NRSP PROJECT R8115

Improvement of Soil Fertility Management Practices in Rainwater Harvesting Systems

ANNEX B2

A MANUAL ON PROCEDURES AND METHODS FOR PARTICIPATORY ASSESSMENT OF SOIL FERTILITY STATUS, IDENTIFICATION AND DEVELOPMENT OF SOIL FERTILITY MANAGEMENT STRATEGIES

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PREFACE

The purpose of Project R8115 "Improvement of Soil Fertility Management Practices in Rainwater Harvesting System" is to increase the awareness of stakeholders on the low fertility status of their soils and the need and means of addressing the problem.

The main outputs addressed by this project are:

- To define the current status of soil fertility and management strategies under RWH systems.
- To identify and promote sustainable strategies for managing soil and plant nutrients in RWH systems.
- To increase the capacity of stakeholders who are actively in evolved in extension to plan and provide extension on strategies for integrated nutrient management.
- To identify and promote alternative sources of information to support farmers crop production decisions under RWH conditions.

The following steps were followed:

- Participatory mapping of target villages to demarcate areas perceived to be of high, medium and low fertility status.
- Carried out limited soil sampling followed by laboratory analysis to determine fertility status of areas mapped in (i) above.
- Identification of the soil fertility management techniques currently practiced in the target villages through participatory means.
- Development of knowledge sharing products (KSPs) aimed at achieving outputs (ii) and (iii) of the project.

This manual describes the procedures and methods that were developed and used by Project R8115 in participatory evaluation of soil fertility status and development and designing of appropriate soil fertility management strategies in semi-arid areas under rainwater harvesting.

The preparation of this manual is part of the project funded by the Department for International Development (DFID) of the United Kingdom (UK). However, the views expressed in this booklet are not necessarily those of DFID.

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1. INTRODUCTION

Inadequate understanding of the dynamics of plant nutrients in rainwater harvesting (RWH) systems, coupled with inadequate and inappropriate use of soil amendments, limits the productivity of water, and jeopardizes the sustainability of the RWH systems in Tanzania. A great deal of information on soil fertility management (SFM) is available from past research and indigenous knowledge, but has not been fully exploited. This Project, therefore, intends to use this information to provide tools for developing SFM strategies, which are compatible with the experience and needs of local extension services, NGOs, other service providers, and farmers. Therefore, this manual describes procedures that are under development by- and being used in the project to undertake participatory evaluation of soil fertility status as well as develop management strategies. The manual was being continually developed and updated as it was being used in the Project.

2. LOCAL INDICATORS OF SOIL QUALITY AND FERTILITY

2.1 Overview

Soil quality is the capacity of the soil to be functional within the limits imposed by the ecosystem and land use, to preserve the biological productivity and environmental quality and promote plant, animal and human health (Doran and Parkin,1994). On the other hand, soil fertility is the ability of a given soil to supply the essential plant nutrients in adequate quantities or amounts, forms, proportions and at the appropriate times and stages in the growth of plants for optimum growth and development (Pennamperuma, 1985). Judicious use of soil is dependent on the availability of simple and easy to interpret indicators of soil quality that enable users of soils mainly farmers and those responsible for assisting farmers in formulating management strategies to make an early diagnosis of soil degradational processes.

Indicators of soil quality and soil fertility are useful for a variety of users including farmers, researchers, extension agents and policy makers (Doran and Safley, 1997; Beare *et al.*, 1997). These indicators should, therefore, be easy and practical such that they can be used under field conditions, relatively accurate and easy to interpret, economical, able to integrate soil physical, chemical and biological properties and processes. Further, such indicators should be sensitive enough to reflect the impact of soil management practices and climate on long-term changes. Furthermore, such indicators of soil quality should be well correlated with the ecosystem processes, plant and animal productivity and that can ideally be components of the existing soil databases. However, they should not be too sensitive as to be affected by short-term meteorological patterns.

Indicators of soil quality and soil fertility (LISQ and LISF, respectively) help in identifying the main soil biophysical limitations of the agricultural system under study. Such indicators should be identified from the local and technical knowledge base and critical levels defined followed by the definition of guidelines to establish a Soil Quality Monitoring System (SQMS). To develop a SQMS for the land users, the local indicators of soil quality must be included in the monitoring system. This manual focuses on LISQ and LISF with emphasis on Rainwater Harvesting Systems.

2.2 Usefulness of the LISQ and LISF

To make better soil management decisions, it is necessary to have an effective communication between the different stakeholders. Therefore, it is necessary that farmers knowledge on the indicators of soil quality and fertility are integrated with technical scientific knowledge in the development of appropriate soil fertility management strategies/options. Different farmers have different indicators of the quality of soils that guide them in making appropriate management decisions. These local indicators correspond to a language traditionally adopted by a community of farmers to describe soil characteristics by using words that are easily understood by the respective communities.

For the indigenous/local management of soil fertility, local indicators of the fertility status of soils have been developed by farmers and tested for many years and passed from one generation to the next. On the scientific front, researchers have also developed a set of Technical Indicators for Soil Quality (TISQ) and soil fertility (TISF), respectively. Farmers and other stakeholders cannot easily grasp the scientific jargon used by researchers when referring to these technical indicators. However, researchers are in a better position to understand the LISQ and LISF developed by farmers and even match them with or find their equivalents in the TISQ and TISF. Integrating the two and coming up with nomenclature common to all stakeholders is a major step towards developing technological options in soil management that can be adopted by farmers. Therefore, adequate knowledge of the local indicators of soil quality (SQ) and soil fertility (SF) is essential in bridging the gap between the different stakeholders, researchers and all other specialists learning from farmers and farmers learning from researchers and specialists in the improvement of soil fertility management practices under RWH systems.

The LISQ and LISF are based on visual observations of plants and soils properties and characteristics like soil colour, soil depth, ease of cultivation as related to plant growth and performance and animal activities in the soil. The LISQ and LISF commonly used by farmers in East Africa are as presented in Table 1 and Table 2.

Plants/weeds and soil organisms have been used in many communities as indicators of soil quality and fertility. This is because of their integrative nature enabling them to capture changes in soil quality and fertility. These indicators are integrative because they can simultaneously reflect changes in the physical, chemical and biological characteristics of the soils. For example, the composition and abundance of weed species growing on agricultural soils is a useful indicator of the fertility status of the soils frequently used by farmers. Biological indicators such as plants (weeds) and soil organisms have been used in many communities as indicators of the fertility status of the soils. Natural and agricultural ecosystems respond similarly to degradation and regeneration processes through natural selection. During these processes best-adapted plants and soil organisms gradually replace those least adapted through a selection exerted by changes in soil characteristics. The process of local knowledge generation about native plants as indicators of soil quality is summarized in Fig. 1 (Barrios *et al.*, 2000).

Other indicator plants of soil quality and fertility include *Amaranthus* and *Commelina difusa*, which are indicative of fertile soils while bracken ferns, *Striga* and *Digitaria spp*., are indicators of poor soils. Bracken ferns are also indicative of soils with low pH (acid soils). The presence of many diverse weeds and the ability of a soil to support many different types of crops are indicative of fertile soils. The colour of crops growing on a given soil gives an indication of the quality and fertility status of the soil.

Table 1: Local Indicators of Soil Quality and Fertility (LISQ and LISF) Based on Soil Characteristics and Animal Activities

Good soil	**Poor soil**
Well drained soil	Poorly drained/water logged soils
Workable soil /easy to cultivate (friable)	Stoniness / rock outcrops
Deep soil	Shallow soils
Virgin soil	Cracking soils (Vertisols)
Valley bottom soils (Alluvial)	Salty soils (White surface patches)
Black / dark soils (High organic matter content)	Clayey soils/sticky soils
High water retaining capacity	Difficult to cultivate /hard pan/ compacted soils
Smell of rotting materials	Excessive run-off/gullies/erosion
Sedimentary rock (Parent material)	Red/brownish soils on steep slopes
Sandy – clay loams	Murram soils
Many ant-hills (mounds)	No ant-hills (mounds)
Abundance of worms	Few / limited worms

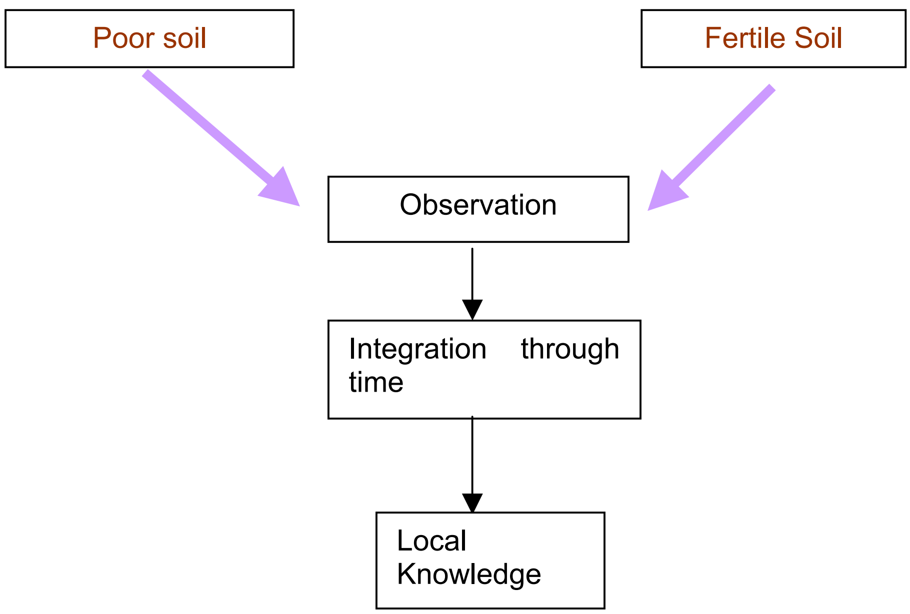

Figure 1: The Process of Local Knowledge Generation of LISQ

Table 2: Local Indicators of Soil Quality and Fertility Based on Plants/ Weeds*

Shambaa name	Equivalent botanical name	Indicative soil quality/fertility
Mbwembwe	*Bidens pilosa* L.	Fertile soils in valley bottom
Mashiu	*Pteridium equilinum* (L.) Kuhn	Soils with low pH, compacted and infertile
Hombo	*Zanthocylum chalibeum* Engl. Or Grewia *sp.*	Very fertile soils (high in plant nutrients
Mzono	*Racinus cummunis* L.	Very fertile soils (high in plant nutrients
Sopolwa (Imboko)	*Kalanchoe crenata* (Andrews) Haw.	Very fertile soils (high in plant nutrients
Eza	*Solanancio angulatus* (Vahl) C. Jeffrey	Very fertile soils (high in plant nutrients
Tongotongo (with thick roots like cassava)	*Rhosisiscus tridentate* (L.f.) Wild & Drum	Very infertile soil
Boho	*Erlangea duemmeri S. Moore*	Very fertile soils
Shangazi (ndago)	*Cynodon dactylon* (L.) Pers.	Hard soils, intermediate fertility
Ngage (narrow leafed)	*Cyperus digitatus* Roxb	High pH soils/salt affected soils
(Ma)shuuti)	*Phillipia usambarensis* Alm. & Th.	Grows on rocky areas, marginal lands not suitable for agricultural production.
Inde	*Panicum maximum* Jack.	Grows on areas with high water table, springs or former springs
Tambwe	*Esente ventricosum* (Welw) Cheesm	Wild banana, common in areas with plenty of water
Kongo (Kengera in Chagga)	*Commelina africana* L.	Fertile soils with high OM content
Mhasha	*Vernonia lasiopus* O. Hoffn	Fertile soils
Tughutu	*Vernonia subigera* (myriantha)	Fertile soils
Donondo	*Pycnostachys umbros* (Vatke) Perkins	Fertile soils

* *Examples derived from the Wasambaa in the West Usambara Mountains-Tanga, Tanzania*

2.3 Procedures Used in the Assessment of Soil Fertility Based on Local Indicators of Soil Fertility in RWH Systems

Over time farmers' have accumulated important knowledge that they use in assessing their soils before they make soil management decisions. So in using the LISF one is actually asking farmers to pool their knowledge of soil fertility and offer practical and realistic assessment of the fertility status of their soils. In assessing the fertility of the soils use is made of the participatory maps prepared by farmers, extension staff and researchers.

Participatory methods will therefore be employed in establishing what farmers perceive to be the current fertility status of their soils. Soil fertility assessment will be done for each of the major landscape positions (upper, middle and lower) along the toposequence in one RWH system (X1), one cropping system/pattern (Y1) and one farmer category (Z1) using LISF.

2.3.1 Plan of action

i) Collect all materials/literature required and participatory maps already made/prepared,
ii) Identify farmers for the exercise based on the criteria mentioned above,
iii) Hold a brief meeting with all actors (farmers, extension officers and researchers) to explain the purpose of the exercise, expected outcome and the use of the final product,
iv) Assess the current fertility status of the soils in the farmers' fields with the farmers taking a leading role,
v) Collect soil samples from the farmers' fields for laboratory analysis, and
vi) Collect and compile the information from farmers and soil data from laboratory and write a report.

2.3.2 Materials (tools)

i) Participatory field maps
ii) Manual/literature on LISQ and LISF
iii) Soil augers, sampling bags, labels and sisal twine
iv) Laboratory chemicals and stationary including flip charts, field note books, marker pens, pencils etc)
v) Global Positioning System (GPS) equipment.

2.3.3 Procedures/methodology

i) Explain to farmers and extension staff why soil fertility assessment is important and what will be the outcome of the exercise.

ii) For each farmer category (Z1), cropping systems/pattern (Y1) and RWH system (X1) on each landscape position (upper, middle and lower) representative farmers be required/asked to locate their fields on the map.

iii) The representative farmers will be requested to draw sketch maps of their fields in collaboration with the extension staff. Different teams/groups can be formed to speed up the work/exercise

iv) The team (farmers, researchers and extension staff) should take a walk around the field and identify different soil types based on farmers' criteria on the local indicators of soil fertility (e.g. visually observable soil characteristics, presence of certain types of plants/weeds, animal activities or colour of plant leaves etc). GPS grid along soil boundaries be recorded by the researcher/ extension staff in the presence of the farmers.

v) Farmers be requested to show areas of low, intermediate and high soil fertility and this should be indicated or marked on the sketch map.

vi) Researchers and extension staff using the manual/literature on LISF should where necessary, confirm the farmers' findings with the technical indicators of soil fertility backed with simple tests where possible. For example, if the farmers conclude that the white salt like appearance on the soil surface is indicative of poor soil, which technically could be a salt affected soil, the pH would be on the high side. This can be proved using pH papers.

vii) The extension officers and researchers should follow closely the farmers' arguments without patronizing them. The farmers should be fully in charge of the exercise but the research team should come in when necessary.

viii) The whole process should be documented. If possible one of the farmers should do it otherwise the extension officers should help.

ix) At the end of the assignment or exercise, the whole group should look into the results obtained. One of the farmers would be requested to present the results and group discussion/exchange of information should be promoted. Where necessary extension staff and researchers should chip in.

x) The exercise is then wrapped up and a summary of major points agreed upon by the research team is presented

xi) For ground truthing one composite soil sample (0 – 20 cm) from one farmers' soil unit will be collected for laboratory analysis. A composite soil sample is made up of 4 – 5 sub samples, thoroughly mixed to give a fair representative sample of the soil unit.

xii) Where soil salinity is suspected, auger soil samples at 3 different depths should be taken/collected.

xiii) The final or ultimate product of the above exercise will be a soil fertility map based on LISF and TISF showing the soil fertility patterns on the landscape/fields.

3 SOIL FERTILITY MANAGEMENT STRATEGIES/ OPTIONS

3.1 Introduction

Under RWH system, water, an important component in plant growth is already taken care of. In the absence of adequate supply of nutrients plant growth under RWH system will lead to nutrient mining calling for concerted efforts towards developing strategies for soil and plant nutrients management, that will optimize crop yields. For successful soil fertility management, strategies should be developed that are holistic and integrative, site specific and responsive to the different categories of farmers (resource endowment, age, gender, etc). It is for this reason that a thorough study on the soil fertility status, the different categories of farmers, the farmers' indigenous knowledge on soil fertility management and available local resources for addressing soil fertility (Wickama and Mowo, 2001) is important in developing sound soil fertility management strategies/options.

Soil fertility is influenced by the soil physical, chemical and biological factors, the interaction of which determines to a great extent the capacity of the soil to support plant life (soil productivity). Some of the soil physical factors influencing crop growth include soil structure, texture and the size, number and distribution of pores which affect root growth directly and indirectly. Further, the size, number and distribution of pores influence water infiltration, drainage, water holding capacity, aeration and soil workability. The structure of the soil is in turn influenced by soil texture, organic matter content, biological activities and soil cultivation practices. For optimal crop yields it is important that the soil physical limitations are eliminated or controlled. Farmers, therefore, should focus on soil fertility management practices that maintain optimum soil structure and control physical soil degradation.

Soil chemical factors influencing crop growth include the nutrient contents of the soil, nutrient availability, soil pH and soil salinity/sodicity. For optimum plant growth, the plant nutrients in soils should be readily available in sufficient amounts to meet the variable demands for nutrients at the different stages of the growth of the plants (Pennamperuma, 1985). Soil biological factors influencing soil fertility include contents and qualities of soil organic matter and soil living organisms.

3.2 Soil Fertility Management Strategies under RWH Systems

Effective soil management strategies should focus on addressing the physical, chemical and biological limitations of the soils with respect to plant growth in an integrated way thus coming up with a basket of options targeting the biophysical and socio-economic categories of farmers. Some examples of soil fertility management strategies under RWH systems include;

i) Improvement of the soil physical conditions so as to maintain optimum soil structure (Barrios *et al*., 2000). This can be achieved through organic manure application and appropriate tillage operations.

ii) Combined application of organic and inorganic nutrient sources. There are numerous sources of organic materials most of which are available on the farm and these include: kraal manure, compost manure, green manure, crop residues and household wastes. Inorganic nutrient sources are many but often out of reach by the majority of the farmers due to high prices and transport problems.

iii) Intercropping with nitrogen fixing leguminous plants to exploit biological nitrogen fixation.

iv) Incorporating leguminous tree species on the farm as sources of green manure (agroforestry) and capitalizing on their ability to fix atmospheric nitrogen.

v) Use of indigenous herbaceous species known to have fertilizing effect on soils such as *Vernonia subligera* (Wickama and Mowo, 2001) and *Tithonia diversifolia.*

vi) Rotation/improved fallow involving leguminous species (Ndakidemi and Mmbaga, 2000)

vii) Mulching to minimize evaporation losses and maintain suitable soil temperature and structure hence reduce surface run-off and soil erosion.

viii) Choice of crop to match the prevailing local conditions including use of crops sharing different niches, as this will ensure better nutrient exploitation.

ix) Use of acid forming fertilizers such as sulphate of ammonia or acidifying crops (Hoffland, 1991) in areas where soil pH is high. Under saline-sodic conditions (salt affected soils) use can be made of gypsum (e.g. in Makanya where it is available) or improving drainage and using good quality irrigation water to flush out the soluble salts.

3.3 Procedures to be Used in the Identification of Local Soil Fertility Management Strategies in RWH Systems

This activity will use maps created from participatory mapping of the soil fertility patterns or status based on LISF and TISF. In each soil fertility unit representative farmers would be identified based on wealth, age group and soil unit on the toposequence.

3.3.1 Plan of action

This exercise will be based on the participatory soil fertility map prepared by the farmers, extension staff and researchers. Farmers will be requested to describe the management strategies currently being practiced on their farms.

3.3.2 Materials (Tools)

i) Manual/literature on LISQ and LISF
ii) Participatory soil fertility maps prepared/drawn subsequent to the completion of activity in 2.3.3.
iii) Stationery (flip charts, marker pens, note books, pencils)
iv) Global Positioning System (GPS) equipment

3.3.3 Procedure

i) Collect Participatory soil fertility maps
ii) Farmers would be requested to located or identify areas on the participatory soil fertility maps of low, intermediate and high soil fertility.
iii) Farmers be requested to draw soil resource maps. All enterprises will be recorded and approximate areas for each enterprise indicated on the map.

iv) Farmers be requested to indicate the reasons for choice and location of each enterprise on the map.
v) Farmers be required to indicate soil fertility management strategies for each area/enterprise on the map.
vi) The farmers' soil fertility management strategies for each area/enterprise will be listed (refer to (v)
vii) The result obtained in (vi) be discussed by farmers, extension staff and the researchers to seek common agreement on the correctness of information or data developed in (vi).
viii) Overlay results from step (iii) into the map from step (i) to create a map of soil fertility management strategies
ix) Transfer GPS points into GIS and create a resource use map
x) Group discussion of the results obtained among the researchers, extension staff and farmers to be conducted.

The outcome/product of the above exercise is participatory soil fertility management strategies/options map that can be superimposed on the participatory soil fertility patterns map.

3.4 Procedures to be Used in Designing Soil and Plant Nutrient Management Options/Strategies Under RWH Systems

This exercise would be done after the preparation of the participatory soil fertility patterns and management options maps.

3.4.1 Plan of action

For this activity, small group of farmers for each category will be constituted. The groups would be facilitated/assisted by the researchers and extension staff to draw up/suggest priority lists of soil fertility management strategies. Farmers would further be asked to design the best soil fertility management strategies according to farmers wealth categories and their position on the landscape.

3.4.2 Materials (Tools)

i) Sketch maps of farmers' fields
ii) Participatory soil fertility patterns and management strategies maps
iii) A list of current soil fertility management strategies on the landscape
iv) Stationery (flip charts, marker pens, pencils, field note books etc).

3.4.3 Procedure

i) Farmers would be divided into small groups. The farmers would be requested to form groups as they wish but it is advisable that the groups are homogenous in terms of resource endowment

ii) The soil fertility patterns and management strategy maps would be distributed to farmers and the major findings summarized. It is advisable at this stage to probe the farmers to see if they still remember something from the past exercises so as to gauge their interest in the work

iii) Farmers will be requested to list possible soil fertility management practices appropriate or feasible in their respective areas and be requested to rank these practices in order of priority specifying the criteria used in the ranking.

iv) Enquire from farmers what factors influence the choice of what practices to follow in soil fertility management. Let the farmers rank these factors in order of priority (matrix ranking) specifying the criteria used in the ranking

v) Farmers would be classified in terms of their soil fertility management strategies and a list of farmers in each class prepared and discussed.

vi) Soil fertility management strategies currently being used by farmers would be identified and find out if there are any gaps for improvement

vii) Together with farmers the appropriate soil fertility management strategies be designed so as to address the gaps identified in (vi).

On completion of the above exercise a participatory soil fertility management strategies/option map will be drawn/produced.

3.5 Procedures to be Used in Developing and Testing Different Soil Fertility Management Strategies/Options

In developing and testing soil fertility management options each category of farmers based on wealth, gender, and age, RWH systems, toposequence (ie Upper, middle and lower) and enterprise will be identified and used as the basis in testing the selected soil fertility management strategies.

3.5.1 Plan of action

i) Identify farmers for each category
ii) Farmers to be briefed on the various soil fertility management options
iii) Purchasing of the necessary materials required for testing strategies (e.g. manures, inorganic fertilizers, seeds, pesticides etc).

3.5.2 Materials (Tools)

i) Manual for soil testing for soil qualitative fertility evaluation
ii) List of soil fertility management strategies
iii) Organic nutrient sources
iv) Inorganic fertilizers
v) Paper bags, harvesting bags, weighing balances, sisal twines, field tools (hand hoe, knives spades etc.

2.5.3 Procedure

(a) Develop with farmers procedures to be followed in testing the selected soil fertility management strategies, protocol of trial management, objectives of the trials, management of the trials, monitoring and data collection.

(b) With farmers, lay down the trials for testing the selected soil fertility management strategies

(c) The research team (including the extension staff) should work closely with the farmers advising them as the need arise

(d) Frequent visits to the sites at critical times to assess the performance of the tests and discuss pertinent issues /observations with the farmers, extension staff and the research assistant

(e) Monitor and record farmers observations/opinion (to be done by the research assistant)

(f) Institute farmer-to-farmer visits within and between sites so as to enhance exchange of ideas between farmers.

(g) All information/data collected including yield data to be processed and interpreted and a report written. Some farmers might be tempted to harvest the crop for consumption before the required yield data is collected. Assure them that the yield is theirs.

After the completion of the above exercise (this will take about 3 – 5 years/seasons) the best soil fertility management strategies for the various categories of farmers, their positions on the landscape and the fertility status of the soils on the landscape for different crop enterprises would have been identified under RWH systems.

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