UNIVERSITE DE DSCHANG
FACULTY OF AGRONOMY AND AGRICULTURAL SCIENCES
DEPARTMENT: CROP SCIENCES
COURSE: Phytotechnie spécial
LEVEL: IV

Course description: The course aims to examine the management of crops in a given production environment and according to the purpose of the activity. Specialized cultivation techniques will be examined as well as their application to ensure successful cultivation.

Course content: Food crop management - Plantation crop management - Fodder crop management- Soilless crop production management.

PART 1 : FORAGE CROPS 1

PART 2 : SOIL-LESS FARMING/AGRICULTURE HORS-SOL 10

PART 3 : PLANTATION CROPS 21

PART 5 : COVER CROPS ERROR! BOOKMARK NOT DEFINED.

1.0 Introduction

The domestication of our most important grazing animals—cattle, sheep and goats—is believed to have begun about 8000, 11 000 and 9000 years ago, respectively. The domestication of other important grazing animals, buffaloes, horses, Asses and camels, is assumed to date from about 5000 years ago. Since these times, animals have played an important role in the existence and development of humans.

- These animals provide **food** (meat and milk) but also **clothing** (skin and wool), **fertilizer** (faeces and urine), **fuel** (faeces), and **physical power** as draft and packing.
- They serve as a source of family savings and economic security in the event of failure of food crops and natural calamities.
- They are a vital factor of **human culture** (exhibitions and shows, religion and ceremony, fighting, racing, pets and recreation, status symbol, and bride price and dowry).

Grazing animals require forage as **basal food**. Therefore the most important aspect of the husbandry of grazing animals to humans is that we can obtain many diverse products from forage, which we cannot eat **directly.** At the same time, the husbandry of grazing animals requires that humans make forage available to the animals. Forage crops have served as an important source of feed of domestic animals for a long period, although the history of their use is shorter than that of the use of native forages. Nearly 200 plant species have been known as forage crops.

The benefit of forage crops to humans, however, is not limited only to livestock production. They also contribute to food crop production and many other aspects of human life through the following:

(a) Soil conservation and amelioration;

(b) Landscape and wildlife conservation;

(c) Improvement and protection of the environment from pollution;

(d) Reclamation and ecological repair of degraded land;

(e) Outdoor recreation and pleasure;

(f) Potential conversion of biomass to energy;

(g) Sources of fiber for the manufacture of paper and building materials; and

(h) Sources of extracts for high-quality proteins and medical and pharmaceutical products.

The term **forage** is defined as herbaceous plants or plant parts fed to domestic animals. Generally the term refers to such material as pasturage, hay, silage, and green chop, in contrast to less digestible material known as roughage. Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage (cut green and fed fresh), silage (preserved under anaerobic condition) and hay (dehydrated green fodder).

In practice, however, the concept is often extended to woody plants producing succulent growth and indeed in the tropics some shrubs and trees are of considerable importance in this respect. Forage crops may be used in **pastures** or may be cut and carried to the animals that are expected to eat them.

The most important forage plants are the **grasses.** About 75% of forage consumed in the tropics is grass. The family of grasses, Graminae (Asteraceae), includes about 620 genera and 10,000 species. While the number of cultivated grasses reaches 350 or more, nevertheless, a relatively small number of grasses predominate and can be considered principal forage species.

A second major group of forages is the **legumes.** The family Leguminosae (Fabaceae) is one of the largest of flowering plants with an estimated 700 genera and 14,000 species. Legumes are not as prominent in tropical pastures as are grasses, chiefly because they are **difficult to maintain in a mixed pasture**. **Nevertheless, they are extremely important in improvement of the fertility of the soil, and in furnishing protein to the diet of grazing animals.** A relatively few species have now been established as suitable for **semi-permanent stands** similar to **alfalfa** in the Temperate Zone. A few leguminous trees are useful as forage, and these might be especially valuable for some small farms.

In addition to these principal classes of forage, may other kinds of plants are at times valuable. Although seldom cultivated, they may be parts of the unimproved pasture and be convenient to use under some circumstances. They can be called the miscellaneous group. This group includes annual herbs and woody shrubs and trees (browse).

1.2 Land selection for forage crops

On the small tropical farm, space must be used as efficiently as possible. The most **fertile and easily managed lands should be reserved for food crops and grains**. Land that is steep, difficult to manage, or with shallow soils can frequently be used for pasture. On some very steep lands, pasture can constitute the most easily managed crop.

Once established animals themselves can harvest it, for they climb to the places where forage cannot be harvested in any other way. Forage **lands should also be selected with respect to long-term uses of other lands of the farm.** Forages need to be rotated or replanted. In some cases the lands used for several years as forages can then be planted to forests. With continued use pasturelands can become so **compacted** that future use for intensive agriculture can be impeded. Occasional deep plowing can eliminate this problem.

The management of animals is an important consideration in selection of lands for forage and pasture. Animals can walk long distances through fenced lanes to pastures, but on the small farm cut forages should be near where they will be used, for they are heavy. Practical matters such as location of other crops, provision for watering, provision of shade for animals, protection of animals from dogs and thieves are also important considerations in selecting a site for pasture and forage.

1.3 Selecting forage species

The site itself will determine in part the forage to be grown. The decision will have to be made whether the area will be grazed or the forage will be cut and removed. **Adaptability of the forage to the site is the most important consideration**. This will be determined by **elevation, soil type, rainfall amount and distribution, and temperatures.** Some important characteristics for the choice of a good forage species include:

- Good forage should grow well and survive with a minimum of care. Even though it is desirable to treat pastures and fields of forage crops as carefully as possible, nevertheless, a good forage crop should resist neglect and abuse.
- **Good forage should also resist the dry season** of the year, continuing to grow or maintaining foliage and nutritive value and, above all, **living through the dry season so that growth is resumed again with rains.** Or, in the case of forage cut as hay, it should be **uniform, timely, manageable, have good keeping qualities, and be nutritious.**
- **Naturally, good forage should be palatable to the animals for which it is grown.** This palatability should extend throughout the year.
- When the forage is used through cutting or pasturing, it should **regenerate rapidly.** The overall yield should be high, and this depends in part on previously mentioned factors.
- **Finally, nutritional value should be high.**
- Height of forage is an important characteristic. Tall forages are easy to cut but difficult to graze. Improved cultivars might be available of any particular forage species, and technology might be developed for maximum production. Thus, for every region a certain body of information is usually available. Seeking for this information before establishing pasture or forage will be time saving. Local information on suitable forages is often available from agricultural extension agents.

1.4 Management of forages

1.4.1 General principles

i) Forages are produced either in pastures, controlled grasslands used as feed for grazing animals, or in protected fields from which forage is cut to carry to animals. Such cut forage can be used **fresh** (fodder), dry as hay, or fermented as silage. Forages may be annuals or perennials. ***Annual grasses such as sudan grass, sorghum, their hybrids, and corn need more careful attention than perennial forages, but usually repay such careful attention with very high yields.***

ii) **Cut forage** generally yields more per unit area than grazed forage and is the technique of choice for some, especially **tall grasses.** On the other hand, cutting forage is laborious. When animals graze they often select the forage richest in protein and their weight gains may be greater than those from the same forage presented to them in cut form.

iii) Some features are common to each form of use and must be understood in order to manage forages well. As forage grows it rapidly occupies the space that is available to it. In a mature field for forage, for example, the ground will be covered with forage, plants and the soil will be filled with the roots. Each individual plant will occupy a space that is limited by competition with neighboring plants. Eventually a static state will be achieved in which growth slows or even halts. Before this mature state is reached forage should be cut or grazed in order to make room for new growth. This use is comparable to the harvest of any other crop. **Timing is very important.**

iv) When forage is mowed and carried away to feed animals, all plants are cut to similar heights and all have equal opportunities to regrow. **However certain species will always grow more rapidly than others will and thus the relative amounts of different kinds of forage in the field can change and this may be beneficial, or a detriment.** Thus, it is important that the forage species used are a suitable combination. If not, one species will come to dominate the others. On the other hand, a combination of forage species might be such that some **species dominate in one season and others in another season.**

v) **Inadequate grazing also affects a pasture in a negative way.** Animals will select the most palatable species to eat first and, in doing so, afford to the less palatable more space to grow. The composition of the pasture will change so drastically that within a short time undesirable or less desirable forages or unusable weeds will predominate. Therefore, either many animals should be introduced to a pasture at a time or a few animals should be introduced to a small area so that all plants are grazed more or less equally. **Undergrazing should be avoided.**

vi) **Rotational grazing** is an important practice for it permits regrowth after appropriate grazing. **Overgrazing** due to too many animals on the land for too much time, or to over frequent use of a pasture, must also **be avoided.** There are some situations where rotational grazing is not preferred, especially in a pasture where production is low and where special techniques for management are not used. In such pastures, which often are found on poor tropical farms, animals receive a more uniform feed from non-rotated pastures. When pastures are used more or less continuously it is very important to eliminate periodically the species not used as feed or they will eventually predominate.

Other destructive changes can take place in a pasture or forage field. **Undercut or undergrazed fields may develop large quantities of old, tough, lignified stems that are not palatable.** It may be necessary to cut or burn such fields in order to obtain palatable new growth. Burning is a destructive technique that can eliminate some desirable plants, especially legumes, but it can be desirable at times.

vii) **Fields of forage can also exhaust the nutrients, particularly the nitrogen of the soil**. While this can be replaced by applications of mineral fertilizers or manure, legumes in the forage provide nitrogen and extend the life of the pasture.

viii) **Although pasture may be long lived, rotation of pastures with other crops is often usefu**l. Such rotation permits the soil to be broken by the plow, organic materials can be incorporated, necessary changes to improve drainage and controls for erosion can be made, and the resulting situation can be more suitable for replanting to forage crops.

Rotation of pasture with trees permits nutrients that are deep in the soil to be removed and, when trees are destroyed, such minerals can become available for other classes of plants, including shallow-rooted grasses.

ix) **A good pasture should produce foliage throughout the year, including the dry season.** To make this possible, forages of several classes must be grown either together in a complementary fashion, or in separate plots. Mixed forage, which consists chiefly of grasses and legumes, has some advantages over forages of pure stands. Nitrogen fixed by legumes is useful for the production of grasses, which probably fix little or none of their own nitrogen.

Combinations of grasses and legumes in the tropics as well as the Temperate Zone yield more protein and minerals than other grass or legumes grown separately. A ration of 25 percent legumes to 75 percent grasses in pastures is recommended.

1.4.2 Cut-and-carry fodder

Mechanised harvesting and feeding of fresh forage is practiced in some commercial systems. Fodder crops are of increasing importance in smallholder systems since population pressure has led to disappearance of grazing land in mixed farming areas. Cultivated fodder is increasingly used by smallholders in China, Southeast Asia, South Asia and parts of Africa. Where livestock is economically interesting, notably for **dairying,** fodder is grown to supplement crop residues. It is cut and carried to stall-fed stock. Livestock are important for **income, food security** and as **a store of capital** in many smallholder systems. Fodder trees and shrubs are also involved.

1.5 Soil preparation and planting

As in the case of other crop plants, soil preparation is desirable before forage crops can be grown. Nevertheless on the small farm in the hot, humid tropics, soil preparation will often be minimal. As a general rule, preparation begins by removing old vegetation. Burning is sometimes the best way to remove old and undesirable grasses and, in fact, in some cases it is an important technique in removing old, lignified, inedible stems, returning minerals to the soil. On the other hand, burning followed by heavy rains leads to leaching of the soil and possibly erosion. Therefore, where practical, a strip system is recommended. Vegetation can be cleared from strips following contours. This vegetation can be piled in continuous piles following the contour at the lower edge of the strip. The rotting of this vegetation over a period of time will restore its nutrients to the soil.

Newly planted forages need the stimulation of a loose and penetrable soil for maximum growth. However plowing will often be impossible or, when erosion is expected, impractical. Unless soils are naturally loose some provision for opening them will have to be made, particularly in the immediate area of the individual plant.

Herbicides are sometimes used before establishing new forage plantings. Those that kill broad-leaf weeds and trees might be very economical in eliminating brush and trees, even on the small farm.

If plowing is done ridges or furrows can be prepared 60-100 cm. apart. If planting is done by hand these are appropriate distances between plants or planting holes. Lime should be applied to very acid soils when it is available and economical to use. When available, lime is justified in terms of the increased forage that can be expected from its application.

Propagation of the various forage species depends on the nature of the seed or cuttings used. There are many variations of these practices. Forages are usually planted in rows for convenience, but seed can be broadcast if the soil is prepared to receive it.

Table 1. **PROPAGATION MATERIALS AND PRACTICES FOR SOME PRINCIPAL GRASSES.**

Scientific Name	Common Name	Nature of Propagation	Amount per hectare	Other Notes
Panicum maximum	Guinea Grass	Seeds,3-5% viable	25 kg	Do not cover with soil
Melinis minutiflora	Molasses Grass	Seeds, 80% viable	2 kg	Do not cover with soil
Pennesetum purpureum	Napier Grass	Mature Stem Cuttings	4.5 tonnes	Lay in furrows Cover with 2-5 cm soil
Digitaria decumbens	Pangola Grass	Mature Stem Cuttings	2-3 tonnes	Lay in furrows Cover with 5-8 cm soil
Brachiaria mutica	Para Grass	Mature Stem Cuttings	2-3 tonnes	Lay in furrows Cover with 5-8 cm soil
Cynodon nlemfuensis	Star Grass	Mature Stem Cuttings	2-3 tonnes	

1.6 Post-planting care

Newly planted pastures need protection from grazing until they are well established. This may require 4-8 months. Fences can be established, and five separated plots for rotational grazing have been recommended.

For the small farm, living fence posts of local materials such as *Gliricidia sepium*, *Erythrina berteroana*) or other trees which are planted as large cuttings which root readily can be recommended. Fertilizers are often applied to pastures several months old at the rate of about 400 kg per hectare. Weeds must normally be controlled until pastures are well established. Mowing vigorous grasses, or cutting with machete will tend to eliminate weeds. Vigorous weeds and trees should be carefully removed. Herbicides are sometimes used in intensively managed pastures. Pasturing or cutting removes mineral nutrients from the soil. Where use is intensive, materials are removed more rapidly. On the small farm where purchase inputs are to be minimized it is not desirable to use pastures so intensively that they suffer loss of plants or do not regrow sufficiently rapidly for regular reuse. Nevertheless, when used on a rotational basis, even unfertilized pastures have the capacity to regrow after pasturing. The sources of nitrogen to sustain such pastures are the minimal amounts: deposited with rains, that fixed by legumes and possibly some grasses, and manures left behind by animals. Other elements, potassium and phosphorous, are slowly released to the soil by weathering. The regrowth capacity of an unfertilized pasture varies. Rotation of pasture with forest permits accumulation in the upper soil of very deeply buried minerals.

Pasture should be grazed heavily for up to one week by the appropriate number of animals. Grazing animals should remove the major part of the available forage of all species of forage present. After animals are removed from a pasture, untouched, undesirable plant species should be killed, so that they do not multiply and spread. This single management practice can do much to increase the value of an unfertilized pasture on the small farm.

While five pastures are suggested, a particular farm may in fact have many more. The period of grazing may be less than a week, but to reduce it means that the pasture will not be used with sufficient intensity and preferred forages will be eaten first, giving the less palatable forages a competitive advantage.

1.7 Forage conservation

Forage is usually most readily available at the height of the growing season and loses quality rapidly if not consumed or conserved at the appropriate stage of growth. Storage of forage for later use is a preoccupation of stock-rearers in many areas. The emphasis on conservation depends on the climate. In areas with a marked winter it is usually a necessity, except in transhumant systems. In areas with a continuous thermal growing season, as in much of the tropics, stock rearers try to maintain green-feed. Year-round grazing is rarely feasible in temperate conditions.

Hay is the oldest, and still the most important, conserved fodder despite its dependence on suitable weather at harvest time. It can be made with simple equipment, manually but most is highly mechanized.

Ensiling, a fermentation process, is now a major conservation method on large exploitations in sub-humid and humid climates, but is laborious without heavy machinery and not readily adaptable to smallholder conditions: silage is unsuitable for transport over any but the shortest distance since it has a high moisture content and must be protected from the air; it is not marketable.

Ensiling is the best method of conservation of moist crop by-products. Commonly ensiled crop residues are: rejected bananas, banana leaves and pseudostems, roots and leaves of cassava and other starch crops (sweet potato, taro, yams), citrus and pineapple pulps and leaves, tomato pulp, oil-crop residues (oil palm fronds) and by-products (olives, oil palm), seeds and pulp of grapes, brewers'extracted malt and spent grain, fish by-products and poultry litter.

1.8 Fodder trees and shrubs

Leguminous forage trees and shrubs supply high quality, protein-rich forage for subsistence and commercial livestock and yield forage during dry and cold periods when herbaceous species are dormant. They are:

- a source of N-rich mulch in farming systems,
- provide support for climbing crops,
- supply rods and round-wood and
- the give shade.

Their cultivation as browse is very recent although many have been used for non-forage purposes, such as shade in plantation agriculture, for millennia. *Leucaena*-grass systems have been adopted in commercial farming in Australia because they are sustainable and highly productive. In Southeast Asia small farmers grow leguminous trees as hedges and on field boundaries for multiple benefits: **firewood, control of livestock, forage and soil conservation**.

The most commonly grown forage tree legumes are shown in the table below.

Most used tree legumes

Higher quality species	Lower quality species
Albizia lebbek	*Acacia aneura*
Chamaecytisus palmensis	*Acacia nilotica*
Cratylia argentea	*Acacia tortilis*
Desmodium rensonii	*Albizia chinensis*
Desmanthus virgatus	*Albizia saman*
Gliricidia sepium	*Calliandra calothyrsus*
Leucaena leucocephala	*Erythrina spp.*
Leucaena diversifolia	*Faidherbia albida*
Sesbania grandiflora	*Flemingia macrophylla*
Sesbania sesban	*Prosopis juliflora*

Source. Derived from Shelton (2005)

Part 2 : Soil-less Farming/Agriculture hors-sol

Table 1 The value of fodder trees in agroforestry systems

For livestock

- Valuable source of high quality, protein-rich forage for subsistence, and commercial production of livestock, including cattle, sheep, goats, rabbits, poultry, fish, and bees
- Able to supply foliage during dry periods when herbaceous species are not productive
- Being deep rooted, they are drought tolerant and thus are important components of adaptation strategies to climate change
- Living fences, around homesteads and fields
- Some species have important medicinal attributes for treating livestock health issues

For farming systems

- Source of nitrogen-rich mulch for cropping systems
- Enhance the sustainability of farming systems due to fertility enhancement, longevity, soil cover, and control of soil erosion
- Timber for trellises and stakes for climbing crops
- Source of fruit, vegetables, and medicines

For people and the environment

- Opportunity to intensify sustainable agricultural production
- Means to stabilize sloping lands against soil erosion, due to their deep-rooting habit and permanent soil cover
- Often an important source of timber, firewood, and charcoal, particularly for domestic consumption
- Habitat for wildlife
- As woody perennials, a sink for CO_2 and contributor to climate change mitigation and adaptation
- Source of cash income when sold as forage or when seed are marketed
- A means to lower water table and to limit rise in salinity

1.0 **Introduction**

Over the years, due to continuous increase in **human population among other reasons**, there has been a drastic rise in the **demand for food production**, which has depended almost entirely on **soil** as a **growing medium for crops**. A soil is a **complex mixture of minerals** obtained from the **breakdown of underlying rocks or sub-soils**, **organic matter** obtained from the **decay of plant and animal material, water, air and other gases**, plus **biological life** in the form of worms, insects and microbes. It provides a **basic medium for plant growth**, supporting the production of crops and fodder and assisting a range of ecosystem activities. Research reports by the UN (2009) have estimated that by 2050, the world population is expected to rise from its present 7 billion to 9 billion. However, **soil degradation** has been identified as a major global challenge facing land use for food production, which has been further, worsened by the effect of climate change. In addition to this, the use of soil for **crop production in order to feed this ever-growing population** is been stiffly competed with by the need for shelter, transport, urbanization and industrialization and other socio-economic needs. All these and many more challenges possess a great deal of opposition to the actualization of the "zero hunger" (sustainable development goals/SDG) and raises a question of whether or not soil farming can be relied upon solely for food production and food security in order to consistently feed her estimated population.

Some authors have mentioned that soil is not necessarily required for plant growth. It only provides all the essential macronutrients and micronutrients for growth and development of plants. Soil-based conventional agriculture has drawbacks like wastage of irrigation water, large land requirements, use of large quantity of chemical fertilizers, soil degradation. The requirement of large quantity of nutritional food to fulfill the high demand of the population world wide, justifies the priority of introducing new and advanced technologies and techniques in agriculture, which **synchronize water and nutrient demand in order to achieve optimum yield**. New modern agriculture system has several benefits like water efficiently, high yield, and under controlled environment it can be designed for crop production throughout the year.

Advanced agriculture technology including hydroponics, aeroponics and aquaponics culture techniques utilizes nutritive medium for plant nourishment. **On an average, hydroponics system consumes 10–20 times less water compared to soil-based cultivation systems. Earlier studies have shown that the yield of closed-loop soilless farming (hydroponics) increased by almost 5% compared to open system. Cultivating plants without soil open the pathway to extensive research for the evaluation and popularization of alternative farming systems**.

Into this grim scenario, comes an expanding new sector: **soil-less agriculture**. While hydroponic production has been around for some time, its incorporation into '**vertical farming'** has been a more recent innovation that is taking hold. It falls into a family of practices known as '**Controlled Environment Agriculture' (CEA)** which includes heated glasshouses and indoor crops sown in soil as well as varied types of hydroponic production, including aquaponics.

Soilless culture is the modern cultivation system of plants that use either inert organic or inorganic substrate through nutrient solution nourishment. Possibly it is the most intensive culture system utilizing all the resources efficiently for maximizing yield of crops and the most intense form of agricultural enterprises for commercial production of greenhouse vegetables

1.1 **Origin of soilless culture methods**

Although soilless cultivation technology came into existence since ancient times, the first known publication was in 1627 by Francis Bacon in his book *Sylva Sylvarum*. In 1699, experiments on soilless culture (water culture) of spearmint were reported by John Woodward. Soilless culture gained its popularity in the 20th century when W. F. G. Berkeley (1929) used solution culture for production of agricultural crop. He also introduced the term hydroponics in 1937 from Greek words 'hydro' = 'water', and 'ponos' = 'labour' meaning culture of plants in water. A preliminary success of hydroponics culture was identified on Wake Island, where this technique was utilized for growing vegetables for travellers. W. J. S. Duglas during 1946 started hydroponics in India and established a laboratory in Kalimpong area, West Bengal and also wrote a book on Hydroponics, "The Bengal System". In India, crops such as potato, tomato, green bean, carrot, cucumber, etc. were successfully grown by soilless culture.

1.2 **Categories of soilless farming**

Generally, two types of soilless farming methods are widely used. These systems are classified base on the circulating methods: (i) open farming culture and (ii) close farming culture.

1.2.1 **Open farming culture**

In this method, diluted nutrients are utilized for every irrigation pattern. The plants uptake nutrient solutions, which are usually delivered by dripping system. Through this method adequate amount of nutrients are synchronized in the root zone. Open cycle systems are normally adopted to reduce salinity level in the substrate. But, higher wa-ter use efficiency is obtained with closed cycle sys-tems. Under open soilless systems, the volume of nutrient solution supplied can be reduced to limit the amount of nutrient loss, but there must be at least 30% of leaching to **avoid salt accumulation in the substrate**. No significant differences were found in tomato yields between open and closed soil-less systems, the closed system accumulated more nutrient; Ca^{+2}, chloride (Cl), and Zn in the root environment. Studies have showed that in terms of water and nutrient use efficiency, the closed soilless system saved 42.5% of water, 42.1% N- ammonium (NH^{4+}), 56.0% NO^{3-}, 31.4% phosphorus (P), 52.1% K, 63.5% Ca^{+2}, 47.9% Mg^{+2}, 49.4% sulfur (S)- sulfate (SO4), 51.9% Cl, 50.9% iron (Fe), 47.9% Zn, 24.6 % manganese (Mn), 53.3% copper (Cu) and 47.2% boron (B) compared to open non-recirculating nutrient solution system.

Some techniques of open soilless culture are;

1.2.1.1 **Root dipping techniques**

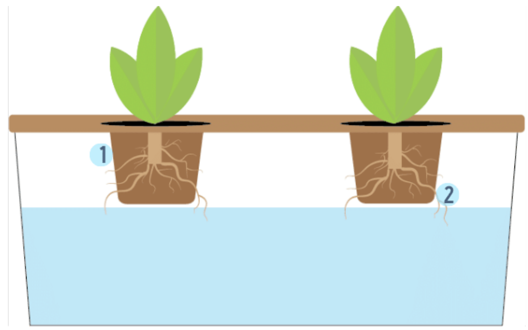

Figure 1. Root dipping technique

Root dipping technique: Under this process, plants are cultured in pots having small holes at the bottom. These are filled with substrate medium like coconut fibre and are placed in a container having nutrient solution. Minimum 1–3 cm of the lower portion of the pots remain in close contact with the nutrient medium. Only few roots are partly submerged in the nutrient media and some just hang in the air. This is a simple and cost-effective system to cultivate small herbs or flowering plants.

1.2.1.2 **Hanging bag technique**

In this technique, long cylinder-shaped polythene bags are utilized. These are closed at the lower end and connected to PVC pipes at the upper portion. These are hanged vertically above a nutrient supplement tank. Planting materials such as seeds, fruits, etc. acclimatized in netted pots are firmly pressed into holes on the hanging bags. A micro sprinkler is used to circulate the nutrient medium to the top of each hanging bag. The nutrient solution is proportionately spread inside the hanging bag by the sprinkler. The solution stock tank is placed at the bottom of the bag for collection of excess nutrient solution. Tubes that contain the nutrient solution should be black in colour to prevent mould growth inside. Using this technique, vegetables such as lettuce, climbers, etc. are grown.

1.2.1.3 **Trench methods**

In this method, small herbs and shrubs are grown on trenches constructed using bricks or concrete blocks on or above ground. To prevent the growth media from direct contact with the ground, the inner linings of trenches are covered with thick polythene sheets. The shape and size of the trenches vary from crop to crop grown in them. All nutrient supplements along with water are delivered through the dripping process. This system is suitable for growing herbs as well as tall vine plants.

1.2.2 **Closed farming culture**

Agriculture demands for a sustainable and environmental friendly culture system, especially in soilless cultivation systems highlights the benefits of using closed recirculating systems and the re-use of nutrient solution to avoid nutrient losses. Closed cycle soilless systems have been recommended in commercial production be-cause they can minimize water and fertilizer losses. However, **salt accumulation in the growing substrate is the main challenge in recirculating systems.** In this technique, the diluted concentrations of nutrients are marked and balanced for reuse. It is difficult to maintain the calibration of nutrients in a hydroponic system as the dissolved supplements must be tested in a regular time interval to obtain better results. Some closed farming techniques include;

1.2.2.1 Hydroponic technique

Hydroponics is growing plants without soil. Hydroponics in general means the cultivation of plants in water and covers a plethora of cultivation operations and techniques. It uses a nutrient system in a substrate to grow plants without the need for soil. Vegetables, herbs, climbers and flowers are grown hydroponically. For growing plants hydroponically, inert media such as coconut fibre, rock pieces, etc. are used. The plants are fed with nutrient solution containing all minerals and nutrients. This system has a wide range of advantages which include **high-yielding capacity, less pollution, better nutrient and water efficiency,** etc. This method is highly beneficial which varies from simple setups to modern types. Hydroponic systems consist of, minimally;

- ❖ Water reservoir
- ❖ Extensive nutrient/fertilizer inputs
- ❖ Pump or wicks
- ❖ Growing bed
- ❖ Non-soil medium to hold the plant steady (at least in the beginning) like rockwool, gravel, etc.

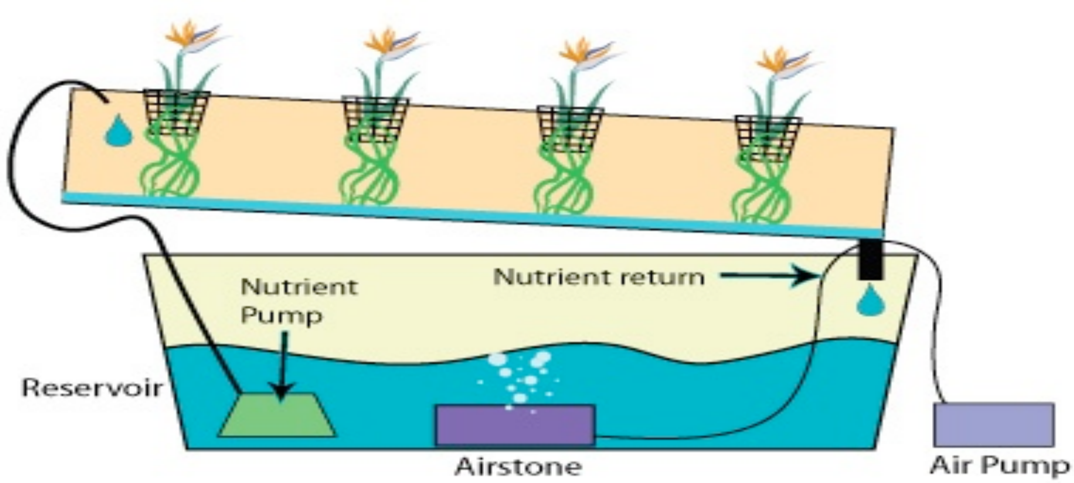

Figure 2. A simple hydroponic system

1.2.2.2 Hydroponics Advantages:

- A water efficient method of cultivation
- Optimal use and reuse of nutrients and minerals.
- Freedom from soil borne diseases/infections/weeds/pests
- Faster growth rate of crop than traditional farming.
- Amiable to cultivation in areas with water shortage or lacking soil-cover.
- Suitable for farming on ships/floating gardens, roof top farming in urban areas.
- A precursor to vertical farming.

1.2.2.3 Aquaponics or Aqua agriculture

In this technique aquatic animals like fish, prawns, etc. are grown in water tanks in a symbiotic environment with combination of plants which are grown in hydroponics. The water from the tank gets cleaned and recycled back to the aquaculture system while moving through hydroponics system, whereas the byproducts are broken down by micro-organisms which live on the surface of the culture media and utilized by plants as nutrients.

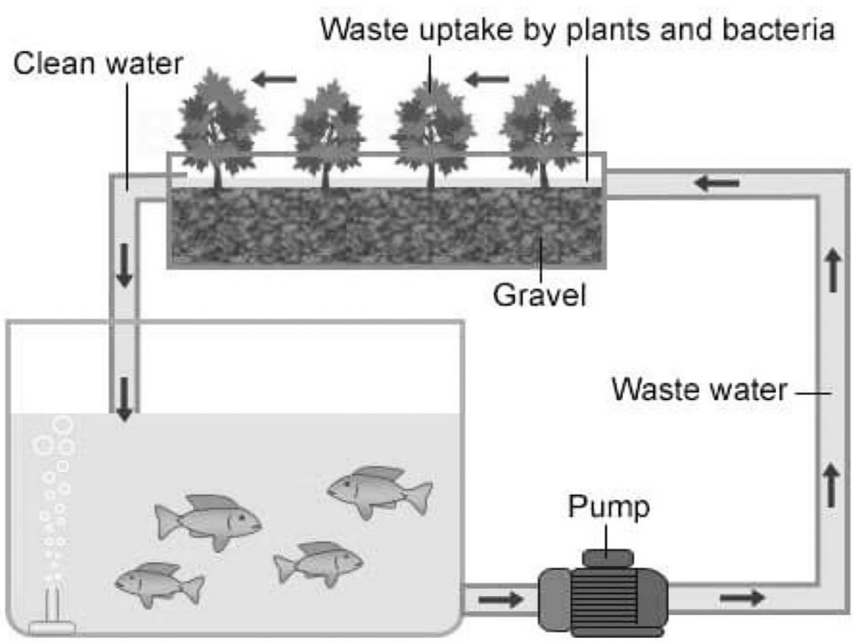

Figure 3. Aquaponic system

1.2.2.4 Aeroponic technique

The aeroponics system is one of the most advanced types of hydroponics system. In this technique, the supplement solution is sprayed to create a fine mist around the root system inside the chamber. For growth of the plants, expanded polystyrene or other inert materials with holes are used. The roots of plants growing in the chamber are suspended in mid-air just below the panel and enclosed inside a spraying box. Just like other methods of hydroponics, a timer regulates the nutrient pump. However, in the case of aeroponics system, a short cycle timer is used to run the pump for 5– 10 sec for every 2–3 min time interval. Mostly leafy vegetables like lettuce, spinach, etc. are grown through aeroponic culture. The most important advantage of this system is the **utilization of minimum space**. Through this culture system, plants can be grown on per unit floor area twice as compared to other systems. The major disadvantage of this process is that, if the nutrient spreading cycles are not working properly the roots will dry out rapidly, causing death of the plant.

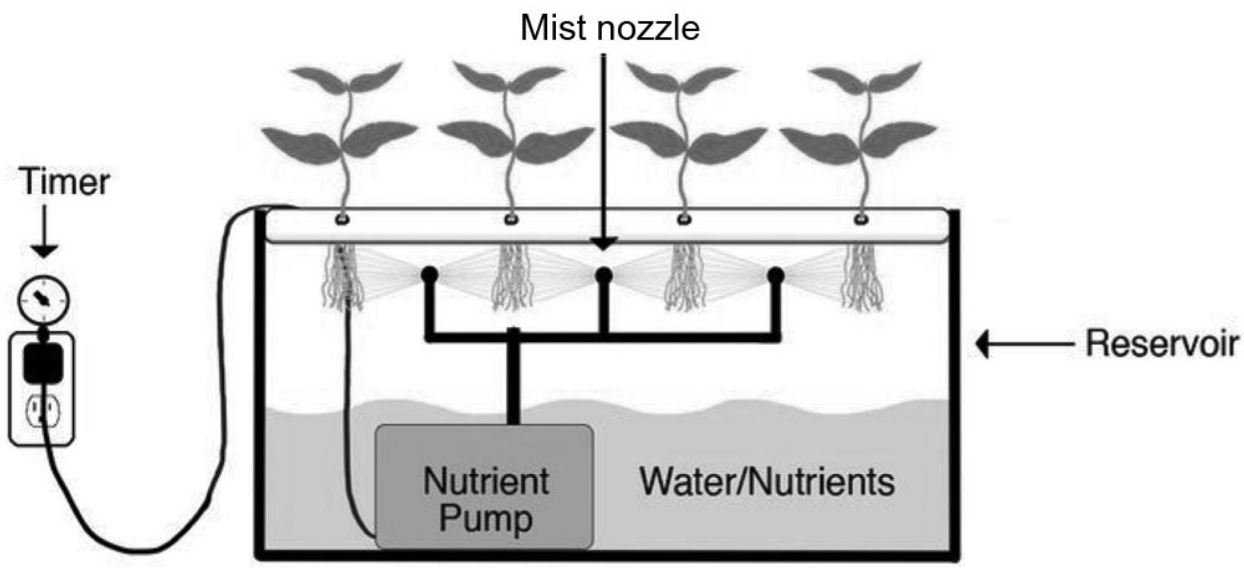

Figure 4. Aeroponics system

1.2.2.5 Nutrient Film Technique (NFT)

This technique was developed by A. Cooper in England during 1960s. NFT is an example of hydroponics system where the plant roots remain in contact with the nutrient solution. In NFT, continuous supply of nutrient solution is maintained by submerged motor pump inside the culture vessel. Only air is used as a growing medium and plants are cultured inside containers with their roots hanging inside the nutrient media. As the solution remains in a continuous flow, there may be changes in the nutrient solution's salinity in comparison to the soil. One of its advantages is that plants can be grown in much higher salinity than soil-based cultivation.

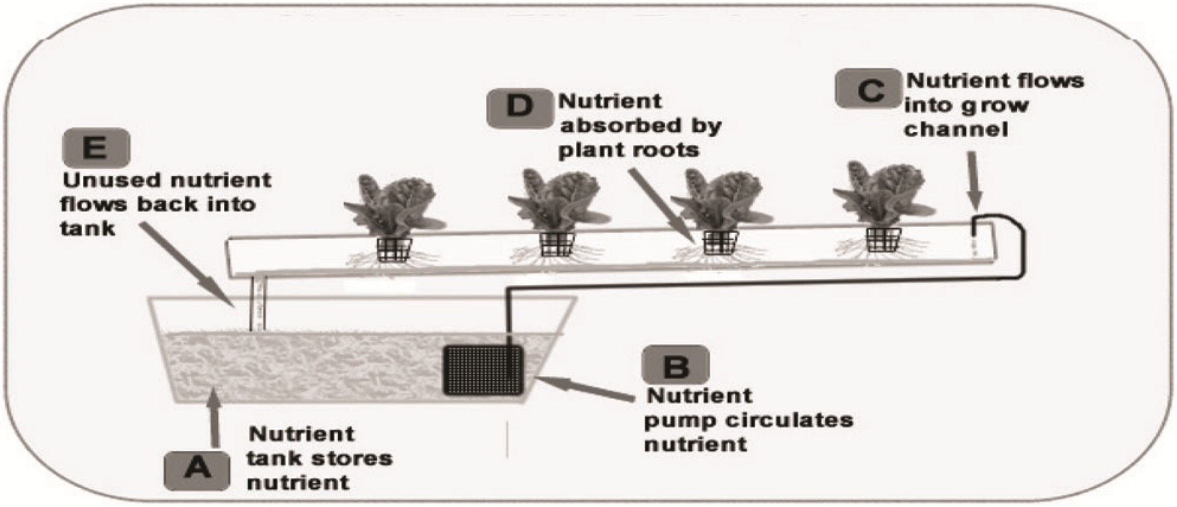

Figure 5. Nutrient film technique (NFT)

1.2.3 Classification of hydroponics/aeroponics

a. Solution culture or liquid hydroponics circulating methods (closed system)

i. Nutrient film technique (NFT)
ii. Deep flow technique (DFT).

b. Non-circulating method (open systems)

i. Root dipping technique
ii. Floating technique
iii. Capillary action technique.

c. Solid media culture (Aggregate systems)

i. Hanging bag technique
ii. Grow bag technique
iii. Trench or trough technique
iv. Pot technique.

d. Aeroponics

i. Root mist technique
ii. Fog feed technique.

1.3 Important parameters in soilless farming

1.3.1 Nutrient solution

Soilless culture plants also need other essential elements (nitrogen, potassium, magnesium, calcium, sulphur, phosphorus, iron, copper, manganese, zinc, molybdenum, boron, etc.), which play important roles in plant growth and development. But the quantities of these nutrients required by particular plant species remain the same despite being cultivated on soil or in any soilless system. The soilless culture grower has the benefit of regulating nutrient concentrations in the solution for optimizing plant growth, proliferation and yield. This can also become one of the limitations of soilless farming as man- aging nutrients concentration in nutrient solution for different plants requires a couple of months of intensive training.

1.3.2 pH level

The availability of essential nutrients for plants is con- trolled by the pH of a nutrient solution. The pH of the nutrient solution ranges between 5.8 and 6.5 which is suitable for soilless cultures, but it mostly depends on the plant species to be cultured. If the pH of the nutrient solution is not regulated from the recommended range, it can create a barrier against the development of plants.

1.3.3 Electrical conductivity (Ec)

The electrical conductivity (*Ec*) measured in dS/m represents the strength of nutrient solution. One of the drawbacks of *Ec* is, it indicates the concentration of the solution rather than the concentration of individual nutrient components. For hydroponics systems the ideal *Ec* ranges between 1.5 and 2.5 dS/m. Imbalance in *Ec* of solution can obstruct the uptake of nutrients by plants due to osmotic pressure, affecting plant growth and yield.

1.4 Eco-friendly soil-less farming unit

Eco-friendly soil-less farming units (EFSFUs) are frameworks which can be established anywhere on a larger scale for mass cultivation of different crops. These units work on the principle of closed-loop hydroponics and aeroponics technology. It is eco-friendly as it uses solar energy to run the electrical equipment's used in the units through solar panels attached on the roofs. The air flowing between the outer and inner environment will be filtered to prevent emission of greenhouse gases as well as entry of disease-causing pathogens. The units have a separate chamber at the entrance which contains sterile equipment's to wear before entering the culture chamber. The plants will be cultured on inert natural media like coconut fibre, pebbles and sawdust or in artificial media like sponge, glass wool on a plastic platform slanted by 30°. This will make the nutrient solution flow downwards.

On the bottom of each rack, two rows of fluorescent bulbs/tubes are attached so that light is provided evenly to each corner. A supplement tank is attached to a corner of the unit from which the nutrient solution will be distributed through pipes connected to the top of each culture rack. At the bottom of each rack, there will be another pipe system to collect the excess nutrient solution. The pipes collecting excess solution are slanted at 10°–15° to prevent storage of solution in pipes which may cause contamination. The excess solution will be pumped back to supplement tank by passing through a filtering unit.

1.5 Smart hydroponics

This can be defined as part of smart farming that involves monitoring and controlling agricultural production and feed using advanced sensor systems. Such systems uses sensors including a pH sensor to give real-time information about the pH level of the water flowing through the system and in the reservoir; an electric thermometer to continuously measure and record the temperature of the water flowing through the system as well as the air surrounding it and an electric Hygrometer to measure and record the humidity.

Through an internet connectivity, a user will be able to interact with the system remotely using a wireless device via a mobile phone. He/she will be able to check water levels, pH level, both water and surrounding air temperature, air humidity, etc. The system will be powered from the building it's being used in.

1.6 Importance of soil-less culture system

Soilless culture system has been used widely in protected agriculture to :

- Improve the growing environment and provide optimal water and nutrient supply for cultivated crops.
- Soilless culture can potentially improve cropping systems by optimizing the use of inputs (nutrient, pesticides and water), controlling diseases more efficiently and make it possible to increase crop production regardless of the climatic conditions
- Soilless culture could increase total yields and facilitate the off-season production of several crops.
- Vegetables grown in soilless culture can be biofortified.
- Increase the calcium (Ca^{+2}) content of baby leaf vegetables (basil, mizuna, tatsoi and endive) without affecting crop growth and marketable quality.
- Soilless culture can be used to successfully introduce new crops into a region e.g medicinal and aromatic herb species can be successfully grown in an arid region.

1.7 Composition of soil-less substrates

The composition of soilless substrates significantly affects plant physiology, yield and fruit quality. The ideal substrate should have fundamental physical, chemical, and biological properties that will improve nutrient availability and plant growth and provide an anchor for the plants. The ideal soilless substrate has is one that has:

- Great total porosity,
- Low bulk density,
- Adequate aeration and

- High water holding capacity to facilitate root penetration and increase nutrient availability to the plants for multi-season applications.

The use of different soilless substrates sources (inert organic and inorganic), **substrate particle size**, N-forms and the **control of single nutrients**, such as potassium (K), Ca+2, and sulphate in the nutrient solution, can also influence soilless product quality and related characteristics (e.g. yield, flower size and number, and fruit sugar and phenolic compounds).

Summarily, a good soilless substrate (growing media) is one with the following characteristics;

Physical and Chemical properties

a) Nutrient retention; low soluble salts content, but need to have an adequate cation exchange capacity, pH should be between 5.0 and 6.5

b) Gas exchange/aeration and porosity; High total porosity (60-85%), sum of all the space in the macro-pores and micro-pores, Aeration (10-20%).

c) Water retention and drainage; Porous and well drained, but must retain enough moisture between irrigations (50-65%) to satisfy plant water requirements.

d) Biologically and chemically stable; Organic substrates need to be well composted - no nitrogen negative period at the onset of production • Inorganic substrates that are inert and well composted organic substrates work best.

e) Standardized and uniform batches; Allow grower to use standardized production practices, such as fertilization and irrigation, with every crop.

f) Free from harmful soil pathogens; Inorganic substrates like rockwool and perlite are sterilized by virtue of the production process.

Inorganic Media		Organic Media
Natural	**Synthetic**	
Sand	Foam mats (Polyurethane)	Sawdust
Gravel	Polystyrene Foam	Pine Bark
Rockwool	"Oasis" (Plastic Foam)	Wood chips
Glasswool	Hydrogel	**Sphagnum Peat moss**
Perlite	Biostrate Felt® (Biobased Product)	**Coir** (Coconut Peat/Fiber)
Vermiculite		Rice Hulls
Pumice		
Expanded Clay		
Zeolite		
Volcanic Tuff		

Moreover, apart from the above-mentioned characteristics, the **Shape and volume of the container**, affects water-holding capacity. **Cost and availability**, **irrigation equipment and strategy**, adapt according to physical properties of substrate environmental impact.

Popular soil-less substrates/media