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Sustainable Agricultural Livelihood Restoration, Rehabilitation and Resilience in Kenya

Training Manual

2.2.2 SUB-MODULE 2: INTEGRATED SOIL FERTILITY AND WATER MANAGEMENT

Soil management is the application of operations and practices that enhance soil health and performance. These practices may be broadly classified as soil fertility management by application of fertilisers, adoption of practices that enhance maximum soil moisture retention and minimum plant nutrient losses or losses of soil biodiversity.

Sustainable soil management is fundamental to effective soil function, particularly in intensive production systems where optimal plant growth is required to deliver maximum crop yield and quality. In intensive cropping systems, when sustainable soil management is not practised, soil structural degradation in all forms is widespread and pervasive

Stakeholders in a maize variety and soil fertility demonstration trial at KALRO-Kakamega

Soil Fertility management

Soil Fertility Management (SFM) strategies centre on the combined use of mineral fertilisers, locally available soil amendments and organic matter to replenish lost soil nutrients. They include Integrated Soil Fertility Management (ISFM) which involves a set of agricultural practices and germplasm adapted to local conditions to maximise the efficiency of nutrient and water use and improve agricultural productivity. ISFM is defined as ‘A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. ISFM strategies are anchored on the combined use of mineral fertilisers and locally available soil amendments (such as lime and phosphate rock) and organic matter (crop residues, compost, and green manure) to replace lost soil nutrients. This improves both soil quality and the efficiency of fertilizers and other agro inputs. ISFM also promotes improved germplasm, agroforestry, and the use of crop rotation and/or intercropping with legumes (a crop which also improves soil fertility).

Integrated soil fertility management demonstration trials at KALRO-Kabete

Fertilisers

A fertilizer is any material (organic or inorganic) of natural or synthetic origin that is applied to soils or to plant tissues to supply one or more plant nutrients essential to the growth of plants. However, liming materials are not considered as fertilizers. Many sources of fertilizer exist, both natural and industrially produced. Fertilizers enhance the growth of plants. Fertilisers supplement plants with the vital nutrients needed for optimal, healthy growth. There exist two major categories of fertilisers: organic and inorganic. Organic fertilisers are derived from naturally occurring substances, such as plant or animal by-products and mineral rock, but inorganic fertilisers are synthetically manufactured. Organic fertilisers undergo little processing and include ingredients such as composts and manure, while inorganic fertilisers are synthetic and typically made from petroleum.

Organic fertilisers

The cementing agent that binds the soil particles together is the organic matter, which is found in organic fertilisers. It is both of animal and plant origin. Besides adding necessary nutrients to soil, organic fertilisers boost soil fertility status by improving all soil physical, chemical, and biological properties which most plants rely on for healthy growth and development. They play the following roles in the soils:

- Improves soil temperature regulation
- Improves soil aeration and reduces soil compaction.
- Improve infiltration rate
- Improves soil organisms' population
- Improves soil water and nutrient holding capacity.

Practices that increase organic matter in the soils include crop rotations that contains high plant residues, leaving crop residues in the field, growing cover crops, use of low or no tillage systems, mulching, growing perennial forage crops, using optimum nutrient and water management strategies for healthy plant production with large number of residues and roots, growing cover crops and application of compost or manure.

Apart from in- situ organic matter accumulation, there exists a wide range of locally available organic amendments. They include farmyard manure, green manure, compost manure, sewage/sludge, and marine by-products

Farmyard manure

Farmyard manure is made from livestock such as cattle, chickens, horses and sheep waste and their beddings. The amount of nutrient that manure provides and its subsequent availability to plants is influenced by a several factors:

- Nutrient content of the animal feed
- Storage and handling procedures of the manure
- Amount and type of materials added to the manure
- Timing and method of application
- Properties of the soil
- Choice of crop.

Legume /green manure

Green manure is made from crops that are generally grown for less than a growing season and are ploughed and incorporated in the soil before producing seeds. Examples of common green manure crops are annual ryegrass, Sudan grass, tithonia and sesbania. Legumes are particularly beneficial since they are nitrogen fixing species and are a good source of nitrogen. A particular advantage of implementing a legume/green manure rotation into the soil/cropping system is the added source of organic matter. Green manures also improve soil structure by reducing bulk density.

Sewage sludge

Sewage sludge consists of the solid products formed during sewage treatment. It is not uniform in mineral composition but generally, it contains between 1 to 3% total nitrogen

Compost

Composting is the controlled biological and chemical decomposition and conversion of animal and plant wastes with the aim of producing humus. Humus is the dark organic material in soils, produced by the decomposition of vegetable or animal matter and is essential to the fertility of the soil.

Compost functions as a form of organic fertiliser made from leaves, weeds, manure, household waste and other organic materials, thus it can reduce the cost of fertiliser from other sources**.**

- Proper compost management leads to an increased proportion of humid substances in the soil due to high micro-organic activity, and therefore applying compost leads to quantitative and qualitative improvements of the humus content of the soil, which leads to an increase in crop yields.
- Composting helps to improve soil fertility which is helpful in reducing the impacts of climate change.
- Composting helps increase soil moisture and soil cover, as well as reduce soil loss.
- Compost is made from decomposed plant only on animal matter increased soil carbon such as vegetable peels, eggshells, coffee grounds and other organic scraps. Regardless of the source, compost provides soil with a well-balanced mix of nutrients, including nitrogen, phosphorus, and potassium.

Manure

Manure management activities involve the handling of animal dung and urine (farmyard manure) predominantly in the solid form when applying it to croplands**.**

Applications of manure in the croplands enable achieving and maintaining a fertile soil, which can increase crop yields.

The application of manure can improve productivity and produce greater crop yield which is important for adapting to climate change.

Manure comes from livestock such as cattle, chickens, horses and sheep, although bat and bird guano are also effective organic fertilisers. Like compost, manure also does double duty by adding essential nutrients to the soil as well as improving soil quality and its water-retention ability. Because manure can cause food-borne illness, use either composted manures or apply fresh manure well in advance.

Marine by-products

Fish emulsion, fish scrap and seaweed extracts are important sources of soil nitrogen, phosphorus, and potassium. Fish emulsion, which is derived from partially decomposed ground fish, is an organic fertiliser that provides high levels of nitrogen to soil. Fish scrap is another marine byproduct and organic fertiliser that contains both nitrogen and phosphorus. Seaweed extracts provide nitrogen and potassium as well as trace elements to soil and have a less intense odour than the fish derivatives.

Meals

Meal supplements are agricultural byproducts from the meat and farming industries. Common examples of meals used as organic fertilisers include blood meal, which provides high levels of nitrogen and iron; bone meal, which is rich in both nitrogen and particularly phosphorus; and cottonseed meal, which contains all three macronutrients – nitrogen, phosphorus and potassium.

Rock minerals

Although mined rock minerals differ from other organic fertilisers in that they are not derived from a previously living organism, they are still considered organic fertilisers because they have not undergone extensive processing and provide soil with nutrients vital to healthy plant growth and development. Common examples of mined rock mineral fertilisers include rock phosphate, greensand, and sulphate of potash magnesia.

Mulch

Mulching is the process of covering the soil surface with organic matter to create conditions that are more favourable for plant growth (i.e., creating an optimal climate independent of weather conditions), improving the decomposition and mineralization of organic material in the soil (i.e., surface composting), and protecting the soil from erosion.

Mulching can improve the productivity of the land (i.e., crop yields) by making conditions more favourable for plant growth, i.e., conserving soil moisture, improving soil fertility and reducing soil erosion.

This can be derived from organic or inorganic materials. Organic mulch improves soil fertility through decomposition of the materials. Examples of organic mulches include grass clippings, shredded leaves and old hay. Annual applications of mulch, along with compost, improve soil's ability to absorb nitrogen and other nutrients. Inorganic mulch contributes to soil fertility management through soil moisture retention and regulation of soil environment making it suitable for micro-organism action.

Improved fallow

The planting of fast-growing species of leguminous trees or crops into a short-term fallow for one or more years to improve soil fertility.

Improved fallows help restore fertility to land whose nutrients are depleted. Plant species like grasses or legumes that fix nitrogen grow during the fallow period. As the nitrogen fixing plants grow, excess nitrogen is released back into the soil. Nitrogen is a vital nutrient for plants and plant growth. Planting nitrogen fixing plants is very important for rebuilding soil fertility and improving crop yields.

- Improved fallows can help restore degraded land which can be important for adapting to climate change.
- They also can help to protect the soil from excessive heat, exposure to wind, and moisture loss.
- Improved fallows require less fertiliser and therefore have fewer greenhouse gas emissions.
- The leaves of the leguminous plants can be incorporated into the soil, increasing the carbon in the soil.

Plant leguminous shrubs, such as Sesbania, Tephrosia, Crotalaria and Cajanus, in fallow lands. These plants are better than natural fallows for enhancing soil fertility, especially for restoring nitrogen and improving other soil properties, and they ease the work of tilling the soil.

Inorganic Fertilisers

Inorganic fertilisers come in single-nutrient or multi-nutrient formulas. Multi-nutrient formulas include compound and single fertilisers, which contain basic nutrients, such as nitrogen, phosphorus, and potassium, as well as secondary and micronutrients such as calcium, magnesium, boron and manganese. The percentage of nitrogen, phosphorus and potassium contained in both complete and balanced fertilisers is indicated by three numbers on the package. For example, a 5-10-5 formula is a compound fertiliser, containing 5 percent nitrogen, 10 percent phosphorus and 5 percent potassium. Balanced fertilisers are those that contain equal nutrient amounts, such as a 10-10-10 formula.

Inorganic fertilisers include slow-release formulas. These formulas contain larger molecules that are coated, helping them to break down slowly in the soil. A typical slow-release fertiliser releases nutrients over a period of 50 days to a year, reducing the chance of burning the plant or root system. Specially formulated inorganic fertilisers are those that are created for a specific type of plant. Specially formulated fertilisers are usually highly acidic and should be used only on the plants for which they are indicated.

Nitrogen Fertilisers

Inorganic nitrogen fertilisers come in many different forms, such as ammonium nitrate, potassium nitrate, calcium nitrate and urea. These fertilisers contain high levels of nitrogen, one of the most vital nutrients for plant growth. However, these inorganic fertilisers tend to increase the pH of the soil upon application, increasing the chances of burn and damage to seedlings. Others pull moisture from the air, making them difficult to apply and store.

Phosphorus Fertilisers

Inorganic phosphorus fertilisers such as Superphosphates (single superphosphate, triple superphosphate) are forms of phosphorus fertiliser. These do not affect the pH of the soil upon application, while ammonium phosphates (Di- ammonium phosphate (DAP) and Mono ammonium phosphate (MAP)) come in water-soluble, granular forms.

Potassium Fertilisers

Inorganic potassium fertilisers include potassium sulphate and potassium nitrate, as well as muriate of potash, also known as potassium chloride. Muriate of potash is the most commonly used potassium fertiliser. In some cases, plants may be sensitive to chloride. If a plant is sensitive to chloride, potassium sulphate, also known as sulphate of potash, is a better choice, as it does not contain chloride. Potassium nitrate is easy to apply, because it does not pull moisture from the air, but it does slightly increase the pH of the soil upon application.

Fertiliser Application Methods

The method of applying fertilisers depends on the nature of crops, their nutrient needs, and the soil.

Broadcast

Fertiliser is spread on the soil surface. It precedes tillage so that the fertiliser can be mixed with the soil this results in uniform fertiliser applications. Both fluid and pellet fertiliser may be broadcast. This provides the most uniform distribution of nutrients within a given soil volume. This method is suited particularly well to high rates of applied fertiliser. It is inefficient and may be wasteful.

Broadcasting of fertilisers is carried out at time of planting and during crop growth.

At time of planting depending on the crop, broadcasting of the fertiliser is carried out prior to sowing/planting or just before the last ploughing and incorporated in the field. Broadcasting of fertilisers at the time of planting is generally done under conditions:

- When the soils are highly deficient in nitrogen and
- When the previous crop has been exhaustive such as sugarcane, maize, etc.

During crop growth period, broadcasting in standing crop is done mainly for nitrogenous fertilisers and mostly for close spaced crops like paddy rice and wheat. It is called top dressing. Muriate of potash is also applied as top dressing in some crops, but this is not a general practice.

Banding

Fertiliser is placed in a continuous band at the bottom of the furrow opened during ploughing. Each band is covered with soil after the application. In single band placement fertiliser is applied on one side of the planted row. Band applications of fertiliser concentrate nutrients within a specific soil volume. The goal of band applications is to limit the contact of the applied fertiliser with the soil. This application method is desirable when fertiliser reacts with soil to produce compounds that reduce its availability to the crop. It is an efficient way of supplying plants with nutrients.

Drill Application

Drill application refers to the drilling of fertiliser at sowing time. Drilling the fertiliser together with seed should be avoided as it may adversely affect the germination, or the young plants may get damaged due to high or concentration of chemicals in the root zone. It is advisable to use a separate attachment for seed and fertiliser drilling. This is one of the best methods for applying phosphatic (P) and potassium (K) fertilisers to closely spaced row planted crops like wheat, maize, etc. This method is also better for applying nitrogenous fertilisers. However, it is safer to drill only small quantities of fertilisers so that germination may not be adversely affected.

Foliar Application

Foliar application refers to the spraying of fertilizer solution on foliage (leaves) of growing plants. Normally, these solutions are prepared in low concentration (2-3%) either to supply anyone plant nutrients or a combination of nutrients. It is the most suitable form of topdressing when there is inadequate soil moisture.

Starter Solutions

The use of liquid fertilisers as a means of fertilisation has assumed considerable importance in foreign countries. Solutions of fertilisers, generally consisting of N, P2O5, and K2O in the ratio of 1: 2: 1 and 1:1:2 are applied to young vegetable plants at the time of transplanting.

These solutions are known as 'Starter Solutions'. They are used in place of the watering that is usually given to help the plants to establish. Only a small amount of fertiliser is applied as a starter solution.

Irrigation Water/Fertigation

Fertilisers are allowed to dissolve in the irrigation stream. The nutrients are thus carried into the soil in solution. This saves the application cost and allows the utilisation of relatively inexpensive water.

Fertigation

Fertigation is the technique of supplying dissolved fertilisers to crops through an irrigation system. Intensification of agriculture by irrigation and enhanced use of fertilisers may generate pollution by increased levels of nutrients in underground and surface waters. Therefore, judicious management of plant nutrients available through different fertilisers need to be catered. A higher efficiency is possible with the help of a pressurised irrigation system that is placed around the plant roots uniformly and allows for rapid uptake of nutrients by plants. Small application of soluble nutrients saves labour, reduces compaction in the field and thereby enhances productivity.

Inorganic Fertilisers vs. Organic Fertiliser

Both organic and inorganic fertilisers provide plants with the nutrients needed to grow healthy and strong (Table 2.1). However, each contains different ingredients and supplies these nutrients in different ways. Organic fertilisers work overtime to create a healthy growing environment, while inorganic fertilisers provide rapid nutrition. Determining which is better for crops depends largely on the needs of the crops and preferences of the farmer in terms of cost and environmental impact. Organic fertilisers are environmentally friendly. Overuse of inorganic fertilisers cause pollution of groundwater, stripping of soil nutrients, and plant and root burn if utilised improperly. The continual use of inorganic fertilisers reduces the soil's resistance to pests and diseases killing off the natural microbial activity.

TABLE 2.1. COMPARISON OF ORGANIC AND INORGANIC FERTILISERS

	Organic	Inorganic
Composition	• Contain only plant- or animal-based materials that are either a byproduct or end product of naturally occurring processes • Low in soil nutrients	• Mineral processed fertiliser • Supplement the soil with macronutrients needed in large amounts: nitrogen, phosphorus and potassium
Nutrient Availability	• Rely on soil organisms to break down organic matter -Release nutrients only when the soil is warm and moist • Nutrients are released slowly • Reduces the risk of nutrient leaching	• Provide this nutrition in plant-ready form • Nutrients may leach deeply into the soil and water table
Application	• Bulk application • Analysis needed to determine the amount of nutrients being applied	• Application is simple, easily mechanised -amount of a given element • Rate of application can be easily calculated • Expensive
Cost/availability	• Locally available and relatively cheap	• Expensive
Environmental Impacts	• -Organic materials are able to fully decompose. • -Lower release of greenhouse gas	• Heavy applications can burn crop • Build up toxic salt concentrations in the soil, which can create chemical imbalances • High release of greenhouse gas

Assessment of soil health: tools for assessment

Soil health assessment involves processes where many potential indicators are evaluated for their use in standardised, rapid, quantitative assessment of soil health based on relevance to key soil processes, response to management, and complexity of measurement.

Soil assessment or testing starts with the correct procedure of taking soil samples using appropriate tools. Soil sampling is a systematic collection of soil samples in a farm for analysis.

Soil analysis is the chemical, physical or microbial technique that estimates the availability of nutrients, particles, and organisms in the soil for plant growth. Soil contamination and presence of toxic elements is also done through soil analysis. The basic soil test involves the determination of components that are of significance to crop growth such as pH, phosphorus, calcium, potassium, magnesium, sodium, cation exchange capacity, base saturation, and bulk density.

The test methods used in nutrient determination in soils and plant tissue correlate the relationships between the quantity and mineral form of the essential elements present in the soil and plant. This enables the land user to know what is needed to ensure the condition of the soil is suitable for the crop to reach its genetic yield potential. The soil and plant tissue tests are the most reliable method for identifying and confirming the nutrient deficiencies.

Soil sampling at KALRO-Kabete

Steps of Soil Sampling

- Remove debris from the ground surface at the point where the sampling is to be done.
- Use an auger to dig a small hole about 20cm deep (topsoil sample).
- Place into a clean container.
- Optional - At each of the 10 sub-sample locations, collect soil hardness information with a penetrometer.
- Record maximum hardness (in psi) from the 0-6” and at the 6-18” depth ranges on the Submission

Form.

- Repeat the steps as above A-D to collect the remainder of the sub-samples. Mix thoroughly and transfer 3-6 cups of soil into a clearly labelled re-closable freezer bag. The amount of soil required depends on the analysis package selected.

Importance of Soil Sampling and Testing

- To establish baseline soil nutrient status.
- To measure changes in soil nutrient status over time.
- To assess the overall nutrient status of different soil types essential for crop growth and development.
- To predict nutrient deficiencies in current or succeeding crops.
- Establish fertiliser application recommendations (types and rates). This helps to avoid excessive nutrient application or accumulation of soluble salts.
- To assess nutrients removed in crop residues.
- To monitor the soil pH (acidity and alkalinity) and organic matter content.
- For soil biological characterization.
- For soil physical characteristic evaluation (soil physical characteristics are crucial determinants of the plant rooting pattern).

What to Consider When Undertaking Soil Sampling

When carrying out soil sampling, it is important to ensure that the samples are representative of the whole farm, portion of the farm or the locality being mapped out. It is important to always take separate soil samples where farm features differ because they have an effect on soil fertility. Features associated with soil fertility variability in the farm include:

- Topography (slope length or gradient, rocky outcrops).
- Soil types (texture, colour).
- Land degradation intensities (erosion sites, vegetation cover and type).
- Land-use history (past land use, cropping systems and fertility inputs applied)
- Current land use, - including farm structures, trees/crop(s) grown and soil conservation measures in place
- Distance from the roads (paths), homestead and livestock facilities.