INTRODUCTION TO AGRICULTURE

Early man was a hunter of wild animals and a gatherer of fruits from forests. With the advent of civilization, man started practising agriculture by domesticating some animals and growing crops.

Definition

- Agriculture is the art (practice) and science of growing crops and rearing of livestock.
- It's a science as it requires us to apply knowledge from science subjects and fields such as biology, physics, chemistry, mathematics, geography, entomology, botany, climatology, pedoligy, agricultural engineering, zoology, etc.
- On the other hand it's an art as it requires us to apply some practical skills as we carry out agriculture as tilling, use or operation of machines, maintenance of tools and machinery, construction of structures, harnessing crops, feeding and handling animals, measurement and marketing of produce.
- There are also scientific skills required of a farmer such as experimentation, discovery, observation, hypothesizing, data collection, recording analysis, evaluation, drawing of scientific conclusions, etc.

AGROSNOMOS: Field cultivation (Greek)

AGER – CULTURA: Field cultivation (Latin)

Branches and scope of agriculture

Agriculture as a subject is divided into five major branches and these are:

a) Soil science

- This deals with soil formation, soil properties, soil fertility and soil & water conservation.

b) Crop husbandry.

- Study of the practice carried out to produce crops. It includes land precipitation, agronomic practices following in raising crops, plant breeding, genetics, pest/disease control, weeding.

c) Animal husbandry

- Science dealing with production of animals. It involves practices like feeding, housing, reproduction, health care, breeding, marketing, etc.

d) Agricultural economics

- Deals with economic practices required during farm production, it involves farm records, marketing, farm management, farming organization, land tenure, production economics, etc.

e) Agricultural engineering

- Is concerned with farm machines, tools, equipment, farm structure and their maintenance.

Within the branches mentioned above, there are fields of specialization as shown below.

Crop husbandry

(i) Forestry: Study of forest resources their management conservation and utilization.

(ii) Horticulture: Study of cultivation of fruits, vegetables, flowers and namental plants i.e. pomology, olericulture and floriculture: N.B. Viticulture in also another broader field of fruit group.

(iii) Agro-forestry (Agroculture & Pastrorations)

Animal husbandry:

(i) Pack animals

(ii) Apiculture (bee farming / keeping)

(iii) Aquaculture (fish farming)

(iv) Dairy

(v) Beef

(vi) Poultry

(vii) Sheep

(viii) Rabbit

(ix) Pig production

(x) Sericulture (silk worms)

Objectives of teaching agriculture (in secondary schools)

Formal training and teaching in agriculture has been introduced in schools at all levels to meet the needs of modern scientific farming.

In secondary schools; these are the major objectives; Help learners to:

(i) Relate the value of agriculture to food security and welfare of the family, school, the community and the nation.

(ii) Develops a positive attitude and interest in agric. as a respectable occupation that is both profitable and honourable.

(iii) Recognise the existing challenges and opportunities in agric. as a major contribution to the national development.

(iv) Acquire a practical manner basic principles and skills in agriculture to enable him / her to manage agricultural enterprise profitably for self-reliance and contribute to agricultural modernisation.

(v) Acquire background knowledge and skills for advanced studies in agriculture.

Importance of agriculture to man and the economy

Importance of agriculture to man. It provides:

(i) Food for man and his livestock.

(ii) Raw materials for clothing e.g. cotton, hides, skins.

(iii) Medicinal plants (herbal materials) e.g. Moringa, Neem tree.

(iv) Domestic animals for cultural function e.g. paying bride price & sacrificing to gods.

(v) Home income.

(vi) Farm labour from draught animals e.g. oxen, camels, donkeys & horses.

(vii) As a way of life

(viii) Fuel from crop residues e.g. coffee husks, cotton, stalks of maize & combs.

(ix) Shelter from tree, shrubs, wattle, grass which are all resources from agriculture.

To the economy

(i) Food for the general population.

(ii) Employment

(iii) Raw materials for agro-based industries

(iv) Source of foreign exchange.

(v) Source of government local revenue.

(vi) Source of capital.

(vii) Provide a market for industrial goods.

(viii) Rural transformation & limits of rural-urban income gaps & migration.

Problems faced by agricultural sector in Uganda

Uganda agricultural development has not reached high commercial development levels due to the following reasons

(i) Inadequate capital due to low income of the farmers.

(ii) Shortage of land & land fragmentation due to high population in some areas.

(iii) Unfavourable climatic conditions e.g. inadequate rainfall and unreliable rainfall.

(iv) Conservativeness and low education of farmers makes it hard for them to accept innovations.

(v) Inadequate extension services and poor communication facilities.

(vi) Poor transport facilities e.g. roads.

(vii) Lack of good and adequate storage facilities.

(viii) Pests and diseases

(ix) Poor crop and livestock varieties.

(x) Price fluctuation for agricultural commodities.

(xi) High costs of farm inputs.

(xii) Political instability in some areas.

(xiii) Lack of adequate and proper markets for agricultural produce.

(xiv) Low prices for offered for agricultural produce.

(xv) Poor attitude towards agriculture.

(xvi) Labour shortages.

(xvii) Religious and traditional beliefs e.g. keeping very many livestock and not rearing some types of livestock.

Possible solutions to the problems

(i) Government to avail affordable credit / loans to farmers.

(ii) Setting up of settlements and resettlement schemes.

(iii) Construction of irrigation facilities, dams.

(iv) Engage in good crop and livestock varieties e.g. high yielding, quick growing, disease & pest resistant.

(v) Improve mechanisation of agricultural operation to enable timeliness.

(vi) Training more extension workers and improving extension provision.

(vii) Increase mass media communication to farmers.

(viii) Improve road network and create more access / feeder roads.

(ix) Creation of a stabilisation fund to protect farmers from declining market prices.

(x) Government to put up more storage facilities and processing plants.

(xi) Diversification of farming activities.

(xii) Improve research.

(xiii) Government to put up a mechanism to combat insecurity.

(xiv) Effective and organised control of animal and crop pests/diseases.

(xv) Acquisition of more markets and organising of the marketing of produce e.g. through co-operatives and boards.

The farm layout

Activity: Visit a nearby farm and do the following:

- Write down the components / things on the farm you find and their roles.
- Draw a simple ground map of the farm.
- Write down the components of a typical mixed farm.
- Factors to consider while setting firm components.

The characteristics and structure of agricultural production in Uganda.

See Notes in Economics.

- Generally subsistence.
- Mainly annual crops.
- Low output per homestead.
- Production is on small holdings.
- Farmers use simple and primitive tools.
- Farmers use poor traditional methods of farming.
- Limited degree of diversification and specialisation in crops and animals.
- Use poor breeds of crops and livestock.
- Mainly employ family labour.

- Land is held under several land tenure systems.
- Generally there is low capital input.
- It's dominated by the less educated people

Factors affecting agricultural production in Uganda.

(a) Climate

- Rainfall amount
- Rainfall distribution
- Wind
- Humidity
- Temperature

All these influence the type of crops and livestock kept and their distribution and vegetation.

(b) Land available

- Determines level of production and profitability.

(c) Land tenure

E.g. communal ownership Vs individual ownership

- The system will influence the incentive to develop land and thus improve agric. production

(d) **Soil**

- E.g. fertility level, type of soil, soil depth all will influence the type of crop and vegetation.

(e) Topography

- Influences the type of soil, the drainage of soil and the source of water which in turn will have a marked effect on plant and animal life and the distribution of crops and animals, rainfall patterns, etc.

(f) **Altitude**

- Influences temperature changes and therefore crop and livestock distribution.

(g) Social factors

- Such as political stability, religious, customs, peoples' tests and preferences.

(h) Government policy

- The government sets up policy on agric. production which may influence the agric. pattern in the country e.g. production, quotas, pricing, crops to grow, livestock to keep, quarantine, etc.

(i) Biotic factors

- E.g. pests and diseases that hinder and lower production, vegetation cover can make cultivation expensive and difficult.

(j) Population size

- Influences land availability, levels of production and production methods.

(k) Economic factors

These mainly include

- Availability of inputs, quality of inputs.
- Market of availability
- Presence of skilled labour.
- Mechanisations and technology level.
- Storage and processing facilities.
- Research and agricultural extension staff.
- Communication facilities e.g. roads, railways, etc.

Factors affecting or influencing crop and livestock distribution

These are the same as above with the exception of some economic factors. So they include:

(a) Climate factors. E.g. temperature, humidity, wind, light/sunshine.

(b) Physical factors. E.g. rainfall, altitude, soil factors

(c) Relief / topography

(d) Altitude

(e) Pasts and diseases

(f) Population density

(g) Social factors. E.g. customs and religion

(h) Political factors

Farming systems and practices in Uganda

A farming system refers to the way people carry out farming and the type of crops and animals they rear.

Or. The various methods used by different groups of people to produce crops and livestock.

Farming systems can be practiced on a large scale e.g. ranching, plantation, etc. or on a small scale e.g. subsistence.

The choice of a farming system is dictated by the following factors.

(i) Climatic factors e.g. rainfall

(ii) Soil type and fertility

(iii) Cultural factors e.g. traditions and values

(iv) Knowledge and skills of the farmer

(v) Government policy

(vi) Population size

(vii) Land available

(viii) Land tenure system

(ix) Topography

(x) Altitude

(xi) Aims / objectives of commercial or subsistence

Local farming systems

These farming systems are recognised according to location, type of crop combination, climate and livestock kept.

They therefore include:

1. Banana – robusta coffee
2. Banana – millet – cotton system
3. The northern system
4. The montane system
5. The Teso system
6. The pastoral system
7. The West-Nile system

Factors of the different local farming systems.

1. **Banana – robusta coffee**

- Carried out around the fertile region of Lake Victoria
- Excised by bi-modal rainfall distribution
- Major cash crop is coffee others tea, sugarcane
- Major food crops banana others sweet potatoes, cassava and maize
- Only a few animals are kept
- Food storage structure are no common
- Land tenure system is free hold with registered land title
- Intercropping is a common practice

NB: this system modifies into the banana – millet – cotton system towards its drier boundaries e.g. towards Nakasongola.

2. **Banana – millet – cotton system**

- Carried out in Tororo, Iganga, Hoima, Masindi and Kamuli, Luwero, Nakasongola.
- Has bimodal distribution of rainfall.
- Major crops are finger millet, Cotton, Banana, Coffee, others maize, beans.
- They also keep livestock especially beef cattle and goats, others are bee keeping, piggery, and fish farming.

3. **The Northern system**

- Carried out in Lango, Lira, Gulu, and Kitigum.
- Major cash crops are cotton and tobacco and finger millet as the food crops.
- The area has mono-modal rainfall favouring the group of annual crops.
- Communal land ownership is practised
- Granaries are constructed to be used in the storage of farm produce.

4. **The Montane system**

- Located around the mountainous regions of Kigezi, Sebei, Mbale and Rwenzori.

- The soils are deep and fertile
- Temperatures are low due to the high altitude.
- Major cash crops are Arabica coffee food crops include bananas, irish potatoes, wheat, sorghum, sweet potatoes and a variety of vegetables and legumes.
- Contour ploughing and terracing are common methods of soil and water conservation.
- Livestock is also carried out though it is limited by topography.
- The areas are densely populated.

5. The Teso system

- Carried out in the regions of Teso and Tororo.
- The major cash is cotton and food crop is millet.
- The area has flat land with sandy loam soils.
- Ox-plough cultivation is carried out extensively in the region.
- Large number of cattle are kept
- Mono modal rainfall distribution
- Fallowing is also practiced.

6. The Pastoral system

- Practiced by the pastoral tribes such as Karamojong and Bahima of Ankole.
- A large number of cattle and goats of low quality are kept.
- Little farming of annual crops such as millet, sorghum and maize is done.
- There is constant over grazing bush burning and random mating of livestock.
- They live a nomadic life style
- Poor short grasses with scattered thorny bushes.
- The land is communally owned.

7. The West-Nile system

- Practiced in the districts of Arua, Kotido, Koboko, Ajumani and Nebbi.

- One long rainy season.
- Major cash crops are Arabica Coffee, cotton and tobacco.
- Food crops are mainly finger millet, cassava, Simsim, sorghum, cowpeas, etc.
- They live a settled life and carry out livestock keeping as well.

Agricultural practices / systems

(a) Commercial farming

- Dairy
- Beef (ranching)
- Mixed farming (commercial)
- Plantation / estate

(b) Subsistence farming

(i) – Settled mixed farming (alternate husbandry)

- Settled mono cropping (sole cropping)
- Settled mixed cropping
- Settled intercropping / planting

(ii) – Unsettled pastoralism / nomadism

- Unsettled shifting cultivation

(c) Arable farming

(d) Ley farming

(e) Crop rotation

(f) Home gardening / market gardening

(g) Agro forestry

(h) Relay cropping / farming

(i) Bush fallowing

Commercial farming

Is a system of farming where the farmer aims at making profit or money.

Characteristics of commercial farms

- Large estates / farms
- Use heavy machines
- Large scale production
- Most farms are highly specialised
- Hired labour may be used
- Most of them are owned by companies, corporations, governments or foreigners.
- The products are normally processed for export.
- Skilled and non-skilled labour is used.
- It employs many people
- The marketing and management is highly organised.
- External land may be used for out growers.
- Scientific methods of farming are used.

Plantation farming

These are normally perennial crops grown on estates. E.g. Tea, sugar cane, rubber, sisal. However extensive farms of low growing annual crops such as cotton may be established as plantations and leads to **track farming**.

Characteristics of plantation farming

All those above in commercial farming

Advantage of plantation farming

- There is regular supply of produce because of centralised and efficient management.
- Processing increases value of the produce and they archive improved quality.
- It curbs unemployment as many labourers are used / employed.

- Machines are economically used because of the large farm holdings.
- They are good source of government revenue.
- The workers become trained and skilled as they specialise in the production process.
- The farmer employs economics of large scale production.
- It leads to improved transport and communication in the areas and other social benefits / infrastructure e.g. schools, health centre, electricity.
- Specialised skills and advice to help the out growers offered, helps to improve the farming activities in the neighbourhood.

Disadvantages / Limitations

- It requires a lot of capital to set up.
- The system causes soil erosion, exhaustion and loss of soil structure.
- Specialisation in one crop may lead to total loss in case of disaster or price failure.
- The system has a negative impact on food production as it emphasises mainly cash crops and uses much labour force.
- Any slight mismanagement may cause heavy losses.
- Most plantation crops have long gestation periods therefore the owners take some time to earn profits.
- It requires a lot of land at the expense of the original settlers.

Ranching

This is large-scale animal rearing especially beef and or dairy animals.

Characteristics of ranching

- Many animals are kept
- Large areas of land are used.
- There is a lot of capital investment involved
- The animals are specifically kept for sale
- Only highly productive breeds are kept

- The land is always individually owned.
- There is less movement of the animals
- More scientific methods of management are used than in pastoral nomadism.
- Normally carried out in the drier areas
- There is specialisation either beef or dairy
- The is less variety of animals kept
- Pastures are well established and improved.

(b) Subsistence farming

Is a system of producing agricultural produce for home consumption, the surplus is either stored for future use or partly sold for petty cash. It is the commonest system practiced in East Africa as also called peasantry farming.

Characteristics of peasantry / subsistence farming.

- The products are mainly for domestic consumption, with the surplus for storage or sale.
- Family labour is used.
- Simple and inefficient tools are used
- Small fields are cultivated.
- Farmers have a low standard of living with almost no transport or marketing infrastructure.
- Modern farming methods are not used.
- Intercropping of crops is common.
- Gardens are scattered / fragmented.
- Poor crop and livestock varieties are used.
- They mainly specialise in short term crops (annual crops).
- Little processing is done on produce.

Advantages of subsistence farming

(i) Many and diversify crops can be grown.

(ii) Growing many different crops protects soil fertility.

(iii) Dense population can easily be supported.

(iv) Production for home consumption saves transport and other marketing costs.

(v) It requires small capital investment to start.

(vi) Farmers are not affected by price fluctuations and other market effects.

(vii) It meets domestic and the local food demand.

Disadvantages of peasantry farming

(i) It tends to keep farmers poor.

(ii) It does not encourage mechanisation.

(iii) The farms are scattered which makes it hard / difficult to work.

(iv) Labour is kept idle between planting and harvesting.

(v) The law of diminishing returns quickly sets in.

(vi) The rate of investment is very small and economic development is slow.

(vii) In the event of a crop failure, the survival of the farmer is threatened.

How to improve subsistence farming

(i) The system should be diversified so that many enterprises and activities are carried out.

(ii) Use improved farming methods e.g. crop rotation, manure / fertilisers application pest and disease control.

(iii) Adoption of information and advice from NAADS officials.

(iv) Provision of agricultural incentives to farmers in form of subsidised inputs.

(v) Improved seeds and improved domestic animals be used for production.

(vi) Provision of markets for agricultural for agricultural produce.

Unsettled subsistence farming systems

(a) Shifting cultivation

Is an old practice of clearing and cultivating land continuously ($\cong$ 3 – 5 years) after which the land is abandoned when exhausted to obtain another fertile one elsewhere.

Conditions which favour shifting cultivation

- Land must be abundant or low population density.
- Land is owned communally.
- Sparse population.
- Low livestock density.
- Few crops are grown for domestic use only.
- Lack of modern farming techniques and facilities to improve the exhausted land.

Advantages of shifting cultivation

(i) Fires destroy some pests and diseases.

(ii) Less labour is used to allow other practices such as fishing and hunting to take place.

(iii) Burning cracks the ground to allow water to infiltrate into the soil.

(iv) Ash released from burning vegetation enriches the soil with minerals.

(v) Burning controls weeding too.

(vi) Soil fertility is ensured as the land is given rest / bush fallowing.

(vii) Good / high yields are obtained as virgin plots are used every season.

(viii) Production is independent of market

(ix) It is easy and cheap to carry out

(x) Pest and disease build up is discouraged due to shifting tendency.

(xi) The soil is less disturbed since small tools are used.

(xii) It is self-reliant since the farmer does not depend on so many types of inputs and expertise.

Disadvantages of shifting farming

(i) Volatile nutrients e.g. C, S & N are easily lost during bush burning.

(ii) The average yields are low since fertilisers are and management is poor.

(iii) Movement is inconveniencing since property has to be moved and new construction made.

(iv) The regular migration does not allow land development.

(v) Only a few crops can be grown for food.

(vi) Difficult in densely populated areas.

(vii) It wastes useful forestry resource.

(viii) Soil organisms and are useful can be killed by fire.

(ix) The rainfall pattern is affected due to destruction of forests.

(b) Pastoralism and nomadism

Is where farmers keep large herds of livestock (cattle, sheep, goats) and allow them to graze at random and they put up temporally camps where they find water and fresh pasture.

NB: Pastoralism is the profession / occupation of herding animals especially cattle but nomadism means “not settled” in one place or wondering.

– **Sedimentary pastoralism**

These graze their animals near permanent established homesteads and neighbouring marginal land while at night they keep their cattle / animals in enclosure or pens (Borma) for security.

Pastoralists are held in low esteem because.

(i) They do not value education.

(ii) Move from one place to another.

(iii) Find prestige in keeping large herds of cattle.

(iv) Do not cultivate a lot.

(v) Reluctant and difficult to change to modern ways.

(vi) Mismanage livestock and overgraze pastures.

Characteristic of nomadic herding.

– They are extensive and specialize in livestock.

– Large stock of animals are kept.

– Keep local /indigenous stock of poor yield

– They keep on moving from place to place.

– Prefer quantity of stock them quality.

– Animals are grazed and watered communally

– There is communal land ownership.

– Overstocking and over grazing are common.

– Pests/parasite and diseases are rarely controlled.

– Pastures are not improved.

– Movement of the animals in determined by climate condition of rain.

– Poor animal management.

– Practiced in areas with poor soil and with low rain fall.

– Low education, conservation and not ready to change to modern farming.

Problems faced by nomadic pastoralism in East Africa

(i) Climatic problems

- Low rain fall thus and water pasture shortage.
- High temperatures leading to loss of condition of animal.
- Low humidity thus animals lose a lot of water.

(ii) Parasites and diseases

- E.g. Tsetse flies, locusts, army worms, Ander pest, E.C.F., F.M.D.

(iii)Poor pasture species

- Coarse pasture with tall shrubs which are not palatable to livestock.

(iv)Bush fire

- E.g. In the rift valley regions fire are used to clear large areas of old and unpalatable pastures. This however destroys humus and lead to soil erosion due to cleared vegetation.

(v) Wild beasts

- Especially the lions, jackal and hyenas attack their animals while in pastures and kraal.

(vi) Overgrazing

- This results from over stocking which then leads to soil erosion and degradation.

(vii) Poor breeds of cattle

- Small in size, slow growers, low milk and meat producers.

(viii) Inadequate capital

- No money to invest in dips, water reservoirs, drugs, storage structures, etc.

(ix) Long distances

- Animals walk long distance and therefore they lose weight and become susceptible to disease.

(x) Transport and marketing problem

- Transporting of animals to the processing plants and their products in difficult. Their prices are uncertain since they fluctuate from year to year depending on the buyers.

(xi) Poor extension services and veterinary Services are inadequate.

(xii) Cattle rustling in some places

(xiii) Low education conservativeness, literacy and ignorance.

Measures to improve the livelihood of nomadic leaders (pastoralists)

(i) Introduction of ranches with bore holes, wells and dams to minimise drought effects and cattle movement.

(ii) Clearing of tsetse fly infested arrears of bush, spraying with insecticide.

(iii) Building strong enclosure to protect the animal in the bomas against wild animals.

(iv) Increasing/improving disease control programmes through vaccination and dipping, fencing and paddocking.

(v) Establishing demonstration farms where farmers learn about modern techniques of livestock farming.

(vi) Introducing new / improved varieties of pastures and improving the existing ones with the help of research scientist.

(vii) Cross breading exotic bread with the local ones to improve the latter.

(viii) Improvement of marketing facilities e.g. roads, storage and processing facilities opening new markets and fixing of good prices for their animal products.

(ix) Reduce the stocking rate of animals.

(x) Land reform to encourage individual land ownership.

(c) Cropping systems

(i) Shifting cultivation

- Already discussed.

(ii) Plantation farming

- Already discussed.

(iii) Mono cropping (sole cropping)

This is the growing of individual crops in pure stands. One type of crops only is found in the gardens.

Advantages

- Weeding is made easy.
- Spraying is easy e.g. against pest and diseases.
- It is easy to estimate the yields and crop population.
- It is easy to harvest.
- Field operations often plating are easy to be mechanized.

Disadvantages

- Disease and pest outbreak are more likely to spread fast in a pure stand.
- If the plant / crops does not offer good ground cover, soil erosion is encouraged.
- The land may not be fully utilized if tall and widely spaced crops e.g. bananas are grown.
- Crops failure or drop in market price for the crop may adversely affect the farmer's income.

(iv) Inter-cropping and inter-planting and mixed cropping

(a) **Mixed cropping:** Is the growing of many crops inter-cropped or in different plots of pure stands on the same piece of land at the same time.

(b) **Inter – cropping:** this is the planting of a quick growing and quick maturing crop between a slow growing and slow maturing crop (annual and per annual) e.g. beans with bananas. The slow growing crop is left in the field as the quick maturing in harvested or major and minor crops.

(c) **Inter-planting:** It is the planting of a major crop with another major crop food or cash crop on the same land.

Advantages:

- The total yields per unit area are higher than in a mono cropping since more plants are established per unit area.
- There is better and full utilization of labour.
- It controls weeds since little space is left between crops.
- The ample vegetation (crop) cover controls soil erosion and conservation the soil moisture.
- Crops maturity at different time safe guide against famine as the early matures can be used for food.
- There is maximum utilization of the environmental resource such as the nutrients and moisture.
- Legume in the mixture enrich the soil with nitrogen.
- It interrupts the spread of pests and diseases in the crop field especially if the pest in monophagous (limited to one crop).
- It helps the farmer to have a varied and balanced diet.
- It acts an insurance against poor yield and price failure on market failure of any of the crops.

Disadvantages:

- It is not easy to carry out operations such as spraying, weeding and harvesting.
- Spacing to get optimum plant population is not easy.
- It makes mechanization almost impossible after planting.
- It sometime waste fertilizers that have to be applied to even those crops in the mixture which are of low value or do not need them.

- There many competition between crops for growth factors especially where the crop combination used was not carefully chosen.
- The slow growing crops may be damaged during the harvesting of the early maturing crops.
- Sometime it may encourage spread and build-up of some pests and diseases organisms (if they have a variety of host plants).

(v) Arable farming

Is where short term crops are grown on available land. The crops are grown either in pure or mixed stand. A good crop rotation is usually followed allowing fallowing. Fertilisers are applied and machines for ploughing, planting, weeding and harvesting are used.

N.B. Arable means suitable for cultivation.

(vi) Bush fallowing.

Is system of growing crops for some years or till the soil is exhausted after and the land in rested in bush form to regain fertility while cultivation continues in succession on alternative pieces. This sometimes it's called land rotation.

(vii) Lay farming

Is a system of alternating temporarily planted pastures with crop production. After the arable crop, the field is temporarily put under pasture for one or more seasons before it is ploughed and utilized. It is also called alternate husbandry.

Advantages

- The rested land is fertilized by the humus from the grass dug into the soil.
- The land is used all the time and is not kept idle.
- Weeds are controlled because of frequent weeding.
- The planted grass pasture checks on soil erosion.
- Leys provide cheap feeds for the livestock.
- It helps to break the pests and disease cycle.
- The soil structure is improved by the added organic matter.

- Legumes add nitrogen to the soil.
- Grasses and legumes help in nutrient recycling.

However the system requires more labour in establishing and management of pastures than when permanent grass is used.

(viii) Relay cropping / relay farming.

Is the growing of more than one crop in the field. One following the other before the harvesting of the first one.

(ix) Market gardening.

Is a system of growing crops for sale in the nearby market.

In this system, the farms near the market centres are intensively managed, sophisticated, mechanised and technology is used, perishable products such as fruits and vegetables are grown and produced.

(x) Crop rotation.

Involves growing of different crops in alternate succession, season after season on the same piece of land. After say 3-4 years the system is repeated to make a continuous cycle in a sequential order. It's designed in such a way that it makes use of land and climate to the best advantage.

Benefits of crop rotation

(i) It maintains the soil fertility and protects the soil structure thus erosion control.

(ii) There is maximum utilisation of soil nutrients in the soil e.g. different crops feed at different depths.

(iii) It controls pests and diseases by breaking their life cycle.

(iv) Parasite weeds e.g. driga that attack cereals can be easily controlled by planting crops that are not cereals in the rotation.

(v) Where legumes are included, soil fertility is increased.

(vi) Where grasses are used, the soil structure is improved.

(vii) Soil erosion is controlled by crops with effective ground cover.

(viii) It helps to avoid a complete crop failure because different crops are grown at same time.

(ix) It ……….. out labour requirements over the years.

(x) It spreads financial risks over several crops.

What to consider while fixing a crop rotation

1. **Climatic conditions**

   Understand the crop growing seasons in a year for a particular place so as to know when to grow and harvest the crop in question. Also the rainfall distribution e.g. mono modal or bi-modal is important.

2. **Soil conditions of the farm**

   Check if the soil is light, heavy, alkaline or acidic to choose a suitable crop.

3. **Market condition and transport.**

   This is to ensure or enable efficient marketing especially for the perishable produce.

4. **The farmer's need.**

   The programme should be able to supply the family with the desired variety of food.

5. **The crop rotation principles**

   These govern the success of the rotation.

Principles of crop rotation

When fixing a crop rotation, one should bear the following in mind.

(i) Only annual crops should be included in the rotation.

(ii) Crops having similar and / or diseases should not follow one another in the rotation to minimise spread.

(iii) Crops that withdraw a lot of nutrients from the soil should be planted first in a newly cultivated field to take advantage of the accumulated nutrients before they are lost. E.g. Maize, cassava, cotton.

(iv) Crops with different rooting systems should utilize the soil nutrients e.g. shallow rooters (millet) should follow a deep rooter like cotton.

(v) Legumes e.g. beans, cowpeas, etc. should be included in the rotation to provide nitrates (NO_3)

(vi) Crop which do not cover the ground properly should alternate with those that do to minimise soil erosion.

(vii) Cover crops should be included in the rotation to minimise erosion and protect the soil structure.

(viii) A good rotation should include a fallow period (retire phase) during that grass / bush is allowed to grow, this is to enable soil replenish nutrients.

(ix) Crops with similar weeds should not follow each other to control weeds.

(x) Crops with similar type of requirements e.g. nutrients should not follow each other to minimise depletion of those nutrients.

(xi) It's desirable to include a cleaning crop which ether kills the weeds through competition or requires frequent cultivation. This should be grown in the early part of the rotation.

Examples of crop rotation.

(a) A five year / season crop rotation program

(a) 1st season / year a legume e.g. beans, cowpeas
2nd season / year a root crop e.g. cassava, sweet potato
3rd season / year a cereal crop e.g. maize, millet
4th season / year a general crop e.g. yam, carrot
5th season / year a grass fallow

(b) In a cotton, millet, bean – grass rotation, give reasons for the order and inclusion those crops.

Cotton: – Is a deep rooter and brings nutrients from lower layers.
– It's also a heavy feeder it has to be planted first in the rotation before nutrients are lost.

Millet: – Is a shallow rooter and so benefits from nutrients left on the upper layers by cotton, and those brought on top of the soil.

Beans: – Is a legume thus fixes nitrogen
– is a cover crop thus controls erosion.
– is also a source of green manure

Grass: – Is a ley phase that minimises soil erosion, restores fertility and soil structure

(b) A three year crop rotation in an area with a bi-modal pattern of rainfall.

Year	Seasons	Plot 1	Plot 2	Plot 3
1	1	Maize	Cassava	G. nuts
	2	Cassava	G. nuts	Maize
2	1	G. nuts	Maize	Cassava
	2	Maize	Cassava	G. nuts
3	1	Cassava	G. nuts	Maize
	2	G. nuts	Maize	Cassava

(c) A three year crop rotation for an area with mono-modal pattern of rainfall.

Year Seasons	Plot 1	Plot 2	Plot 3
1	Maize	Cassava	G. nuts
2	Cassava	G. nuts	Maize
3	G. nuts	Maize	Cassava

(d) A four year crop rotation with a grass ley for am mono modal area.

Year Seasons	Plot 1	Plot 2	Plot 3	Plot 4
1	Maize	Cassava	G. nuts	Grass
2	Cassava	G. nuts	Grass	Maize
3	G. nuts	Grass	Maize	Cassava
4	Grass	Maize	Cassava	G. nuts

(d) Mixed farming

Is the integration of crops and domestic animals on the same farmland at the same time each contributing to the production and success of the other.

Advantages:

(i) It is self-sustaining as animals and crops benefits from each other.

(ii) The farmer and his family get a balanced diet.

(iii) Some animals can be used to work on the farm thus increasing productivity.

(iv) There is a continuous flow of cash throughout the year due to the sale of the various farm products.

(v) It is one way of diversifying production therefore if crops fail or price fluctuate, the farmer is insured.

(vi) Capital, labour and land are used optimumly or intensively.

(vii) The farmer gets a continuous income.

(viii) As bush clearing in done to give way for crops, tsetse flies are controlled to the benefit of livestock.

(ix) Soil fertility is maintained since animals are confined in paddocks away from farm land

(x) The farmer's income is doubled as he is able to earn from not only crops but also livestock or vice versa.

However:

(i) The system requires a lot of labour to manage both enterprises.

(ii) It requires a lot of land or a large piece of land to accommodate both enterprises.

(iii) Animals tend to interfere with crops where there are no fences.

(iv) A lot of financial capital and machinery is required to start it.

(v) The Routine management of both crops and various types of livestock requires a fairly high level of technical known how or skill.

(vi) It is confined to area where both crop growing and rearing of livestock are possible.

(vii) The system with the advantage associated with specialization.

(e) Agro – forestry

It is a land use system where trees and shrubs are included in a farming unit. Or a practice of including trees and shrubs in a farming system or the same land unit. Or is where trees and shrubs are grown on the same land unit on which crops are grown or animals are reared.

Thus there are the three major kinds of agro forestry systems identified according to the components involved.

(a) **Agrisilvo culture:** The trees are grown together with crops e.g. the trees could have been wild but then left in the garden as it is cleared for crop growing.

(b) **Silvo pastoralism:** This is where trees and pastures are grown on the same land use system.

(c) **Agrislvo pastoralism:** This is where trees, crops, pastures and animal are found on same land use unit.

However there are other agro – forestry systems such as:

– Hedge rows / Alley farming.
– Protein banks
– Home gardening.

Characteristics of agro forestry tree species.

– Should have a narrow / non – spreading canopy to avoid excessive shedding crops.
– Be quick growing.
– Have deep roots and few surface roots to reduce competition for nutrients with crops.
– Provide many valuable products e.g. Timber, medicine, fruits, etc.
– Be easy to establish and eradicate.
– Provide little that decomposes easily to provide nutrients for crops.
– Harbour no pests and disease that can damage the other components of the system.
– Be non-toxic/poisonous to animals/man.
– Not alleloparthic so as to enable crops grown in association with it.
– Should be able to re-sprout easily and quickly after pruning or coppicing.
– Adapted to the local condition.
– Have litter decompose easily.

The role of trees in an agro forestry system

(i) Trees create humid and a micro-climate in the field suitable for the growth of crops
(ii) Deep rooted trees open up the land which improves the soil drainage.
(iii) Trees and shrubs minimise both wind and water soil erosion.
(iv) Trees protect animal from extremes of temperature.

(v) Trees provide litter in form of dry leaves and later decompose to form organic matter to improve soil fertility.

(vi) Some trees provide fodder for livestock.

(vii) The leguminous tree help to fix N_2 in the soil and also provide a good source of proteins to livestock.

(viii) Trees provide fruits that can be sold or consumed.

(ix) The leaves of trees which fall, provide a soil mulch in the field and improve the soil productivity by nutrient recycling

(x) Trees provide useful products e.g. fruits, firewood, charcoal, construction timber.

(xi) They lower soil temperature and so reduce the rate of loss of organic matter and some nutrients by oxidation.

Adverse effects of trees.

- Some trees are allelopathic e.g. some species of eucalyptus.
- Some are habitats for pests and disease.
- Trees accumulate large quantities of nutrients in the structure and so make them temporarily unavailable to crops.
- Increase in humidity caused by the trees tend to increase incidence of fungal disease of the grey leaf spot of maize.
- They compete with crops for spaces nutrients and water.
- Some use up too much water and so lower the water table of eucalyptus.

The management practice in an agro forestry system.

(i) Irrigation where rainfall is inadequate.

(ii) Application of fertilizers/manure.

(iii) Pruning/pollarding to reduce canopy.

(iv) Coppicing; to encourage new more branched shoots.

(v) Root pruning/trenching, to reduce roots extending too much laterally and competing with crops.

(vi) Browsing/grazing: Animals are allowed to eat some of the foliage to control canopy size and reduce tree growth.

(vii) Pest and disease control by spraying trees with relevant chemical.

(viii) Typing up/shaping the shoot so that it's forced to grow into a required shape.

(ix) Ring barking / thinning; mainly to kill the tree if they are too many.

(x) Topping to encourage spreading of canopy.

(xi) Shading; by allowing other plants to excessively shed the trees and reduce their growth.

Factors limiting agro forestry/ growing of trees.

- Taboos associated with some trees.
- Limited availability of tree seedlings.
- Trees take long to mature.
- Unfavourable land tenure system.
- Limited land.
- Government regulation on tree cutting and ownership.

Principles of land use.

Land refers to all the natural materials of the earth which are freely given by nature. They include, soil, water bodies, mineral resource, air, light, heat, forest, etc. It's geographically immobile. It is productivity and fertility can be reduced or increased. But it is limited and thus cannot be increased.

Ways of acquiring land for farming in Uganda

(i) Inheriting a piece of land from one's parents or relative.

(ii) Borrowing a piece of land from people who have plenty of it.

(iii) Buying a piece of land with or without a land title.

(iv) Leasing land from the state for a specified period.

(v) Rending or hiring a piece of land for a season from individual or families owning plenty of land.

(vi) Getting a piece by being settled or resettle by the government in a place where there is land.

(vii) Getting an allocation of land from relative or parents.

(viii) Receiving land as a gift from a well wishes or sympathizes.

(ix) Winning land say in promotion.

(x) Grabbing / stealing land especially where there are absent landlords.

Forms of land use in Uganda

Uganda's land consists of 35% farmland, 21% water bodies, 20% forests woodland, 15% water bodies, 6% bush land, 3% commercial farms and urban areas.

Uganda's land is used for the following purposes or activities.

(a) Agriculture: Takes the highest percentage $\cong$ 181,584 km^2 is arable land and it's also used for rearing livestock.

(b) Forestry: Trees have been planted while others exist as natural forests. Forests are an important resource.

(c) Communication: This is through road construction, railways, air ports, airstrips, and landing sites. These are for transportation of agro-goods to markets.

(d) Recreation centres: Some places have been set aside where people go and are entertained or go to relax during leisure time. E.g. Theatres museums, stadia, beaches and botanical gardens.

(e) Mining: Minerals, sand and stones are some of the items mined from land to be used as resources.

(f) Construction of buildings and settlements: Commercialism of some form of trading centres, shops, markets has been done. Buildings have also been setup as residential facilities, schools, hospitals, worshiping, industries, industries, barracks, power stations, etc.

(g) Mortgages of land.

Land can be used as security in order to obtain a loan from a money lending organisation. Titles for the land are submitted to the money lending organisation and money released. After repaying, the tile is give back to the owner and failure, the organisation may sell off the land to recover the money.

(h) Wet lands: Such as swamps are a good source of fibre materials for baskets and mats. Wet lands also offer habitat for some organisms, they purify water, act as water catchment areas and can be a source of water for irrigation purposes.

(i) Wildlife conservation: This is in the form of game parks, game reserves, zoos, etc.

(j) Internal fishing grounds: Such as lakes, rivers and streams.

Forestry

- A forest is any area occupied by trees or vegetation by at least 20% or more and the area should be more than 0.5ha. Real forests in Uganda occupy ≅ 6.5% of the total land area.
- Forests are mainly in the high altitudes, which receive ≅ 1,000mm per annum of rainfall.
- Forests are in two categories:
  - (i) Natural forests: E.g. Budongo, Bugoma, Mabira, Mafuga (Kabale) and Maramagambo. These forests are self-established.
  - (ii) Artificial forests: These are man-made or planted by man e.g. Lendu in Arua district.
- 70% of the forests are on private or customary land while 30% are on government land.
- Tropical forests cover ≅ 924,000ha.

The forest creates the conditions for its own survival.

(i) It reduces soil temperature and evaporation thus conserving the soil moisture.

(ii) They recycle soil nutrients; this is by drawing nutrient from the deeper soil layers and depositing them by the leaf fall on the surface, thereby improving the organic matter content of soil.

(iii) Improving the soil fertility, its permeability for plant roots and its capacity top hold water. Leguminous species fix nitrogen in the soil which is used by the other species.

(iv) Their roots endure the earth soil thus bind the soil from being eroded.

(v) They increase the infiltration of rain water into the soil by reducing surface flow.

(vi) They counteract the effects of erosive torrential rain storms.

(vii) Their canopies protect the earth / soil from the sweep of winds and the splash of rain drops.

(viii) They play a part in the water cycle by increasing the amount of rain brought about by transpiration.

(ix) Act as catchment areas for water and control floods by reducing the speed of water and increasing water infiltration.

Hard wood trees found in natural forests

- African mahogany
- Iron wood (cynometra Alexandria)

- Chlorphora milicia (Muvule)
- Podo (Podocarpus milanfianus)
- Albizia species
- Maesopsis emini (Musizi)

Importance of forests

- Pride timber for furniture and construction.
- Provide poles for construction of farm structures and electric poles.
- Act as wind breaks to minimise wind erosion.
- Their roots bind soil and reduce soil erosion.
- Provide fuel as charcoal and firewood.
- When wood and leaves decompose they add organic matter to the soil that increases the soil fertility.
- They are a source of conventional rain because of transpiration.
- They are O_2 factories that gas makes the ………. Habitable and fresh.
- Source of employment to those involved in lumbering trade and carpentry.
- Provide wood pulp for the paper industry, glue, dyes, fibre, soft wood, etc.
- Some are sources of herbal medicines.
- They promote the tourism industry.
- They are a home of wild game.
- Source of revenue to government from the taxes charged on timber dealers and also foreign exchange from wood products exported.
- Source of aesthetic value (beauty)
- They act as genetic banks from where crop breeders obtain useful genes for crop improvement.

Methods of conserving forests

(i) Any tree felled, should be replaced preferably by two trees.

(ii) Stumps should be preserved so that they regenerate to give fresh trees.

(iii)Controlling of forest fires.

(iv) Fast growing artificial forest trees be planted e.g. pine, cypress.

(v) Forest reserves be established and the encroachment on forests be prohibited.

(vi) Tree pests, parasites and diseases be controlled.

(vii) Afforestation and reforestation programmes be increased especially on marginal land or land where cultivation is impracticable e.g. river banks, hill tops, hills and mountain slopes.

(viii) Protect young trees by falling on the mature ones.

(ix) Avoid infamy to the under growth while cutting trees so that the seedlings grow.

(x) People should be sensitised about the value of forests and the importance of forest conservation.

Factors that determine the various forms of land use in Uganda

(a) **Physical**: - Topography, soil type, climate, vegetation

(b) **Social**: - Culture of the people, land tenure system, religious belief, population pressure, education level, skills and knowledge.

(c) **Economic**: - Capital available, market forces, price levels, power supply and entrepreneurship skill.

Population and its effects

Population is the number of people living in an area.

Population density is the number of people living in a given area per sq. km. It can be calculated as: $\text{Population density} = \frac{\text{Number of people in an area}}{\text{Area (km)}}$

Population pressure is a situation where population density is too high for the resources to support it adequately.

Problems associated with high population density on agriculture.

- Increased land fragmentation resulting in reduced productivity.
- Overgrazing leading to soil erosion and low animal productivity.
- Soil degradation through continuous cultivation, pollution from the use of agro-chemicals, polythenes and dumping non-biodegradable chemicals and soil erosion.

- Land reclamation e.g. deforestation and draining swamps leading to change in the rain fall pattern.
- Adoption of intensive farming method.
- Land shortage, reduced food production, increased food demand and thus famine. However there would be increased market size, increased labour supply, increased utilisation of resources and thus productivity.

Climate

This refers to the average weather conditions of an area taken or recoded for a long period $\cong$ 30years

Weather: are daily or average atmospheric conditions of a place at a particular time.

Elements of weather

(i) **Rainfall**: Is a source of water for crops and animals. It is defined as the amount of rain falling within a given area in a given time.

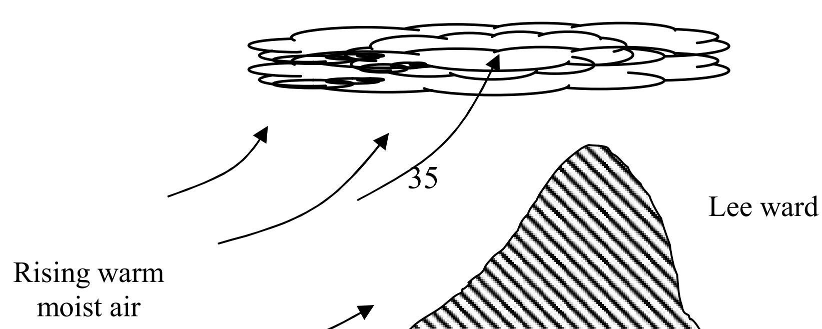
Types of rain and the causes of rainfall

Rainfall is caused when air containing water vapour is cooled. The atmosphere has very cold and warm layers. When air containing water vapour condenses, condensation process forms clouds that eventually yield rain.

Types of rain

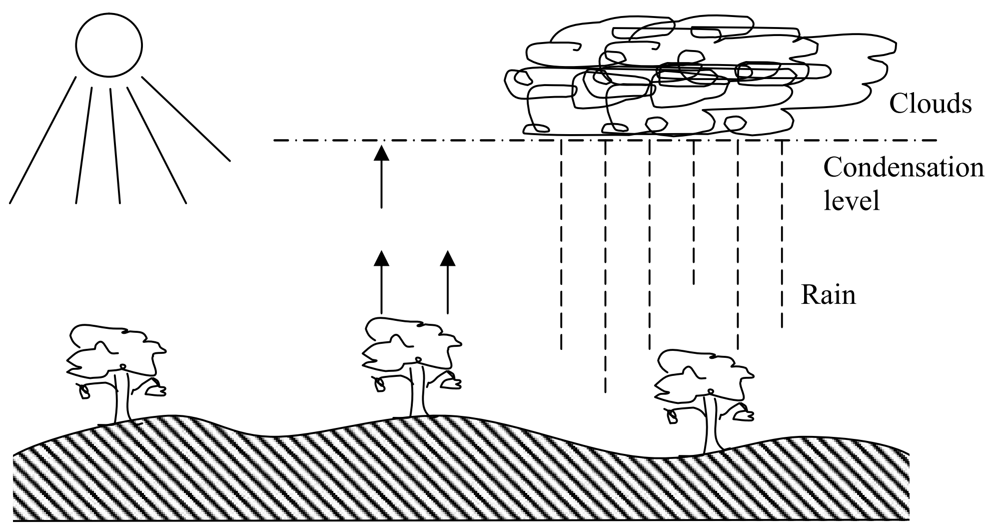
a) Relief rain or Orographic rainfall

Moisture laden wind is forced to ascend a mountain barrier, it is then cooled by the upper layers to saturation and condensation resulting into cloud formation and later rain. More rain is formed on the wind ward side and little or no rain is formed on the lee ward side or rain shadow.



b) Conventional rain fall

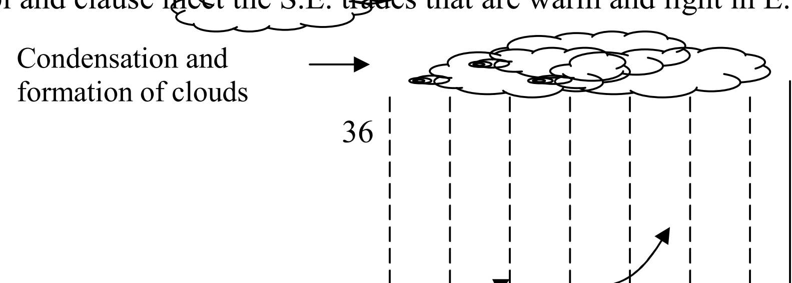
On heating the ground, the sun rays heat up air immediately in contact with the ground. The heated air rises together with water vapour from evapotranspiration process. When this air reaches a condensation level, water vapour condenses out to form droplets of water which then become clouds. The droplets grow bigger, heavier and eventually come down as rain.



This type is everywhere in Uganda and normally late in the evening or at night especially in the dry seasons.

c) Frontal rain fall (cyclonic)

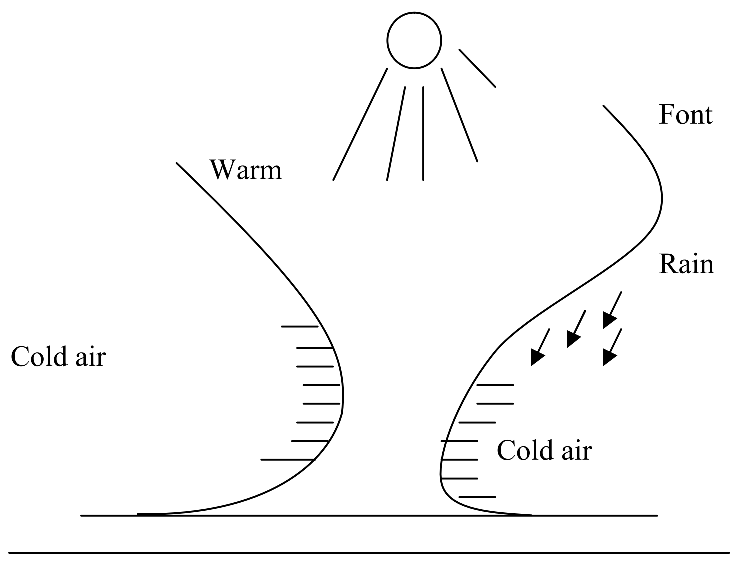
This type of rain is rare in Uganda but common in areas of islands. Large volumes of hot and cold air meet, forming a front. At the front, warm air rises above the cold air and clouds are formed at the border. Rain results from thin cloud. E.g. the N.E trades that are cool and clause meet the S.E. trades that are warm and light in E. Africa.



d) Convergence (ITCZ)

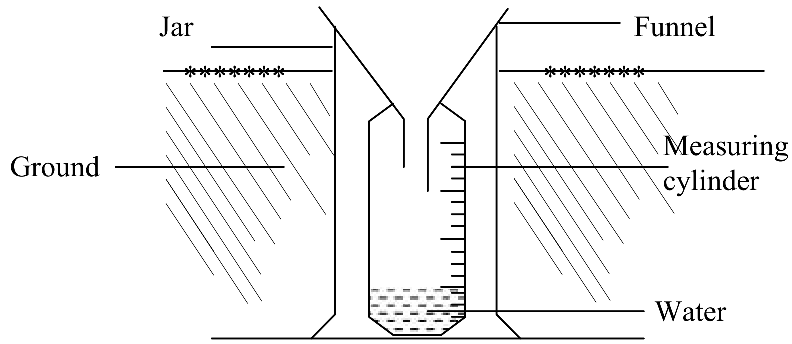
This is characteristic of the tropics and is strictly seasonal. It follows the movement of the earth in relation to the position of the sun (inter-tropical Convergence Zone (ITCZ)). A particular section of the earth is heated intensively by the sun. This creates a low pressure belt around the earth and the heated air raises.

It is the replaced by cold air full of moisture from the N.E. and S.E. that is also heated. The process goes on but later results into heavy cloud formation and rain. This behaviour is seasonal and results in bi-modal and mono-modal rainfall patterns.



Rainfall measurements

Is measured by using a standard rain gauge which is 12.5cm in diameter. The rain fall during the previous 24 hrs is usually measured and recorded at 9.00am each day. At the end of each month, the daily figures are added to give a monthly total. The mean rain fall figure for a place is the average taken over several years.



NB: Isohyets: lines joining places with the same mean annual rainfall.

Terms describing rainfall

(a) Rainfall distribution

This means the way the rain is spread over the year or the pattern in which rain is received in a given area over a given time. E.g. mono modal (uni-modal) or bi-modal. Crop growing and livestock keeping are affected by the way rain fall is received in an area e.g.

- It affects the availability of pasture and water hence affecting animal production.
- Areas with a bi-modal rainfall pattern favour growing of both annual and perennial crops and double production of annual crops.
- Mon-modal pattern favours growing of short term (annual) crops.

(b) Rainfall effectiveness

Is ability of the rainfall to effectively ensure successful growth of vegetation in general and crops in particular.

(c) Rainfall quantity

Is the amount of rain fall received in a given area over a given term. Rainfall received in an area determines what type of crops to grow. N.B: rainfall of 759mm annually is considered to be good for crops.

(d) Rainfall reliability

It is the amount of a place's mean annual rainfall that can be expected. Or. Ability of the rainfall to come as when expected. It is useful in assessing the risks involved in growing a particular crop in any area in a particular year. E.g. unreliable rainfall will disorganise the farming activities and can lead to heavy crop losses.

- It determine the type of farming practice in an area.
- It ensures timely planting so that crops will not be affected by the dry season.
- Unreliable rainfall pattern may delay planting.
- Sudden drought may destroy already planted crops already planted crops and may also affect the growth of the pastures.

(e) Rainfall intensity

Is a measure of the heaviness of rain over a given time. It is measured by recording the amount of rain that fall in a short period e.g. 5-10mins using a recording rain gauge.

NB: The heavier the storm, the higher the intensity.

- High rain intensity will lead to heavy surface runoff and soil erosion and crop destruction but will favour pasture growth while low intensity favours water infiltration.

Humidity

Amount of water vapour in the atmosphere or a measure of the dampness of the atmosphere. It varies with temperature. Warm are can hold more water vapour than cooler air. The max amount of water vapour in a given air at a given temperature can hold is said to be <u>saturated</u> and the temperature is called the dew point.

- The amount of water vapour in a given volume of air, compared to the amount of water vapour required to saturate that volume of air at the same temperature is called <u>Relative humidity</u>

Importance

- Some crops e.g. cocoa and bananas are adapted to the conditions of high humidity.
- High humidity encourages the multiplication of pests and fungal diseases.
- High humidity makes the drying of crops difficult and slow.

- Transpiration is inhibited by high humidity yet transpiration aids water / mineral movement in the plant. This can then lead to accumulation of water in root crops.

Evaporation

Is the process through which liquid water changes into water vapour.

Transpiration

Is the evaporation of water from plant surfaces. Or Process by which plants lose water from the surfaces mostly leaves.

Evapotranspiration

This loss of water from the bare soil, water surface and the leaf surfaces of plants. E.g. evaporation and transpiration processes occurring together of concurrently.

It is measured with the use of and evaporimeter (open container 122cm diameter and 30cm deep)

Wind

Moving air will influence the rate of evaporation and if heavy it can break crops, seed dispersal, pollination, soil erosion.

Temperature

The degree of hotness or coldness. It is measured using a thermometer and temperature influences the rate evapotranspiration, photo synthesis, soil microbe activity, germination of seeds, type of livestock in an area, type of crops.

The hydrologic cycle (water cycle)

This describes the ways in which water is lost from the earth's surface and its return to the earth in form of rain.

Steps / process of the water cycle

(i) The sun rays heat the ground

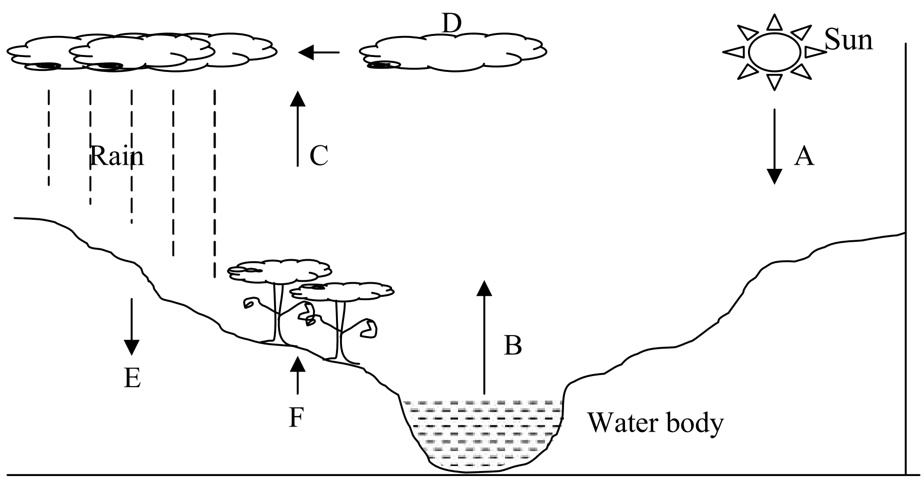
(ii) Evaporation and evapotranspiration from water bodies, plant and animal surfaces and soil surfaces.

(iii) Water vapour rises to the higher levels of atmosphere where it condenses to form clouds

(iv) Rain-bearing clouds will give rain

(v) Rain falls on the ground and water percolates into deeper soil layers and surface run off into water bodies

(vi) Percolated water is absorbed by plants and used in photosynthesis and later lost to the atmosphere through transpiration.



Key

A. Heating of the earth surface by sunrays

B. Evaporation

C. Transpiration

D. Condensation

E. Percolation / sinking

F. Absorption

G. Surface run off

Soil science

1. Introduction.
   - Definition and importance.
   - Composition of the soil.
2. Soil formation (genesis).
   - Weathering.
   - Factors influencing weathering.
3. Properties of soil.
   - Chemical properties (PH. CEC).
   - Physical properties (texture, structure).
4. Classification of soil.
5. Soil profile.
6. Soil fertility.
7. Soil and water conservation.

Introduction

In order to raise crops and animals, the former needs land. Soil forms part of land surface and farmers carry out agriculture on land.

Definition:

Soil can be defined in several ways such as

(i) Soil is a product of the breakdown of rocks by various weathering processes and the decomposition of plant and animal remains.

(ii) Soil is a mixture of weathered rocks, air, water, organic matter and living organisms.

(iii) Soil is part of the earth's crust that supports plants and animals life.

(iv) Soil is a mass of particles with a network of channels filled with air and water bounded by solid surfaces in which roots of plants and animals are found.

(v) Scientifically soil is a mixture of weathered (broken) rock particles and organic matter.

(vi) According to purpose it's where crops are grown or where building are fixed etc.

Function of soil

To an agriculturalist soil performs the following functions:

(i) Provides mineral salts for normal plant growth.

(ii) Provides air which is used by plant roots and living organisms for respiration.

(iii) Provides water in which mineral salts are dissolved before they are translocated within the plant.

(iv) Provides anchorage (support) to plants. (Holds plants in position).

(v) Holds farm structures e.g. building.

(vi) It's a medium for microbial activity or it's a home for soil organisms.

Soil formation (soil genesis)

Soil is formed through two major processes:

(i) Decomposition
(ii) Weathering

As defined above, soil is a mixture of decayed plant and animal material (organic matter) and broken rock particles; therefore it's formed through the process of decomposition of organic materials (plant and animal remains) and weathering (breakdown of rocks into simpler particles).

When rocks break, their particles must be transported and mixed with organic matter to make a soil mixture.

Decomposition

This is the process of decay of dead organisms (plant and animals). This process is aided by organisms and other physical and chemical factors.

Weathering

Is the process whereby rocks are broken down into simpler particles. There are **three** major weathering processes:

(i) Physical weathering
(ii) Chemical weathering
(iii) Biological weathering

In all, weathering is affected by agents such as wind, water, living organisms and temperature changes and chemicals.

Physical (mechanical) weathering

In this type of weathering, rocks break down into smaller particles but their chemical composition remains unchanged.

(i) Changes in temperature

- When the sun heats up the rocks during the day, the rocks expand and at night they contract; this constant expansion and contraction causes cracks in the rocks. The cracks are due to the stresses created as a result of the differences in the rates of expansion of minerals in the rocks.

(ii) Exfoliation

- The outer layer of the rock tents to get heated up easily than the inner one. It expands during the day and contracts during the night when temperatures fall.

  This causes stress that results into peeling of the outer layer.

(iii)Freezing of water (frost action)

- Water enters rock cracks and crevices and when it gets frozen due to temperature fall during winter, it forms ice which exerts force (due to expansion) on the rocks that end up widening the cracks and weakening the rocks.

(iv)Plant roots.

- Expansion of plant roots in the cracks in the rocks exerts pressure in the rock. In the process, rocks disintegrate into smaller particles.

(v) Erosion

- Surface run off carries obstacles that rub against rocks which then breakdown due to the abrasion.
- In addition running water and strong winds dislodge soil particles and deposit them elsewhere.
- Landslides in the mountainous areas also lead to peeling off of rocks and deposition of rock materials to areas in the valleys.

(vi)Earthquakes

- During earth tremors, rocks in the earth's crust may crack, become weak and even break.

(vii) Man's activities

- Such as during construction of buildings, roads, constant cultivation, rocks are constantly broken down into smaller particles.

Biological weathering

This is when rocks are broken down by living organisms or biological agents such as animals, micro-organisms, plants, etc.

- Plants such as lichens, fungi, bacteria colonise rocks. They moisten the rocks and produce organic acids which weaken rocks.
- Later higher plants especially flowering plants grow on the weakened rock surfaces, their roots expand and this puts more force on the rocks.
- Animals are also attracted to these rocks and their activities like burrowing and feeding will further break the rocks. **Earth worms** create drainage routes in the soil. Similarly macro and micro-organisms break down plant and animal remains into humus that is added to the weathered rocks.
- The activities of **large animals,** their movement and trampling effect cause rocks to break down into smaller particles.

Chemical weathering

This involve chemical reactions that change the chemical composition of the rock and in the process they weaken the rocks. It's caused by the reaction of the minerals in the rocks with atmospheric gases such as O_2, CO_2 and H_2O vapour. These reaction are often assisted by higher environmental temperatures. Therefore the major chemical weathering agents are: O_2, CO_2 and H_2O.

Chemical weathering processes

(i) Acidification or solution.

Acids e.g. carbonic acid is formed between the atmospheric CO_2 and rain water. Acidified water reacts with the calcareous rocks formed in the limestone area to form carbonate that are dissolved and corroded by the carbonic acid.

$H_2O + CO_2 \rightarrow H_2 CO_3$. Carbonic acid.

(ii) Carbonation

Occurs when the CO_2 in the atmosphere reacts with the bases in the rocks to form carbonates and bi-carbonates. Many bi-carbonates are soluble and then washed away by water or absorbed by plant roots.

e.g. $Ca(OH)_2 + CO_2 \rightarrow CaHCO_3 + H_2O$

$2 KOH + CO_2 \rightarrow K_2 CO_2 + H_2O$

(iii)Oxidation

- The minerals in the rocks react with the atmospheric O_2 to form metallic oxides that are weaker than their original minerals. These minerals then easily crumble especially in dump conditions. E.g. Laterites (reddish hydrated aluminium and Fe oxides are produced by oxidation)

  $Fe CO_3 + O_2 \rightarrow 2 Fe_2 O_3 + 4 CO_2$

- Oxidation is mainly common in rock minerals containing iron a reason why clays in poorly aerated and poorly drained areas are blue-grey while those in well aerated and well drained areas are red or brown due to oxidation.

(iv)Hydration

Is a reaction between water and minerals in rocks to form hydrated compounds (hydrates). The hydrates formed are weaker than their original minerals.

$Fe_2 O_3 + H_2O \rightarrow Fe_2 O_3 H_2O$

Red

Haematite + water → yellow hydrated

Iron oxide (goethite or limonite)

Note: the hydrated compound also contains water of crystallisation and when this occurs, the rocks will expand and when the water evaporates, the rocks contract and this leads to stress. That leads the breakdown of the rocks.

(v) Hydrolysis

– Is chemical reaction between water and the chemical bonds of the rock element. The H_2 in water reacts with the rock elements by replacing the metallic cations of minerals with H-ions. E.g.

$CaSiO_3$	+	$2H_2O$	→	H_2SiO_3	+	$Ca(OH)_2$
Calcium silicate	+	water		Silic acid	+	calcium hydroxide

Note: Hydrolysis helps in the decomposition of Feldspars that disintegrates by dissolution.

e.g. $KAlSi_3O_3 + H_2O \rightarrow HAlSi_3O_3 + KOH$

(vi) Reduction

Is a reaction that occurs when O_2 molecules are removed from mineral compounds in the rocks. This leads to decomposition and crumbling of the mineral compounds.

$2Fe_2O_3 \rightarrow 4FeO + O_2$

Factors affecting soil formation

The rate of weathering / soil formation, the type of soil formed and the depth and chemical nature of soil formed is influenced by the following factors.

(i) Climate e.g. rainfall, temperature, wind
(ii) Parent rock material
(iii) Topography / relief / terrain
(iv) Living organisms
(v) Time

Climate

- Influences the nature of weathering, type of vegetation and living organisms in an area.
- Rain carries out both physical and chemical weathering.
- Rainfall also determines the rate of erosion of soil in the area.
- Temperature changes causes peeling of rock layers and breakage of rocks.
- Wind blows sand particles against rocks causing abrasion of rock surfaces.
- Chemical weathering is faster in warm and damp conditions.

Parent rock materials

- This refers to the material or type of rock from which a given soil originates, e.g. sedimentary, igneous, granitic and metamorphic rocks.
- Soil from the different rocks are different both in physical and chemical composition. E.g. granite rocks form sandy soil while volcanic rocks produce clay soils.
- Soft rocks e.g. igneous are easier to break thus produce more deeper and fertile soil than the hard sedimentary rocks like sand stone.

Topography

- The nature of the landscape will affect the rate of weathering, soil depth, soil type as a result of the nature of vegetation.
- On a flat land, there is more soil formed and accumulated due to little erosion, steep slopes have higher rate of rock weathering because of exposed rock surfaces are acted on by weathering agents.
- In the valleys there is soil accumulation and thus deep fertile soil are formed.
- Topography influences the type of vegetation and amount of vegetation thus the type of soil formed.

Time

Soil formation is a slow process thus the longer an area experiences soil formation processes, the more the soil that is formed thus, soil that are deep are usually associated with longer periods of soil formation, while young soil are associated with limited time of soil formation.

Living organisms

These include vegetation cover, plant roots, lichens, bacteria, fungi, burrowing animals, earth worms, termites, large animals and man's activities.

E.g.
- Vegetation decomposes to form organic matter. The type of vegetation determines the type of soil formed.
- Lichens and fungi colonise rocks and weaken them.
- Burrowing animals break up weakened rocks.
- Animal's hooves breaks up rocks.
- Man through his activities breaks up rocks.
- Micro-organisms e.g. bacteria help in decomposition of vegetation.

- Plant roots widen and break rocks as they enter their cracks.
- Termites break vegetation and aid in decay. Earth worms mix up the soil particles and organic matter.

The process of soil formation.

This can be summarised into four major stages.

(i) Disintegration

This is the breakdown of rocks into smaller particles by agents

(ii) Decomposition

Is when organic material produced by plants and animals are broken down by other living organisms (decay) to form organic matter. Organic matter produces nutrients which are used by plants which plants further break rocks. Organic matter also produces organic acids and help in weathering rocks.

(iii)Translocation:

Is the removal of organic material and rock material by agents such as water and wind. This help in the mixing up of the materials to form soil.

(iv)Deposition

Is the laying down of the translocation materials as soil. These mixed and deposited material form soil but still under go further transformation to form mature soil.

The soil profile

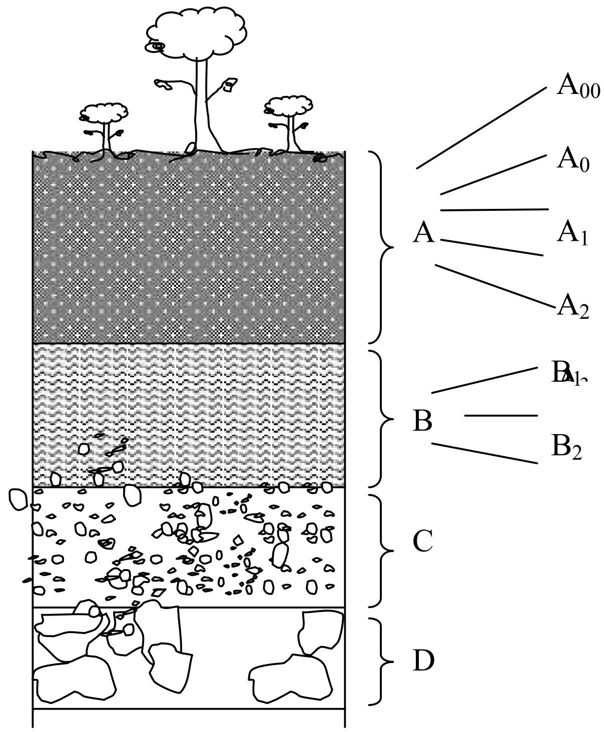
This is the vertical arrangement of soil layers from top to bottom. It can also be defined as the cross section of soil layers from top to bottom. The soil profile has got layers called **HORIZON**

- The horizons are made up of small layers called **solumns**. These layers are different in colour, texture composition and mineral matter.
- The depth of the profile varies from place to place and this is due to:-
  - amount of soil deposited as result to weathering.
  - the effects of soil erosion.

– The distinct horizons in the profile represent soil layers at different stages of development. The formation of these layers takes a long time, and soil that have distinct profiles are known as **MATURE** while those without clear profiles are referred to as **YOUNG SOIL**.

Layers of atypical profile

A. ~~Top so~~il
B. ~~Sub so~~il
C. ~~Stony~~ layer (partially weathered rocks).
D. ~~Bed ro~~ck (parent rock)



Characteristics of the horizon.

D. Bed rock:

– This forms the bed rock (parent rock) which has not been weathered. It is impervious water.

C. Substratum (stony layer)

– It is a region composed of small stones (gravel) that originate from the parent rock and some red soil.

- These stones are still undergoing weathering. It is also called the unconsolidated parent material.
- The region is more compact than the B-horizon and is poorly aerated.

B. **Sub soil**

- It is brown / reddish in colour due to iron oxide.
- It is a zone of illuviation (accumulation) where mineral salts washed away from the A-horizon are deposited.
- It is more compact and poorly aerated.
- It has fewer micro-organisms and organic matter.
- There is a tendency of developing a hard pan in this region due to ploughing at the same depth seasonally.
- This horizon can be divided into **three** colums.

B_1, B_2 – It has all characteristics of the above

B_3 Transitional layer

- In B, there is maximum development of blocky and prismatic soil structures.

A. **Top soil.**

- It is dark in colour due to humus.
- Most of the plant nutrients are found in this layer.
- It is well aerated, more subjected to cultivation and weathering.
- It is sometimes called the zone of eluviation as minerals are washed away and deposited in B horizon.
- It has a crumb structure due to frequent cultivation and deposition of organic matter from decomposing plants and animal remains. The top soil can also be devided into several solums as shown below.

A_{oo} - Litter.

A_o - Raw humus (particularly humified).

A_1 - Humus incorporated (humified).
- Dark coloured mineral horizon.

A_2 - Leached (eluvial zone) and bleached.
- Light coloured mineral horizon.

A_3 - A transitional layer i.e. it exhibits some characteristics of B_1 zone or solum.

Influence of soil profile on crop production

Depending on its depth, the profile;

- Provides anchorage to crops.
- Provides water, air, favourable PH
- Provides the environment for optimum micro-organism activity.
- Determines water holding capacity, surface run off and ease of erodability.
- Determines soil workability as deep soil are easier to work and mechanise than shallow soil.

  NB. A good soil profile;
  - Should have a well developed structure
  - Should have a well developed texture
  - Should have a well developed depth
  - Should be firm enough to resist erosion

    All the above are intended to influence
    - Soil aeration
    - Water holding capacity of the soil drainage
    - Plant root penetration and development

Soil constituents

Soil is composed of the following

(i) Air
(ii) Water
(iii) Mineral matter
(iv) Organic matter
(v) Living organisms

Qn. Give the importance of the above soil constituents and describe experiments to determine their presence as well as estimating their qualities in a given soil sample.

The major processes of soil profile formation.

These mainly include:

(i) Weathering
(ii) Leaching
(iii) Eluviation
(iv) Illuviation
(v) Laterization due to oxidation of minerals.
(vi) Mineralisation, where organic residue are broken down to form inorganic chemical components.
(vii) Humification, where organic matter is decomposed to form humus.

NB. A soil profile lacking some layers due to soil erosion is called a **truncated** soil profile.

The soil catena

This is the horizontal sequential arrangement of different types of soil along a slope. The soil types though different, develop from the same parent rocks but differ from the top of a hill along the slope to the valley bottom due to: - Weather, vegetation, drainage and topographical changes.

Soil catena is important practically because it helps to determine sustainable land use.

The difference between soil profile and soil catena.

Soil profile

- Vertical section of layers.
- Largely influenced by climate through weathering, leaching and eluviation.
- Classified according to its characteristics in terms of colour, mineral content, organic matter, content of the same soil type.

Soil catena

- Horizontal arrangement of soil along a slope.
- Mainly influenced by relief and drainage.
- Centres around changes in surface soil types and therefore it is about variation in types of soil profile.

Diagram to show a soil catena according to drainage

Key:

1. Excessively drained
2. Freely drained
3. Perfectly drained
4. Poorly drained
5. Very poorly drained.

Soil composition

(a) The mineral particles

- These are inorganic compounds formed from weathered rocks. They form 45% of the volume of the soil. They also make up the mineral part of the soil that supplies the elements for plants and animals and are referred to as mineral salts.

Importance of the mineral particles.

- They supply the necessary plant nutrients for plant and animal nutrition.
- They provide the surface on which soil water is held.
- They hold plant roots in place.
- They form spaces in soil for air and water.
- They make the frame work or skeleton of the soil.
- They influence the chemical and physical properties of the soil.

The mineral particles differ in size and in texture. They can be classified as:

Gravel	2 mm > 2.0 mm
Coarse sand	2.00 – 0.2 mm
Fine sand	0.2 – 0.02 mm
Silt	0.02 – 0.002 mm
Clay	< 0.002 mm

An experiment can be carried out to show that soil is made of different sized mineral particles (rock particles)

Materials:

Loam soil (150g), water, a measuring cylinder 250mls, sodium carbonate.

Method:

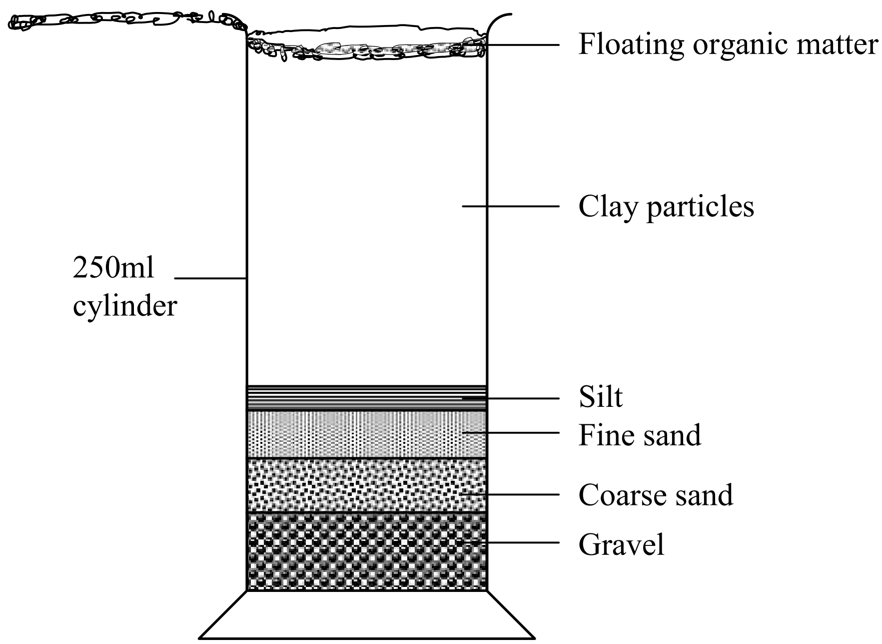
– A handful of soil 150g, is put in a measuring cylinder. Water is added to the soil about 4x the soil volume.

– Some $NaCO_3$ is added to the mixture to help in the dispersion of soil particles.

– Shake vigorously to mix the contents and allow the contents to settle for ≅ 40 minutes.

Observations

The mineral particles sediment and settle according to size. Gravel settles first, course sand, fine sand, silt and clay. Humus with the smallest colloidal particles floats at the top as shown below.



Soils often inherit the mineral content of the parent material though this may be altered leaching and deposition or by human action.

– Soils may be termed "mineral soils" if they consist predominantly of inorganic matter; and not more than 10% organic matter.

– Organic soils are those that contain 75% - 90% organic matter. They are formed by extensive deposits of organic matter in swamps and marshes where the rate of decomposition is low due to the poor drainage and thence poor aeration.

(b) Soil water (soil moisture)

– Water is held between the soil particles in the macro and micro pores (spaces)

Importance of soil moisture

– Needed for seed germination.
– Necessary for photosynthesis and starch formation in plants.
– Necessary for cell division hence growth of plants.
– It dissolves the plant nutrients in the soil so that they can be absorbed by the plant roots.
– It dissolves and dilutes salts and other toxic substances in the soil that may be harmful to the plants.
– Maintains the humidity of the plant cells so as to function effectively.
– Provides nourishment to the soil organisms.
– Regulates soil PH
– When absorbed, it makes the protoplasm and cell sap of the growing plants.
– Necessary for the transportation of mineral salts and translocation of the manufactured food.
– Necessary for the formation of proteins.
– Maintains the life of soil organisms.
– Has a cooling effect on the soil and plants; eases cultivation.
– Needed in the chemical weathering of rocks during soil formation.
– Provides a conducive habitat for the water-loving and dwelling microbes.
– Controls the amount of soil air.
– It is essential to satisfy the plants' "evapo-transpiration" requirements.
– Minimises soil erosion especially due to wind.
– The availability of soil water to plants is influenced by several forces that reduce the ease of flow or the free energy of water. These forces include:

(i) Adsorption by soil solids

- This water is tightly held by the soil solids in very tiny pores or as a thin film around the soil particles that it cannot be used by the plant.
- Also the soil water molecules so held attract other water molecules by cohesion.
- Water so held is called **HYGROSCOPIC** water.

(ii) Gravitational pull

- This removes some of the water from the rooting zones making it unavailable to the plants. It makes some of the water to flow through the soil to the lower layers. Where it cannot be used by plants.

(iii)Capillary forces

- These resist soil water movement except to the differences in the free energy of water between adjoining layers.

(iv)Osmotic forces

- The water may be attracted by ions and other solutes in the soil solution making it hard for the plants to absorb it.

  NB. Available water for plant use is that water that is in excess of that held by these forces.

Water levels in the soil (Types of soil water)

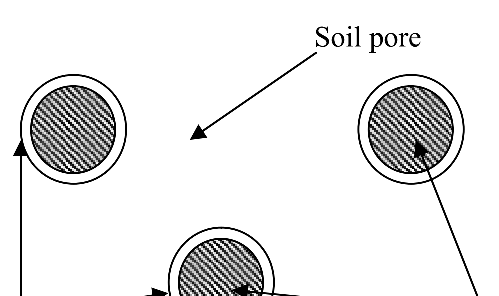
1. **Gravitational water**
   - Is the excess water that even overflows on the soil surface. It occupies the all the soil pores reducing soil aeration.

2. **Field capacity water**

   Is the water level that just fills up the soil mass. It fills up the macro and micro pores becoming unavailable.

3. **Capillary water (available)**

   Is the water that is held in the micro pores of the soil particles and it surrounds the particles. It is easily absorbed by the plant roots. And thus is available water.



4. Hygroscopic water (unavailable)

Is water held tightly by the soil particles. It is so little that it is almost in the vapour or gaseous form. Higher plants cannot absorb it by some micro-organisms may use it.

Permanent wilting point.

Is a situation where plants remain wilted throughout the day and night due to limited soil moisture.

At this point, the soil is so dry the even the little water that remains in the micro-pores is tightly held by particles particularly the colloids.

An experiment to find out the amount of water present in a given soil sample.

Requirements

Evaporating dish

Fresh farm soil

Heat source

Method

Heat the evaporating dish containing the soil with a Bunsen burner flame at 100^0C sor $\cong$ 1hr.

Calculation

– Weight of the evaporating dish	D gms
– Weight of the fresh farm soil	5 gms
– Weight of the fresh farm soil and dish before heating	(5+D)gms
– Weight of the fresh farm soil and dish after heating	(5+E)
– Weight of soil alone after heating	(S+E-D) = Egms

NB: In order to detect the presence of water, cover the evaporating dish with a glass as the heating is going on.

Observation

Presence of moisture on the glass under side is a resultant of water evaporating from the soil sample.

– Weight of water that has evaporated S-E
– As a percentage.

$$\frac{S-E}{S} X\ 100 = \frac{\text{Wgt of evaporated water}}{\text{Wgh of fresh soil sample}} X\ 100$$

(c) Sol air. (O_2, CO_2, N_2)

This air is found in the spaces between particles that are not occupied by water. **There are two types of air pores.**

Types of air pore.

– Macro air pores
– Micro air pores

Importance of soil air.

– It is necessary for the respiration of plant roots and the soil organisms.
– CO_2 helps to dissolve nutrients and make them more available for plants.
– N_2 is needed by microbes for their protein formation.
– Water vapour prevents desiccation by the plant roots and soil microbes and helps in the transfer of water within the soil.
– O_2 is needed for the seed germination
– Good air circulation dilutes dissolved CO_2 that may be toxic to the plants and other organisms.

NB: A balanced supply of O_2 is essential since too much O_2 encourages a very rapid breakdown of organic matter while too little O_2 encouraged the multiplication of anaerobic bacteria that use up the O_2 in organic and inorganic compounds, reducing them to sulphides, nitrites and others are reduced to compounds that are dangerous to plants.

- O_2 is needed in the decay process
- N_2 is used by plants for their metabolism.
- Soil air is usually renewed by the processes of diffusion, mass flow and rain.

The amount of soil air is affected by:-

(i) Amount of water: The more the water the less air in the soil.

(ii) Soil depth: The deeper one goes in the soil, the less air because of compaction and shortage of organic matter.

(iii) Soil structure and texture; A granular and crumb structure encourages better aeration than a platy structure.

(iv) Type of soil; Sandy soils are aerated than clay soils.

(v) Organic matter content; This improves the soil structure and thus creating more pores.

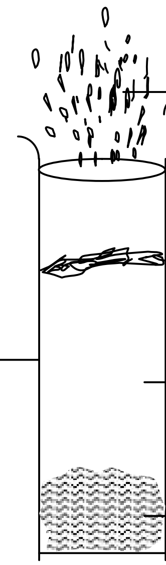
Effects of poor aeration.

- Reduced microbial activities, reason why earth worms come out of the soil on a rainy day.
- Increased denitrification.
- Reduced root growth
- Reduced energy for root absorption leading to wilting and yellowing of leaves.
- Toxic substances are formed such as hydrogen sulphide and methane from organic residues.
- Discolouration and mottling of soil due to reduced metallic oxides.
- Harmful V.F.A. from fermentation due to anaerobic conditions damage seedlings.
- Cell membranes become leaky.
- Endogenous ethylene is produced that causes abnormal plant growth like leaf epinasty (the leaf's down ward curvature of the leaf axis).
- Ammonia, amines, sulphides, Fe, Mn and nitrates that are toxic increase as nitrates and sulphates decrease.

Experiment to determine air presence and estimation of air in soil sample

Materials

- Dry soil sample
- Measuring cylinder
- Water



Method

- Add the dry sample of soil to the cylinder containing water.
- Bubbles are seen as air escapes from the dry soil sample to be replaced by the water molecules
- Shake well to mix and let the mixture to settle.

Calculations

Expected volume	=	100 + 100	$200cm^3$
Actual volume	=		$198cm^3$
Air volume	=	200 – 198	$2cm^3$

$$\% \text{ Air} = \frac{2}{100} \times 100 = 2\%$$

$$\text{i.e.} \quad \frac{\text{Vol. of Air}}{\text{Vol. of soil}} \times 100$$

(d) Living organisms

Some of these organisms are large enough to be seen with the naked eye. i.e. macro-organisms, while some are too small to be seen with the naked eye. i.e. micro-organisms. (Microscopic)

Others belong to the plant kingdom i.e. soil flora while others belong to the animal kingdom i.e. soil fauna. Examples, bacteria, fungi, algae, plant roots, rats, snakes, moles, termites, ants, earthworms, nematodes, snails and other insects.

The contribution of the soil organisms depends on whether they are symbiotic, parasitic or saprophytic in their feeding. Rhizobia, mycorrhiza and algae with azotobacter are all symbiotic relationship; eelworms in tomatoes, basidiomyceter in maize are parasitic relationship.

So they are both useful and harmful.

Importance of soil living organisms

- They add humus to the soil when they die and decompose.
- They help in the decomposition of organic matter.
- The symbiotic and non-symbiotic bacteria fix N_2 in the soil i.e. rhizobia and azotobacter
- Burrowing animals such as regents help to mix up different soil layers and organic matter with the main body of soil.
- They produce organic acids that help in the weathering of rocks.
- Burrowing animals help to improve aeration, drainage and water infiltration into the soil.
- Some increase the nutrient content of the soil such as Ca from earthworms.
- They increase stability of soil aggregates e.g. earthworms, snails and some bacteria, earthworms ingest soil particle and egest them in granular form, snails have a slimy / gummy substance on their bodies that binds soil particles together. Some bacteria secret substances that help to hold the soil particles together.
- Some fungi and bacteria produce antibiotics e.g. aspergillus and penicillium that are both fungi, actinomyceters produce streptomycin and aerobic spore producing bacteria produce tyrothricin.

- Some produce toxins that cause many plant diseases e.g. wilt in tomatoes, root gals on plants, scab on plants.
- They carry out inorganic transformations e.g. in well drained soils, Fe and Mn are oxidised to higher oxidation states that have lower solubility at medium PH. This minimises the risk of nutrient toxicity.
- Algae temporarily transforms soluble forms of Na and other nutrients into organic or insoluble forms and thus reduces leaching of soil nutrients.

Factors influencing abundance of soil living organisms

(i) Tillage practices

- Tillage equipment can kill some organisms
- Improves aeration and drainage increasing breakdown of organic matter.
- Can lead to a drop in organism population due to reduced organic matter from increased breakdown of organic matter.

(ii) Soil depth

- Deep soils favour abundance of living organisms as they offer more space for escape from extreme environmental conditions, however at a certain soil depth their population reduces due to limited food and air.

(iii) Types of crops grown

- Blue-green algae is common in rice fields, rhizobial in legumes while mycorrhiza is common in tree crops e.g. pine and oak.

(iv) Amount of water in the soil.

- Most organisms require moist soil conditions but too much water may encourage some moulds.

(v) Soil aeration

- Absence of O_2 may reduce the population of aerobic organisms but will increase that of anaerobic and facultative organisms.

(vi) Soil temperature

- Most organisms live only within a given temperature range.

(vii) Soil PH

- Most bacteria and earthworms do well in slightly alkaline soil while fungi will be favoured by acidic soils.

(viii) Mineral nutrients in the soil.

- Especially Ca and N. Most if not all organisms require these nutrients for their bio-chemical activities.

(ix) Competitions between organisms.

- Some organisms produce substances that kill others e.g. some fungi produce antibiotics that kill bacteria.

(x) Organic matter content

- Many soil organisms use organic matter for food. Thus the higher the organic matter the higher their population.

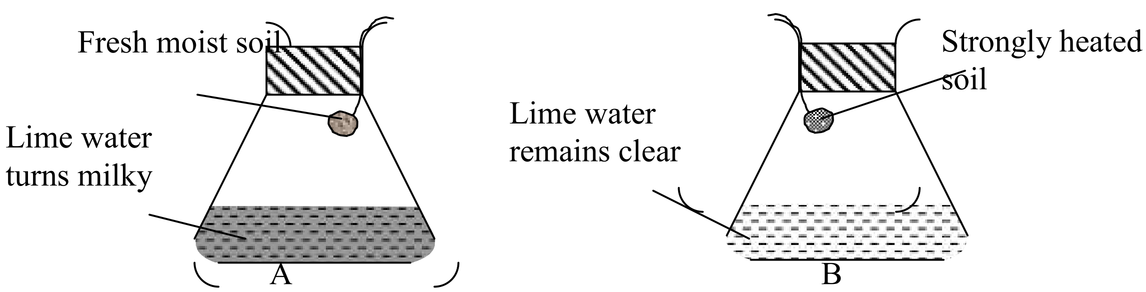
(xi) Pollution

- This reduces their population

(xii) Introduction by man

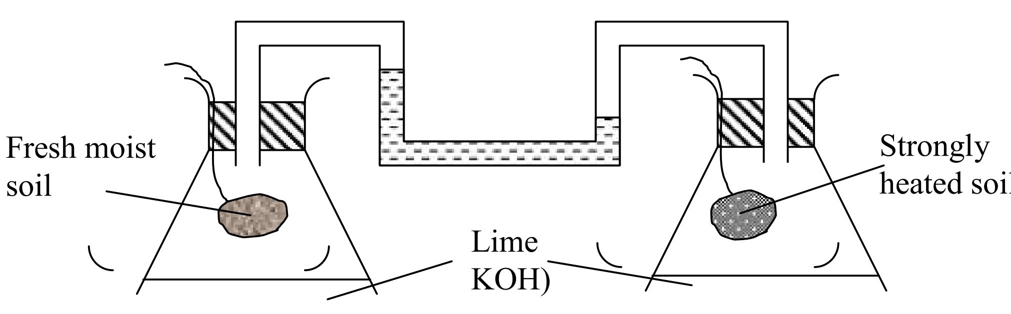
- Addition of manures introduces more living organism into the soil.

Experiment to show that soil contains living micro-organisms.



In B lime water remains clear as the soil hanging does not have living organisms that were killed by strong heating. In A the organisms produce CO_2 that reacts with lime water.

Experiment to find whether soil contains mico-organisms which take in O_2 to give of CO_2



- The water level in the left hand arm raises up due to the vacuum created by the absorbed CO_2 produced by respiration of the living organisms.

(e) Organic matter

This is the non-mineral position of the soil solids. It is composed of partially decayed plant and animal residues.

Organic matter is composed of carbohydrates, lignin, proteins, minerals, fats, resins, tannins and pigments. However, lignin and proteins make up the bulk of the organic matter in the soil because they are more resistant to decay.

Organic matter is grouped into three main components.

(i) Litter; the relatively undecomposed dead parts of the plants and animal excreta that have first recently been deposited onto the soil surface.

(ii) Residues; the dead parts of plants, animals and excreta that is still actively decomposing.

(iii)Humus; the well decomposed and stable organic matter that is relatively resistant to further decay. It's dark brown, semi liquid and is composed of CH_2O, protein and small amounts of S and P.

Soil colloids.

These include all organic and non-organic particles that are very small in size and with a large surface area per unit of mass. They include clay and humus.

Importance of organic matter in the soil

- Is a source of plant nutrients.
- Provides food and shelter for the soil living organisms.
- Makes the soil dark in colour and this helps in temp conservation.
- Improves the soil structure by binding the soil particles together especially in sandy soil.

- Holds more water for the soil.
- It improves soil aeration and capillary in the soil.
- It's a source of energy and general nourishment for the soil microbes.
- It buffers / controls the soil PH.
- It increases the CEC of the soil.
- It improves the water drainage and infiltration in the soil.
- It contains hormones and vitamins that stimulate plant growth e.g. auxins and gibberellins.
- It releases organic acids during decomposition and also helps in the process of soil weathering.
- It provides sites for attachment of mineral ions thus increases the nutrient holding capacity of the soil and reduces leaching. It also adsorbs gaseous N_2 released from the soil and prevents its escape.

Factors affecting the rate of decomposition of organic matter.

(i) Plant factors e.g. age moisture content C:N ratio e.g. legumes decompose faster as they have a narrow C:N ratio thus microbes do not suffer from N- surface unlike in the cereals.

(ii) PH of the material and other chemicals e.g. extreme PHs do not favour decomposition.

(iii) Presence of living organisms.

(iv) Climatic factors e.g. suitable temperature and rainfall.

(v) Soil factors e.g. suitable soil structure, moisture, nutrient level for the microbes to use. All these influence the speed of bi-chemical reactions.

Properties of organic matter.

Has both physical and chemical properties that makes it suitable for crop production.

Physical properties.

- Low plasticity and cohesion i.e. it cannot be moulded unlike clay particles.
- Black or dark in colour.
- It is gummy and has a cementing action on soil particles.
- It is spongy i.e. has many spaces or pores that may be used to hold water or air.

- It becomes more colloidal with further decay and humus is typically colloidal giving it a large surface area for adsorption of ions.
- It becomes amorphous with further decomposition.
- It is a light material with a low bulk density.
- It is insoluble in water but soluble in dilute alkaline.

Chemical properties.

- It has a high C.E.C. i.e. high capacity to adsorb and lose cations or exchange one cation for another.
- It has a strong adsorbing power for mineral ions.
- It has a zwitterion capacity i.e. the ability to release either cations or anions to plants. It contains plenty of mineral ions that can be used as nutrients.
- It can release both H^+ and OH^- ions and so can buffer soil PH.

Factors affecting the level of organic matter in the soil.

(i) Climate's influence on amount of vegetation and microbes.

(ii) Type of vegetation e.g. forests vs. grass lands.

(iii) Topography e.g. valleys have more organic matter.

(iv) Time and age of soil e.g. young soil Vs old soil.

(v) Parent materials e.g. clay absorb humus.

(vi) Cultivation practices e.g. over cultivation, bush burning removal of vegetation, minimum tillage.

How can the level of organic matter be increased?

- Apply organic manure.
- Minimum tillage or zero tillage.
- Organic mulching.
- Ploughing back organic residues.
- Liming to increase microbe activities.
- Proper drainage.

Experiment to find out the amount of organic matter in the soil

Heat a known vol. of dry soil at 100^0C for 45mins stirring to evaporate all the water (oven drying)

- Allow it to cool down and weigh it.
- Heat again and observe the colour changes as humus is burnt. Cool the soil when there is no further colour change and weigh it again.

Calculations

- Weight of dry soil + crucible before strong heating Xgms.
- Weight of dry soil + crucible after strong heating Zgms.
- Weight of organic matter / humus that is burnt

$= X - Z$ gms

$$= \text{of O.m} = \frac{\text{weight of O.m}}{\text{Weight ofdrysoil}} X100 = \frac{X = Z}{X} X100$$

Soil Properties

This is the description of the nature of soil. The properties are divided into physical and chemical properties.

Physical properties include: - Texture - Structure

Chemical properties include:

– Colour	– Drainage	– Cation exchange capacity
– Fertility	– Percolation	– Water holding capacity
– Capillarity	– Aeration	– Soil mineral salts
– Percentage base saturation	– Organic matter content	– Buffer capacity
– Soil temperature	– Soil ph or soil reaction	– Soil consistence
– Bulk of density	– Particle density	– Plasticity

Chemical properties of soil

Cation Exchange capacity

A cation is a positively charged element and an anion is a negatively charged element in the soil solution.

Cation and anion exchange is the exchange of one of them for another similarly charged element on the surface of the colloid.

C.E.C. is the capacity of the soil calloids to adsorb nutrients or release them at a particular soil PH. It is measured in milli-equivalent weights. C.E.C increases as PHincreases while AEC increases as the PH decreases.

Percentage base saturation

This is the proportion of the cation exchange that is occupied by bases as Ca, K, P, Mg, Na, etc.

Buffer capacity

It is the capacity of the soil to resist abrupt changes in PH, hence maintaining equilibrium (balance)

Soil PH / Soil reaction

This is the acidity and alkalinity of the soil.

Causes of soil acidity

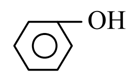
Soils high in H^+ and Al^{s+} ions tend to be acidic in nature this is common in areas with very high pacipitation that leaches the bases out of the soil (bases include Ca^{2+}, Na^+, Mg^{2+}, Mn^-, Mo).

- On the other hand alkalinity occurs in soils with a comparatively high degree of base saturation. The presence of salts especially Ca^{2+}, Mn^{2+} and $Na_2\ CO_3$ causes alkalinity.
- This is common in arid and semi-arid areas.
- Where the H^+ or Al^{3+} and the OH^{-1} or bases balance, the soil in said to be neutral.
  (i) Presence of soil soluble salts in the soil which may be acidic.
  (ii) Presence of sulphides that causes the production of H^+.
  (iii) Application of acidic fertilizers e.g. urea, ammonium, nitrate, $NH_4\ SO_4$ and others containing the NH_4 group that hydrolyse to give many H^+.
  (iv) Leaching of bases that are then replaced by either H^+ or Al^{3+}. This is common in heavy rain fall areas and where there is frequent irrigation.

(v) Acidification due to rain water and factory emissions e.g. carbonic acid, sulphur dioxide from factories mixes with rain to form H_2SO_4, nitric acid from atmosphere N_2 mixing with rain.

(vi)Formation of soil from acidic rocks e.g. granite that contains quartz or silica. The reaction between silica and H_2O leads to the formation of silic acid.

(vii) Inorganic acids from microbial decay e.g. H_2SO_4, HNO_3.

(viii) Presence of organic matter or humus. These have the OOH, Phenolic 

and the NH_4. The H^+ saturated groups behave like acids in the soil.

- Humus also reacts with Fe and Al^{3+} to form complexes and hydrolyse to produce more H^+.

$$Al(OH)^{2+} \rightarrow OH\ Al(OH)_2 \rightarrow H^+$$

(ix)Water logging; excess water causes hydrolysis of some cations in the soil and are replace by H^+.

(x) Absorption of by the cultivated plants. The cations absorbed are replaced by $H^{+.}$ Decomposition of O.m to form CO_2lead to carbonic acid.

(xi)Nitrification, as an oxidative process that causes soil acidity because H^+ are released.

Sources of Hydrogen ions

The sources of H^+ may be classified as permanent or PH dependant. Permanent sources are those located on the internal surfaces of the clay crystal.

- PH dependant are found at the broken edges and are external surfaces of silicate clays and from the humus calloids. As the PH increases, the H^+ are released into the soil solution.
- Aluminium causes soil acidity by first forming Al. hydroxyl ions.

  $Al^{3+} + OH \rightarrow Al(OH)^{2+}$ or

  $Al(OH)^{2+} + OH \rightarrow Al(OH)_2$

  The Al. hydroxyl ions react with the H_2O to release H^+ i.e.

  $Al(OH)^{2+} + H_2O \rightarrow Al(OH)_2 + H^+$

  $Al(OH)^{2+}$

Sources of hydroxyl ions

- If the H^+ and Al^{3+} are replaced by cations e.g. Ca, Mg, and K, the concentration of H^+ will decrease. The OH^- concentration will simultaneously increase since there is an inverse relationship between H^+ and OH^-.
- The cations liberate OH^- when they hydrolyse i.e.

  Ca (micelle) + $2H_2O$ → 2H(micelle) + Ca^{2+} + $2OH^-$

Active and reserve acidity

- The hydrogen ions in the soil solution constitute the active acidity of the soil.
- The H^+ and Al^{3+} ions held on the soil colloids are the reserve or exchange acidity of the soil.
- Soils therefore have a buffering capacity whereby removal of H^+ from the soil solution results in their being replenished by the reserve acidity, where H^+ would move out of the soilcolloids into the soil solution ensuring only a slight change in PH.
- When more H^+ are added to the soil to the soil, a temporally increase in the concentrate of H^+ occurs in the soil solution and H^+ would the be removed from the soil colloids and adsorbed on the soil colloids, and the PH change would be small.

  NB. The buffering capacity of soils is dependant on the adsorbed cations in the soil.

Influence of soil PH

(i) It affects the availability of plant nutrients e.g. N at 6-8, P is unavailable at extreme PHs, Mn, K, Bo, Fe and Zn are less available at PHs above 8.5, Ca is deficient at low PH the same with N, P, Mo.

(ii) Affects the activity and distribution of micro-organisms in the soil e.g. bacteria are more available and common at high PH while fungi are common at low of PH. This influences disease prevalence in the soil.

(iii) It determines different crops to grow in different soils e.g. Barley grows best in alkaline soils, Tea in acidic soils while Oats in neutral soils.

(iv) Controls the type of fertilizer to be applied e.g. sulphate of ammonia should not be applied in acidic soils continuously.

(v) Acidic PH makes some nutrients to be toxic e.g Al, Fe, Mn.

Causes of alkalinity

Any process which encourages the build up of exchangeable bases e.g. Ca, Mg, K and Na or those that permit them to remain in the soil encourage alkalinity. E.g.

(i) **Weathering**: The soil may have been formed from alkaline parent material e.g. limestone or calcitric rocks.

(ii) Addition of base containing materials to the soil e.g. lime.

(iii) **Irrigation:** The water contains salts that release cations that are adsorbed by the soil colloids increasing alkalinity.

(iv) **Drought;** reduces precipitation and leading of the bases.

(v) **Ground water** may carry bases into the soil in low topographic positions and leave them there when it evaporates.

Measurement of (soil) PH

It's measured using a scale ranging from 1-14 and 7 is the neutral PH. The acidity of the soil increases as the PH values decrease, while alkalinity increases as the PH values increase.

PH colour chart

PH	**1 – 2**	**3 – 4**	**5 – 6**	**7 – 8**	**9 – 10**	**11 – 12**	**13 – 14**
Colour	Red	Pink	Yellow	Green	Blue	Indigo	Dark blue
Degree	Strong	Moderate	Weak	Neutral	Weak	Moderate	Strong

Determination of soil PH

Soil PH of a sample can be tested using the following procedure.

Materials

- Sample of soil
- Distilled water
- PH colour chart
- $BaSO_4$ – test tube

Method (BDH indicator method)

- Put 10gm of soil in a test tube.
- Add $BaSO_4$ to break down the soil particles and to make the soil particles settle down quickly.
- Add $10cm^3$ of distilled water.
- Add a few drops of the universal indicator to the solution.
- Shake the test tube and its contents to stand for sometime in the test tube rack.
- A clear area will appear in the middle of the test tube.
- Hold the clear area against the PH chart.
- Decide / compare the colour of the clear soil with the chart and read of the PH.

  Note. Red colour indicates acidic while blue colour indicates alkaline.
- Soil PH can also be determined by use of the electromagnetic method and dye method and litmus paper method.

Electromagnetic method

- This is done by use a PH meter where the H^+ conc. of the soil is balanced against a standard hydrogen electrode.

Dye method

Indicators (dyes) change colour with increase and decrease in PH. A soil sample is saturated with the dye and after a few minutes, the colour of the dye is compared with a suitable colour chest and read off.

NB. PH stands for potential of H^+ or H^+ concentration or parts of H^+ and this is a measure of the concentration of the H^+. It is expressed as the negative log of H^+ concentration.

$PH = -Log[H^+] \quad = \quad Log\frac{1}{[H^+]}$ therefore if the concentration of H^+ is unknown, it's PH can be calculated using the above formula.

Soil amendment

Rising of the soil PH to a reaction nearer to neutral is done by addition of lime a process called liming.

Liming materials

- Calcium carbonate (calcite) ca CO_3
- Dolomite Ca Mg $(CO_3)_2$
- Corals and sheds
- Calcium oxide or burned lime or quick lime.
- Calcium hydroxide $Ca(OH)_2$ or slaked lime
- Blast furnace (basic) slug; is a product of Pg Fe that is manufactured from Fe ore and limestone.
- Paper mill refuse that contains Ca $(CO_3)_2$
- Sugar factory lime

Qualities of a good liming material

- Should be cheap / affordable.
- Easy to handle, store or apply.
- Has no diverse residual effect on the soil.
- Should have a mild effect on the soil alkalinity so that over application is not harmful.
- Should last long in the soil.
- Should be able to improve the structure.
- Easily dissolves in the soil solution.
- Should contain desirable cations e.g. Ca^{2+} Mg^{2+} and therefore add to the exchange capacity

Factors considered before liming

(i) PH of the existing soil; should be low (acidic).

(ii) Buffer capacity or reserve acidity of the as this tends to resist changes in PH.

(iii) Percentage base saturation. The availability and activity of the base should be considered as they have the capacity to replace H^+ on the exchange sites.

(iv) Type of crop to be grown; as different crops have different PH requirements.

(v) Fineness of the lime; if fine, smaller amounts should be used than when rough.

(vi) Economic returns in relation to the cost of the lime. The benefits of liming should be able to offset the cost of the lime.

(vii) Mineral content of the soil e.g Mn and Fe are more available in acid soil and less available when the soil is limed.

(viii) Texture and organic matter content of the soil; coase textured soil with a low organic matter content you will use less lime than the fine texture soil with a high organic matter content.

How does lime reduce soil acidity?

Lime reduces acidity by: -

1. Reducing the amount of CO_2. It reacts with the CO_2 or carbonic acid to form bi-carbonates e.g.

   $CaO + H_2O \rightarrow Ca(OH)_2$

   $Ca(OH)_2 + 2H_2CO_3 \rightarrow Ca(HCO_3)_2 + 2H_2O$

   $CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$

2. Replacing the adsorbed hydrogen ion on the soil colloidal complex i.e.

   $2H\,[micelle] + CaCO_3 \rightarrow Ca\,[micelle] + H_2O + CO_2$

   - The CO_2 is freely evolved by these reactions and is lost from the soil.
   - The adsorption of Ca^{2+} and Mg^{2+} raises the percentage base saturation of the colloidal complex and hence the PH of the soil solution

Loss of lime from the soil

- Soil erosion
- Crop removal
- Leaching

Benefits of liming

(i) Provides essential nutrients e.g. Ca, Mg.

(ii) Neutralises the organic acids produced by the breakdown of organic matter. It also replaces the H^+ adsorbed on the soil particles (micelles) with Ca^{2+} and Mg^{2+} and thus reduces acidity.

(iii) It converts P and Fe into usable or available forms as there are more readily available in neutral to slightly acidic soils.

(iv) Enables utilisation of soluble acidic manures e.g. phosphates, dissolved bones and ammonium sulphate.

(v) Makes clay soils or sticky soils easy to work by flocculation or coagulation of soil particles. This also increases aeration and drainage.

(vi) In sandy soils it binds light soil particles more closely together and so improves the water holding capacity.

(vii) In increases the activities of some soil micro organisms, this in turn hastens (quickens) decomposition of organic matter, nodulation, nitrification ans N2-fixation.

(viii) It reduces the toxicity of Al and Mn that are toxic in acidic soils.

(ix) It prevents build up of certain fungal diseases that flourish in acidic soils such as club root diseases.

Negative effects of liming

- It can lower the yields of crops in later years if the PH is allowed to increase continuously.
- It is expensive thus increases production costs.
- It decreases the future supply of plant nutrients.
- Accelerated organic matter decomposition causes a decline in organic matter content of the soil.

Over liming

- Reduces availability of some nutrients e.g. Mn Cu, Zn, P and Bo
- The drastic changed in soil PH also affects some plants adversely.
- It induces the spread of diseases e.g. potato scals.

The effect of over liming can be reduced by.

- Application of manure
- Applying dolomitic limestone that is milder than caleitic limestone.
- Using coarse lime that is milder than fine lime and has more long term effects.

Alkaline soils

It may be necessary to lower soil PH in order to: -

- Enable the growing of certain crops e.g. tea and ornamentals.
- Eliminate deficiencies of Fe, Mn and Zn in highly alkaline soils.
- Discourage certain diseases e.g. potato scals caused by actinomycetes

There are two common methods used to modify alkaline soils.

(i) Application of acidic matter e.g. pine needles, saw dust, moss, peat.

(ii) Use of chemicals e.g. Fe SO_4 and other acidic fertilizers. These hydrolyse to produce H_2SO_4

Physical properties of soil

a) Soil colour

Is a physical property which indicates the presence or absence humus.

The colour is determined by presence of humus or the effect of leaching.

Loam soil is dark in colour due to the presence of humus and the sub soil is brown due to Fe_2O_3 and Al_2O_3.

Importance / significance of soil colour

- Influence heat absorption by the soil.
- Used to determine the age of the soil
- Used to reveal the soil profile horizon.
- Shows the presence of carbonate lime deposits in the soil (e.g. white – grey)
- Indicates leached soils

- Indicates presence of organic matter
- Indicates presence of certain minerals.

b) Soil temperature

Is a measure of the hotness and coldness of soil.

Importance of soil temperature

- It controls the moisture content of the soil by acting the rate of evaporation.
- Controls germination of seeds.
- Controls the uptake of water and mineral salts as it controls mineral solubility, water movement and root extension.
- Controls microbe activity.
- Influences soil aeration by controlling soil moisture.
- Affects the rate of weathering by influencing the rate of chemical reactions and microbial activity.
- It indirectly affects soil PH by affecting microbial activity, aeration and break down of organic matter.
- It indirectly affects the availability of plant nutrients by affecting the rate of break down of organic matter.
- Controls root extension and development as roots need warmth to grow and indirectly by controlling aeration plus the moisture content of the soil.
- Controls the rate of nitrification.

How to optimally maintain soil temperature.

- Mulching; keeps soil cool and warm on cold days.
- Shading; keeps soil surface cool.
- Irrigation; keeps the soil cool.
- Cover cropping; keeps soil cool.
- Application of organic matter.
- Drainage raises the soil temperature.

c) Soil plasticity

Is the capacity of the soil to be molded without breaking or rupturing. Soil can be plastic, non-plastic, slightly plastic or very plastic.

d) Soil consistence

Is the degree of cohesion of soil or the resistance of the soil to deformation.

It is measured by feeling and manipulating the soil by hand or pulling tillage equipments through it.

e) **Soil porosity.** (% pore space) $\frac{B.D}{P.D}100$

This is the measure of the size of pore space in soil. In soils where the particles are closely packed together, there is limited pore space and therefore less air and poor plant development.

f) Percolation / drainage

This is the ability of water to pass through a soil sample, it is directly influenced by pore spaces in soil.

g) Retention

This is the ability of the soil to retain or keep water. Its also directly influenced by pore spaces in the soil.

h) Capillarity

This is the upward movement of water in the soil. It is helped by both cohesion and adhesion forces. It's determined by pore spaces in the soil. It influences or affects the crops' ability to access water for absorption and dissolved nutrients as they are moved from the lower levels of the profile.

i) Soil profile

Is the vertical arrangement of soil layers / horizons. Change in a horizon is characterised by change in soil colour.

There are two types of soil profiles:

a) **Podzol profile;** This displays a sharp contrast between the horizons and its widely distributed in humid temperate areas.

b) **Ferralsol profile;** It is San example of soil that has developed under humid tropical conditions through progressive weathering of rocks.

j) Bulk density

Is the weight per unit volume of an air dry sample of soil with its natural structure undisturbed or mass per unit vol. of undisturbed soil dried to consistent weight at 105^0C.

$$BD = \frac{\text{weight of dry soil (g)}}{\text{Vol. of oven dry soil (cm}^3\text{)}}$$

OR $$\frac{\text{Weight of a given soil (gm)}}{\text{Vol. of the same soil.}}$$

The bulk density of a soil is influenced by:

(i) Organic matter content:

O.m is very light, spongy and so encourages a fluffy (soft and spongy or scaltheory). Porous condition in the soil that results in a low BD

(ii) **Soil texture: -** Sandy soils have higher BD because the particles lie in closer contact so their volume is less.

Also, sandy soils generally contain less water and organic matter.

(iii) **Soil depth:** BD increases with soil depth, this is due to a lower O.m content, less aggregation and root penetration and the compaction caused by rhe weight of the overlying layers of soil.

(iv) **Level of cultivation;** Intensive cultivation increases the bulk density because it causes rapid break down of O.M and also causes compaction of the soil.

(v) **System of soil management;** Addition manures in large amounts to the soil lowers its B.D

(vi) **Cropping systems;** Continuous cropping reduces the amount of O.M and so increases BD while fallowing increases the amount of O.M and decreases BD.

k) Particle density.

This is the mass per unit vol. of the soil solids. The oven dry soil is compressed and then its PD is found using the formula.

$$P.D = \frac{\text{Weight of the soil solids}}{\text{Volume of the solids}}$$

P.D is influenced by O.M, nature of minerals present e.g. heavy minerals (magnetite) increase P.D

l) Soil structure.

This is the overall arrangement of soil particles within a given soil. Individual soil particles (clay and sand soil) are bound together by organic matter to form secondary aggregates.

Formation of soil structure or soil aggregates

This is favoured and influenced by these factors: -

(i) Organic matter: Is sticky and so binds the soil particles together, thus stabilising the aggregates.

(ii) Soil water; moist soils are more plastic than dry ones and so are easier to bind together. However too much water causes dispersion of soil structure and destroys them.

(iii) Liming; Ca has the capacity to flocculate soil colloids thus encouraging formation of soil aggregates. This is due to formation of bridges between the Ca^{+} and the velly charged colloids.

(iv) Living organisms; Some produce gummy substances that cement soil particle together while others e.g. earth worms ingest the soil.

(v) Compaction; leads to formation of platy structures as others are destroyed.

(vi) Frequency of cultivation; frequent cultivation destroys the structure but may lead to formation of a crumb structure from a blocky structure.

(vii) Soil texture; soil with large particle are not plastic enough to attach onto one another therefore most sandy soils are structureless.

(viii) Vegetation cover; vegetation binds soil particles thus encourages aggregate formation.

(ix) Soil depth; the type of structure formed varies with depth of soil e.g. crumb and granular structures are on the top soil while platy is common at deeper levels of the soil.

(x) The physical and chemical nature of parent material e.g. clay and lime for a good and stable structure.

(xi) Inorganic compounds e.g. Fe_2O_3 form stable granular.

Classes of soil structures

Soil structure is classified according to size of soil particles, degree of aggregation, and shape of soil particles / aggregates.

Size: According to size of the different soil structures, the plate-like structure has the biggest size of the soil particles, followed by prism-like structure, block-like structure and then spheroids structure.

Degree of aggregation:

Different soils have different degrees of aggregation. Degree of aggregation is strength with which soil particles are formed; thus

(i) Loosely packed or structureless e.g. sandy soils.

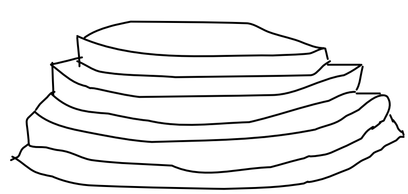
(ii) Moderately packed or moderate structure e.g. the loam soils.

(iii) Tightly packed or strong structure e.g. clay soils.

Shape:

(a) Platy structure

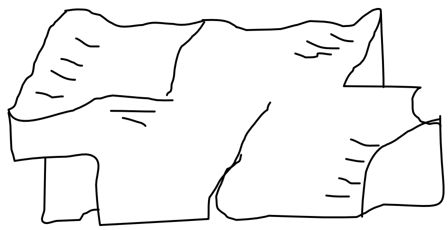
- Soil aggregates are arranged on top of one another in negatively thin horizontal plates / planes or lengths. It can be found in any part of the profile.



- Water moves laterally through such soil.

(b) Blocky structure:

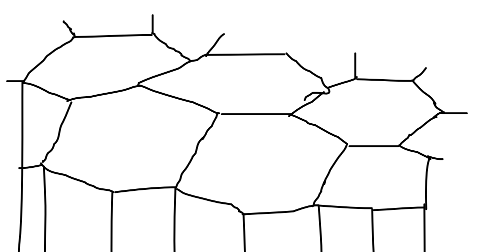
Soil particle are in form of blocks that can fit together. Some have round corners (cuboids) and others angular or sharp corners. They are $\cong 8-10\text{cm}$ and may be located on top soil, sub soil of some heavy clays or well structured soils.



(c) Prismatic structures

The aggregates or peels are vertically arranged with distinct columns

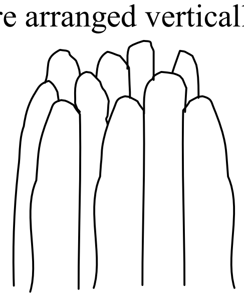
NB: When the prismatic peels suffer eluviation, the top corners become more rounded to form columnar structure.



Prismatic structure has a coarse structure with 15 cm in diameter. They are located in sub soil of heavy clays or bricks earths. They are common in arid and semi-arid areas.

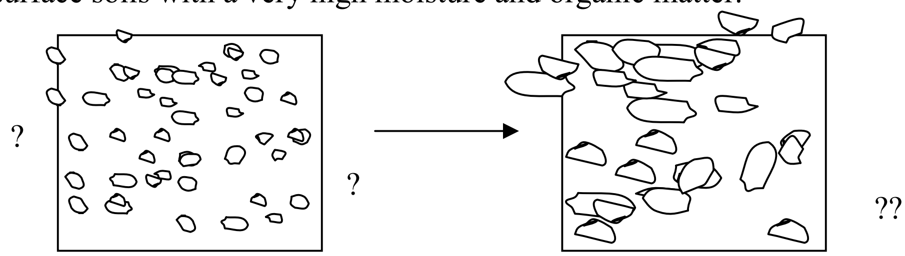
(d) Columnar

The soil particles are arranged vertically with their top smoothly curved.



(e) Crumb and granular

These loosely arranged aggregates, roughly spherical are porous. Water can be held between the granules and its good structure for crop growth. It's common in surface soils with a very high moisture and organic matter.



Granular Crumb

When several granules come together, they form a crumb structure.

Causes of loss of soil structure

- Soil erosion by either water or wind.
- Bush burning destroys the organic matter and exposes soil to agents of erosion.
- Pollution as it decreases the population of micro-organisms that breakdown O.M hence the binding of property of organic matter is lowered due to absence of organism to decompose plant remains.
- Over cultivation, over stocking and ploughing up and down the slope.
- Use of heavy tillage machines for a long time causes compaction, making aeration poor. Also soil particles are broken into smaller particles that are easily carried away.
- Water logging; causes dispersion of the soil particles destroying the soil structure and creating puddle soils (water socked).
- Man's activities e.g. construction, mining.
- Natural disasters e.g. landslides, earth quakes and other earth moving phenomenons.
- Leaching of bases e.g. Ca^{2+} and Mg^{2+} lead to deflocculating of colloids.

Maintenance of soil structure

(i) Minimum tillage; Reduces destruction of structure by compaction breakdown and allows the soil to restore its structure and also destruction of organic matter.

(ii) Cover cropping; reduces evaporation and controls soil erosion.

(iii) Addition of organic manure; has colloidal properties that bind particles together.

(iv) Bush fallowing; the thick vegetation controls erosion and adds organic matter to the soil.

(v) Mulching; minimises soil erosion, evaporation and organic mulches provide organic matter to the soil.

(vi) Agro-forestry and afforestation; tree canopies control erosion, shed leaves which provide organic matter on decomposition.

(vii) Pollution control; to maintain the population of living organisms and add organic matter and also bind soil particles.

(viii) Liming; limestone is a granulate agent through its affect on biotic forces and also through the ability of Ca^{2+} to cause flocculation of soil colloids.

(ix) Drainage; removal of excess water from the soil particles reducing puddling and encourages living organisms that add organic matter and also it reduces leaching of bases.

(x) All soil erosion control methods.

Stability and consistence of soil structure

Stability of soil structure is the resistance of that soil to any changes caused by external forces, such as rainfall, cultivation, etc.

Consistency of a good soil of a soil is the degree of cohesion of the individual soil particles and resistance of these aggregates to breakage when they are handled.

Stability of a soil structure is influenced by: -

- Soil texture e.g. clay soils are more stable than sandy soils.
- Organic matter content; the higher the amount of humus, the higher the stability of the soil.

m) Soil texture

It is the relative proportion of clays, silt and sand in a sample of soil. Or it is the smoothness or roughness of the soil when rubbed between fingers.

Therefore some soils may be fine textured when they contain high proportions of clay, coarse textured when they contain high proportions of sand and medium textured when they contain balanced proportions of clay, sand, silt and organic matter.

Soil textural classification

(a) Sandy soils

(b) Loam soils

(c) Clay soils

Influence of texture and structure on crop production

(i) They influence the degree of soil erosion.

(ii) They influence soil PH through leaching of bases and accumulation of Co_2 and cause acidity.

(iii) They determine the workability of the soil e.g. sandy / lights Vs heavy sticky.

(iv) They determine the ease of root penetration in the soil.

(v) They determine plant anchorage in the soil.

(vi) They control the water holding capacity of the soil.

(vii) Influence the ease with which soil can be destroyed by tillage and other external forces.

(viii) They influence soil aeration, soil temperature.

Review

Classes of soil structure

a) **Structureless:** or single grained e.g. sand

b) **Mass structure:** soil particles unite with others without leaving pores and the particles are more or less cemented e.g. clay.

c) **Aggregated:** particles stick together to form secondary particles / structures that are large.

Experiments on soil particles

1. Demonstrating structural stability

Materials

- Different soil samples
- Glass beaker
- Coarse wire screens

Method / procedure

- Submerge completely several dry clods or granules of about the same size on a wire screens in a beaker of water.
- After five minutes, note the level of disintegration of the different samples.

2. **Demonstrating structural consistence**

- Attempt to crush a handful of the soil or manipulate it between the fore finger and the thumb depending on the moisture content of the soil.
- For wet soils, consistence is described in terms of stickiness or plasticity. For stickiness, soils may be classified as non sticky, slightly sticky, sticky and very sticky.
- Plasticity is the ability of the soil to be moulded into different shapes. Soils may be classified as non-plastic, slightly plastic, plastic and very plastic.

3. **To determine the rates of percolation and water retention for different soil samples**

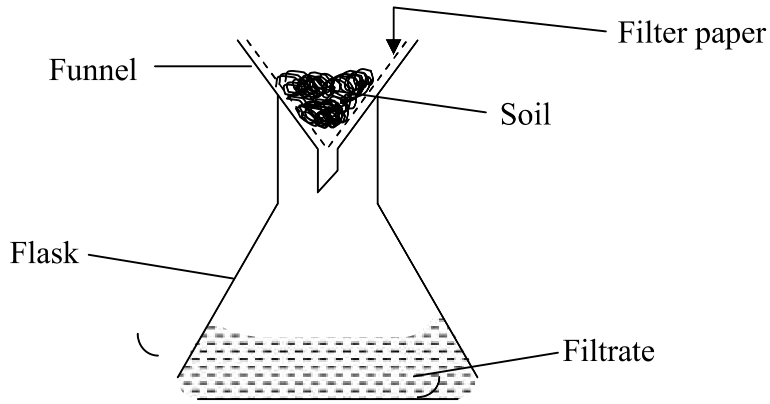
Materials / apparatus

- Funnels
- Water
- Beakers / conical flasks
- Soil samples
- Stop clock
- Measuring cylinder
- Beam balance
- Filter paper / cotton

Methods / procedure

- Weigh equal amounts of crushed dry soil samples.
- Measure equal volumes of water using the measuring cylinder.
- Cotton wool / filter paper is put in the funnels and put on the beakers or conical flasks.
- Weighed soil sample is put in funnels.
- Pour the water in one soil sample slowly until it is finished.

- Set the clock working and note the time taken for the first drop to come out.
- Repeat the experiment for the second and third samples as shown in the diagram.



- Measure the amount of water that collects from each soil sample and record your results.

Observation

- Water drains through the samples at different rates.
- The first drop takes a shorter time to come out in one of the soil samples than in the other two.
- More water is collected in one sample than in the others.

  Examples: $100cm^3$ of water is added to the soils.

Samples	Time of first drop	H_2O collected	H_2O retained
Sand	3 sec	80cc	100-80 = 20cc
Clay	20 sec	30c	100-30 = 70cc
Loam	10 sec	58cc	100-58 = 42cc

Conclusion

The soil sample where the water drop comes out faster is quick draining and where more or most water collects has a high a drainage and the sample where there is least water collected has a poor drainage and retains more water.

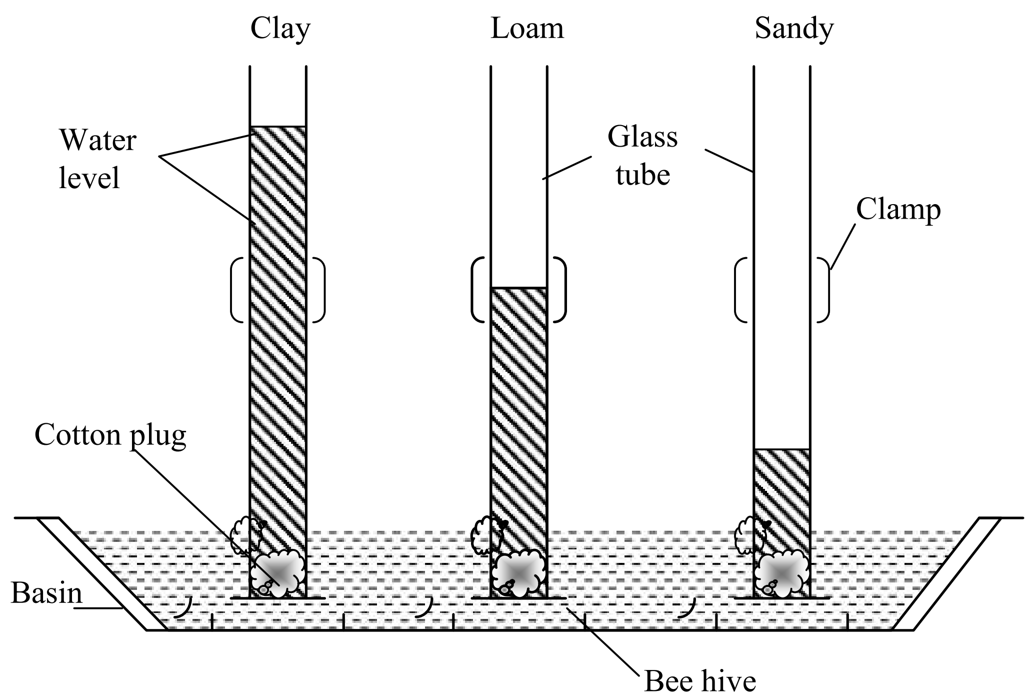
4. To determine the capillarity of different soil samples.

Apparatus / materials

Capillary tubes, cotton wool, samples of soil, basin / beaker, clamp and water.

Method / procedure

- Plug the capillary tubes with cotton wool.
- Fill each capillary tube / glass tube with equal volume of clay, 10 om and sand.
- Pack the sample by tapping on the sides of the tubes gently.
- Put the plugged end of the tubes in a basin or beaker of water.
- Clamp the tubes and let them stand perfectly overnight.



Observation

- Water moves upward in different soils at different rates, fastest in sand, average in loam and lowest in clay.
- After standing overnight, the water level is highest in clay, average in loam and lowest in sand.

Reason: - Clay and loam have very fine and small pore spaces in addition to that they have some organic matter especially in loam that helps to absorb water. Sandy soil has wide pore spaces

5. **To determine the texture of a given sample of soil**

Sample soil

(a) Feel method

Materials - Water and soil samples.

Method - Get a small lamp of soil from a given soil sample. Add some water to moisten it. Get a small lamp and rub it between the fingers.

Observation

Sand feels rough / coarse / gritty / sharp. Clay feels smooth and sticky. Loam feels powdery

(b) Cylinder method / or rolling experiment

Materials

Sample of soil, water

Method

- Get a small lamp of soil, add some water to moisten it. Make a paste out of it and roll it into a ribbon, or a ball.
- Try to mould the ribbon into a ring.

Observation

Sand fails to make a paste, a ribbon nor does it make a ring.

Loam makes a paste, a ribbon and a ring with cracks.

Clay makes a paste, ribbon and a perfect ring that is smooth and without cracks.

(c) Mechanical analysis methods materials.

Sample of soil, water, measuring cylinder, a millimetre sieve.

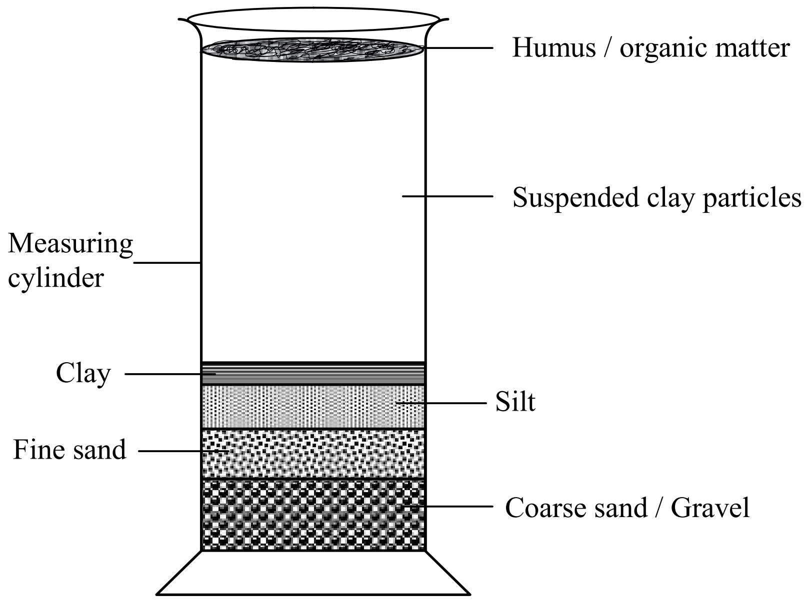
Method

A 2mm sieve is used to separate big soil particles (gravel) from small ones. The bigger soil particles remain on the sieve and the small ones pass through. The fine particles are then put in the cylinder containing water.

- Shake the cylinder so that so that the particles break up.
- Allow it to stand overnight.

Observation

Formation of layers (sedimentation) takes place with big ones first, followed by the small ones, in order of coarse sand, fine sand, silt, clay and floating humus / organic matter.



Classification of soil

Soil can be classified according to particle size, colour, location, depth, formation process, pedological systems and is based on origin of the soil influenced by environmental conditions e.g.

(i) **Zonal soils: -** These soils are characterised and influenced by climate and world vegetation. They are most widespread, mature and well developed.

(ii) **Intrazonal: -** Includes soils characterised and influenced by the local conditions such as drainage especially rivers, soil PH, mineral content. Their soil profiles are not well developed. Examples include saline soils, peat soils, bog soils.

(iii) **Azonal:** - Soils whose characteristics are determined by the parent rocks of origin e.g. the stony soils.

Colour: - Red clay, brown soils, e.g. the volcanic soils of East Africa, reddish sandy soils and the yellow sandy soils.

Depth: - deep soils and shallow soils

Location: - Forest soils, arid and semi-arid soils, tropical soils.

Texture: - There are three main types of soils according to texture, namely, sany, clay and loam.

(a) Sandy soils: - 80% sand, 20% silt, clay and very little organic matter

(b) Loam soil: - 45% sand, 10% clay, 40% silt, 5% organic matter.

(c) Clay soils: - 10% sand, 25% silt, and 65% clay.

The percentages are determined by using their weights or volumes as a percentage of the whole mass.

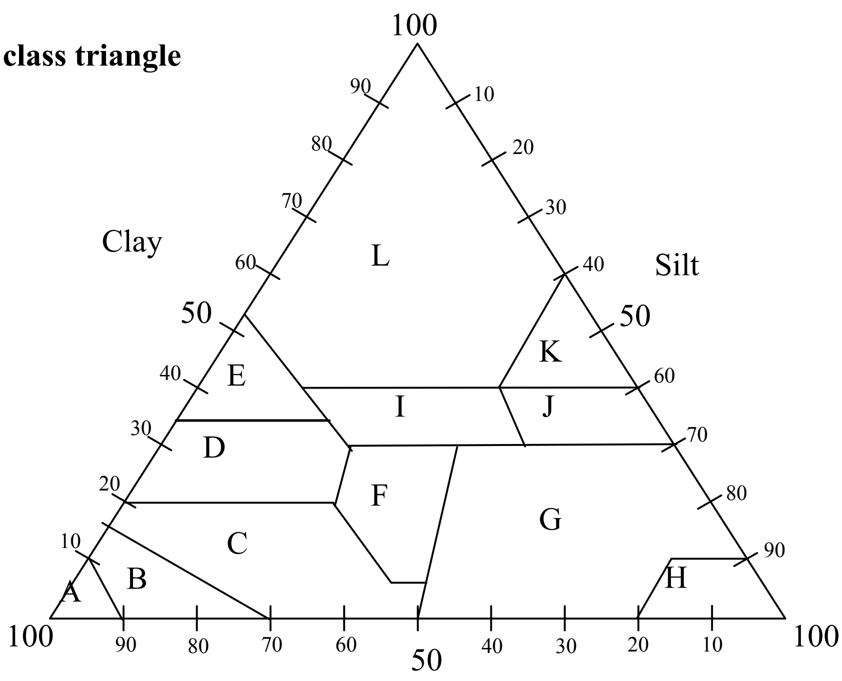
The above classes are further subdivided into subclasses (types) due their differences in the percentages of particle sizes present in each;

(i) Silt loam 20 – 30% sand, 70% silt, 10% clay 0.1 organic matter.

(ii) Clay loam 20 – 50% sand, 20 – 30% silt, 20 – 60% clay

(iii) Sandy loam 50 – 80% sand, 20 – 30 silt, 0.1% organic matter.

The soil textural class triangle



Key: A – Sand (90% sand, 10% clay)
B – Loamy sand (70% sand, 15 clay)
C – Sandy loam (60% sand, 20% clay)
D – Sandy clay loam (60% sand, 35% clay)
E – Sandy clay (60% sand, 40% clay)
F – Loam (40% sand, 25% clay, 35% silt)
G – Silt loam (75% silt, 25% clay, 20% sand0

H – Silt (90%silt, 10% sand)
I – Clay loam (40% clay, 30% sand, 30% silt)
J – Silty clay loam (60% silt, 10% sand, 30% clay)
K – Silty clay (60% clay, 40% clay)
L – Clay (60%, 40% silt)

Soil separates:

Soil can be sieved into the following soil particles.

Soil separates	Diameter limits (mm)	
	US Dep. of Agric	**International system**
Gravel (very coarse sand)	2.00 – 1.00	
Coarse sand	1.00 – 0.50	2.00 – 0.20
Medium sand	0.50 – 0.25	
Fine sand	0.25 – 0.10	0.20 – 0.02
Very fine sand	0.10 – 0.05	
Silt	0.05 – 0.002	0.02 – 0.002
Clay	Below 0.002	Below 0.002

Characteristics of sandy, clay, loam and silt soils

Sandy soils

- Large, rough particles which are loosely packed.
- Rough / coarse / gritty texture
- Few but large air spaces and its more permeable to air and water (porous)
- Low water – holding capacity.
- High erosibility and leaching.
- Easier to dig and clumps easily break.
- High drainage or well drained.
- Light in weight.
- Low in nutrient content.
- Warms up quickly.
- Low capillarity.
- Usually acidic due to leaching.
- Consists of largely quartz particles i.e. $SiCO_2$

Clay soils

- Has very tiny particles < 0.002mm.
- Very many tiny air spaces
- High capillarity
- High water retention capacity
- Low leaching rate and erodibility
- Fertile due to high nutrient retention capacity and low leaching.
- Heavy and difficult to work
- High chemical reaction C.E.C.
- High Fe and Al accumulation and their oxides; Slightly acidic to alkaline.
- Rich in bases especially nutrients such as phosphate.

Silt

- Smooth and powdery
- High water holding ability.
- Consists of very small quartz particles mainly SiO_2.

Loam soil

Characteristics by equal amounts of clay and sand particles plus silt and humus.

- Dark in colour due to presence of humus.
- Moderately fine textured.
- Well drained.
- Fertile and slightly acidic.
- Moderate water-holding capacity.
- Moderate capillary.
- Easy to dig.
- Powdery texture.
- Has sufficient air for respiration of plant roots and soil organisms.
- Fertile and the most productive soil for farming.

Qn. Describe ways of making the different soil types more productive. (Liming, draining, manure and fertilizer application, mulching crop rotation, control of soil erosion)

Soil fertility

Soil fertility; is the ability of the soil to supply the required crop nutrients and other crop needs adequately in order to sustain plant growth and high crop yield for a long time.

Soil productivity; is the capacity of the soil to produce high crop yields under a specific system of management. Therefore soil fertility is a factor of soil productivity i.e. a fertile soil is productive and a productive soil is fertile.

Other crop needs include factors such as moisture, warmth, air, PH, structure, texture, depth, microbe, etc.

Factors that contribute to soil fertility

(i) **Adequate plant or soil nutrients:** These should be in their right amount and right proportions and combination.

(ii) **Soil depth;** should be of the right depth so as to supply adequate nutrients, water, hold plants firmly and allow proper root growth and extension to absorb nutrients.

(iii) **Soil structure;** should be good to ensure proper aeration, water holding, heat transfer, root growth, water percolation.

(iv) **Soil texture;** should be good to ensure good soil nutrient status, water holding capacity, stability, aeration, drainage and water permeability.

(v) **Soil drainage;** should be well drained to avoid water logging and ensure good aeration, temperature, structure, PH, etc.

(vi) **Soil aeration;** good soil aeration influences nutrient uptake and ware uptake by plants, encourages better root development and microbial activity.

(vii) **Soil PH;** should have a suitable PH that would ensure proper nutrient availability, microbial activity and avoid prevalencey of certain plant pathogens.

(viii) **Organic matter;** should contain adequate organic matter as it adds nutrients, and improves the soil structure.

(ix) **Toxic substances;** should be free from toxic substances that would inhibit proper crop growth.

(x) **Pests and diseases;** should be free from soil pests and diseases that would affect normal crop growth.

(xi) All other good farming practices e.g. weed control, land drainage.

Common ways in which soil fertility is lost

(i) **Soil erosion:** Fertile top soil is carried away by wind and water.

(ii) **Change of soil PH:** For example through the misuse of fertilizers and failure to drain the water from the soil.

(iii) **Soil capping:** Formation of an impervious layer of soil on the surface of the soil which abstracts rain infiltration leading to surface run off.

(iv) **Development of hard pans:** These develop a short distance below the surface of the soil and impede water percolation as well as root penetration.

(v) **Loss of organic matter:** Due to rapid oxidation by soil micro-organisms, frequent cultivation, bush burning, etc.

(vi) **Leaching:** The draining of the soluble plant nutrients from the top layers to the bottom layers of the soil makes them unavailable to plants.

(vii) **Loss of nutrients through crop removal:** Crop removal from the garden during harvesting carry away nutrients they had absorbed, thus if not returned to the soil, the soil losses these nutrients.

(viii) **Excessive irrigation:** this leads to loss of nutrients through leaching.

(ix) **Draining land:** The running water carries the dissolved nutrients.

(x) **Weeds:** these directly remove water and nutrients from the soil.

(xi) **Pests and disease build up:** These lower the crops' ability to utilise plant nutrients.

(xii) **Poor aeration:** This may result from water logging; water logging causes acidity and encourages leaching of nutrients.

(xiii) **Pollution:** Is the addition of unnatural level of substances into the soil e.g. polythene, toxic chemicals prevents proper growth and utilisation of plant nutrients.

(xiv) **Accumulation of salts:** When they accumulate, they become toxic to plants e.g. Zn and Fe high concentration affects cassava taste.

(xv) **All poor farming methods:** Such as continuous cropping, monoculture, over cropping and over cultivation all can lead to faster loss of nutrients than they can be recycled naturally and soil erosion plus build up of pests and diseases.

Ways of maintaining and restoring soil fertility.

(i) Application of organic manure and artificial fertilizer.

(ii) Agronomic practices e.g. crop rotation, cover cropping, mixed cropping and inter planting.

(iii) Weed control.

(iv) Control of pests and diseases.

(v) Control of soil PH by using amendments.

(vi) Proper draining to prevent H_2O logging.

(vii) Bush fallowing to enable soil rebuild its nutrient capacity.

(viii) Soil erosion control e.g. through mulching.

(ix) Minimum tillage especially where there is a risk of soil erosion.

(x) Afforestation to help in erosion, increasing the amount of organic matter and nutrient recycling.

(xi) Pollution control.

(xii) Irrigation especially during drought.

(xiii) Breaking the hard soil pans.

Assessing soil fertility

There are three basic ways of testing or assessing soil fertility.

a) **By observing the plants growing on the land:** If the land is fertile these plants should be health i.e. deep green, large stems, thick leaves and vigorous. There are also certain plants associated with fertile and infertile soils.

Crops may also be sown on the land in different locations and observe how they are doing.

b) **The colour of the soil:** Usually a black colour of the soil is an indication of the presence of organic matter and organic matter provides most of the essential soil nutrients.

c) **Soil sampling and testing:**