the GST Lab provides the applicant with an account number and amount of money (in Tsh) to be deposited. Using local transportation again the applicant must go to the prescribed bank, deposit the money (95,000/- Tsh per sample for testing) and bring back the bank receipt. The bank receipt is then attached to a form filled out at the Sample Reception at the GST Lab and then taken to the Accounts department, which is in the building across the road, from where an official receipt is issued. The GST Lab also takes the applicants contact information, particularly the local phone number so that they may contact the applicant once the testing is complete. The amount of time it takes for the testing is not guaranteed but may take one to three days. The GST Lab contacts the applicant when the results are ready.

3) When the results are ready at the GST Lab, the applicant receives a call and collects the results and the accompanying letter after verifying that all the information on the documentation, such as names and dates, are correct. These documents are then taken back to the Kizota Office where the officers prepare an invoice for payment, which must be taken to the prescribed bank. This payment is for the export permit application (USD$ 100), royalty for export (USD $10), and processing fee (USD $1), totaling USD$ 111. At the prescribed bank, a copy of an identification document such as a passport or local voting or ID card is required to complete the deposit. Once the funds have been deposited, the receipt from the bank must be taken back to the Kizota Office's accounts department.

4) At the Kizota Office the applicant then fills out an export permit application form while the accounts department issues a receipt and a receipt number that must be included in the application form. The applicant must also fill out details regarding the soil samples, including in how many packages the soil will be transported and the commercial value of the samples. The paperwork is then taken to the officers who prepare the export permit application, which includes a copy of the initial introduction/justification letter from the applicant's organization, the GST Lab test results and letter, the application form, and a signature page. While this application is being prepared, the applicant makes holes in the bucket (bought and brought by the applicant) and packs the soil samples into the bucket. Depending on the number of soil samples that the applicant has, the applicant can buy a small bucket (10 L) or a big bucket (20 L) from town.

5) Next the bucket is taken to the TRA office where four representatives are required to complete the sealing process and sign the application form: one person from the District Office who checks the contents of the bucket in detail, one person from the Ministry of Energy and Minerals to apply the sealing tags, one person from the TRA to verify the sealing process, and the applicant as well. The buckets are tied with string between two of the holes, and the other two holes were sealed with wire and metal tags. Upon instruction from the TRA and Ministry of Energy and Minerals representatives, the top of the buckets are also sealed with a red seal on top of the string to ensure that the package is not reopened once sealed. Five copies of the permit application documents are signed, and one copy each is given to each representative: TRA, Ministry of Energy and Minerals, District Office, and the applicant.

6) The last copy must be taken to UDOM where the export permit is finally issued and signed, after which it can be picked up by the applicant. The permit is only valid for 30 days from the date the permit was issued and signed.

7) At the Dar es Salaam international airport, the sealed container of soil samples must be taken to the cargo area minerals office. There the officers provide two documents: an assessment and a clearance to travel. They keep the original export permit document and provide the applicant with a photocopy for travel purposes. The original export permit document is then returned to the Ministry of Minerals and Energy head office to be filed.

The amount of time it takes for each step in the process and a breakdown of costs associated the steps are compiled into Supplementary Table 2 for ease of reference. Only costs associated with the process have been included in the cost breakdown; costs for accommodation and daily living expenses have not been included.

**Table 2:** Time requirement and cost of each step associated with the export permit application process.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Time Requirement | Costs (Tsh) | Details of Cost |
| Step 1 | 2 – 3 hours | 2,000 | Container |
| 5,000 | Transport\* to Kizota office from Dodoma center |
| Step 2 | 1 – 2 hours | 5,000 | Transport to GST from Kizota office |
| 2,000 | Transport to and from bank |
| 95,000 | Analysis of one sample |
| Between Steps 2 and 3 | 1-3 days | n/a\*\* | n/a\*\* |
| Step 3 | 3 – 4 hours | 15,000 | Transport |
| USD 111.00 | Permit application and processing fee |
| Step 4 | 2 – 3 hours | 6,000 | Bucket for packing in soil samples |
| 5,000 | Local Transport |
| Step 5 | 3 – 4 hours | 10,000 | Local Transport |
| Step 6 | 1 – 2 hours\*\*\* | 15,000 | Transport to and from UDOM |
| \*All transport costs are estimates based on direct observation and transportation using a *bajaj.* These costs will vary depending on starting location and the mode of transportation used. \*\* Costs of accommodation in Dodoma have not been included in the cost breakdown. \*\*\* The last step can be complete in the estimated hour time frame if the signatories are present at the time. If the signatories or personnel authorized to issue an export permit are unavailable (e.g., out of town), then this process may take longer (e.g., 1 – 3 days). |
|  |

## Concluding Remarks

Institutions within Tanzania for research on soil and agriculture have the capacity to conduct various soil and plant analyses. The price ranges for the analyses offered are reasonable for researchers, though may be steep for farmers to use as a resource for gauging soil fertility of their cultivated land. For research on soil within Tanzania, it is recommended that experiments be designed to align with the availability and accessibility of local resources.

However, due to the limited capacity of local institutions, it is reasonable to expect that researchers conducting soil research in Tanzania from countries outside of Tanzania may wish to export soil samples for more in-depth analyses. The export process is lengthy and arduous because all export processes must go through ministry offices in Dodoma. Researchers are advised to take into consideration the length and costs of the tasks involved. Therefore, the steps provided in this document are intended to be a useful guide for researchers planning soil-related research that requires export of soils from Tanzania.

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