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STATE FOREST SERVICE

2025

Detailed Syllabus Based study material + **Linkage of Concepts with PYQs** + **Infused with Infographics & Maps**

Module - 2

- Silviculture systems
- Important Indian tree species
- Agroforestry
- Social forestry
- Urban forestry
- Tree Improvement
- Exotics Introduction
- Seed production areas & Seed orchard
- Seed Technology (Seed certification)
- Soil Conservation & Watershed Management

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FORESTRY

UKPSC STATE FOREST SERVICE (MAIN) 2025

EDITION : 2025

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Gole ka mandir, Morar, Gwalior (MP) 474005

SYLLABUS

Uttarakhand PSC Assistant Conservator of Forest, Logging Officer & Forest Range Officer Combined Examination–2025
[Paper 1]

Silviculture Systems

◈ Clear felling, shelter wood, selection, coppice and conversion systems. ◈ Choice of species, establishment and management standards of enrichment methods, technical constraints, intensive mechanized methods. ◈ Traditional and recent advancement in dry tropical forest, forest Silviculture research.

Important Indian Tree Species

◈ Silviculture of some of the economically important species in India such as **A***cacia nilotica*, *Acacia auriculiformis*, *Albizzia lebbeck*, *Anogeissus latifolia*, *Azadirachta indica*, *Bambocaceae*, *Bamboos bamboos*, *Dendrocalamus strictus*, **B***ombex ceiba*, **C***asuarina equisetifolia*, **D***albergia latifolia*, **E***mblica officinalis*, *Eucalyptus hybrid*, **G***melina arborea*, **H***ardwickia binata*, **L***argerstroemia lanceolata*, **P***terocarpus marsupium*, *Prosopis julifora*, **S***antalum album*, **T***ectona grandis*, *Terminalia tomentosa*, *Terminalia arjuna*, *Terminalia paniculata*, *Tamarindus indica*, **X***ylia Xylocarpa*.

Agro-forestry, Social forestry & Urban Forestry

◈ Agroforestry, social forestry and their requirements, neurobehavior of tree – crops combination, selection of species. ◈ Classification of agroforestry systems. ◈ Agro-forestry systems under different agro-ecological zones of Uttarakhand. ◈ Role of multipurpose trees and NTFP's, in food, fodder and fuel security. ◈ Urban forestry, extension and necessity. People's participation. Agro wood group, dry and water-logged land forestry.

Tree Improvement

General concept of tree improvement, methods and techni ques, natural stands, variance and its uses. Seed production and seed orchards, their establishment, evaluation, maintenance and usefulness. Progeny tests for tree and stand improvement. Tree selection for tree improvement and its techniques. Forest genetic resources and gene conservation (in-situ and ex-situ). Modern propagation techniques, seed certification.

Soil Conservation and Watershed Management

◈ Forest soil, classification of soil formation. ◈ Physical, chemical and biological properties of soil. ◈ Soil conservation – definition, causes for erosion, erosion types – wind and water erosion. ◈ Problems of soil protection and improvement. ◈ Role of forests in conserving of soil. Maintenance and buildup of soil organic matter, role of micro-organisms in ameliorating soils. ◈ ***Watershed management***, concepts of watershed – watershed development in respect of torrent control, river channel stabilization, avalanche and landslide controls, rehabilitation of degraded areas, hilly and mountain areas, integrated watershed management. ◈ Water-harvesting, its conservation and ground water recharge.

Module - 2

CONTENTS

CHAPTER 0

UKPSC STATE FOREST SERVICE (MAIN) EXAMINATION

Silviculture systems + Tree Species + Agroforestry, Social Forestry

RFO 2021	• Explain in brief the distribution, phenology, Sericultural characteristics, artificial regeneration and uses of following tree species / निम्नलिखित वृक्ष प्रजातियों का वितरण, ऋतु जैविकी, वन वर्धन विशेषताओं, अप्राकृतिक (कृत्रिम) पुनर्जनन एवं उपयोगों का संक्षिप्त विवरण दीजिए [1(b) | 20 M]. (i) *Santalum album* / चन्दन (ii) *Terminalia arjuna* / अर्जुन • Describe the important criteria of selection of tree species in Agroforestry. Write the aims, objectives and scope of social forestry / कृषि वानिकी में पेड़ों की प्रजातियों के चयन के मापदण्डों का वर्णन कीजिये । सामाजिक वानिकी के प्रयोजन, उद्देश्यों एवं व्यापकता का विवरण दीजिये । [2(a) | 20 M]. • Differentiate between windbreaks and shelter belt. Discuss in brief their impact on environment / वायुरोधक (विंड ब्रेक) एवं रक्षा पट्टी (शेल्टर बैल्ट) में विभेद कीजिये। इनका वातावरण पर पड़ने वाले प्रभावों का संक्षिप्त में वर्णन करें। [3(b) | 10 M]. • Define coppice with standard system. What are the advantages and disadvantages? Differentiate it from coppice with two–rotation system / स्थूण कर्तन (कापिस) की मानक पद्धति को परिभाषित कीजिए। इस प्रणाली के लाभ एवं हानियों का वर्णन कीजिए। इस पद्धति का स्थूण कर्तन द्वि-आवर्तन पद्धति से विभेद कीजिये। [3(c) | 20 M].
ACF 2019	• What do you understand by selection system of forest management? Explain / आप वन प्रबन्धन में चयन पद्धति (सिलेक्शन सिस्टम) के बारे में क्या जानते हैं? विवरण दें। [2(a) | 10 M]. • निम्नलिखित में से किन्हीं दो पौधों की ऋतुजैविक शास्त्र, पुनर्जनन और वनवर्धन अभिलक्षण लिखें / Write phenology, regeneration and silvicultural characters of any two of the following [2(b) | 2 x 10 = 20 M]. (a) *Dendrocalamus strictus* / लाठी बाँस (c) *Tectona grandis* / सागवान (b) *Dalbergia sissoo* / शीशम (d) *Pinus roxburghii* / चीड़ • What is the role of multipurpose trees and NTFP's in forestry? / वानिकी में बहुउद्देशीय एवं गैर-काष्ठ उत्पादों का क्या महत्त्व है? [2(c) | 10 M].
RFO 2015	• Explain the forest conversion process of coppice with standard system to uniform broad leaved high forest by natural regeneration / कापियस प्रबंधन से यूनीफार्म चौड़े पत्तेदार, उच्च वन रूपांतरण की कुदरती पुनः उत्थान की प्रक्रिया के बारे में लिखें । [1(b) | 20 M]. • Write short note on the following / निम्नलिखित पर संक्षिप्त टिप्पणी लिखें (a) **Exotic** Trees in Forestry / वानिकी में विदेशी वृक्ष [2(a) | 10 M]. • Explain the Phenology, Silviculture characters and artificial regeneration of ***Albizzia lebbeck*** and ***Eucalyptus hybrida*** / अलविजिया लेबक और नीलगिरी संकरण के ऋतुजैविक शास्त्र, सिल्वीकल्चर गुण एवं कृत्रिम पुनर्जनन के बारे में लिखें । [3(a) | 20 M]. • Describe the benefits and constraints of Agroforestry / कृषि वानिकी के लाभों और बाधाओं का वर्णन करें। [4(a) | 10 M]. • Inter behaviour of tree-crops in agroforestry / कृषि वानिकी में वृक्षों का पारस्परिक प्रभाव [4(c) | 10 M].
RFO 2012	• Write short notes on the following / निम्नलिखित पर संक्षिप्त टिप्पणियाँ लिखें : (a) **High Forests** / उच्च वन [2(a) | 10 M]. (c) **Multipurpose Trees** / बहुउद्देशीय पेड़ [2(d) | 10 M].

	(b) ***Low Forests*** / निम्न वन [2(b) | 10 M]. • Explain distribution, phenology and regeneration behaviour of ***Tectona grandis*** and ***Dalbergia latifolia*** / सागवान और रोजवुड के विस्तार, ऋतुजैविक शास्त्र एवं पुनर्जनन का वर्णन करें। [3(a) | 20 M]. • Which agroforestry systems are suitable to hilly areas? Support your answer with appropriate reasons / पहाड़ी क्षेत्रों के लिए कौन सी कृषि वानिकी प्रणालियाँ अनुकूल हैं? अपने उत्तर का कारणों सहित समर्थन करें। [4(c) | 10 M].

Tree Improvement + Soil Science + watershed Management

RFO 2021	• Define ***Seed Orchard***. Write the types of seed orchards. Enlist the various aspects considered important prior and after establishment of seed orchards for its management / बीजोद्यान (बीज बाग) को परिभाषित कीजिए। बीजोद्यान (बीज बाग) के प्रकार लिखिए। बीजोद्यान के प्रबन्धन हेतु स्थापना से पहले और स्थापना के बाद में विचारित विभिन्न पहलुओं (दृष्टिकोण) को सूचीबद्ध कीजिए। [2(b) | 20 M]. • Define Provenance. Describe different phases of a ***Provenance Trial***. What is the role of provenance trial in tree improvement? / उत्पत्तिस्थान (प्रोविनेंस) की परिभाषा दीजिए। उत्पत्तिस्था (प्रोविनेंस) परीक्षण के विभिन्न चरणों का वर्णन कीजिए। वृक्ष सुधार में उत्पत्तिस्थान (प्रोविनेंस) परीक्षण की क्या भूमिका है? [4(a) | 20 M]. • What is ***Water Harvesting***? List the different methods of water harvesting and suggest various practices for efficient use of conserved water / जल संचयन क्या है? जल संचयन की विभिन्न विधियों को सूचीबद्ध कीजिए और संरक्षित जल के कुशल उपयोग की विभिन्न पद्धतियों (प्रथाओं) का वर्णन कीजिए। (सुझाव दीजिए) [4(b) | 20 M].
ACF 2019	• How integrated ***Watershed Management*** will help in rehabilitation of degraded hilly areas? Explain / इन्टीग्रेटेड (समग्र) जलागम प्रबंधन किस तरह क्षरित पहाड़ी भागों का पुनरुद्धार करेगा? विवरण दें। [3(b) | 20 M]. • What is ***Seed Certification***? Write about its role in forestry / बीज प्रमाणीकरण क्या होता है? वानिकी में इसके योगदान के बारे में लिखें। [4(a) | 15 M]. • Explain in-situ and ex-situ conservation of genetic resources in forestry / वानिकी में स्वस्थानों और अन्यत्र जीन संसाधनों के संरक्षण का विवरण दें। [4(b) | 10 M]. • Write short notes on the followings / निम्नलिखित पर लघु टिप्पणी लिखें [4(c) | 3 × 5 = 15M]. (a) ***Seed Production Area*** / बीज उत्पादन क्षेत्र (b) ***Seed Orchards*** / बीज उद्यान (c) ***Progeny Test*** / वंश परीक्षण
RFO 2015	• Write short note on the following / निम्नलिखित पर संक्षिप्त टिप्पणी लिखें (b) ***Seed certification*** in Forestry / वानिकी में बीज प्रमाणीकरण [2(b) | 10 M]. (c) ***Seed Production*** area / बीज उत्पादन क्षेत्र [2(d) | 10 M]. • Explain ***Watershed*** concept. Write down the botanical names of two species of different genera for the different type of soils *viz.*, waterlogged soils, Sandy soils, Saline soils and Alkaline soils / जलागम की अवधारणा को परिभाषित कीजिए। विभिन्न मिट्टी के प्रकारों जैसे – जलाक्रान्त, रेतीली, लवणीय एवं क्षारीय के लिये अलग पीढ़ी की दो प्रजातियों का वनस्पति नाम लिखों [3(b) | 20 M].
RFO 2012	• What is the importance of ***Progeny Testing*** in forestry? Explain / वानिकी में सन्तति परीक्षण का क्या महत्त्व है? वर्णन करें। [4(b) | 10 M]. • Is there any forest ***Seed Certification*** in India? What can be its role in our future forestry programmes? Explain / क्या भारतवर्ष में वन बीज प्रमाणीकरण होता है? हमारे वानिकी प्रोग्राम में इसका क्या योगदान हो सकता है? विस्तार से लिखें। [4 (a) | 10 M]. • How integrated ***Watershed Management*** will help in rehabilitation of degraded hilly areas? Explain / एकीकृत जलाशय प्रबन्धन कैसे पहाड़ी क्षेत्रों के पुनर्स्थापन में सहायक होंगे? वर्णन करें। [3(b) | 20 M].

CHAPTER 1

SILVICULTURE SYSTEM
INTRODUCTION

Silviculture is the art and science of cultivating forest crops. It encompasses the natural laws governing tree and forest growth, the influence of environmental factors, and the techniques for both natural and artificial regeneration, as well as ongoing forest management.

Due to the diverse nature of forest types and their specific environmental conditions, a variety of silvicultural methods are required to effectively regenerate and manage different forest sub-types in varying locations. These specific methods or techniques are known as *Silvicultural Systems*.

➢ **SILVICULTURAL SYSTEM** : *a method of the silvicultural procedure worked out in accordance with accepted sets of silvicultural principles, by which crops constituting forests are tended, harvested and replaced by new crops of distinctive forms.*

OR

Silviculture system is a planned silvicultural treatment which is applied to a forest crop, throughout its life, so that it assumes a distinctive form. It begins with regeneration fellings, tending the crop to its final felling.

✍ Silviculture system deals with the removal of a forest crop.

1.1 CLASSIFICATION

In India, silvicultural Systems have been classified primarily based on the ❶ *mode of regeneration* and then the ❷ *pattern of felling*.

HIGH FOREST SYSTEMS : All those silvicultural systems in which the *regeneration is usually of* ***seedling origin****, either natural or artificial*[***] (or a combination of both). So, *rotation is generally long*. These are further classified based on *the pattern of felling*, which in turn, affects the *concentration or diffusion of regeneration* and characteristics of the new crop [Figure 1.1].

COPPICE SYSTEMS : In these silvicultural systems, the *crop* ***originates from coppice*** *growth*[***], leading to a *shorter rotation* period compared to high forest systems. Coppice systems are further categorized based on the *pattern of felling* into the

IFoS 2018 : Enlist the classification of silvicultural systems on the basis of mode of regeneration and pattern of felling (15 m).

Hints : For questions like this, we can start answer writing by defining the silviculture system as its introduction part (the most straightforward way), then classified it into two major groups based on regeneration (as per given 1st basis); The 1st one is High forest system, and another one is coppice system, then further divide them according to the mode of fellings.

CHAPTER 2

CLEAR FELLING SYSTEM

The Clear-felling system is defined as *a silvicultural system in which equal or equi-productive areas of mature crops are successively clear-felled in one operation and regenerated, most frequently, artificially but sometimes naturally*

- The area to be clear-felled each year in uniformly productive sites is 1/n of the total area allotted to this system, where n is the number of years in the rotation and is usually referred to as the ***Annual Coupe****

2.1 SPECIFICATIONS

- **Removal or felling of the mature crop** : The *coupe should be felled and removed in a single operation*. However, some mature trees may be retained as a frost protection measure or as insurance against failure, but their number should be minimal.
- Methods of obtaining regeneration :-

  (a) **Artificial regeneration** : Primarily achieved through artificial means, either by departmental plantations or through various Tungya methods (village Tungya, lease Tungya, departmental Tungya).

  (b) **Natural regeneration** : Occasionally supplemented by seeds stored in the area or received from outside sources.

> The clear-felling system was introduced for the first time by **Heinrich Von Cotta** in Saxony (Germany).

- Tending : Employed as a crucial *tool to control weed growth* and its detrimental effects on plantation efforts. The frequency (Number) of weeding is determined by the growth rate and density of weeds, alongside the growth rate of the forest plants themselves. Cleaning, climber cutting, replacement of old casualties, thinning, etc. followed subsequently.
- Characteristics of the new crop : **Absolutely** *Even-Aged*. If there is no regeneration failure or forest fire accident, the system gives a *normal series of age gradation*.

2.2 ADVANTAGES

- It is one of the *simplest types of silviculture systems*. All things are removed in one operation. So, it does *not require a high degree of skill* in marking and cutting.

CHAPTER 3

SHELTARWOOD SYSTEM

As described in the previous chapter, the entire cropped area is clear-felled in one operation and restocked, either artificially or naturally (occasionally), in the Clear-felling System. However, this creates some issues, such as :

- Artificial regeneration requires a lump sum investment and a one-time, high labour demand.
- Its success depends on the correct choice of species, the use of proper techniques, favourable climatic conditions (such as adequate rainfall), and freedom from adverse biotic factors.
- Soil erosion is an issue due to the opening up of the tree cover.

Therefore, when large sums of money are not available for artificial regeneration, or when natural regeneration of the species is not possible on a clear-felled site due to inadequate seed supply or adverse climatic and soil conditions, **alternative methods must be considered**.

The alternative is to emulate nature and remove the over-wood gradually, in two or more successive fellings, depending on the progress of regeneration. Since regeneration occurs under the shelter of the over-wood, such systems are called ***Shelterwood Systems***. As the over-wood is removed in multiple operations, they are also known as ***Systems of Successive Regeneration Fellings***.

In other words, Shelterwood Systems involve the *gradual removal of the entire stand in two or more successive fellings that extend over a portion of the rotation*. The process begins with the opening of the canopy to allow natural regeneration under the shelter of the remaining over-wood. As the natural regeneration progresses, the over-wood is gradually removed. When the regeneration no longer requires protection, the shelterwood is removed completely, allowing the newly established crop to utilize the growing space effectively.

The varying patterns of regeneration fellings, and their distribution in space and time, result in a variety of shelterwood systems.

- Uniform shelterwood system or simply called 'Uniform system'.
- Group system
- Shelterwood strip system
- Strip and group system
- Wagners blender saumschlag system
- Eberhard's *Wedge* system
- Irregular shelterwood system
- Indian irregular shelterwood system

> Define and classify silvicultural system. What is shelterwood system? Write, in detail, about different shelterwood systems [OPSC Forest Service 2015-16].

CHAPTER 4

SELECTION SYSTEM

Unlike systems of concentrated regeneration, where trees of different age-classes are found in distinct areas, natural forests consist of trees of various ages intermingled throughout. As mature trees naturally die, younger trees regenerate and take their place. The Selection System mirrors this natural pattern of tree replacement in its approach to felling.

SINGLETREE SELECTION SYSTEM	GROUP SELECTION SYSTEM

⇩

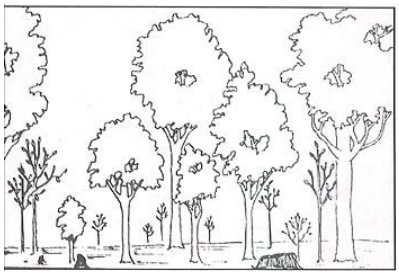
The Selection System is a Silvicultural System in which fellings and regeneration are distributed over the whole of the areas, and the resultant crop is so uneven-aged that trees of all ages are found mixed together over every part of the area.

- Therefore, the crop is referred to as "***Selection Forest***" or ***"all-Aged Forest"***
- Felling and regeneration works distributed over the whole area.
- Resultant crop : Completely uneven-aged as all age-classes are mixed together on every unit of area.
- In the other system of concentrated regeneration, the regeneration operations are carried out only during a part of the life of the crop, after which only thinning are done to improve the growth and form of the remaining trees, whereas in Selection System, regeneration operations are carried out throughout the life of the crop and thinning are done simultaneously for improving the growth and form of trees.

⊳ **PATTERN OF FELLING** : Scattered mature trees (having DBH above the exploitable diameter) are selected all over the area and felled.

– + Dead, dying, diseased and mis-shaped and defective trees.
– + Trees of undesirable species.

The above classes of trees are to be removed in such a way that the remaining crop has all age-classes in balanced proportion on every unit of areas.



⊳ **MODE OF REGENERATION** : Natural regeneration may further be supported by artificial regeneration.

⊳ **NATURE OF CROP** : Absolutely ***un-even-aged*** with all age-classes mixed together on each unit of areas.

⊳ **TENDING OPERATION** : weeding, cleaning, climber cutting etc.

SINGLETREE SELECTION SYSTEM	**GROUP SELECTION SYSTEM**

⇩

CHAPTER 6

COPPICE SYSTEM

Instead of regeneration by *Seed*, here in the coppice system, we depend upon the coppicing power of tree *Stools* where the adventitious buds on the *Stump* of the felled trees produce new plants.

Difinition : Those silvicultural systems in which the new crop originates mainly from stool coppice and where the rotation of the coppice is short.

TYPES : Based on the pattern of felling

- The *Simple Coppice System****
- The Shelterwood Coppice System
- The Coppice Selection System
- The *Coppice-with-Standards System****
- The *Coppice-with-Reserves System****
- The *Pollard System****

6.1 SIMPLE COPPICE SYSTEM

a silvicultural system based on stool coppice, in which the old crop is clear-felled completely with no reservation for shelterwood, and the new crop grows naturally through stool coppice.

- **Pattern, Method & Season of felling** : Clear-felled a fixed area (Annual coupe).

  Season : Little before the beginning of Spring season (*November to February/March*). At this time, the roots contain ample stored food reserves.

  Method : Depending on labour availability, local topography. Ensuring the bark does not detach.

  Stup height : *15 to 25 cm*. in case of Eucalyptus – 5 to 10 cm

- **Mode of regeneration** : *Stool coppice*. But trees cannot keep on coppicing indefinitely and they progressively lose their coppice vigour at every felling and ultimately die. Therefore, in every coppice coupe, some stools do not coppice in each rotation. These blanks are filled up usually by planting stumps or container plants but seldom by sowing.

- **Tending operation** : Cleaning, Climber cutting, ***Singling*** (if the aim to produce logs), etc. Whether thinning is necessary or not depends on the management objectives. If the objective is solely fuel production in coppice crops, no thinning is required because it does not affect total volume production.

CHAPTER 9

MANAGEMENT OF BAMBOO SYSTEM

Bamboo is considered minor forest produce and plays a crucial role in our national economy. It serves as the common man's timber, widely used in house construction and for numerous other purposes. Additionally, bamboo is a significant long-fibered cellulosic raw material for the paper and pulp industry. Among the more than 100 species of bamboo found in Indian forests, ***Dendrocalamus strictus*** stands out as the most important and widely distributed species.

- **Silviculture system** : As bamboo, fellings are done on a selection basis in such a way that the production of new culms takes place continually = ***Culm Selection System***.

  In some working plans, foresters also used the term "***Selection cutting*" *combined with Cleaning and Cultural Operations*** for this, but it didn't get popularity.

- **Felling (cutting) cycle and felling rules** : Bamboos are generally worked on felling (cutting) cycles of *3 or 4 years*, and of these two, or four years is usually adopted in a central Indian forest. The felling rules vary from state to state. Here, we give standard felling rules that are used in north India.

  - Restriction on the cutting of one-year-old culms (In MP it's called *Kurla*, in UP *Nauda*), and sometimes even two-year-old (*Mahila*).
  - Retention of some older bamboo for support of immature culms.
  - Prohibition on the digging of rhizomes.
  - Regulation of the height at which bamboo should be cut. The *minimum height at which the bamboo should be cut is generally 15 cm*, with the condition that at least one node should be left. The maximum height varies from place to place, *i.e.*, ***25 cm in U.P***. and 45 cm in M.P.
  - Insistence on cutting with a sharp instrument so that the stump does not split.
  - In the case of flowering, the bamboo should be cut only when the seed has been shed.
  - The period of working : in winter

- **Method of Regeneration** : by *Rhizomes*. New clumps are formed by natural *Seedlings* resulting after sporadic flowering. In the case of gregarious flowering, when all the clumps in the area die, regeneration comes up profusely from the seeds, so they need some protection against rodents before germination and against cattle grazing after germination.

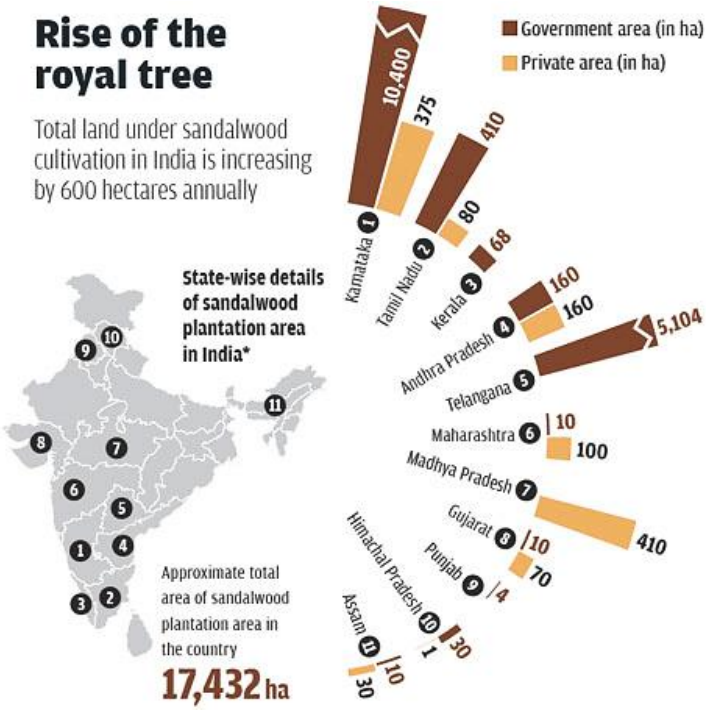
- **Tending** : In fully developed clumps, bamboo does not require weeding and cleaning in the same sense as is required by tree species, as it grows very fast and attains its total height by the end of rains. But cleaning and tending of clumps have to be done to facilitate the growth of new culms. + in areas where natural seedlings appear gaps, gap-planting & three weeding also required for 1st year.

- **Character of the crop** : *uneven-aged* = Rhizome produces CULMS every year.

2.5 *Santalum album (Sandalwood)*

- **Common / Vernacular Name** : Indian Sandalwood, Chandan (Sanskrit, Hindi, Marathi), Srigandha (Kannada), Sandanam (Tamil)
- **Family :** Santalaceae
- **Distribution** : Sandalwood trees are primarily found in *tropical moist & dry deciduous* and *moist semi-deciduous* forests in the southern peninsular region of India, up to 1500 meters altitudes. The main sandalwood-producing regions are the southern part of Karnataka and the northern part of Tamil Nadu.

  Non-traditional sandalwood-growing areas include Andhra Pradesh, Assam, Gujarat, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Telangana, and Uttar Pradesh.



  - **Rainfall** : 600 to 1200 mm
  - **Temperature** range 25 to 35° C
  - **Altitude** : 500 to 1000 m
  - **Topography** : undulating topography, gentle to moderate slopes
  - **Geology and soil** : grow mainly over *red soil* and moist, fertile alluvial soil lies along the banks of rivers and streams. Sandalwood is *not able to tolerate conditions of salinity* and *waterlogging*.

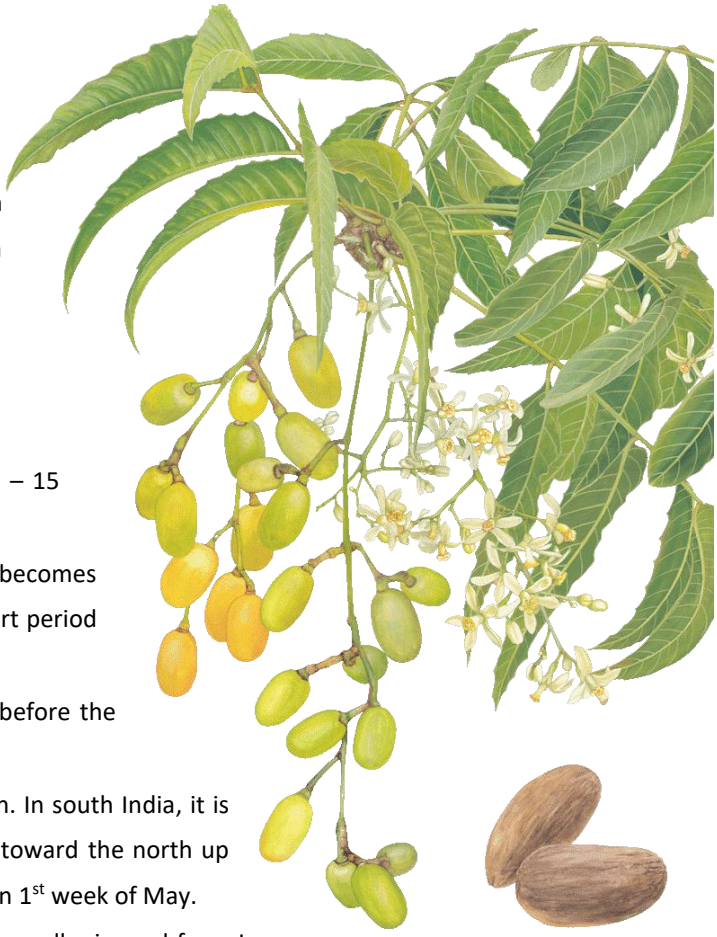
- **PHENOLOGY** : A small to medium-sized, *Evergreen*, *light-demanding*, *partially root parasite tree* found in a large group.
  - **Leaf fall** : Sandalwood is more or less evergreen in character. Hence there is no specific period of leaf fall. It occurs all around the year.
  - **Leaf renewal** : A new flush of leaves appears at the onset of the monsoon season and another just after the monsoons.
  - **Flowering** : Twice in a year, *May–June* and *November–December*; It may be earlier in hotter localities. In Some varieties, it extends from *mid-Feb* to *March-End*.
  - **Fruiting** : June and December

- **SILVICULTURAL CHARACTERS**
  - **Light** : at the initial stage, it required shade but later required overhead light.
  - **Frost** : Conditions of frost do not occur in the natural habitat of sandalwood, hence susceptible to it.
  - **Coppicing power** : Fairly high coppicing power
  - **Root suckers** : freely produced when roots are exposed or when cut.
  - Extremely *fire tender species*, even a small fire may cause irreparable damage.

- **Spacing** : 5 m × 5m

► **UTILIZATION** : Babul yields *timber*, *fuelwood*, *bark gum* and *fodder leaves*. Timber is used for construction, *agricultural implements*, and sports and athletic goods. The wood makes excellent fuel, and the calorific value of heartwood is 4946 kcal/kg. The wood yields a high-grade *charcoal*. The bark and pods of the tree is used for *tanning* by local tanneries. The tree yields a black gum known as *Indian gum Arabic* which is used for matches, ink paints, calico-printing

4.2 *Azadirachta indica*



► **Common / Local Name** : Neem

► **Family** : Meliaceae

► **DISTRIBUTION** : Neem generally grows in tropical dry deciduous and thorn forests in drier parts up to 1500 m.

- Climate : 15° C to 45°C
- Rainfall : 450 to 1400 mm
- Soil : Sandy, semi-arid and black soil.

► **PHENOLOGY** : Neem is a medium size (12 – 15 m) with a broad rounded crown.

- It is an almost evergreen tree but becomes near leafless in dry localities for a short period during February – march.
- New leaves appear in March – April before the old ones are shed.
- Flowing occurs from January to March. In south India, it is in January and progressively delayed toward the north up to the Himalayan subtract where it is in 1st week of May.
- Fruiting followed the flowering and generally ripened from June to August.

► **SILVICULTURE CHARACTERISTICS** : it is a light-demander species but sensitive to frost and fire. However, it is drought-hardy, so it can quickly grow in the semi-arid tract of Rajasthan.

- Coppicer well
- Produce root suckers

► **NATURAL REGENERATION** : (1) Seed + (2) stool coppice

► **ARTIFICIAL REGENERATION** : (1) Seed, (2) stool coppice, (3) Nursery-raised seedlings, (4) Cutting, (5) Air layering, and (6) Artificial seeds produced by tissue culture techniques.

- Plantation work was carried out at the spacing of 5 m × 5 m.
- The rotation period for timber can be for 20-25 years extending to 40-50 years in arid and semi-arid regions.

► **USES** : Tree of the Twenty-first Century. Insecticide (seed oil), insect repellent, oral dentifrice, and traditional medicine to treat malaria, diabetes, worms, and cardiovascular and skin diseases. Large scale

CHAPTER 7

BAMBOO

- **FAMILY :** Gramineae (old name Poaceae)
- **DISTRIBUTION** : The most commonly distributed bamboo of the Indian peninsula is Dendrocalamus strictus or male bamboo which is easily growing in the tropical dry deciduous locality. The culms in this bamboo are solid = and have high commercial value. The other common bamboo of the Indian peninsula is *B. Arundinaria (B. bamboo)* which is often grown in moist soil, along the river beds.

  Some of the important bamboo in its growing region

SN	Scientific name	Common name	Distribution
1.	*Arundinaria falcata*	Ringal	The low-level bamboo of the western Himalayas, at elevations between 1000-2200 m. It grows gregariously, forming an undergrowth in the forests of deodar, oak, etc., usually in moist shady locations.
2.	*Bamboosa bamboo* (Syn. *B. Arundinaria*)	Thorny bamboo	Pan India particularly along the river valley and in moist locality *i.e.* Indo-Gangetic plains. Useful in paper manufacturing.
3.	*Bambusa vulgaris*	Yellow bamboo	
4.	*Dendrocalamus strictus*	Male bamboo (Narbans), Solid bamboo	Distributed in deciduous forests almost all over India especially in drier zones usually up to an altitude 1000 m. it is commonly cultivated throughout India in the plains and foothills.
5.	*Melocanna bambusoides*	Muli bans	NE region

- **PHENOLOGY** : Bamboos are perennial grasses. The woody stem arises from the underground rhizome. The stems are called **culms** and a group of culms is called **clumps**. Culms are usually hallowed but it is ***solid in Dendrocalamus strictus***. The height and size vary from small shrubs to more than 30 m.

  - May be evergreen (Moist/shady localities) or deciduous (dry localities).
  - Flowering : Bamboos have a specific physiological cycle of flowering. Till date, the physiology of bamboo flowering is not understood fully. Even rhizomes maintain the physiological cycle, due to this reason certain culms flower even after planting immediately. The various kinds of flowering in bamboos are briefed below :
    - ❑ Annual Flowering
    - ❑ Periodic flowering
    - ❑ Sporadic flowering

CHAPTER 1

AGROFORESTRY

[INTRODUCTION]

Agroforestry is a collective name for **sustainable land-use systems** involving ***trees combined with crops*** *and/or* ***animals*** on the ***same unit of land***. It combines the -

- The production system of food crops with protection covers of trees especially in fragile ecosystems.
- Emphasis on the use of *indigenous trees has multi-purpose uses* (MPFTs) and *High yield short rotation* (HYSR) tree varieties.
- It is structurally and functionally *more complex than monoculture*.
- It also *provides alternative investment opportunities* with insurance coverage that if our main agricultural crops fail, we still have the trees covered to sell them and sustain their house economy.
- This concept is *based on our ancient tradition and Socio-cultural values, to grow trees* on the boundaries of the farm, protect them and harvest them at a necessary point in time to reduce village dependency on the Forest.

► **DEFINITION** : Agroforestry is a *sustainable land-use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time* while using management practices that suit the local social-cultural characteristics of society and Economic and ecological conditions of the area.

Remember "Crop + Tree ± Domestic animals". 1st two are the essential requirement, 3rd component is optional it may be present or absent.

Nair (1979) defines agroforestry as a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers

Land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers [**Bene, *et.al.***]

► **ATTRIBUTES OF AGROFORESTRY**

Productivity : maintain or increase the production of preferred crops & productivity of the soil.
Sustainability : By conserving the production potential of the resource base, mainly through the beneficial effects of woody perennials on soils; **Cornerstone of agroforestry**]
Adaptability : The word "adopt" here means "accept" (not "modify" or "change). The implication here is that improved or new agroforestry technologies that are introduced into new areas should also conform to local farming practices.

► **SCOPE/NECESSITY** : Agroforestry has an excellent scope in the context of Indian Agriculture due to its intrinsic relation with traditional agricultural practices. Agroforestry practices are beneficial in –

CHAPTER 4

CHOICE OF AGROFORESTRY SYSTEM

4.1 | CHOICE OF SPECIES FOR AGROFORESTRY

Agroforestry requires trees with special characteristics like –

- The tree should be fast-growing & easy to manage
- Should have the ability to fix atmospheric nitrogen.
- Should not compete with food crops for light, Moisture, Nutrients, and space, etc.
- Do not release toxic chemicals (*i.e.*, Mimosine), allelopathy & allergy (remember the issue of Poplar in J&K).
- Excellent copping ability, also amenable for pruning and pollarding. High germination capacity and survival rate.
- Has wider adaptability & acceptability without any controversy.
- Tree species should have higher productivity, higher yield, and maximum profit.
- High market demand and local acceptability
- Multipurpose utility, *i.e.,* timber, fodder, fuelwood etc.

IFoS 2013 : What are the unique requirements for tree improvement in agroforestry? (8m).

IFoS 2011 : While *selecting the species* for agroforestry, the below-ground and above ground interaction between the component species need to be considered. Discuss (10 m).

IFoS 2002 : What should be the basis for the choice of species in agro-forestry system (20 m).

- Give brief account on choice of species for an agroforestry system [OPSC Civil (Main) 2018].
- What should be the basis of choice of species under agroforestry system? [Arunachal PSC Civil (Main) 2015-16].
- Throw light on the selection of the Tree species for Agro-Forestry aimed at higher economic returns [GPCS RFO (Main) 2021 | 10 M]

4.2 | AGRO-FORESTRY SYSTEMS UNDER DIFFERENT AGRO-ECOLOGICAL ZONES OF UTTARAKHAND

Based on remote-sensing and GIS-derived studies, Uttarakhand (excluding snowbound areas) is divided into **3 broader agro-ecological zones (AEZs)** determined by elevation, slope, soil texture, temperature and growing period.

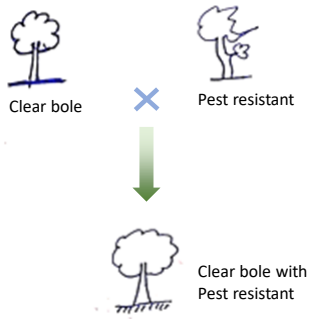
- **Low-lying plains / Tarai-Bhabar** (slope < 5°, loamy or sandy soil, high temperature >15 °C, LGP >120 days)—e.g. Haridwar, Udham Singh Nagar.
  - **Agri-silviculture** : e.g. ***Poplar*** (*Populus deltoides*) intercropped with ***Cereals*** or *Pulses* (*wheat*, barley, *masoor*). Districts practicing this system: **Udham Singh Nagar**, **Haridwar**, **Nainital (low-lying parts)**.
  - **Agri-horticulture** : fruit trees like ***Mango***, ***Litchi***, ***Jackfruit***, ***Papaya*** intercropped with short-duration pulses/vegetables.
- **Mid-hills (5–15° and 15–30° slopes)** with loamy soils and moderate thermal regime (0–15 °C and >120 day growing seasons)—covering parts of Dehradun, Pauri, Almora, Chamoli, Pithoragarh region.

CHAPTER 1

TREE IMPROVEMENT INTRODUCTION

Tree improvement is the process of improving the genetic quality of a tree species. It is also referred to as genetic improvement. The process involves selecting the best trees in a population and using them as parents for the next generation of trees. The goal is to produce trees that are better adapted to their environment and have desirable characteristics such as faster growth, better form, and resistance to pests and diseases.

- *Genetics* is a branch of biology that deals with the study of heredity and variation.
- *Heredity* : It is the transmission of genetic characteristics from parents to the offspring. It deals with the phenomenon of 'like begets like', *i.e.,* human babies are like human beings in overall traits.
- *Variation* : Individuals of the same species have some differences; these are called variations, *i.e.,* Dogs come in many different sizes, People have many different hair colours, etc.
- *Forest Genetics* : Branch of forestry deals with the study of heredity and variation in a forest tree.
- *Tree Breeding* : Tree breeding is the application of genetic, reproductive biology, and economic principles to the genetic improvement and management of forest trees.
- *Tree Improvement* : Improvements in overall yield & quality of forest produce by combining silviculture, tree breeding, and forest management [The *Silvicultural tool* deals with the *genetic makeup* of trees]



► *Heritability* : it is a statistic used in the fields of breeding and genetics that *estimates the degree of variation in a phenotypic trait in a population due to genetic variation between individuals in that population*.

- Heritability is the degree to which progeny resemble their parents. Heritability is the proportion of the total phenotypic variation controlled by genetic rather than environmental factors.
- Values come in between 0 (Zero) to 1. "0" indicates the sampling population has only environmental variations, and there are no genetic variations in the inbreeding population. In contrast, "1" Indicates absolute genetic variations without any environmental effects.

IFoS 2023 : Define *heritability* and its types. How does Narrow Sense Heritability differ from Broad Sense Heritability? [10 M]

IFoS 2019 : Define - (iv) *Heritability* (2.5 m).

IFoS 2018 : What is the importance of *heritability* and how can *genetic gain* be estimated in tree improvement programme? (10 m).

Types of heritability

CHAPTER 2

VARIATIONS

Variation refers to the variability in a species that includes genetic and morphological variances, *i.e.,* Dogs come in many different sizes, People have many different hair colours, etc.

► **CAUSES OF VARIABILITY** : Variability arises in a population due to the following –

- The trees grow in *differing environments*, *i.e.,* in foothills *v/s* coastal areas.
- When the trees have *different genetic makeups* due to mutation, polyploidy, genetic drift, natural selection, interbreeding depression, mating systems, man-made variations, etc.

► **IMPORTANCE OF VARIATIONS** : variations mean species of the same genus have different adaptation mechanisms and survival strategies to similar growing conditions, or members of the same species have this under different growing conditions due to changes in their genotypes and phenotypes, *i.e.,* leaf variations in *Dalbergia sissoo* and *Dalbergia latifolia*.

These variations provide us with vast genetic resources linked with particular insect-pest resistance, quality or quantity of wood, or any specific characteristics to easily select them and choose to develop a species of desired characteristics.

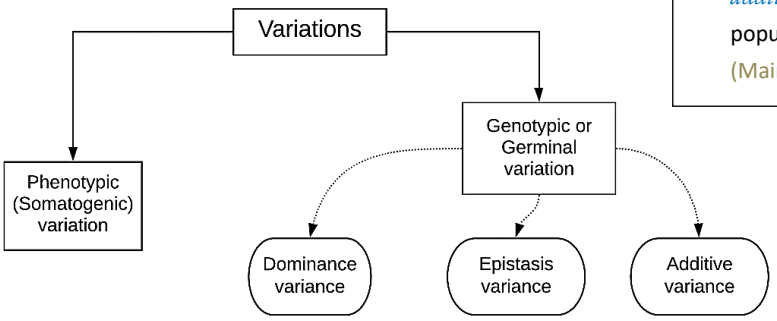
IFoS 2023 : Discuss the *significance of variation* in tree improvement [10 M]

IFoS 2019 : Define - (i) *Variation* (2.5 m).

IFoS 2015 : How can *magnitude and type of variability* be manipulated to obtain good gains in some tree characteristics ? (8m).

- Differentiate between (a) *Genotypic* and *phenotypic* variations [Himachal PSC Civil (Main) 2011; UPPSC (ACF) 2018].
- What are the *additive* and *non-additive* genetic variations in a tree population? [Arunachal PSC Civil (Main) 2015-16].

► **TYPES OF VARIATIONS**



1. **PHENOTYPIC (SOMATOGENIC) VARIATION** : when trees grow under different environmental conditions, they will alter various physiological mechanisms, the colour of leaves, shape, and size of

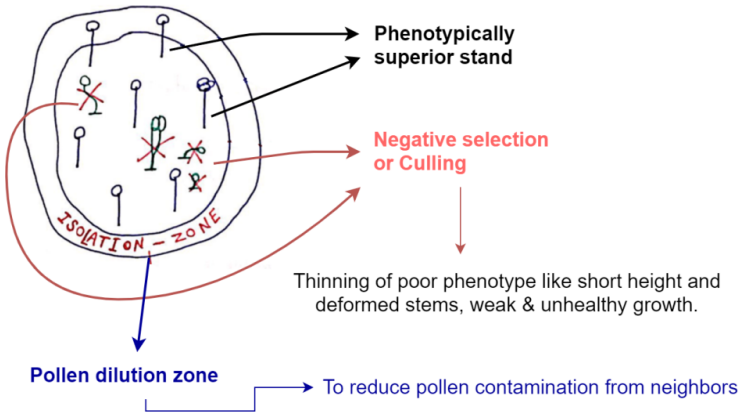
CHAPTER 5

SEED PRODUCTION ARES

The seed production area is a *phenotypically superior stand* of important *commercial forest tree* species in the *Permanent Forest Estate*, consisting of *vigorously growing trees* upgraded by *thinning of poor phenotypes* and treated and managed in such a manner as to *produce large quantities of seed*.

Another definition - The seed production area is a phonologically superior stand made up of *vigorously healthy trees*, upgraded by thinning to remove poorer phenotypes and treated and managed to cause *abundant seed production*. Seed stands are a stage before the formation of a seed orchard.

Furthermore, the seed production area is a *natural or planted stand* or group of stands, set aside, periodically rouged, and treated to stimulate seed production. The genetic quality of the seed is not known.



PURPOSE

- To ensure the continuous supply of larger quantities of high-quality seeds with the known origin for our Afforestation/reforestation and other plantation works. Until such time the seed orchards come into production.
- Reduce harvesting pressure from wild populations.
- Reduce collecting costs
- Increase reliability of supply and enable seed bank stockpiling (including of seed of species that are rare or difficult to collect in the wild).
- Providing opportunities for alternative land use like windbreaks, soil improvement, etc., with income generation.

ADVANTAGES

- Increase reliability of supply and enable seed bank stockpiling (including of seed of species that are rare or difficult to collect in the wild).
- Reduce harvesting pressure from wild populations.

CHAPTER 1

FOREST SOIL

[INTRODUCTION]

1.1 WHAT IS SOIL ?

Soil is the *unconsolidated mineral material on the immediate surface of the earth* that serves as a natural medium for the growth of land plants.

Forest soil is a portion of the earth's surface that serves as a medium for the growth and sustenance of forest vegetation.

PEDON ?

A *pedon* is a 3-dimensional smallest unit or volume of soil that contains all the soil horizons of a particular soil type with 1 m^2 at the surface and extends to the bottom bedrocks of the soil.

Term Soil is derived from the *Latin* term – *Solum*, which means *Floor****

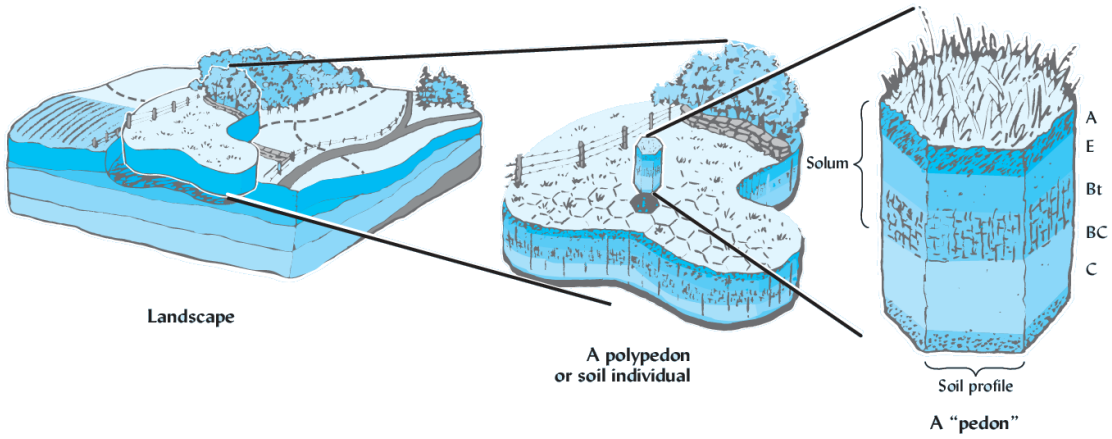


Figure 1.1 : Pedon is a natural body of soil that is large enough to allow classification of the soil.

PEDOLOGY : Pedology = Pedon + Logos = Greek word

↓ ↓

Soil/Earth Study

Pedology is the study of *soil genesis*, *classification*, and *mapping*/description of soil for land use planning. Therefore, it is helpful in forestry, forest road construction, and land capability classification.

- *Soil genesis* : the mode of origin of soil with particular reference to the processes and soil-forming factors responsible for the development of solum or true soil.
- *Soil survey* : consists of morphological examination, description, classification, and mapping of soils in their natural environment.
- *Soil classification* : is the process of logical grouping based on the properties and characteristics of representative units (pedon).

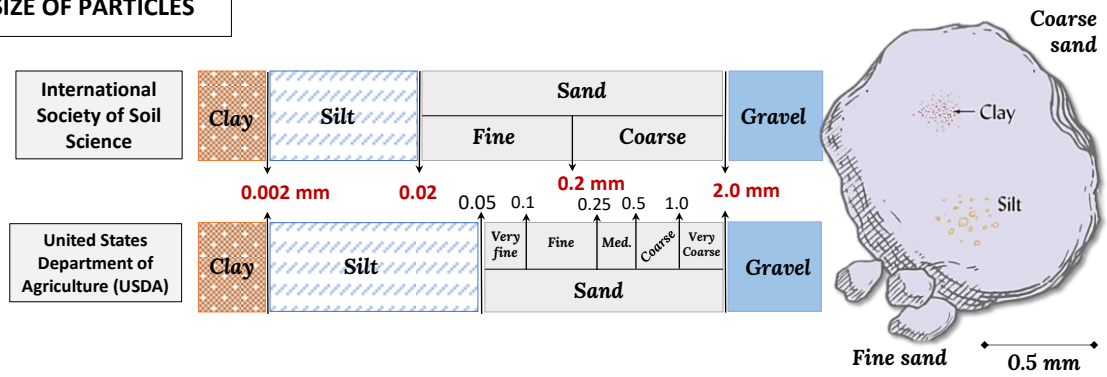
CHAPTER 6

SOIL PHYSICAL PROPERTIES

6.1 SOIL TEXTURE

The *relative percentage of sand, silt, and clay in the soil*[***]. Where *sand and silt work as a skeleton* of soil in which *clay particles fill as flesh*. The size of particles in mineral soil is not subject to change (*i.e.,* by cultural practices). Therefore, this composition is considered a permanent feature and a *basic property* of soil. Mechanical analysis of soil separates, *i.e.,* the percentage of sand, silt, and clay done by the *hydrometric method*.

SIZE OF PARTICLES



- Clay particle size : < 0.002 *mm*[***]
- Soil texture refers to the relative amounts of sand, silt, and clay, and it directly affects a soil's *cohesion*, *adhesion*, and *plasticity*. Clay soils have a characteristically *fine/heavy texture*.
- **Loam soil** – (a) best suitable soil for agriculture purposes, (b) it contains *sand, silt and clay minerals in an equal property*[***] proportional and *not in equal percentage*.

6.2 SOIL STRUCTURE

The *arrangement of primary soil particles*[***] and their aggregation into a certain definite pattern is called soil structure.

Primary soil particles : Sand, Silt, clay

Types

- **Plate-like** : arrangement of soil aggregates in a thin horizontal plane like plates or lamina, *i.e.,* Alluvial soil.
- **Prism** or **Columnar-like** : vertically oriented aggregation or pillars. Occurs in the B horizon of clay soil in *arid* and *semi-arid* regions (Salt-affected soil).
- **Block-like** : aggregation shape like a block of the irregular face. Found in *Humid zone*.
- **Spheroidal** : has good development along all sides. This may be ***granular*** (non-porous) or ***crumb*** structure (Porous). Crumb structure is considered better for arable farming practices as it shows the *highest hydraulic conductivity*.

CHAPTER 9

WATERSHED MANAGEMENT

9.1 WHAT IS WATERSHED ?

A watershed is a geohydrological unit of land that feeds all the water running under it and drains at a common point.

Or

A watershed is a geohydrological unit of land that feeds all the water running under it and drains at a common point.

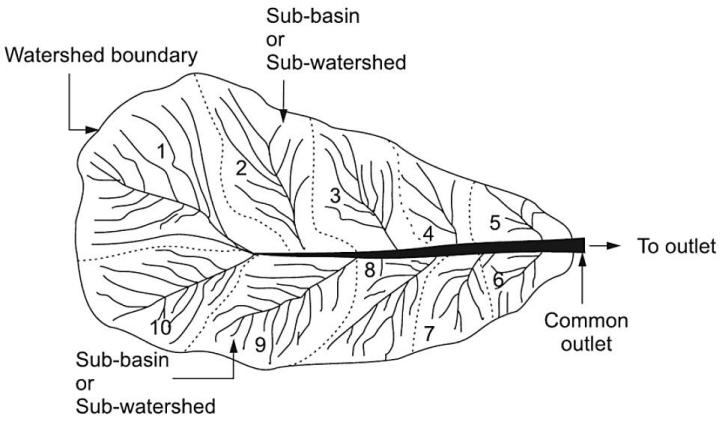


Figure 1.1 Definition sketch of watershed.

WATERSHED MANAGEMENT

Watershed management is the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources and *the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the Plants, Animals, and human communities within a watershed boundary.*

OBJECTIVES OF WATERSHED MANAGEMENT?

- Soil and water conservation by controlling damaging run-off.
- Improve the ability of the land to hold water
- Rainwater harvesting and recharging
- Employment generation
- Maintain ecological balance by Growing greeneries - trees, crops, and grasses
- Increase farmers' income (doubling income by 2022)
- Moderate floods in the downstream areas.
- Developing fuel, fodder, and timber resources for the local population.

9.13 RAINWATER HARVESTING

Rainwater harvesting is the collection and storage of rainwater that runs off from rooftops, parks, roads, open grounds, etc. This water runoff can be either stored or recharged into the groundwater. A rainwater harvesting system consists of the following components -

- The catchment from where water is captured and stored or recharged,
- Conveyance system that carries the water harvested from the catchment to the storage/recharge zone,
- First flush that is used for flushing out the first spell of rain,
- Filter used to remove pollutants,
- Storage tanks and/or various recharge structures.

Rain may soon be the only source of clean water. Rainwater harvesting systems use the principle of conserving rainwater where it falls and has the following benefits –

- Helps meet ever-increasing demand for water
- Improves quality and quantity of groundwater.
- Reduces flooding.

IFoS 2017 : what is Water harvesting ? List the different methods of water harvesting and suggest various practices for efficient use of conserved water (20 m).

Differentiate between the (a) Rain water harvesting and ground water recharge [Himachal PSC Civil (Main) 2017, 2018].

Groundwater is depleting at an alarming rate in many states, especially in Punjab and Haryana. Nearly 60 and 40% of the blocks of these states have turned 'dark' due to overexploitation of groundwater to meet the water requirement of wheat-paddy rotation in the paddy growing belt. Free electricity in Punjab has further aggravated this problem. The term 'dark' indicates that no further groundwater development should be undertaken as the groundwater recharge is considerably less than the groundwater withdrawal.

► Methods

A) **MICRO CATCHMENTS** : This system collects surface run-off, as sheet flow over a short distance, from a small catchments area (around 1000 sq. m).

- On-farm systems : to collect and store rainwater on the farm through the construction of *Contours Bunds* (Across the slope, Suitable for 2 – 8% land slope), *Contour Trenching*, *Nala Bunding*, *terracing*, *Small Pits* and *run-off strips*.
- Rooftop system : to collect rainwater from buildings, courtyards, lawns etc.

B) **MACRO-CATCHMENTS** : This system collects run-off water from a relatively large catchment. Often the catchment is natural rangeland, the steppe, or a mountainous area.

- Wadi-bed systems : wadi bed is used to store the water, either on the surface by blocking the water flow or in the soil profile by slowing down the flow and allowing it to infiltrate the soil.
- Off-wadi systems : The rainwater harvested in run-off wadi systems is applied outside the wadi bed. Structures may be used to force the water to flow toward nearby areas suitable for agriculture.

Figure : A wadi system.

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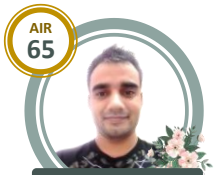

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